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Human Landing System (HLS) Program Extravehicular Activity (EVA) Compatibility Interface Requirements Document (IRD)

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National Aeronautics and
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EVA-EXP-0070
REVISION D
EFFECTIVE DATE: FEBRUARY 14, 2023

HUMAN LANDING SYSTEM (HLS) PROGRAM

EXTRAVEHICULAR ACTIVITY (EVA) COMPATIBILITY INTERFACE REQUIREMENTS DOCUMENT (IRD)

Verify that this is the correct version before use

REVISION AND HISTORY PAGE

Revision No.	Change No.	Description	Release Date
Draft		Initial Release Draft for HLS BAA Appendix H	08-15-19
Baselining –Draft		Revised Baseline Draft - Still requires EVA Change Request (CR) and associated technical reviews	09-23-19
Baseline	EVA-CR-00076 /DSG-C-0086	Baseline - Initial Release	02-13-20
Draft Rev A		High-level summary of technical changes are as follows: 1. Updated Section 1.4 2. Updated all references to HLS-RQMT-001 to reflect either HLS-RQMT-002 Contractor SRD in accordance with the appropriate Tech Authority Annexes in Section 2.1 3. Removed <TBR-HLS-EVA-002> in [EVASC.0154] 4. Corrected value reference in [EVASC.0050] table for Tool Impact and Force Application 5. Updated missing “shall” in [EVASC.0098] 6. Updated [EVASC.0099] to point to EVA-EXP-0067 requirements 7. Provided rationale for [EVASC.0107] 8. Clarified [EVASC.0113] requirement/rationale 9. Included new EVA verification strategy that aligns with HLS-PLAN-005 and restructured Verification Cross Matrix (updates to a couple verification methods) 10. Added new non-EVA Best Practice in App C 11. Restructure Appendix G Applicability Matrix and resolved <TBD-HLS-EVA-005> by addressing all requirements applicability 12. Resolved 7 Forward Work Items in Appendix F-3.0 13. Added 1 new Forward Item in Appendix F-3.0	09-04-20
A	HLS CR-C0125	Remaining changes are considered editorial – mainly clarification of requirements and rationales, addition of dual units, grammar, and updates to Acronyms and Glossary Reference HCB.10.05.2020, dated 10/05/2020 High-level summary of changes from CR include: 1. Updates to Applicable/Reference Document Sections 2.1 and 2.2 2. Two new requirements [EVASC.0158] EVA Procedure Reviewer and [EVASC.0157] EVA Egress/Ingress Methods which resolved a Forward Work Item	10/20/20

Revision No.	Change No.	Description	Release Date
		3. Significant update to: [EVASC.0079]. [EVASC.0113] which resolved <TBR-HLS-EVA-003> 4. Requirement clarifications for following: [EVASC.0154], [EVASC.0047], [EVASC.0065], [EVASC.0145], [EVASC.0141], [EVASC.0086], [EVASC.0137], [EVASC.0123], [EVASC.0156] 5. Clarification in Section 4 a. Roles and Responsibilities b. New note for [EVASC.0131] 6. Resolved Forward Work Item associated with Appendix D consolidates sections into one table and adds new <TBD-HLS-EVA-007> 7. Remainder of changes were considered to be editorial/grammatical, or just provided clarification to items within the Appendices	
	HLS-MD-0001	EVASC.0008 edit to remove parenthetical	10/30/20
Revision B Draft		1. Updates to Sections 1.5, 2.2 2. Update all references to HLS SRD to point to respective contract Annexes to this document (remove all references to HLS Partner SRD Annexes) a. Section 1.2 and 2.1/2.2 b. Requirements – [EVASC.0052], [EVASC.0092], [EVASC.0093], [EVASC.0095], [EVASC.0096], [EVASC.0097], [EVASC.0098], [EVASC.0100], [EVASC.0123] c. Rationales – [EVASC.0001], [EVASC.0010], [EVASC.0031], [EVASC.0050], [EVASC.0055], [EVASC.0108], [EVASC.0110], [EVASC.0157] 3. Requirement clarification [EVASC.0013], [EVASC.0018], [EVASC.0027], [EVASC.0032], [EVASC.0050], [EVASC.0051], [EVASC.0067], [EVASC.0105], [EVASC.0109] 4. Rationale clarification [EVASC.0038] 5. Updates to Section 4.2	09/15/21

Revision No.	Change No.	Description	Release Date
		6. Updates to verification cross matrix in Section 4.3 7. Appendix A – updates to Acronyms (remove no longer used and add missing) and Glossary to include verification term for Audit 8. Appendix B – add couple metric conversions 9. Appendix F – Updated to include steps for closing TBD/TBRs and latest ECDs and closed one Forward Work Item 10. Editorials only Section 1.3 Table, Section 2.3 [EVASC.0002], [EVASC.0127], [EVASC.0087], [EVASC.0029], [EVASC.0149], [EVASC.0048], [EVASC.0057], [EVASC.0071], [EVASC.0072], [EVASC.0079], [EVASC.0151], [EVASC.0082], [EVASC.0091], [EVASC.0103], [EVASC.0121] Appendix B, Appendix C, Appendix D, Appendix F3 11. Updated footer for Export control designation	
B	HLS-C0211	Reference Joint HCB with EVA&GW (Reference HCB.12.08.2021) High-level summary of changes from CR include: 1. Clarifications of intent for pointers to HLS mission-specific SRDs: a. [EVASC.0001], [EVASC.0010], [EVASC.0031], [EVASC.0157], [EVASC.0050], [EVASC.0052], [EVASC.0092], [EVASC.0093], [EVASC.0097] 2. Updated requirements to capture vehicle responsibilities to the xEVA System: a. [EVASC.0095], [EVASC.0096], [EVASC.0092], [EVASC.0093], [EVASC.0097], [EVASC.0098], [EVASC.0100], [EVASC.0110], and [EVASC.0123] 3. Deletion of [EVASC.0108] Burrs requirement 4. Clarifications to requirements: a. [EVASC.0013] Hatch Transfer Constraint, adds new <TBD-HLS-EVA-008> b. [EVASC.0125] Soft Capture, adds new partial gravity case	01/05/22

Revision No.	Change No.	Description	Release Date
		5. Clarifications to Section 4 for Verifications, including updates to Verification Cross Matrix 6. Clarifications/updates to Sections 1, 2, and Appendices 7. Updates to Forward Work Appendix F-3 a. Updates to 2 existing FW items 8 and 9 b. Three new FW items 10-12 8. Editorial updates to various sections/requirements	
	HLS-MD-0010	Updates to include the following: 1. Update all HLS document titles to align with guidance on provided glossary definitions in applicable Sections of the document (includes updates from mission specific SRDs to requirements documents) 2. Added new glossary definitions to Appendix A2.0, which included new reference document in Section 2.2 3. Update all references from EVA Office to EHP with the exception of those references that specify a document title previously published under the EVA Office 4. Updated [EVASC.0155] from TBD table to include load categories with no values and changed to TBR (includes updates in Appendix F) – closed <TBD-HLS-EVA-006> and added new <TBR-HLS-EVA-002> 5. Corrected applicable document that was in reference table 6. Reference added to kickloads table line item for [EVASC.0050] pointing back to [EVASC.0010] hardware preclusion table 7. Provided xEVA AIT action numbers for 2 FW items in Appendix F-3 and added information on FW Item for [EVASC.0079]	4/28/22
C	HLS-C0264 Initial CR Release	Updates to the following: (editorials included as well) 1. Clarifications in Sections 1.1, 1.2,1.3, and 2.2 2. Added note to [EVASC.0004] Figure 3. Clarification rationale of [EVASC.0017] 4. Update [EVASC.0156] Lunar Surface Dust Requirement 5. EVA Fastener update to metric a. Update [EVASC.0074] EVA Hand-Actuated Fasteners Contingency Operation	06/23/22

Revision No.	Change No.	Description	Release Date
		b. Update [EVASC.0079] from English to Metric c. Update [EVASC.0084] Fastener Drive Height d. Update EVA-BP-1 e. Update FW #1 description 6. Updates to Section 4.3 Verification Cross Matrix (L2 Fitchecks) 7. Close <TBD-HLS-EVA-002> 8. Clarify Appendix C NEBP-5 9. Updates in Appendix D 10. Updated Forward Work Item #8 and add new forward work Item #13 in Appendix F3	
C	HLS-C0264	Reference Joint HCB with EHP (Reference HCB.06.22.2022) High-level summary of changes from CR include: 1. Clarification in Section 1.2 Scope 2. Clarification in requirements a. [EVASC.0156] Lunar Surface Dust Tolerance b. [EVASC.0096] Lasers 3. Appendix A.2 Glossary Term 4. Editorial clarifications a. Section 1.1 Purpose b. Requirements [EVASC.0156] and [EVASC.0051] c. Appendix B EVABP-1 d. Appendix D2.1	6/27/22
Rev D	EHP-C0051	Approved via Joint Program Control Board on 2/14/2023: Reference Directive EHP-D0051 Update to include the following: (not all inclusive of some additional editorials) 1. Section 1.0, 1.1, 1.2 – clarifications 2. Section 1.3.4 Units – reflect use of metric units as primary (implementation of metric action throughout document, with exception of Appendix D that is still under review) 3. Transition of document ownership from HLS to EHP – Section 1.4 Change Authority 4. Section 2.1/2.2 based on changes to requirements and revision control authority 5. Section 3 Requirement Updates a. Deleted 2 requirements – [EVASC.0095] Emitted Radiation and	2/14/2023

Revision No.	Change No.	Description	Release Date
		[EVASC.0122] Hardware Compatibility with xEMU Suit EMI b. Added 4 new partial gravity requirements – [EVASC.0159] Partial Gravity EVA Contact Hazards Preclusion, [EVASC.0160] Partial Gravity EVA Handling Capability, [EVASC.0161] Crew Safety Restraint, and [EVASC.0162] Partial Gravity Step Design Parameter c. Updates to requirements to include partial gravity application - [EVASC.0001], [EVASC.0008], [EVASC.0031], [EVASC.0032], [EVASC.0035], [EVASC.0041], [EVASC.0042], [EVASC.0155], [EVASC.0018], [EVASC.0053], [EVASC.0057], [EVASC.0085], [EVASC.0091] d. Requirements mainly updated for metric action - [EVASC.0002], [EVASC.0007], [EVASC.0003], [EVASC.0004], [EVASC.0005], [EVASC.0006], [EVASC.0010], [EVASC.0012], [EVASC.0135], [EVASC.0153], [EVASC.0124], [EVASC.0125], [EVASC.0126], [EVASC.0128], [EVASC.0129], [EVASC.0030], [EVASC.0144], [EVASC.0036], [EVASC.0148], [EVASC.0045], [EVASC.0046], [EVASC.0048], [EVASC.0134], [EVASC.0050], [EVASC.0051], [EVASC.0143], [EVASC.0071], [EVASC.0073], [EVASC.0075], [EVASC.0078], [EVASC.0151], [EVASC.0090], [EVASC.0103], [EVASC.0011], [EVASC.0104], [EVASC.0105], [EVASC.0109], [EVASC.0110] e. Updating references from xEMU to xEVA Suit only – [EVASC.0158], [EVASC.0021], [EVASC.0038], [EVASC.0058], [EVASC.0132], [EVASC.0133], [EVASC.0067],	

Revision No.	Change No.	Description	Release Date
		[EVASC.0112], [EVASC.0113], [EVASC.0114] f. Clarifications not associated with partial gravity assessment - [EVASC.0135a], [EVASC.0040], [EVASC.0047], [EVASC.0033], [EVASC.0052], [EVASC.0065], [EVASC.0141], [EVASC.0092], [EVASC.0093], [EVASC.0097], [EVASC.0098], [EVASC.0189], [EVASC.0100], [EVASC.0117], [EVASC.0118], [EVASC.0121], [EVASC.0123] 6. Section 4 Verification a. complete section rewrite b. updated Section 4.3 Verification Cross Matrix - remove L2 Facility Demo column, updated L2 methods - [EVASC.0138], [EVASC.0060], [EVASC.0063], [EVASC.0132], [EVASC.0067], and updated L3 methods - [EVASC.0154], [EVASC.0013], [EVASC.0135], [EVASC.0153], [EVASC.0157], [EVASC.0042], [EVASC.0048], [EVASC.0134], [EVASC.0053], [EVASC.0054], [EVASC.0055], [EVASC.0058], [EVASC.0059], [EVASC.0061], [EVASC.0062], [EVASC.0066], [EVASC.0063], [EVASC.0139], [EVASC.0146], [EVASC.0085], [EVASC.0113] 7. Appendix A – updates to acronyms and glossary terms 8. Appendix F – close 3 TBDs, updates to ECDs, addition of 4 new TBDs, resolution of 12 Forward Items	
D	Admin Chg 1	Change document marking from EAR99 to not Export Controlled per EHP ECR review.	3/30/2023

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TABLES

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1.0 INTRODUCTION

Extravehicular Activity (EVA) is considered to be a significant capability for the Human Landing System (HLS) Program. The EVA and Human Surface Mobility Program (EHP) will provide Exploration EVA (xEVA) suits, xEVA tools and crew aids along with vehicle integration/support hardware. Being a distributed and dynamic capability (moving components), xEVA System hardware will interface with almost all elements of the HLS Program architecture. As such, it is important to document a singular set of EVA compatibility requirements at the programmatic level to articulate "how to interface with xEVA suit hardware" and "how to design hardware that EVA crewmembers will access and manipulate."

1.1 PURPOSE

The purpose of this document is to establish a set of EVA compatibility design requirements for the HLS Program. This document contains the fundamental information required for building hardware compatible with suited EVA flight crewmembers to perform EVAs. Compatibility requirements are located in section 3.0 with a gravity field applicability table provided in APPENDIX G, Human Landing System Program Applicability Matrix. Each HLS Provider will use the EHP-provided matrix in Appendix G to assess applicability to the awarded mission provider on a per-mission basis. Providers will negotiate applicability with EHP, and this will be documented in the appropriate Annex (reference section 2.2).

1.2 SCOPE

This document defines requirements controlled by the EHP that ensure that the HLS architecture and design is compatible with the xEVA suits and EVA activities. It also includes requirements for vehicle-provided hardware like handrails and some (mainly structural) EVA interfaces. HLS-RQMT-001, *Human Landing System (HLS) Program System Requirements Document (PSRD)*, provides a requirement for the HLS to support EVA operations through compliance with this document (per HLS-RQMT-001 requirement HLS-R-0323) that is flowed to HLS-RQMT-002, *Human Landing System (HLS) Partner System Requirements Document (PaSRD)*, (Initial) and associated appropriate HLS Provider Annex, HLS-RQMT-002-ANX-XX, *HLS PaSRD Technical Authority Agreements* [per Vendor] (reference section 2.2). The same EVA operations requirement is covered for sustained missions through HLS-RQMT-006, *Human Landing System (HLS) Program Integrated Lander Requirements Document – Sustained Phase*, and HLS-RQMT-007, *Human Landing System (HLS) Program Human-Class Delivery Lander (HDL) Requirements Document – Sustained Phase*. EVA-EXP-0070 Annexes, section 4.1 of each, will document the agreements of the EVA-EXP-0070, section 3.0 requirements applicability, which is located in APPENDIX G.

This document was constructed from the program-agnostic equivalent document controlled by EHP, EVA-EXP-0035, *EVA Office Exploration EVA System Compatibility*, and is considered to be a child. The requirements herein are applicable to any hardware internally or externally that will be in close proximity to, come in contact with, or has features that can present hazards in any way to xEVA suits. This document will incorporate necessary changes and additions to compliment the unique concept of operations and architecture for HLS. EVA-EXP-0070 does not include information on the interfaces for space suit servicing, performance, and checkout equipment (e.g., items that directly interface with the space suit, such as fluid and electrical connectors), or non-mechanical HLS-EVA interfaces (such as wireless communication, data, video, and audio). All of these items will be defined in EVA-EXP-0067, *Human Landing System (HLS) Program – Exploration Extravehicular Activity (xEVA) Interface Requirement Control Document (IRCD)*. As the HLS Program progresses through the development cycle, new scenarios/concept of operations pertaining to EVA operations will be assessed for impacts to this document.

In many cases the values used for defining microgravity compatibility with a space suit are based on heritage United States (US) EVA capabilities as carried over from the Space Shuttle Program and modified for the International Space Station (ISS) Program. Each requirement was assessed for application in a partial gravity environment and captures partial gravity considerations in the requirement. As the xEVA suit design matures and/or as other suppliers of EVA hardware are identified, updates to the requirements will be proposed to the appropriate change authority to reflect the improvement/changes in EVA capabilities. This document covers both microgravity and partial gravity EVA requirements (reference APPENDIX G).

1.3 CONVENTIONS AND NOTATIONS

1.3.1 Shall Statements (Requirements)

The convention used in this document which indicates requirements, goals, and statements of facts is as follows:

TABLE 1.3.1-1 CONVENTION AND NOTATIONS DESCRIPTIONS

Designation	Description
"Shall"	used to indicate a requirement which must be implemented, and its implementation verified (binding requirements)
"Should"	used to indicate a goal which must be considered
"Will"	used to indicate a statement of fact or declaration of purpose and is not verified

Those statements that fall more into a design consideration/best practice are located in APPENDIX B and APPENDIX C. While not considered requirements, these best practices are highly desirable for the design of hardware compatibility with EVA.

1.3.2 Requirement Identification

As documents are revised, there are cases where sections will move; therefore, each requirement in this requirements document is uniquely numbered, and identified by the presence of a tag. The requirements tag "**[EVASC.XXXX]**" provides a trace to historical information across multiple Programs and Projects.

1.3.3 Rationale

A rationale statement is included for each requirement only when necessary. The purpose of the rationale statement is to indicate why the requirement is needed, the basis for its inclusion in a requirements document, and to provide context and examples to stakeholders. It is important to note that a rationale is not binding, and it only provides supporting information. In the event there is an inconsistency between the requirement and the rationale, the requirement is binding and takes precedence.

1.3.4 Units

EHP and HLS Programs both utilize NIST SP 811, *Guide for the Use of International System of Units (SI)*, for standardization and conversions of the units of measure. For the purposes of this document, the unit of measure should be considered as metric as primary with English units in parenthesis unless otherwise noted. The English units are considered the driver for metric conversions.

NOTE: Some referenced drawings and documents may use English units as primary and may or may not have metric units as secondary.

1.4 CHANGE AUTHORITY/RESPONSIBILITY

Proposed changes to this document shall be submitted by an EHP Change Request (CR) to the Joint EHP Control Board (CB) / HLS Control Board for consideration and disposition per EHP-20000, *Extravehicular Activity and Human Surface Mobility Program (EHP) Configuration and Data Management Plan*.

The appropriate NASA Office of Primary Responsibility (OPR) identified for this document is EHP Systems Engineering and Integration (SE&I). As such, the EHP manages this document on behalf of the HLS Program. Content in this document is under the control of the EHP/HLS Joint Control Board for approval.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in Table 2.1-1 are applicable to the extent specified herein. Applicable documents and standards have been designated by EHP as either Type 1, 2, or 3 in accordance with EHP-10012, *Extravehicular Activity and Human Surface Mobility Program (EHP) Systems Requirement Document*, section 2.2.1. HLS Program applicable document revisions listed in Table 2.1-1 are in accordance with HLS-RPT-006, *HLS Program Applicable Documents Revision Control*.

TABLE 2.1-1 APPLICABLE DOCUMENTS LIST

Document Number	Document Title
ANSI Z136.1	American National Standard for Safe Use of Lasers
EHP-20000	Extravehicular Activity and Human Surface Mobility Program (EHP) Configuration and Data Management Plan
EVA-EXP-0049	Extravehicular Activity (EVA) Office Exploration EVA System Labeling Guidelines
EVA-EXP-0067	Human Lander System (HLS) Program – Exploration Extravehicular Activity (xEVA) Interface Requirements Control Document (IRCD)
HLS-STD-007	Human Landing System (HLS) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
JPR 5322.1	Contamination Control Requirements Manual
NASA-STD-4003	Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment
SDG33107728	Tube – Handrail and Handgrip (via SEG33106347, Top Mounted Handrail Assy)

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document and can include Type 3 Technical Authority (TA) Standards. Reference Documents may be called out in any section or as a part of a requirement rationale and are not binding. Table 2-2.1 only lists the reference documents and revisions for this product.

TABLE 2.2-1 REFERENCE DOCUMENTS LIST

Document Number	Document Revision	Document Title
ACD-50012	Current	Artemis Campaign Development (ACD) Enterprise Verification and Validation Plan
AML-01-02-R1		Title Unknown - TBD
EHP-10004	Baseline	Extravehicular Activity and Human Surface Mobility Program (EHP) Systems Engineering Management Plan (SEMP)
EHP-10012	Baseline Draft	Extravehicular Activity and Human Surface Mobility Program (EHP) Systems Requirements Document
EVA-EXP-0031	Baseline	EVA Office Extravehicular Activity (EVA) Airlocks and Alternative Ingress/Egress Methods Document
EVA-EXP-0032	Baseline	EVA Office EVA-ISS Interface Definition Document
EVA-EXP-0034	Revision C	Extravehicular Activity (EVA) Office Exploration EVA System Technical Standards
EVA-EXP-0035	Draft Rev A 09/30/22	EVA Office Exploration EVA System Compatibility
EVA-EXP-0070 ANX-01	Draft	Human Landing System (HLS) Program Extravehicular Activity (EVA) Compatibility Interface Requirements Document (IRD) Annex – Initial Phase
EVA-EXP-0070 ANX-02	Revision A	Human Landing System (HLS) Program Extravehicular Activity (EVA) Compatibility Interface Requirements Document (IRD) Annex – Integrated Lander Sustained Phase
EVA-EXP-0070 ANX-03	Revision A	Human Landing System (HLS) Program Extravehicular Activity (EVA) Compatibility Interface Requirements Document (IRD) Annex – Human-Class Delivery Lander Sustained Phase
HLS-RPT-006	Current	HLS Program Applicable Documents Revision Control
HLS-RQMT-001	Current	Human Landing System (HLS) Program System Requirements Document (PSRD)
HLS-RQMT-002	Current	Human Landing System (HLS) Partner System Requirements Document (PaSRD)
HLS-RQMT-002 ANX-01	Current	Human Landing System (HLS) Partner System Requirements Document (PaSRD) Annex – Technical Authority Agreements – SpaceX
HLS-RQMT-002 ANX-02	Current	Human Landing System (HLS) Partner System Requirements Document (PaSRD) Annex – Technical Authority Agreements – Dynetics

TABLE 2.2-1 REFERENCE DOCUMENTS LIST

Document Number	Document Revision	Document Title
HLS-RQMT-002 ANX-03	Current	Human Landing System (HLS) Partner System Requirements Document (PaSRD) Annex – Technical Authority Agreements – Blue Federation
HLS-RQMT-006	Current	Human Landing System (HLS) Program Integrated Lander Requirements Document – Sustained Phase
HLS-RQMT-007	Current	Human Landing System (HLS) Program Human-Class Delivery Lander (HDL) Requirements Document – Sustained Phase
JSC 28528	A	Preparation and Revision of Cx Mockup Development Requirements Document
JSC 39117	C	Extravehicular Mobility Unit (EMU) International Space Station (ISS) Extravehicular Activity (EVA) Thermal Environment Requirements for Certification
JSC 39198	3/14/2018	Incidental Contact Temperature Test on Extravehicular Mobility Unit (EMU) Softgoods Materials Lay-Up
JSC 65828	B w/ Change 1	Structural Design Requirements and Factors of Safety for Spaceflight Hardware
MIL-PRF-19500	R	Semiconductor Devices, General Specification for
MIL-DTL-81381	C Amendment 1	Wire, Electric, Polyimide-Insulated, Copper, or Copper Alloy, Detail Specification
MPCV 70024	D	Orion Multi-Purpose Crew Vehicle (MPCV) Program: Human-Systems Integration Requirements (HSIR)
NASA/SP-2010-3407	Rev 1	Human Integration Design Handbook
NASA-STD-5020	B	Requirements for Threaded Fastening Systems in Spaceflight Hardware
NASA-STD-6016	C	Standard Materials and Processes Requirements for Spacecraft
NIST SP 811	3/2008	Guide for the Use of the International System of Units (SI)
NPR 8705.4	A	Risk Classification for NASA Payloads
SDG33107506	Latest	Knob, Push, Pitch Joint Assembly APFR, ISS
SED33107181	Latest	EVA Knob Assembly, Bridge Clamp
SEG33114987	Latest	1.0 Inch QD Button Depress Tool Assy
SLS-SPEC-159	I	Cross-Program Design Specification for Natural Environments (DSNE)

TABLE 2.2-1 REFERENCE DOCUMENTS LIST

Document Number	Document Revision	Document Title
SSP 30256	Revision K	Extravehicular Activity (EVA) Standard Interface Control Document
SSP 30423	L	Space Station Approved Electrical, Electronic and Electromechanical (EEE) Part List
XA-08-015	February 29, 2008	EVA Office Sharp-Edge Policy for Work Site/Incidental Contact of Space Shuttle Payloads and International Space Station Vehicle

2.3 ORDER OF PRECEDENCE

For EVA Compatibility interfaces defined and controlled in this document, this document will take precedence.

3.0 REQUIREMENTS

This section defines the minimum requirements and constraints that apply to performance, design, interoperability, maintainability, and safety of hardware that may come in contact or be operated by crew in pressurized EVA suits. The gravity field applicability is included after each requirement (reference APPENDIX G for complete requirement applicability matrix). Variances to these requirements may be proposed to EHP, considered by the EHP Requirements, Interfaces, Verification, Analysis (RIVA) Panel in accordance with EHP-10004, *Extravehicular Activity and Human Surface Mobility Program (EHP) Systems Engineering Management Plan (SEMP)*, and approved via the EHP Variance Change Request process described in EHP-20000, *Extravehicular Activity and Human Surface Mobility Program (EHP) Configuration and Data Management Plan*.

3.1 CLEARANCES

3.1.1 Translation Path Hardware Protrusion

The HLS shall design or configure equipment to not protrude into the minimum 1.1 m (43 in) diameter translation path envelope, excluding translation aids (handrails/handholds) in microgravity as outlined in Figure 3.1.1-1 Translation Path Hardware Protrusion Envelope and Figure 3.1.1-2 Translation Path Minimum Diameter, and provide a translation path free of equipment and protrusions that accommodates the volume of the crewmember in partial gravity as outlined in Figure 3.1.1-3 Top View Partial Gravity Crew Envelope **<TBR-HLS-EVA-006>** and Figure 3.1.1-4 Side View Partial Gravity Crew Height **<TBR-HLS-EVA-006>**. **[EVASC.0001]**

> *Rationale: In microgravity, the minimum diameter of the translation corridor of 1.1 m (43 in) is to accommodate hand-over-hand EVA crewmember translation. In partial gravity, the breadth and height of the translation path must accommodate the volume of the crewmember in any direction which the crew is expected to move. Interference in translation paths may pose hazards to EVA crewmembers or impact the success of EVA activities by precluding translation to worksites. This includes any obstructions or intrusions in the envelope. This microgravity minimum diameter is based on the heritage ISS EMU suit and is associated with microgravity application. Partial gravity application ensures crewmembers can traverse around, to and from vehicle worksite areas (e.g., catwalk around a cargo lander, walking under the lander, ingress/egress of vehicle to the surface, areas around unpressurized and pressurized rovers).*
>
> *Applicability: Microgravity, Partial Gravity*

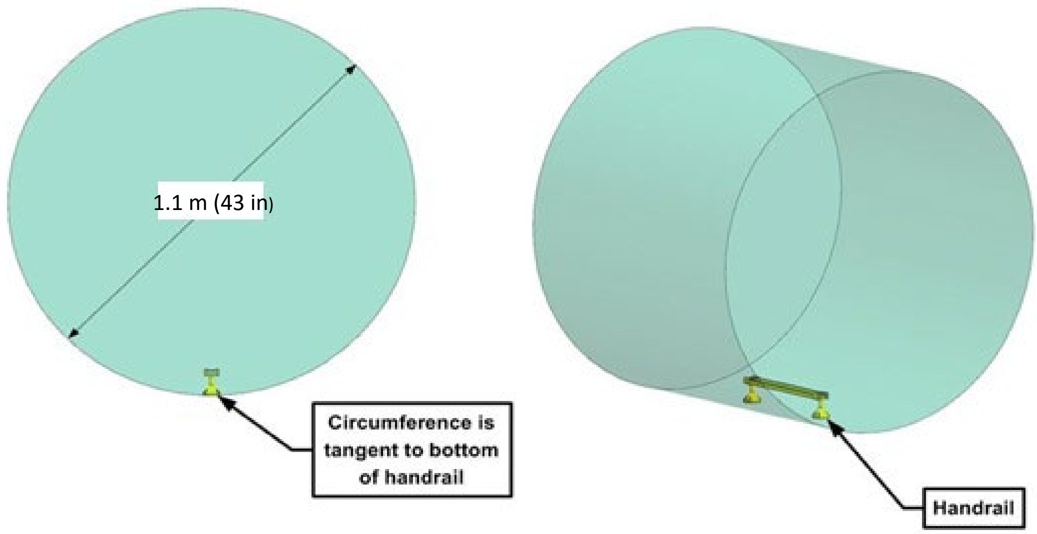


FIGURE 3.1.1-1 TRANSLATION PATH HARDWARE PROTRUSION ENVELOPE

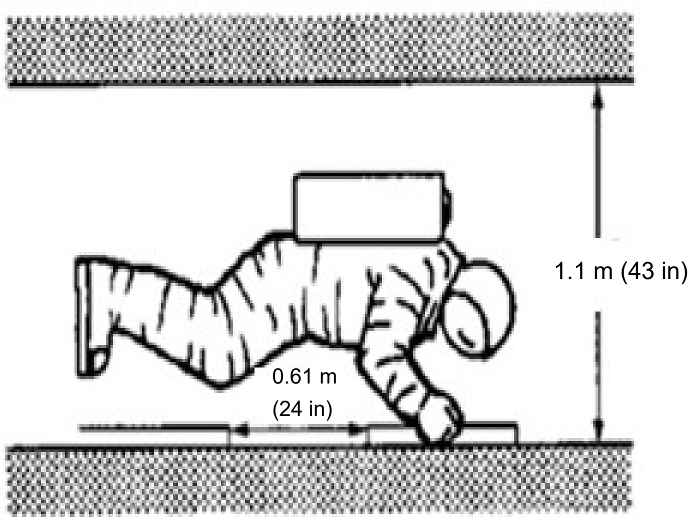


FIGURE 3.1.1-2 TRANSLATION PATH MINIMUM DIAMETER

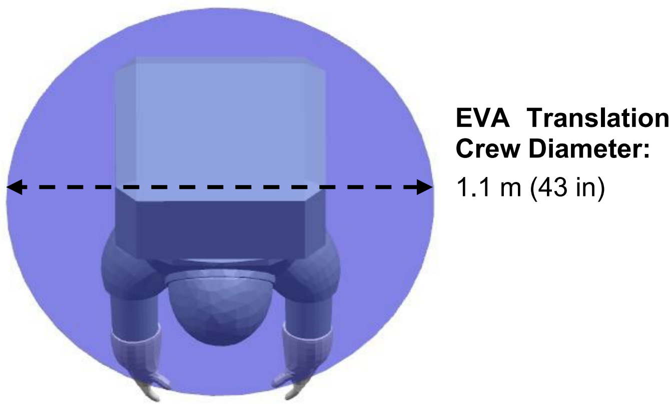


FIGURE 3.1.1-3 TOP VIEW PARTIAL GRAVITY CREW ENVELOPE <TBR-HLS-EVA-006>

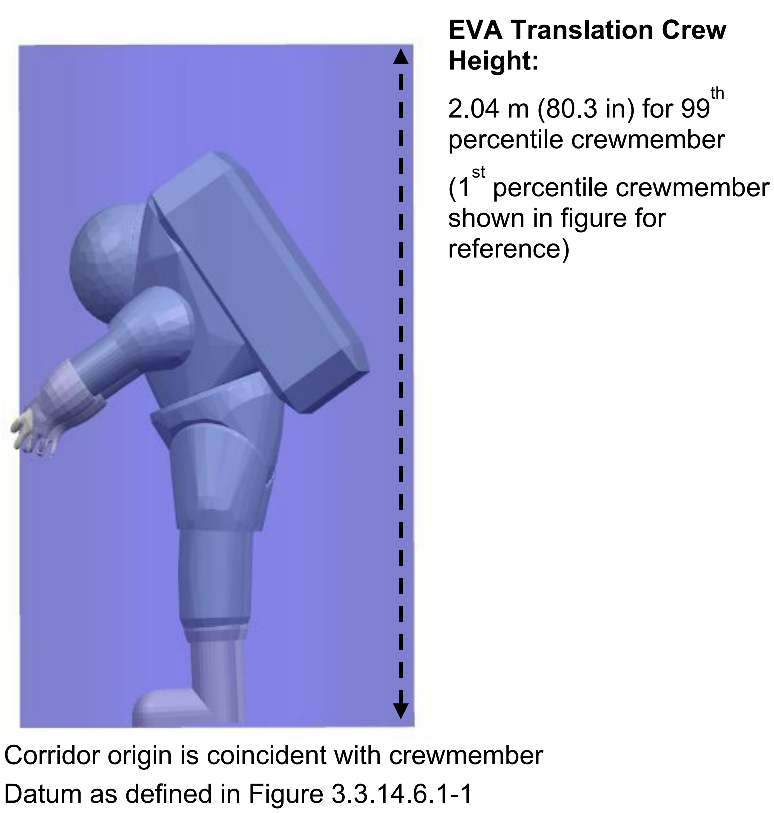


FIGURE 3.1.1-4 SIDE VIEW PARTIAL GRAVITY CREW HEIGHT <TBR-HLS-EVA-006>

3.1.2 Tool Interface Clearance

The HLS shall maintain 7.6 cm (3.0 in) of clearance between the gripping portions of a tool interface and any surrounding hardware or obstructions with a tool handle offset maximum of 35.6 cm (14.0 in) as defined in Figure 3.1.2-1 Tool Interface Clearance. **[EVASC.0002]**

Rationale: Tools to be used during EVAs are to be identified by the HLS, and clearances for efficient application are to be accommodated to ensure that the EVA task can be accomplished. The intent is that this requirement applies to EVA crew operated manual tools interfacing with EVA fasteners. In order to ensure the task can be accomplished, the clearance between the work surface and the tool design needs to include operation by a pressurized gloved hand. Reference [EVASC.0004] which defines the handrail mounting clearance distance that accommodates grasp of the pressurized gloved hand. The bolt head tool clearance is defined in requirement [EVASC.0007].

Applicability: Microgravity, Partial Gravity

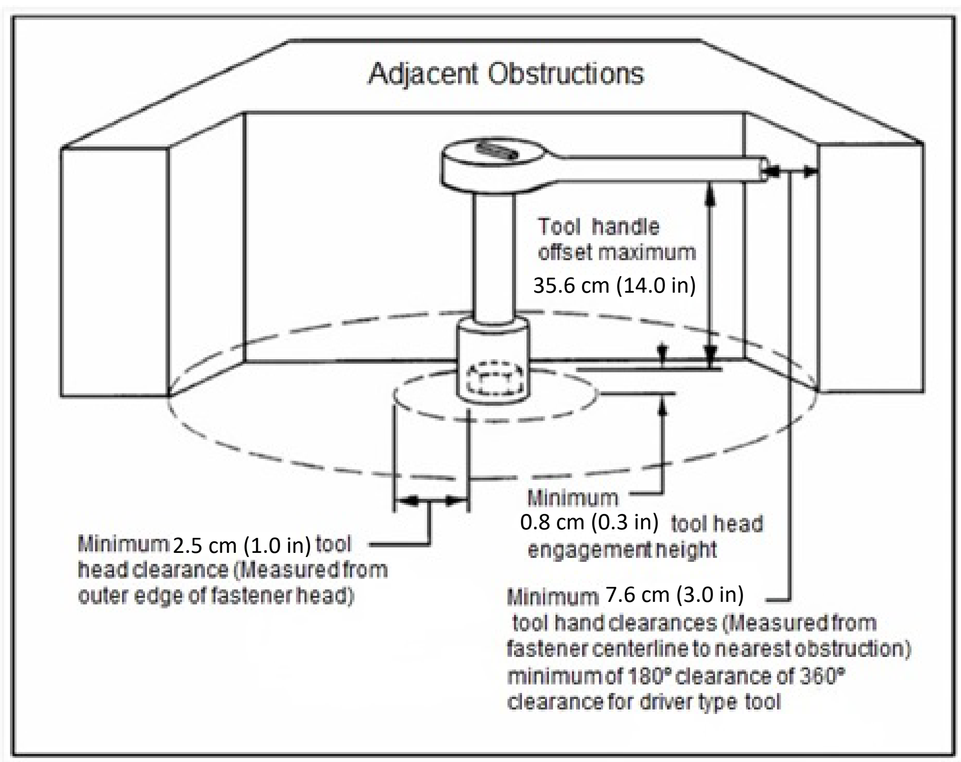


FIGURE 3.1.2-1 TOOL INTERFACE CLEARANCE

3.1.3 Bolt Clearance

The HLS shall maintain a 2.5 cm (1.0 in) clearance around the bolt head outer edge with a minimum tool head engagement height of 0.8 cm (0.3 in) to ensure access as defined in requirement [EVASC.0002] Figure 3.1.2-1 Tool Interface Clearance. **[EVASC.0007]**

Rationale: The intent of this requirement is to ensure tool access with the fastener head.

