UNEXMIN

AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

UNEXMIN PROJECT – AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

LUÍS LOPES & UNEXMIN CONSORTIUM

REAL-TIME MINING CONFERENCE

AMSTERDAM, THE NETHERLANDS

10 OCTOBER, 2017

LPRC LA PALMA RESEARCH CENTRE

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

KEY FACTS

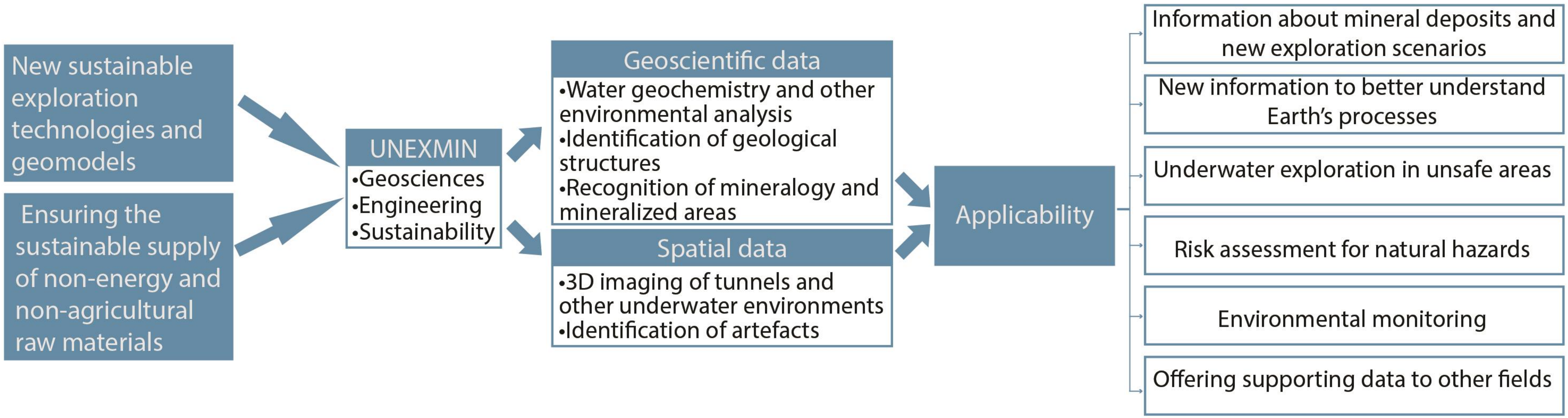
- EU funded H2020 project (RIA: Research and Innovation Action)
- 13 partners / 7 countries
- 45 month duration (February 2016 – October 2019)
- Funding: 4.87 million Euros
- Final outcomes:
  - Three prototype multi-platform robots
  - Company offering the technology to market

UNEXMIN

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

WHERE DO UNEXMIN COME FROM?

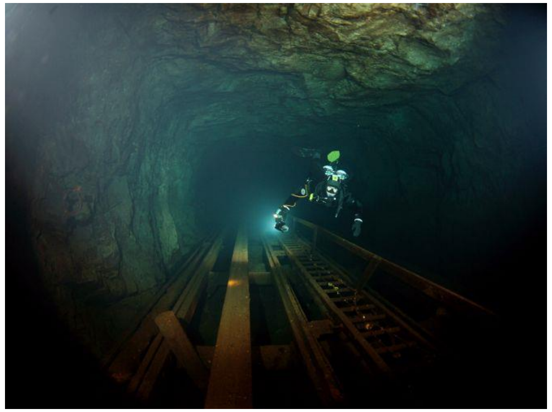
UNEXMIN: **Un**derwater **Ex**plorer for Flooded **Min**es



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

CONCEPT AND APPROACH

Dependence on import of raw materials → 30,000 closed mine sites in Europe → Abandoned deep underground mines become interesting → Most of them are now flooded → Lack of information on status and layout



UNEXMIN

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

GOALS

"… develop a ***fully autonomous robotic surveying*** solution for ***mapping abandoned and flooded deep mines.***"

Specific goals

- Design and build a **multi-platform robotic Explorer** for autonomous 3D mapping of flooded deep mines
- Demonstrate the operation of the prototype at a set of representative **pilot sites**
- Develop an **open-source platform** for technology transfer and further development
- Develop a **research roadmap** in support of further technology development
- Develop **commercial services** for exploiting the technology

UNEXMIN

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

OUTPUTS

Autonomous exploration and 3D mapping of flooded mines using **non-invasive methods** and not risking human lives

Valuable geoscientific data that **cannot be obtained by other means** without having significant costs

New and improved **geological models and new exploration scenarios**

UNEXMiN

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

CHALLENGES

Explorer structural design for robustness and resilience

Data processing and evaluation

Localization, navigation and 3D mapping

Autonomous operation and supervision

Guidance, propulsion and control

“Requirements and specifications are the easy part. The hardest is to design a robot complying them all.”

