SIDENAV

A flexible solution for deep sea positioning

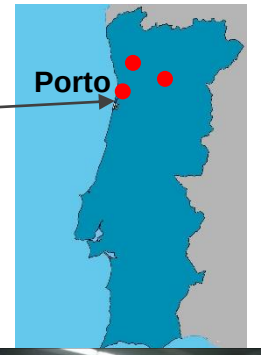
Eduardo Silva, Hugo Ferreira, Nuno Dias, Luís Lima,
António Ferreira, Ricardo Pereira, Bruno Matias,
José Almeida, **Alfredo Martins**

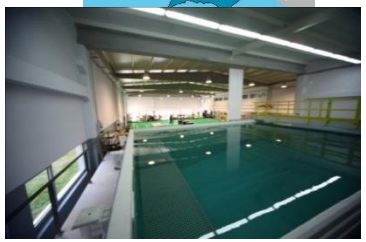
INESC TEC - ISEP

Workshop EMSO – WoSOOO
Toulon, 25-26 Sep, 2019

INESC TEC

isep Instituto Superior de Engenharia do Porto





- 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

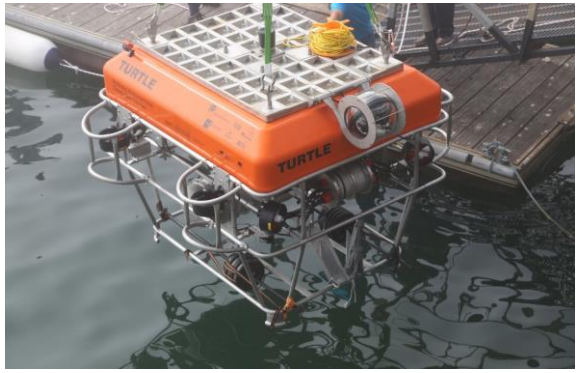
INESC TEC driving objectives for Marine Robotics

