MINE.IO
A Holistic Digital Mine 4.0 Ecosystem

INESCTEC

MuoN solutions

Sustainable Exploration

A new paradigm

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Sustainable Exploration – A New Paradigm

Pilot Site: Malaposta
Mine.io WP and Tasks: WP3 T3.1-T3.2
Technologies: Muon detection systems, underwater robots, advanced data analysis

- **Summary:**

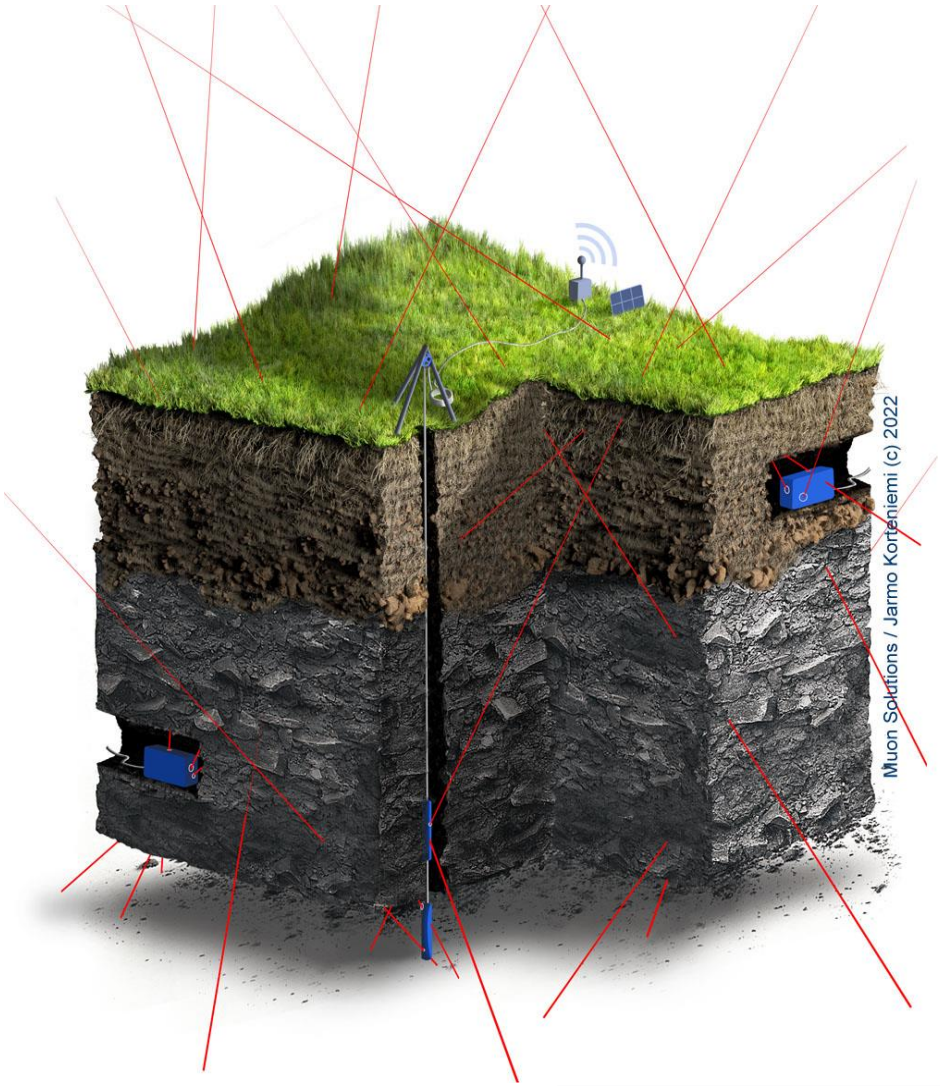
-New exploration methods such as subaqueous by using muon detectors will transform how we explore critical resources.
-Innovations are set to improve efficiency and accuracy.
-Reduce the environmental footprint of exploration activities.

What Are Muons?

- “Heavy electrons”
- Generated in upper atmosphere
- Travel at 95–99% of the speed of light
- Constant flux of particles on the surface

- Penetrate all materials
  - Usability depends on the detection depth: Average density of the medium
  - Dense area → Fewer muons pass through
  - Less dense → More muons pass through

Detectors map the density distributions by measuring muon flux in different directions



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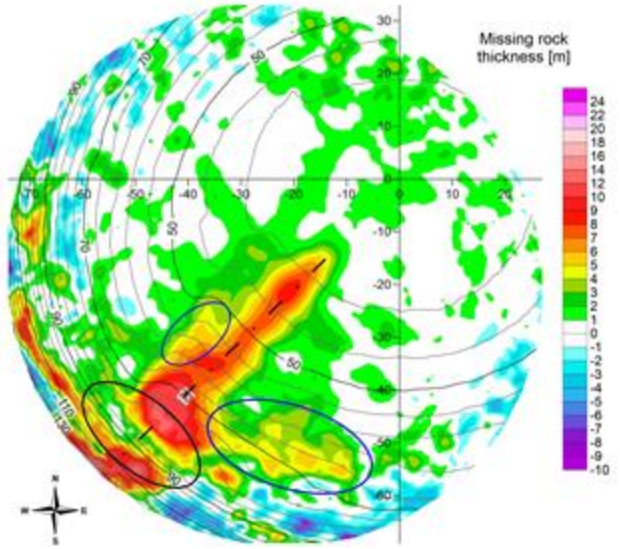
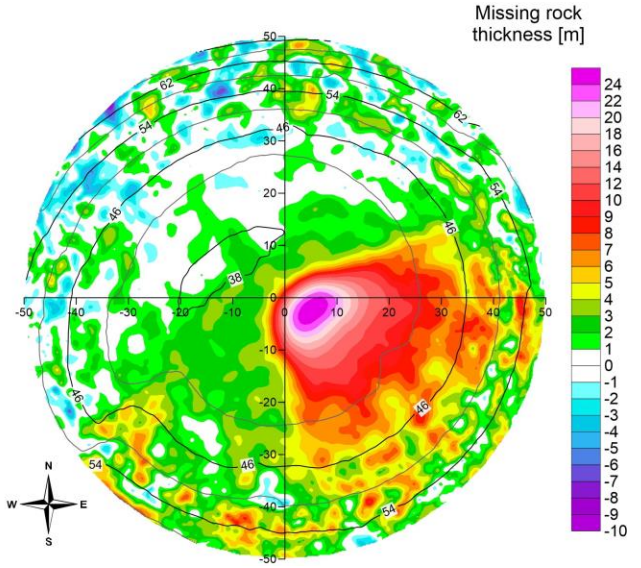
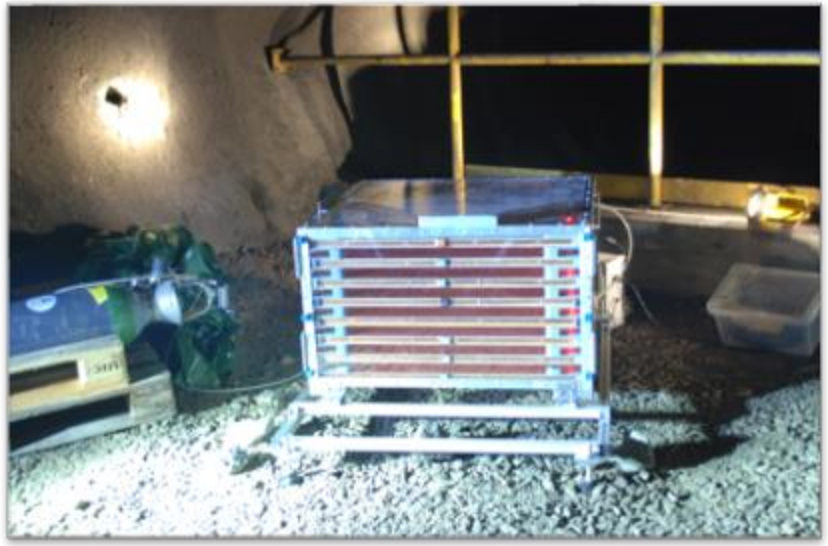
Muon Data & Data Visualisation

