HELMHOLTZ
GEMEINSCHAFT

ROBEX Allianz

HGF-Alliance ROBEX
Robotic Exploration of Extreme Environments

ESA - ASTRA Conference
13. May 2015, Noordwijk, The Netherlands

Robotics and Mechatronics Center, RMC
Münchner Str. 20, D-82234 Wessling

Armin Wedler, http://www.robex-allianz.de/
(1) DLR - German Aerospace Center, Institute of Robotics and Mechatronics (Germany) armin.wedler@dlr.de
(2) DLR - German Aerospace Center, Institute of System Dynamics and Control (Germany), matthias.hellerer@dlr.de
(3) DLR - German Aerospace Center, Institute of Space Systems (Germany), lars.witte@dlr.de
(4) DLR - German Aerospace Center, Institute for Planetary Research (Germany), nicole.schmitz@dlr.de
(5) Jacobs University, Ocean Lab, Earth and Space Sciences (Germany), l.thomsen@jacobs-university.de
(6) University of Bremen, MARUM (Germany), waldmann@marum.de
(7) GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel (Germany), sfloegel@geomar.de
(8) Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (Germany), martina.wilde@awi.de
(9) Department of Mechanical and Aerospace Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology (Japan), takei.yuto@jaxa.jp

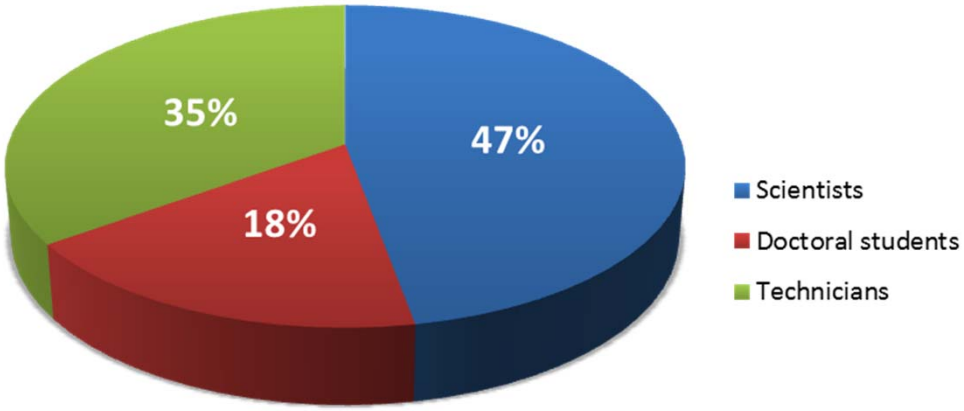
ROBEX

HELMHOLTZ | GEMEINSCHAFT
ROBEX Allianz

ROBEX Consortium

About 100 scientists, engineers and technicians spread over Germany are involved in ROBEX

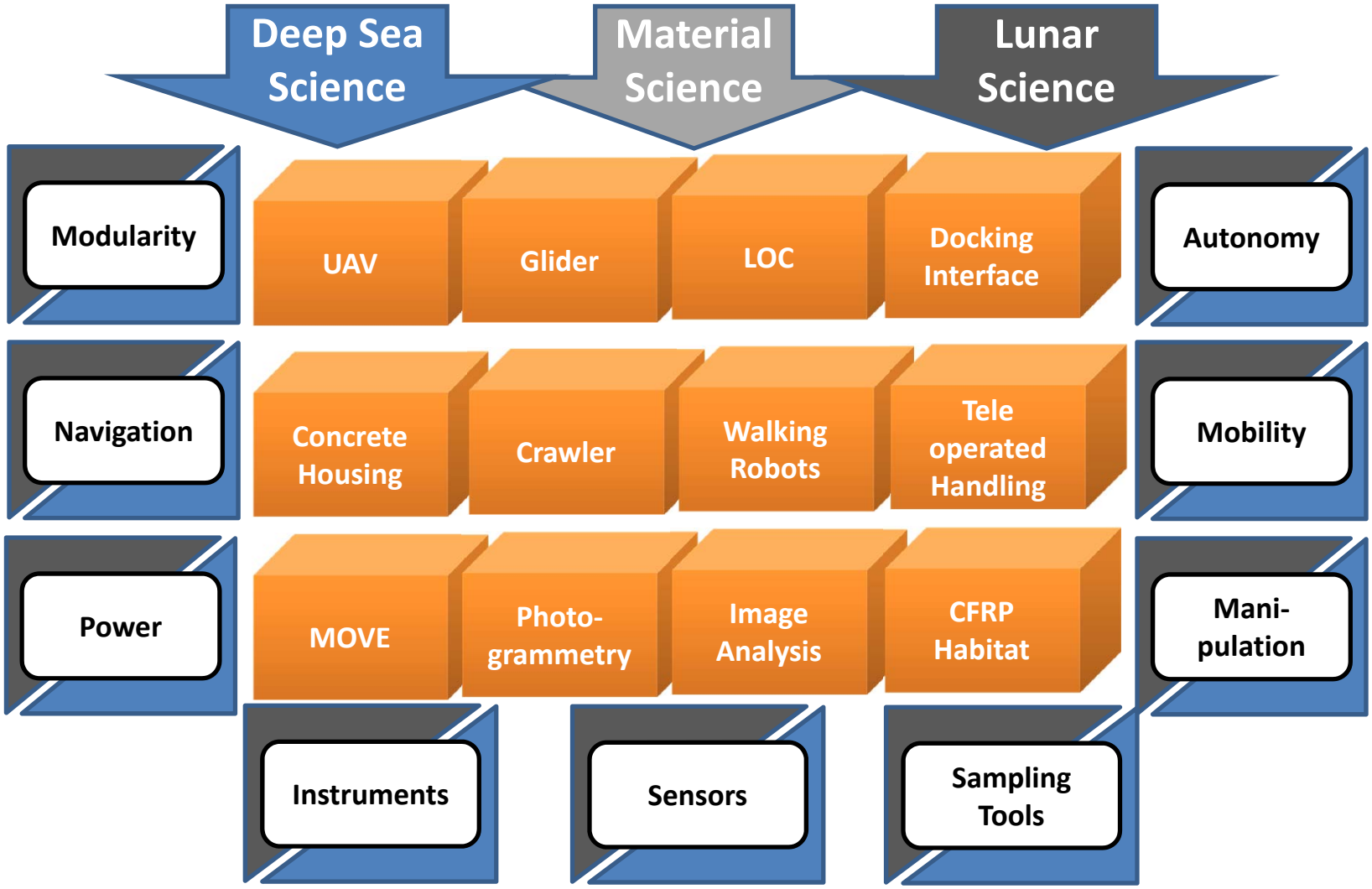
http://www.robex-allianz.de/



ROBEX

HELMHOLTZ | GEMEINSCHAFT
ROBEX Allianz

WPs and Design teams



ROBEX

Agenda

- ROBEX introduction
- Important marine design team developments
- Standardization of a modular docking system
- Demo mission space in robex
- Simulation environment
- Conclusion

