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Ares I Upper Stage Element
Human Factors Engineering Design Criteria

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Launch Vehicles Project
Upper Stage Element
Human Factors Engineering Design Criteria

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1.0 EXECUTIVE SUMMARY

The human factors engineering (HFE) requirements herein are applied to the design of the Ares I Upper Stage (US). These design requirements and criteria define the relevant HFE requirements necessary for US assembly, pre-launch processing, and maintenance by the ground crew. Also addressed are the HFE requirements and design criteria for US pre-launch console equipment at Kennedy Space Center (KSC) during pre-launch activity. The Level IV HFE requirements herein are enabled through the US Element Requirements Document (ERD), USO-CLV-SE-25710, and include traceability to the Human-Systems Integration Requirements (HSIR), CxP 70024 Ground Maintenance and Assembly section 3.9. The HSIR is enabled by Constellation Architecture Requirements Document (CARD), CxP 70000.

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2.0 INTRODUCTION

2.1 PURPOSE

This document defines the Human Factors Engineering (HFE) requirements applicable to the Ares I Upper Stage (US) for its assembly, pre-launch processing, and maintenance tasks. This document provides detailed and derived requirements to assist US designers and ensures application and traceability to the requirements in upper level HFE documents. Application and adherence to the HFE requirements promotes supportability, operability and sustainability of the US, lowers the life cycle costs of operations, and supports safety.

2.2 SCOPE

The requirements herein apply to US systems and hardware that will be installed, assembled, or maintained by a human operator any time before launch, as well as to US ground systems equipment at Kennedy Space Center (KSC) to support pre-launch activity. These requirements are constrained to US components, structures, and processes which involve ”direct human contact” during the design, build, test, operations and maintenance phases of the vehicle lifespan. Hardware fabricated at manufacturing sites should follow standard industry practice for HFE and be in accordance with the design criteria herein.

2.3 REQUIREMENT TRACEABILITY

The Constellation HFE requirements are initially imposed by the Constellation Architecture Requirements Document (CARD), CxP70000, 3.3.4 Human Engineering requirement, which references the Human Systems Integration Requirements (HSIR) document, *CxP70024*. The requirements flow through Ares I Systems Requirements Document (SRD), CxP72034, which specifies Section 3.9 of the HSIR for Ground Crew Interfaces. The requirements then flow to the US Element Requirements Document (ERD), USO-CLV-SE-25710. The US ERD Human Engineering requirement (3.3.7 [R.US_DC.0054]) enables the requirements listed herein. This document is traceable to the HSIR Section 3.9 to ensure application of the required Ground Crew Interfaces requirements to the US element. In addition, it includes derived specific and detailed requirements from MIL-STD-1472F, "DOD Design Criteria Standard, Human Engineering;" which are the industry-accepted standards for ground-based human engineering processes pertaining to government acquisition and are accepted by Level II for the Constellation Program. Requirements included herein are those directly applicable to the human factors design, including those also applicable to and overlapping with Logistics Support Infrastructure (LSI) and Safety and Mission Assurance (S&MA).

2.4 ADDITIONAL INFORMATION

2.4.1 Assumptions

The HFE requirements herein are applicable to both the US element structure and equipment, as well as to support structure and equipment (i.e., Ground Support Equipment) necessary for assembly, transportation, and pre-launch configuration activities of the integrated vehicle. Any other element directly interfacing with the US element shall meet the HFE requirements at the interface. Likewise, HFE requirements flowed down from Ares I integrated vehicle and for the Constellation Program are applicable to the US elements. Level III and IV requirement interpretations may be required from the flow-down requirements.

Industry standard practice HFE requirements will be imposed for manufacturing and fabrication of the US components prior to their arrival and integration at Michoud Assembly Facility (MAF). It is further assumed that the requirements herein will be imposed for assembly of US components and subassemblies at MAF.

The US and Upper Stage Engine (J2X Engine) will be fully assembled, integrated, and verified at the element level when it departs the MAF. It is assumed that the US will be transported by barge to KSC where it will be integrated into the Ares I stacked assemblage for launch.

Planned and unplanned maintenance on US will be accomplished to the HFE requirements herein under the auspices of the Ares I US LSI. These requirements are assumed to be for pre-flight ground maintenance operations and configuration activities, and will not apply as flight maintenance. This assumes that the responsibility for Ares I Upper Stage / J2X Engine element maintainability ceases at liftoff, unless there is a specific interface with Crew Exploration Vehicle (CEV) for the flight period until Ares I US separation from CEV (though First Stage maintenance and refurbishment is necessary). It is further assumed that Level II and Level III maintenance requirements may be flowed to Ares I US, as applicable.

2.4.2 Definitions and Terminology

- Operator – Ground personnel performing assembly, maintenance, or other tasks required for processing of the hardware for assembly, integration, maintenance and pre-launch operations.

- Element – Any aspect of the US including primary and secondary structure, mounted hardware, utility lines, Line Replaceable Units, and Ground Support Equipment provided by US.

- Integrated Vehicle – the assemblage and integration of the various Ares I elements into a verified and acceptable launch vehicle

- Workstation: Assumed to be the volume and architecture where the ground operator or maintainer can directly interface physically and/or visually with equipment necessary to accomplish work. (SEE MIL-HDBK-1908).

- Worksite: An area where an operator or maintainer will be performing work in a one-g ground-based environment. Worksite includes controls, displays, limiting structure, and peripheral hardware and equipment which positively or negatively impact the work to be accomplished. (SEE MIL-HDBK-1908).

- Workarea: Assumed to be same as Worksite. (SEE MIL-HDBK-1908).

2.4.3 Document Structure

Each design criterion is accompanied by a rationale statement. Requirements that must be applied are denoted with a "shall" statement while guidelines that should be followed if possible and appropriate are denoted with a "should" statement.

Requirements have been organized into main groupings to facilitate document comprehension. However, the categories are not necessarily mutually exclusive. In addition, the heading titles and requirement titles are not intended to constrain the applicability of the requirement. Designers should review the requirement verbiage in the entire document to ensure that relevant and applicable requirements are identified.

A verification approach for each requirement is also included in Section 4.0. Design guidelines do not require verification. Figures and tables are included where appropriate to support or further define a requirement. Acronyms are defined at the first usage and an acronym list is provided in the Appendices.

2.4.4 Compliance Processing

All design criteria denoting the word, "shall" are contractually applicable for in-house and contracting organizations. Any deviations or interpretations shall be coordinated through the proper organizations and US program processes as defined in:

- Ares I Crew Launch Vehicle (CLV) Upper Stage (US) Element Integrated Logistics Support Plan (ILSP), USO-CLV-LS-25401, APPENDIX C Human Factors Engineering Plan
- Upper Stage System Validation and Verification Plan , USO-CLV-SE-25703

2.5 DOCUMENTS

CxP 70000	Constellation Architecture Requirements Document
CxP 72006	Ground System Systems Requirements Document GS SRD Human Engineering Sections
CxP 72141	Ground Operations Systems Engineering Management Plan GO SEMP, Human Factors 7.1.3
CxP 72210	Ground Systems Human Factors Requirements Document
CxP-70024	Human-Systems Integration Requirements
CxP-70067	Constellation Program Human Rating Plan
HF-STD-001	Federal Aviation Administration Human Factors Design Standard
ISO 2631-1	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 1: General requirements; 1997
ISO 2631-2	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 2: Vibration in buildings; 1997
MIL-HDBK-1908	Definitions of Human Factors Terms
MIL-STD-1472F	Department of Defense Design Criteria Standard; Human Engineering
MIL-STD-1474	Department of Defense; Noise Limits
NASA-STD-5005	Ground Support Equipment Requirements
NIOSH	NIOSH Lifting Equation Applications Manual
USO -CLV-25710	Upper Stage Engineering Requirement Document

USO-CLV-LS-25401	Ares I Crew Launch Vehicle (CLV) Upper Stage (US) Element Integrated Logistics Support Plan (ILSP)
USO-CLV-SE-25703	Upper Stage System Validation and Verification Plan
MSFC-STD-512A	Man/System Requirements for Weightless Environments
SSP50005 C	International Space Station Flight Crew Integration Standard

3.0 REQUIREMENTS AND DESIGN CRITERIA

The following requirements and design criteria are applied to the Ares I US design. All design criteria denoting the word, "shall" are contractually applicable for in-house and contracting organizations. Any deviations or interpretations shall be coordinated through the proper organizations and US program processes.

3.1 Architecture

This section contains requirements for the overall layout of the element and support work areas to aide the ground crew in performing launch processing and assembly. Specific topics include layout of functional areas, translation paths, and structure that supports operators in moving around in and working on the element. This section is not exhaustive; there may be requirements in other sections of this document that are also applicable.

3.1.1 General Architecture

3.1.1.1 External Service Points: External service points for launch pad operations shall be located within 60 degrees, radially, of the plane between the vehicle and the service structure.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors logistics requirements, constraints, and design criteria for access for the ground-based one-g assembly and maintenance personnel. Traces to CxP70024 3.9.7.6.6 [HS8013].

3.1.2 Operator Support Structure & Equipment

3.1.2.1 Handholds and Footholds: Handholds or footholds shall be furnished where needed to assist personnel in climbing onto equipment or in performing intended tasks.

Rationale: One-g restraints are required in some workstations to stabilize maintenance and assembly personnel in elevated or critical positions.

3.1.2.2 Removable Handhold/Platform Accommodations: Accommodations shall be provided for placing or withdrawing removable personnel restraints (including handholds), and platforms as necessary to support ground operations.

Rationale: Physical access and support for ground support equipment and ground personnel is necessary for vehicle launch preparation.

3.1.2.3 Passive Restraint: All restraints shall provide positive passive restraint with no danger of entrapment.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety requirements, constraints, and design criteria for workstands, platforms and scaffolding for the ground-based one-g assembly and maintenance personnel.

3.1.2.4 Portable Restraint Attachments: Attachments on portable restraints shall be removable for repair or reuse. Portable restraint attachments shall be interchangeable throughout the worksite.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety requirements, constraints, and design criteria for workstands, platforms and scaffolding for the ground-based one-g assembly and maintenance personnel.

3.1.3 Workstation Arrangement

3.1.3.1 Work Station Layout Interference: The element should separate functional areas where ground processing activities would detrimentally interfere with each other.

Rationale: Co-location of unrelated activities could degrade operations resulting in increased workload and operational delays. This consideration will be difficult to meet in a small volume, but every effort should be made to separate functions and capabilities that could operationally conflict with each other, or that produce environmental conditions that will conflict with other tasks--e.g. SCAPE ops with wire testing, soldering next to cleanroom environments. Traces to CxP70024 3.9.4.1 [HS10047]

3.1.3.2 Work Station Layout Sequential Operations: The element should co-locate functional areas in which sequential ground operations are performed.

Rationale: Co-location of related, functional work areas can reduce transit time, communication errors, and operational delays. This consideration may seem to be met simply because of a vehicle's small size, but every effort should be made to group functions and capabilities supporting a task in as efficient a manner as possible to reduce crew workload. For example,time to build access platforms inside the vehicle could be reduced if all similar operations are performed sequentially in a co-located area before platform removal. Traces to CxP70024 3.9.4.2 [HS10048].

3.1.4 Passageway and Pass-throughs

3.1.4.1 Traffic Flow: Pathways shall be designed to optimize traffic flow for both nominal and emergency passage.

Rationale: This requirement establishes that the Ares I US will meet the HFE passage requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.1.4.2 Simultaneous Passage: Pathways and corridors shall be sized per Table IX to accommodate simultaneous passage of two 95th-percentile persons, as traffic needs dictate.

Rationale: This requirement establishes that the Ares I US will meet the HFE passage requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.1.4.3 Adequate Pathways: Corridors and pathways shall not interfere with planned assembly or maintenance worksites or workstations.

Rationale: This requirement establishes that the Ares I US will meet the HFE passage requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.1.4.4 Entry and Exit Ways: All entry and exit ways of the element shall be sized in order to accommodate the body size of 95th percentile ground-based personnel.

Rationale: This requirement establishes that the Ares I US will meet the HFE sizing requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.1.4.5 Safe Exit: All element compartments which require human presence after element assembly shall be configured to allow a safe and rapid exit of personnel present.

Rationale: This requirement establishes that the Ares I US will meet one of the HFE safety requirements, constraints, and/or design criteria for the ground-based one-g assembly and maintenance personnel.

3.1.4.6 Hatch Dimensions: Hatches shall accommodate suitable equipped and clothed 95th percentile user personnel in terms of limiting dimensions for location and operability, and clearance dimensions for size and passage factors. Where personnel must carry equipment through the hatch, allowance shall be made for clearance of 90% of suitably clothed male personnel. Unless otherwise restricted, hatch dimensions shall conform to Figure 3.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors accessibility safety requirements and constraints for hatches for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472, Figure 33.

3.1.4.7 Whole-Body Access: Dimensions for rectangular access openings for body passage shall be not less than those dimensions depicted in Figure 3. The diameter of any circular hatch shall be not less than 76 cm (30 in). Diameters of oval hatches ...shall be not less than 43 and 71 cm (17 and 28 in). Where rescue of personnel may be required because of environmental hazards (e.g., toxic fumes) within the worksite, larger access openings for two-person egress - ingress may be necessary. Where "step-down" through a top-access exceeds 69 cm (27 in), appropriate foot rests or stops shall be provided.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors accessibility safety requirements and constraints for hatches for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472, Figure 33.

3.1.5 Stairs, Ladders, and Ramps

3.1.5.1 Stair Safety: Stairs, including incline, step risers, and treads shall conform to standard safe design practice including skid-proof flooring, stair and step treads and , here conditions warrant special precaution, nonslip coating.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety requirements, constraints, and design criteria for stairs for the ground-based one-g assembly and maintenance personnel.

3.1.6 Workstands, Platforms, and Scaffolding

3.1.6.1 Locks: Self-locking and other fail-safe devices shall be incorporated on elevating stands, work platforms and "draw bridges" to prevent accidental or inadvertent collapsing or falling.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety requirements, constraints, and design criteria for workstands, platforms and scaffolding for the ground-based one-g assembly and maintenance personnel.

3.1.6.2 Handrails, Safety Bars, and Chains: Handrails, safety bars, and chains shall be installed around platforms and across stair or step openings in platforms, ledges, and catwalks. Such guards shall be placed 91-110cm (36-43 in) above the standing surface. An intermediate guardrail shall be provided. Chains shall be used only where it is not feasible to install handrails or safety bars. Kickboards, 15 cm (6 in) high shall be installed.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety requirements, constraints, and design criteria for workstands, platforms and scaffolding for the ground-based one-g assembly and maintenance personnel.

3.1.6.3 Safety Mesh: Screen or safety mesh shall be installed on the underside of open gratings, platforms, or flooring surfaces where small tools, parts, or debris may fall through the grating on workers or equipment beneath the platforms.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety requirements, constraints, and design criteria for workstands, platforms and scaffolding for the ground-based one-g assembly and maintenance personnel.

3.1.6.4 High Center of Gravity: Equipment that may tip over and injure personnel due to a high center of gravity shall have anchors or outriggers for stability and shall display an appropriate warning.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety requirements, constraints, and design criteria for workstands, platforms and scaffolding for the ground-based one-g assembly and maintenance personnel.

3.2 Worksite

This section contains requirements applicable to the immediate area where operators will perform their tasks. Specific topics include reach and access and strength. . This section is not exhaustive; there may be requirements in other sections of this document that are also relevant to the design of the element, element components or hardware.

3.2.1 General Worksite

3.2.1.1 Worksite Dimensions: All worksites, including but not limited to launch site processing and maintenance worksites, shall be sized to meet the body size, functional reach limits, visual envelopes, and strength limits of the 5^{th} to 95^{th} (CxP70024 TBR-006-060) percentile of the ground-based assembly and maintenance worker population, as defined herein.

Rationale: This requirement establishes that the Ares I US will meet the general human factors physiological and biomechanics requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. The 5th to 95th (TBR-006-060) is the suggested standard which includes 90% of the population. This range conforms to the recommendations of other ground task standards,including HF-STD-001 and MIL-STD-1472. The anthropometric study on which to base the dimensions is TBR. Traces to CxP70024 3.9.1.1 [HS10008].

3.2.2 Physical Access & Clearance

3.2.2.1 Work Envelope: Personnel work envelope volume shall be provided for the operators, tools, and equipment to perform tasks including but not limited to assembly and maintenance, and launch processing..

Rationale: The element components/subsystems shall be designed to be assembled by the ground crew with sufficient work envelope to accomplish tasks. Many of these tasks will constitute mating of components (bolts, connectors, etc.) across the interface between element subsystems (1st: 2nd stage, e.g.) or between elements. The envelopes will therefore be identified by element-level task analyses and documented in Interface Control Documents (ICD's). Sufficient envelope is defined by task analyst, based on anthropometric requirements and task definition. This requirement establishes that the Ares I US will meet the workstation human factors safety and logistics requirements, constraints, and design criteria for labels and markings for the ground-based one-g assembly and maintenance personnel. Traces to CxP70024 3.9.6.6 [HS10002].

3.2.2.2 Physical Access: Equipment design and installation shall provide the operator with complete physical access and a favorable working position for all parts of a system on which maintenance is performed, including Line Replaceable Units (LRU's), workstand interfaces, support equipment interfaces, access openings, adjustment points, test points, maintenance points and connections.

Rationale: Safety in the design is needed in order to protect personnel and flight systems.

3.2.2.3 Whole Body Access: Where whole body access is required, the opening shall accommodate assembly and maintenance personnel in the range of the 5th to 95th percentile body sizes.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety and logistics requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.2.2.4 Multiple Operators: Physical access openings to equipment for the purpose of assembly and maintainability shall provide volume for the required number of operators.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety and logistics requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.2.2.5 Reach Envelope: Reach envelope from the personnel work orientation shall be provided for the operators to perform tasks including but not limited to assembly, maintenance, and launch site processing.

Rationale: The element components shall be designed to be assembled by the ground crew with sufficient reach envelope to accomplish tasks. Many of these tasks will constitute mating of components (bolts, connectors, etc.) across the interface between element subsystems or between elements. The reach envelopes will therefore be identified by element-level task analyses and documented in ICD's. Sufficient reach envelope is defined by task analyst, based on anthropometric requirements and task definition. Traces to CxP70024 3.9.6.7 [HS10004].

3.2.2.6 Provision for Access Openings: An access shall be provided if frequent maintenance would otherwise require removing a case or covering, opening a fitting, or dismantling an item of equipment.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.2.2.7 Special Clothing: Access openings for maintenance and assembly tasks shall accommodate special clothing constraints, as required by the task.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety and logistics requirements, constraints, and design criteria for labels and markings for the ground-based one-g assembly and maintenance personnel.

3.2.2.8 Tool Access Dimensions: Access openings shall be large enough to operate tools required for assembly and maintenance of the equipment reached through the access.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety and logistics requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. Ref MIL-STD-1472F 5.9.9.4.1.3.

3.2.2.9 Tool Clearance: The element shall provide tool (single or combined component tools) clearances for tool installation and actuation for all tool interfaces.

Rationale: Tool access for ground support equipment is necessary for vehicle launch preparation. Traces to CxP70024 3.9.7.4.2 [HS10024].

3.2.2.10 Access Design: Where arm and hand access is required, the following practices shall be followed in order of preference:
a. An opening with no cover unless this is likely to degrade system performance, safety, or contamination survivability.
b. A hand operated (latched, sliding, or hinged) cap or door where dirt, moisture, or other foreign

materials might otherwise create a problem.
c. A quick-opening cover plate using 1/4 turn captive fasteners if a cap will not meet stress requirements or space prevents a hinged cover.
d. A screw-down cover, when captive fasteners cannot be used because of stress, structure or pressurization constraints. Use minimum number of interchangeable screws to fasten door.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors logistics requirements, constraints, and design criteria for access for the ground-based one-g assembly and maintenance personnel.

3.2.2.11 Hand Access: The dimensions of access openings for two hands, one hand, and fingers shall be not less than those shown in Figure 4.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety and logistics requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472

3.2.2.12 Cable Access: The element shall provide access to cables for scheduled inspections and maintenance during ground operations.

Rationale: Access to cables is required, to ensure that ground personnel can see and reach cables for inspection and maintenance activities. Traces to CxP70024 3.9.7.6.5 [HS8011]

3.2.2.13 Equipment Item Interconnecting Devices: The element shall provide utility line attachment/mounting length to allow removal/replacement of equipment items.

