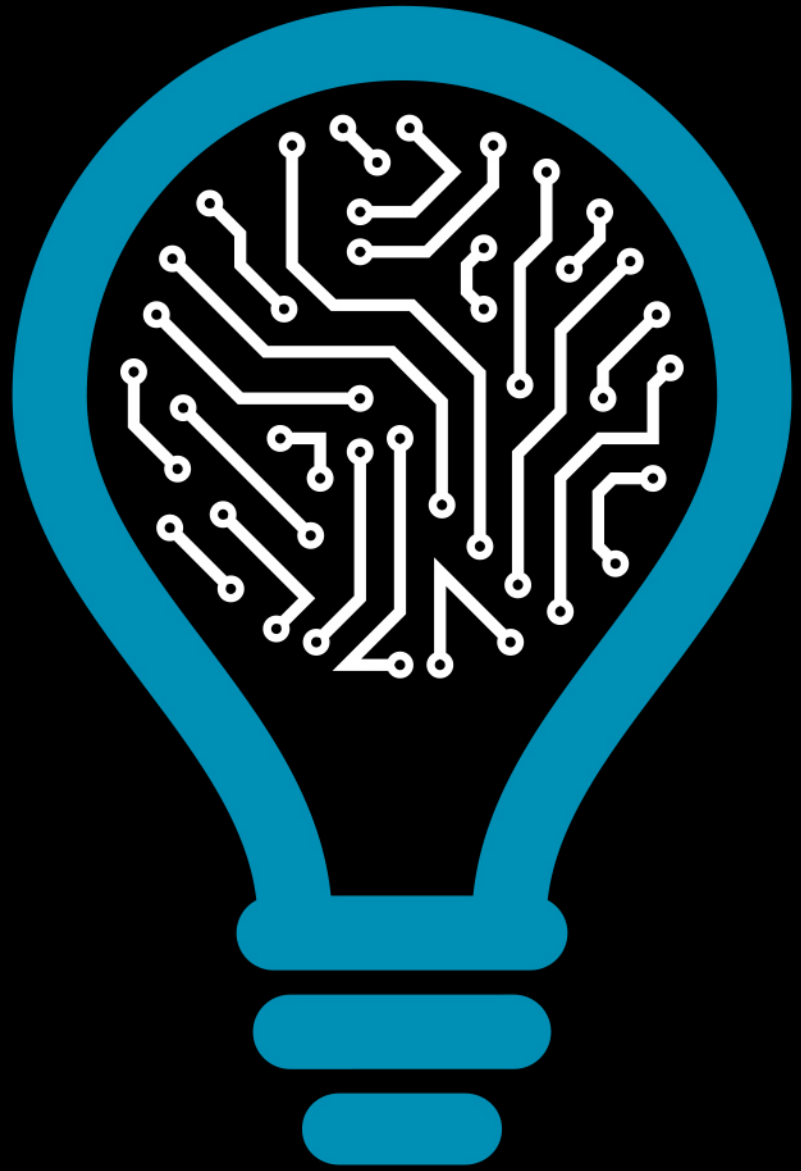
from knowledge production to science-based innovation



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Robotics and Autonomous System for marine minerals

