5th International Workshop on Verification and Testing of Space Systems

Session 9
Special Test

End-to-End Simulation and Verification of Rendezvous and Docking/Berthing Systems using Robotics

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- Overview Project "On-Orbit Servicing – End-to-End Simulation"
- Rendezvous and Docking / Berthing Concept
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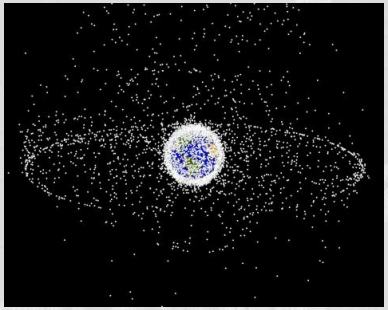
- Status of the Project, Conclusion

Motivation – De-Orbiting, Active Debris Removal, On-Orbit Servicing

- Increasing number of non-operative, in-active satellites in strategic, important orbits (LEO, GEO)
- High collision risks → cascade effect/ Kessler syndrome

→ De-orbiting, active debris removal



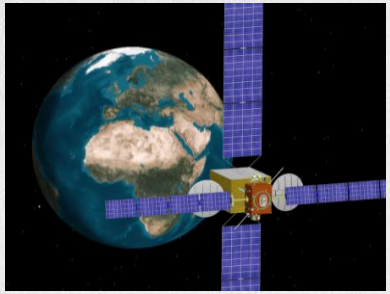
- Active satellites: high complexity, increasing costs

→ Life-time extension by servicing and repairing

Challenges:

- Passive, non-cooperative target satellite, not prepared for rendezvous and docking (RvD)
- Target with lost attitude control or other damages
- Safety and robustness requirements in case of full autonomous RvD

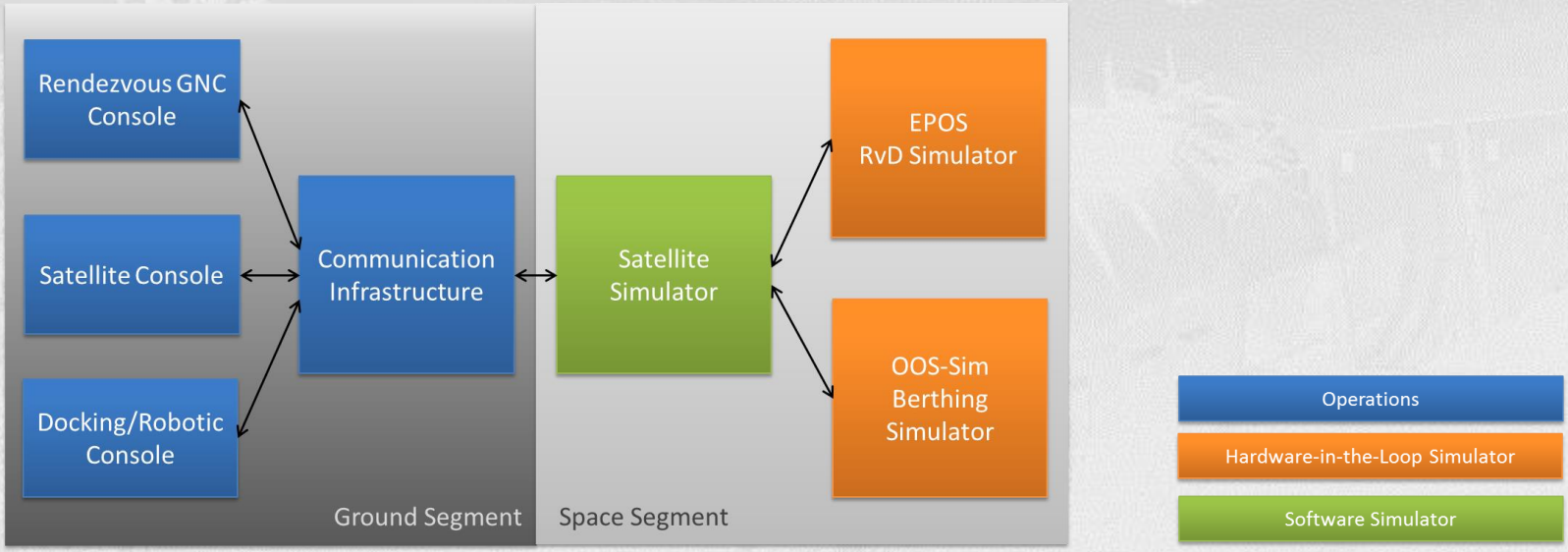
→ Advanced test and simulations necessary



