Automation and Robotics within the German Space Program

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German Aerospace Center, DLR, Space Management

ASTRA 2011
11th Symposium on Advanced Space Technologies in Robotics and Automation
Noordwijk, The Netherlands

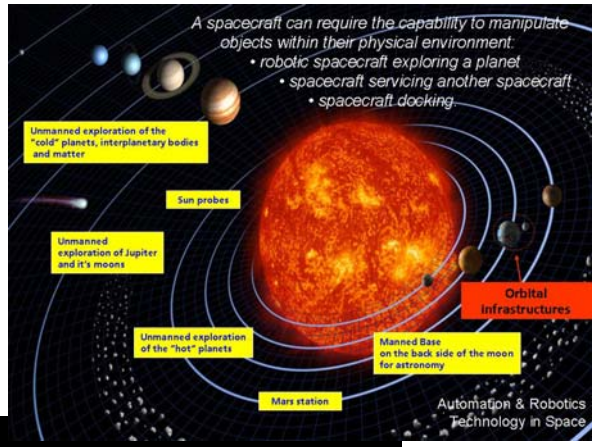
Services in Space
The German Space Robotics Program

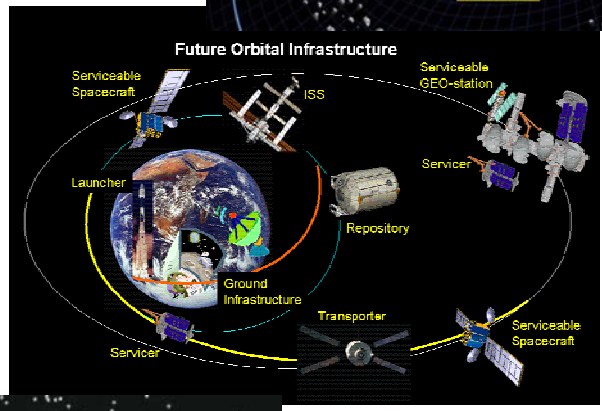
- **Motivation: Why did DLR declare Space Robotics a program of special emphasis?**
- Status: What did DLR achieve so far?
- Goals: What does DLR want to achieve for Germany and the national Space Program by focusing on Space Robotics
- Measures to achieve the goals

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





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Technological Heritage

- Basic Mechatronics (arms, hands, tools)
- Mobility concepts and vehicles
- Remote control and autonomy concepts
- Tools for ground control
- Test facilities
- Business segment evaluation
- …

On Orbit Servicing & Exploration

DEOS 2010,ΦB1

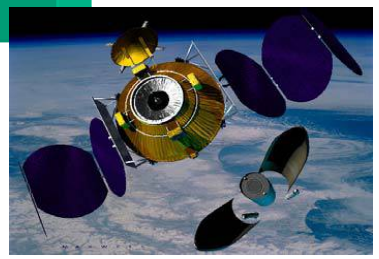
DEOS 2007,Φ0,A

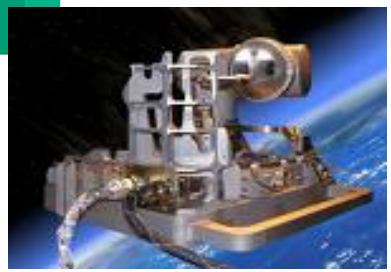
CX-OLEV 2006

TECSAS 2005

Manipulator on ISS

ROKVISS 2004





GETEX 1999

ETS VII Mission

ESS / ESST 1997

MARCO 1997

VITAL

ROTEX 1993

D2 Mission

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Federal Ministry of Economics and Technology

Federal Ministry of Economics and Technology (FMET) strongly promotes Space-Robotics within its technology program launched in order to take provision for Germanys future economy

In recognition of the

- **Potential**
- **Special skills** of German companies and academia in Space-Robotics
- **Multitude of technology transfer opportunities** from and to terrestrial applications

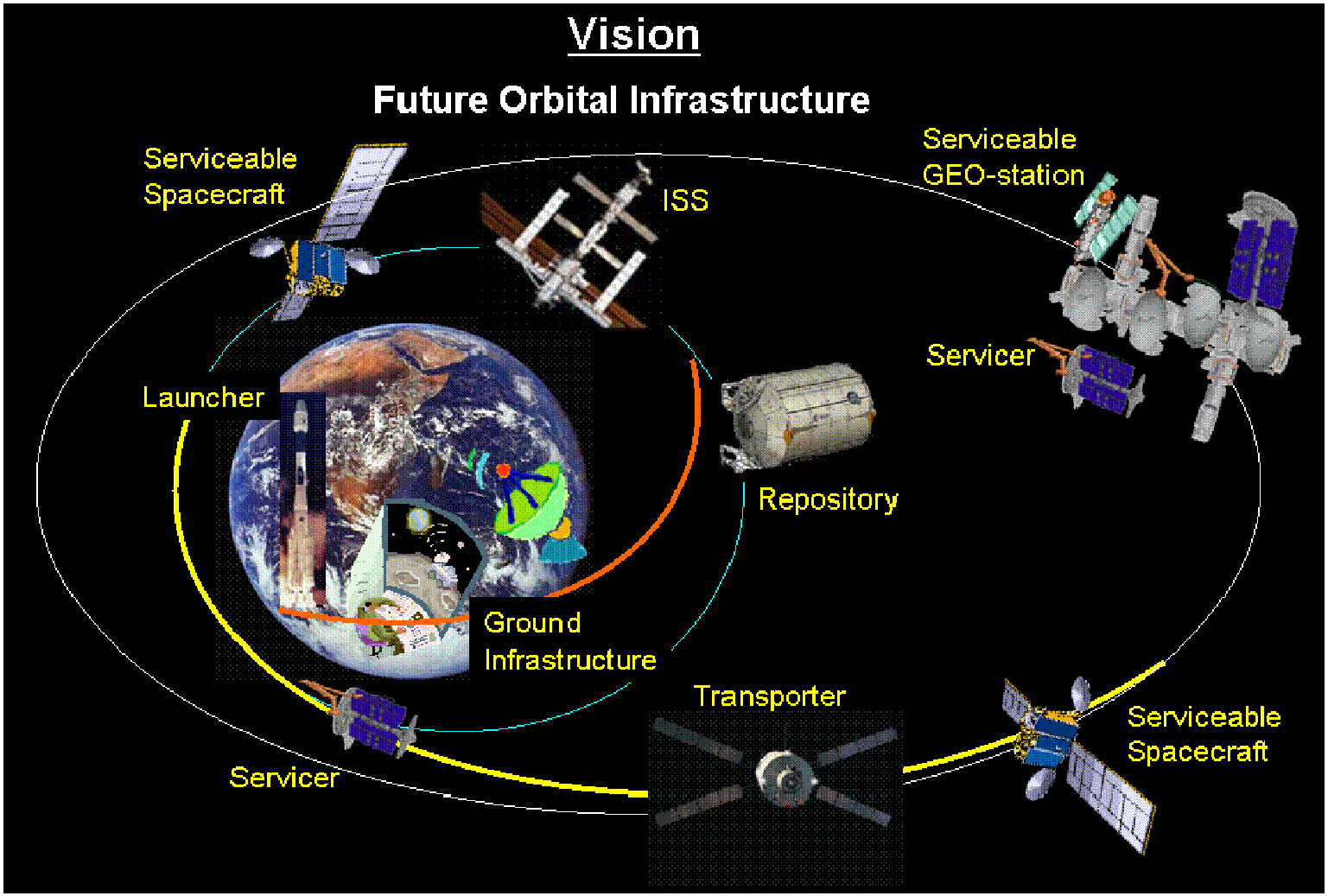
FMET declared Space-Robotics to be a core area within the German Space Program

High level goals

- Shape and sharpen **Germany**‘s profile as a **“High-tech Country”**
- Achieve and maintain a **technological key position in future cooperative international space projects** through:
  - Introduction of *new unmanned orbital infrastructure* concepts
  - Sound contributions to the *robotic exploration* of the solar system
- Contribute to set up **international rules an regulations** to enforce **responsible and considerate** treatment of space assets
- **Boost economy** by applying technological solutions for space to terrestrial applications

Programmatic goals (1)