Rationale: Sufficient cabling must be provided for an LRU or critical moveable equipment to move from its attached location to where the operator can comfortable mate/demate connectors.

3.2.3 Visual Access

3.2.3.1 Visual Envelope: Visual envelope (visual access) shall be provided for operators to perform tasks including but not limited to assembly, maintenance, and launch site processing..

Rationale: The element components shall be designed to provide the ground crew with visual access of the tasks to be performed as part of element assembly and maintenance. That is, all tasks should have the object of the task (bolt, connector, etc.) in the direct line of sight of the ground crewmember performing the task, with the element in the assembled, vertical configuration. Traces to CxP70024 3.9.6.8 [HS10006].

3.2.3.2 Visual-Line-of-Sight: The element should provide direct line-of-sight visual access to all equipment, except blind-mate connectors, on which maintenance is performed by ground personnel, including maintenance requiring Personal Protective Equipment.

Rationale: Direct line of site visual access reduces the likelihood of human error that can occur when blind (by feel) operations or operations requiring the use of specialized tools (e.g., mirrors or bore scopes) are performed. PPE may be required for certain maintenance activities and must be accommodated. Direct line of site for pin inspection is not required, though desired where possible. A blind-mate connector is one which is automatically demated and mated as a piece of equipment is removed and replaced. Traces to CxP70024 3.9.7.6.7[HS8048].

3.2.3.3 Direct Access: All maintenance and assembly interfaces shall be within the operator's direct visual envelope without the use of mirrors, bore scopes, periscopes, and similar devices.

Rationale: Visual access for ground support equipment and ground personnel is necessary for vehicle launch preparation.

3.2.3.4 Inspection Access: Element components which require inspection shall be visually accessible during launch site processing.

Rationale: Access is required for inspection and must be accommodated in the design. Traces to CxP70024 3.9.7.6.4 [HS10025].

3.2.3.5 Visual Access Openings: Where visual access is required, the opening shall provide a visual angle sufficient to view all required information at the assembly, normal operation, or maintenance positions.

Rationale: This requirement establishes that the Ares I US will meet the general human factors safety and logistics requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel

3.2.3.6 Display Access: Displays supporting a task shall be located within the field of view of the ground operator performing the task when not viewing the display correctly could result in a hazard.

Rationale: When performance of assembly or maintenance tasks requires that feedback be provided to ground crew (e.g., bolt torquing of a critical component), the ground crew must have clear view of the display. Absence of such access to displays could result in hazard to ground personnel or hardware. Traces to CxP70024 3.9.7.7.7 [HS10029].

3.2.3.7 Blind Screwdriver Adjustments: Screwdriver adjustments made without visual access are permissible only if mechanical guides are provided to align the screwdriver. Screw travel shall be limited to prevent the screw from falling out of its intended position.

Rationale: All Ares I US equipment must be designed such that equipment adjustment and calibration is accomplished efficiently and without risk to flight or support hardware or equipment.

3.2.4 Strength and Lifting

3.2.4.1 LRU Weight Limit: LRU's that are required to be installed by one ground crewperson without ground support equipment shall not exceed the safe weight limit as determined by the NIOSH lifting equation.

Rationale: Traces to CxP70024 3.9.7.1.7 [HS10045].

3.2.4.2 Strength Design Requirements: Strength limitations, including strength reduction limitations, shall be applied to the element design as defined in Tables IV and V.

Rationale: This requirement establishes that the Ares I US will meet the general human factors physiological and biomechanics requirements, constraints, and design criteria for nominal unloaded body positions in worksites for the ground-based one-g assembly and maintenance personnel.

3.2.4.3 Push/pull forces: Manual horizontal push and pull forces required, to be applied initially to an object to set it in motion or to be sustained over a short period of time, SHALL not exceed the values of Table I, as applicable, or those given in Figure 1 if more appropriate to the force and movement characteristics of the task. The values shown in Table I apply to males only and SHALL be modified for females. (Two-thirds of each value shown is considered to be a reasonable value for females.). NOTE: Use 5th %tile strength as a minimum.

Rationale: This requirement establishes that the Ares I US will meet the general human factors physiological and biomechanics push-pull requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472F.

3.2.4.4 Vertical Push and Pull: Manual vertical push and pull forces required to be applied initially to an object to set it in motion or to be sustained over a short period of time SHALL not exceed the applicable fifth percentile peak or mean force values of Table II or those given in Figure 1. if more appropriate to the force and movement characteristics of the task. NOTE: Use 5th percentile strength as a minimum.

Rationale: This requirement establishes that the Ares I US will meet the general human factors vertical push-pull physiological and biomechanics requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472F.

3.2.4.5 Manual Torque: Manual torque, rotation, and grip values to be applied initially to an object to set it in motion or to be sustained over a short period of time SHALL not exceed the applicable tenth percentile force values of Table III, or those given in Figure 2., if more appropriate to the force characteristics of the task. NOTE: Use 5th %tile strength as a minimum.

Rationale: This requirement establishes that the Ares I US will meet the general human factors physiological and biomechanics requirements, constraints, and design criteria relative to manual torque, rotation, and grip for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472F, MSFC-STD-512A, and SSP50005.

3.2.4.6 Grip Force: The grip force design limits for the element shall be a function of the size of the gripped object and the distance between the gripped objects and are defined in Figure 1.

Rationale: This requirement establishes that the Ares I US will meet the human factors general human strength requirements, constraints, and design criteria as defined in the Ares I US HFE requirements document for the ground-based one-g assembly and maintenance personnel. HSIR Tables IV and V have dynamic strength and joint strength data, as well as strength reduction factors for repetitive tasks. This includes push-pull and lifting data.

3.2.4.7 Arm, Hand, Thumb-finger Strength: All planned worksites shall be designed to meet the human arm, hand, and thumb-finger strength limits of the 5th to 95th percentile of the ground-based assembly and maintenance worker population, as defined in Figure 1.

Rationale: This requirement establishes that the Ares I US will meet the HFE general human grip requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.2.4.8 Hatch Force Requirements: When a handle is used for unlocking a hatch, the unlocking force required shall be not more than 90 N (20 lbs). Hatches placed in the overhead position shall require no more than 220 N (50 lb) force for opening or closing and be operable by suitably equipped and clothed users.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors accessibility safety requirements and constraints for hatches for the ground-based one-g assembly and maintenance personnel.

3.3 Hardware

This section contains requirements applicable to the design or performance of individual components of the element, LRU's, or portable equipment and hardware. This section is not exhaustive; there may be requirements in other sections of this document that are also applicable to individual component design or to other hardware.

3.3.1 General Hardware

3.3.1.1 Worksite Standardization: Standard parts should be used whenever practicable.

Rationale: This recommendation establishes that the Ares I US will meet the workstation human factors safety and logistics requirements, constraints, and design criteria for labels and markings for the ground-based one-g assembly and maintenance personnel.

3.3.1.2 Hardware Installation: Hardware, including LRU's, shall include physical features (e.g., supports, guides, size, or shape differences, fastener locations, and alignment pins) that prevent incorrect installation.

Rationale: Each LRU is verified for flight in its designed orientation and configuration. Not only is functionality of the item at risk if it is improperly installed, structural failure could result. Physical features which ensure proper installation will at the same time assure that cables and fluid lines are not improperly stressed and that all fasteners are appropriately torqued. Traces to CxP70024 3.9.7.1.1 [HS10012].

3.3.1.3 Similar Items: Similar items shall utilize a common mounting design and orientation within the unit..

Rationale: All Ares I US equipment must be designed such that removal and replacement does not disable or deintegrate a functional, certified, and fully-tested component or system. Such disabling of a certified system results in costly retest and recertification.

3.3.2 Cases

3.3.2.1 Orientation: The proper orientation of an item within its case shall be made obvious by design of the case or use of appropriate labels.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on the Ares I US Vehicle.

3.3.2.2 Removal: Cases should lift from items rather than the converse. Equipment should be protected from damage when cases are removed or replaced. Cases shall not require manual support to remain in the open position during maintenance.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.2.3 Size: Cases shall be sufficiently larger than the items they cover to facilitate installation and removal with little or no case manipulation.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.2.4 Guides: Guides, tracks, and stops shall be provided as necessary to facilitate handling and to prevent damage to equipment or injury to personnel.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.3 Covers

3.3.3.1 Self-supporting Covers: Hinged access covers that are not completely removable shall be self-supporting in the open position. The cover in the open position shall not obstruct required visual or physical access to the equipment being maintained or to related equipment during maintenance. Self-supporting covers should be capable of being opened and closed with one hand.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.3.3.2 Securing of Covers: It shall be made obvious when a cover is not secured, even though it may be in place.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.3.3 Instructions: If the method of opening a cover is not obvious from the construction of the cover itself, instructions shall be permanently displayed on the outside of the cover. Instructions shall consist of simple symbols such as arrows or simple words such as "push" or "push and turn."

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.3.4 Ventilation Holes: If a cover or shield requires ventilation holes, the holes shall be small enough to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.3.5 Orientation: A removable access cover that requires a particular orientation shall be designed to prevent attachment in any other orientation.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.3.6 Fasteners for Covers: Fasteners should give a clear indication that they are fastened.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.3.7 Opening Covers: Access covers shall be equipped with grasp areas or other means for opening them. Covers shall accommodate handwear or special clothing that may be worn by the operator.

Rationale: Requirement addresses equipment housing for accomplishing assembly and maintenance work on Ares I US vehicle.

3.3.4 Controls

3.3.4.1 Reference Scale for Adjustment Controls: A scale or other appropriate reference shall be provided for all adjustment controls. Reference scales shall be readily visible to the person making the adjustment. Mirrors or flashlights should not be required for adjustments.

Rationale: All Ares I US LRU and critical equipment must be designed such that removal and replacement, adjustment and calibration is optimized and can be accomplished in situ under otherwise difficult circumstances.

3.3.4.2 Control Limits: Calibration or adjustment controls which are intended to have a limited degree of motion shall have mechanical stops sufficiently strong to prevent damage by a force or torque 100 times greater than the resistance to movement within the range of adjustment.

Rationale: All Ares I US LRU and critical equipment must be designed such that removal and replacement, adjustment and calibration is optimized and can be accomplished in situ under otherwise difficult circumstances.

3.3.4.3 Power Supply Control: Switches shall be used to control power supply in lieu of circuit protection devices.

Rationale: Circuit protection devices shall not be used in place of switches for controlling power to systems. They are not designed for this function, and their use for this function results in excessive wear.

3.3.4.4 Knob Adjustments: Knobs rather than screwdriver controls shall be used whenever adjustments must be performed more often than once per month and where access, weight, and related considerations permit their use.

Rationale: All Ares I US LRU and critical equipment must be designed such that removal and replacement, adjustment and calibration is optimized and can be accomplished in situ under otherwise difficult circumstances.

3.3.5 Tools

3.3.5.1 Toolset: Tools used in assembly and maintenance tasks shall be only those identified in the Launch Site Task Tool List (CxP70024 Table 3.9-1) (CxP70024 TBD-006-050).

Rationale: The LSI cost drives the need for a minimized tool list. Traces to CxP70024 3.9.7.4.1 [HS10028].

3.3.5.2 Special Tools: Special tools shall be used only when common hand tools cannot be used, when they provide significant advantage over common hand tools, or where required by security considerations.

Rationale: The LSI cost drives the need for a minimized tool list.

3.3.5.3 Tool Grip Span: Grip span for tools requiring exertion of high force should be approximately 75 mm (3 in.).

Rationale: The LSI cost drives the need for a minimized tool list.

3.3.6 Fasteners

3.3.6.1 Minimize Needed Tools: The type of fastener used should minimize the number of tools needed.

Rationale: The LSI cost drives the need for minimizing fastener numbers and types.

3.3.6.2 Multiple Fastener Types: When more than one size or type fastener is used on the same equipment or cover, the fasteners-equipment-cover interface shall permit the operator to readily distinguish the intended location of each fastener.

Rationale: The LSI cost drives the need for minimizing fastener numbers and types.

3.3.6.3 Non-Standard Tools: Fasteners requiring non-standard tools shall not be used.

Rationale: The LSI cost drives the need for minimizing fastener numbers and types.

3.3.6.4 Left-Hand Fasteners: Left handed fasteners shall not be used.

Rationale: The LSI cost drives the need for minimizing fastener numbers and types.

3.3.6.5 Captive Fasteners: Fasteners on LRU's and deployable equipment used during maintenance activities shall be captive.

Rationale: Protection of ground support equipment and ground personnel from loose small items which could cause injury or impairment of equipment. Traces to CxP70024 3.9.7.3.1 [HS10026]

3.3.6.6 Hand-Operated Fasteners: Hand-operated fasteners shall be used on maintenance-significant items unless loads, torque, strength, bonding, frequency of use requirements prohibit.

Rationale: Protection of flight and support equipment from damage by tool capabilities and insensitivities provides a safe system and controls costs.

3.3.6.7 Engagement Indication: Latches and catches shall give a clear visual indication that they are engaged.

Rationale: Protection of flight and support equipment from damage or inadvertent operation provides a safe system and controls costs.

3.3.6.8 Inadvertent Operation: Latches and catches shall be located, positioned and/or designed to avoid inadvertent operation.

Rationale: Protection of flight and support equipment from damage or inadvertent operation provides a safe system and controls costs.

3.3.6.9 Captive and Lock Washers: Captive washers and lock washers shall be used when loss would otherwise present a hazard to equipment or personnel

Rationale: Protection of ground support equipment and ground personnel from loose small items which could cause injury or impairment of equipment.

3.3.7 Connectors

3.3.7.1 Connector Mating Protection: Connector design shall prevent a plug from being inserted into an incorrect receptacle and preclude damage to the plug or receptacle resulting from such an attempted insertion.

Rationale: Protection of flight and support equipment from damage or inadvertent operation provides a safe system and controls costs.

3.3.7.2 Connector Mismating: The element shall have physical features that preclude mismating and misalignment of connectors that are in the same physical location and accessed during launch site processing and maintenance and assembly tasks

Rationale: Improper mating or misalignment of connectors can lead to short circuit or open circuit conditions that can reduce the safety of flight or ground crews, can increase the risk of LOC or LOM events, and may cause damage to hardware. Physical features are often used to lessen the likelihood of human error. Traces to CxP70024 3.9.7.2.1 [HS10015].

3.3.7.3 Earth Ground Potential: The element shall permit its external parts, other than antennae and transmission line terminals, to be maintained at earth ground potential during ground processing.

Rationale: During ground maintenance, ground personnel must not be exposed to a shock hazard while working on the exterior of the Ares I US vehicle. Ref CxP70024 3.3.3.3.

3.3.7.4 Isolation Valves: The element shall provide isolation or disconnect valves for subsystems that contain pressurized fluids during launch site processing and ground maintenance.

Rationale: Ground personnel must not be exposed to high pressure or toxic liquids or gases. Lack of methods from controlling pressurized fluids could lead to equipment damage or personnel injury Traces to CxP70024 3.9.7.7.3 [HS10020].

3.3.8 Component Lubrication

3.3.8.1 Self-Lubricating Components: Where feasible, self-lubricating components should be used.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or

surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.2 Lubricant Application and Checking: Configuration of equipment requiring lubrication shall permit lubrication and, as applicable, checking of lubricant reservoir levels without disassembly.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.3 Lubricant Type Limits: The number of types of required lubricants should be minimized.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.4 Lubricant Points: Lubrication points should be accessible, clearly labeled, and, where applicable, provided with captive caps or covers.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.5 Extended Fittings: Extended fittings shall be provided to lubricant ports that would not otherwise be readily accessible or visible.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.6 Service Point Quality Limits: The number of service ports should be minimized by routing service lines to a centralized servicing location(s).

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.7 Lubrication Indication: A clear indication that lubrication is completed shall be provided to ensure proper servicing level.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.8 Lube Fittings: Lube fittings shall be sized to prevent coupling with improper servicing devices.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.3.8.9 Lubricant Warning Indicator: Where lubrication is system or mission critical, a "low lubrication level" warning message or indicator should be provided.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel.

3.4 Environment

This section contains requirements for the environment in which the operators will perform their tasks. This section is not exhaustive; there may be requirements in other sections of this document that are also relevant to element environmental design or related issues.

3.4.1 Acoustics

3.4.1.1 General: Personnel shall be provided an acoustical environment which will not cause personnel injury, interfere with voice or any other communications, cause fatigue, or in any other way degrade system effectiveness. The fact that a component which contributes to the overall noise may be government furnished equipment shall not eliminate the requirement that the total system conform to the criteria herein.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.2 Hazardous Noise: Equipment shall not generate noise in excess of maximum allowable levels prescribed by MIL-STD-1474, Noise Limits.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.3 Worksite Noise: Workspace noise shall be reduced to levels that permit necessary environment. Criteria for workspaces are defined by either the A-weighted sound level (dB(A)) or the direct (person-to-person) and telephone communication and establish an acceptable acoustical work speech interference level (SIL) and are given in Figure 5 and Table XI. The A-weighted sound level is the desired requirement. Where it is not possible to meet the specified A-weighted sound level, the corresponding SIL requirement shall be met. Figure 5 provides guidance on the relationship between required vocal-effort, speaker-to-listener distance and noise level. Procedures for determining speech intelligibility are provided in Table XII.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs. Ref. MIL-STD-1472F.

3.4.1.4 General Workspace: Areas requiring occasional telephone use or occasional direct communication at distances up to 1.5 m (5 ft) shall not exceed 75 dBA SIL.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.5 Operational Areas: Areas requiring frequent audio communication (e.g., telephone) use or occasional direct communication at distances up to 150 cm (5 ft) shall not exceed 65 dBA SIL.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.6 Large Workspaces: Areas requiring no difficulty with telephone use or requiring occasional direct communication at distances up to 460 cm (15 ft) shall not exceed 55 dBA SIL.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.7 Small Office Spaces/Special Areas: Areas requiring no difficulty with direct communication shall not exceed 45 dBA SIL.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.8 Extreme Quiet Areas: Areas requiring extreme quiet shall not exceed 35 dBA SIL.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.9 Ambient Noise Control: The workspace or facility design shall minimize the ambient noise level to the extent feasible through effective sound reduction or attenuation to meet the criteria herein.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.10 Attenuation by Materials: Acoustic materials with high sound-absorption coefficients shall be provided as necessary in the construction of floors, walls, and ceiling to provide the required sound control.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.11 Reverberation: Excessive reverberation in rooms and work stations shall be controlled. *(Examples are by applying sound absorbing materials on floor, ceiling tiles, and special wall treatments).*

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs.

3.4.1.12 Reduction of Reverberation Time: Where speech communication is a consideration, the acoustical treatment of facilities shall be sufficient to reduce reverberation time below the applicable limits of Figure 6.

Rationale: Protection of ground crew from acoustical injury or impairment of communication controls operations costs. Ref. MIL-STD-1472F.

3.4.2 Atmosphere

TBD

3.4.3 Thermal

TBD

3.4.4 Vibration and Acceleration Limits

The following provisions apply to whole body vibration, as defined by CXP 70024, HSIR, where the vibratory motions are limited to those transmitted to the human body as a whole through supporting surfaces. This includes the feet for the standing occupant, the buttocks, back, and feet for the seated occupant, and the supporting surface of the occupant lying on his or her back. The applicable frequency range is defined as: a. 0.1 to 0.5 Hz for motion sickness; and b. 0.5 to 80 Hz for health, comfort, and perception.

3.4.4.1 Equipment Vibration: Where whole-body vibration of the human operator or parts of the body is not a factor, equipment oscillations shall not impair required manual control or visual performance.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors physiological and safety requirements, constraints, and design criteria for equipment vibration for the ground-based one-g assembly and maintenance personnel.

3.4.4.2 Performance: The RMS value of the frequency-weighted translational acceleration should fall below the health guidance caution zone for the expected daily exposures defined in ISO 2631-1, Annex B. Whole body vibration should also be minimized in the frequency range below 20 Hz where major body resonances occur. To preclude impairment of visual tasks, vibration between 20 and 70 Hz should be minimized. The transmission of higher frequency vibration through the seating system should also be minimized, especially where transmission of vehicle vibration to the head at such higher frequencies that can occur for seating conditions in which the body or head come in contact with the seatback or a headrest.