- **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

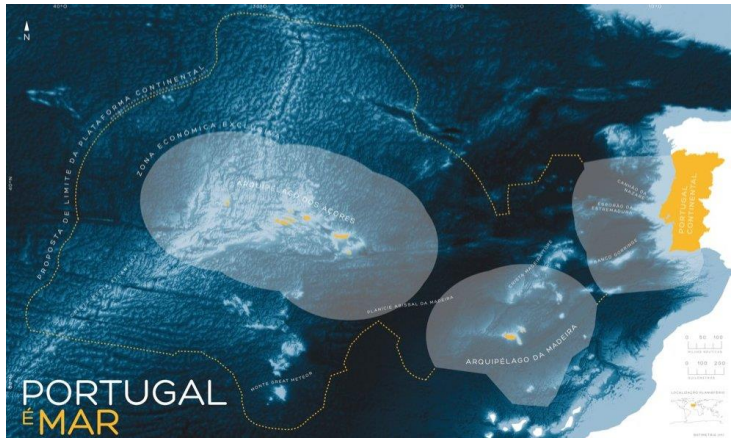
Research towards these goals

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



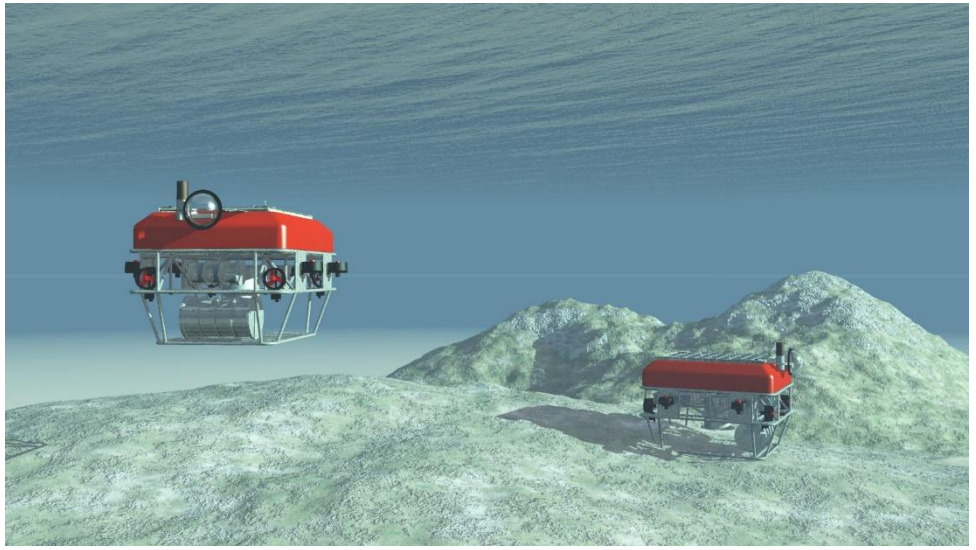
Motivation

- 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

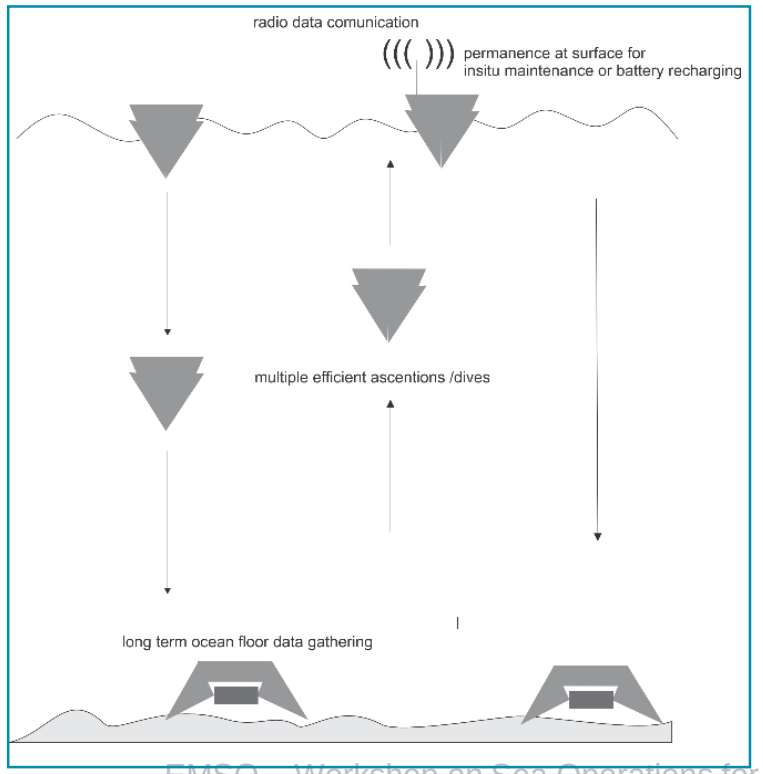
- **Hybrid lander / AUV**
  - **Long term permanence on bottom (lander)**
  - **Autonomous locomotion for positioning/re-positioning (AUV)**
- Efficient vertical ascent/dive
  - Variable buoyancy system
- Acoustic communications
- Custom developed pressure tolerant batteries
- Autonomous navigation
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