Applicability: Microgravity, Partial Gravity

3.1.4 Gloved-Hand Clearance

The HLS shall maintain minimum clearance envelope for a gloved hand access as specified in Figure 3.1.4-1 Gloved-Hand Clearance. **[EVASC.0003]**

Rationale: Pressurized EVA gloves have their own thickness in addition to the human hands they protect. Interfaces to be operated by the EVA crewmember must accommodate the dimensions of the hand/glove combination.

Applicability: Microgravity, Partial Gravity

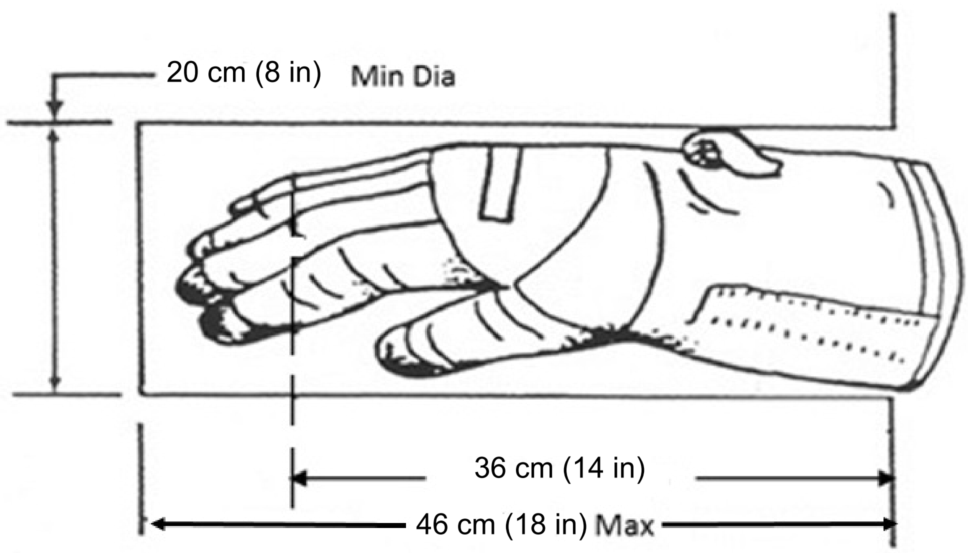


FIGURE 3.1.4-1 GLOVED-HAND CLEARANCE

3.1.5 Handrail/Handhold Mounting Clearance

The HLS shall maintain a minimum clearance distance between the lower surface of the handrail/handhold and the mounting surface of 5.72 cm (2.25 in) as shown in Figure 3.1.5-1 EVA Handrail/Handhold Mounting Clearance Envelope. **[EVASC.0004]**

Rationale: EVA handrail cross sections themselves have been designed to facilitate grasping by the gloved EVA crewmember's hand. However, it is theoretically possible to mount a handrail in such a way (such as immediately next to structure or over an exposed structural rib) that the EVA crewmember's gloved hand cannot access the EVA handrail. To ensure EVA handrails are mounted in a manner that preserves/facilitates their use, the area around and underneath handrails/handholds must be free of obstructions within the specified clearance dimensions. Adequate clearance is required to facilitate use by a pressurized gloved hand. This also supports clearance for tether hook attachment to the stanchions.

Applicability: Microgravity, Partial Gravity

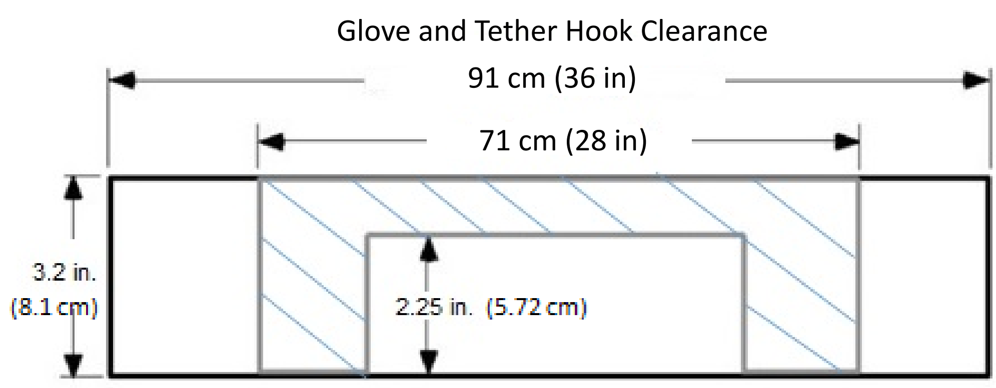


FIGURE 3.1.5-1 EVA HANDRAIL/HANDHOLD MOUNTING CLEARANCE ENVELOPE

Note: The 71 cm (28 in) handrail is an example.

3.1.6 Handrail/Handhold Side Clearance

The HLS shall maintain a minimum 10 cm (4 in) clearance to both sides of handrail/handholds as defined in Figure 3.1.6-1 Handrail/Handhold Side Clearance. **[EVASC.0005]**

Rationale: To ensure EVA handrails are mounted in a manner that preserves/facilitates their use, the area around and underneath handrails/handholds must be free of obstructions within the specified clearance dimensions. Adequate clearance is required to facilitate use by a pressurized gloved hand.

Applicability: Microgravity, Partial Gravity

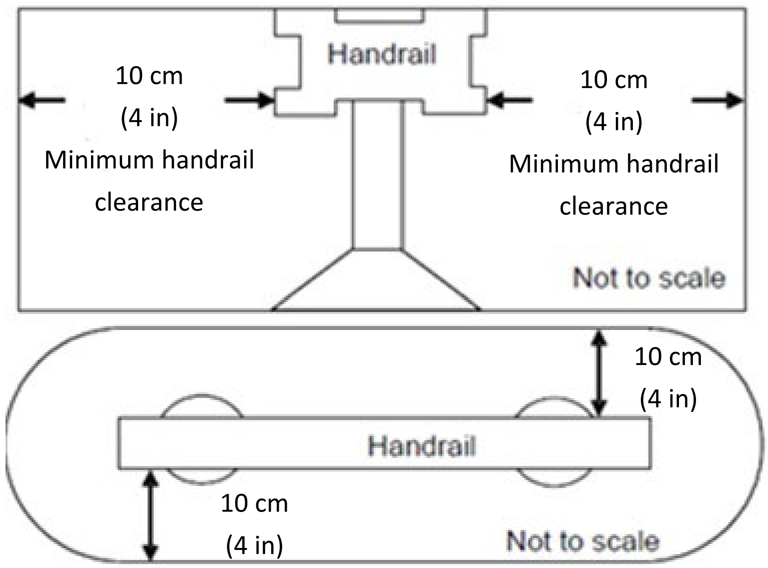


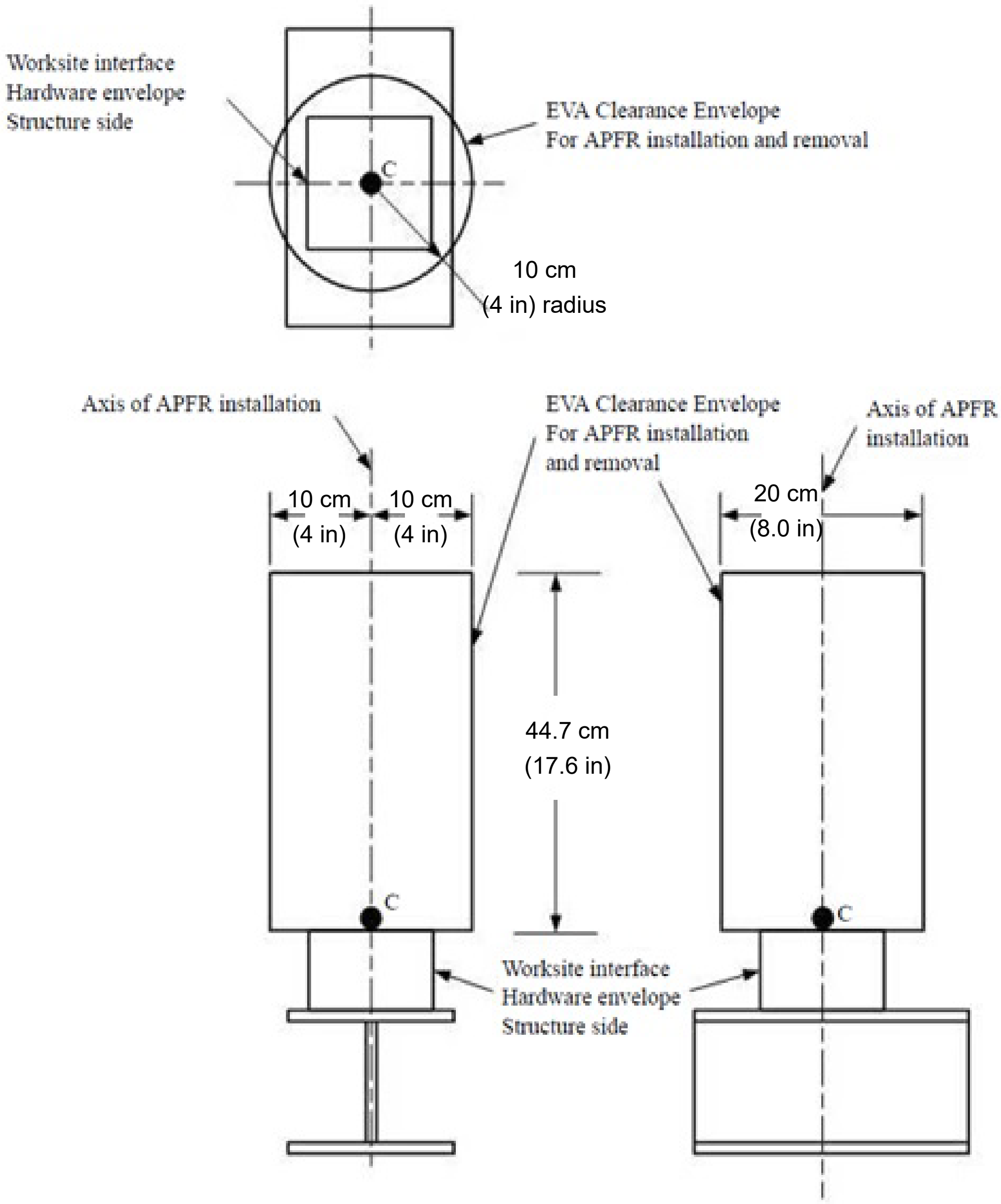
FIGURE 3.1.6-1 HANDRAIL/HANDHOLD SIDE CLEARANCE

3.1.7 APFR EVA Installation/Removal Clearance

The HLS shall maintain a clearance envelope around the Passive Worksite Interface (WIF) to support EVA installation/removal of the Articulating Portable Foot Restraint (APFR) as defined in Figure 3.1.7-1 APFR Installation/Removal EVA Clearance Envelope – Top Mounted Worksite Interface. **[EVASC.0006]**

Rationale: The intent is to ensure adequate clearance is provided to support installation/removal of hardware designed to interface with the passive WIF. For other EVA WIF configurations, refer to SSP 30256, Extravehicular Activity (EVA) Standard Interface Control Document, section 3.6.4.2.2. Nominally used in microgravity environment.

Applicability: Microgravity



Notes:

1. Drawing not to scale
2. Point C is the centroid of the bolt pattern

FIGURE 3.1.7-1 APFR INSTALLATION/REMOVAL EVA CLEARANCE ENVELOPE – TOP MOUNTED WORKSITE INTERFACE

3.2 TRANSLATION

3.2.1 Contiguous EVA Translation Path

The HLS shall provide EVA compatible accommodations to support contiguous translation paths while docked to staging vehicle. **[EVASC.0152]**

Rationale: A contiguous translation path is defined as the path from/to the airlock to/from any worksite that a crewmember needs to access for EVA operations. Intentionally designed translation paths include features such as handrails and tether points that promote EVA crew movement and are free from contact hazards. These translation paths allow the EVA crewmember to safely access worksites as well as to return to the vehicle/airlock safely and quickly in case of an emergency.

Applicability: Microgravity

3.2.2 Translation Path

The HLS shall design a translation path to all EVA worksites. **[EVASC.0008]**

Rationale: Intentionally designed translation paths include features such as handrails and tether points that promote EVA crew movement and are free from contact hazards. These translation paths allow the EVA crewmember to safely access worksites as well as to return to the airlock safely and quickly in case of an emergency for microgravity application. Partial gravity application ensures crewmembers can traverse around, to and from vehicle worksite areas (e.g., catwalk around a cargo lander, walking under the lander, ingress/egress of vehicle to the surface, areas around unpressurized and pressurized rovers).

Applicability: Microgravity, Partial Gravity

3.2.3 Incapacitated Crewmember Interfaces

The HLS shall provide hardware that aids a suited crewmember in the rescue of an incapacitated suited crewmember from the surface and into the vehicle through the EVA hatch, culminating to positioning the suited incapacitated crewmember in a xEVA System for extraction. **[EVASC.0154] <FWD-0070-004>**

Rationale: Incapacitated pressurized-suited crewmembers may be unable to ingress the vehicle on their own and may require assistance from a second crewmember. Depending on architecture and hatch height from the lunar surface, this can include items such as winch and rescue harness, deck space/porch, hatch seal cover, etc. Devices may need to be operated by a suited crewmember both internal and external to the vehicle. This includes the volume to perform the assisted task, hatch opening size and operation, as well as the external translation path and mobility/stabilization aids. Removing an incapacitated crewmember from *a rear entry suit could be challenging and could require extra support structure, or possible tools to assist the crewmember inside as well as removal from the suit.*

Applicability: Partial Gravity

3.2.4 EVA Contact Hazards Preclusion Beyond Translation Corridor

The HLS shall preclude EVA contact hazards (e.g., EVA Kick loads as defined in [EVASC.0050] and EVA safety requirements defined in section 3.9) within 0.61 m (24 in) beyond the translation corridor dimension as outlined in Figure 3.2.4-1 EVA Contact Hazard Preclusions Envelope. **[EVASC.0010]**

Rationale: The additional 0.61 m (24 in) radius around the translation corridor protects for inadvertent contact hazards outside of the nominal translation corridor (1.1 m (43 in) + 1.2 m (48 in) = total diameter of 2.3 m (91 in) referenced in Figure 3.2.4-1 EVA Contact Hazard Preclusions Envelope for EVA kickloads and sharp edges). This additional envelope is based on the heritage ISS EMU suit.

Applicability: Microgravity

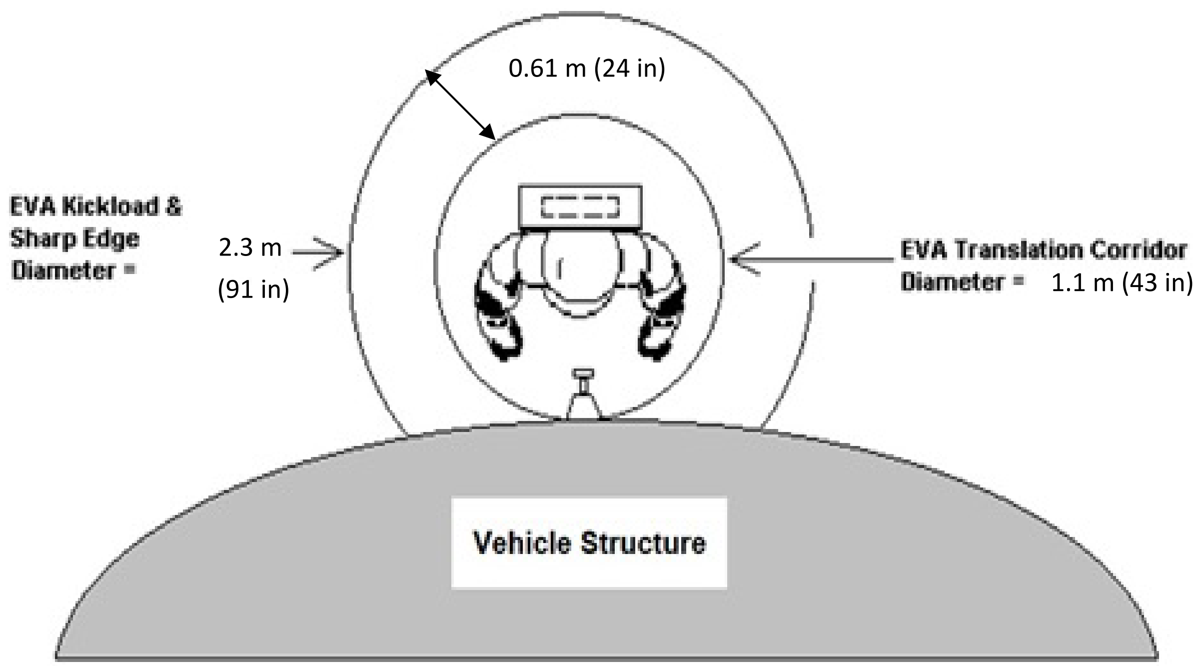


FIGURE 3.2.4-1 EVA CONTACT HAZARD PRECLUSIONS ENVELOPE

3.2.5 Partial Gravity EVA Contact Hazards Preclusion

The HLS shall preclude EVA contact hazards (e.g., loads as defined in [EVASC.0155] and EVA safety requirements defined in section 3.9) within the specified constraints outlined in Figure 3.2.5-1 Top View Partial Gravity EVA Contact Hazard Preclusions Envelope **<TBR-HLS-EVA-007>** and Figure 3.2.5-2 Side View Partial Gravity EVA Contact Hazards Height **<TBR-HLS-EVA-007>**. **[EVASC.0159]**

Rationale: Intent is to outline constraints that can cause a safety concern for the EVA crewmember while working on the lunar surface.

Applicability: Partial Gravity

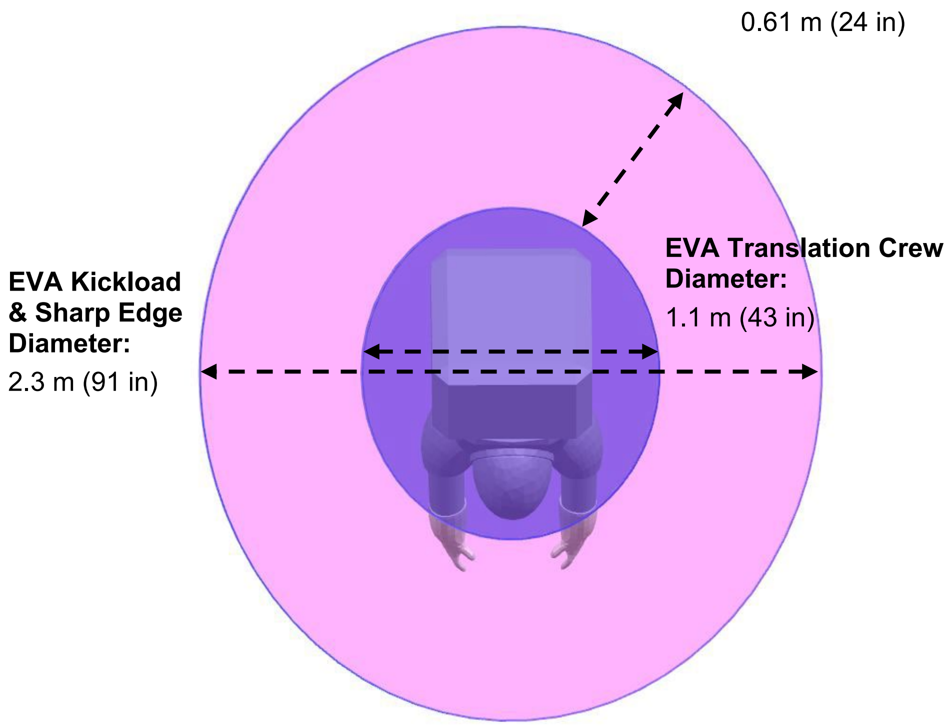


FIGURE 3.2.5-1 TOP VIEW PARTIAL GRAVITY EVA CONTACT HAZARD PRECLUSIONS ENVELOPE <TBR-HLS-EVA-007>

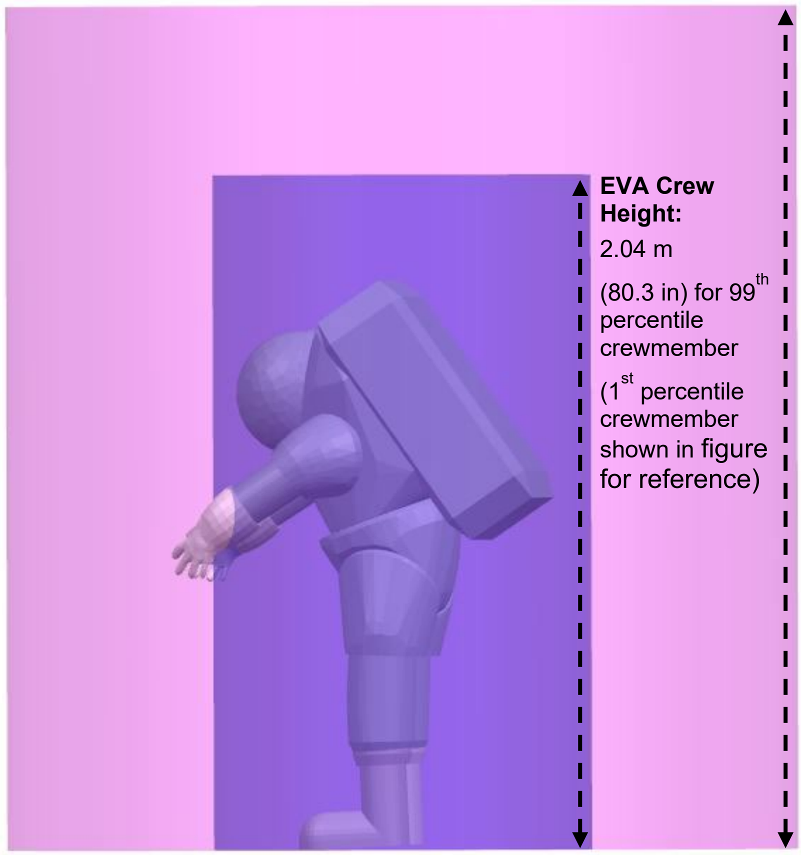


FIGURE 3.2.5-2 SIDE VIEW PARTIAL GRAVITY EVA CONTACT HAZARDS HEIGHT <TBR-HLS-EVA-007>

3.3 EVA HANDLING

3.3.1 Microgravity EVA Equipment Handling Features

The HLS shall include EVA handling features that are commensurate with the size of the hardware and the expected EVA operations as defined in Table 3.3.1-1 Constraints for EVA Transport of Objects. **[EVASC.0012]**

Rationale: This is to ensure that there will be provisions for proper EVA handling and transport. The handling features required progress from a simple tether point, to handrails, and fixture for robotic arm translation. Similarly, the translation mode of the crewmember progresses from hand-over-hand to Remote Manipulator

System (RMS) with object on a tether. For shorter distances, Body Restraint Tether (BRT) or foot restraints can be used for transfer of Orbital Replacement Units (ORUs). The larger or more massive the object, the more extensively the object must be tethered. Items that an EVA crewmember needs to manipulate that are over 340 kg (750 lbm) require robotic arm transport through a support fixture (e.g., grapple, micro square, etc.) for robotic arm translation.

Applicability: Microgravity

TABLE 3.3.1-1 CONSTRAINTS FOR EVA TRANSPORT OF OBJECTS

Object/Size	Object Translation Mode	Object Handling Method	Design Features Required for Translation
0 – 9 kg (0 – 20 lbm), 0 – 0.056 m³ (0 – 2 ft^3) max dim: 0.61 m (24 in)	Hand-over-hand crew translation with object on a tether	Tether	Tether point
0 – 136 kg (0 – 300 lbm), 0.056 – 0.14 m³ (2 – 5 ft^3) max dim: 1.52 m (60 in)	Hand-over-hand crew translation with object on a BRT	BRT	Handrail section[1]
0 –340 kg (0 – 750 lbm), 0.14 – 2.83 m³ (5 – 100 ft^3) max dim: 2.44 m (96 in)	Object on a transfer device (Crewmember on robotic arm with an APFR)	Transfer device interface	Two handrails are required[1]

[1] Handrail requirements can also be met using handling aids like scoops interfacing with fixtures on the object (e.g., ISS used square or round scoops). The HLS must supply the fixture. A universal fixture is highly desired over multiple types of fixtures.

3.3.2 Partial Gravity EVA Handling Capability

The HLS shall limit the properties of items to be handled by suited crewmember to the values outlined in Table 3.3.2-1 Constraint for Partial Gravity Large Mass Items **<TBR-HLS-EVA-003>** and Table 3.3.2-2 Partial Gravity Volume Limit Surface Carry **<TBR-HLS-EVA-003>**. **[EVASC.0160]**

Rationale: The limitations levied by this requirement apply to items intended for handling (i.e., relocation by carrying) by a single, suited crewmember, in one- or two-handed operations. Suited EVA crewmembers perform tasks to meet the mission goals and operate human-system interfaces required for use during suited EVA operations. Pressurized suits can limit the crew's mobility, dexterity, and tactility below that of an unsuited crewmember. The center of gravity (CG) of the suit impacts the ability of the crewmember's ability to run/walk/ambulate in a gravity environment. The intent of this requirement is to provide physical attributes (i.e., mass and volume) of an item that is carried by a suited crewmember during surface operations. It is anticipated that the crew will be expected to relocate items on the surface, including payloads and cargo, between a surface worksite or rover and the originating vehicle. The recommended mass limit for suited lifting was *determined using the revised National Institute for Occupational Safety and Health (NIOSH) lifting equation with a suited decrement factor included to account for reduced suited strength capabilities. The recommended mass limit for a suited crewmember carrying was determined by using the Liberty Mutual "Snook" tables. These tables provide psychophysical capabilities and limitation of the workers as they performed manual tasks with a suited decrement factor included to account for the reduced suited strength capabilities. Variances to this requirement, based on mission objectives or contingency operations, may be proposed to EHP via the EHP RIVA Panel.*

Applicability: Partial Gravity

TABLE 3.3.2 -1 CONSTRAINT FOR PARTIAL GRAVITY LARGE MASS ITEMS <TBR-HLS-EVA-003>

Task	Mass Limit for Suited Lifting in 1/6g kg (lbm)	Distance	Assumptions
Two-handed lifting and carry from the ground	31.3 (69)	8.23 m (27 ft)	1, 2, 3, 4, 5, 6, 13

Note:

a. This requirement is applicable to transfer of payloads or other equipment on the surface and is not applicable to small hand-carried or body-worn items (e.g., tools).
b. Is applicable to items that are intended for relocation.
c. Items of large mass and relocation distance should not be designed for one-handed lift.

TABLE 3.3.2 -2 PARTIAL GRAVITY VOLUME LIMIT SURFACE CARRY <TBR-HLS-EVA-003>

Task	Maximum Width cm (in)	Maximum Depth cm (in)	Maximum Height cm (in)	Assumptions
Two-Handed Carry	37.8 (14.9)	39.5 (15.6)	36 (14.2)	5,7,8,9, 13
One-Handed Carry	21 (8.3)			5,10,11,12

<u>Assumptions for Tables 3.3.2-1 and Table 3.3.2-2:</u>

1 Distance refers to the physical distance over which crew is expected to comfortably handle and relocate the item.
2 Item is lifted from the ground with handles at a height of 22.9 cm (12.3 in) or greater along the vertical axis, prior to traveling a distance.
3 Load is less than 40.6 cm (16.0 in) forward of the feet centerline
4 Assumes symmetric lift without back twisting
5 Crew are walking upright (neutral posture) on level ground; this limit will decrease on sloped terrain

[6] Two-handed carry occurs with arms outstretched with slightly bent elbows
[7] Two-handed carry occurs with arms outstretched with slightly bent elbows at waist level
[8] Container is a box with opposing handles on the lateral sides and the handles are positioned even with the center of mass/load of the loaded container
[9] Allowable height and depth of the box for two-handed carry are based on reach extrapolated for 1st percentile hand-arm length, and to allow suited leg clearance while walking. Allowable width of the two-handed carry box is based on bideltoid breadth of 1st percentile female. Size of the box includes handles.
[10] One-handed carry occurs with the arm at neutral posture along the side of the body.
[11] Container is a box with a handle on the top surface
[12] Allowable width of the box for one-handed carry is based on reach extrapolated for 1st percentile hand-arm length, and to allow suited leg clearance while walking. Size of the box includes handle.
[13] Does not apply to small, hand-carried tools or to portable, well-balanced items with a form factor where one dimension (e.g., the length) is more than **<TBR-HLS-EVA-003>** times greater than its other largest dimension (for example, a narrow mast of antenna with a much greater length than diameter)

3.3.3 Partial Gravity Step Design Parameter

The HLS shall limit the height of a crewmember's step to the values outlined in Table 3.3.3.-1 Partial Gravity Step Design Parameter **<TBR-HLS-EVA-004>**. **[EVASC.0162]**

Rationale: Pressurized suits can limit the crew's mobility, dexterity, and tactility below that of an unsuited crewmember. Step height needs to be considered for scenarios such as moving through a hatch, up into a vehicle or rover, and getting down off a vehicle or rover. An overhead restriction refers to the top of a hatch or other overhead obstruction that requires crew to simultaneously reduce their height while elevating their foot to move through an area (e.g., crew bending over/crunching while lifting their leg to move through a hatch of the dimensions in [EVASC.0153]). Taller crew may not have the capability to duck low enough to translate through a given hatch size. Variances to this requirement, based on mission objectives or contingency operations, may be proposed to EHP via the EHP RIVA Panel.

Applicability: Partial Gravity

TABLE 3.3.3-1 PARTIAL GRAVITY STEP DESIGN PARAMETER <TBR-HLS-EVA-004>

Type of Step / Threshold	Overhead Restriction cm (in)	No Overhead Restriction cm (in)	Assumptions
Front Step Up/Down		Maximum of 35.6 (14)	1,2,3
Front Step Over			
Sidestep Up/Down			
Sidestep Over	Maximum of 40.6 (16)		1,4,5

Assumptions:

[1] Deltas in lunar boot thickness, mobility or suit overall size may impact step heights.

[2] Available data set is not comprehensive across all ranges of anthropometry; a decrement factor was applied to the minimum step-up height seen in suited subject testing.
[3] Increments of attempted step height were defined by discrete platform heights used by test team.
[4] Subjects performed a side squat step while crossing a simulated threshold.
[5] Available data set is not comprehensive across all ranges of anthropometry; the sidestep threshold height was chosen as a compromise value that could be cleared by smaller suited subjects while still allowing taller suited subjects to duck below a set overhead restriction.

3.3.4 Hatch Transfer Constraint

The HLS shall limit dimensions of any hardware to be transferred between pressurized and unpressurized environments not to exceed the free volume of the airlock minus the volume of the two crewmembers (per Figure 3.3.4-1 Two Crew Envelope for Airlock Ingress/Egress **<TBD-HLS-EVA-008>**) with access to airlock systems, controls and procedures for ingress, egress, or emergency operations. **[EVASC.0013]**

Rationale: Crew may be expected to transfer hardware as part of normal or contingency operations. The free space within the vehicle airlock must accommodate the crew, the to-be-transferred hardware and crew's access to airlock systems. Using the volumetric dimensions of two suited crew members, vehicles shall define the volumetric limits of their ORUs. Once defined, those limits should be provided to EHP for inclusion in interface definition documents for tool and payload providers.

Applicability: Microgravity, Partial Gravity

RESERVED FOR FIGURE

FIGURE 3.3.4-1 TWO CREW ENVELOPE FOR AIRLOCK INGRESS/EGRESS <TBD-HLS-EVA-008>

3.3.5 Pressurized xEVA Suit Transfer through Airlock Hatch

The HLS shall design hatches to comply with xEVA suited pressurized crewmember transfer between pressurized and unpressurized environments with minimum hatch diameter of 1000 mm (39.37 in). **[EVASC.0135]**

Rationale: Suited pressurized crewmembers cannot fit through NASA Docking System (NDS). Analysis and experience have shown that a 1000 mm (39.37 in) hatch (e.g., circular, square, "D" hatch) allows a pressurized suited crewmember to transfer through the hatch in microgravity. The intent is to prevent the vehicle hatch hinge from intruding into the transfer corridor.

Applicability: Microgravity

3.3.6 EVA Lunar Hatch Dimensions

The HLS shall provide a minimum EVA Lunar hatch opening of 1.02 m (horizontal dimension) X 1.52 m (vertical dimension) (40 in X 60 in) for EVA egress/ingress. **[EVASC.0153]**

Rationale: A minimum EVA hatch opening is needed to allow a pressurized crewmember to enter and exit a structure in partial gravity without the xEVA suit coming in contact with the surrounding hatch structure. A sufficiently sized hatch opening allows a crewmember to ingress/egress without crawling, without contorting their body such as to cause undue strain (due to size, shape, transition frame), and without spending time aligning themselves with direct center of the opening. These dimensions assume that the EVA crewmember translates horizontally through the hatch and does not account for other potential hatch configurations or dimensions. Alternative configurations and dimensions can be approved by EHP as a part of a waiver to this requirement. EVA Hatch sizes must allow for the incapacitated crewmembers or crewmember requiring assistance to pass through the EVA hatch. Apollo-sized EVA hatches caused undue strain to crewmembers and caused their metabolic rate to increase during ingress/egress and did not allow for incapacitated crewmember operations.

Applicability: Partial Gravity

3.3.7 EVA Procedure Display Method

The HLS shall provide a method for displaying procedures during internal EVA operations. **[EVASC.0158]**

Rationale: Procedures are required for internal EVA operations like Prep and Post, suit assembly and checkout, xEVA maintenance. These procedures may be electronic for non-suited operations or hard copy for suited operations and emergencies, i.e., cue cards.

Applicability: Microgravity, Partial Gravity

3.3.8 Handling Alignment Criteria

3.3.8.1 Mounting Alignment Devices

The HLS shall provide alignment devices for hardware that requires mounting to preclude incorrect installations. **[EVASC.0014]**

Rationale: Alignment devices are preferred over markings alone. Alignment devices are often used to preclude incorrect installation and help provide gross alignment.

Applicability: Microgravity, Partial Gravity

3.3.8.2 Handling Alignment Marks

The HLS shall incorporate alignment marks to aid in proper interface orientation, installation, and mechanism operation. **[EVASC.0015]**

Rationale: Alignment marks can also be used to help indicate complete installation or actuation. This could include alignment marks, color coding, appropriate visual cues, and/or orientation arrows. A method for visual alignment (e.g., straight, or curved lines of a width and length to allow for accurate alignment) can also be applied to both mating parts of the hardware to assist in alignment in the operational position. Alignment devices are preferred over markings alone.

Applicability: Microgravity, Partial Gravity

3.3.9 Manual Locking Features

3.3.9.1 Locking Device

The HLS shall design mechanism locking devices (such as latches and latch locks) to travel at least 30% of their full travel before changing state (locked to unlocked or vice versa). **[EVASC.0016]**

Rationale: The intent is to travel beyond 30% before changing state. Designing a locking device mechanism that requires a large range of travel before changing state ensures that the EVA crewmember is aware what position the device is in at all times. Locking devices that have safety-critical functions may require additional locking features like Push-in-Pull (PIP) Pins to maintain sufficient failure tolerance as determined during the safety review process.

Applicability: Microgravity, Partial Gravity

3.3.9.2 Over Center Device Force

Over center devices shall have a minimum peak force of twice the force required to initiate travel, not to exceed 44 N (10 lbf). **[EVASC.0124]**

Rationale: Dexterity and tactility are degraded when wearing a pressurized xEVA suit, thus requiring increased levels of tactile feedback. Maximum force does not exceed 44 N (10 lbf) to comply with the finger actuation force requirement [EVASC.0018]. See Appendix A-2 Glossary of Terms for definition and examples of over the center devices.

