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ROBEX Allianz

HGF-Alliance ROBEX
Robotic Exploration of Extreme Environments

Helmholtz Alliance ROBEX Overview

Martina Wilde
Coordinator ROBEX
at AWI

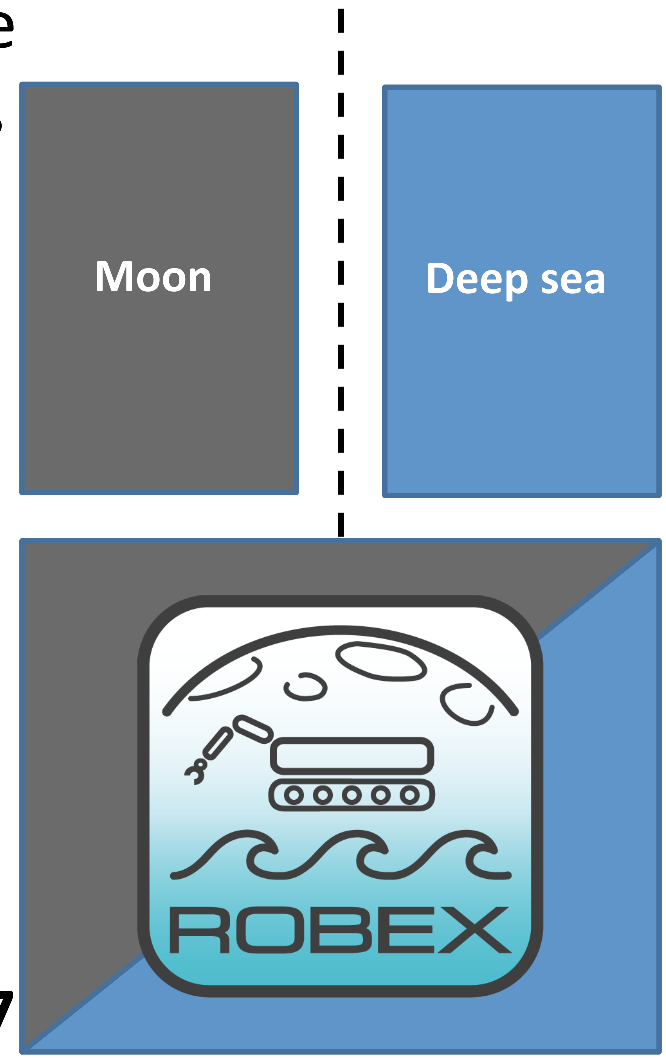
Special aims of Helmholtz Alliances

- Identifying and adressing key future research topics
- Conducting research on new topics with the necessary critical mass
- Develop current research topics in innovative ways

ROBEX „genesis“

In 2011 two separate proposals were submitted for robotic infrastructures for

- Moon
- Deep Sea



The evaluators recommended to merge both initiatives in one Alliance

→ **Start of ROBEX in October 2012**

End of ROBEX in December 2017

ROBEX Consortium

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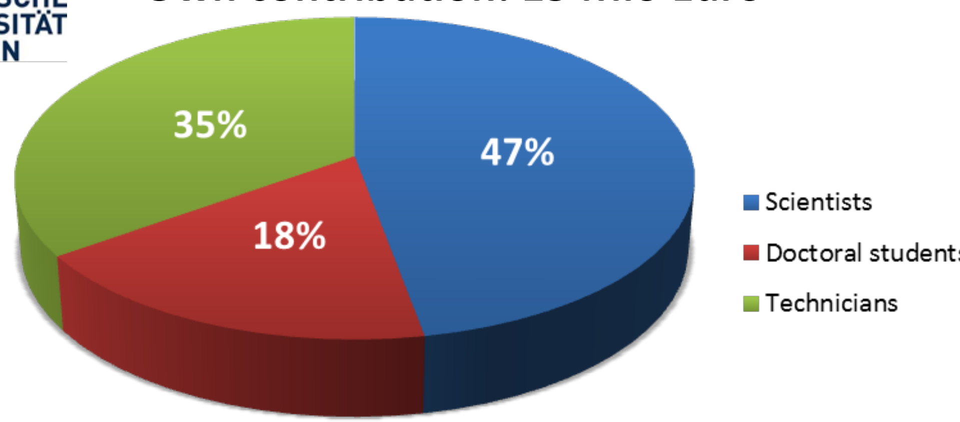
About 160 scientists, engineers, technicians and PHD students spread over Germany are involved in ROBEX

HGF Funding: 15 Mio Euro
Own contribution: 15 Mio Euro



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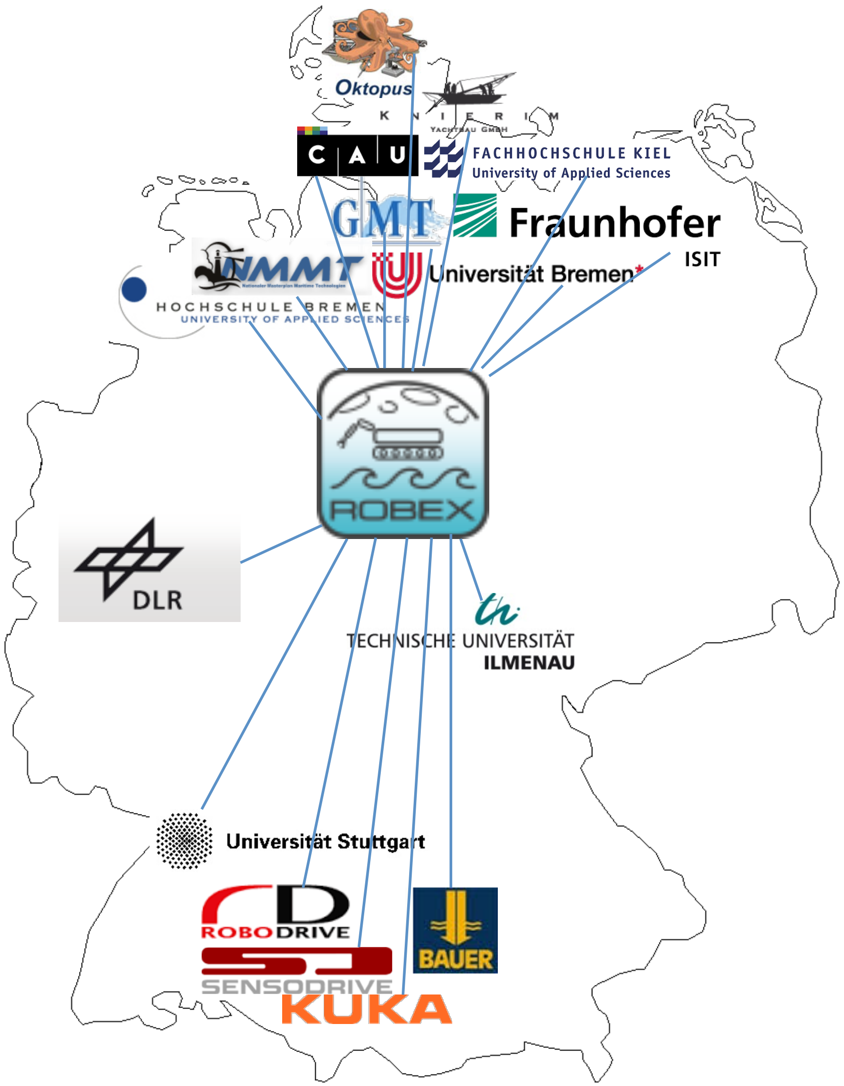
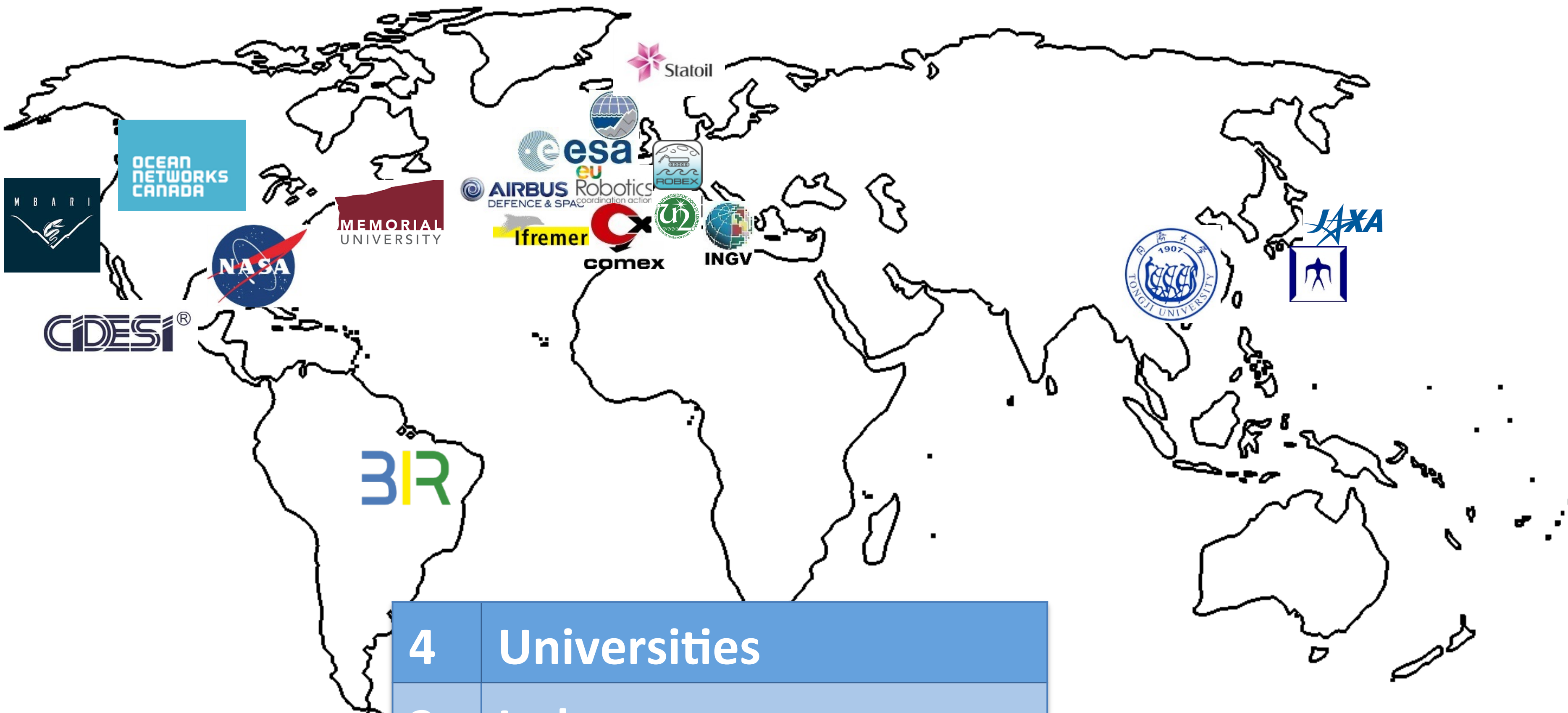
ROBEX Networking national