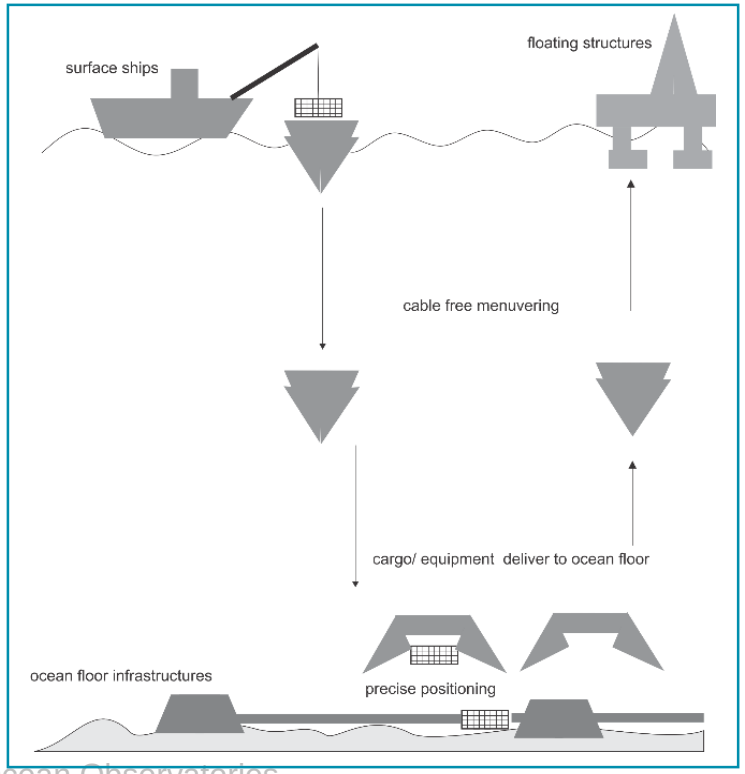
Operation

- 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

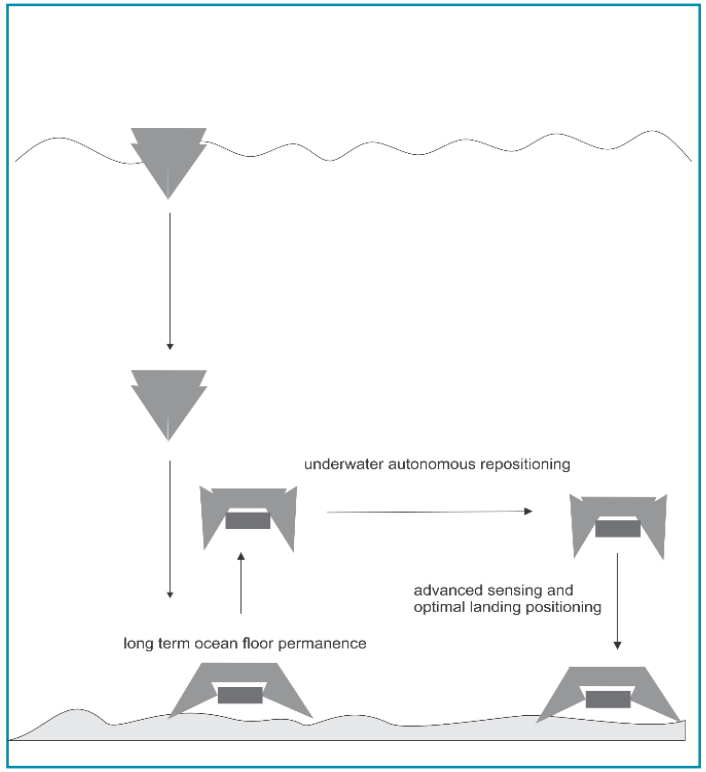
Multiple dives/ascents



Cargo transport/ positioning



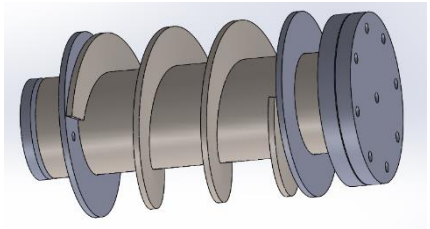
Autonomous repositioning

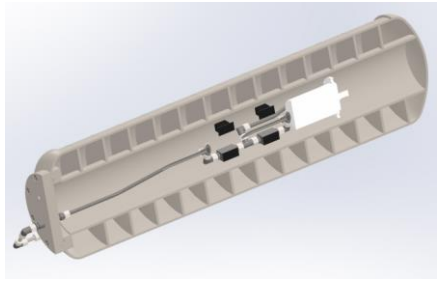


