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Compatibility between Exploration EVA System and Exploration Spacecrafts

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Need for EVA Compatibility between Exploration EVA System and Exploration Spacecrafts



- Over the life of the current ISS EMU, numerous products have detailed “how to build EVA System hardware” and “how to design hardware that EVA crewmembers will access and utilize” were generated to provide interoperability between the suited crew and the specific vehicle’s EVA task

For EVA-suited crewmember tasks beyond Low Earth Orbit, new Exploration vehicles would need a single consolidated location for EVA requirements, best practices, and lessons learned from the EVA community

- EVA Office began generation of a new single source document that involved reviewing multiple active heritage documents to capture all EVA requirements necessary for compatibility with the xEVA System
 - Cross-comparison analysis was performed over span of a couple years to inform the new product
- Outline:
 - Documenting EVA Requirements and Best Practices/Lessons Learned
 - Common Requirements for EVA Compatibility
 - Benefits of EVA Compatibility Requirements Consolidation
 - Tailoring for Multiple Program Use
 - Partial Gravity Requirement Gap Assessment and Re-evaluation of approach for EVA Compatibility documents





Documenting EVA Requirements and Best Practices/Lessons Learned



- **Defining EVA Compatibility versus EVA Interface Requirements**

- Did not include EVA interfaces internal to vehicle such as spacesuit servicing, performance, and checkout equipment (e.g., items that directly interface with the suit such as fluid and electrical connectors) or non-mechanical Exploration Spacecraft to xEVA System (such as wireless communication, data, video, and audio)
- Did not include human-to-suit interfaces (like anthropometric requirements) or IVA suit-to-vehicle interfaces

- **Purpose and Scope**

- Contained the fundamental information required for building and verifying that hardware would be compatible with pressurized EVA suited crewmembers to perform successful EVAs

- **Applicability**

- Requirements applicable to development of all Programs/Projects/Spacecraft that perform EVA operations or would interact with the xEVA System

- **Document Structure**

- Requirements issued static ID tag [EVASC.XXXX]
- Comprised of following topics:

Sections	
Clearances	Connectors
Translation	Fasteners
EVA Handling	Hardware Design
Worksite Outfitting	Safety
Loads	Environments

- Verification Methods identified
- Appendices
 - ISS EVA Lessons Learned
 - IVA/EVA tools/fastener drives





Common Requirements for EVA Compatibility

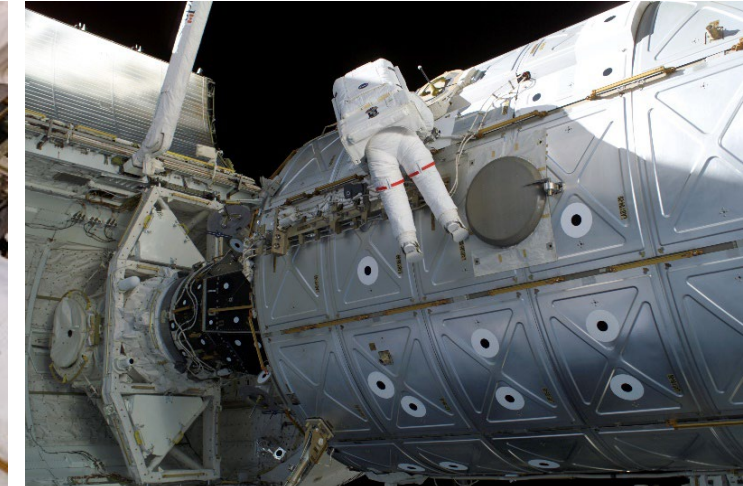


- **EVA Translation and Worksites**

- EVA translation and worksite compatibility with the xEVA System has evolved over Space Shuttle and ISS
- The EVA translation path corridor defines the dimensions that provide clearance around the crewmember to perform the task
- An EVA worksite also requires specific clearance to translate to it, allow for crew stabilization, as well as clearance at the worksite to successfully perform the operations (e.g., free-float, dedicated, or robotic (in a foot restraint))
- Design of EVA translation paths and worksites are critical for any Spacecraft or Integrated Stack (e.g., ISS) design so that can fully support EVA operations



