Automation and Robotics within the German Space Program & the DEOS Mission

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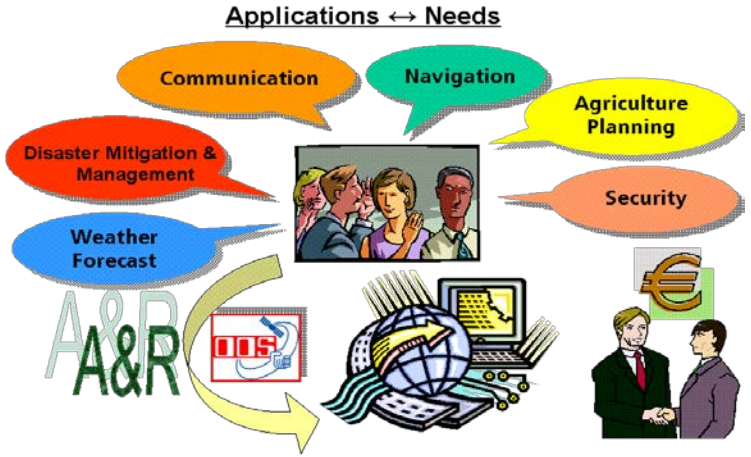
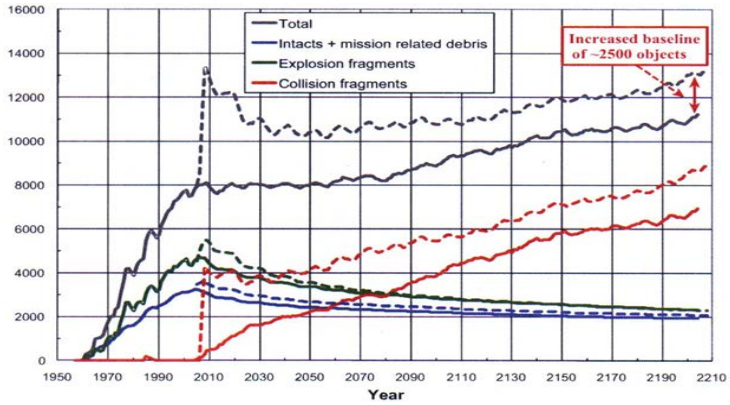
Outline

- Motivation
- Political guidelines and programmatic goals
- Roadmap
- The DEOS Mission

Setting the scene - Motivation

- **Hundreds of satellites populate** the Earth **orbits from LEO to GEO** in order to respond to increasing needs of society for tele-communication and navigation, weather forecasts, transnational agriculture planning etc..
- Space flight follows **“throw away mentality” -** Existing satellites **are not prepared** for any intervention
- International agreements [IADC] call for **removal of satellites** from their orbits at EOL - **many don’t get removed**.
- **Cascading effect** increases space debris even w/o any launches – **prevention measures are not enough** to maintain save access to space
- Mastering the **capabilities for OOS** are major **stepping stones** on the way to explore the Solar System.





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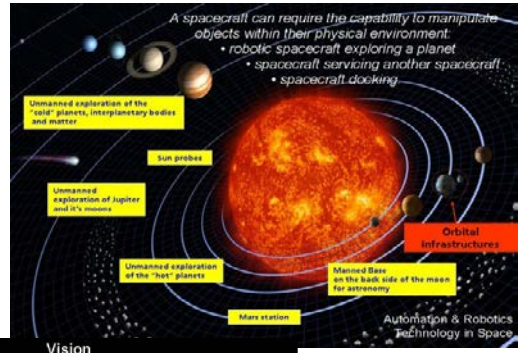
IDEOS

Automation & Robotics combines key technologies for manned and unmanned space flight

Automation & Robotics

- Makes distant worlds directly accessible for scientific exploration and exploitation
- Helps to built the future by breaking new ground for space flight
- Helps to secure save access to space and to mitigate threats to public and space assets



Space Robotics - Core area within the German Space Program

Since 2009 part of the High-Tech Strategy of the German government in the fields of innovation and technology policy

Political Goals:

- Extend existing capabilities of German industry and academia in the area of Space Robotics
- Achieve and maintain a technological key position in future cooperative international space projects
- Support technology transfer from and to terrestrial applications
- Contribute to set up international rules an regulations to enforce responsible and considerate treatment of space assets

