TURTLE – Hybrid Robotic Landers

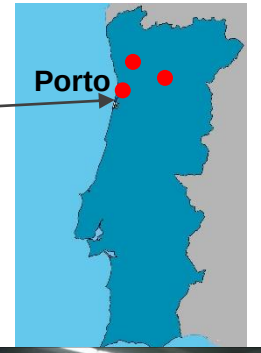
Sea bottom permanence with autonomous repositioning capabilities

Hugo Ferreira, Nuno Dias, Luís Lima, António Ferreira, Ricardo Pereira, Bruno Matias, José Almeida, Alfredo Martins, Eduardo Silva

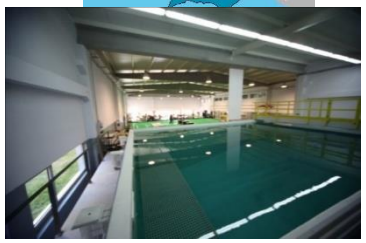
INESC TEC - ISEP

MARINETECH - Workshop Tecnologias Marinhas
Estoril, 03-05 Dez, 2019

INESC TEC



- R&D non-profit research center and technology interface institution
- Researchers from multiple universities in northern Portugal
  - University of Porto
  - **Porto Polytechnic Institute**
  - Univ. Minho
  - UTAD
- 725 Researchers
- Robotics and Autonomous Systems
  - **Aerial, land and water robotics**
  - Reconfigurable systems
  - Distributed perception
  - Cooperative robotics
  - Long term autonomy



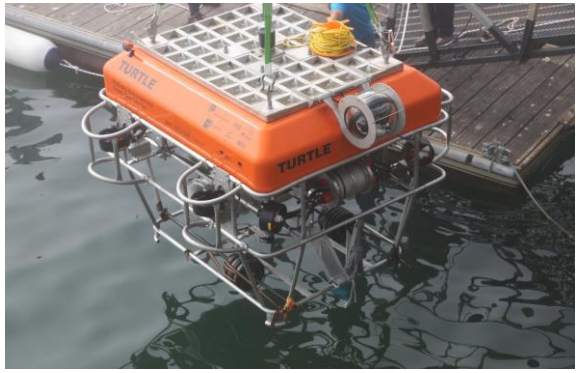
INESC TEC driving objectives for Marine Robotics

- **Going deep**
- **Extended autonomy**
- **Safety**
- **Sustainability**
- **Harsh and complex environments**

- Integrated approach
  - Research
  - Technology transfer and economic development
  - Wider (than robotics) view for the sea

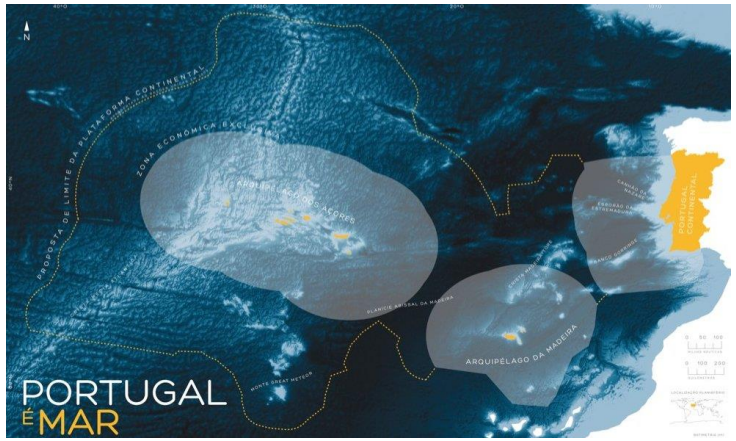
Research towards these goals

- Sensing & Perception
- Multi-robot cooperation
- Distributed navigation
- System development
- Energy and communications at sea



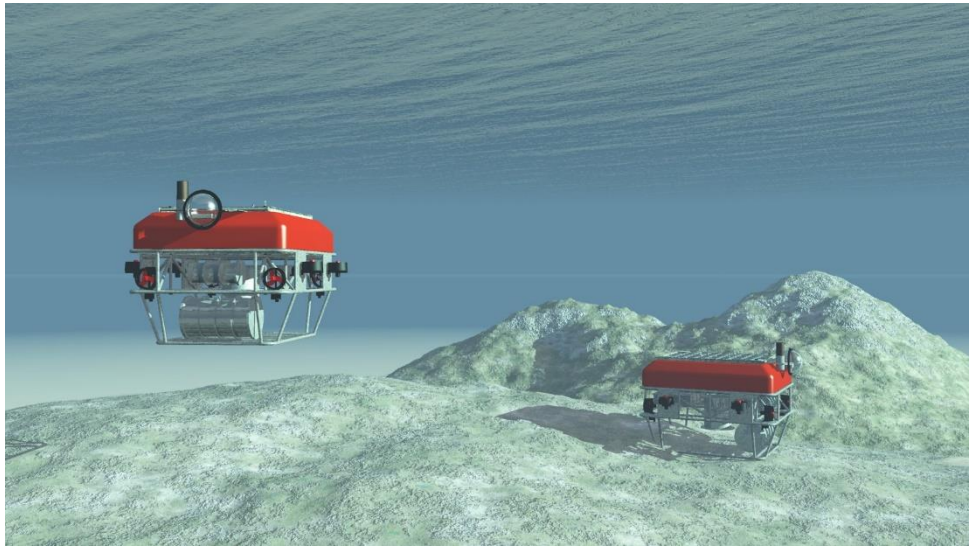
Motivation

- The increase of economic and scientific interest in the deep-sea exploration lead to the crucial need for new marine technologies
- Research interests in marine robotic vehicles/systems
- Work in control and navigation in field robotics
- European Defense Agency dual-use (civilian and military) calls
- Portuguese expansion of the continental-shelf
- “Addressing … national needs in undersea technologies”



