

# UNEXMIN

AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

## FINAL MEETING OF THE PROJECT

ROYAL BELGIAN INSTITUTE OF NATURAL SCIENCES, BRUSSELS, 25<sup>TH</sup> OF SEPT. 2019



**TODAY'S EXPLORATION FOR FUTURE EXPLOITATION:  
UNEXMIN UNDERWATER EXPLORER FOR FLOODED MINES**

NORBERT ZAJZON, UNIVERSITY OF MISKOLC  
COORDINATOR OF THE PROJECT

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



# UNEXMIN PROJECT OVERVIEW

**UNEXMIN** is an EU-funded project that develops a novel **robotic system** for the **autonomous exploration and mapping** of **flooded underground mines**. The robotic explorer (UX-1) will use non-invasive methods for autonomous 3D mine mapping for **gathering geological information**.

- **EU funded H2020 research project** (RIA: Research and Innovation Action)
- Grant Agreement number: **690008** (H2020-SC5-2015)
- **13 partners** (now 12) (7 countries)
- **45 months duration**
  - (1<sup>st</sup> of February 2016 – 31<sup>st</sup> of October 2019)
- Funding sum: ca. **4.87 million Euro**
- Outcomes: **Three working prototype robots**



Spin-off company offering the technology



[unexmin.eu](http://unexmin.eu)

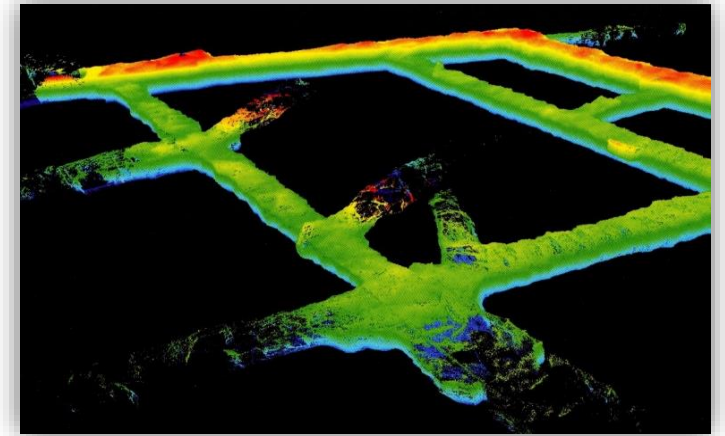
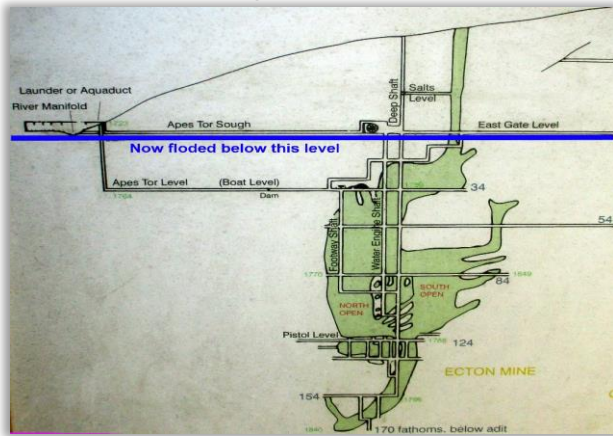


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# UNEXMIN PROJECT CONCEPT

- There are of the order of 30,000 closed mine sites in Europe and many of them flooded and potentially contain considerable amounts of valuable mineral raw materials.
- The closure of a mine is usually more related to actual economics and technological challenges than to the actual depletion of mineral resources.
- Often commodities were disregarded during the operational life of the mine (such as fluorite in lead/zinc mines).
- These mines are now flooded and the last piece of information of their status and layout is decades, or over a hundred years old.



# UNEXMIN CONSORTIUM

- University of Miskolc
  - Tampere University of Technology, Department of Mechanical Engineering Systems
  - Universidad Politécnica de Madrid, Centre for Robotics and Automation
  - INESC TEC – Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência
  - Resources Computing International Ltd
- 
- La Palma Research Centre for Future Studies
  - Geological Survey of Slovenia
  - ~~■ Geoplano Consultores Sa~~
  - The European Federation of Geologists
  - Geo-montan Kft
- 
- Empresa de Desenvolvimento Mineiro
  - Ecton Mine Educational Trust
  - Center za Upravljanje z Dediscino Zivega Srebra Idrija

## Technology development

## Technology exploitation

## Key stakeholders



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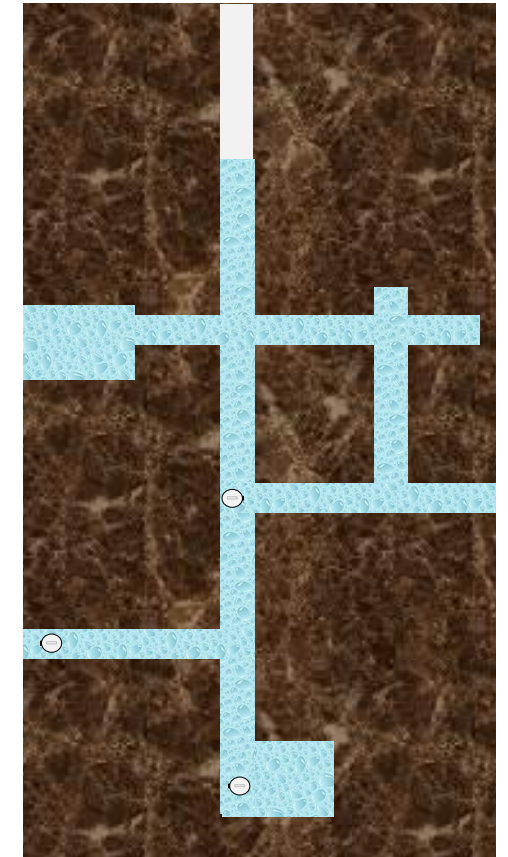
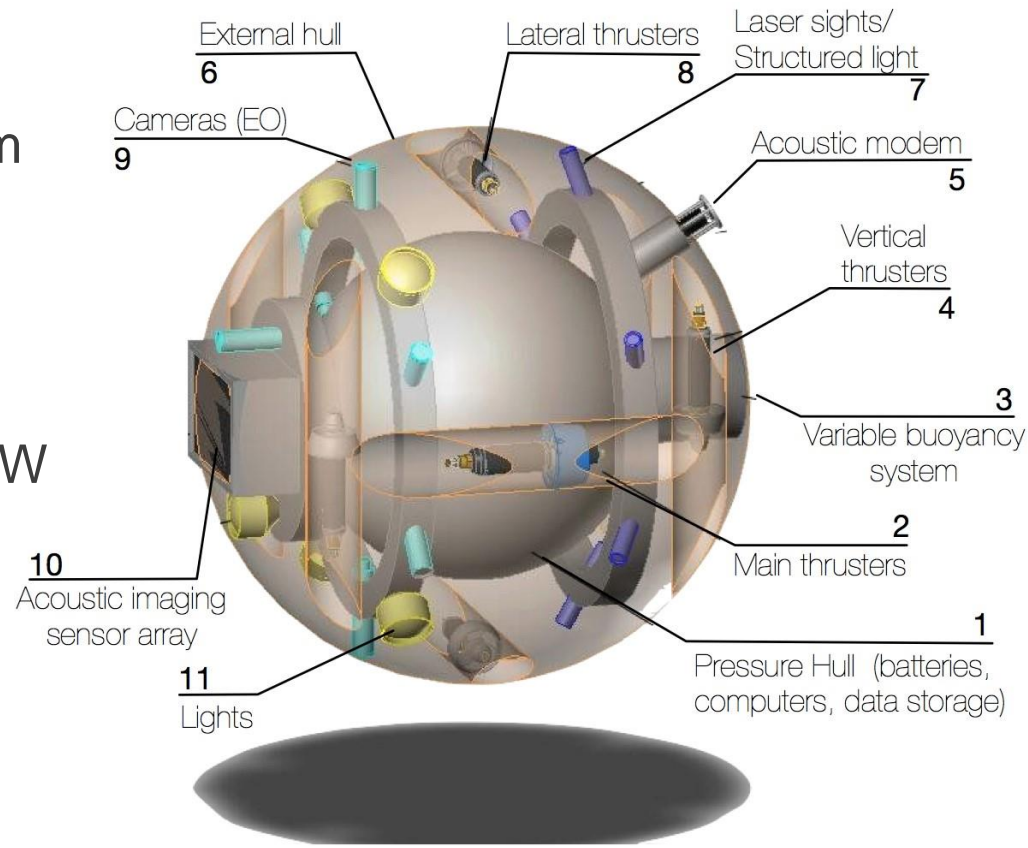