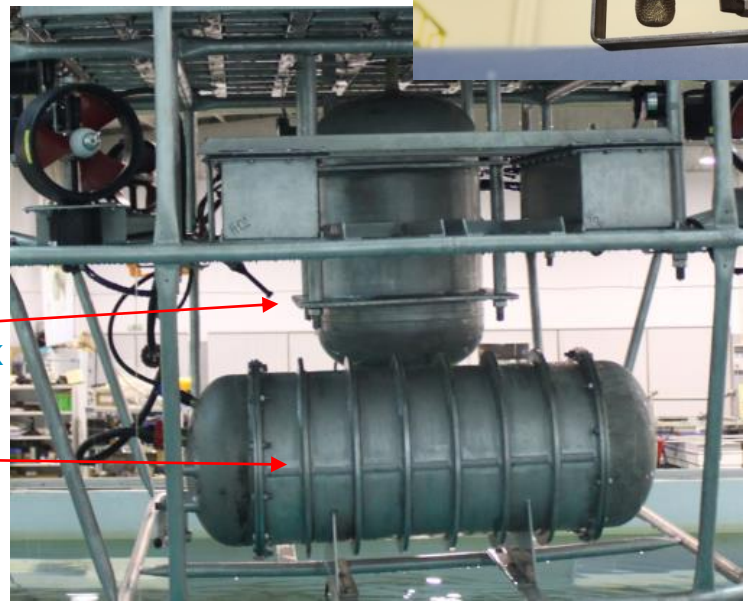
Variable Buoyancy System

- 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
- Two designs
  - Separate water tank and hydraulics housing
  - Integrated pressure vessel

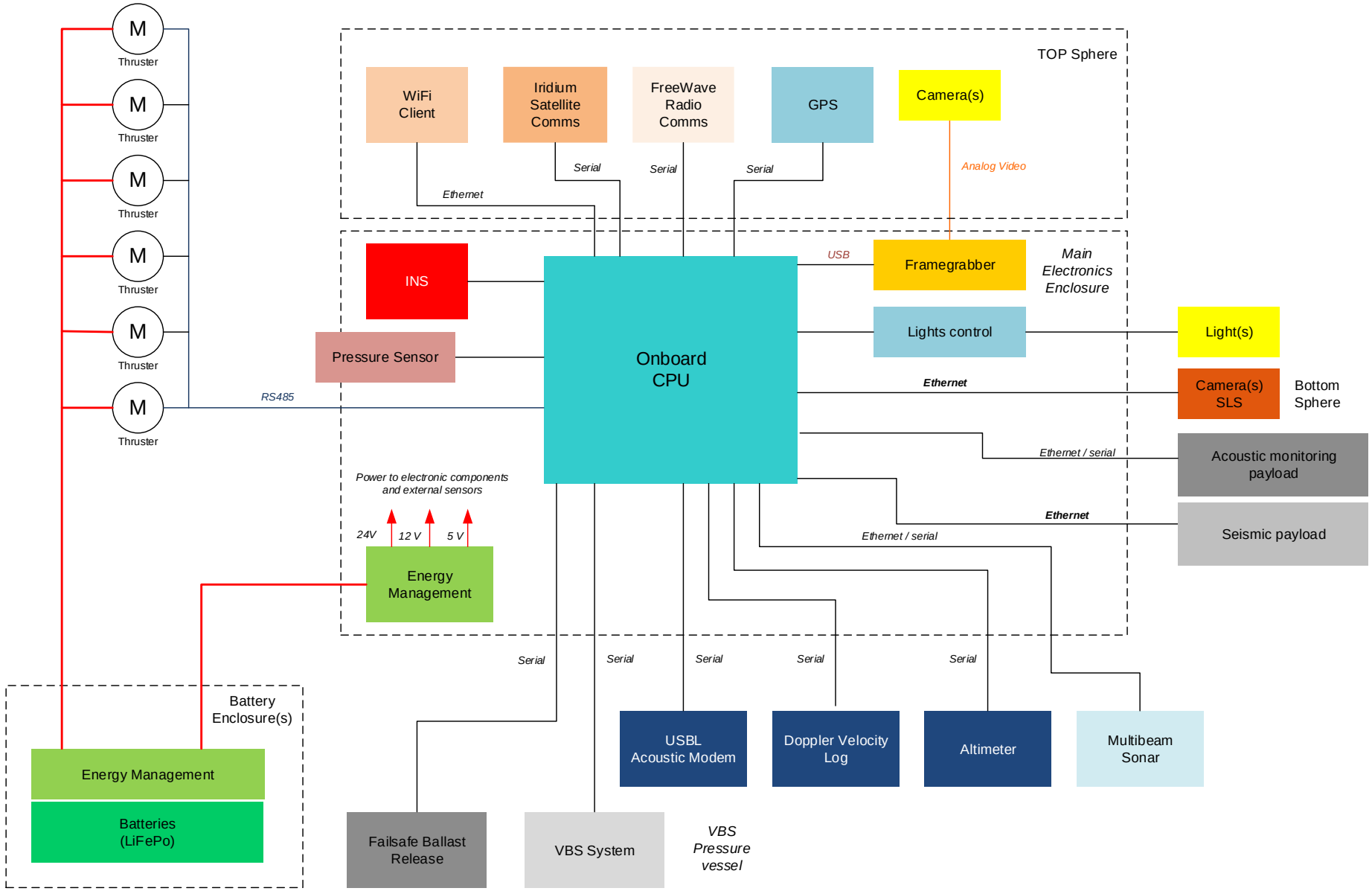
Integrated pressure vessel
(water + hydraulics/electronics)