Operation of serviceable satellites and stations



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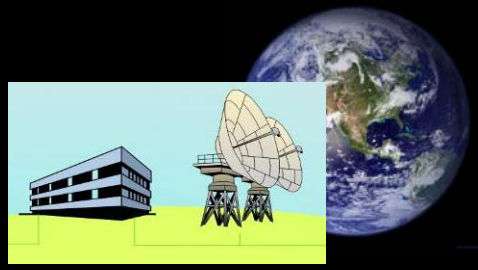
Programmatic goals (2)

Moon exploration as stepping stone to explore the solar system

Key elements

Orbiter

- Communication
- Science



Ground Control

↗ Return of Samples ↗

<- Return of Samples <-

Lander

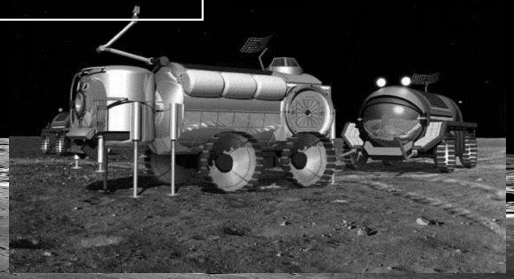
- Soft and precise landing
- Science
- Re-launch capability

Mobile Robot

- Mobility / Autonomy
- Assembly / installation
- Science
- Resource supply

Lab

- Science
- In situ resource utilization



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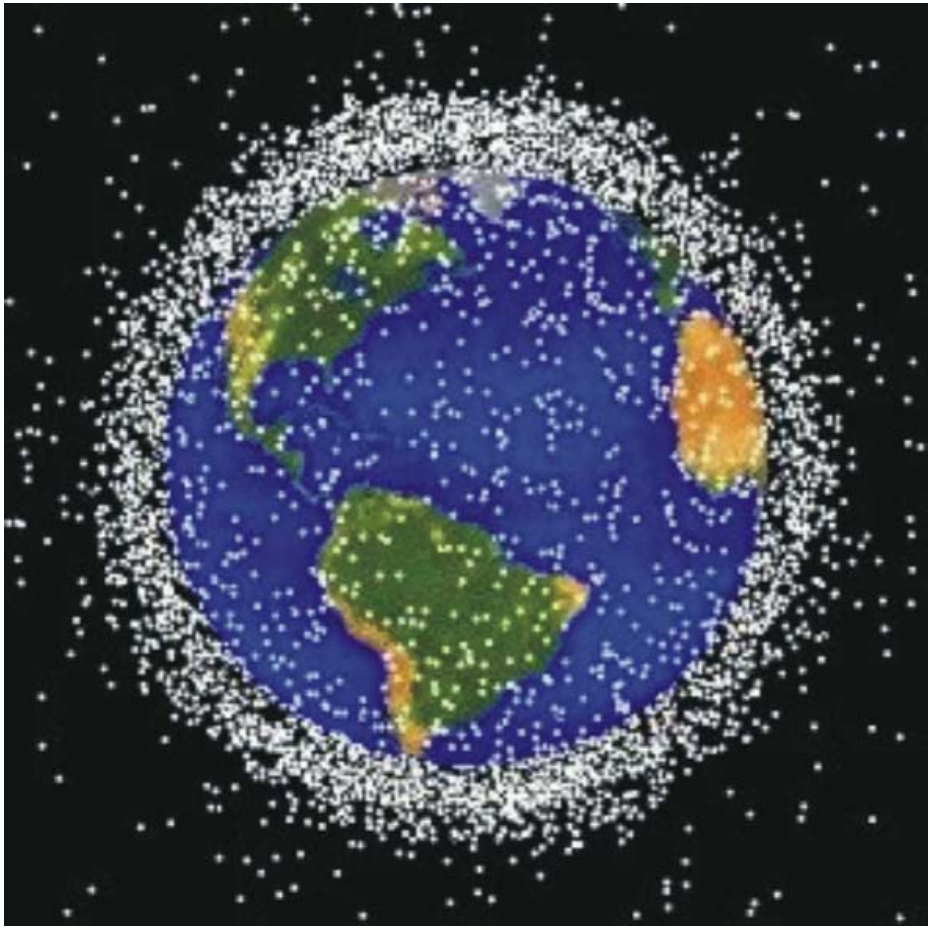
Programmatic goals (3)

Disposal of space debris – safety for human population on earth and space assets on orbit



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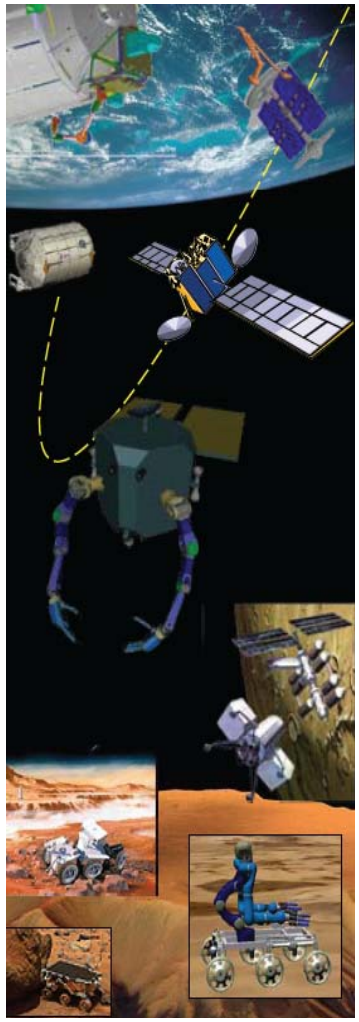
Programmatic goals (4)
Transfer of Technology from and to Space-Robotics



Space-Robotics ←Technology Transfer →Terrestrial Robotics

- In unknown Environment
  - Locating and connecting
  - Flight control und navigation
  - Detection and monitoring
- For Servicing
  - Assembling/Disassembling of equipment and stations
  - Supply, operation & maintenance of equipment, platforms and stations
  - Transport of equipment and goods
- For Automation
  - Local/artificial intelligence
  - Autonomous navigation
  - Autonomous activities/workflows

In space → robustness-reliability-accuracy ← On earth

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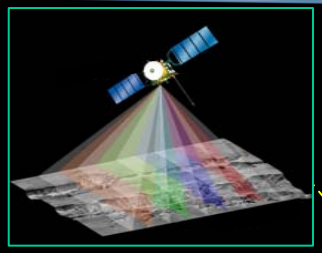
- Status: What did we achieve so far?
- Goals: What do we want to achieve for the national Space Program by focusing on Space Robotics
- **Measures to achieve the goals**

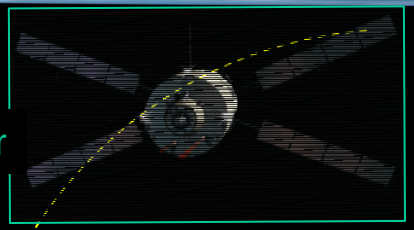
National Conference on Space-Robotics in May 2009 marked the starting point for the extended robotics program

FMET assigned an additional budget to the program !