From land underwater flooded Mines to Sea

Eduardo Silva and CRAS team

Robotics & Autonomous Systems

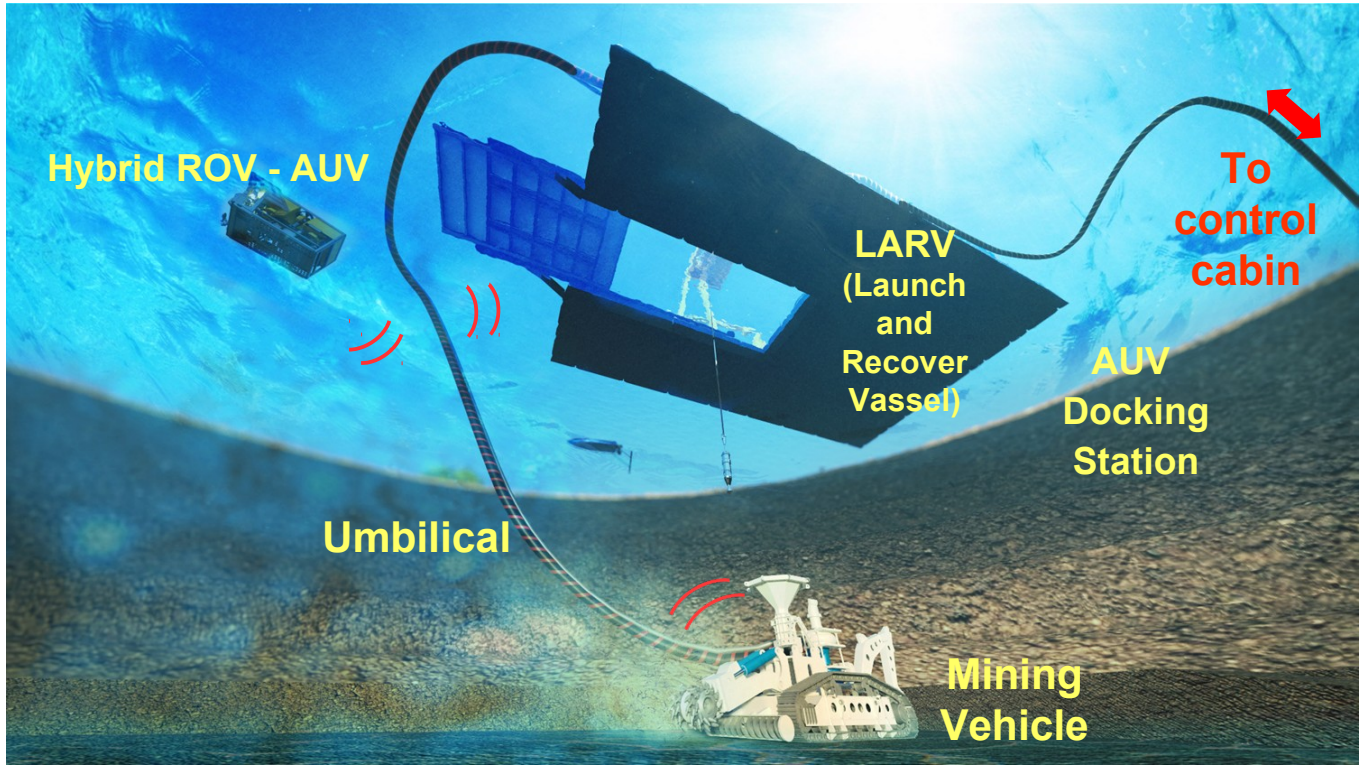
- >1000m^2 lab space
- 19 m coastal research ship
- 2 test tanks (largest: 10x6x5 m^3)
- Multiple funding sources
  - H2020, P2020, FCT
  - Industry (direct contracts)
- Robotics and Autonomous Systems
  - **Aerial, land and water robotics**
  - Reconfigurable systems
  - Distributed perception
  - Cooperative robotics
  - Long term autonomy

VAMOS – Viable Alernative Operating System

- EU H2020 Raw Materials project
- **New underwater, commercial viable robotic mining technology**
- 12.9 M€, 2015-2019, 17 partners, 9 countries
- Partners: BMT, SMD (UK), INESC TEC, Damen Dredging (NED), Trelleborg (NED), Sandvik (AU)...
- Real mine production capability tests:
  - Lee Moor, Devon UK
  - Silvermines, Ireland
- INESC TEC: Positioning, navigation and awareness system

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642477.

