ICARUS VR Tool Derisk – Final presentation

ATG Restricted

ASSEMBLY, INTEGRATION, TEST (AIT)

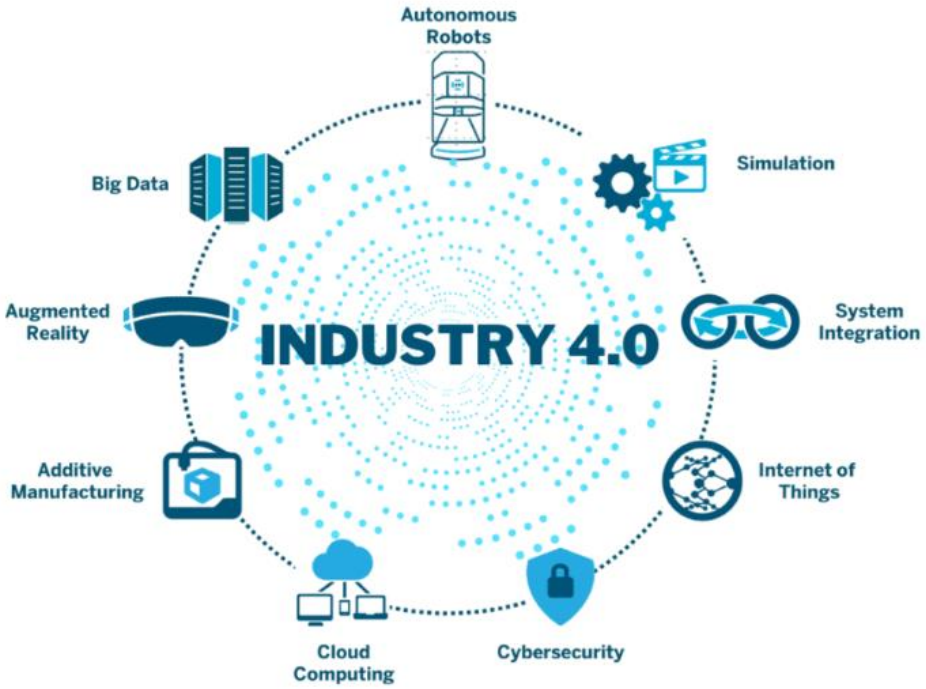
The integration of the system components into the overall (satellite) system, following standardized procedures

Source: ISISpace

ID	Job to be done	Current Method
1	**Training** for assembly procedures	Use of physical models of the actual hardware, where the actual moment of training is predefined and fixed in relation to the hardware manufacturing
2	**Knowledge retention** of applied processes and procedures in mechanical assembly and integration	Knowledge retention of recurring operations using written guidelines and best practices
3	**Support integration** of the satellite(s) into the launcher, at the launch site	Employees are asked to work at the launch site for several days or weeks, which can result in significant cost due to travel as well as time spent on the activity

INDUSTRY 4.0

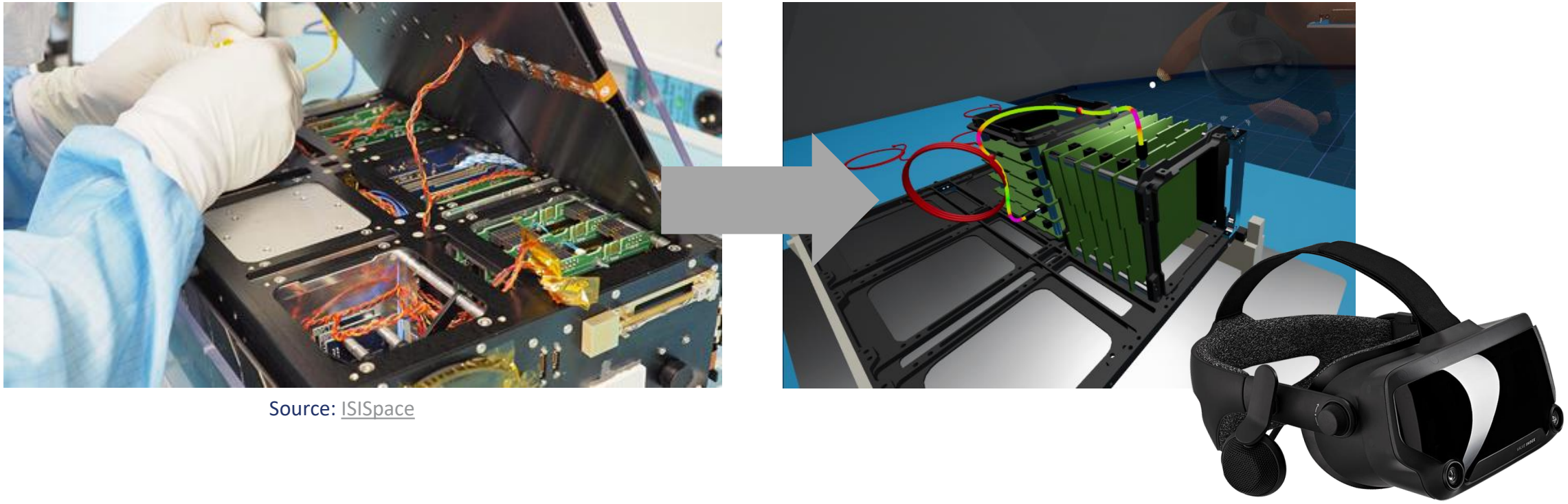
- A new **digital transformation** of industry that focuses on interconnectivity, automation, machine learning, and real-time data
- Driving improvements in efficiency, productivity, quality and safety of industrial processes
- **Virtual Reality (VR)** and **Augmented Reality (AR)** are two essential technologies for the transition to Industry 4.0, to provide benefits in among others:
  - Operations instructions and personnel training
  - Design optimization
  - Plant maintenance and control



Source: Calsoft

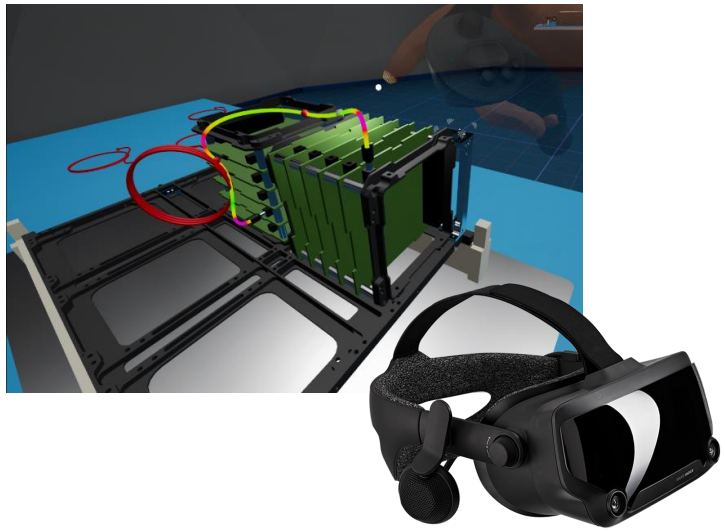
ICARUS

ICARUS, a **VR training tool** which provides 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**.