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Federal Ministry
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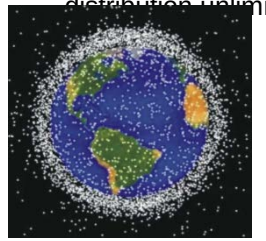
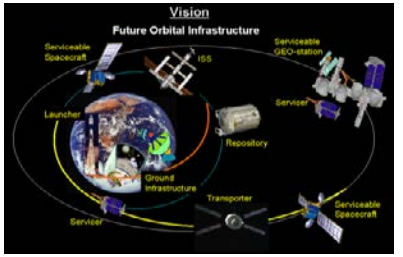
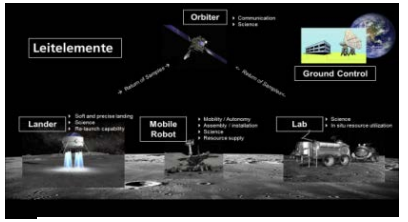
and Technology

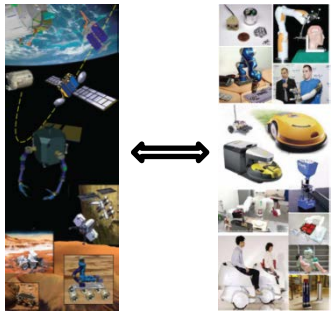
Programmatic goals in Space Robotics

- **Disposal of space debris – safety for human population on earth and space assets on orbit**
- **Preparation and operation of serviceable satellites and stations**
- **Moon exploration as stepping stone to explore the solar system**
- **Transfer of Technology from and to Space-Robotics**



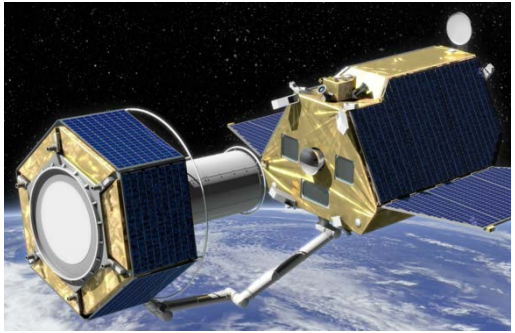


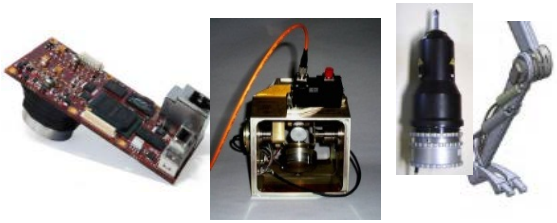




Space Robotics roadmap

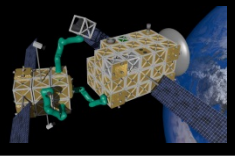
Orbital demos & analogue missions





Technology Development

Orbital operations

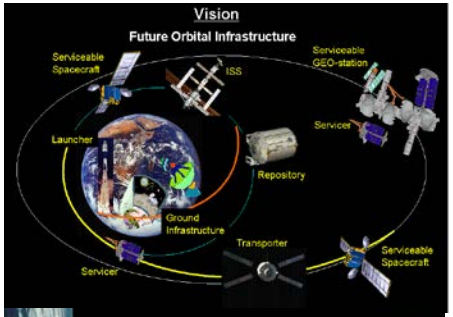


Exploration

Transfer

2010 **2020** **2030**

System capability **International cooperation**



DLR's approach to OOS

- **Demonstrate the availability of technology** and verify procedures and techniques for rendezvous, capture, maintenance and removal of an uncontrollable satellite from its operational orbit through a demonstration mission -> **DEOS** (Deutsche Orbitale Servicing Mission)

- Translate the increasing needs of society and lessons learned from DEOS into **technical and technological requirements for** the extension and operation of **next generations orbital infrastructure**

- **Create serviceability/maintainability through "cooperative" satellite design**, standardization, modularity.