On-Orbit Servicing – End-to-End Simulation

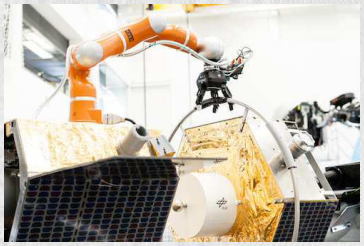
Development of the infrastructure to simulate an entire rendezvous and docking/berthing process of an on-orbit servicing mission including

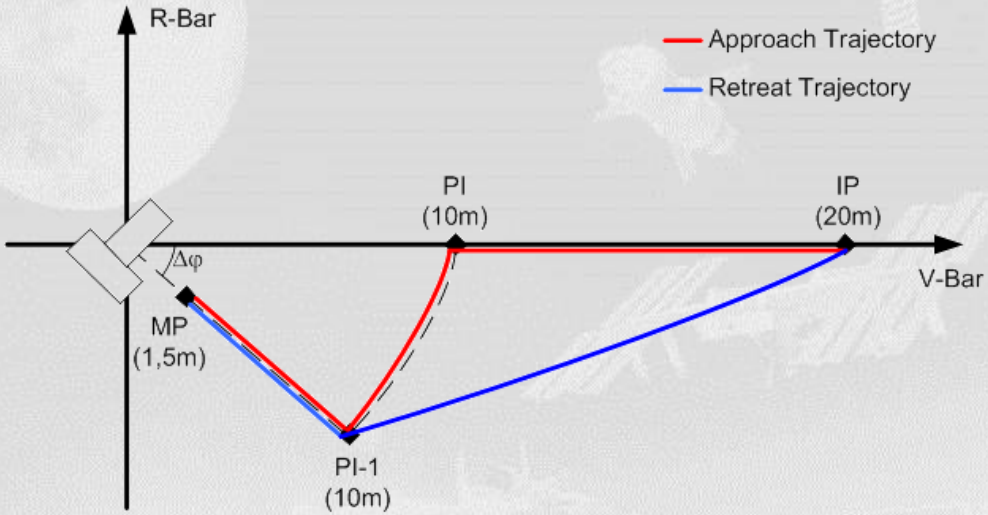
- space segment simulation incl. software and hardware simulators
- ground segment development incl. communicational and operational infrastructure

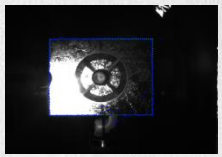


Rendezvous and Docking/Berthing Concept

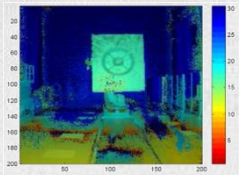
- Far and Mid Range Rendezvous to Inspection Point (IP) at 20m distance
- Straight Line Approach to Pose Initialization Point (PI) at 10m distance
- Observation of the tumbling motion, approach planning
- Fly around to PI-1 (with angle $\Delta\varphi$)
- Straight Line Approach to Mating Point (MP)
- Capturing of the client with a robotic arm



