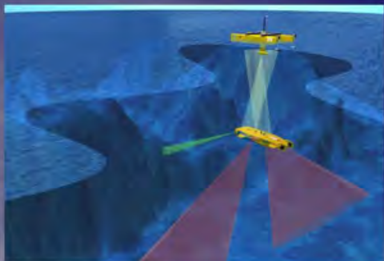
   

Cooperative Marine Robotic Systems for Environmental Monitoring and Surveillance

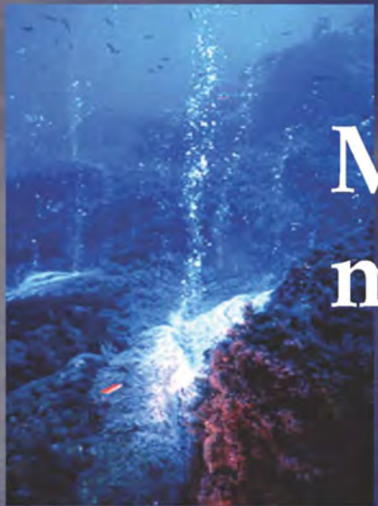
Technology and Operational Challenges

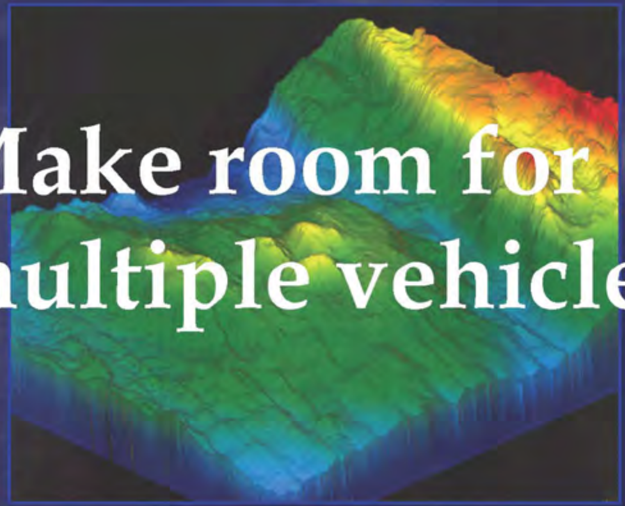
António Pascoal

Lab. Robotics and Systems in Eng. and Science (LARSyS)
Institute for Systems and Robotics (ISR)
IST - Univ. Lisbon Portugal

EMS2014 Porto Calém, Gaia, Portugal

Sea: the Ultimate Frontier





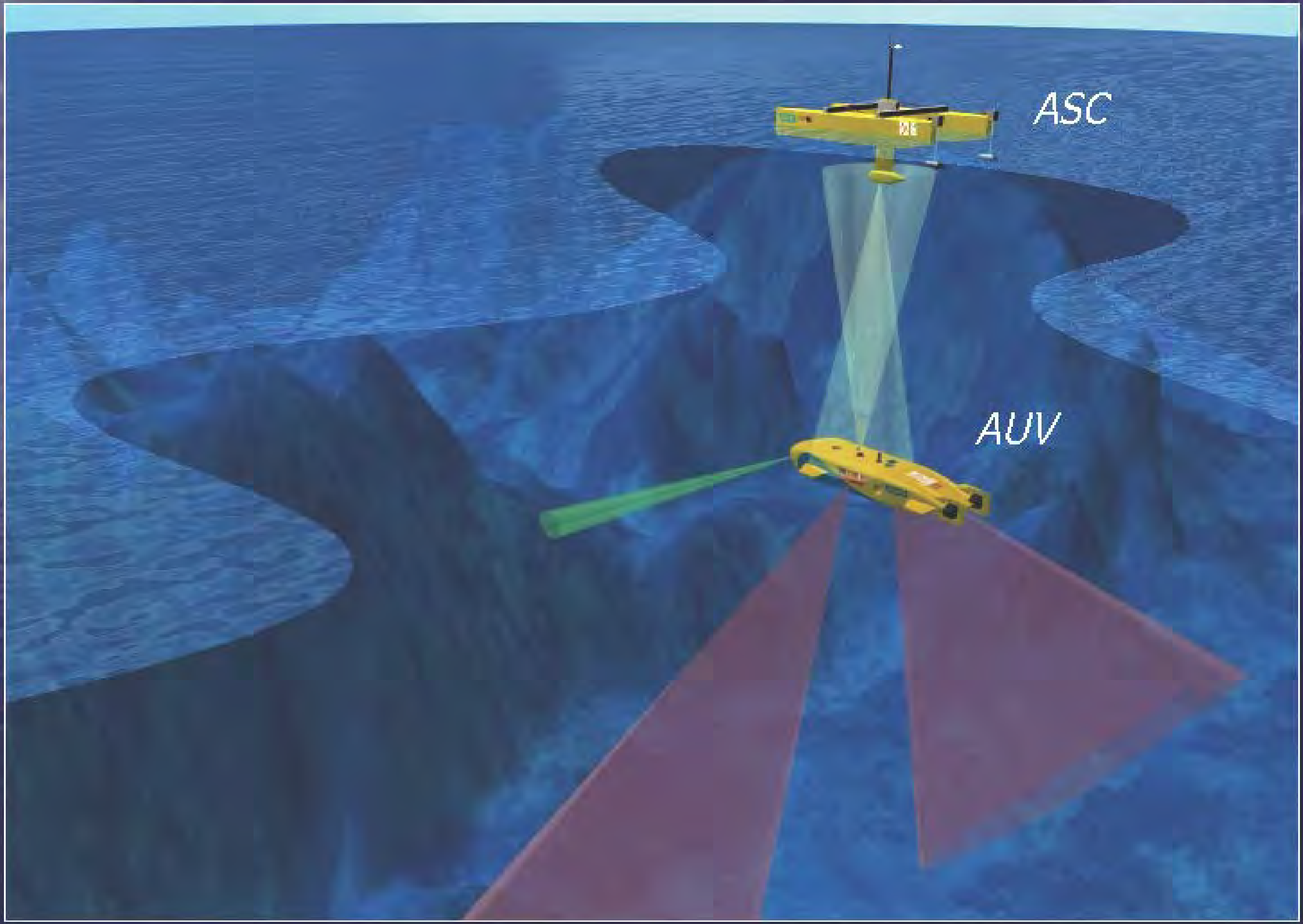
Make room for multiple vehicles!

Explore the Ocean

Advanced technology is mandatory

Future: Networked Mobile/Fixed Sensors (Moored systems, AUVs, ASCs, Gliders, Submersibles, Vessels, etc)

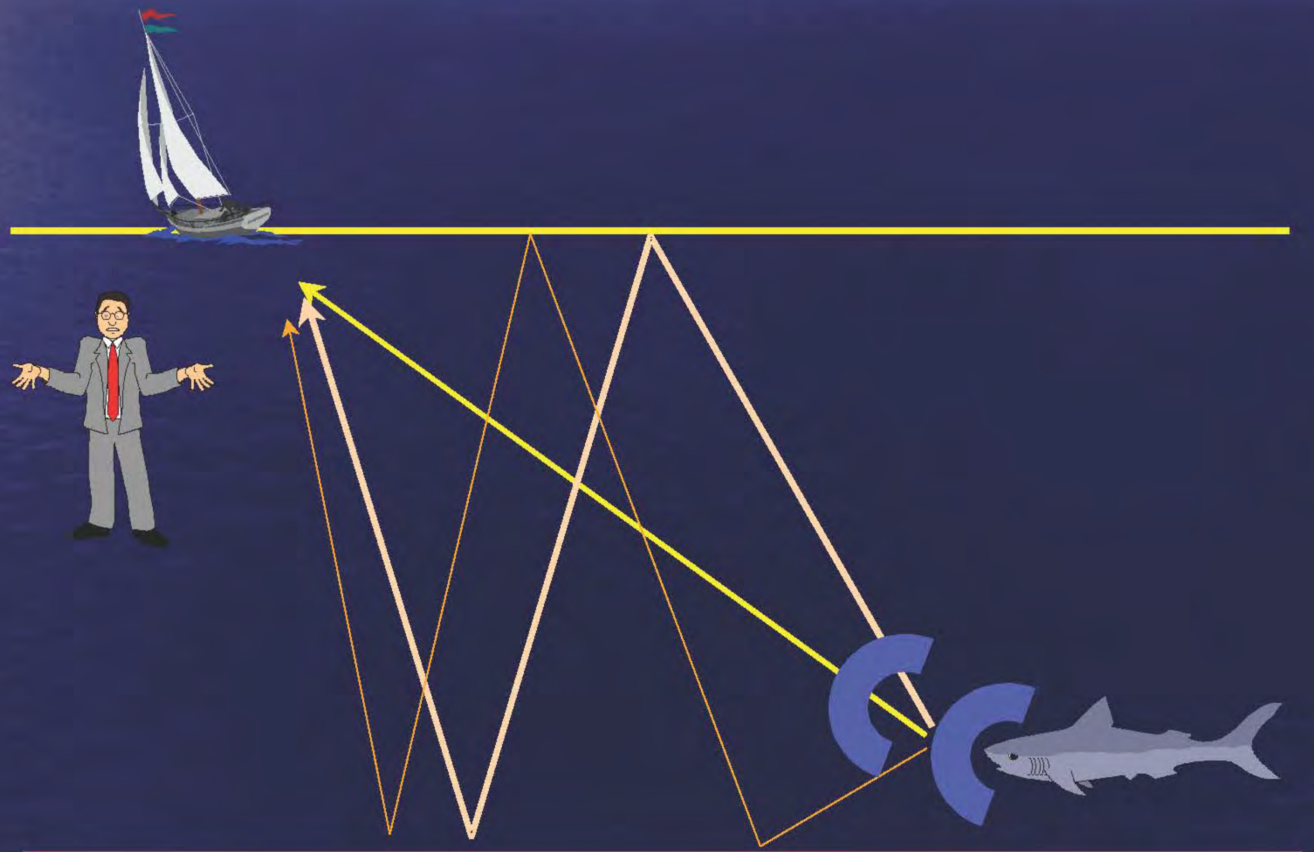
Cooperative Missions at Sea: the ASIMOV project



Surface and underwater vehicle operating in master / slave configuration (ASIMOV, 2000)

Problem to be solved: Communications

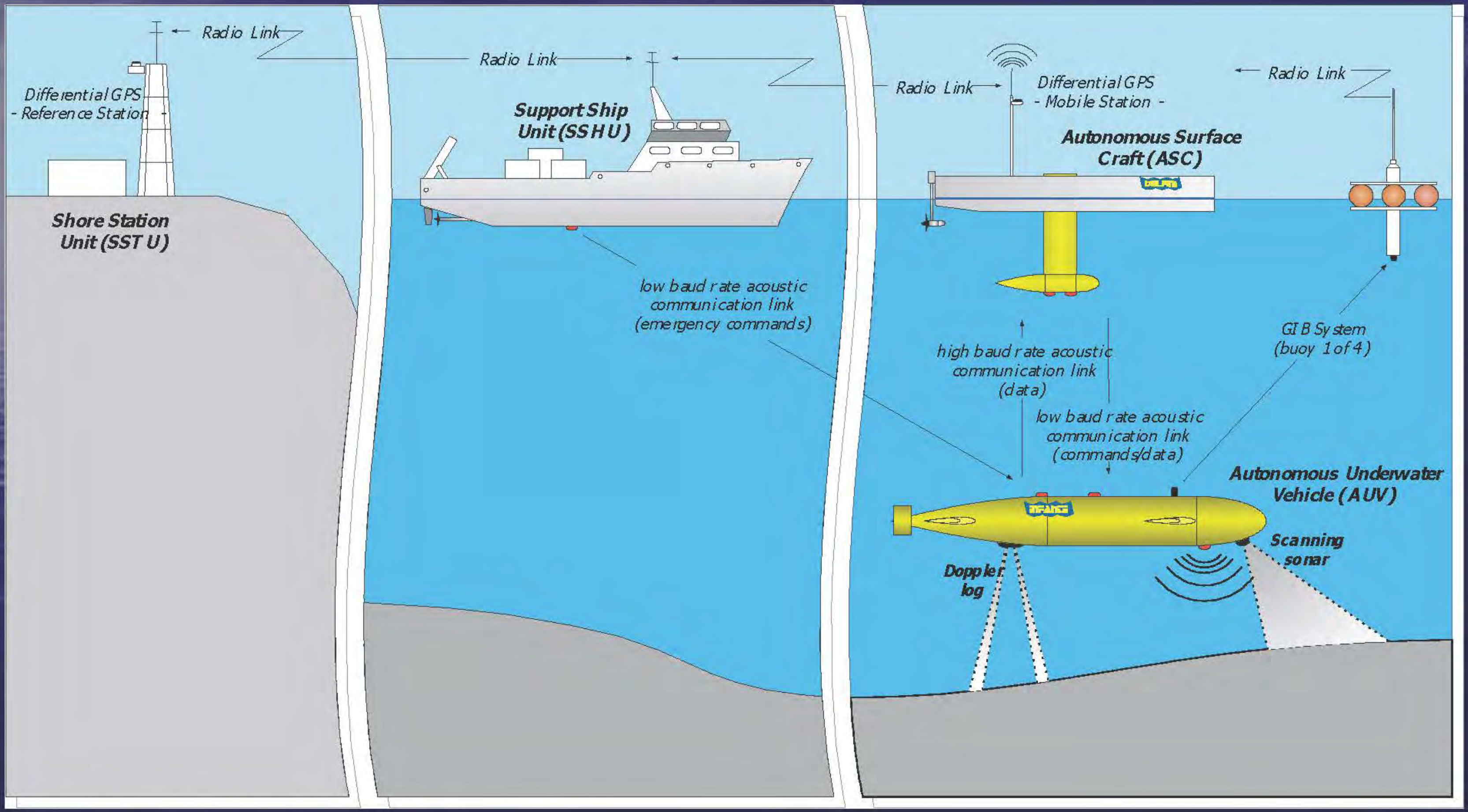
Underwater Communications – *very hard!*



Underwater Communications

Transmit in the vertical !