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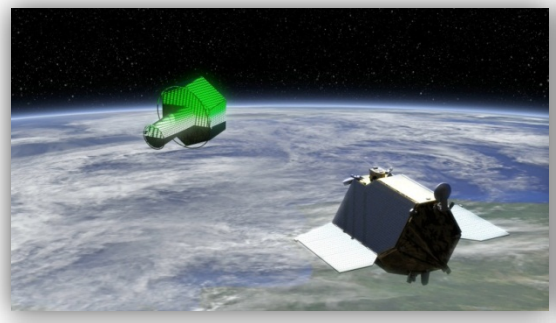
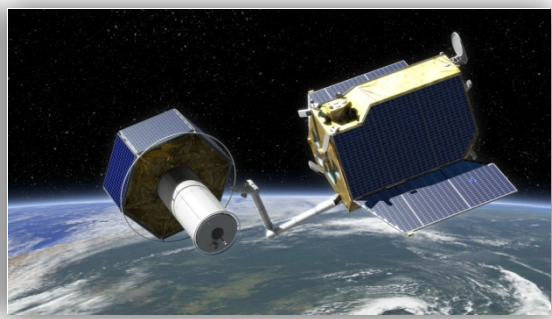
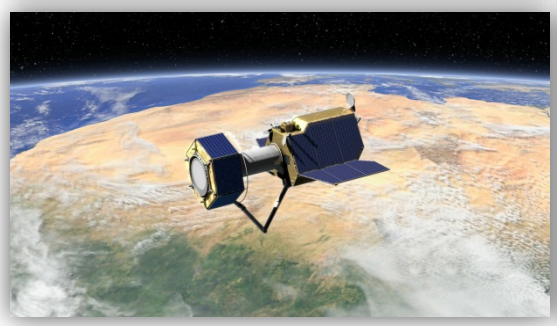
DEOS

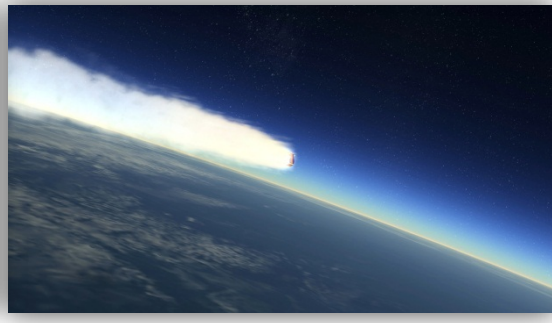
The DEOS Mission Statement

- Locate and approach a client satellite
- Capture a tumbling, non-cooperative satellite using a manipulator mounted on a free flying service-satellite
- Demonstrate servicing tasks: refuel, module exchange etc.
- De-orbiting of the coupled satellites within a pre-defined re-entry corridor









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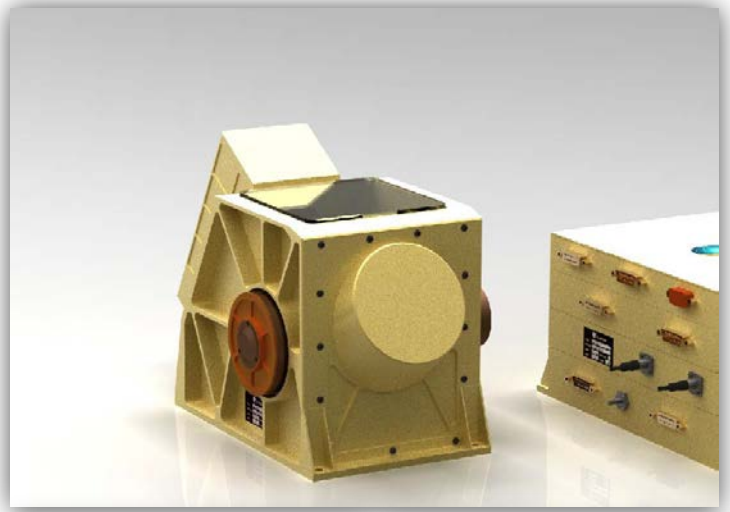
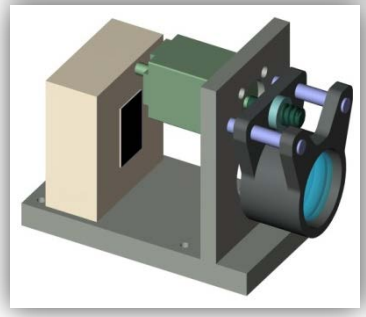
Technological Challenge

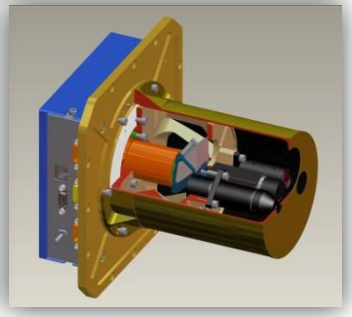
Localize, recognize and observe

- Laser Optical Sensors: 3D-LIDAR
  - General maturity proven by ISS-mission Autonomous Transfer Vehicle (ATV)
  - Changes to cope with non-cooperative targets
  - Space-qualification of components

- Optical Sensors: Zoom-Camera System
  - Replace several cameras needed for different operating ranges
  - field-of-view changer with fixed zoom settings
  - highly robust and accurate