Exploration



Orbiter



Orbital infrastructure

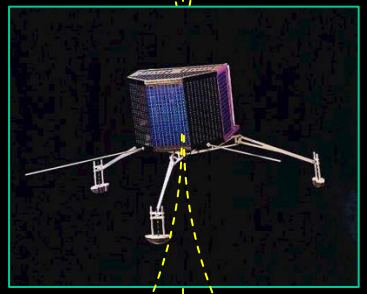
Remote
and on-site sensing

Mapping

In-situ – scientific analyses

In-situ – resource utilization

Sample return



Autonomy

Docking & capturing

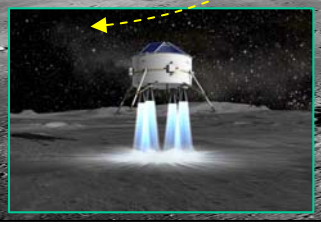
Assembly
maintenance, repair

Guidance, Navigation & Control

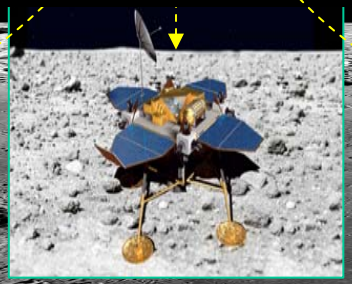
Rendezvous & Docking

Self localization

Operational stations



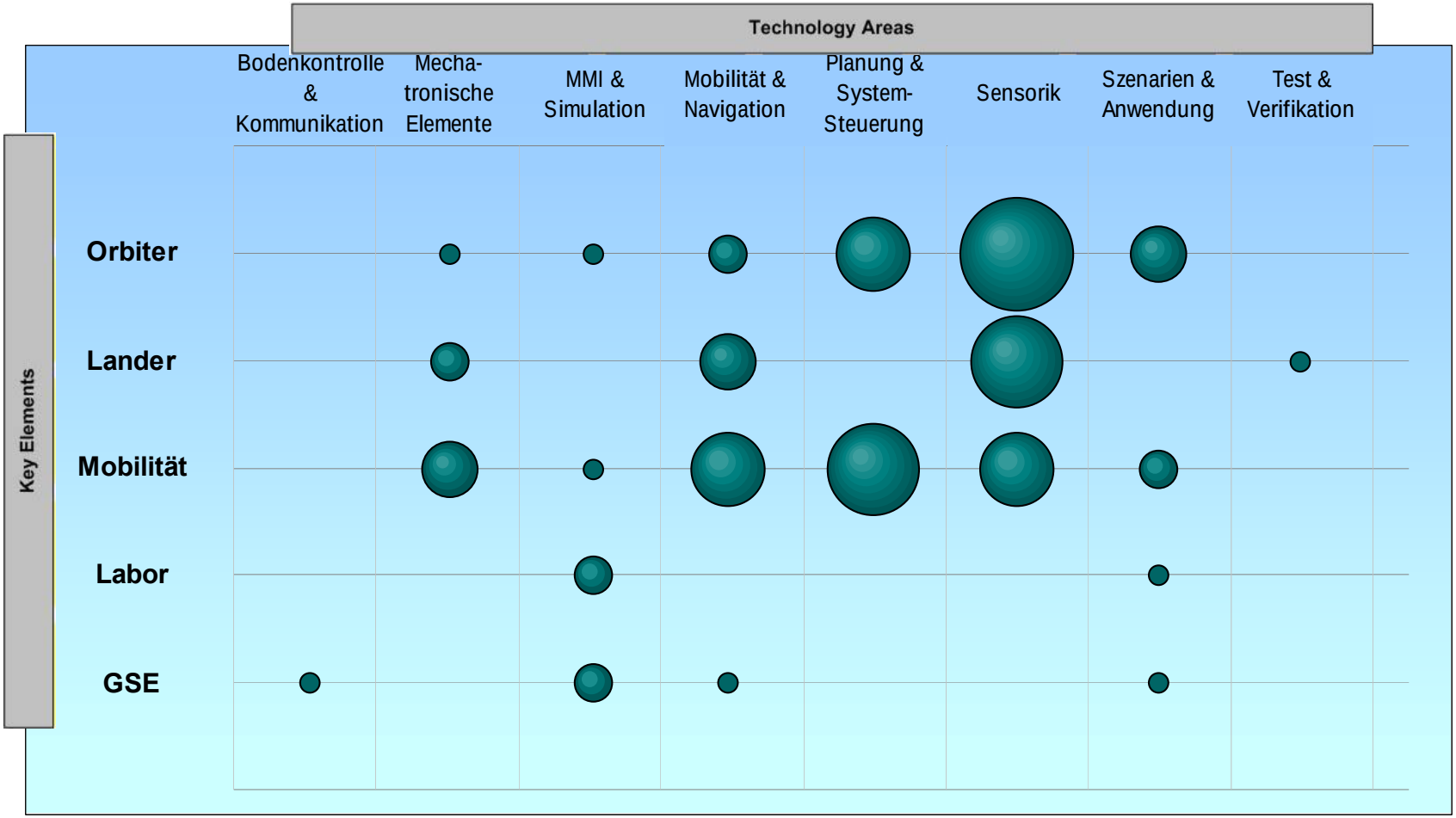
Soft and precise landing



Mobility

One underlying technological basis !

Assessment of technological sectors with respect to their application potential for multiple mission elements



Selection criteria for activities and projects:

- **Key technology with potential for further development?**
- **Multiple employment in space exploration and orbital servicing ?**
- **Transfer potential to terrestrial applications ?**

Assessment of technological sectors with interdisciplinary application

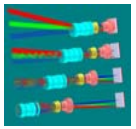
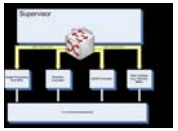
Roadmap of activities, topics and projects to be pursued

Robotic key-technologies

tools, gripper, hands, arms, torso, controller, sensors, …





Multiple employment in space exploration and orbital servicing

ARAMIES

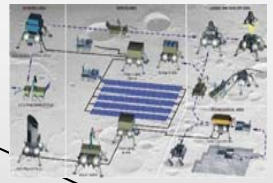
LUNARES

MoMo

ROBEX

Space Climber

RovoNaut



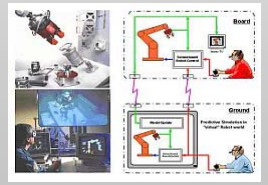
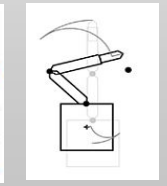
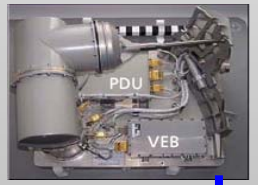
Lunar/planetary environment

Servicing from LEO to GEO

?