6	Universities
6	Industry
3	Associations
1	Research Institutions

ROBEX Networking international



4	Universities
3	Industry
3	Associations
7	Research Institutions
2	Agency / Organisation

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Extreme environments

Moon

-130°C to + 160°C
Vacuum
Light
Solar radiation

Deep Sea

-1°C to + 400°C
1.000 bar in 10.000 m water depth
Darkness
Water

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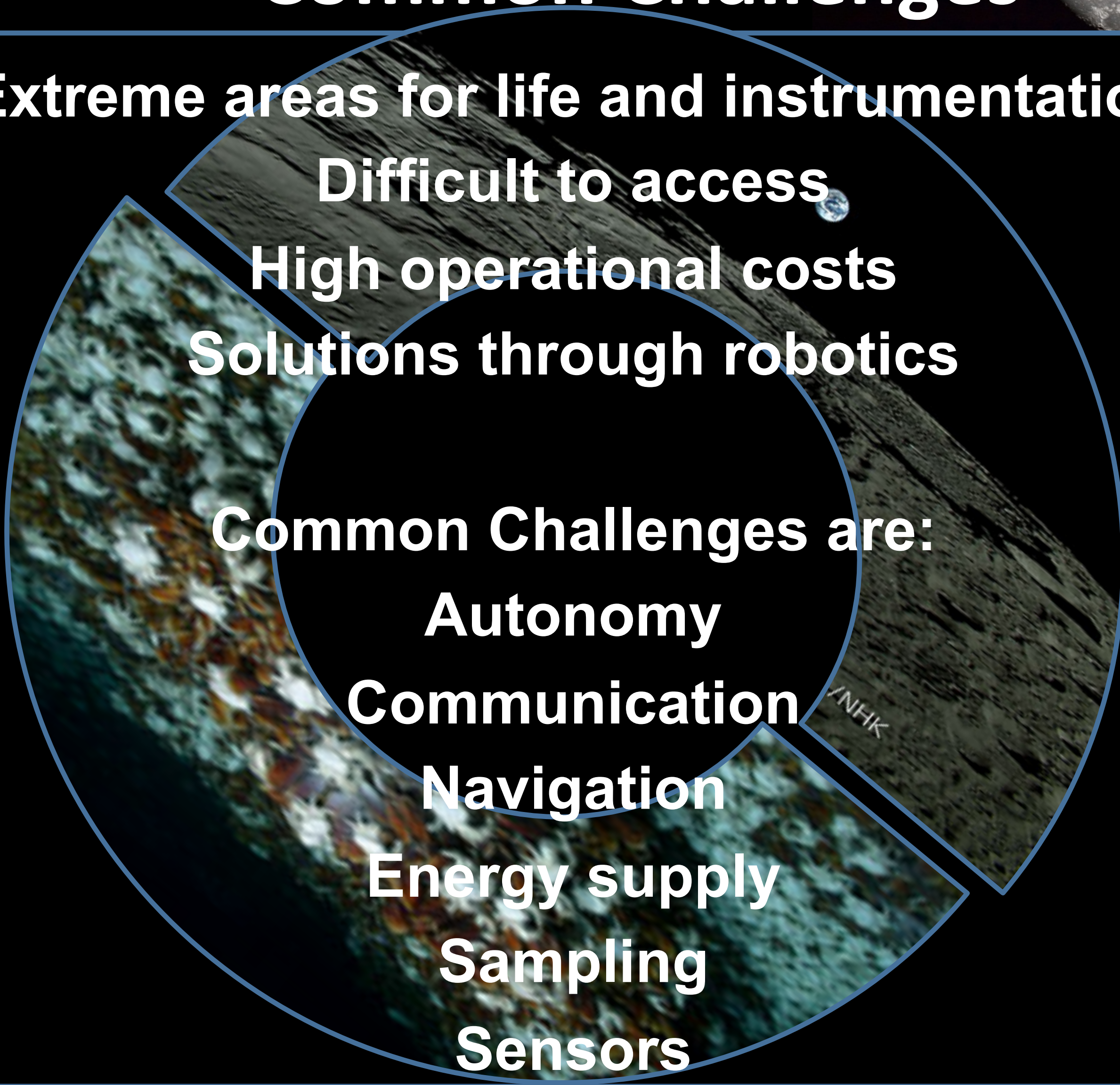
Common Challenges



Extreme areas for life and instrumentation

Difficult to access

High operational costs

Solutions through robotics

Common Challenges are:

Autonomy

Communication

Navigation

Energy supply

Sampling

Sensors

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ROBEX approach

Scientific & Administrativ Coordination — **Education and Outreach**

- **Topic 1000 Scientific Challenges**
  - 1100 Deep-Sea Science
  - 1200 Lunar Science
  - 1300 Material & Structural Design
- **Topic 2000 System Infrastructure**
  - 2100 Reconfigurability, Modularity, Standardization
  - 2200 Infrastructures for Navigation & Communication
  - 2300 Power Systems / Energy Management
- **Topic 3000 Robotic Developments**
  - 3100 Autonomous Operation
  - 3200 Mobility
  - 3300 Manipulation
- **Topic 4000 Instrumentation**
  - 4100 Instrument Integration
  - 4200 Integrated Sensor Systems
  - 4300 Sampling Tools

Demonstration Missions

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Scientific Challenges

Deep-Sea Science

Methane hydrates in the deep sea

Hydrothermal vent systems

Spread of hypoxia in the oceans affecting ecosystem services

Dynamics of under-ice environments

Lunar Science

Formation & Evolution of lunar crustal structure

Lunar impact flash monitoring

Lunar seismic activity (ASN)