Design team
Deep-sea Glider

marum
Zentrum für Marine Umweltwissenschaften

DLR
Institute of Robotics and Mechatronics

Julius-Maximilians-
UNIVERSITÄT WÜRZBURG

MEMORIAL UNIVERSITY

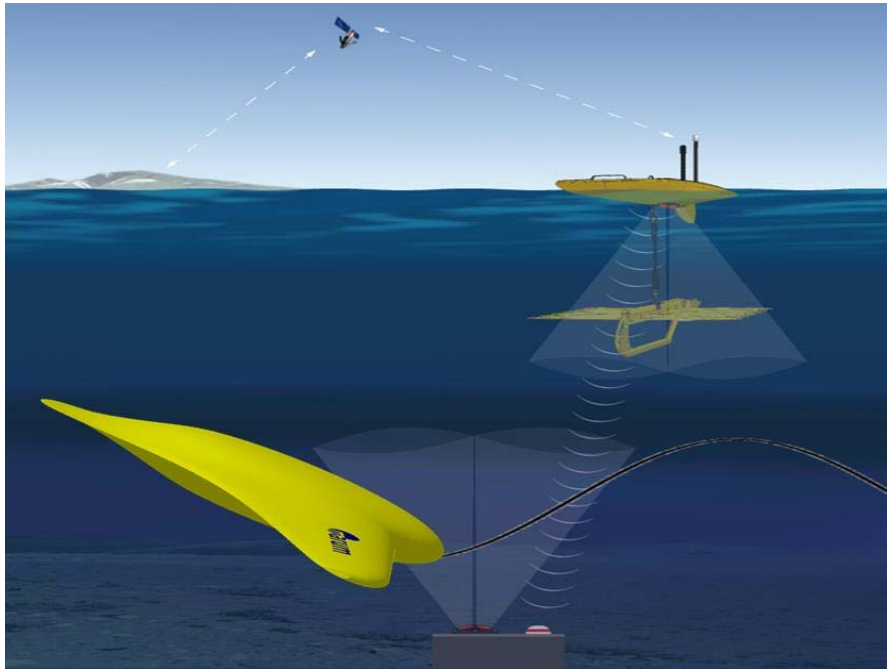
AIRBUS DEFENCE & SPACE

ROBEX

Aims

- Develop an underwater sensor carrier that allows for
  - Long-term
  - Unattended
  - By the platform undisturbed
  - Multidisciplinary

  measurements in the water column



- Underwater gliders are the logical next step to allow for global observation of ocean processes as has been exemplified within the ARGO program

Design team
MOVE-Seismic

marum
Zentrum für Marine Umweltwissenschaften

GEOMAR
Helmholtz Centre for Ocean Research Kiel

Technische Universität Kaiserslautern

DLR
Institute of Robotics and Mechatronics

Aims

Develop a mobile platform to carry:

- seismometers
- electromagnetic sensors
- and instruments for basic
- physical parameters

- ... to allow for better quantification and localisation of gashydrates in deep-sea sediments
- system consists of group of vehicles that will operate autonomously in concerted fashion

Design team
Deep-sea Crawler

GEOMAR
Helmholtz Centre for Ocean Research Kiel

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

JACOBS UNIVERSITY

German Research Center for Artificial Intelligence

DLR

AIRBUS
DEFENCE & SPACE

ROBEX

HELMHOLTZ GEMEINSCHAFT
ROBEX Allianz

Aims

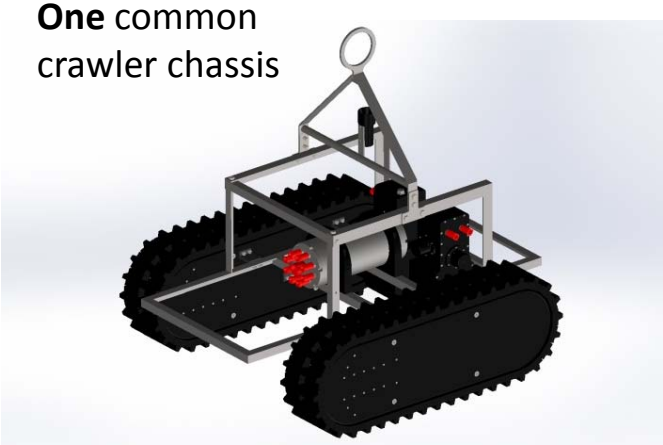
... develop a modular caterpillar driven crawler system for deep-sea studies

autonomous long-term operation

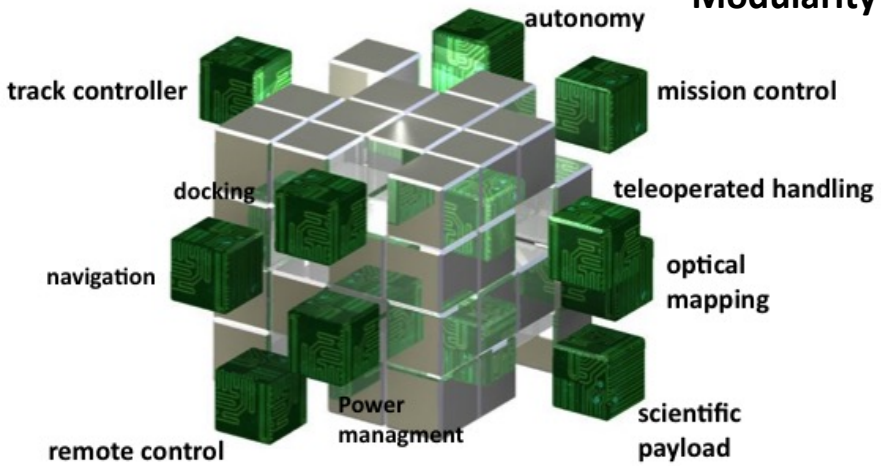
autonomous detection, sampling and measurements