TURTLE Concept – A deep sea autonomous robotic lander

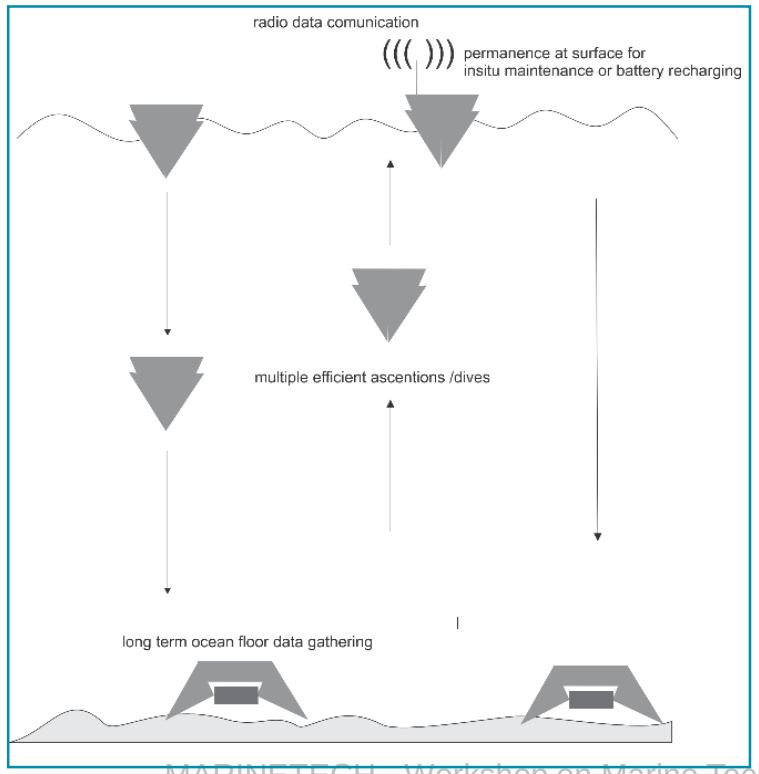
- **Hybrid lander / AUV**
  - **Long term permanence on bottom (lander)**
  - **Autonomous locomotion for positioning/re-positioning (AUV)**
- Efficient vertical ascent/dive
  - Variable buoyancy system
- Acoustic communications
- Custom developed pressure tolerant batteries
- Autonomous navigation
  - INS
  - DVL
  - USBL/LBL acoustic positioning when in range
  - Multibeam sonar
- On board processing



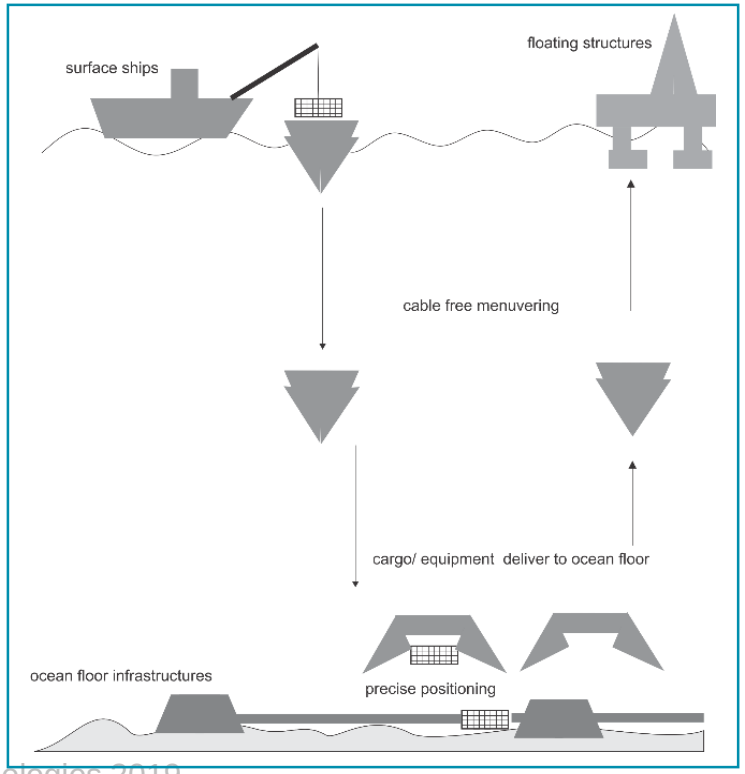
Operation

- Deployment
  - From support vessel
  - Towed to diving location
- VBS based ascent/descent
- Autonomous repositioning at the sea bottom
- Surfacing for maintenance / battery recharging or high-volume data transfer