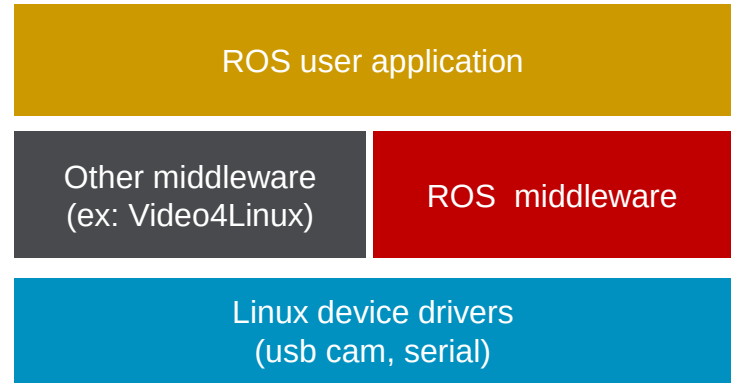


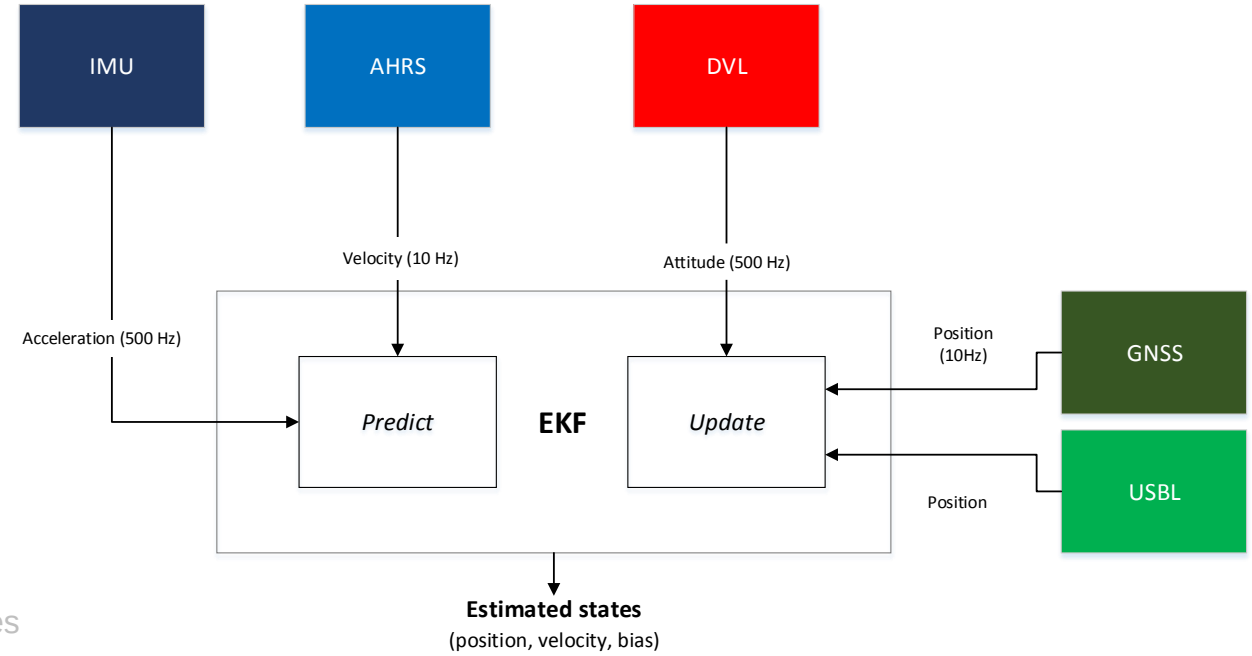
System architecture



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

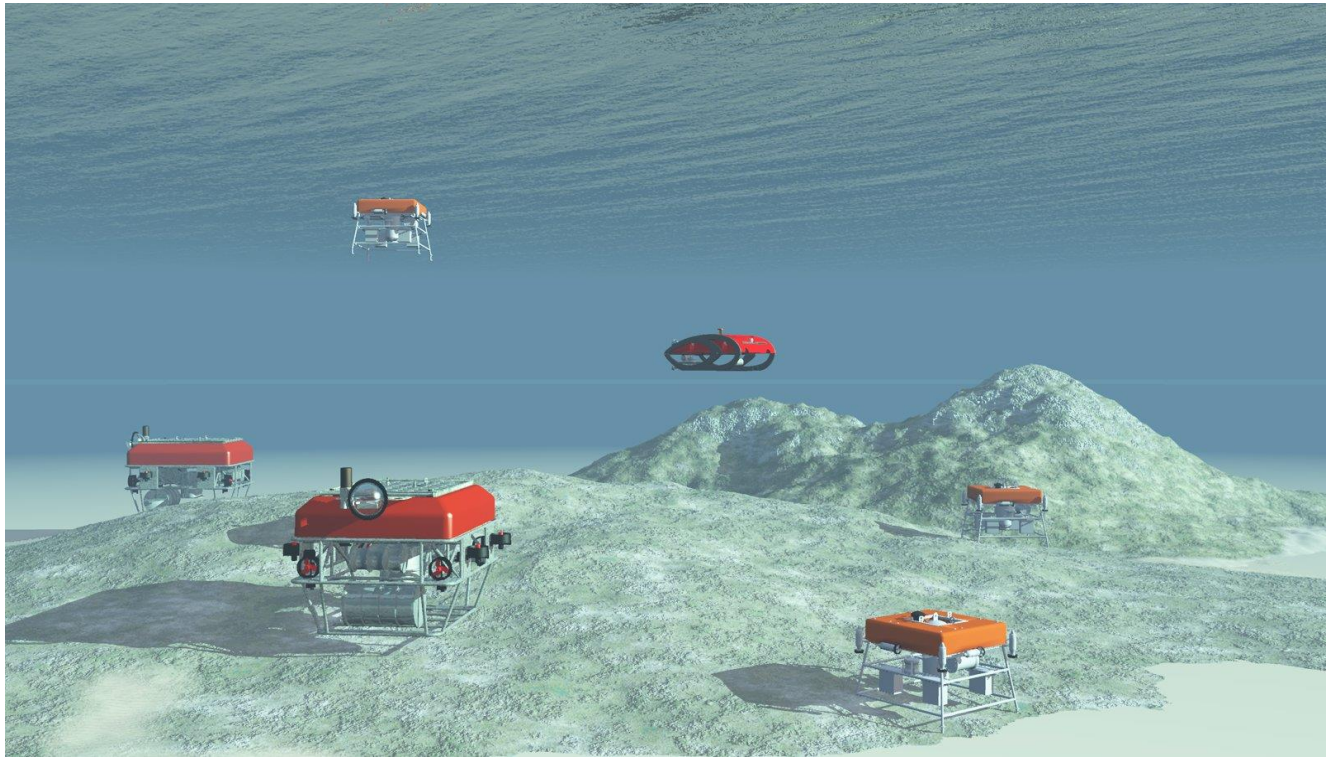
- **1400 Kg weight**
- 200 Kg payload
- 1000m depth rated
- VBS designed for 6000m depth (water pump)
- 8 KWh LiFePo4 pressure tolerant batteries
- Vitrovex glass sphere for communications
- RDI Explorer DVL