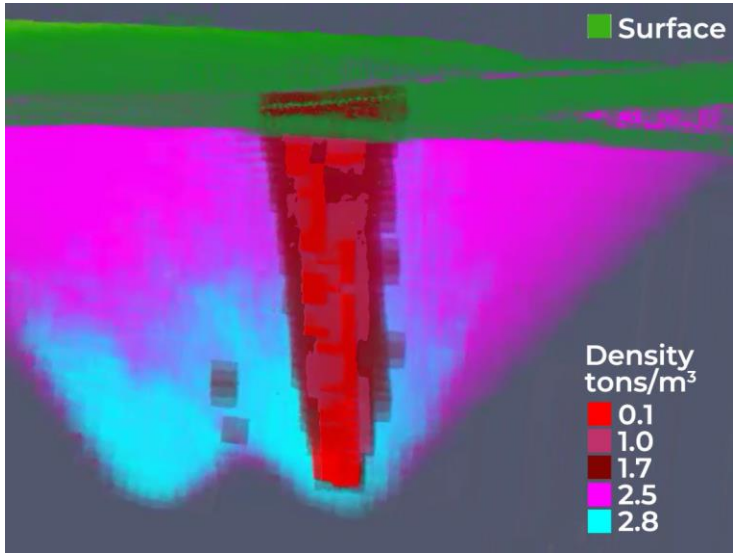
Polar coordinate plots, based on muon radiography





Muon telescope

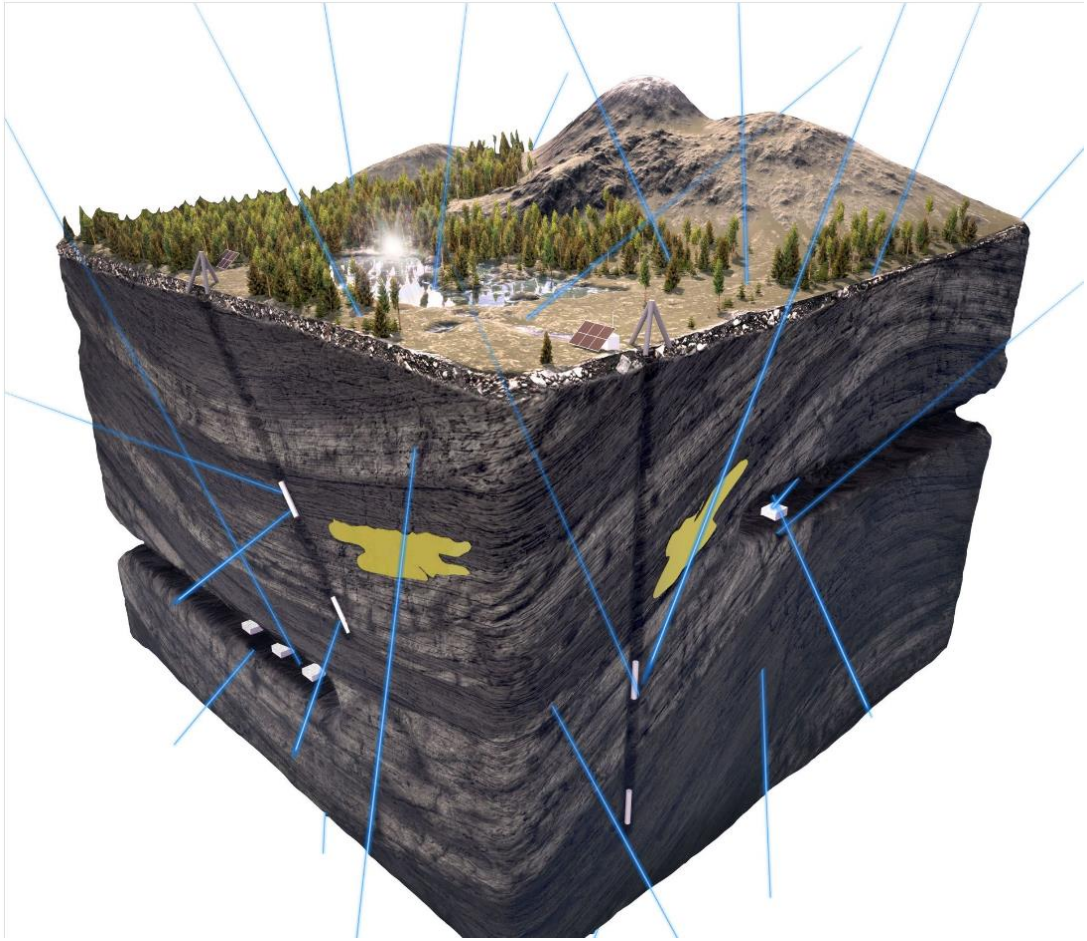




Muon tomography survey

Muon Imaging = Muography

- Muography utilises muons to image the **internal structures** of objects by detecting density variations in the matter
- **Imaged objects** can be as big as pyramids or volcanoes, and as small as a few meters in across
- **Safe**: no radiation sources
- **Passive and non-destructive method:** no man-made geophysical fields, no explosives
- **Complementary** to conventional geophysical methods (e.g., gravity, seismics)



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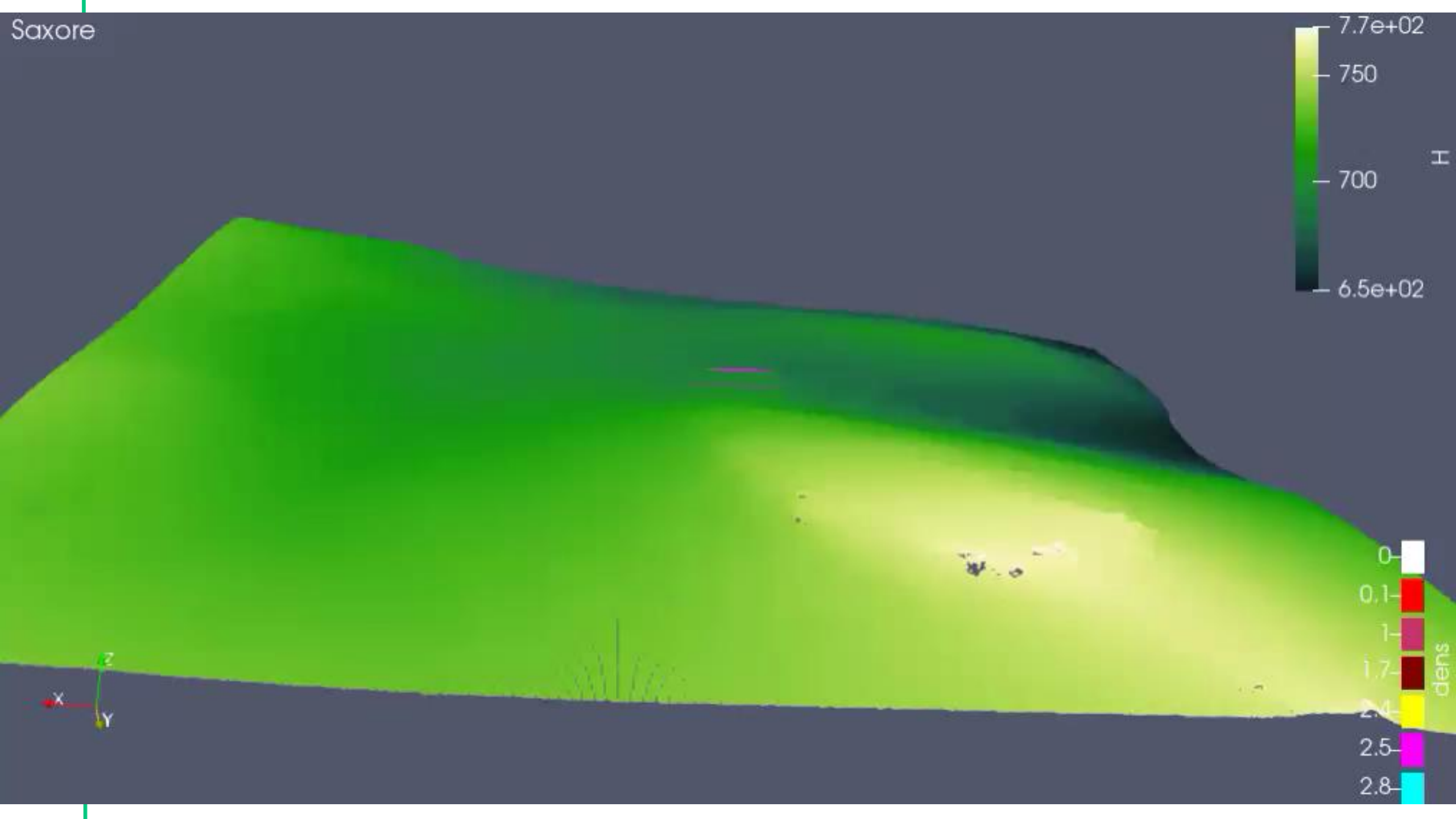
Muography in Mineral Exploration and Mining