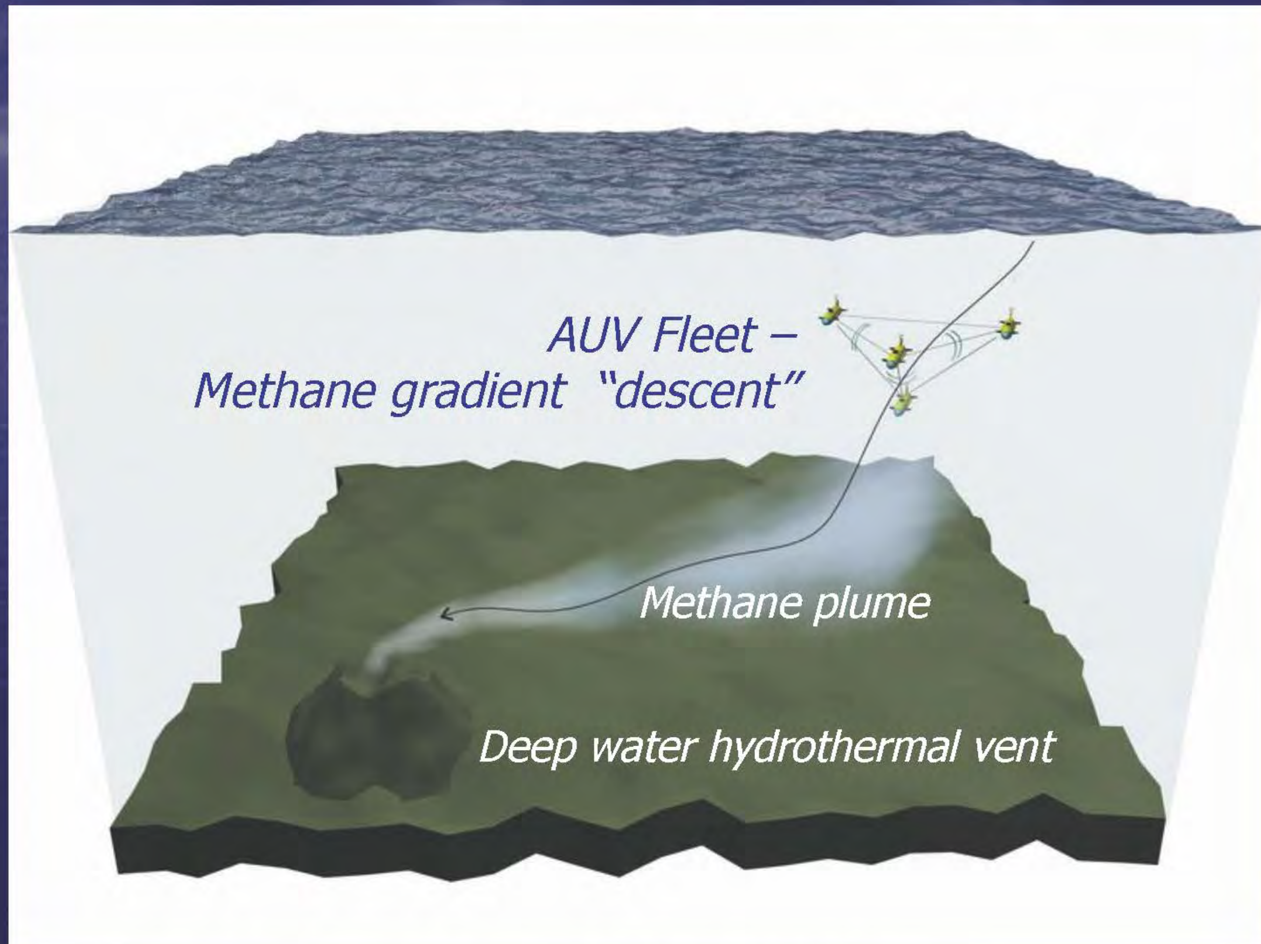
Cooperative Motion Control



The ASIMOV concept
(ASIMOV project, EC - 2000)

GREX

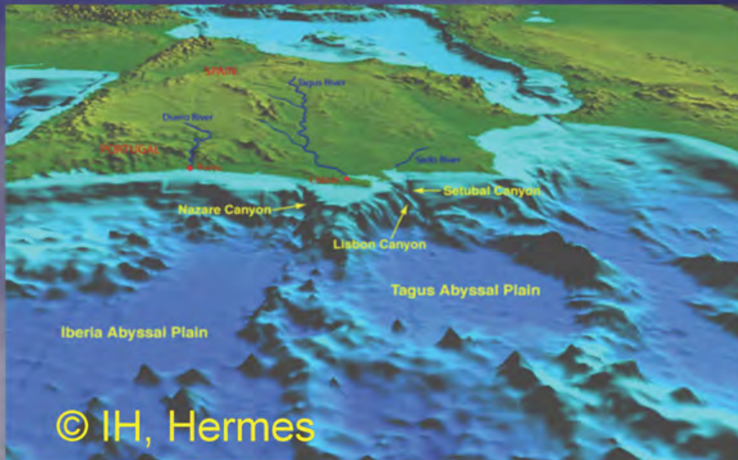
DSOR
dynamical systems and
ocean robotics LAB

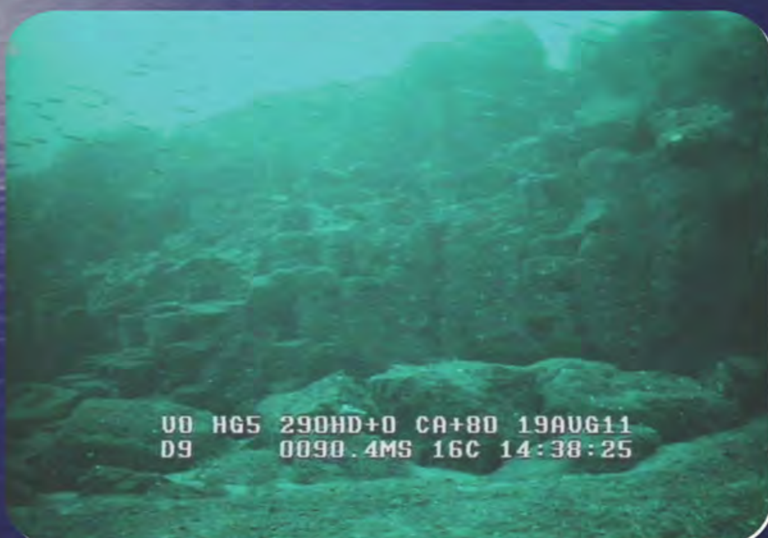


The quest for mid-water column
hydrothermal vents, Azores, PT

New Challenges

Deep Sea Habitat Mapping near hydrothermal vents and in complex 3D environments

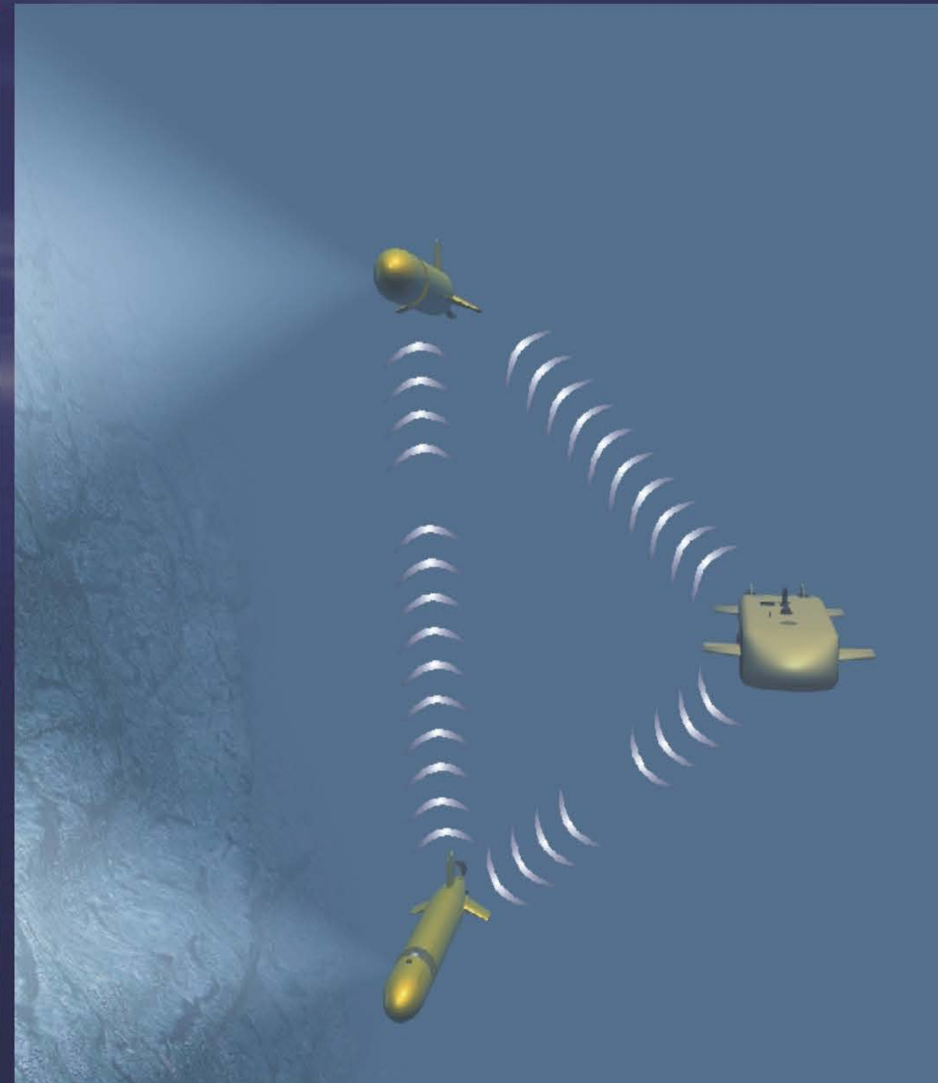




Underwater cliffs, canyon walls, mass wasting walls, mid-ocean ridges, fracture zones, seamount flanks, continental margins, hydrothermal vent edifices

The cliff scenario

Key challenge: i) obtain *marine habitat maps* of complex underwater structures including steep cliffs and "overhangs" with a negative slope

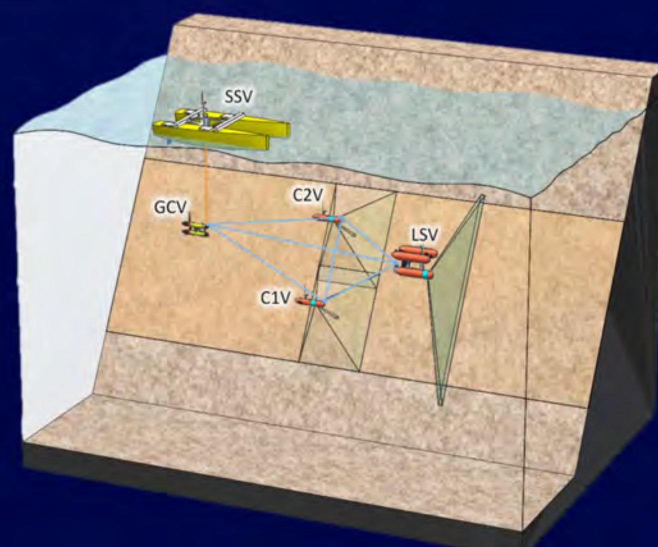


Proposed technological solution: from single to *supra-vehicles with spatially self-organizing capability*

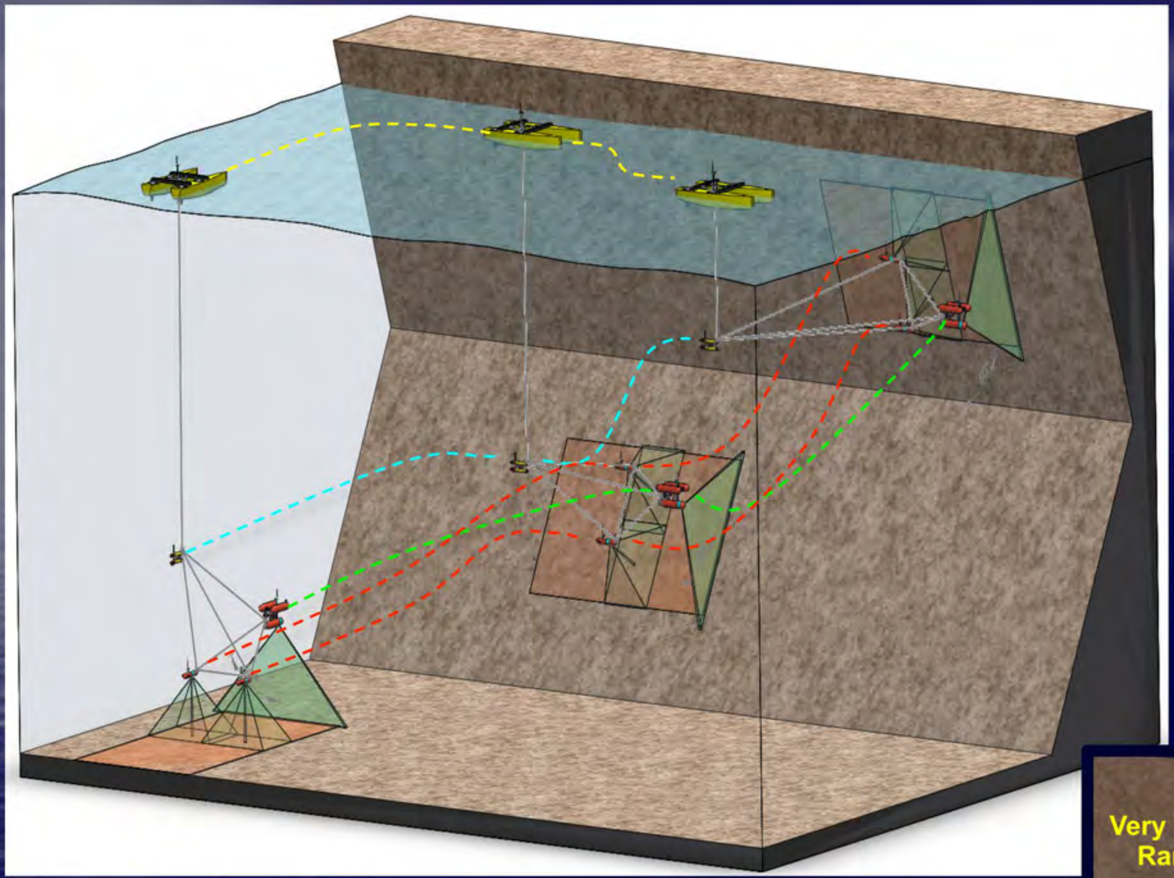
FP7-ICT-2887704
MORPH PROJECT

Marine robotic system of self-organizing, logically linked physical nodes

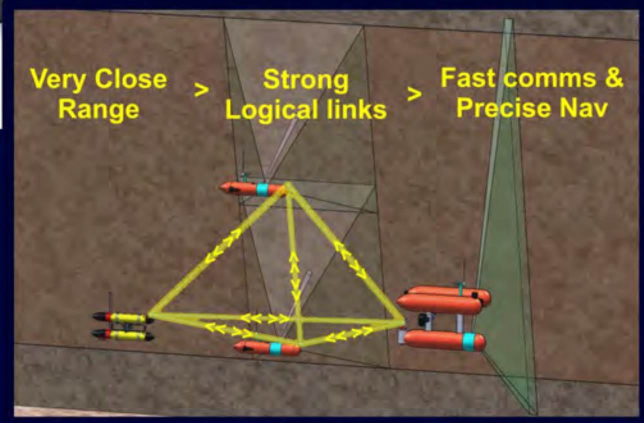
MORPH
Consortium



A new Paradigm is needed for Adaptive Mapping



A cluster of modules operating as a virtual marine vehicle



Key MORPH concept:
a self-reconfiguring robot for operations in complex 3D marine environments