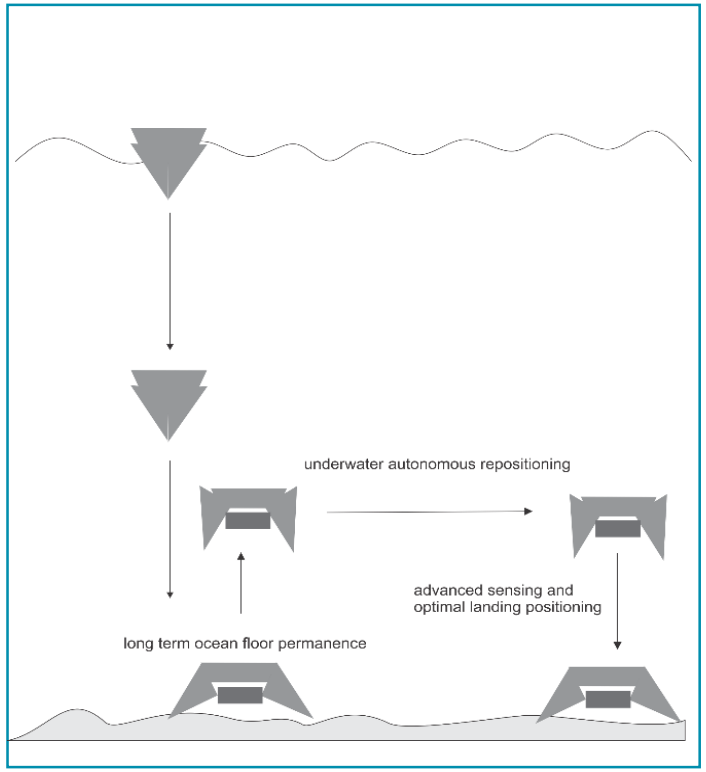
Multiple dives/ascents



Cargo transport/ positioning



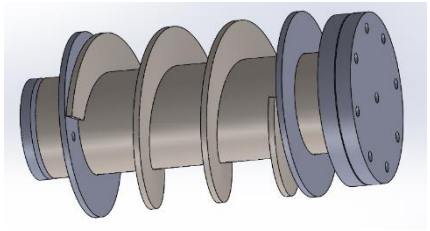
Autonomous repositioning

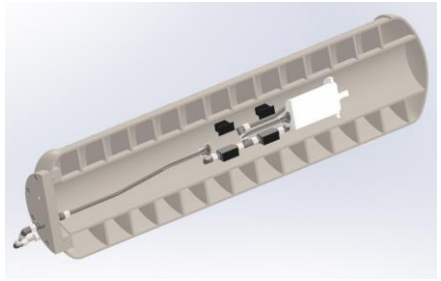


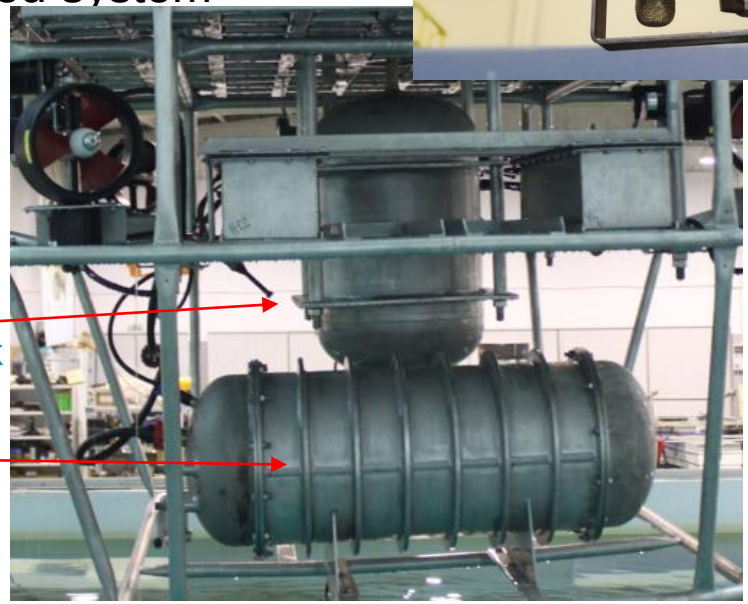
Variable Buoyancy System

- Steel pressurized water tank
- 1 kW brushless motor
- 6-11 lpm hydraulic pump
- Embedded electronics and control (ARM microcontroller and drives)
- Controlled from vehicle main CPU or internal Embedded system
- Two designs
  - Separate water tank and hydraulics housing
  - Integrated pressure vessel

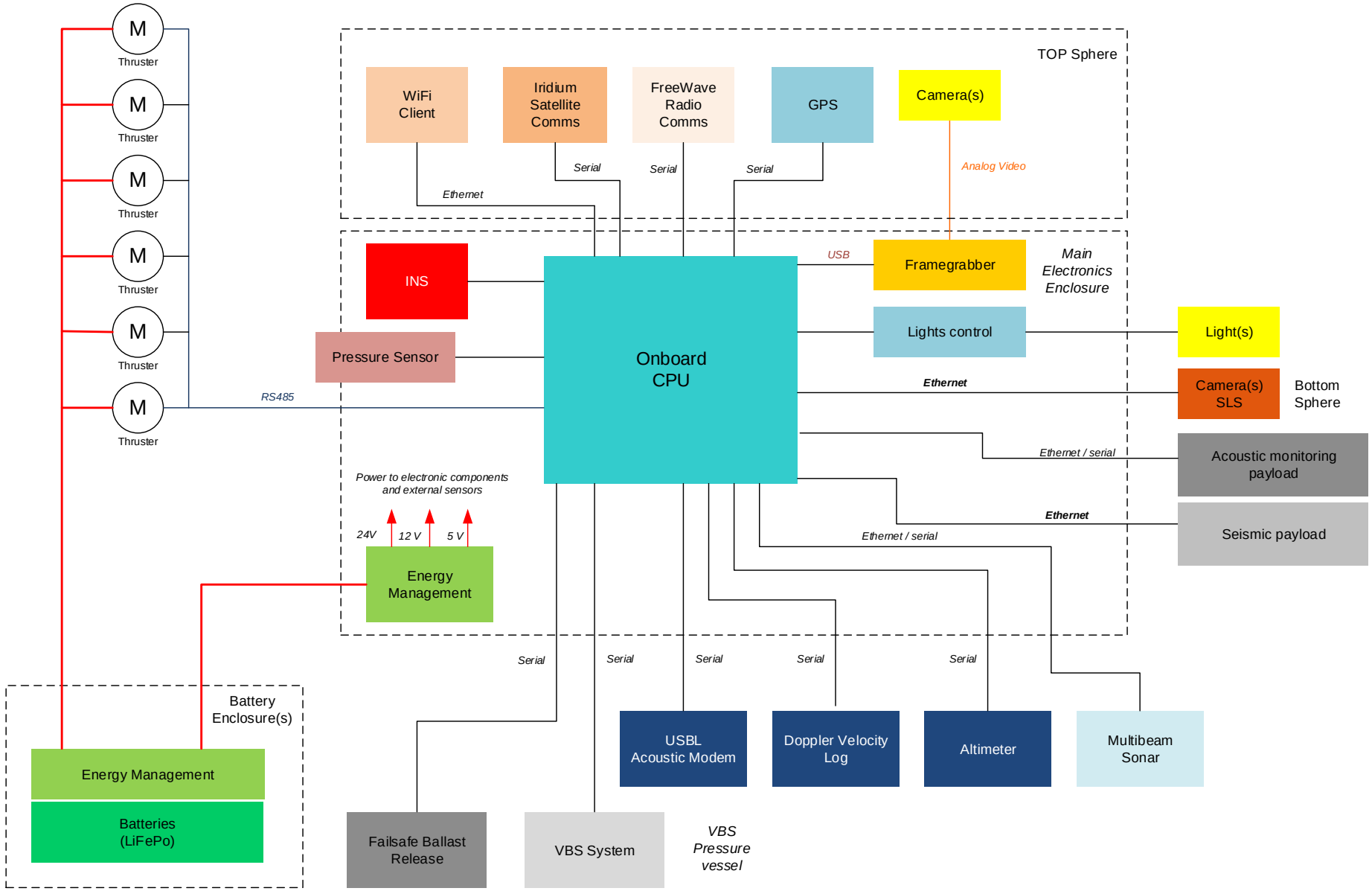
Integrated pressure vessel
(water + hydraulics/electronics)