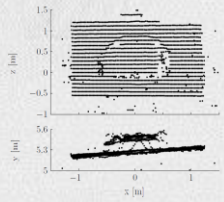




CCD Camera



PMD Camera

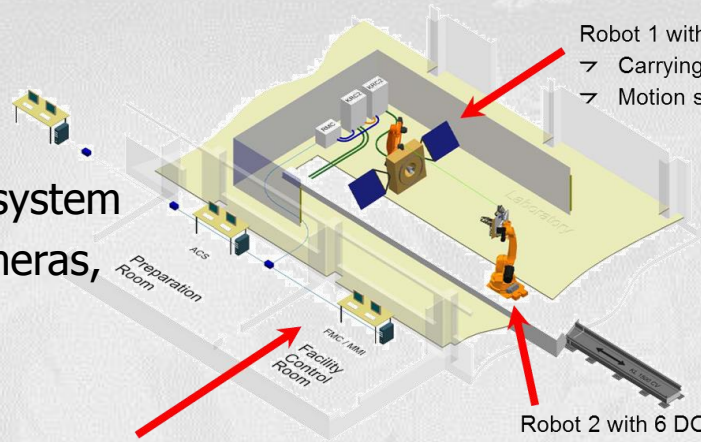


LiDAR

Components of End-to-End OOS Simulation 1/4

EPOS Simulator

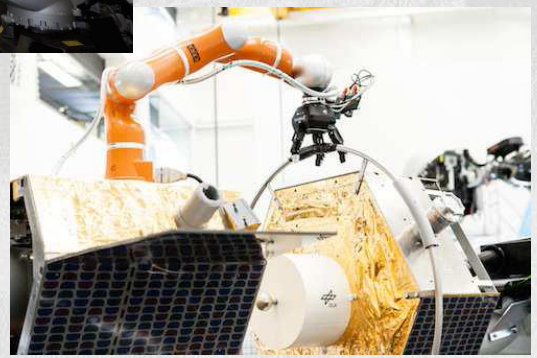
- EPOS (European Proximity Operations Simulator)
- RvD Simulator
- 2 robots with each 6 degrees of freedom to simulate motion of servicer and client satellite
- 1 linear slide/rail system (25m)
- Mounted target mockup
- Installed RvD sensors
- GNC (Guidance, navigation and control) system
- Navigation based on optical sensors (cameras, LiDAR)
- Real-time control of the facility

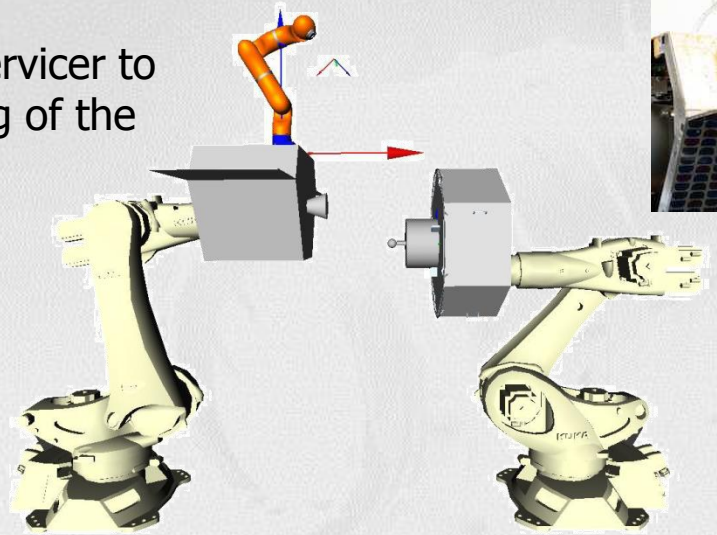


Components of End-to-End OOS Simulation 2/4

OOS Simulator

- OOS Sim (On-orbit servicing simulator)
- Berthing Simulator
- 2 robots with each 6 degrees of freedom to simulate motion of servicer and client satellite
- Mounted target mockup
- Installed robotic arm on the servicer to perform the grasping/capturing of the client