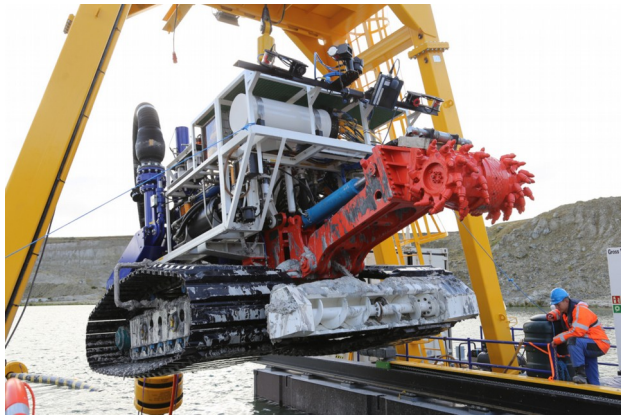
VAMOS System Overview



Command and Control
VR based interface

Hybrid ROV / AUV

Remoted operated Mining Machine



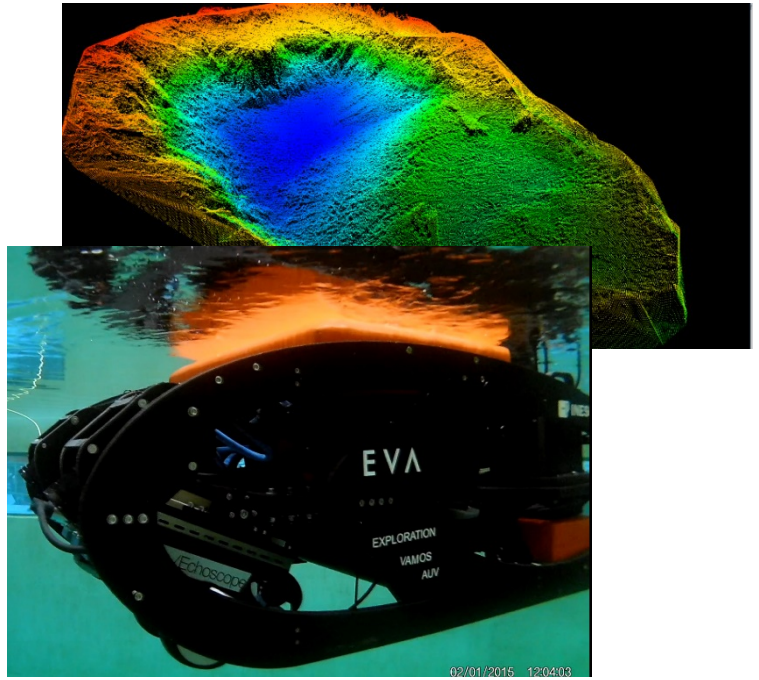
Support Vessel

Positioning, Navigation and Awareness (PNA)

- Accurate Positioning of VAMOS vehicles (MV, LARV, EVA)
- Real time mine model
- Sensing for mining operations
- Integrated virtual reality operations support (planning, launch, operations recovery)

- PNA information
  - LARV vessel positioning
  - MV positioning
  - **Mine pit pre-survey map**
  - **Mine pit pos-survey map**
  - **Support HROV /AUV positioning**
  - **Support HROV/AUV sensor data**

➡ ***EVA***



PNA high level requirements - overview

- Time and cost effective setup and maintenance
  - Don’t require to infrastructure the bottom with acoustic beacons network -> avoid relocation of beacons due to the mining process
  - Easy to calibrate and maintenance of the hardware
- Support the simultaneous accurate positioning of multiple vehicles (MV(s), LARV, EVA)
- Do not require/depend on timely heading initialisations (north seeking process)
- (Sub-)Decimetric accuracies in positioning and mapping
- Positioning with Low latency for operation with a Virtual Reality environment
- Support real-time environment mapping

PNA Overview

LARV

MV

EVA AUV

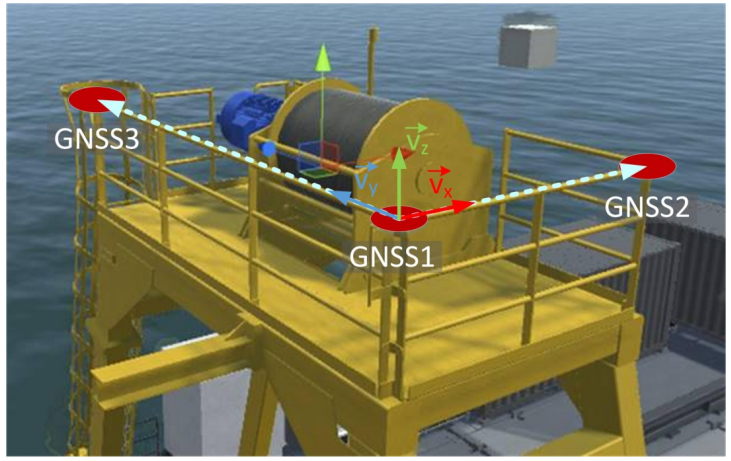
PNA

(Positioning, Navigation and Awareness System)

VR HMI
Control Centre

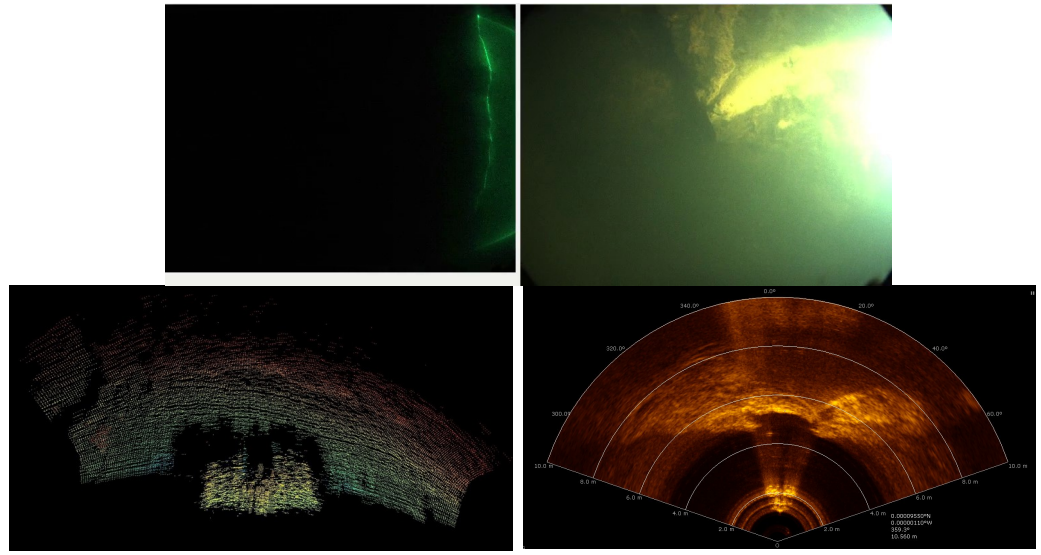
LARV PNA

- Multiple GPS Antennas
  - RTK differential corrections
  - Attitude determination
- Acoustic transponders/modems for the SBL/iUSBL
- Hoist and anchoring cables sensors
- Cameras
- [IMU/INS]