Source: ISISpace

ICARUS VALUE PROPOSITION



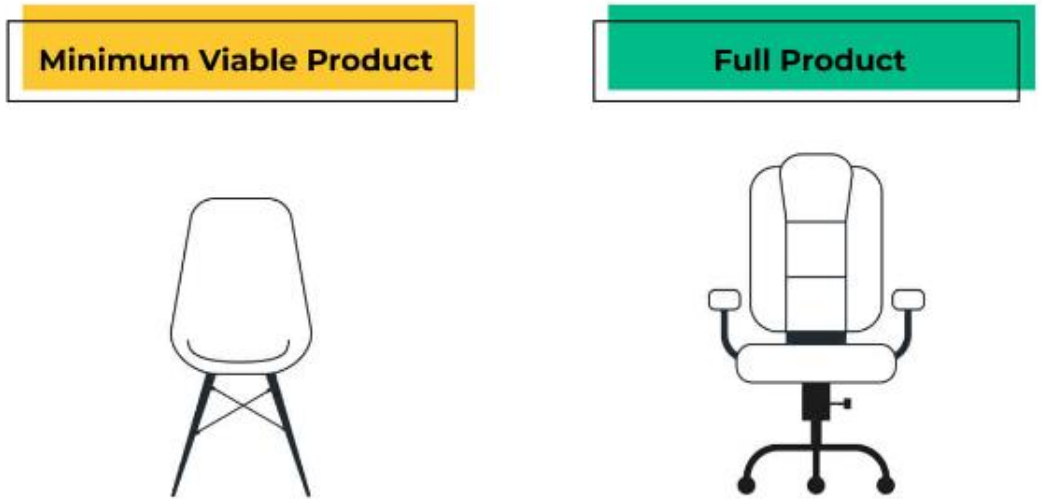
ID	Job to be done	ICARUS value proposition
1	**Training** for assembly procedures	Virtual training for mechanical assembly and integration in a digital environment. This will provide **more flexibility** in the timing of the training and much **lower cost** by not using actual physical flight hardware for training purposes.
2	**Knowledge retention** of applied processes and procedures in mechanical assembly and integration	Knowledge retention of the recurring operations through a virtual representation of the customers guidelines and best practices. Thereby enabling an **easier transfer of knowledge** to new employees, increasing their productivity, and lowering the initial skill level required
3	**Support integration** of the satellite(s) into the launcher, at the launch site	Training of launcher integration using a virtual representation of the satellite, to be carried out remotely in a collaborative digital environment. Thereby **saving valuable time** of all parties involved and **providing more flexibility** in the timing of this integration testing.

MINIMUM VIABLE PRODUCT

The initial focus is on developing an **ICARUS Minimum Viable Product (MVP)**: a product with just enough features to be usable by early customers who can then provide feedback for future product development.

The MVP will consider two main use cases:

1. **Virtual training** for mechanical assembly and integration in an environment with recurring operations, either guided (instructions) or non-guided (trying-out what is possible)
2. **Knowledge retention** of the recurring operations through a virtual representation of the customers guidelines and best practices



Source: Uptech

ICARUS VR TOOL DERISK PROJECT

Goal: to Derisk a number of key features required for the successful development of the ICARUS MVP

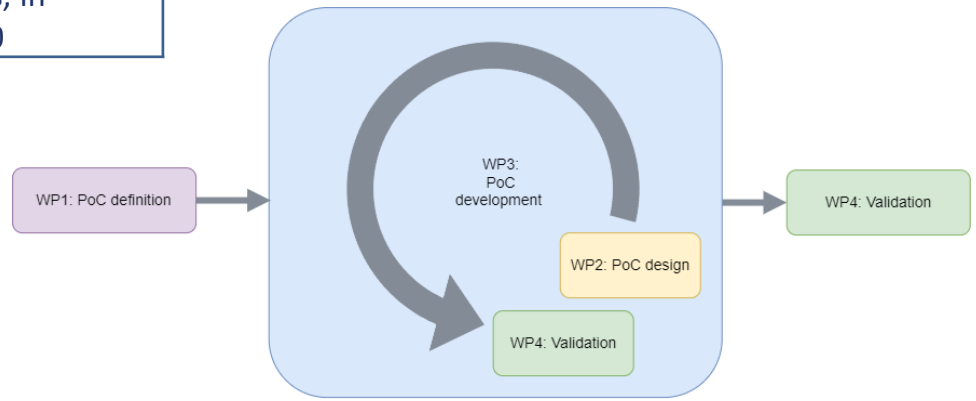
- Focusing on the virtual representation of **tooling** and of **cables and their routing**
- To assess whether these can be represented with **sufficient realism** for the intended purposes
- Through the development of a **Proof of Concept (PoC)**

Risk ID	Description	Likelihood [0 – 3]	Impact [0 – 3]	Mitigation action
1	Cad import too hard to implement	1	3	Manual model conversion by ATG Europe
2	Multi-user set up too hard to implement	1	3	Screen mirroring used for spectating
3	Baseline training lacks realism because of oversimplistic representation of tooling	2	3	Detailed simulation of tooling motion and interaction with structure
4	Baseline training lacks realism because of oversimplistic representation of cable(s) and cable routing	2	3	Detailed representation of cable routing including representation of physical cable properties
5	3D Model sizes of CAD data too complex or big for untethered headset solution	2	2	Model reduction to a lower polygon count, either automated (direct cad conversion) or manually by ATG OR not moving to an untethered solution