teleoperated manipulator operations

One common crawler chassis



Modularity



Tramper
AWI

Mansio-Viator
GEOMAR

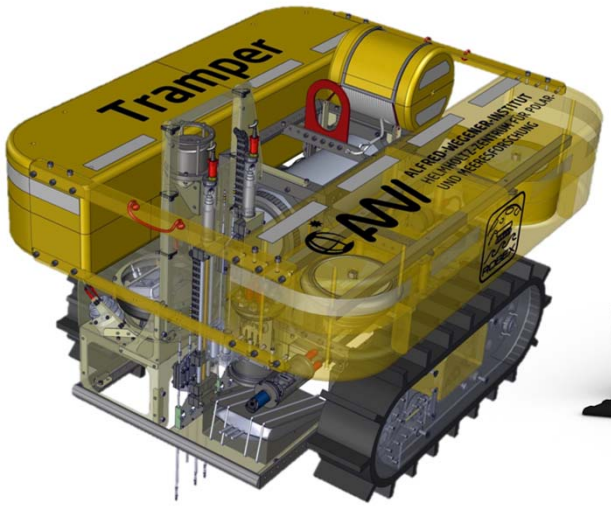
iWally
JUB

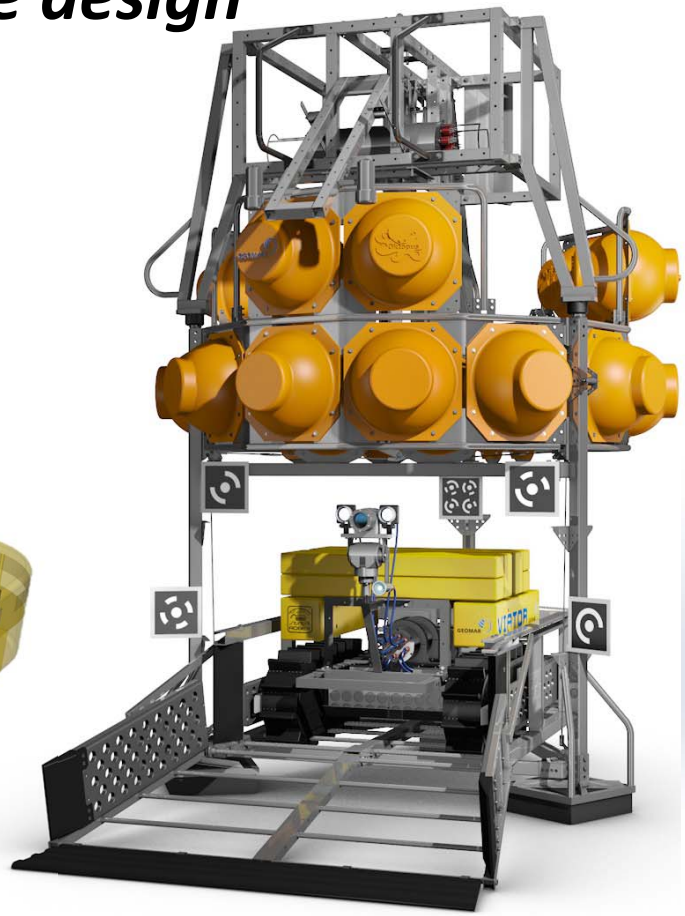
ROBEX

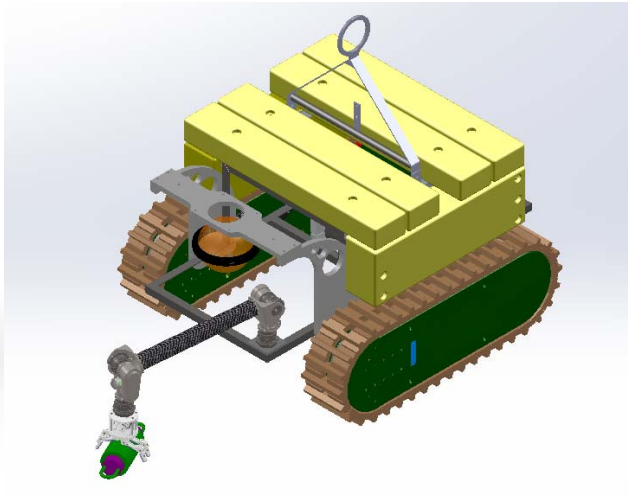
Aims

Modular hardware design

- buoyancy foam
- drivetrain
- frame section
- energy source
- scientific payload



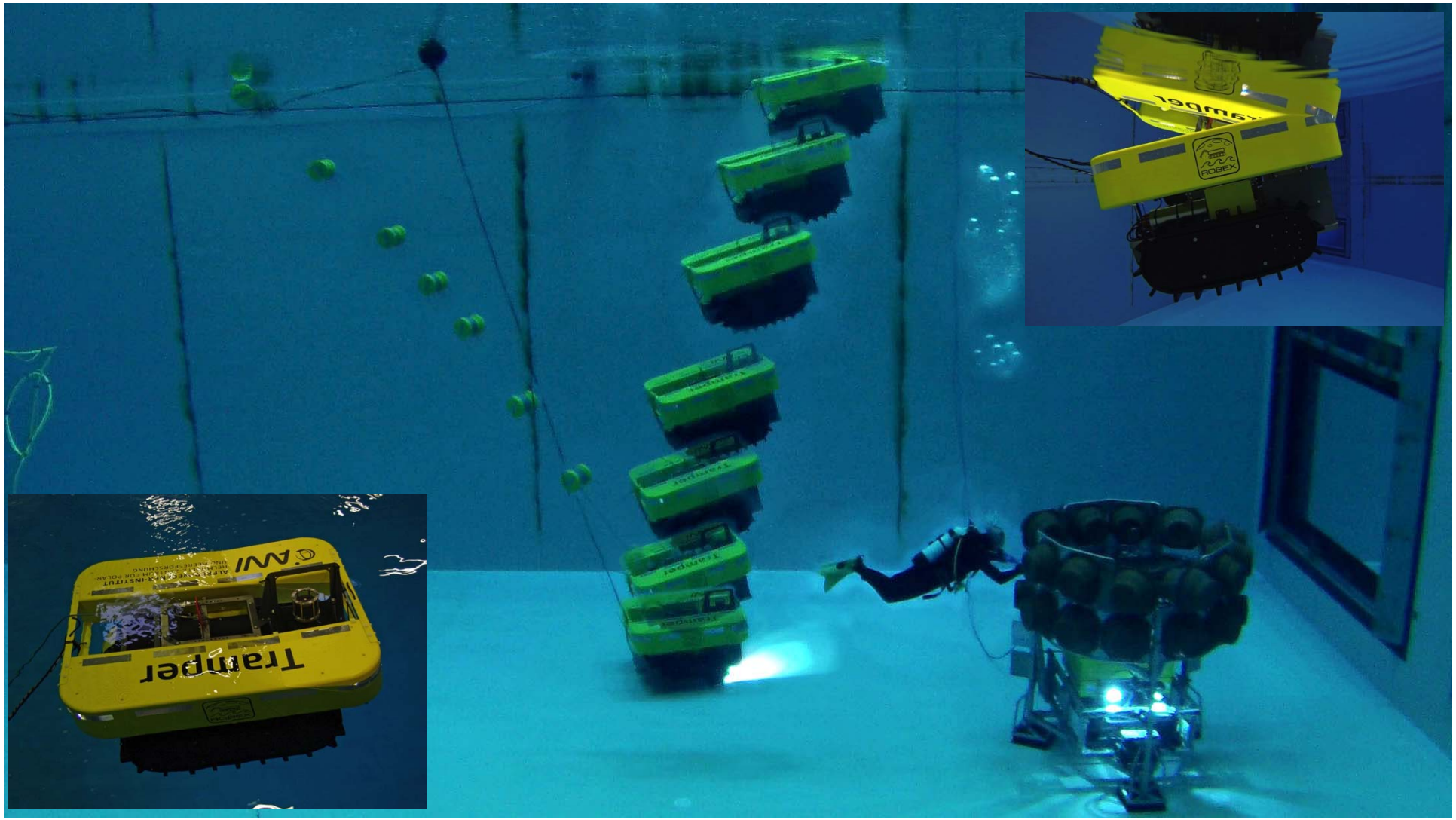




Tramper	*Mansio-Viator*	*iWally*
AWI	GEOMAR	JUB

HELMHOLTZ GEMEINSCHAFT
ROBEX Allianz

Achievements



... fully autonomous crawler system for long-term monitoring and sampling at the sea-floor (e.g. under ice).