# UNEXMIN H2020 PROJECT OVERVIEW

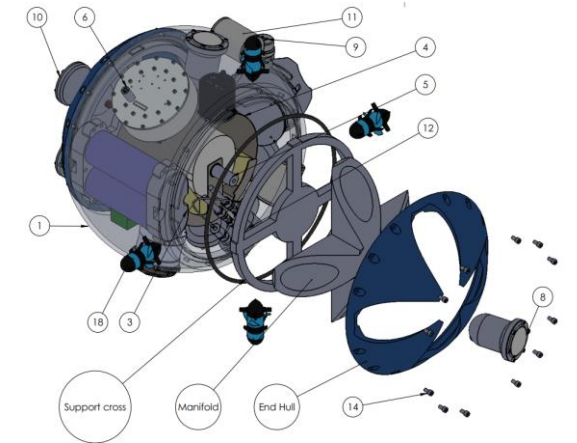
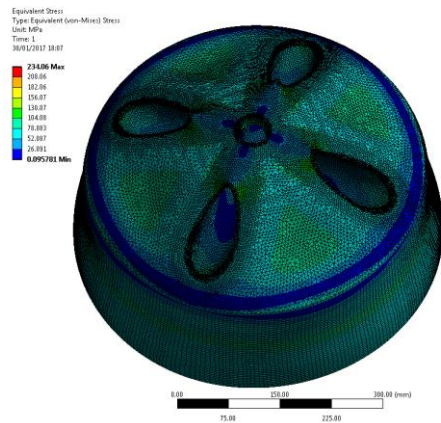
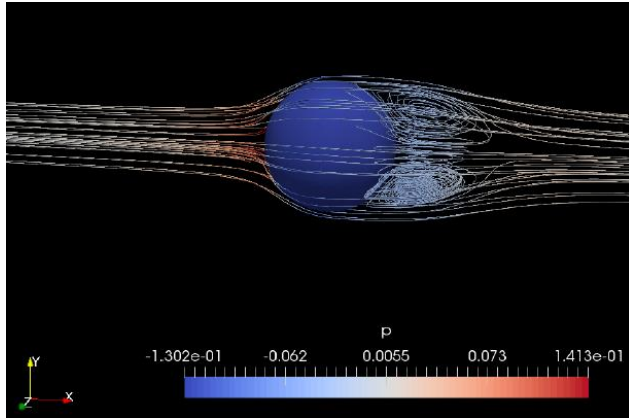
## PRELIMINARY PLANS/IDEAS

### Physical characteristics

- **Max operational depth:** ~500 m
- **Shape:** spherical
- **Size:** ~ 0.6 m diameter
- **Expected weight:** 112 kg
- **Neutral buoyancy**
- **Power consumption:** 150-300 W
- **Max speed:** 1-2 km/h
- **Autonomy:** up to 5 hours
- **Thrusters power:** 2-5 kgf

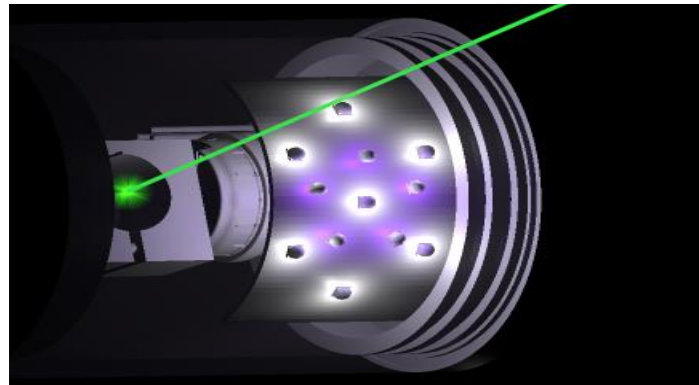
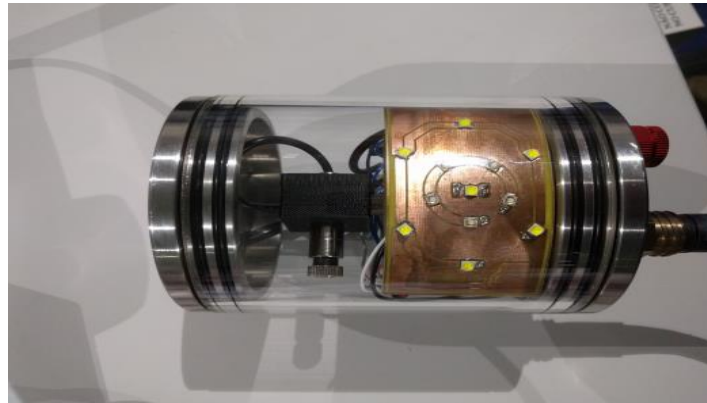