Rationale: This recommendation establishes that the Ares I US should meet the workstation human factors safety requirements, constraints, and design criteria for frequency-weighted translational acceleration for the ground-based one-g assembly and maintenance personnel. This is not a verifiable requirement, as it has only 'should' statements.

3.4.4.3 Comfort: Where specific levels of comfort listed in ISO 2631-1, Annex C must be maintained, the applicable overall vibration RMS values indicated therein shall not be exceeded.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety requirements, constraints, and design criteria for comfort-driven translational acceleration for the ground-based one-g assembly and maintenance personnel.

3.4.4.4 Building Vibration: Buildings intended for occupation by personnel should be designed / located to control the transmission of whole body vibration to levels that are acceptable to the occupants as specified by ISO 2631-2.

Rationale: This recommendation establishes that the Ares I US should meet the workstation human factors safety requirements, constraints, and design criteria for whole-body vibration for the ground-based one-g assembly and maintenance personnel. This is not a verifiable requirement, as it has only 'should' statements.

3.4.4.5 Acceleration: To minimize the effects of whole-body vibration on health, the root-mean square value of the frequency-weighted translational accelerations should not exceed the health guidance caution zones for the expected daily exposures defined by ISO 2631-1, Annex B. If possible, exposure within the health guidance caution zone should be avoided. Frequencies below 20 Hz should be avoided. Evaluation of environments where the vibration crest factor is above 9, or for environments containing occasional shocks of transient vibration, should conform to paragraph 6.3 of ISO 2631-1.

Rationale: This recommendation establishes that the Ares I US should meet the workstation human factors safety requirements, constraints, and design criteria for whole-body vibration for the ground-based one-g assembly and maintenance personnel. This is not a verifiable requirement, as it has only 'should' statements.

3.4.4.6 Motion Sickness: The weighted RMS acceleration in the z-axis (between 0.1 and 0.5 Hz) shall sufficiently low to preclude or minimize motion sickness as assessed by the methods and assessment guidance specified by CxP 70024; Human-Systems Integration Requirements.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors physiological and safety requirement for motion sickness for the ground-based one-g assembly and maintenance personnel.

3.4.5 Illumination

3.4.5.1 Lighting: General and supplemental lighting for element assembly and maintenance functions shall be provided to ensure illumination is compatible with each operator task situation.

Rationale: This requirement establishes that the Ares I US will meet the general human factors illumination requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.4.5.2 Levels: Illumination levels shall be specified by Tables VII .

Rationale: This requirement establishes that the Ares I US will meet the general human factors illumination requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472F Tables XV.

3.4.5.3 Perceptible Flicker: Light sources shall not have a perceptible flicker.

Rationale: This requirement establishes that the Ares I US will meet the general human factors illumination requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.4.5.4 Safety Illumination: Illumination levels as defined in Table VII shall be provided in all areas where hazardous conditions would otherwise be possible.

Rationale: This requirement establishes that the Ares I US will meet the general human factors illumination requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. Ref. MIL-STD-1472F Tables XV

3.5 Safety

This section includes requirements related to human interface or human factors which are focused primarily on the safety of the operator. This section is not intended to be a comprehensive collection of requirements related to the safety. Topics covered in this section include mechanical, electrical, fire and touch temperature hazards. Other safety topics are covered in their respective sections of the document

3.5.1 General Safety

3.5.1.1 Human Factors Safety: Design shall reflect applicable system and personnel safety factors, including minimizing potential human error in the operation and maintenance of the system, particularly under the conditions of fuel loading, or other emergency or non-routine conditions. Design of worksites and equipment shall conform to OSHA standards unless applications require more stringent limits (e.g., maximum steady-state noise in personnel-occupied areas).

Rationale: Ref. MIL-STD-1472F; Para. 4.8, Safety

3.5.1.2 Alerting Device: A hazard-alerting capability shall be provided to warn personnel of impending danger or existing hazards (e.g., fire, the presence of combustible or asphyxiating gas, smoke, and radiation)

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety requirements, constraints, and design criteria for labels and markings for the ground-based one-g assembly and maintenance personnel.

3.5.1.3 System Safing Controls: The element shall provide controls which allow ground personnel to safe the system prior to performing maintenance.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety requirements, constraints, and design criteria for vehicle system safing for the ground-based one-g assembly and maintenance personnel. Traces to CxP70024 3.9.7.7.5 [HS10022].

3.5.1.4 Guarding Hazardous Conditions: If a hazardous condition (such as exposed, high voltage conductors) exists behind the access, the physical barrier over the access shall be equipped with an interlock that will de-energize the hazardous equipment when the barrier is open or removed. Both the presence of the hazard and the fact that an interlock exists shall be noted on the equipment case or cover such that it remains visible when the access is open.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.5.1.5 Critical Controls: Critical and sensitive adjustment controls shall incorporate features to prevent inadvertent or accidental actuation. Operating any locking device used to prevent inadvertent actuation shall not change the adjustment setting. Where the operator is subjected to disturbing vibrations or acceleration during the adjustment operation, suitable hand or arm support shall be provided near the control to facilitate making the adjustment.

Rationale: All Ares I US LRU and critical equipment must be designed such that critical equipment adjustment and calibration is optimized and can be accomplished in situ under otherwise difficult circumstances.

3.5.1.6 Hazardous Locations: Adjustment controls should not be located close to dangerous voltages, moving machinery, or any other hazards. If such location cannot be avoided, the controls shall be appropriately shielded and labeled

Rationale: All Ares I US LRU and critical equipment must be designed such that critical equipment adjustment and calibration is optimized and can be accomplished in situ under otherwise difficult circumstances.

3.5.2 Access

3.5.2.1 Access: Equipment items shall be so located and mounted that access to them can be achieved without danger to personnel from electrical, thermal, mechanical, chemical radiological, or other hazards.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety requirements, constraints, and design criteria for labels and markings for the ground-based one-g assembly and maintenance personnel.

3.5.2.2 Hazardous Access: Where access areas must be located over dangerous mechanical or electrical components, the access door or cover shall be designed to turn on an internal light when opened. A highly visible warning label shall be provided on the outside of the door or cover.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety requirements, constraints, and design criteria for labels and markings for the ground-based one-g assembly and maintenance personnel.

3.5.3 Markings

See x.x Labeling for all Safety labeling and marking requirements.

3.5.3.1 Safety Pins and Streamers: Safety pins and streamers shall be clearly visible during ground assembly and maintenance.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors safety requirements, constraints, and design criteria for labels and markings for the ground-based one-g assembly and maintenance personnel.

3.5.4 Mechanical Hazards

3.5.4.1 Latch or Catch Force: The latch or catch spring action or snap-down force shall not be so strong that it could injure the operator.

Rationale: Protection of flight and support equipment from damage or inadvertent operation provides a safe system and controls costs.

3.5.4.2 Ventilation openings: Ventilation openings within the reach envelope of operators shall preclude inadvertent insertion of foreign objects which might damage the contents or injure the crew.

Rationale: Ventilation openings are needed by some flight components. If these components are within the reach envelope of ground crew during performance of assembly and maintenance activities, they should be protected from accidental insertion of tools or body parts. Such insertion could pose a hazard to crew or to the hardware. Traces to CxP70024 3.9.3.1 [HS10027]

3.5.4.3 Access Item Retention: The element shall provide a means (e.g., hinges, tethers, etc.) to retain access covers, caps, and other structural parts clear of the worksite.

Rationale: This requirement establishes that the Ares I US will meet the human factors safety requirements for access item retention for the ground-based one-g assembly and maintenance personnel.

3.5.4.4 Interlocks and Alarms: The operation of switches or controls which initiate hazardous operations (e.g., ignition, movement of a crane, etc.) shall require the prior operation of a related or locking control. Where practicable, the critical position of such a control shall activate a visual and auditory warning device in the affected work area.

Rationale: This requirement establishes that the Ares I US will meet the human factors safety requirements for interlocks and alarms for the ground-based one-g assembly and maintenance personnel.

3.5.4.5 Guards: A guard shall be provided on all moving parts of machinery and transmission equipment, including pulleys, belts, gears, and blades, on which personnel may become injured or entangled.

Rationale: This requirement establishes that the Ares I US will meet the human factors safety requirements for guards for the ground-based one-g assembly and maintenance personnel.

3.5.4.6 Telescoping Ladders: Adequate finger clearance shall be provided between rungs of telescoping ladders.

Rationale: Protection of ground crew from injury controls operations costs. The requirement may be implemented through the provision of spacing between moving ladder surfaces.

3.5.5 Sharp Corners and Edges

3.5.5.1 Sharp Edges and Corners: The element shall protect operators against injury from sharp edges

Rationale: Protection of ground crew from injury controls operations costs. In those areas that ground crew would access for ground processing and maintenance, the design should protect them from sharp edges and corners. The intent of this requirement is for a design solution, not an operational solution, as the latter results in expensive recurring costs. An example of an operational solution is remove-before-flight protective structure. Examples of potential design solutions include flight structure that hides sharp edges or rounding edges and corners. Traces to CxP70024 3.9.3.2 [HS10030].

3.5.5.2 Rounding Sharp Edges and Corners: When rounding sharp edges and corners to protect crew, edges and corners shall be rounded to a radius not less than 0.75 mm (0.3 in). Sharp edges and corners that can present a personnel safety hazard or cause equipment damage during usage shall be suitably protected or rounded to a radius not less than 1.3 mm (0.05 in).

Rationale: Protection of ground crew from injury controls operations costs. Rounding corners and edges is one design option to control for sharp edges and corners. This traces to MIL-STD-1472, 5.13.5.4.

3.5.6 Electrical Hazards

3.5.6.1 Circuit Protection: An indication shall be provided to reveal that a fuse or resettable circuit protection device (e.g., circuit breaker) has opened a circuit.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs. Traces to CxP70024 3.9.7.5.1 [HS10010].

3.5.6.2 Fuse Accessibility: Fuses shall be readily accessible for removal and replacement.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.3 Fuse Access: No other components shall require removal in order to gain access to fuses.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.4 Special Tools: No special tools shall be required for fuse replacement unless required by safety considerations.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.5 Breakers: When resetting of circuit breakers is permissible, and is required for system operation during a mission, the breakers shall be located within reach of crew members in their normal operating posture.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.6 Emergency Shutdown: The element shall provide emergency shutdown capability for personnel protection.

Rationale: Emergency shutdown devices, lockable controls, electrical cut-out switches, or warning signs or guards should be positioned to ensure safety of operators when it is necessary to perform maintenance on or near a live/working system. Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.7 Insulation of Tools: Tools and test leads to be used near high voltages shall be adequately insulated.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.8 Plugs and Receptacles: Plugs and receptacle configurations shall preclude inserting a plug of one voltage rating into a receptacle of another rating.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.9 Voltage Exposure: All hot contacts shall be socket contacts.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.10 Dangerous Voltage or Current: Guards, grounding interlocks, and warning placards shall be provided to minimize exposing personnel to dangerous voltages or currents.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.11 Ground Potential: Equipment shall be designed so that all external parts, other than antennae and transmission line terminals, will be at ground potential.

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.6.12 Electrically Operated Hand Tools: Electrically operated hand-held power tools shall be designed with three-wire power cords with one wire at ground potential and shall have exposed surfaces which are either non-conducting or are electrically connected to the ground wire. (Portable tools, protected by an approved system of double insulation or its equivalent, may be used without a ground wire when approved by the procuring activity).

Rationale: Protection of a circuit from damage provides safe system operations and controls operations costs.

3.5.7 Touch Temperatures

3.5.7.1 Thermal Contact Hazards: Equipment which, in normal operation, exposes personnel to surface temperatures greater than those depicted in Table X or less than 0^{o}C (32^{o}F) shall be appropriately guarded.

Rationale: Ref MIL-STD-1472F, Table XXI.

3.5.7.2 Cryogenic systems: Cryogenic systems shall be guarded.

Rationale: Ref MIL-STD-1472F,

3.6 Interfaces

Interfaces are any part of the element or element support work areas through which contact is made or information is transferred between the operators and the element, whether by sight, sound or touch. A display is anything that provides information to crewmembers on a display device. A display device is the hardware that displays information to crewmembers. A control is anything that accepts ground crewmember commands or inputs, whether hardware or software. The requirements stated herein apply to all ground crew activities, with or without personnel protective equipment (PPE).

3.6.1 General Interfaces

3.6.1.1 Consistent Crew Interfaces: The element should provide ground crew interfaces that are consistent in appearance and operation across systems.

Rationale: The vehicle should provide ground crew interfaces that are consistent in appearance and operation across flight systems. Rationale: The intent of this statement is to ensure commonality and consistency across flight systems. This will facilitate learning and minimize interface-induced ground crew error. Traces to CxP70024 3.9.6.2 [HS10050].

3.6.1.2 Standardization: Controls, displays, markings, coding, labeling, and arrangement schemes (equipment and panel layout) shall be uniform for common functions of all equipment. Criterion for selecting off-the-shelf commercial or Government equipment shall be the degree to which the equipment conforms to this standard. Where off-the-shelf equipment requires

modification in order to interface with other equipment, the modification shall be designed to comply with the criteria herein.

Rationale: Per MIL-STD-1472F; Para. 4.2; Standardization

3.6.2 Display Lighting

3.6.2.1 Display Lights: Display lights shall be specified by Table VIII.

Rationale: Display lighting must be at levels and performance criterion that are best perceived by the human eye. Display lighting that is sub-optimal will increase task time and probability of errors. Ref.MIL-STD-1472F; Table XVI.

3.6.3 Color

3.6.3.1 Use of Color: The element should provide an additional cue to convey ground crew interface information when color is used to convey meaning.

Rationale: Redundant coding is required to accommodate the variability in people's capability to see color under different lighting conditions, and to increase the saliency of identification markings. Redundant cues can include labels, icons, and speech messages. Traces to CxP70024 3.9.6.5 [HS10053]

3.6.3.2 Color Deficient Vision: Where not in conflict with color codes specified herein, colors used for functional purposes (e.g., visual displays, controls, workspaces, equipment connections), shall accommodate users with color deficient vision, as defined by the controlling medical institution.

Rationale: Per MIL-STD-1472F; Para. 4.13; Functional Use of Color

3.6.3.3 Action Colors: Warm colors (those with longer wavelengths, such as red or orange) should be used to convey action or the requirement for a response.

Rationale: This requirement establishes that the Ares I US will meet the workstation and passageway human factors safety and logistics performance requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.6.3.4 Background Colors: Cool colors (those with shorter wavelengths, such as blue or green) should be used to convey status of background information.

Rationale: This requirement establishes that the Ares I US will meet the workstation and passageway human factors safety and logistics performance requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.6.3.5 Color Discriminability: To avoid mismatch of color and color association that can slow recognition time and increase errors, each color as defined below should represent only one category of displayed data.

a. Red (700nm)
b. Orange (600 nm)
c. Yellow (570 nm)
d. Yellow-green (535 nm)
e. Green (500 nm)
f. Blue-green (493 nm)
g. Blue (470 nm)

Rationale: This requirement establishes that the Ares I US will meet the workstation and passageway human factors safety and logistics performance requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel.

3.6.4 Labeling

3.6.4.1 General Labeling

3.6.4.1.1 General Labeling: The element shall provide labels in accordance with TBD Upper Stage Labeling document.

Rationale: The Ares I US hardware must be labeled to support accurate, efficient and safe ground processing and maintenance. TBD Upper Stage Labeling document will define labeling processes and requirements. Traces to CxP70024 3.9.6.1 [HS10039], 3.9.6.3 [HS10051], 3.9.6.4 [HS10052], 3.9.7.7.1 [HS10018], 3.9.3.3 [HS10033], 3.9.7.7.8 [HS10043], 3.9.7.2.2 [HS10017], 3.9.7.1.5 [HS10032], 3.9.7.1.4 [HS10031], 3.9.7.1.2 [HS10013].

3.7 System

This section includes requirements specific to the software or system design of the element and element components which have an impact for human factors and human performance. This section is not exhaustive; there may be requirements for avionics and software in other sections of this document including but not limited to the Safety section.

3.7.1 General System

3.7.1.1 Malfunction Identification: Equipment design shall facilitate rapid and positive fault detection and isolation of defective items to permit their prompt removal and replacement.

Rationale: Fault detection isolation is necessary in order to protect interfacing and surrounding equipment.

3.7.1.2 Automation. Automation in system and task design shall ensure that the human operator is in command, and automation is capable of being overridden by the operator.

Rationale: Per MIL-STD-1472F; Para. 4.12; Automation

3.8 Maintainability

This section contains requirements specific to the maintenance process or maintenance hardware or LRU's that have a human factors or human performance aspect. This section also includes requirements specific to any US-specific Ground Support structure or vehicles. This section is not exhaustive; there are requirements in other sections of this document applicable to the design of LRU's and maintenance operations.

3.8.1 General Maintainability

3.8.1.1 Modular Replacement: Equipment should be replaceable as modular packages and shall be configured for removal and replacement by one person where permitted by structural, functional, and weight limitations.

Rationale: Cost effective to package in modular form for maintenance operations and for personnel safety.

3.8.1.2 Equipment Interchangeability: Equipment (including LRU's) that are not interchangeable functionally shall not be interchangeable physically.

Rationale: While some equipment and LRU's may be used for the same function in multiple instances (e.g., redundant strings), many may be physically similar but functionally distinct. In such cases, installation in the wrong location could result in damage to the LRU or to the system into which it is inserted. This requirement is intended to preclude such installation in the wrong location. Traces to CxP70024 3.9.7.1.3 [HS10014].

3.8.1.3 LRU Independence: Element subsystems and LRU's shall be functionally, mechanically, electrically, and electronically independent in order to facilitate maintenance on one subsystem without affecting operation of another.

Rationale: All Ares I US subsystems and LRU's must be designed such that removal and replacement does not disable or deintegrate a functional, certified, and fully-tested component or system. Such disabling of a certified system results in costly retest and recertification.

3.8.1.4 LRU Removal and Replacement: A single maintenance activity (LRU removal and replacement) should be achievable by a single technician (CxP70024 TBR-006-061) within four hours (CxP70024 TBR-006-062) of direct technician labor.

Rationale: System designs should support efficient maintenance. Total maintenance time includes safing, access, removal, replacement, and restoration of original hardware configuration. Combining these task times should result in a maximum total allocated technician time of four hours. Traces to CxP70024 3.9.7.1.9 [HS8004].

3.8.1.5 Support Equipment: Accommodations shall be provided for placing or withdrawing removable support equipment (e.g., lights, tool boxes, etc.) for maintenance and/or assembly activities.

Rationale: Physical access and support for ground support equipment and ground personnel is necessary for vehicle launch preparation.

3.8.1.6 Use of Tools and Test Equipment: Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

Rationale: The LSI cost drives the need for a minimized tool list.

3.8.1.7 Appropriate Clothing: The element shall provide for assembly, launch site processing and maintenance by personnel wearing clothing and equipment appropriate to the environment during assembly and maintenance tasks.

Rationale: The flight system components/subsystems (CLV stages, CEV SM & CM, e.g.) must be assemblable and maintainable by the ground crew with sufficient work envelope and other accommodation to accomplish tasks, under the constraints demanded by the task. The constraints for some tasks will include the use of protective equipment. This protective equipment (e.g., SCAPE suits) may be bulky, and the design must accommodate this. Traces to CxP70024 3.9.7.6.3 [HS10011].

3.8.2 Operations without Disassembly

3.8.2.1 Assembly: The element shall be assembled by ground crew without the removal of any component of the element or subsystem, or without damage to any components, assemblies, utilities, or structure.

Rationale: The Ares I US integrated design shall be such that ground crew is able to mate the components as they arrive at the launch site. The intent is to preclude deintegration of the Ares I US or its subsystems, as such deintegration would constitute an extremely expensive,

recurring, addition to ground operating costs. This can only be accomplished through integrated design, so that the design of one subsystem does not force deintegration of the subsystem to which it mates. The same principle applies across element interfaces for assembly tasks.

3.8.2.2 LRU Replacement: The element shall allow removal and replacement of LRU's without requiring the removal or disabling of other LRU or other subsystems.

Rationale: All maintenance worksites must be designed such that removal and replacement does not disable or deintegrate a functional, certified, and fully-tested component or system. Such disabling of a certified system results in costly retest and recertification. Traces to CxP70024 3.9.7.1.8 [HS10054] and to 3.9.7.6.2 [HS10009].

