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Augmented and Virtual Reality for Ground Station and Telescope Maintenance at ESOC

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Technical Themes:

- AR/VR authoring environments, including standards for models and procedures input
- Development and availability of 3D models
- Interfaces between AR/VR and other systems, how to integrate

Abstract

The activity presented here focused on the use case of introducing and utilizing AR and VR technologies in support of (remote) maintenance tasks in ground stations and telescopes at ESA/ESOC.

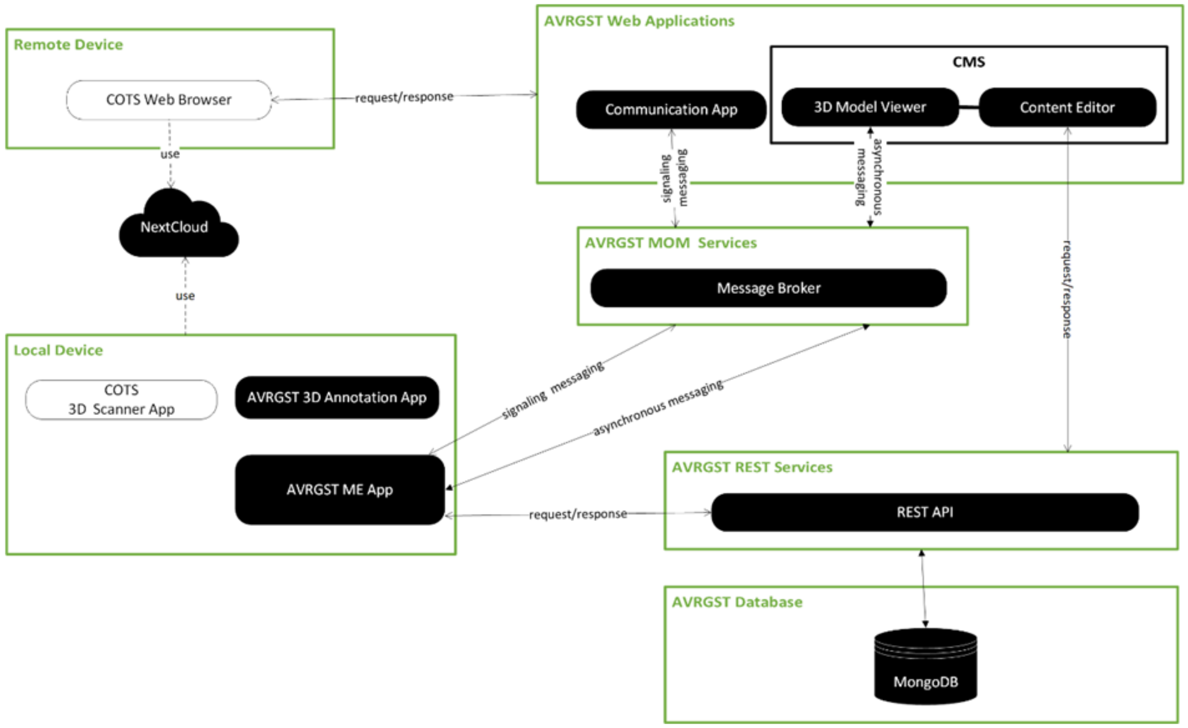
The study is executed in the context of previous and parallel activities on leveraging AR/VR for space operations activities at ESOC. The previous and parallel activities focused on technology assessment, demonstrators and use case discovery, and developments of proof-of-concept demonstrators in spacecraft operations.

Unique to this activity compared to other AR/VR related activities in spacecraft operations is the in-situ handling of real hardware, e.g., ground station or telescope equipment. In contrast to this, in spacecraft mission operations, no real hardware can be accessed directly as spacecraft or rovers typically operate in space or on other celestial bodies without physical access. This has a strong implication on the suitability for using AR. Due to the nature that in ground stations and telescope operations, real hardware can be directly accessed, advantages of AR can be better leveraged. It is possible to combine real objects with augmented functionality like virtual computer-generated content for, e.g., displaying instructions, interactively taking notes, recording status information, or navigating in real environments with the help of AR overlays.