- 8 Seaeye thrusters (13 Kgf)
- Evologics USBL/modem (S2C R 7/17, S2C R 18/34)

TURTLE II

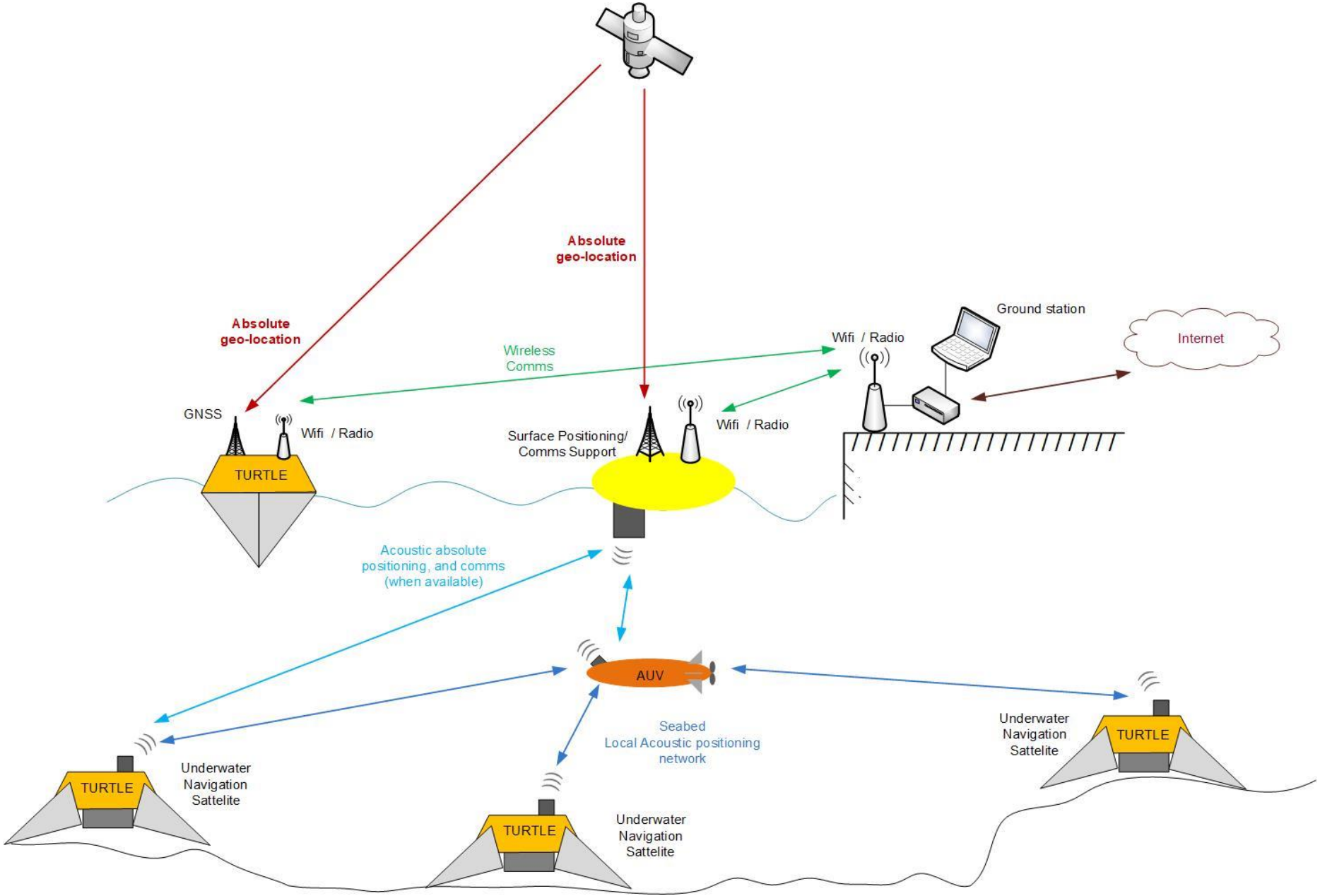
- **600 Kg weight**
- 100 Kg payload
- 1000m depth rated
- VBS for 6000m
- 8 KWh LiFePo4 pressure tolerant batteries
- Two antenna GPS receiver
- Nortek 1MHz DVL
- 8 Kenzo thrusters (400W, 12 Kgf)
- Evologics USBL/modem (S2C R 18/34)
- **New VBS mechanical design**