ACTIVITIES AND TIMEFRAME

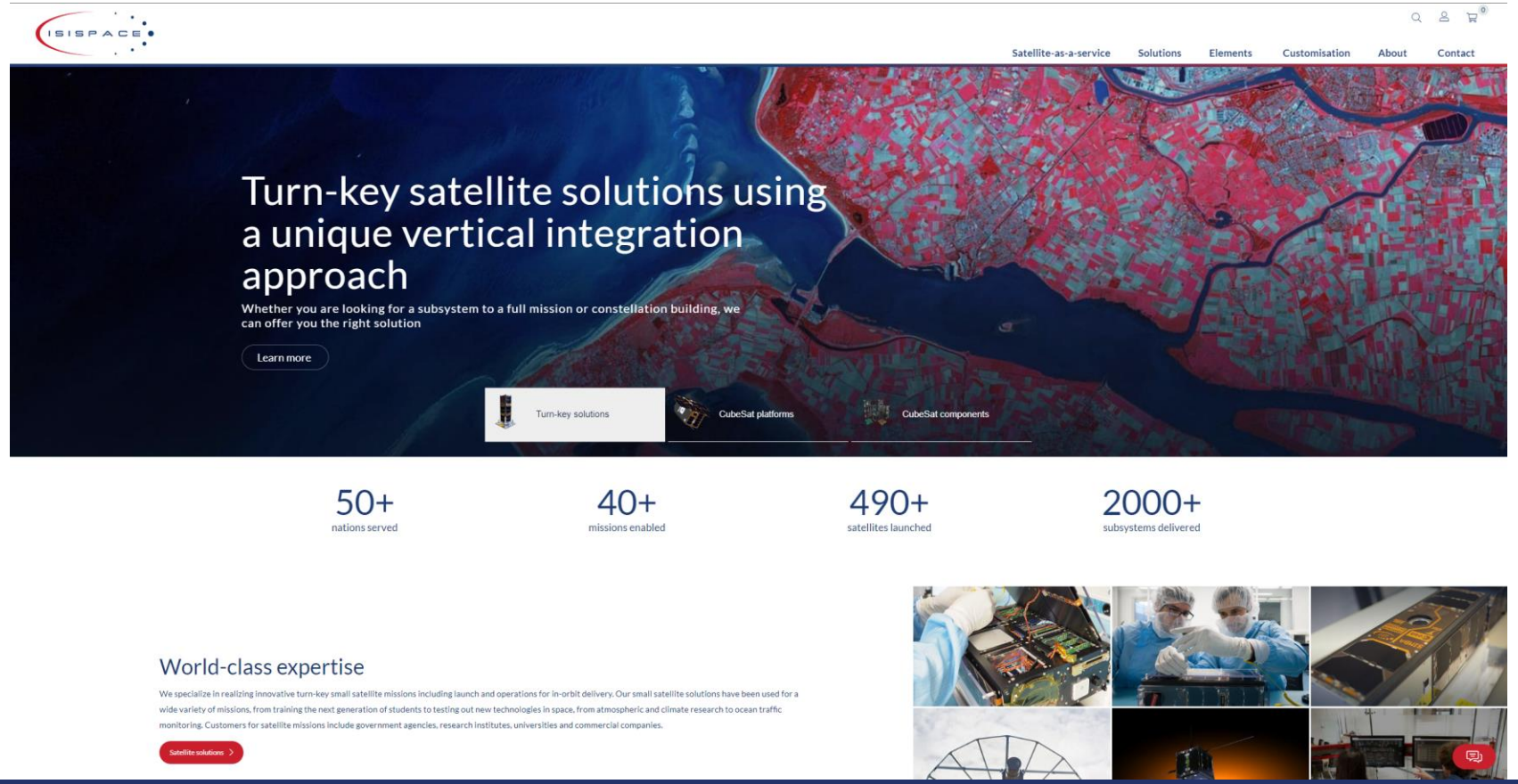
February – December 2022:

WP ID	Title	Description
WP1000	**Proof of Concept definition**	Defining the ICARUS requirements (user stories, non-functional software requirements, functional software requirements) with ISISpace user representatives and refining the PoC definition. This includes the definition of the training scenario to be used for validation.
WP2000	**Proof of Concept design**	Refining the architectural design of ICARUS and developing UX/UI design for the key user interactions required in the PoC.
WP3000	**Proof of Concept development**	The software development work required to develop the PoC, following the requirements from WP1000 and design from WP2000
WP4000	**Validation**	The validation of the PoC with ISISpace user representatives, in accordance with the training scenario as defined in WP1000



LAUNCHING CUSTOMER

ISISpace participates in the project as **launching customer**, to provide input (user needs, requirements, …) and to test and validate the results



USER NEEDS AND REQUIREMENTS

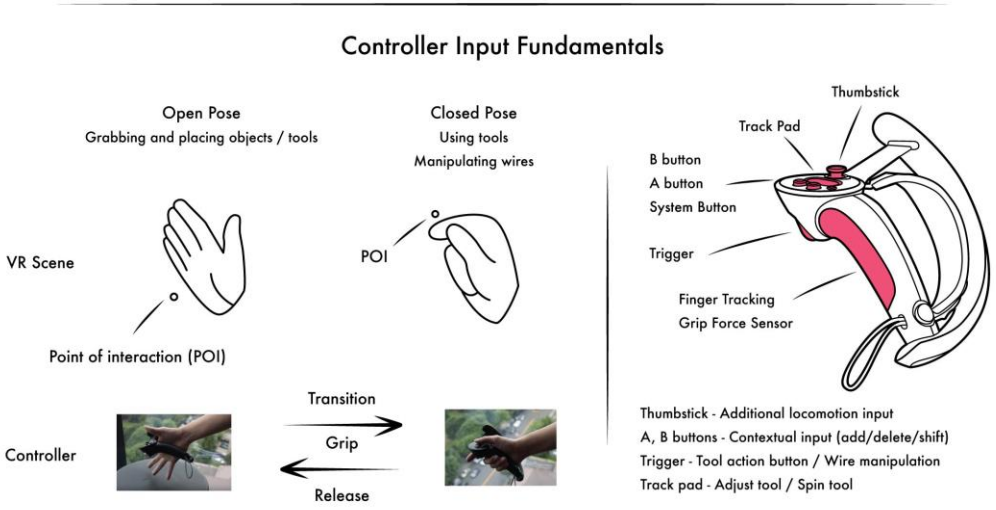
ID	User Story
US-01	As a Trainee I can ready my workspace, so I know where my tools and parts are
US-13	As a Trainee I can tighten fasteners using a tool, so the parts are fixed with respect to each other but still able to be disassembled
	Etc

