¡vamos!

Viable and Alternative Mine Operating System

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INESC TEC /ISEP

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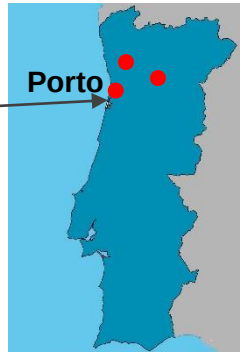
Who we are: INESC TEC

- **R&D non-profit research center and technology interface institution**

isep Instituto Superior de Engenharia do Porto



- Joins researchers from several schools
  - Porto University
  - Porto Polytechnic Institute
  - Minho University
  - UTAD

- 800 researchers, 350 PhDs

- **Robotics and Autonomous Systems**
  - **Aerial, land and water robotics**
  - Reconfigurable systems
  - Distributed perception
  - Cooperative robotics
  - Long term autonomy

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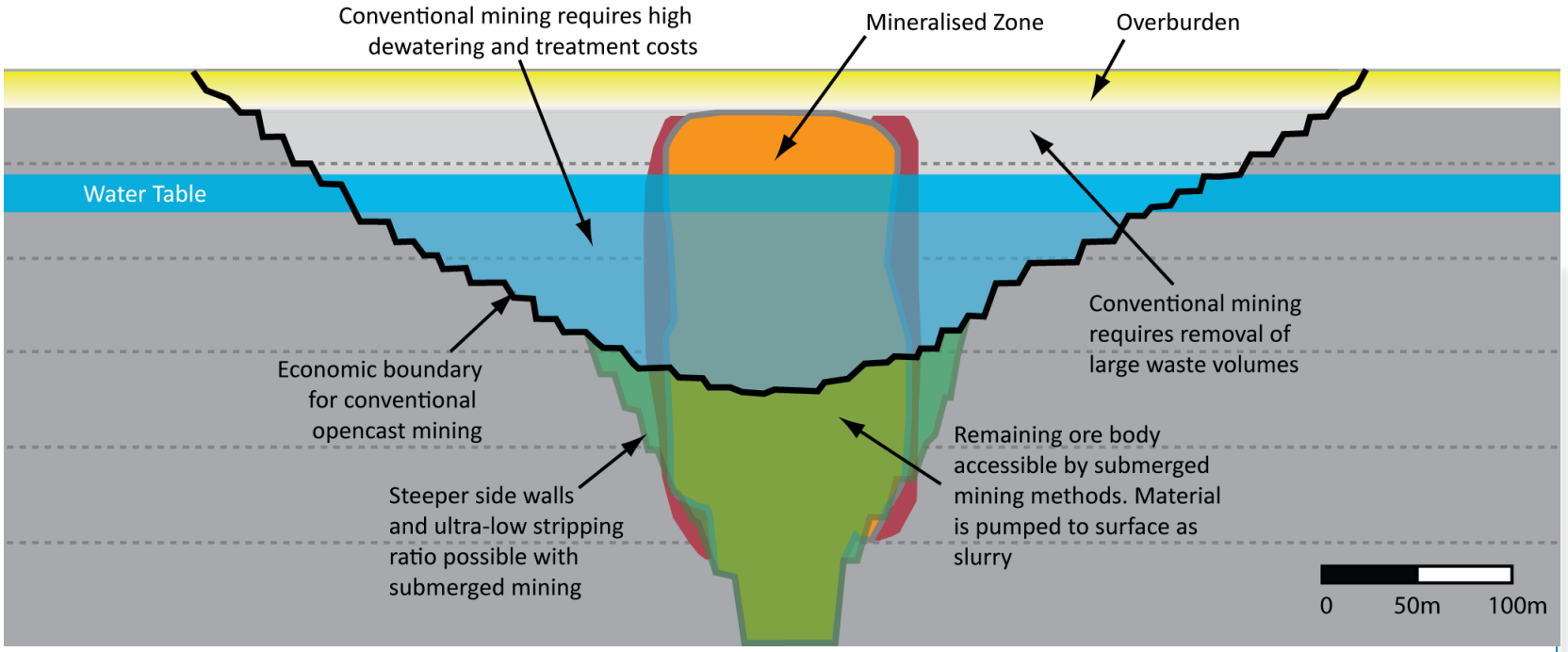
Current underwater mining machines

Images courtesy of SMD

Inland flooded mines

Open pit flooded mines

- Europe consumes 25-30% worlds metal and extracts only 3%
- €100 billion estimated value of unexploited European mineral reserves up to 1000m [1]



[1] European Comission Press Release "Innovation Partnerships: new proposals on raw materials, agriculture and healthy ageing to boost European competitiveness", Sept. 2013, http://europa.eu/rapid/press-release_IP-12-196_en.htm?locale=en

VAMOS - Viable and Alternative Mine Operating System

- European H2020 Societal Changes 5 (Raw Materials) RIA
- New underwater robotic mining technology comercially viable
- 12.4 M€
- 2015- 2018, 17 partners, 9 countries
- Partners: BMT, SMD (UK), INESC TEC, Damen Dredging (NED), Trelleborg (NED), Sandvik (AU)...
- INESC TEC: Positioning, navigation and awareness system