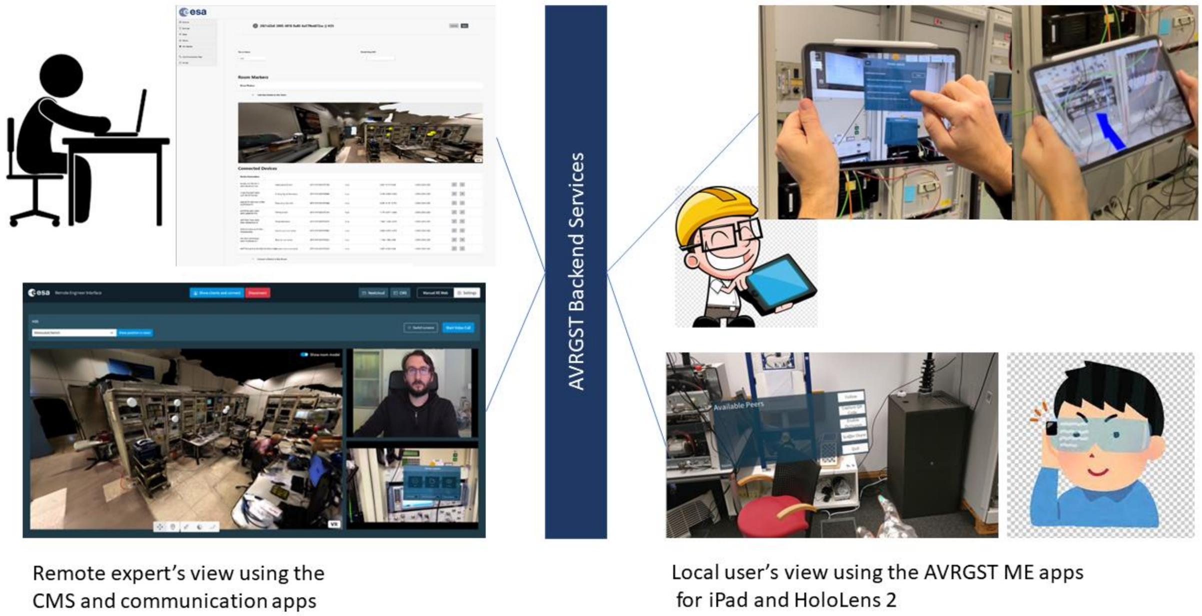
The main activity was split into three phases. In addition, a follow up activity aims on operationalizing the results from the main study activity:

- **Explorative phase:** This phase explored potential use cases of AR/VR with the domain and the required technology assessments. The use case analysis aimed to identify useful application scenarios and use cases which could also streamline the design and development of the actual prototype to be developed later. The technology assessment aimed to allow a methodologically driven approach for the selection of required Commercial-off-the-Shelf (COTS) hard- and software solutions, which are an integral part of the prototype. The use case scenarios influenced the technology assessment on one hand, while the feasibility of use cases depended on available technologies on the other hand. Because of this interdependence, both tasks were executed simultaneously in an iterative process.
- **Development phase:** In this phase, a prototype was implemented covering the selected use cases and their assessment. It was initiated by an architectural design followed by the agile and iterative implementation of the envisaged prototype. The architecture principle and the design of the system followed the client-server model. The system was divided into three layers: the client layer, the service layer, and the resource layer.
- **Deployment and Application phase:** In this phase, a demo application using our developed proof-of-concept (PoC) implementation was applied at ESOC. In cooperation with the users, the system was further improved, and an operational system deployed to ESOC Ground Stations.
- **Operationalizing the Study Results:** The results of the main activity were well received by the prospective users. As follow-up to the main activity, currently, additional work is done to deploy the study results operationally. This includes, e.g., operational client/server deployment at ESOC and at ground stations, polishing of prototypical implementations, further improving the solution for the operational use.
  In addition, operational integration into operational ESA systems such as the ESTRACK asset database will be investigated. One key aspect is that this must not violate operational security demands.

The developed AVRGST software provides different kinds of applications and services as depicted in the figure below:



An overview of the AVRGST applications is depicted in the figure below. The left side of the figure presents the remote expert being supported with the developed Content Management System (CMS) and the communication applications. The right side of the figure shows the Maintenance Engineer (ME) being supported with the ME applications. Both Remote Expert (RE) and ME applications are based on the AVRGST services.



Augmented and Virtual Reality for Spacecraft Operations at ESOC

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Technical Themes:

- AR/VR authoring environments, including standards for models and procedures input
- Reduction of the AR/VR scenarios preparation time
- Development and availability of 3D models
- Interfaces between AR/VR and other systems, how to integrate

Abstract

This presentation reports results of an activity on using AR/VR for spacecraft operations at ESOC. It is situated in the context of previous activities on leveraging AR/VR at EAC and ESOC. Previous activities had a more general scope, considering, e.g., technology assessments and a wider range of use cases not only in spacecraft operations but also human spaceflight.

Aims of this activity were:

- Find meaningful application areas, where AR or VR could bring value to spacecraft operations.
- Put AR/VR in operational deployment for spacecraft operations.
- Identify use cases, where AR/VR adds real value to the operational team in their day-to-day tasks.
- Surpass the “novelty” and “PR-effect”.