MV PNA Sensors

- Cameras + Laser & light projectors
- M3 Multibeam + camera on P&T
- CODA Echoscope 3D multibeam sonar
- Altimeter
- INS / USBL /pressure sensor
- [DVL]
- Machine status sensors (homeostatic)
- Environmental sensors

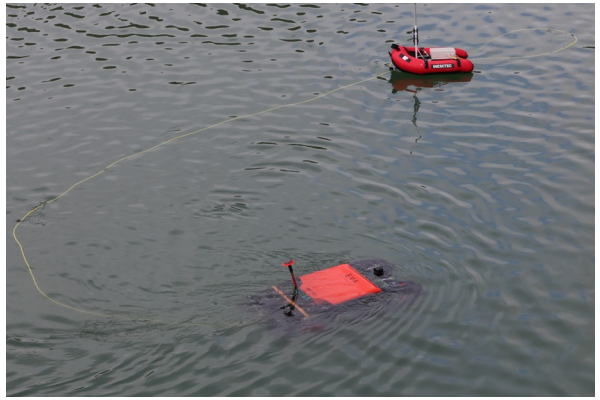


EVA – Exploration VAMOS AUV

- Mine pit preliminar survey
- Real time mine bathymetry data
- MV Operations support (“other perspective”)
  - MV deploy and recovery
  - Cutting supervision
  - Tool change

Operation modes

- Full AUV mode (Autonomous)
- Tethered (Surface support radio comms)
- Wireless ROV/AUV – Short range UW RF comms



Please see the

VAMOS movie

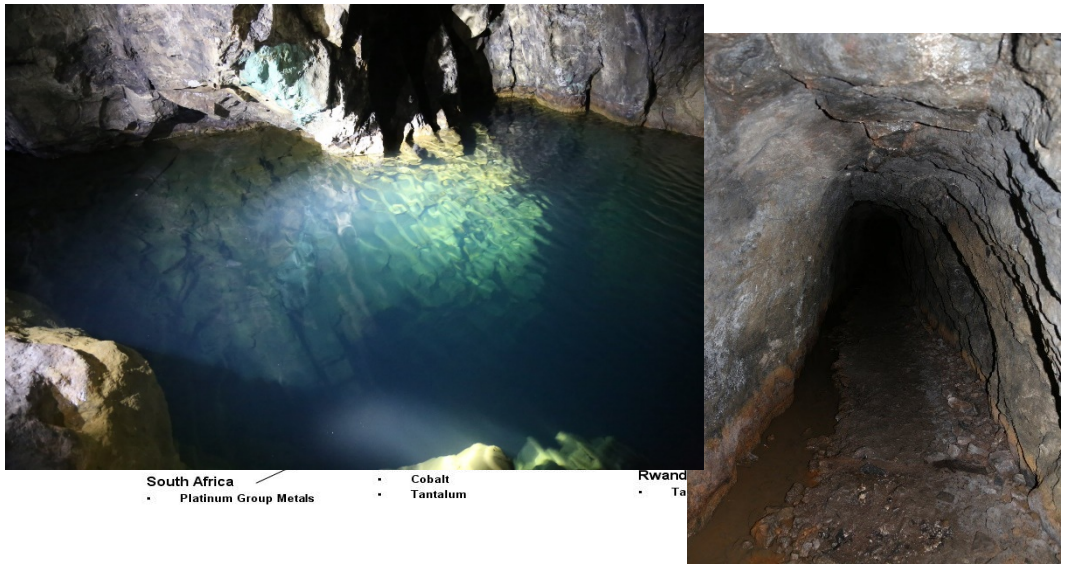
https://www.youtube.com/watch?v=XALp8YniNiI&t=9s

Also see

https://www.vamos-project.eu/media-links/

Flooded underground mine exploration

- Europe dependence on raw materials
- 30 000 mine sites closed in Europe
- Cultural heritage and history
- Environmental concerns and terrain stability