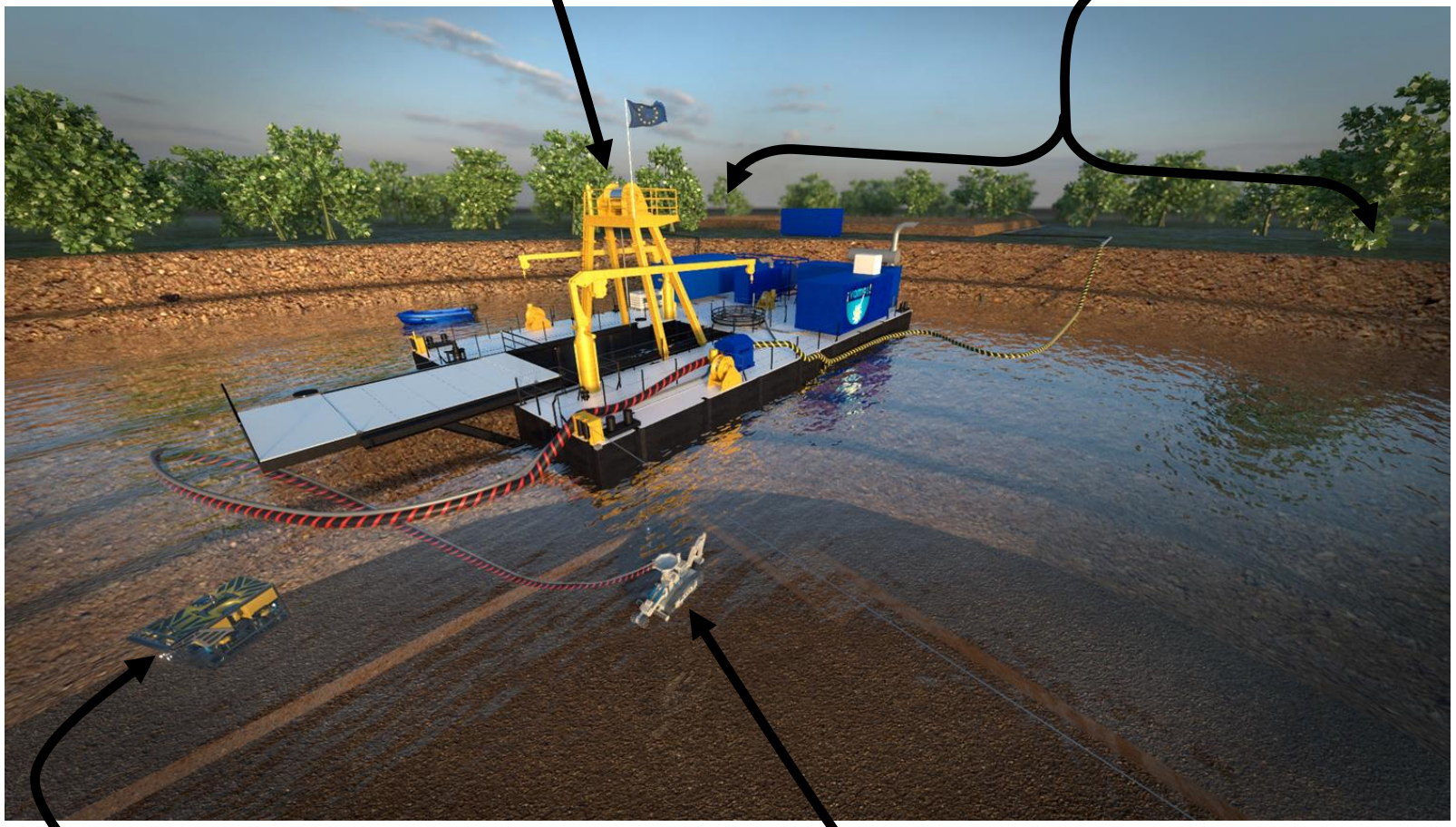
Objectives

- **Underwater robotic mining machine**
- **Underwater sensing, spatial awareness, navigation and positioning**
- **Ensuring grade sensing and control**
- **Conduct field tests in representative field mines**
- **Evaluate productivity and cost of operations**

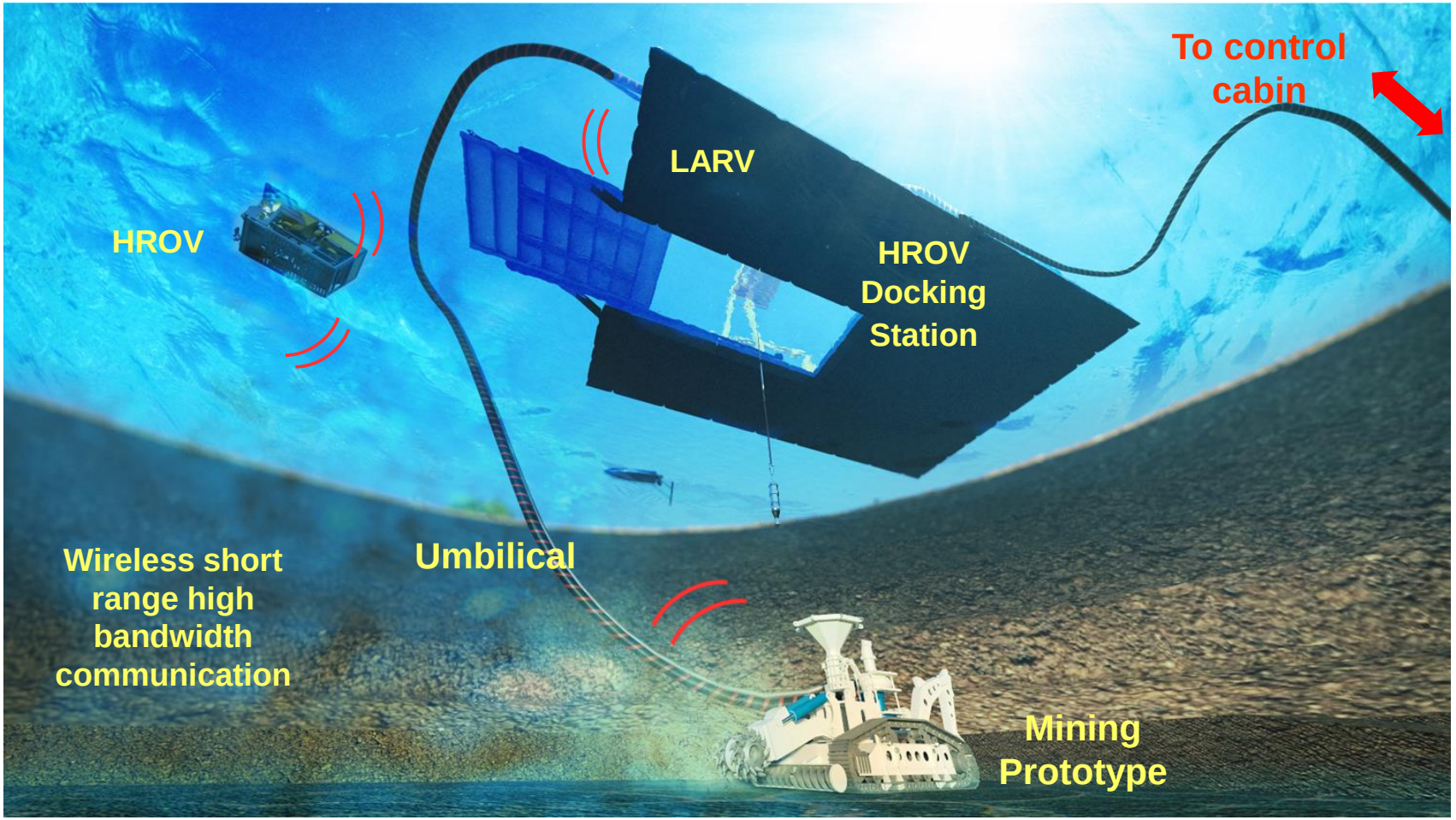
Reduce EU dependence on raw materials import
Provide new sustainable underwater mining technology