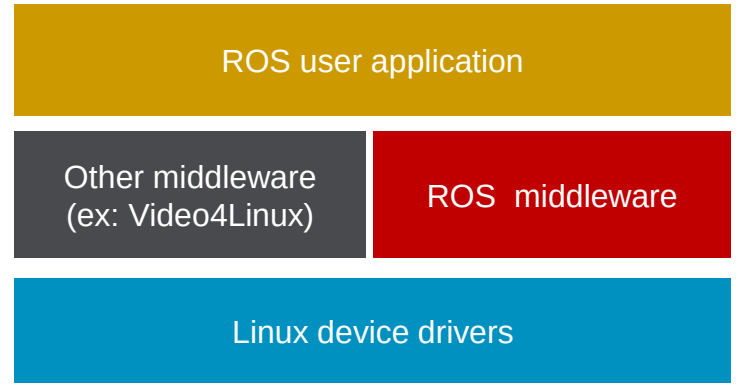


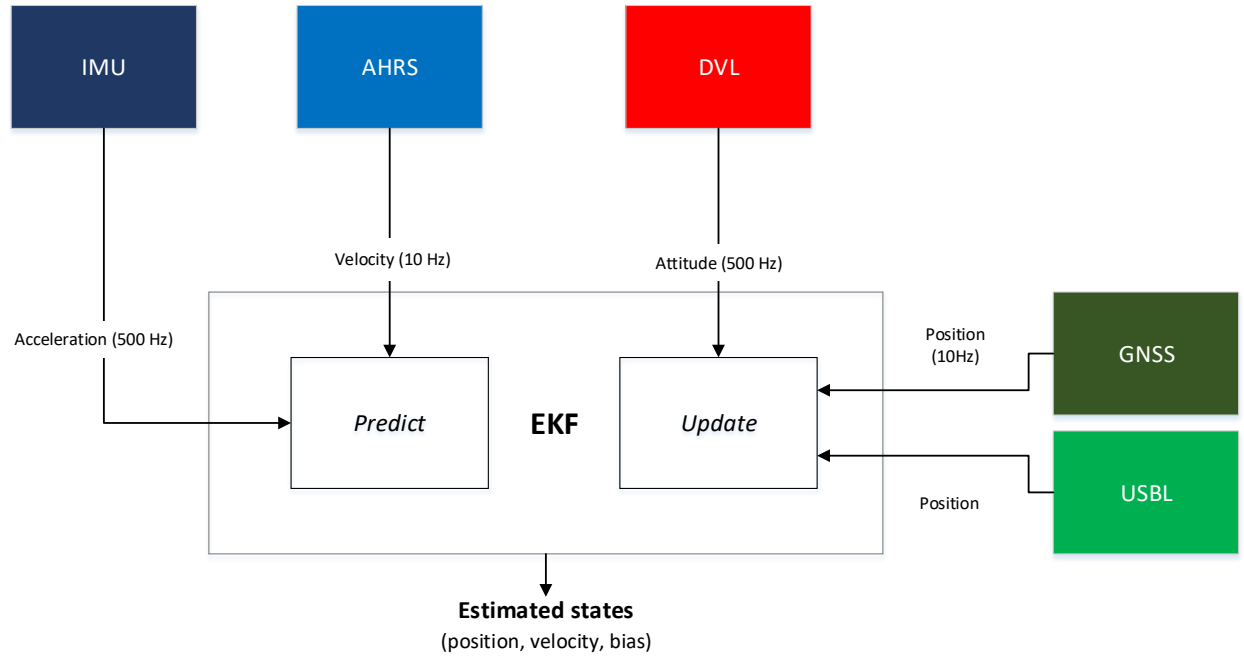
System architecture



Control and navigation

- FOG INS (KVH 1770)
- Teledyne RDI Explorer DVL / Nortek 1MHz DVL
- Evologics USBL/acoustic modem (8km range)
- On board CPU
  - Linux / ROS based guidance and control software
  - Embedded form factor
- EKF for 6 DOF state estimation
- USBL/GNSS positioning when available