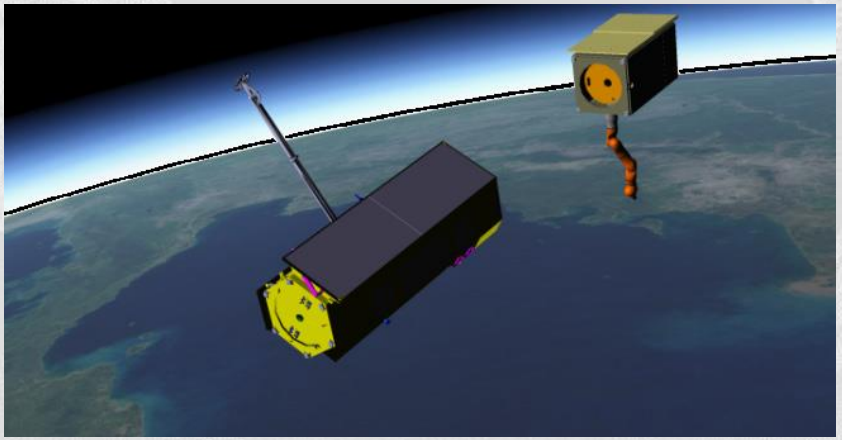


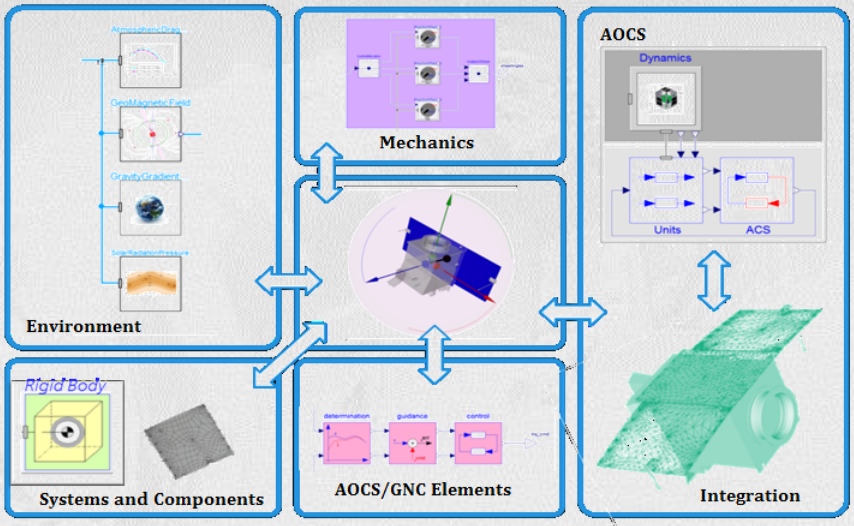


Components of End-to-End OOS Simulation 3/4

Satellite Simulator

- Software simulator
- Satellite dynamics simulation (translational and rotational motion of servicer and client spacecraft)
- Simulation of the servicer's subsystems: AOCS (attitude and orbit control system), power and thermal
- Provision of the servicer's onboard data handling system and the infrastructure to communicate with the ground control center

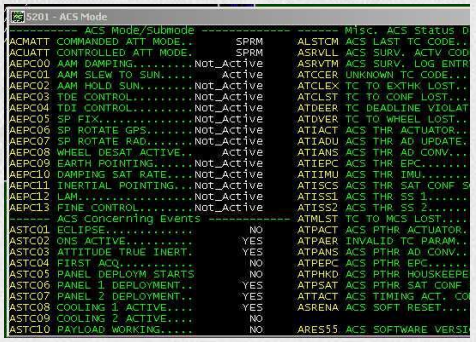




Components of End-to-End OOS Simulation 4/4

Communication and Operation Systems

- Communication and operation software and hardware components as used for a real mission
- Preparation of all facilities and control rooms
- Network installation
- IT infrastructure
- Mission Control Center
- Flight Operations System (Mission Planning, Spacecraft Control Operations, Archiving, Logging)
- Ground Data System (Telemetry and Telecommand, Services, Voice Communication, etc.)
- Consoles (Satellite, Rendezvous, Robotic)



EPOS RvD Simulator (EPOS Robots + GNC Payload)

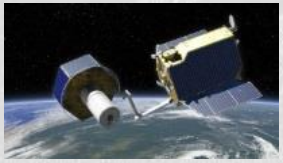
OOS Sim Berthing Simulator (OOS Sim Robots + Robotic Payload)