VAMOS Consortium

iVAMOS! overview…

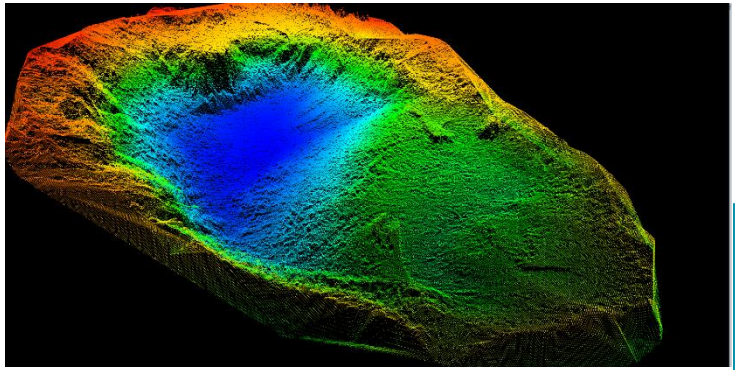


iVAMOS! underview…



Positioning, Navigation and Awareness System

- Real time mine model
- Sensing for mining operations
- Integrated virtual reality operations support (planning, launch, operations, recovery)



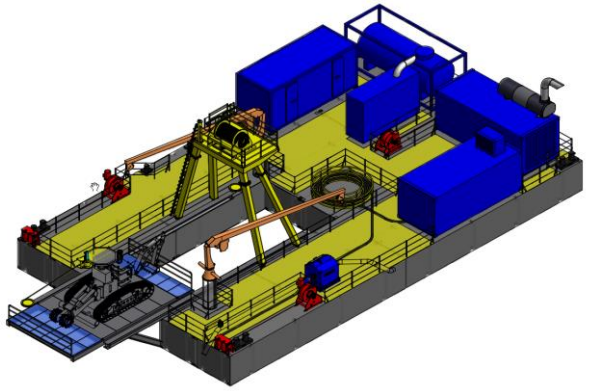
PNA information

- Mine pit pre-survey map
- L&R vessel positioning
- MV positioning
- MV mining operation assistance
  - mined volume and dynamic world model
  - direct support for operation and MV control (imaging, world model, aiding tools)
- Support HROV / AUV positioning

Launch and Recovery Vessel

DAMEN DREDGING EQUIPMENT

- Launch and recovery
- Anchored
- Provides power and comms
- In assembling stage



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Robotic Mining Vehicle

- Small scale prototype
- Sensors
  - Front and back tooling cameras
  - Pan&Tilt mounted Multibeam/FLS sonar
  - Pan&Tilt mounted camera
  - 3 structured light systems