- Target discovery
- Drilling optimisation
- Lithological characterisation
- Structural mapping
- Improving model uncertainty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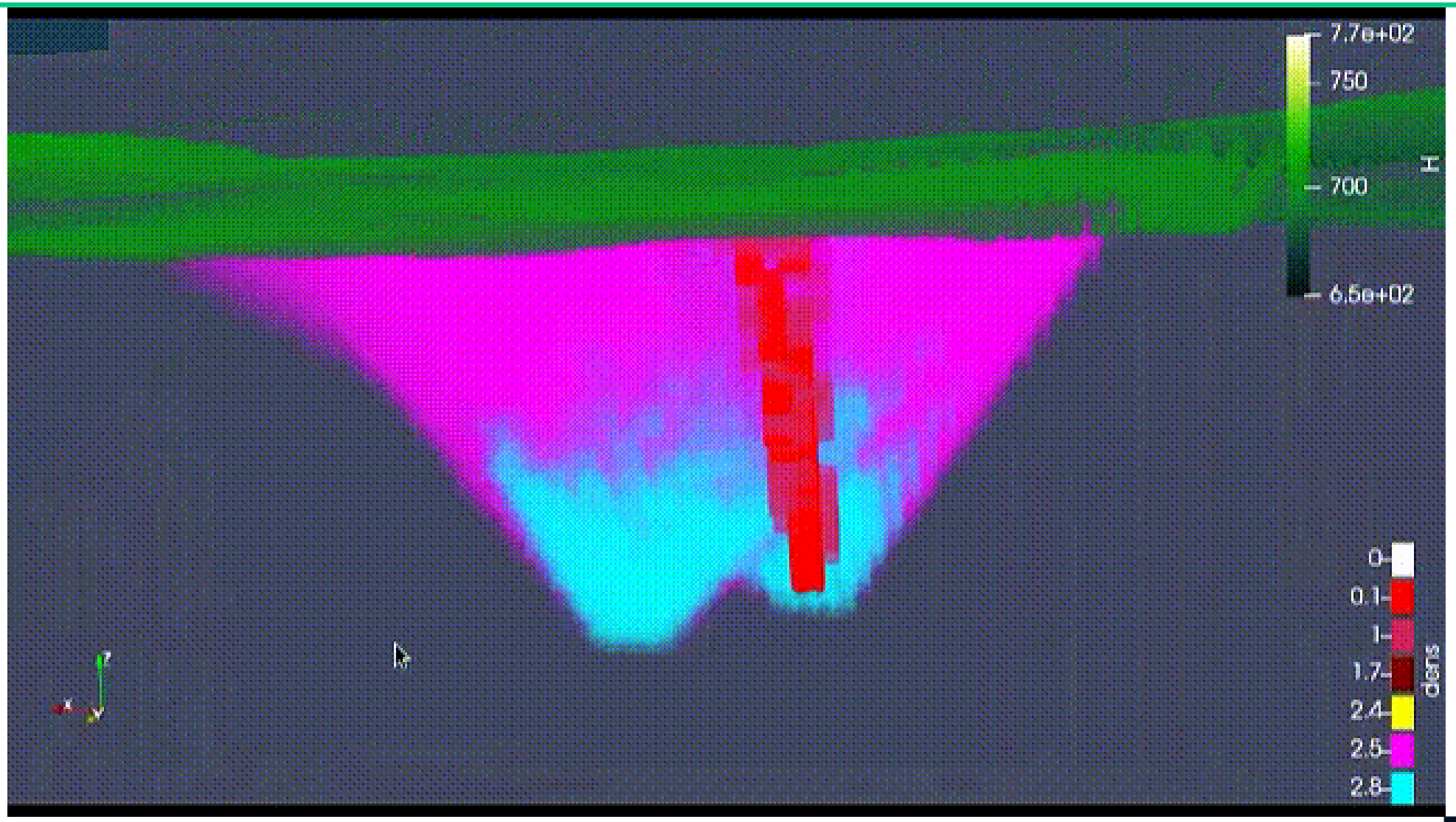
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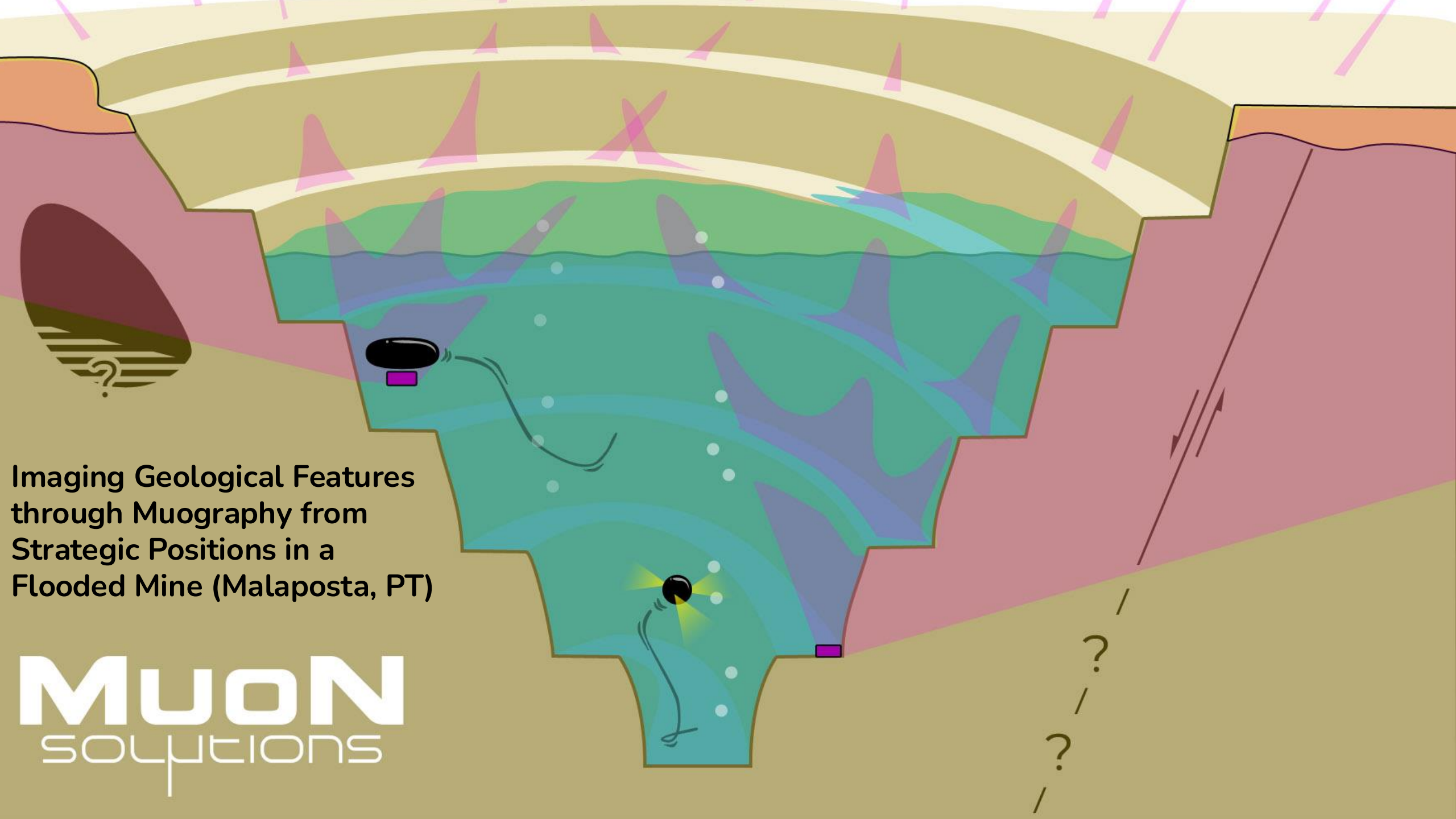
Muography in Flooded Mines

- Closed mines may still contain resources that can be explored using new methodologies
- Compliance with eco-efficient technological solutions for ore sourcing is essential

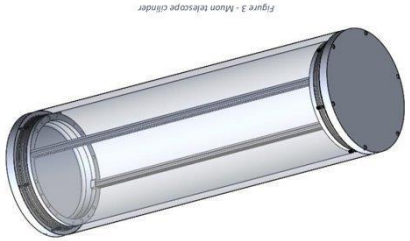


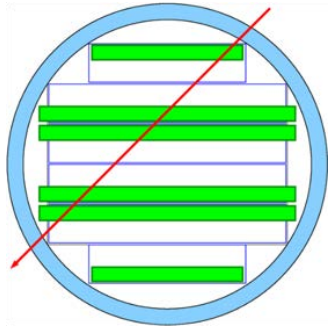
Imaging Geological Features through Muography from Strategic Positions in a Flooded Mine (Malaposta, PT)