Applicability: Microgravity, Partial Gravity

3.3.9.3 Soft Dock or Soft Capture Mechanisms

The HLS shall provide a soft dock or soft capture mechanism for hardware that is not held in place while being permanently installed. **[EVASC.0017]**

Rationale: Soft dock or soft capture is utilized to hold hardware in place during installation in microgravity. A soft dock mechanism holds the item in place, but the crewmember can remove it by applying a slight force to overcome the mechanism (i.e., magnets or ball detents, reference [EVASC.0126] for minimum soft dock forces). Soft capture release requires an additional operation of a mechanism for release (i.e., mechanical latch). The intent of this requirement is from the perspective of what works best for EVA. This may or may not be acceptable for Extravehicular Robotics (EVR) Systems. Depending on the Program this requirement is applied to and their plans for EVA and EVR, tailoring may be required. While docked to staging vehicle, EVR is considered to be the primary mode of mating/demating external payloads. Soft docks should be avoided as much as possible, especially those requiring high loads.

Applicability: Microgravity

3.3.9.4 Soft Capture

The HLS shall use soft capture for hardware that is not held in place while permanently installed, as opposed to soft dock in the following cases to increase safety:

1) Hardware more massive than 272 kg (600 lbm)
2) Large hardware that presents crewmember visibility problems when verifying position for mating
3) Complex hardware with unusual shapes or centers of gravity
4) Hardware installations where partial gravity effects can be used in lieu of a soft capture feature. **[EVASC.0125]**

Rationale: Soft capture helps restrain hardware items, while final alignment/attachment can be made. Hardware that does not require a soft dock/soft capture may still employ these devices to improve EVA operability. The intent of this requirement is from the perspective of what works best for EVA. This may or may not be acceptable for EVR systems. Depending on the Program this requirement is applied to and their plans for EVA and EVR, tailoring may be required. While docked to staging vehicle, EVR is considered to be the primary mode of mating/demating external payloads. Soft docks should be avoided as much as possible, especially those requiring high loads. Soft capture can be the first step in the process for a very large object. Soft capture can be used instead of soft dock for these cases in microgravity. However, once captured, additional *soft dock may also be used to establish fine alignment prior to final mechanical attachment, such as bolt torques or latch throws.*

Applicability: Microgravity, Partial Gravity

3.3.9.5 Soft Dock Force

The force required to initially and temporarily secure an object (soft dock) shall be sized proportionally to the mass of the object per Table 3.3.9.5-1 Soft Dock Force. **[EVASC.0126]**

Rationale: The larger the mass, the more difficult it may be to perceive the tactile feedback that soft dock has been achieved. Existing rigidizable tether configurations only support applying forces of up to 22 N (5 lbf). Imparting forces beyond 22 N (5 lbf) will require alternate methods of restraining the crewmember. The intent of this requirement is from the perspective of what works best for EVA. This may or may not be acceptable for EVR systems. Depending on the Program this requirement is applied to and their plans for EVA and EVR, tailoring may be required. While docked to staging vehicle, EVR is considered to be the primary mode of mating/demating external payloads. Soft docks should be avoided as much as possible, especially those requiring high loads.

Applicability: Microgravity

TABLE 3.3.9.5-1 SOFT DOCK FORCE

Hardware Mass kg (lbm)	Soft dock Force N (lbf)	Soft Dock Force Tolerance N (lbf)
20.4–90.7 (45–200)	22 (5)	2.2 (0.5)
91.2–181.4 (201–400)	44 (10)	4.4 (1.0)
181.9–272.2 (401–600)	67 (15)	6.7 (1.5)
272.6–340.2 (601–750)	89 (20)	8.9 (2.0)

3.3.10 Hand Grip Surface/Boot Contact

The HLS shall incorporate a non-abrasive, non-slip surface on hand-gripping/EVA foot contact surfaces that have a repetitive-use potential to prevent EVA glove/boot slippage and abrasion. **[EVASC.0023]**

Rationale: A non-abrasive non-slip surface can be achieved through surface finish (e.g., prevents abrasion of EVA glove material) or shape of the object (e.g., a knob) for microgravity applications. Partial gravity application includes areas where crew need to grasp with the pressurized EVA glove but adds considerations *for crew traversing on the surface given that there may be a layer of dust between the surface and the boot.*

Applicability: Microgravity, Partial Gravity

3.3.11 Unique Labeling

The HLS shall code and/or mark translation paths, worksites, and any other callouts for the EVA crewmember with appropriate cues/indicators/labels for intended use as defined in EVA-EXP-0049, *Extravehicular Activity (EVA) Office Exploration EVA System Labeling Guidelines*. **[EVASC.0024]**

Rationale: Labeling can include alignment markings, operating instructions (bolt turns/torque/direction), Connector identification, Orbital Replacement Unit (ORU) part number and serial number (to prevent confusion during change out), caution and warning labels, location identification, etc.

Applicability: Microgravity, Partial Gravity

3.3.12 Hand Tools

3.3.12.1 Hand Tool Operations

The HLS shall design hand tools to be capable of being operated one-handed, ambidextrously for engagement/disengagement. **[EVASC.0025]**

Rationale: EVA operations require the crewmember to actively use both hands to fully complete a task. In microgravity, this can mean that one hand is used to stabilize the crewmember while the other is used to operate the tool.

Applicability: Microgravity, Partial Gravity

3.3.12.2 Ratchet Wrenches

3.3.12.2.1 Hand Ratcheting

The HLS shall design worksites, equipment, and tools to accommodate a throw angle for manual EVA ratcheting of at least 90º on all EVA operable fasteners. **[EVASC.0135a]**

Rationale: This requirement applies to all EVA operable fasteners (bolts, screw, nuts, etc.) and hex-head drive shafts. Ratchet wrenches can be used where at least 90° of handle movement is possible.

Applicability: Microgravity, Partial Gravity

3.3.12.2.2 Throw Angle

The HLS shall design tools that incorporate a ratcheting handle that are capable of providing torque with a minimum throw angle of 45º. **[EVASC.0026]**

Rationale: Efficient tool usage requires adequate access space.

Applicability: Microgravity, Partial Gravity

3.3.12.2.3 Ratchet Mechanism

The HLS shall design hardware requiring use of a ratchet wrench that incorporates a fine-tooth mechanism allowing engagement every 10º maximum. **[EVASC.0127]**

Rationale: Ratchet increments should be as small as possible. The 10º increments provides 18 ratchet cycles in 180º of handle movement.

Applicability: Microgravity, Partial Gravity

3.3.12.2.4 Back Drive Torque

The HLS shall design EVA wrenches to have a maximum back drive torque of 0.05 Nm (7 in-oz) while operated by a pressurized glove. **[EVASC.0128]**

Rationale: Incorporating this will ensure one-handed operation by the crewmember.

Applicability: Microgravity, Partial Gravity

3.3.12.2.5 Running Torque

The HLS shall design fasteners to be used with an EVA ratchet wrench to have a running torque that is greater than the maximum back drive torque of 0.05 Nm (7 in-oz). **[EVASC.0129]**

Rationale: Incorporating this will ensure one-handed operation by the crewmember.

Applicability: Microgravity, Partial Gravity

3.3.13 EVA Actuated Controls

3.3.13.1 Pressurized Glove Compatibility

The HLS controls operated by an EVA suited crewmember shall be compatible with a pressurized glove. **[EVASC.0027]**

Rationale: Controls that necessitate actuation by a pressurized glove are to have the appropriate features for pressurized suited operation (controls can include the following and are not all inclusive: touch screens, toggle switches, fasteners, knobs, latches, etc.). The controls may need to be adjusted to accommodate the appropriate tactile feedback when used by the pressurized-glove hand to ensure accurate operation of the control compared to unsuited performance. While dexterity and tactility are degraded when using a pressurized EVA suit, fatigue is also an issue. Fatigue happens when repeatedly applying a significant load to achieve a task.

Applicability: Microgravity, Partial Gravity

3.3.13.2 Inadvertent Actuation of EVA-Actuated Controls

The HLS shall design EVA-actuated controls to prevent inadvertent actuation. **[EVASC.0087]**

Rationale: This can be accomplished via switch guards, recessing, etc. EVA worksites are often congested, and inadvertent contact is often hard to avoid.

Applicability: Microgravity, Partial Gravity

3.3.14 EVA Handrails/Handholds

3.3.14.1 Handrail/Handhold Cross-Section

The HLS shall design cross-sectional profiles for handholds/handrails to meet Figure 3.3.14.1-1 Handrail/Handrail Profile Dimensions, for microgravity/dual gravity field application with tolerances per SDG33107728, via Top Mounted Handrail drawing SEG33106347 latest revision or Figure 3.3.14.1-2 Partial Gravity Handrail/Handhold Profile Dimensions. **[EVASC.0029]**

Rationale: The intent of this requirement is to ensure that all handholds/handrails are designed to accommodate the various EVA interfaces (e.g., pressurized glove, tools, tethers, etc.). The HLS is encouraged to contact the Johnson Space Center (JSC) EHP before manufacturing handrails/handholds to ensure that the handrail/handhold meets interface requirements. Handrail cross-section is intended for use in microgravity environment with heritage ISS EVA tools. The microgravity environment application of handrail cross-section design needs to meet the loads outlined in [EVASC.0050] for use of existing heritage ISS tools (e.g., BRT). If HLS is to dock with Gateway and has a potential for performing an EVA, then the preferred handrail/handhold profile is outlined in Figure 3.3.14.1-1. In partial gravity, there is an additional envelope profile that can be utilized and is outlined in Figure 3.3.14.1-2.

Applicability: Microgravity, Partial Gravity

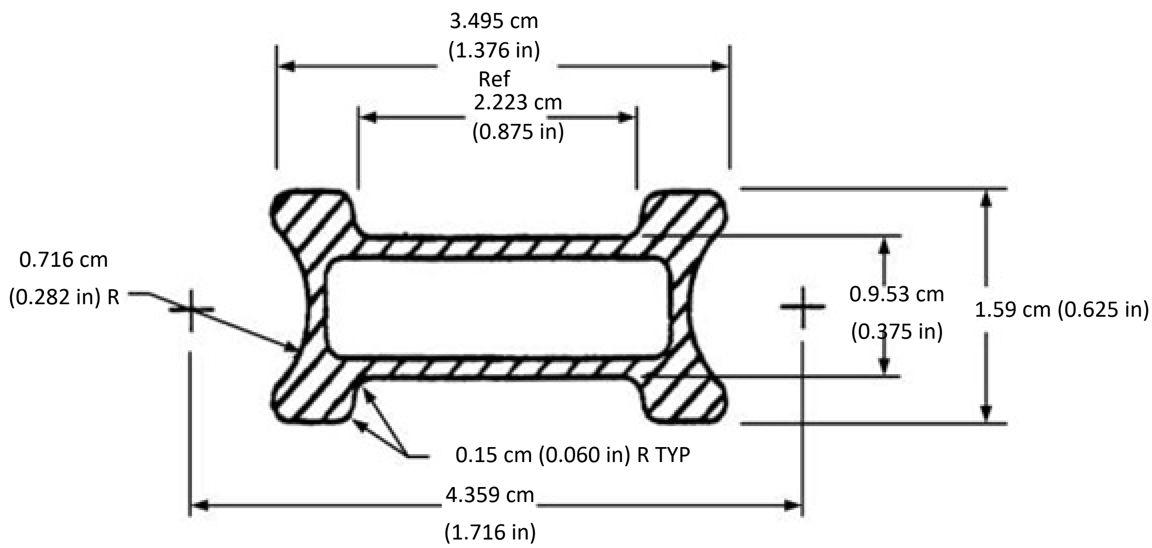
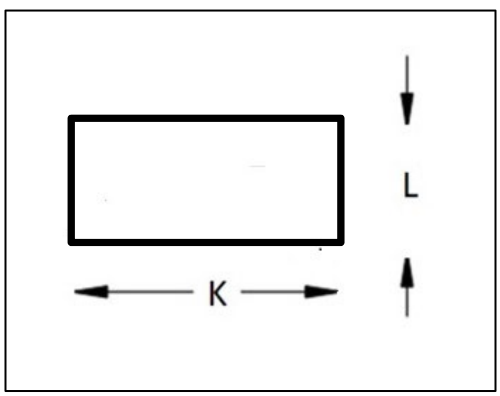


FIGURE 3.3.14.1-1 HANDRAIL/HANDRAIL PROFILE DIMENSIONS



	cm	in
K	3.50	1.376
L	1.59	0.625

FIGURE 3.3.14.1-2 PARTIAL GRAVITY HANDRAIL/HANDHOLD PROFILE DIMENSIONS

3.3.14.2 Handrail/Handhold Length

The HLS shall design handholds/handrails with a minimum grip length of 0.15 m (6 in) that can be operated by a pressurized glove. **[EVASC.0030]**

Rationale: Grip length is essential in designing translation aids for EVA crewmembers. There needs to be adequate length for the EVA pressurized glove to access for EVA activities. In microgravity, this also will accommodate attachment of a BRT if it meets the torsional loading on the handrail/handhold from the interface connection point.

Applicability: Microgravity, Partial Gravity

3.3.14.3 Handrail/Handhold Accessibility

The HLS shall design handrail/handholds and other EVA interfaces located in the defined crew translation path or worksite to be left exposed and usable to the crew as a translation/stability aid. **[EVASC.0031]**

Rationale: Obscured or blocked handholds/handrails can impede the accomplishment of EVA tasks. Thermal covers on spacecraft and hardware should be designed such that handholds/handrails remain accessible. For handrails which are used only as handling aids (and not translation aids), the handrail may be covered if it is accessible via an EVA-operable access cover or flap. This addresses HLS-[Mission requirements document] HMTA-0189 from the appropriate HLS requirements document specified in associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity, Partial Gravity

3.3.14.4 Continuous Handrail/Handhold Spacing

The HLS shall space continuous handholds/handrails and the integral safety tether attach points to not exceed 0.61 m (24 in) between the standoff and handrail/handhold as defined in Figure 3.3.14.4-1 Handrail/Handhold Gaps. **[EVASC.0032]**

Rationale: The 0.61 m (24 in) spacing is the comfortable and acceptable arm reach for EVA crewmembers. In microgravity, this spacing enables hand-over-hand translation by a pressurized suited crewmember. In partial gravity, this spacing enables ascent or descent from a ladder by a pressure suited crewmember (reference requirement [EVASC.0162] for step height).

Applicability: Microgravity, Partial Gravity

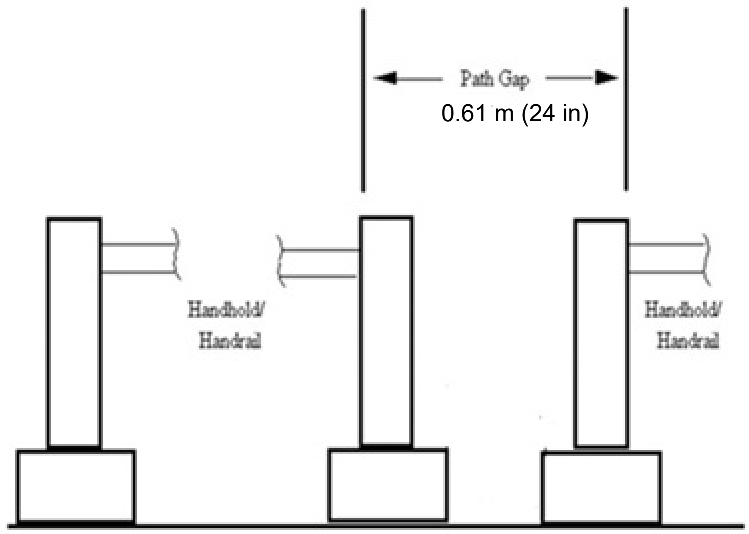


FIGURE 3.3.14.4-1 HANDRAIL/HANDHOLD GAPS

3.3.14.5 EVA Egress Handrail Spacing

The HLS shall space handrail/handholds required for EVA egress to be within 30.5 cm (12 in) of the EVA egress location. [**EVASC.0144]**

Rationale: Need to ensure that there is adequate aid for EVA egress operations. The nominal continuous handrail/handhold spacing is defined in [EVASC.0032].

Applicability: Microgravity, Partial Gravity

3.3.14.6 EVA Worksites

3.3.14.6.1 Optimum Work Envelope

The HLS shall ensure EVA worksites with either one- or two-handed EVA glove operations reside within the working volumes as defined in the following: Figure 3.3.14.6.1-1 Optimum Work Volume – Microgravity, Figure 3.3.14.6.1-2 Partial Gravity Optimum Work Volume **<TBR-HLS-EVA-005>**, Table 3.3.14.6.1-1 Partial Gravity Optimum Work Volume **<TBR-HLS-EVA-005>**, and Figure 3.3.14.6-3 Partial Gravity Work Volume – Reach Envelope **<TBR-HLS-EVA-005>**. **[EVASC.0035]**

Rationale: If the microgravity EVA task requires two-handed operations, the two-handed working volume should be used. If the EVA task can be done one-handed, the one-handed work volume should be used and is based on the heritage ISS EMU suit. Partial gravity application work volume is not associated with the use of a foot restraint for surface operations and is based on the Exploration EMU (xEMU) reference design. Crewmembers will be traversing around, to and from vehicle *worksite areas (e.g., catwalk around a cargo lander, walking under the lander, ingress/egress of vehicle to the surface, and areas around unpressurized and pressurized rovers).*

Applicability: Microgravity, Partial Gravity

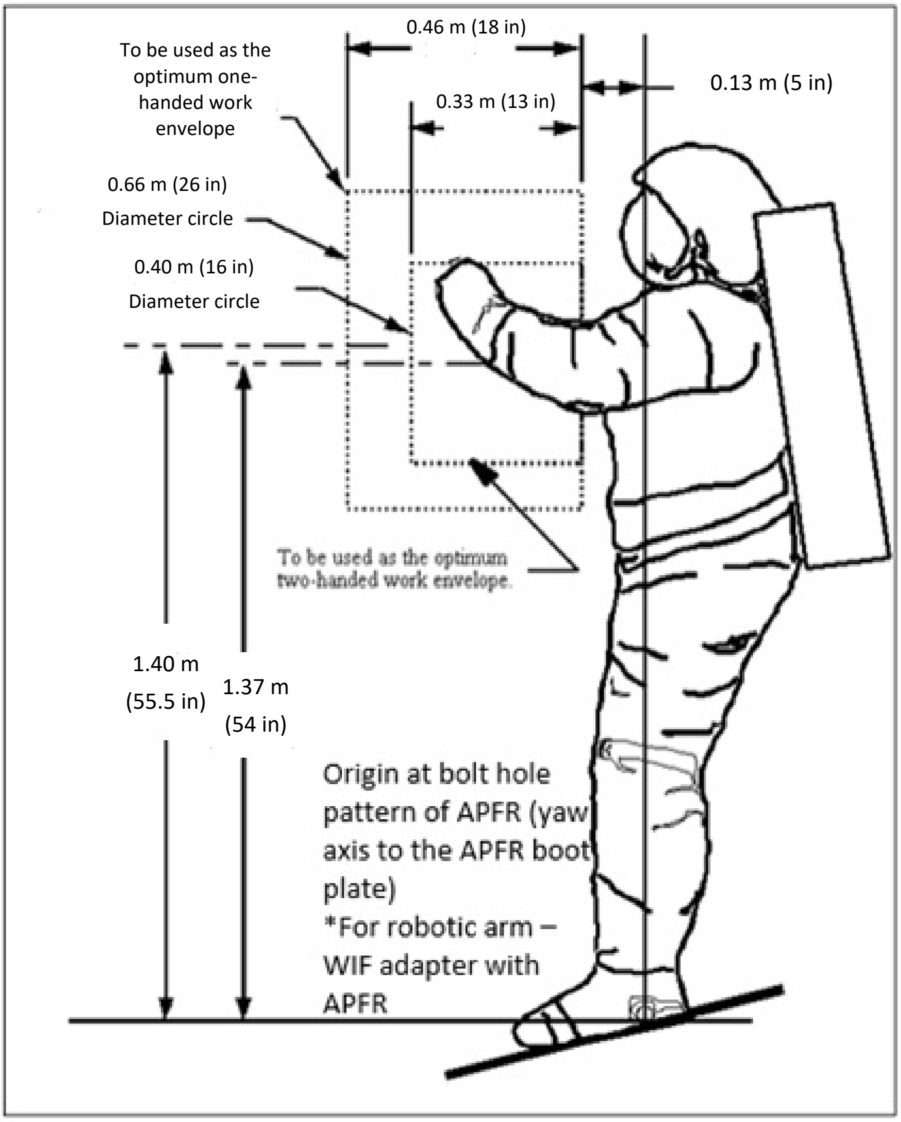


FIGURE 3.3.14.6.1-1 OPTIMUM WORK VOLUME – MICROGRAVITY

Note:
1. Reach/work envelope values are from a fixed foot restraint platform and include torso motion

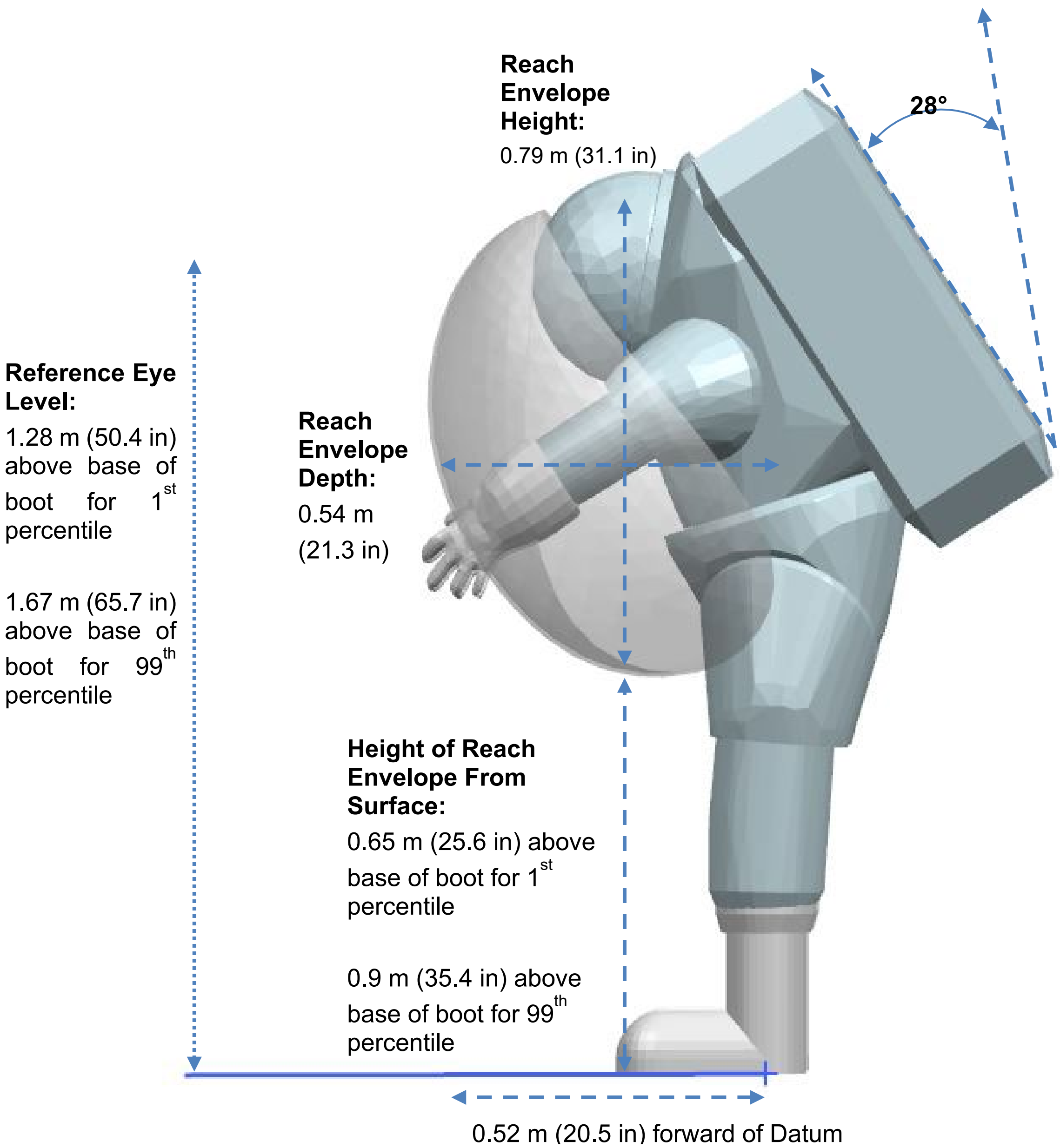


FIGURE 3.3.14.6.1-2 PARTIAL GRAVITY OPTIMUM WORK VOLUME <TBR-HLS-EVA-005>

TABLE 3.3.14.6.1-1 PARTIAL GRAVITY OPTIMUM WORK VOLUME <TBR-HLS-EVA-005>

	Width (1-Handed) m (in)	Width (2-Handed) m (in)	Width (Total) m (in)	Height (1-Handed) m (in)	Height (2-Handed) m (in)	Depth (1-Handed) m (in)
Maximum	0.77 (30.3)	0.18 (7.1)	1.35 (53.1)	0.79 (31.1)	0.51 (20.1)	0.54 (21.3)
Preferred	0.31 (12.1)	0.07 (2.8)	0.54 (21.3)	0.32 (12.4)	0.20 (8.0)	0.22 (8.5)

Assumptions:

1. Reach/work envelope values are Hard Upper Torso-fixed and do not include torso motion
2. Person-to-person variability is substantial for reach envelope shapes and dimensions. The listed envelopes represent the worst-case capability of a 1st percentile hand-arm length crew in an xEMU thus correspond to a “worst-case” condition.
3. It is assumed that he hand targets should be placed in of the envelope to allow small persons to reach. However, due to the mechanical constraints and pressurization of the suit, large persons may need to exert a higher force for objects close to the body.
4. Preferred reach envelope is approximately 40% of the maximum envelope size, of which measurements are from a prolonged duration EVA test. However, the specific location within the maximum reach envelope may differ.
5. The reach envelope was measured from the simulated 1/6-g posture, with the upper body slightly bent forward. The envelopes were also measured from the “natural” motions of the subjects, namely the straight elbow near the periphery and about 90° elbow bending at the central and overhead regions.

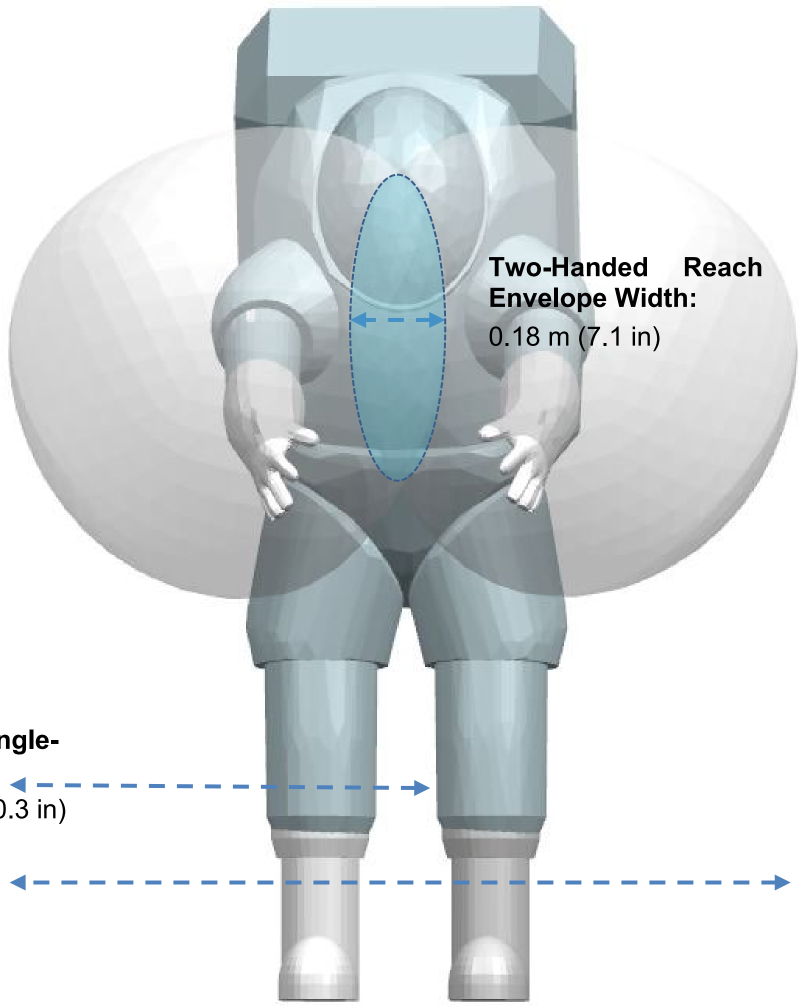


FIGURE 3.3.14.6.1-3 PARTIAL GRAVITY WORK VOLUME – REACH ENVELOPE <TBR-HLS-EVA-005>

3.3.14.6.2 EVA Egress/Ingress Methods

The HLS shall provide EVA egress/ingress methods from/to the vehicle that accommodates the pressurized crewmember's mobility. **[EVASC.0157]**

Rationale: The intent of this requirement is to ensure that the pressurized crewmember has a compatible egress/ingress method from the vehicle to the lunar *surface, and back to the vehicle after the EVA. If the vehicle design includes a method, such as a ladder, gate, step, etc., then the design has to accommodate the pressurized crewmember mobility with regards to pressurized glove interface, handhold spacing and width, as well as lower torso mobility to climb. In addition, safety of the crewmember will also need to be taken into consideration with regards to fall protection. Vehicles will need to jointly develop and demonstrate the egress/ingress methods with the EVA suit provider to ensure compliance with this requirement. The following requirements aid in addressing intent for portions of this requirement: HLS- [Mission requirements document]-HMTA-0002, HLS- [Mission requirements document]-HMTA-0167, and HLS- [Mission requirements document]-HMTA-0189 from the appropriate HLS requirements document specified in associated EVA-EXP-0070 Mission Annex (reference section 2.2).*

Applicability: Microgravity, Partial Gravity

3.3.14.6.3 Crew Aids for Stability

The HLS shall place crew stability aids or grasp points for a dedicated, robotic, or free-float worksite within 0.46 m (18 in) above or below the center of the crewmember's optimum two-handed envelope, 0.61 m (24 in) to the left or right of the body centerline, and between 0.13 m (5.0 in) and 0.58 m (23 in) from the bolt hole pattern of the foot restraint (same depth as the one-handed work envelope) as defined in Figure 3.3.14.6.3-1 Crew Aids for Stability. **[EVASC.0036] <FW-0070-005>**

Rationale: Stability aids in the specified envelope provide usable and reachable interfaces to enable performance of EVA tasks. Stability aids might include handrails, handholds, or equivalent structure. The one and two-handed envelopes are defined in requirement [EVASC.0035] and are depicted in Figure 3.3.14.6.3-1 below, pink for the two-handed and yellow for the one-handed envelope. This is based on the heritage ISS EMU suit. The intent is to preserve the envelopes for microgravity EVAs.

Applicability: Microgravity

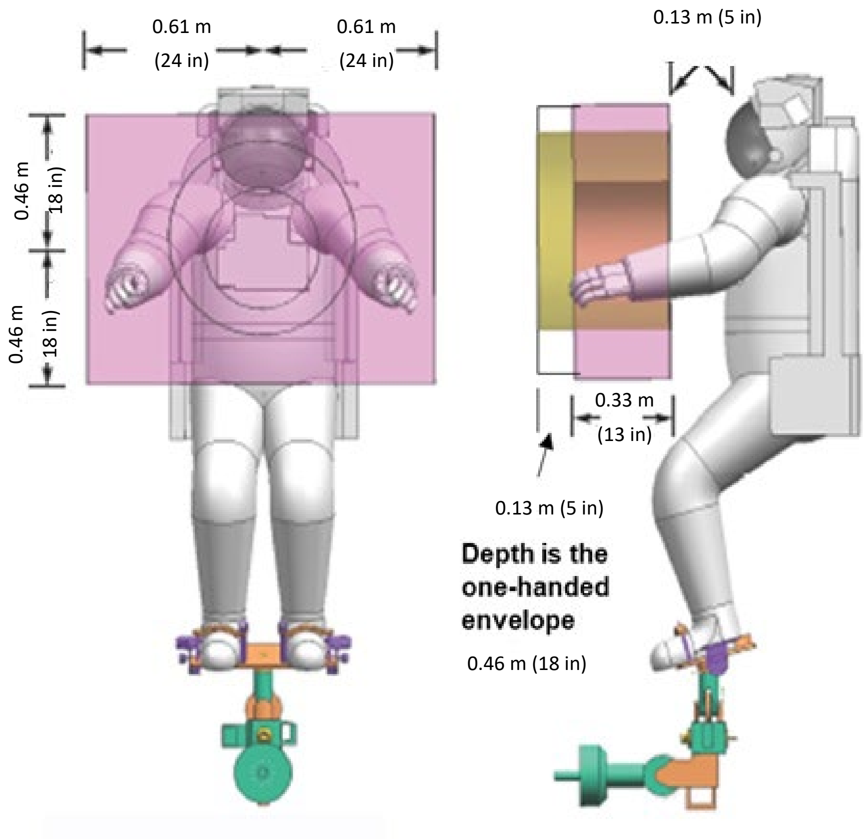


FIGURE 3.3.14.6.3-1 CREW AIDS FOR STABILITY

NOTE: For definitions of the one- and two-handed envelope, reference Figure 3.3.14.6.1-1 Optimum Work Volume – Microgravity, in requirement [EVASC.0035].

3.3.14.6.4 EVA Worksites Using Robotic Work Platform

The HLS shall design worksites requiring a robotic work platform to include handholds/handrails within the EVA crewmember worksite area to react forces or moments and provide stability. **[EVASC.0037]**

Rationale: Intent is to ensure that the forces or moments created by the crewmember do not back-drive the robotic work platform. It is intended that the handrails/handholds meet the Crew Aids for Stability requirement [EVASC.0036].

Applicability: Microgravity, Partial Gravity

3.3.14.7 EVA Hardware

3.3.14.7.1 Lubricant Use

The HLS shall use hardware lubricants that precludes transfer to the xEVA glove or must accept that the lubricant area will be designated as a “no touch” area. **[EVASC.0038]**

Rationale: It has been shown that dry films are the best for EVA cleanliness purposes but may not be appropriate for all tool performance applications. Other lubricants may be acceptable but must not transfer to the xEVA glove/suit. This requirement applies only to vehicle areas that will be interacted with by the suited crewmembers.

Applicability: Microgravity, Partial Gravity

3.4 WORKSITE OUTFITTING

Worksites are defined in Appendix A-2 Glossary of Terms.

3.4.1 Worksite Mobility

The HLS shall utilize foot restraints that accommodate the crewmember’s range of motion within the constraints of the xEVA suit while at the EVA worksite defined in Figure 3.3.14.6.1-1 Optimum Work Volume – Microgravity, in requirement [EVASC.0035]. **[EVASC.0040]**

Rationale: The work volume is based on the heritage ISS EMU suit. The intent is to preserve the envelopes for microgravity EVAs.

Applicability: Microgravity

3.4.2 Worksites

3.4.2.1 Worksite Field of View

The HLS shall configure worksites such that the EVA crewmember shall have an unobstructed line of sight to the worksite. All providers will provide a list of EVA tasks. **[EVASC.0041]**

Rationale: The intent is to ensure that EVA interfaces are not obstructed by surrounding hardware and includes time periods a crewmember is driving or at worksites during surface operations. EVA suits limit the field of vision and range of motion of EVA crewmembers when compared with non-suited activities. The location of equipment to be operated during EVA must accommodate these limitations.

Applicability: Microgravity, Partial Gravity

3.4.2.2 Working Volume

The HLS shall design equipment to be EVA-manipulated to provide the working volume as specified in Figure 3.4.2.2-1 Working Volume for Manipulative EVA Tasks, and Figure 3.4.2.2-2 Partial Gravity Working Volume **<TBD-HLS-EVA-013>**. **[EVASC.0042]**

Rationale: The work volume allows the crewmember to work comfortably without entrapment or confinement concerns and preserves a free area around the crewmember to reduce the risk of inadvertent EVA contact hazards. The work volume is based on the heritage ISS EMU, but still intend to apply the 1.2 m (48 in) cylinder around the base of the surface vehicle. This requirement volume does not apply once the crewmembers are away from the vehicle.