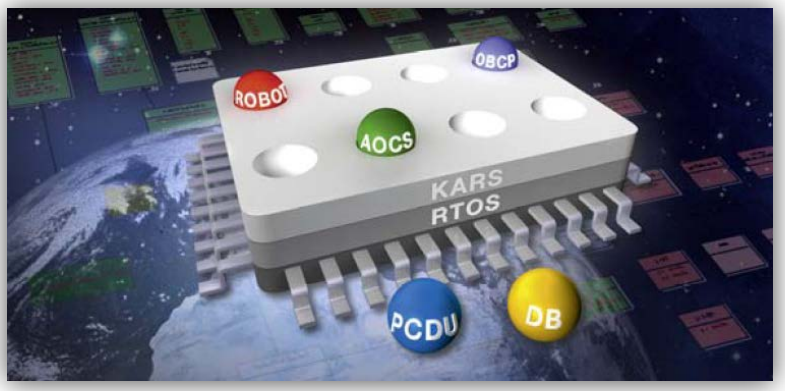






Technological Challenge

Navigation and close approach



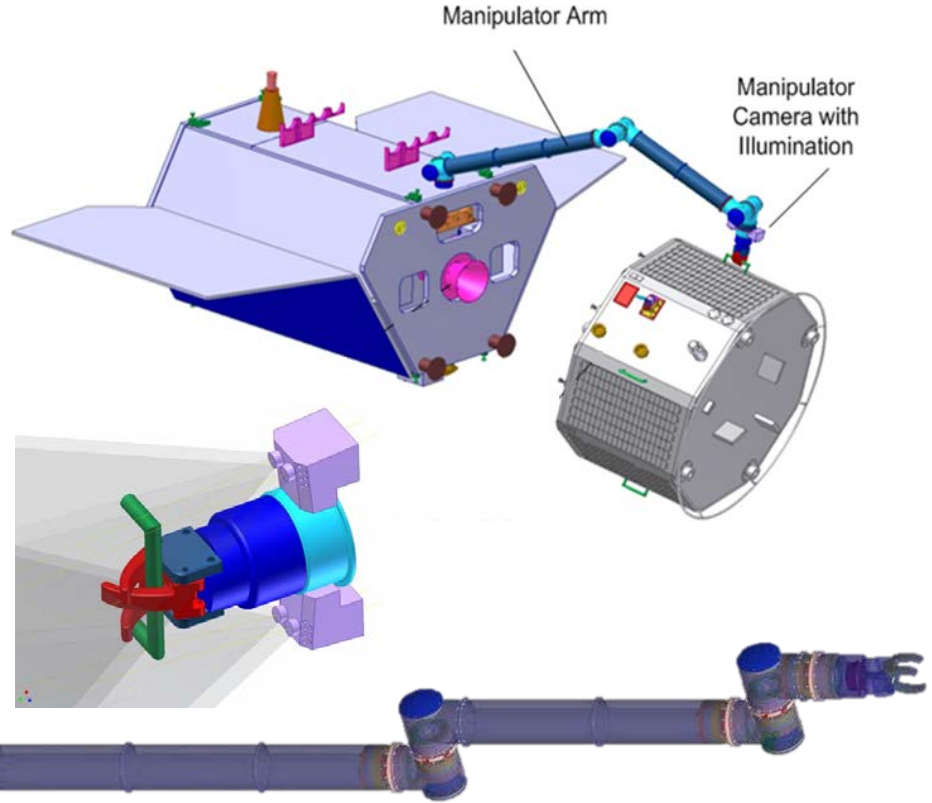
- Hardware: Multi-Core CPUs
  - Provide sufficient computing power using COTS PowerPC P4080
  - Utilize redundant resources to achieve fault tolerance by implementing effective FDIR strategies

- Software: Avionics and Data-Handling
  - Interaction between classical satellite system tasks and payload functions rises
  - Component-based design and time & space partitioning