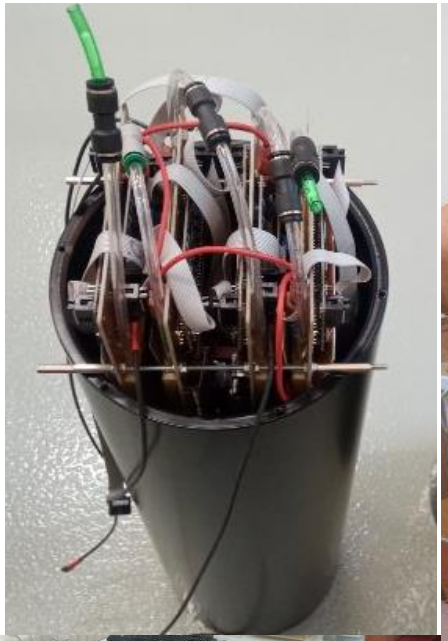
MUON solutions

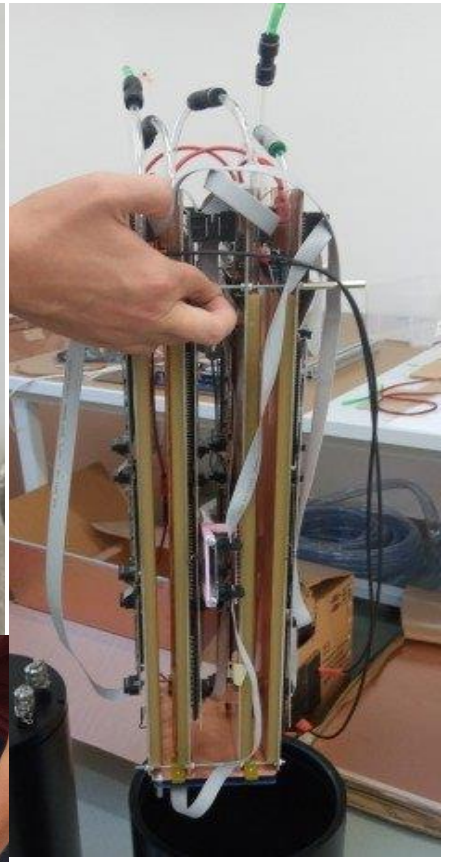
T3.1 Development Progress

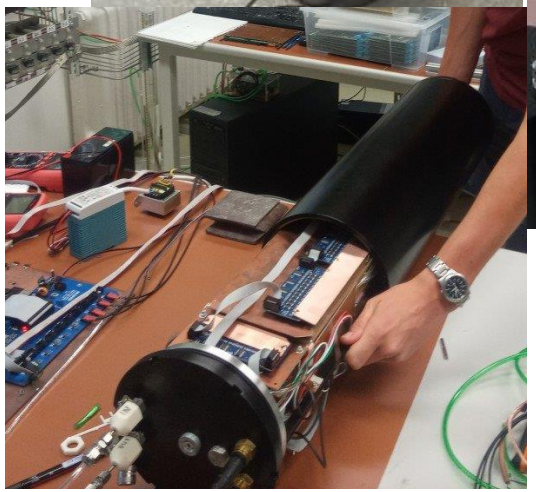
Muon detector + vessel



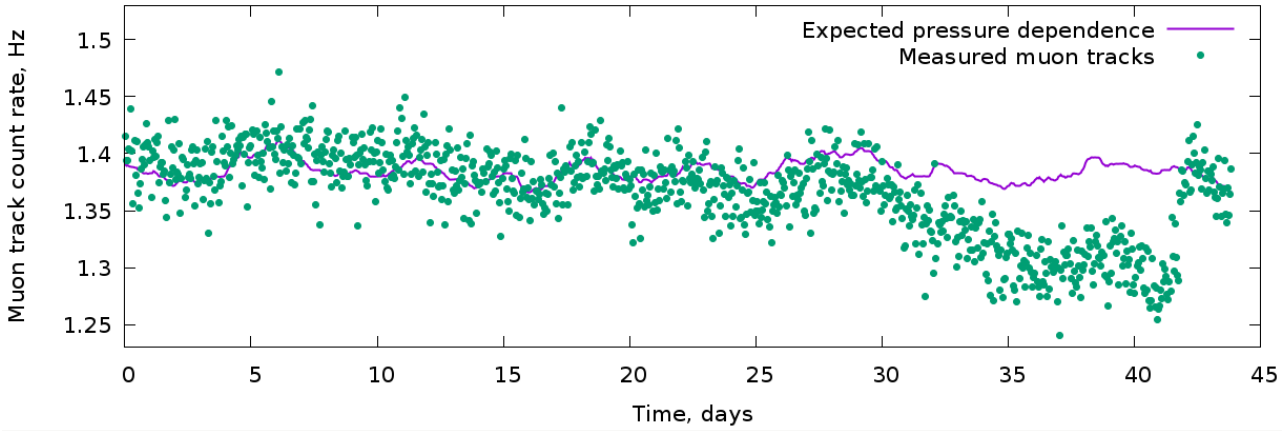






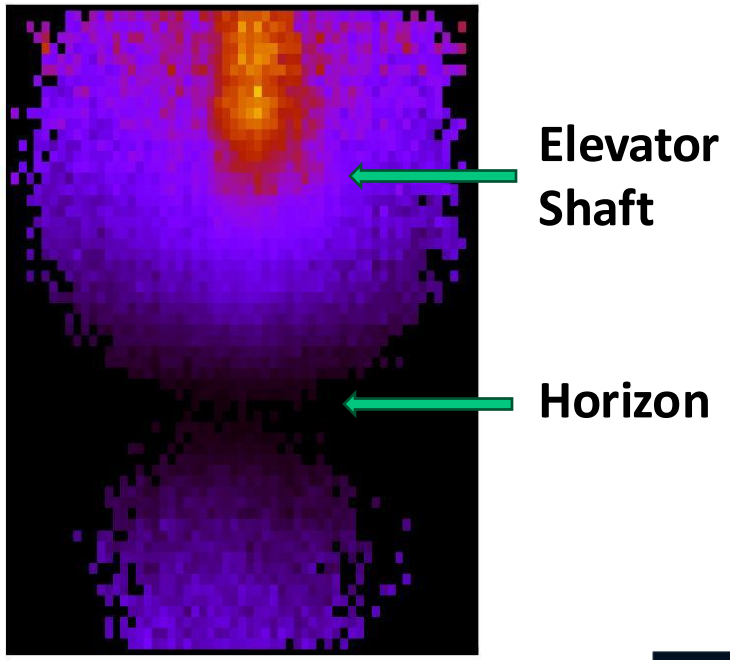


IN LAB→ 6 weeks operation sealed mode!



First Long-Term Sealed Measurement (Nov. 2024)

- Detector is now underground (20 m depth), and underwater in a shallow water tank!
- 42 days confirmed operation



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Transition

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Pilot 6 - Portugal

Use Case: In-Situ Underwater Exploration Technology Validation for Water-Filled Mines

Pilot 6.1

1) Muon imaging and monitoring instrumentation for mining applications and for in situ underwater mining exploration.

- Test and validation of Underwater muon telescope and muon imaging system
- In Malaposta Open Pit
- Underwater Muon Telescope prototype
- EVA AUV to transport/deployment and recover of the Muon Telescope

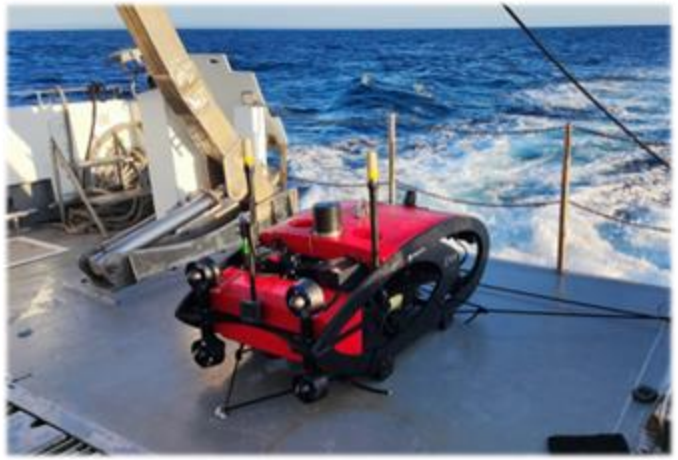
Pilot 6.2

2) Underwater vehicle for in situ exploration in flooded mines and **AUV** derived 3D imaging