ServoNaut

ROTEX → GETEX → ROKVISS → DEOS → RoboNaut

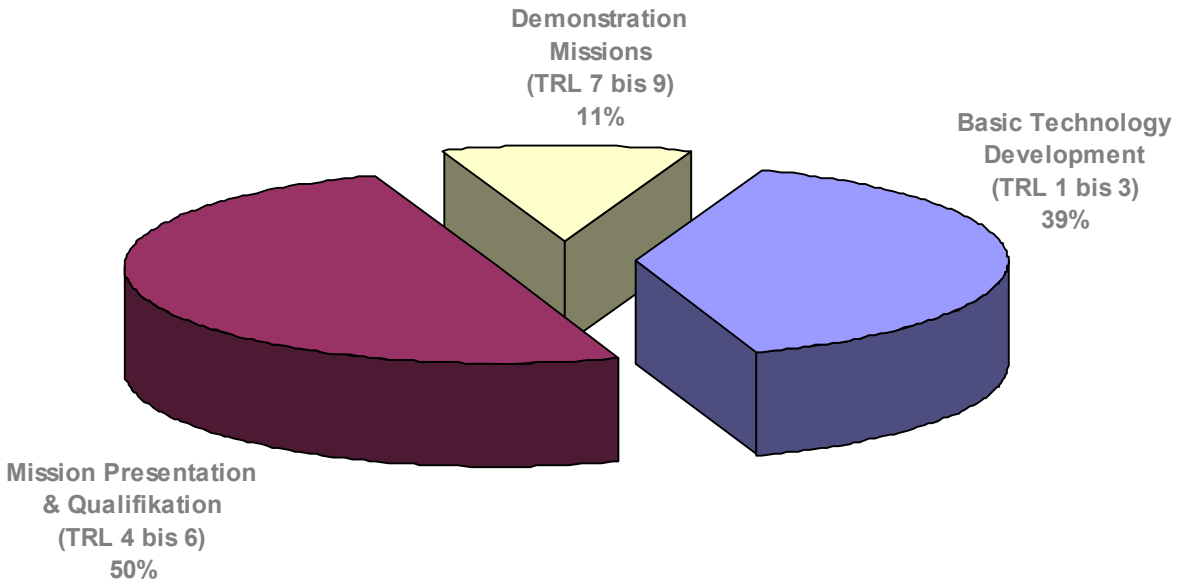





Transfer potential to terrestrial applications

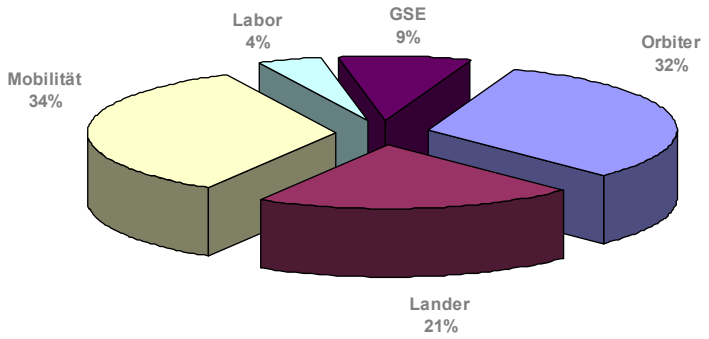
Industry *Service* *Space und security*



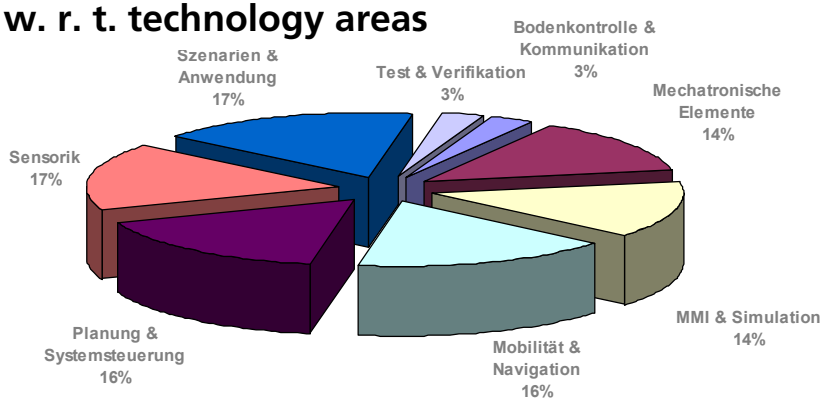
Budget allocation w. r. t. TRLs



Budget allocation w. r. t. key elements

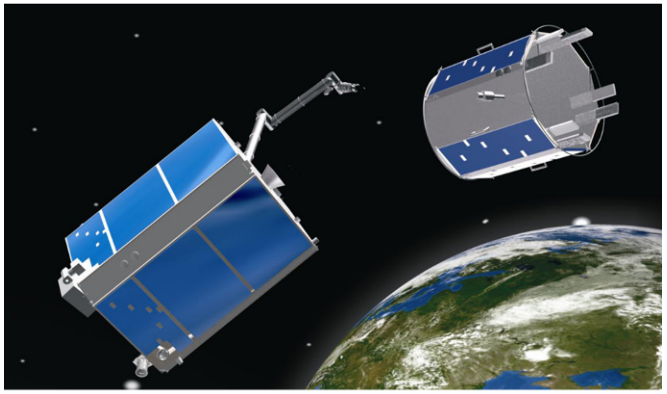


Budget allocation w. r. t. technology areas



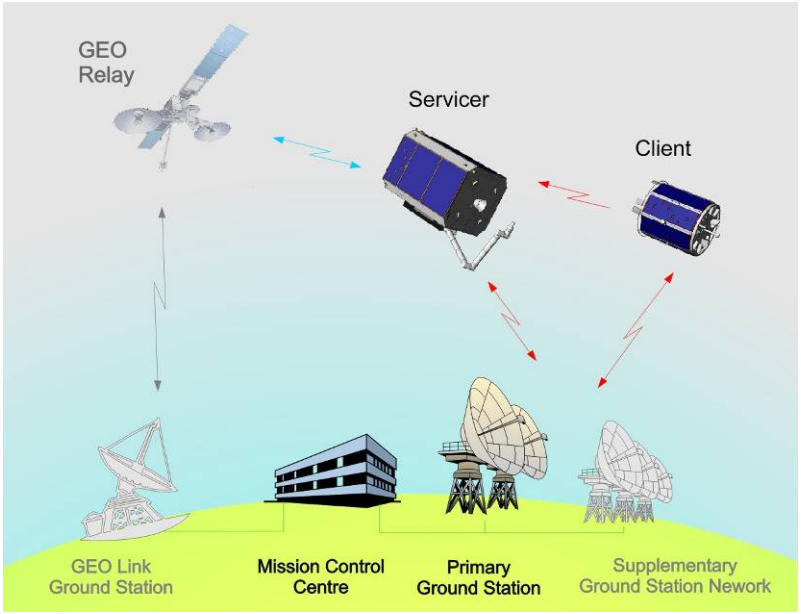
Thank your for your patience !

DEOS
Deutsche Orbitale Servicing Mission



Mission statement:

- Autonomous rendezvous
- Capture of a non-cooperative satellite
- Demonstration of satellite servicing
- Controlled disposal of the satellite



Status:

Phase 0 :	**Concept evaluation by DLR 04/07-07/07**
Phase A:	**Feasibility Study 07/08-02/09**
Phase B:	**Preliminary Design currently running**

More detailed information in separate presentation !

Space Climber

Biologically inspired, energy-efficient, six-legged, semi-autonomous, free climbing robot for steep slopes and rough terrain

- **Provide unique terrain adaptive robot mobility through biologically inspired motion patterns**
- **"Passive dynamic" through intelligent morphology (motion patterns arise from body shape and structural elements)**

  → High energy efficiency
- **Distributed control of the robot**

Term of Contract: **01.07.2007 – 30.11.2010**

Status: : **Assembly and integration completed**

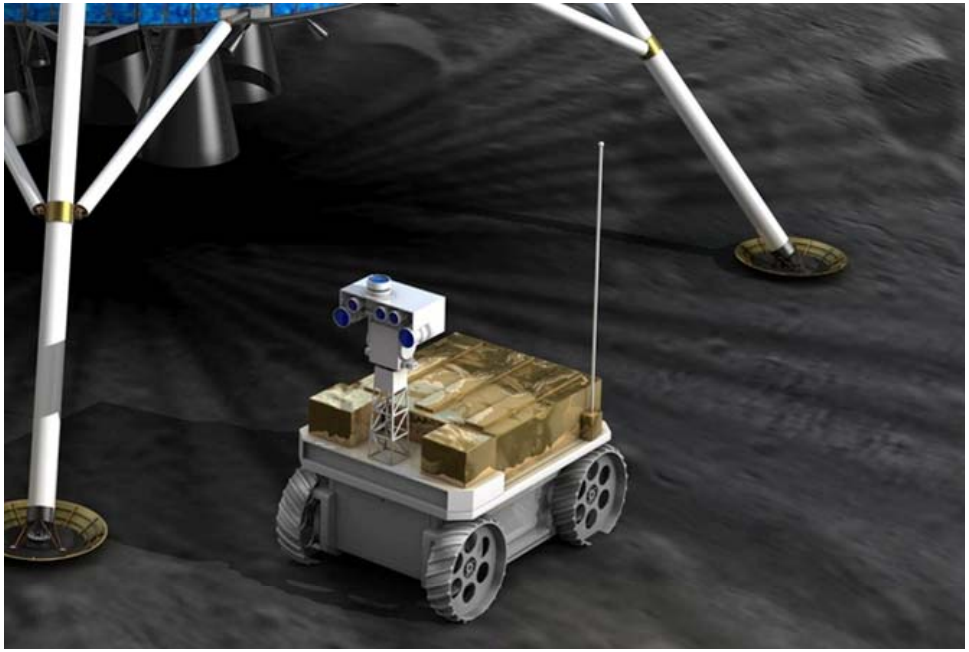
Test phase completed

System demonstration this week here at ESTEC during ASTRA on Thursday 14th of April 2011!!!

