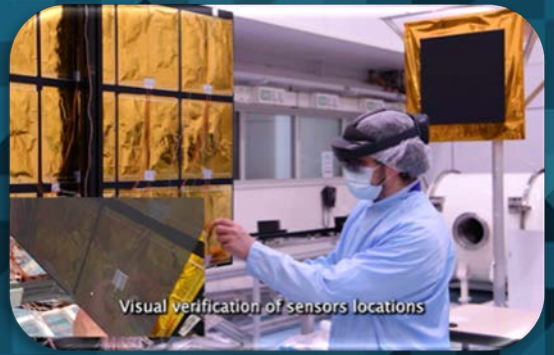
Digitalisation of Procedure and Introduction of Augmented Reality



Kaj Helin (VTT), Jaakko Karjalainen (VTT),
Paul Kiernan (SKYTEK), Gianluca Casarosa (ESA)

Content of presentation

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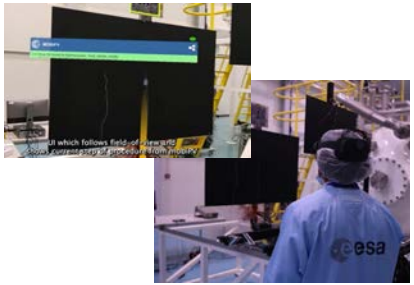
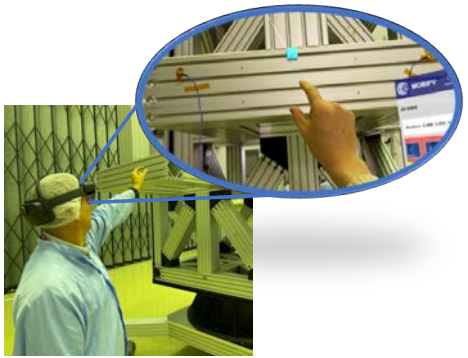
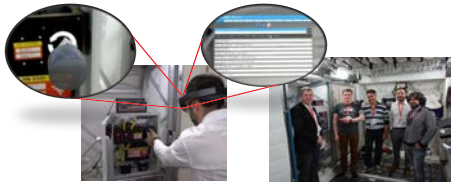
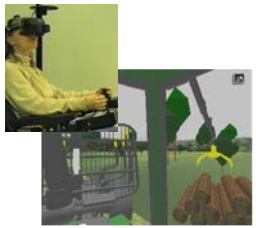


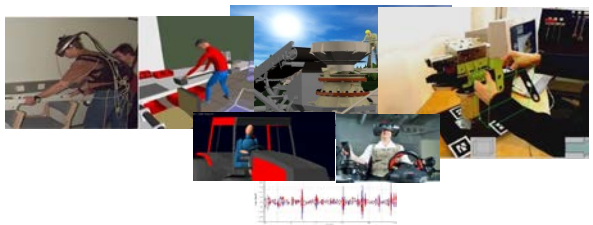


30 years history of **eXtended Reality (XR)**
More than **100 cases** with end-users



1994	1996	1997	1998	2002	2006	2007	2009	2010	2012	2014	2016	2018	2019	2021	2022	2023
The First Virtual Environment in projects	The first vehicular machine simulations for design	Several industrial cases, e.g. Rauta-ruukki	VR and MoCap for manual task design	Easy-to-use DHMs (kinetics and kinematics)	Maintenance work design and training in VR	Augmented assembly (AugAsse)	Manual work System lifecycle & VR&AR	Next Generation HCD VE for Mobile Machines	VR & MR to increase human comfort	VR/MR/AR Continuum – design to factory floor	ESA – AR for AIT, AIV and Orbit Operations	Drone control via MR	AR for situation awareness for border security	ESA – AR based ISS and ground applications	AR supported BIM	XR supported remote operation of Off-Highway Machinery





Space related VR/MR/AR research ~18 years

2005 - Multimodal astronaut virtual reality training prototype (View-of-the-future)

2013 - Multimodal AR-presence system with Mars rover prototype (VR-HyperSpace)

2016 - Augmented Reality for AIT, AIV and Orbit Operations (ESA-EdcAR)

2018 – AR based Rover Maintenance in Mars Terrain Demonstrator (WEKIT)

2019/21 – Augmented reality based ISS and ground applications (ESA-AROGAN)

2023 – Digitalisation of Procedure and Introduction of Augmented Reality (Step 1) (ESA-DPIAR-V1)

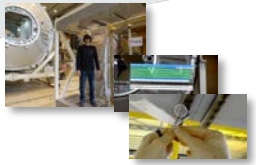
2024

2022 – Virtual workplace for AIT & PA training and operations support (ESA-VirWAIT)

2022/23 – Lightfield-enhanced immersive teleoperation system for space (ESA-LightSpace)

2005

2009 - Satellite assembly design in VE (ManuVAR)