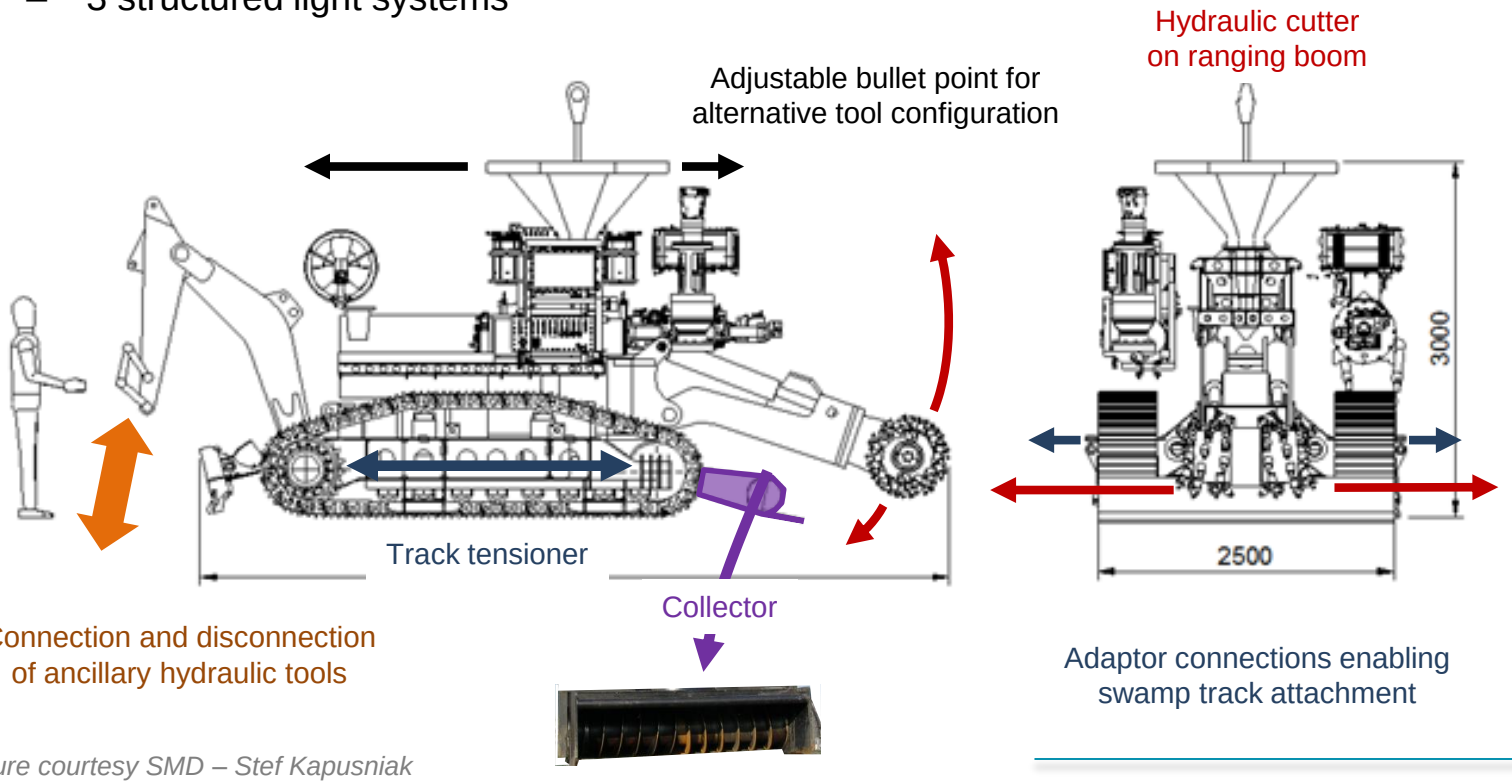
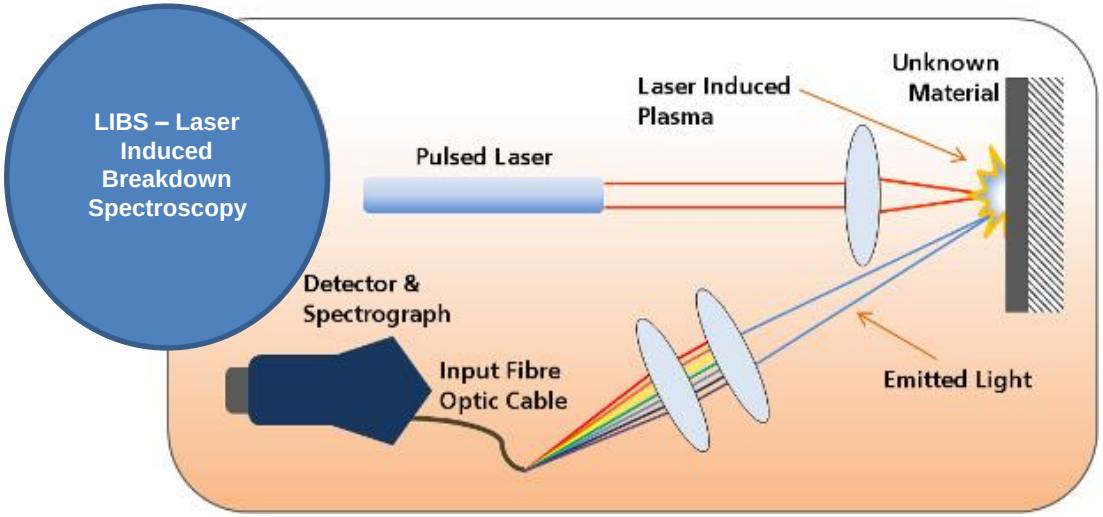
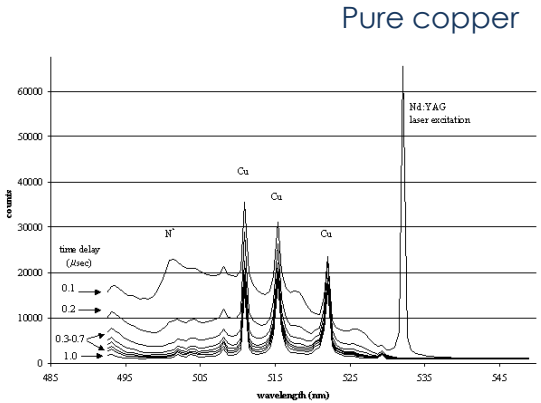