Mobile Payload Element, MPE

Potential German contribution to ESA's NEXT Lunar Lander Mission

- Mobility range > 100 m from lander module (LM) position
- Collection and transfer of probes to scientific instruments on the LM
- Cooperation of MPE and LM for communication, navigation, probe handling and re-charging purposes
- In-situ scientific experiments
- Passive survival of the lunar night, no RHU or RTG
- Lifetime: 6 – 9 month



Artist's view of MPE

Term of Contract: April 2011 – January 2012

Status: : Award of contract effected for combined phase 0/A

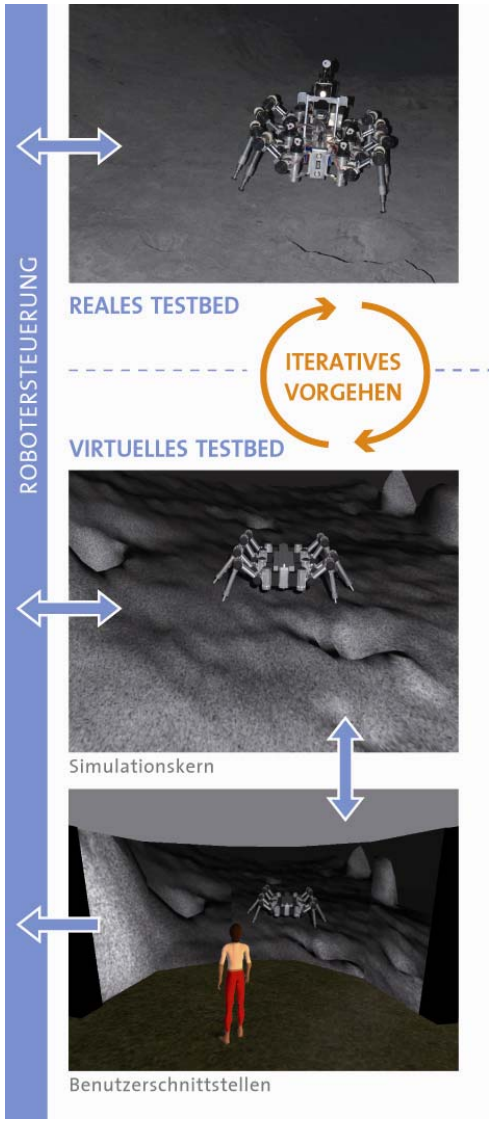
Due to discrepancy between LM requirements and goals Phase B/C/D-decisions to be taken after successful completion of Ph. 0/A

Virtual Crater

- **Development of a virtual test environment for programming and optimization of robotic systems in a realistically simulated lunar crater scene.**
- **Interconnection of the virtual environment with an existing laboratory test bed.**
- **Adjustment of the two test beds in order to achieve convergence.**

Term of contract: **01.05.2009 – 30.04.2012**

Status: **Analysis of requirements completed, design phase and bread boarding running**



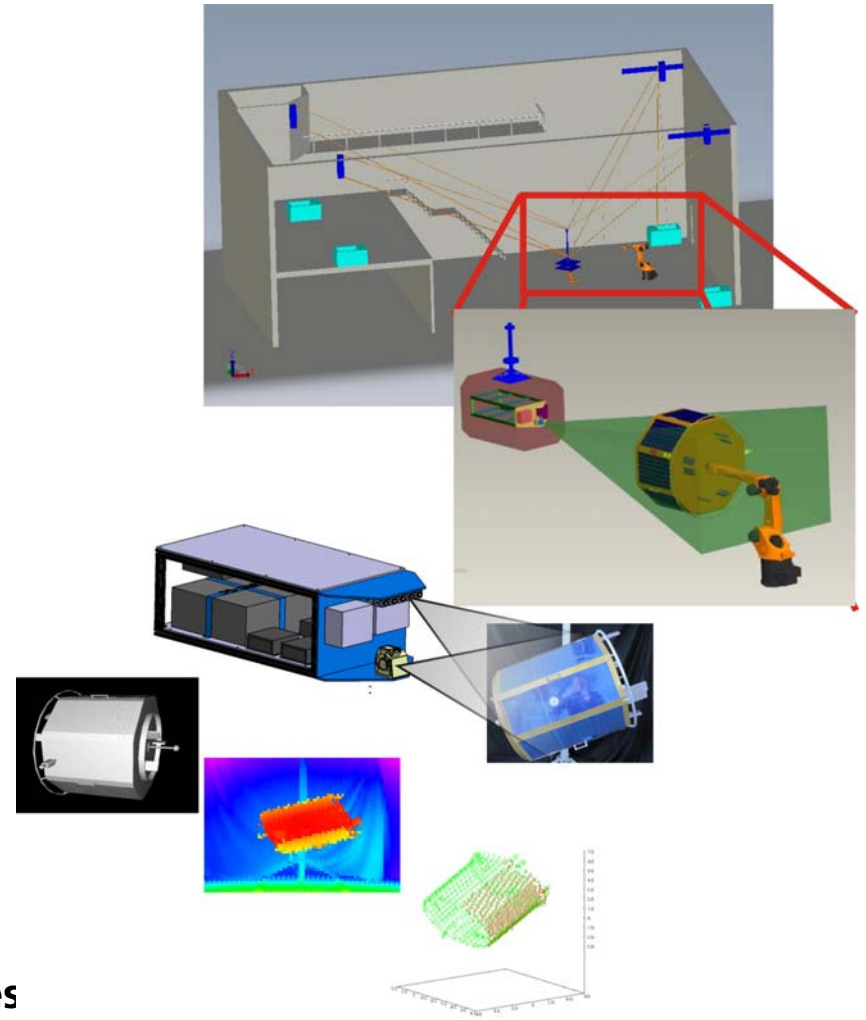
INVERITAS

Innovative technologies for relative navigation of mobile autonomous systems

Integrated sensor head for :

- **relative navigation to perform on-orbit rendezvous, docking and capture**
- **SLAM and navigation on planetary surfaces**
- **Control of the touch-down trajectory of a lander**

Set-up of a 3D-laboratory test bed in order to achieve TRL 5 - 6

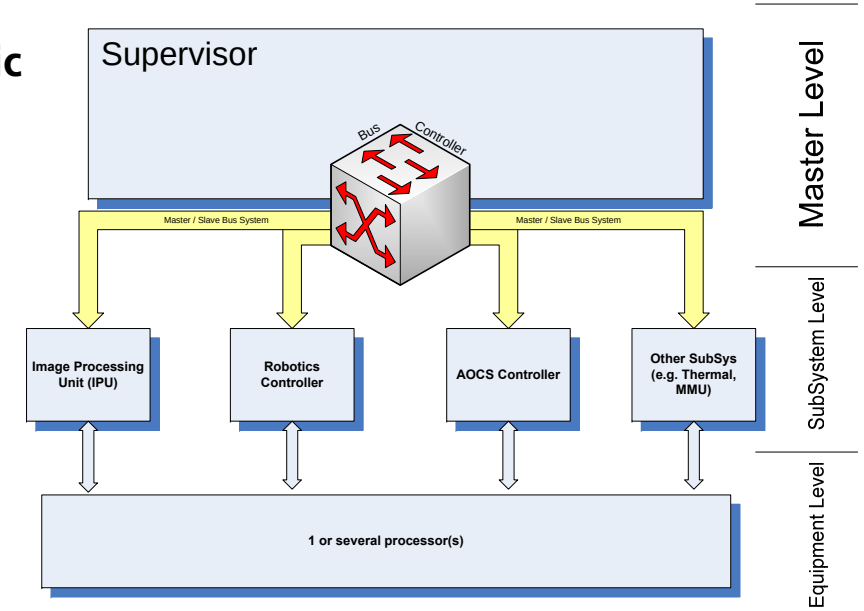


Term of contract:	**01.05.2009 – 31.01.2012**
Status:	**Analysis of requirements completed, preliminary des phase and bread boarding running**

KARS

Controller for autonomous spacecrafts

- Flexible high level system control software suitable for various mobile platforms in robotic missions
- Adjustable autonomy levels
- Data base driven hierarchical control and command structure
- Structuring of the whole platform system into subsystems
- Subsystems coordination, scheduling, messaging, data distribution, inter process communication etc. through a central supervisor