Applicability: Microgravity, Partial Gravity

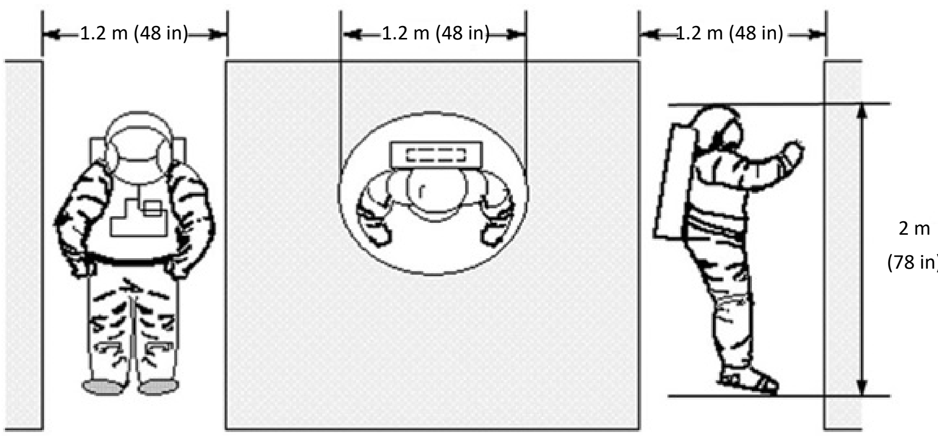


FIGURE 3.4.2.2-1 WORKING VOLUME FOR MANIPULATIVE EVA TASKS

RESERVED FOR FIGURE

FIGURE 3.4.2.2-2 PARTIAL GRAVITY WORKING VOLUME <TBD-HLS-EVA-013>

3.4.3 Dedicated EVA Worksite

Dedicated EVA worksites shall restrain the crewmember at the worksite with either an APFR or BRT where any of the following conditions apply as specified in Table 3.4.3-1 Worksite Forces, for contingency cases where robotic crew transport and restraint capability cannot be used:

(1) Two-handed operations are required to complete the task

(2) Forces are required which exceed the following:

TABLE 3.4.3-1 WORKSITE FORCES

Linear Force	Duration
4.4 N (1.0 lbf)	4.5 sec
22.2 N (5.0 lbf)	2.1 sec
44.5 N (10.0 lbf)	1.4 sec

(3) Tools are required to complete the task

(4) Objects for manipulation do not have a soft dock/soft capture mechanism to aid in installation **[EVASC.0148]**

Rationale: Restraint provisions at a worksite vary, depending on the complexity and specific requirements of the task. Reference Figure 3.3.14.6.3-1 Crew Aids Stability [EVASC.0036] for relative placement of stability aids. Typically, the remote manipulator arm (with crew attached), requires the use of a foot restraint and would limit crew translation – the BRT does not require foot restraint, and as such does ***not*** *limit translation.*

Applicability: Microgravity

3.4.4 Robotic Assisted EVA Worksites

EVA worksites requiring crew positioning when the robotic arm platform is stationary shall provide a force reaction mechanism (e.g., crew stability aid or grasp point) as defined in requirement [EVASC.0036], independent of the robotic stabilization platform for EVA worksite operations requiring crew-generated forces greater than 10 lbf (44 N). **[EVASC.0149]**

Rationale: The intent is to ensure that if a robotic assisted worksite is needed, that the hardware provider considers definition of the worksite to be within the kinematic and reach envelope of the manipulator utilized. In addition, that the robotic arm platform satisfies the Crew Aids for Stability requirement [EVASC.0036].

Applicability: Microgravity

3.4.5 Free-Float Worksites

All tasks to be performed by a free-float crewmember shall be located within the one-handed envelope defined in Figure 3.3.14.6.1-1 Optimum Work Volume – Microgravity, in requirement [EVASC.0035]. **[EVASC.0150]**

Rationale: Free-float worksites must not be a dedicated worksite as defined in requirement [EVASC.0148] or a Robotic Assisted EVA Worksite as defined in [EVASC.0149].

Applicability: Microgravity

3.4.6 Installation of Passive Worksite Interface Sockets

The HLS shall design any EVA worksites which include passive WIF sockets to additionally provide handholds/handrails located within 0.61 m (24 in) of the passive WIF to support installation of the foot restraint by the EVA crewmember. **[EVASC.0045]**

Rationale: Based on previous ISS experience, the intent of this requirement is to ensure that interfaces necessary to interface with the foot restraint socket are considered part of the EVA worksite and include the appropriate stability aids for installation.

Applicability: Microgravity

3.4.7 Foot Restraint Ingress/Egress Aids

The HLS shall design worksites with WIFs to include crew mobility aids located within 0.91 to 1.2 m (36 to 48 in) above the foot restraint/boot interface, 0.61 m (24 in) to the left or right of the foot restraint/boot interface centerline, and 0.46 m (18 in) in front of the centerline axis of the foot restraint/boot interface to aid in ingress and egress of the foot restraint as specified in Figure 3.4.7-1 Ingress and Egress Aids for Foot Restraint. **[EVASC.0046]**

Rationale: Ingress and egress aids should be placed at appropriate positions to accommodate the limitations of the xEVA Suit design. This requirement only applies to those HLSs that require the use of a WIF. These dimensions are based on the heritage ISS EMU suit. The intent is to preserve the envelopes for microgravity EVAs.

Applicability: Microgravity

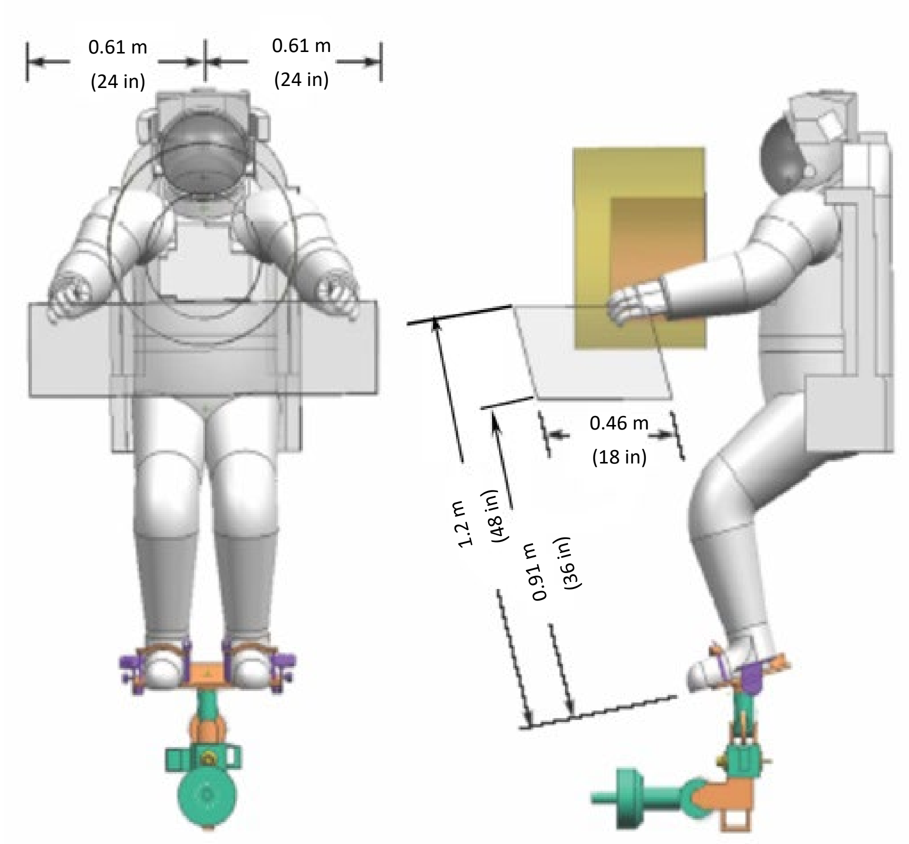


FIGURE 3.4.7-1 INGRESS AND EGRESS AIDS FOR FOOT RESTRAINT

3.4.8 Visual Contrast at Worksite

The HLS shall design worksites and all associated equipment, such as labeling, markings, displays, and installation cues to be clearly readable by crewmembers in extreme lighting conditions. **[EVASC.0047] <FW-0070-003>**

Rationale: EVA crewmembers require adequate lighting to perform EVA tasks safely and efficiently, including reading of hardware labels while EVA. Extreme lighting conditions range from both maximum solar irradiance (1370 W/m² at 1 Astronomical Unit (AU)) and darkness with widely varying angles of incidence; these conditions can challenge the crewmember's ability to interpret EVA labels. Thus, all labels to be read by the EVA crewmember while EVA must all be designed with extreme lighting conditions in mind. For instance, EVA crewmembers utilize EVA Helmet Visors that reduce glare and direct sunlight incidence on the EVA crewmembers' eyes. Similarly, the xEVA suit provides its own EVA suit-mounted lights (or supplied by the xEVA System) that ensure minimum required lighting is immediately available at the EVA worksite during *eclipse or shaded operations. Vehicle and hardware builders must demonstrate designs are legible in these extreme conditions and that the design, while acceptable in one condition (such as maximum solar irradiance), does not render it illegible in the other (such as darkness). For any EVA interface that has an installed and removed position, the vehicles must also clearly visually indicate successful installation and removal.*

Applicability: Microgravity, Partial Gravity

3.5 LOADS

3.5.1 Tether Attach Points

3.5.1.1 Color for EVA Handling and EVA Tether Points

Handholds or tether points intended to be used only for equipment handling and not crew translation, tethering or restraint, shall be colored according to Table 3.5.1.1-1 EVA Handling and EVA Tether Point Colors. **[EVASC.0033] <FW-0070-006>**

TABLE 3.5.1.1.-1 EVA HANDLING AND EVA TETHER POINT COLORS

Item	Gravity Field Applicability	Color	Notes
EVA Handles on removable equipment intended to be used only for equipment handling	Microgravity, Partial Gravity	Silver or white	EVA Handles on hardware for handling (i.e., ORU handles) need not be designed for translation or safety loads and therefore shall not be colored the same.
EVA Tether Points	Microgravity, Partial Gravity	Silver or white	EVA Tether Points are defined in [EVASC.0048].

Rationale: The intent is to ensure that if the crewmember only needs to handle the ORU versus translate over or across it, the additional loading requirements on the handle are not necessary. Similarly, EVA Tethers [EVASC.0048] are available for tethering equipment at loads less than those required for Crew Safety Tethers [EVASC.0116] or Crew Safety Restraints [EVASC.0161]. Reference requirement [EVASC.0117] for handhold/handrails that can withstand the loads.

Applicability: Microgravity, Partial Gravity

3.5.1.2 EVA Tether Point

The HLS shall design a non-softgoods tether point for a minimum load of 334 N (75 lbf) or the weight of the item (whichever is greater) in any direction per Figure 3.5.1.2-1 EVA Tether Point Dimensions, in order to accommodate EVA Tether hooks. **[EVASC.0048]**

Rationale: This requirement applies to the equipment tether attach points, and not to crewmember safety attach points (reference [EVASC.0050] Table 3.5.2-1 Microgravity EVA-Induced Loads, Design Limit Load Type: "Tether Point"). The tether attach point is designed such that two equipment hooks can attach to it for transfer of hardware from one tether to another. Other types of tether attach points, like tether points integral to existing structure, are also acceptable, but shall meet the intent of Figure 3.5.1.2-1 EVA Tether Point Dimensions, in minimum hole size and maximum cross-sectional dimensions. Tether point design features should allow the tether point to be accessed with a hook without manipulation. This is a crewmember one-handed operational task. For example, softgoods tether loops will be stiff, and keyring-type tether loops will be rigidly secured to prevent movement during tethering operations. EVA Tether Points are not required for partial gravity application, but if used, must meet the requirement.

Applicability: Microgravity, Partial Gravity

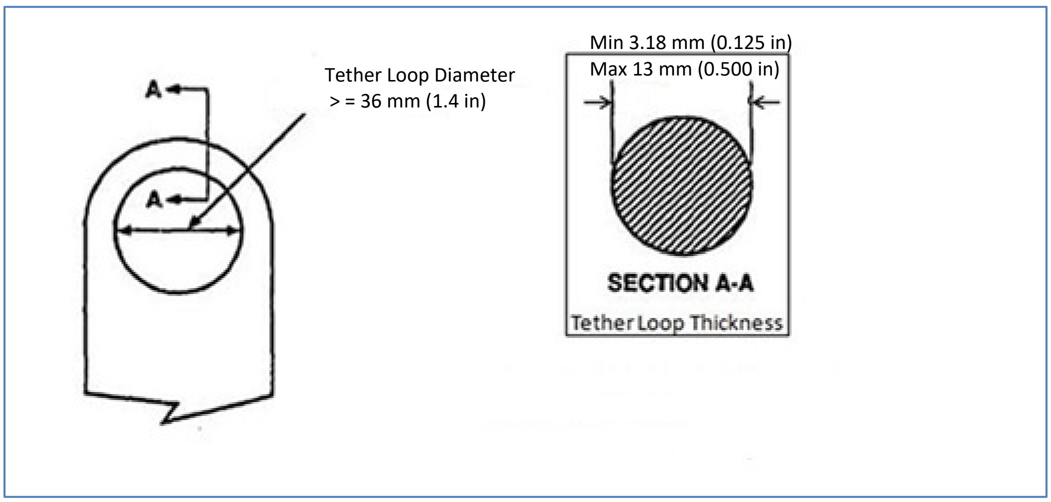


FIGURE 3.5.1.2-1 EVA TETHER POINT DIMENSIONS

3.5.1.3 Soft Goods Tether Point Loads

The HLS shall design any soft goods tether point to be attached to soft good hardware to be within the tether loop thickness limits defined in requirement [EVASC.0048] Figure 3.5.1.2-1 EVA Tether Point Dimensions, across its entire length for a minimum load of 133 N (30 lbf) or the weight of the item (whichever is greater) in any direction in order to accommodate EVA Tether hooks. **[EVASC.0134]**

Rationale: This requirement is applicable to any hardware that includes an integral soft good tether point attached to soft good hardware (reference [EVASC.0050] Table 3.5.2-1 Microgravity EVA-Induced Loads, Design Limit Load Type: "Soft Good Tether Point for Handling"). [EVASC.0048] Figure 3.5.1.2-1

Tether Point Dimensions, outlines the cross-section diameter (tether loop thickness) maximum of 13 mm (0.500 in). The cross-section needs to be maintained to ensure that the EVA crew hook does not slide off. EVA Tether Points are not required for partial gravity application, but if used must meet the requirement.

Applicability: Microgravity, Partial Gravity

3.5.2 Microgravity EVA Crew-Induced Loads

The HLS shall design external hardware to withstand specified EVA crew-induced loads as defined in Table 3.5.2-1 Microgravity EVA-Induced Loads. **[EVASC.0050]**

Rationale: External hardware is defined to be anything that is in the EVA crewmember's pressurized, suited translation path. This includes anything (e.g., structures) inside the vehicle cabin/airlock that is in the vicinity of the pressurized, suited crewmember, as well as outside the vehicle within the translation path corridor. The hardware, when exposed to Microgravity EVA-crew-induced loads should not create a hazardous condition, suffer loss of structural integrity, or suffer a loss of functionality. These loads apply to any hardware that is susceptible to EVA crew contact. Reference EVA-EXP-0032, EVA Office EVA-ISS Interface Definition Document, for loads that are induced into the xEVA suit by historically used ISS EVA tools. This addresses HLS-[Mission requirements document]-DCS-0003 from the appropriate HLS requirements document specified in associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity

TABLE 3.5.2-1 MICROGRAVITY EVA-INDUCED LOADS

Design Limit Load Type	Limit Load	Type of Loading	Direction	Category of Structure	Application Comments
Loads for Handrails/Handholds and Structure Supporting Handrails/Handholds for Translation					
EVA Handrail/ Handhold–Primary Translation Path	979 N (220 lbf)	Quasi–static load applied over 7.6 cm (3.0 in) length of handrail or handhold at worst location	Any direction	Handrails, handholds, and structure to which handrails and handholds are mounted	This load applied to the translation path used by the crewmember to return to the Airlock. Can also apply to payloads that are in the EVA translation path.
Crew Safety Tether Attachment	890 N (200 lbf)	Quasi–static load applied to crew tether loop attachment	Any direction	Crew tether loops/handrail tether point, attach hardware	Primary path handrail loads envelope this load. Can also apply to payloads that are in the EVA translation path.

TABLE 3.5.2-1 MICROGRAVITY EVA-INDUCED LOADS

Design Limit Load Type	Limit Load	Type of Loading	Direction	Category of Structure	Application Comments
				and support structure	
Other EVA-Induced Loads					
EVA Handling Load	200 N (45 lbf) 3.95 Nm (35 lbf-in) for connector paths for mate/de-mate of connector)	Quasi-static concentrated load over a 3.18 cm-radius (1.25-in) circular area	Any direction	ORUs and nonstructural closures and covers (including shields, cables, cable connector brackets, cable connector panels, cable clamps)	All hardware shall be designed to this load as a minimum. This load can be applied anytime to any hardware by the EVA crewmember. This force would be applied by a crewmember manipulating hardware. Payloads that are handled by the crew shall meet this load.
Soft-good Tether Point for Handling	133 N (30 lbf) or weight of the item (whichever is greater)	Concentrated load-pull (tension)	Any direction	Tether point for handling a soft-good item	This load is applied to the tether point on any soft good. A tether point shall exist on any soft good that could be handled by EVA. This tether point is not to be used for local tethering after the item is installed. This shall apply to a payload if it includes soft goods that would be handled by EVA.
Inadvertent Kick, Bump	556 N (125 lbf)	Quasi-static, concentrated load over a 13 mm (0.5 in) diameter circular area	Any direction	Secondary structure near (within 0.61 m (24 in)) a translation path or worksite Reference [EVASC.0010]	This is an accidental impact. It should be applied to hardware near (within 0.61m (24 in)) translation paths and/or worksites. Reference [EVASC.0010]) This applies to any payloads in the vicinity of EVA translations paths and worksites.
EVA Load for Design of APFR[1] Supporting Structure	1220 N (274 lbf) force;	Quasi-static loads applied at APFR socket to structure interface	Force in any direction; moment about any axis	All structures on which a foot restraint is attached	Force and moment applied simultaneously. Reference requirement [EVASC.0143]

TABLE 3.5.2-1 MICROGRAVITY EVA-INDUCED LOADS

Design Limit Load Type	Limit Load	Type of Loading	Direction	Category of Structure	Application Comments
	474 Nm (4200 lbf-in) moment				
APFR Ingress/Egress	267 N (60 lbf)	Quasi−static load applied over 7.6 cm (3.0 in) length of handrail or handhold at worst location	Any direction	Handrails, handholds, and structure to which handrails and handholds are mounted	This load applied to any handrail used by crew to assist in APFR ingress and egress
Local Maneuvering	267 N (60 lbf)	Quasi−static load applied over 7.6 cm (3.0 in) length of handrail or handhold at worst location	Any direction	Handrails, handholds, and structure to which handrails and handholds are mounted	This load is applied to any handrail/handhold used to position the crewmember body at a worksite. This maneuver is defined to occur within 1.2 m (48 in) after translation has been completed. These handrails/handholds are not primary translation path aids. Not applicable to external payloads.
Tool impact	556 N (125 lbf)	Concentrated load on a 0.15 cm-radius (0.06-in) circular area.	Any direction	Shatterable materials such as windows and exposed glass surfaces	Intended to protect shatterable materials from an EVA tool impact. This load applies to all payloads.
Tethering Loads					
Tether Point	334 N (75 lbf)	Quasi−static Concentrated load applied at worst location	Any direction	Any interface to which a tether is attached and the supporting structure of that interface	This is a local tethering load that is applied to any interface for waist tether/and or Retracting End Effector Assy (REEA) attachment. It is also applicable to both tool and tether attach points where tools are attached by a tether. This tether is not for safety tethering. Applies to payloads that contain EVA tether points.

TABLE 3.5.2-1 MICROGRAVITY EVA-INDUCED LOADS

Design Limit Load Type	Limit Load	Type of Loading	Direction	Category of Structure	Application Comments
BRT (loose or rigidized)	F = 334 N (75 lbf) M = 34 Nm (300 lbf-in)	Quasi−static Concentrated load applied at worst location	Any direction	EVA Handrail	This is a local tethering load that is applied to an EVA handrail for BRT attachment. EVA crewmembers use the BRT to provide body stabilization at a worksite. EVA crewmembers may need to BRT to handrails after the payload is in its installed location.

Table Footnotes:

[1]Articulating Portable Foot Restraint (APFR) – EVA load for design of APFR supporting structure incorporates the evaluation for kick load, layback, quick grab, handling, and oscillatory loads.

Overall General Notes:

a. Pry loads, as defined as the load imparted to a handrail by a U.S. EVA crew hook, have been determined to have a sufficiently low probability of occurring such as to render the load case non−credible. Therefore, pry loads are not to be considered as an EVA Induced Load.

b. EVA Microgravity EVA Induced Loads for inadvertent kick do not apply to hardware or worksites, which are assembled or maintained using only robotic systems (or only a crewmember restrained on robotic system).

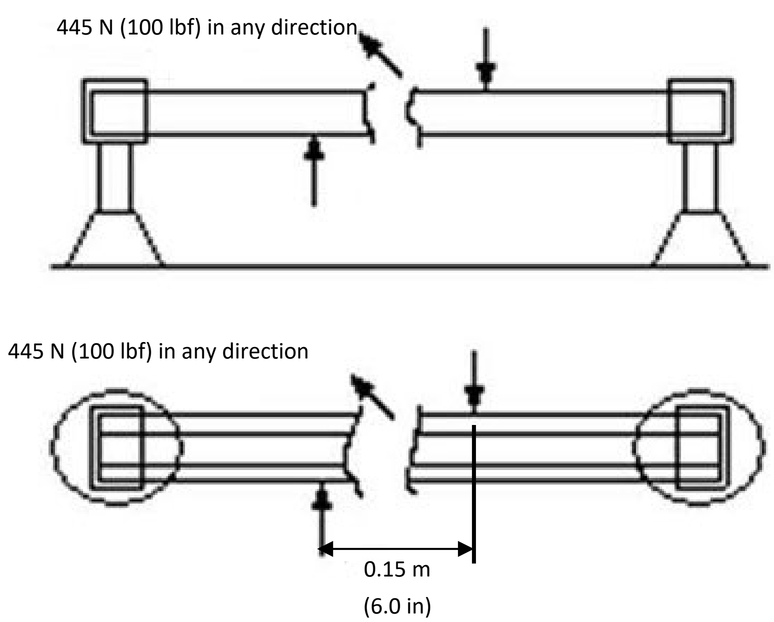


FIGURE 3.5.2-1 OPPOSING FORCES ON HANDRAIL/HANDHOLD

3.5.3 Partial Gravity EVA Crew-Induced Loads

The HLS shall design external hardware to withstand specified EVA crew-induced loads as defined in Table 3.5.3-1 Partial Gravity EVA-Induced Loads. **[EVASC.0155]**

Rationale: The hardware, when exposed to Partial Gravity EVA-crew-induced loads should not create a hazardous condition, suffer loss of structural integrity, or suffer a loss of functionality. These loads apply to any hardware that is susceptible to EVA crew contact. Loads provided are Limit loads. Emergency/contingency events were also taken into consideration when appropriate; the emergency/contingency load cases are used to assess structural capability and are enveloped by Ultimate loads as defined in JSC 65828, Structural Design Requirements and Factors of Safety for Spaceflight Hardware. Emergency/contingency load cases are severe with low probability of occurring events.

Applicability: Partial Gravity

TABLE 3.5.3-1 PARTIAL GRAVITY EVA-INDUCED LOADS <TBR-HLS-EVA-002>

Legend: Load Categories

Force	Energy

LOAD/ENERGY CATEGORIES		Maximum Magnitude Metric Units (English units)	Notes#
L1*	Bump Energy @ Impact	**27 J** (20 ft-lbf)	
L2	Kick Energy @ Impact	**77 J** (57 ft-lbf)	
L3*	Crew mass support load	**445 N** (100 lbf)	
L4*	Drop Energy @ Impact	**12.3*H J** (2.8*H ft-lbf)	H=height from which object is dropped, in meters or feet
L5*	Fall Energy @ Impact	**460 J** (340 ft-lbf)	
L6*	Crew Handling Loads	**720 N** (162 lbf)	
L7*	Tools Handing Loads	**720 N** (162 lbf)	
L8*	Stomp/Jump Energy @ Impact	**488 J** (360 ft-lbf)	
L9*	Suited crew mass load	**601 N** (135 lbf)	
L10*	Walking or stepping load	**819 N** (184 lbf)	

LOAD/ENERGY CATEGORIES		Maximum Magnitude Metric Units (English units)	Notes#
L11* +	Handrails Grasp/Pull load	**1096 N** (247 lbf)	
L12*	Swinging or Falling **<TBD-HLS-EVA-015>**	**<TBD-HLS-EVA-015>**	

*Magnitude value is maximum of subcategories. See individual tables below for additional options, including lower magnitude loads for specific load cases.

+Emergency/Contingency load considered

All values assume xEMU government reference design mass and dimensions of EVA suit and tools.

L1	Bump Energy	
	Crew contact point	**Energy**
	Helmet PLSS/Upper Torso	19 J (14 ft-lbf) 27 J (20 ft-lbf)

L3	Crew Mass Support Load	
	Crew Action	**Load**
	Using crew aid or walking stick to stand from falling	316 N (71 lbf) +
	Leaning against a wall	316 N (71 lbf) +
	Leaning on crew aid or walking stick	263 N (64 lbf)

L4	Drop Energy	
	Mass of item dropped	**Drop Load**
	Hand Tool	2.5*H J (0.56*H ft-lbf)
	Large Tool	5.8*H J (1.3*H ft-lbf)
	Payload Avg.	8.0*H J (1.8*H ft-lbf)
	Payload Max	12.5*H J (2.8*H ft-lbf)
	Sample Avg.	2.7*H J (0.6*H ft-lbf)
	Sample Max	4.0*H J (0.9*H ft-lbf)

L5	Fall Energy	
	Fall Type	**Energy**
	Face plant /whole body	461 J (340 ft-lbf)
	Fall to knees	102 J (75 ft-lbf)
	Catch with hands	184 J (136 ft-lbf)

L6	Crew Handling Loads	
	Crew Action	**Load**
	Push	547 N (123 lbf)
	Pull	721 N (162 lbf)

L6A	Crew Handling Loads		
	Push Load		
	Structure	**Direction**	**Load**
	Top Panels	Upwards Push	547 N (123 lbf)
	Side Panels	Horizontal Push	316 N (71 lbf) +
	Floor Panels	Downward Push	263 N (59 lbf)

L6B	Crew Handling Loads		
	Pull Load		
	Structure	**Direction**	**Load**
	Floor Panels	Upwards Push	720 N (162 lbf)
	Side Panels	Horizontal Push	209 N (47 lbf) +
	Top Panels	Downward Push	356 N (80 lbf)

L7	Generic Tool Handling Loads		
	Direction	**Non-critical**	**Critical**
	Concentric	53 N (12 lbf)	391 N (88 lbf)
	Generic	120 N (27 lbf)	721 N (162 lbf)

L8	Stomp/Jump Energy	
	Crew Action	**Energy**
	Stomping	212 J (156 ft-lbf)
	Jumping	488 J (360 ft-lbf)

L9	Suited Crew Mass Load		
	Crew position	**Crew contact surface(s)**	**Load**
	Standing	Load at boots	601 N (135 lbf)
	Seated	Load at waist brief	601 N (135 lbf)
	Single Kneel	Load at knee (does not include load at other points)	449 N (101 lbf)
	Double Kneel	Load at the knees	596 N (134 lbf)

L10	Walking Load	
	Crew Action	**Load**
	Carrying Payload	681 N (153 lbf)
	Going down/up Ramp	712 N (160 lbf)
	Stepping down/up stairs	818 N (184 lbf)

L11	Handrails Grasp/Pull Load	
	Crew Action	**Load**
	Pull Push	1096 N (247 lbf) 939 N (211 lbf)

Footnote for L5 and L8:

- Total weight = 3272.1 N (735.6 lbf) earth | 545.3 N (122.6 lbf) moon
- Human weight = 1081 N (243 lbf) earth | 180.1 N (40.5 lbf) moon
- Suit (xEMU government reference) = 1966 N (442 lbf) earth | 327.8 N (73.7 lbf) moon
- Tools = 225.1 N (50.6 lbf) earth | 37.4 N (8.4 lbf) moon
- Jump height used = 74.62 cm (29.38 in) from the extreme jumps seen from Apollo Charlie Duke
- Stomp leg stroke = 30.5 cm (12 in)

3.5.4 EVA Actuated Loads

HLS will have a crew or crew actuated tool interface that shall be operable by the loads defined in Table 3.5.4-1 Miscellaneous Crew Induced Limit Loads. **[EVASC.0018]**

Rationale: Dexterity and tactility are degraded when using a pressurized suit which necessitates increased levels of tactile feedback. This does not include the EVA on-orbit induced loads (reference requirement [EVASC.0050] for EVA induced loads or those outlined in [EVASC.0155] for partial gravity). The intent of this requirement is from the perspective of what works best for EVA, by aiding in reducing fatigue and repetition while working with pressurized gloves. It is anticipated that there will be issues with getting proper reaction on lunar surface, e.g., as illustrated in analog testing for drilling applications. This may or may not be acceptable for EVR systems. Depending on the Program this requirement is applied to and their plans for EVA and EVR, tailoring may be required.

Applicability: Microgravity, Partial Gravity

TABLE 3.5.4-1 MISCELLANEOUS CREW INDUCED LIMIT LOADS

Crew System	Type of Load	Limit Load	Direction of Load
Repetitive Actuation Force	Concentrated Load	Actuation forces shall not exceed 89 N (20 lbf) for hand tools and other hardware items which require repetitive/continuous operation.	Any Direction
Finger Actuation Force	Concentrated Load	The actuation of hardware designed for finger operation shall be 9 to 44 N (2 to 10 lbf).	Any Direction
Actuation Torque	Concentrated Load	Knobs, fasteners, latches, and other hardware requiring a twisting/turning hand/wrist motion shall have a maximum actuation torque of 3.4 Nm (30 lbf-in).	CW or CCW

TABLE 3.5.4-1 MISCELLANEOUS CREW INDUCED LIMIT LOADS

Crew System	Type of Load	Limit Load	Direction of Load
		Actuation forces for hardware that requires fine motor activity by a pressurized gloved hand, such as knobs and devices, shall not exceed 0.2 Nm (30 in. oz).	Any Direction
Non-repetitive Actuation Force	Concentrated Load	Actuation forces of hardware shall not exceed 111 N (25 lbf) for momentary, non-repetitive gross motor skill operations in foot restraints or BRT, such as operating a latching mechanism or opening/closing a door.	Any Direction
EVA driven bolts	Concentrated Load	<89 N (<20 lbf) for engagement or disengagement of the ratchet type tools onto the bolt. * This force should not be required to be maintained while driving the bolt. 0.17 Nm (24 in-oz) minimum torque for installation of bolt.**	Axial
		0.17 Nm (24 in-oz) minimum torque for installation of bolt**	CW or CCW
EVA Hatches, Doors, and Drawers	Concentrated Load	<111 N (<25 lbf)	Any Direction
EVA Connectors	Concentrated Load	3.95 Nm (<35 lbf-in) (mate/demate) for twisting-type connectors (i.e., NATC)	CW or CCW
		<111 N (<25 lbf) for bail and pull connectors (i.e., NZGL)	Any direction
Mounting Hardware (install/remove) (EVA)	Concentrated Load	<111 N) (<25 lbf)	Any Direction
Fastener Torque (without torque reaction interface)	Concentrated Load	*** <34 Nm (<25 ft-lb)	CW or CCW
High Torque Fasteners (with torque reaction interface)	Concentrated Load	<136 Nm (<100 ft-lb)	CW or CCW
Push and Turn Fasteners	Concentrated Load	<13 N (3 lbf)	Any direction

*Note: Example – A tool must overcome the anti-rotation device inside a modified micro fixture.

**Note: The rationale for this is 0.05 Nm (7 in-oz) maximum torque for back drive of the ratchet wrench.

***Note: The Pistol Grip Tool (PGT) with associated sockets has lower limits that are based on tool stack-up and RPMs. The details are shown in SSP 30256:001 section 3.2.1.4.

3.5.5 EVA Mechanical Feedback

The HLS shall provide EVA mechanical feedback actuation force that is greater than 15.5 N (3.5 lbf). **[EVASC.0164]**

Rationale: Mechanical control feedback needs to be sufficient such as to override the EVA glove attenuation and allow the EVA crewmember to receive positive indication that the control function has been completed.

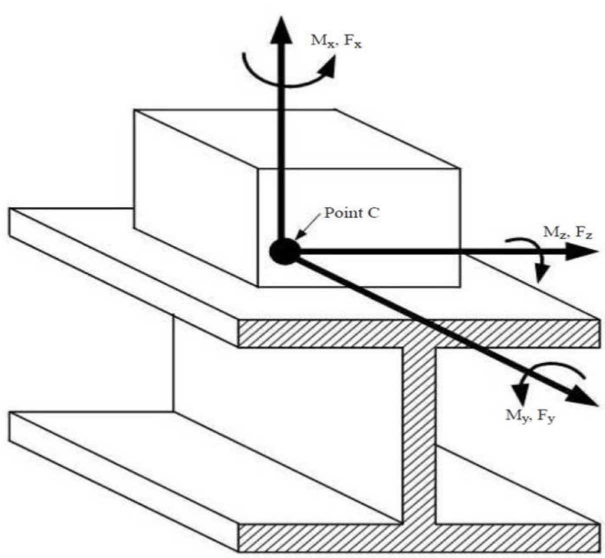
Applicability: Microgravity, Partial Gravity

3.5.6 WIF Structural Loading

The HLS shall maintain positive margins of safety for loads at the WIF to structure interface of 1220 N (274 lbf) in any direction and a moment of 474 Nm (4200 lbf-in) in any direction, simultaneously, as defined in Figure 3.5.6-1 Top Mounted WIF Worksite Half Loading Criteria. **[EVASC.0143]**

Rationale: Ensures that the structural loading for the hardware where the WIF is attached has been defined. This provides additional clarification to Table 3.5.2-1 Microgravity EVA-Induced Loads, Requirement [EVASC.0050] table line item for "EVA Load for Design of APFR Supporting Structure."

Applicability: Microgravity



Maximum Interface Loads	
Moment	**Force**
Any Direction 474 Nm (4200 lbf-in)	Any Direction 1220 N (274 lbf)
Notes: 1) The above loads should be applied simultaneously. 2) All loads are to be applied at Point C. 3) Point C, the force and moment origin, is located at the center of the bolt pattern at the mating surface.	

FIGURE 3.5.6-1 TOP MOUNTED WIF WORKSITE HALF LOADING CRITERIA

3.6 CONNECTORS

Unless otherwise specified, the requirements in this section apply to all types of EVA operable connectors, including electrical, fluid, fiber optic, structural, etc. It is important to note that in this context when the word "design" is used, it does not preclude hardware developers from using previously existing products that may or may not have been uniquely created for this application. Instead, the intent is to communicate that regardless of how the parts are sourced, the resulting assembly must be operable by the EVA crewmember.

3.6.1 One-Handed EVA Operable Connectors

The HLS shall design connectors to be aligned and mated/demated one-handed and ambidextrously in microgravity, while wearing a pressurized glove, and without the use of a tool. **[EVASC.0053]**

Rationale: The intent for microgravity application is to not require the use of a foot restraint for stabilization to operate the connectors. One-handed alignment and mating are necessary so that the other hand can be used for stabilization if foot restraints are not provided. If a foot restraint is provided, connectors can be held in two hands and reacted against each other.

Applicability: Microgravity

3.6.2 Connector Accessibility

The HLS shall design individual connectors capable of being mated, demated, or replaced without having to remove or replace other connectors. **[EVASC.0054]**

Rationale: Experience has shown that proper spacing connectors can be utilized to provide easier accessibility without having to remove or replace other connectors.

Applicability: Microgravity, Partial Gravity

3.6.3 Gloved-Hand Connector Accessibility

The HLS shall provide gloved hand access per Figure 3.1.4-1 Gloved-Hand Clearance, in requirement [EVASC.0003], around any point of the connector that the crew has to actuate, including sweep of the actuating mechanism if applicable. **[EVASC.0138]**

Rationale: It does not preclude the use of protective hardware such as covers, caps, etc. Experience has shown that closer spacing for small, simple connectors can be utilized to provide more efficient packaging of the EVA worksite (reference EVABP-27).

Applicability: Microgravity, Partial Gravity

3.6.4 Incorrect Connector Mating Prevention

The HLS shall design connectors to prevent incorrect mating or cross-connection. **[EVASC.0055]**

Rationale: Intent is to provide only one possible mechanical combination for connector mating to ensure that all system connections are manufactured as designed and installed so they cannot be mated/demated incorrectly or in the wrong orientation. Identification alone is not sufficient to preclude incorrect orientation. This addresses the intent of the HLS-[Mission requirements document]-HMTA-0240 from the appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity, Partial Gravity

3.6.5 Connector Coding

The HLS shall locate unique identifier labels or codes on both sides of mating connectors and associated items that are visible when both connected and disconnected. **[EVASC.0056]**

Rationale: Mechanical methods of ensuring correct mating of connectors are not sufficient alone. To ensure efficient EVA operations, labels are also needed to mate the correct connectors. Matching EVA connector pair coding simplifies training, eliminates confusion, and speeds operations. Reference EVA-EXP-0049, Extravehicular Activity (EVA) Office Exploration EVA System Labeling Guidelines, for details on connector labeling.