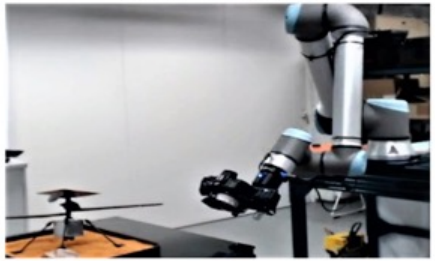


2017 – AR supported installation of the Temporary Stowage Rack in the ISS (WEKIT)

2019 – ISS procedure viewer to Hololens (ESA-MobiPV4Hololens)

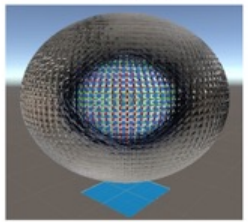
LightSpace - 'Lightfield-enhanced immersive teleoperation system for Space'

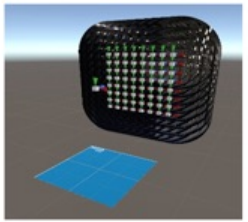
Data capture → *Data processing* → *Lightfield authoring* → *Lightfield rendering*



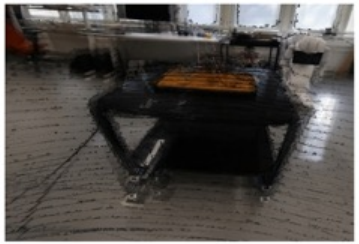
UR10e / Canon EOS R5 / Canon RF 5.2mm F2.8L Dual Fisheye lens

Python / OpenCV





Unity Real-Time Development Platform



XR HMD

Vladimir.Goriachev@VTT:FI

Lightfield rendering

Planar lightfield

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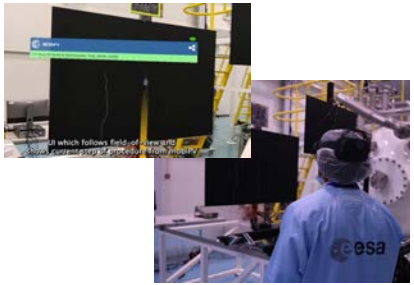
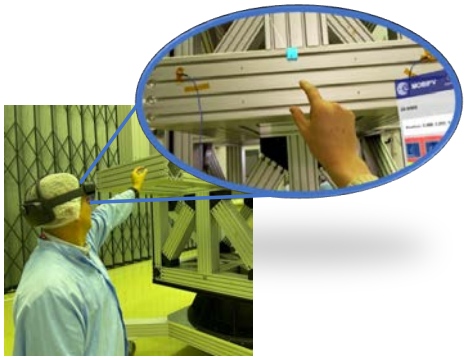
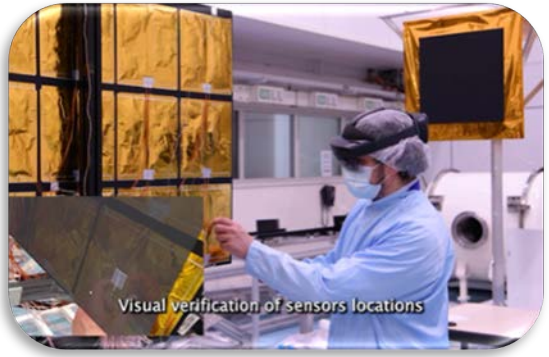




VirWAIT & DPIAR-v1

Digitalisation of Procedure and Introduction of Augmented Reality



Kaj Helin (VTT), *Jaakko Karjalainen (VTT),*
Paul Kiernan (SKYTEK), Gianluca Casarosa (ESA)

esa

VTT skytek

VirWAIT - Virtual Workplace for AIT & PA Training and Operations Support
Project objective

These studies has been funded by the European Space Agency under contract 4000129549/19/NL/BJ “Virtual Workplace for AIT & PA Training and Operations Support ”.

Main objective of these activities are to develop a virtual workplace supporting training, AIT and verification tasks of operators in order to reduce system& design induced human errors severely impacting the AIT schedule.

The sub-objectives of the proposed development are to

- The activity shall assess the state-of-the-art of technologies suitable for supporting AIT and verification tasks;
- Identify a pilot case where a Virtual Workplace can be applied across different locations/sites using AR/VR e.g. to execute ground system compatibility verifications and end-to-end tests;
- Perform the tasks as required to implement and test the pilot case and evaluate benefits based on criteria to be agreed with the Agency;