3.8.2.3 Ground Maintenance: The element shall be maintainable by the ground crew in its assembled form, without the removal of any other flight components, with the exception of flight covers and hatches, or without damage to any components, assemblies, utilities, or structure, or without deintegration or demating of previously tested and certified interfaces.

Rationale: The Ares I US integrated design shall be such that ground crew is able to maintain the components and subsystems, in the integrated element state and orientation. The intent is to preclude deintegration of the elements or their subsystems during or after element assembly. Such deintegration would constitute an extremely expensive, recurring, addition to ground operating costs. This can only be accomplished through integrated design, so that the design of one subsystem does not force deintegration of the subsystem to which it is mated in order to affect maintenance on the integrated element. Traces to CxP70024 3.9.7.6.1 [HS10001] and 3.9.7.7.2 [HS10019].

3.8.2.4 Component/System Test: Component and system test shall be accomplished without the removal of flight components other than access covers and test point covers.

Rationale: All maintenance worksites must be designed such that removal and replacement for test purposes does not disable or deintegrate a functional, certified, and fully-tested component or system. Such disabling of a certified system results in costly retest and recertification.

3.8.3 Equipment Protection

3.8.3.1 LRU Protrusions: LRU protrusions capable of being used for handles by ground-support personnel shall support the LRU weight without LRU damage or deformation.

Rationale: All Ares I US LRU and critical equipment requiring lubrication must be designed to optimize the lubrication task without adversely affecting the hardware or

surrounding hardware or structure, and it shall not inadvertently provide a dangerous condition to the attending personnel. Traces to CxP70024 3.9.7.1.6 [HS10042].

3.8.3.2 Equipment Protection: The element should protect equipment susceptible to damage during launch site processing tasks.

Rationale: Components and LRU's which are susceptible to damage during assembly or maintenance activities should be protected from ground crew activities. Structural elements which might be utilized as supports should be either designed to support ground crew-induced loads or be protected in some manner. This includes protrusions that resemble handles or steps but which are not designed to be; use of such protrusions to support either the hardware or the ground crew represents a hazard to both the equipment and personnel. Traces to CxP70024 3.9.7.7.6 [HS10023]

3.8.3.3 Spillage Control: The element shall incorporate a means to control spillage and the release of gases and liquids during maintenance and launch processing.

Rationale: Lack of methods from controlling fluid leakage could lead to equipment damage or personnel injury. Traces to CxP70024 3.9.7.7.4 [HS10021].

3.8.3.4 Lifting Aids: All equipment in excess of 35 lb mass requiring operator handling shall have lifting equipment designed in accordance with NASA-STD-5005, Ground Support Equipment Requirements.

Rationale: Removable GSE handles may be used for positioning of items of any size.

3.8.3.5 Equipment Tethers: All tools, tool boxes and caddies, test equipment, and other GSE used in element assembly and/or maintenance shall be tethered or otherwise secured in a fashion that precludes contact with the flight vehicle except in the manner for which the item was intended. If use of the item is hindered by securing system, it may be removed for use.

Rationale: All support equipment must be restrained so as not to inadvertently impact the flight vehicle or other critical equipment in order to protect cost and schedule

3.8.4 Mounting Of Items Within Units

3.8.4.1 Stacking Avoidance: Parts should be mounted in an orderly array on a "two-dimensional" surface, rather than stacked (i.e., a lower layer should not support an upper layer) so subassemblies do not have to be removed to access other subassemblies within the equipment.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.4.2 Structural Members: Structural members or permanently installed equipment shall not visually or physically obstruct adjustment, servicing, and removal of replaceable equipment or other required maintenance tasks. Panels, cases, and covers removed to access equipment shall have the same access requirements as replaceable equipment. Mounting provisions shall be directly visible and physically accessible to the operators.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.4.3 Large Items: Large items which are difficult to remove shall be mounted so that they will not prevent convenient access to other items.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.4.4 Rear Access: Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate their full distance and remain in the open position without being supported by hand. Rear access shall also be provided to plug connectors for test points, soldering, and pin removal where connectors require such operations. Aircraft installed equipment shall be configured for one-sided access.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.4.5 Relative Accessibility: Mission critical items that require rapid maintenance shall be most accessible. When relative criticality is not a factor, items that require the most frequent access shall be most accessible.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.4.6 High Failure Rate: High-failure-rate items should be accessible for replacement without moving non-failed items.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.4.7 Skills: Access to items maintained by one technical specialty shall not require removal of items maintained by another technical specialty.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.4.8 Case and Cover Mounting: Cover or shield holes shall be large enough for mounting screw clearance without perfect case alignment.

Rationale: Ground personnel interface with flight hardware must be designed to optimize the access to the task site for safety and maintainability.

3.8.5 Ground Support Vehicles

3.8.5.1 Visual field: The operator shall have forward visibility through a lateral visual field of at least 180° and preferably 220°.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements and constraints for the ground-based one-g assembly and maintenance personnel. Ref MIL-STD-1472F 5.12.5.1.

3.8.5.2 Ground view: Support vehicle design should enable the operator, in the normal operating position, to view the ground at all distances beyond 3 m (10 ft) in front of the vehicle. When necessary, mirrors may be used to meet this requirement, if tactical requirements permit. Upward visibility shall extend to not less than 15° above the horizontal.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements for the ground-based one-g assembly and maintenance personnel. Ref MIL-STD-1472F 5.12.5.2

3.8.5.3 Rear view (vehicle): Side and rear enclosures should be designed to permit the operator to view the rear of the vehicle (directly or by use of mirrors) in order to observe the load and to facilitate trailer attachment and backing maneuvers.

Rationale: This recommendation establishes that the Ares I US will meet human factors windows and viewing preference for the ground-based one-g assembly and maintenance personnel. Ref MIL-STD-1472F 5.12.5.3

3.8.5.4 Rear view (road): A glare-proof, west-coast type and spotter-rearview mirror shall be provided on each side of the cab, located in such a manner as to afford the operator rearward vision from the normal operating position.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements and constraints for the ground-based one-g assembly and maintenance personnel. Ref MIL-STD-1472F 5.12.5.4

3.8.5.5 Glare: Visors or other means should be used to preclude performance degradation due to glare from external sources such as sunlight or headlights; however, windshields or other transparent areas through which high acuity vision is required not be tinted or colored.

Rationale: This requirement and recommendation establishes that the Ares I US should meet one of the human factors windows and viewing requirements and recommendations for glare when viewing by the ground-based one-g assembly and maintenance personnel. Ref MIL-STD-1472F 5.12.5.5.

3.8.5.6 Windshields and Windows: Transparent materials selected for windshields and windows shall be shatter-proof and shall neither distort nor obscure vision.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements and constraints for the ground-based one-g assembly and maintenance personnel. MIL-STD-1472F 5.12.5.6

3.8.5.7 Windshield Wipers and Washers: Windshield wipers and washers shall be provided. Blades shall return to the stored position when turned off. Provision shall be made for manual operation in event of power failure.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements and constraints for the ground-based one-g assembly and maintenance personnel. MIL-STD-1472F 5.12.5.7

3.8.5.8 Fork Lifts: The configuration of fork lift mechanisms and fork lift truck cabs shall permit the operator to have direct view of the tips of the forks in all typical modes of material loading and in all likely operator positions.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements and constraints for the ground-based one-g assembly and maintenance personnel. MIL-STD-1472F 5.12.5.8

3.8.5.9 Night operation: Indicators required by the vehicle operator during night operation shall be illuminated. The display luminance shall be adjustable from 0.1 to 3.5 cd/m2 (0.03) to 1.0 foot lamberts).

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements and constraints for the ground-based one-g assembly and maintenance personnel. MIL-STD-1472F

3.8.5.10 Lighting for dark adaptation: When light security is not a consideration and dark adaptation is required, low level white lighting (achromatic lighting with an intensity not greater than that of red/blue illumination) should be used.

Rationale: This requirement establishes that the Ares I US will meet one of the human factors windows and viewing requirements and constraints for the ground-based one-g assembly and maintenance personnel. MIL-STD-1472F 5.12.5.10

3.8.5.11 Vehicular Vibration: Unique element support vehicles shall be designed to control the transmission of whole body vibration to levels that will permit safe and effective operation and maintenance. Evaluation of support vehicle vibration and its possible effects on health, comfort, and perception, and motion sickness shall conform to ISO 2631; Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 1: General requirements.

Rationale: This requirement establishes that the Ares I US will meet the workstation human factors physiological and safety requirements, constraints, and design criteria for vehicle vibration for the ground-based one-g assembly and maintenance personnel.

4.0 VERIFICATION

Verification is required for each stated HFE requirement stated herein. Each 4.0 verification statement below is keyed to the corresponding 3.0 requirement in the previous section.

4.1 Architecture Verification

4.1.1 General Architecture Verification

4.1.1.1 External Service Points Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine the location of all service points and the arrangement of hardware and utilities behind it. Inspection of drawings shall verify that the external service points are within 60 degrees of the vehicle and the service structure. The verification shall be considered successful when the analysis and inspection demonstrate that external service points for launch pad operations are all located within 60 degrees, radially, of the plane between the vehicle and the service structure.

4.1.2 Operator Support Structure & Equipment Verification

4.1.2.1 Handholds and Footholds Verification: Verification shall be by analysis. An analysis shall be conducted to determine if handholds or footholds are needed to assist Ares I US assembly and maintenance personnel in climbing onto equipment or in performing intended tasks, and where they should be located. The verification shall be considered successful when the analysis indicates assembly and maintenance personnel have all needed handholds and footholds necessary to accomplish planned and unplanned tasks.

4.1.2.2 Removable Handhold/Platform Accommodations Verification: Verification shall be by inspection. Drawings shall be inspected for each fragile item. Verification shall be complete when it has been shown that accommodations are provided for placing or withdrawing removable personnel restraints (including handholds), and platforms as necessary to support ground operations. The verification shall be considered successful when the inspection shows that there are sufficient removable personnel restraints and platforms for guaranteeing safe passage and maneuverability for the ground personnel.

4.1.2.3 Passive Restraint Verification: Verification shall be by analysis and inspection. An analysis is required to determine all possible entrapment situations. An inspection of documentation and drawings shall be performed to determine that personnel restraints provide

safe and flexible restraint in all work situations. The verification shall be considered successful when the inspection shows that all restraints used at the worksite meet the requirement.

4.1.2.4 Portable Restraint Attachments Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that personnel restraints provide safe and flexible restraint in all work situations. The verification shall be considered successful when the inspection shows that all restraints used at the worksite meet the requirement.

4.1.3 Workstation Arrangement Verification

4.1.3.1 Work Station Layout Interference Verification: Not verifiable requirement.

4.1.3.2 Work Station Layout Sequential Operations Verification: Not a verifiable requirement. Design guideline.

4.1.4 Passageway and Pass-throughs Verification

4.1.4.1 Traffic Flow Verification: Verification shall be by analysis. The analysis shall examine all pathways and corridors within the Ares I US elements and its interfaces, for safe and efficient nominal and emergency passage. The analysis may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification will be complete when all assembly and maintenance personnel can quickly and efficiently traverse under nominal and emergency conditions.

4.1.4.2 Simultaneous Passage Verification: Verification shall be by analysis. The analysis shall examine all pathways and corridors within the Ares I US elements and its interfaces, for safe and efficient nominal and emergency passage by required two 95th percentile persons simultaneously. Verification will be complete when all assembly and maintenance personnel can quickly and efficiently traverse under nominal and emergency conditions.

4.1.4.3 Adequate Pathways Verification: This requirement will be verified by analysis and establishes that the Ares I US will meet the HFE passage requirements, constraints, and design criteria for the ground-based one-g assembly and maintenance personnel. The analysis may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations.

4.1.4.4 Entry and Exit Ways Verification: Verification shall be by analysis. The analysis shall examine all entry and exit ways within the Ares I US elements and its interfaces, for safe and efficient personnel passage within the 90th percentile constraint. Verification will be complete when all assembly and maintenance entry and exit ways will accommodate the 90th percentile responsible person.

4.1.4.5 Safe Exit Verification: Verification shall be by analysis. The analysis shall examine all entry and exit ways within the Ares I US elements and its interfaces, for safe and efficient emergency passage. The analysis may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification will be complete when all assembly and maintenance personnel can quickly and efficiently escape under emergency conditions.

4.1.4.6 Hatch Dimensions Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that all hatch forces are within the requirement limitations in all work situations. The verification shall be considered successful when the inspection determines that hatch dimensions are within the requirement limitations.

4.1.4.7 Whole-Body Access Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that all hatch dimensions are within the requirement limitations in all work situations, and that appropriate footing is provided for "step-down" through top-access hatches. The verification shall be considered successful when the inspection determines that hatch dimensions and footings are within the requirement limitations.

4.1.5 Stairs, Ladders, and Ramps Verification

4.1.5.1 Stair Safety Verification: Verification shall be by analysis and inspection. An analysis shall be performed from drawings, integration documentation, and operational procedures to locate stairs and to verify that they meet safe design practices, including proper surface treatments. An inspection shall verify that surface treatments are in place. Verification shall be considered successful when the analysis and inspection show that all stairs meet safety requirements and can be safely traversed by personnel.

4.1.6 Workstands, Platforms, and Scaffolding Verification

4.1.6.1 Locks Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine where needed self-locking and other fail-safe devices should be located, and which ones are appropriate for the human interface. An inspection of drawings and hardware shall be performed using data from drawings to determine that such fail-safe devices are properly located and positioned. The verification shall be considered successful when the

analysis and inspection show that adequate fail-safe devices are incorporated in the hardware design.

4.1.6.2 Handrails, Safety Bars, and Chains Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine where handrails, safety bars, and chains are needed and should be located, and what types are required for the human interface. An inspection of drawings and hardware shall be performed using data from drawings to determine that such fail-safe devices are properly located and positioned. The verification shall be considered successful when the analysis and inspection show that adequate fail-safe devices are incorporated in the hardware design.

4.1.6.3 Safety Mesh Verification: Verification shall be by inspection. An inspection of drawings and hardware shall be performed to determine that screen or safety mesh is properly located and positioned. The verification shall be considered successful when the inspection demonstrates show that adequate protection is on the underside of open gratings, platforms, or flooring surfaces.

4.1.6.4 High Center of Gravity Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine what equipment may be susceptible to tipping over due to high center of gravity; to determine the best type of restraint to prevent tipping, and to determine where to best display warning labeling. An inspection shall be performed using drawings to determine that anchors and/or outriggers are provided for stability, and that appropriate warning displays are properly provided. The verification shall be considered successful when the analysis and inspection show that adequate deterrents and warnings are provided.

4.2 Worksite Verification

4.2.1 General Worksite Verification

4.2.1.1 Worksite Dimensions Verification: Verification shall be by analysis. The analysis shall examine all ground assembly and maintenance tasks, as identified in the element assembly and maintenance Critical Task Analysis. Verification will be complete when all Ares I US worksite sizing meets the body size, functional reach limits, visual envelopes, and strength limits of the appropriate worker population.

4.2.2 Physical Access & Clearance Verification

4.2.2.1 Work Envelope Verification: Verification shall be by analysis. Verification will consist of worksite analysis to determine adequate personnel work envelope. Task analysis will

determine personnel work envelope assumptions and constraints and assess available work envelope. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the analysis demonstrates that an adequate personnel work envelope is provided for each worksite.

4.2.2.2 Physical Access Verification: Verification shall be by analysis. Worksite analysis will be performed using CAD models and human models that display physical access of the ground crew. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification shall be complete when physical access is demonstrated to be provided for all tasks associated with element assembly and maintenance.

4.2.2.3 Whole Body Access Verification: Verification shall be by analysis. A worksite analysis will be performed using CAD models and human models that display whole body access for the 95th percentile ground crew and access interfaces to assess whole body access at each worksite. Verification shall be complete when all tasks associated with element assembly and maintenance has been shown to be adequate whole body access for the assembly and maintenance personnel.

4.2.2.4 Multiple Operators Verification: Verification shall be by analysis. Worksite analysis will be performed using CAD models and human models that display physical access of the ground crew. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification shall be complete when physical access is demonstrated to be provided for all tasks associated with element assembly and maintenance.

4.2.2.5 Reach Envelope Verification: Verification shall be by analysis. Verification will consist of worksite analysis to determine adequate reach envelope. Task analysis will determine reach envelope assumptions and constraints and assess available work envelope. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the analysis demonstrates that adequate reach envelopes are provided for each worksite.

4.2.2.6 Provision for Access Openings Verification: An analysis shall be performed using engineering drawings and test results data. The verification shall be considered successful when the analysis and test data proves that the access openings for maintenance and assembly tasks will accommodate special clothing constraints for Ares I US.

4.2.2.7 Special Clothing Verification: An analysis shall be performed using engineering drawings and test results data. The verification shall be considered successful when the analysis and test data proves that the access openings for maintenance and assembly tasks will accommodate special clothing constraints for Ares I US.

4.2.2.8 Tool Access Dimensions Verification: An analysis shall be performed using equipment/installation drawings, maintenance procedures, maintainability analysis and test data to assess and validate tool access as required for mission support. The verification shall be considered successful when the analysis proves that tool access and tool clearances meet the requirement constraints herein.

4.2.2.9 Tool Clearance Verification: An analysis shall be performed using equipment/installation drawings, maintenance procedures, maintainability analysis and test data. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the analysis proves that utility line attachment/mounting length has been provided for maintenance.

4.2.2.10 Access Design Verification: Verification shall be by analysis. An analysis shall be conducted to determine that openings provided for access to interior equipment are located and sized to permit the required adjustment or handling and provide an adequate view of the item being manipulated. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the analysis shows all adjustment and handling can be accomplished with proper viewing.

4.2.2.11 Hand Access Verification: Verification shall be by analysis for the three sub-requirements. A worksite analysis will be performed using CAD models and human models that display hand access of the ground crew and access interfaces to assess hand access at each worksite. Verification shall be complete when all tasks associated with element assembly and maintenance has been shown to be adequate hand access for the assembly and maintenance personnel.

4.2.2.12 Cable Access Verification: Cable accessibility shall be verified by analysis. The maintenance and inspection task list will identify those cables requiring inspection. The analysis shall consist of an assessment of the visibility and reach access to cables for ground operations. The verification shall be considered successful when the analysis shows that the ground crew can gain access to all cables.

4.2.2.13 Equipment Item Interconnecting Devices Verification: An analysis shall be performed using equipment/installation drawings, maintenance procedures, maintainability analysis and test data. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware

implicated in relevant operations. The verification shall be considered successful when the analysis proves that utility line attachment/mounting length has been provided for maintenance.

4.2.3 Visual Access Verification

4.2.3.1 Visual Envelope Verification: Verification shall be by analysis. Worksite analysis will be performed using Computer Aided Design (CAD) models and human models that display field of view of the ground crew. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification shall be complete when all tasks associated with element assembly have been shown to be within the field of view of the crew.

4.2.3.2 Visual-Line-of-Sight Verification: Not a verifiable requirement. Design guideline.

4.2.3.3 Direct Access Verification: Verification shall be by analysis. Worksite analysis will be performed using CAD models and human models including visual cones. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification shall be complete when physical access is demonstrated to be provided for all tasks associated with element assembly and maintenance.

4.2.3.4 Inspection Access Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine where vehicle inspections are required and that inspection capability exists for ground personnel. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the inspection determines that vehicle element and components are accessible for inspection.

4.2.3.5 Visual Access Openings Verification: Verification shall be by analysis. Worksite analysis will be performed using CAD models and human models including visual cones. Verification shall be complete when visual access is demonstrated to be provided for all tasks associated with element assembly and maintenance.

4.2.3.6 Display Access: Display placement for tasks that could result in a hazard shall be verified by analysis. Task analysis shall determine which tasks require operator views of displays for successful task completion. Worksite analysis shall evaluate the position of the display while the task is being performed. The verification shall be considered successful when the analysis shows that all tasks requiring visual access to displays are within the field of view of the personnel performing the task.

4.2.3.7 Blind Screwdriver Adjustments Verification: Verification shall be by analysis. An analysis shall be conducted to determine in the design all potential screwdriver adjustments without visual access. The analysis will indicate that if any exist, mechanical guides are included in the design, along with limited screw travel. The verification shall be considered successful when the analysis shows all blind screwdriver adjustments have guides and limited thread travel.