Applicability: Microgravity, Partial Gravity

3.6.6 Connector Protective Caps

The HLS shall design tether capable (or integral tethered) protective caps for plugs and jacks whenever they are not connected to the mating part to prevent physical damage and contamination that account for the following:

1) Protection from moisture, lunar dust, and other foreign materials
2) Protection against damage to sealing surfaces, threads, or pins
3) Resistance to abrasion, chipping, or flaking
4) Same finish and material as the connector it is protecting (ensuring compatibility with the connector material)
5) Brightly colored red (for those not used in flight); ensure that is removed prior to flight
6) Maintained at cleanliness level equivalent to plug or jack that is being protected. **[EVASC.0057]**

Rationale: The intent is to protect the plugs and receptacles from moisture, lunar dust, and other foreign materials and damage to sealing surfaces, threads, and pins. Also, to ensure compatibility with the connector that is being protected.

Applicability: Microgravity, Partial Gravity

3.6.7 Connector Rotational Travel

The HLS shall ensure that the rotational travel of the connector is limited to a maximum of 180° for installation or removal of twist-on connectors. **[EVASC.0058]**

Rationale: Performing a twist on/off motion is considered awkward and difficult in a pressurized xEVA suit.

Applicability: Microgravity, Partial Gravity

3.6.8 Connector Locking Feature

The HLS shall provide connector plugs that include a locking feature to prevent inadvertent demate. **[EVASC.0059]**

Rationale: Experience has shown that many of the EVA worksites are congested. Design of the worksite should include features which aid in precluding inadvertent demate that could result in a hazardous situation.

Applicability: Microgravity, Partial Gravity

3.6.9 Visible Connector Alignment Markings

The HLS shall design visible alignment markings or other features on connectors to ensure proper alignment during mating/demating. **[EVASC.0060]**

Rationale: Connector alignment should not require so much precision as to be difficult to operate one-handed.

Applicability: Microgravity, Partial Gravity

3.6.10 Connector Locking Ring

The HLS shall design or use connectors with a locking ring that cannot turn independently from the connector body, such that the crewmember does not have to align both the ring and the body of the connector separately. **[EVASC.0061]**

Rationale: The crew should not have to align both the ring and the body of the connector separately. Pressurized, EVA suited operation of hardware in microgravity is more difficult than typical 1-g operation of the same hardware. Experience has shown that to ensure successful completion of EVA tasks, hardware operations must be kept as simple as possible. Utilizing a connector, which requires the alignment of both the ring and the body of the connector separately, is an unnecessary complication.

Applicability: Microgravity, Partial Gravity

3.6.11 Connector Mating Status

The HLS shall design connectors that indicate full mate/demate status. **[EVASC.0062]**

Rationale: Full connector mating includes pin engagement. Alignment markings, pin detents, or an over-center feature are examples of features that can indicate connector mating status. It is especially important that EVA crewmembers know if connectors have been successfully mated/demated during periods of Loss of Signal (LOS).

Applicability: Microgravity, Partial Gravity

3.6.12 Electrical Connectors

3.6.12.1 Mating/Demating of Powered Connectors

The HLS shall design connectors mated/demated during an EVA that prevent shock hazards to the EVA crewmember. **[EVASC.0052]**

Rationale: Reference requirement HLS-[Mission requirements document] HMTA-0241 and HLS-[Mission requirements document]-HMTA-0229 from the *appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2). Intent of requirement is to ensure that EVA safety hazards are considered when designing connectors that need to be operated by a suited pressurized crewmember.*

Applicability: Microgravity, Partial Gravity

3.6.12.2 Connectors – Electrical Bonding

The HLS shall provide electrical bonding of electrical connector assemblies and conductive outer surfaces of electrical and electronic assemblies in accordance with NASA-STD-4003, *Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment*, Class H (or approved alternate electrical bonding standard), as a minimum to prevent electrical shock hazards to EVA crewmembers. **[EVASC.0065]**

Rationale: Intent of this requirement is to address floating connectors and electrical assembly housing issues. Proper bonding ensures the majority of harmful electrical current under hazardous fault conditions is shunted away from the EVA crewmember, preventing a shock hazard. Reference NASA-STD-4003.

Applicability: Microgravity, Partial Gravity

3.6.12.3 Scoop-Proof Electrical Connector Design

The HLS shall design electrical connectors to prevent electrical pins from incorrectly contacting the opposing connector half during mating/demating. **[EVASC.0066]**

Rationale:: Using scoop-proof connectors is one way to meet this requirement. Scoop-proof connectors minimize creation of potential hazards (electrical shock, sparks, arcs, or molten metal) as well as potential pin damage leading to the inability to connect the connector.

Applicability: Microgravity, Partial Gravity

3.6.12.4 Connector Grip Point

The HLS shall design connector backshells to provide for engagement/disengagement with the pressurized gloved hand. **[EVASC.0063]**

Rationale: A grip point provides access for the pressurized gloved hand to operate the connector.

3.6.12.5 Arc Containment

The HLS shall design electrical connectors that confine and isolate electrical arcs and sparks during mating/demating. **[EVASC.0131]**

Rationale: Certain provisions are required when electrical connectors must be mated or demated during EVA to protect the crew from generation of molten metal, damage to safety critical circuits, and, potentially, shock, all of which are considered catastrophic hazards.

Applicability: Microgravity, Partial Gravity

3.6.13 Fluid Connectors

3.6.13.1 Tethering

The HLS shall restrain or otherwise capture serviceable fluid flex hoses and lines with delta pressure or under pressure. **[EVASC.0132]**

Rationale: Delta pressure in a line could cause the line to move/flex, and pressurized lines can rigidize in unwanted configurations, so both should be accounted for. Hose whip can occur as a result of release of pressure in a line or from hose memory, and captive features are required to prevent hose whip that could result in crew injury or damage to adjacent hardware. This requirement does not apply to an xEVA suit umbilical.

Applicability: Microgravity, Partial Gravity

3.6.13.2 Venting Feature

The HLS shall ensure that serviceable fluid connectors and lines contain a method for removing pressure before demating. **[EVASC.0133]**

Rationale: Excess fluid and pressure in a connector during demating may expose the crewmember to hazardous materials (either to the suit or to the Intravehicular Activity (IVA) environment if brought back inside the vehicle), or to hazardous forces when the pressure is released during separation. This requirement does not apply to an xEVA suit umbilical.

Applicability: Microgravity, Partial Gravity

3.6.13.3 Indication of Pressure Flow – Nonbrazed or Nonwelded

All nonbrazed or nonwelded gas and liquid lines shall be provided with a positive indication of the gas pressure/fluid flow to verify that the line is passive before disconnection of connectors. **[EVASC.0145]**

Rationale: Need to ensure flow and pressure is zero via gauge indication prior to maintenance on fluid connectors. The intent is to protect the crewmember from pressurized lines in operations on non-Quick Disconnect (QD) connections. These *types of connections should be avoided in anticipated EVA operations as QDs are typically used to facilitate operations with a pressurized EVA glove possible.*

Applicability: Microgravity, Partial Gravity

3.6.13.4 Indication of Pressure Flow – Quick Disconnect

Any liquid or gas lines equipped with QD connector which are designed to be EVA operated under pressure shall not be required to be fitted with pressure/flow indicators. **[EVASC.0146]**

Rationale: Indication of pressure/flow state is not necessary if the QD is designed to be operated regardless of system state.

Applicability: Microgravity, Partial Gravity

3.7 EVA OPERABLE FASTENERS

The following section outlines those fasteners that are to be operated by an EVA crewmember in a pressurized xEVA suit. It is important to note that in this context when the word "design" is used, it does not preclude hardware developers from using previously existing products that may or may not have been uniquely created for this application. Instead, the intent is to communicate that regardless of how the parts are sourced, the resulting assembly must be operable by the EVA crewmember.

3.7.1 Captive Fastener Design

The HLS shall design all EVA operable fasteners to be captive without the use of tethers or lanyards as the captive method. **[EVASC.0068]**

Rationale: In microgravity, loose parts or hardware poses an impact hazard to the EVA crewmember or the vehicle. Loss of parts/hardware required for critical functions is also considered a hazard and an impact to mission success.

Applicability: Microgravity, Partial Gravity

3.7.2 Locking Features

3.7.2.1 Prohibited Locking Methods for Fasteners

The HLS shall provide a method for locking EVA operable fasteners that does not involve the use of safety wire, cotter pins, or jam nuts. **[EVASC.0069]**

Rationale: Safety wire and cotter pins may be a source for sharp edges and are, therefore, prohibited. Safety wire and cotter pins may be used on internal fasteners only. The use of anaerobic locking compounds as the sole secondary *locking feature on structural or critical fasteners has been shown to be ineffective in the vacuum environment.*

Applicability: Microgravity, Partial Gravity

3.7.3 EVA Hand-Actuated Fasteners Operation

3.7.3.1 One-Handed Fastener Operations

The HLS shall design fasteners intended to be manipulated without a tool to be operable one-handed using a pressurized xEVA glove. **[EVASC.0067]**

Rationale: The hand-operable fastener should not require a high degree of dexterity such that it necessitates two-handed operation. Hand-operated fasteners do not require a tool.

Applicability: Microgravity, Partial Gravity

3.7.3.2 Scalloped Knobs

The HLS shall design scalloped knobs for actuation by the pressurized EVA gloved-hand with no fewer than four (4) and no more than eight (8) scallops. **[EVASC.0072]**

Rationale: Knob design specifications will improve performance when used with a pressurized, gloved hand. Three examples of knobs designed for EVA hand actuation are Knob, Push, Pitch Joint Assembly APFR, ISS (SDG33107506), EVA Knob Assembly – Bridge Clamp (SED33107181), and 1.0 Inch QD Button Depress Tool Assy (SEG33114987). Reference Figure 3.7.3.3-1 Flight Knob Examples in requirement [EVASC.0073]; the minimum scallop value allows for deeper scallops as needed.

Applicability: Microgravity, Partial Gravity

3.7.3.3 Knobs Head Diameter and Height

The HLS shall design knobs for xEVA suited, pressurized, gloved hand operation to have head diameters between the ranges of 3.8 cm – 5.1 cm (1.5 in – 2.0 in) with a minimum head height of 1.9 cm (0.75 in). **[EVASC.0073]**

Rationale: Knob design specifications will improve performance when used with a gloved hand. For reference only, Figure 3.7.3.3-1 Flight Knob Examples, provides example shapes that are known to be compatible with Phase VI gloves; implementation of mounting shaft interface will be design-dependent and vary.

Applicability: Microgravity, Partial Gravity

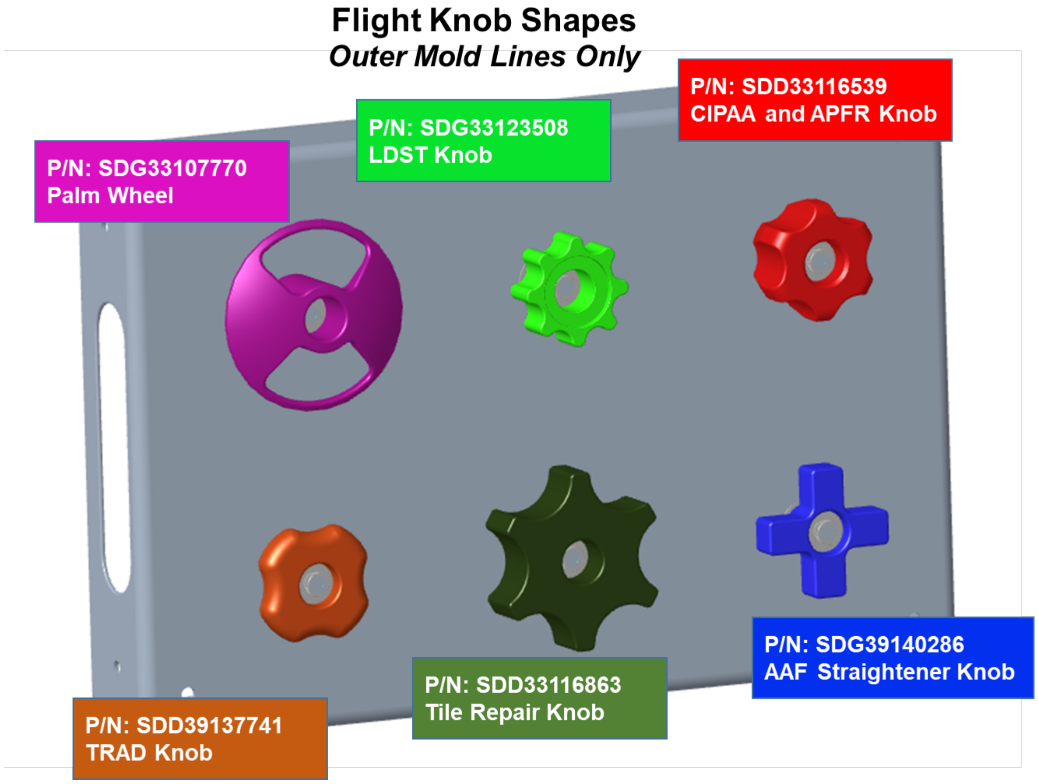


FIGURE 3.7.3.3-1 FLIGHT KNOB EXAMPLES

3.7.3.4 EVA Hand-Actuated Fasteners Contingency Operation

The HLS shall provide an external 11 mm hexagonal drive interface on rotational fasteners per section 3.7.5 for contingency operation with a hand tool. **[EVASC.0074]**

Rationale: Same size fastener leads to a single tool that works for all cases.

3.7.4 EVA Push-in-Pull (PIP) Pins

Refer to APPENDIX B EVA Best Practices (BPs) for PIP Pins (EVABP-2). Use of PIP Pins has been closely scrutinized by the JSC Structures and Mechanisms System, and these pins are considered to be designed so reliably that the item on its own is considered one fault tolerant, however, receive appropriate risk acceptance from the customer Program. Please verify acceptability of specific part numbers or design with EHP for the NASA Structures and Mechanisms System Team review when using PIP pins.

3.7.4.1 EVA PIP Pin Grasping Interface

The HLS shall mount a 3.8 cm (1.5 in) minimum diameter ring or T-handle to the pin that is compatible with a pressurized glove. **[EVASC.0075]**

Rationale: T-handles or rings large enough to use with a pressurized, gloved hand are required to simplify use with a gloved hand and to minimize the risk of lost hardware. It is preferred that the ring is mounted to the actuation shaft.

Applicability: Microgravity, Partial Gravity

3.7.4.2 PIP Pin Restraint Tether

The HLS shall attach a restraint tether to the body of the PIP pin and not to the activation mechanism. **[EVASC.0076]**

Rationale: PIP pins may also be captive to the structure, which is preferable to a separate tether.

Applicability: Microgravity, Partial Gravity

3.7.5 Tool-Actuated Fasteners

3.7.5.1 Driver-Type Push Force Tools

The HLS shall design fasteners that do not require a driver-type hand tool that requires a push force greater than 9N (2 lbf) to maintain tool engagement while providing torque. **[EVASC.0078]**

Rationale: Slotted and Phillips screws and screwdrivers are prohibited for EVA interface use. The dexterity that is lost when using pressurized EVA gloves makes using fasteners, which require a constant force to remain engaged, impractical.

Applicability: Microgravity, Partial Gravity

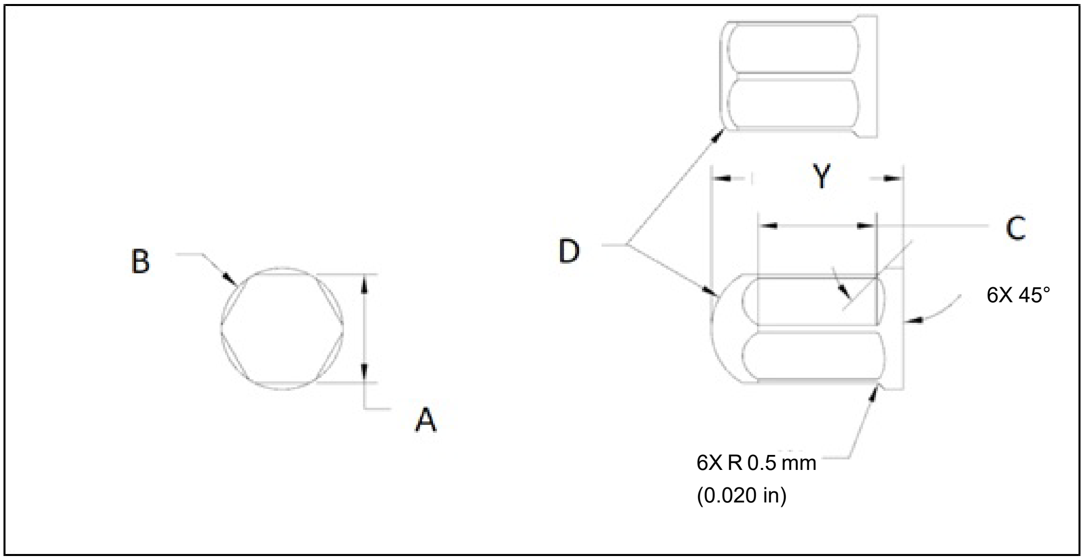
3.7.5.2 EVA Fastener Head

All EVA-actuated bolts shall conform to the following configuration from the minimum to maximum operational temperatures to enable interface with the standard EVA hand and power tools:

1) Figure 3.7.5.2-1 11 mm Hexagonal EVA and Robotic Compatible Bolt [**EVASC.0079]**

Rationale: This requirement ensures compatibility with future xEVA tools and provides for common EVA tool interface between vehicles. If required by hardware design, alternate EVA fasteners may drive design and certification of different sizes of EVA tools such as socket extensions, and should be worked with EHP personnel.

Applicability: Microgravity, Partial Gravity



11 mm Nominal bolt head size	Max/Min dimensions (mm)
(A) Flat to Flat	10.96 10.83
(B) Peak to Peak	12.35 12.22
(C) Effective height	9.55 9.30
(D) Wrench guide	Full R 2.75
(Y) Overall height	22.35 10.90

FIGURE 3.7.5.2-1 11 MM HEXAGONAL EVA AND ROBOTIC COMPATIBLE BOLT

3.7.5.3 Fastener Drive Height

The HLS shall design fasteners, which are planned to be operated by a hand or power tool, to have a minimum bolt head dimension as specified in the EVA Fastener Head requirement [EVASC.0079] incorporating an extra deep well on the socket and/or a wobble feature. **[EVASC.0084]**

Rationale: An extra-deep well in the socket and/or a wobble feature helps mitigate stripping concerns. The double bolt height is recommended for ease of use and versatility.

Applicability: Microgravity, Partial Gravity

3.7.5.4 Fastener Torque Data

Data Deliverable: When fastener torquing to specifications is required, provide per Table 3.7.5.4-1 Fastener Torque Data. **[EVASC.0151]**

Rationale: The intent is to ensure that the HLS delivers the torque instructions for on-orbit actuation. Additional materials in contact with threads (such as lubricants, locking compounds or mechanical locking features), need to be evaluated for effects within the environmental conditions, and are taken into consideration for torque calculations during EVA installation/ removal. Depending on the state of lubrication, the effects of temperature and pressure (i.e., vacuum) can significantly affect the friction characteristics of the sliding interfaces. Recorded tightening, running, and release torque values are to be provided upon request from Program Management.

Applicability: Microgravity, Partial Gravity

TABLE 3.7.5.4-1 FASTENER TORQUE DATA <TBR-HLS-EVA-001>

Row #	Description	Additional Information
1	Fastener Part Number	Additional cautions, in the form of training and updates to EVA procedures, should be taken
2	Next Assembly Part Number of Fastener	
3	Insert or Part Number	
4	Next Assembly Insert of Nut Part Number	
5	EVA Label for Bolt or Nut Next Higher Assembly	
6	Name/Description	
7	Bolt is used to secure ORU (Yes/No)	
8	ORU Part Number	
9	Ground Installation Torque	
10	Maximum On-Orbit Installation Torque	
11	Minimum On-Orbit Installation Torque	
12	No. of bolt turns for clamp-up/Removal	
13	More important: Torque OR Turns OR Both	During on-orbit installation, state if it is more important for the crewmember to achieve the torque value specified or the number of turns specified. If both torque and turns are required, enter “Both”.

TABLE 3.7.5.4-1 FASTENER TORQUE DATA <TBR-HLS-EVA-001>

Row #	Description	Additional Information
14	Maximum Expected Breakaway Torque	This should be a value for breakaway that is the highest you would expect to see, whether the bolt was installed on the ground or on-orbit. For non-microconical interfaces, if value is greater than 35 Nm (310 lbf-in), fill in row 15.
15	Maximum Expected Breakaway Torque when install torque is per Row 11. (This row is filled in only if value in Row 14 is greater than 35 Nm (310 lbf-in) for non-microconical interfaces)	This value should also account for on-orbit temperature effects.
16a	Recommended Torque to use for Removal	This is the recommended torque value to set the EVA tool for removal of the bolt. If Row 15 has been filled in, enter the value in Row 16 based on Row 15.
16b	Recommended Torque to use for Installation	This is the recommended torque value to set the EVA tool to for installation of the bolt.
19	Absolute Max. Torque not to be exceeded in order to prevent failure. Factor of Safety (FS) = 1.	Torque values specified are the torque applied at the head of the fastener independent of the tool or extension used. (This differs from all other rows where torque calculations are done with the approved Structural Integrity Factor for Safety Requirements).
20	Failure Mode if torque exceeded.	That is, what item will fail first? What are the expected failure results: bolt thread failure, nut thread failure, bolt shank failure, secondary structure yield, secondary structure failure, primary structural yield, and primary structural failure, etc.? Again, the failure predictions are based on a FS of 1 (Row 19).
21	Failure data from Analysis (A) or Test (T)	Specify whether data has been obtained from testing or from analysis.
22	Special Operations or constraints in order to minimize binding	If there are any special operations or constraints in order to minimize binding, please specify. If none, leave blank. For example, describe any steps taken to prevent galling; however, galling is a very specific failure mode. Bolt binding does not always equal galling. Side loads, misalignment, thermal mismatch are all sources of binding that present similar to galling, and if the design is vulnerable to these or any others, they should be described in this table.
23	Potential Recovery/Repair Schemes (including captive fastener replacement methods, if applicable)	Potential Recovery/Repair Schemes (including captive fastener replacement methods, if applicable). Expand on Row 23 in note form: e.g., Note 2. Recovery scheme for this fastener is…etc.

TABLE 3.7.5.4-1 FASTENER TORQUE DATA <TBR-HLS-EVA-001>

Row #	Description	Additional Information
24	Has this bolt been analyzed to be out/absent?, while all others remain installed to meet a Fail-Safe Condition? Yes or No Note: This Row (24) is for contingency reference only and must not be used for nominal or work-ahead EVA planning.	This row should be filled in “Yes” or “No” based on existing strength analysis.

General Notes:
1) Rows 17 and 18 are intentionally not used.
2) Format for torque values: torque lbf-in (torque ft-lbs)

3.7.5.5 Power and Hand Tool Operability

The HLS shall design or use fasteners installed with power tools to also be removable and/or installable with a hand-operated tool. **[EVASC.0080]**

Rationale: Hardware should be designed to be operated/torqued by a power tool and a hand operated tool for contingency/clearance issues. There is an option to use the ratchets or wrenches with sockets for the fasteners.

Applicability: Microgravity, Partial Gravity

3.7.5.6 Fastener Gauge/Measurement

EVA bolt heads shall be gauged/measured ensuring they meet dimensional requirements at the minimum to maximum operational temperatures prior to installation into assembly to verify all bolt head features can be inspected. **[EVASC.0141]**

Rationale: Gauging allows thermal and manufacturing tolerances to be assessed. Hardware should be designed to accept torque values with as wide a tolerance as possible. Thermal extremes can adversely affect the ability for a tool to achieve a specific torque. Provide verification of bolts prior to installation into assembly to prevent future issues with undersized/oversized bolt heads.

Applicability: Microgravity, Partial Gravity

3.7.5.7 Fastener Alignment Features

The HLS shall provide alignment features to ensure initial engagement and preclude cross-threading. **[EVASC.0083]**

Rationale: Examples include chamfered threaded ends and/or bolt guides.

Applicability: Microgravity, Partial Gravity

3.8 HARDWARE DESIGN

3.8.1 Battery Powered Devices

3.8.1.1 Battery Replacement

The HLS shall design any batteries that necessitate changeout via EVA to be replaceable at the worksite. **[EVASC.0085]**

Rationale: The intent is to ensure that if the battery must be changed during EVA, it is done at the worksite without the overhead of bringing it back inside the vehicle/pressurized environment. This provides flexibility for the development of vehicle design operational concepts. Time is better managed with replacement of batteries at the worksite, e.g., if they do not last as long as the intended task.

Applicability: Microgravity, Partial Gravity

3.8.1.2 Battery Voltage Monitoring

Battery-powered devices shall include battery monitoring capability during usage to protect against catastrophic hazards and insufficient capacity to support mission time. **[EVASC.0086]**

Rationale: Battery power indication should be incorporated as part of a power device, not the battery or battery pack itself. The function of battery power indication is intended to inform the EVA crewmembers of battery charge before and during the EVA, so crewmembers can ensure safety critical hardware is sufficiently charged for the duration of the EVA. Battery voltage monitoring is necessary for safe function and mission success of those operable devices.

Applicability: Microgravity, Partial Gravity

3.8.1.3 Auxiliary Controls

Auxiliary controls shall be positioned such that an EVA-gloved hand can activate the control without disturbing the tool/fastener position. **[EVASC.0028]**

Rationale: The intent is to ensure that if an auxiliary control on the device must be operated while holding it, that there is sufficient clearance to not perturb the tool/fastener position.

Applicability: Microgravity, Partial Gravity

3.8.2 EVA Tools

The HLS shall utilize EVA tools listed in the EHP-approved configuration-managed tool list **<TBD-HLS-EVA-016>**. **[EVASC.0088]**

Rationale: The EHP configuration-managed list contains tools intended to enable EVA crew to perform operations externally either in microgravity or partial gravity. Vehicle designs should consider these available tools when planning for operations that are needed for maintenance or contingent vehicle activity. EVA tools designated to be used for maintenance on any hardware outside of the habitable volume, such as an external antenna, solar arrays, a rover, or an external science payload, are included in the EHP-approved configuration-managed tool list ***<TBD-HLS-EVA-016>****. Tools should be selected from the tool list while considered for destination environment; EHP can assist with selection of tools. Any designs that create the need for an additional EVA tool outside of this set of tools should be routed through the appropriate Program Control Boards for approval.*

Applicability: Microgravity, Partial Gravity

3.8.3 IVA Tools to Maintain EVA Equipment

The HLS shall provide the IVA tools listed in the EHP-approved configuration-managed tool list **<TBD-HLS-EVA-016>** to maintain EVA equipment. **[EVASC.0163]**

Rationale: Exploration missions beyond Low Earth Orbit (LEO) are mass and volume limited and, accordingly, all vehicles should provide a limited but consistent set of IVA tools for EVA maintenance. The HLS IVA Tool Kit includes tools to perform maintenance on any hardware inside the habitable volume. The subset of tools included in the EHP-approved configuration-managed tool list ***<TBD-HLS-EVA-016>*** *includes tools that may be employed by the crew for the maintenance of the spacesuit, EVA tools, or other xEVA System hardware inside the habitable volume. Any designs that create the need for an additional IVA tool outside of this set of tools shall be routed through the appropriate Program Control Board(s) for approval.*

Applicability: Microgravity, Partial Gravity

3.8.4 Cable Routing/Restraint

The HLS shall design cable routing/restraint for hardware exclusive of using EVA handling and translation aids as those routing paths or restraints. **[EVASC.0089]**

Rationale: EVA handling and translation aids are not to be used as routing or restraints for cabling.

Applicability: Microgravity, Partial Gravity

3.8.5 Cable Routing Spacing

The HLS shall design EVA-installed cable routing to include restraints spaced a distance appropriate for the field of gravity. **[EVASC.0090]**

Rationale: Designers are to define areas of activity and route fixed lines and cables so that they are both protected from and do not interfere with these activities. Also, system designers are to focus on non-fixed lines and cables that may be unstowed or moved for a specific task or temporary rearrangement. While the rerouted cable or line may accommodate a specific need, the routing path may interfere with other, non-related activities. Designers are to identify potential uses for lines and cables and ensure the start points, end points, and cable and line routes in between will accommodate all crew activities. For ISS, EVA-installed cables are typically secured every 0.61 m (24 in).

Applicability: Microgravity, Partial Gravity

3.8.6 Paint

The HLS shall design hardware such that it does not require use of paint on EVA worksites and within EVA translation paths/traverses, or areas on the vehicle which the EVA crewmember will access. **[EVASC.0091]**

Rationale: Paint (often considered the "simple" solution to improve passive thermal properties or provide corrosion control) needs to be avoided on EVA equipment, on EVA worksites, and near EVA translation paths for microgravity application. Paint is difficult to apply properly, difficult to maintain without damage preflight and during processing, and may flake off in a vacuum environment after thermal cycles. Additionally, paint is easily damaged by any contact from an EVA crewmember. Damaged paint will change the surface optical properties and can become Foreign Object Debris (FOD) which clogs mechanisms and increases Micrometeoroid Orbital Debris (MMOD) risk. Partial gravity application includes any hardware or portions of the vehicle that the EVA crewmember will need to access.

Applicability: Microgravity, Partial Gravity

3.9 SAFETY

3.9.1 Hazardous Material Control

The HLS shall provide means of containment commensurate with the hazard level for toxic or hazardous chemicals/materials to preclude contaminating an EVA crewmember or xEVA suit (hazardous to EVA crewmember, xEVA suit performance, or to IVA environment if brought back inside habitable volume). **[EVASC.0092]**

Rationale: Hazardous materials may need to be intentionally present for mission operations. However, to protect the safety of the EVA crewmember during the EVA and of IVA crewmembers following EVAs, those materials should be contained in accordance with the particular perspective on fault tolerance of each program . This is addressed in requirements HLS-[Mission requirements document]-HMTA-0041, HLS- [Mission requirements document] HMTA-0042, and HLS-[Mission requirements document]-HMTA-0043 from the appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity, Partial Gravity

3.9.2 Venting of Hazardous Materials

3.9.2.1 Venting or Exposure Compatibility

The HLS shall design hardware to preclude venting or exposure of hazardous materials to an EVA crewmember (hazardous to EVA crewmember or to IVA environment if brought back inside habitable volume). **[EVASC.0093]**

Rationale: Exposure of hazardous materials may impact/damage xEVA suit materials. Examples of IVA-contaminated environment that can impact the xEVA suit include consumables such as water, oxygen, etc. Exposure to hazardous material contamination could induce a very serious health condition to an EVA crewmember or IVA crew. This is addressed in HLS-[Mission requirements document]-HMTA-0230, HLS-[Mission requirements document]-HMTA-0226, HLS-[Mission requirements document]-HMTA-0227, and HLS-[Mission requirements document]-HMTA-0229 from the appropriate HLS requirements document specified in associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity, Partial Gravity

3.9.2.2 Deliberate Hazardous Venting

The HLS shall direct deliberate hazardous venting away from the EVA crewmember and translation path/worksite. **[EVASC.0094]**

Rationale: Hazardous materials may need to be intentionally vented for successful spacecraft operation. However, to protect the safety of crewmembers during and after the EVA, the orientation and operation of those vents need to be designed and operated so that crewmembers and translation paths/worksites are *not directly impinged upon by hazardous materials during the EVA. Likewise, such venting operations should not deposit hazardous materials on any surface prior to an EVA, with which the crewmember might intentionally or inadvertently come into contact. These steps preclude contact/transference with vented substances and the possibility of bringing such materials inside the habitable volume following EVA activities.*

Applicability: Microgravity, Partial Gravity

3.9.3 Lasers

The HLS shall maintain EVA suit exposure to laser systems below the limits specified in ANSI Z136.1, *American National Standard for Safe Use of Lasers*, Table 5 (Ocular). **[EVASC.0096]**

Rationale: Attenuation of light cannot be assumed from the helmet protection. Design requirements are to cover exposure to both continuous and repetitively pulsed lasers to protect against skin and ocular injury. This requirement applies to lasers used both internal and external to the spacecraft. The limits are adopted from the Laser Institute of America publication ANSI Z136.1, 2014. The term "laser system" includes the laser, its housing, and controls. The safety analysis of all lasers will be carried out by ANSI Z136.1 methodology as specified in the verification requirement. This addresses the ocular portion of requirement HLS-[Mission requirements document]-HMTA-0096 from appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity, Partial Gravity

3.9.4 Electrical and Safety Design

The HLS shall design equipment to preclude exposure of hazardous electrical potential to the EVA crewmember. **[EVASC.0097]**

Rationale: Electrical hazards could include shock, corona discharge, and high electromagnetic fields. Electrical hazards may not be visibly obvious and so should be controlled by means other than the awareness of EVA crewmembers. Ways to meet this are through inhibits/safing systems when EVA is present, and lock out/tag out. For Voltage Potential Discharge, reference requirement [EVASC.0123]. This is addressed in HLS-[Mission requirements document]-HMTA-0230, HLS-[Mission requirements document]-HMTA-0226, HLS-[Mission requirements document]-HMTA-0227, and HLS-[Mission requirements document] -HMTA-0229 from the appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity, Partial Gravity

3.9.5 Shock Protection

Any exposed conducting surfaces that are accessible to EVA crewmember contact (e.g., translation corridors, work areas, and incidental contact zones) shall prevent shock hazards. **[EVASC.0098]**

Rationale: Reference NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment, for electrical bonding procedures as invoked in requirement HLS-[Mission requirements document]-DCS-0030 from the appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2).

Applicability: Microgravity, Partial Gravity

3.9.6 Operation During Pressure Change

The HLS shall design or use equipment expected to function during depressurization per EVA-EXP-0067, *Human Lander System (HLS) Program – Exploration Extravehicular Activity (xEVA) Interface Requirements Control Document (IRCD)*, requirement HLS-xEVA.0186, or repressurization per EVA-EXP-0067 requirement HLS-xEVA.0188, to operate without producing hazards to the EVA crewmember. **[EVASC.0099]**

Rationale: EVA hardware needs to withstand the differential pressure of depressurization, repressurization, and the depressurized condition without resulting in a hazard.

Applicability: Microgravity, Partial Gravity

3.9.7 Component Hazardous Energy Provision

The HLS shall preclude exposing the EVA crewmember to the release of hazardous energy. **[EVASC.0100]**

Rationale: Stored energy can exist in mechanical systems and pressurized flex hoses, hence, tether hoses to prevent hose whip when pressurized. Implementing vehicle/hardware design features that allow for safing of potential energy, along with confirmation that safing is successful, aids in ensuring that the hazard is controlled. This is addressed in HLS-[Mission requirements document] HMTA-0241 and HLS-[Mission requirements document]-HMTA-0229 from the appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2)

Applicability: Microgravity, Partial Gravity

3.9.8 Detachable Parts

The HLS shall design provisions for securing detachable parts. **[EVASC.0101]**

Rationale: Detachable parts could include safety pins, caps, etc. All detachable parts must be secured to prevent inadvertent release. This is necessary in order to prevent inadvertent interference with mechanisms or unintentional re-contact with spacecraft elements. For Partial Gravity applications, this minimizes contamination or loss of cap if dropped on Lunar Surface. Securing detachable parts should not rely on the continuous grasp of an EVA crewmember.

Applicability: Microgravity, Partial Gravity

3.9.9 Touch Temperatures

The HLS shall design the hardware to protect the xEVA suit from specified high- and low-touch-temperature extremes as defined in Table 3.9.9-1 Touch Temperatures **<FW-0070-007>,** in the translation corridors, work areas, and incidental contact zones. **[EVASC.0103]**

Rationale: For ISS, the continuous touch temperature requirement is -43°C to 63°C (-45°F to +145°F), and incidental touch temperature requirement is -118°C to 113°C (-180°F to +235°F). The touch temperature requirement shall be verified using Beginning of Life (BOL) optical property data for cold temperature design, and End of Life (EOL) optical property data for hot temperature design. The requirement can be verified based on the absolute temperature range, or by heat transfer analysis in accordance with the performance of the xEVA suit. These incidental and extended brush limits on the Thermal Micrometeoroid Garment (TMG) have been determined by test and analysis (JSC 39198, "Incidental Contact Temperature Test on Extravehicular Mobility Unit (EMU) Softgoods Materials Lay-Up," AML-01-02-R1, and JSC 39117, "Extravehicular Mobility Unit (EMU) International Space Station (ISS) Extravehicular Activity (EVA) Thermal Environment Requirements for Certification"). In rare cases, EVA operations and/or hardware design require long-duration compression of the TMG orthofabric, thereby, thermally shorting the multilayer insulation and making TMG layers vulnerable to thermal damage. Examples of these are tools with gauntlets or grips that extend around the backside of the glove, or hardware in or containing confined space that requires any portion of the EMU to be compressed during EVA operations. These extended EMU TMG contact limits have been determined by analysis (JSC 39117).