# MECHANICAL DESIGN, TESTING AND PRODUCTION



# SLS – ROTATING LASER AND ILLUMINATION – PROTOTYPE PRESSURE TEST

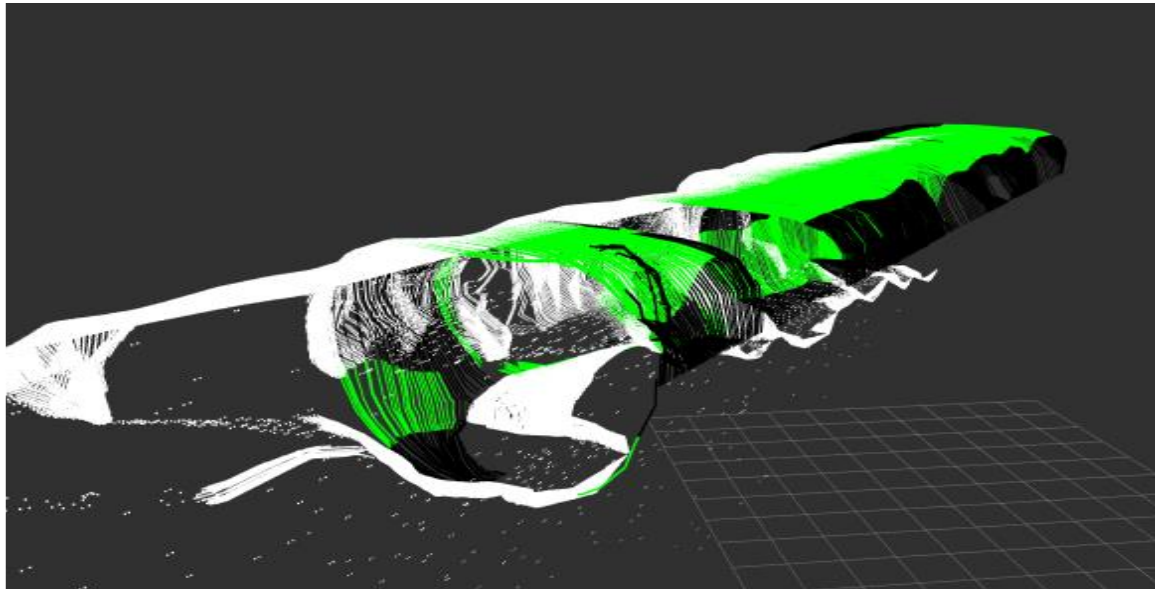
- **Completed first working prototype**
- Laser and LEDs in 100x100 diam. cylinder
- 120° rotating laser plane
- 7 light LED
- 5 UV LED (3W each)
- Curved PCB for LEDs
- Trigger control for Laser, lights and UV ...
- Current prototype resisted **130 bar**  
(max. limit of the chamber)



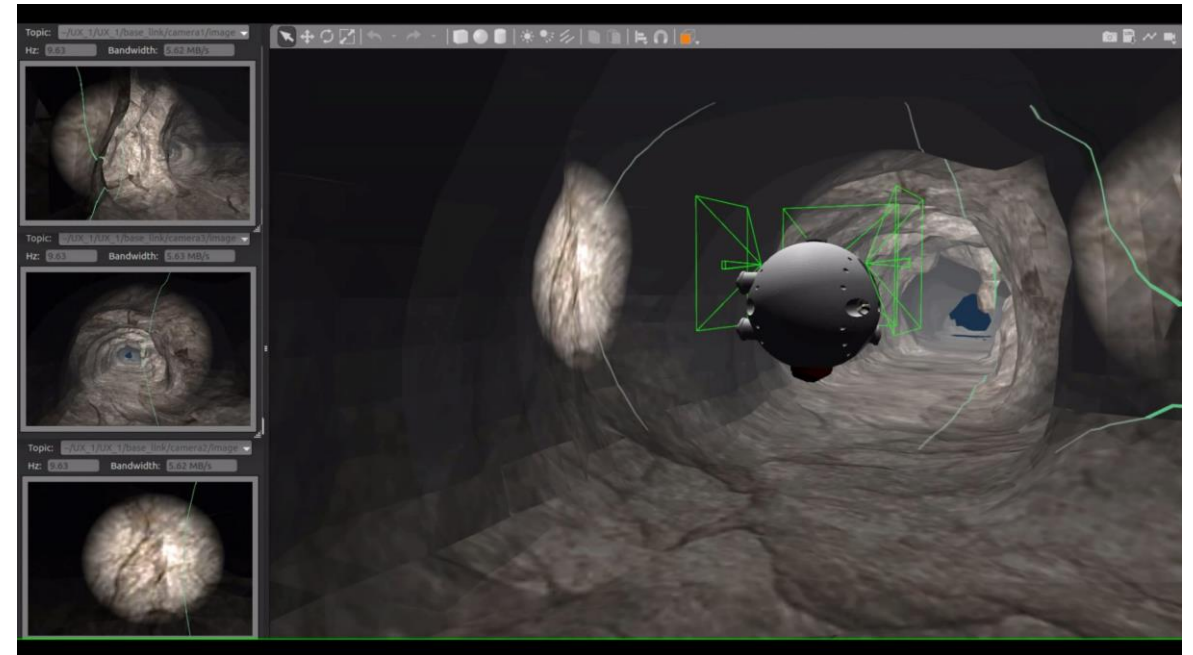


# SLS AND MULTIBEAM COVERAGE SIMULATION NAVIGATION

- Sensor simulation in UWSim /ROS
- Coverage analysis (Ecton mine data)
- Cameras, laser stripes and multibeam sonar



- Analysis of possible scenarios going on
- Creating virtual environment (in GAZEBO) for GNC simulations





# GEOSCIENTIFIC INSTRUMENTATION

## SELECTED METHODS / FINAL SOLUTIONS

### ■ Water testing methods

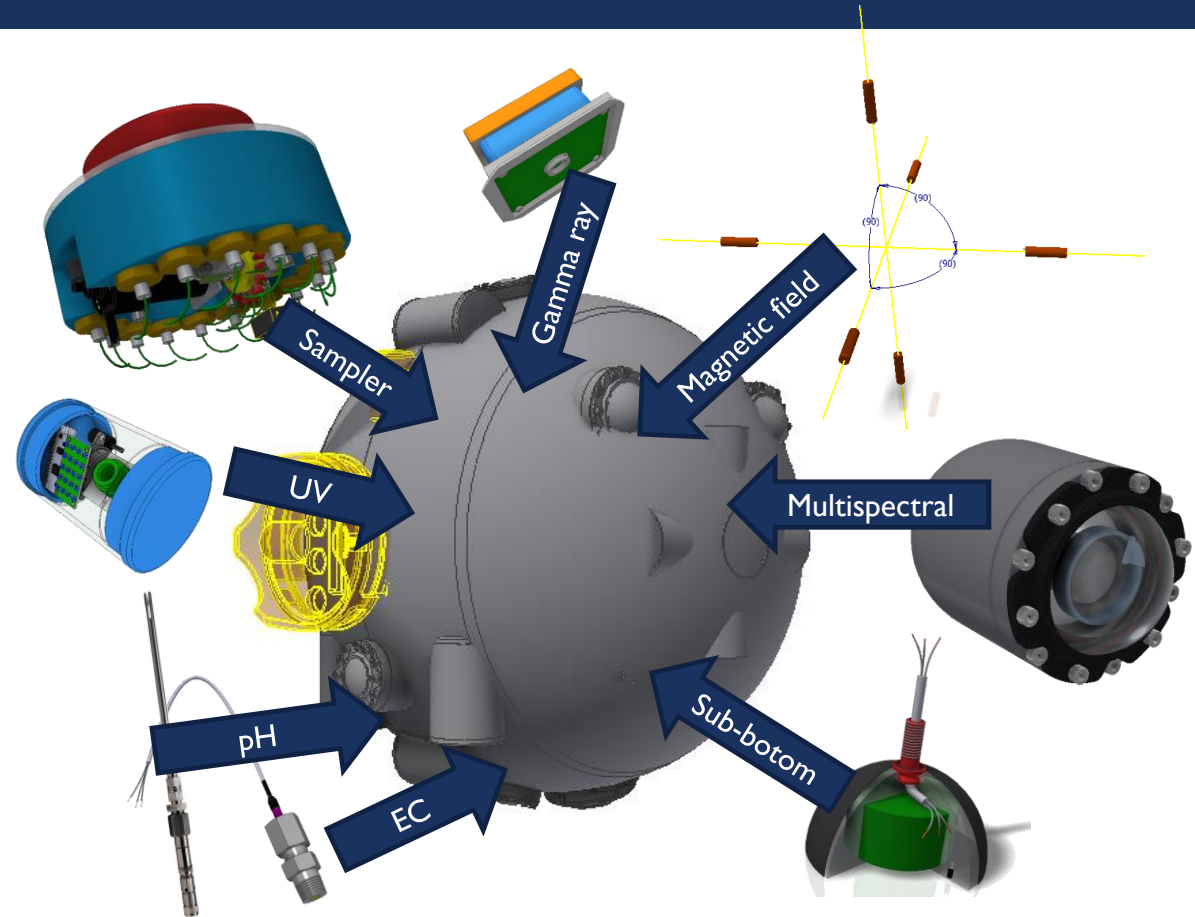
- Temperature
- Pressure
- pH
- Electrical conductivity
- Water sampling