Material Science

Intelligent material systems

Innovative structural design

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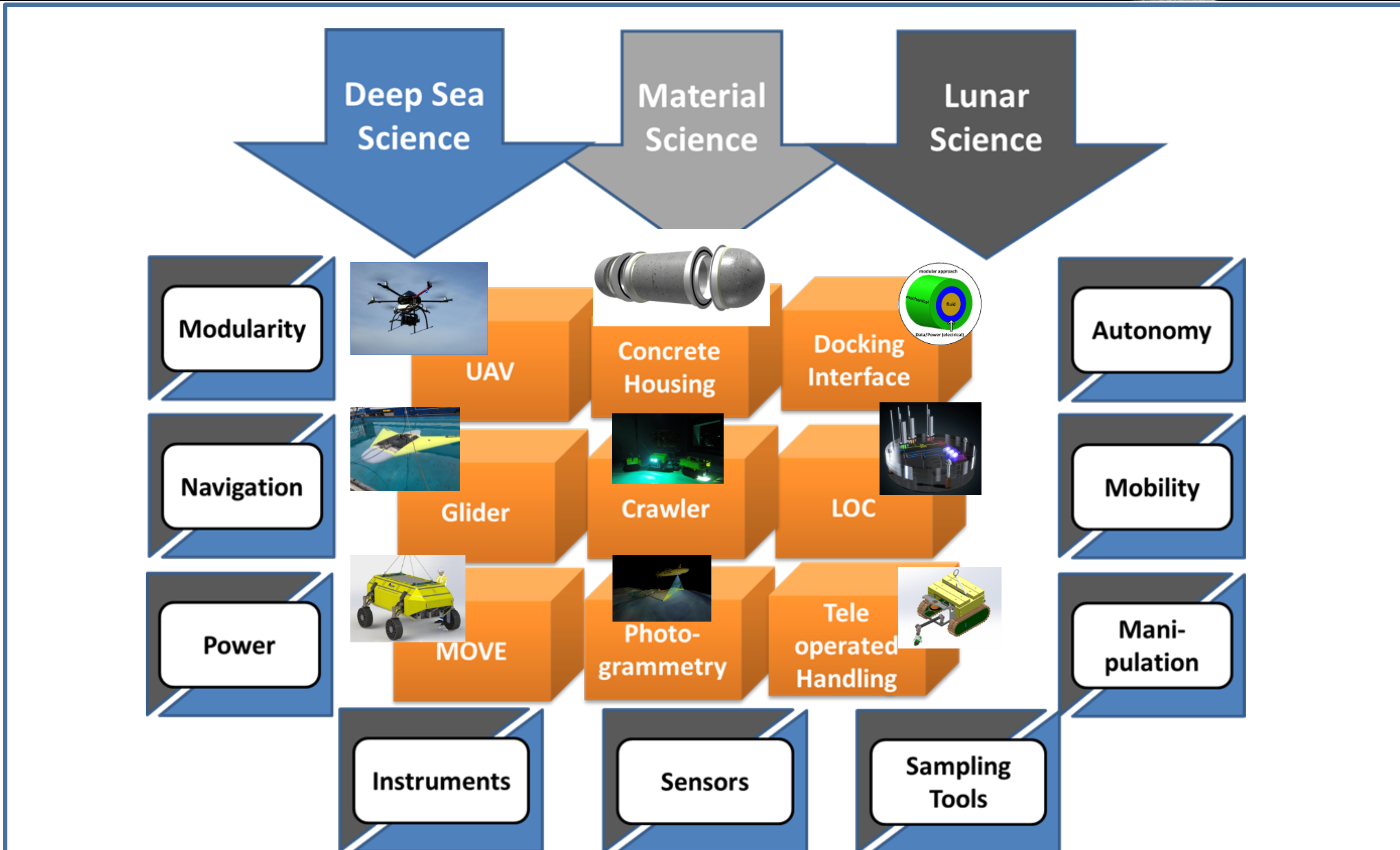
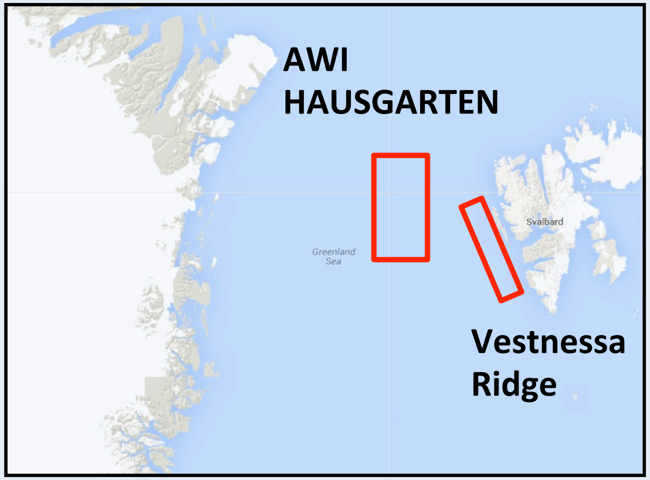
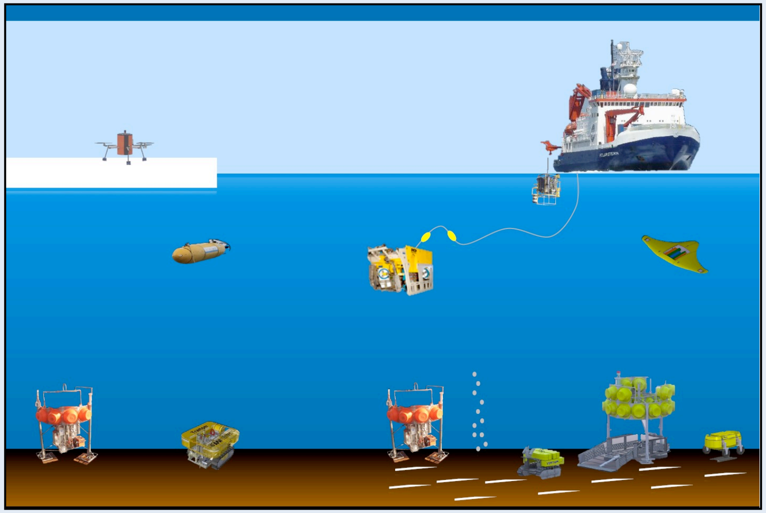
Interdisciplinary Designteams



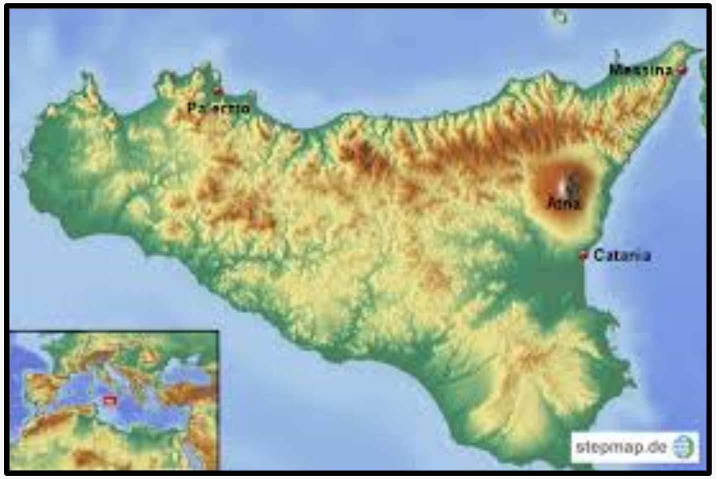
Demonstration Missions

Deep Sea





Space:



Design Team
Deep-Sea Glider

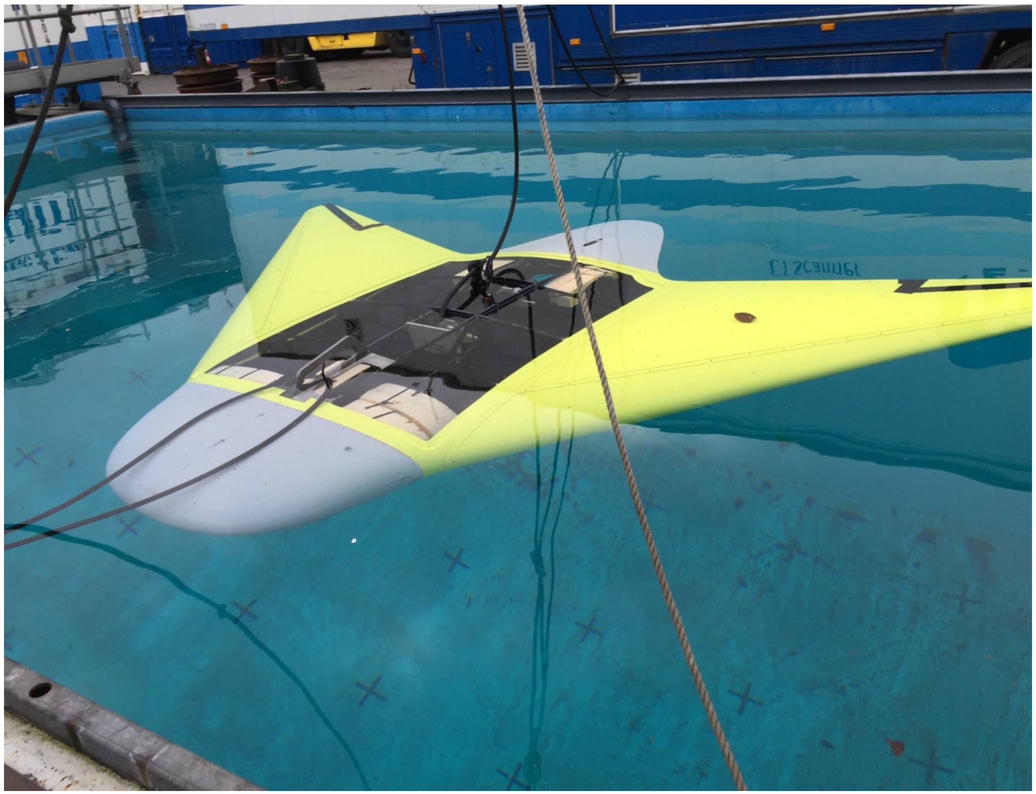
GOAL

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



Characteristics

Wing span 3.4 m
Weight up to 150 kg in air
Primary payload bay – Nose section

Application Scenario

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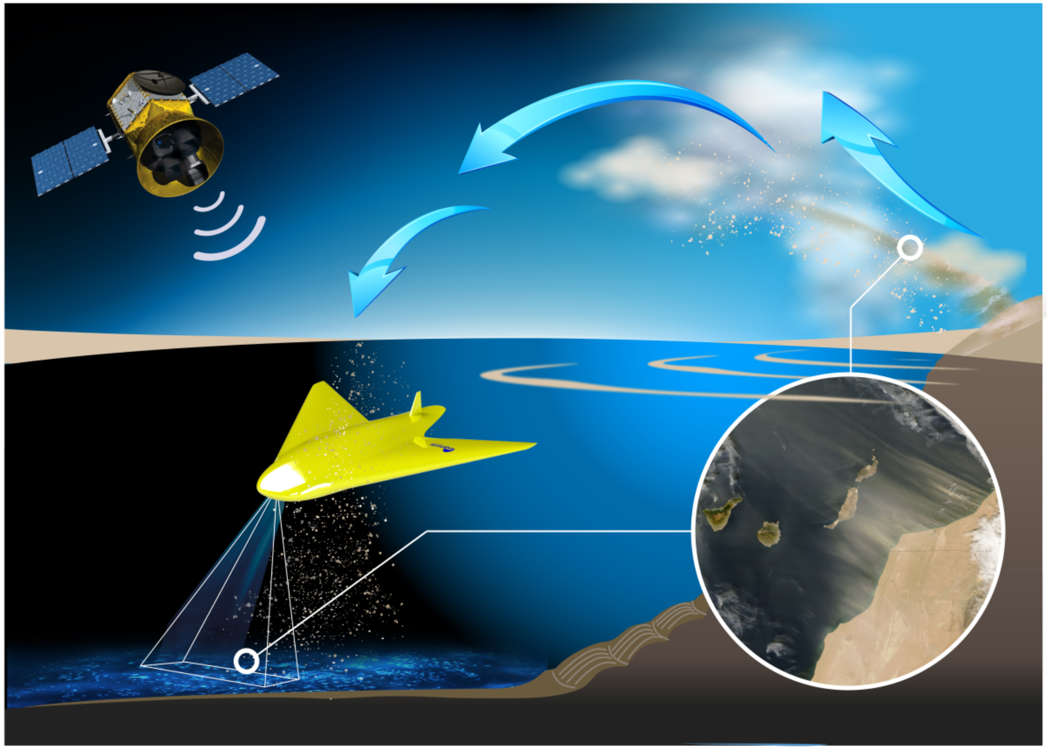
Particle transport through the water column – the biological pump

Quantification of zooplankton and mineral particles in the upper 200 m of the water column with a newly developed underwater glider.



Northwest African Coast

Development in cooperation with

Memorial University, St. John's (Bachmayer)

and

Monterey Aquarium Research Institute **MBARI** (Kirkwood)

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Design Team
Lab-on-chip (LOC)

GEOMAR Helmholtz Centre for Ocean Research Kiel

DLR Institute of Planetary Research

Fraunhofer ISIT

University of Southampton

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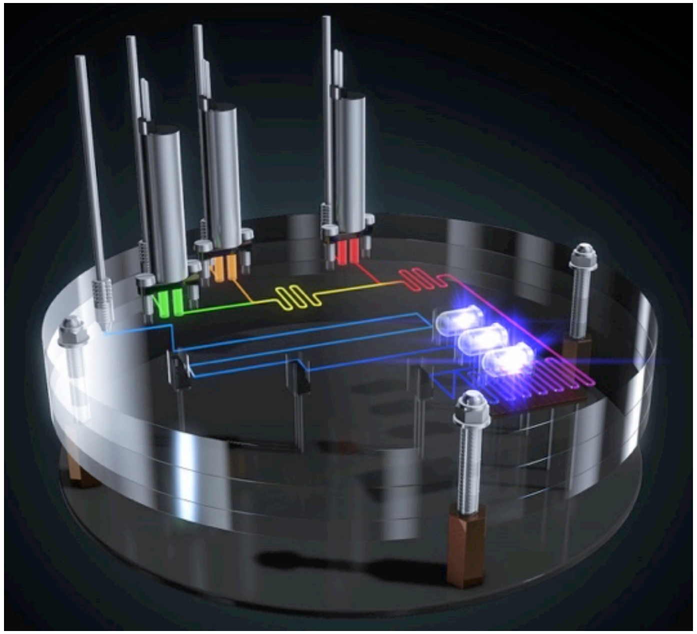
Goal

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, ...)

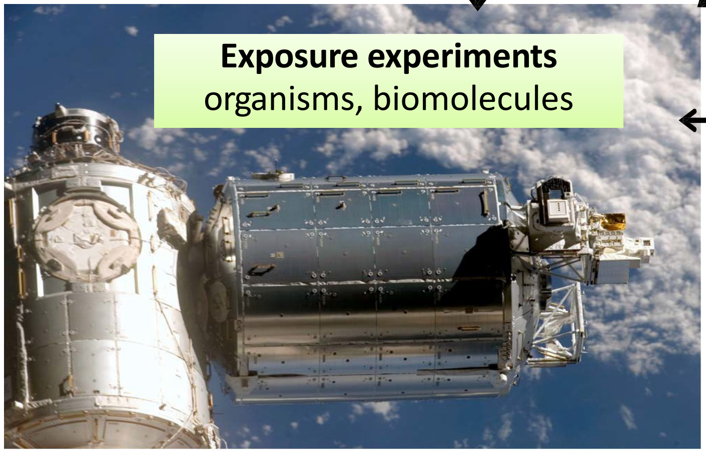
all on one chip!

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**

DT LOC – Aims / Achievements

1. Establishment of LOC technology
2. Integrate LOC technology on ROBEX underwater vehicles
3. Demonstrate it´s suitability for (long-term time series) biogeochemical measurements during ROBEX demonstration mission
4. Explore the use of LOC technology for in-situ experiments & measurements on the ISS (BIOSIGN proposal submitted to ESA)



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Design Team
Concrete housing

TECHNISCHE UNIVERSITÄT DRESDEN

German Research Center for Artificial Intelligence

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

JACOBS UNIVERSITY

GEOMAR Helmholtz Centre for Ocean Research Kiel

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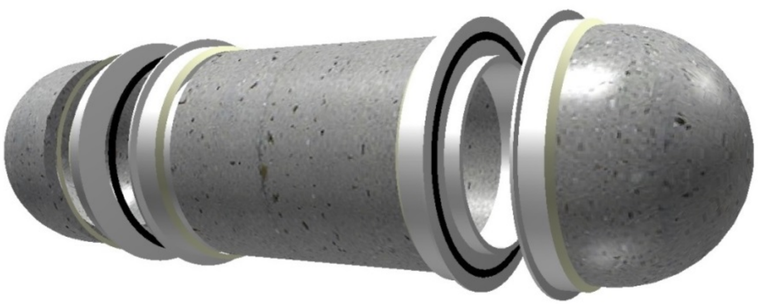
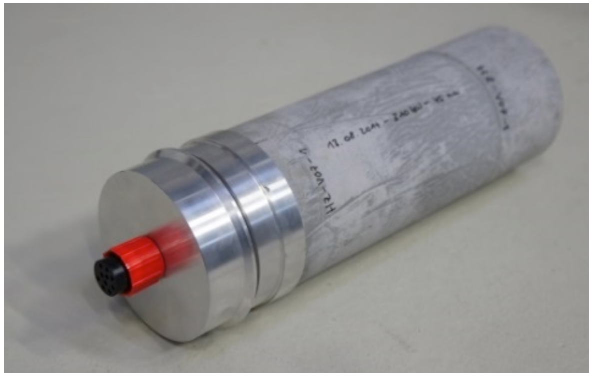
Goal

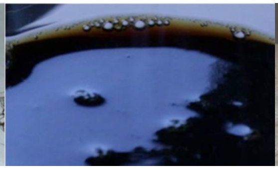
Development of **low-cost**, **corrosion-free** and **big scale** pressure housings made of Ultra High Performance Concrete for depths up to **6000 m,** e.g. for energy storage units





Concrete +

fibers



plasticizers

silica

= **U**ltra **H**igh **P**erformance **C**oncrete (UHPC)