ROBEX

Design team
Lab on a chip, LOC

GEOMAR
Helmholtz Centre for Ocean Research Kiel

DLR Institute of Planetary Research

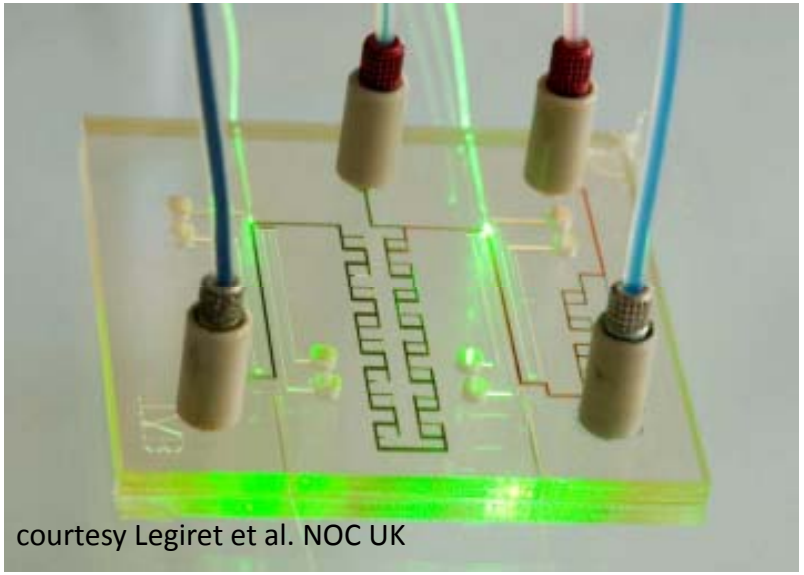
Fraunhofer ISIT

University of Southampton

ROBEX

Lab on a chip (LOC)

Vision: miniaturised and autonomous laboratories –„Lab on a Chip“
innovative sensors for biogeochemical oceanography and space sciences


courtesy Legiret et al. NOC UK

Sample handling
- Preparation e.g. extraction
- Mixers
- Pumps
- Valves

Reactors (small reaction volumina)
Detection (e.g Laser, RAMAN, photometry, ...)

all on one chip!

LOC advantages: small, low reagents, low cost, low power consumption, fast analysis times, potential mass fabrication allows establishment of **sensor networks** etc.

→ meets technical demands within ROBEX

Aims / Achievemnets

1. Establisch LOC technology
2. Integrate LOC technology on ROBEX under water vehicles
3. Explore the use of LOC technology for in-situ experiments & measurements on the ISS or other space missions
4. Demonstrate it´s suitability for (long-term time series) biogeochemical measurements during ROBEX demo mission

... first successful under water test of nitrate/ nitrite chip off Mauritania

... set-up of LOC lab open to all ROBEX partners

Design team
Docking & Interfaces

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Technische Universität München

marum
Zentrum für Marine Umweltwissenschaften

JACOBS UNIVERSITY

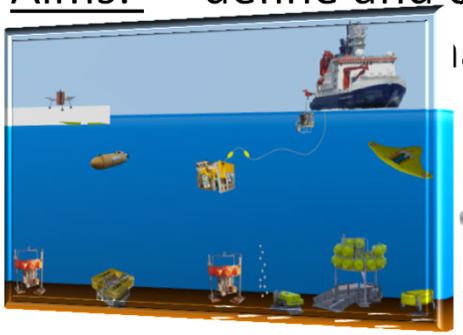
GEOMAR
Helmholtz Centre for Ocean Research Kiel

DLR

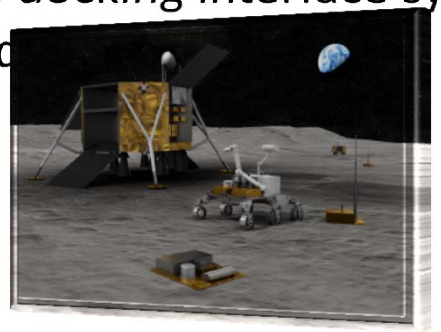
Institute of Robotics and Mechatronics
Institute of Planetary Research
Institute of Space Systems

Docking-Interface

Aims: define and develop appropriate docking interface systems for both ıarios – deep sea and **space**

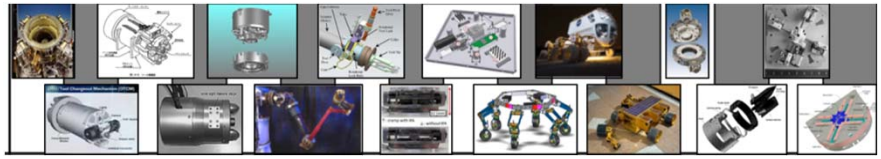


deep sea



Achievements:

Review docking interface systems

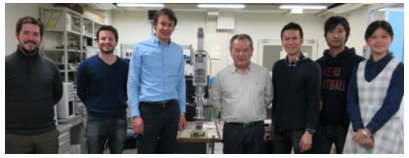


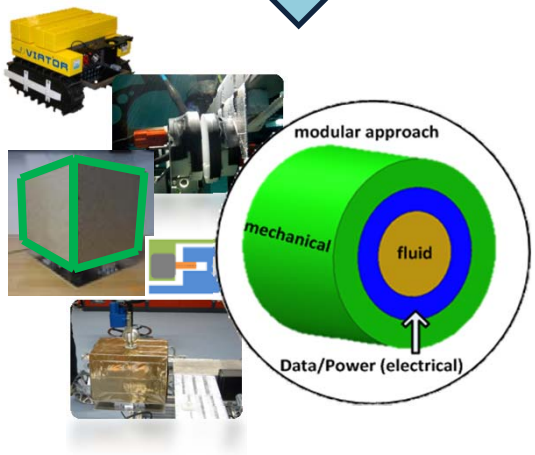
State of the art – **no standard system**

Database for the requirements of all scientific instruments and tools for space and under water

Docking-Interface

Reduction of different systems regarding application (transportation, handling, operation)

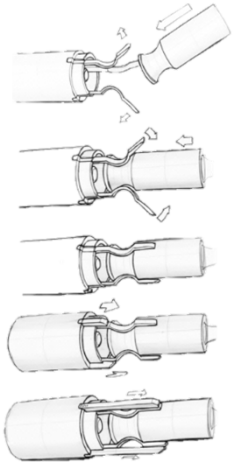




Cooperation with JAXA and TokyoTech in Japan and invention of a **novel** semi-automatically **docking process** to achieve higher safety, better reliability and adequate robustness

Modular approach combines different mechanical inserts with different **data**, **power** and **fluid** transmission inserts

Docking process

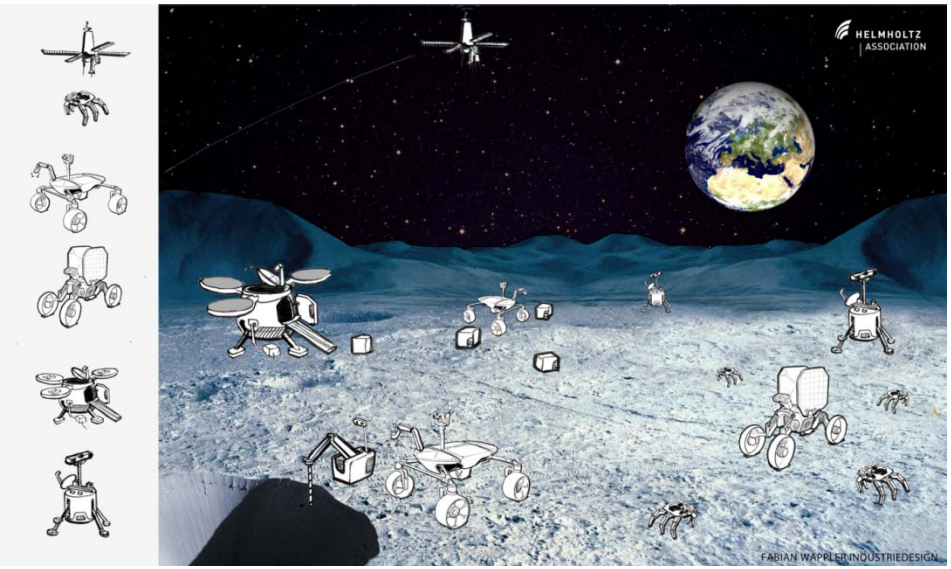


Design idea

Realisation/Test

Aims

- **The ROBEX Demomission SPACE**
  - **Shall prove that a robotically deployed, maintained and operated seismic network (*) can produce high-quality and publishable science data that is suitable to support meaningful scientific progress.**
  - **Shall validate an autonomous surface exploration mission concept involving several robotic assets**
  - **Shall demonstrate interoperability and verification of mission critical technology required to operate in a hostile environment**



(*) The mission set-up is usable for different, additional or complementary science objectives as well. Some other options will be assessed during pre-tests, but are excluded from the field test.