4.2.4 Strength and Lifting Verification

4.2.4.1 LRU Weight Limit Verification: Verification shall be by analysis. The analysis shall determine the safe lifting weight per the NIOSH lifting equation for the LRU's identified in task analyses that require one person installation without ground support equipment. The verification shall be considered successful with the analysis shows that the identified LRU's do not exceed the safe lifting weight for one ground crewperson.

4.2.4.2 Strength Design Requirements Verification: Verification shall be by analysis and test. The analysis shall examine all ground assembly and maintenance tasks, as identified in the element assembly and maintenance Critical Task Analysis, for strength requirements as identified herein. Verification will be complete when human activities in all planned Ares I US worksites do not exceed nominal strength limits the manual horizontal push and pull forces values of Tables IV and V.

4.2.4.3 Push/pull forces Verification: Verification shall be by analysis and test. The analysis shall examine all ground assembly and maintenance tasks, as identified in the element assembly and maintenance Critical Task Analysis. Verification will be complete when all Ares I US worksites do not exceed the manual horizontal push and pull forces values of Table I or those given in Figure 1 using 5th percentile strength as a minimum.

4.2.4.4 Vertical Push and Pull Verification: Verification shall be by analysis and test. The analysis shall examine all ground assembly and maintenance tasks, as identified in the element assembly and maintenance Critical Task Analysis. Verification will be complete when all Ares I US worksite sizing meets the body size, functional reach limits, visual envelopes, and strength limits of the appropriate worker population.

4.2.4.5 Manual Torque Verification: Verification shall be by analysis. The analysis shall examine all ground assembly and maintenance tasks, as identified in task analyses. Verification will be complete when all assembly and maintenance tasks can be shown to be accomplishable without deintegration of components.

4.2.4.6 Grip Force Verification: Verification shall be by analysis and test. The analysis shall examine all grip force requirements for the Ares I US ground assembly and maintenance tasks, as identified in the element assembly and maintenance Critical Task Analysis. Verification will

be complete when all Ares I US worksites are proven not to exceed the manual grip forces values of Table I, or those given in Figure 1 using 5th percentile strength as a minimum.

4.2.4.7 Arm, Hand, Thumb-finger Strength Verification: Verification shall be by analysis and test. The analysis shall examine all ground assembly and maintenance tasks, as identified in the element assembly and maintenance Critical Task Analysis, for human arm, hand, and thumb-finger strength requirements and compare against the defined limits. Verification will be complete when all human arm, hand, and thumb-finger strength requirements are proven to be within the limit values of Table I or those given in Figure 1 using 5th percentile strength as a minimum.

4.2.4.8 Hatch Force Requirements Verification: Verification shall be by inspection and test. An inspection of documentation and drawings shall be performed to determine that all hatch forces are within the requirement limitations in all work situations. A test shall be administered to all hatches to validate they are within requirement limitations. The verification shall be considered successful when the inspection and test demonstrate that hatch forces are within the limitations.

4.3 Hardware Verification

4.3.1 General Hardware Verification

4.3.1.1 Worksite Standardization Verification: Not a verifiable requirement. Design guideline.

4.3.1.2 Hardware Installation Verification: Features to prevent incorrect hardware and LRU installation shall be verified by inspection. The inspection shall examine the hardware and LRU drawings and their interfaces to the vehicle for features which preclude incorrect installation. The verification shall be considered successful when the inspection shows that all hardware and LRUs have features to preclude incorrect installation

4.3.1.3 Similar Items Verification: Verification shall be by analysis. An analysis shall be conducted to determine that all similar items utilize common mounting design and orientation, and that physical interchangeability is not possible for items not functionally interchangeable. The verification shall be considered successful when the analysis shows similar items have common mounting designs and orientations, and that the design precludes the interchange of items which are not functionally interchangeable.

4.3.2 Cases Verification

4.3.2.1 Orientation Verification: Verification shall be by analysis. An analysis shall be conducted to determine that the proper orientation of an item within its case is obvious by design of the case or use of appropriate labels. The verification shall be considered successful when the analysis shows that the case is designed with obvious orientation of the encased item.

4.3.2.2 Removal Verification: Not a verifiable requirement. Design guideline.

4.3.2.3 Size Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that cases are sufficiently larger than the items they cover to facilitate installation and removal with little or no case manipulation. The verification shall be considered successful when the inspection shows when the items are easily removed or installed in their cases with little case manipulation.

4.3.2.4 Guides Verification: Verification shall be by analysis. An analysis shall be conducted to determine that guides, tracks, and stops are provided as necessary to facilitate handling and to prevent damage to equipment or injury to personnel. The verification shall be considered successful when the analysis shows that adequate guides, tracks, and stops are included in the design.

4.3.3 Covers Verification

4.3.3.1 Self-supporting Covers Verification: Verification shall be by analysis for "shall" requirements. An analysis shall be conducted to determine that hinged access covers that are not completely removable are self-supporting in the open position, and that covers in the open position shall not obstruct required visual or physical access to the equipment being maintained or to related equipment during maintenance. The verification shall be considered successful when the analysis shows that hinged access covers are self supporting and do not obstruct visual or physical access.

4.3.3.2 Securing of Covers Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to verify is obvious when a cover is not secured, even though it may be in place. The verification shall be considered successful when the inspection shows obvious lack of cover securing, even with the cover in place.

4.3.3.3 Instructions Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to verify that instructions shall be permanently displayed on the outside of the cover if a method of opening a cover is not obvious from the construction of the cover itself. Further, an inspection shall verify that panel instructions consist of simple symbols such as arrows or simple words such as "push" or "push and turn." The verification shall be considered successful when the inspection shows cover opening is obvious, utilizing simple instructions as defined herein.

4.3.3.4 Ventilation Holes Verification: Verification shall be by inspection. An inspection of CLV documentation and drawings shall be performed to verify that for those covers or shields requiring ventilation holes, the holes are small enough to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts.. The verification shall be considered successful when the inspection shows that it is impossible to inadvertently insert objects into ventilation holes of covers over high voltages or moving parts.

4.3.3.5 Orientation Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to verify removable access covers that require particular orientations are designed to prevent attachment in any other orientations. The verification shall be considered successful when the inspection shows that the panel can only be attached in one location.

4.3.3.6 Fasteners for Covers Verification: Not a verifiable requirement. Design guideline.

4.3.3.7 Opening Covers Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine what special hardware or special clothing the covers will have to accommodate. An inspection of Ares I US documentation and drawings shall be performed to determine that all access covers in the design are equipped with grasp areas or other means of opening the covers, including interfacing with special hardware or special clothing. The verification shall be considered successful when the analysis and inspection show that covers can be opened using grasp areas or other means, and can accommodate special hardware or clothing.

4.3.4 Controls Verification

4.3.4.1 Reference Scale for Adjustment Controls Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that an easily visible scale or other appropriate reference shall be provided for all adjustment controls. The verification shall be considered successful when the inspection shows that the scale or reference shall be readily visible without the aid of mirrors or flashlights.

4.3.4.2 Control Limits Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that all calibration or adjustment controls with limited degree of motion have mechanical stops which prevent damage as defined herein. The verification shall be considered successful when the inspection shows that all limited motion calibration or adjustment controls have mechanical stops sufficiently strong to prevent damage by a force or torque 100 times greater than the resistance to movement within the range of adjustment.

4.3.4.3 Power Supply Control Verification: Verification shall be by inspection. A drawing and hardware inspection shall show that equipment circuitry includes power supply control

switches are included in the design. Verification shall be considered successful when the inspection shows that there are power control switches at all needed locations.

4.3.4.4 Knob Adjustments Verification: Verification shall be by analysis. An analysis shall be conducted to determine the frequency of mechanical and electronic adjustments in the design and will take into consideration access, weight, and related considerations. The analysis shall indicate knobs included in the design for frequent (once a month or less) adjustment requirement. The verification shall be considered successful when the analysis shows that all frequent adjustments are accomplished with knobs versus screwdriver.

4.3.5 Tools Verification

4.3.5.1 Toolset Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine what tools are required to conduct ground-based one-g assembly and maintenance tasks. An inspection of Ares I US documentation and drawings shall be performed to determine that the proper tools from the Ground Task Tool List are identified for use. The verification shall be considered successful when the analysis and inspection show that the tools as defined in the Ground Task Tool List are the ones utilized to assembly and maintenance.

4.3.5.2 Special Tools Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine common hand tools are implemented to the greatest extent possible. The analysis shall also define the need for, and identify any special tools. An inspection of Ares I US documentation and drawings shall be performed to determine what common hand tools and any special hand tools are required. The verification shall be considered successful when the analysis and inspection identify all common and special hand tools.

4.3.5.3 Tool Grip Span Verification: Not a verifiable requirement. Design guideline.

4.3.6 Fasteners Verification

4.3.6.1 Minimize Needed Tools Verification Not a verifiable requirement. Design guideline.

4.3.6.2 Multiple Fastener Types Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine what types of fasteners are necessary in the design and that the requirement constraints are met. An inspection of Ares I US documentation and drawings shall be performed to determine that the requirement constraints are met in fabrication documentation. The verification shall be considered successful when the analysis and inspection show that the number and diversity of fasteners are minimized; that fastener location is obvious; that hand or finger tightened fasteners are utilized; and no non-standard tools are required for fasteners.

4.3.6.3 Non-Standard Tools Verification: Verification shall be by analysis and inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that all fasteners use standard tools.

4.3.6.4 Left-Hand Fasteners Verification: Verification shall be by inspection. A worksite inspection will be performed to verify that no left handed fasteners are included in the Ares I US design. Verification shall be complete when all worksites associated with element assembly and maintenance are proven to be devoid of left handed fasteners.

4.3.6.5 Captive Fasteners Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine where fasteners might fall and damage equipment or create difficult or hazardous removal problems. An inspection of Ares I US documentation and drawings shall be performed to determine the location of captive fasteners as defined by the analysis. The verification shall be considered successful when the analysis and inspection show that all potentially harmful fallen fasteners have been replaced by captive fasteners.

4.3.6.6 Hand-Operated Fasteners Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that hand-operated fasteners are used on maintenance-significant items unless loads, torque, strength, bonding, frequency of use requirements prohibit. The verification shall be considered successful when the inspection shows that all hand-operated fasteners are included for maintenance-significant equipment and support items.

4.3.6.7 Engagement Indication Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that latches and catches give clear visual indications that they are engaged. The inspection will verify that the spring action or snap-down force is not so strong that it could injure the operator. The verification shall be considered successful when the inspection shows that all latches have clear visual indications that they are closed and that the snap-down feature will not injure the operator.

4.3.6.8 Inadvertent Operation Verification: Latches and catches shall be located, positioned and/or designed to avoid inadvertent operation. Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that latches and catches give clear visual indications that they are engaged. The inspection will verify that the spring action or snap-down force is not so strong that it could injure the maintainer. The verification shall be considered successful when the inspection shows that all latches have clear visual indications that they are closed and that the snap-down feature will not injure the maintainer.

4.3.6.9 Captive and Lock Washers Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that captive washers and lock washers shall be used when loss would otherwise present a hazard to equipment or personnel when loss would otherwise present a hazard to equipment or personnel.

The verification shall be considered successful when the inspection shows that all captive washers and lock washers were utilized if they would otherwise offer a threat to equipment or personnel.

4.3.7 Connectors Verification

4.3.7.1 Connector Mating Protection Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that Ares I US connector design will prevent a plug from being inserted into an incorrect receptacle, and will preclude damage to the plug or receptacle resulting from such an attempted insertion. The verification shall be considered successful when the inspection shows that all connectors can be properly mated without damage to the mating pieces.

4.3.7.2 Connector Mismating Verification: Verification shall be analysis and inspection. The analysis shall identify which connector plugs might possibly be mated to which jacks and the cable lengths associated with each connector. The inspection shall review all drawings for the connector assemblies identified by the analysis that could be possibly mated. The verification shall be considered successful when the analysis and inspection show that connectors within the same physical location cannot be physically mismated.

4.3.7.3 Earth Ground Potential Verification: Verification shall be by analysis. A worksite analysis will be performed to demonstrate that the Ares I US element will permit its external parts, other than antennae and transmission line terminals, to be maintained at earth ground potential during ground processing. Verification shall be complete when the analysis demonstrates a safe equivalent earth ground potential exposed to ground-based personnel.

4.3.7.4 Isolation Valves Verification: Verification shall be analysis. Task analyses shall identify those systems containing pressurized fluids. The verification shall be considered successful when the analysis shows that all subsystems with pressured fluids that require ground crew intervention have isolation features

4.3.8 Component Lubrication Verification

4.3.8.1 Self-Lubricating Components Verification: Not a verifiable requirement. Design guideline.

4.3.8.2 Lubricant Application and Checking Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that equipment configuration permits lubrication and provides a capability of checking lubricant reservoir levels without disassembly, as required. The verification shall be considered successful when the inspection shows the lubrication concerns addressed herein are met.

4.3.8.3 Lubricant Type Limits Verification: Not a verifiable requirement. Design guideline.

4.3.8.4 Lubricant Points Verification: Not a verifiable requirement. Design guideline.

4.3.8.5 Extended Fittings Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that extended fittings are provided to lubricant points as required.

4.3.8.6 Service Point Quality Limits Verification: Not a verifiable requirement. Design guideline.

4.3.8.7 Lubrication Indication Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine a clear indication of lubricant service level.

4.3.8.8 Lube Fittings Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine fittings are sized to prevent coupling with improper servicing devices.

4.3.8.9 Lubricant Warning Indicator Verification: Not a verifiable requirement. Design guideline.

4.4 Environment Verification

4.4.1 Acoustics Verification

4.4.1.1 General Acoustics Verification: Verification shall be by analysis. An analysis shall be conducted to determine that the workarea acoustical environment will not cause personal injury, interfere with voice or any other communications, cause fatigue, or in any other way degrade system effectiveness. Verification shall be considered successful when the analysis demonstrates a safe acoustical environment in the hardware design.

4.4.1.2 Hazardous Noise Verification: Verification shall be by analysis. An analysis shall be conducted to determine noise levels from local and surrounding machinery and to demonstrate that they are safely within the constraints of allowable levels of MIL-STD-1474. The verification shall be considered successful when the analysis demonstrates acceptable levels of equipment noise.

4.4.1.3 Worksite Noise Verification: Verification shall be by analysis and test. An analysis shall be conducted to determine the workspace noise levels, and that levels fall within the limits

as defined in Figure 5. A test of the workspace with sound measuring equipment shall be conducted to validate sound levels. The verification shall be considered successful when the analysis and test demonstrate that the A-weighted sound level (dB(A))) or corresponding Speech Intelligibility Level (SIL) requirement is met in the hardware design.

4.4.1.4 General Workspace Verification: shall be by analysis. An analysis shall be conducted to determine sound levels for areas requiring occasional telephone use or direct communication at distances up to 1.5 m (5 ft). The verification shall be considered successful when the analysis demonstrates that the sound levels shall not exceed 75 dBA SIL in the workspace design.

4.4.1.5 Operational Areas Verification: Verification shall be by analysis. An analysis shall be conducted to determine sound levels for areas requiring frequent telephone use or occasional direct communication at distances up to 150 cm (5 ft). The verification shall be considered successful when the analysis demonstrates that the sound levels shall not exceed 65 dBA SIL in the workspace design.

4.4.1.6 Large Workspaces Verification: Verification shall be by analysis. An analysis shall be conducted to determine maximum sound levels for areas requiring no difficulty with telephone use or requiring occasional direct communication at distances up to 460 cm (15 ft). The verification shall be considered successful when the analysis demonstrates that the sound levels shall not exceed 55 dBA SIL in the workspace design.

4.4.1.7 Small Office Spaces/Special Areas Verification: Verification shall be by analysis. An analysis shall be conducted to determine sound levels for areas requiring no difficulty with direct communication. The verification shall be considered successful when the analysis demonstrates that the sound levels shall not exceed 45 dBA SIL in the workspace design.

4.4.1.8 Extreme Quiet Areas Verification: Verification shall be by analysis. An analysis shall be conducted to determine sound levels for areas requiring extreme quiet. The verification shall be considered successful when the analysis demonstrates that the sound levels shall not exceed 35 dBA SIL in the workspace design.

4.4.1.9 Ambient Noise Control Verification: Verification shall be by analysis. An analysis shall be conducted to determine sound levels for workspace or facility design and to determine how to minimize the ambient nose level via use of effective sound reduction or attenuation. The verification shall be considered successful when the analysis demonstrates that ambient noise levels meet the criteria of the subparagraphs herein.

4.4.1.10 Attenuation by Materials Verification: Verification shall be by analysis. An analysis shall be conducted to determine that a) acoustic materials with high sound-absorption coefficients are provided as necessary in the construction of floors, walls, and ceiling to provide the required sound control.

4.4.1.11 Reverberation Verification: Verification shall be by analysis. An analysis shall be conducted to determine that excessive reverberation in rooms and work stations is controlled.

4.4.1.12 Reduction of Reverberation Time Verification: Verification shall be by analysis. Where speech communication is a consideration, an analysis shall be conducted to determine that the acoustical treatment of facilities is sufficient to reduce reverberation time below the applicable limits defined in the requirement. The verification shall be considered successful when the analysis demonstrates that reverberation noise levels meet the criteria of the requirement.

4.4.2 Atmosphere Verification

TBD

4.4.3 Thermal Verification

TBD

4.4.4 Vibration and Acceleration Limits Verification

4.4.4.1 Equipment Vibration Verification: Verification shall be by analysis. The analysis shall determine that equipment oscillations shall not impair required manual control or visual performance where whole-body vibration of the human operator or parts of the body are not a factor. Verification will be considered successful when the design demonstrates that equipment oscillations do not impair required manual control or visual performance of the operator.

4.4.4.2 Performance Verification: Not a verifiable requirement. Design guideline.

4.4.4.3 Comfort Verification: Verification shall be by analysis. The analysis shall determine that where specific levels of comfort listed in ISO 2631-1, Annex C must be maintained, the applicable overall vibration RMS values indicated therein are not exceeded. Verification will be considered successful when the design demonstrates that equipment vibration supports comfort and permits safe and effective assembly and maintenance.

4.4.4.4 Building Vibration Verification: Not a verifiable requirement. Design guideline.

4.4.4.5 Acceleration Verification: Not a verifiable requirement. Design guideline.

4.4.4.6 Motion Sickness Verification: Verification shall be by analysis. The analysis shall determine that the weighted RMS acceleration in the z-axis (between 0.1 and 0.5 Hz) will be sufficiently low to preclude or minimize motion sickness as assessed by the methods and assessment guidance specified by HSIR. Verification will be considered successful when the

design demonstrates that motion sickness is properly controlled during assembly and maintenance activities.

4.4.5 Illumination Verification

4.4.5.1 Lighting Verification: Verification shall be analysis and test. An illumination analysis shall be performed using qualification data and illumination test measurements and lighting installation drawings to determine lighting needs. Illumination test measurements shall be taken as appropriate at primary work surface areas and worksite floor surfaces. The verification shall be considered successful when the analysis, with test input, shows that the general worksite illumination is as specified.

4.4.5.2 Levels Verification: Worksite general illumination shall be verified by analysis and test. An illumination analysis shall be performed using qualification data and illumination test measurements and lighting installation drawings. Illumination test measurements shall be taken at the primary work surface areas and 7620 mm (30 inches) above the worksite floor surface, equidistant for the fronts of the worksite surface(s) with surface doors closed. The verification shall be considered successful when the analysis, with test input, shows that the general worksite illumination is as specified.

4.4.5.3 Perceptible Flicker Verification: Verification shall be by analysis. An analysis shall be conducted to determine nondetectable flicker in the design.

4.4.5.4 Safety Illumination Verification: Verification shall be analysis and test. An illumination analysis shall be performed using qualification data and illumination test measurements and lighting installation drawings. Illumination test measurements shall be taken at the primary work surface areas and 7620 mm (30 inches) above the worksite floor surface, equidistant for the fronts of the worksite surface(s) with surface doors closed. The verification shall be considered successful when the analysis, with test input, shows that the general worksite illumination is as specified.

4.5 Safety Verification

4.5.1 General Safety Verification

4.5.1.1 Human Factors Safety Verification: Verification shall be by analysis. The analysis shall determine that the ground-based design is safe for the ground personnel, the flight hardware, and the ground-based support system. Verification will be considered successful when

the design demonstrates applicable system and personnel safety factors, including minimizing potential human error in the operation and maintenance of the system.