→ 5x compressive strength of normal concrete

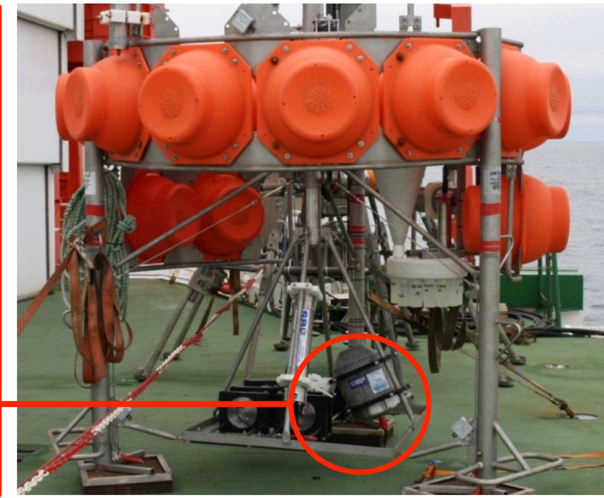
→ high density and waterproof

Achievements

Recovery of long-term test at the Arctic Sea in 2500 m depth (07/2015 → 09/2016)

Test site at the Arctic Sea, openstreetmap.org

Housing PII-4 before the test, photo: Lehmenhecker



AWI lander with housing PII-4, photo: Lehmenhecker

Actually: Long-term test Arctic Sea 2016/17 in <u>2500</u> m depth

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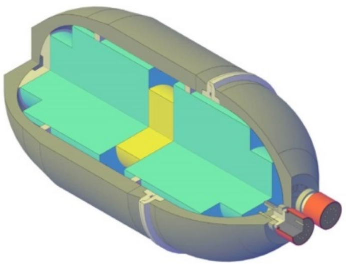
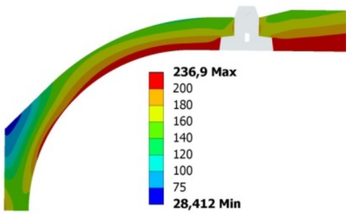
Achievements

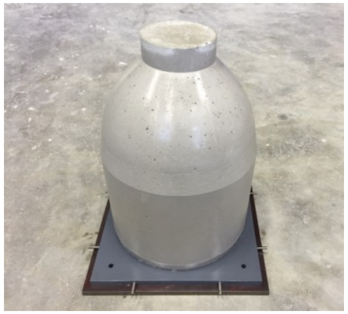
Concrete pressure housing: TDG-PII-5 (No. 15)



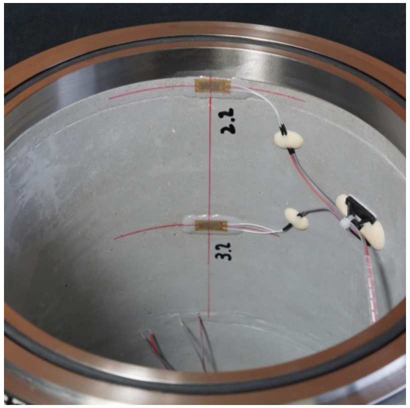
design



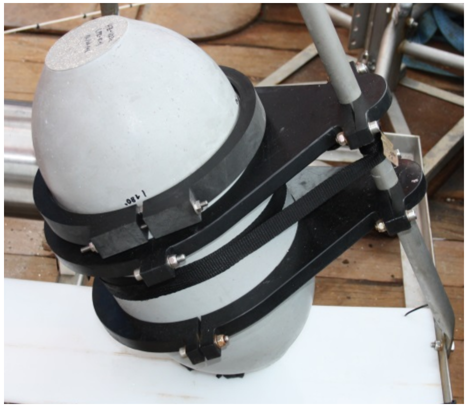
simulation



manufacturing



Long-term test Arctic Sea 2016/17 in 2500 m depth



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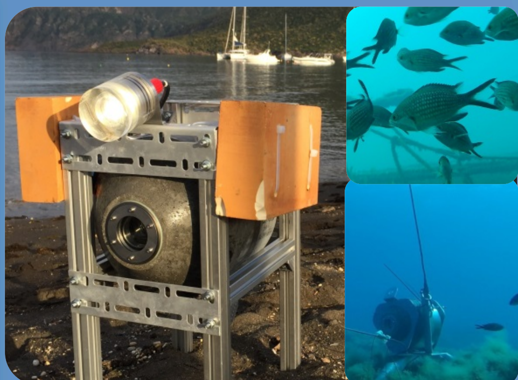
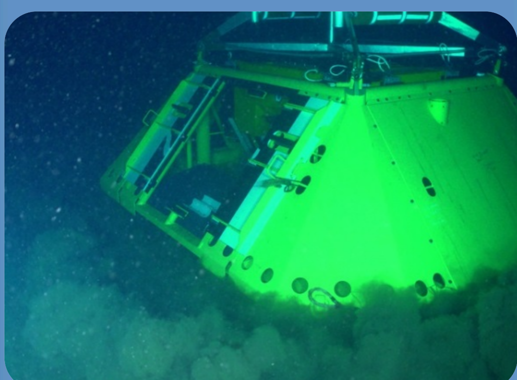
Next Steps and Outlook

Science



Camera observation system, tested on Vulcano Island, Italy



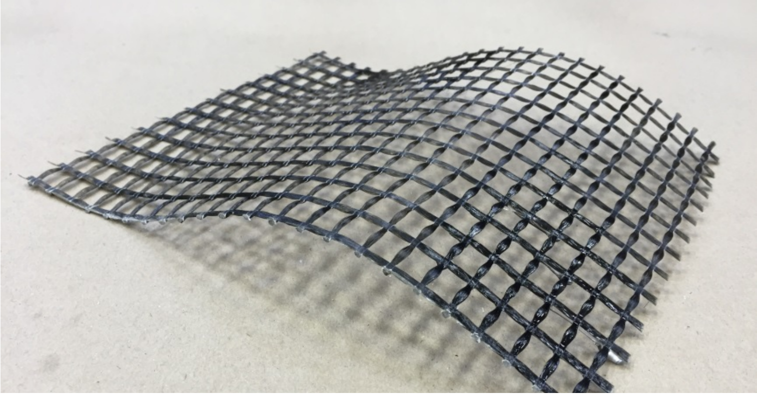
Replacing steel nodes,
Photo: NEPTUNE Canada [7]

Offshore industry

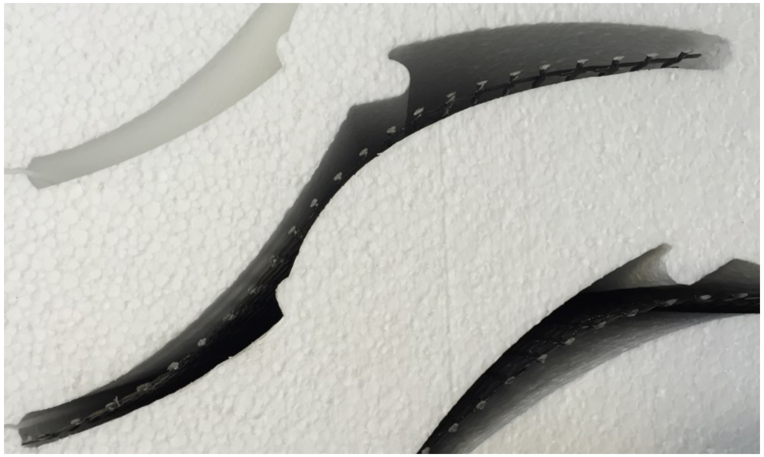
- offshore containments
- processing plants of minerals and natural resources
- pump housing, e.g. oil
- storage