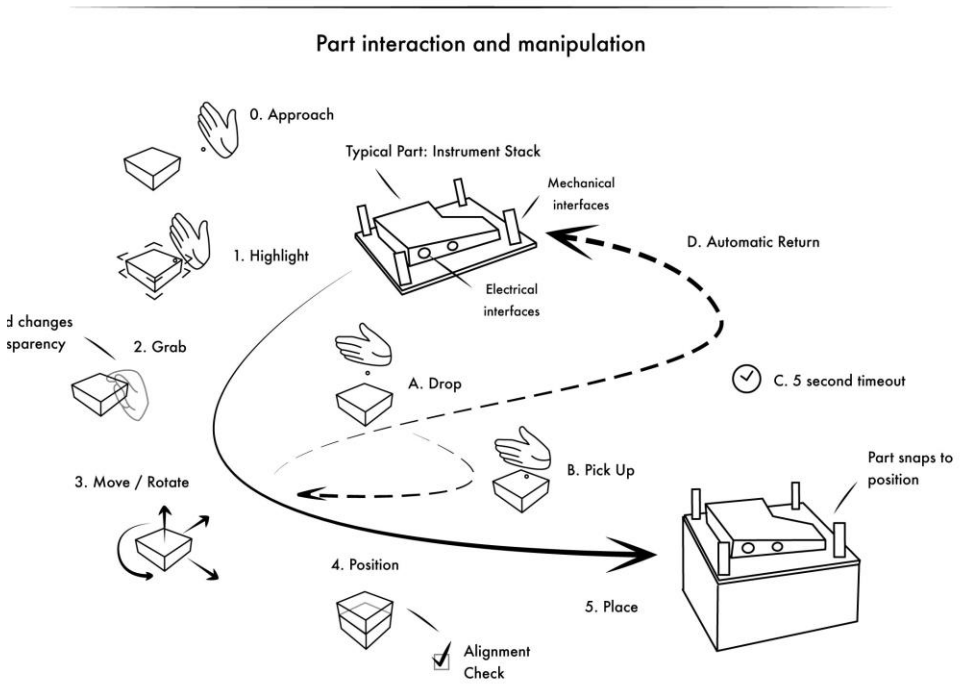
ID	Non-functional requirements
NF-001	The VR training tool is designed as a single user stand-alone tool, which is operated on a local device, and also holds the data locally
NF-003	The VR training tool is run on commercially available hardware
	Etc

ID	Functional requirements
SR-002	The user shall have additional means of locomotion (controller input) besides natural movement to move around the virtual environment, to avoid exiting the work area of the VR setup
SR-016	When the real version of a tool provides user feedback in a form that is unavailable virtually, it shall be approximated or given to the user through visual, audio and/or haptic means
	Etc

UX/UI DESIGN

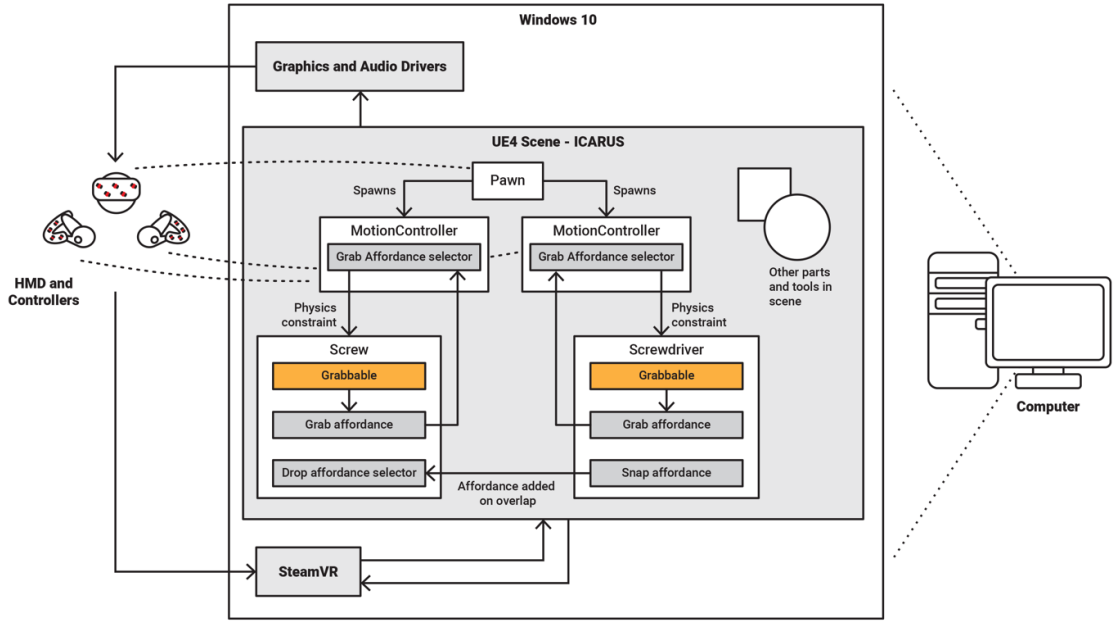
To enable user-friendly and intuitive interaction in the virtual environment, a good **User Experience / User Interface (UX/UI) design** is essential