### ■ Geophysical methods

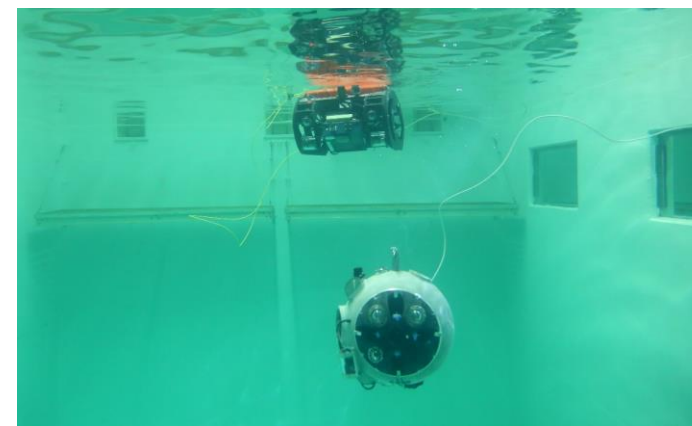
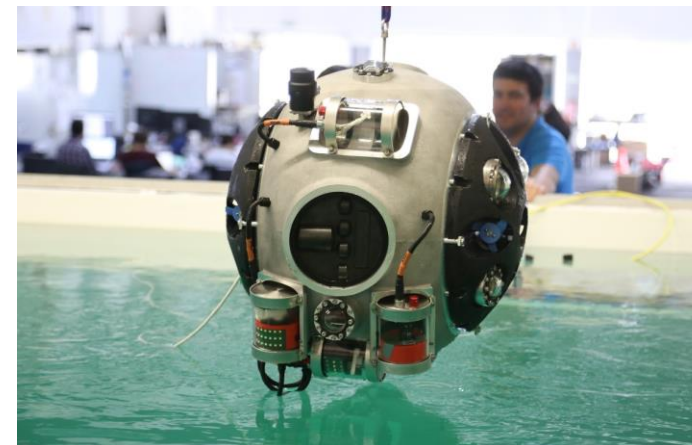
- Magnetic field measurement
- Natural (integral) gamma ray activity
- Sub-bottom sonar

### ■ Optical methods

- Multispectral unit
- UV Fluorescent imaging



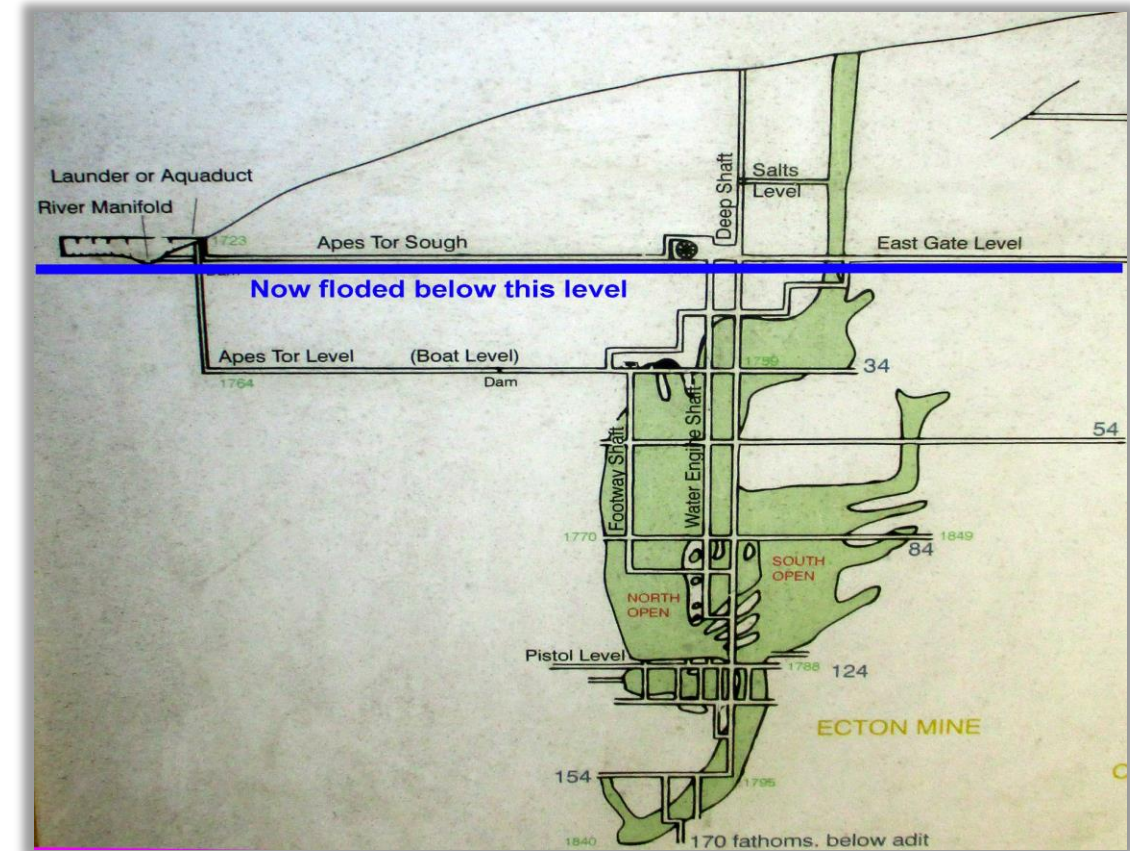
# ASSEMBLY AND TESTING OF UX-1A (NATA)