Figure courtesy SMD – Stef Kapusniak

Mining Vehicle

LIBS - Real time grade control

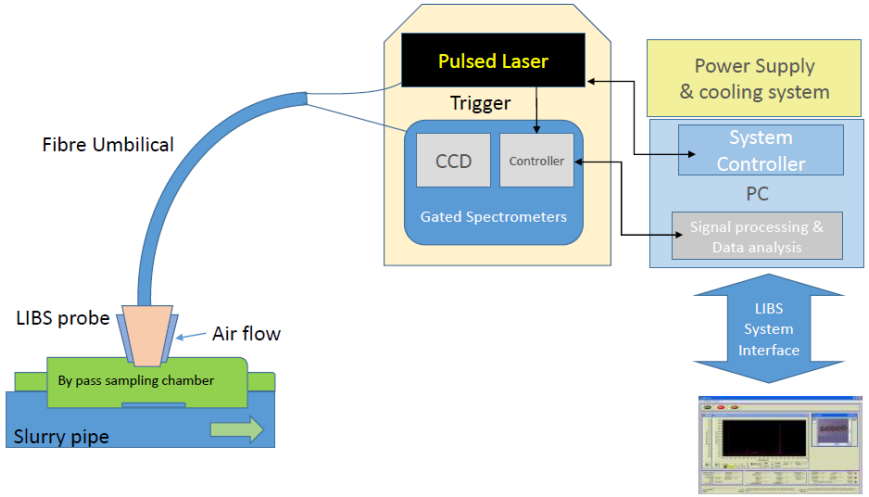


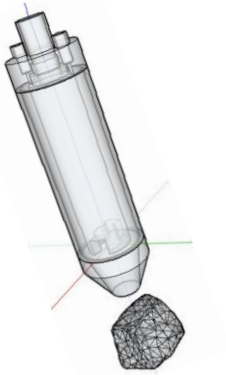


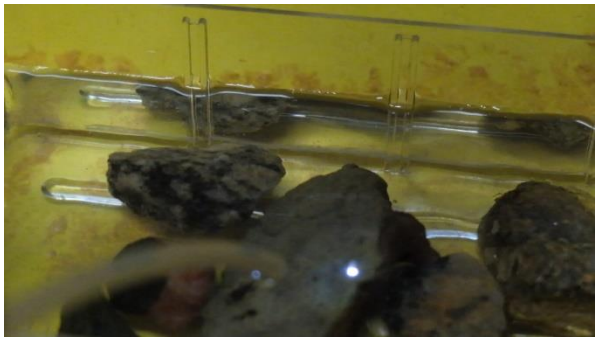
- Solid state Laser (eg. Nd : YAG laser at 1064 nm; ~100 mJ)
- Laser Power supply and cooling system (~1kW, up to 20 kg)
- Laser light delivery optics (fiber) and collecting optical fibers.
- LIBS sensing head or sampling probe
- Gated Spectrometer and collecting optics (~20 W, 2 Kg).

LIBS - Real time grade control

- Validated in shallow water
- Installed in the slurry circuit
- Statistical characterization of each site

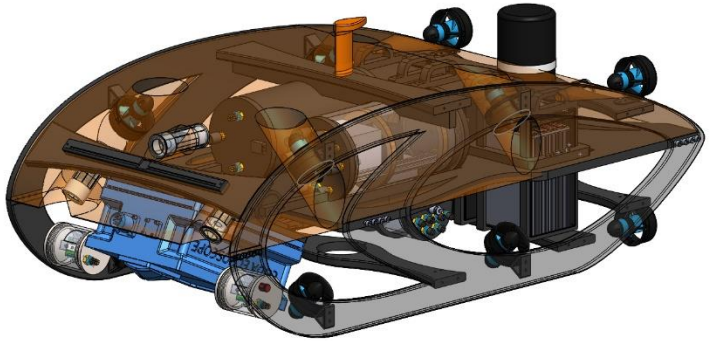


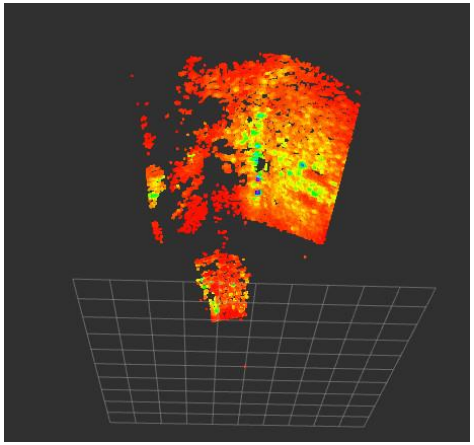


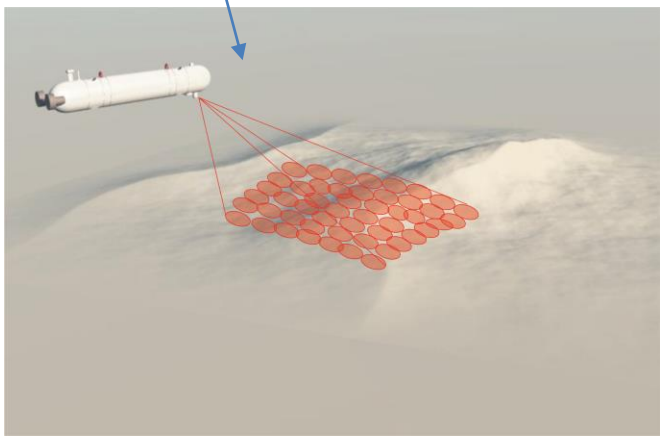


Operations support HROV/AUV

- Mine pit preliminary survey
- Real time mine bathymetry data
- Operations support (“other view perspective”)
  - Mining vehicle deploy
  - Cutting supervision
  - Mining Vehicle recovery
- Vehicle dock in LARV