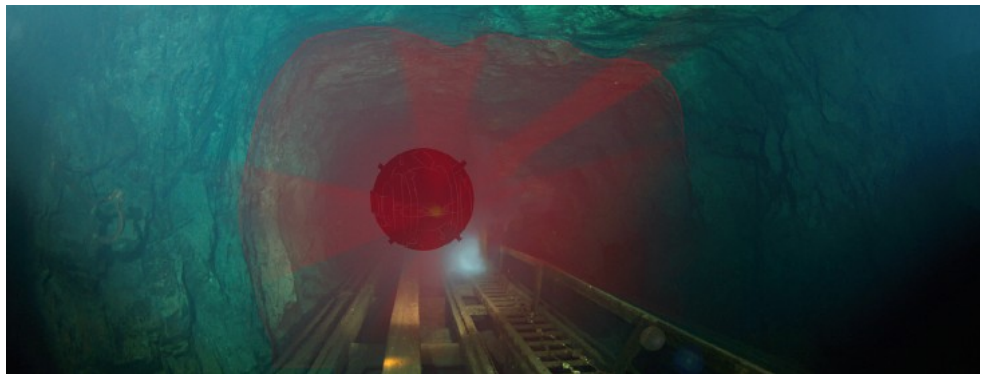


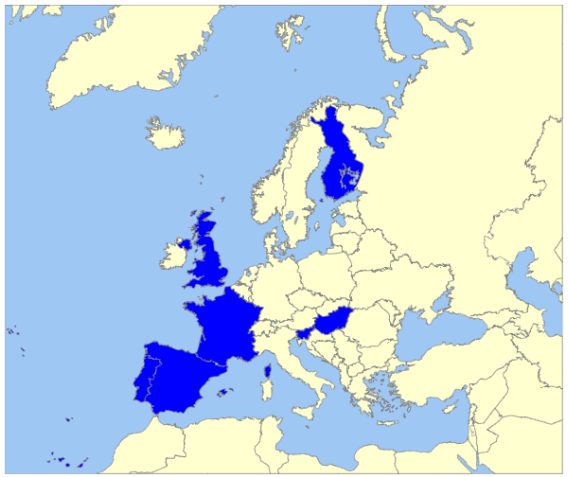
- Most underground mines are flooded
- Unknown map, state and available resources
- Exploration is difficult and expensive

Robots can help!

UNEXMIN

- **Robotic exploration of flooded mines**
- European Union H2020 research project
- 2016 - 2019
- 13 partners, 7 countries
- 4.8 M€
- INESC TEC Role: Robot development, navigation, mapping
- UNEXMIN mine test sites
  - Kaatiala, Finland
  - Idrija, Slovenia
  - Urgeiriça, Portugal
  - Ecton, UK

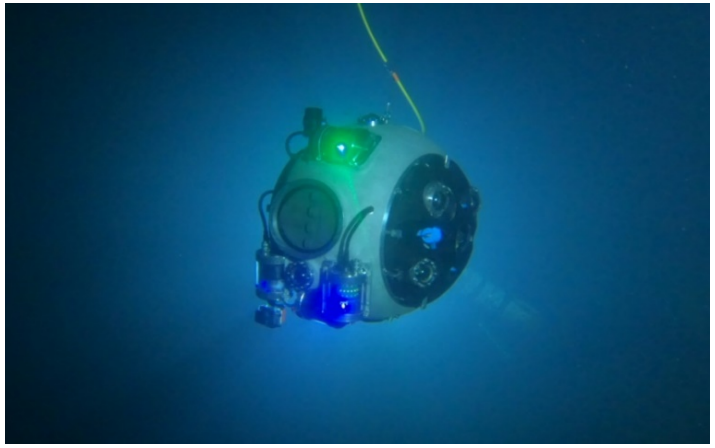




This project has received funding from the European Union's Horizon 2020research and innovationprogramme under grant agreement No 690008.

Submerged galleries / water conducts inspection

UNEXMIN / UNEXUP UGR

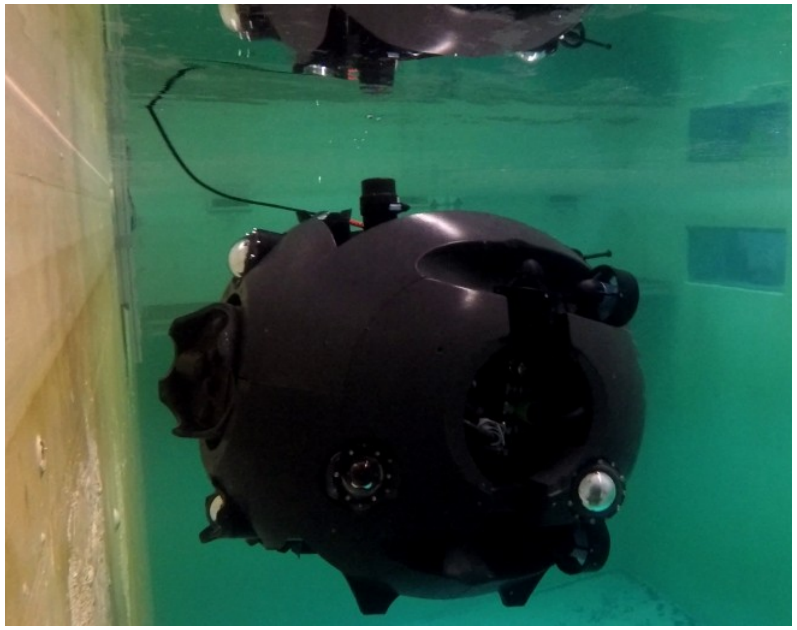


- Autonomous exploration of underwater tight spaces
- Multibeam sonar
- 5 cameras
- 4 Laser based structured light systems (precise mapping)
- 60 cm diameter, 120 Kg
- 500m max depth
-
-

