2.3.9. Future Engineering

Generic Technologies

Future Engineering

GT17-868SF – Maturation of extended reality solutions for space environments

Budget: 900 k€ - **Duration**: 18 months - **Current / Targeted TRL:** 3 / 7 - **TD** 8

Objective:
To develop solutions to overcome the limitations of commercial off-the-shelf Extended Reality headsets for their usage in Space environments.

Description:
In recent years, Extended Reality (XR) technology has shown great potential for various applications on-orbit, including astronaut training, science, maintenance and operations.

Some Commercial Off-The-Shelf (COTS) XR devices have recently introduced different experimental “Travel Modes” that were tested during a Parabolic Flight Campaign in 2025. Results showed robust localization and tracking when relying on visual cues only (no inertial sensors were used). As a result, a Meta Quest 3 headset is planned to be delivered to the ISS in 2026 for further testing. However, some other challenges still remain, like the lack of a non-invasive solution integrated in the visor of spacesuits, environmental challenges (e.g. radiation hardening, thermal management, power and battery constraints, dust and particle contamination, device durability, etc.), limited bandwidths, weight and balance distribution affected by lower-zero-G conditions, psychological effects of using XR in Space, among others.

The present activity must address the remaining challenges by proposing XR solutions with higher maturity for (1) Intra-Extravehicular Activities (IVA/EVA) in microgravity (e.g. Launch & Entry, International Space Station) and (2) Moon / Mars environments. These XR solutions shall propose non-invasive projection systems, adapted in the visor of spacesuits to allow Mixed Reality interactions. This technology could support astronaut operations in Space by providing navigation assistance, scientific site identification, procedure guidance, equipment troubleshooting, teleoperation of robotic devices, immersive training for countermeasure, virtual mapping, data visualization or enhanced collaboration between astronauts and ground personnel, among others.

The following tasks are foreseen in this activity:
- Define specifications and guidelines for XR hardware used in space and extraterrestrial environments and develop strategies to ensure their technological maturity and readiness.
- Create a non-invasive Mixed Reality solution integrated in the visor of spacesuits.
- Create a roadmap to address the upcoming challenges, environments and use cases of using XR in Space environments.

Deliverables: Flight Model, Report, Software

Application/Need Date: Intra-Extravehicular Activities (IVA/EVA), Moon / Mars environments. TRL 7 by 2028
Mission Classification: alpha, beta, gamma, delta

THAG Roadmap: Not relevant to any Harmonisation topic.

Generic Technologies

Future Engineering

GT17-869SF – Facility-less setup for enhanced virtual presence

Budget: 900 k€ - **Duration**: 24 months - **Current / Targeted TRL:** 3 / 6 - **TD** 8

Objective:
To develop a self-contained system using Extended Reality and interactive devices to allow space personnel to train and operate remotely and safely through immersive digital environments.
Description:
Virtual Presence refers to the sense of realism or immersion when interacting with a digital environment without being physically present. Human-machine interfaces and interaction technologies have evolved to evoke this feeling in users by leveraging familiar and intuitive cues. Virtual Presence is particularly advantageous in applications where interactions or complex visualizations are required from remote and safe locations. Virtual Presence can be used generically across a wide range of space use cases because it enables immersive interaction with complex systems or environments, making it valuable not only for astronaut training but also for robotic operations, telemaintenance, mission planning, payload integration, and expert support—any scenario where safe, intuitive, and effective human involvement is needed without physical presence.

The utilization of Extended Reality (XR) technologies in such space applications has attracted significant attention for their potential to enhance user interaction, improving usability, and enabling more natural interactions. However, as space exploration and missions become increasingly complex, the need for higher levels of immersion and efficient human-computer interaction has grown.

Virtual and Augmented Reality headsets and glasses are maturing with commercial off-the-shelf solutions, usually offering visual, aural and vestibular feedback. However, such stimuli are often insufficient for achieving higher levels of Virtual Presence in areas like training, where kinesthetics or force feedback are also crucial to feel object shapes, inertias or outer-Earth gravities. Therefore, the combination of XR technologies with other interaction devices like motion platforms, exoskeletons, haptic, tactile or neural devices, could potentially offer a more immersive, multimodal, scalable and embodied training experience.

The following tasks are foreseen in this activity:
- Define specifications and guidelines for XR interaction devices in space applications and outline the development of a multimodal framework to ensure their technological maturity and readiness.
- Design a self-contained, immersive hardware setup for training and teleoperation, tailored to specific space use cases, integrating XR technologies and interaction devices.
- Integrate the hardware solutions with a multimodal software framework capable of hosting multiple users while monitoring and orchestrating the XR and interaction devices.
- Collect and analyse learning analytics to develop custom training or teleoperation programs and provide personalized feedback to users.

Deliverables: Engineering Model, Report, Software

Application/Need Date: All missions. TRL6 by 2028 **Mission Classification:** alpha, beta, gamma, delta

THAG Roadmap: Not relevant to any Harmonisation topic.

Generic Technologies

Future Engineering

GT17-875SF – Adaptive human-machine interfaces for enhanced data monitoring and operations

Budget: 1200 k€ - **Duration**: 24 months - **Current / Targeted TRL:** 3 / 6 - **TD** 8

Objective:
To develop an adaptive and immersive interface that enhances real-time monitoring and decision-making by integrating advanced visualization tools, extended realities (XR), digital twin data and Model Based Systems Engineering (MBSE) to support co-engineering in design, training, Assembly, Integration, and Test (AIT) and operations.
Description:
Modern aerospace operations demand continuous monitoring and interpretation of vast telemetry and design datasets to ensure mission success. Traditional monitoring methods are increasingly challenged by data overload, leading to high cognitive workload, slower response times, and reduced anomaly detection effectiveness. These challenges are especially critical during spacecraft operations, astronaut activities, testing, and mission planning.

This activity aims to develop an intelligent, adaptive, and immersive user interface that enhances operator efficiency, reduces cognitive load, and improves situational awareness and decision-making across design, integration, and operational contexts. By integrating XR, artificial intelligence, MBSE and digital twin technologies, the solution will provide advanced visualization tools capable of:
- Presenting telemetry, test, and design data in a structured, semantically rich, and interactive 3D environment.
- Dynamically highlighting critical insights using real-time data analytics and predictive models.
- Supporting collaborative engineering and reviews, root-cause analysis, and predictive maintenance.
- Enhancing spatial and temporal understanding through immersive AR/VR environments tailored to operator needs.
The outcome will be a reference approach and software architecture for next-generation human-machine interfaces in space missions. The prototype will demonstrate improved operator performance, more efficient spacecraft control, and faster, more informed decision-making.

The activity includes the following tasks:
- Analyse use cases, state-of-the-art solutions, user requirements, and trade-offs for enhanced monitoring across design, AIT, and operations.
- Develop a prototype adaptive interface leveraging XR, AI, and digital twin integration with MBSE and ontology-based semantics.
- Evaluate the solution’s performance across multiple domains and define a roadmap for technology maturation.

Deliverables: Prototype, Report, Software

Application/Need Date: All missions. TRL6 by 2028 **Mission Classification:** alpha, beta, gamma, delta

THAG Roadmap: Model Based for System Engineering (2024) – Consistent with activity AIM H12 “Model Based System Engineering Explorer (MB-SEE)”.