Mission specification

Cooperative motion planning

Nominal trajectories & desired vehicle formation

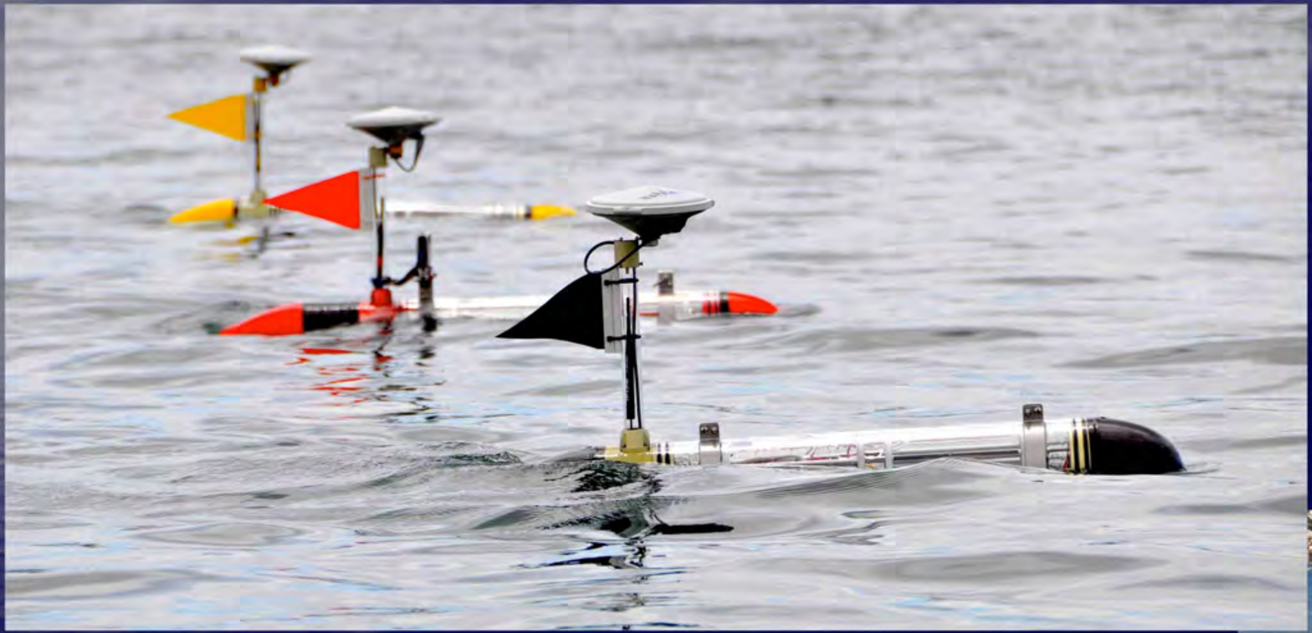
Cooperative motion control

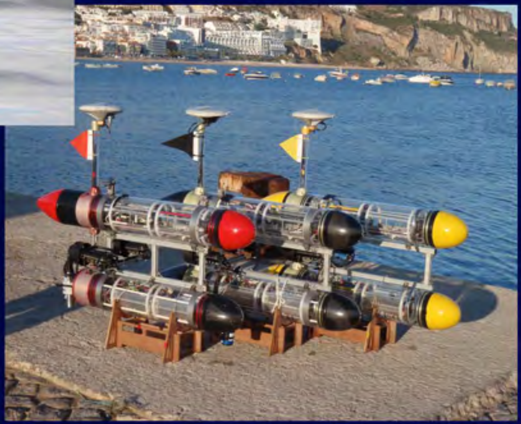
Global and local, relative vehicle positions

Cooperative navigation

Cooperative systems: key blocks required

From theory to practice: the MEDUSA ASVs/ AUVs

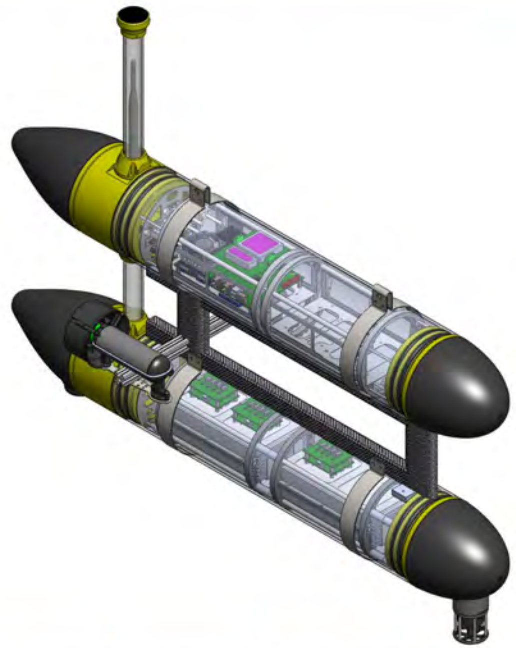


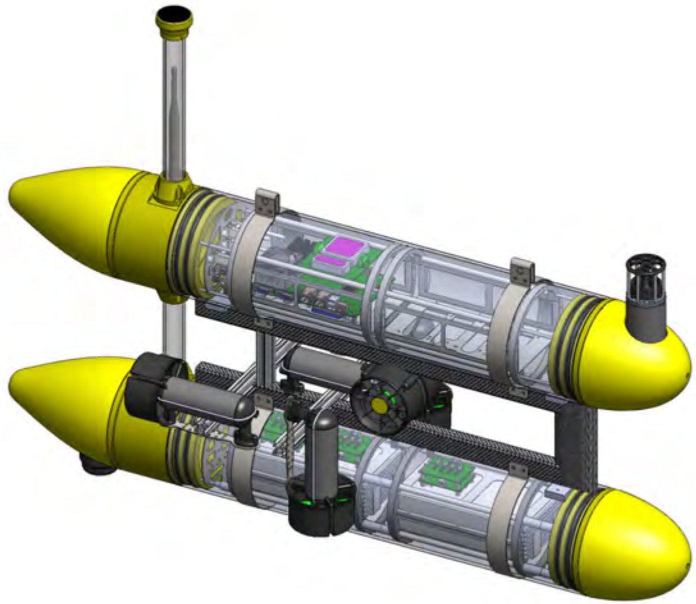


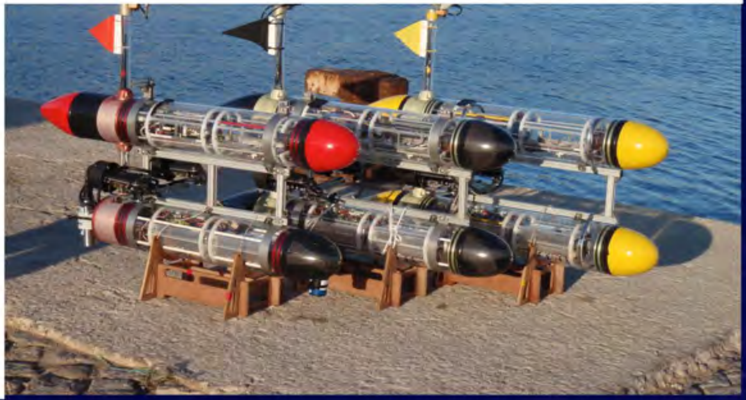
. *3 autonomous vehicles (cooperative motion control capability)*