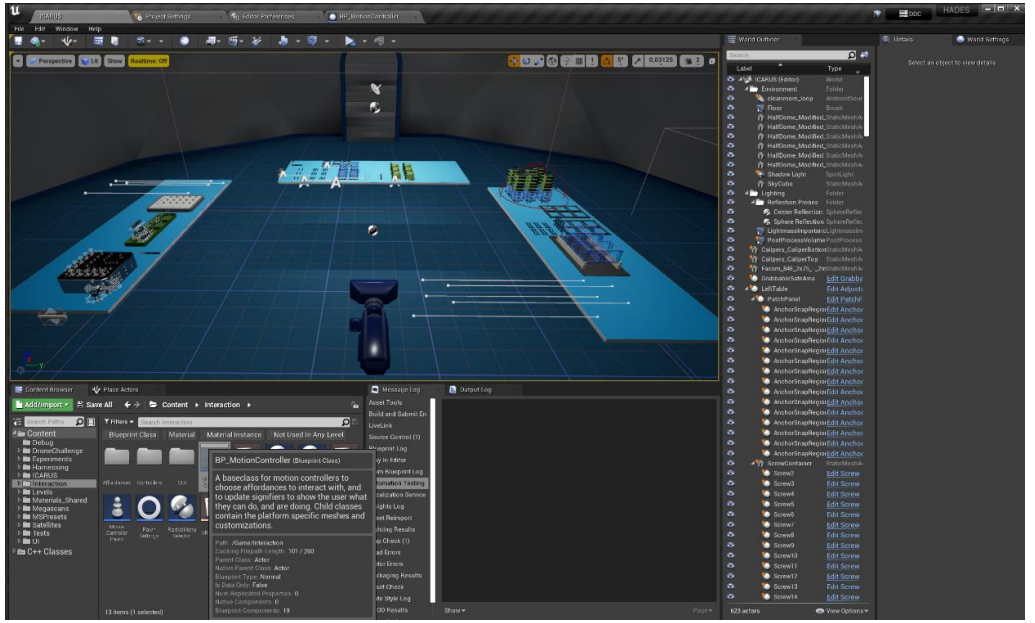




SOFTWARE DEVELOPMENT

ICARUS is developed in **Unreal (game) engine**



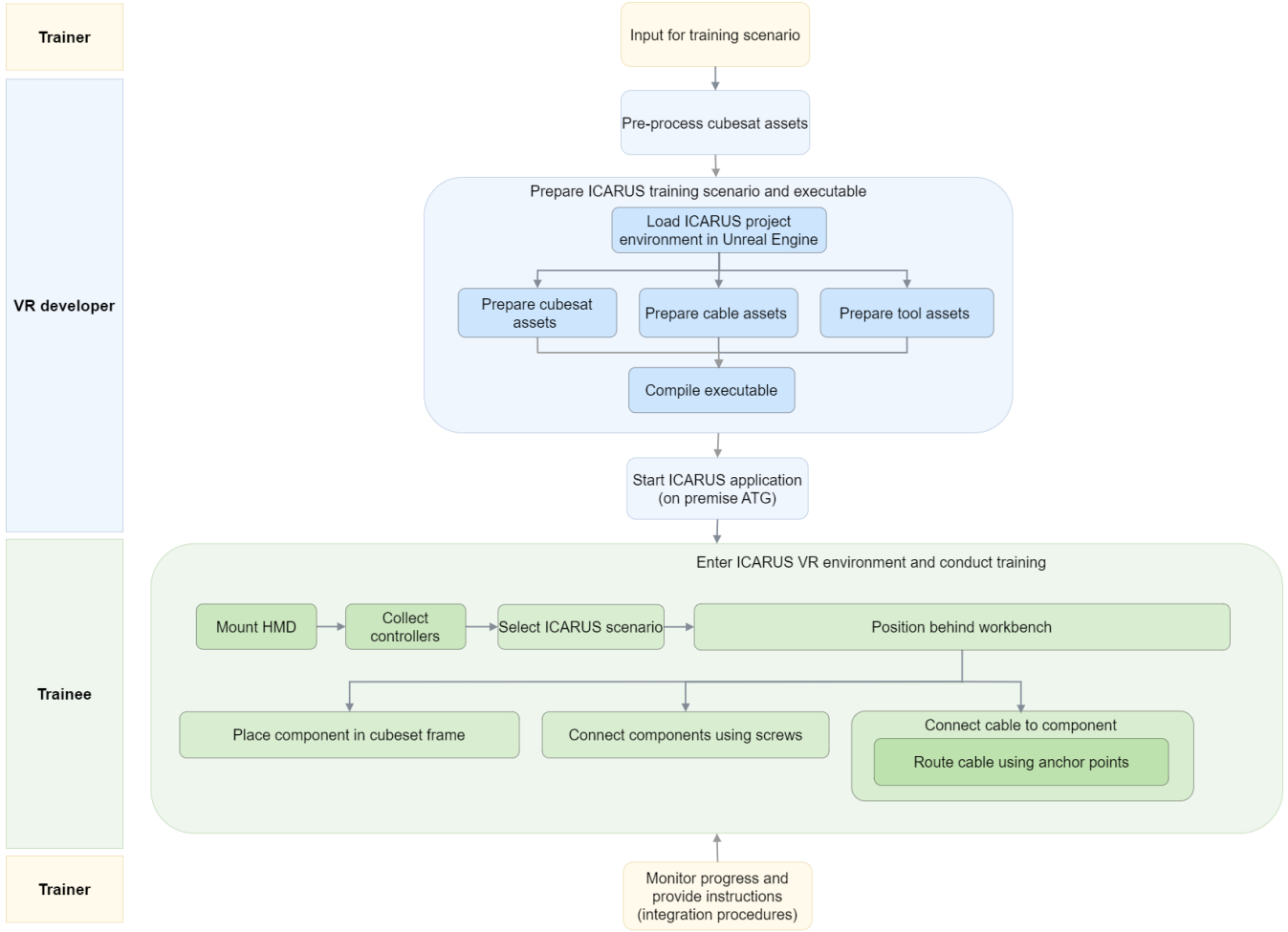


VR SETUP

The ICARUS PoC uses a **tethered desktop setup**. For development and testing, the Valve Index HMD and Motion Controllers are used. This is a commercial of the shelf solution.

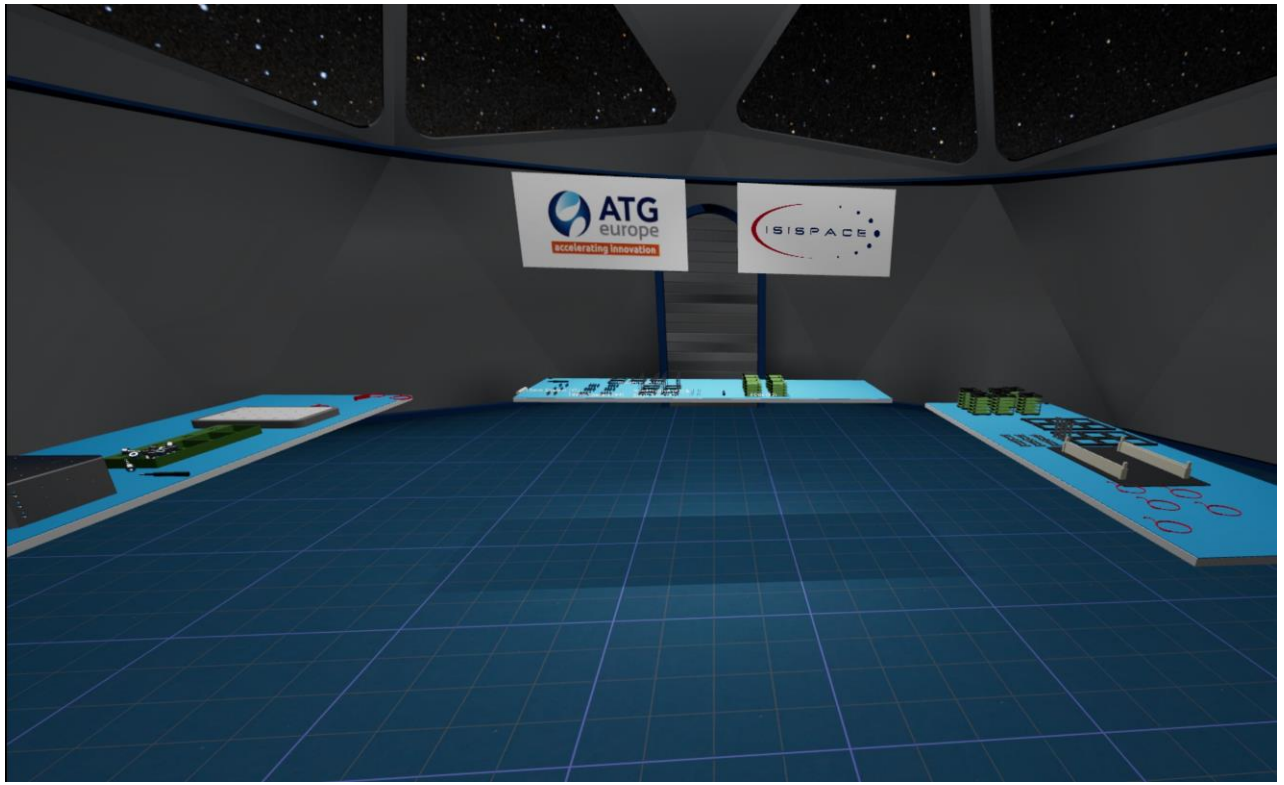
Test facility in **SCN-AVATAR**.

