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Bremen



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für Luft- und Raumfahrt
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University Bremen
Workgroup High-
Performance
Visualization

Faculty 3
Mathematics and Computer Science

DigiTwinAIT

Augmented Reality and model-based AIT Support

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Satellite Manufacturing

- Human centred approach
- Divided into many phases assessed through reviews

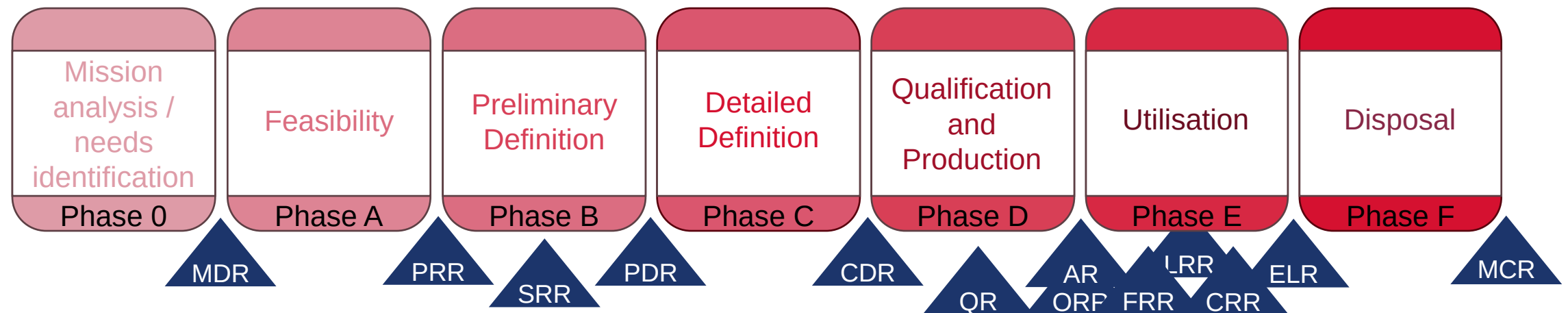


Fig 1: Visualisation of Project Phases and Reviews in regard to ECSS-M-ST-10C [1]

Satellite Manufacturing

- Focus point: Assembly, Integration and Testing (AIV/AIT)
- Time consuming tasks with high importance
- Precise documentation combining before reviews are done



Fig 2: Person assembling an sounding rocket spacecraft at DLR Moraba [2]

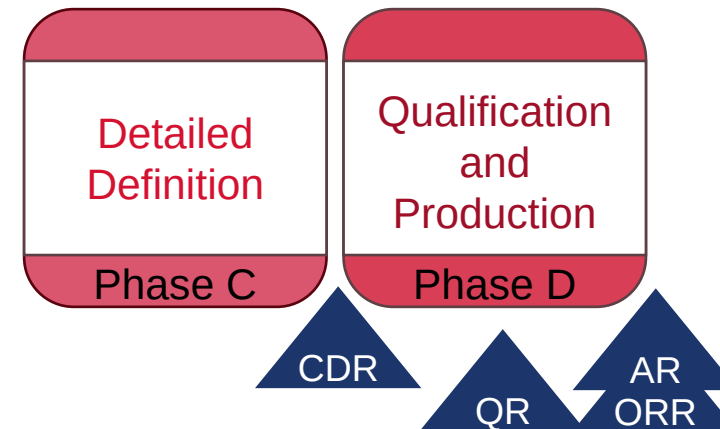


Fig 3: Project Phases involving AIT in regard to ECSS-M-ST-10C [1]

Satellite Manufacturing

- Complex spacecraft systems with many sub-structures
- Comprising of heterogenous interlinked components
- Single parameter change triggers chain reaction of re-adjustments and re-adaptations

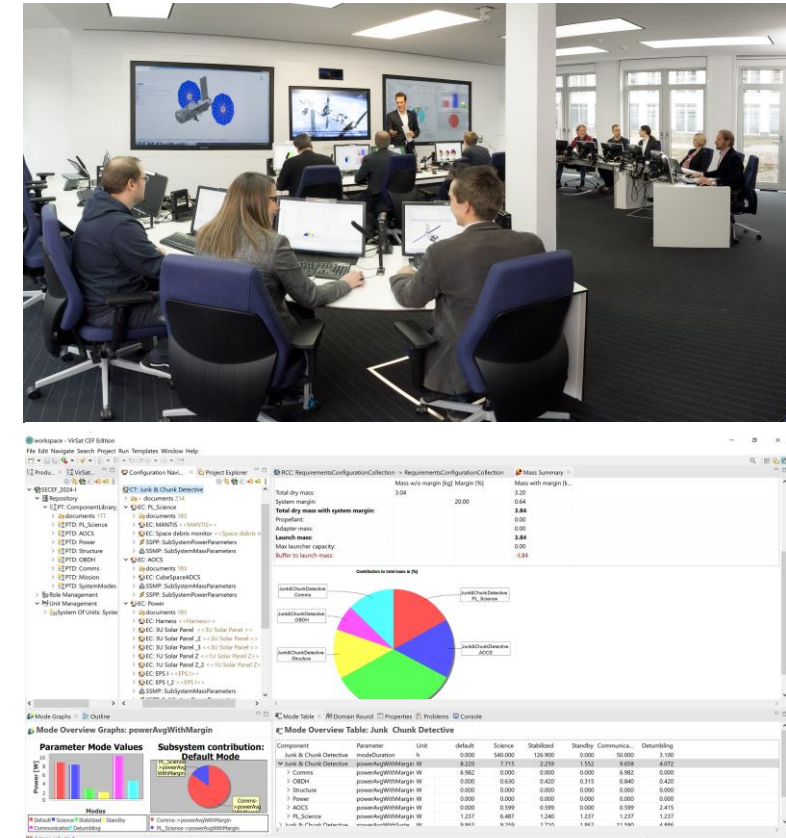


Fig 4: Upper Picture: CEF Facility at DLR [3]
Lower Picture: Screenshot from the Software "VirSat CEF" developed by DLR [4]