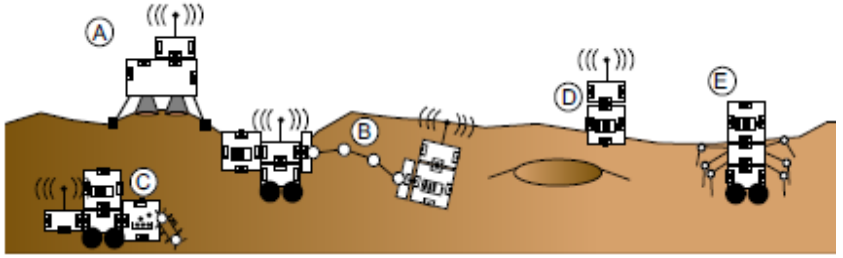


Term of Contract: **01.01.2011 – 31.07.2013**

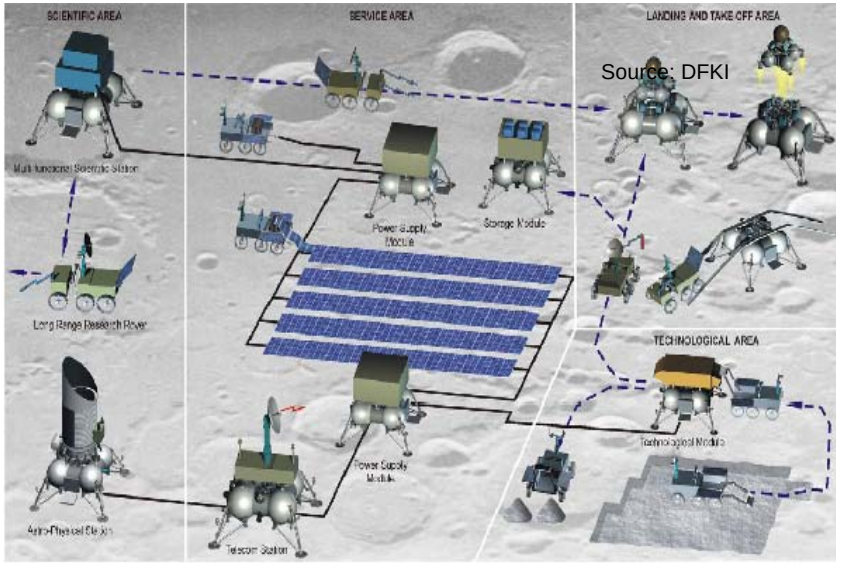
Status: : **MARCO V.1.0 to control ROKVISS**
Award of contract effected,
design phase running

RIMRES

Reconfigurable integrated multiple-robot exploration system



- **Assembly of robotic agents with varying properties based on standardized components for mobility, manipulation, power supply, communications etc.**
- **Highly modular system concept – Compilation of a robot team out of robotic agents based on mission objectives and requirements**
- **Inherent redundancy through modularity**



Term of contract: 01.09.2009 – 31.08.2012

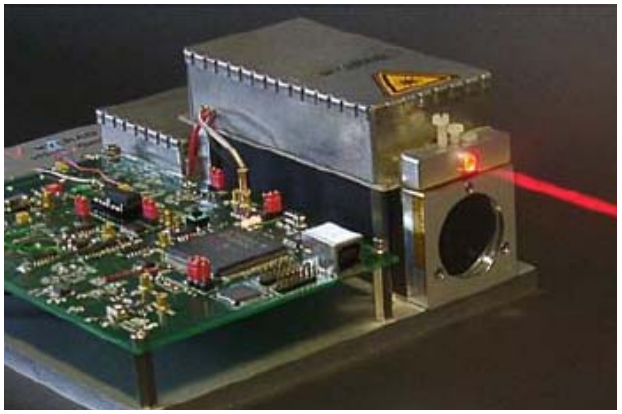
Status: Analysis of requirements completed, design phase and bread boarding running

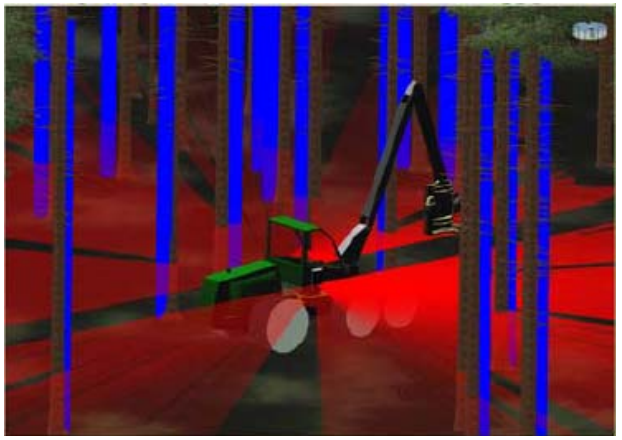
Source: Roskosmos - ,,Lunar Polygon"

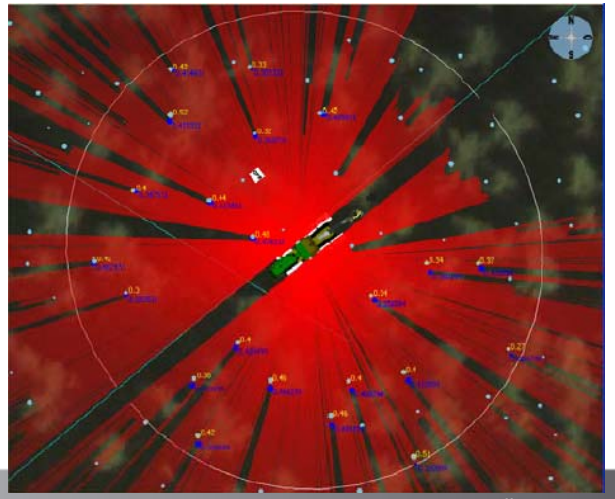
SELOC

Self-localization of robots on planetary surfaces

- Two major components:
  - High resolution laser scanner for detection and measuring of landmarks in the vicinity of the robot
  - Advanced localization algorithms based terrestrial applications in forestry
- Position determination through comparison of the detected landmarks with low resolution maps of the area, 3d resolution 30 cm
- Set-up of a prototypic self localization unit
- Test and verification in relevant environment, goal TRL 5







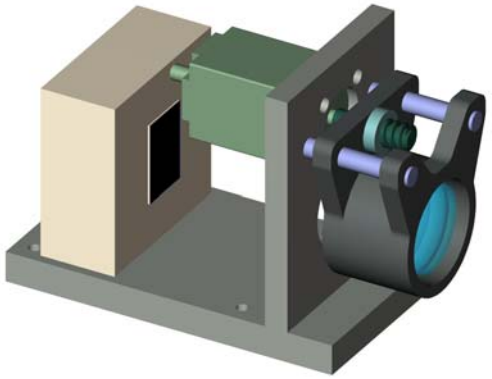
Term of Contract: 01.01.2010 – 31.03.2013

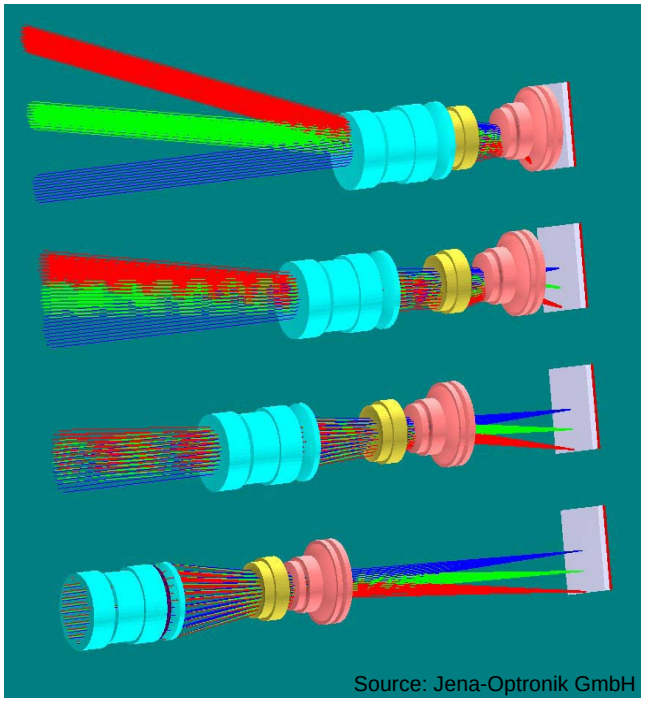
Status: : Derivation of requirements completed, H/W and S/W design running, bread boarding running

ZoomOb

Feasibility study of a zoom lens for rendezvous sensors in space

- **Image-guided method to measure relative position, orientation and motion between two mission elements like servicer and client satellite, or rover and target object**
- **Stereoscopic vision possible using twin zoom lenses**
- **Determination of distance irrespective of target rotation or missing markers/ reflectors, e.g. applicable to non-cooperative satellites or space debris**





Source: Jena-Optronik GmbH

Term of contract: **01.11.2009 – 28.02.2011**

Status: **Feasibility study and analysis of requirements completed, preliminary design phase and bread boarding running**