ICARUS POC USER FLOW

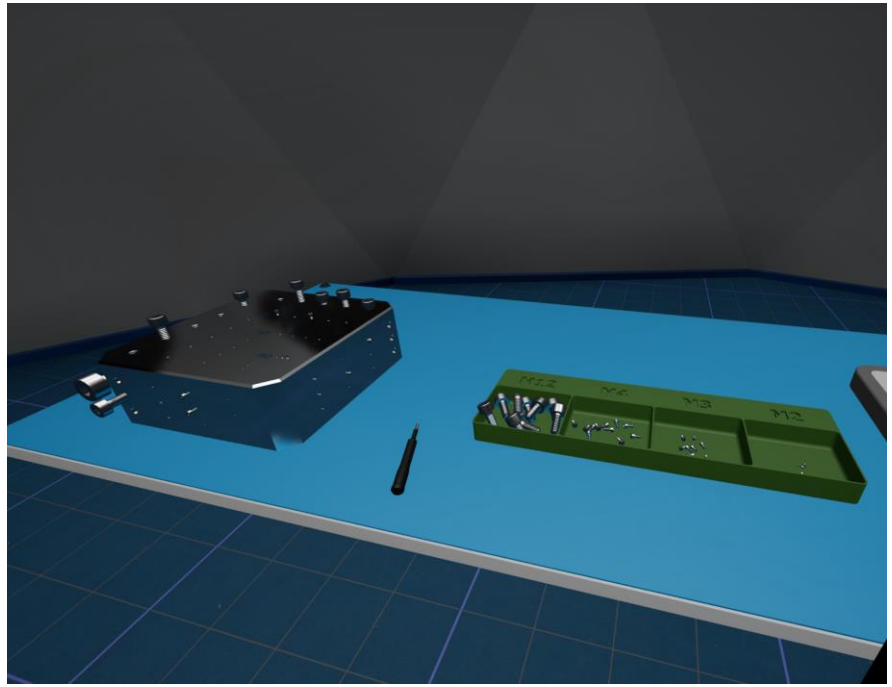


TEST SCENARIO

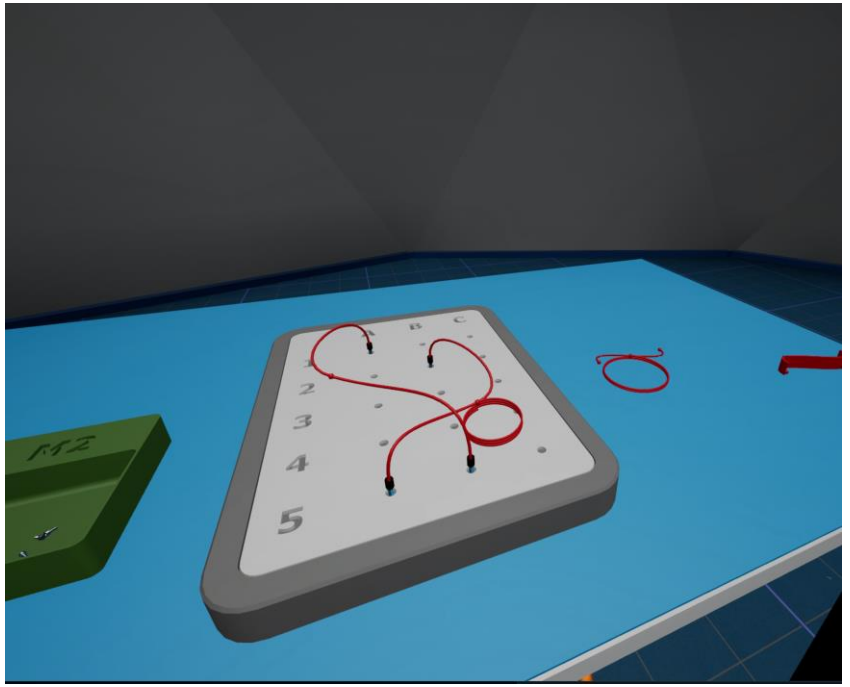
Test / validation scenario focusing on test cases for tools and cables (left table), and on the assembly of a simple example cubesat (center and right tables)