. *Acoustic network (Tritech / Evologic modems)*

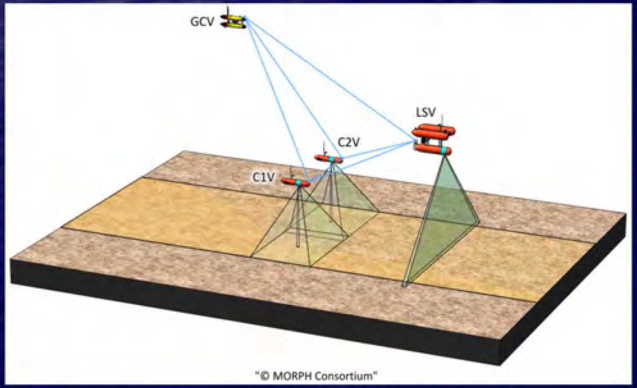
The MEDUSA ASVs/AUVs







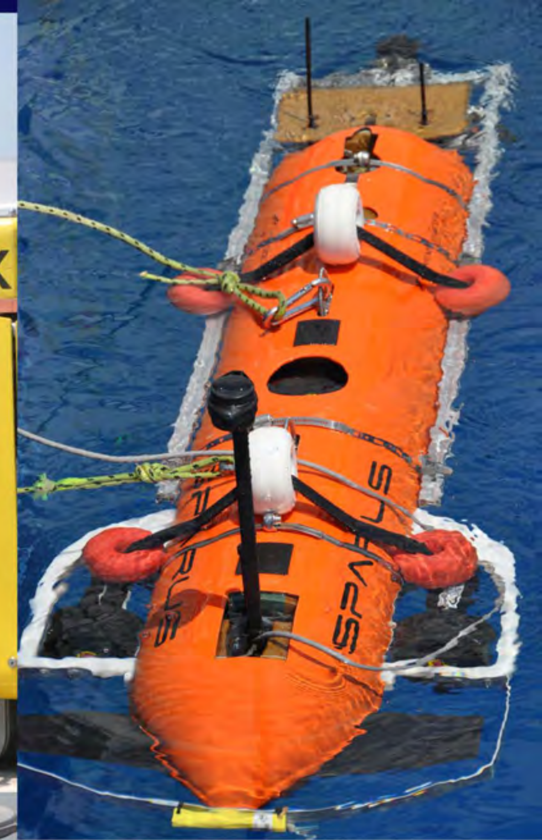
MORPH PROJECT

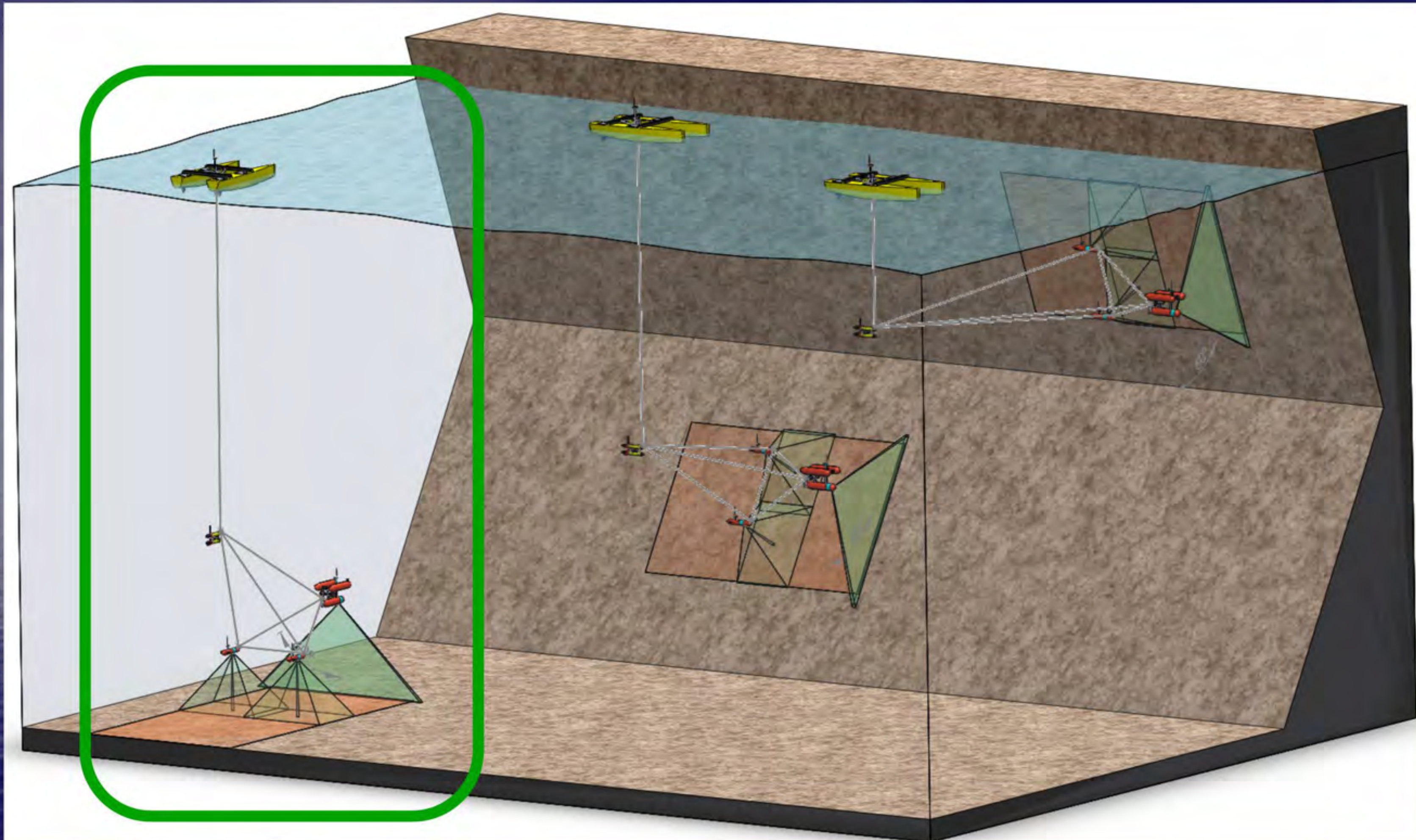


Toulon, France
July 2013

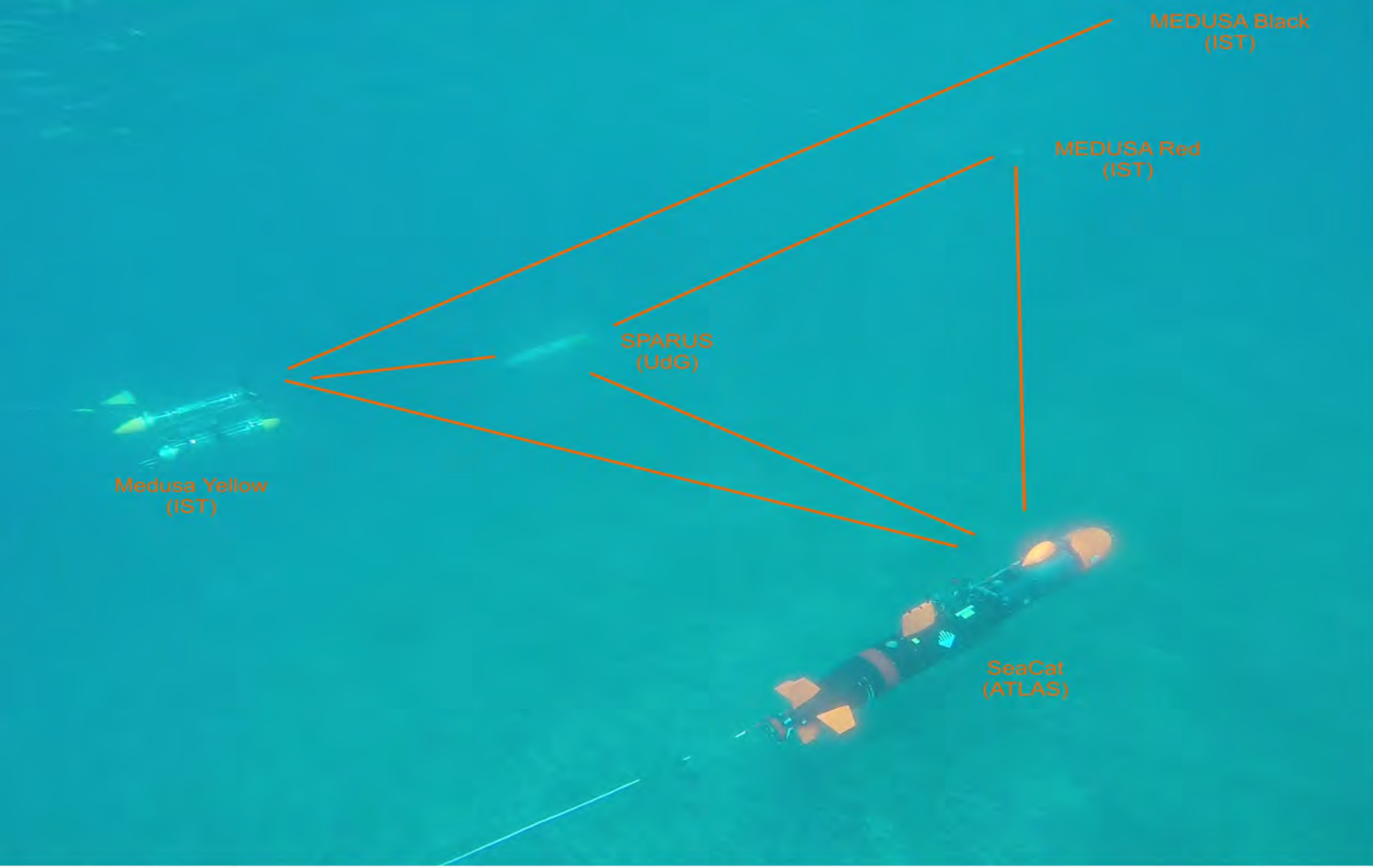

MORPH
3, 2, 1 ... MORPH TAKES OFF AT TOULON
GIRONA 500


vortex
Ifremer
AU
RO
vortex

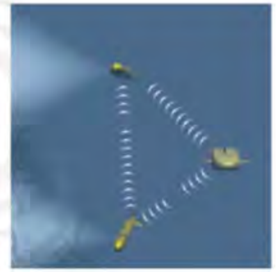

SPARUS
SPARUS



The FULL MORPH SEGMENT


MEDUSA Black
(IST)
MEDUSA Red
(IST)
SPARUS
(UdG)
Medusa Yellow
(IST)
SeaCat
(ATLAS)

MORPH



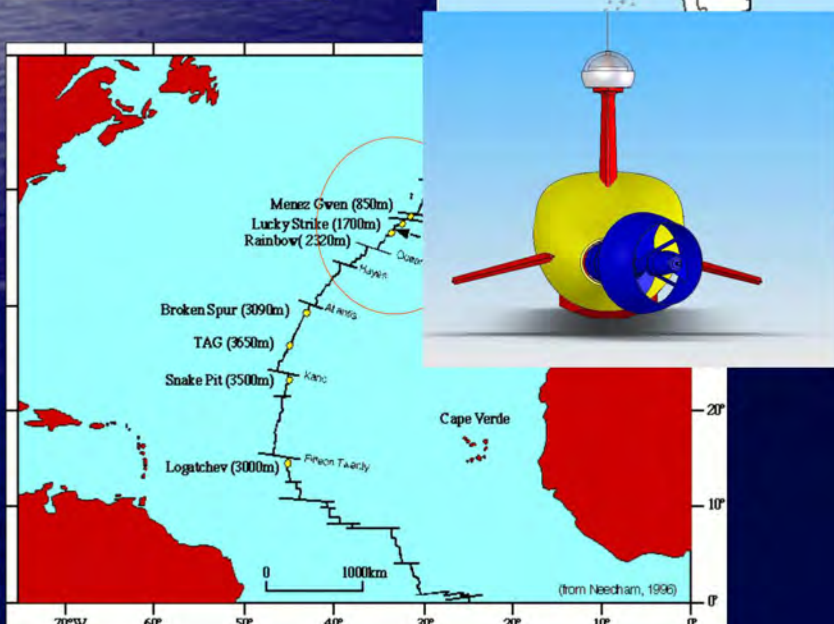
Marine robotics system of self-organizing logically linked physical nodes

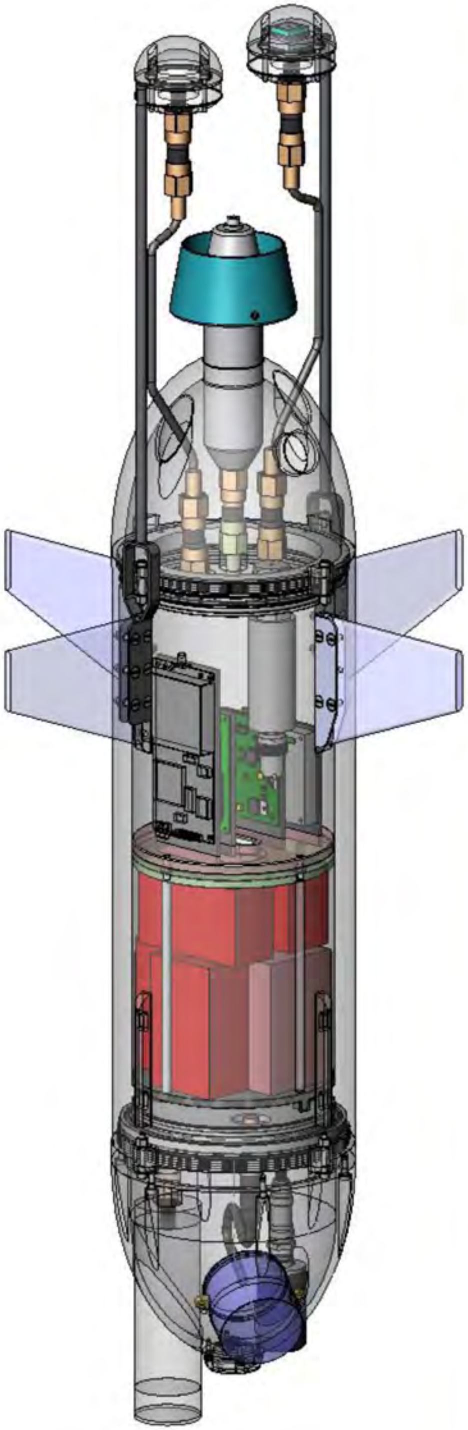
Azores trials 2014

Work Package 5

September 2014

Meeting with Índia (1999-)





Autonomous Vertical Profiler (AVP)

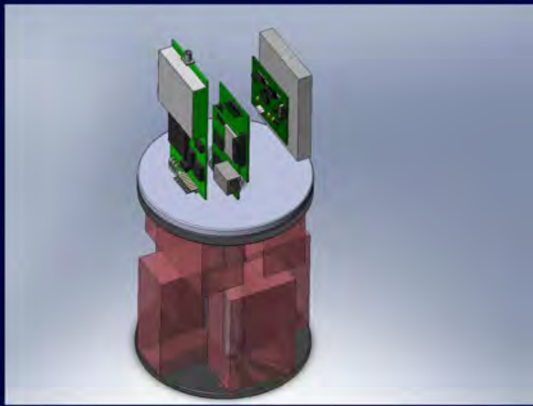
Features:

- Delrin hull
- Weight: ~20 kg
- Length: 880 mm
- Dia: 180 mm
- Propulsion: 24V thruster
- Energy: Li Poly batteries
- sensor loaded nose
- +vely buoyant

sensor loaded nose

electronics,

batteries

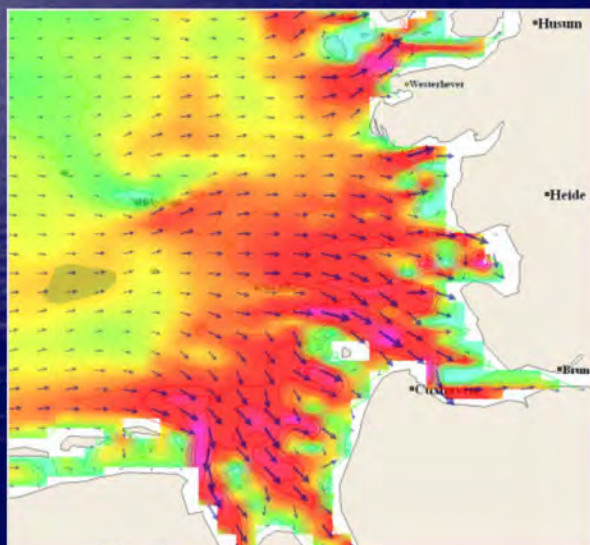


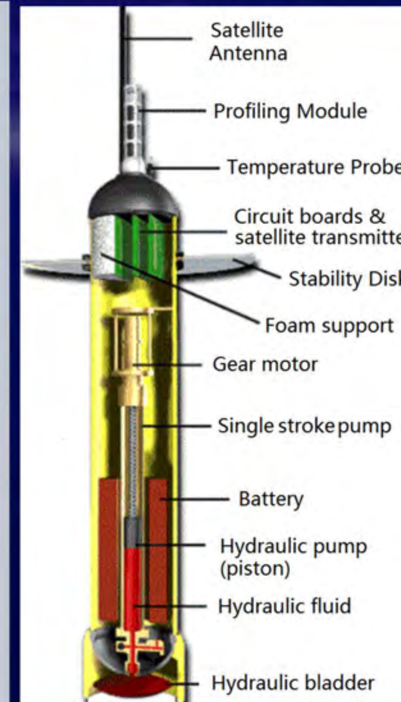
Jerome Jouffroy, MCI, jerome@mci.sdu.dk

Selective Tidal-Stream Transport for Lagrangian profilers

Lagrangian profiler/profiling float:

- Horizontally passive: follow ocean currents
- Used mostly in a deep water environment

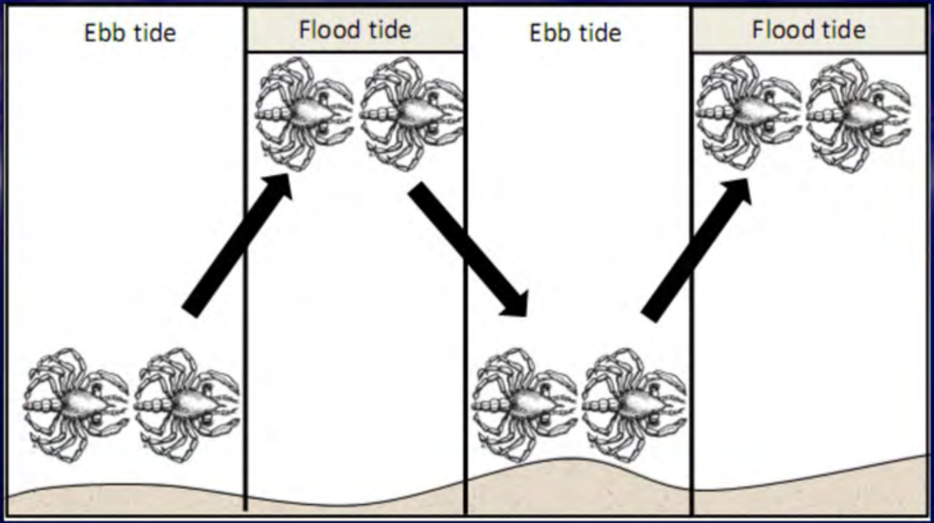




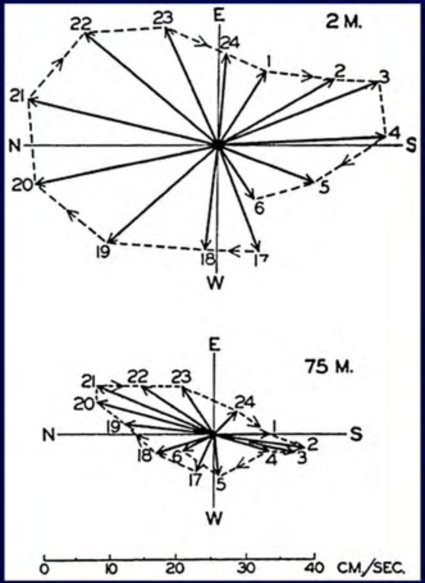
Can a profiler use
tidal currents actively?
(for recovery, re-deployment, …)