Digital Twins

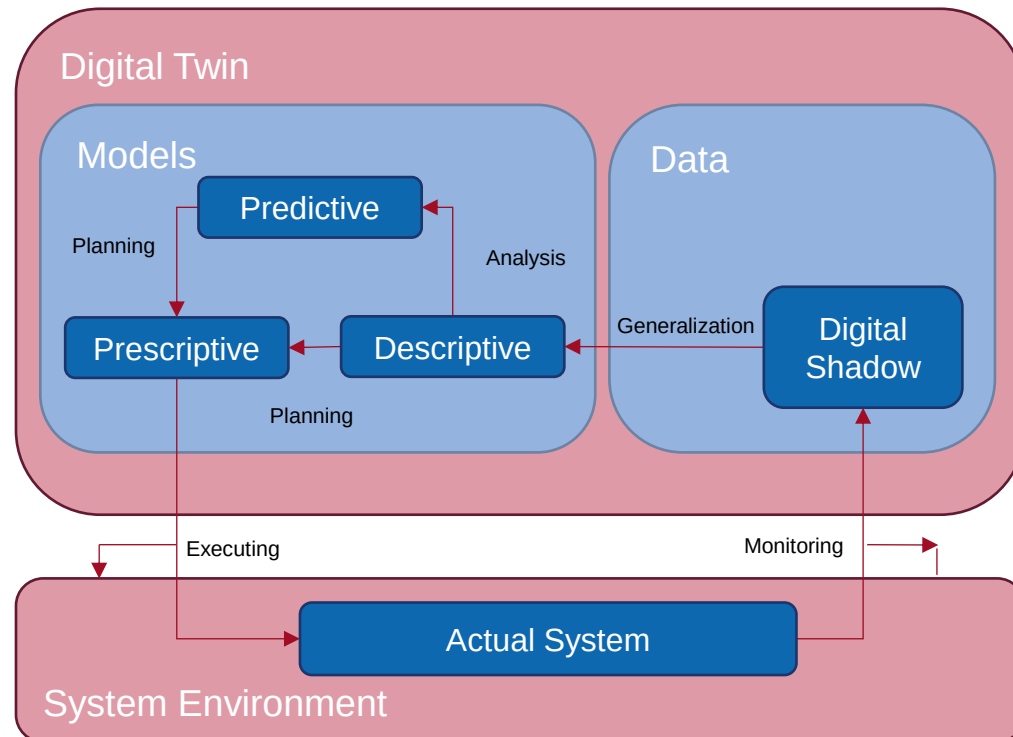


Fig 5: Conceptualized Model of an Digital Twin in regard to Eramo et. al [5]

- **Descriptive Model**
 - Describes system and environment
 - Current and past aspects
- **Predictive Model**
 - Decision Making
 - Trade-off Analysis
- **Prescriptive Model**
 - Decision Support
 - Deploys actions
- **Digital Shadow**
 - Data from monitoring and sensing
 - Environment, tech. data, constraints

Augmented Reality (AR)

- **AR devices** allow in-context display of information as holograms
- **AR applications** form a natural connection to Digital Twins as a bridge between real and virtual content
- **AR headsets** also capture a variety of sensor data to feed back to the Digital Twin



Fig 6: Working with AR-Glasses using hand-interaction

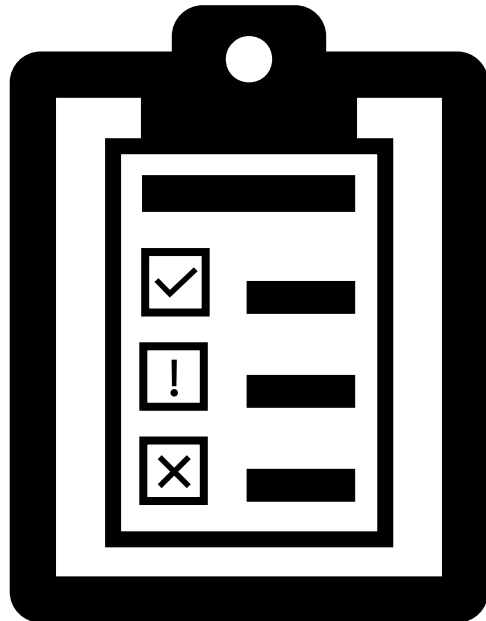
XR and Digital Twins for AIT/AIV

- State of the art:
 - Computer-aided design (CAD) and simulations
 - Model-based systems engineering (MBSE) is commonly embedded in development process
 - Reviews and plans stored digitally
- Shortcomings:
 - No interconnection between data
 - No common formats
 - No cross-phase data connection