ISS Airlock Egress on US EVA 16 (iss024e16103)



ISS EVA Translation on US Lab (s114e6523)



ISS EVA Translation on EVA3 Joint Expedition (iss028e005283)





Common Requirements for EVA Compatibility (continued)

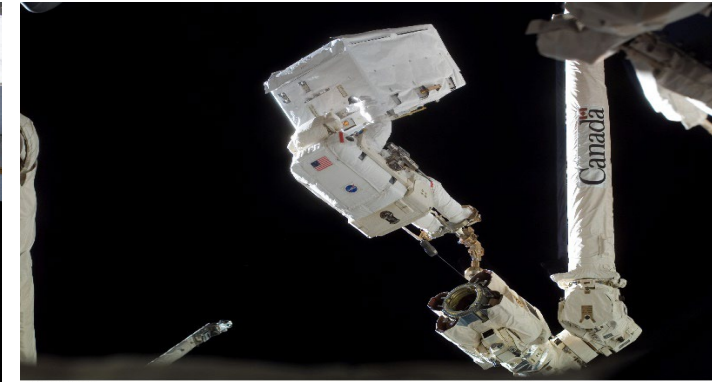


- **Mass Handling and Work Volume**

- Mass handling of various size Orbital Replacement Units (ORUs) was common during the assembly and maintenance of ISS
- Crewmembers carried smaller ORUs on the Body Restraint Tether (BRT) while translation to/from a dedicated worksite
- Crewmembers handled larger ORUs while in a foot restraint on the end of the robotic arm
- Crewmembers have a specific work envelope (volume) for EVA translation and worksite operations
- Information contained here and on the previous slide is specific to ISS microgravity EVAs
- Partial gravity fields such as the Moon and Mars are anticipated to be approached differently



ISS EVA Translation (iss061e066433)



ISS Robotic Arm Mass Handling during STS-122 EVA 2 (s122e008149)



Worksite Operation during ISS EVA 50 (iss055e071264)





Benefits of EVA Compatibility Requirements Consolidation



- During the cross-comparison analysis, it was observed that there were discrepancies between current accepted values in requirements versus those contained in outdated documents
- Consolidation of the EVA requirements into a single source provided a “one-stop shop” for the requirements needed for Exploration vehicles to use in design of their hardware so that they would be compatibility with the xEVA System
 - EVA Office EVA Compatibility document was Baselined in September 2018
- Originally, it was considered multi-purpose, to be applicable to xEVA System as well as act as a template for development of requirements on the Exploration Program/Project/Spacecraft
- The document took a risk-reducing approach for levying EVA compatibility requirements for Exploration missions
- Considering incompatible schedules and potential for multiple vendors on both sides of the interface, the document provided the capability for “meeting in the middle” (i.e., each side of the interface meets the xEVA suit work envelope, then it will ensure that the envelope would work with the new suit)





Tailoring for Multiple Program Use



- **The Gateway Program was the first to have a tailored version of EVA compatibility requirements that was Baselined in late August 2019**
- **The Human Landing System (HLS) Program was the next to have a tailored version that was Baselined in February 2020**
- **The critical part of the tailoring process was to document the applicability of the EVA compatibility requirements**
 - An Appendix was included in both the Gateway and HLS EVA Compatibility documents to capture this in the form of an applicability matrix
 - Each requirement was listed with the appropriate document section and requirement tag
 - Especially important for Gateway Program as it consists of multiple modules, robotic arm, and external payloads
 - Considerations for applicability to requirements included:
 - Is the vehicle visiting that could protrude into the EVA translation path - Invoke a subset of EVA Compatibility requirements in a Visiting Vehicle IRD
 - Determine if EVA capability will be needed – levy associated translation requirements
 - Will there be a dedicated worksite – all requirements in EVA capability (as applicable) and add worksite related requirements
 - Will there be ORUs/payloads – all previous plus EVA fasteners and connectors (depending on intended EVA operation)