Lunar Concrete

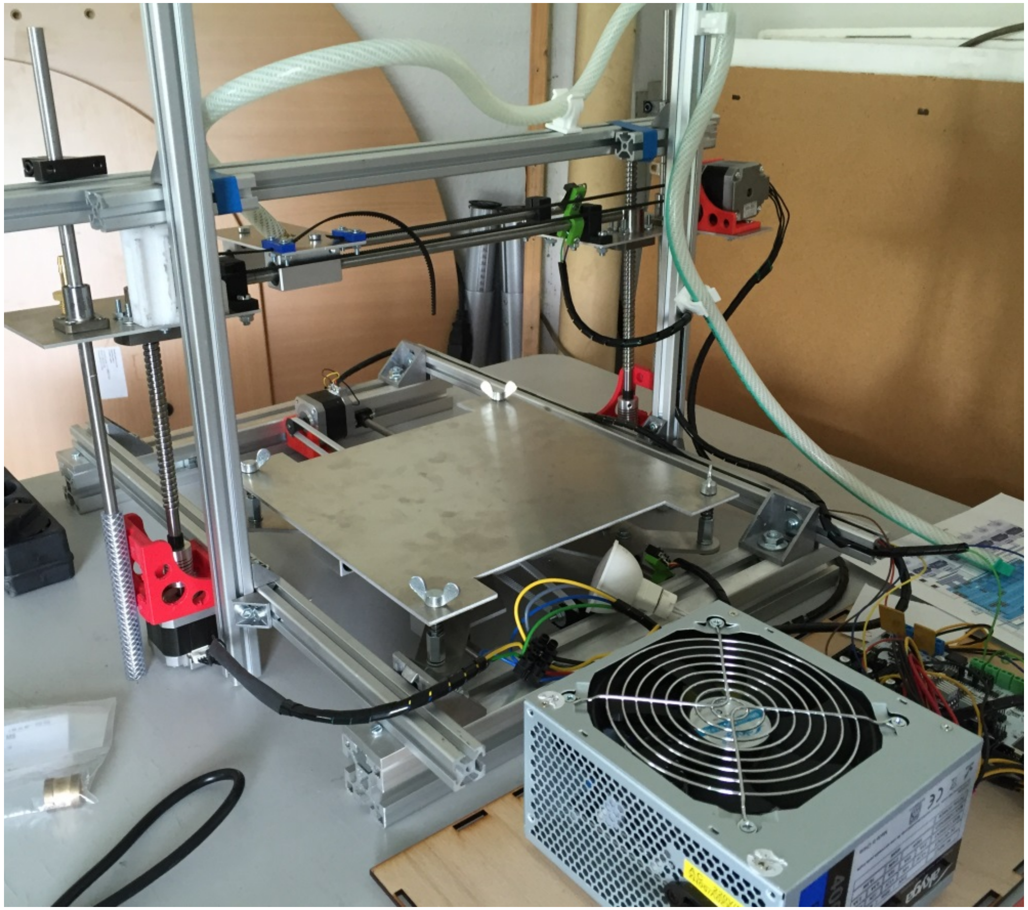
3D-printing lunar base as shelter construction



Textile of basalt



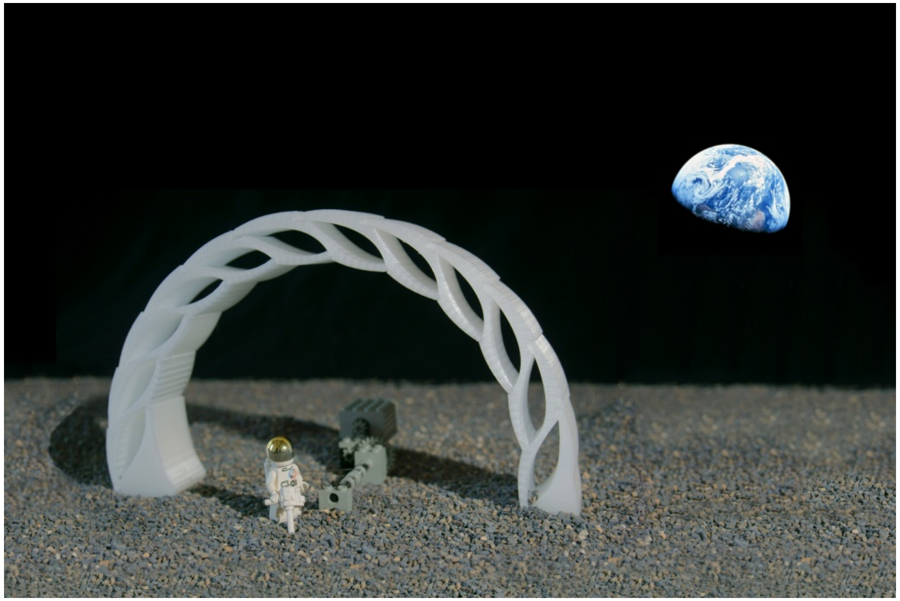
Styroporschalung



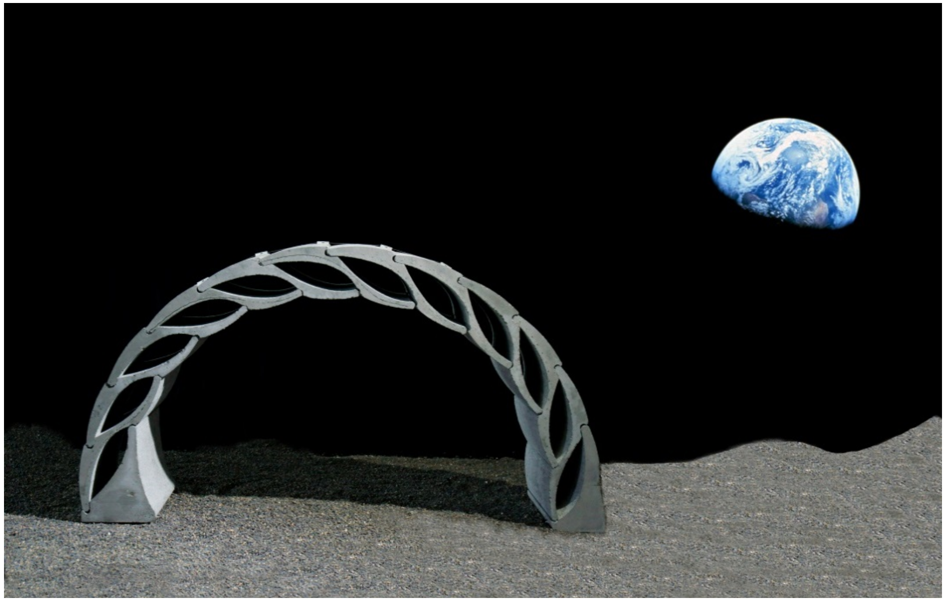
3D-printer for concrete, Wilhelm

Lunar Concrete

3D-printing lunar base as shelter construction



3D-printed model from plastics, D = 25 cm



3D-printed model from concrete, D = 50 cm

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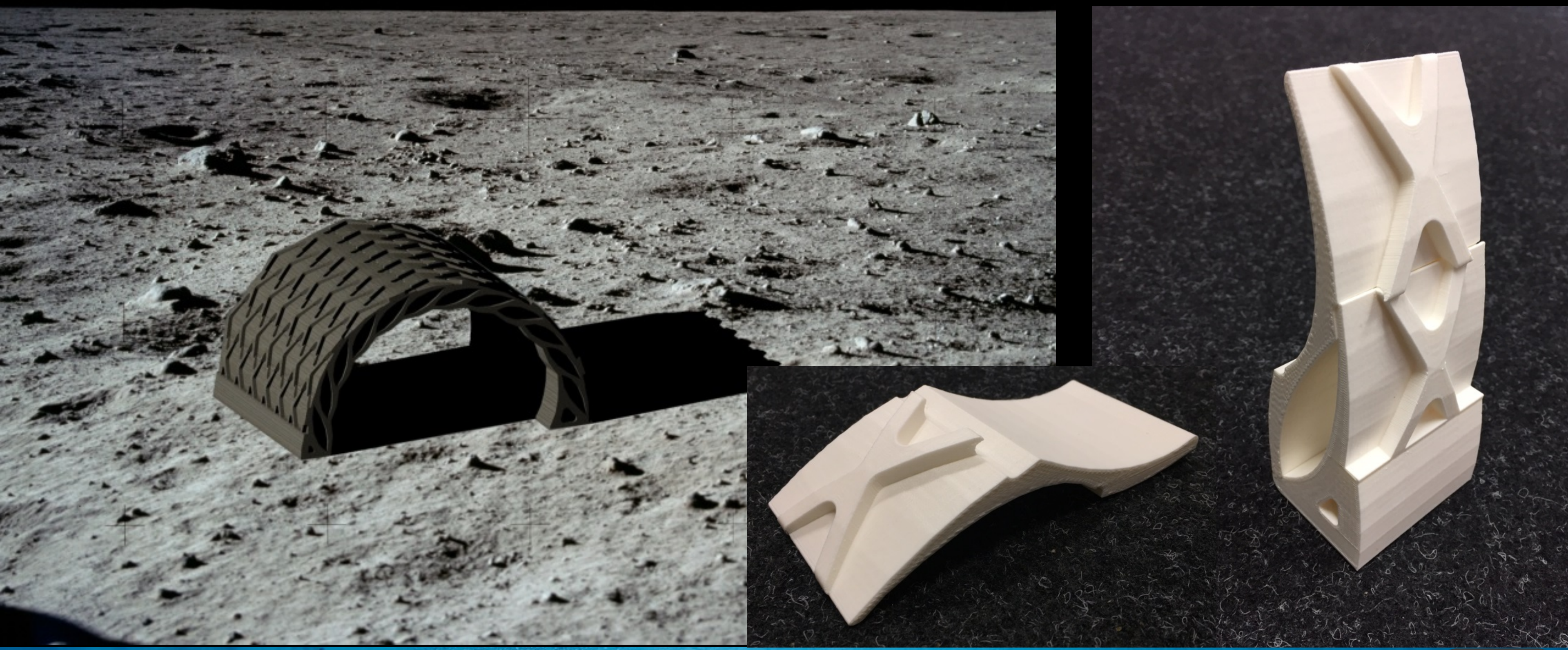
3D-printing lunar base as shelter construction



