ICARUS GSTP Executive Summary

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Applicable Documents

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Reference Documents

Item reference	Title	Date	Issue	Comment
[RD1] ATG-NL-TNO-AE-23-02411	ICARUS GSTP – TN1 –MVP consolidation	16 Oct 2023	1.0	
[RD2] ATG-NL-RP-AE-23-03069	ICARUS GSTP – TR1 – Architectural design consolidation & Checklist and tutorial design	8 Dec 2023	1.0	
[RD3] ATG-EN-EX-AE-24-09005	Validation Report	4 Oct 2024	1.0	
[RD4] ATG-EN-EX-AE-24-09005	ICARUS GSTP Final Report	22 Oct 2024	2.0	

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Acronyms

The acronyms used within this document are described in the following:

Acronym	Meaning
GSTP	General Support Technology Programme
HMD	Head Mounted Display
MVP	Minimum Viable Product
PoC	Proof of Concept
UX/UI	User Experience / User Interface
VR	Virtual Reality

1 Executive summary

Assembly, Integration and Testing (AIT) of complex systems is far from trivial in any industrial setting, especially in the space domain with high development cost, due to quality requirements and low risk tolerance. To carry out such work effectively and efficiently, AIT engineers should be meticulous, patient, and highly focused, with strong technical skills and attention to detail. Additionally, they need thorough knowledge of procedures, both with respect to the AIT job and the cleanroom operation. New hires or customers that are new to cubesat development need to understand the entire AIT process to effectively contribute to a safe development process. In summary, this requires specialized skills and knowledge, and a certain attitude to the job.

To develop the appropriate skills, knowledge, and attitude, requires training. Either in dedicated training programs, or on the job. Often, this involves training by doing, and by learning from experienced AIT engineers. Given the specialized nature of the work, this may be a time consuming and costly process. And if new users end up lacking the proper attitude for this work, lost costs may be significant.

The ICARUS application aims to decrease ramp-up time of new hires for AIT and cleanroom positions, by providing an immersive environment that allows for training of AIT and cleanroom procedures in a controlled environment. ICARUS provides an overview of the AIT process and allows users to practice without the risk of damaging equipment or making critical errors, thereby building confidence. The virtual training environment makes the training process more scalable and resource-efficient. By introducing users to new environments and procedures in this virtual training environment, ICARUS helps users to gain a basic understanding of the AIT process before transitioning to real-world tasks. This reduces both risks and costs related to AIT and cleanroom operations.

Within the ICARUS GSTP project, a Minimum Viable Product (MVP) for ICARUS is developed, to serve as a **VR training and evaluation tool** with the objective to provide its customers the means to easily and unambiguously **train their employees** on the general processes they need to follow in the **mechanical assembly and integration of satellites** as well as **cleanroom operations**. The initial focus lies on the following main use-cases:

1. Virtual training for mechanical assembly and integration in an environment with recurring operations
2. Virtual training for cleanroom operations in an environment with recurring operations
3. Knowledge retention of the recurring operations through a virtual representation of the customers guidelines and best practices
4. Virtual evaluation of new hires for AIT engineering and cleanroom operation positions

The main requirements for the ICARUS MVP are provided by ISISpace, the leading cubesat manufacturer in the Netherlands.

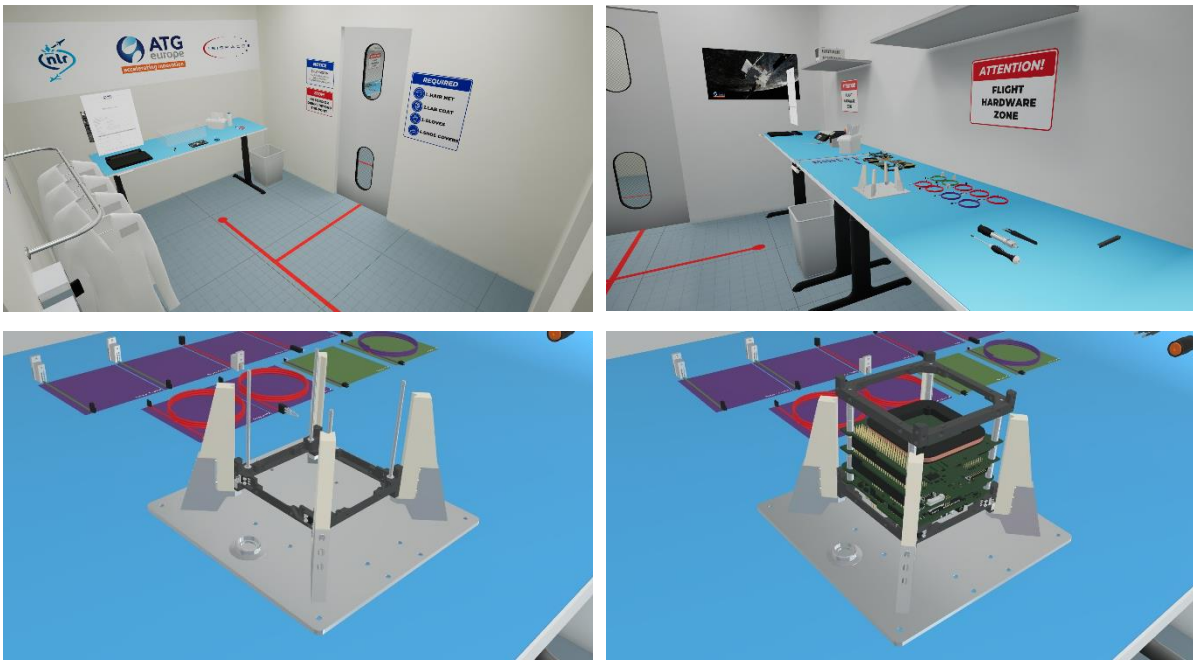

Figure 1 Screenshots from ICARUS VR, focusing on cleanroom design (upper left and right) and 1U stack integration (lower left and right)

The ICARUS MVP takes a holistic approach to cleanroom operations and AIT, by incorporating important steps in both processes based on real-world procedures and hardware (see Figure 1). The AIT process and training need is elaborated in a training scenario and operational competence profile defined for ISISpace during the project.