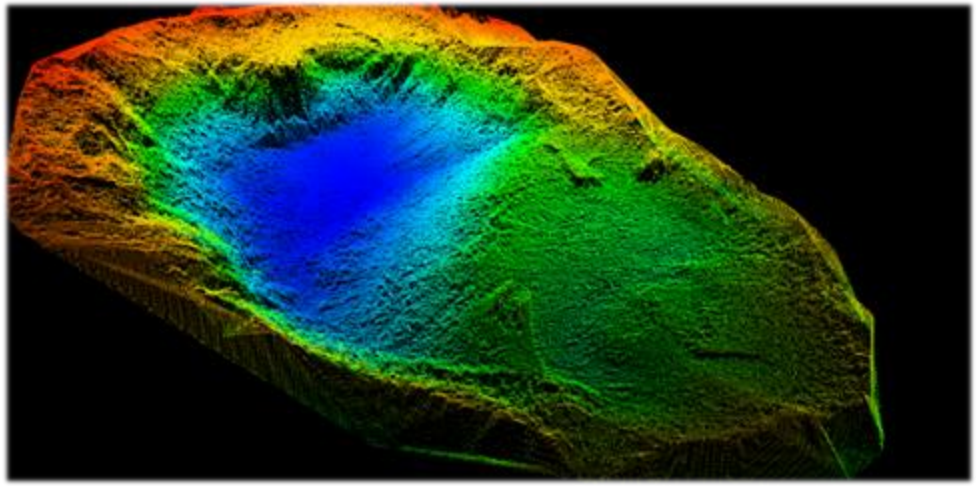
- Test and validation of new autonomy capabilities and support systems
- In Urgeiriça & Malaposta Open Pit
- With the Adapted UX1Neo

EVA ROV/AUV

Muon telescope precise Transporter/ Deployer & Recover (T3.1)



- Hybrid ROV/AUV
- Full 6DOF control
- Autonomous navigation
- Precision & accurate localization
- Advanced perception sensors and systems
- Used in multiple sea deployments for inspection & mapping applications



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Pilot 6 - Portugal

Malaposta Open Pit

- “Malaposta” gneissic quarry
- Flooded open pit with multiple plateaus and 80m depth
- Ramp access to water
- Possible local storage facilities
- Electrical power generator available
- 4G communications
- Partial aerial lidar scan of environment

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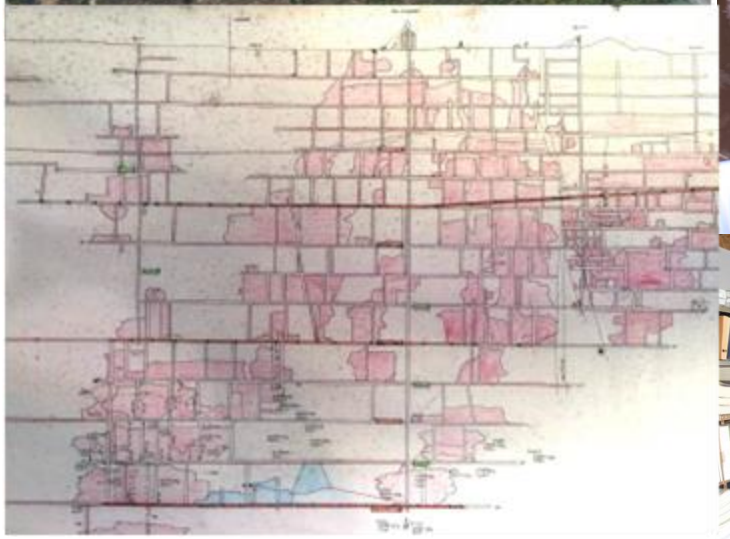
Pilot 6 - Portugal

Urgeiriça Mine

- Main shaft easily accessed
- Water level at around 7m depth (easy access)
- “Control room” next to the shaft entrance (around 20m)
- Fiber optic infrastructure to the shaft
- Power and internet communications
- Deployment winch at the shaft



UX1-Neo Underwater Explorer

- Full 6 DOF thruster control
- HDPE frame
- Flotation foam
- Multibeam sonar
- 2 Scanning sonars
- Main electronics cylinder
- 6 SLS units
- 6 Cameras with onboard processing

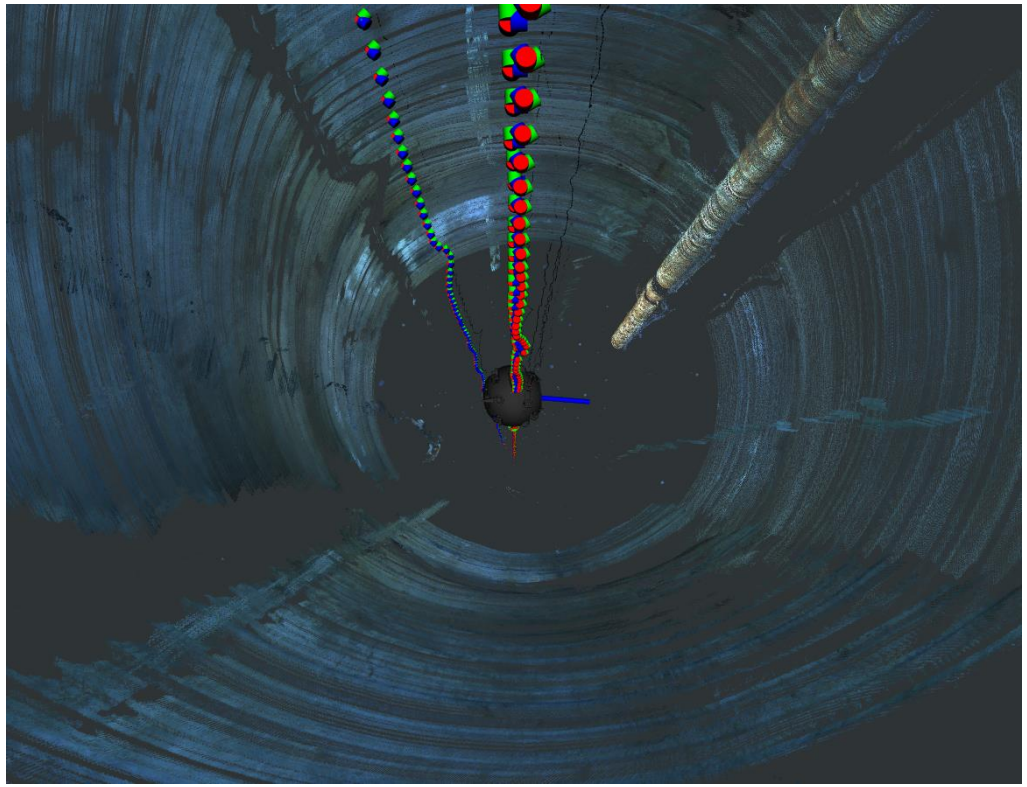
- Motor controllers and power distribution cylinder
- Fibre optic connector
- Pressure tolerant pendulum
- Pressure tolerant and removable batteries
- Removable disk enclosure
- 700x620 mm
- Less than 90 Kg

On the site

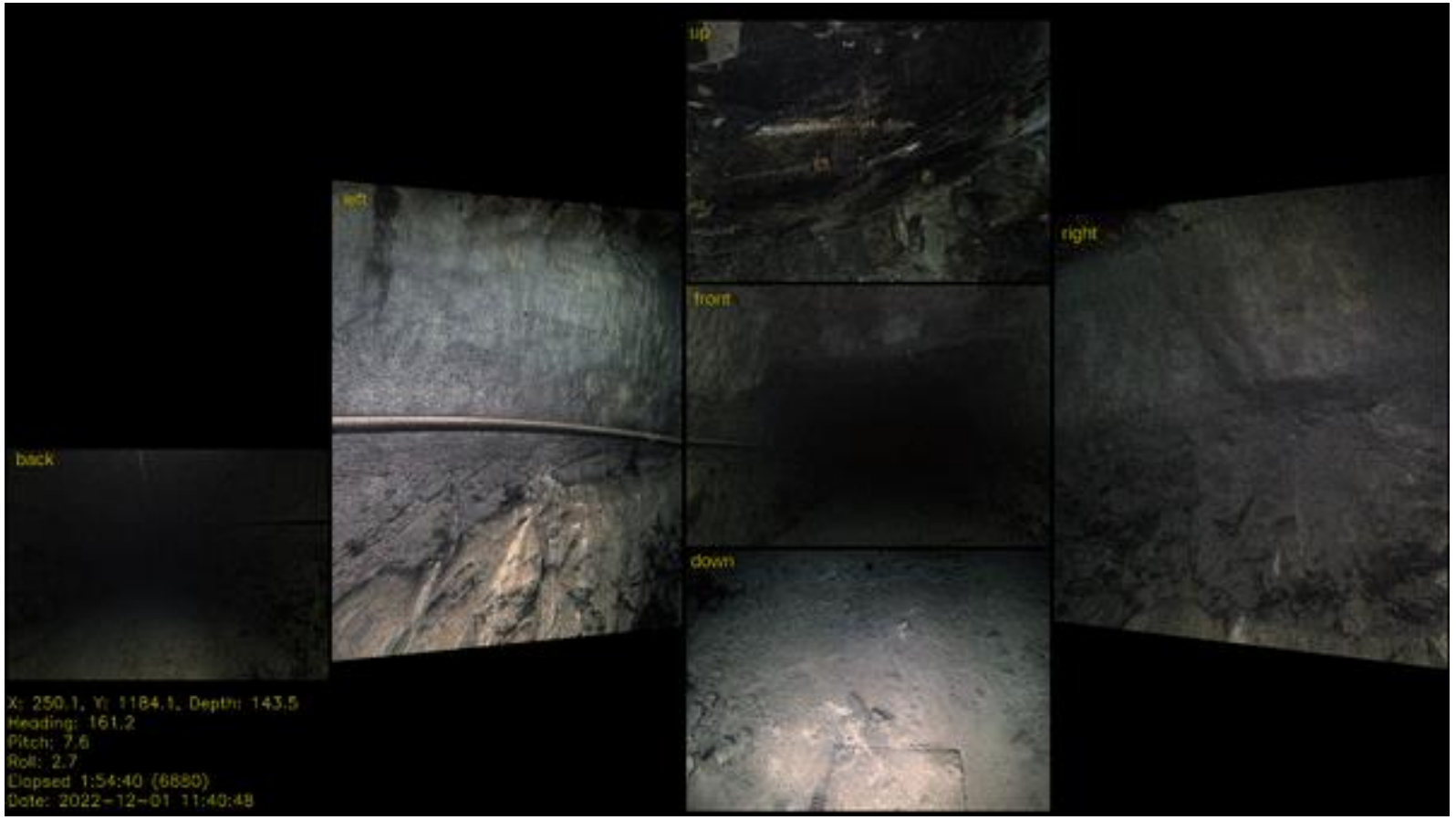
All data can be displayed in real-time during the dive