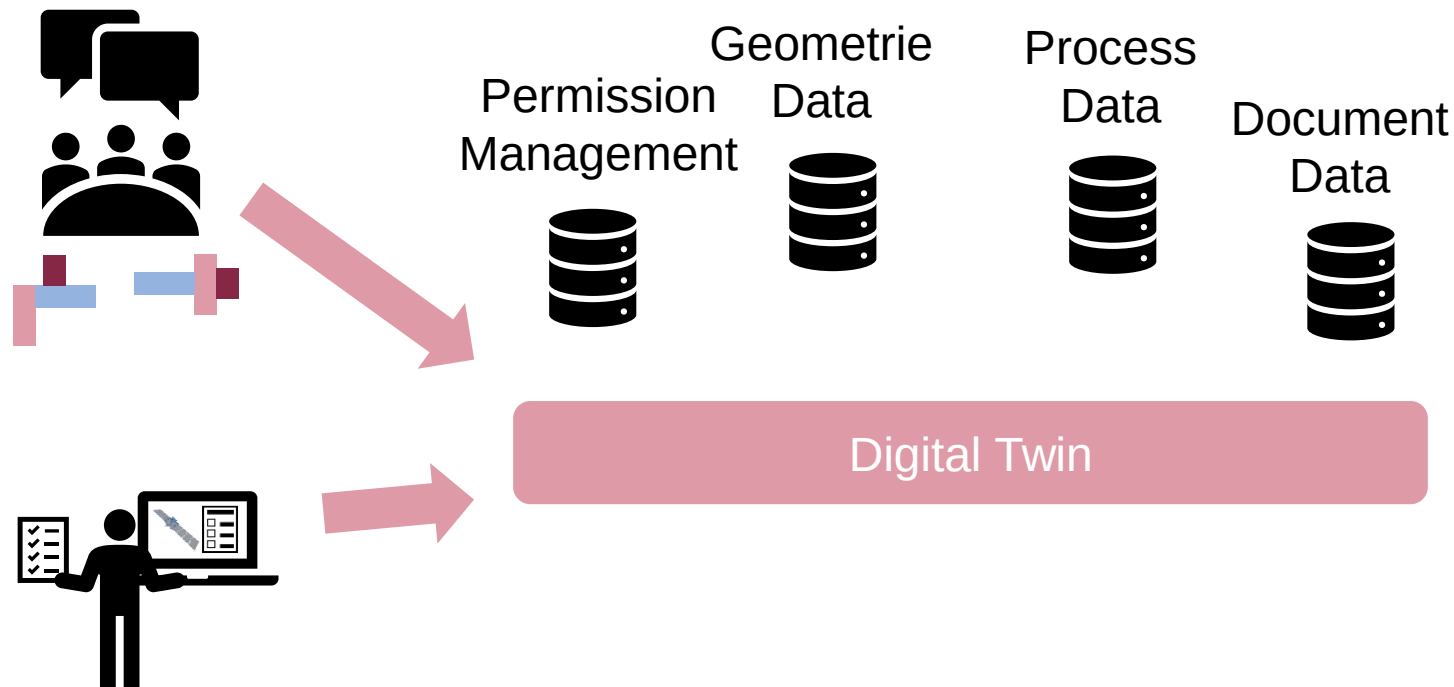
Fig 7: Multiple users using AR-Headsets for the early phase planning of an satellite mission [6]

XR and Digital Twins for AIT/AIV



- Availability of data
 - Data storage and connectivity
 - Interoperability of data
- Priority and progress of process steps
 - Decision and highlighting on prioritisation
 - Missing task visualisation
- Position guiding for assembly elements
 - Detailed position guidance, especially for small elements