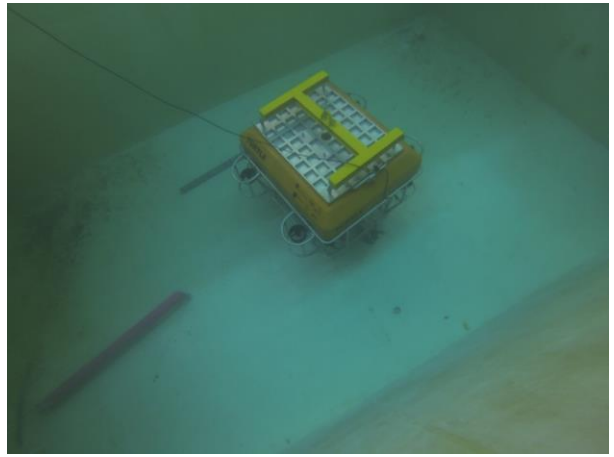


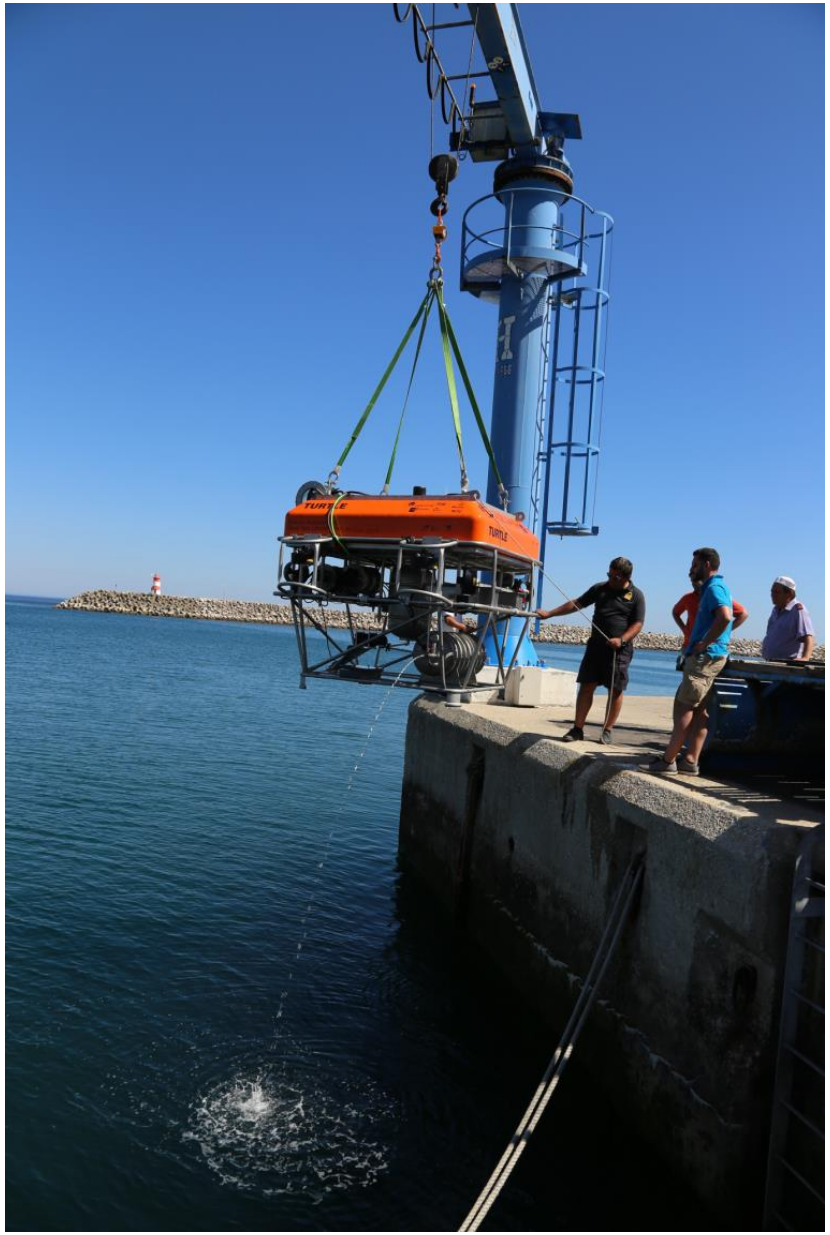


TURTLE

- **1400 Kg weight**
- 200 Kg payload
- 1000m depth rated
- VBS designed for 6000m depth (water pump)
- 8 KWh LiFePo4 pressure tolerant batteries
- Vitrovex glass sphere for communications
- RDI Explorer DVL
- Advanced Navigation (KVH 1775) FOG INS
- 8 SAAB Seaeye thrusters (13 Kgf)
- Evologics USBL/modem (S2C R 7/17, S2C R 18/34)
- WiFi / RF / Iridium comms