LiQuaRD

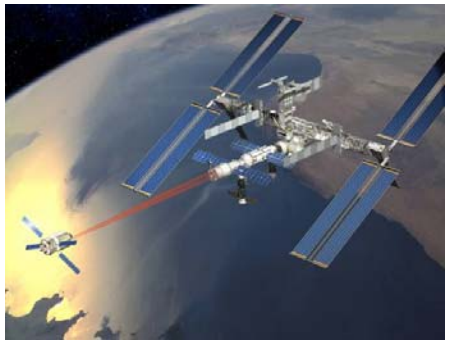
3D-lidar pre-qualification for rendezvous and docking with non-cooperative satellites

- **Further development of the existing lidars from ATV and HTV for the approach of non-cooperative targets:**
  - **Reduction of size, power consumption, mass, image integration time, data transfer rate**
  - **Increase of resolution and sampling rate**
- **Focus on o**ptical scanner unit and suitable fiber laser
- **Qualification tests of main components in relevant environment, achieve TRL 5**

Term of Contract: **01.08.2010 – 31.01.2012**

Status: : **Design phase and bread boarding running**

Source: Jena-Optronik GmbH

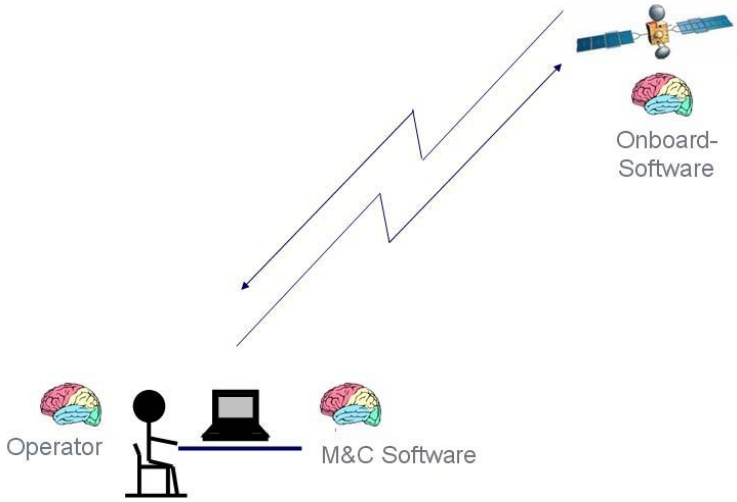


Source: Jena-Optronik GmbH

MiCCRo

Mission Control Concepts for interactive Robotic Platforms

- Concept and design of a ground control station for highly mobile robotic platforms on orbits and on planetary surfaces
- Data handling, e. g. storage, update distribution, communication
- Evaluation and implementation of adjustable autonomy levels
- Design of suitable MMI's for monitoring, control, (re-)planning, reprogramming, troubleshooting, etc.



Term of Contract: 01.10.2010 – 31.07.2012

Status: : Proposal evaluation completed

Award of contract effected

iStruct

Intelligent structural elements as building blocks for mobile robots

- Development and construction of biologically inspired standardized structural elements such as traction-supporting structures or flexible body structures
- Integration of sensors, data pre-processing, communication-, data-, power-I/F etc.
- Set-up of an exemplary application by integration and test of basic building blocks and demonstration of intelligent structures

Term of Contract: 15.05.2010 – 15.08.2013

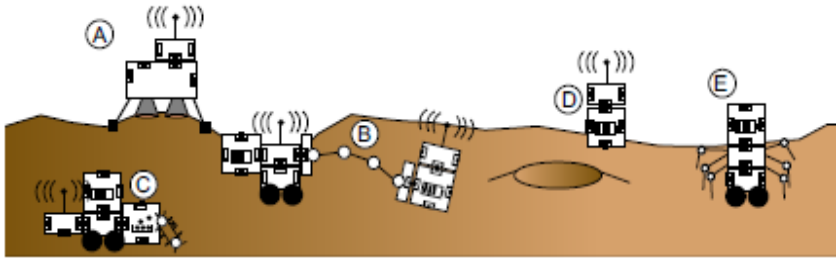
Status: : Evaluation of concept, derivation of requirements completed, design phase running

Source: DFKI

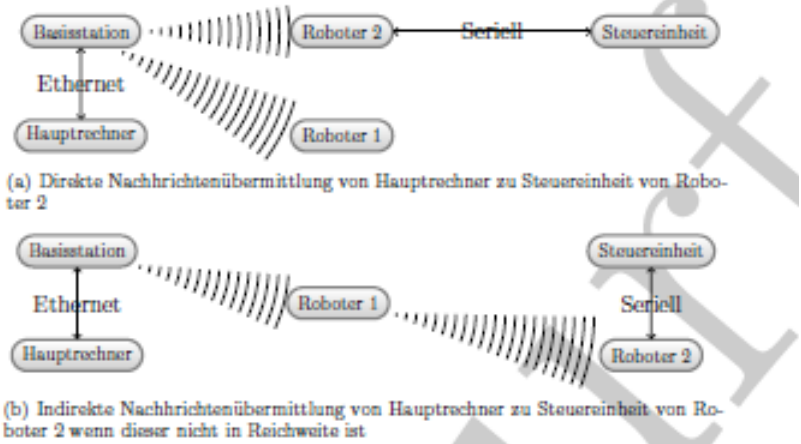
CoHoN

Communication in Heterogeneous Networks

- Communication Library for a distributed software architecture on embedded systems (multi robot communication)
- Application oriented, event driven communications paradigm as basis for transparent distribution of processor load
- Assessment of system status for selectior of communication channel
- Data re-routing in case of failure
- Parallel operation of different communications channels
- Simple and unified interface



Source: DFKI



(a) Direkte Nachhrichtenübermittlung von Hauptrechner zu Steuereinheit von Roboter 2

(b) Indirekte Nachhrichtenübermittlung von Hauptrechner zu Steuereinheit von Roboter 2 wenn dieser nicht in Reichweite ist

Abbildung 4: Beispiel für eine sich automatisch anpassende Kommunikation in Funknetzen

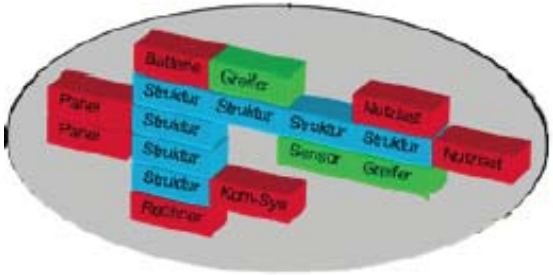
Term of contract: **01.04.2010 – 31.03.2013**

Status: **Design phase and bread boarding running**

iBOSS

Intelligent Building Blocks for On-Orbit Satellite Servicing

- Development of building blocks for highly flexible and modular S/C design increasing maintainability with focus OOS applications
- Combination of different building blocks or re-configuration of existing ones result in new building block chains (S/C) which can be adapted depending on mission objectives
- Building blocks consist of “intelligent” interfaces in order to identify new configurations



Source: TU Berlin

Term of contract: 01.07.2010 – 30.06.2012

Status: Analysis of requirements, system analysis, derivation of theoretical basics

IMMI

Intelligent Man - Machine Interface

- **Advanced brain-reading**
- **Development of key technologies**
- **Demonstration of key features in laboratory environment**

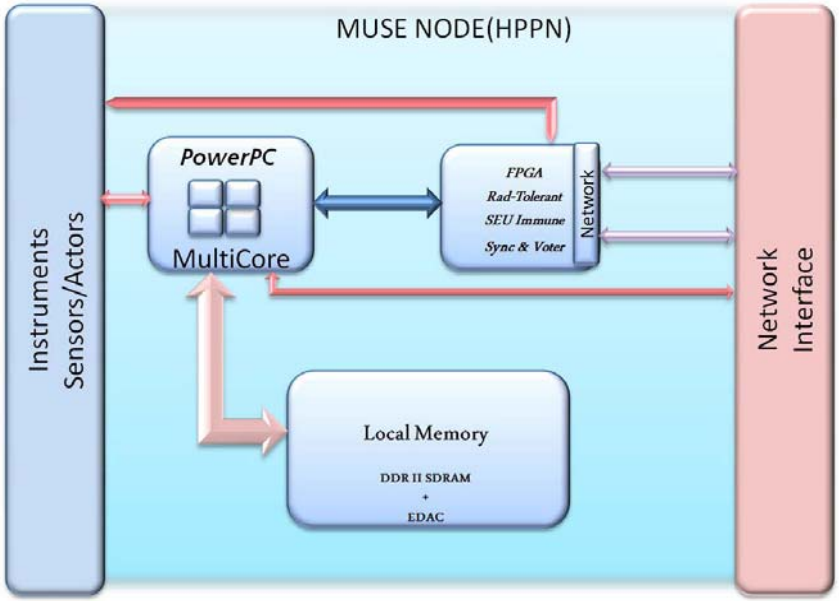
Term of Contract: **01.05.2009 – 31.01.2012**