https://www.unexmin.eu/videos/

Unexmin Geo- Robotics & UNEXUP

- New spinoff for UNEXMIN results exploitation
- UNEXMIN technology upscaling
- Second generation robotic explorer
- Modular robot with extended capabilities



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Applications Places

Default - rqt

File Plugins Running Perspectives Help

Image View (7)

/cam_top/led_div | 0 | 10,00m

/cam_top/led_div_mouse_left | Smooth scaling | 0° | Gray

Image View (4) | Image View (2) | Image View (8)

/cam_ | 0 | 10,00m

ise_left | Smoc | 270° | Gray

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ise_left | Smoc | 90° | Gra

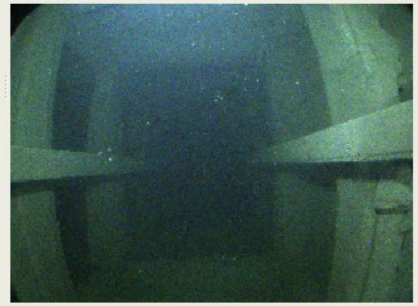
Image View (3) | Image View (9)

/cam_l | 0 | 10,00m

ise_left | Smoot | 0° | Gray

/cam_back/led_div | 0 | 10,00m

/led_div_mouse_left | Smooth scaling | 0° | Gray



tanque_lsa_neo.rviz* - RViz

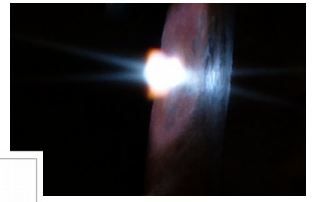
File Panels Help

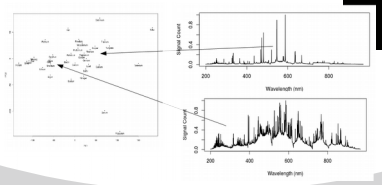
Interact | Move Camera | Select | Focus Camera | Measure | 2D Pose Estimate | 2D Nav Goal | Publish

Reset **Left-Click:** Rotate. **Middle-Click:** Move X/Y. **Right-Click/Mouse Wheel:**: Zoom. **Shift**: More options.

https://www.unexmin.eu/videos/

INSite - In situ ore grading system using LIBS in harsh environments

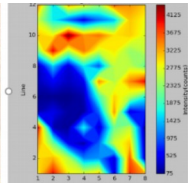




Area: D2 Acceleration

Segment: **D2.2 Upscaling**

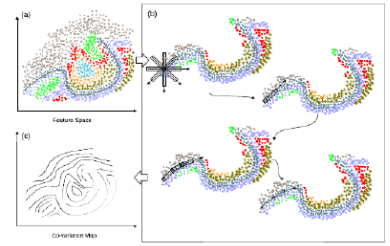
Duration: **2020-01-01 to 2022-12-31**



This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

INSite Vision and main goals

- **Portable Smart LIBS** wiht **AI based software**, with reliable analytical performance.



- **Smart LIBS Database**. A referenced mineral spectra database.

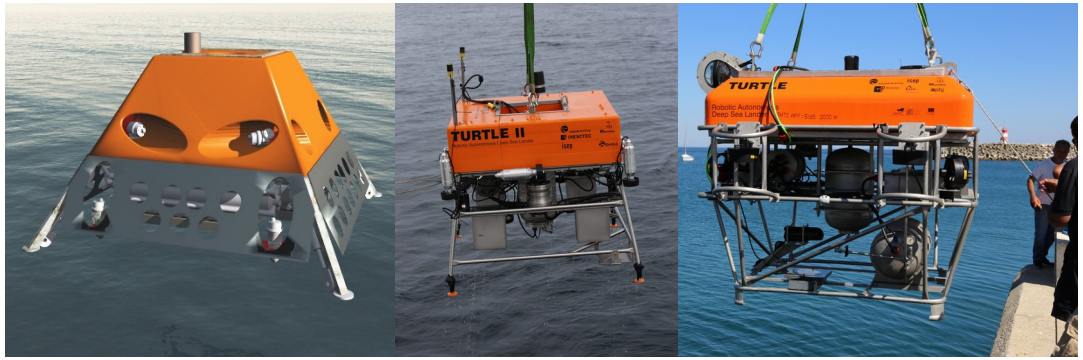
- New **Modular** technologies for **LIBS in harsh mining environments**
  - **Underwater** LIBS
  - Small size LIBS tools
  - **Robust** skin for harsh environments
  - **Robotic tools empowering LIBS** systems
- Business model and market assessment for the tech outputs