Development tests



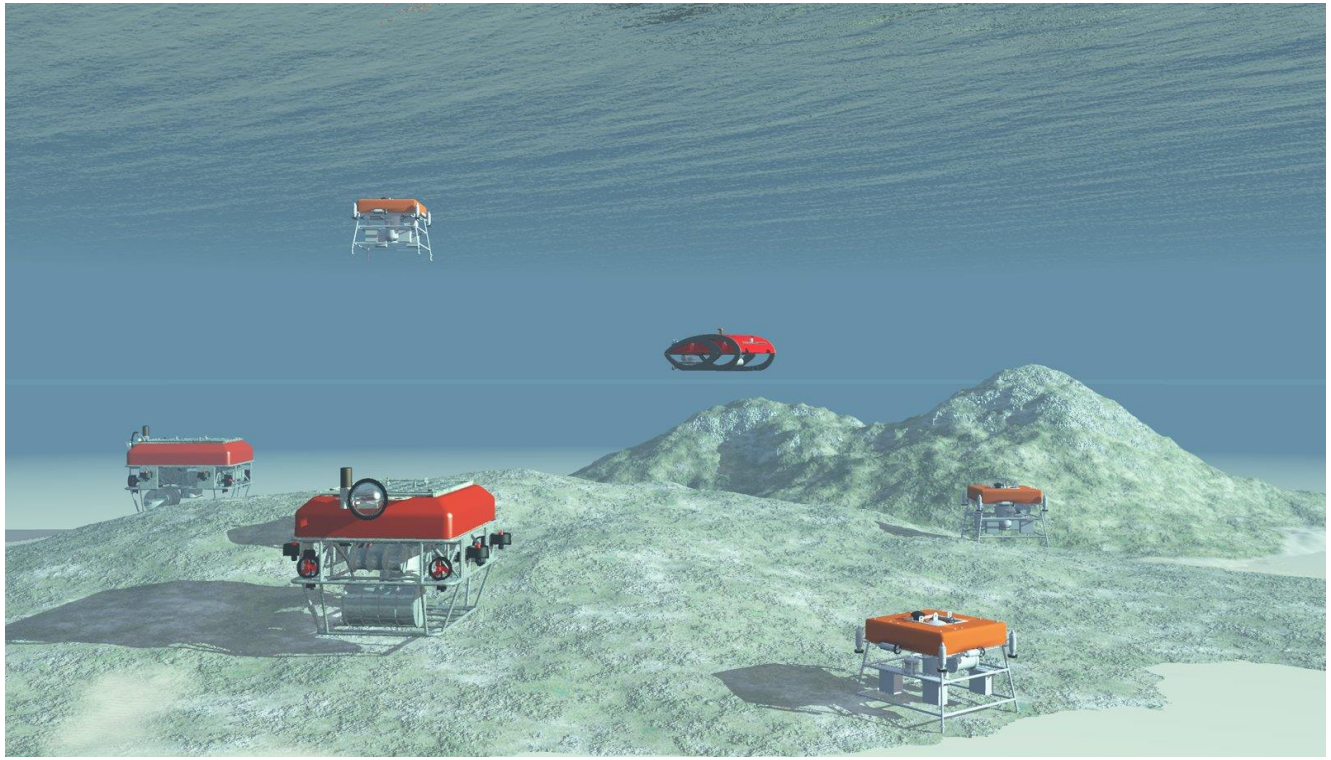


TURTLE II

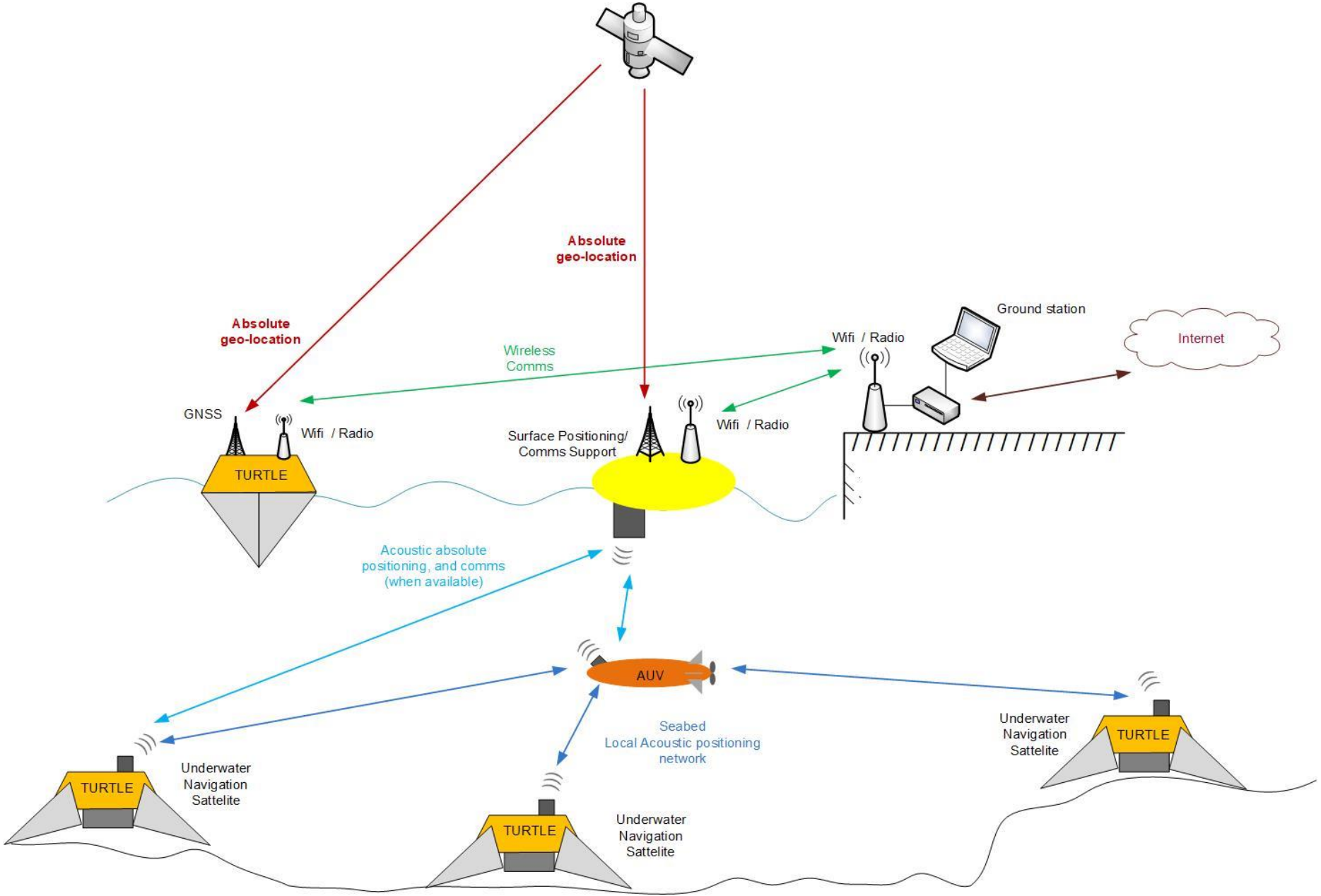
- **600 Kg weight**
- 100 Kg payload
- 1000m depth rated
- VBS for 2000m
- 8 KWh LiFePo4 pressure tolerant batteries
- Two antenna GPS receiver
- Nortek 1MHz DVL
- 8 KenzenRC thrusters (400W, 12 Kgf)
- Evologics USBL/modem (S2C R 18/34)
- **New VBS mechanical design**

SIDENAV – a sea-bottom navigation operations support

- **TURTLE landers provide acoustic beacon navigation support (Underwater navigation satellites)**
- Change of operating area can be performed without resurfacing
- Additional support to underwater robotic assets (ex: charging)
- Mobile seabed bases
- Sea bottom Resident Robots