STST in the animal world


Blue crab megalopa



Adult Plaice

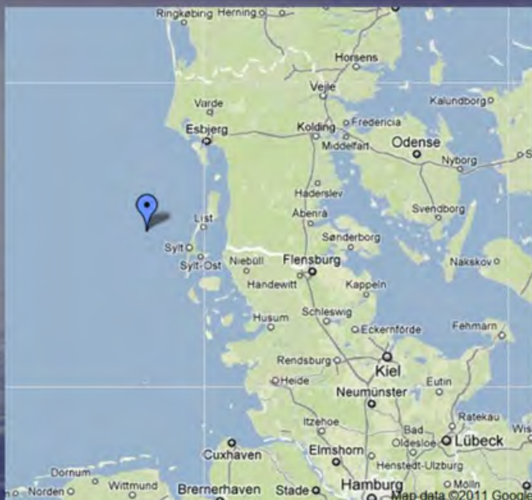


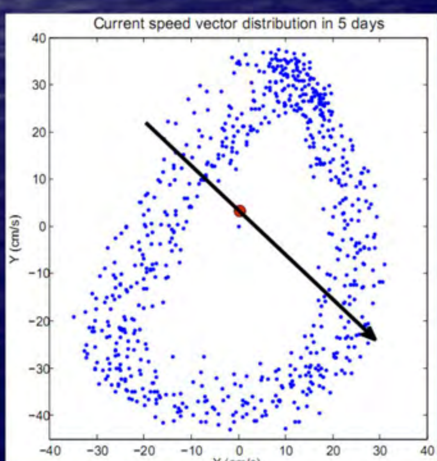
Jerome Jouffroy, MCI, jerome@mci.sdu.dk

Jerome Jouffroy, MCI, jerome@mci.sdu.dk

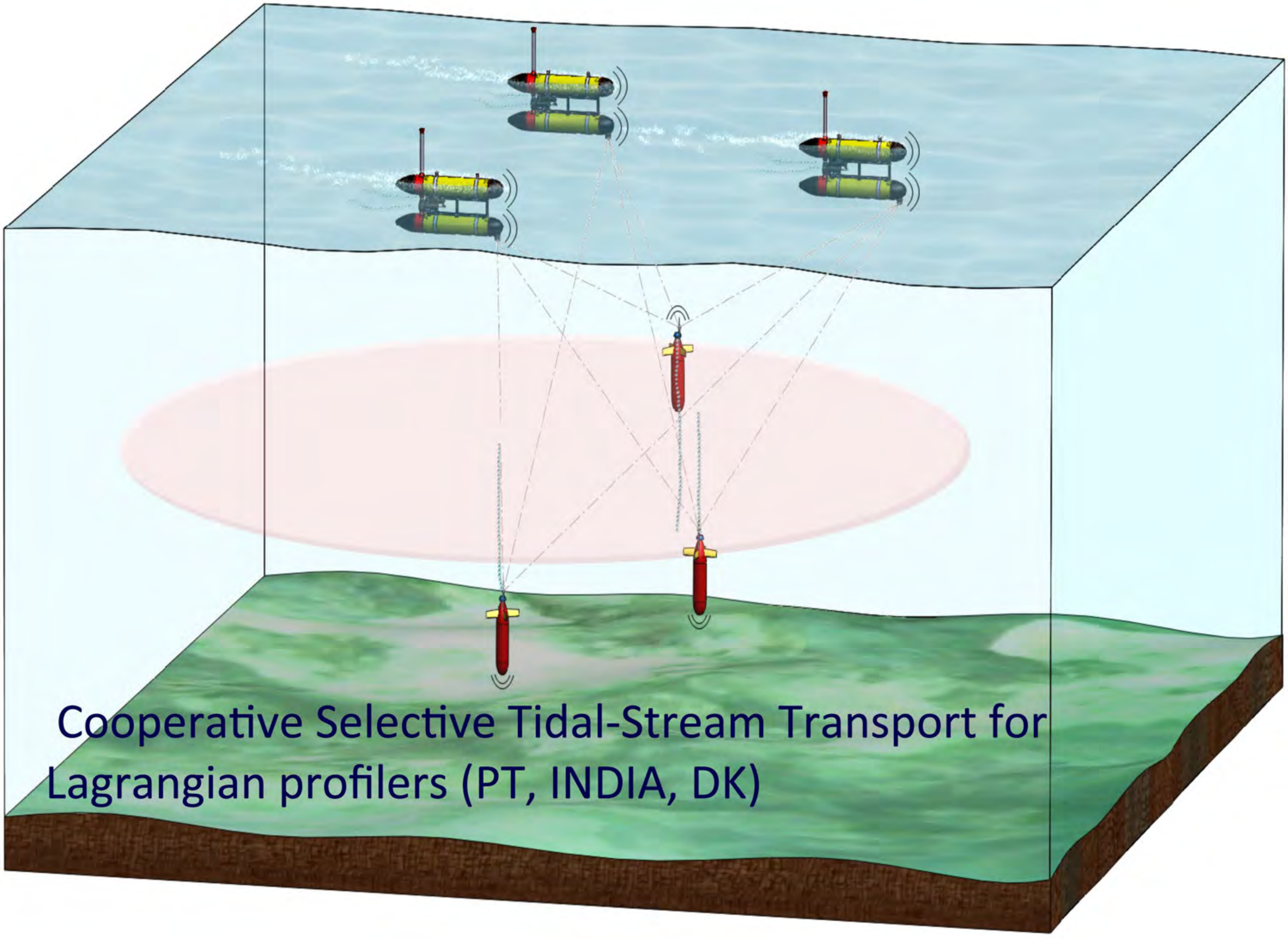
Test results in a re-deployment scenario

Current data profiles from the North Sea

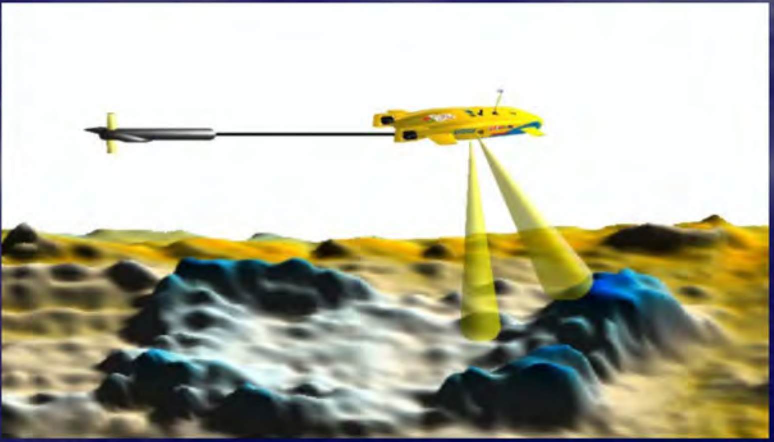


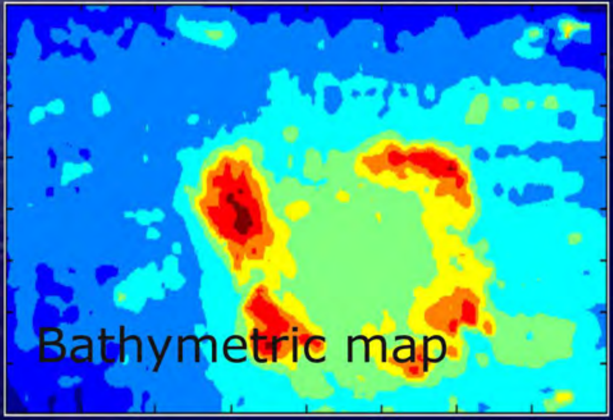


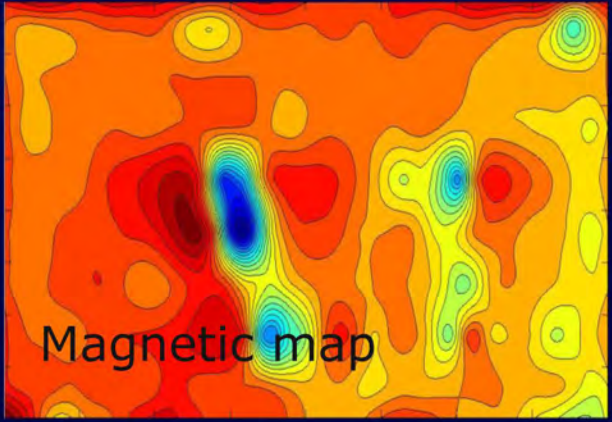
Mean current: 3.2cm/s


Cooperative Selective Tidal-Stream Transport for
Lagrangian profilers (PT, INDIA, DK)

Geophysical-Based Navigation



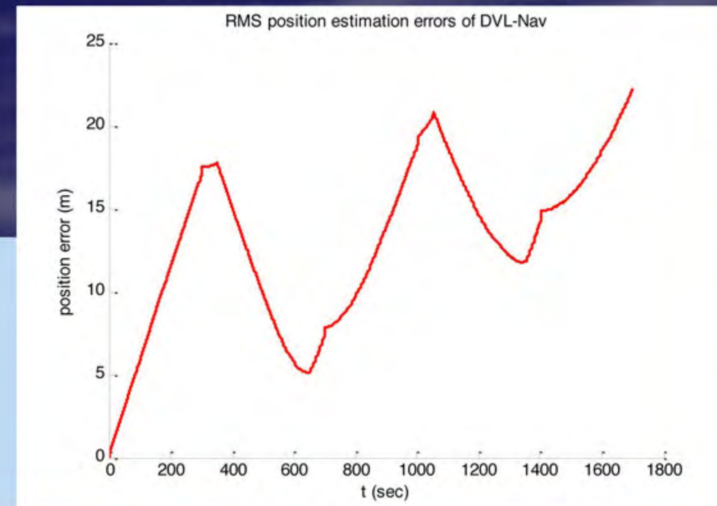


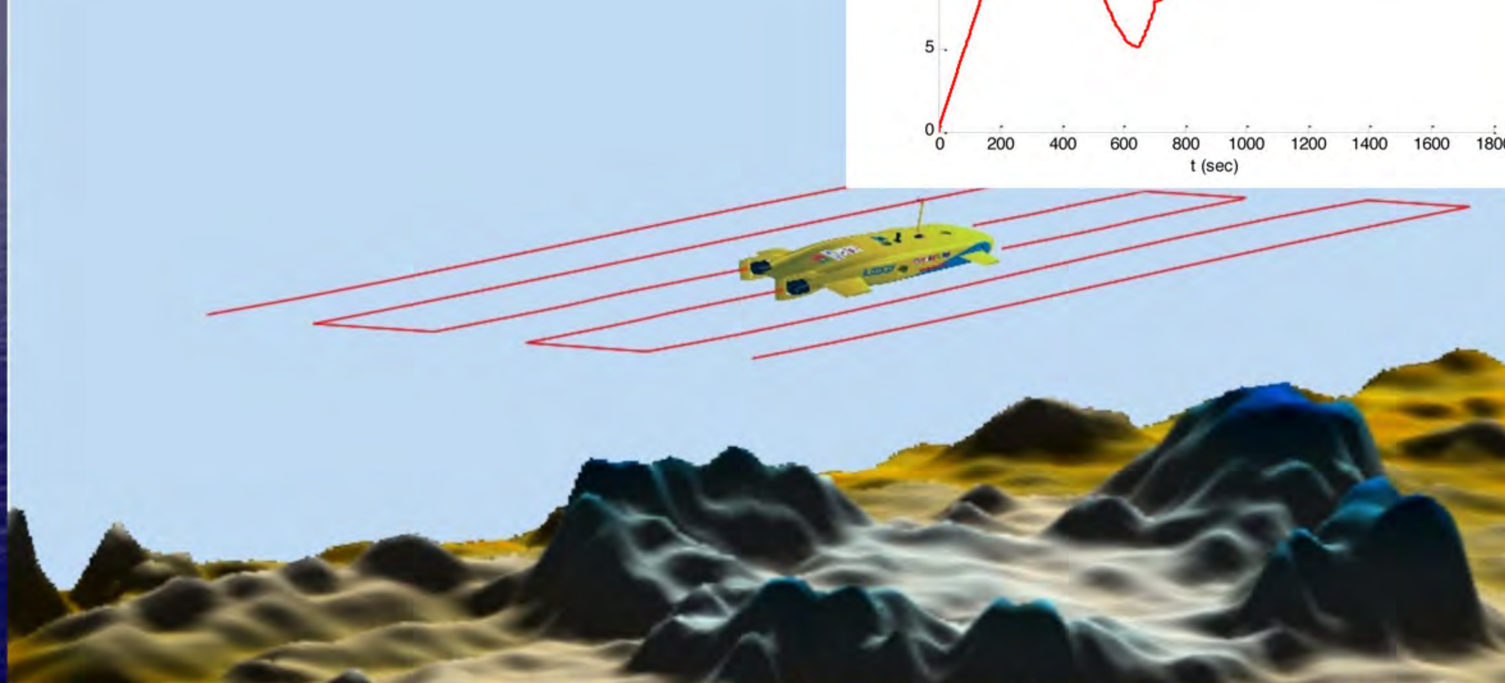


(IST-PT, UAveiro-PT,NIO-Goa, India; KAIST. Korea)

Conventional Navigation Solutions

- AHRS/DVL limitations

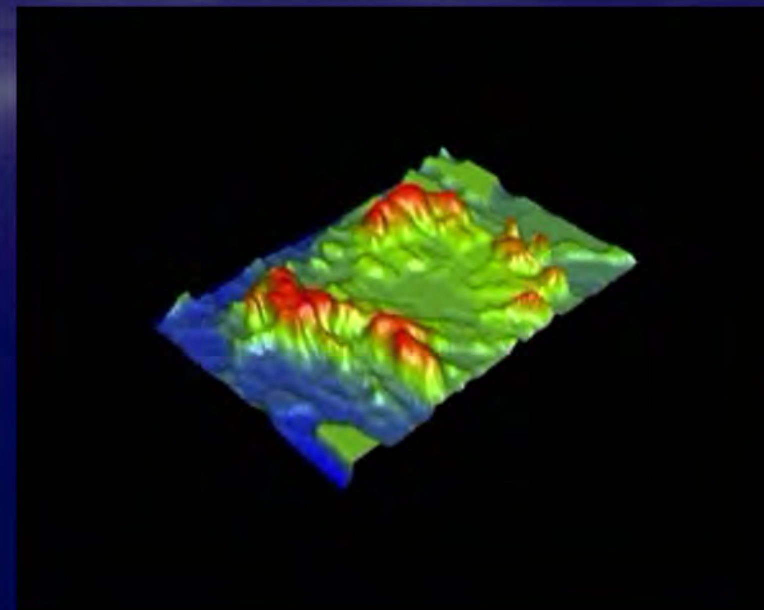


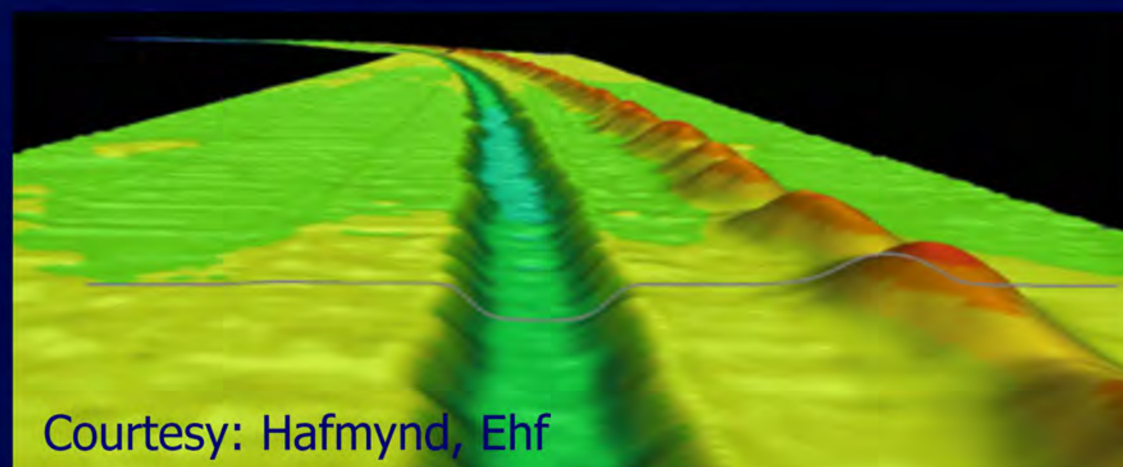


- LBLs are expensive and complex to deploy

Non-conventional Navigation Solutions

- **Exploit information from the environment for self-localization**
  - Natural features: elevation; reflective properties…
  - Artificial features: submarine cables or trenches; moorings; ship wrecks…