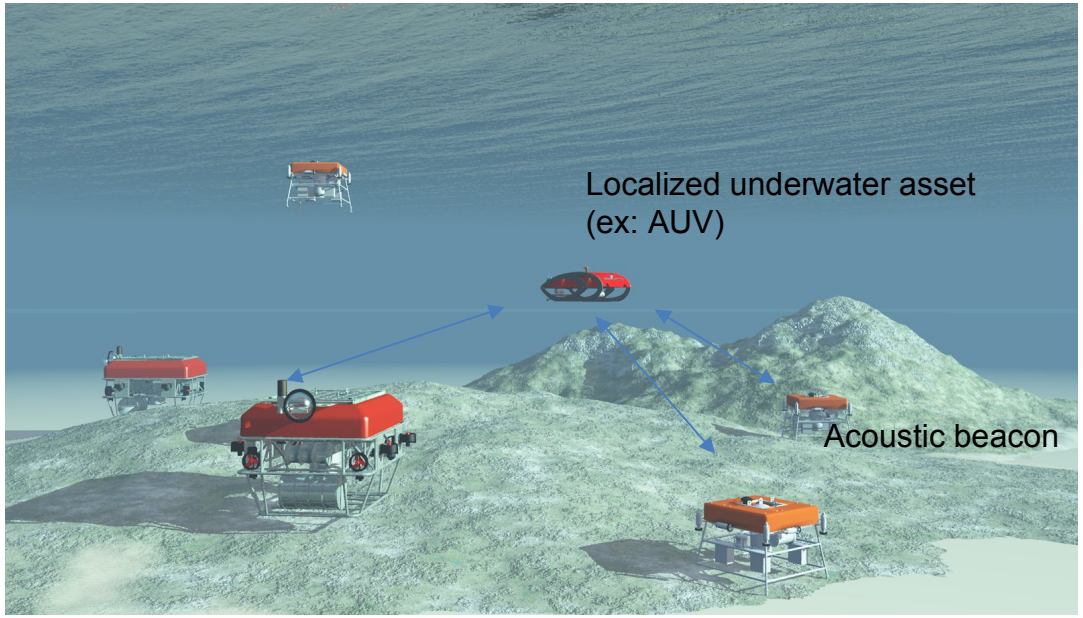
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Supported by: eit RawMaterials Connecting matters

TURTLE Concept – A deep sea autonomous robotic lander

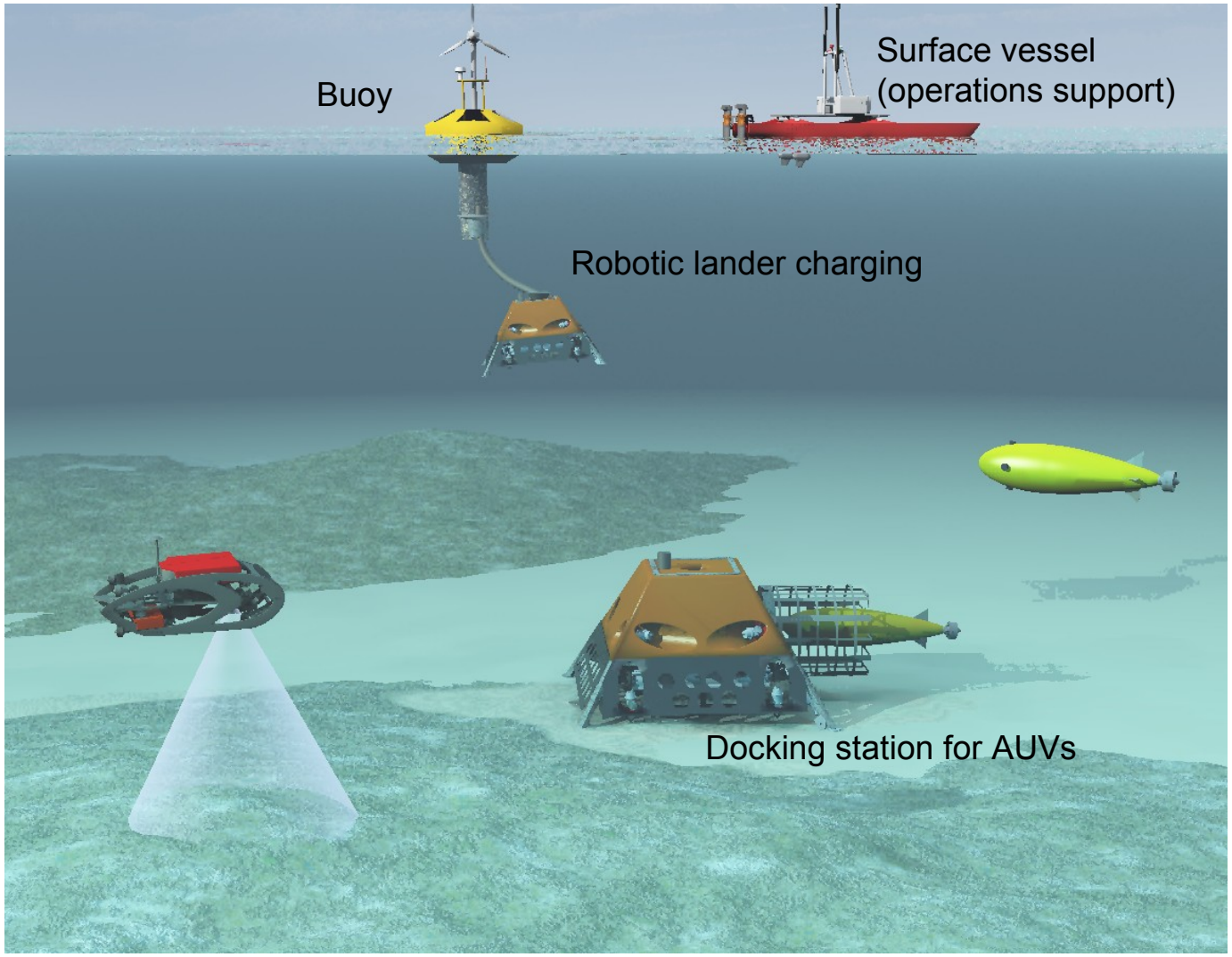
- **Hybrid lander / AUV**
  - **Long term permanence on bottom (lander)**
  - **Autonomous locomotion for positioning/re-positioning (AUV)**
- Efficient vertical ascent/dive
  - Variable buoyancy system
- Acoustic communications
- Custom developed pressure tolerant batteries
- Autonomous navigation
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