UX1-Neo Underwater Explorer

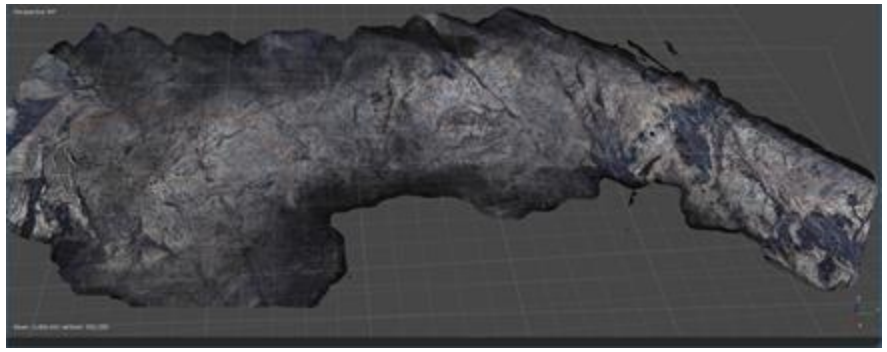
Example of UX1-neo cameras and SLS precise mapping

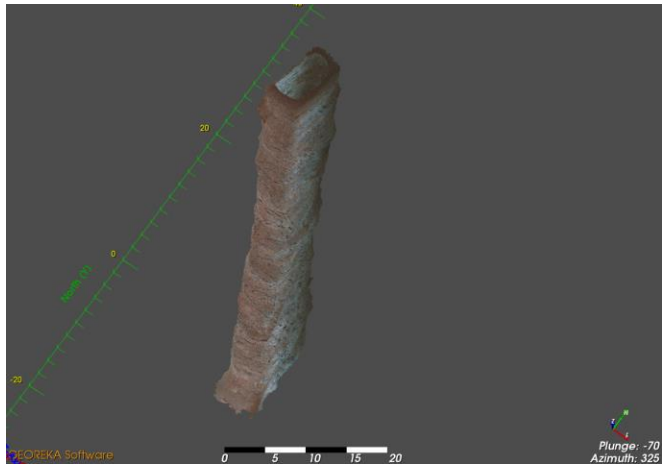


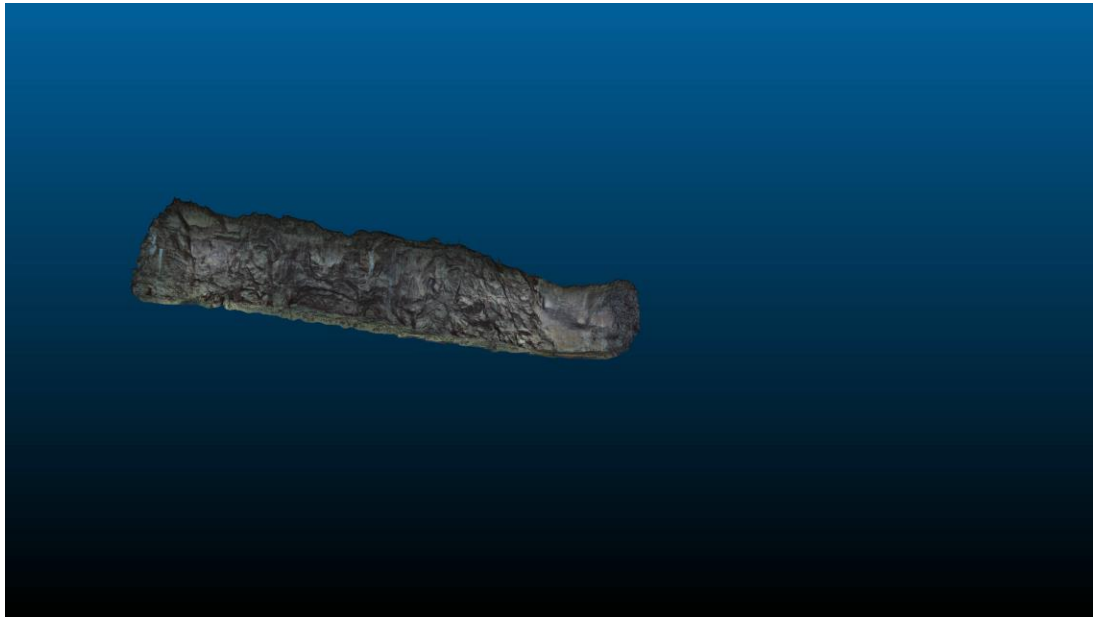
Cameras – Video stream



Cameras – Photogrammetry

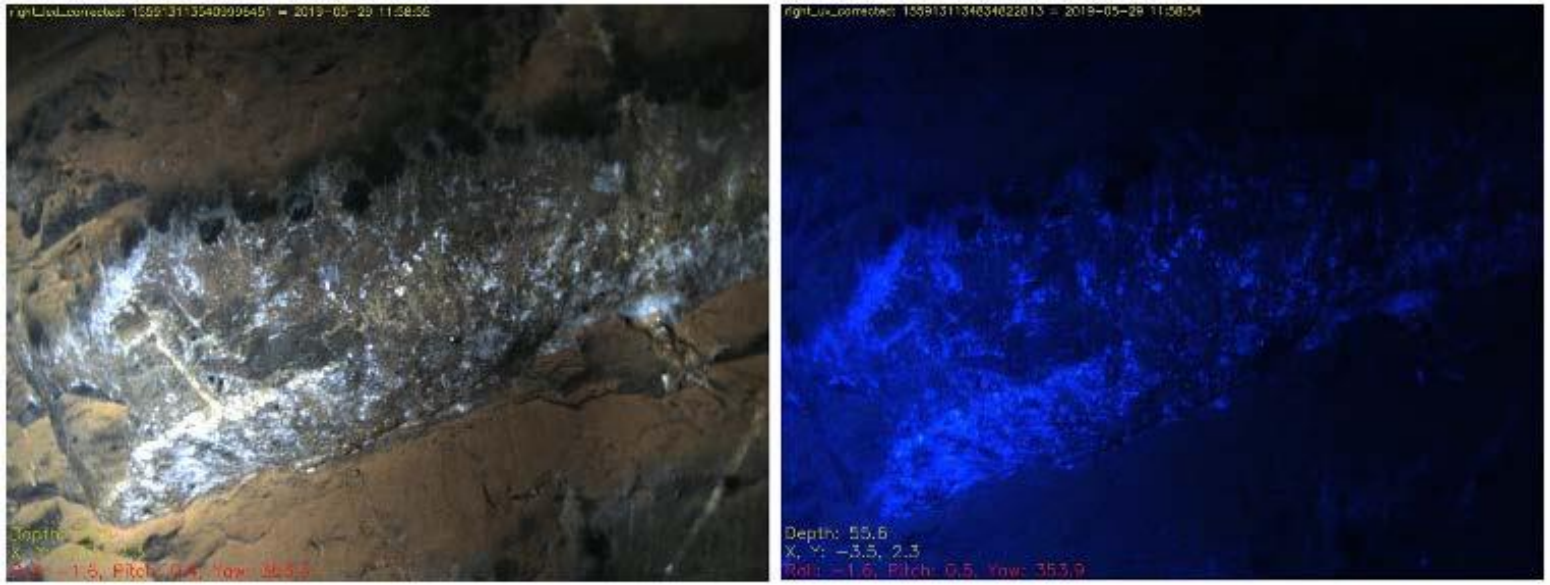