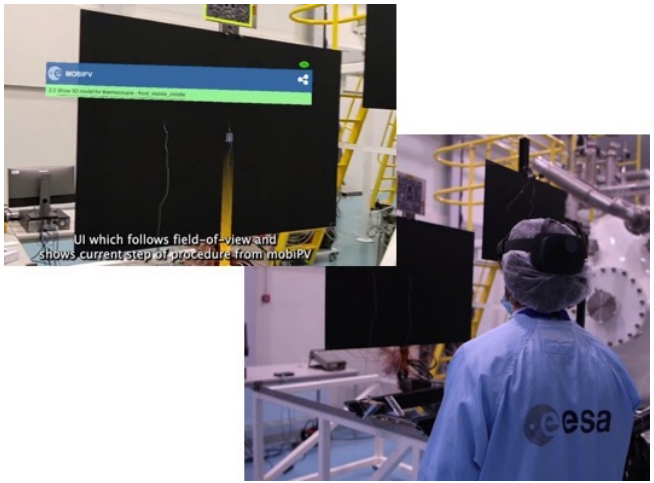
Use cases

To verify the main project objectives, two most relevant use cases were selected:

- MR supported installation of thermocouples on *an Heat Plate used as GSE for the Solar wind Magnetosphere Ionosphere Link Explorer – SMILE*
- MR supported phase 2 sensor installation on *TEDY (Test DummY) for a vibration test campaign on the Hydra facility*

The system was preliminary tested for the configuration of the JUpiter ICy moons Explorer's (Juice) Network Data Interface Unit (NDIU) in preparation to the Thermal Vacuum test campaign held at ESTEC.

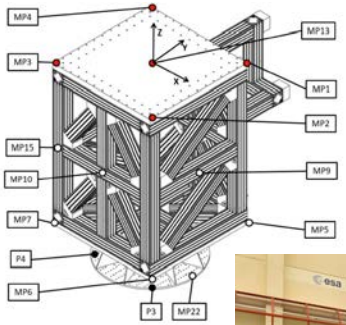
MR supported installation of thermocouples on an Heat Plate used as GSE for the Solar wind Magnetosphere Ionosphere Link Explorer – SMILE

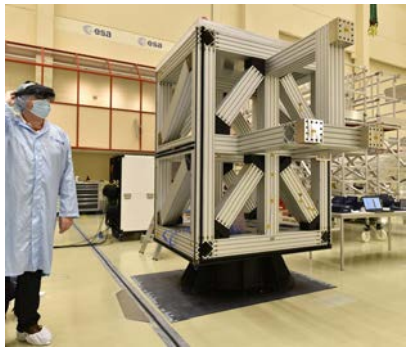


- Main objective of SMILE's use case was installing thermocouples
- Visually evaluate already installed sensor's location
- Procedure includes 32 steps
- Procedure was authored based on STEP 3D model and procedure description

(Video in later on presentation)

MR supported phase 2 sensor installation on TEDY (TEst DummY) for a vibration test campaign on the Hydra facility

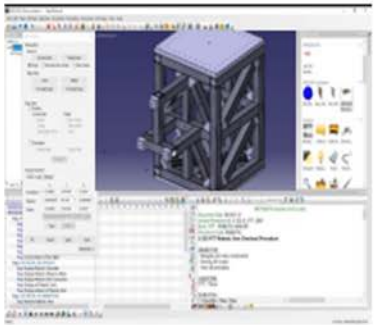




- Main objective was installing phase 2 accelerometers to TEDY
- Visually evaluate phase 1 installed sensors location
- Procedure includes 28 steps
- After sensor installation user used MR application to locate final position of sensor and took picture of its location

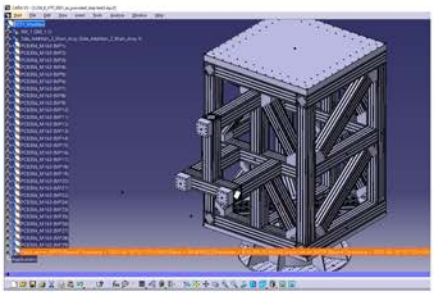
  => The system were able to update STEP model based on information
- Procedure was authored based on STEP 3D model and procedure description