Partial Gravity Requirement Gap Assessment



- **Transition from EVA Office to EVA and Human Surface Mobility (HSM) Program (EHP) in early 2022**
 - Over the first year of EHP, it became evident that trying to manage three different versions of EVA Compatibility documents was becoming a challenge
 - Continued to provide revisions for both Gateway and HLS Programs to meet required milestones
- **Partial Gravity Requirement Gap Assessment**
 - EHP SE&I Requirements, Interfaces, and Verification (RIV) Team convened several Subject Matter Experts (SMEs) during the summer of 2022 to evaluate the existing EVA compatibility requirements to assess the following:
 - Intent of requirement, is it applicable to partial gravity?
 - If yes, does existing requirement satisfy, or does it need to be modified?
 - If no, is a new requirement needed?
 - RIV was provided an opportunity in October of 2022 perform a quick turn-around CR to update HLS tailored document
 - Results from the assessment were included in this document and formal Joint Board approval was concluded in February 2023 with updated Revision provided





Re-evaluation of approach for EVA Compatibility documents



- **RIV Team given action from EHP management to determine feasibility of minimizing number of interface documents (included both physical vehicle interfaces and EVA compatibility)**
 - RIV proposed consolidation of the three EVA compatibility documents into one at various EHP Boards for direction
 - EHP Control Board approved proposal of one document for EVA Compatibility that would be treated as a Standard
 - This document would be given a new document number associated with the Program and a new Annex generated to include applicability matrices for EHP Projects, External Programs/spacecraft, payloads, etc.
 - RIV team is working on maturing this draft document based on latest work completed on the HLS tailored version with goal of Baselineing later this year
 - Future work to work with External Programs to accept EHP's recommended approach and implementation
- **The capability to standardize the EVA requirements that enable Exploration Programs/Spacecraft compatibility with the pressurized suited crewmember is a crucial step forward in achieving successful EVA operations across any destination that NASA dreams to pursue**



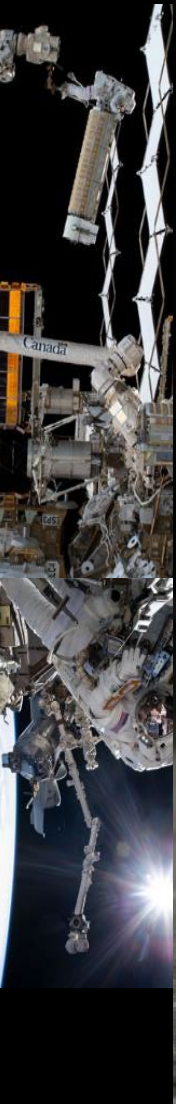
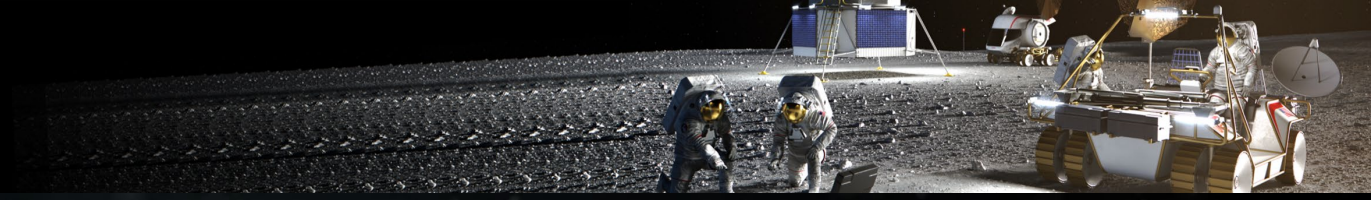


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- **During the maturation of the EVA Compatibility requirements and various Program-tailored versions, we appreciated all the assistance from the EVA community and Program SE&I counterparts (especially during transition from EVA Office to the new Program (EHP) in early 2022**
- **Since formulation of EHP, I am thankful for the support from my co-author Caitlin Meyer and fellow RIV team members as this journey has truly been a team effort**





Questions?

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