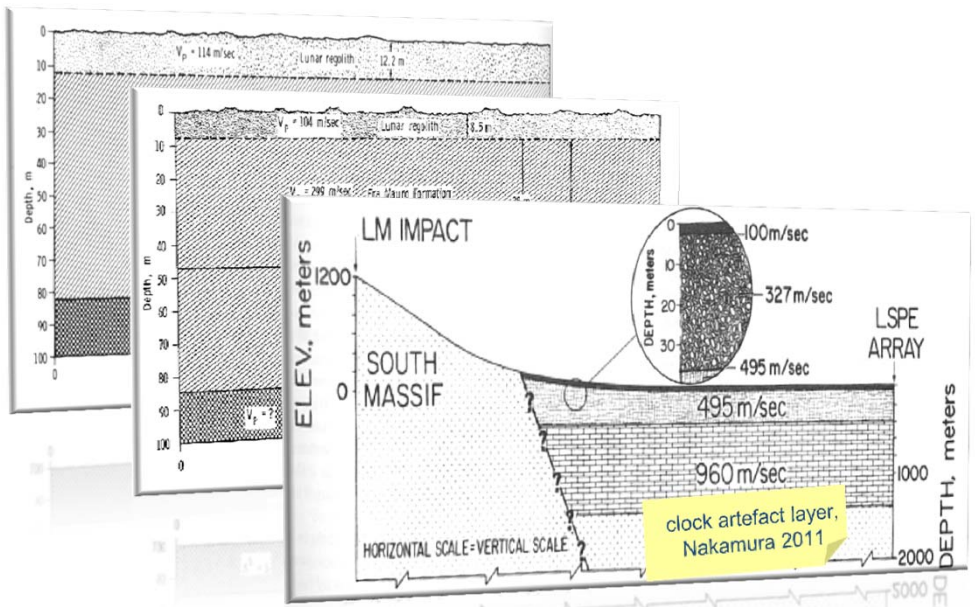
ROBEX

Origin of the Scenario

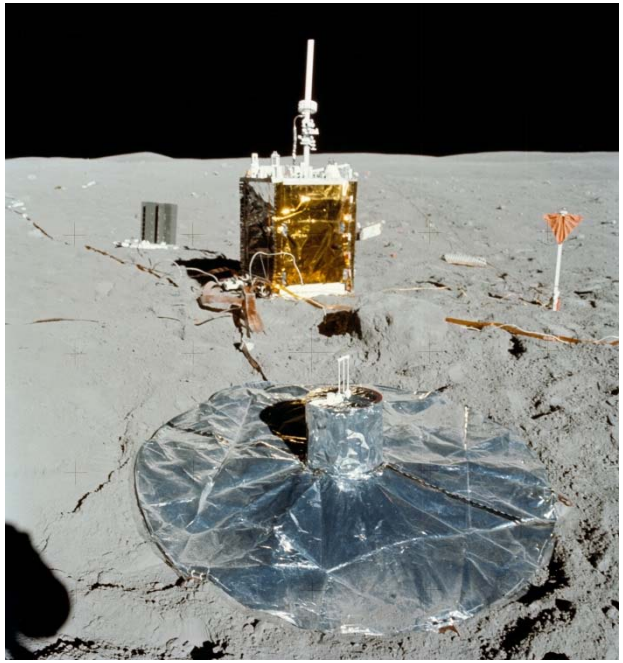
- **The Robex ASN Reference Scenario**

…To investigate the lunar surface, the crustal layering, the deep lunar interior and the source mechanisms of moon quakes and other natural seismic events

- **Active and Passive Seismic Experiment**



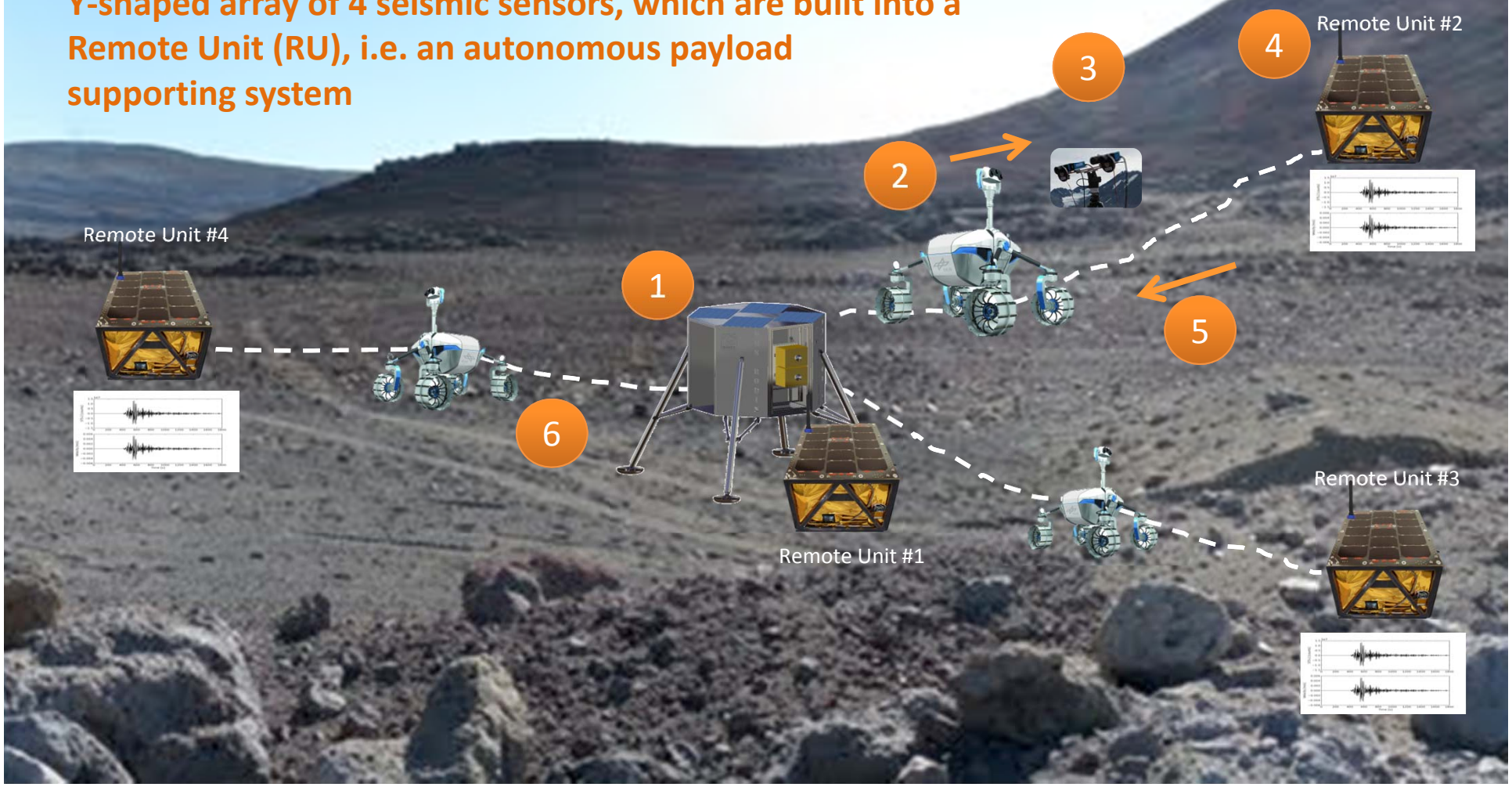
Apollo 14 & 16 Prel. Sci. Rep., 1971, 1972, Cooper et al, 1974