System workflow



Content Authoring

Mixed Reality based procedure support

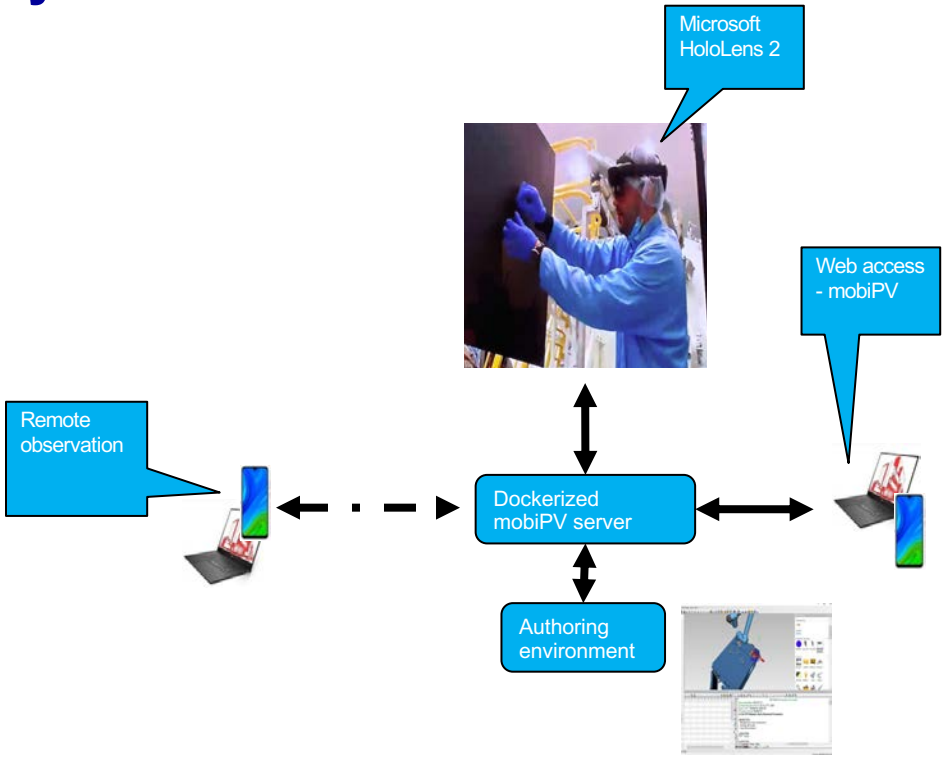


Automatic reporting and As-build 3D model

Main functionalities of MR system

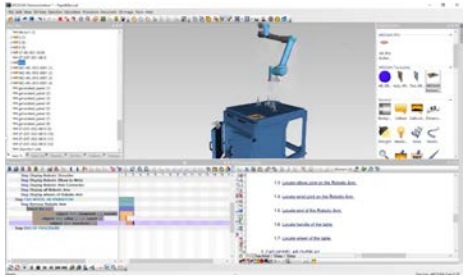
System includes:

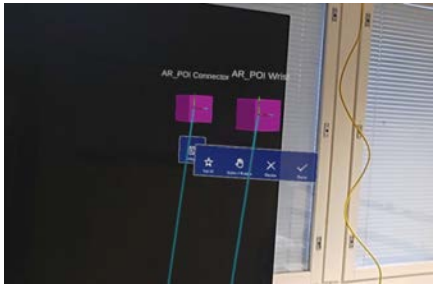
- Microsoft HoloLens 2 with MR-player app,
- mobiPV – server for all Operations Data File (ODF) content, MR annotation and 3D models with animation
- mobiPV's web interface, which also allows to the user interact with systems
- Authoring environment, which is including on-site and off-site authoring.
- Remote observation via web access
- Reporting, including the as-build STEP model



The authoring environment

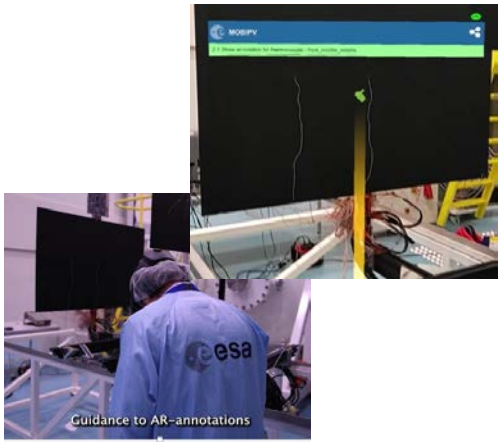
- Off-site authoring:
  - Usage of a 3D model for interactive definition of Point-of-interests
  - Associated of icons to be used for highlighting of POI items
  - Create of 3D animations through applying simple verb E.g., Screw/Detach Object etc.
  - Link these to ODF step
- On-site authoring:
  - Create new Object and Trackable Instances
  - Create and/or modify Resource Messages containing the AR Object and POI data needed for mapping the real-world environment





MR-player

- Voice and gesture based control
  - Voice commands e.g. “Betsy Next” *
- Augmented reality annotation in 3D space
  - 3D models
  - 3D models animation
  - 2D symbols
- Guidance to information in 3D space
- Pictures and videos
- Linked to mobiPV server (websocket)
- Using the built-in HoloLens 2 camera for Notes images and video clips capture
- Text-to-speech
- Select installed sensor and cable from list
- Add the final location of installed sensor