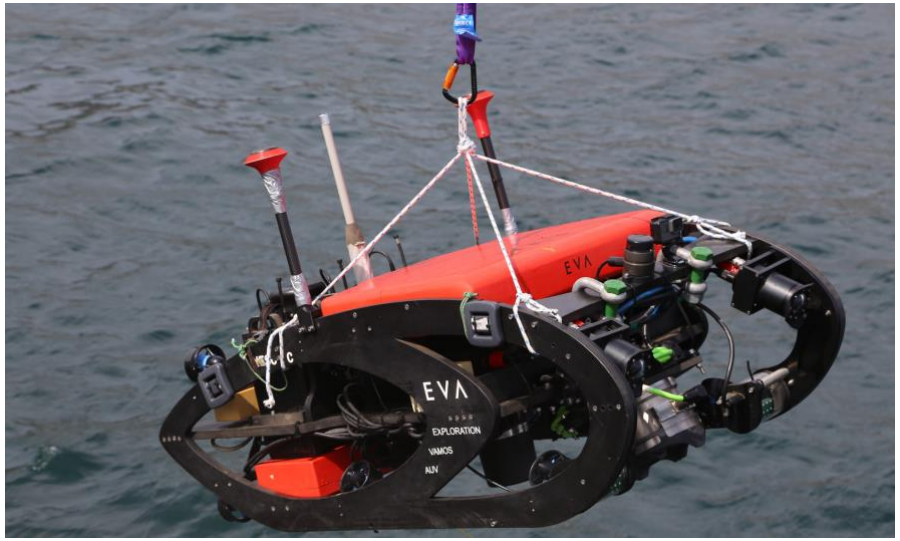


Communications and localization



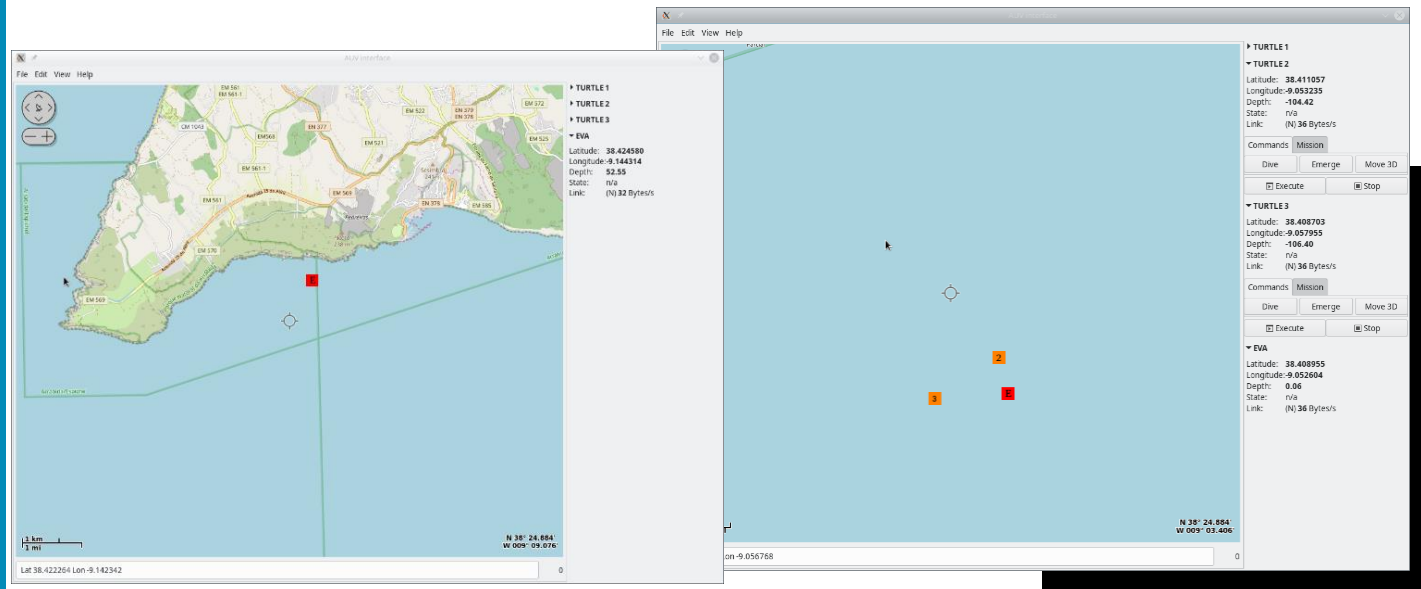
SIDENAV 2019

- Sesimbra, July 2019 (REX 2019 exercises)
- Support from Portuguese Navy, *NRP Gago Coutinho*
- EVA AUV used as target to be localized
- 2 TURTLES deployed at 100m depth)
- TURTLES with fiber connection to the surface

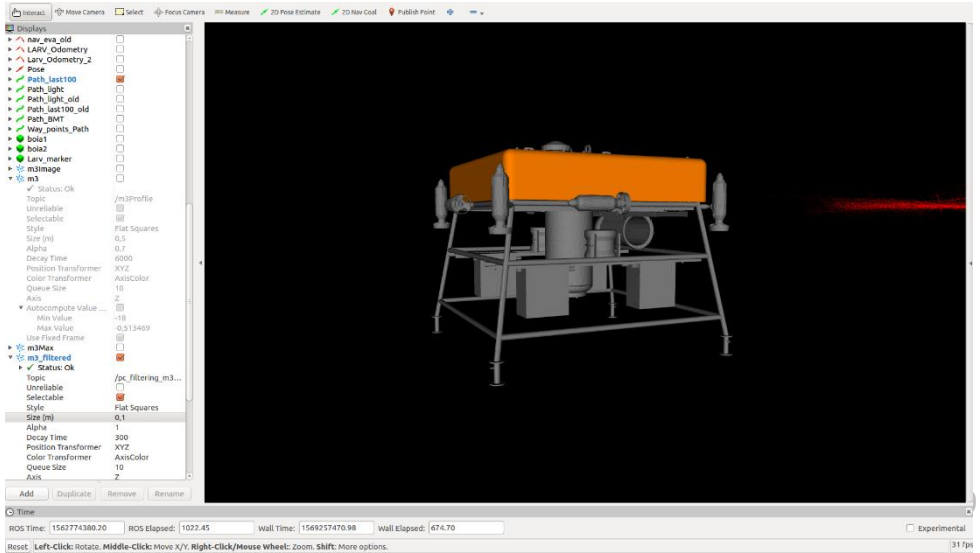


SIDENAV 2019

Remote supervision GUI and 3D visualization (ROS RVIZ)