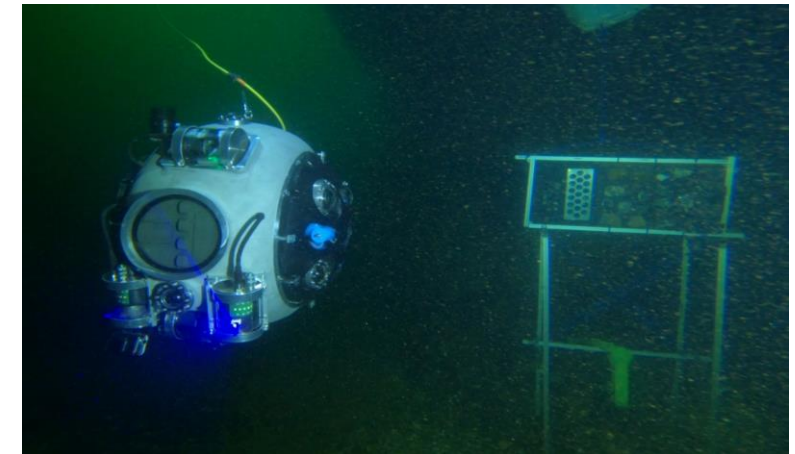
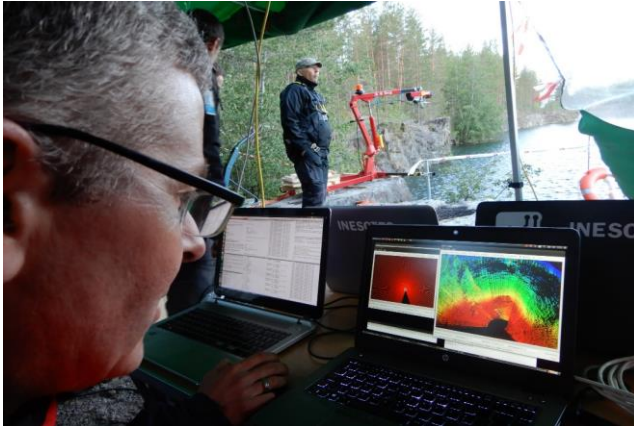


# DEMONSTRATIONS, PILOTS

- **Kaatiala, Finland (11-21<sup>st</sup> of June 2018)**
  - Pegmatite mine
  - Open-pit and small underground part
- **Idrija, Slovenia (10-21<sup>st</sup> of September 2018)**
  - Mercury mine, UNESCO Word Heritage site
- **Urgeiriça, Portugal (6<sup>th</sup> of March to 7<sup>th</sup> of April 2019)**
  - Uranium mine in granite pegmatite
  - Water level 7 m below surface
- **Ecton-mine, England (9-31<sup>st</sup> of May 2019)**
  - Cu – (Zn-Pb) mine (Mississippi Valley type mineralization)
  - National monument site
- **Molnár János cave, Budapest (24<sup>th</sup> of June to 5<sup>th</sup> of July 2019)**
  - 20 – 28 °C water reservoir for a thermal bath (Lukács Spa)
  - >7 km corridors, >100 m water depth

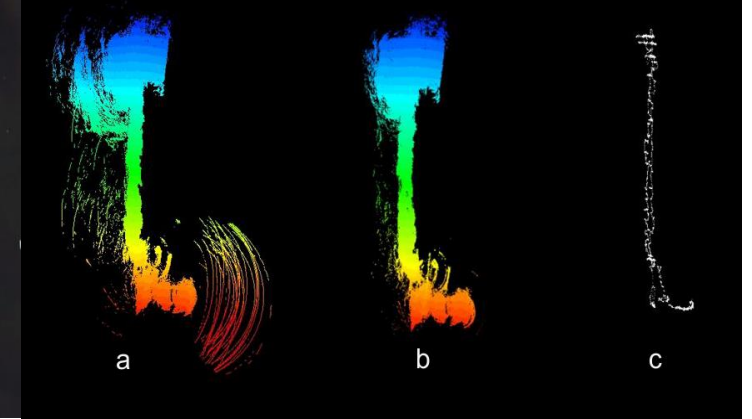
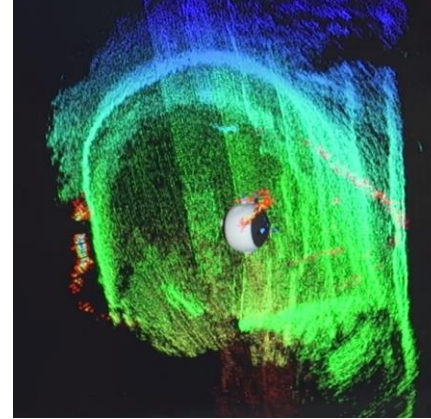
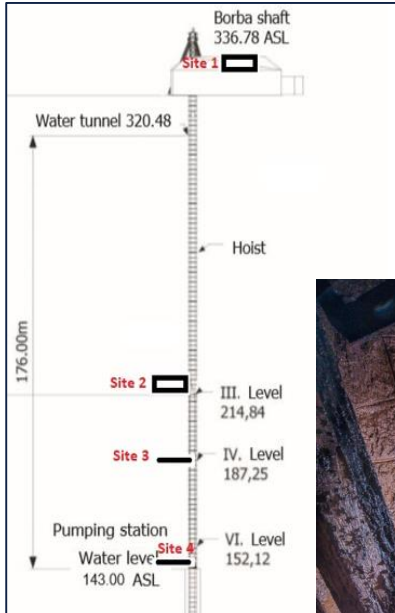


# 1<sup>ST</sup> REAL ENVIRONMENT TEST OF UX-1A (NATA) KAATIALA, FINLAND (11-21<sup>ST</sup> OF JUNE 2018)





# 1<sup>ST</sup> REAL MINE TEST OF UX-IA (NATA) IDRIJA MERCURY MINE, SLOVENIA (10-21<sup>ST</sup> OF SEPTEMBER 2018)



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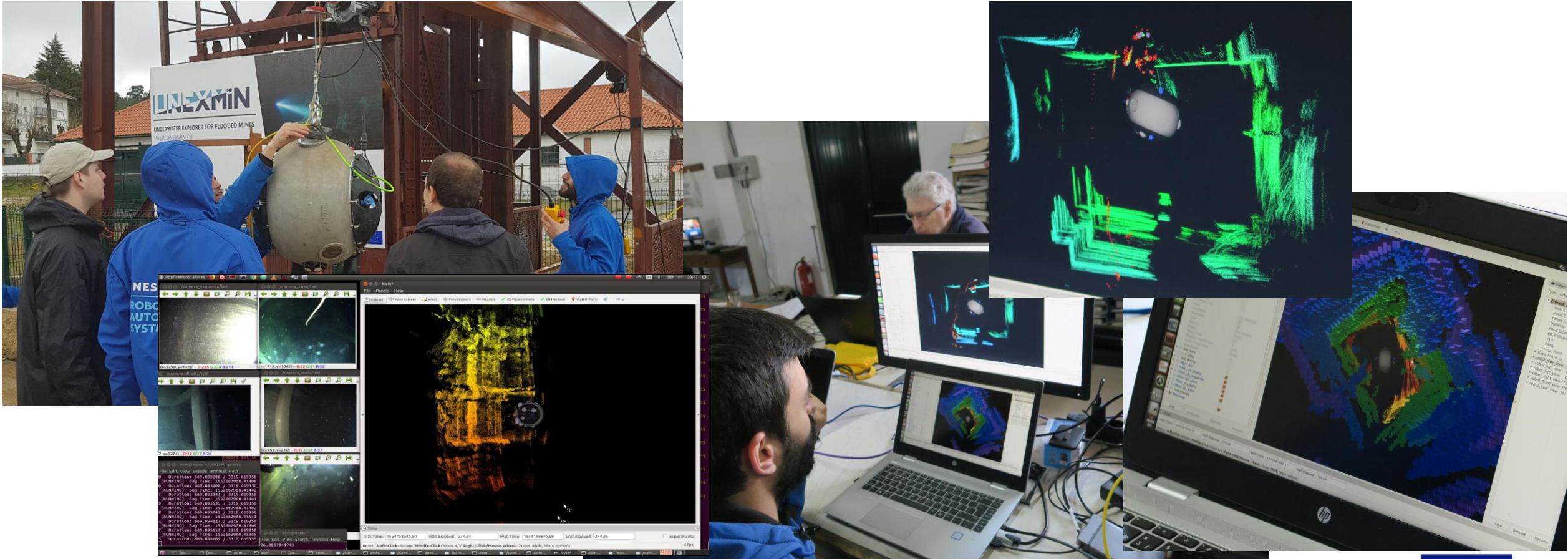