* “Betsy” added to all navigation commands to minimize side-talk issues

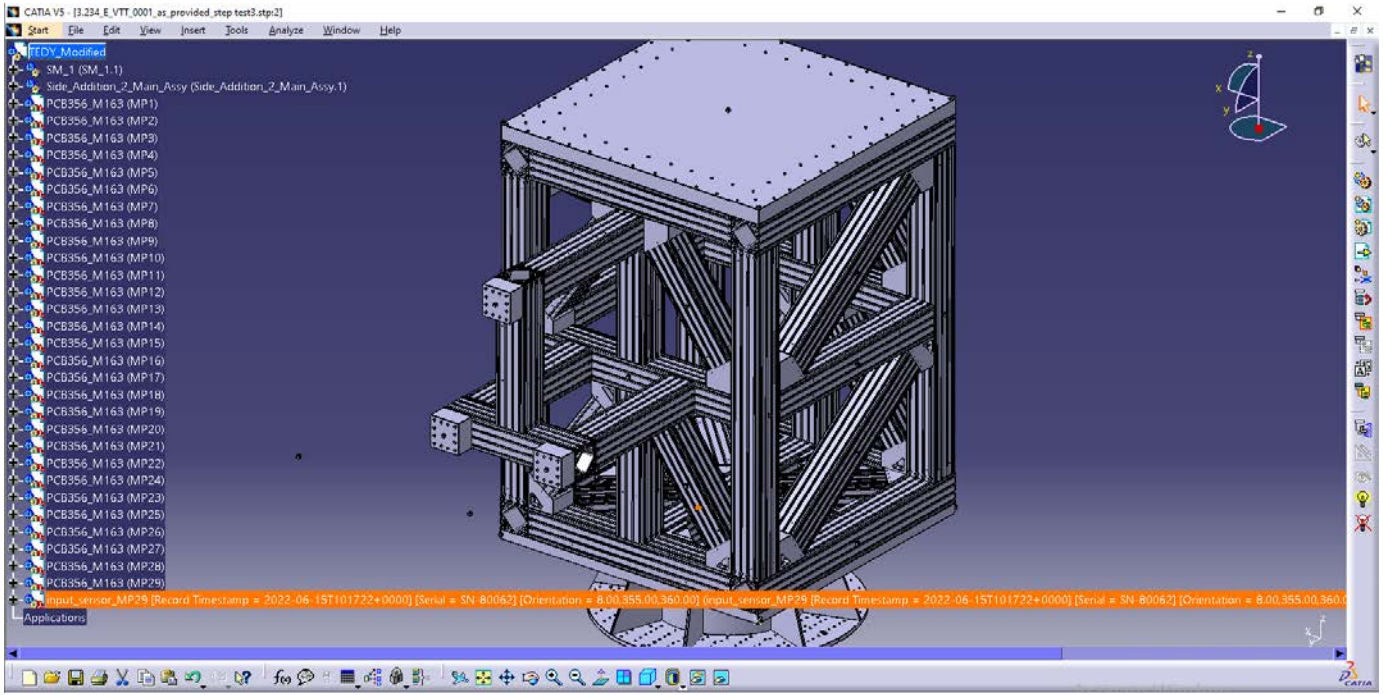
Remote observation

- Video streams are captured both from the iOS tablet and from video camera e.g. GoPro device connect to Hololens 2
- Streams are accessible via WebRTC during execution from remote server i.e. https://ant.skytek.com:5443/ by a remote observer using standard browser
- Streams are also stored for later access, playback and download
- Archived streams can be searched for and accessed via:
  - Procedure number
  - Procedure identifier
  - Date/Time of test campaign
  - Sensor identifier
  - Cable identifier
- Result launches related video at relevant timestamp