4.5.1.2 Alerting Device Verification: Verification shall be by analysis and inspection. An analysis shall be performed from drawings, integration documentation, and operational procedures to identify potential hazards and hazard alerting devices integrated into the design. An inspection shall define how and where the alerting devices are incorporated. Verification shall be considered successful when the analysis and inspection show that all hazards have some form of acceptable hazard-alerting capability.

4.5.1.3 System Safing Controls Verification: Verification shall be by analysis and inspection. An analysis shall be performed from drawings, integration documentation, and operational procedures to identify all safing needs in the design, and will identify the safing options which may be incorporated. An inspection shall define how and where the safing methods are incorporated. Verification shall be considered successful when the analysis and inspection show that the vehicle can be safed prior to maintenance.

4.5.1.4 Guarding Hazardous Conditions Verification: Verification shall be by analysis and inspection. An analysis is required to determine all hazards lurking behind access panels in the design. An inspection of Ares I US documentation and drawings shall be performed to determine any hazardous conditions which exist behind the access, and to verify that the physical barrier over the access is equipped with an interlock that will de-energize the hazardous equipment when the barrier is open or removed. An inspection of the case or cover shall ensure that both the presence of the hazard and the fact that an interlock exists is noted on the equipment case or cover such that it remains visible when the access is open. The verification shall be considered successful when the analysis and inspection shows that interlocks are incorporated that will de energize hazardous conditions and that the hazard and the presence of the interlock are noted are visible to the operator at all times.

4.5.1.5 Critical Controls Verification: Verification shall be by analysis. An analysis shall be conducted to assess the design to identify critical and sensitive adjustment controls. The analysis will verify that such controls have features to prevent inadvertent or accidental actuation, and that such controls cannot be inadvertently actuated by locking devices. The analysis shall verify that arm or hand stabilization is provided for controls exposed to disturbing vibrations. Verification shall be considered successful when the analysis shows that critical or sensitive adjustment controls can be safely adjusted.

4.5.1.6 Hazardous Locations Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that adjustment controls which are located close to dangerous voltages are appropriately shielded. The verification shall be considered successful when the inspection shows proper shielding of adjustment controls from dangerous voltages.

4.5.2 Access Verification

4.5.2.1 Access Verification: Verification shall be by analysis and inspection. An inspection shall be performed using data from drawings to identify equipment mounting locations. An analysis shall be conducted to prove that personnel are safe from electrical, thermal, mechanical, chemical, radiological, or other hazards. The analysis may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the analysis shows that relevant displays and controls are in place per specification.

4.5.2.2 Hazardous Access Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine dangerous mechanical and electrical components. An inspection shall be performed using data from drawings, to determine if illumination and/or labels are provided. The verification shall be considered successful when the analysis shows that adequate illumination and labeling is provided for protection from the dangerous components.

4.5.3 Markings Verification

4.5.3.1 Safety Pins and Streamers Verification: Verification shall be by inspection. A drawing and hardware inspection shall show that the required safety pins and streamers are properly located and installed. Verification shall be considered successful when the inspection shows that all safety pins and streamers have been properly installed and are highly visible to all personnel.

4.5.4 Mechanical Hazards Verification

4.5.4.1 Latch or Catch Force Verification: The latch or catch spring action or snap-down force shall not be so strong that it could injure the operator. Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that the spring action or snap-down force is not so strong that it could injure the operator. The verification shall be considered successful when the inspection shows that snap-down feature will not injure the operator.

4.5.4.2 Ventilation openings Verification: An analysis shall be performed using engineering drawings and test results data. The verification shall be considered successful when the analysis and test data proves that ventilation openings in the Ares I US preclude inadvertent insertion of foreign objects.

4.5.4.3 Access Item Retention Verification: An analysis shall be performed using engineering drawings and test results data. The verification shall be considered successful when the analysis and test data proves that the access items will not interfere with the planned maintenance task and are capable of being retained clear of the worksite working volume.

4.5.4.4 Interlocks and Alarms Verification: An analysis shall be performed using data from drawings, integration documentation, and operational procedures to identify hazardous operations and protective locking controls. The verification shall be considered successful when the analysis shows that relevant displays and controls are in place per specification.

4.5.4.5 Guards Verification: Verification shall be by inspection. An inspection of hardware shall be performed to determine that guards are provided on all moving parts of machinery and transmission equipment, including pulleys, belts, gears, and blades, on which personnel may become injured or entangled. The verification shall be considered successful when the inspection shows that guards are incorporated to ensure safe use of US equipment, prohibiting injury or entanglement.

4.5.4.6 Telescoping Ladders Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine which ladder models provide adequate finger clearance when properly used. An inspection of hardware shall be performed to determine that adequate finger clearance exists for ladder in use with Ares I US equipment. The verification shall be considered successful when the analysis and inspection show that personnel cannot jam fingers between rungs of telescoping ladders.

4.5.5 Sharp Corners and Edges Verification

4.5.5.1 Sharp Edges and Corners Verification: Verification shall be by analysis and inspection. A task analysis shall identify all equipment with which the ground crew will interact. The verification shall be considered successful when the inspection of shows that the identified areas have rounded edges or structure prevents access

4.5.5.2 Rounding Sharp Edges and Corners Verification: Verification shall be by inspection. A drawing and hardware inspection shall show that equipment and structures making up the worksite are rounded to a radius not less than 0.75 mm (0.3 in) and 1.3 mm (0.05 in) for edges offering a personal safety hazard. Verification shall be considered successful when the inspection shows that assembly or maintenance personnel are not exposed to sharp edges from the vehicle or Ground Support Equipment (GSE).

4.5.6 Electrical Hazards Verification

4.5.6.1 Circuit Protection Verification: Verification shall be by inspection. A drawing and hardware inspection shall show that equipment circuitry includes positive indication that a fuse or resettable circuit protection device has opened. Verification shall be considered successful when the inspection shows that there are positive indicators for open circuitry at all needed locations.

4.5.6.2 Fuse Accessibility Verification: Verification shall be by analysis. The analysis will include any of all of the following data: procedure data and documents, engineering drawings

and data, maintenance or operations analyses, CAD and human models. The analysis will identify locations of fuses requiring removal and replacement and show fuses are readily accessible to the operator:

4.5.6.3 Fuse Access Verification: Verification shall be by analysis. The analysis will include any of all of the following data: procedure data and documents, engineering drawings and data, maintenance or operations analyses, CAD and human models. The analyses will indicate that no other components have to be removed to gain access to fuses tat must be removed and replaced.

4.5.6.4 Special Tools Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine common hand tools are implemented to the greatest extent possible. The analysis shall also define the need for, and identify any special tools. An inspection of Ares I US documentation and drawings shall be performed to determine what common hand tools and any special hand tools are required. The verification shall be considered successful when the analysis and inspection identify all common and special hand tools.

4.5.6.5 Breakers Verification: An analysis shall determine instances and hardware that requires resetting of circuit breakers. The analysis shall determine that the breakers are located within reach of crew members in their normal operating posture.

4.5.6.6 Emergency Shutdown Verification: Verification shall be by analysis and inspection. An analysis shall determine all potential problem areas requiring potential emergency shutdown. It shall confirm that the design provides the capability. A drawing and hardware inspection shall show that the system includes emergency shutdown capability. Verification shall be considered successful when the analysis and inspection demonstrate that emergency shutdown exists at all needed locations.

4.5.6.7 Insulation of Tools Verification: Verification shall be by inspection. An inspection of hardware shall be performed using data from drawings to determine that tools and test leads used near high voltages provide adequate insulation to protect user personnel. The verification shall be considered successful when the inspection shows that adequate insulation is incorporated in the tool and test lead design.

4.5.6.8 Plugs and Receptacles Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine plug and receptacle layout and how to position them to prohibit improper plug insertion. An inspection of drawings shall be performed to determine that it is not possible to improperly insert plugs into receptacles. The verification shall be considered successful when the analysis and inspection show that plugs cannot be improperly inserted into receptacles within the immediate area.

4.5.6.9 Voltage Exposure Verification: An analysis shall be performed using data from drawings, integration documentation, and operational procedures to determine that the sockets provide the hot path until connectors are mated. The verification shall be considered successful

when the analysis shows that only the receptacles contain hot connections, thereby protecting the personnel against possible shock.

4.5.6.10 Dangerous Voltage or Current Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that guards, grounding interlocks, and warning placards are provided to minimize exposing personnel to dangerous voltages or currents. The verification shall be considered successful when the inspection shows that adequate guards, grounding interlocks, and warning placards are provided.

4.5.6.11 Ground Potential Verification: Verification shall be by analysis. A worksite analysis will be performed to demonstrate that the Ares I US element will permit its external parts, other than antennae and transmission line terminals, to be maintained at earth ground potential during ground processing. Verification shall be complete when the analysis demonstrates a safe equivalent earth ground potential exposed to ground-based personnel.

4.5.6.12 Electrically Operated Hand Tools Verification: Verification shall be by inspection. An inspection of hardware shall be performed to determine that electrically operated hand-held power tools have three-wire power cords with one wire at ground potential and have exposed surfaces which are either non-conducting or are electrically connected to the ground wire. The verification shall be considered successful when the inspection shows that the electrically operated hand-held power tools are safe for use on the Ares I vehicle.

4.5.7 Touch Temperatures Verification

4.5.7.1 Thermal Contact Hazards Verification: An analysis shall be performed using data from drawings, integration documentation, and operational procedures to determine that equipment which, in normal operation, exposes personnel to surface temperatures greater than those depicted in Table X or less than 0^{o}C (32^{o}F) is appropriately guarded. The verification shall be considered successful when the analysis shows that all equipment with unacceptable heat levels is appropriately guarded.

4.5.7.2 Cryogenic systems Verification: Verification shall be by inspection. Inspection of drawings shall indicate that cryogenic systems are guarded.

4.6 Interfaces Verification

4.6.1 General Interfaces Verification

4.6.1.1 Consistent Crew Interfaces Verification: Not a verifiable requirement. Design guideline.

4.6.1.2 Standardization: Controls, displays, markings, coding, labeling, and arrangement schemes (equipment and panel layout) shall be uniform for common functions of all equipment. Criterion for selecting off-the-shelf commercial or Government equipment shall be the degree to which the equipment conforms to this standard. Where off-the-shelf equipment requires modification in order to interface with other equipment, the modification shall be designed to comply with the criteria herein.

4.6.2 Display Lighting Verification

4.6.2.1 Display Lights Verification: Verification shall be analysis. An analysis of light levels emitted by displays shall be performed and compared to levels specified by Table VIII.

4.6.3 Color Verification

4.6.3.1 Use of Color Verification: Not a verifiable requirement. Design guideline.

4.6.3.2 Color Deficient Vision Verification: Verification shall be by analysis. The analysis shall assess the Ares I US ground-based design for potential opportunities when color should be used for functional purposes. The analysis will address conflicts with program color codes. Verification will be considered successful when the color design will accommodate users with color deficient vision, per the controlling medical institution.

4.6.3.3 Action Colors Verification: Not a verifiable requirement. Design guideline.

4.6.3.4 Background Colors Verification: Not a verifiable requirement. Design guideline.

4.6.3.5 Color Discriminability Verification: Not a verifiable requirement. Design guideline.

4.6.4 Labeling Verification

4.6.4.1 General Labeling Verification

4.6.4.1.1 General Labeling Verification: TBD

4.7 System Verification

4.7.1 General System Verification

4.7.1.1 Malfunction Identification Verification: Verification shall be by analysis. An analysis shall be conducted to determine equipment design facilitates rapid and positive fault detection and isolation of defective items. The verification shall be considered successful when the analysis demonstrates prompt removal and replacement of defective items based on rapid and positive fault detection and isolation of those items.

4.7.1.2 Automation Verification: Verification shall be by analysis. The analysis shall determine that the ground-based design ensures command and manual override capability. Verification will be considered successful when the design demonstrates that automated functions are shown to be under the command of the operator, and capable of being overridden by the operator.

4.8 Maintainability Verification

4.8.1 General Maintainability Verification

4.8.1.1 Modular Replacement Verification: Verification shall be by analysis. The analysis shall be conducted to determine that all Ares I US equipment is configured for removal and replacement by one person where permitted by structural, functional, and weight limitations. The verification shall be considered successful when the analysis confirms that no more than one person is required to remove or replace any one piece of equipment within the design constraints of the requirement.

4.8.1.2 Equipment Interchangeability Verification: Verification shall be by analysis. An analysis shall be conducted to determine that all similar items utilize common mounting design and orientation, and that physical interchangeability is not possible for items not functionally interchangeable. The verification shall be considered successful when the analysis shows similar items have common mounting designs and orientations, and that the design precludes the interchange of items which are not functionally interchangeable.

4.8.1.3 LRU Independence Verification: An analysis shall be performed using equipment/installation drawings, maintenance procedures, maintainability analysis and test data to assess and validate that Ares I US subsystems and LRU's are functionally, mechanically, electrically, and electronically independent in order to facilitate maintenance on one subsystem

without affecting operation of another. The verification shall be considered successful when the analysis proves that Ares I US subsystems and LRU's are fully independent.

4.8.1.4 LRU Removal and Replacement Verification: Not a verifiable requirement. Design guideline.

4.8.1.5 Support Equipment Verification: Verification shall be by inspection. Drawings shall be inspected for all support equipment. Verification shall be complete when it has been shown that accommodations shall be provided for placing or withdrawing removable support equipment (e.g., lights, tool boxes, etc.) for maintenance and/or assembly activities. The verification shall be considered successful when the inspection shows that there is sufficient support equipment for completing all maintenance and assembly by the ground personnel.

4.8.1.6 Use of Tools and Test Equipment Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine that there is sufficient space available for the defined test equipment and required tools. An inspection of Ares I US documentation and drawings shall be performed to determine that check points, adjustment points, test points, cables, connectors, and labels are accessible and visible during maintenance. The analysis may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the analysis and inspection show that testing can be accomplished without difficulty or hazard.

4.8.1.7 Appropriate Clothing Verification: Accommodation for ground crews wearing protective clothing and equipment shall be verified by analysis. The analysis shall consist of worksite analyses for each assembly task, as defined by the Vehicle Assembly Task Analysis. Task analysis shall identify those tasks which require protective equipment for assembly. Worksite analysis shall assess task feasibility under the constraints of protective equipment. The verification shall be considered successful when the analysis shows that tasks requiring protective clothing and/or equipment can be accommodated within the worksite.

4.8.2 Operations without Disassembly Verification

4.8.2.1 Assembly Verification: Verification shall be by analysis. The analysis shall examine all assembly tasks, as identified in the Vehicle Assembly Critical Task Analysis. The analysis may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification will be complete when all assembly tasks can be shown to be accomplishable without de-integration of components.

4.8.2.2 LRU Replacement Verification: Verification shall be by inspection. For each maintenance task, procedures shall be inspected for steps that call out impacts to adjacent subsystems. Additionally, drawings of adjacent subsystems shall be inspected for potential

impacts. A report will summarize the findings. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be complete when all maintenance tasks have been shown to not have impacts to other systems.

4.8.2.3 Ground Maintenance Verification: Verification shall be by analysis. The analysis shall examine all ground maintenance tasks, as identified in the element assembly and maintenance Critical Task Analysis. The analysis may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. Verification will be complete when all Ares I US worksite sizing meets the body size, functional reach limits, visual envelopes, and strength limits of the appropriate worker population.

4.8.2.4 Component/System Test Verification: Verification shall be by inspection. Drawings shall be inspected for each workstation requiring systems test interfaces. Verification shall be complete when it has been shown that component and system tests are accomplished without the removal of flight components other than access covers and test point covers.

4.8.3 Equipment Protection Verification

4.8.3.1 LRU Protrusions Verification: Verification shall be by analysis. An analysis shall be conducted to determine that the proper orientation of an item within its case is obvious by design of the case or use of appropriate labels. The verification shall be considered successful when the analysis shows that the case is designed with obvious orientation of the encased item.

4.8.3.2 Equipment Protection Verification: Not a verifiable requirement. Design guideline.

4.8.3.3 Spillage Control Verification: Verification shall be by analysis. A worksite analysis will be performed to demonstrate that Ares I US components and LRU's incorporate a means to control spillage and the release of gases during removal or replacement activities. Verification shall be complete when the analysis demonstrates that no spillage or release of gases can occur during removal or replacement activities.

4.8.3.4 Lifting Aids Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to determine all safety critical display needs and to define what types of safety critical displays should be used at each worksite.. An inspection of Ares I US documentation and drawings shall be performed to determine that displays for safety critical tasks are within the field of view of a single ground crewmember. The verification shall be considered successful when the analysis and inspection show that there is lifting equipment per NASA-STD-5005 for Ares I US equipment weighing over 35 lbs which must be handling during assembly and maintenance.

4.8.3.5 Equipment Tethers Verification: Verification shall be by analysis and inspection. Drawings shall be inspected to identify all tools, tool boxes and caddies, test equipment, and other GSE used in Ares I US element assembly and/or maintenance. Analysis shall identify where tethers are necessary to tether or otherwise secure the equipment in a fashion that precludes contact with the flight vehicle except in the manner for which the item was intended. Verification shall be complete when it has been shown that via tethers, no equipment can adversely impact the flight vehicle or critical support hardware.

4.8.4 Mounting Of Items Within Units Verification

4.8.4.1 Stacking Avoidance Verification: Not a verifiable requirement. Design guideline.

4.8.4.2 Structural Members Verification: Verification shall be by analysis and inspection. An analysis shall be conducted to verify that panels, cases and covers removed to access equipment meet the same access requirements, as stated in Section 2.4.1 and 2.8 as any replaceable equipment. An inspection of Ares I US documentation and drawings shall be performed to verify that no structural members or permanently installed equipment can visually or physically obstruct adjustment, servicing, or removal of replaceable equipment or other required maintenance tasks, and that mounting provisions are directly visible and physically accessible to the operators. The verification may be supported by demonstrations with volumetrically representative mockups, (whole or part-task) including volumetric mockups or visual indication of hardware implicated in relevant operations. The verification shall be considered successful when the analysis and inspection show that replaceable equipment and other maintenance tasks are not adversely affected by structural members or permanently installed equipment; that removable panels, cases, and covers meet access requirements; and that mounting provisions are directly visible and physically accessible to the operators.

4.8.4.3 Large Items Verification: Verification shall be by analysis. An analysis shall be conducted to determine that large, difficult to remove items shall not prevent convenient access to other items. The verification shall be considered successful when the analysis shows convenient access to items is possible, even in the presence of large, difficult to remove items.

4.8.4.4 Rear Access Verification: Verification shall be by analysis. An analysis shall be conducted to determine that sliding, rotating, or hinged equipment requiring rear access shall be free to open or rotate the full distance and remain in the open position without being supported by hand. Additionally, analysis shall verify that rear access is available to provide plugging of connectors for test points, soldering, and pin removal as required. Analysis will further verify one-sided access for aircraft installed equipment. The verification shall be considered successful when the analysis shows that tasks requiring rear access t equipment can be accomplished within the stated constraints.

4.8.4.5 Relative Accessibility Verification: Verification shall be by analysis. An analysis shall be conducted to verify that mission critical items requiring rapid maintenance are most

accessible; while items that require the most frequent access shall be most accessible, disregarding criticality. The verification shall be considered successful when the analysis shows that mission critical items requiring rapid maintenance are most accessible, followed by the most frequently accessed items are the most accessible when criticality is not a factor.

4.8.4.6 High Failure Rate Verification: Not a verifiable requirement. Design guideline.

4.8.4.7 Skills Verification: Verification shall be by analysis. An analysis shall be conducted to verify access to items maintained by one technical specialty do not require removal of items maintained by another technical specialty. The verification shall be considered successful when the analysis shows that items of one specialty do not adversely impact another specialty.

4.8.4.8 Case and Cover Mounting Verification: Verification shall be by inspection. An inspection of Ares I US documentation and drawings shall be performed to determine that cover or shield holes are large enough for mounting screw clearance without perfect case alignment. The verification shall be considered successful when the inspection shows that mounting screw clearance is adequate in covers and shields.

4.8.5 Ground Support Vehicles Verification

4.8.5.1 Visual Field Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that all worksites and support vehicles with forward viewing provide the viewing scope in all work situations. The verification shall be considered successful when the inspection determines that the field of view at a minimum is met.