Heterogeneous robotic permanence at sea

- TURTLE landers provide docking and energy charging to AUVs
- Surface buoy provides charging to landers
- Surface vessel for maintenance and deployment
- Partners: ASM, INESC TEC, Composite Solutions, Estaleiros Navais de Peniche, ISEP,FEUP

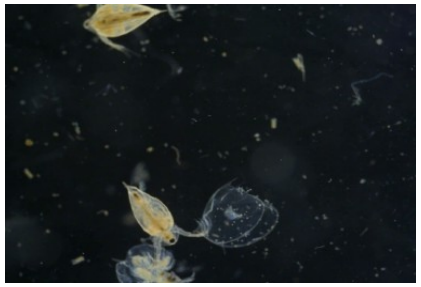


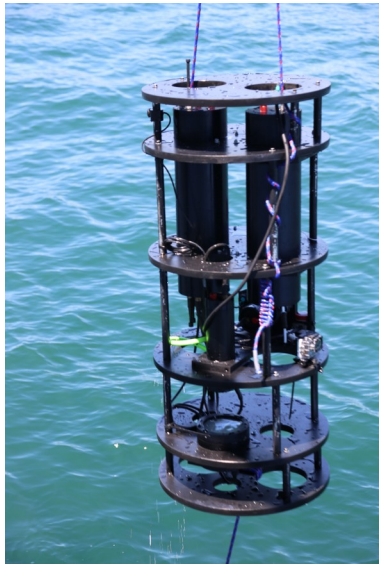
SIDENAV 2019

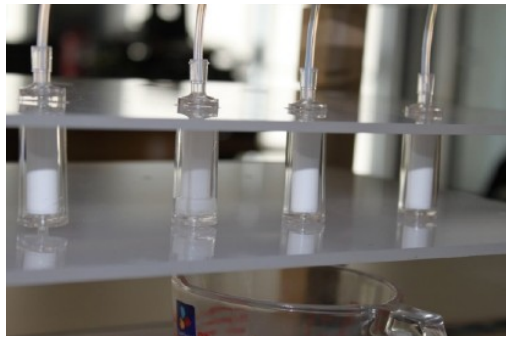
- Sesimbra, July 2019 (REX 2019 exercises)
- Support from Portuguese Navy, NRP Gago Coutinho
- EVA AUV used as target to be localized
- 2 TURTLES deployed at 100m depth)
- TURTLES with fiber connection to the surface

MarinEYE - Biological information multisensory system

- **Autonomous biosampler** – in situ water filtration for DNA sample collection
- **Zooplankon imaging system** – high-definition imaging
- On board data storage and processing
- Additional water parameter data and acoustic information
- Field sensor prototype







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Thanks for your attention

eduardo.silva@inesctec.pt