The ICARUS MVP is based on a modern, state-of-the-art game engine (Unreal Engine 4.27), and utilizes commercial of the shelf Virtual Reality (VR) hardware. During the development, good UX/UI plays a central role, to represent real-world processes and operations in a fit-for-purpose manner within the constraints of VR. The MVP was iteratively developed, taking feedback from the main stakeholders into account in the development process, to focus on key features adding value.

Key features included in the ICARUS MVP are among others:

- Gowning and cleaning processes and equipment (cleaning wipes, air blower),
- Safety processes and equipment (ESD bracelet and grounding cables),
- Procedure viewing and annotation,
- Tooling (screwdrivers and torque tools among others),
- Satellite assembly based on a real-world 1U cubesat model,
- Cables and cable routing,
- Kapton tape and epoxy,
- Verification processes and equipment (measuring and weighing).

During a validation campaign, trainees from the key stakeholders involved provided feedback on the ICARUS MVP (see Figure 3) and the main training scenario implemented. Trainees consisted of a mix of experienced AIT engineers and staff members without AIT experience.

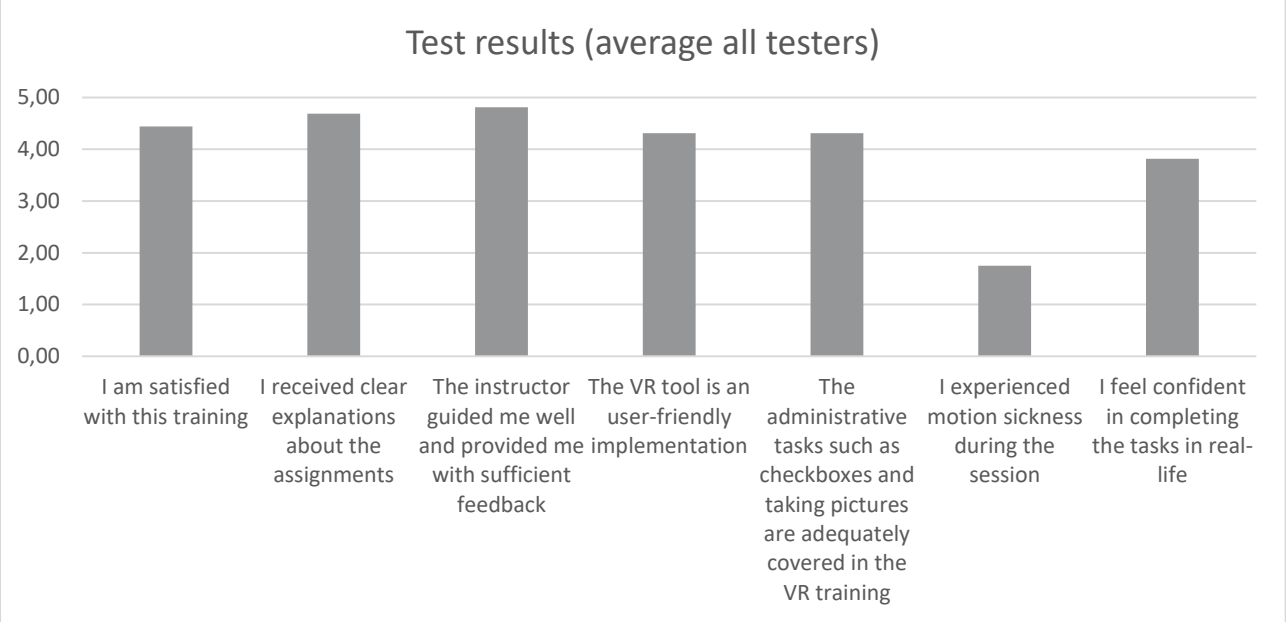

Figure 2 Average test results for all testers (part 1). 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree.

Based on the outcome of the validation campaign (see Figure 2), the main conclusions are as follows:

1. ICARUS' functionality is considered suitable for general training, with most of the trainees agreeing that the cleanroom environment and workflow are realistically resembled. Although ICARUS could benefit from further enhancements, for example related to precision tasks in VR, the key functionality required for the MVP has been implemented successfully.
2. ICARUS is considered user-friendly by most of the trainees.
3. ICARUS is considered valuable for initial training and familiarization, making it a useful supplement to traditional methods. Indeed, most trainees would feel more confident in completing similar tasks in real-life, after following a training in ICARUS.

Figure 3 Test sessions at NLR (left) and ISISpace (right)

Based on the feedback collected, it is concluded that ICARUS MVP can adequately showcase its benefits related to the main use-cases described above. It will thus serve as a suitable basis to further test viability, gather feedback and validate assumptions related to these value propositions in the market. Lastly, the tool can already be used towards this end by ISISpace and similar cubesat manufacturers. For more details, the reader is referred to the ICARUS GSTP Final Report [RD4], which also contains a roadmap describing further post-GSTP steps in the ICARUS development. This roadmap distinguishes between short-term topics, medium-term topics and long-term topics, where for the short-term bugfixes, a tutorial (in VR) and support for Quest 2/3 are considered to have the highest priority. On the medium-term, recording functionality, UX improvements, feedback or automatic pass/fail, upgrading to UE5, saving/reloading the training progress, another satellite model and branding are considered highest priority at this stage.