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# 2<sup>ND</sup> MINE TEST OF UX-1A (NATA) AND UX-1B URGEIRIÇA URANIUM-MINE, PORTUGAL (6<sup>TH</sup> OF MARCH TO 7<sup>TH</sup> OF APRIL 2019)



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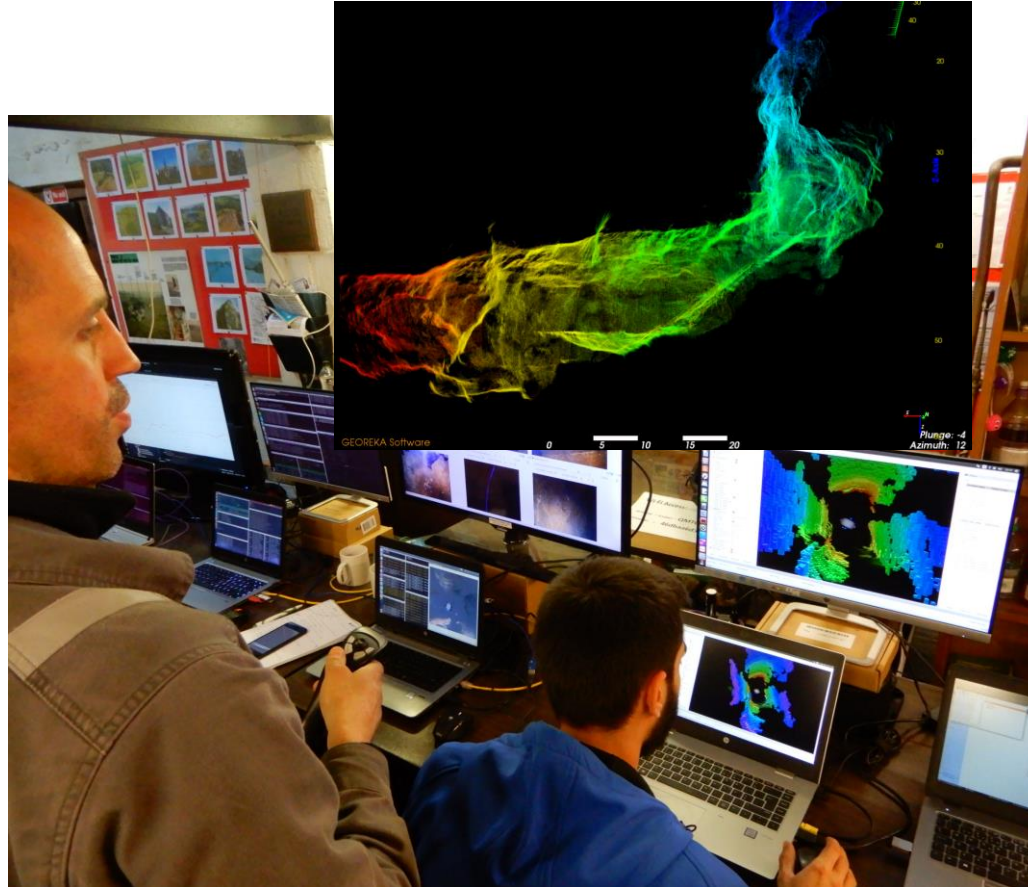
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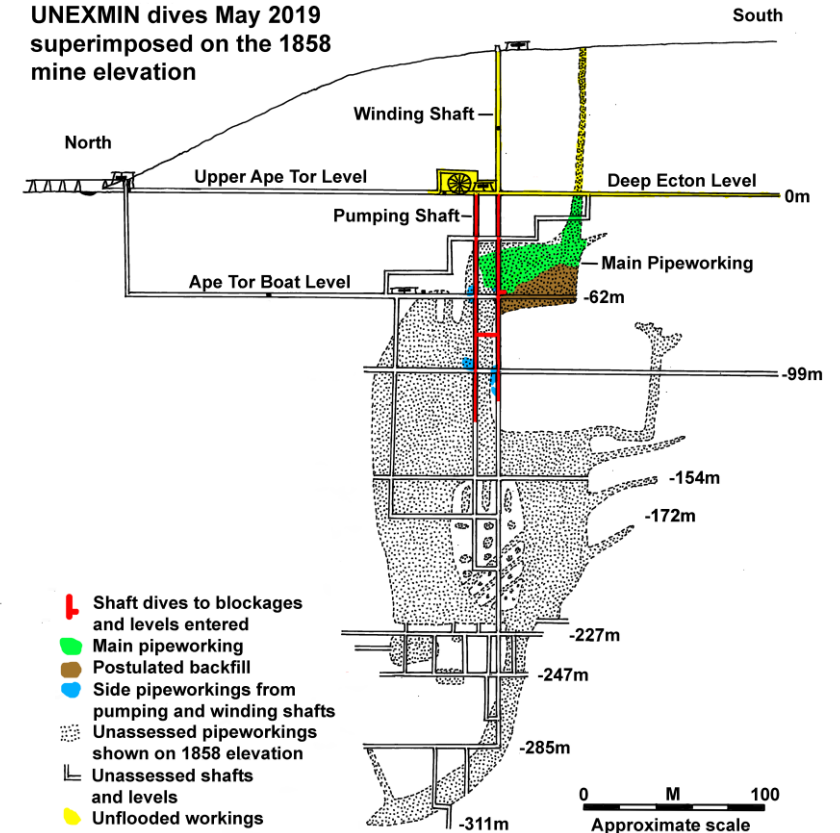