TEST CASES FOR TOOLS AND CABLES

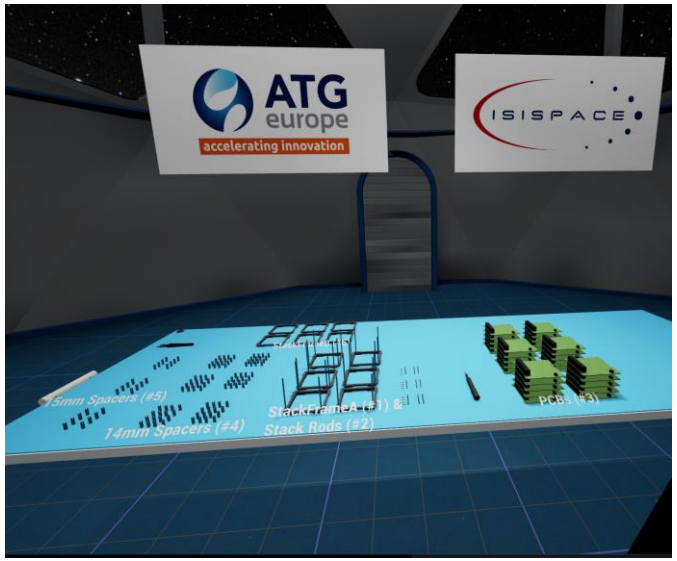


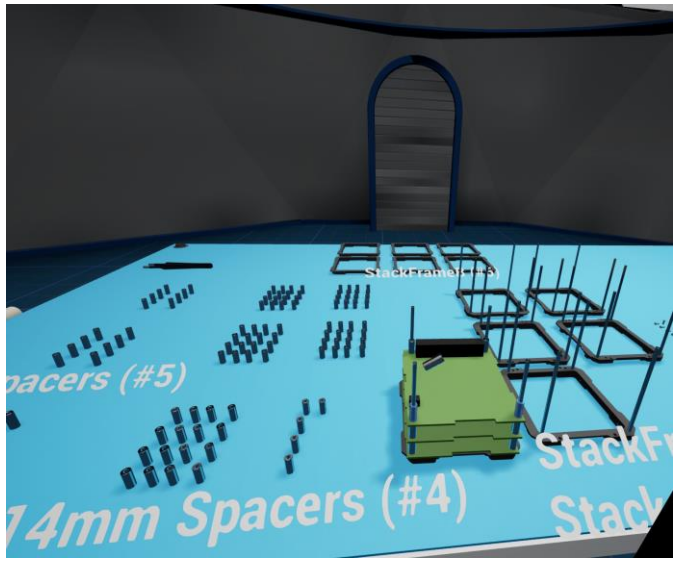
Testing the screwdriver and tweezers with screws of varying dimensions

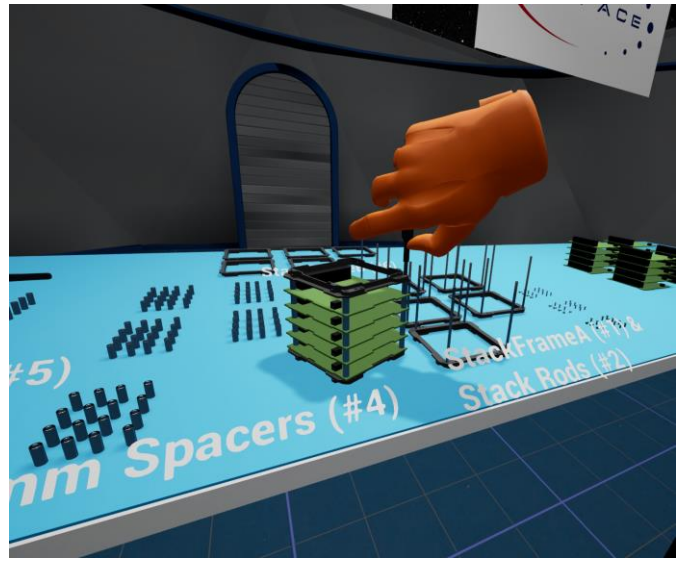


Testing cable patching and routing

ASSEMBLING PCB STACK

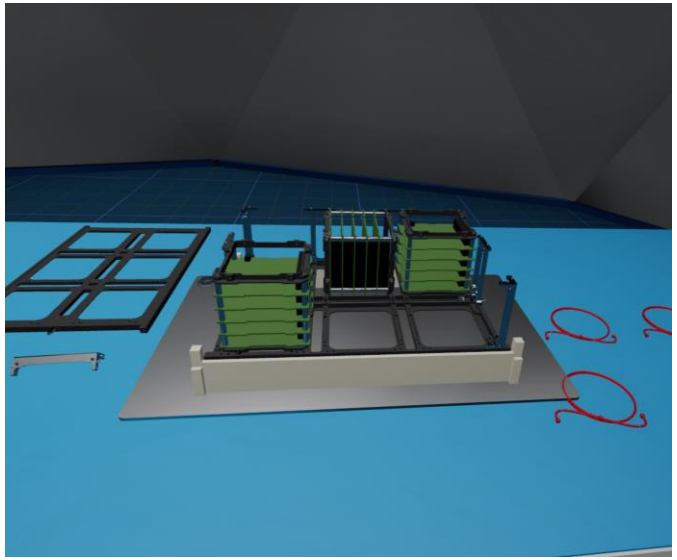


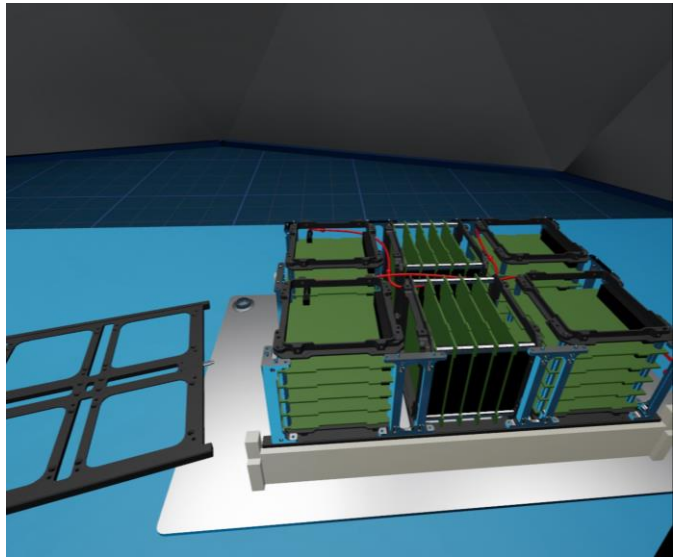


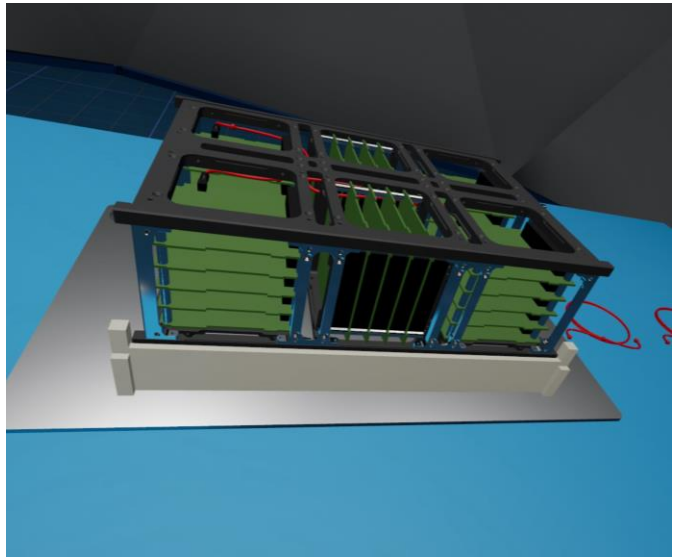


Assembling a PCB stack, by mounting PBCs and spacers of the frame, and fixing them using screws