HELMHOLTZ GEMEINSCHAFT
ROBEX Allianz

Passive Array

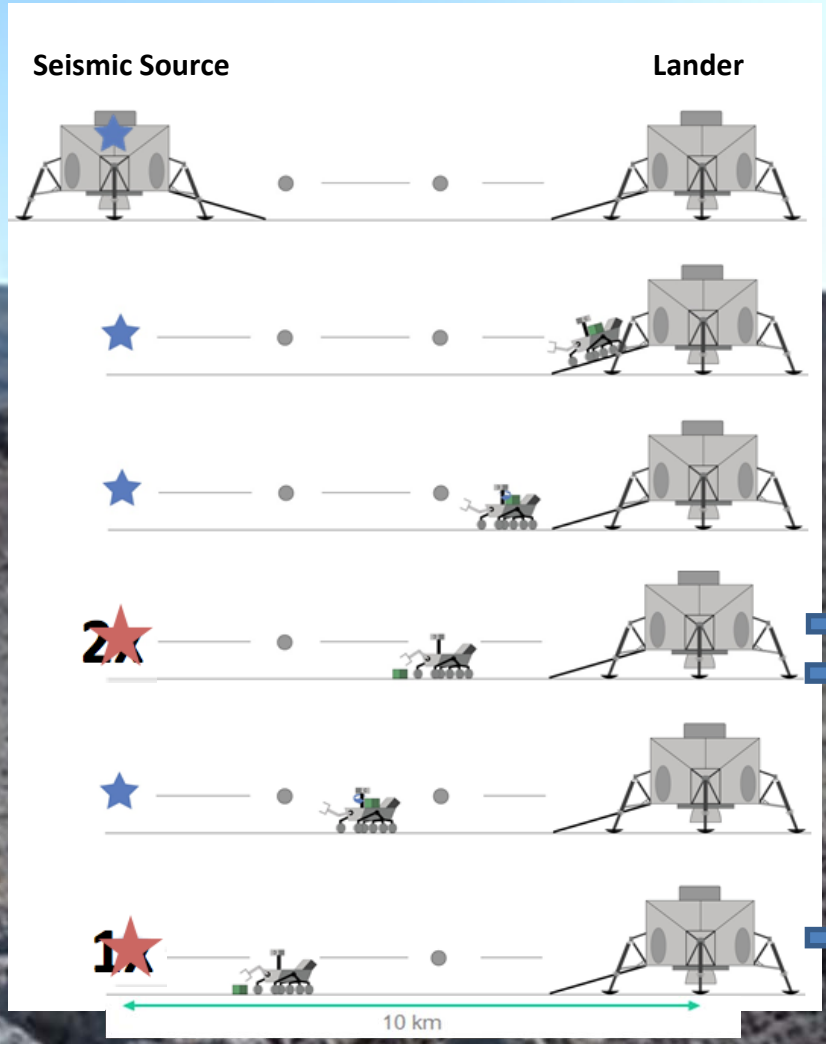
Objective:
Perform passive seismic measurements, listening mode, impact registration, and event location
Architecture:
Y-shaped array of 4 seismic sensors, which are built into a Remote Unit (RU), i.e. an autonomous payload supporting system

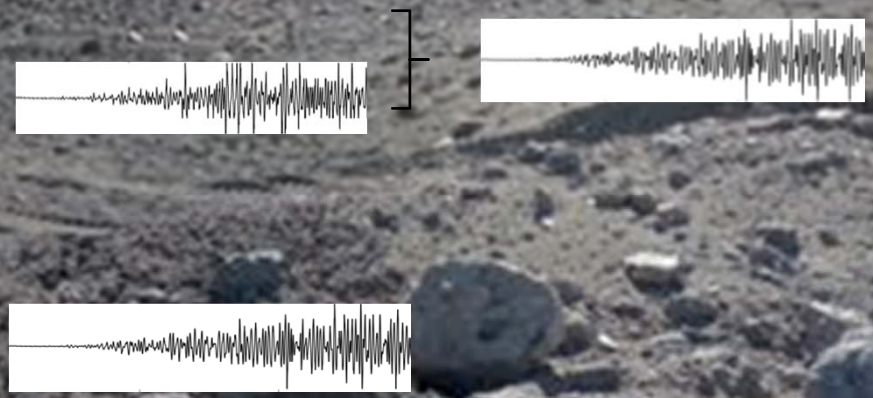


HELMHOLTZ GEMEINSCHAFT
ROBEX Allianz

Active Experiment

Objective:
Perform active seismic measurements on the lunar surface by using an active seismic source and a mobile sensor (seismic profile)
Architecture:
Combination of two stationary elements and one mobile element