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Design Team
Unmanned Aerial Vehicle (UAV)

AWI

DLR Institute of Robotics and Mechatronics

Julius-Maximilians-UNIVERSITÄT WÜRZBURG

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DT UAV - Aims

Long range exploration vehicle

- Exploration of ice condition
- Long range missions (> 100 km)
- Cameras, Radar
- Fully autonomous flight

Landing vehicle

- Landing on Ice
- "Drift Buoy"
- Sending position updates
- Autonomous Return

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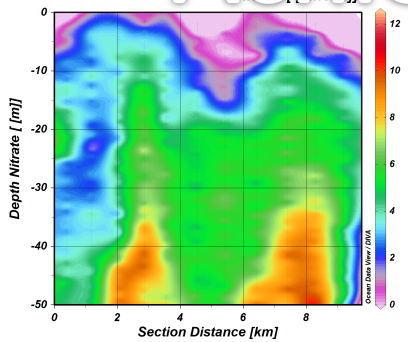
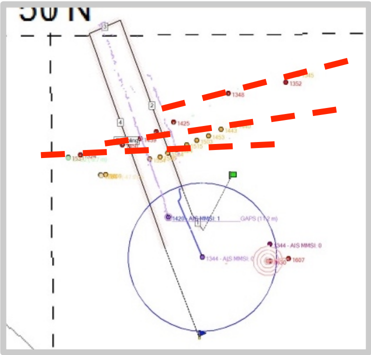
DT UAV - Achievements

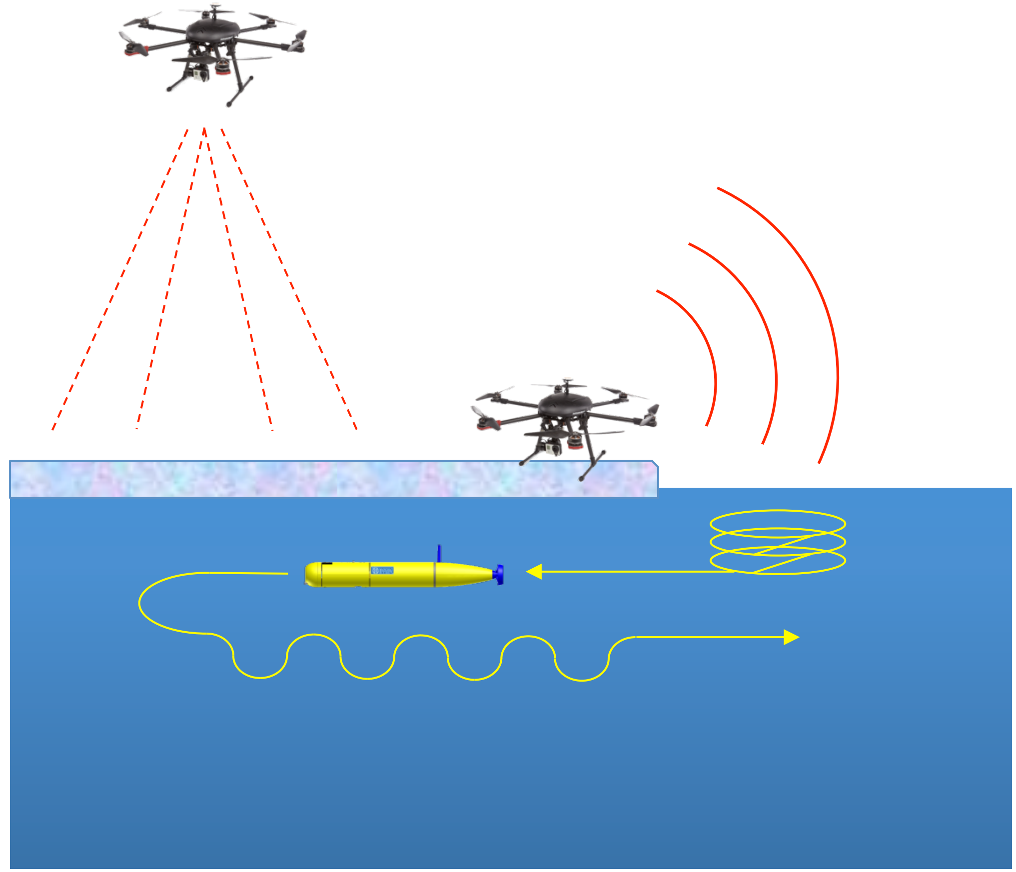


AWI



Julius-Maximilians-UNIVERSITÄT WÜRZBURG

DLR



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Technology Transfer

Spin Off company ISeaMC

- Crawler technology further developed by ROBEX
- For environmental monitoring in the deep sea and offshore areas (oil-, gas-, energy-, mining-industry)
- The company will offer autonomous/tele-operated crawlers / consulting services/ training

Education and Outreach

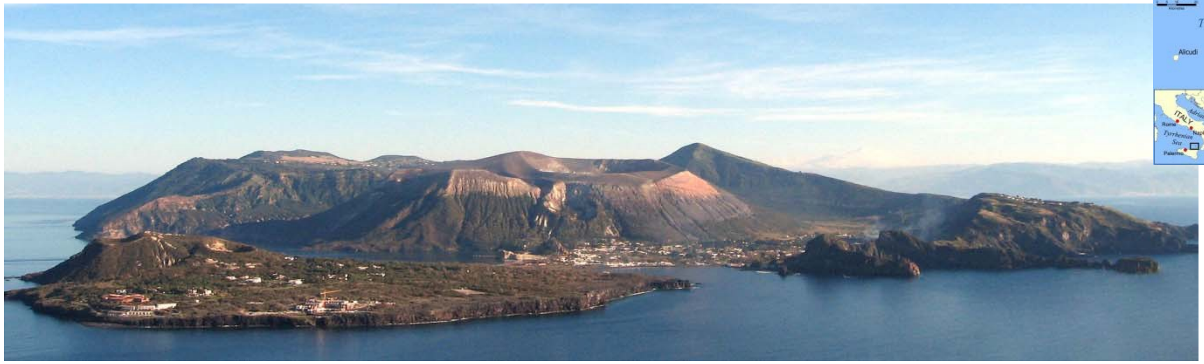
Robotic Exploration of Extreme Environments: Image Analysis and Spatial Statistics

WEBCOURSE

http://imageanalysis.weebly.com/

- Introduces image quantification and statistics techniques, useful in marine and planetary science.
- Wherever possible, uses ROBEX data.
- Successfully tested in 2014.
- Students may direct control seafloor crawler. This is unique to ROBEX and of interest to educators.

Eudcation and Outreach



Summerschools

Carry out pre-tests for a possible demo-site (e.g., determination of the level of background seismicity, rover trafficability, soil properties) in an easily accessible environment

- Become acquainted with volcanic and coastal environments
- Carry out small demo-missions (land/ocean)
- Carry out a small research campaign in coastal oceanography
- Learn to use GIS
- Carry out transect analyses

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Education and Outreach

Exhibition ROBEX – Explore new worlds

2-month exhibition for the general public, especially for young people

Das Bild kann nicht angezeigt werden. Dieser Computer verfügt möglicherweise über zu wenig Arbeitsspeicher, um das Bild zu öffnen, oder das Bild ist beschädigt. Starten Sie den Computer neu, und öffnen Sie dann erneut die Datei. Wenn weiterhin das rote x angezeigt wird, müssen Sie das Bild möglicherweise löschen und dann erneut einfügen.

