HGF-Alliance ROBEX
Robotic Exploration of Extreme Environments

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Robotics and Mechatronics Center, RMC
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About 100 scientists, engineers and technicians spread over Germany are involved in ROBEX

http://www.robex-allianz.de/
WPs and Design teams

Deep Sea Science
- Modularity
- UAV
- Glider
- LOC
- Docking Interface

Material Science
- Navigation
- Concrete Housing
- Crawler
- Walking Robots
- Tele operated Handling

Lunar Science
- Power
- MOVE
- Photogrammetry
- Image Analysis
- CFRP Habitat

Autonomy
- Manipulation
- Instruments
- Sensors
- Sampling Tools

Roberts
Agenda

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

Develop a mobile platform to carry:

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

- ... to allow for better quantification and localisation of gas hydrates in deep-sea sediments
- system consists of group of vehicles that will operate autonomously in concerted fashion
Design team
Deep-sea Crawler
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

track controller

docking

navigation

remote control

Power management

autonomy

mission control

teleoperated handling

optical mapping

scientific payload

Tramper

AWI

Mansio-Viator

GEOMAR

iWally

JUB
Aims

Modular hardware design

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

Tramper
AWI

Mansio-Viator
GEOMAR

iWally
JUB
Achievements

... fully autonomous crawler system for long-term monitoring and sampling at the sea-floor (e.g. under ice).
Design team
Lab on a chip, LOC
Lab on a chip (LOC)

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

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 / Achievements

1. Establish 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 its 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
Docking-Interface

Aims: define and develop appropriate docking interface systems for both scenarios – deep sea and space.

Achievements:

Review docking interface systems

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

State of the art – no standard system
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
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.
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

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

- Requirements for the terrestrial demobmission 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
- 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)
• 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
Current work: Validation of all the contact models

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)
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

- Lightweight Rover Unit (LRU) from DLR-RM
- ExoMars BB2 breadboard
Rover Simulation Toolkit: ROBEX

- 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
• 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 ... .

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Thank you ...

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