Applicability: Microgravity, Partial Gravity

TABLE 3.9.9-1 TOUCH TEMPERATURES <FW-0070-007>

Temperature Range °C (°F)	Type of Contact
-43°C to 63°C (-45°F to +145°F)	Unlimited touch
-118°C to 113°C (-180°F to +235°F)	Incidental glove palm contact
-153°C to 160°C (-244°F to 320°F)	Incidental TMG brush & bump*
-126°C to 116°C (-195°F to 240°F)	Extended compression of TMG for anything longer than a brush or bump*~
-122°C to 97°C (-187°F to 206°F)	Extended compression of TMG for back of glove for anything longer than a brush or bump*

* Brush or bump is defined as 3 seconds for bump at 7k Pa (1 psi) or 30 seconds for brush at 0.7 kPa (0.1 psi). These may be invoked if or when the first order thermal analysis for items EVA contacts does not meet the values for unlimited glove palm touch or incidental glove palm contact as appropriate.

~ EVA hardware that causes glove or xEVA suit compression during nominal operation shall be evaluated via a hazard/safety analysis.

3.9.10 xEVA Suit Glove Palm External Touch-Temperature Compliance for Small, Handheld Hardware

The HLS shall design hardware that complies with the 30-minute xEVA suit glove palm touch temperature limits for crewmember protection from high and low skin touch temperatures as defined in Table 3.9.10-1 30-Minute Touch Temperature Compliance For Small, Handheld Hardware **<FW-0070-007>,** and Table 3.9.10-2 30-Minute Touch Temperature Heat Rate Compliance **<FW-0070-007>**. **[EVASC.0011]**

Rationale: This requirement applies for hardware that should meet the unlimited glove palm temperature limits. As an alternate, this Table 3.9.10-1 30-Minute Touch Temperature Compliance for Small, Handheld Hardware, can be used to demonstrate 30-minute touch-temperature compliance of hardware, subject to the following limitations: small, handheld hardware with no more than 320 cm² (50 in²) surface area, and materials predominantly of aluminum, stainless steel, titanium, and/or soft goods. These limits do not apply to the backside of the glove which is made from different material that meets other standards.

Applicability: Microgravity, Partial Gravity

TABLE 3.9.10-1 30-MINUTE TOUCH TEMPERATURE COMPLIANCE FOR SMALL, HANDHELD HARDWARE <FW-0070-007>

Hardware Mass kg (lbm)	Allowable Touch-Temperature Range °C (°F)
0 to 0.09 (0.0 to 0.2)	-129 to 121 (-200 to +250)
>0.09 to 0.10 (0.2 to 0.23)	-129 to 116 (-200 to +240)
>0.10 to 0.11 (0.23 to 0.25)	-129 to 110 (-200 to +230)
>0.11 to 0.13 (0.25 to 0.28)	-129 to 104 (-200 to +220)
>0.13 to 0.14 (0.28 to 0.30)	-129 to 99 (-200 to +210)
>0.14 to 0.16 (0.30 to 0.35)	-129 to 93 (-200 to +200)
>0.16 to 0.18 (0.35 to 0.40)	-129 to 88 (-200 to +190)
>0.18 to 0.27 (0.40 to 0.60)	-118 to 82 (-180 to +180)
>0.27 to 0.36 (0.60 to 0.80)	-101 to 79 (-150 to +175)
>0.36 to 0.54 (0.80 to 1.2)	-90 to 77 (-130 to +170)
>0.54 to 0.91 (1.2 to 2.0)	-82 to 74 (-115 to +165)
>0.91 to 1.8 (2.0 to 4.0)	-71 to 71 (-95 to +160)
>1.8 (4.0)	-62 to 66 (-80 to +150)

TABLE 3.9.10-2 30-MINUTE TOUCH TEMPERATURE HEAT RATE COMPLIANCE <FW-0070-007>

Object Temperature °C [°F] *Before Contact*	Continuous Contact Duration (minutes)	Contact Boundary Temperature °C [°F]	Contact Conductance W/m²-°C [BTU/hour square inch-° F]	Maximum Average Heat Rate (1,2) W/m² [BTU/hour-square inch]
> 66 [150]	30	38 [101]	2.698 [0.0033]	93.12 [0.205]
< -62 [-80]	30	24 [75]	2.698 [0.0033]	-264.8 [-0.583]

Notes:

(1) Positive denotes heat out of the object

(2) Averaged over 30 minutes of simulated contact

3.9.11 Incidental and Unlimited Contact Heat Transfer Rates

The HLS shall limit heat transfer rates for incidental and unlimited contact to the values defined in Table 3.9.11-1 Heat Transfer Rates **<FW-0070-007>**. **[EVASC.0104]**

Rationale: Limiting heat transfer is an alternative method to maintaining the touch temperature values for incidental and unlimited contact as defined in the requirement [EVASC.0103] Table 3.9.10-1 30-Minute Touch Temperature Compliance for Small, Handheld Hardware ***<FWD-0070-007>*** *and Table 3.9.10-2 30-Minute Touch Temperature Heat Rate Compliance* ***<FWD-0070-007>****. End item temperature can be controlled passively or actively. Passive controls include the choice of material, coatings, or insulation, while active controls include items such as heaters or cold plates. The incidental contact temperatures in Table 3.9.11-1 Heat Transfer Rates* ***<FW-0070-007>,*** *assumes the skin temperature as the boundary (from medical limits and testing), with a linear conductor to account for resistances and material thermal resistances of the glove (based on testing), and the maximum allowable heat rate (based on testing). The end item provider must apply these values to the object to be contacted by the skin boundary through the prescribed linear conductor. The object initial temperature and material properties must be considered. These values are based on the heritage ISS EMU suit.*

Applicability: Microgravity, Partial Gravity

TABLE 3.9.11-1 HEAT TRANSFER RATES <FW-0070-007>

Object Temperature	Contact Duration (minutes)	Boundary Node Temperature ° C [° F]	Linear Conductor K/W [BTU/hr ° F]	Maximum Average Heat Rate [1] W [BTU/hr]
Hot Object	Unlimited	45 [113]	2.179 [1.149]	13.34 [2] [42.52]
	Incidental (0.5 max)	45 [113]	2.739 [1.444]	51.64 [3] [176.2]
Cold Object	Unlimited	4 [40]	2.015 [1.062]	-38.89 [2] [-132.7]
	Incidental (0.5 max)	4 [40]	2.804 [1.4782]	-95.31 [3] [-325.2]

Notes:

[1] Positive denotes heat out of the object, negative denoted heat into the object.

[2] Averaged over 30 minutes of simulated contact (excursions up to 1.5 times this rate for 3-minute intervals is allowable).

[3] Averaged over 2 minutes of simulated contact (excursions up to 2.5 times this rate for 12-second intervals is allowable)

3.9.12 Sharp Edge and Protrusions Protection

The HLS shall protect the EVA crewmember from end item edges and protrusions on all hardware located within 0.61 m (24 in) of a translation path (reference requirements [EVASC.0010] and [EVASC.0159]), within a worksite envelope, and on each equipment item needing an EVA interface through compliance with Table 3.9.12-1 Edge, Corner, and Protrusion Criteria – Edge and In-Plane Corner Radii, Figure 3.9.12-1 Exposed Corner and Edges, and Table 3.9.12-2 Edge, Corner, and Protrusions Criteria – Protrusions and Outside Corners. **[EVASC.0105]**

Rationale: Sharp edges could damage the softgoods of the xEVA suit and potentially create a catastrophic hazard due to pressure loss. It is critical that hardware designers address both sharp edges that may be considered "on purpose" as well as those that can be generated during the manufacturing process "accidental". A swatch test can also be used to evaluate potential sharp edges. Only trained personnel can perform a swatch test per the procedure documented in the EVA Office Memo XA-08-015, EVA Office Sharp-Edge Policy for Work Site/Incidental Contact of Space Shuttle Payloads and International Space Station Vehicle .

Applicability: Microgravity, Partial Gravity

TABLE 3.9.12-1 EDGE, CORNER, AND PROTRUSION CRITERIA – EDGE AND IN-PLANE CORNER RADII

Application	Radius				Remarks	Figure
	Outer mm	Outer in	Inner mm	Inner in		3.9.12 Referenced
(a) Openings, panels, covers (corner radii in plane of panel)	6.4 3.0	0.25 0.12	3.0 1.5	0.12 0.06	Preferred Minimum	
(b) Exposed corners:	13	0.5	–	–	Minimum	(a)
(c)Exposed edges: (1) 2.0 mm (0.08 in) thicker than 2.0 mm (0.08 in)	1.0	0.04	–	–		(b)
(2) 0.5-2.0 mm (0.02 to 0.08 in) thick	Full Radius		–	–		(c)
(3) less than 0.5 mm (0.02 in) thick	Rolled or Curled					(d)
(d) Flanges, latches, controls, hinges, and other small hardware operated by the pressurized-gloved hand	1.0	0.04	–	–	Minimum required to prevent glove snagging	–
(e) Small protrusions (less than approximately 4.8 mm (3/16 in)) on toggle switches, circuit breakers, connectors, latches, and other manipulative devices	1.0	0.04	–	–	Absolute minimum unless protruding corner is greater than 120°	

Edge and In-Plane Corner Radii - A 45° chamfer by 1.5 mm (0.06 in) (minimum) with smooth broken edges is also acceptable in place of a corner radius. The width of chamfer should be selected to approximate the radius corner described above.

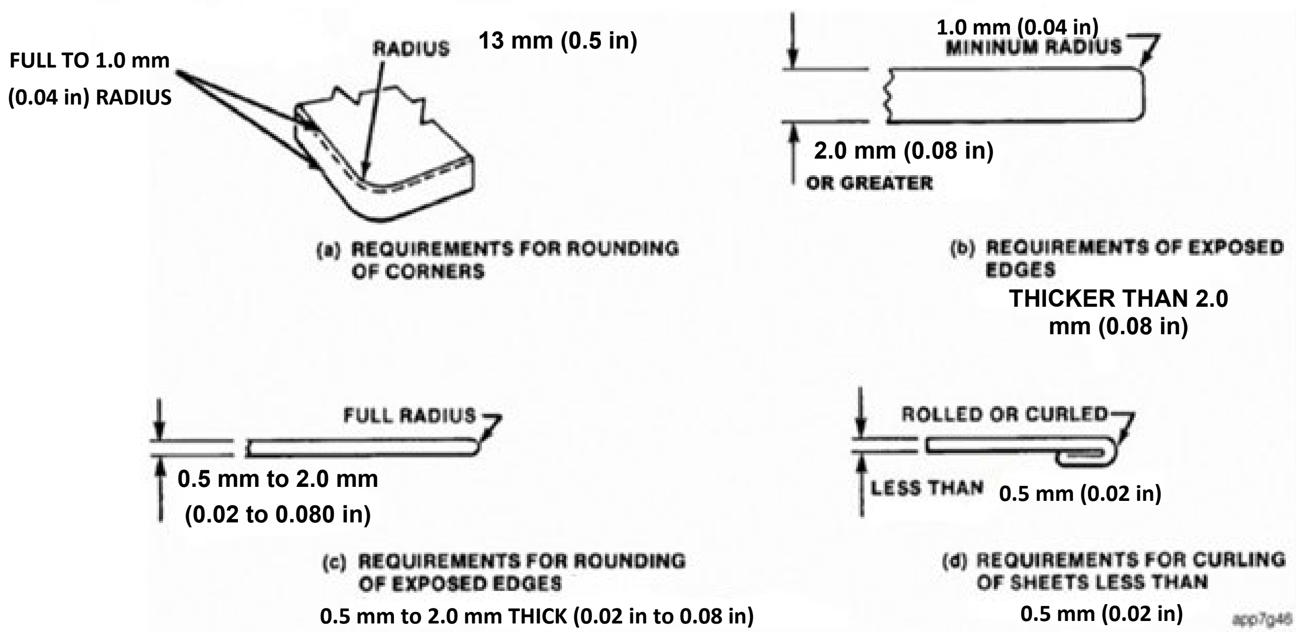


FIGURE 3.9.12-1 EXPOSED CORNER AND EDGES

TABLE 3.9.12-2 EDGE, CORNER, AND PROTRUSIONS CRITERIA – PROTRUSIONS AND OUTSIDE CORNERS

APPLICATION	CRITERIA/REMARKS
Latching devices	Cover or design all latching devices to preclude gaps or overhangs that can catch fabrics or pressure xEVA suit appendages. All surfaces and edges must be smooth, rounded, and free of burrs.
Lap joints in sheet metal and mismatching of adjacent surfaces	All surfaces must be mated within 0.8 mm (0.03 in) of flat surface at edges or must be butted or recessed. All exposed edges must be smooth and radiused 1.5 mm (0.06 in) minimum, chamfered 45°, or must be covered with an appropriate material to protect EVA gloves.
Safety wire (lock wire) and cotter pins	Ensure that no safety wire is used on external surfaces. Reference requirement [EVASC.0069] for prohibited locking fasteners.
Sheet metal structure, box and cabinet three-plane intersecting corners	Use spherical welded or formed radii unless corners are protected with covers.
Thin Materials	Materials less than 2.0 mm (0.08 in) thick, with exposed edges that are uniformly spaced, not to exceed 13 mm (0.5 in) gaps, flush at the exposed surface plane and shielded from direct EVA interaction, must have edge radii greater than 0.08 mm (0.003 in). Note - this is for radiator-type applications.

TABLE 3.9.12-2 EDGE, CORNER, AND PROTRUSIONS CRITERIA – PROTRUSIONS AND OUTSIDE CORNERS

APPLICATION	CRITERIA/REMARKS
Screw heads, bolts, nuts, and nut plates, excess threads and rivets that can be contacted by crewmember (reference requirement [EVASC.0106])	Design all screw heads and bolt heads to face the outside of the structure, if possible. Where nuts, nut plates, and threads are exposed, cover the nuts, nut plates, and threads in a secure manner that does not preclude removal of the fastener. Recessed heads or the use of recessed washers is recommended. Overall height of heads shall be within 3.18 mm (0.125 in) or covered unless more than 7 head diameters apart from center to center. Height of roundhead or oval head screws is not limited. Screw heads or bolt heads more than 6.4 mm (0.25 in) deep must be recessed or be covered with a fairing, except those intended to be EVA crew interfaces.
	Design rivet heads to face out on all areas accessible to crewmembers and to protrude no more than 1.5 mm (0.06 in) unless spaced more than 3.5 head diameters from center to center. In all exposed areas where unset ends of rivets extend more than 3.1 mm (0.12 in), or 13 mm (0.50 in) of unset and diameter if more than 3.1 mm (0.12 in), install a fairing over them. This applies to explosive, blind, or pull rivets, etc. Unset ends of rivets must have edges chamfered 45° or ground off to a minimum radius of 1.5 mm (0.06 in).
	Allow a maximum gap of 0.5 mm (0.02 in) only between one side of a fastener head and its mating surface.
	Prevent or eliminate burrs. Use of Allen heads is preferred. For torque-set, slotted, or Phillips head screws, cover with tape or other protective materials or individually deburr before flight.
	Screws or bolts with exposed threads protruding greater than 3.1 mm (0.12 in) in length, must have protective features that do not prevent installation or removal of the fastener.

3.9.13 Screws and Bolts

The HLS shall include protective features on screws or bolts in established worksites (planned and contingency) and translation routes to prevent snagging, and to protect against sharp edges. **[EVASC.0106]**

Rationale: Sharp edges and potential snag hazards pose a threat to EVA crewmembers translating along a vehicle.

Applicability: Microgravity, Partial Gravity

3.9.14 Levers, Cranks, Hooks, and Controls

The HLS shall locate levers, cranks, hooks, and controls where they cannot pinch, snag, cut, abrade, or provide kickback to the EVA crewmember appendages or equipment such as tethers. **[EVASC.0107]**

Rationale: Levers, cranks, hooks, and controls can generate snag/safety hazards that may pose a threat to EVA crewmembers during translation.

Applicability: Microgravity, Partial Gravity

3.9.15 Exposed Holes or Slots

The HLS shall ensure that exposed holes that are round or slotted, within the range of 13 mm (0.5 in) to 36 mm (1.4 in) in diameter are covered to preclude entrapment of a xEVA-gloved finger. **[EVASC.0109]**

Rationale: Holes with diameter in the range of 13 mm (0.5 in) to 36 mm (1.4 in) could entrap the crewmember's finger. Irregularly shaped holes will be evaluated individually during the safety review process. EVA crewmembers are trained to recognize tether points, so although they are specified to be in the entrapment range, they are exempt from this requirement. This requirement should also be applied to loose equipment and to holes, even if the back side is accessible, because the hazard is not only that the crew will entrap the finger, but that damage may occur to the finger in the effort to remove it from the entrapped condition.

Applicability: Microgravity, Partial Gravity

3.9.16 Pinch Hazard Protection

The HLS shall protect the EVA crewmember from pinch hazards. **[EVASC.0110]**

Rationale: This applies to, but is not limited to, any hardware that pivots, retracts, flexes, has the potential to pinch any appendage, (including legs or other body parts), or has a configuration such that a gap in the range of 13 mm (0.5 in) to 36 mm (1.4 in) (glove pinching), exists between the equipment and adjacent structure (reference requirement [EVASC.0109]. This addresses requirement HLS-[Mission requirements document]-HMTA-0221 from the appropriate HLS requirements document specified in associated EVA-EXP-0070 Mission Annex (reference section 2.2) and is applicable to any hardware located in the EVA translation path, established EVA worksite, or associated with a planned or contingency EVA.

3.9.17 Equipment Clearance for Entrapment Hazard

The HLS shall provide clearance for equipment removal and replacement to prevent the creating of a crew entrapment hazard that can be caused by insufficient clearance that results in not meeting any or all of the following requirements:

1) Exposed Holes or Slots (entrapment of crew fingers) – reference [EVASC.0109]

2) Gloved Operation (entrapment of crew hand) – reference [EVASC.0003]

3) Translation Paths (entrapment of crew body) – reference [EVASC.0001]. **[EVASC.0111]**

Rationale: Other hardware-specific entrapment hazards can also exist that are outside of the three listed above; hazard analyses conducted as part of the safety review process can determine other potential entrapment concerns to be addressed. This requirement applies to hardware in translation paths and worksites. It assumes that hardware (e.g., all latches, fasteners, etc.) are designed to preclude entrapment of the equipment or crewmember. Worksites for equipment removal/replacement tasks must prevent crewmember entrapment hazard.

Applicability: Microgravity, Partial Gravity

3.9.18 Protection from Moving or Rotating Equipment

The HLS shall protect EVA crewmembers from impacts from moving, rotating equipment, or inadvertent deployment, separation, or jettison of hardware. **[EVASC.0112]**

Rationale: Moving or rotating equipment can present a hazard to the EVA crewmember. Equipment that gets separated can present a contact hazard for the EVA crewmember and for the spacecraft. The vehicle needs to include design features to protect EVA crewmembers from hazards due to movable or rotating equipment that could come into contact with an EVA crewmember, snagging or cutting the xEVA suit or umbilical, resulting in catastrophic leak or injury to the EVA crewmember. These design features could include the use of a two-fault tolerant design, use of physical barriers, use of two inhibits to prevent accidental actuation of these types of hardware, or a combination of these design features. Components that contain stored energy (springs, pyro activated devices, pressure vessels, etc.) could constitute a hazard to an EVA crewmember if not properly controlled.

Applicability: Microgravity, Partial Gravity

3.9.19 Emergency Ingress Capability

The HLS shall design EVA translation paths and aids so that an EVA crewmember can complete an emergency ingress within ten minutes (threshold) and five minutes (goal), starting from first contact with the vehicle and ending when the vehicle cabin reaches > 13.3 kPa (1.92 psia) Inspired Partial Pressure of Oxygen (PIO2). **[EVASC.0113]**

Rationale: xEVA suit design includes 1 hour of emergency life support to protect for most contingencies. It is assumed that tools/samples would be discarded prior *to touching the lander and there would be no lunar dust mitigation prior to ingress. After ingress and hatch closure, an emergency repress to > 13.3 kPa (1.92 psia) PIO2 (minimum survivable inspired O_2 pressure from MPCV 70024, Orion Multi-Purpose Crew Vehicle (MPCV) Program: Human Systems Integration Requirements, Table 3.2.2.1-1) would occur such that the crewmember can begin doffing the suit. PIO2 is a function of cabin pressure, oxygen partial pressure and the vapor pressure in psia of water at 37° C (98.6° F) body temperature given in MPCV 70024, section 3.2.1.2. The 1 hour- contingency life support duration must account for identifying the failure, physically returning to the vehicle (walking or traversing in a rover) and ingress. Accordingly, an emergency ingress needs to be as quick as possible, since it is only one component of a larger contingency timeline which depends on the type of failure, distance from the vehicle and terrain. A 10 min ingress/repress would force an aggressive walkback with no margin while a 5 min ingress/repress would allow conservatism in walkback speed and/or a small margin. While hardware limitations and crew safety considerations make the problem challenging, alternate solutions to allow additional ingress/hatch/repress time may be considered.*

Applicability: Microgravity, Partial Gravity

3.9.20 External Surface Cleanliness Level

The hardware that interfaces with external surfaces of xEVA System hardware shall meet a Visibly Clean-Sensitive (VC-S) level upon delivery as identified by JPR 5322.1, *Contamination Control Requirements Manual*, or higher. **[EVASC.0140]**

Rationale: This is intended for any hardware that interfaces with EVA. At the completion of Pre-Delivery Acceptance/Pre-Installation Acceptance (PDA/PIA), hardware is expected to be verified as VC-S or higher and that cleanliness level maintained through the receive-in process at NASA or NASA's Cargo Integrator controlled storage. It is assumed that contamination sources in flight will be controlled by higher-level Program mechanisms. In general, xEVA System hardware delivered for launch as VC-S is not expected to be maintained to VC-S once launched unless specific documentation such as Hazard Controls, Flight Rules, and Operational Control Agreement Database (OCADs) specifically request such precautions.

Applicability: Microgravity, Partial Gravity

3.9.21 Tethering / Restraint

Hardware items shall provide at least one means of positive restraint independent of EVA grasp. **[EVASC.0115]**

Rationale: Grasping is not considered an acceptable form of positive restraint for a translating EVA crewmember, so tethers and tether points are required on hardware with handholds. This requirement applies for microgravity EVA operations. Surface EVAs may not necessarily require the use of tethers for translation.

Applicability: Microgravity

3.9.22 Crew Safety Tether Attachment

Handholds/handrails on microgravity translation paths intended for crewmember restraint shall incorporate a safety tether attachment point into its support structure to withstand the specified EVA crewmember safety tether loads identified in [EVASC.0050] Table 3.5.2-1 Microgravity EVA-Induced Loads, Design Limit Load Type “Crew Safety Tether Attachment”. **[EVASC.0116]**

Rationale: The 890 N (200 lbf) Crew Safety Tether load protects for crew in microgravity conditions should they lose physical grip or structural restraint. This load is encompassed by the Primary Translation path load requirement of 979 N (220 lbf) for General worksite loads outlined in [EVASC.0050].

Applicability: Microgravity

3.9.23 Crew Safety Restraint

Attachment point for Crew Safety Restraints, employed in areas of EVA operations where reaction to Crew Slips or Falls is necessary for safety of crewmember, shall be incorporated into support structure that withstands the specified EVA crewmember loads identified in requirement [EVASC.0155], Table 3.5.3-1 Partial Gravity EVA-Induced Loads, under Load/Energy Category “L12, Swinging/ or Falling” **<TBD-HLS-EVA-015>**. **[EVASC.0161]**

Rationale: Anticipating that crew may utilize a fall arrest system or restraint system during high-risk operations identified during the safety review process, the restraint attachment point needs to withstand emergency loads. In one potential application, the load in [EVASC.0161] corresponds to the anticipated load transferred into the vehicle structure if a rip-stitch tether is employed, to arrest the fall of a suited crewmember to 1 m (39.4 in).

Applicability: Partial Gravity

3.9.24 Color for Crew Load-Rated Handhold/Handrails, Crew Safety Tethers and Safety Restraint Attachment Points

Handholds/handrail, Crew Safety Tethers and Crew Safety Restraint attachment points intended for use by the crew shall be colored according to Table 3.9.24-1 Crew Load-Rated Colors, where the color value has a contrast ratio of 5:1 or greater than the background. **[EVASC.0117] <FW-0070-006>**

TABLE 3.9.24-1 CREW LOAD-RATED COLORS

Item	Gravity Field Applicability	Color	Notes
Handrail/ Handhold–Primary Translation Path	Microgravity, Partial Gravity	Gold or yellow	Handrail/handholds are defined in [EVASC.0050] for microgravity application. Handholds/Handrails are defined in [EVASC.0155] for partial gravity application under Load/Energy Category L11 Handrails Grasp/Pull Load Limit Load %.
Crew Safety Tether	Microgravity	Gold or yellow	Crew Safety Tethers are defined in [EVASC.0116].
Crew Safety Restraint	Partial Gravity	Blue	Crew Safety Restraints are defined in [EVASC.0161].

Rationale: The EVA crewmember needs to be able to readily identify handholds/handrails that, when attached to the vehicle structure, are designed to withstand loads to enable crew translation and safety. Designs and materials selected for color must meet NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft, a Type 2 standard levied in EHP-10012, Extravehicular Activity and Human Surface Mobility Program (EHP) Systems Requirements Document, (is addressed by HLS-[Mission requirements document] DCS-0014 from the appropriate HLS requirements document specified in the associated EVA-EXP-0070 Mission Annex (reference section 2.2), and accordingly maintain their unique, colored identification for the intended life of the vehicle. Human-rated handrails/handholds in the primary translation path are defined as those that meet microgravity EVA-induced loads (requirement [EVASC.0050], Table 3.5.2-1, Microgravity EVA-Induced Loads, Design Limit Load Type "EVA Handrail Handhold – Primary Translation Path" loads), and sharp edges. For partial gravity handholds/handrails that enable surface mobility (i.e., ascent, descent, ingress, and egress), partial gravity EVA-induced loads (requirement [EVASC.0155], Table 3.5.3-1, Partial Gravity EVA-Induced Loads, under Load/Energy Category L11 Handrails Grasp/Pull Load Limit Load%) are enveloped by the microgravity EVA-induced load. Accordingly, all handrails/handholds will be colored gold or yellow. The Crew Safety Restraint is *a restraint attachment point for partial gravity that is intended to meet an emergency operational load ([EVASC.0155], Table 3.5.3-1, L11). This corresponds to the load anticipated on the restraint attachment point if a rip-stitch tether is employed to arrest the fall of a suited crewmember to 1m (39.4 in). In order for crew to differentiate between attachment points and identify those that are rated for partial gravity fall arrest, those Crew Safety Restraint attachment points will be colored blue. Loads for the design of the handrails/handholds in the primary translation path, Crew Safety Tether and Crew Safety Restraint are captured in the following requirements: [EVASC.0050], [EVASC.0155], [EVASC.0116], and [EVASC.0161]. Handrails that are not intended for enabling crew attachment or as handholds/handrails attached to vehicle structure will be colored differently as outlined in [EVASC.0033] so as not to misinform crew. The recommended contrast ratio and color coding can be found in the NASA/SP-2010-3407/REV1, NASA Human Integration Design Handbook, sections 9.7.2.2.2 and 10.4.7.3.*

Applicability: Microgravity, Partial Gravity

3.9.25 Manual Overrides

For remotely commanded mechanisms that require EVA as a backup, the HLS shall include a manual override that accommodates EVA operation with a hand tool. **[EVASC.0118]**

Rationale: The intent is to ensure that the hardware design for the remotely commanded mechanism (e.g., robotic work platform) provides access to an EVA override or equivalent drive out/back drive feature. This is like the tasks associated with release of a potentially stuck robotic arm end effector.

Applicability: Microgravity, Partial Gravity

3.9.26 Entanglement, Cable Clamps, Ducts, or Retractors

Cables, conductors, bundles and hoses within an EVA worksite or translation path shall be secured by means of restraints (e.g., clamps, wire ties, etc.) unless they are contained in a cable management system (wiring ducts or cable retractors). **[EVASC.0137]**

Rationale: Intent is to ensure that the connector worksites and translation paths are free from obstructions.

Applicability: Microgravity, Partial Gravity

3.10 ENVIRONMENTS

3.10.1 Magnetic Field Limit

The HLS shall not generate static or time varying magnetic fields that exceed values outlined in HLS-STD-007, *Human Landing System (HLS) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*, RE101A and RE101D in crew translation corridors, work areas, and incidental contact zones during EVA operations internal and external to the HLS pressurized volume. **[EVASC.0121]**

Rationale: The intent of this requirement was to prevent magnetic interference with the xEVA suit and xEVA tools. Magnetic field strengths inside the HLS pressurized volumes are far lower and would pose no threat to any portion of the xEVA suit.

Applicability: Microgravity, Partial Gravity

3.10.2 Voltage Potential Discharge

The HLS shall meet performance requirements during and after exposure to voltage/current transients of **<TBD-HLS-EVA-014>** that occur during contact with xEVA operations when the vehicle and xEVA suit or payloads come to equilibrium. **[EVASC.0123]**

Rationale: Prior to contact, xEVA hardware and Exploration vehicles/payloads/ hardware could be at extremely different potential discharge due to interactions with the natural environment. Exploration vehicles/hardware (e.g., HLS, payloads, etc.) should be immune to the resulting voltage and transient currents that occur when the xEVA/Exploration vehicles/hardware potentials come to equilibrium.

Applicability: Microgravity, Partial Gravity

3.10.3 Lunar Surface Dust Tolerance

The HLS shall tolerate the liberation of at least 100 grams of lunar surface dust in the cabin environment from the xEVA system after each two-crew lunar surface EVA. **[EVASC.0156]**

Rationale: The total value per two-crew EVA in this requirement is established to provide a best-case bounding condition for nominal scenarios so that surface assets such as Human Landers can size Environmental Control/Life Support System (ECLSS) filters and other mitigation features provided by the vehicle to meet or exceed the vehicle system cleanliness requirements established for lunar dust. This requirement only identifies the amount of dust that may be liberated from the xEVA system after an EVA. Utilization payloads, instruments, or other *items returned to the vehicle after an EVA are not part of this 100g value. This value assumes that EVA crew had adequate time at the end of the EVA, before vehicle ingress, to remove excess dust. 100 grams is based upon an allocation of no more than 50 grams per crew. EVA tools are not nominally returned into the cabin/airlock between EVAs unless needed for battery recharge. It is likely that contingency scenarios will have the potential to bring in more dust than prescribed in the requirement. It is acknowledged that this requirement is for nominal scenarios only; contingency events which lead to the termination or abort of a lunar surface EVA will likely reduce or eliminate the time and ability to execute dust mitigation activities.*

Applicability: Partial Gravity

4.0 VERIFICATION

This section contains the EVA compatibility matrixed requirements that are necessary to show compliance with each “shall” statement in section 3.0 of this document. Non “shall” statements are not required to be checked for compliance.

4.1 VERIFICATION METHODS

This section contains a description of verification methods, roles and responsibilities, and a verification matrix describing the methods recommended for each requirement. Verification methods are partitioned between EHP and vehicle hardware providers, with some contribution from EVAS suit providers. As this document describes how programs can interface with and accommodate the suited EVA crewmember, it is to be expected that verifications to these requirements may require input and coordination between both interfacing parties. Where interface requirements are designated “EHP” in the Verification Matrix (section 4.2), programs should jointly plan the verification event(s) in a Bilateral Integration and Verification Plan (BIVP). Deliverables, dependencies, and other cross-program exchanges noted in the plan should then be incorporated into cross-program Joint-Technical Agreement Memos (JTAMs) and/or Joint Agreement Memorandums (JAMs). EHP verification methods currently include EHP Model Analysis, Vehicle Integration Test Office (VITO) fitcheck, VITO sharp edge inspection and inspection of records and are described in the following sections.

Hardware provider verification methods describe those coordinated and performed by HLS and/or its vendor(s). Many Artemis-supporting hardware deliverables and mission capabilities are vendor-provided. Accordingly, contract terms often dictate the terms of developing verification methods, arriving at verification agreements and providing verification compliance evidence. Where interface requirements are described “Hardware provider” in the Verification Matrix (section 4.2), the matrix provides guidance for the expected verification methods. Whether verification plans are solely vendor-provided for NASA review and approval, or jointly developed between vendors and NASA project teams, the Verification Matrix provides the guidance for verifying the implementation of the EHP EVA suit, tools, and support hardware compatibility. Hardware provider verification may be accomplished by inspection, analysis, demonstration, test, or any combination. The methods used to accomplish the verification are defined in the following sections.

Notably, though a verification may be marked for “EHP,” Hardware providers (including HLS vehicle and EVAS) may often participate in demonstrating compliance. Roles and responsibilities are described in the following sections, but a more detailed explanation of participation in cross-program verification plans will be collected in the cross-program BIVP.

4.1.1 EHP Verification Methods

4.1.1.1 EHP Model Analysis

EHP Model Analysis is a method of verification utilizing Computer-Aided Design (CAD) modeling to simulate and assess the interface between the suited EVA crewmember, their tools or their support hardware and the vehicle or external environment.

EHP is tasked with the integration of EHP Projects and external program vehicles/payloads (e.g., the HLS Program). Accordingly, the NASA EHP EVA Model Analysis team will provide integrated, model-based verification between suit providers within EHP and one or more external vehicle/payload interfaces. The difference between NASA and Hardware provider analyses, when both may employ CAD modeling, is summarized as follows:

EHP Model Analysis team will assess the integrated, joint interface between EHP projects and external vehicles/payloads.

While a Hardware provider analysis may show that the provider is compliant with a requirement, the EHP Model Analysis team will assess the final, integrated, mission-integrated configuration, for systems and elements that may reach across multiple Projects and/or Programs for proper requirement compliance. The EHP Model Analysis team verification product will include an analysis report, describing the requirements verified with the models (and associated assumptions used). EHP Model Analysis team is expected to identify any violations, risks or general concerns associated with the results of the analysis to EHP SE&I for further investigation.

To support the EHP Model Analysis team, EHP EVA Development Project will provide the suit model to be used in the analysis.

In addition to verification, the EHP Model Analysis team CAD modeling may provide an end-to-end mission validation to support the program mission readiness assessment. EHP Model Analysis team may also aid in real-time mission support for anomalies or unplanned contingency maintenance. The EHP Model Analysis team may also be employed during the development lifecycle to assist with preliminary design, layouts and even “back-of-the-envelope” approximations during the design cycle, and prior to final verification.

The inputs, outputs, and the responsible parties in support of an EHP Model Analysis team are described in Figure 4.1.1.1-1 Inputs and Outputs Supporting EHP Model Analysis.

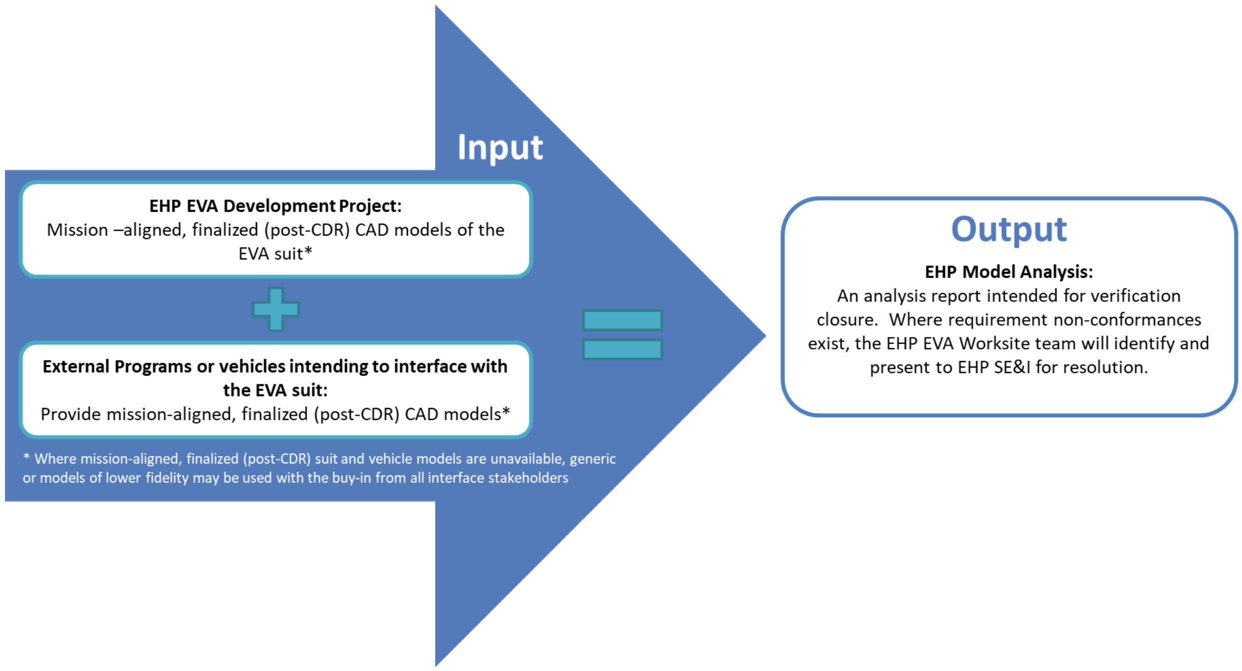


FIGURE 4.1.1.1-1: INPUTS AND OUTPUTS SUPPORTING EHP MODEL ANALYSIS

Below is a narrative that dives deeper into a verification using the example of a requirement that, according to the Verification Matrix, is expected to utilize EHP Model Analysis to demonstrate compliance:

- **Example [EVASC.0001]:**

  [EVASC.0001], "Translation Path Hardware Protrusion," ensures that there are no protrusions into the EVA translation path corridor. In the Verification Matrix (section 4.2), this requirement is intended for analytical verification by the Hardware provider and EHP via EHP Model Analysis. Levied on external vehicles in both partial and microgravity environments, hardware providers would provide an independent analysis (or agreed-upon alternative verification method) that shows that there are no protrusions into the translation path/traverse as described in the requirement. In addition to a hardware provider analysis to meet the requirement, these external programs will also provide CAD models to EHP Model Analysis team with post-CDR design and sufficient fidelity to model and analyze intended areas for crew translation/traverses in either microgravity or partial gravity. EHP EVA Model Analysis team would provide an analysis that includes a mission-specific assessment which includes any and all contributions from adjacent Elements, Payloads, or other systems, projects, or programs to assess if unique protrusions that are created in the translation path/traverse.