Example of UX1-neo Photogrametry

Cameras – UV light



Ecton Mine, UK - Mineralisation examples

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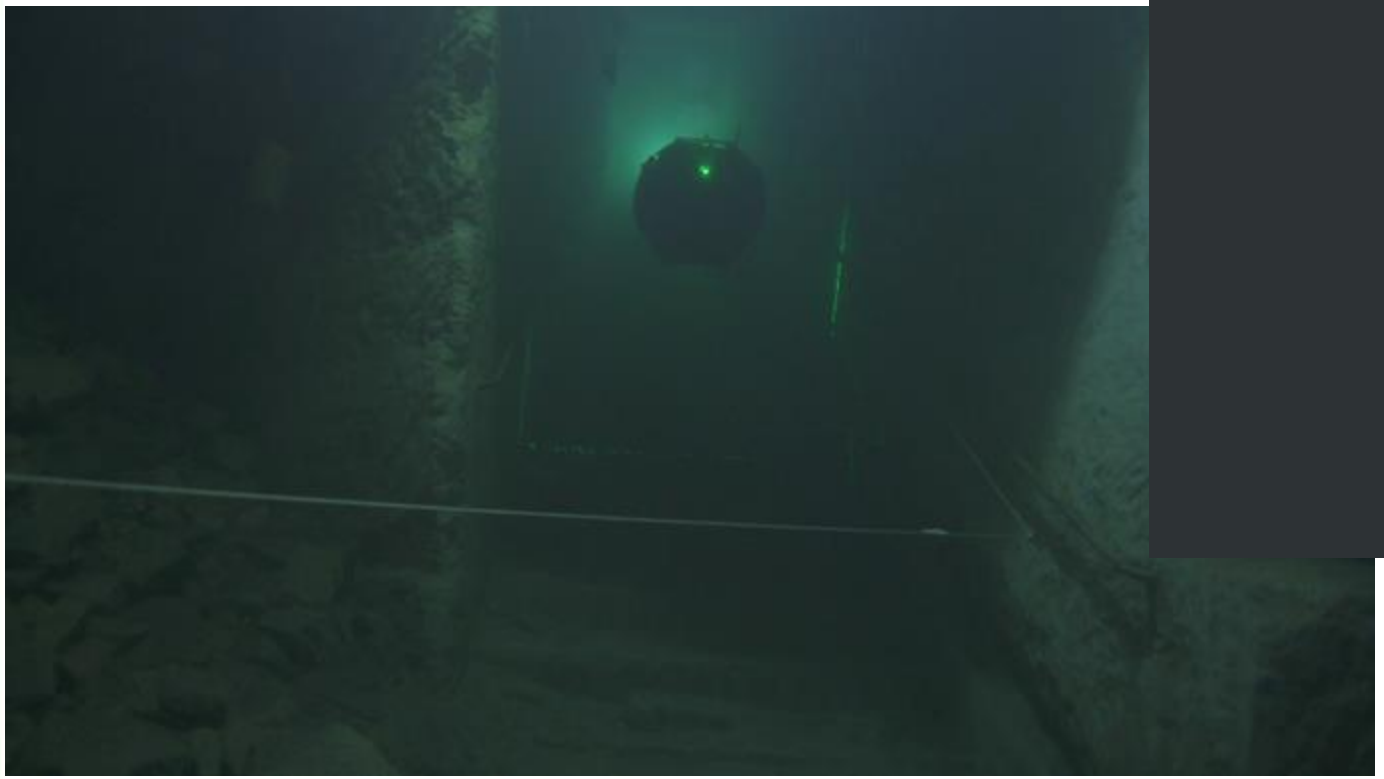
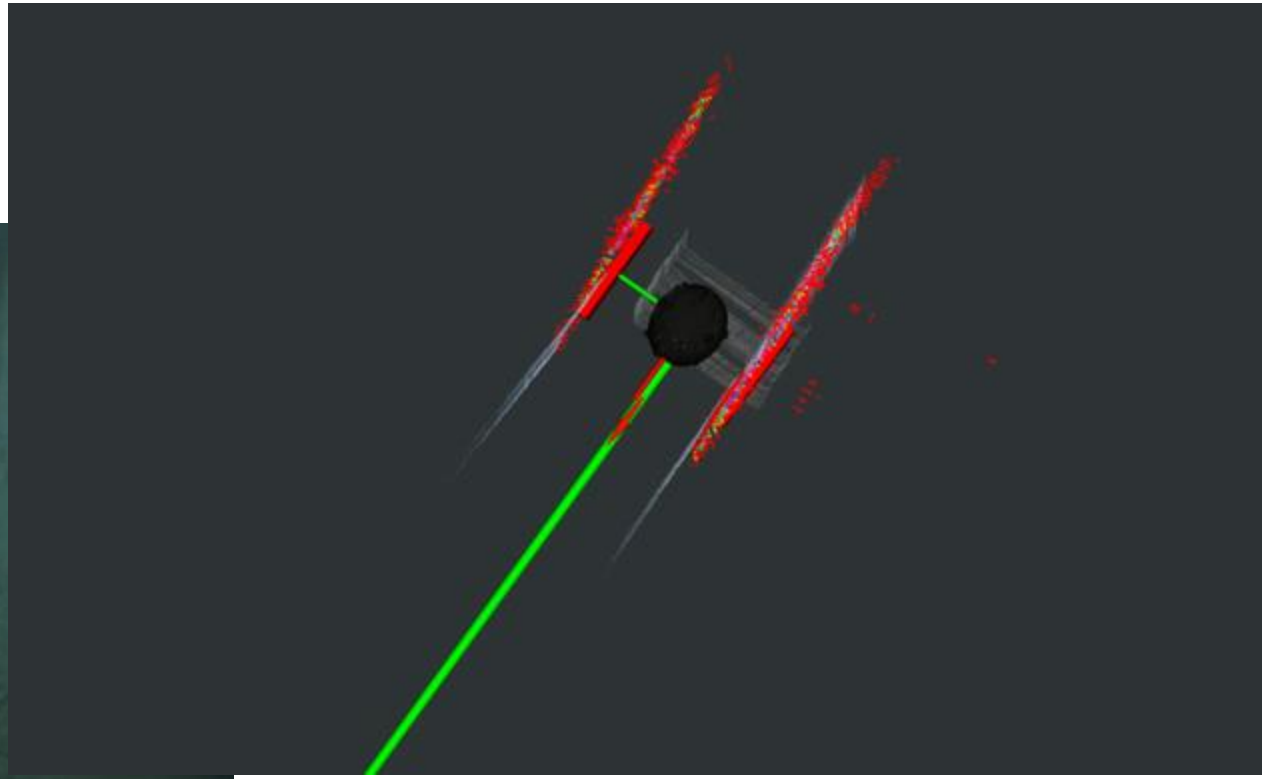
Example of UX1-neo autonomous operation (untethered)