EPOS & GNC CMD

REF & GNC DAT

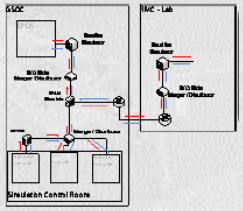
OOS Sim & ROB CMD

REF & ROB DAT



Satellite Simulator

Communication System



GNC TC

GNC TM

SAT TC

SAT TM

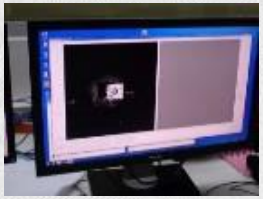
ROB TC

ROB TM

Rendezvous Console

Satellite Console

Robotic Console

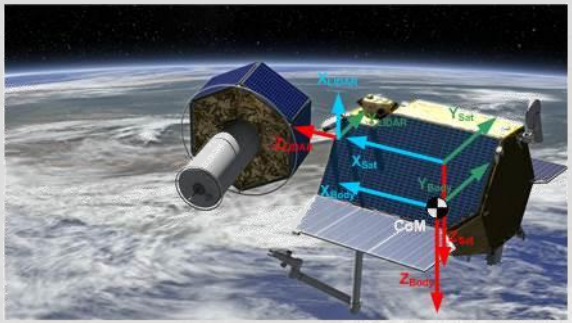


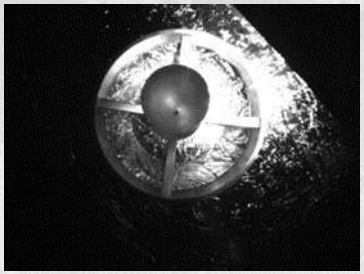
Status of the Project

Project 01/2014 – 07/2017

Current Phase: Implementation Phase

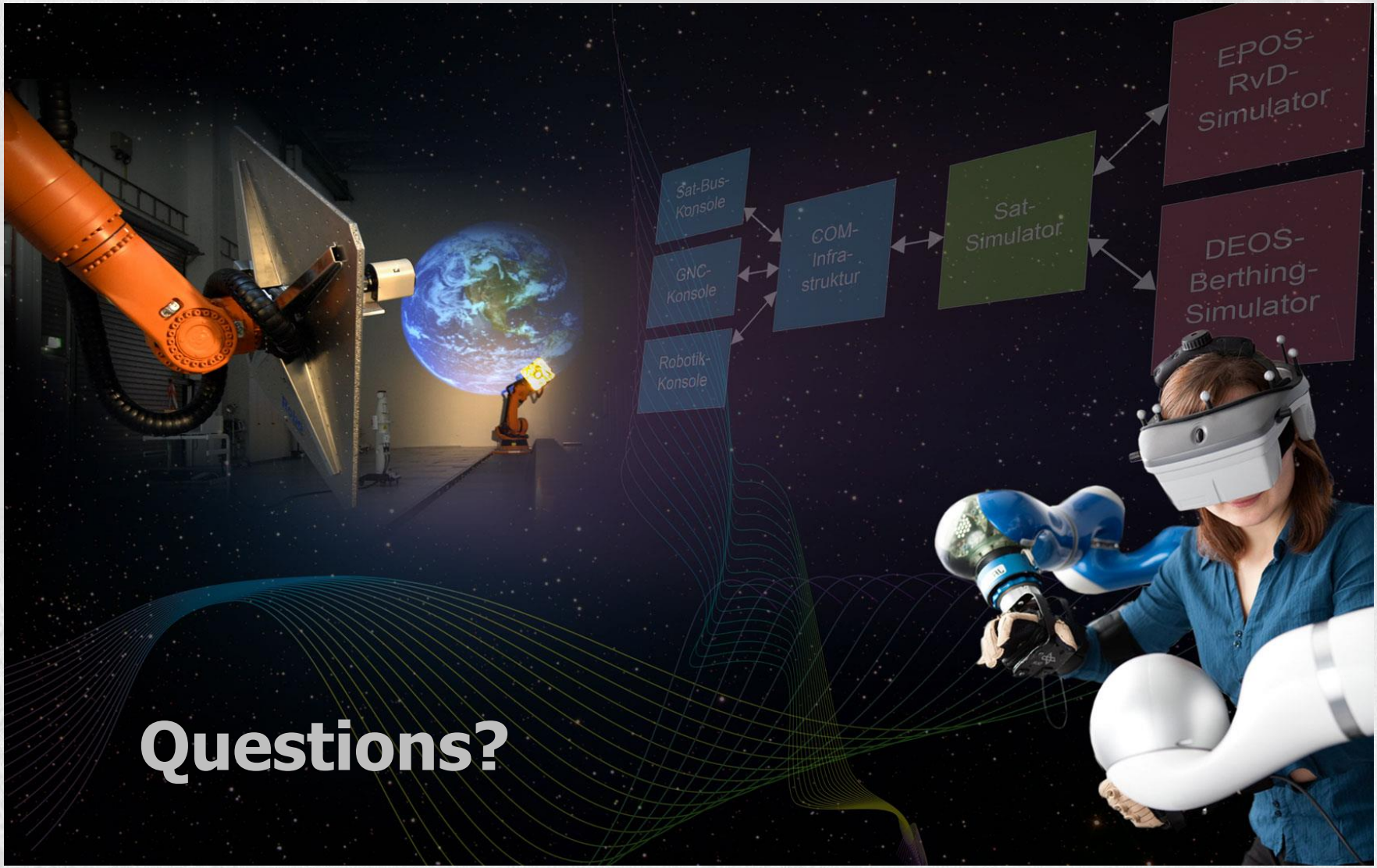
- Implementation of the single components nearly finished
- Test of the single sub-systems
- First interface tests between the sub-systems
- Development of a detailed test and integration plan





10/2016 – 07/2017: Test & Verification Phase

- Integration
- Test of the entire system
- Demonstrations
- Publications


Sat-Bus-Konsole
GNC-Konsole
Robotik-Konsole
COM-Infra-struktur
Sat-Simulator
EPOS-RvD-Simulator
DEOS-Berthing-Simulator
Questions?