SIDENAV – a sea-bottom navigation operations support

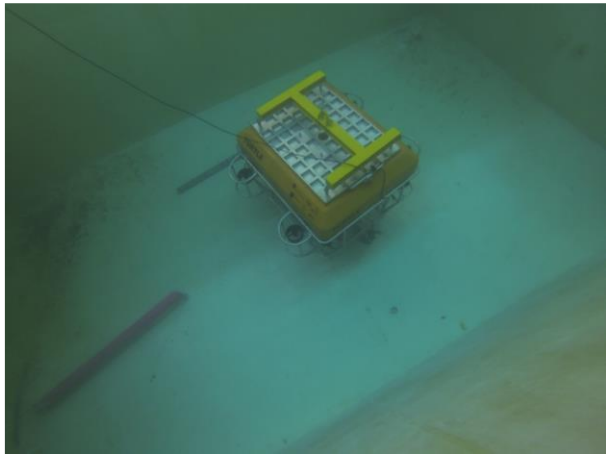
- **TURTLE landers provide acoustic beacon navigation support (Underwater navigation satellites)**
- Change of operating area can be performed without resurfacing
- Additional support to underwater robotic assets (ex: charging)
- Mobile seabed bases

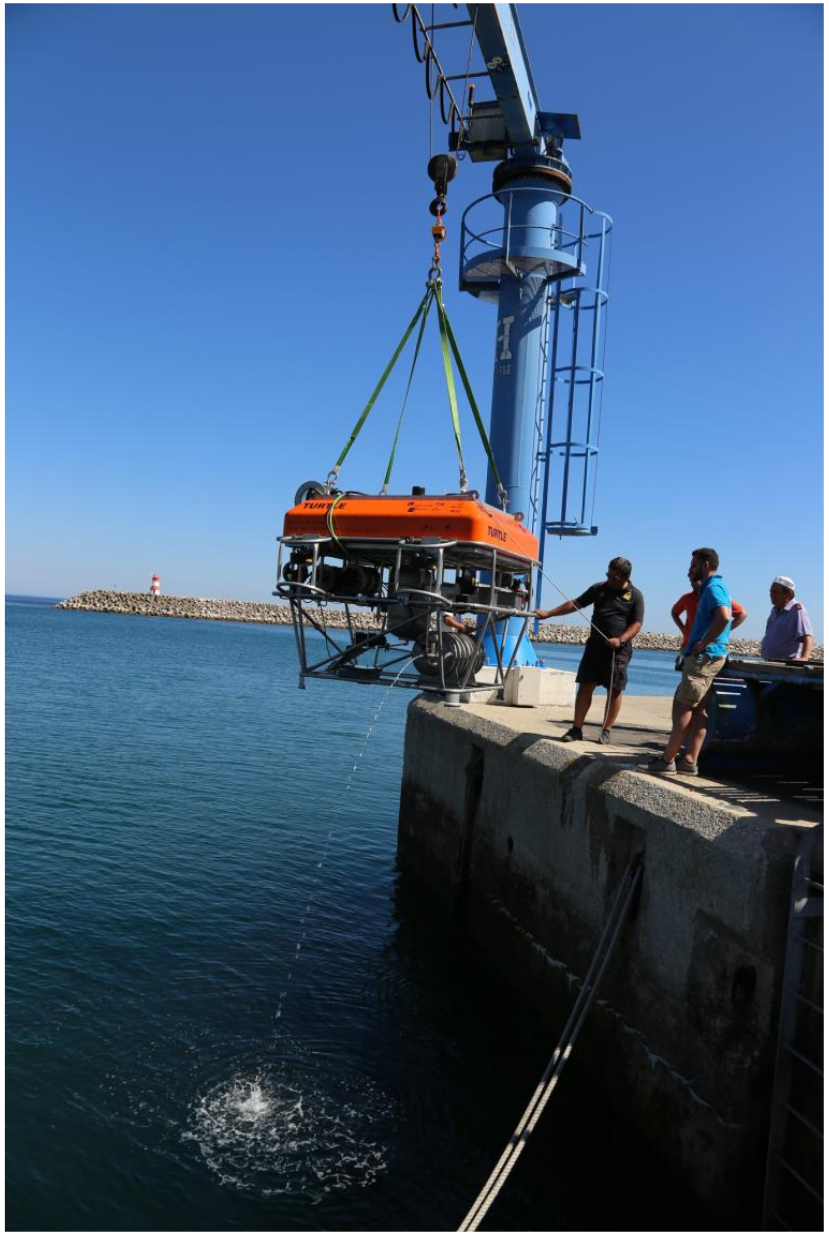


Communications and localization



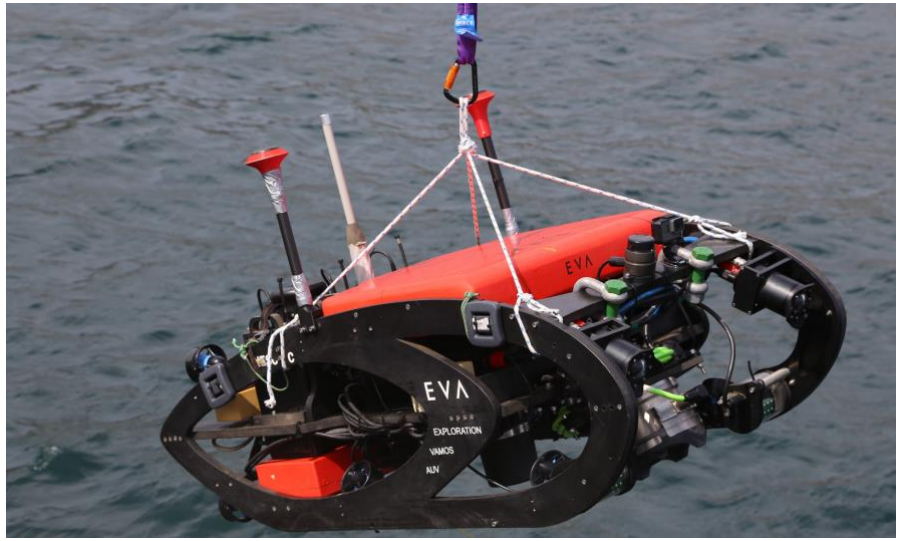
Development tests



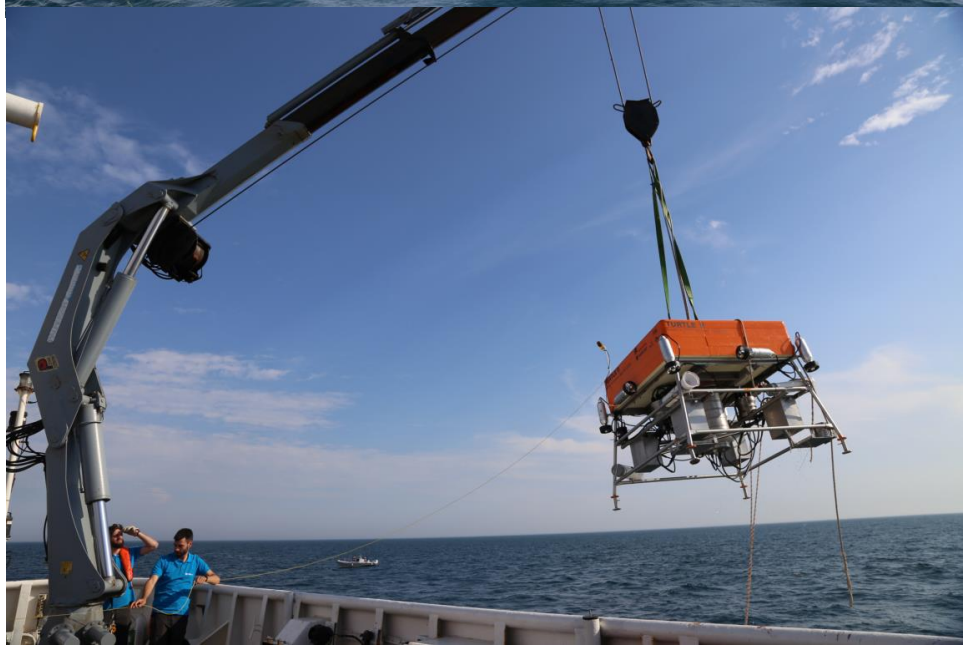


SIDENAV 2019

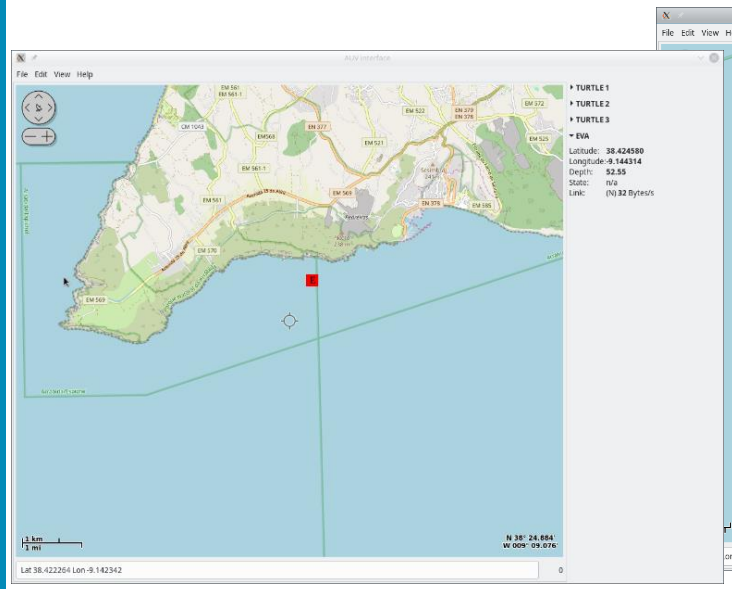
- Sesimbra, July 2019 (REX 2019 exercises)
- Support from Portuguese Navy, NRP Gago Coutinho
- EVA AUV used as target to be localized
- 2 TURTLES deployed at 100m depth)
- TURTLES with fiber connection to the surface