Key results of the activity are:

- Survey of Use Cases for AR/VR in Spacecraft Operations
  To provide real value, we identified key properties of AR/VR such as immersion, 3D view perception, etc. to assess the applicability of AR/VR to day-to-day activities. E.g., a peculiarity when considering AR/VR for spacecraft operations is that, typically, the involved assets, i.e., the spacecraft in space, are not physically accessible by operators. This activity explicitly set out to focus on spacecraft operations in contrast to other scenarios such as Assembly Integration and Testing (AIT), in which physical access to the real devices is possible. While there may still be physical models on ground, generally, for operations, the access to the real device is reduced. This impacts the applicability of AR features which require real counterparts on which virtual content can be overlayed on.
  Furthermore, spacecraft, unlike, e.g., a future Moon or space station or a rover operating on the surface of a celestial body, are no environment in which one would “go” as a person, which limits the utility of the immersive properties of AR/VR.
- Prototype of a Content Creation and Management Pipeline for 3D/AR/VR Content
  The pipeline is used to create all required 3D assets and to manage them and the associated metadata, e.g., from the SCOS 2000 (S2K) mission control system (MCS).
- Experiments for using 3D scanning with off-the-shelf consumer hard-/software for creating 3D models.
  In many activities we observed that availability of 3D models is problematic because of, e.g., Intellectual Property Rights (IPR) constraints, 3D model conversions, geometry reduction, etc. For this activity, we experimented with 3D scanning using off-the-shelf consumer hard- and software for enabling quick and cost-efficient creation of 3D models.
- AR/VR for Annotating 3D Models
  Displaying telemetry on top of a 3D model requires that 3D models are annotated with location information regarding where a telemetry display or marker shall be shown. To make this process easier and more accessible, we implemented an AR prototype application for placing annotations on a 3D model.

- Prototype of a Hybrid Data Display, of 3D and Timeseries Views, for Showing Spacecraft Telemetry
  Displaying telemetry data on top of a 3D model makes it easier to recognize spatial relationships in the data. Showing telemetry in a timeseries x/y plot over time makes it easier to recognize time relationships. The hybrid display combines both views to show telemetry data in the dimensions time and space.
- Integration with ESOC Data Retrieval Service

One goal set during the activity was to reduce the complexity of creating 3D/AR/VR content. The goal was to make creation of content quick and inexpensive. Ideally, it should be possible to create content ad hoc within about 30 minutes from zero to a working minimum viable solution. This would enable users to create content themselves on demand as needed such that the advantages of 3D/AR/VR content can be easier leveraged and further spread. While the concrete duration for preparing content still depends on the current use case, we consider that the applied technologies and content creation pipeline support this goal.

Another result of this activity is that AR/VR is used more in supplemental tasks than in a prominent core use case. However, we consider that this is still an important application as we think it enables use cases that would not be possible otherwise. We consider that AR-supported 3D scanning, AR/VR-based 3D model annotation, and the content creation pipeline, make the creation of 3D/AR/VR content less costly and more accessible.

The picture below shows actions in a typical use case:

- Create a 3D model with 3D scanning.
  Alternatively, existing models can be imported.
- Annotate the 3D model.
  The implemented proof-of-concept supports annotations with tablets using AR and non-AR modes and with a Desktop PC application.
- Integrate with spacecraft data sources.
- Display the spacecraft data in the Hybrid data display web app, showing 3D and timeseries plots.

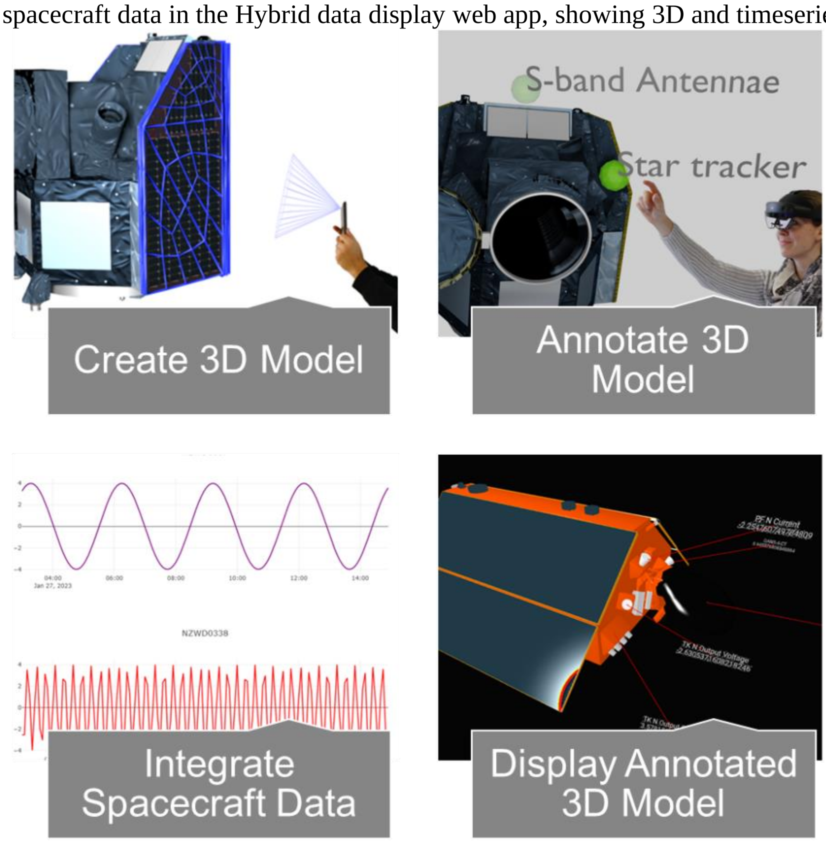

Figure 1 Example of Actions in a Use Case