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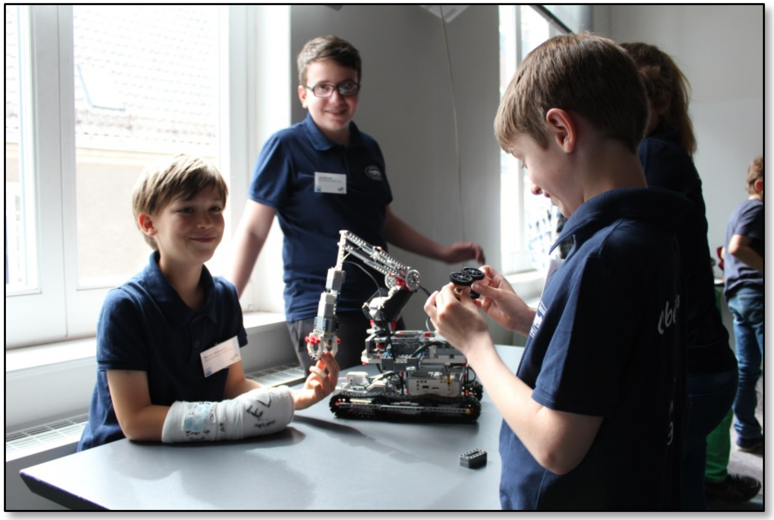
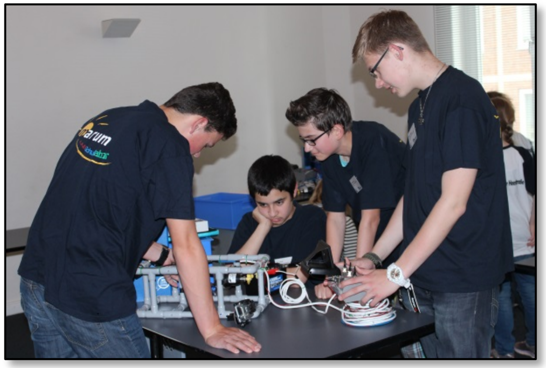
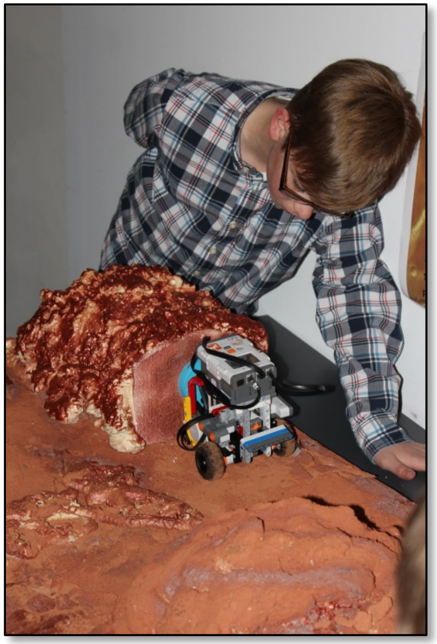
Education and Outreach

ROBEX – School project

schoolboys and girls from marine and space school labs developed their own exploration roboter in a competition


Overall Schedule

Work Description	Year 1 Oct12-Oct13	Year 2 Oct 13-Oct 14	Year 3 Oct14-Oct15	Year 4 Oct 15-Oct16	Year 5 Oct16-Dec17
Preparatory phase					
Design and development of components					
Field tests and Demo-missions					
Training of young scientists					
Final evaluation, technology transfer activites					

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Different approaches

- Normally the two areas are working in completely different time cycles

  Deep sea: relative pragmatic approach in development and testing based on frequent research vessel campaigns

  Space: much more effort in the study phase because of rare and costly missions

- Within ROBEX both have to synchronize their steps in order to realize **the two parallel demonstration missions in 2017** with similar system elements

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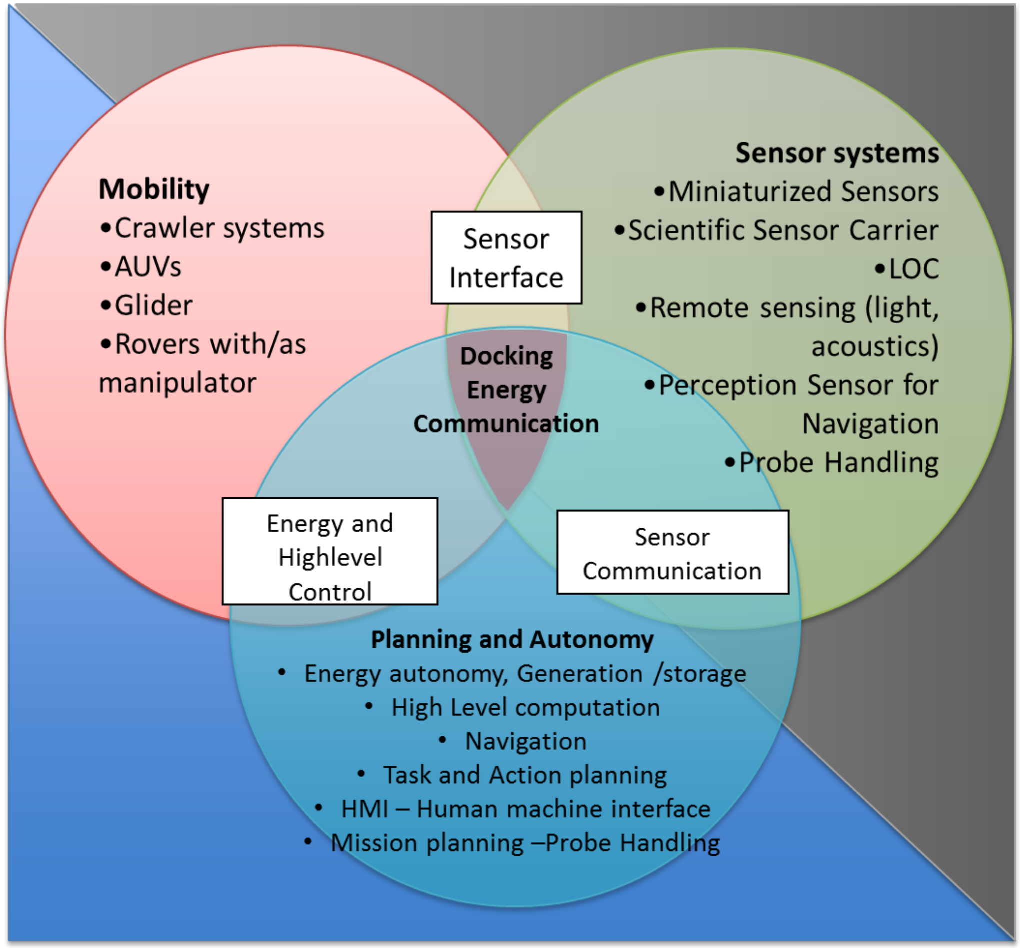
Overall synergies and added value

…are illustrated by the progress in the design teams

- Both communities profit from their different approaches
- **Deep sea** profits from developments of autonomous space systems
- **Space** profits from deep sea
  - by implementing more pragmatic mission oriented approaches and the establishment of complex and more frequent Earth-based analogue testbeds
  - by considering the use of „off the shelf" products also for space

Future Fields of joint acitivities



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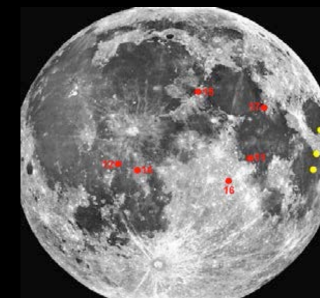
Today‘s Limitations

Insitu deep-sea and space exploration consists of single missions with spatial and time-limited coverage

Deep-sea Exploration	Space Exploration
Depends on research vessels	Only a few local landings
Local observations near the ship	Limited mobility
Depending on weather conditions	No long-term research lab



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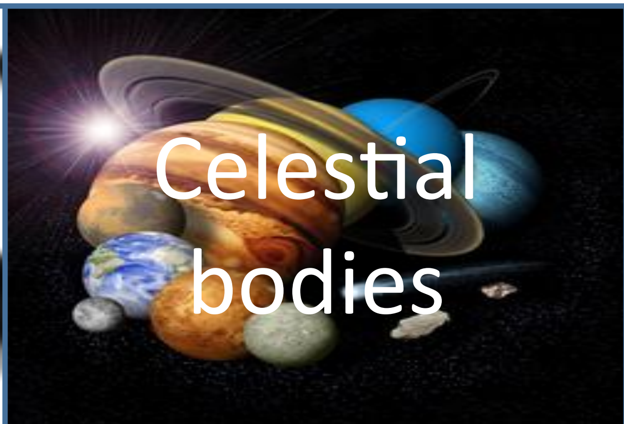
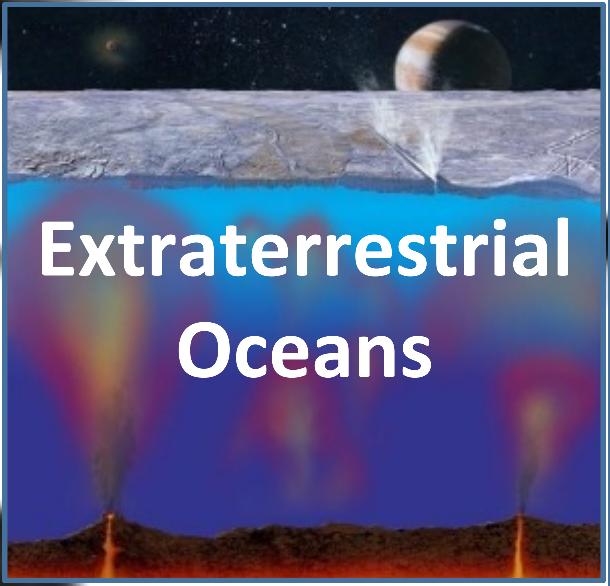
Aims for 2018+

Demonstration of interconnected autonomous robotic systems operating in swarms





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Long-term structural goal

„Expert Group for Extreme Environment Technology“

as basis for one of the most advanced research consortium for extreme environments

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Long-term Vision

- Search for extraterrestrial life on planets and moons
- Exploration of extra-terrestrial oceans