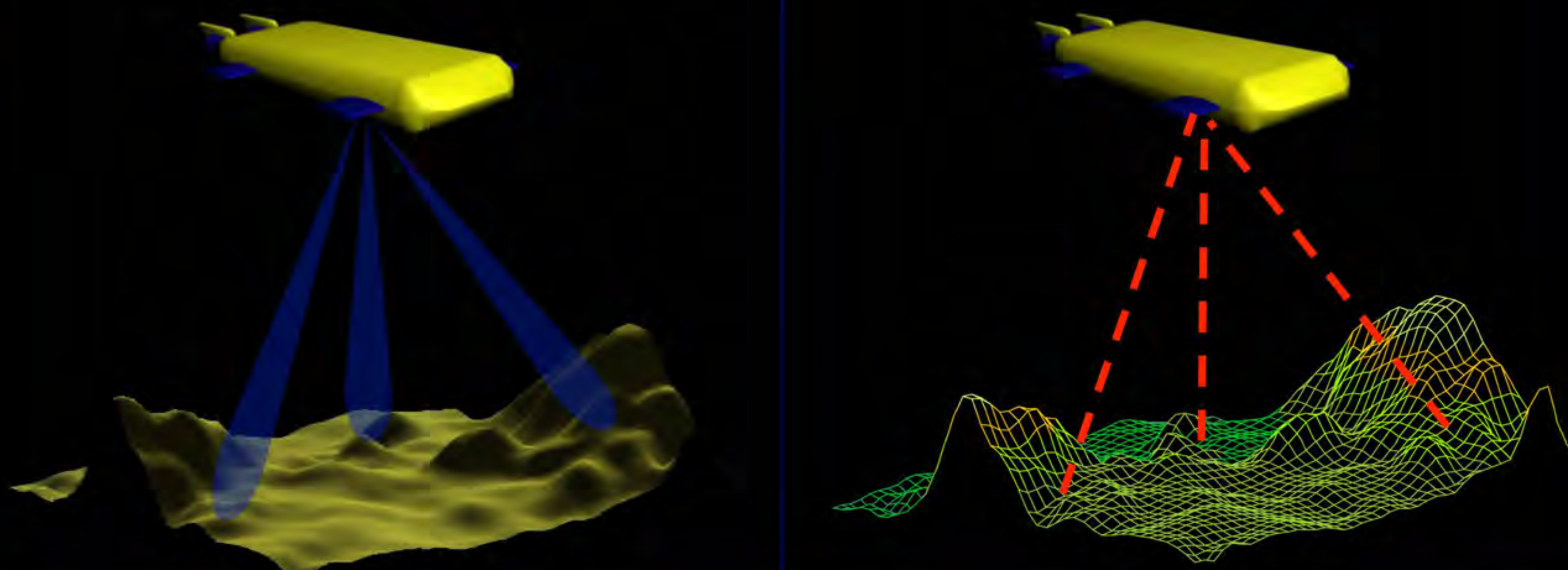


Courtesy: Hafmynd, Ehf

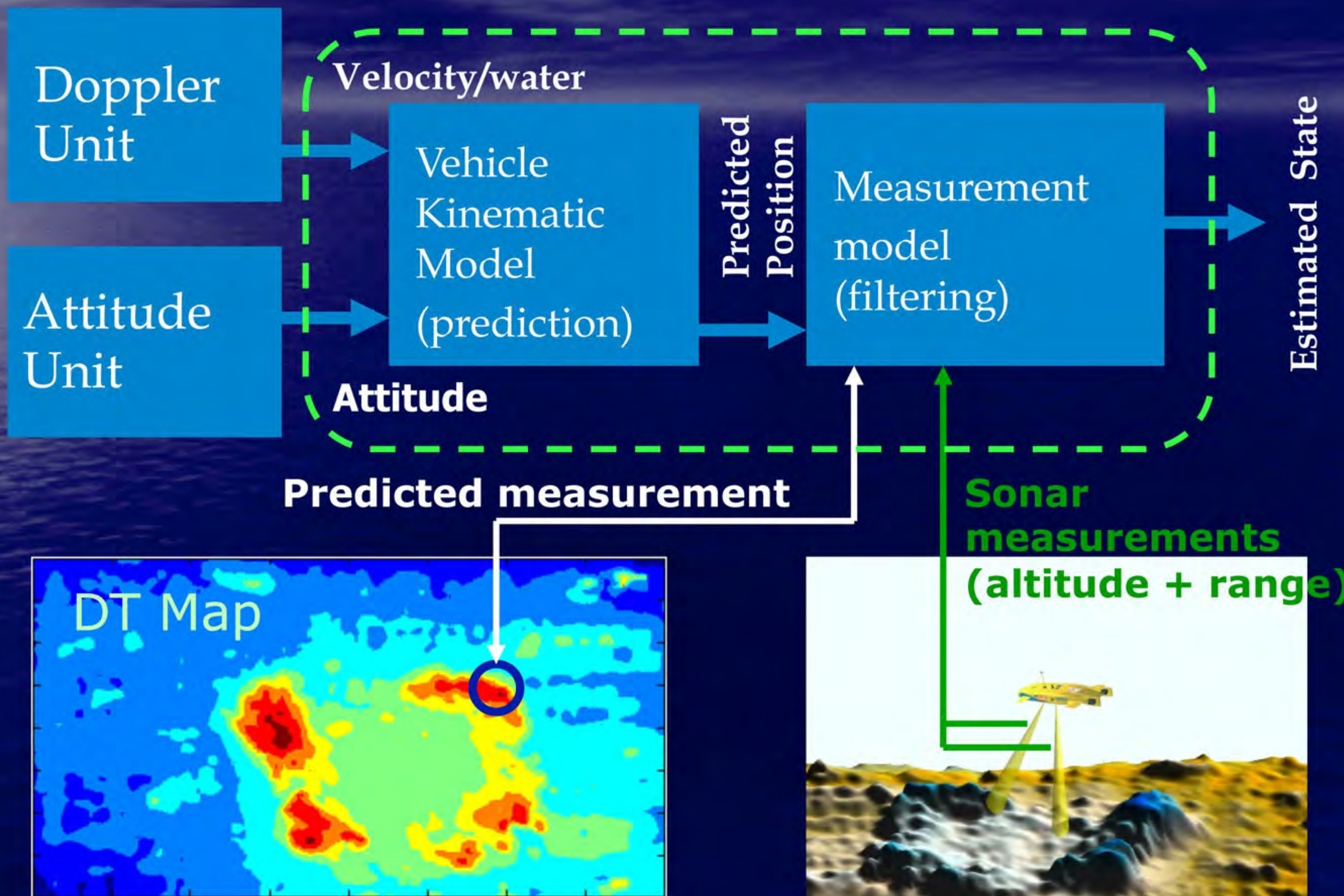
- **TAN**
- **SLAM**

Non-conventional Navigation Solutions

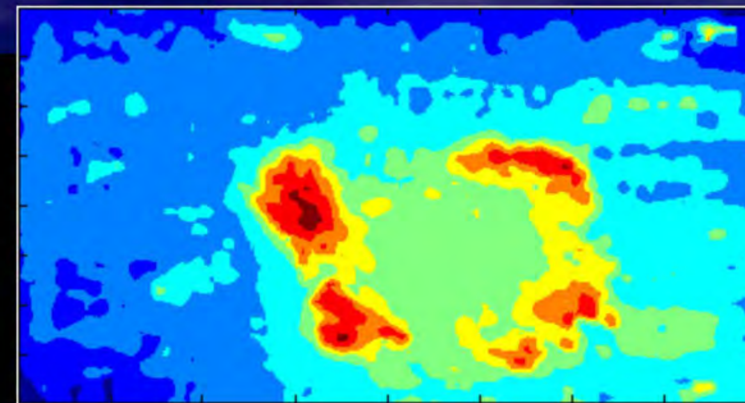
- **Terrain-Aided Navigation (TAN** a.k.a. TRN,TBN**)**
  - Use a prior map of the environment.
  - Make observations of the terrain
  - Match observations against the map to estimate position.

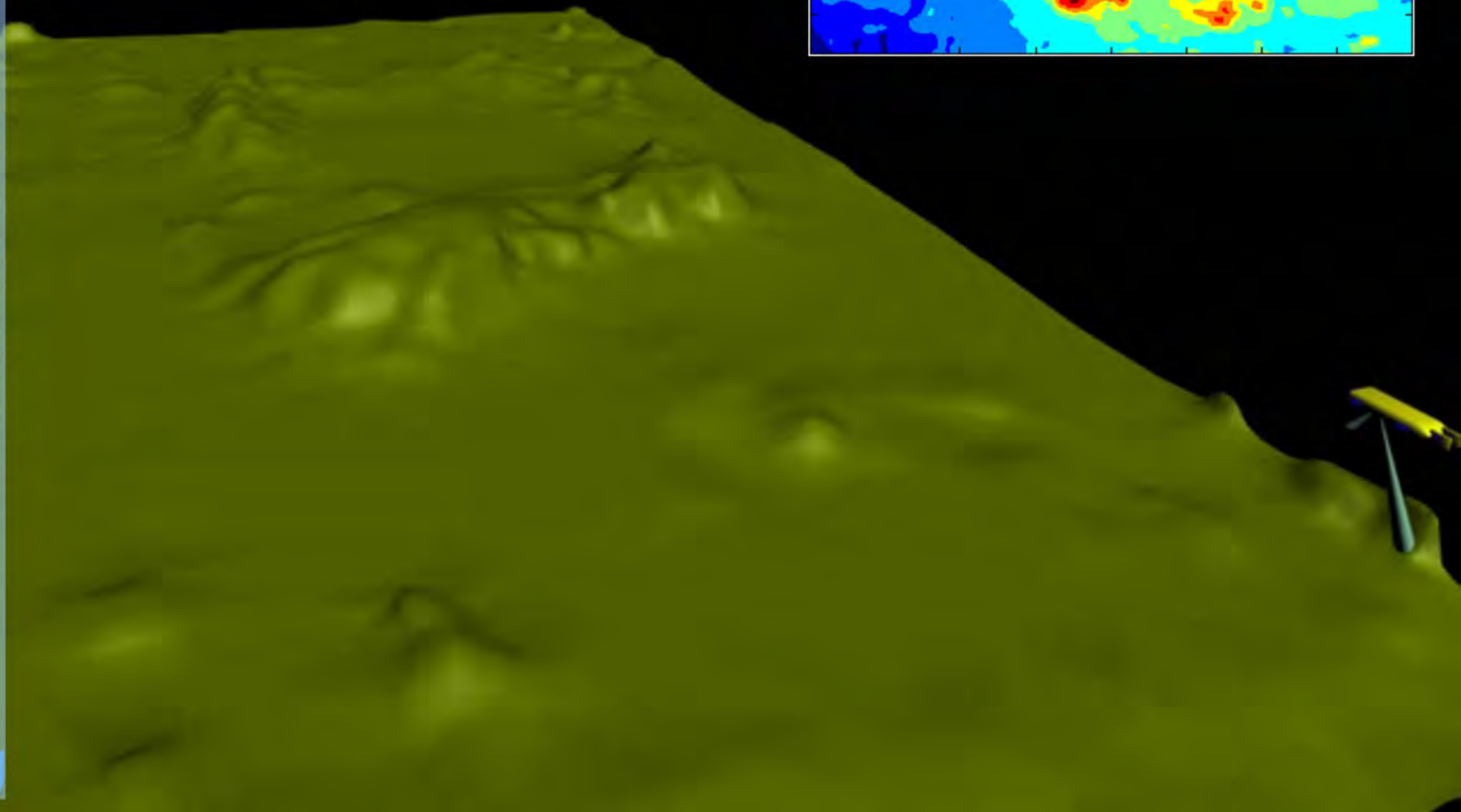


TAN Filters


Doppler Unit
Attitude Unit
Velocity/water
Attitude
Vehicle Kinematic Model (prediction)
Predicted Position
Measurement model (filtering)
Estimated State
Predicted measurement
DT Map
Sonar measurements (altitude + range)

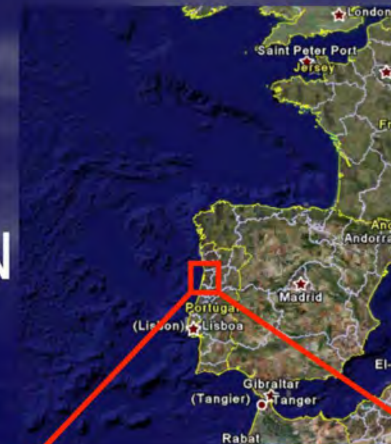
TAN Filters (Monte Carlo Methods – Particle Filters)

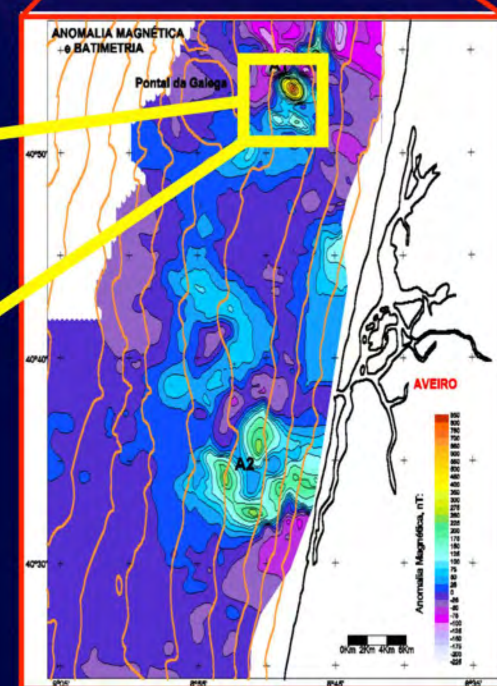


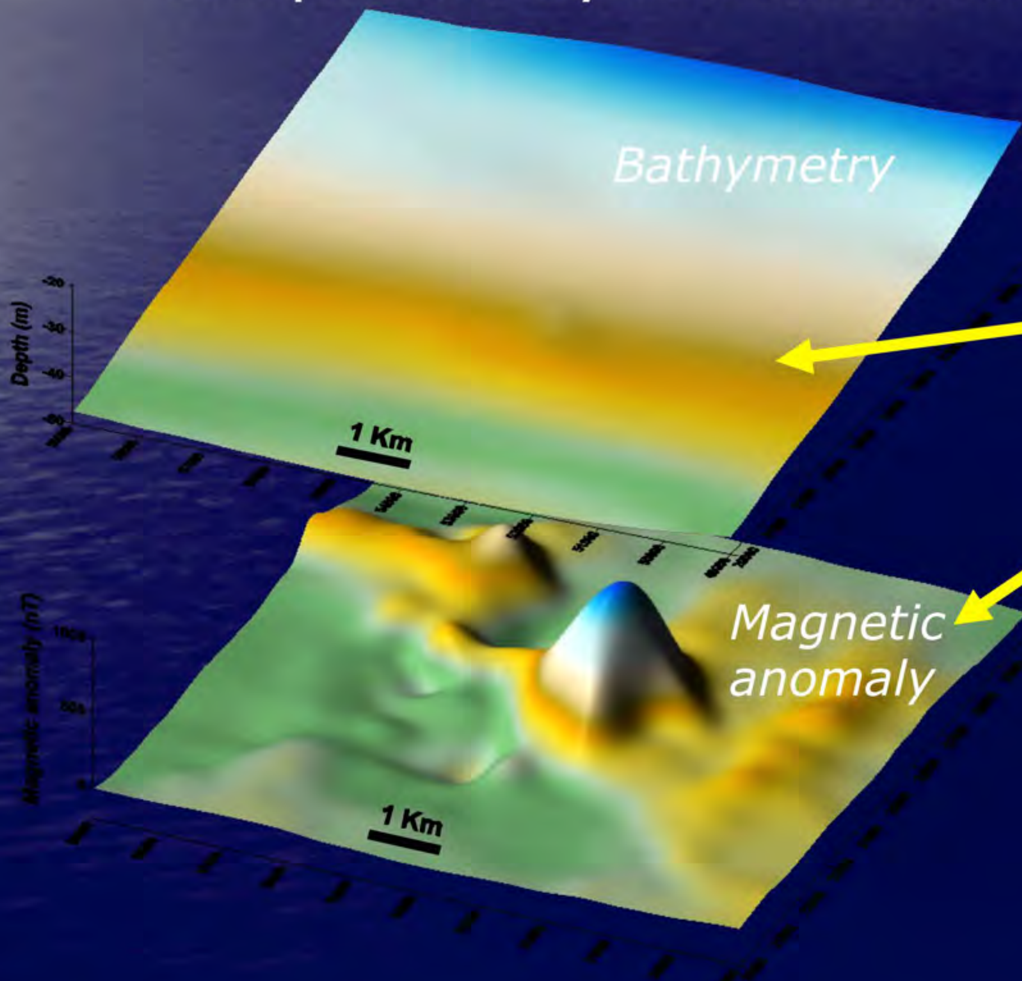


Magnetic Navigation (MN)