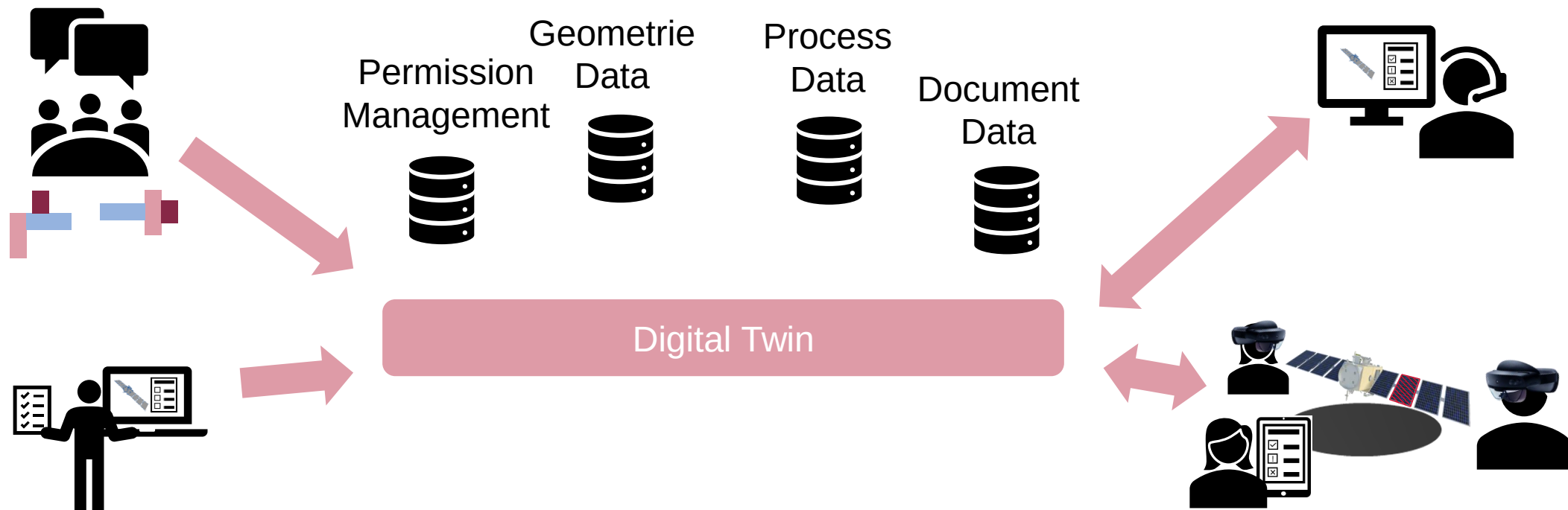
Application Architecture



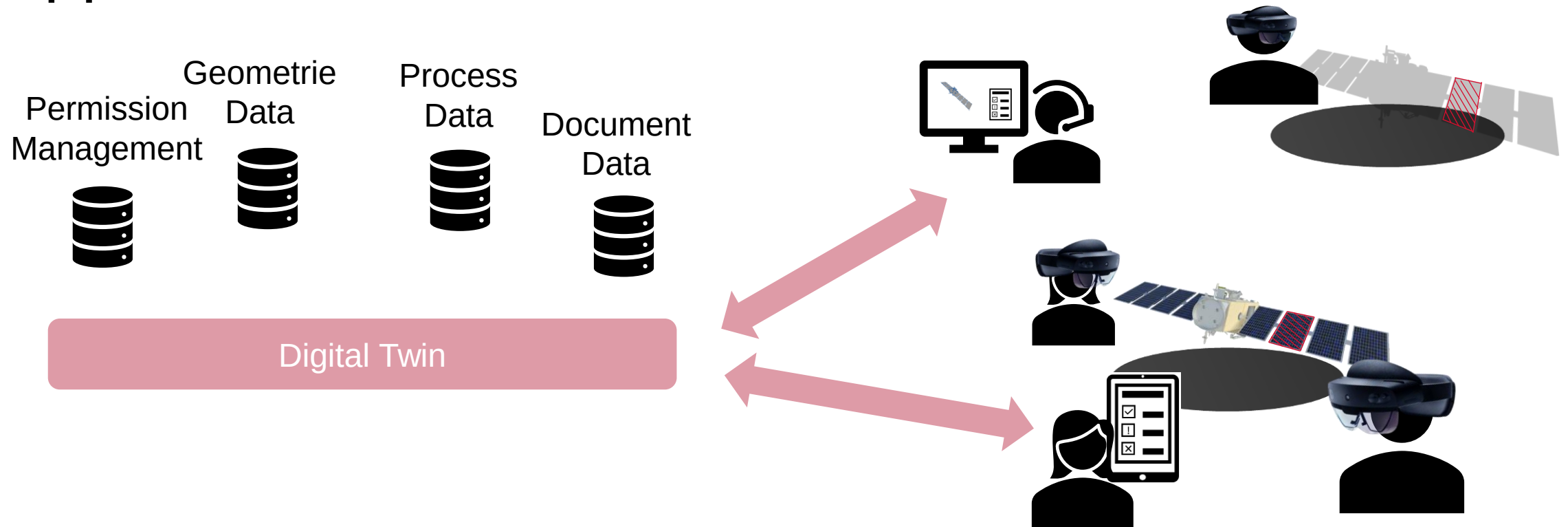
One System - All data

- Planning of components in discussion with multiple people
- Preparation of process lists and step to step instructions
- Creation of geometry and selection of material