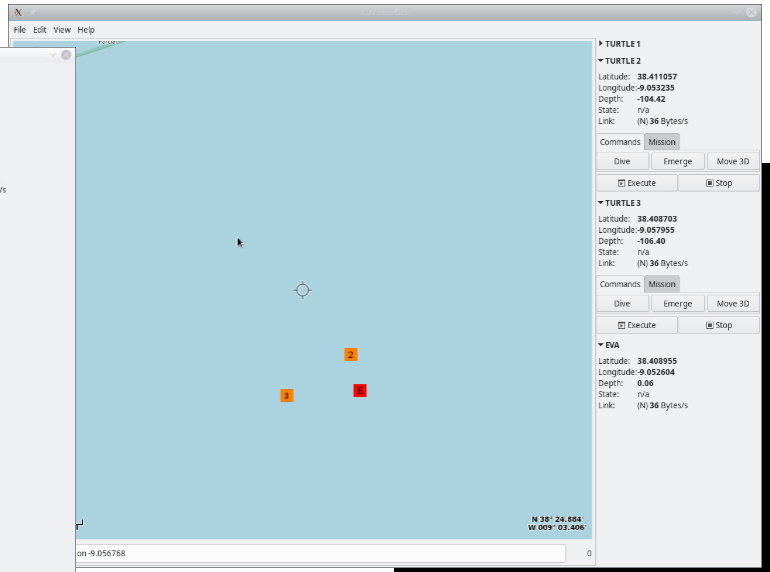


SIDENAV 2019

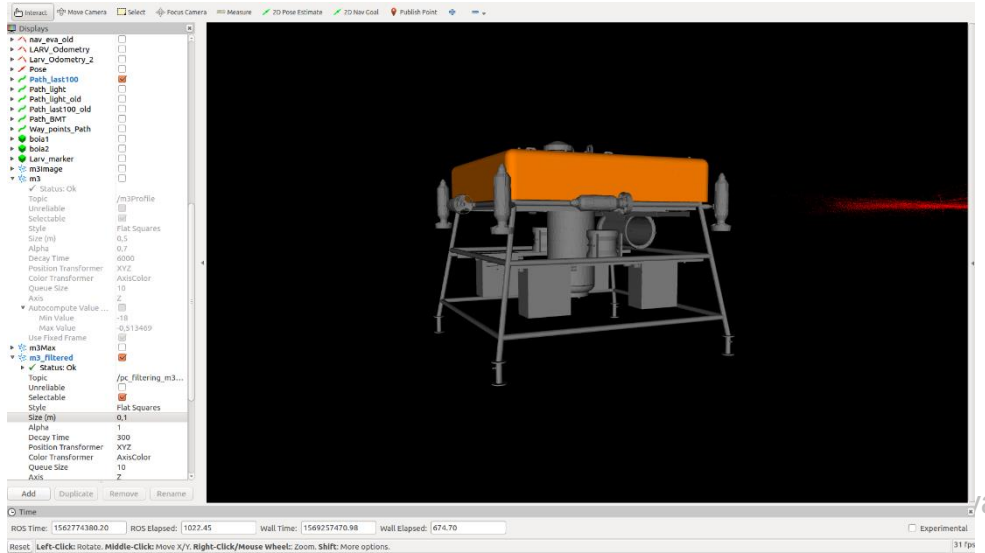


Remote supervision GUI and 3D visualization (ROS RVIZ)





EVA



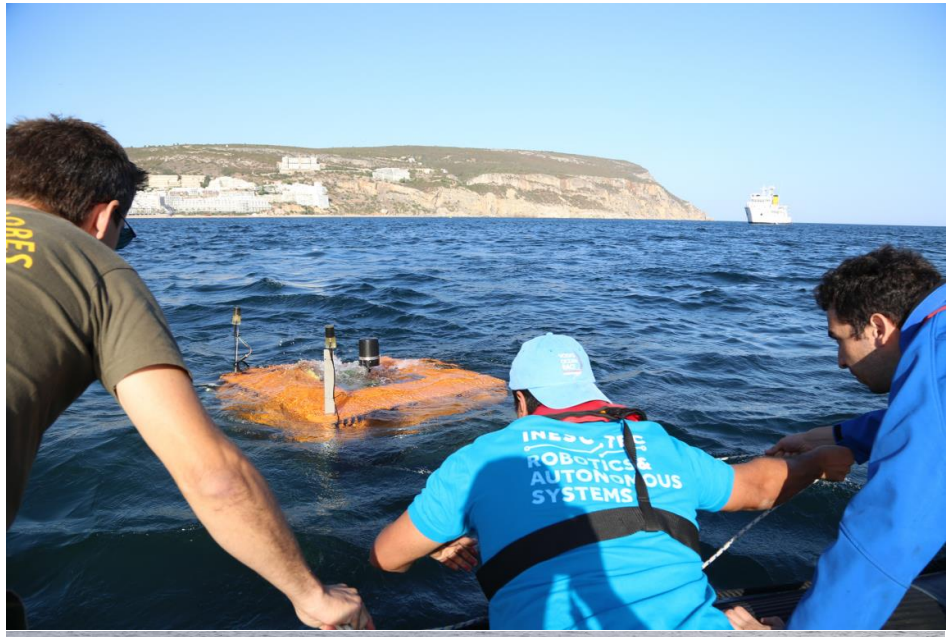
multibeam sonar scans

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



Conclusions

- Innovative robotic hybrid lander prototypes developed and tested at sea
- Efficient ascent/dive with custom designed variable buoyancy system
- EDA (European Defence 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

Alfredo Martins
alfredo.martins@inesctec.pt

Marineye Payload