Reporting and STEP model update

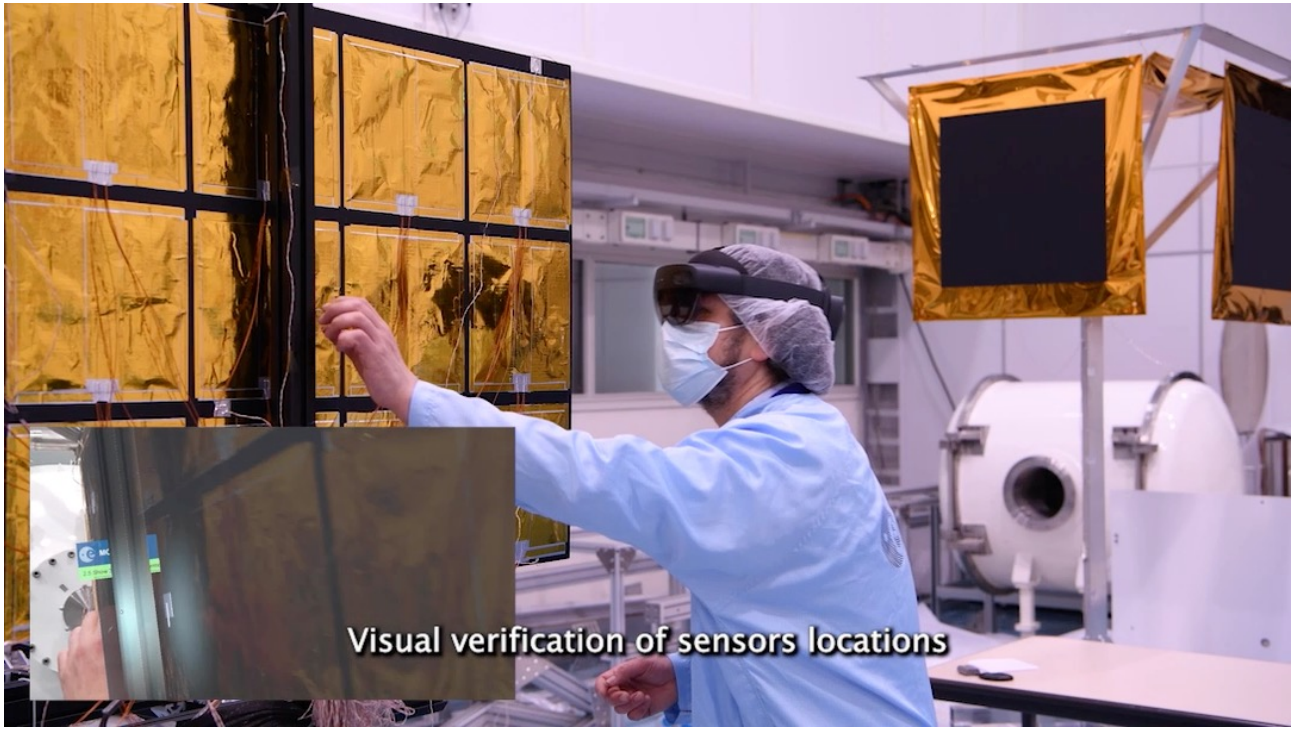
- ‘As run’ STEP model with placed sensor positions and metadata are generated during procedure execution
- Reports i.e. STEP files and Excels saved onto central server for access via a standard web browser
- Generation of STEP file implementation updated to support Catia V5 compatibility with stricter STEP parsing
  - Unique and increasing without gaps in numbering of each line in STEP file
  - Removal of not allowed symbols in meta-data

Reporting and STEP model update



Catia V5 showing ‘as-run’ configuration with sensor placed

Video of AR-player



https://youtu.be/gefrH8EJXWU

Main outcome and Conclusion

- Main results based on User Review
  - The MR-system is seen to have the potential to improve the work task (and similar tasks) as the sensors have to be placed based on printed CAD models and guides.
  - The MR-system can significantly speed up the work
  - The system calibration is critical function for system reliability
  - Experienced and non-experienced user viewpoint could be utilized in UI
  - The SUS score averages (73) from the both tests indicate acceptable system usability
    - But do not provide statistical significance due to low number of test users

- Based on project results, we could conclude the developed MR-system has potential to become a useful tool for AIV/AIT applications
- And the MR-system could significantly speed up the current work and provide motivating novel tool for the operators and engineers

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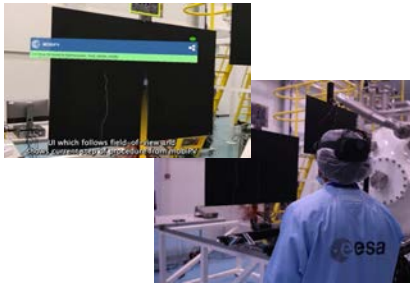
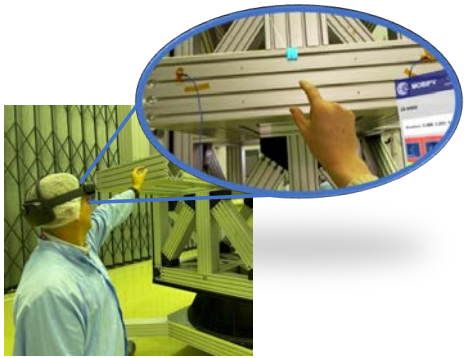
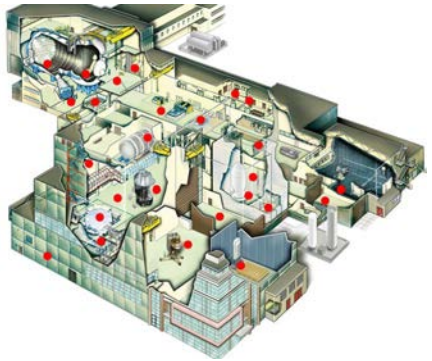




DPIAR-V1 - Digitalisation of Procedure and Introduction of Augmented Reality (Step 1)
Project objective

These studies has been funded by the European Space Agency under contract 4000140015/22/NL/MG “Digitalisation of Procedure and Introduction of Augmented Reality (Step 1)”.