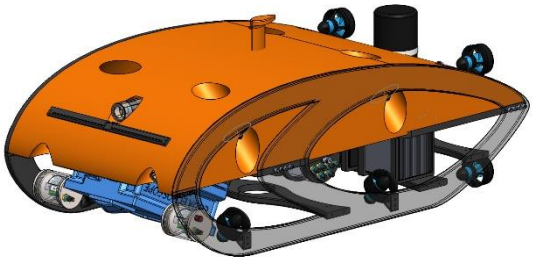


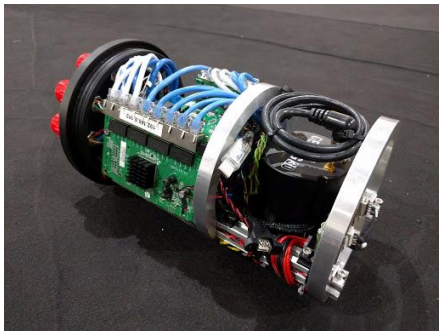




Operations support HROV/AUV

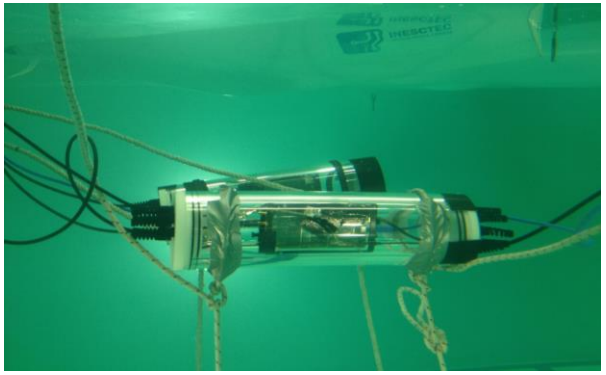
- **3D multibeam sensing (Coda Octopus Echoscope)**
- **Multiple laser scanning**
- On board batteries (3KWh)
- ROV/AUV modes
- USBL/SBL positioning (Evologics)
- FOG INS (KVH) and DVL (Nortek)
- **High speed short range wireless communications**
- 500m depth rating





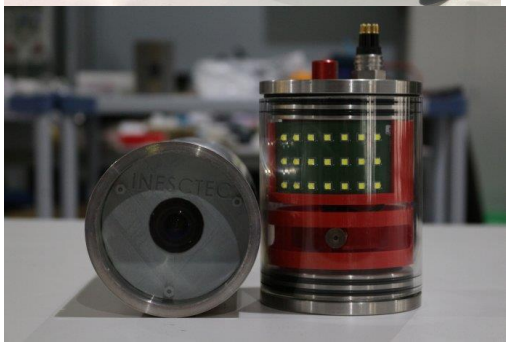
Short range broadband communications

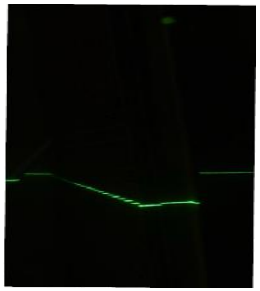
- RF wireless communication
- Based on Wifi radios using subGHz frequencies
- up to 10m range in mine typical waters
- 2 to 4 Mbits at 5m
- 30cm antenna
- Validated in test tank
- Used for realtime AUV mining operations assistance

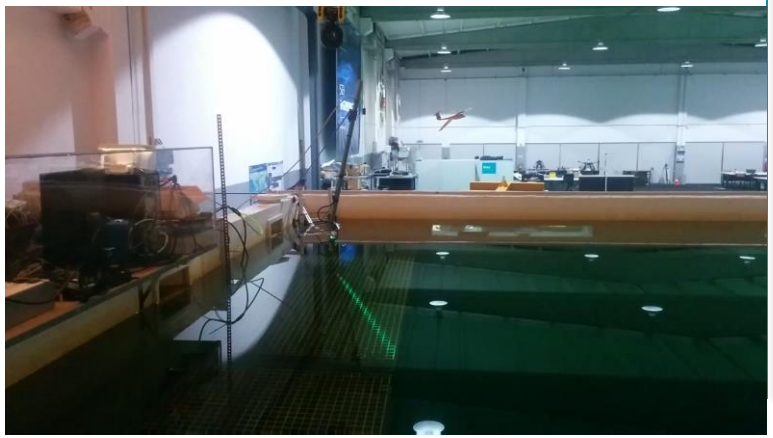


Laser Rotating Scanner

- Custom developed
- 120º Rotating laser scan
- LED lights for standard imaging
- Synchronized camera trigger
- Embedded laser image processing