4.8.5.2 Ground View Verification: Verification of the single requirement shall be by inspection. An inspection of documentation and drawings shall be performed to determine that all worksites and support vehicles provide at least the 15^{o} upward visibility in all work situations. The verification shall be considered successful when the inspection determines that at least the minimum field of view is met. The two recommendations are not verified, as they cannot be contractually imposed.

4.8.5.3 Rear view (vehicle) Verification: Not a verifiable requirement. Design guideline.

4.8.5.4 Rear view (road) Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that all support vehicles be provided with glare-proof, west-coast type and spotter-rearview mirrors on both sides of the vehicle. The verification shall be considered successful when the inspection determines that the mirrors are mounted on the support vehicle.

4.8.5.5 Glare Verification: Not a verifiable requirement. Design guideline.

4.8.5.6 Windshields and Windows Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that all windshields and windows of transparent material be shatter-proof, without either distorting or obscuring personnel vision. The verification shall be considered successful when the inspection determines that the transparent windows or windshields provide clear, undistorted, unobscured vision.

4.8.5.7 Windshield Wipers and Washers Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that operators have direct view of the tips of the forks in all typical modes of material loading and in all likely operator positions in all work situations. The verification shall be considered successful when the inspection determines that the tips are always in the field of view.

4.8.5.8 Fork Lifts Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that windshield wipers and washers are provided as determined necessary to perform the tasks per the Ares I US element assembly and maintenance Critical Task Analysis. The verification shall be considered successful when the inspection determines that the transparent windows or windshields provide clear, undistorted, unobscured vision.

4.8.5.9 Night Operation Verification: Verification shall be by inspection. An inspection of documentation and drawings shall be performed to determine that illuminated indicators are provided by the vehicle operator during night operation, and that display luminance is adjustable within the designated range of the requirement. The verification shall be considered successful when the inspection determines that indicators are illuminated, and displays are adjustable in intensity per the requirement range.

4.8.5.10 Lighting for Dark Adaptation Verification: Not a verifiable requirement. Design guideline.

4.8.5.11 Vehicular Vibration Verification: Verification shall be by analysis. The analysis shall determine that unique Ares I US support vehicles are designed to control the transmission of whole body vibration for safe and effective operation and maintenance, and shall conform to ISO 2631. Verification will be considered successful when the design demonstrates that equipment vibration permits safe and effective assembly and maintenance.

APPENDIX A TABLES & FIGURES

Table I. Horizontal Push and Pull Forces

Exertable Intermittently or for short periods of time (male personnel)

(MIL-STD-1472F Table XVIII)

HORIZONTAL FORCE	APPLIED WITH[2]	CONDITION (m=Coefficient of Friction)
100N (25 lb) push or pull	Both hands or one shoulder or the back	Low traction: $0.2 < \mu < 0.3$
200N (45 lb) push or pull	Both hands or one shoulder or the back	Medium traction: $\mu \sim 0.6$
250N (55 lb) push or pull	One hand	If braced against a vertical wall 51-152 cm (20-60 in) from and parallel to the push panel
300N (70 lb) push or pull	Both hands or one shoulder or the back	High traction: $\mu > 0.9$
500N (110 lb) push or pull	Both hands or one shoulder or the back	If braced against a vertical wall 51-178 cm (20-70 in) from and parallel to the panel or if anchoring the feet on a perfectly nonslip ground (like a footrest)
750N (165 lb) push or pull	The back	If braced against a vertical wall 51-178 cm (20-70 in) from and parallel to the panel or if anchoring the feet on a perfectly nonslip ground (like a footrest)

[1] May be doubled for two and tripled for three operators pushing simultaneously. For a fourth and each additional operator, not more than 75% of their push capability should be added.

2 See Figure **1** for examples.

NOTES:

1. Values are predicated upon a suitable surface for force exertion, i.e., a vertical, rough surface, approximately 40 cm (16 in) wide, and 510 – 127 cm (20 – 50 in) above the floor to allow force application with the hands, the shoulder, or the back.
2. Where applicable, force requirements, should be modified for females (Two thirds of each values shown is considered to be a reasonable adjustment.)

Table II. Static Muscle Strength

(MIL-STD-1472F Table XIX)

Strength Measurements (see Figure XX)	Percentile Value in Newtons (Pounds)			
	5th Percentile		95th Percentile	
	Men	Women	Men	Women
A Standing two-handed pull: 38 cm level				
Mean Force	738 (166)	331 (74)	1354 (304)	818 (184)
Peak Force	845 (190)	397 (89)	1437 (323)	888 (200)
B Standing two-handed pull: 50 cm level				
Mean Force	758 (170)	326(73)	1342 (302)	841 (189)
Peak Force	831 (187)	374 (84)	1442 (324)	905 (203)
C Standing two-handed pull: 100 cm level				
Mean Force	444 (100)	185 (42)	921 (209)	443 (100)
Peak Force	504 (113)	218 (49)	988 (222)	493 (111)
D Standing two-handed push: 150 cm level				
Mean Force	409 (42)	153 (34)	1017 (229)	380 (85)
Peak Force	473 (106)	188 (42)	1094 (246)	430 (97)
E Standing one-handed pull: 100 cm level				
Mean Force	215 (48)	103 (23)	628 (141)	284 (64)
Peak Force	259 (58)	132 (30)	724 (163)	322 (72)
F Seated one-handed pull: Centerline, 45 cm level				
Mean Force	227 (51)	106 (24)	678 (152)	392 (88)
Peak Force	273 (61)	126 (29)	758 (170)	451 (101)
G Seated one-handed pull: Side, 45 cm level				
Mean Force	240 (54)	109 (25)	604 (136)	337 (76)
Peak Force	273 (61)	134 (30)	659 (148)	395 (89)
H Seated two-handed pull: Centerline, 38 cm level				
Mean Force	595 (134)	242 (54)	1221 (274)	770 (173)
Peak Force	699 (157)	285 (64)	1324 (298)	842 (189)
I Seated two-handed pull: Centerline, 50 cm level				
Mean Force	525 (118)	204 (46)	1052 (237)	632 (142)
Peak Force	596 (134)	237 (53)	1189 (267)	697 (157)

Table III. Torque, Rotation, and Grip Values

(MSFC-STD-512A, Table 2.5-14)

Hand Torque, Rotation, and Grip Strength Values		Unpressurized Suit, Bare Handed		Unpressurized Suit and Glove		Suit and Gloves Pressurized	
		Mean	SD	Mean	SD	Mean	SD
	Maximum Rotation: Supination, deg	221.7	33.0	188.5	35.0	120.2	27.3
	Maximum Rotation: Pronation, deg	157.8	28.8	128.5	28.2	78.3	20.4
	Grip Strength N (lb)	470.6 (105.8)	84.1 (18.9)	351.4 (79.0)	62.7 (14.1)	295.8 (66.5)	46.7 (10.5)
	Maximum Torque: Supination, Nm (lb-in)	13.73 (121.5)	3.41 (30.1)	13.49 (119.4)	2.84 (25.1)	10.83 (95.9)	3.28 (29.0)
	Maximum Torque: Pronation, Nm (lb-in)	17.39 (153.9)	5.08 (45.0)	18.25 (161.5)	5.38 (47.6)	17.09 (151.3)	5.54 (49.9)

Table VII. Specific Task Illumination Requirements

(MIL-STD-1472F; Tables XV)

Illumination Levels		
	lux (foot-candles)[1]	
Work area of type of task	Recommended	Minimum
Assembly, missile component	1075 (100)	1075 (100)
Assembly, general		
Coarse	540 (50)	325 (30)
Medium	810 (75)	540 (50)
Fine	1075 (100)	810 (75)
Precise	3230 (300)	2155 (200)
Bench work		
Rough	540 (50)	325 (30)
Medium	810 (75)	540 (50)
Fine	1615 (150)	1075 (100)
extra fine	3230 (300)	2155 (200)
Bomb shelters and mobile shelters, when used for rest and relief	20 (2)	10 (1)
Business machine operation (calculator, digital input, etc.)	1075 (100)	540 (50)
Console surface	540 (50)	325 (30)
Corridors	215 (20)	110 (10)
Circuit diagram	1075 (100)	540 (50)
Dials	540 (50)	325 (30)
Electrical equipment testing	540 (50)	325 (30)
Emergency lighting	NA	30 (3)
Gages	540 (50)	325 (30)
Hallways	215 (20)	110 (10)
Inspection tasks, general		
Rough	540 (50)	325 (30)
Medium	1075 (100)	540 (50)
Fine	2155 (200)	1075 (100)

extra fine	3230 (300)	2155 (200)
Machine operation, automatic	540 (50)	325 (30)
Meters	540 (50)	325 (30)
Missiles:		
repair and servicing	1075 (100)	540 (50)
storage areas	215 (20)	110 (10)
general inspection	540 (50)	325 (30)
Office work, general	755 (70)	540 (50)
Ordinary seeing tasks	540 (50)	325 (30)
Panels:		
Front	540 (50)	325 (30)
Rear	325 (30)	110 (10)
Passageways	215 (20)	110 (10)
Reading:		
newsprint	325 (30)	110 (10)
large print	540 (50)	325 (30)
handwritten reports, in pencil	755 (70)	540 (50)
small type	755 (70)	540 (50)
prolonged reading	755 (70)	540 (50)
Recording	755 (70)	540 (50)
Repair work:		
General	540 (50)	325 (30)
Instrument	2155 (200)	1075 (100)
Scales	540 (50)	325 (30)
Screw fastening	540 (50)	325 (30)
Service areas, general:	215 (20)	110 (10)
Stairways	215 (20)	110 (10)
Storage:		
inactive or dead	55 (5)	30 (3)

general warehouse	110 (10)	55 (5)
live, rough or bulk	110 (10)	55 (5)
live, medium	325 (30)	215 (20)
live, fine	540 (50)	325 (30)
Switchboards	540 (50)	325 (30)
Tanks, containers	215 (20)	110 (10)
Testing:		
Rough	540 (50)	325 (30)
Fine	1075 (100)	540 (50)
extra fine	2155 (200)	1075 (100)
Transcribing and tabulation	1075 (100)	540 (50)

[1] As measured at the task object or 76 cm (30 in) above the floor.
Note: As a guide in determining illumination requirements the use of a steel scale with 1/64 inch divisions requires 1950 lux (180 foot-candles) of light for optimum visibility.

Table VIII. Display Lighting

(MIL-STD-1472F; Table XVI)

Condition of Use	Lighting Technique[1]	Brightness of Markings cd/m^2 (foot lamberts)	Brightness Adjustment
Indicator reading, dark adaptation necessary	Red flood, indirect, or both, with operator choice	0.07-0.35 (0.02-0.1)	Continuous throughout range
Indicator reading, dark adaptation not necessary but desirable	Red or low-color-temperature white flood, indirect, or both, with operator choice	0.07-3.5 (0.02-1.0)	Continuous throughout range
Indicator reading, dark adaptation not necessary	White Flood	3.5-70 (1-20)	Fixed or continuous
Panel monitoring, dark adaptation necessary	Red edge lighting, red or white flood, or both, with operator choice	0.07-0.35 (0.02-0.1)	Continuous throughout range
Panel monitoring, dark adaptation not necessary	White Flood	35-70 (10-20)	Fixed or continuous
Possible exposure to bright flashes, restricted daylight	White Flood	35-70 (10-20)	Fixed
Chart reading, dark adaptation necessary	Red or white flood with operator choice	0.35-3.50 (0.1-1.0)	Continuous throughout range
Chart reading, dark adaptation not necessary	White Flood	17-70 (5-20)	Fixed or continuous

[1] Where detection of objects by image intensifier night vision devices must be minimized, blue-green light (incandescent filament through a filter which passes only wave lengths shorter the 600nm) should be used in lieu of red light.

Table IX. Simultaneous Passage in Pathways and Corridors

(HSIR Table 3.7.1-2)

	Light Clothing	Protective Gear
Major Corridor	TBD	TBD
Restricted Pathway	183 cm (72 in) high X 81 cm (32 in) wide	183 cm (72 in) high X 152 cm (60 in) wide

Table X. Temperature Exposure Limits

(MIL-STD-1472F; Table XXI)

	TEMPERATURE LIMITS		
EXPOSURE	Metal	Glass	Plastic or Wood
Momentary Contact	60°C (140°F)	68°C (154°F)	85°C (185°F)
Prolonged Contact or Handling	49°C (120°F)	59°C (138°F)	69°C (156°F)

Table XI. Workspace Acoustical Noise Limits

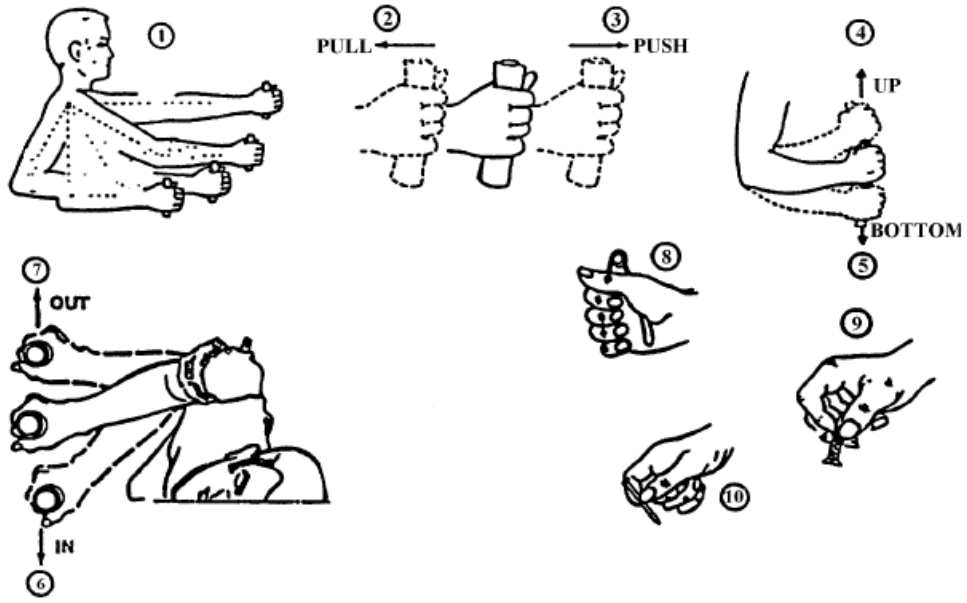
(MIL-STD-1472F; 5.8.3.3.1 through 5.8.3.3.6)

LOCATION	TASKS	LIMIT (shall not exceed)
General Workspace	Occasional telephone use; Occasional direct communication up to 1.5 m (5 ft)	75 dBA SIL
Operational Areas	Frequent telephone use; Occasional direct communication up to 1.5 m (5 ft)	65 dBA SIL
Large Workspaces	No difficulty w/telephone; Occasional direct communication up to 460 cm (15 ft)	55 dBA SIL
Small Office/Special Area	No difficulty w/direct communication	45 dBA SIL
Extreme Quiet Areas	Requires extreme quiet	35 dBA SIL

Table XII. Intelligibility Criteria for Voice Communication Systems

(MIL-STD-1472F, Table VI; paragraph 5.3.14).

COMMUNICATION REQUIREMENT	SCORE		
	PB	MRT	AI[1]
Exceptionally high intelligibility; separate syllables understood	90%	97%	0.7
Normal acceptable intelligibility; about 98% of sentence correctly heard; single digits understood	75%	91%	0.5
Minimally acceptable intelligibility; limited standardized phrases understood; about 90% sentences correctly heard (not acceptable for operational equipment)	43%	75%	0.3



ARM STRENGTH (N)												
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L*	R*	L	R	L	R	L	R	L	R	L	R
180	222	231	187	222	40	62	58	76	58	89	36	62
150	187	249	133	187	67	80	80	89	67	89	36	67
120	151	187	116	160	76	107	93	116	89	98	45	67
90	142	165	98	160	76	89	93	116	71	80	45	71
60	116	107	98	151	67	89	80	89	76	89	53	76

HAND, AND THUMB-FINGER STRENGTH (N)				
	(8)		(9)	(10)
	HAND GRIP			
	L	R	THUMB-FINGER GRIP (PALMER)	THUMB-FINGER GRIP (TIPS)
MOMENTARY HOLD	250	260	60	60
SUSTAINED HOLD	145	155	35	35

*L = Left; R = Right

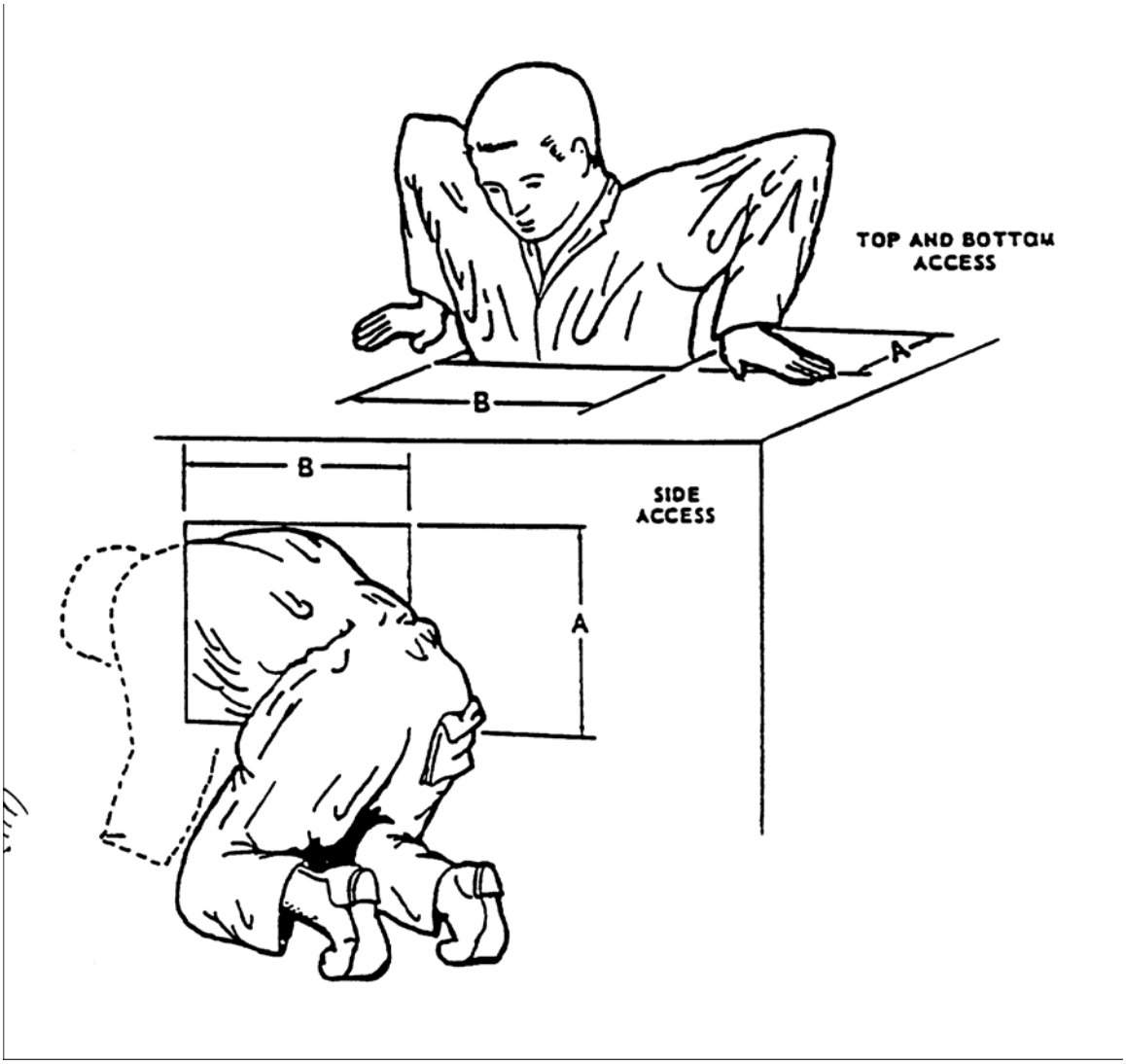
Figure 1. Arm, Hand and Thumb-Finger Strength
5th percentile male data

(MIL-STD-1472F Figure 23)

	Bare handed	
	Mean	SD
Maximum torque: Suppination Nm (lb-in)	13.73 (121.5)	3.41 (30.1)
Maximum torque: Pronation Nm (lb-in)	17.39 (153.9)	5.08 (45.0)