Note: As this requirement (noted in the requirement statement) is based on the heritage ISS EMU suit, it is known forward work with EHP to confirm that future vendor-provided suit designs meet the work envelope constraints in the requirement statement. That effort is not included as part of the verification work described here.

4.1.1.2 Vehicle Integrated Test Office Process for EVA Hardware Evaluation

Vehicle Integration and Test Office (VITO) fitcheck and VITO sharp edge inspection are demonstration and inspection methods, respectively, performed by the EHP VITO, within the Flight Operations Division (FOD) at JSC. VITO works on behalf of the EVA community to integrate space flight hardware manufacturers' knowledge, experience, resources, and requirements to help execute safe and successful human space flight. The purpose of the VITO is to ensure that human-to-machine interfaces are safe and operable for all phases of flight, and that all NASA centers, International Partners (IPs), and Commercial Providers (CPs) properly incorporate FOD requirements into their programs and projects. To this end, VITO engineers identify, coordinate, integrate, and implement functional and/or operational test requirements for FOD participation in payload and spacecraft flight preparation. VITO engineers undergo extensive training for sharp edge inspection techniques and maintain extensive EVA operability knowledge to aid in fitcheck assessments. VITO is considered an EHP verification, performed on the final vehicle configuration prior to launch, to account for any sharp edges or access restrictions that were potentially unplanned, but came as a result of the final configuration. To support these demonstrations and inspections on as-built hardware, the VITO team may travel to vendor sites or launch sites.

To support the VITO team, and in support of requirements marked for VITO verification, Hardware providers will provide access to their hardware in the final configuration, with sufficient time to perform VITO demonstrations and inspections.

VITO fitchecks chiefly verify interfaces between the host vehicle and either tools or suited crew interfaces. Requirements identified as "VITO Fitcheck" in the Verification Matrix (section 4.2) include requirements for accommodations for crew access, tool access/operation and other crew-actuated components or hardware that are verified by the VITO team in the vehicle as-built configuration.

VITO sharp edge inspections employ a swatch test of the as-built host vehicle per the procedure documented in the EVA Office Memo XA-08-015, *EVA Office Sharp-Edge Policy for Work Site/Incidental Contact of Space Shuttle Payloads and International Space Station Vehicle*. Identified issues shall be adjudicated per approved procedure in that Memo.

The EHP SE&I office will coordinate with all parties with whom a VITO inspection requirement is applicable (as identified by the Verification Matrix, section 4.2) and facilitate VITO access to the hardware in its final flight configuration. For both VITO demonstration and inspection, VITO provides an independent verification and issues a final report.

VITO may be a resource to hardware providers, vendors, and external programs if additional interpretation of the requirement is needed.

Below is a narrative that dives deeper into a verification using the example of a requirement that, according to the Verification Matrix (reference section 4.2), is expected to utilize VITO to demonstrate compliance:

- **Example [EVAS.0138]: VITO Fitchecks**

[EVASC.0138], "Gloved Hand Connector Accessibility" requires that applicable EVA suits, rovers and vehicles provide sufficient access to any connectors intended for EVA suited crewmember operation, which includes an additional envelope allowing for a gloved hand. In the Verification Matrix (section 4.2), this requirement is intended for verification by hardware provider via Analysis, and NASA via VITO Fitcheck Inspection. A vehicle provider is expected to design their systems with connector operability in mind and shall demonstrate that compliance with an analysis or other agreed-upon verification method. VITO fitchecks on the pre-launch hardware will confirm access, using specialized support and inspection hardware, ensuring that any additional access constraints as a result of final vehicle integration are identified. The VITO team will provide EHP with a compliance report for all vehicles and rovers to which this requirement is applicable.

- **Example [EVASC.0105]: VITO Sharp Edge Inspection**

[EVASC.0105], "Sharp Edge Protrusions Protection" requires that applicable EVA hardware, worksites, translation paths and adjacent surfaces be free from sharp edges that may damage the EVA suit softgoods. In the Verification Matrix (section 4.2), this requirement is intended for verification by hardware provider via Inspection, and EHP via VITO Sharp Edge Inspection. A hardware provider, including cross-program vehicle providers, is expected to design their vehicle to mitigate sharp edges and inspect for compliance according to the requirement specifications. However, due to both the level of risk associated with potential suit damage due to sharp edges and the extensive training possessed by VITO personnel, the hardware providers are expected to make their hardware available to VITO to perform these inspections with the necessary specialized support and inspection hardware, prior to launch. The VITO team will provide EHP with a compliance report for all worksites, tools, translation paths and other adjacent surfaces identified in the requirement statement.

4.1.1.3 Inspection of Records

Inspection of Records is a systematic and documented process for reviewing objective evidence (records, statements of fact or other information which are relevant and verifiable) and evaluating it objectively to determine the extent to which the inspection criteria (a set of policies, procedures, or requirements) are fulfilled, is satisfied through the review of lower level compliance generated data.

For a records inspection, the Hardware provider provides verification compliance evidence via Verification Closure Notices (VCNs) or equivalent to EHP for all EVA requirements, including those with EHP verification methods. EHP will track and report closure of the requirements in this document, according to applicability, as part of each Program interface verification compliance obligation specified in ACD-50012, *Artemis Campaign Development (ACD) Enterprise Verification and Validation Plan*.

4.1.2 Hardware Provider Verification Methods

4.1.2.1 Inspection

Verification by Inspection is the visual examination of a realized end product. Inspection is generally used to verify physical design features or specific manufacturer identification. For example, if there is a requirement that the safety arming pin has a red flag with the words "Remove Before Flight" stenciled on the flag in black letters, a visual inspection of the arming pin flag can be used to determine if this requirement was met. Inspection can include inspection of drawings, documents, or other records. This method can also be used to evaluate physical hardware, components, subsystems, and systems.

4.1.2.2 Analysis

Verification by Analysis includes the use of mathematical modeling and analytical techniques to predict the suitability of a design to stakeholder expectations based on calculated data or data derived from lower system structure end product verifications. Analysis is generally used when a prototype; engineering model; or fabricated, assembled, and integrated product is not available. Analysis includes the use of modeling and simulation as analytical tools. A model is a mathematical representation of reality. A simulation is the manipulation of a model. Analysis can include verification by similarity of a heritage product.

Verification by Analysis is a process used in lieu of (or in addition to) testing and inspection. Analysis techniques may include statistics and qualitative analysis, computer and hardware simulations, and computer modeling. Analysis should be used only when all the following conditions apply: (1) rigorous and accurate analysis is possible, (2) verification by test is not feasible or cost effective, and (3) verification by inspection is not adequate. When conducting Verification by Analysis, the models, simulations, and analysis tools must be accredited by the Program to certify appropriate fidelity and software development quality. The accreditation authority ensures that the tools have sufficient pedigree to provide usable information for decision-making, at the level of criticality required.

Examples of Verification by Analysis include thermal analysis and stress analysis to show that the use of the hardware does not exceed specification limits during the mission operation. The critical tasks identified through task analysis are used to define test and demonstration scenarios and procedures to verify functional and performance requirements such as functional volume and layout, operability, usability, workload, and design induced error.

4.1.2.3 Demonstration

Verification by Demonstration shows that the use of an end product achieves the individual specified requirement. It is generally a basic confirmation of performance capability, differentiated from testing by the lack of detailed data gathering. Demonstrations can involve the use of physical models or mock-ups. For example, a requirement that all controls shall be reachable by the pilot could be verified by having a pilot perform flight-related tasks in a cockpit mock-up or simulator. A demonstration could also be the actual operation of the end product by highly qualified personnel, such as test pilots, who perform a one-time event that demonstrates a capability to operate at extreme limits of system performance, an operation not normally expected from a representative operational pilot. It is the actual operation of Flight or Ground Equipment, or Teams to evaluate its functional performance and/or its interfaces to other equipment or teams. The primary distinction between demonstration and test is that demonstrations provide qualitative results, whereas tests provide quantitative results. Human-in-the-Loop (HITL) is a method of demonstration that may be used to verify complex integrated crew requirements.

4.1.2.4 Test

Verification by Test includes the use of an end product to obtain detailed data needed to verify performance or provide sufficient information to verify performance through further analysis. Testing can be conducted on final end products, breadboards, brass boards, or prototypes. Testing produces data at discrete points for each specified requirement under controlled conditions and is the most resource-intensive verification technique. As the saying goes, “Test as you fly, and fly as you test.”

Test method is used when the analytical method does not produce adequate results; failure modes exist which could impact personnel safety, affect flight hardware or payloads, or result in loss of mission objectives. Analysis of data derived from tests is an integral part of performing a test and is not to be confused with the Analysis method identified in section 4.1.2.2.

4.2 VERIFICATION MATRIX

The following Table 4.2-1 Verification Matrix identifies all requirements outlined in this document and identifies guidance for verification methods.

EHP inspection of records for the submission of requirement compliance evidence is anticipated for every requirement, and not listed in the matrix.

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0001]	Translation Path Hardware Protrusion		X			X			If necessary, a facility demonstration could include NBL evaluation and performed to validate translation, work volume, worksites, etc.
[EVASC.0002]	Tool Interface Clearance	X				X	X		
[EVASC.0007]	Bolt Clearance	X					X		
[EVASC.0003]	Gloved-Hand Clearance		X			X	X		
[EVASC.0004]	Handrail/Handhold Mounting Clearance	X				X	X		
[EVASC.0005]	Handrail/Handhold Side Clearance	X				X	X		
[EVASC.0006]	APFR EVA Installation/Removal Clearance	X				X	X		
[EVASC.0152]	Contiguous EVA Translation Path		X			X			If necessary, a facility demonstration could include NBL evaluation and performed to validate translation, work volume, worksites, etc.
[EVASC.0008]	Translation Path		X			X			If necessary, a facility demonstration could include NBL evaluation and performed to validate translation, work volume, worksites, etc.
[EVASC.0154]	Incapacitated Crewmember Interfaces	X		X					Demonstration is critical and NASA teams to ensure that providers work together to produce a high-fidelity demonstration.
[EVASC.0010]	EVA Contact Hazards Preclusion Beyond Translation Corridor		X			X			

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0159]	Partial Gravity EVA Contact Hazards Preclusion		X			X			
[EVASC.0012]	Microgravity EVA Equipment Handling Features	X							
[EVASC.0160]	Partial Gravity EVA Handling Capability		X		X				
[EVASC.0162]	Partial Gravity Step Design Parameter	X							
[EVASC.0013]	Hatch Transfer Constraint	X		X	X				A facility demonstration could include NBL evaluation to provide acceptance rationale for exceptions for translation, work volume, worksites, etc.
[EVASC.0135]	Pressurized xEVA Suit Transfer through Airlock Hatch	X		X	X				A facility demonstration could include NBL evaluation to provide acceptance rationale for exceptions for translation, work volume, worksites, etc.
[EVASC.0153]	EVA Lunar Hatch Dimensions	X		X	X				If necessary, a facility demonstration could include NBL evaluation and performed to validate translation, work volume, worksites, etc.
[EVASC.0158]	EVA Procedure Display Method	X							
[EVASC.0014]	Mounting Alignment Devices	X							
[EVASC.0015]	Handling Alignment Marks	X							
[EVASC.0016]	Locking Device				X				
[EVASC.0124]	Over Center Device Force				X				
[EVASC.0017]	Soft Dock or Soft Capture Mechanisms	X							
[EVASC.0125]	Soft Capture	X							

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0126]	Soft Dock Force				X				
[EVASC.0023]	Hand Grip Surface/Boot Contact	X							
[EVASC.0024]	Unique Labeling	X							
[EVASC.0025]	Hand Tool Operations		X				X		
[EVASC.0135a]	Hand Ratcheting		X				X		
[EVASC.0026]	Throw Angle		X						
[EVASC.0127]	Ratchet Mechanism	X							
[EVASC.0128]	Back Drive Torque		X		X				
[EVASC.0129]	Running Torque		X		X				
[EVASC.0027]	Pressurized Glove Compatibility		X				X		EHP would expect a test or demo as part of the VCN (expect that hardware provider would submit an analysis supported by test or demonstration).
[EVASC.0087]	Inadvertent Actuation of EVA - Actuated Controls	X							
[EVASC.0029]	Handrail/Handhold Cross-Section	X							
[EVASC.0030]	Handrail/Handhold Length	X							
[EVASC.0031]	Handrail/Handhold Accessibility	X	X			X	X		Analyze via EHP Model analysis, with expectation that programs/vendors will provide the appropriate fidelity of CAD models to enable a good assessment of the requirement statement. Once this work is complete, team should assess whether it is necessary to raise a flag to Program Management that the programs aren't positioned to recover from a failed EVA Model Analysis team verification with a

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
									facility demonstration due to procurement plans and schedule misalignments.
[EVASC.0032]	Continuous Handrail/Handhold Spacing	X	X			X			Analyze via EHP Model analysis, with expectation that programs/vendors will provide the appropriate fidelity of CAD models to enable a good assessment of the requirement statement. Once this work is complete, team should assess whether it is necessary to raise a flag to Program Management that the programs aren't positioned to recover from a failed EVA Model Analysis team verification with a facility demonstration due to procurement plans and schedule misalignments.
[EVSC.0144]	EVA Egress Handrail Spacing	X				X			
[EVASC.0035]	Optimum Work Envelope		X			X			A facility demonstration could include NBL evaluation to provide acceptance rationale for exceptions for translation, work volume, worksites, etc.
[EVASC.0157]	EVA Egress/Ingress Methods		X	X		X			Demonstration is critical and NASA teams to ensure that providers work together to produce a high-fidelity demonstration.
[EVASC.0036]	Crew Aids for Stability	X	X			X			
[EVASC.0037]	EVA Worksites Using Robotic Work Platform		X			X			
[EVASC.0038]	Lubricant Use	X							

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0040]	Worksite Mobility		X			X			Suit model approach will need to account for newer EVAS designs or otherwise be very conservative.
[EVASC.0041]	Worksite Field of View		X			X			Suit model approach will need to account for newer EVAS designs or otherwise be very conservative.
[EVASC.0042]	Working Volume		X			X			Suit model approach will need to account for newer EVAS designs or otherwise be very conservative.
[EVASC.0148]	Dedicated EVA Worksite		X			X			Suit model approach will need to account for newer EVAS designs or otherwise be very conservative.
[EVASC.0149]	Robotic Assisted EVA Worksites		X			X			Suit model approach will need to account for newer EVAS designs or otherwise be very conservative.
[EVASC.0150]	Free-Float Worksites		X			X			Suit model approach will need to account for newer EVAS designs or otherwise be very conservative.
[EVASC.0045]	Installation of Passive WIF Sockets	X				X			
[EVASC.0046]	Foot Restraint Ingress/Egress Aids	X				X			
[EVASC.0047]	Visual Contrast at Worksite		X						
[EVASC.0033]	Color for EVA Handling and EVA Tether Points	X							
[EVASC.0048]	EVA Tether Point	X	X		X				
[EVASC.0134]	Soft Goods Tether Point Loads	X	X		X				

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0050]	Microgravity EVA Crew-Induced Loads		X						Analysis supported by test
[EVASC.0155]	Partial Gravity EVA Crew-Induced Loads		X						Analysis supported by test
[EVASC.0018]	EVA Actuated Loads		X		X				All lines within the Miscellaneous Crew-Induced Load Table under Crew System are Analysis and Test.
[EVASC.0164]	EVA Mechanical Feedback				X				
[EVASC.0143]	WIF Structural Loading		X						
[EVASC.0053]	One-Handed EVA Operable Connectors		X			X			
[EVASC.0054]	Connector Accessibility		X			X			
[EVASC.0138]	Gloved-Hand Connector Accessibility		X			X	X		
[EVASC.0055]	Incorrect Connector Mating Prevention	X	X						
[EVASC.0056]	Connector Coding	X							
[EVASC.0057]	Connector Protective Caps	X							
[EVASC.0058]	Connector Rotational Travel	X	X						
[EVASC.0059]	Connector Locking Feature		X						
[EVASC.0060]	Visible Connector Alignment Markings	X					X		
[EVASC.0061]	Connector Locking Ring	X	X						
[EVASC.0062]	Connector Mating Status		X						
[EVASC.0052]	Mating/Demating of Powered Connectors		X						
[EVASC.0065]	Connectors - Electrical Bonding		X						

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0066]	Scoop-Proof Electrical Connector Design		X						
[EVASC.0063]	Connector Grip Point		X			X			
[EVASC.0131]	Arc Containment	X	X						Analysis should include EEE expert to verify For the arc containment evaluation method, demonstration could also be considered since the operational conditions can be applied to demonstrate that there are no arc issues and or any arc produced will be contained.
[EVASC.0132]	Tethering	X			X				
[EVASC.0133]	Venting Feature	X			X				
[EVASC.0145]	Indication of Pressure Flow – Nonbrazed or Nonwelded		X						
[EVASC.0146]	Indication of Pressure Flow – Quick Disconnect		X						
[EVASC.0068]	Captive Fastener Design	X					X		
[EVASC.0069]	Prohibited Locking Methods for Fasteners	X							
[EVASC.0067]	One-Handed Fastener Operations		X			X			
[EVASC.0072]	Scalloped Knobs	X							
[EVASC.0073]	Knobs Head Diameter and Height	X							
[EVASC.0074]	EVA Hand-Actuated Fasteners Contingency Operation	X					X		
[EVASC.0075]	EVA PIP Pin Grasping Interface	X					X		
[EVASC.0076]	PIP Pin Restraint Tether	X							

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0078]	Driver-Type Push Force Tools				X				
[EVASC.0079]	EVA Fastener Head	X					X		
[EVASC.0084]	Fastener Drive Height	X							
[EVASC.0151]	Fastener Torque Data								Considered to be a data deliverable (consists of test and analysis)
[EVASC.0080]	Power and Hand Tool Operability	X							
[EVASC.0141]	Fastener Gauge/Measurement	X					X		
[EVASC.0083]	Fastener Alignment Features	X							
[EVASC.0085]	Battery Replacement	X	X		X	X			
[EVASC.0086]	Battery Voltage Monitoring	X			X				
[EVASC.0028]	Auxiliary Controls	X							
[EVASC.0088]	EVA Tools	X							
[EVASC.0163]	IVA Tools to Maintain EVA Equipment	X							
[EVASC.0089]	Cable Routing/Restraint	X							
[EVASC.0090]	Cable Routing Spacing	X							
[EVASC.0091]	Paint	X							
[EVASC.0092]	Hazardous Material Control		X						
[EVASC.0093]	Venting or Exposure Compatibility		X						
[EVASC.0094]	Deliberate Hazardous Venting		X						
[EVASC.0096]	Lasers		X						
[EVASC.0097]	Electrical and Safety Design		X						
[EVASC.0098]	Shock Protection		X						
[EVASC.0099]	Operation During Pressure Change		X						

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0100]	Component Hazardous Energy Provision		X						
[EVASC.0101]	Detachable Parts	X	X						
[EVASC.0103]	Touch Temperatures		X						
[EVASC.0011]	xEVA Suit Glove Palm External Touch-Temperature Compliance for Small, Handheld Hardware		X						
[EVASC.0104]	Incidental and Unlimited Contact Heat Transfer Rates		X						
[EVASC.0105]	Sharp Edge and Protrusions Protection	X						X	
[EVASC.0106]	Screws and Bolts	X						X	
[EVASC.0107]	Levers, Cranks, Hooks, and Controls	X	X					X	
[EVASC.0109]	Exposed Holes or Slots	X							
[EVASC.0110]	Pinch Hazard Protection	X	X						
[EVASC.0111]	Equipment Clearance for Entrapment Hazard	X	X						
[EVASC.0112]	Protection from Moving or Rotating Equipment	X	X						
[EVASC.0113]	Emergency Ingress Capability		X	X					Demonstration is critical and NASA teams to ensure that providers work together to produce a high-fidelity demonstration.
[EVASC.0140]	External Surface Cleanliness Level	X							
[EVASC.0115]	Tethering / Restraint	X							
[EVASC.0116]	Crew Safety Tether Attachment	X	X						
[EVASC.0161]	Crew Safety Restraint	X	X						

TABLE 4.2-1 VERIFICATION MATRIX

Requirement Number	Requirement Name	Hardware Provider Method				EHP Method			Notes
		I	A	D	T	EVA Model Analysis	VITTO Fitchecks	Sharp Edge Inspection	
[EVASC.0117]	Color For Crew Load-Rated Handhold/Handrails, Crew Safety Tethers And Safety Restraint Attachment Points	X							
[EVASC.0118]	Manual Overrides	X							
[EVASC.0137]	Entanglement, Cable Clamps, Ducts, or Retractors	X							
[EVASC.0121]	Magnetic Field Limit		X		X				
[EVASC.0123]	Voltage Potential Discharge		X						
[EVASC.0156]	Lunar Surface Dust Tolerance		X						

APPENDIX A ACRONYMS AND ABBREVIATIONS AND GLOSSARY OF TERMS

APPENDIX A-1 ACRONYMS AND ABBREVIATIONS

TABLE A1-1 ACRONYMS AND ABBREVIATIONS

AIT	Analysis Integration Team
APFR	Articulating Portable Foot Restraint
ARGOS	Active Response Gravity Offload System
AU	Astronomical Unit
AVT	Acceptance Vibration Test
AXES	ARGOS eXploration EVA Systems (AXES)
BIVP	Bilateral Integration and Verification Plan
BOL	Beginning of Life
BP	Best Practices
BRT	Body Restraint Tether
BTU	British Thermal Unit
C	Centigrade
CAD	Computer-Aided Design
CB	Control Board
CCW	Counterclockwise
CDR	Critical Design Review
CG	Center of Gravity
cm	centimeter
COTS	Commercial-Off-the Shelf
CP	Commercial Provider
CR	Change Request
CW	Clockwise
dia/diam	diameter
DRM	Design Reference Mission
ECLSS	Environmental Control/Life Support System
EEE	Electrical, Electronic, and Electromechanical
EHP	Extravehicular Activity and Human Surface Mobility Program
EMI	Electromagnetic Interference

TABLE A1-1 ACRONYMS AND ABBREVIATIONS

EMU	Extravehicular Mobility Unit
EOL	End of Life
EVA	Extravehicular Activity
EVR	Extravehicular Robotics
F	Fahrenheit
FOD	Flight Operations Directorate, Foreign Object Debris
FPU	Fluid Pumping Unit
FS	Factor of Safety
ft	feet
ft^3	cubic foot
g	gravity
GFE	Government Furnished Equipment
HDL	Human-class Delivery Lander
HFE	Hydrofluoroether
Hg	Mercury
HITL	Human-in-the-Loop
HLS	Human Landing System
HTV	Human Thermal Vacuum
Hz	Hertz
in	inch
in-oz	inch-ounce
IP	International Partner
IRCD	Interface Requirements and Control Document
ISS	International Space Station
IVA	Intravehicular Activity
J	Joule
JAM	Joint Agreement Memorandum
JANTX	Joint Army-Navy Technical Exchange
JSC	Johnson Space Center
JTAM	Joint Technical Agreement Memo

TABLE A1-1 ACRONYMS AND ABBREVIATIONS

K	Kelvin
kg	kilogram
kPa	Kilo Pascal
lb	pound
lbf	pound force
lbf-in	pound force inch
lbm	pound mass
LEO	Low Earth Orbit
LOS	Loss of Signal
m	meter
MDRD	Mockup Development Requirements Document
MEK	Methyl Ethyl Ketone
MHz	Mega Hertz
MLI	Multi-Layer Insulation
mm	millimeter
MMOD	Micrometeoroid Orbital Debris
MPCV	Multi-Purpose Crew Vehicle
N	Newton
NASA	National Aeronautics and Space Administration
NBL	Neutral Buoyancy Laboratory
NDS	NASA Docking System
NIOSH	National Institute for Occupational Safety and Health
Nm	Newton meter
NZGL	NASA Zero Gravity Lever
OCAD	Operational Control Agreement Database
OPR	Office of Primary Responsibility
ORU	Orbital Replacement Unit
PDA	Pre-Delivery Acceptance
PGT	Pistol Grip Tool
PIA	Pre-Installation Acceptance

TABLE A1-1 ACRONYMS AND ABBREVIATIONS

PIO2	Inspired Partial Pressure of Oxygen
PIP	Push-in-Pull
PLSS	Portable Life Support Subsystem
PP&C	Program Planning & Control
psi	Pounds per square inch
QD	Quick Disconnect
REEA	Retracting End Effector Assembly
RF	Radio Frequency
RIVA	Requirements, Interfaces, Verification, Analysis
RMS	Remote Manipulator System
RTV	Room Temperature Vulcanizing (silicone rubber)
sec	second
SE&I	Systems Engineering & Integration
SEMP	Systems Engineering Management Plan
SI	International Systems of Units
SPEC	Specification
SSP	Space Station Program
TA	Technical Authority
TBD	To Be Determined
TBR	To Be Resolved
TMG	Thermal Micrometeoroid Garment
US	United States
V	Volts
VC	Visibly Clean
VCN	Verification Closure Notice
VC-S	Visibly Clean – Sensitive
VITO	Vehicle Integrated Test Office
W	Watt
WIF	Worksite Interface
xEMU	Exploration EMU

TABLE A1-1 ACRONYMS AND ABBREVIATIONS

xEVA	Exploration EVA

APPENDIX A-2 GLOSSARY OF TERMS

TABLE A2-1 GLOSSARY OF TERMS

Term	Description
Contingency EVA	An EVA performed to deal with critical failures or circumstances, which are not adequately protected by redundancy or other means. An EVA not scheduled in the pre-mission timeline required to affect the safety of the crew, outpost, and/or safe return of the vehicle.
Contractor Mission Systems	Mission Systems provided by the contractor.
Crew	Human onboard the spacecraft or space system during a mission.
Demate	The act of isolating umbilical services by physical disconnection and removal of one compatible umbilical connector from another.
Design Reference Mission (DRM)	Typical mission scenario encompassing tasks that are most likely to drive the architecture system design requirements. The DRMs are analyzed for all mission aspects from failure tolerance to hardware layout, software functionality and design suitability.
EVA crewmember	An astronaut wearing an EVA space suit.
Flight	This is the sequence of events that takes place between liftoff and landing of a transportation vehicle.
Flight-like	Non-flight component built, inspected, and tested to flight component specifications, used in flight operating conditions and built with manufacturing processes that are identical to those used for flight equipment.
Human-Class Cargo	Class A or B payload (as defined in NPR 8705.4A, *Risk Classification for NASA Payloads*) that requires crew interaction on the lunar surface. Examples include, but are not limited to, a lunar pressurized rover and lunar surface habitat.
Human-Class Delivery Lander	A single HDL Element or collection of HDL Elements that, when integrated: (1) provide transportation for Human-class Cargo from the Earth to the lunar surface; but (2) do not provide transportation to crew.
Human-Class Delivery Lander Element	A spacecraft capable of operating independently of other spacecraft and that is also either: (1) used to transport Human-class Cargo to the lunar surface during uncrewed missions; or (2) connected to other spacecraft at any time when those spacecrafts are used to transport Human-class Cargo to the lunar surface during uncrewed missions.
Human Landing System (HLS)	All Integrated Lander Elements, Docking Adapter (if proposed), HDL Elements, Contractor Mission Systems, Supporting Spacecraft, and launch vehicles that are designed, developed, and/or utilized by the contractor, its

TABLE A2-1 GLOSSARY OF TERMS

Term	Description
	teammates, subcontractors, and/or suppliers in the performance of this contract.
Integrated Lander	Any combination of Integrated Lander Elements including, potentially, a single Integrated Lander Element that is used for crew transportation, and is integrated at any time crew are onboard. Any docking adapter utilized by the contractor during the performance of this contract is considered a part of the Integrated Lander.
Integrated Lander Element	A spacecraft capable of operating independently of other spacecraft and that is also either: (1) used to transport crew during the performance of crewed missions; or (2) connected at any time to other spacecraft while the other spacecraft is transporting crew during the performance of this contract. Examples of an Integrated Lander Element may include, but are not limited to, Ascent, Descent, or Transfer elements.
Mate	The process of physically joining one compatible umbilical connector to another such that the connectors will, thereafter, remain joined without continued crew effort. This includes the opening of any isolation devices and joining of electrical and data pins and sockets necessary to provide full umbilical services.
Microgravity	An environment where gravity has little or no measurable effect, commonly referred to as "weightlessness" or "zero-g”.
Mission Systems	The end-to-end terrestrial-based hardware and software infrastructure, whether owned or operated by NASA or the contractor, supporting mission operations from the point of Radio Frequency (RF) receipt/transmit at RF communications ground sites, through associated data processing and distribution infrastructure, transport networks, mission control center systems and facilities, interfaces between operations facilities, to the end user display/control systems and support infrastructure. Mission Systems include all associated hardware and software infrastructure supporting crew and flight controller training for operations, including but not limited to simulations, networks, mockups, and interfaces to support infrastructure.
NASA Mission Systems	Mission Systems provided by NASA.
Orbital-Replacement Unit (ORU)	An item that can be removed and replaced as a unit of the organizational on-orbit level of maintenance.
Over the Center Device	An over center mechanism is a bistable mechanical system that has two stable equilibrium (i.e., resting) states. Work must be performed on the system to move the mechanism from one stable position to just past the “peak” system instability, at which point the mechanism goes "over center" to its secondary stable position.

TABLE A2-1 GLOSSARY OF TERMS

Term	Description
	[Examples are an electric wall switch, EVA Bayonet Receptacle slide lock (SEG33106697), or the door latch on the EVA Tool Stowage Device (ETSD) (SEG33106600).]
Pressurized	The suit is considered pressurized at any point that it is sealed and a pressure delta over the ambient is incurred. When pressurized, the softgoods portion of the pressure bladder will inflate, impacting the stiffness of the suit, thereby, impacting the suited crewmember dimensions and mobility. The stiffening may cause the natural position of extremities to shift, thereby, impacting the neutral stance of the crewmember and the field of view.
Reach Envelope	This is defined and illustrated as the range of reach that the EVA Crew can reasonably access from a given position (e.g., such as a Foot Restraint in microgravity, or standing in one place in Partial Gravity). Intended to allow Vehicle or Payload designers to place EVA operable interfaces within reach at defined EVA Worksites.
Requirement	A necessary, quantifiable, and verifiable capability, function, property, characteristic, or behavior that a product must exhibit to solve a real-world problem, or a constraint that it must satisfy or be satisfied.
Safe Haven	A specifically designated area, location or facility that protects crew or ground team from unplanned hazardous or dangerous events. A safe haven provides essential life support functions to keep personnel alive and healthy until the dangerous condition has been mitigated or rescue is performed.
Spacecraft	A spacecraft is considered to be any host vehicles such as habitats, rovers, Landers, as well as orbiting and transit vehicles.
Supporting Spacecraft	A spacecraft capable of operating independently of other spacecraft that is required for the contractor to execute its responsibilities pursuant to the terms of this contract, but that is not an Integrated Lander Element, an HDL Element, nor a launch vehicle. Supporting Spacecraft functions could include, but are not limited to, propellant transfer, propellant storage, or orbital maneuvering and transfer.
Unpressurized	The suit is considered unpressurized at any point that it is not sealed, e.g., visors up. Some minimal pressure may build up in the umbilical and certain areas of the suit due to active inlet breathing gas flow; this has typically been up to approximately 2kPa-d (0.3 psid). However, the suit is not inflated at this pressure. Since this pressure is not associated with sealed suit loop performance, leakage and

TABLE A2-1 GLOSSARY OF TERMS

Term	Description
	pressure drop requirements do not apply to this pressure mode.
Vehicle	Often synonymous with the term spacecraft.
Working Volume	This is defined and illustrated as the region around an EVA crewmember, as warranted by Vehicle or Payloads (dedicated or contingency) EVA Worksites locations. The working volume is intended to be free of obstacles or hazards which may preclude the crew's movement, sight, or access at the worksite to complete the designated worksite task(s).
Worksite – Microgravity	Microgravity EVA Worksites are locations which have been intentionally designed to be compatible with EVA Crew. EVA Worksites come in various forms, including Dedicated EVA Worksites which provide the capability to position the EVA Crew for performing a specified task. A Robotic-Assisted EVA Worksite provides the capability for robotically positioned EVA Crew to conduct tasks. A Free−Float EVA Worksite provides the capability for an unrestrained crewmember to perform specified tasks (such as single-hand operations). EVA, particularly when facilitated by mobility elements such as robotics, can access many areas of a spacecraft which were not formally designed to be EVA Worksites. Although conceptually possible, that should not be used as an automatic reason to apply EVA Worksite Outfitting requirements to the entire vehicle exterior.
Worksite – Partial Gravity	Location at vehicle or payload interface where a suited EVA Crewmember is required to perform a physical task or operation, whether planned or for Pre-defined Contingencies. This may include, but not limited to, tasks such as external vehicle reconfiguration, maintenance/repair/replacement, stowage of Scientific Samples, and deployment/re-stowage of external Payloads.

APPENDIX B EVA BEST PRACTICES

This appendix is a culmination of lessons learned/best practices for performing EVAs.

EVABP-1 Multiple fasteners should be used in cases where single fastener usage would result in excessive torque specification for a single 11 mm fastener head. Currently, only one size of EVA driver is planned for numerous reasons (availability, commonality, EVA overhead, etc.). If required by hardware design, alternate EVA fasteners must be worked with EHP, since this will drive the need for additional sizes of EVA drivers.

EVABP-2 JSC EVA community has found that PIP pins can be particularly problematic since most are Commercial off the Shelf (COTS). The following acceptance cleaning/testing have been implemented at JSC and has resulted in successful screening and use of COTS PIP pins on orbit without failure.

1. Cleaning Provisions
   Flight PIP pins should be cleaned to the following procedure to remove any commercial lubricants and/or contamination that may prevent the PIP pin from operating properly:
   a) Soak in a Hydrofluoroether (HFE) 7100, Methyl Ethyl Ketone (MEK), or other approved solvent bath for 45 minutes
   b) Sonic soak in a HFE 7100, MEK, or other approved solvent bath for 120 minutes
   c) Internal flush for 60 minutes
   d) Dry and verify exterior cleanliness to Visibly Clean (VC)
   e) Section one sample PIP pin from the lot and inspect removed components for grease residue or contamination.

   Rationale: Various types of grease are used on COTS PIP pins. Destructive evaluation of one item from lot post-cleaning is necessary to verify the solvent removes the COTS lubricant.

2. Vibration Testing
   Flight PIP pins should be subjected to an Acceptance Vibration Test (AVT) per Table B-1 PIP Pin Acceptance Vibration Test Levels. The AVT should be performed in both the longitudinal and transverse axes.

TABLE B-1 PIP PIN ACCEPTANCE VIBRATION TEST LEVELS

Load Factor	Frequency Range	Amplitude
	20 - 80 Hz	+3.0 dB/Octave
6.1 Grms	80 - 350 Hz	0.040 g^2/Hz
	350 - 2000 Hz	-3.0 dB/Octave

Test Duration - one minute per axis

3. Thermal Testing
   Flight PIP pins should be actuated at -73º C (-100° F).
4. Destructive evaluations
   Destructive evaluation must be performed on representative samples from the flight lot to verify workmanship.
5. Proven Design
   A design that has proven to perform well is the AviBank Part #56789.
   PIP pins assembled by welding are not recommended as repeated thermal cycles may lead to propagation of weld flaws.

EVABP-3 Double Acting PIP Pin

Equipment should provide double acting PIP pins with ease of actuation of the mechanism both during insertion and removal.

Rationale: This assumes that the actuation shaft is pushed in with the insertion of the PIP pin and pulled out with the removal of the PIP pin.