- **Main motivation**
  - Complementary information for TAN





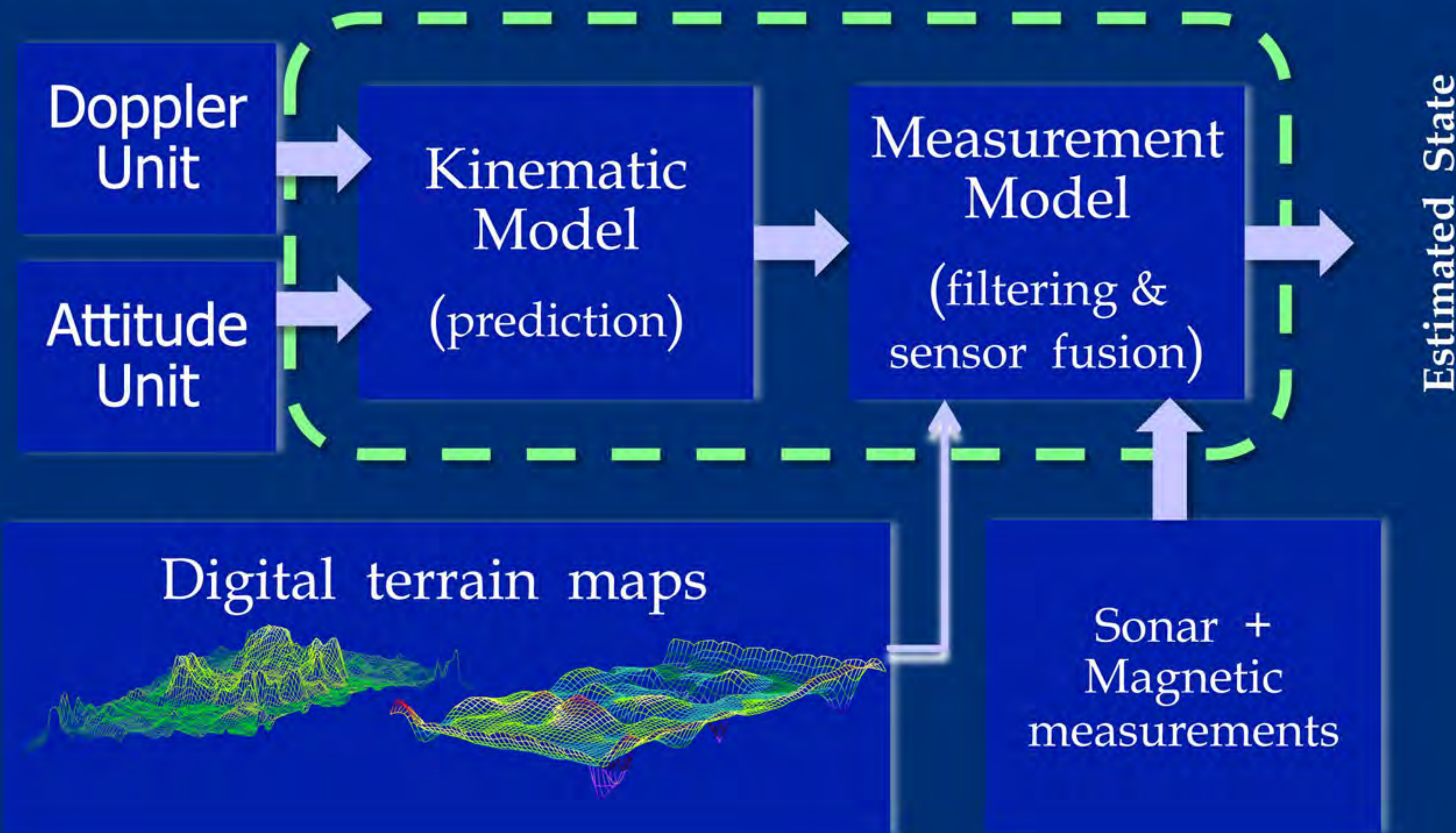


Magnetic Navigation (MN)

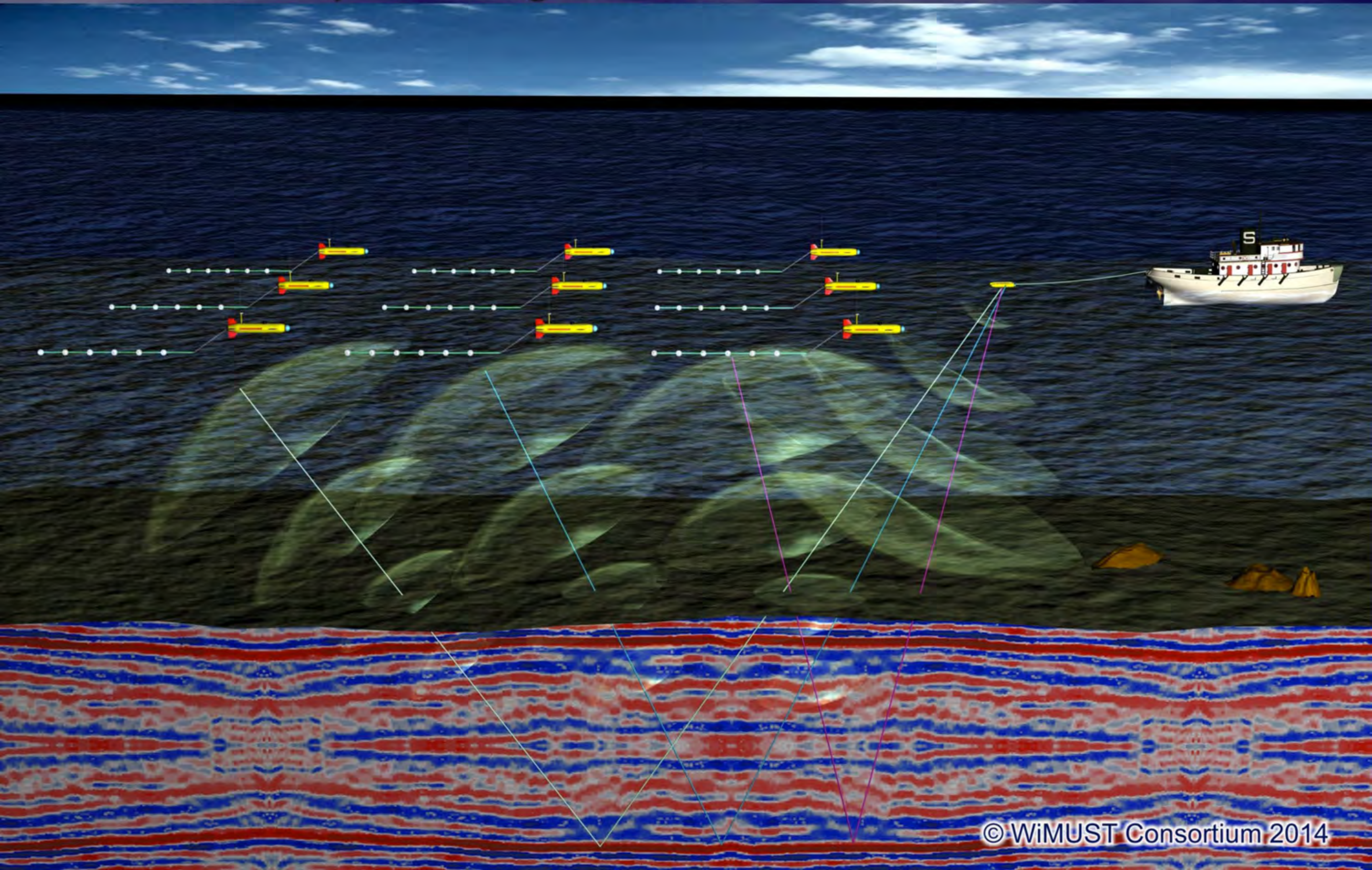
- **"Proof of concept"**
  - Used by animals for long-range navigation

Magnetic Navigation (MN)

Integrating bathymetry and geomagnetics



A Vision of the Future
(cooperative vehicles for geophysical exploration)
EC WiMUST Project, starting Feb. 2015



A Vision of the Future
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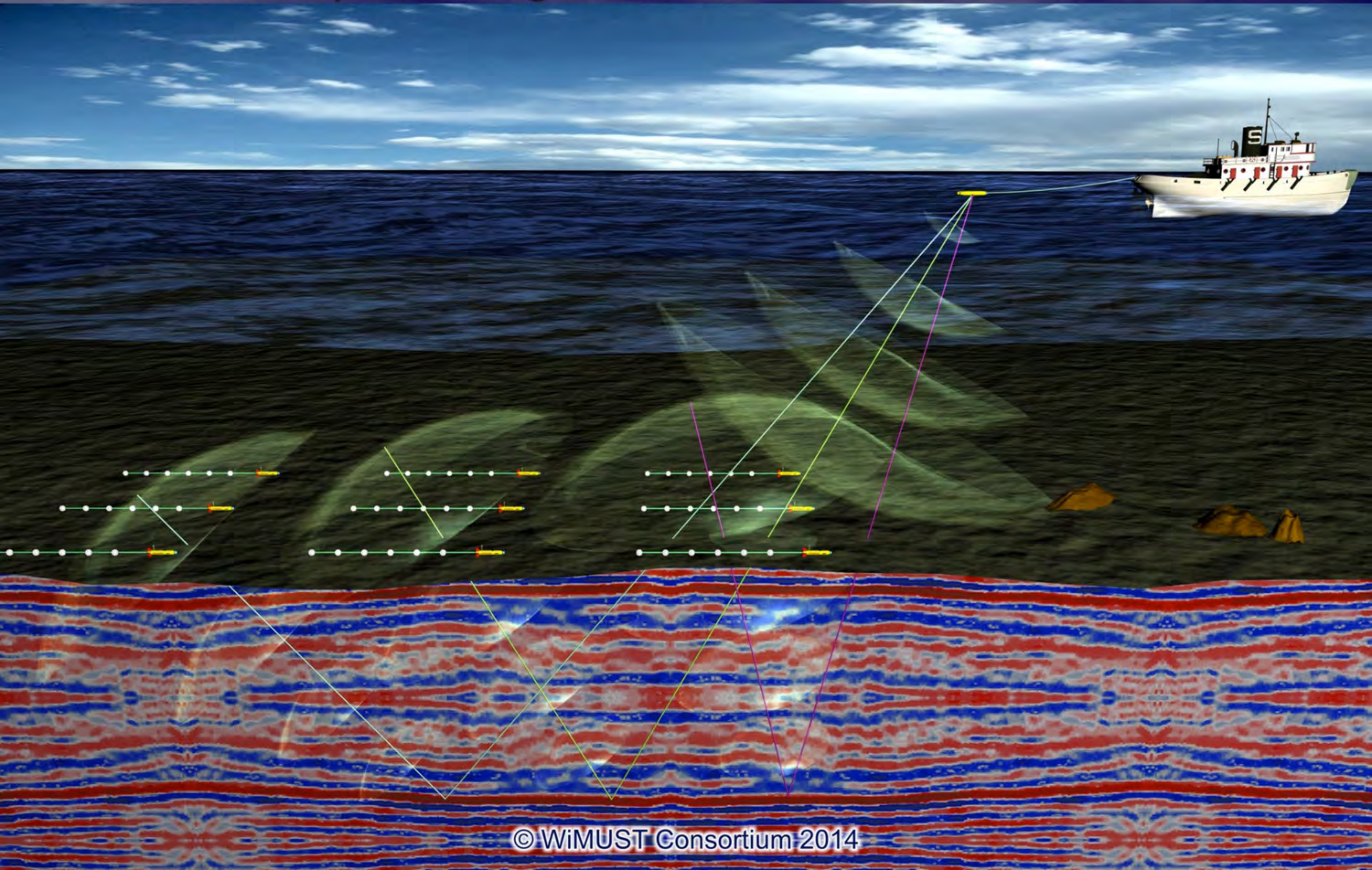
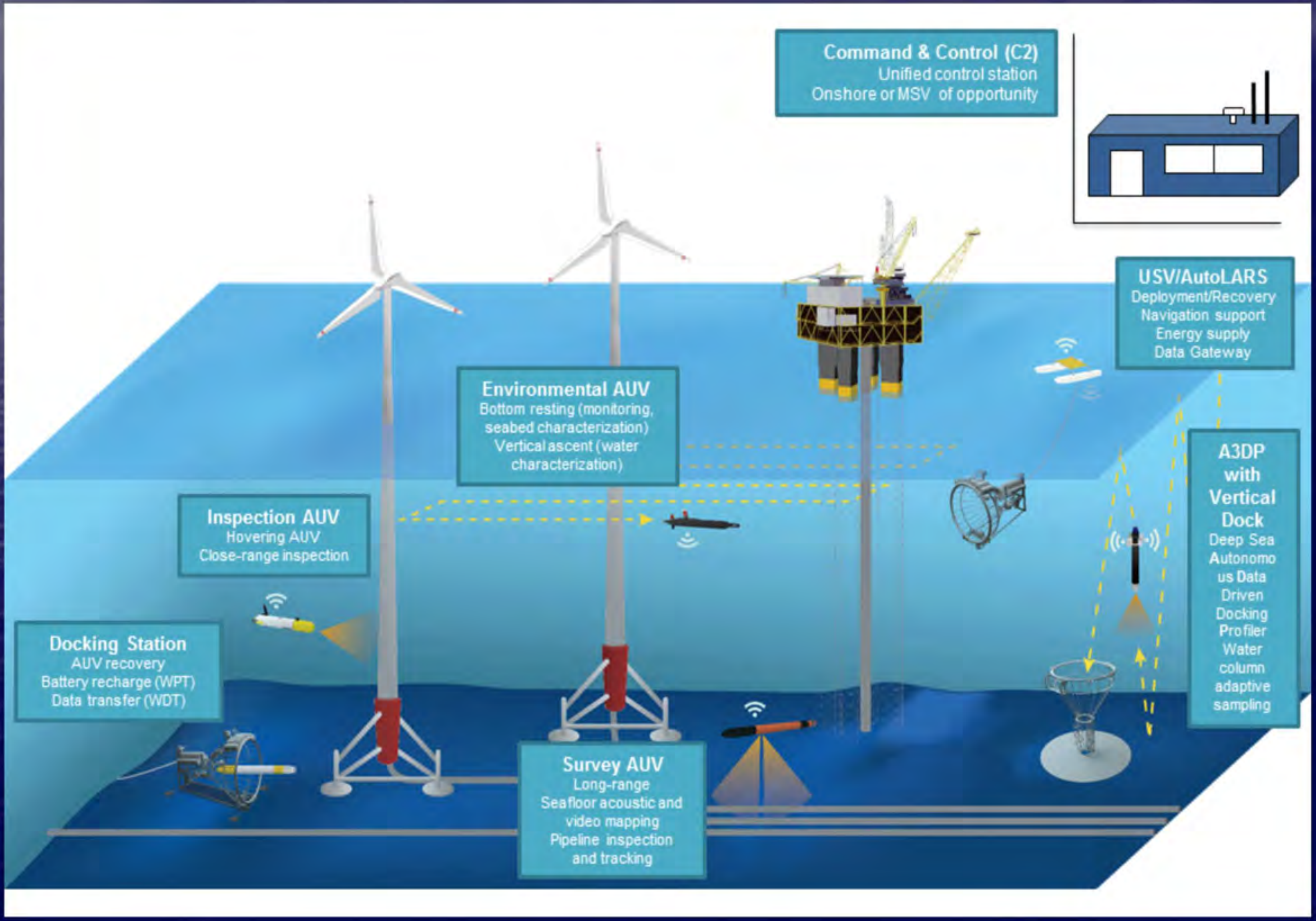