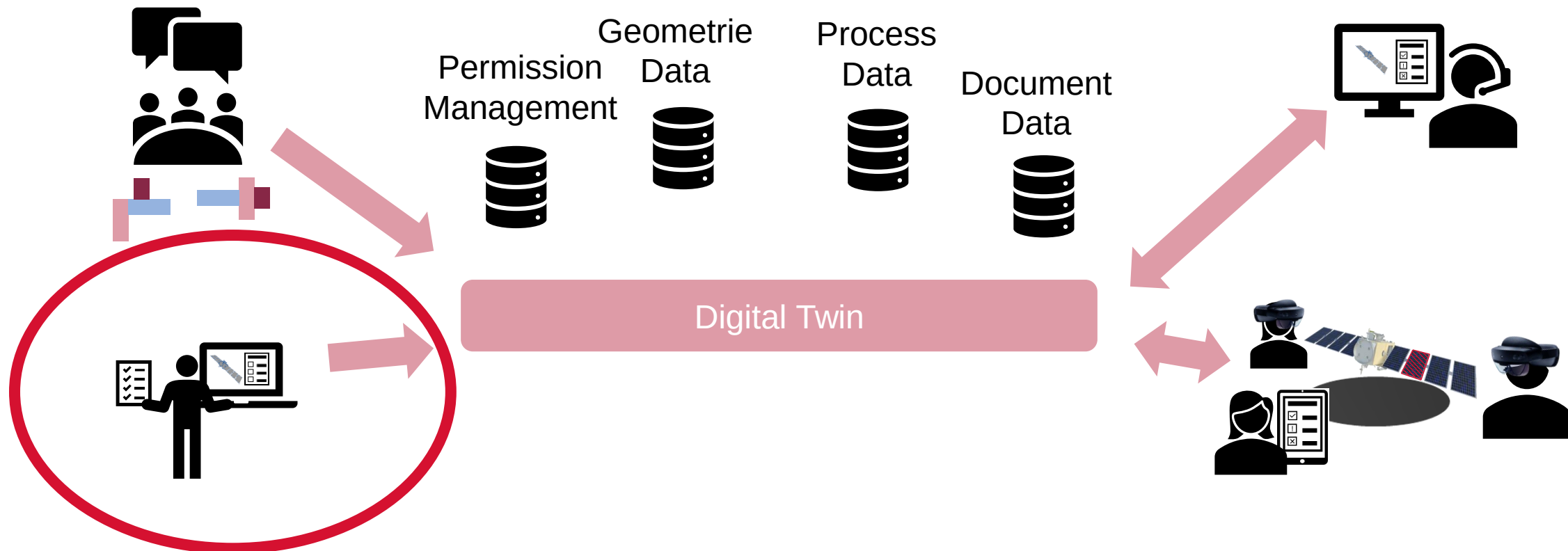
Application Architecture



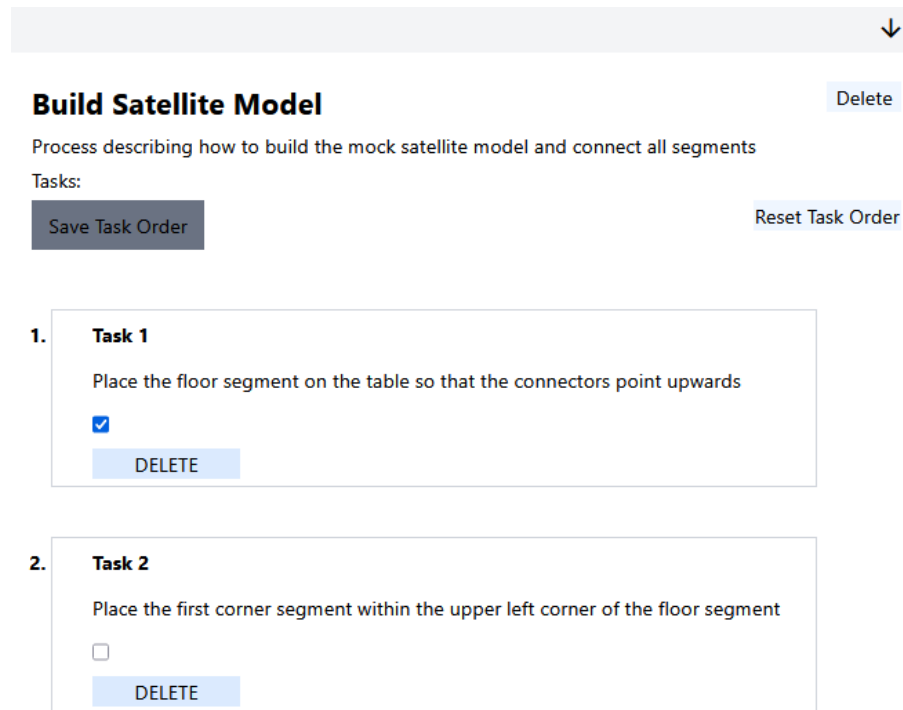
Application Architecture



Application Architecture



Application Presentation



The screenshot shows a web application titled "Build Satellite Model". At the top, there is a grey bar with a downward arrow and a "Delete" button. Below the title, a description reads: "Process describing how to build the mock satellite model and connect all segments". Under the "Tasks:" heading, there are two buttons: "Save Task Order" and "Reset Task Order". The task list contains two items:

- Task 1**
Place the floor segment on the table so that the connectors point upwards
☒
DELETE
- Task 2**
Place the first corner segment within the upper left corner of the floor segment
☐
DELETE

- Web Application allowing to create Procedures
 - Removing and adding new tasks
 - Reordering and restoring task order
 - Changing descriptions and linking real elements
 - Store of status information about each task
- Check for credentials to change data

Fig 8: Web Application connected to digital twin supporting Process and Task creation

Application Presentation

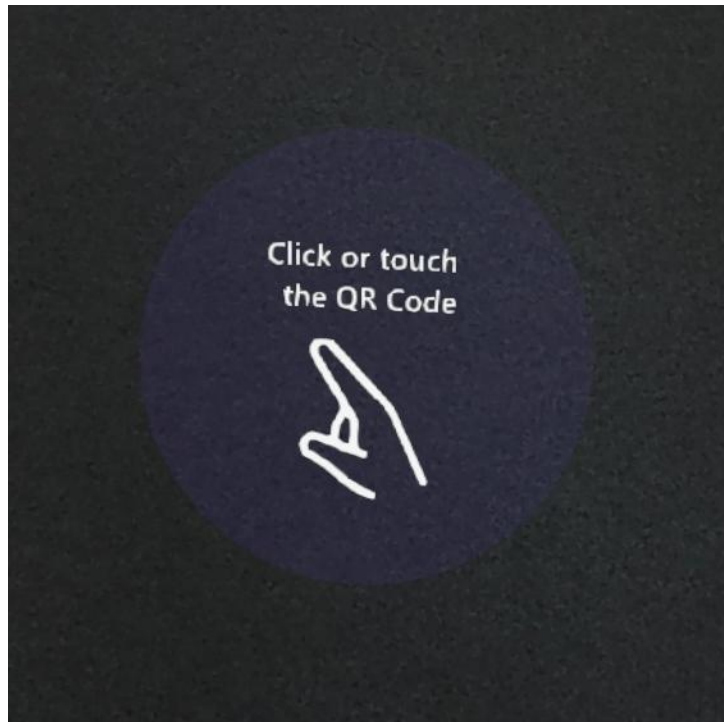


Fig 8: Indication of User Guidance within the DigiTwinAIT Application

- Marker-based Tracking for positioning
 - QR-Code used for position definition
 - Repositioning if needed
- User-Guidance by Application
 - Information on what to do next
 - Gesture based user control
 - Position Registration done at the beginning, no concurrent recognition needed

Application Presentation



Fig 9: Detected QR Code highlighting for position tracking

- Marker-based Tracking for positioning
 - QR-Code used for position definition
 - Repositioning if needed
- User-Guidance by Application
 - Information on what to do next
 - Gesture based user control
 - Position Registration done at the beginning, no concurrent recognition needed