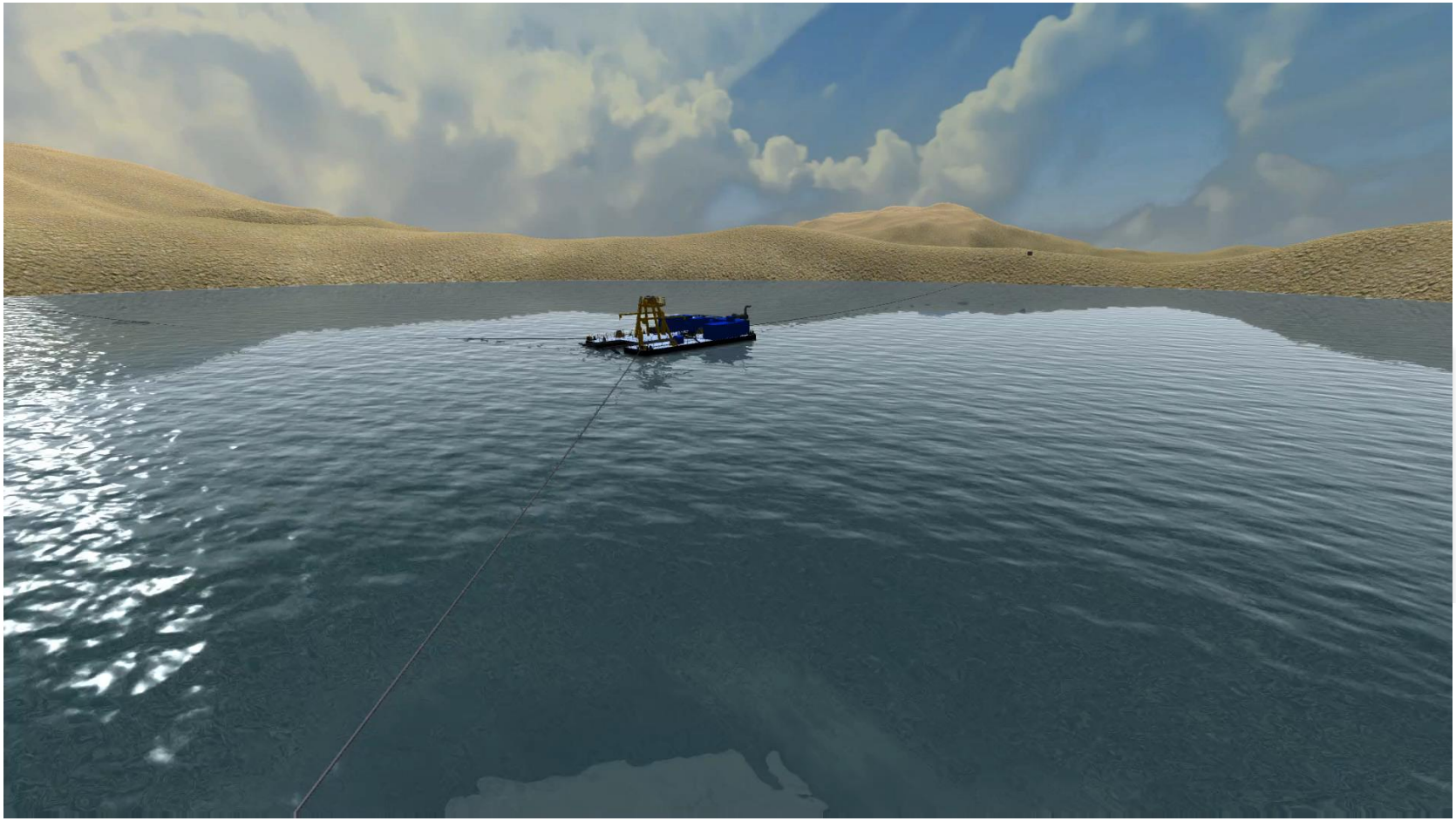




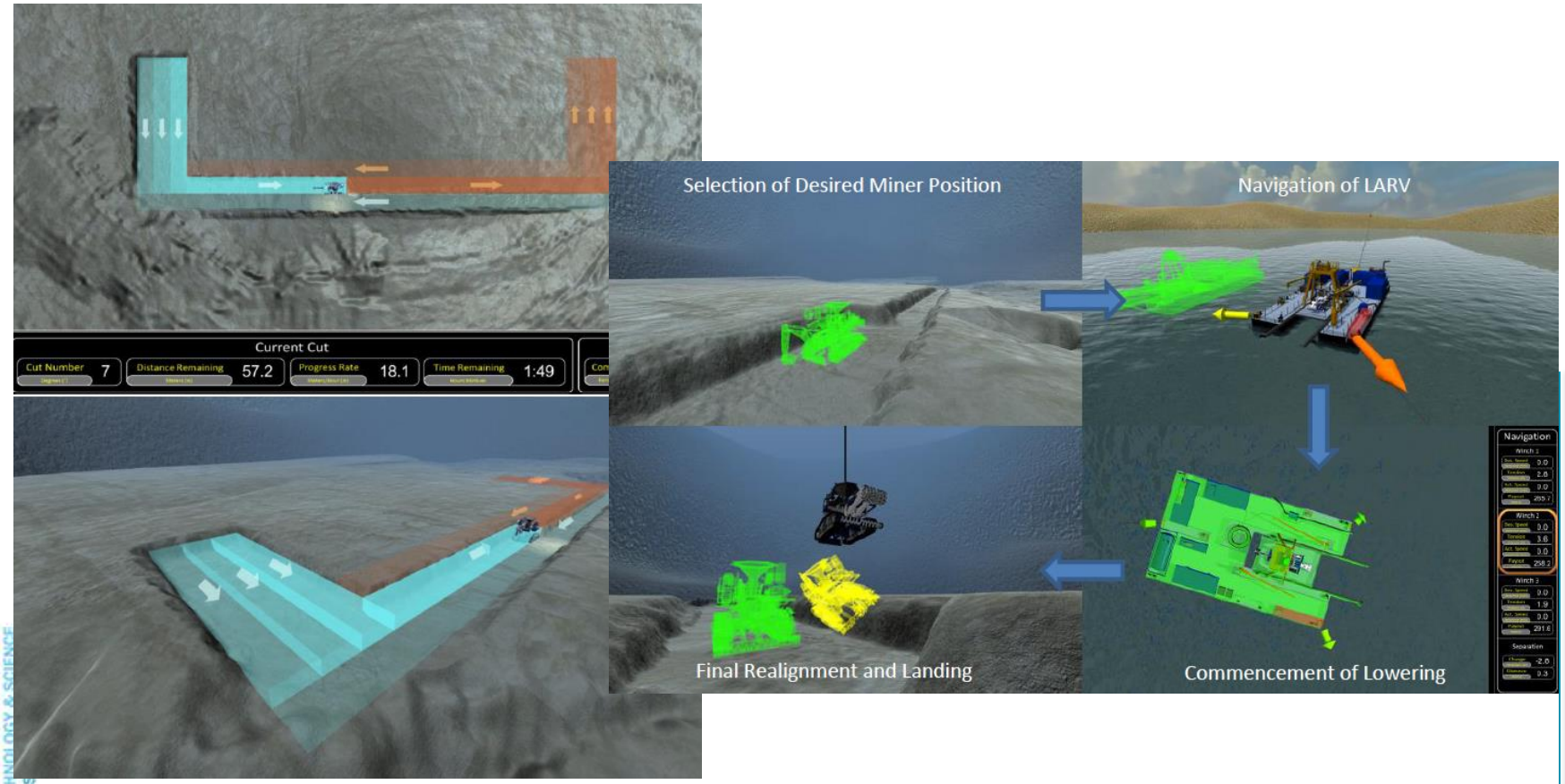


Virtual View

Virtual operational view from fusion of multiple sensory sources, allowing remote operation at night and in turbid water