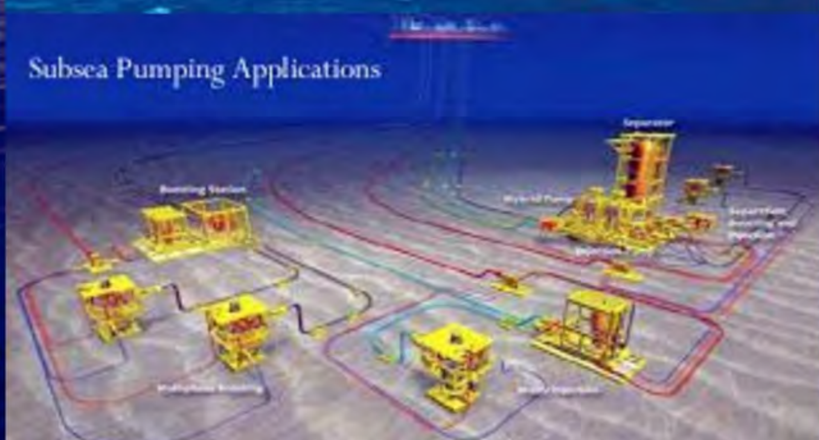
A vision of the future

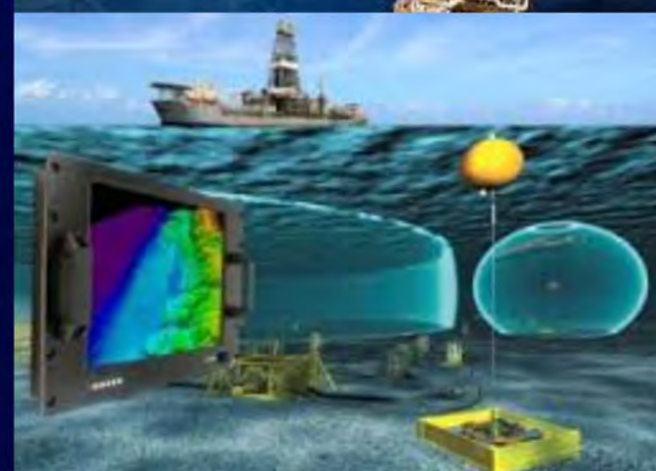
Sustained presence in the Ocean (an European collaborative effort – Horizon 2020 proposal, 2014)



The future: Robots and humans in the loop & Cooperative robots for ocean resources E&E (e.g, oil exploration and deep sea mining)

The future: Robots and humans in the loop & Cooperative robots for ocean resources E&E (e.g, oil exploration and deep sea mining)



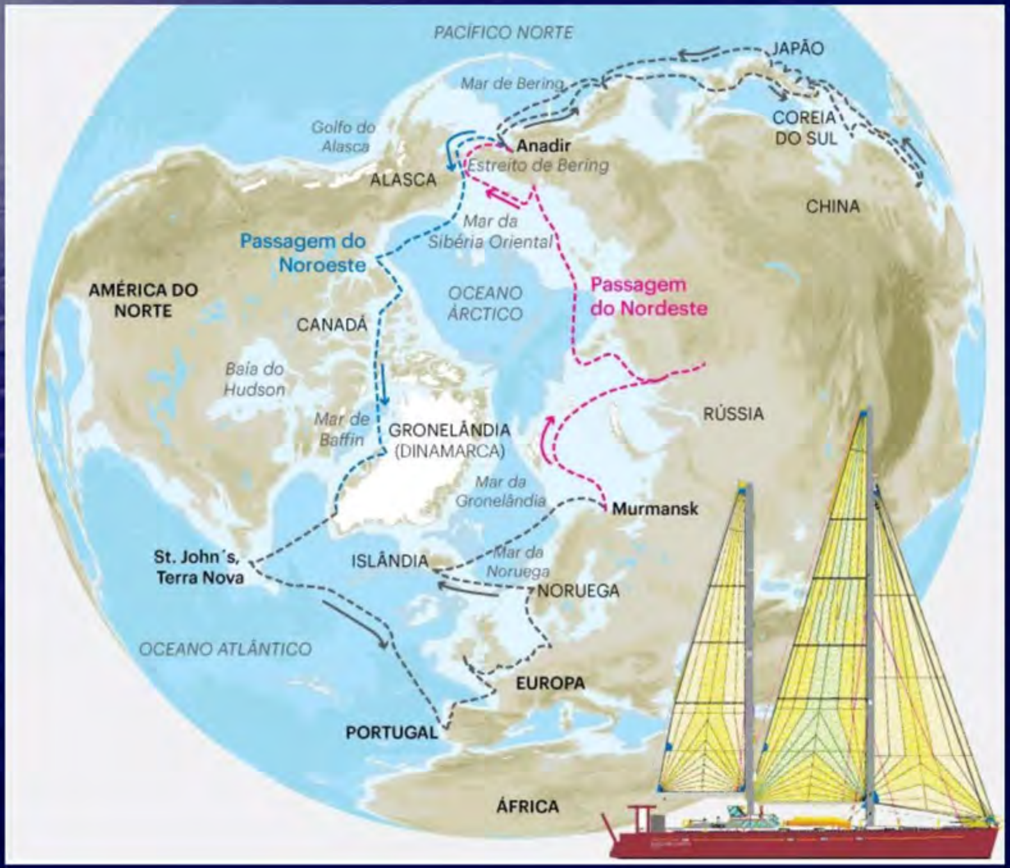


Estimated State

A vision of the future

THE SAILING RESEARCH VESSEL **DAVID MELGUEIRO**

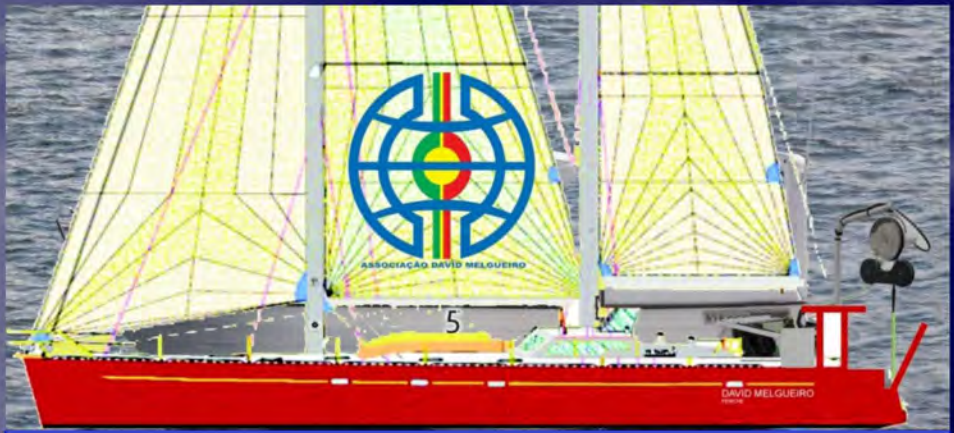
An innovative research vessel capable of navigating in the **polar regions** for research in fields such as: <u>Oceanography, Climate Change, Permafrost, Biology, Archeology.</u>



The "MARBOREALIS" expedition from PORTUGAL to MACAU through the iced seas of the Arctic.

Will replicate the journey of the Portuguese navigator David Melgueiro (XVII century) performing a polar circumnavigation crossing the Northeast and the Northwest Passages.

A vision of the future

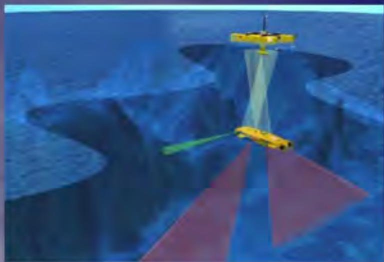


DAVID MELGUEIRO
& Robotics?

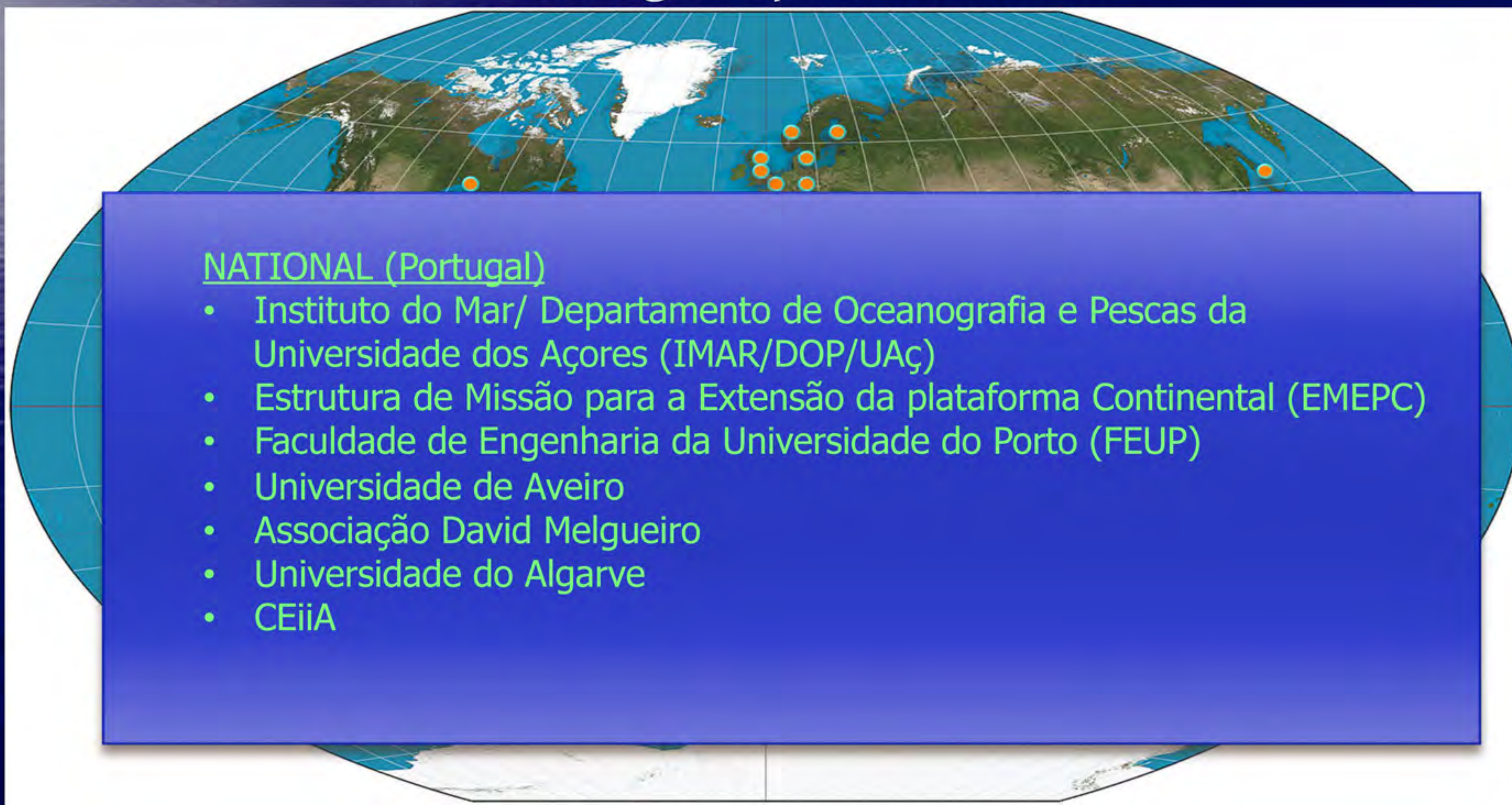
Marine robots as extensions of a research vessel.

- Stable platform
- Dynamic Positioning System
- ROV, AUV and ASV operations in automatic cooperation.
- The vessel will also execute an automatic missions in cooperation with the robots when required.

http://www.davidmelgueiro-org.pt




Strong cooperation links



NATIONAL (Portugal)

- Instituto do Mar/ Departamento de Oceanografia e Pescas da Universidade dos Açores (IMAR/DOP/UAç)
- Estrutura de Missão para a Extensão da plataforma Continental (EMEPC)
- Faculdade de Engenharia da Universidade do Porto (FEUP)
- Universidade de Aveiro
- Associação David Melgueiro
- Universidade do Algarve
- CEiiA

INSTITUTO SUPERIOR TÉCNICO

PÓLO DO I.S.T

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DSOR Lab Projects: http://welcome.isr.ist.utl.pt/labs/dsor/project

DSOR

dynamical systems and
ocean robotics LAB

INSTITUTO SUPERIOR TÉCNICO (IST), UNIV. LISBON
http://www.ist.utl.pt/en/
INSTITUTE FOR SYSTEMS AND ROBOTICS (ISR)
http://welcome.isr.ist.utl.pt/home/

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