EVA



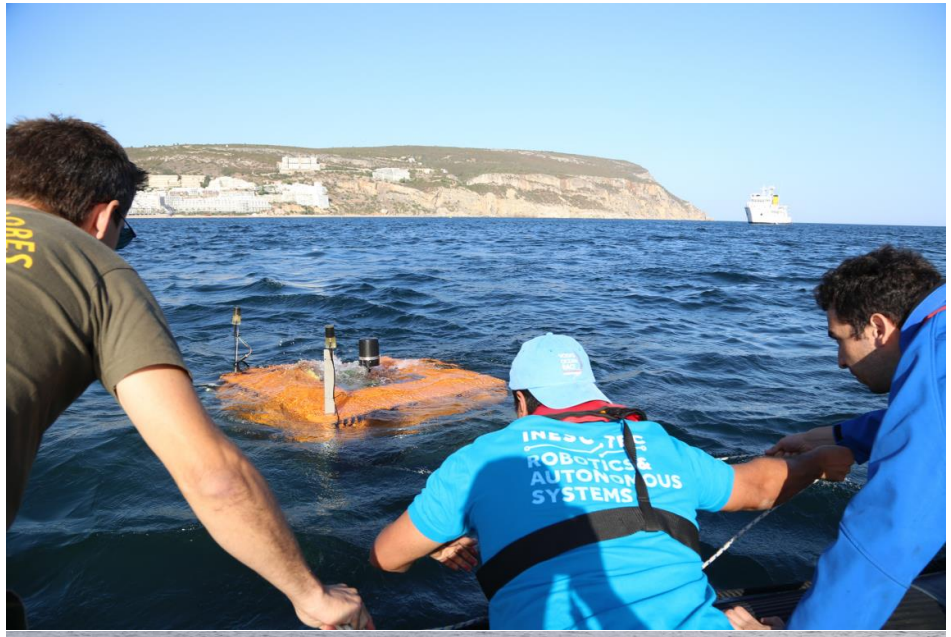
multibeam sonar scans

Turtle

REP(MUS) 2019

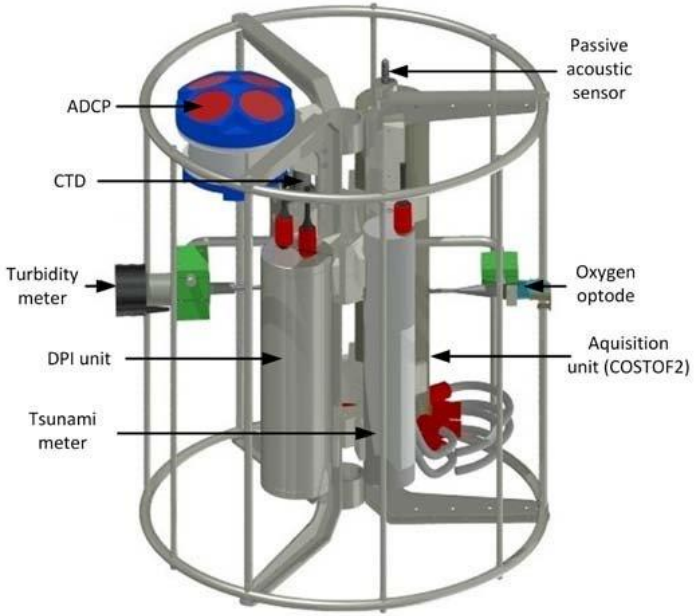
- Recognized Environmental Picture (Marine Unmanned Systems) NATO exercise
- Sesimbra, September 2019
- Support from Portuguese Navy, NRP D. Carlos
- Sea bottom placement in a MCX scenario (24h mission test)

REP(MUS) 2019



EMSO-PT - EGIM

- TURTLE as a sea bottom observatory
- Integration of EMSO Generic Instrument Module
- Re-positioning and periodic maintenance
- Gather data and upload in shorter timelines
- TURTLE used as a generic payload (power/data) mule
- New sea technologies
- Fixed vs Mobile robotic observatory – First trials in 2020



Conclusions

- Innovative robotic hybrid lander prototypes developed and tested at sea
- Efficient ascent/dive with custom designed variable buoyancy system
- EDA (European Defense Agency) dual use projects example case of success
- … *this is only the beginning*

Next steps

- **Integration of EGIM sensors** and deploy off coast Aveiro in northern Portugal
- Assessment of localization precision with external groundtruth sensors
- Next steps in system validation and performance evaluation at high depths and long-term permanence
- New observation modalities (ex: autonomous relocation) and integration of additional sensors
- Initial prototypes part of phased plan to implement systems for 4000m of depth rating covering vast majority of Portuguese sea area depths

Thanks for your attention

Hugo Ferreira
hugo.a.ferreira@inesctec.pt

ABSTRACT

TURTLE – Hybrid Robotic Landers – Sea bottom permanence with autonomous repositioning capabilities

The increase of economic and scientific interest in the deep-sea exploration lead to the crucial need for new marine technologies. The harsh environment and the need of real-time continuous data from the ocean lead to new research interests in marine robotic vehicles/systems.

The current work presents innovative robotic hybrid landers that were developed and already tested at sea. A new concept that consists in a hybrid solution between an AUV and an ROV that can operate as a remote operated vehicle or as a full autonomous system. It uses a new variable buoyancy system that allows efficient ascent/dive operations. Its internal computers, actuators and awareness systems allows it to position in the ocean bottom with high accuracy and its main novelty is its ability to reposition to another zone if needed.

TURTLE is a modular platform that can be adapted to support different operation or use different payloads. Besides supporting both military and civilian operations its current stage allows it to several academic developments. The current goal is to use it as a seafloor and water column instruments platform to gather and analyses ocean data (in-situ data processing).

In the scope of the EMSO-PT infrastructure, these robotic systems will work as an ocean floor observatory that will host several instruments/systems, mainly the EMSO EGIM a generic instruments module.

Future development will lead to continues deep sea resident autonomous marine robots' operations.

From the surface to the deep.

CV

Hugo Ferreira is currently a senior researcher/engineer at INESCTEC Robotics Centre. He has an electrical engineering degree from the Porto Polytechnic Institute (ISEP-IPP). Main scientific interests are: Autonomous Systems and Mobile Robotics. He works with marine robotics, underwater and surface vehicles, sonar and positioning systems. Currently, he is working on several projects involving perception and navigation. He is also teaching at the Superior School of Hospitality and Tourism, Polytechnic Institute of Porto

Marineye Payload