ASSEMBLING CUBESAT







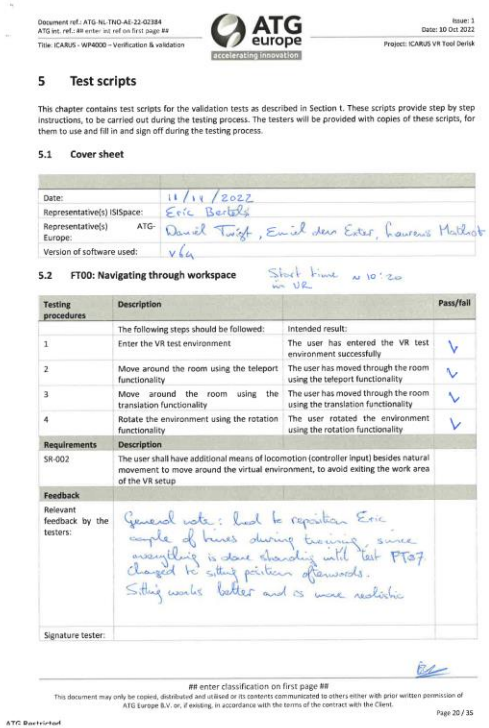
Assembling cubesat frame, mounting PCB stacks, routing cables between connectors

TEST SESSIONS

Testing with user representatives from ISISpace

VALIDATION PROCESS

Validation using scripted tests, the verify whether user stories and requirements are implemented successfully, and to collect feedback and ideas of further improvements



Document ref.: ATG-NL-TNO-AE-22-02384
ATG int. ref.: ## enter int ref on first page ##
Title: ICARUS - WP4000 – Verification & validation

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accelerating innovation

Issue: 1
Date: 10 Oct 2022
Project: ICARUS VR Tool Delisk

5 Test scripts

This chapter contains test scripts for the validation tests as described in Section t. These scripts provide step by step instructions, to be carried out during the testing process. The testers will be provided with copies of these scripts, for them to use and fill in and sign off during the testing process.

5.1 Cover sheet

Date:	11/11/2022
Representative(s) ISISpace:	Eric Berkels
Representative(s) ATG-Europe:	Daniel Tuijt, Emiel den Exter, Laurens Mollet
Version of software used:	v64

5.2 FT00: Navigating through workspace

Start time ~ 10:20 in VR

Testing procedures	Description		Pass/fail
	The following steps should be followed:	Intended result:	
1	Enter the VR test environment	The user has entered the VR test environment successfully	V
2	Move around the room using the teleport functionality	The user has moved through the room using the teleport functionality	V
3	Move around the room using the translation functionality	The user has moved through the room using the translation functionality	V
4	Rotate the environment using the rotation functionality	The user rotated the environment using the rotation functionality	V
Requirements	**Description**		
SR-002	The user shall have additional means of locomotion (controller input) besides natural movement to move around the virtual environment, to avoid exiting the work area of the VR setup		
Feedback			
Relevant feedback by the testers:	General note: had to reposition Eric couple of times during traversing, since everything is done standing until test PT07 changed to sitting position afterwards. Sitting works better and is more realistic		
Signature tester:			

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ATG Restricted

ID	Requirement	Test Case Reference
US-01	As a Trainee I can ready my workspace, so I know where my tools and parts are	FT02
US-02	As a Trainee I can find, navigate to and interact with the assets pertaining to the training with minimal distraction from the surroundings	IT01
US-03	As a Trainee I can to retrieve tools, components or fasteners and lay them out, so I am prepared for an upcoming integration step	FT02
US-04	As a Trainee I can place any training assets in a temporary location, to pick up later	FT06
US-12	As a Trainee I can position hardware elements, so I can secure them with fasteners and have good access with my tools	FT06
US-17	As a Trainee I can connect a wire harness to a specified connector, in order to start or end the wire dressing	FT08
US-18	As a Trainee I can lace a wire harness through/over/under/around/in/out the assembled avionics hardware, in order to match the designed cable paths	FT09
US-19	As a Trainee I can re-arrange the wire harness, in order to match the design cable paths and recommendations	FT09

OVERALL CONCLUSIONS

1. Tools and cables can be represented in ICARUS with **sufficient realism** for the intended purposes.
2. During validation, the current implementation of cables and tools in ICARUS shows no fundamental shortcomings which would jeopardize the successful finalization and utilization in the ICARUS MVP. Several improvements are still possible to further mature the implementation during the ICARUS MVP development. However, none form a significant challenge to implement within the current system design.
3. The feedback collected during the validation process provides clear ideas on how to proceed. Both the effort and the risk associated with these improvements are limited.

Risk ID	Description	Mitigation action	Likelihood		Impact		Risk	
			Pre-Derisk	Post-Derisk	Pre-Derisk	Post-Derisk	Pre-Derisk	Post-Derisk
			[1-3]	[1-3]	[1-3]	[1-3]	[1-9]	[1-9]
Risk 3	Baseline training lacks realism because of oversimplistic representation of tooling	Detailed simulation of tooling motion and interaction with structure	2	0-1	3	3	6	1-2
Risk 4	Baseline training lacks realism because of oversimplistic representation of cable(s) routing	Detailed representation of cable routing including representation of physical cable properties	2	0-1	3	3	6	1-2

The likelihood of the risks considered has been substantially reduced, to the point these risks are well manageable within the further MVP development

IMPRESSIONS

"Would be useful if the tools would automatically snap to the most common position in which these are held"

"Cables are already super useful and good"

"Good to also train situational awareness in the VR environment"

"Would also be useful to define or improve the integration time plan, by means of timing the integration process in the VR environment"

"Useful tool to bridge the gap between design and assembly"

"We're already very enthusiastic about the tool!"

NEXT STEPS

GSTP project (application in progress), to further develop the ICARUS Minimum Viable Product. With a focus on:

- Maturation of functionality included in the PoC and development of additional features required for usage on-site (to enable a more seamless connection with the users' digital models and training procedures)
- Further design of the virtual training environment
- Validation of the MVP in a relevant commercial environment