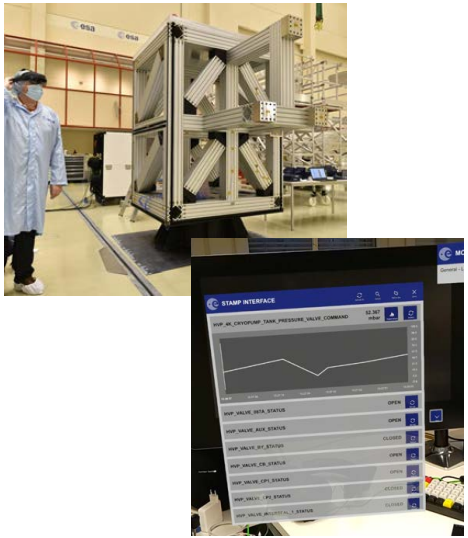
The main objectives of this activity are to provide the Test Centre of the European Space Agency with a tool for the authoring and visualization of maintenance and operations procedures and to support its deployment.



Use cases

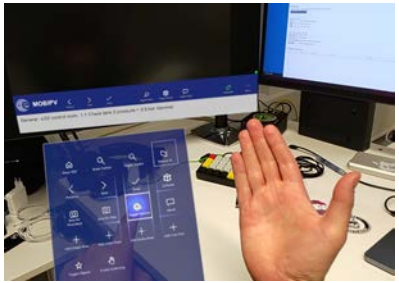
To verify the main project objectives, three most relevant use cases were selected:

- *Large Space Simulator* – LSS Basement procedure
- *Vacuum Test Chamber* - VTC1.5 Operating Procedure and Pre-operation
- Modified *TEDY (Test DummY) for a vibration test campaign on the Hydra facility*

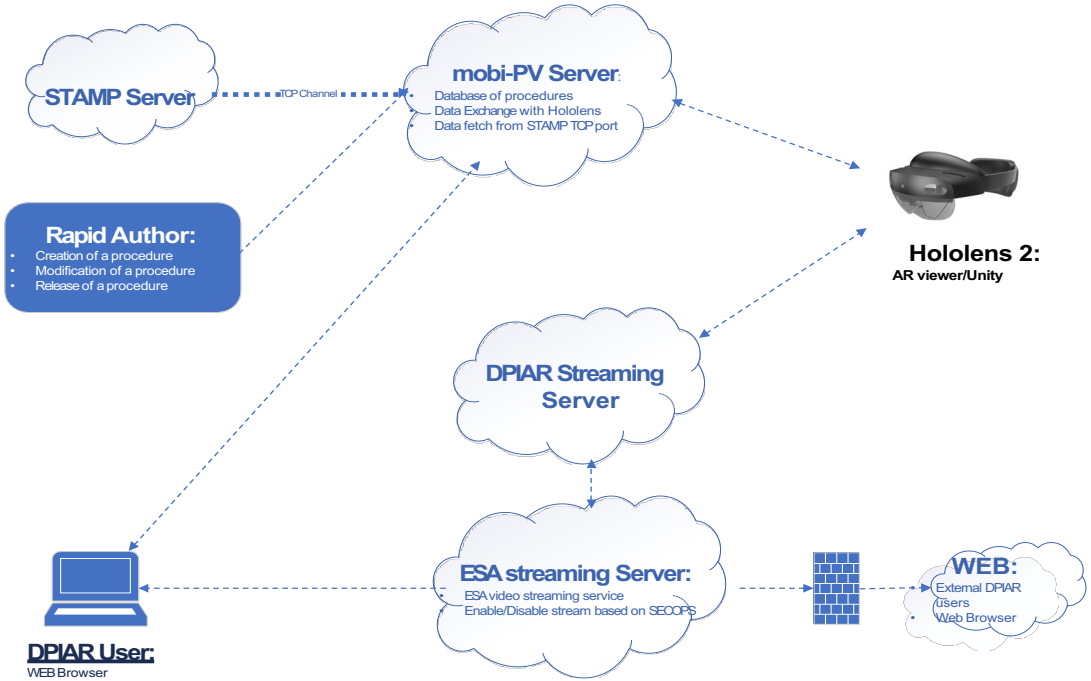


Main improvement to MR system, including authoring

- Implementation to ESA network infrastructure
- Semi-automatic authoring
- Scan market / QR code for procedure and procedure step
  - Automatic generated markers from authoring
- Real time sensor views in AR (STAMP)
- Several usability issues
  - E.g. better and adaptive hand menu
- Reporting
  - Updates needed from AR -viewer
    - Improvements of notes
    - Task lists