# 3<sup>RD</sup> MINE TEST OF UX-I ROBOTS

## ECTON COPPER MINE, UK (9-31<sup>ST</sup> OF MAY 2019)

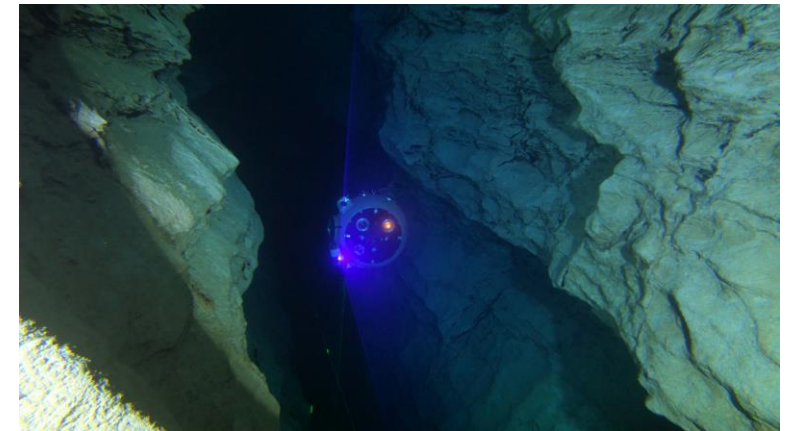
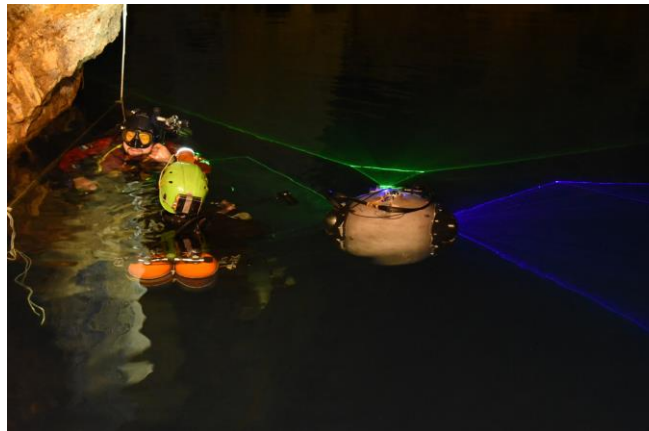
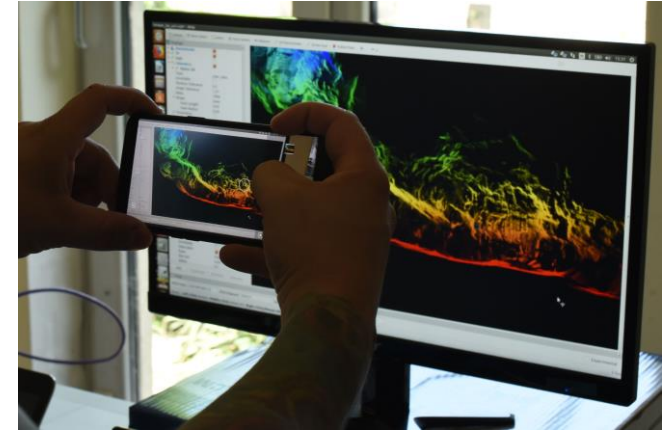
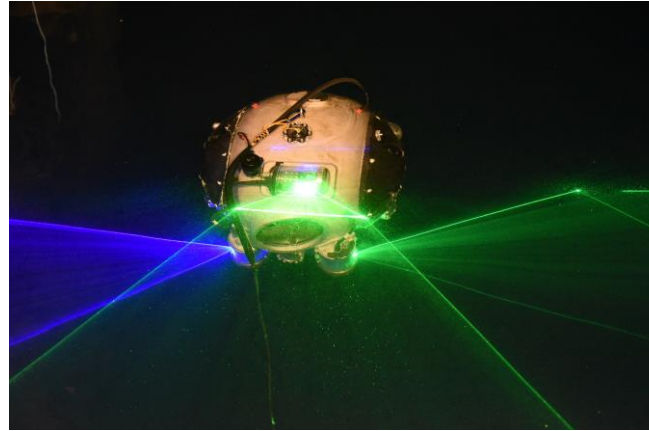
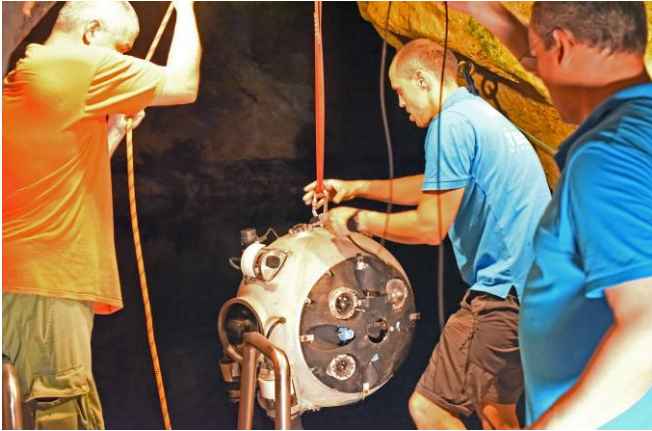


UNEXMIN dives May 2019  
superimposed on the 1858  
mine elevation



# LAST TEST OF UX-I ROBOTS

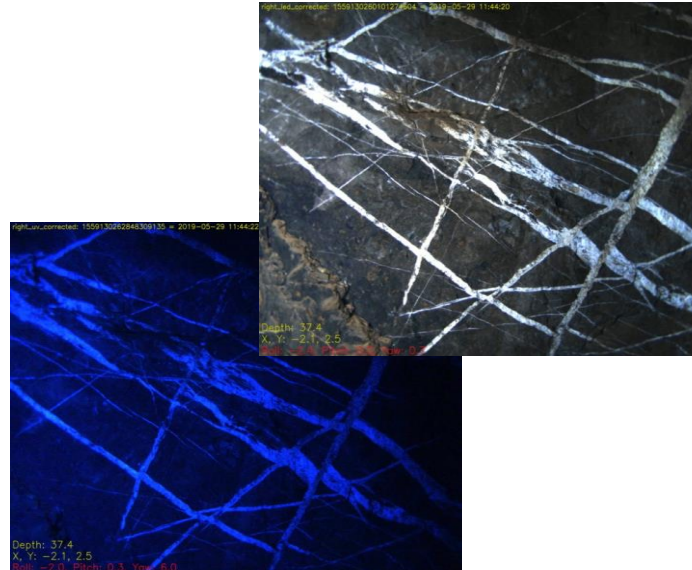
## MOLNÁR JÁNOS CAVE, HUN (24TH OF JUNE – 5TH OF JULY 2019)



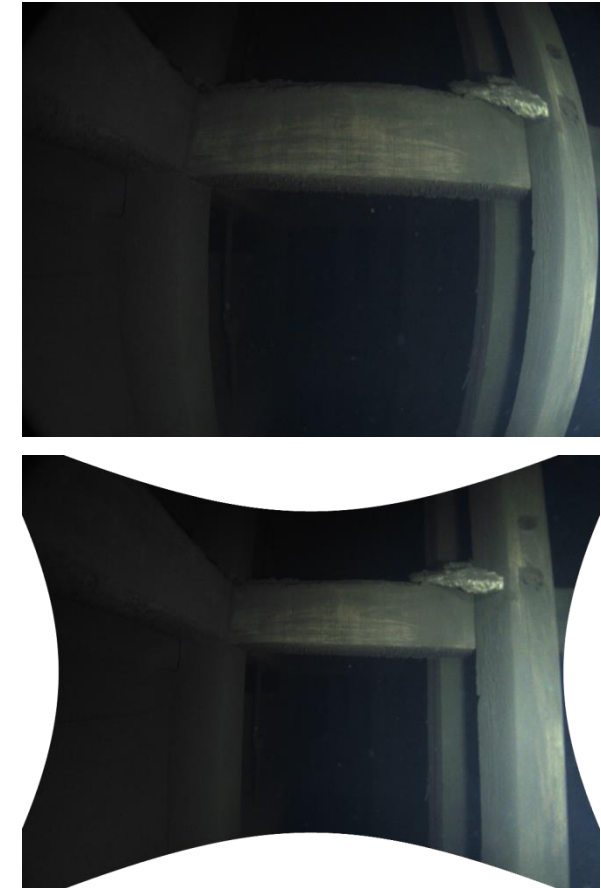


# POST-PROCESSING AND DATA ANALYSIS

- Data standards defined, documented, and agreed
- Database structure defined.
- Database management system selected (SQLite) and import data file formats and content defined for navigation and sensor subsystems
- Core point-cloud modelling and visualisation coding completed and demonstrated on a large sample data set
- Data conversion requirements for navigation and sensor systems agreed with consortium partners
- Post-processing applications requirements and specifications currently under development