Status: : **Evaluation of concept, derivation of theoretical basics, prototyping**

MUSE

MUlti-core architecture for SEnsor based position and orientation tracking in space

- Utilization of a multi-core processor for complex tracking sensor data processing
- Evaluation of the computing performance
- Evaluation and selection of methods for parallelization of algorithms
- Design, implementation and test of a prototypic tracking sensor data processing architecture



Term of Contract: 01.07.2010 – 31.06.2012

Status: : Evaluation processes running

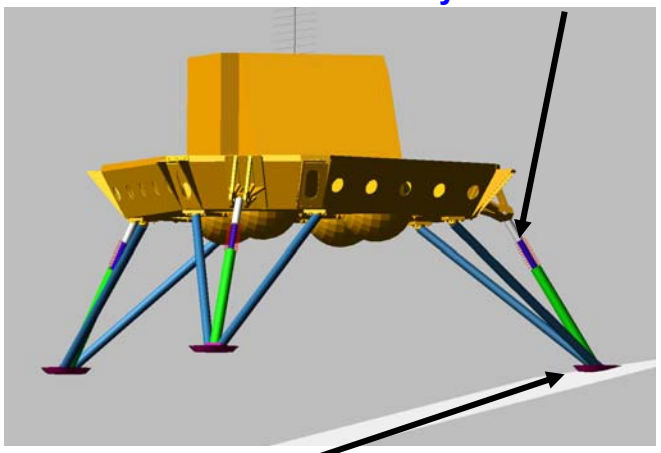
Triple A

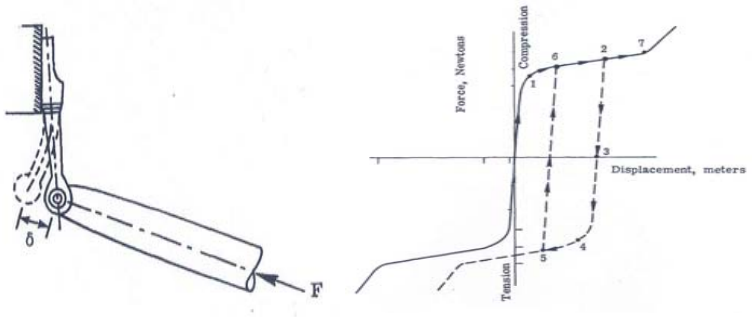
Autonomous Anti-tilt Actuator for Cushioning of touch down, erection and alignment of a planetary lander

- Evaluation of two shock damping methods:
  - Deformable materials in combination with robotic actuators
  - Fully actuated system
- Set-up of a landing trajectory and touch down simulator
- Bread boarding, test of dampers and actuators and sensors

Term of Contract: 01.10.2010 – 31.05.2012

Status: Proposal evaluation complete
Award of contract effected



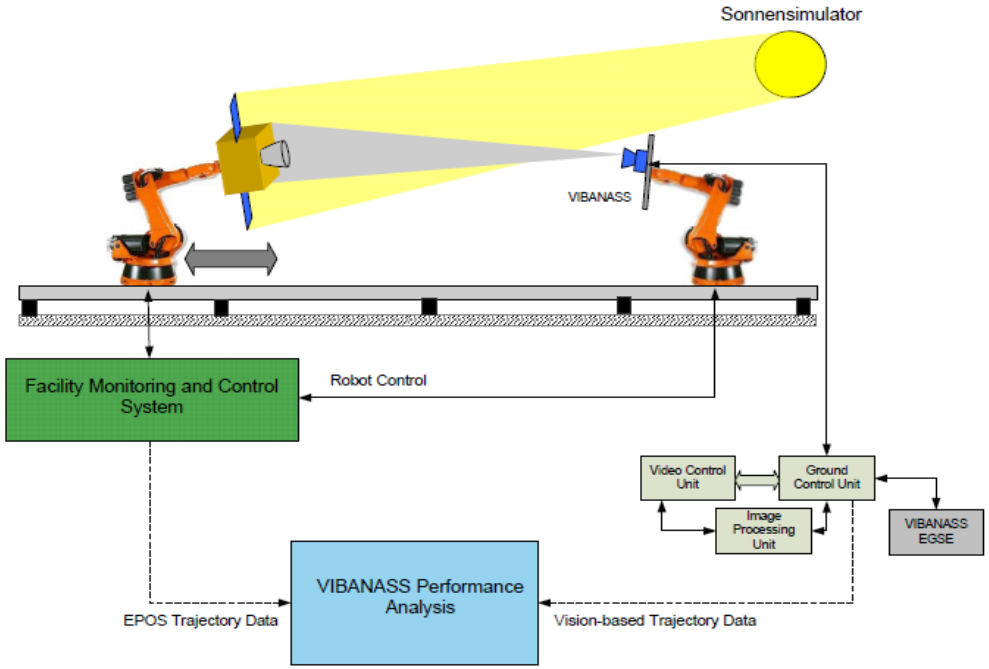


Source: First ASTRIUM internal EDLM Study

VIBANASS

Vision-Based Navigation Sensor System

- Multi-purpose optical camera for orbital RvD, landing, surface navigation etc.
- Development and building of a qualification model
- Set-up of a camera data processing unit to create input signals for GNC algorithms
- Test and verification in relevant laboratory environment, goal TRL 5



VIBANASS in test lab
Source: Kayser-Threde GmbH

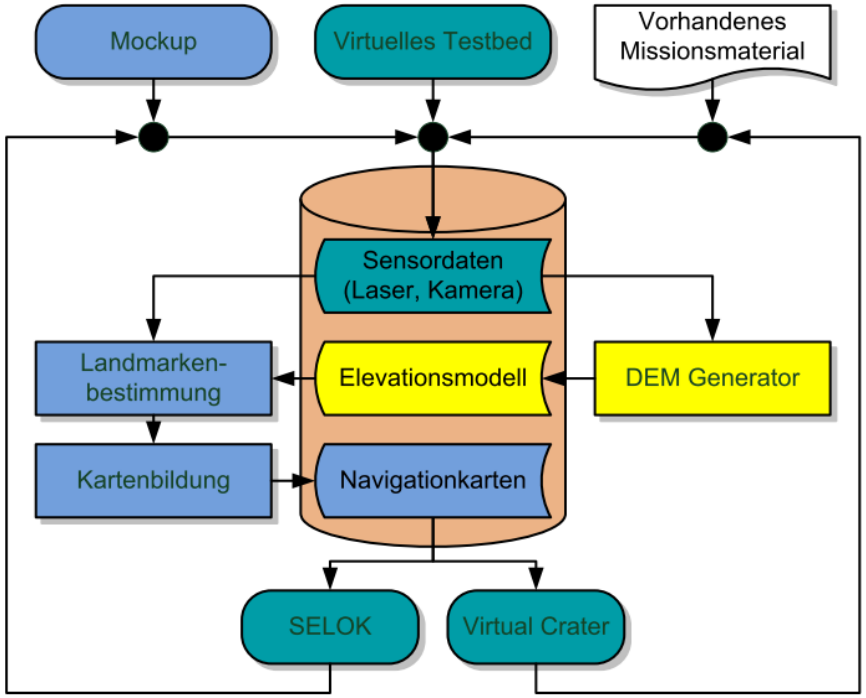
Term of Contract: **01.01.2010 – 30.06.2012**

Status: : **Evaluation of concept, derivation of requirements completed, design phase running**

Fast Maps

Extremely fast generation of 3D maps for planetary landing and operations on the surface

- **Investigation and selection of appropriate methods to rapidly create digital elevation models and maps of planetary surfaces**
- **Localization of vehicles via extraction of suitable landmarks from models and maps**
- **Planetary mockup & virtual test bed for verification of the derived methods**



Term of Contract: **01.07.2010 – 31.12.2012**

Status: : **Derivation of requirements and investigation of methods running**