EVABP-3a PIP Pin Drive-Out Feature

Equipment should be designed to provide access for a drive-out feature.

Rationale: All PIP Pins are subject to jamming. Having a drive-out feature helps limit risk associated with this known failure mode common to all PIP Pins.

EVABP-4 External hardware should always be assessed for EVA contact hazards since planned locations can change and worksites can be created in unexpected places.

EVABP-5 Hardware should be designed to be removed/replaced via EVA in a contingency situation.

EVABP-6 Contact the EHP at NASA JSC early in the hardware development to facilitate design for EVA access and use with minimal cost and schedule impacts. Consider adding an EVA approval signature on all hardware drawings with EVA interfaces.

EVABP-7 Many EVA tools are developed for unique purposes that should not be used for generic purposes. Do not design hardware to use these unique tools without specific needs and discussions with the EHP at NASA JSC. Example: fasteners should use standard bolt heads (reference [EVASC.0088] and [EVASC.0163]).

EVABP-8 Design hardware to accept torque values with as wide a tolerance as possible. Thermal extremes can adversely affect the ability of a tool to provide a specific torque.

EVABP-9 Using established hardware, including COTS hardware, might be more cost effective than designing new hardware if the established hardware meets the requirements and interfaces. However, COTS hardware may have limitations that are not readily apparent, that make them inappropriate for the harsh environment. Several

COTS tools flown have encountered problems, so make the decision with care and as much information as possible. Do not let cost alone decide as there is nothing cost effective in a tool that does not work. Among the problems encountered before:

a) Commercial hardware fabricated from tool steel may be subject to brittle fracture below -29 to -46°C -20 to -50° F). Cold case material properties must be evaluated for all off the shelf equipment.
b) Most commercial lubricants fail at “cold” temperatures that are actually somewhat benign compared to many spaceflight extremes, leading to the surprise that an otherwise acceptable COTS solution must be reworked to utilize a significantly different lubrication approach. Even small amounts of residue lubricant can cause mechanism failure. In order to assure hardware operation at cold case temperature extremes, remove all grease and replace with baked-on dry film coatings. Excess dry film must be removed in order to prevent buildup that can cause contamination and mechanical interference.
c) COTS equipment often exhibits wide variation in end item dimensions and material properties. Fit checks, measurements and lot testing of materials should be implemented to assure that hardware will meet use requirements. Fit checks at ambient environment will not demonstrate on-orbit “thermal fit”. Gauges need to take into consideration thermal fit.
d) Vendors have changed hardware but not part numbers and did not notify the customer. Crucial product lines (for spares/replacements) may become unavailable. For inexpensive, long shelf-life COTS items, a surplus should be purchased to ensure sufficient spares.

EVABP-10 Multi-Layer Insulation (MLI)/Softgoods Good Practices [Design for thermal blankets]

a) Tether loops should be plentiful, concentrated near the mating seams. Use of contrasting color/stitching can improve effectivity and visibility.
b) MLI seams to be mated EVA should have alignment marks both horizontally and vertically (forming a T at the edge) of a contrasting color to aid in EVA installation.
c) Velcro should have either a metal backing or a glove pocket behind the strips to aid in proper mating of hook and pile.
d) Restraint straps should be provided to hold MLI out of the way once opened. Straps should be long enough to reach a handrail or provide a self-restraint method. Velcro should also be used on the strap for stowage. All tether straps should include a tether loop.
e) Velcro that may be exposed for a length of time should be covered with a flap to prevent degrading. Flaps should also be added to MLI for EVA interfaces to allow access without removing entire MLI cover wherever feasible. MLI covers/blankets with multiple flaps should be numbered/labeled sequentially to aid in proper identification during EVA operations.
f) All MLI should be designed to be EVA removable (contingency) with ¼ turn fasteners preferred (no tool required).

g) Stiffeners should be provided on large blankets (more than 1.5 m^2 (16 ft^2) to help in EVA handling).
h) No staples should be left on exposed MLI for sharp edge considerations.

EVABP-11 Connectors exposed to sunlight should be provided with some means of thermal protection to preclude exceeding touch temperature requirements.

EVABP-12 A full complement of EVA testing should be performed on EVA concepts (glove box, 1-g, zero-g aircraft, Human Thermal Vacuum (HTV)) as necessary. Testing environment depends on the complexity of the EVA concept. Testing that involves EVA mockups should be of the appropriate fidelity to perform thorough testing (e.g., functional, volumetric, etc.). If testing at JSC, requirements for mock-up hardware and training simulators should be coordinated with the EHP at NASA JSC. A Mockup Development Requirements Document (MDRD) should be developed in conjunction with EVA Mission Operations Directorate personnel. Instructions for preparing an MDRD are found in JSC 28528, *Preparation and Revision of CX Mockup Development Requirements Document*. EVA testing is always preferable to analysis and takes precedence over analytical results.

EVABP-13 Wherever possible, perform verification of flight hardware by test. If another method is used, documented rationale should substantiate why testing cannot be accomplished.

EVABP-14 Mechanism/robotics commanding and movement should be limited and, if possible, eliminated during EVA to prevent placing the EVA crew at risk.

EVABP-15 Battery power indication should only be active when the battery is integrated into the power device, e.g., by being incorporated as part of a power device.

EVABP-16 Do not cover or interfere with handrails/handholds, tether points, or foot restraint receptacles with MLI or other objects.

EVABP-17 EEE Parts Sources

1. Approved parts are listed in the following locations except for Kapton wire (MIL-DTL-81381, *Wire, Electric, Polyimide-Insulated, Copper, or Copper Alloy, Detail Specification*), which requires written program approval before use.
2. SSP 30423, *Space Station Approved Electrical, Electronic and Electromechanical (EEE) Part List*
3. EVA-EXP-0034, *Extravehicular Activity (EVA) Office Exploration EVA System Technical Standards*
4. SLS-SPEC-159, *Cross-Program Design Specification for Natural Environments (DSNE* – EEE Parts used on the lunar surface may not function properly in the higher ionization radiation environment if designed for use only in the station environment.

5. Semiconductors should be Joint Army-Navy Technical Exchange (JANTX) in accordance with MIL-PRF-19500, *Semiconductor Devices, General Specification*.
6. Evaluate any part not selected by any of the above per the *Engineering Directorate Certified Electrical, Electronic and Electromechanical (EEE) Parts Approval Process*, detailed in JSC-61360, and have it approved by its controlling authority.

EVABP-18 Wire ties should be used only when the use has been analyzed effectively and the wire ties have been shown to safely perform the function proposed. Wire ties are not certified to be used more than once or as launch restraints. Refer questions or concerns with the EVA use of wire ties to the EHP.

EVABP-19 Bolt torques should be limited to less than 34 Nm (25 ft-lbs) for the ratchet wrench and 20.3 Nm (15 ft-lbs) for the power tool, which provides for one-handed operation. For overall EVA efficiency, the HLS should design all bolted interfaces such that the maximum torque required is no more than 20.3 Nm (15 ft-lbs).

EVABP-20 Techniques for lightening material should not include through holes that can act as an entrapment hazard. A back plate or pocket holes can be used to lighten the material without creating an entrapment hazard.

EVABP-21 Hardware should be designed with as much versatility and resiliency as possible to protect for future or unforeseen activities.

EVABP-22 Rolled Threads and Head Height

1. Use of rolled threads for EVA fasteners - Rolled threads are stronger and less likely to yield, gall, or seize. Utilizing a double height head fastener can often lead to machining of fasteners (more expensive than using high quality aerospace grade fasteners with tight tolerances). The rolled fastener heads need to be confirmed with/concurred with ES/JSC Structural Engineering Division.
2. Head Height - EVA fasteners are based on “double height” bolt heads – it is how good engagement is obtained to deliver high torque to fasteners. Even if COTS bolts are used, the heads should still be “double height” to ensure adequate transfer of load between the socket and the fastener bolt head.

EVABP-23 Some crew-applied dynamically loads (oscillatory in nature) may need some restrictions on their frequency of cyclic application and durations in order to avoid or limit structural dynamic amplification and to lower the likelihood of an overload. Vulnerable structures or mechanisms are those that may possess low-frequency natural modes of vibrations (approximately 2 hertz and lower). Examples are mechanisms and cantilevered masses, whether in temporary or permanent configurations.

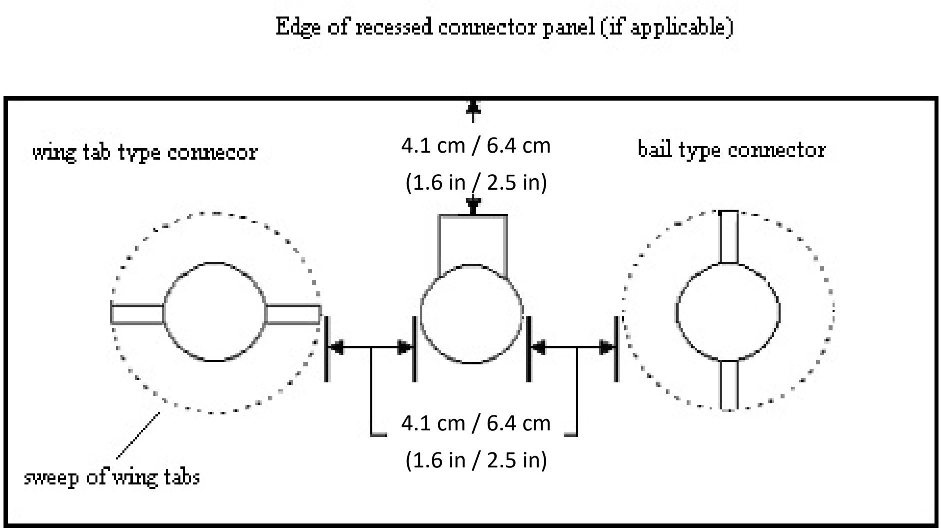
EVABP-24 Design hardware to be assessed for EVA contact hazards.

EVABP-25 Programs should seek to obtain commonly implemented interfaces as Government Furnished Equipment (GFE). Use of GFE for common interfaces is beneficial in that it provides consistency across the vehicle. The NASA EHP has standard items available as GFE; these include handrails, tether hooks and other piece parts, foot restraint interfaces, quarter turn fasteners, and brackets.

EVABP-26 Threaded fasteners that perform a safety-critical function should comply with NASA-STD-5020, *Requirements for Threaded Fastening Systems in Spaceflight Hardware*. This does not apply to fasteners that are considered to be any of the following: not safety critical, are internal to components, or shown to be contained.

EVABP-27 Connector spacing for small to medium bail and wingtab type connectors should be designed to approach the minimum spacing requirements shown in Figure EVABP-27 Connector Spacing.

Rationale: When utilizing the spacing outlined in Figure EVABP-27 Connector Spacing, it may result in greater/or less than the gloved-hand access requirement [EVASC.0003] in certain directions. If there is not sufficient real estate to meet the gloved-hand requirement [EVASC.0003], Figure EVABP-27 Connector Spacing illustrates what was successful on past Programs and can be considered with the appropriate paperwork and EVA evaluations.



*Spacing requirement increases 6.4 cm (2.5 in) for multiple rows of connectors

These are minimum dimensions and should be used only where packaging issues exist

FIGURE EVABP-27 CONNECTOR SPACING

EVABP-28 Connector Ultimate Load

Connector backshells should withstand ultimate load as defined in JSC 65828, *Structural Design Requirements and Factors of Safety for Spaceflight Hardware*.

> *Rationale: Strain relief helps to prevent breakage due to induced loading. Connector backshells designed to provide strain relief, must still preclude sharp edges, pinch points and other hazards as defined in section 3.9.*

EVABP- 29 EVA Secondary Ingress Method – Microgravity

The HLS should provide a secondary ingress method or equivalent for EVA contingency ingress.

> *Rationale: Heritage airlock operations have shown the need to allow for a secondary ingress in the event of a failure of the primary method, thereby taking the burden off of a module to be designed to go to vacuum in case of a contingency. Secondary ingress/egress does not necessarily mean separate hatches on the same volume. It could, for example, be met by two separate volumes linearly aligned, allowing the inner volume to act as the redundant ingress/egress method if the outer volume were to fail. See EVA-EXP-0031, EVA Airlocks and Alternative Ingress/Egress Methods for reference.*

APPENDIX C NON-EVA BEST PRACTICES FOR CONSIDERATIONS

This appendix contains those best practices that are considered to be non-EVA, but worthy of consideration when designing EVA interface.

Fasteners - Orientation/Retention

FAS-1 The HLS should orient and/or retain PIP pins so failure of the mechanism during launch or landing precludes release.

Protruding Fasteners

PFAS-1 The HLS should provide sharp edge protection for protruding fastener threads.

Rationale: If structurally sound, acorn nuts can provide this sort of protection. Room Temperature Vulcanizing (RTV) does not always stay on exposed threads over a long duration.

Handling – Standard Interface Temperature Differential

HAN-1 The HLS should use a standard hardware interface temperature differential per Table C-1 Standard Interface Temperature Differential, when designing all EVA hardware to ensure fit and function of interfacing hardware. Use an interface temperature differential of 38ºC (100°F) when using material surface coatings with a low EOL optical property ratio (0.9 maximum). Use an interface temperature differential of 93°C (200°F) as a design goal for any interface hardware with a high EOL surface coating (greater than 0.9). A reduced temperature differential, determined by analysis, may be used if required for fit/function, and should be documented in the Safety Data Package.

TABLE C-1 STANDARD INTERFACE TEMPERATURE DIFFERENTIAL

EOL Surface Optical Property Ratio	Standard Interface Temperature Differential
≤ 0.9	38° C (100° F)
> 0.9	93° C (200° F)

Materials and Process Best Practice

MP-1 All currently available soft goods, including Velcro, Kevlar, Vectran, nylon, fiberglass and Nomex are affected by prolonged exposure to the EVA environment. The combined effects of atomic oxygen, ultraviolet light, ionizing radiation, and abrasion during use can reduce the load capability of soft goods. Soft goods should not be used in load bearing applications that are exposed to the EVA environment without high safety factors, backup load paths and/or protection from atomic oxygen, ionizing radiation, and ultraviolet effects.

Non-EVA Best Practices

NEBP-1 Real-time access to high fidelity, flight-like hardware is very beneficial for procedure development and troubleshooting in contingency cases.

NEBP-2 Avoid the use of welded hardware. Repeated thermal cycles may lead to propagation of weld flaws.

Note: this refers to ground welding; on-orbit welding is not available.

NEBP-3 Some locking compounds are difficult to apply without contamination of adjacent surfaces and mechanisms. Results of the contamination may not be apparent until the hardware reaches cold case temperatures.

NEBP-4 Jam nuts can be used on non-EVA operable fasteners; however, neither jam nuts nor anaerobic locking compounds alone provide positive locking and must be used in concert with safety wire and tab washers. The preferred method of locking is preload combined with other conventional aerospace locking features. Self-locking features that retain full running torque after preload is relieved or the threads move can also provide positive locking.

NEBP-5 Some fasteners are difficult (spiral cam fasteners) to remove and need to be demonstrated to work with EVA gloved operations. These types of fasteners can be "splayed" if improperly operated during shield installation (ex. MMOD shields on ISS) and are not recommended for EVA operations. Fasteners that require operations by EVA crewmembers should meet the requirements outlined in section 3.7. If a fastener is splayed during installation, it will not release again nominally, and will not re-engage later. Contingent reapplication should evaluate the minimum number of required fasteners. This is a lesson learned from ISS, which replaced the spiral cam fastener for EVA use.

NEBP-6 A lesson learned from past projects on IVA fluid connections is that if they do not have enough flex in the lines to stay a shut-off valve when connected, they can sustain a hydraulic shock and it can cause problems. The hydraulic shock is a pressure surge that is caused when a fluid experiences a momentum change (also referred to as a water hammer). There was a related experience with an ISS Fluid Pumping Unit (FPU) fluid connector - reference the PRACA document at:

https://part.iss.nasa.gov/record/24868?list_id=281286&list_index=364.

APPENDIX D RESERVED

APPENDIX E RESERVED

APPENDIX F OPEN WORK

APPENDIX F-1 TO BE DETERMINED

Table F1-1 To Be Determined Items lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is numbered based on the document number (i.e., **<TBD-xxxx-xxx-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBDs will not be renumbered.

TABLE F1-1 TO BE DETERMINED ITEMS

TBD	Requirement	Description	ECD
<TBD-HLS-EVA-008>	3.3.2 [EVASC.0013]	Define figure for two crew in both partial and microgravity configurations.	06/30/23
<TBD-HLS-EVA-013>	3.4.2.2 [EVASC.0042]	Define the Partial Gravity Working Volume	06/30/23
<TBD-HLS-EVA-014>	3.10.2 [EVASC.0123]	Define the magnitude of voltage potential or current transfer.	06/30/23
<TBD-HLS-EVA-015>	3.5.3 [EVASC.0155] 3.9.24 [EVASC.0161]	Define Load case 12 category and Maximum Magnitude and include in the table	06/30/23
<TBD-HLS-EVA-016>	3.8.2 [EVASC.0088] 3.8.3 [EVASC.0163]	New EHP tool list for EVA and IVA tools to be established to take the place of the tool list formerly in Appendix D. New tool list to be CM at the EHP level. Approval process for list updates to be worked via the RIVA/xEVA AIT. Changes to the new tool list to include: • Remove obsolete/OBE/old tools • Assess for new tools needed for new 11mm bolt head change • Assess for new tools needed to accommodate new partial gravity requirements • Updates to surface science tools based on Artemis Tools PTR	06/30/23

APPENDIX F-2 TO BE RESOLVED

Table F2-1 To Be Resolved Items lists the specific To Be Resolved (TBR) items in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within angle brackets. The TBR issue is numbered based on the document number, including the annex, volume, and book number, as applicable (i.e., **<TBR-XXXXX-001>** is the first unresolved item assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBRs will not be renumbered.

TABLE F2-1 TO BE RESOLVED ITEMS

TBR	Requirement	Description	ECD
<TBR-HLS-EVA-001>	3.7.1.5.4 [EVASC.0151]	The complete complement of Exploration tools has not been formally agreed to and the table is a template for Exploration missions (addresses CR-DSG-C0050 Comment 160). Need to work with HLS and Gateway to determine the required set of Exploration tools with regards to fastener torque data deliverable - need to ensure that ES reviews and compares to SSCN 1819 tables for accuracy. Step 1: This will need to be worked with xEVA Tools, FOD, and Gateway. Need to reach an agreement on what will be provided along with associated need date. Step 2: Once Step 1 is completed, can then provide a more accurate ECD for resolution and determination on how to document the resolution.	12/15/23
<TBR-HLS-EVA-002>	3.5.3 [EVASC.0155]	Loads provided by ES is conservative, over the course of FY23 will be matured with testing and any updates to remove conservatism will be identified for Rev E. Memos will be made available to better define and derive the human interaction associated with the loads. Determine if incapacitated crew that includes addressing load cases/conditions will be included in the final table.	09/30/23
<TBR-HLS-EVA-003>	3.3.2 [EVASC.0160]	Table values will require additions pressurized testing – confirmation of actual pressurized suited lifts and load carrying	06/30/23

TABLE F2-1 TO BE RESOLVED ITEMS

TBR	Requirement	Description	ECD
		capability in lunar simulation activities in the NBL across multiple subject capabilities. Volume limits for surface carry will include testing at the ARGOS facility with empty box, low mass. Quantify Table note 7 - alternative is to apply a conservative scaling factor that will be arbitrary since will not have data on more extreme surface translation. Future Analysis (by midyear CY23) for carry/lift of mass • Assess modification of gravity factor in NIOSH equation • 3D Static Strength Prediction Program assessment of low back compression in partial gravity • Modeling: How much can you lift in 1/6 g given ground reaction force? • Develop suited NIOSH equation to inform updates to the lift table • Metabolic rate data for a long duration mass carry (to scope capability) • Dependent on availability of pressurized suit testing Future Analysis (by mid-year CY23) for carry/lift of mass • CAD model representing volume that can be carried, suit keep out zones Dependent on availability of pressurized testing	
<TBR-HLS-EVA-004>	3.3.3 [EVASC.0162]	Need to perform pressurized testing with large and small objects completing step ups and step overs. Future analysis by mid-year CY23: • Analysis of size of existing subjects that have been tested, gaps Dependent on availability of pressurized suited testing	06/30/23

TABLE F2-1 TO BE RESOLVED ITEMS

TBR	Requirement	Description	ECD
<TBR-HLS-EVA-005>	3.3.14.6.1 [EVASC.0035]	Need to perform pressurized testing with NBL suited reach envelope (partial gravity reach analog) Future analysis by mid-year CY23: • Compare reach envelope across gravity conditions using existing data • Incorporate partial gravity in pressurized suited reach model Dependent on availability of pressurized suit testing Ensure that FOD is included in maturation of this requirement.	06/30/23
<TBR-HLS-EVA-006>	3.1.1 [EVASC.0001]	Further analysis and pressurized testing in the NBL (performed in conjunction with TBR on reach envelope to help determine the protrusion envelopes)	06/30/23
<TBR-HLS-EVA-007>	3.2.4 [EVASC.0159]	Further analysis and pressurized testing in the NBL (performed in conjunction with TBR on reach envelope to help determine the hazard contact envelopes)	06/30/23

APPENDIX F-3 FORWARD WORK

TABLE F3-1 FORWARD WORK

Item #	Forward Work (Topic)	Section/Rqt	Description
FW-0070-003	Address HLS-CR-C0125 Comment #11 and HLS-CR-C0211 Comment # 110, 111	3.4.8 [EVASC.0047]	Intent of this requirement was attempting to address contrast and may need to be more specific with regards to radiance/luminance and applicable surface reflectance for the verification/validation process of objects to be evaluated for visual contrast. This would include providing a reference relative spectral intensity curve for the solar spectrum that includes UV-VIS-IR bands. Work with HLS to ensure that external lighting for performing EVAs is captured as a requirement. Coordinate this forward work with the xEVA AIT, HLS/CHPO for resolution.

TABLE F3-1 FORWARD WORK

Item #	Forward Work (Topic)	Section/Rqt	Description
	Address EHP-C0051 Comment #34		Tracking through Action # 20220419-EVA-xEVAS-AIT-00001. Clarify requirement and work to resolve forward work for incorporation into Revision E
FW-0070-004	Address HLS-CR-C0264 Comment #27 Address comments regarding incapacitated crew associated loads	[EVASC.0029] [EVASC.0154]	C0264 Comment #27 Potential update to the requirement to clarify that the exterior dimensions for references to other hardware (includes, but not limited, to items such as BRT end effectors). Determine Scenario for rescue procedures and handling/maneuvering/manipulation of an incapacitated crew that includes addressing load cases/conditions (determine if loads cases/conditions will be addresses as part of closure for TBR-HLS-EVA-002).
FW-0070-005	Address EHP-C0051 Comment 247	[EVASC.0036]	Clarify dimensions in Figure to include the 0.58 m (23 in). An xEVA AIT action will be issued to track and provide updates in this document as well as for ISS (source EVA document). Action number: 20230120-EVA-xEVA AIT-0001.
FW-0070-006	Address EHP-C0051 Comment 5, 6, 89-92, 147, 153, 287	[EVASC.0117] [EVASC.0033]	Determine viable paths to colored identification of load bearing items: - EHP to engage with M&P to identify viable paint solutions (including cost and schedule for testing as required). - Assess viability of covers/shrouds within xEVA AIT community, including FOD, safety and crew. - Work Cross-Program on issue resolution.
FW-0070-007	Address HLS-CR-C0264 Comment #2 Address EHP-C0051 Comments 70-74	[EVASC.0104] [EVASC.0103] [EVASC.0011] [EVASC.0104] [EVASC.0103] [EVASC.0011]	C0264 Comment #2 Assess updates to xEVAS Glove and PGS Thermal Models needed for EVA Touch Temperature Requirement (reference 20220623-EVA-xEVA AIT-0001). C0551 Comments 70-74 acknowledges that there is forward work to ensure that the provided thermal values derived from the current ISS EMU are updated (ties to C0264 comment #2). In addition, a new suit will most likely have new touch temperature limits that

TABLE F3-1 FORWARD WORK

Item #	Forward Work (Topic)	Section/Rqt	Description
			need to be included in the thermal requirements. Target to resolve this forward work to be included in Revision E.

APPENDIX G HUMAN LANDING SYSTEM PROGRAM APPLICABILITY MATRIX

Assumptions for Applicability Assessment:

1) HLS Program will not require unique (new) EVA tools, crew aids, or restraints. This type of hardware will be provisioned as GFE.
   Assumed microgravity EVA translation only for scenario where the Integrated Lander is docked to staging vehicle (e.g., microgravity EVA column).

TABLE G1-1 APPLICABILITY MATRIX

RQT Section #	Requirement Title	RQT Tag Number	Partial Gravity	Microgravity
3.1.1	Translation Path Hardware Protrusion	[EVASC.0001]	A	A
3.1.2	Tool Interface Clearance	[EVASC.0002]	A	A
3.1.3	Bolt Clearance	[EVASC.0007]	A	A
3.1.4	Gloved-Hand Clearance	[EVASC.0003]	A	A
3.1.5	Handrail/Handhold Mounting Clearance	[EVASC.0004]	A	A
3.1.6	Handrail/Handhold Side Clearance	[EVASC.0005]	A	A
3.1.7	APFR EVA Installation/Removal Clearance	[EVASC.0006]	N/A	A
3.2.1	Contiguous EVA Translation Path	[EVASC.0152]	N/A	A
3.2.2	Translation Path	[EVASC.0008]	A	A
3.2.3	Incapacitated Crewmember Interfaces	[EVASC.0154]	A	N/A
3.2.4	EVA Contact Hazards Preclusion Beyond Translation Corridor	[EVASC.0010]	N/A	A
3.2.5	Partial Gravity EVA Contact Hazards Preclusion	[EVASC.0159]	A	N/A
3.3.1	Microgravity EVA Equipment Handling Features	[EVASC.0012]	N/A	A
3.3.2	Partial Gravity EVA Handling Capability	[EVASC.0160]	A	N/A
3.3.3	Partial Gravity Step Design Parameter	[EVASC.0162]	A	N/A
3.3.4	Hatch Transfer Constraint	[EVASC.0013]	A	A
3.3.5	Pressurized xEVA Suit Transfer through Airlock Hatch	[EVASC.0135]	N/A	A
3.3.6	EVA Lunar Hatch Dimensions	[EVASC.0153]	A	N/A
3.3.7	EVA Procedure Display Method	[EVASC.0158]	A	A
3.3.8.1	Mounting Alignment Devices	[EVASC.0014]	A	A
3.3.8.2	Handling Alignment Marks	[EVASC.0015]	A	A
3.3.9.1	Locking Device	[EVASC.0016]	A	A
3.3.9.2	Over Center Device Force	[EVASC.0124]	A	A
3.3.9.3	Soft Dock or Soft Capture Mechanisms	[EVASC.0017]	N/A	A
3.3.9.4	Soft Capture	[EVASC.0125]	A	A
3.3.9.5	Soft Dock Force	[EVASC.0126]	N/A	A
3.3.10	Hand Grip Surface/Boot Contact	[EVASC.0023]	A	A
3.3.11	Unique Labeling	[EVASC.0024]	A	A
3.3.12.1	Hand Tool Operations	[EVASC.0025]	A	A
3.3.12.2.1	Hand Ratcheting	[EVASC.0135a]	A	A
3.3.12.2.2	Throw Angle	[EVASC.0026]	A	A
3.3.12.2.3	Ratchet Mechanism	[EVASC.0127]	A	A

TABLE G1-1 APPLICABILITY MATRIX

RQT Section #	Requirement Title	RQT Tag Number	Partial Gravity	Microgravity
3.3.12.2.4	Back Drive Torque	[EVASC.0128]	A	A
3.3.12.2.5	Running Torque	[EVASC.0129]	A	A
3.3.13.1	Pressurized Glove Compatibility	[EVASC.0027]	A	A
3.3.13.2	Inadvertent Actuation of EVA - Actuated Controls	[EVASC.0087]	A	A
3.3.14.1	Handrail/Handhold Cross-Section	[EVASC.0029]	A	A
3.3.14.2	Handrail/Handhold Length	[EVASC.0030]	A	A
3.3.14.3	Handrail/Handhold Accessibility	[EVASC.0031]	A	A
3.3.14.4	Continuous Handrail/Handhold Spacing	[EVASC.0032]	A	A
3.3.14.5	EVA Egress Handrail Spacing	[EVASC.0144]	A	A
3.3.14.6.1	Optimum Work Envelope	[EVASC.0035]	A	A
3.3.14.6.2	EVA Egress/Ingress Methods	[EVASC.0157]	A	A
3.3.14.6.3	Crew Aids for Stability	[EVASC.0036]	N/A	A
3.3.14.6.4	EVA Worksites Using Robotic Work Platform	[EVASC.0037]	N/A	A
3.3.14.7.1	Lubricant Use	[EVASC.0038]	A	A
3.4.1	Worksite Mobility	[EVASC.0040]	N/A	A
3.4.2.1	Worksite Field of View	[EVASC.0041]	A	A
3.4.2.2	Working Volume	[EVASC.0042]	A	A
3.4.3	Dedicated EVA Worksite	[EVASC.0148]	N/A	A
3.4.4	Robotic Assisted EVA Worksite	[EVASC.0149]	N/A	A
3.4.5	Free-Float Worksites	[EVASC.0150]	N/A	A
3.4.6	Installation of Passive Worksite Interface Sockets	[EVASC.0045]	N/A	A
3.4.7	Foot Restraint Ingress/Egress Aids	[EVASC.0046]	N/A	A
3.4.8	Visual Contrast at Worksite	[EVASC.0047]	A	A
3.5.1.1	Color for EVA Handling and EVA Tether Points	[EVASC.0033]	A	A
3.5.1.2	EVA Tether Point	[EVASC.0048]	A	A
3.5.1.3	Soft Goods Tether Point Loads	[EVASC.0134]	N/A	A
3.5.2	Microgravity EVA Crew-Induced Loads	[EVASC.0050]	N/A	A
3.5.3	Partial Gravity EVA Crew-Induced Loads	[EVASC.0155]	A	N/A
3.5.4	EVA Actuated Loads	[EVASC.0018]	A	A
3.5.5	EVA Mechanical Feedback	[EVASC.0164]	A	A
3.5.6	WIF Structural Loading	[EVASC.0143]	N/A	A
3.6.1	One-Handed EVA Operable Connectors	[EVASC.0053]	N/A	A
3.6.2	Connector Accessibility	[EVASC.0054]	A	A
3.6.3	Gloved-Hand Connector Accessibility	[EVASC.0138]	A	A

TABLE G1-1 APPLICABILITY MATRIX

RQT Section #	Requirement Title	RQT Tag Number	Partial Gravity	Microgravity
3.6.4	Incorrect Connector Mating Prevention	[EVASC.0055]	A	A
3.6.5	Connector Coding	[EVASC.0056]	A	A
3.6.6	Connector Protective Caps	[EVASC.0057]	A	A
3.6.7	Connector Rotational Travel	[EVASC.0058]	A	A
3.6.8	Connector Locking Feature	[EVASC.0059]	A	A
3.6.9	Visible Connector Alignment Markings	[EVASC.0060]	A	A
3.6.10	Connector Locking Ring	[EVASC.0061]	A	A
3.6.11	Connector Mating Status	[EVASC.0062]	A	A
3.6.12.1	Mating/Demating of Powered Connectors	[EVASC.0052]	A	A
3.6.12.2	Connectors - Electrical Bonding	[EVASC.0065]	A	A
3.6.12.3	Scoop-Proof Electrical Connector Design	[EVASC.0066]	A	A
3.6.12.4	Connector Grip Point	[EVASC.0063]	A	A
3.6.12.5	Arc Containment	[EVASC.0131]	A	A
3.6.13.1	Tethering	[EVASC.0132]	A	A
3.6.13.2	Venting Feature	[EVASC.0133]	A	A
3.6.13.3	Indication of Pressure Flow - Nonbrazed or Nonwelded	[EVASC.0145]	A	A
3.6.13.4	Indication of Pressure Flow - Quick Disconnect	[EVASC.0146]	A	A
3.7.1	Captive Fastener Design	[EVASC.0068]	A	A
3.7.2.1	Prohibited Locking Methods for Fasteners	[EVASC.0069]	A	A
3.7.3.1	One-Handed Fastener Operations	[EVASC.0067]	A	A
3.7.3.2	Scalloped Knobs	[EVASC.0072]	A	A
3.7.3.3	Knobs Head Diameter and Height	[EVASC.0073]	A	A
3.7.3.4	EVA Hand-Actuated Fasteners Contingency Operation	[EVASC.0074]	A	A
3.7.4.1	EVA PIP Pin Grasping Interface	[EVASC.0075]	A	A
3.7.4.2	PIP Pin Restraint Tether	[EVASC.0076]	A	A
3.7.5.1	Driver-Type Push Force Tools	[EVASC.0078]	A	A
3.7.5.2	EVA Fastener Head	[EVASC.0079]	A	A
3.7.5.3	Fastener Drive Height	[EVASC.0084]	A	A
3.7.5.4	Fastener Torque Data	[EVASC.0151]	A	A
3.7.5.5	Power and Hand Tool Operability	[EVASC.0080]	A	A
3.7.5.6	Fastener Gauge/ Measurement	[EVASC.0141]	A	A
3.7.5.7	Fastener Alignment Features	[EVASC.0083]	A	A
3.8.1.1	Battery Replacement	[EVASC.0085]	A	A
3.8.1.2	Battery Voltage Monitoring	[EVASC.0086]	A	A
3.8.1.3	Auxiliary Controls	[EVASC.0028]	A	A

TABLE G1-1 APPLICABILITY MATRIX

RQT Section #	Requirement Title	RQT Tag Number	Partial Gravity	Microgravity
3.8.2	EVA Tools	[EVASC.0088]	A	A
3.8.3	IVA Tools to Maintain EVA Equipment	[EVASC.0163]	A	A
3.8.4	Cable Routing/Restraint	[EVASC.0089]	A	A
3.8.5	Cable Routing Spacing	[EVASC.0090]	A	A
3.8.6	Paint	[EVASC.0091]	A	A
3.9.1	Hazardous Material Contamination Failure Tolerance	[EVASC.0092]	A	A
3.9.2.1	Venting or Exposure Compatibility	[EVASC.0093]	A	A
3.9.2.2	Deliberate Hazardous Venting	[EVASC.0094]	A	A
3.9.3	Lasers	[EVASC.0096]	A	A
3.9.4	Electrical and Safety Design	[EVASC.0097]	A	A
3.9.5	Shock Protection	[EVASC.0098]	A	A
3.9.6	Operation During Pressure Change	[EVASC.0099]	A	A
3.9.7	Component Hazardous Energy Provision	[EVASC.0100]	A	A
3.9.8	Detachable Parts	[EVASC.0101]	A	A
3.9.9	Touch Temperatures	[EVASC.0103]	A	A
3.9.10	xEVA Suit Glove Palm External Touch-Temperature Compliance for Small, Handheld Hardware	[EVASC.0011]	A	A
3.9.11	Incidental and Unlimited Contact Heat Transfer Rates	[EVASC.0104]	A	A
3.9.12	Sharp Edge and Protrusions Protection	[EVASC.0105]	A	A
3.9.13	Screws and Bolts	[EVASC.0106]	A	A
3.9.14	Levers, Cranks, Hooks, and Controls	[EVASC.0107]	A	A
3.9.15	Exposed Holes or Slots	[EVASC.0109]	A	A
3.9.16	Pinch Hazard Protection	[EVASC.0110]	A	A
3.9.17	Equipment Clearance for Entrapment Hazard	[EVASC.0111]	A	A
3.9.18	Protection from Moving or Rotating Equipment	[EVASC.0112]	A	A
3.9.19	Emergency Ingress Capability	[EVASC.0113]	A	A
3.9.20	External Surface Cleanliness Level	[EVASC.0140]	A	A
3.9.21	Tethering / Restraint	[EVASC.0115]	N/A	A
3.9.22	Crew Safety Tether Attachment	[EVASC.0116]	N/A	A
3.9.23	Crew Safety Tether Restraint	[EVASC.0161]	A	N/A
3.9.24	Color For Crew Load-Rated Handhold/Handrails, Crew Safety Tethers And Safety Restraint Attachment Points	[EVASC.0117]	A	A

TABLE G1-1 APPLICABILITY MATRIX

RQT Section #	Requirement Title	RQT Tag Number	Partial Gravity	Microgravity
3.9.25	Manual Overrides	[EVASC.0118]	A	A
3.9.26	Entanglement, Cable Clamps, Ducts, or Retractors	[EVASC.0137]	A	A
3.10.1	Magnetic Field Limit	[EVASC.0121]	A	A
3.10.2	Voltage Potential Discharge	[EVASC.0123]	A	A
3.10.3	Lunar Surface Dust Tolerance	[EVASC.0156]	A	N/A