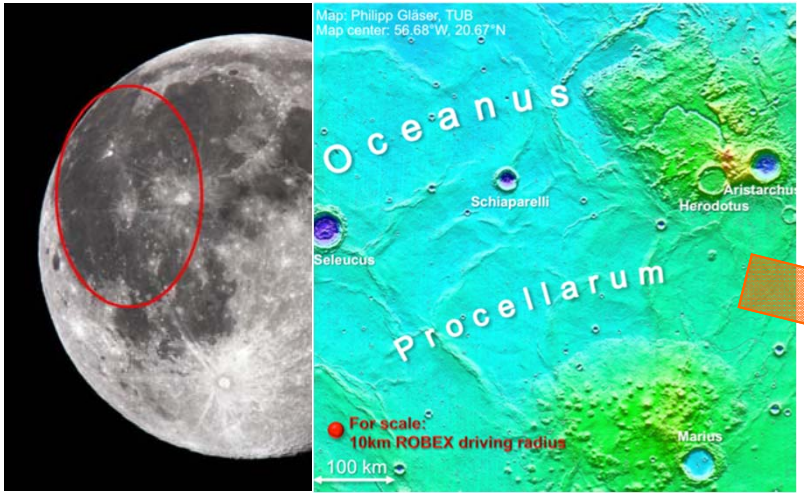


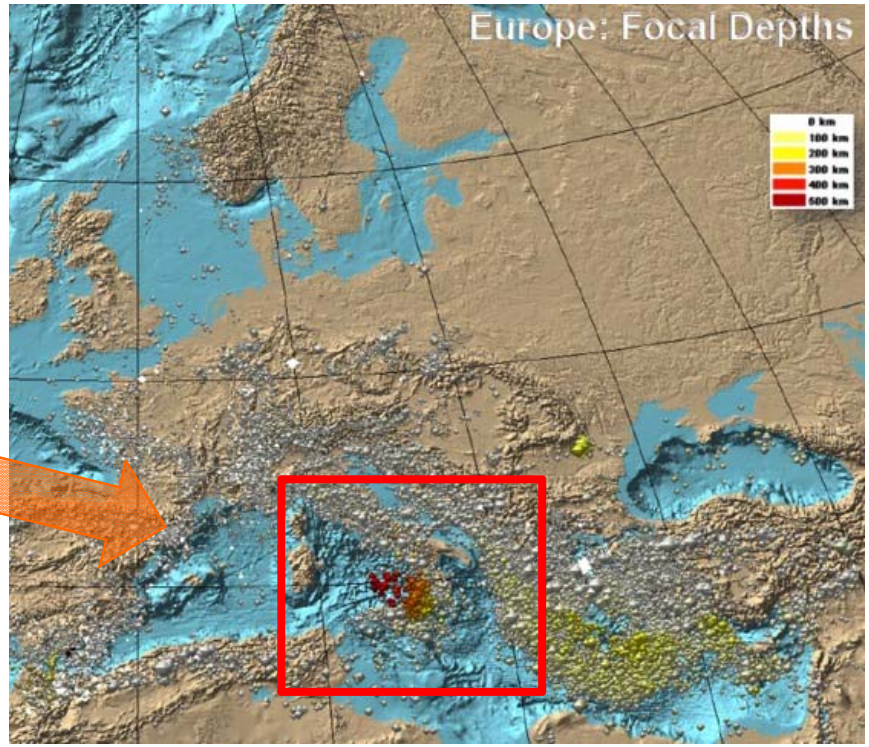


Key Site Requirements

- The target site on the Moon is a **Mare region (Oceanus Procellarum)**, that offeres sufficiently flat areas and probably little scattering

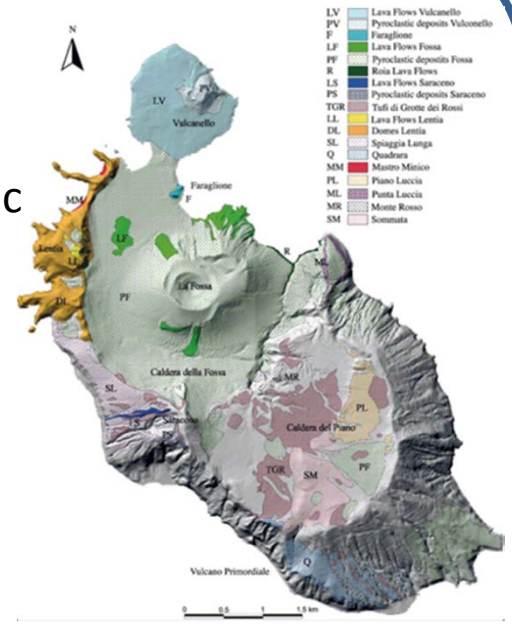
➢ Requirements for the terrestrial demomission site are:
  - ➢ Site of volcanic origin and with seismic activity
  - ➢ Moon-analogue regarding context, shape, physical properties, lithostatigraphy, basaltic composition of surface and subsurface soils
  - ➢ Well characterized by other research projects





Sites

- Small volcanic island in the Tyrrhenian Sea
- Frequent seismic activity
- Three volcanic centers
- Alternating pyroclastic deposits and lava flows



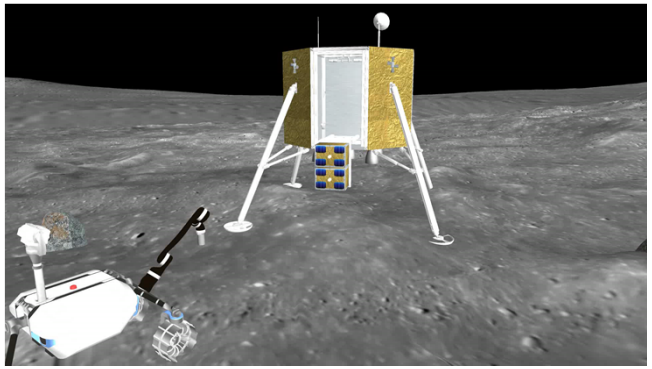
Vulcano

- Active stratovolcano on the east coast of Sicily, Italy
- Almost constant state of activity
- Interesting possible collaboration with local research institute (INGV)

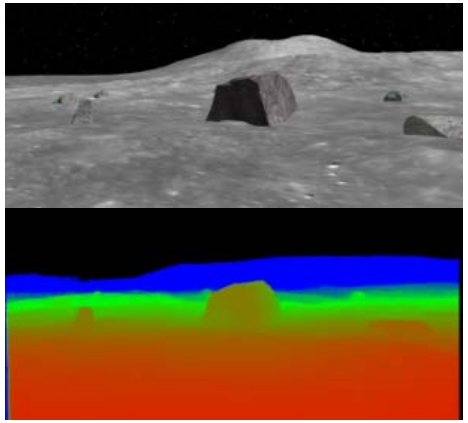
Mt. Etna

Rover Simulation Toolkit

- New multi-physics *Modelica* library
- Objectives:
  - Fast concept evaluation in early mission phase
  - Support rover design with optimization and HIL/SIL
  - Real-time capable models for controller design
- Resulting requirements for the toolkit:
  - Modular design with standardized interfaces
  - Validated and fast sub-components
  - Usability with other Modelica libraries



Concept evaluation

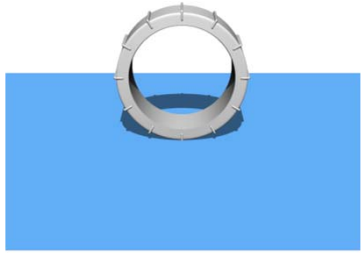


SIL Camera Simulation

Rover Simulation Toolkit: Contact

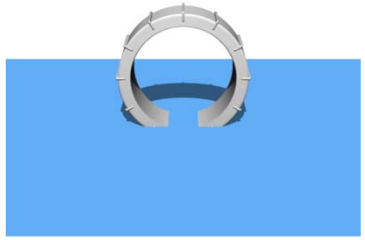
Contact models for wheel-ground contact

Hard contact



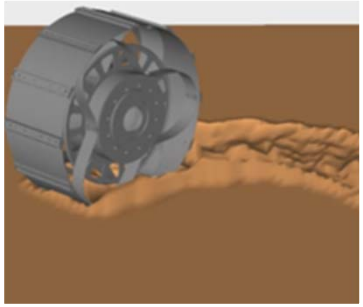
- Rigid bodies, no penetration
- Momentum exchange

Penetration-based



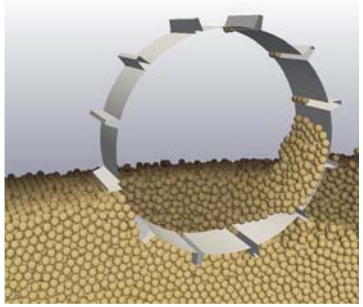
- Bekker/Wong or
- Spring/Damper + coulomb friction