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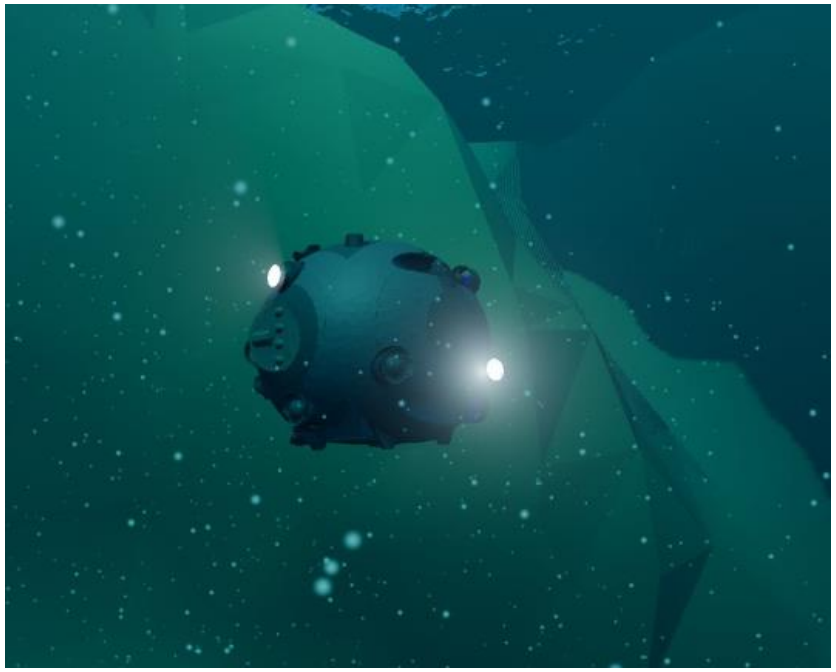
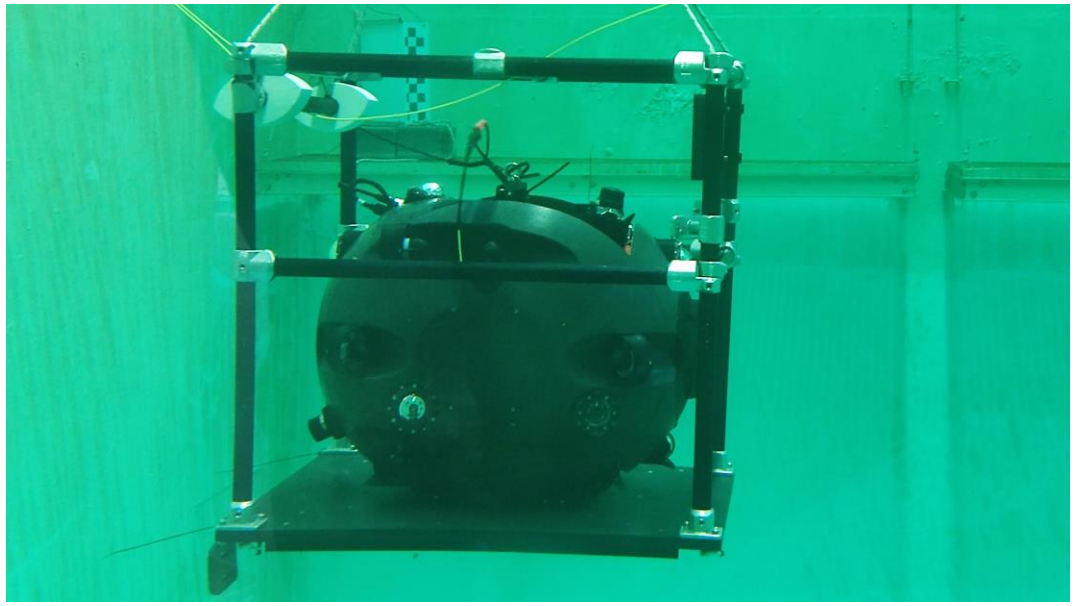
UX1-Neo Simulation

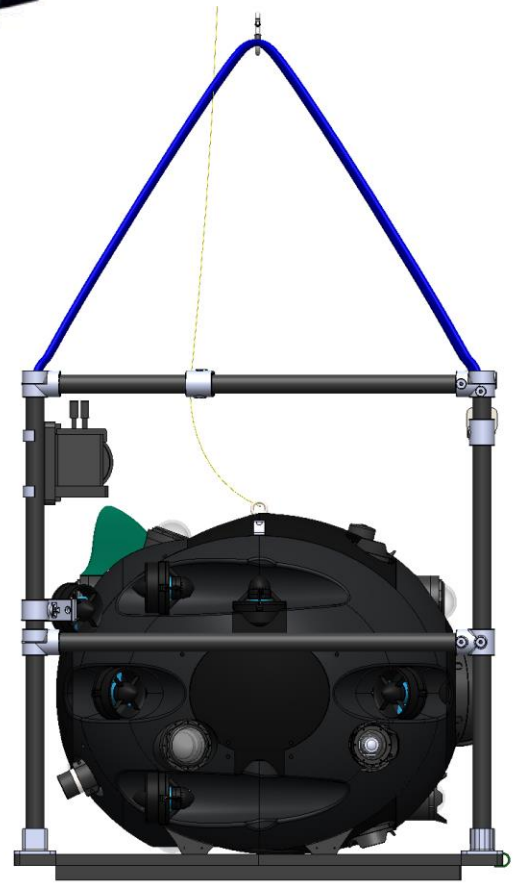


UX1-Neo Underwater Explorer

New autonomy capabilities (optical link)



LUMA X



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Thanks for your attention!

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EXTRA MATERIALS & PHOTOS

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WP3 Eco Efficient technological solutions for exploration, electrification and extraction

Stage one Ore Exploration

T3.1 Muon imaging and monitoring instrumentation for mining applications and for in-situ underwater exploration

T3.2 Underwater vehicle for in situ exploration in flooded mines, and UAV-derived 3D imaging

Stage two Mine Production

T3.4 Electrification of underground trucks

T3.5 Workload scheduling and planning

→ **ORE**[1]

Pipeline and Expected outcomes

T3.3 X-ray scattering and computed tomography

T3.6 CPS for system drill behaviour

1: Ore sourced efficiently by

-New tools for exploration and extraction
-Optimised resource consumption
-Innovative solutions applied to maximize efficiency on the mine cycle


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Underwater Explorer AUV
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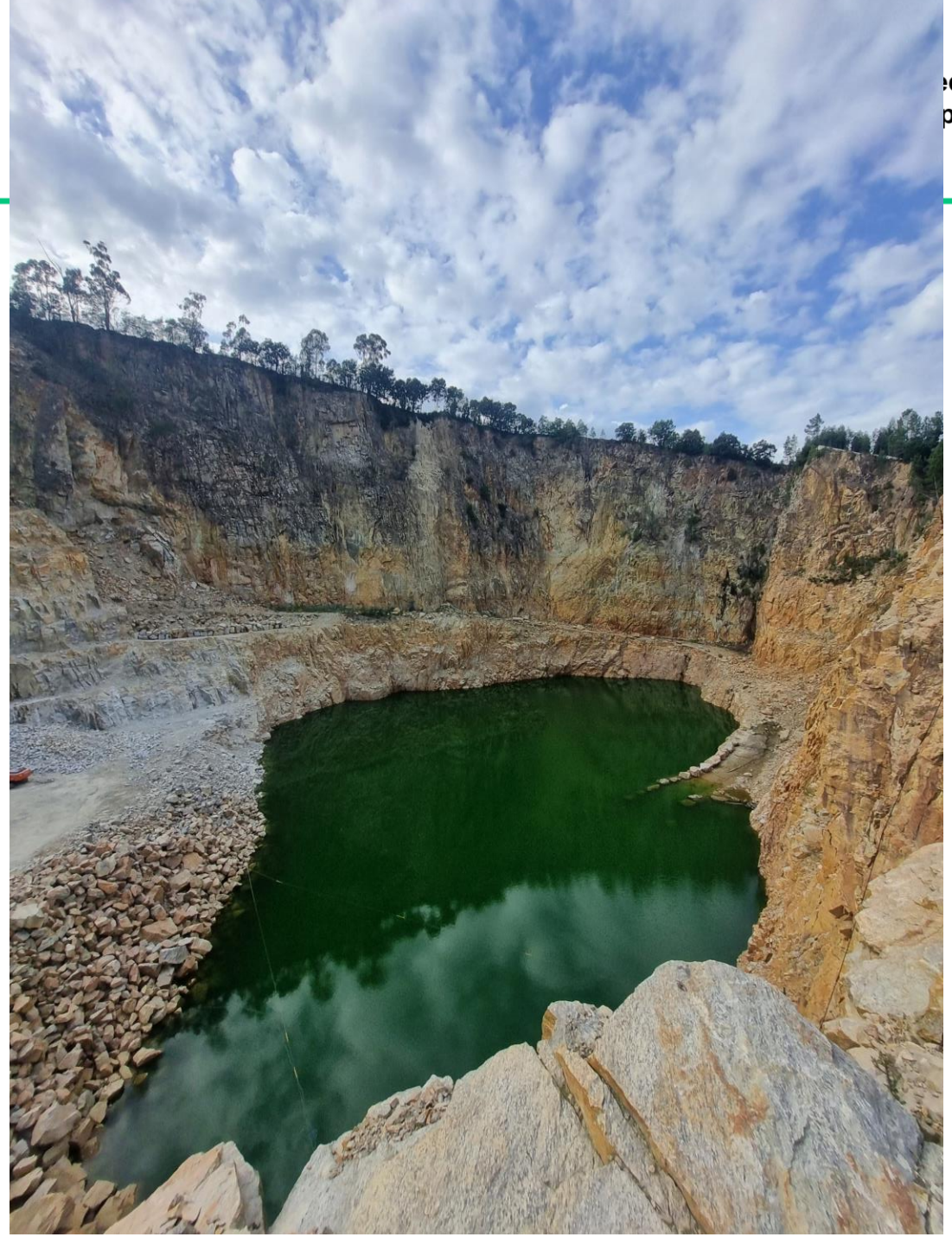

Mines take an average of

16.3 years from discovery to production

Discovery, exploration, studies
12.3 years

Waiting time after feasibility studies
1.7 years

Construction to production
2.3 years

Mines take longer to go online due to longer exploration, permitting, financing, despite shorter construction time