Application Presentation



Fig 10: Fixed QR Code highlighting for position tracking

- Marker-based Tracking for positioning
 - QR-Code used for position definition
 - Repositioning if needed
- User-Guidance by Application
 - Information on what to do next
 - Gesture based user control
 - Position Registration done at the beginning, no concurrent recognition needed

Application Presentation



Fig 11: Unfitted QR Code Position

- Marker-based Tracking for positioning
 - QR-Code used for position definition
 - Repositioning if needed
- User-Guidance by Application
 - Information on what to do next
 - Gesture based user control
 - Position Registration done at the beginning, no concurrent recognition needed

Application Presentation

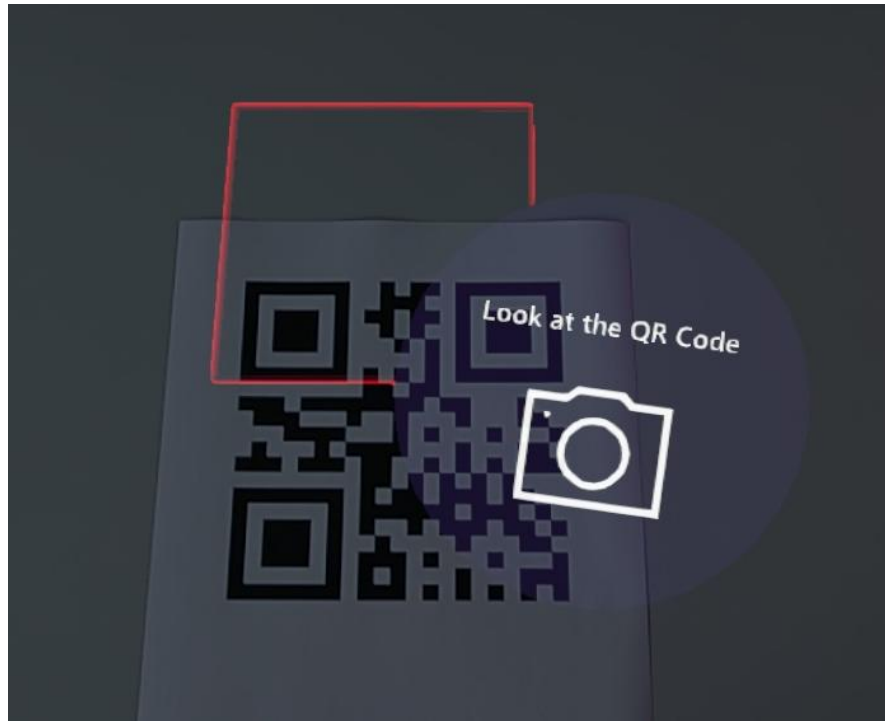


Fig 12: Repositioning the QR-Code

- Marker-based Tracking for positioning
 - QR-Code used for position definition
 - Repositioning if needed
- User-Guidance by Application
 - Information on what to do next
 - Gesture based user control
 - Position Registration done at the beginning, no concurrent recognition needed

Application Presentation



Fig 10: Fixed QR Code highlighting for position tracking

- Marker-based Tracking for positioning
 - QR-Code used for position definition
 - Repositioning if needed
- User-Guidance by Application
 - Information on what to do next
 - Gesture based user control
 - Position Registration done at the beginning, no concurrent recognition needed

Application Presentation



Fig 13: Session discovery after application start

- Collaboration with multiple people
 - Session discovery by Bluetooth and WIFI
 - Common digital world for all participants
 - Visualisation of different steps at the same time possible
 - Simultaneous Cooperation from different places

Application Presentation



Fig 14: Visualisation of possible session to join

- Collaboration with multiple people
 - Session discovery by Bluetooth and WIFI
 - Common digital world for all participants
 - Visualisation of different steps at the same time possible
 - Simultaneous Cooperation from different places

Application Presentation



Fig 15: Listing of all processes available

- Process selection
 - Listing of all available processes within the connected data backend
 - Name of process
 - Short description of process
 - Data getting fetched after process decision, including workflow, geometries and status information

Application Presentation

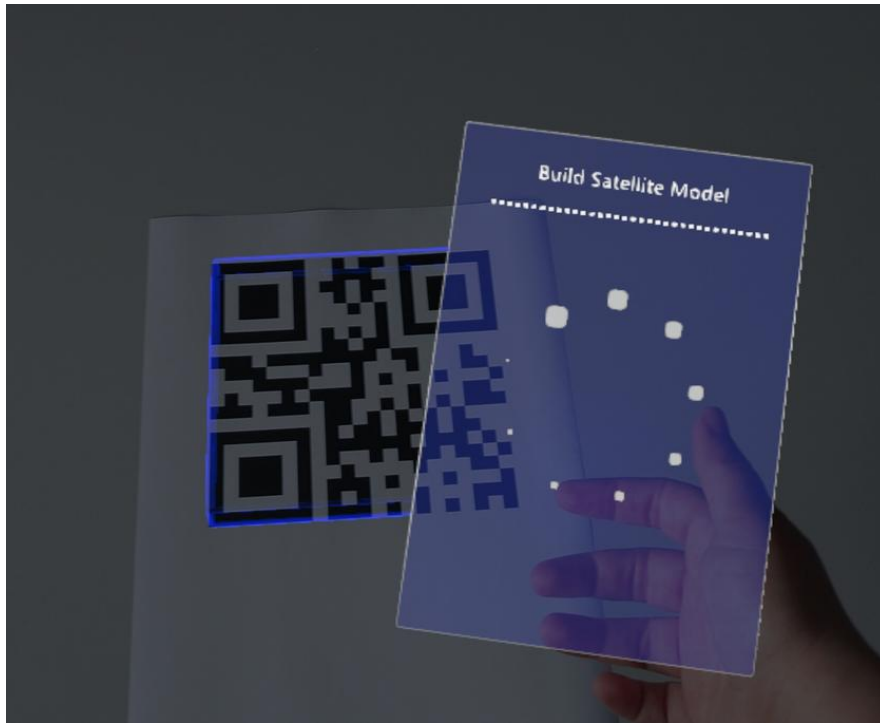


Fig 16: Fetching process related data

- Process selection
 - Listing of all available processes within the connected data backend
 - Name of process
 - Short description of process
 - Data getting fetched after process decision, including workflow, geometries and status information