Technological Challenge

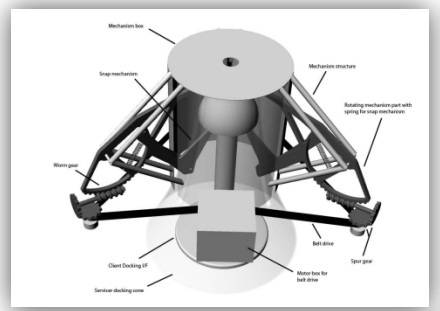
Capture and berthing

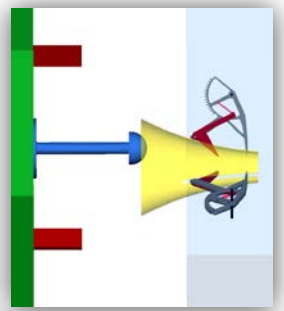
- Manipulator Camera with Illumination
  - Observation of client motion
  - Identification of dynamic parameters
  - Motion estimation
- Manipulator Arm
  - Path-planning
  - Path-control including visual-surveillance
  - Decay the motion between servicer and client

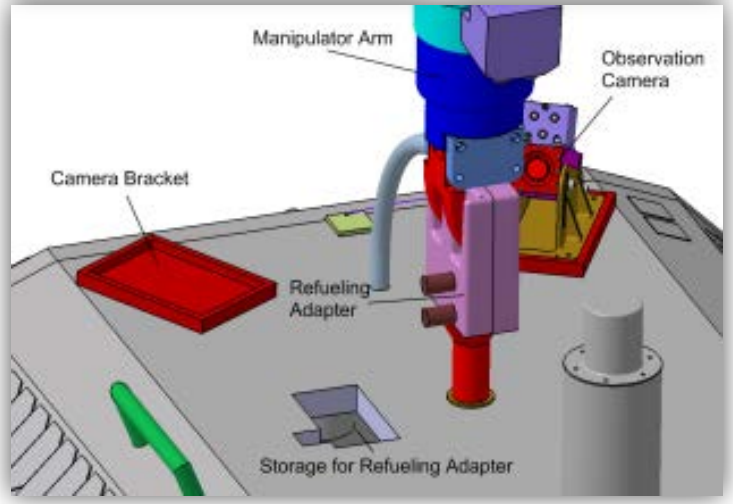


Technological Challenge

Maintenance and repair







- Pivotal question: What are typical tasks of a service robot?
  - Assembly/disassembly of components
  - Exchange of modules
  - Re-fuelling
  - Lock/unlock holders, clamps
  - ….
- Challenge:
  - Satellites are not prepared for any intervention
  - Provide a solid interconnection between servicer and client
  - Develop gripper and manipulator for a broad range of functions

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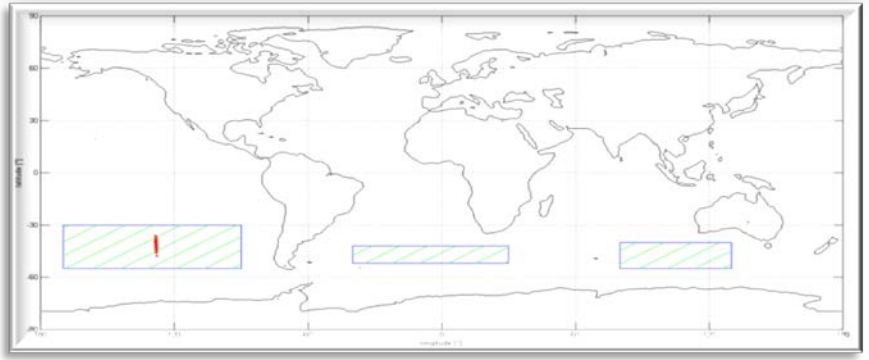
DEOS

Technological Challenge

Transportation and disposal

- Pivotal question: How can we remove a non-cooperative satellite from it's position and orbit?
- Challenge:
  - From GEO: Transport to a grave-yard orbit
  - From LEO: Initiate controlled de-orbiting using a predefined reentry trajectory
- DEOS concept:
  - Manipulator stabilizes satellite composite
  - Satellite composite burns up in the atmosphere
  - Potential remainders hit non-populated areas



Conclusion and Outlook

- **The DEOS mission shall demonstrate and verify techniques to maintain, refuel and repair malfunctioning (non-cooperative, even tumbling) satellites**
- **DEOS approach shall explore the mandatory techniques to remove inoperable satellites and space debris**
- **DEOS shall provide the prerequisites for the establishment and operation of future OOS logistics infrastructures with different lifetime of bus & P/L with**
  - **Remarkably increased reliability**
  - **Mitigation of mission risk per user and unit**
  - **High flexibility and fast reaction to customer wishes and needs**
  - **Fast deployment of technological innovations**
  - **No high, long term/upfront investments for customers**
  - **Costs per user and unit will be reduced**
  - **Mitigation of business risk**
- **DEOS robotic technologies shall stimulate and boost unmanned space exploration**

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