SCM



- Multi-point Bekker/Wong
- Soil deformation
- Contact detection for arbitrary objects

DEM

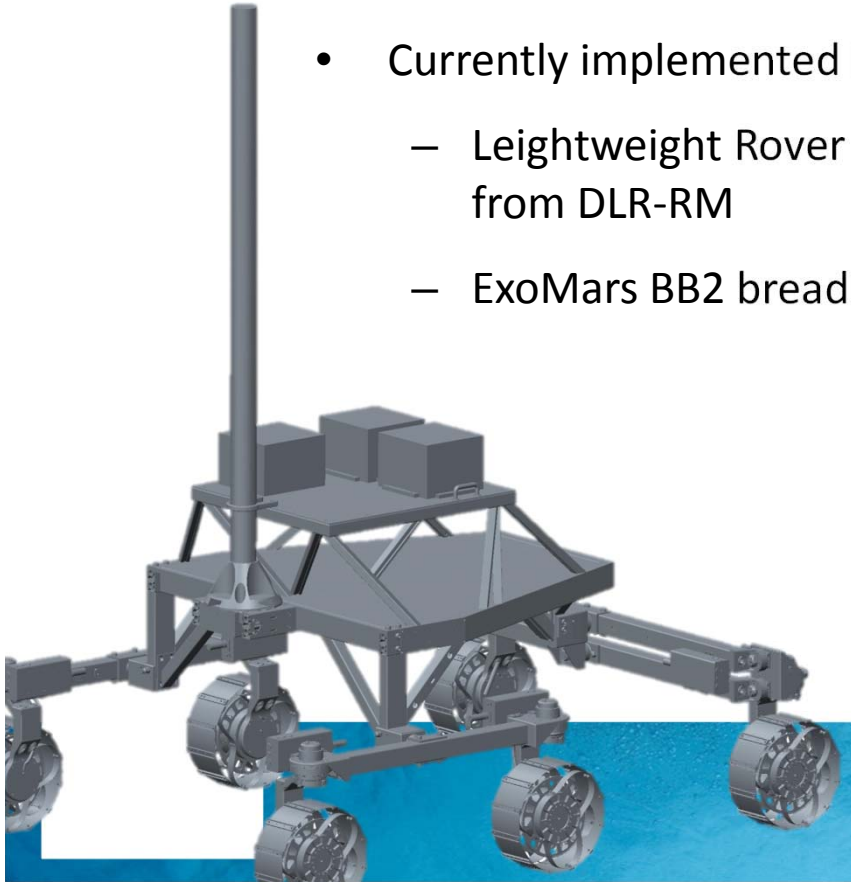


- Soil as discrete granular material
- Validated/verified for certain applications
- Already used in exploration (HP³ Mole)

Current work: Validation of all the contact models

Rover Simulation Toolkit:Model

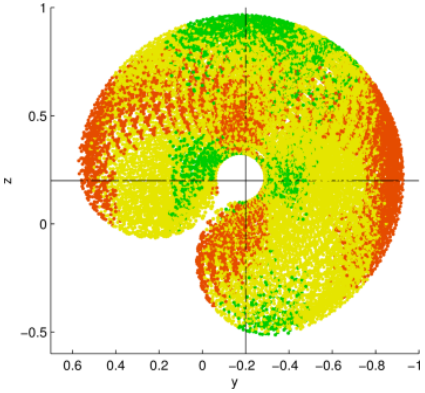
- Rover Components
  - Mechanical: classical multi-body components
  - Electrical: Motors, Low-Level controllers/power electronics
  - High-level controllers and signal busses for communication
- Currently implemented Rover models
  - Leightweight Rover Unit (LRU) from DLR-RM
  - ExoMars BB2 breadboard



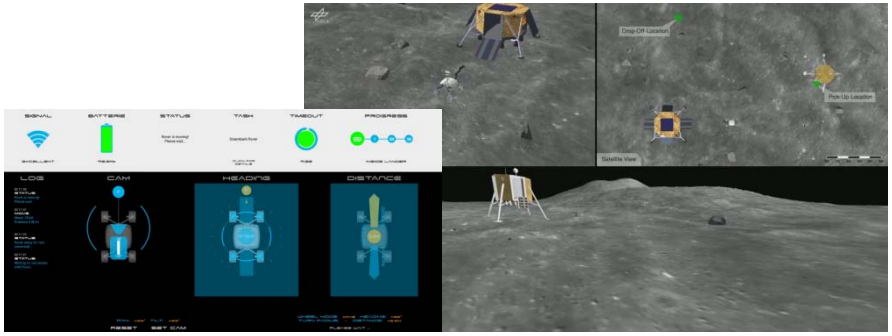
Rover Simulation Toolkit: ROBEX

HELMHOLTZ GEMEINSCHAFT
ROBEX Allianz

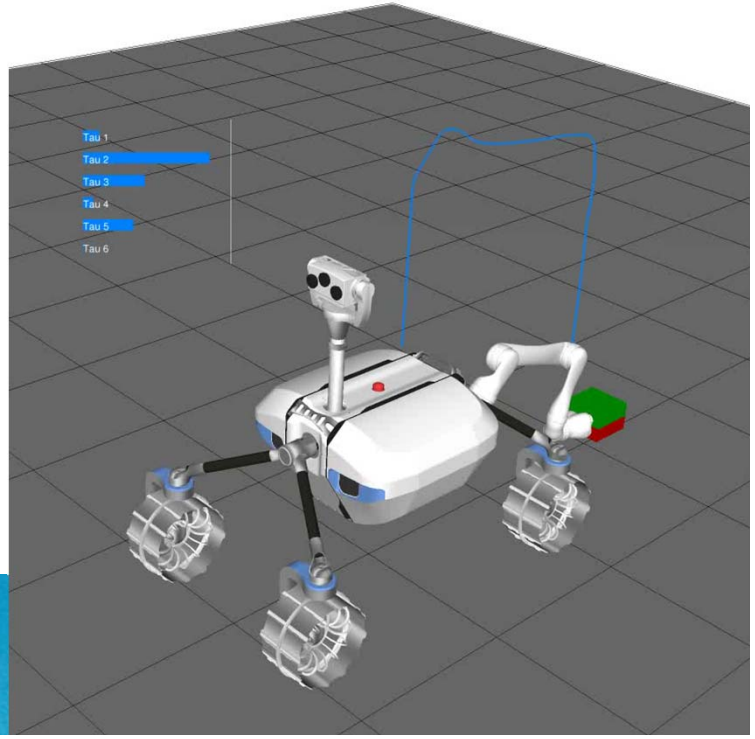
- RMC Rover Sim
  - Software-in-the-loop (SIL)
  - Communication via Links-and-Nodes framework
- Mission demonstrator
  - Simulator for missions tasks
  - Rover control via tablet app
- JACO arm load evaluation



Manipulator
Workspace Analysis



LRU Demonstrator and user interface



Conclusion

- ROBEX shows great synergies with the extreme marine and as well extreme space environment
- The Demo mission shall be a key demonstration of complex robotic missions in real analogue environment
- The goals of the demo mission are gathering real scientific valuable data an technologically include complex autonomous mission planning (navigation & manipulation)
- Helmholtz Association, Contract number HA- 304
- Open for Cooperation and Information's … .

HELMHOLTZ
GEMEINSCHAFT
ROBEX Allianz

Thank you …

http://www.robex-allianz.de/