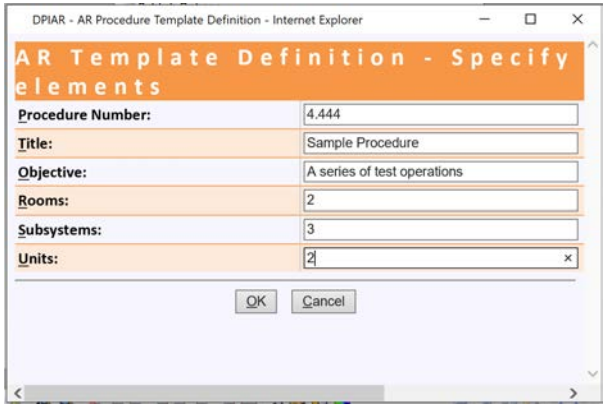


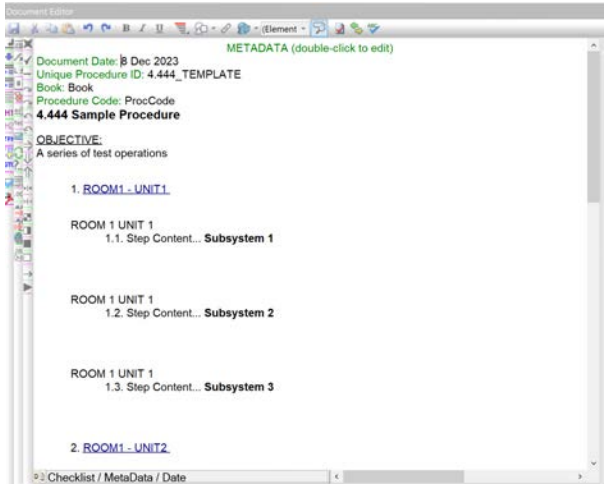
Implementation to ESA network infrastructure

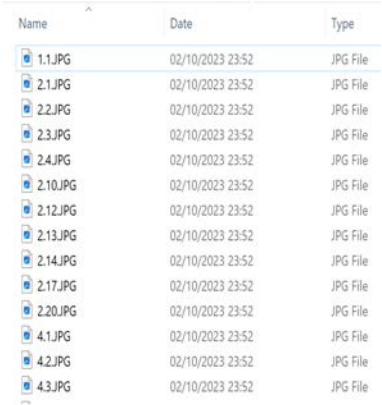


Semi-automatic authoring

- The template add information such as procedure title, number of rooms, subsystems and units.
- Automatic linking of picture / step

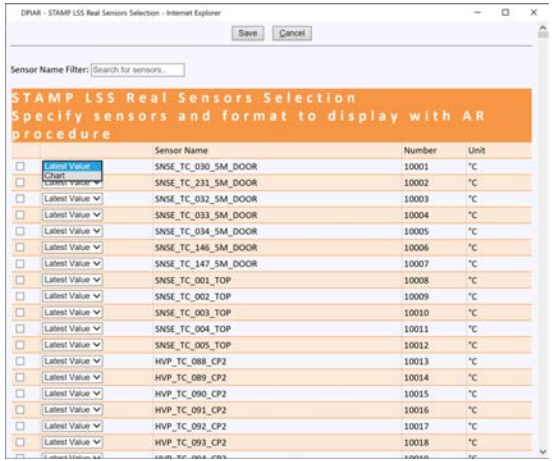






Real time sensor views in AR (STAMP)

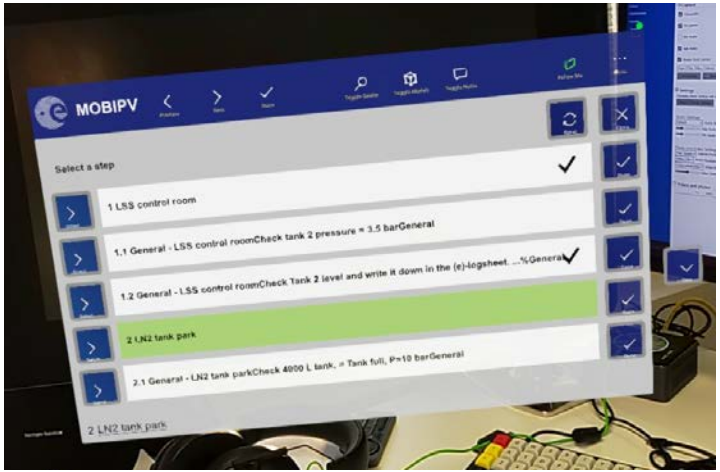
- AR player is able to show STAMP sensor date in real time
  - All sensors (by search)
  - Predefined set of sensor
    - Value / chart



Reporting with and without STEP model

- Report template for procedures which do not use 3D model

- Updates needed from AR -viewer
  - Improvements of notes
    - Audio notes
    - Text note
  - Task list
    - Mark step as done



Next steps

- Tomorrow will be acceptance tests in the Test Centre of the European Space Agency

- Which us Good Luck!!

Kaj Helin

Principal Scientist, Certified Project Manager IPMA

Human, Robot and Mixed reality solutions

VTT Technical Research Centre of Finland Ltd

Kaj.helin@vtt.fi