Figure 2. Manual Torque

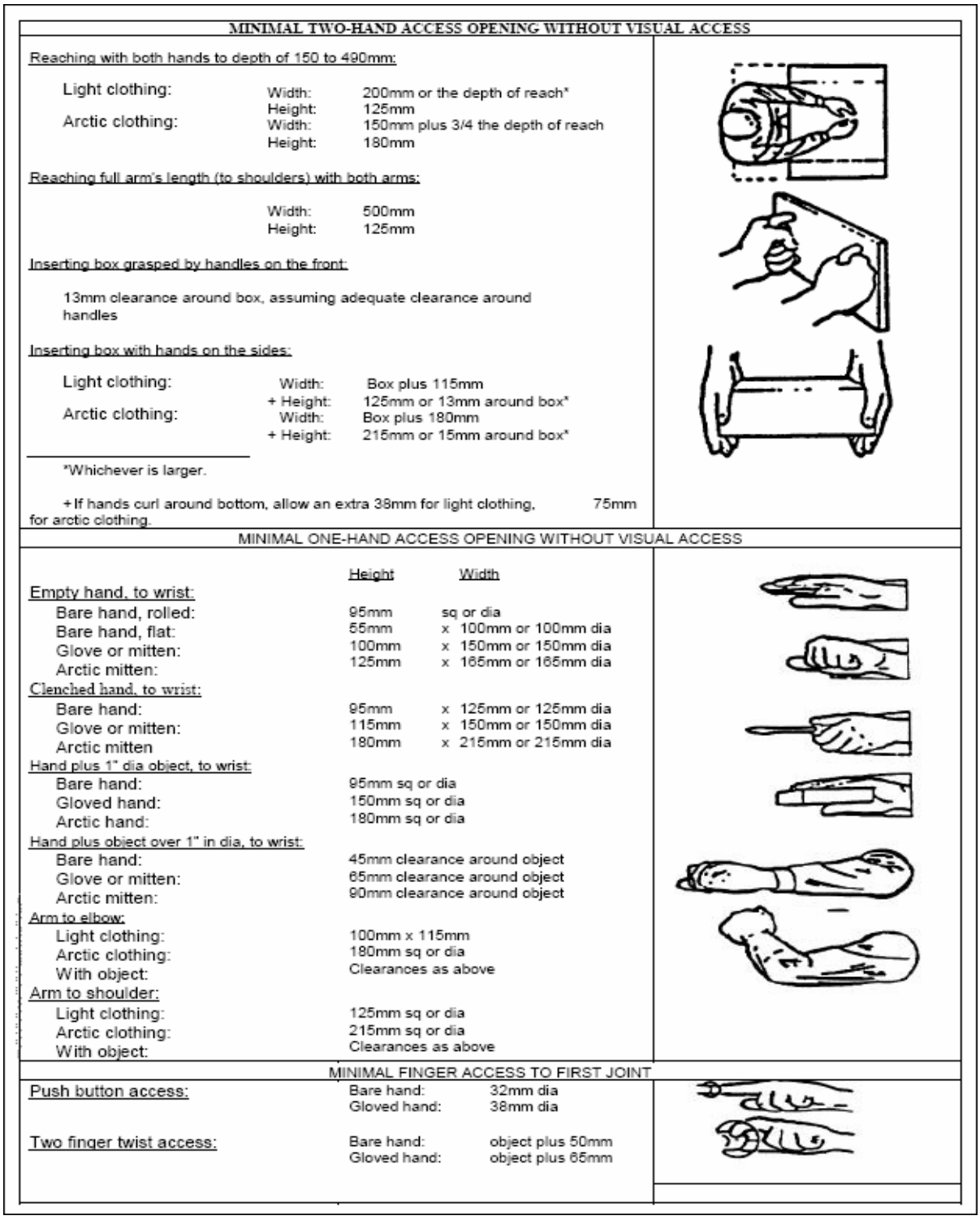
(SSP 50005B, International Space Station Flight Crew Integration Standard)



DIMENSIONS	A. DEPTH		B. WIDTH	
CLOTHING	LIGHT	BULKY	LIGHT	BULKY
TOP AND BOTTOM ACCESS	330 mm (13 in.)	410 mm (16 in.)	580 mm (23 in.)	690 mm (27 in.)
SIDE ACCESS	660 mm (26 in.)	740 mm (29 in.)	760 mm (30 in.)	860 mm (34 in.)
NOTE: DIMENSIONS SHOWN BASED ON MALE DATA.				

Figure 3. Whole Body Access Opening

(MIL-STD-1472F Figure 33)



MINIMAL TWO-HAND ACCESS OPENING WITHOUT VISUAL ACCESS

Reaching with both hands to depth of 150 to 490mm:

Light clothing:	Width:	200mm or the depth of reach*
	Height:	125mm
Arctic clothing:	Width:	150mm plus 3/4 the depth of reach
	Height:	180mm

Reaching full arm's length (to shoulders) with both arms:

Width:	500mm
Height:	125mm

Inserting box grasped by handles on the front:

13mm clearance around box, assuming adequate clearance around handles

Inserting box with hands on the sides:

Light clothing:	Width:	Box plus 115mm
	+ Height:	125mm or 13mm around box*
Arctic clothing:	Width:	Box plus 180mm
	+ Height:	215mm or 15mm around box*

*Whichever is larger.

+ If hands curl around bottom, allow an extra 38mm for light clothing, 75mm for arctic clothing.

MINIMAL ONE-HAND ACCESS OPENING WITHOUT VISUAL ACCESS

	Height	Width
Empty hand, to wrist:		
Bare hand, rolled:	95mm	sq or dia
Bare hand, flat:	55mm	x 100mm or 100mm dia
Glove or mitten:	100mm	x 150mm or 150mm dia
Arctic mitten:	125mm	x 165mm or 165mm dia
Clenched hand, to wrist:		
Bare hand:	95mm	x 125mm or 125mm dia
Glove or mitten:	115mm	x 150mm or 150mm dia
Arctic mitten	180mm	x 215mm or 215mm dia
Hand plus 1" dia object, to wrist:		
Bare hand:	95mm sq or dia	
Gloved hand:	150mm sq or dia	
Arctic hand:	180mm sq or dia	
Hand plus object over 1" in dia, to wrist:		
Bare hand:	45mm clearance around object	
Glove or mitten:	65mm clearance around object	
Arctic mitten:	90mm clearance around object	
Arm to elbow:		
Light clothing:	100mm x 115mm	
Arctic clothing:	180mm sq or dia	
With object:	Clearances as above	
Arm to shoulder:		
Light clothing:	125mm sq or dia	
Arctic clothing:	215mm sq or dia	
With object:	Clearances as above	

MINIMAL FINGER ACCESS TO FIRST JOINT

Push button access:	Bare hand:	32mm dia
	Gloved hand:	38mm dia
Two finger twist access:	Bare hand:	object plus 50mm
	Gloved hand:	object plus 65mm

Figure 4, Arm and Hand Access Dimensions

(MIL-STD-1472F Figure 39)

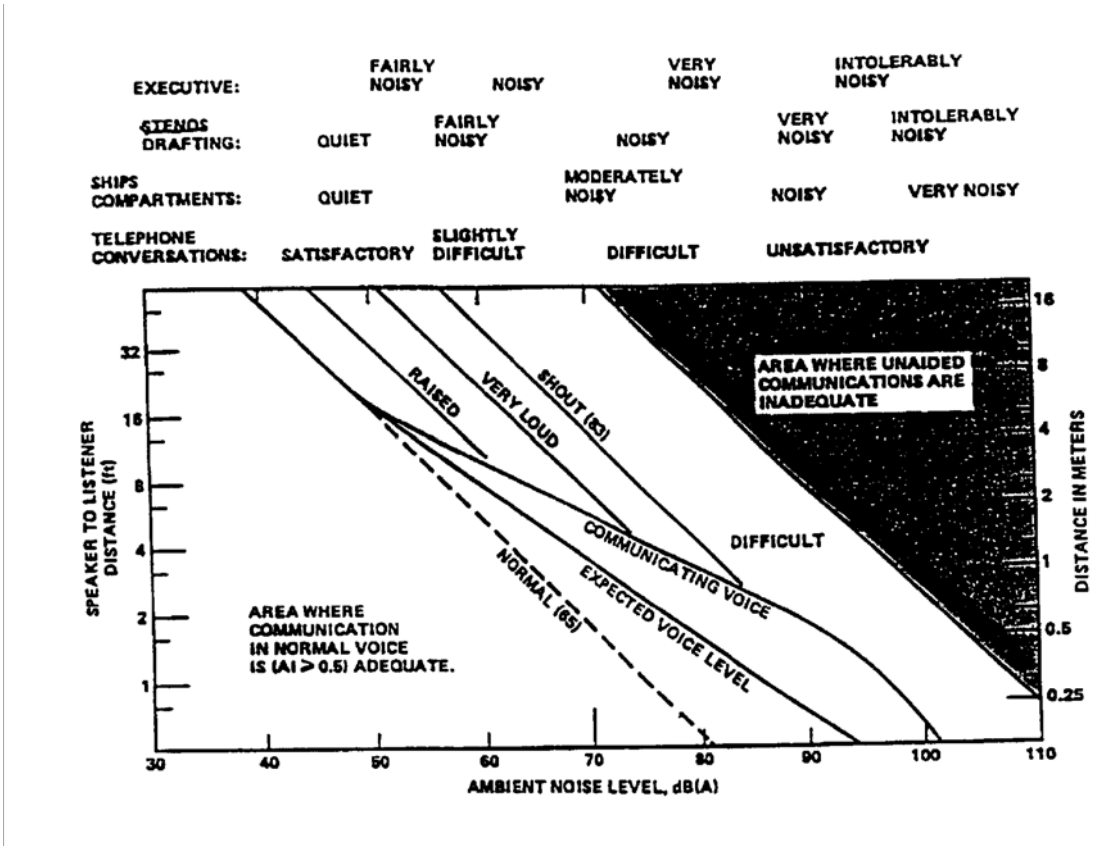


Figure 5. Permissible between a Speaker and Listeners for Specified Voice Levels and Ambient Noise Levels

(MIL-STD-1472F; Figure 37)

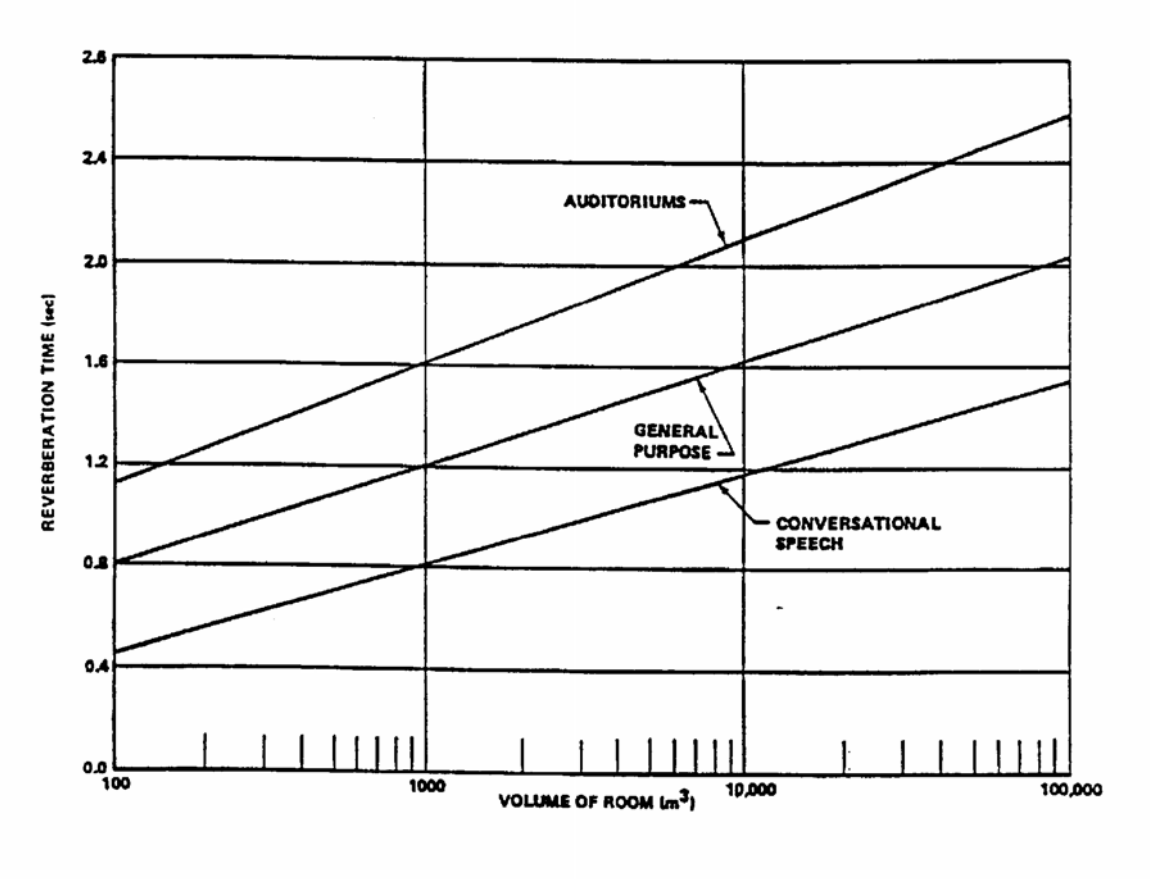


Figure 6. Range of Acceptable Reverberation Time

(MIL-STD-1472F, Figure 38)

APPENDIX B ACRONYM LIST

CARD	CXP-00001; Constellation Architecture Requirements Document
CAD	Computer Aided Design
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
dB(A)	decibel; A-weighted sound level
DDT&E	Design, Development, Test, and Evaluation
ERD	Element Requirements Document
ESMD	Exploration Systems Mission Directorate
FS	First Stage
g	gravity
GSE	Ground Support Equipment
HFE	Human Factors Engineering
HRR	Human Rating Requirements
HSIR	CXP-70024; Human-Systems Integration Requirements
ICD	Interface Control Document
KSC	Kennedy Space Center
LSI	Logistics Support Infrastructure
MAF	Michoud Assembly Facility
MSFC	Marshall Space Flight Center
SRD	System Requirements Document
SE&I	Systems Engineering and Integration
LRU	Line Replaceable Unit
SIL	Speech Intelligibility Level
US	Upper Stage
USE	Upper Stage Engine

APPENDIX C HSIR 3.9 TRACEABILTY

HSIR, CxP70024			US HFE Design Criteria USO-CLV-LS-25404	
Req #	**Req Title**	**Req ID**	**Req #**	**Req Title**
3.9	**GROUND MAINTENANCE AND ASSEMBLY**	**-**		
3.9.1	GRND ANTHROPOMETRY, BIOMECH., & STRENGTH	-		
3.9.1.1	Ground Processing Worksites	HS10008	3.2.1.1	Worksite Dimensions
3.9.2	GROUND NATURAL AND INDUCED ENVIRONMENTS	-		
3.9.3	GROUND SAFETY	-		
3.9.3.1	Ventilation Openings	HS10027	3.5.4.2	Ventilation Openings
3.9.3.2	Ground Processing Hardware Access	HS10030	3.5.5.1	Sharp Edges and Corners
3.9.3.3	Hazards Labeling	HS10033	3.6.4.1.1	General Labeling
3.9.4	GROUND ARCHITECTURE	-		
3.9.4.1	Work Station Layout Interference	HS10047	3.1.3.1	Work Station Layout Interference
3.9.4.2	Work Station Layout Sequential Operations	HS10048	3.1.3.2	Work Station Layout Sequential Operations
3.9.5	GROUND CREW FUNCTIONS	-		
3.9.6	GROUND CREW INTERFACES	-		
3.9.6.1	Labeling	HS10039	3.6.4.1.1	General Labeling
3.9.6.2	Consistent Crew Interfaces	HS10050	3.6.1.1	Consistent Crew Interfaces
3.9.6.3	Legibility	HS10051	3.6.4.1.1	General Labeling
3.9.6.4	Written Text	HS10052	3.6.4.1.1	General Labeling
3.9.6.5	Use of Color	HS10053	3.6.3.1	Use of Color
3.9.6.6	Work Envelope Volumes	HS10002	3.2.2.1	Work Envelope
3.9.6.7	Reach Envelope Volumes	HS10004	3.2.2.5	Reach Envelope
3.9.6.8	Ground Crew Visual Access	HS10006	3.2.3.1	Visual Envelope
3.9.7	LAUNCH SITE PROCESSING & GROUND MAINT.	-		
3.9.7.1	Line Replaceable Units (LRU's)	-		
3.9.7.1.1	LRU Installation	HS10012	3.3.1.2	Hardware Installation
3.9.7.1.2	LRU Mounting/Alignment Labels/Codes	HS10013	3.6.4.1.1	General Labeling

3.9.7.1.3	LRU Interchangeability	HS10014	3.8.1.2	Equipment Interchangeability
3.9.7.1.4	LRU Tracking Labels	HS10031	3.6.4.1.1	General Labeling
3.9.7.1.5	LRU Labeling	HS10032	3.6.4.1.1	General Labeling
3.9.7.1.6	LRU Protrusions	HS10042	3.8.3.1	LRU Protrusions
3.9.7.1.7	LRU Weight Limit	HS10045	3.2.4.1	LRU Weight Limit
3.9.7.1.8	LRU Removal without Component Removal	HS10054	3.8.2.2	LRU Replacement
3.9.7.1.9	LRU Removal and Replacement	HS8004	3.8.1.4	LRU Removal and Replacement
3.9.7.2	Connectors	-		
3.9.7.2.1	Connector Mismating	HS10015	3.3.7.2	Connector Mismating
3.9.7.2.2	Connector Mating Labels	HS10017	3.6.4.1.1	General Labeling
3.9.7.3	Fasteners	-		
3.9.7.3.1	Captive Fasteners	HS10026	3.3.6.5	Captive Fasteners
3.9.7.4	Tools	-		
3.9.7.4.1	Toolset	HS10028	3.3.5.1	Toolset
3.9.7.4.2	Tool Clearances	HS10024	3.2.2.9	Tool Clearance
3.9.7.5	Circuit Protection	-		
3.9.7.5.1	Fuse/Circuit Indication	HS10010	3.5.6.1	Circuit Protection
3.9.7.6	Access	-		
3.9.7.6.1	Maintainability without Deintegration	HS10001	3.8.2.3	Ground Maintenance
3.9.7.6.2	Maintainability without Disabling Subsystems	HS10009	3.8.2.2	LRU Replacement
3.9.7.6.3	Appropriate Clothing	HS10011	3.8.1.7	Appropriate Clothing
3.9.7.6.4	Inspection Access	HS10025	3.2.3.4	Inspection Access
3.9.7.6.5	Cable Access	HS8011	3.2.2.12	Cable Access
3.9.7.6.6	External Service Points	HS8013	3.1.1.1	External Service Points
3.9.7.6.7	Visual-Line-of-Sight	HS8048	3.2.3.2	Visual-Line-of-Sight
3.9.7.7	Damage/Hazard Controls	-		
3.9.7.7.1	Equipment Labels and Codes for Hazards	HS10018	3.6.4.1.1	General Labeling
3.9.7.7.2	Maintenance without Damage	HS10019	3.8.2.3	Ground Maintenance
3.9.7.7.3	Isolation Valves	HS10020	3.3.7.4	Isolation Valves
3.9.7.7.4	Fluid Spillage Control	HS10021	3.8.3.3	Spillage Control
3.9.7.7.5	System Safing Controls	HS10022	3.5.1.3	System Safing Controls
3.9.7.7.6	Equipment Protection	HS10023	3.8.3.2	Equipment Protection
3.9.7.7.7	Safety Displays	HS10029	3.2.3.6	Display Access
3.9.7.7.8	Protrusion Label/Support	HS10043	3.6.4.1.1	General Labeling

APPENDIX D CXP70024 HSIR TBR & TBD LIST

CxP70024 No.	CxP70024 Req. ID	CxP70024 Req. No.	USO-CLV-LS-25404 Req. No.
TBR-006-060	HS10008	3.9.1.1	3.2.1.1
TBR-006-061	HS8004	3.9.7.1.9	3.8.1.4
TBR-006-062	HS8004	3.9.7.1.9	3.8.1.4
TBD-006-050	HS10028	3.9.7.4.1	3.3.5.1