Application Presentation



Fig 17: Task description with aligned hologram visualisation

- Task visualisation
 - Name, Task and status displayed
 - Next and former tasks
 - Only visible when needed

Application Presentation



Fig 18: Task description with corresponding real object

- 3D Visualisation
 - Real scale models indication positioning and rotation of items
 - Color-coded materials used for missing and done tasks
 - Step by step creation of systems supporting real life progress



Fig 19: Step-wise execution of Tasks with color-coded highlighting of current task

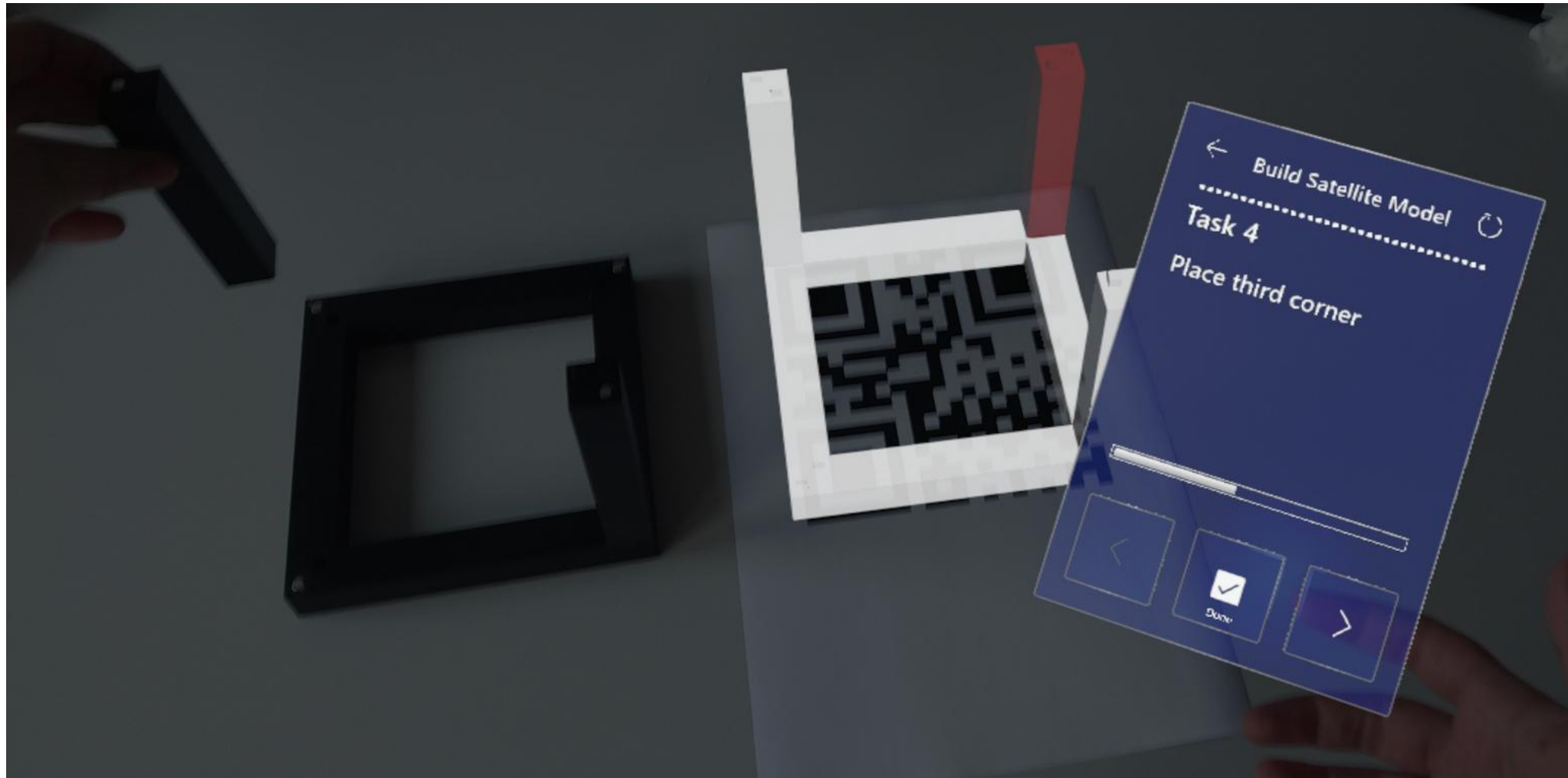


Fig 20: Color-coded highlighting of missed tasks

Application Presentation

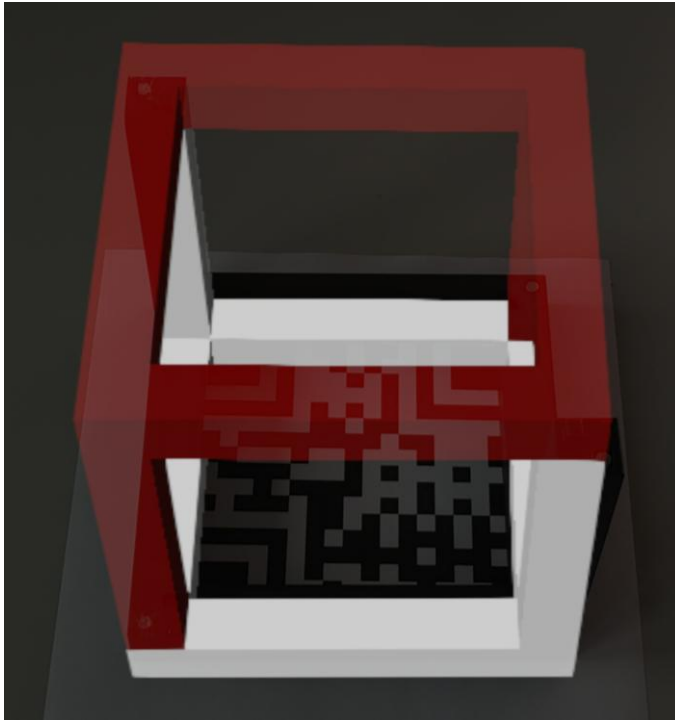


Fig 21: Fully built Hologram with real model below

- Real time collaboration with multiple people
 - Supporting multiple Devices, including HMDs as well as browser based usage
 - Updating done steps from everywhere
 - Joining sessions possible at all times

Application Presentation

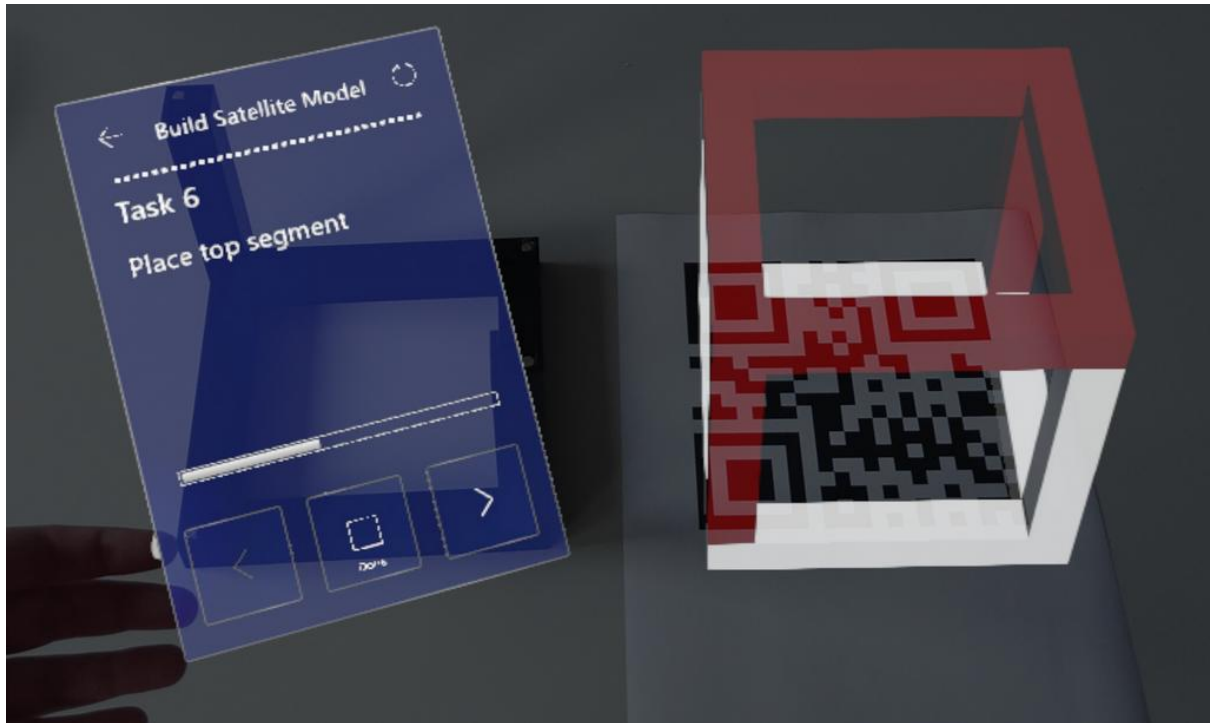


Fig 22: Fully built Hologram with corresponding menu showing current progress

- Real time collaboration with multiple people
 - Supporting multiple Devices, including HMDs as well as browser based usage
 - Updating done steps from everywhere
 - Joining sessions possible at all times

Conclusion:

Summary

- Interactive AR visualisation of tasks and procedures
- Conceptualized digital twin of an satellite available by API
- Synchronized data on different Mixed Reality and Web UI applications

Future Work

- Version update of digital twin and web UI
- Automated state recognition and task completion detection
- Including Sensors data and verification results



Project Website



Contact

References

- [1] <https://ecss.nl/standard/ecss-m-st-10c-rev-1-project-planning-and-implementation/>
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- [4] <https://www.dlr.de/de/irs/ueber-uns/abteilungen/systemanalyse-raumsegment/konzeptentwicklung-satelliten-personenraumfahrt/model-based-systems-engineering>
- [5] Eramo et. al, „Conceptualizing Digital Twins“, IEEE Software, 39(2), 2022
- [6] Bahnmüller, “Using Augmented Reality for Collaborative Concurrent Engineering”, ESA XR Conference 2023,
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