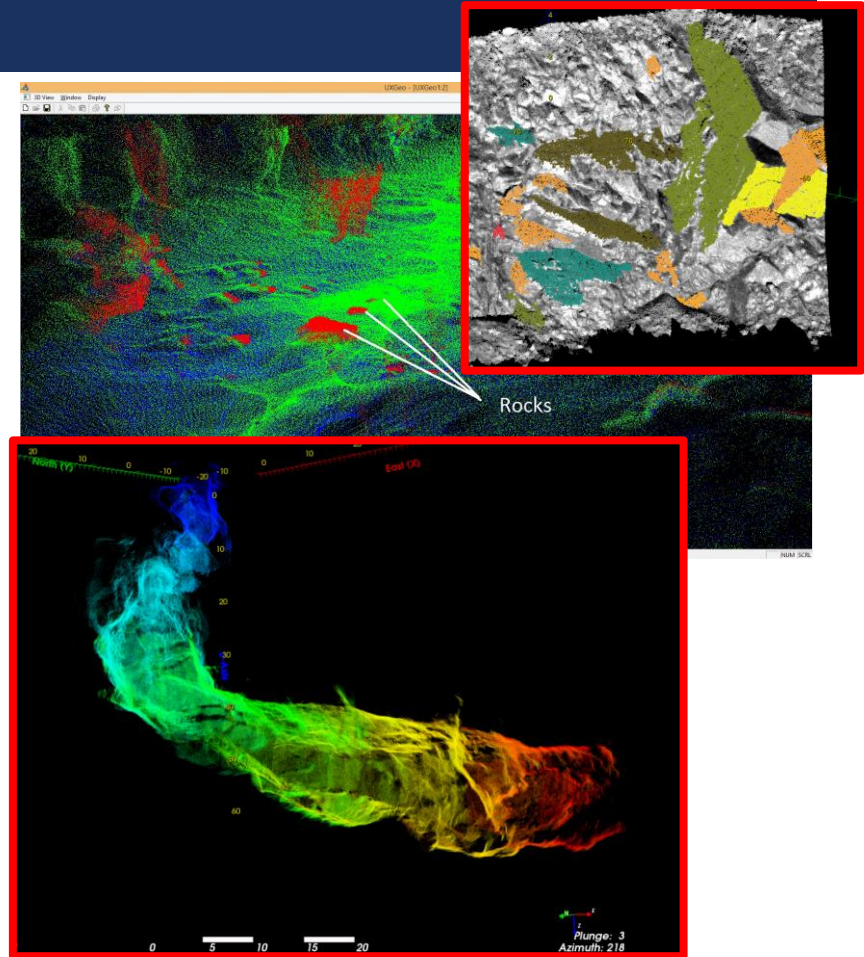
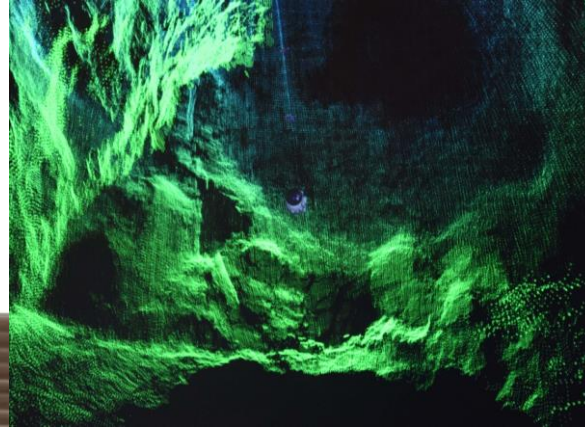


Correction of lens distortion effects, automatically for many thousands of images; conversion to videos, and 3D modelling from images



# 3D MODELS AND THE VIRTUAL REALITY ENVIRONMENT

- 3D modelling combines large point clouds from various sources (e.g. sonar, SLS, RGB, multispectral)
- Specialized tools developed to handle these data
  - Octree visualization
  - Object detection: e.g. falling rocks
  - Detecting planar structures: e.g. faults
  - Filtering and triangulation of noisy point clouds
- Virtual reality software and hardware fully developed and available for anticipated data flow from Ecton Mine





# TECHNOLOGY EXPLOITATION

# UNEXMIN GeoRobotics Ltd.

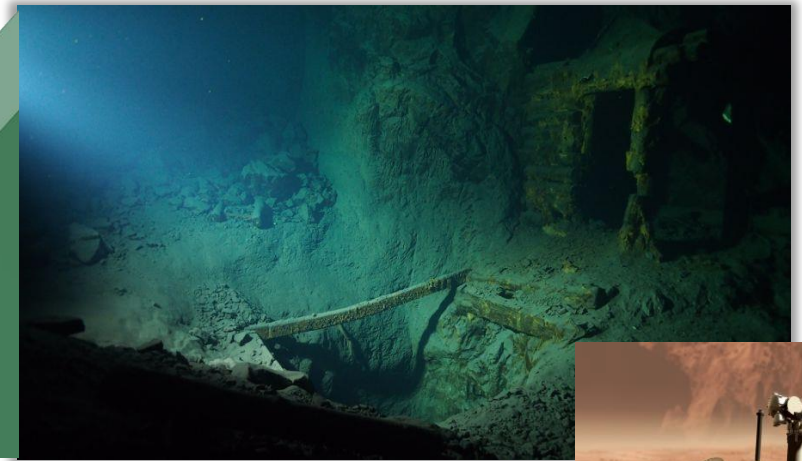
Offering service with the developed equipment, further development

- Raw materials exploration
  - Water reservoirs surveying
  - Cavity measurement (e.g. salt mines)
  - Cave system exploration
  - Cultural heritage sites investigation
  - Environmental monitoring
- 
- Underwater exploration and mining
  - Sensor and instrument development
  - Automated measurements
  - Autonomy, multi-robot platform
  - Data processing, geoscientific evaluation
  - 3D visualization
  - Space applications

**SERVICE  
OFFERED**



**PARTIAL  
UTILIZATION**



**FURTHER  
DEVELOPMENT OF  
THE TECHNOLOGY**



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**To be continued... UNEXUP  
(EIT Raw Materials project 2020–2022)**



**Thank you for your attention!**



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