Integrated virtual model in deploy and recovery, and mine planning

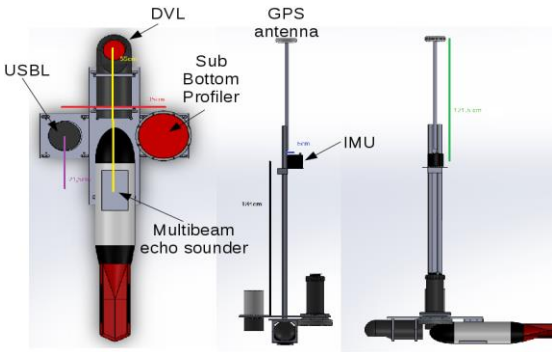


VAMOS sites

- Bejanca – Portugal
  - Tin/Tungsten
- São Domingos – Portugal
  - Copper
- St. Ives – UK
  - Alluvial deposit
- **Lee Moor – UK**
  - China Clay
- **Vares – Bosnia**
  - Iron

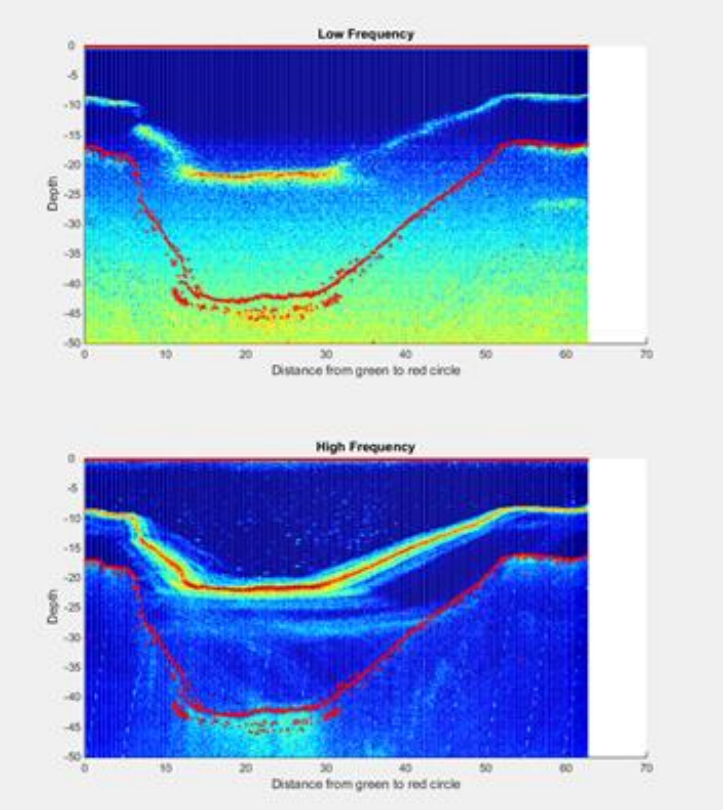
Bejanca mine preliminary survey

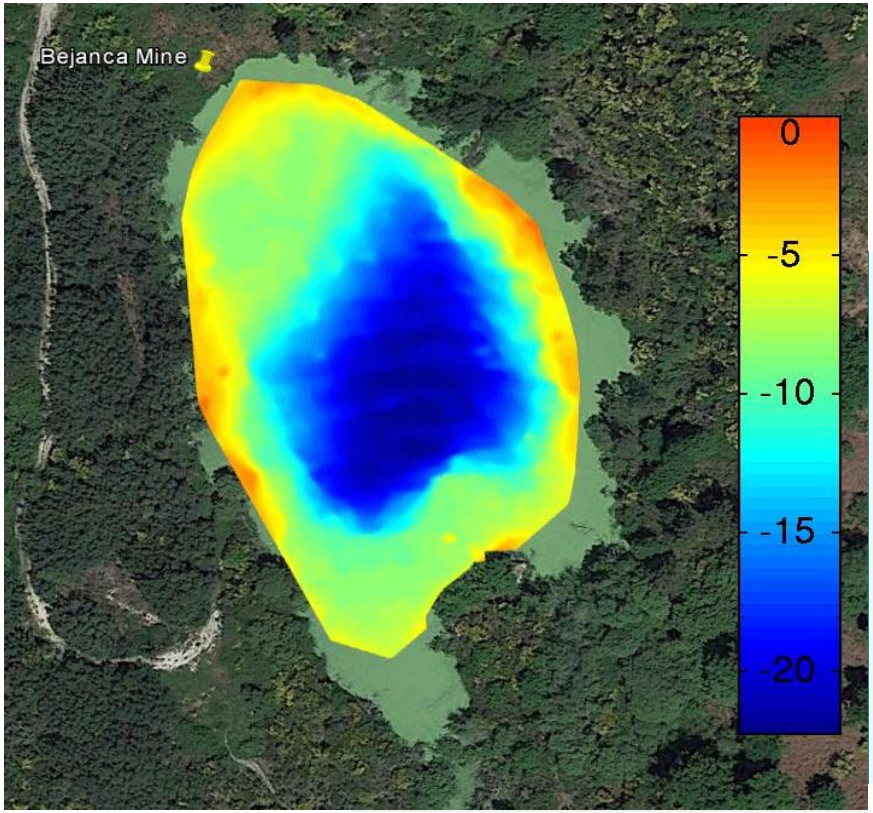
- ROAZ ASV bathymetric and subbottom profiling survey
- OTUS UAV above water survey
- 3D point cloud environment reconstruction



Mine pit survey

- Multibeam Bathymetry
- Autonomous ASV transects
- Subbottom sonar profiles (useful for sediment, mineral knowledge)





Bejanca mine virtual reality model

Concluding remarks

VAMOS - Underwater robotic technology for mining

- Survey and Mapping
- Exploration
- Precise modeling
- Mineral prospecting
- **Awareness and mining operation support**
- **Exploitation – Efficient underwater mining**
- **Reducing mining environmental impact**

Develop/validate a new economic and technical solution for inland flooded open pit mine exploitation

Thanks for your attention …

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