“It would be easier to perform the same task on the surface of the Moon or a planet like Mars.”

UNEXMIN

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

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

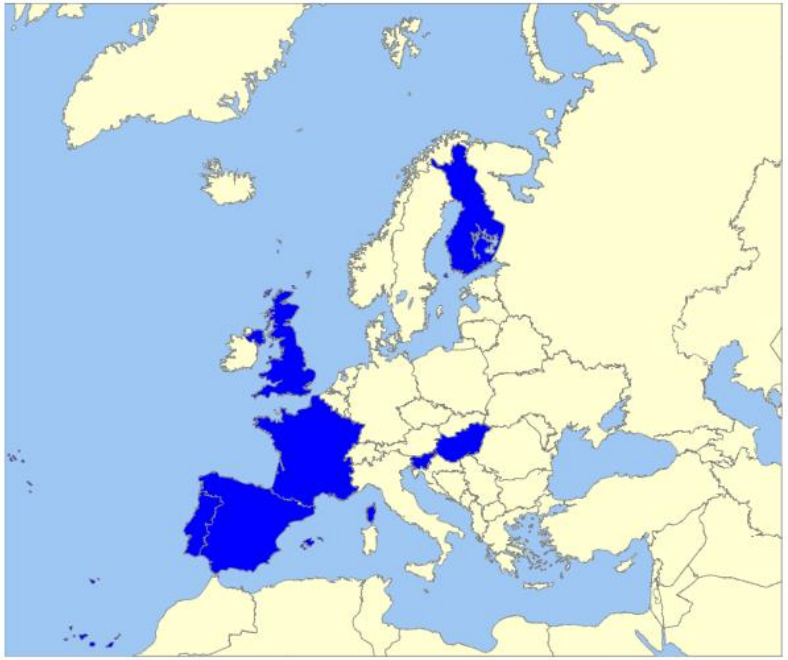
Technology developers

- 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

Technology exploitation

- Empresa de Desenvolvimento Mineiro
- Ecton Mine Educational Trust
- Center za Upravljanje z Dediscino Zivega Srebra Idrija

Stakeholders



UNEXMIN

WORK STRUCTURE

- WP1: Robotic functions validation
- WP2: Scientific design and adaptation
- WP3: Autonomy for mine exploration and mapping
- WP4: Multi-robot platform development

Technology development

- WP5: Stakeholders mobilisation
- WP6: Post-processing and data analysis
- WP7: Demonstration/Pilots
- WP8: Dissemination, technology transfer and exploitation
- WP9: Project coordination and management

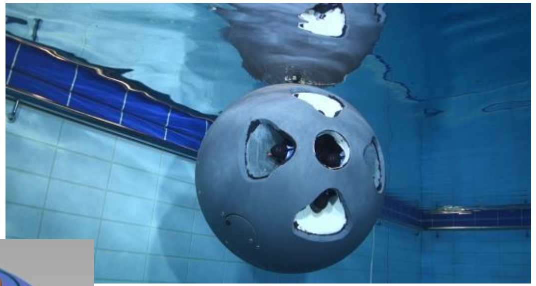
Technology usage

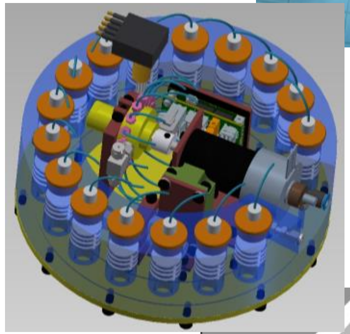
UNEXMIN

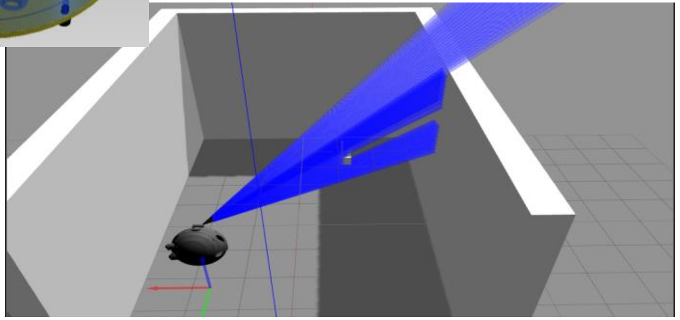
This project has received funding from the European Union's Horizon 2020research and innovationprogramme under grant agreement No 690008.

WORK DEVELOPED & IN DEVELOPMENT

- Validation and simulation of robotic functions
- Designing, testing and adaptation of scientific instruments
- Mine Perception, Navigation, 3D mapping and Exploration
- Development of post-processing and data analysis tools
- Construction of first robotic UX-1 prototype

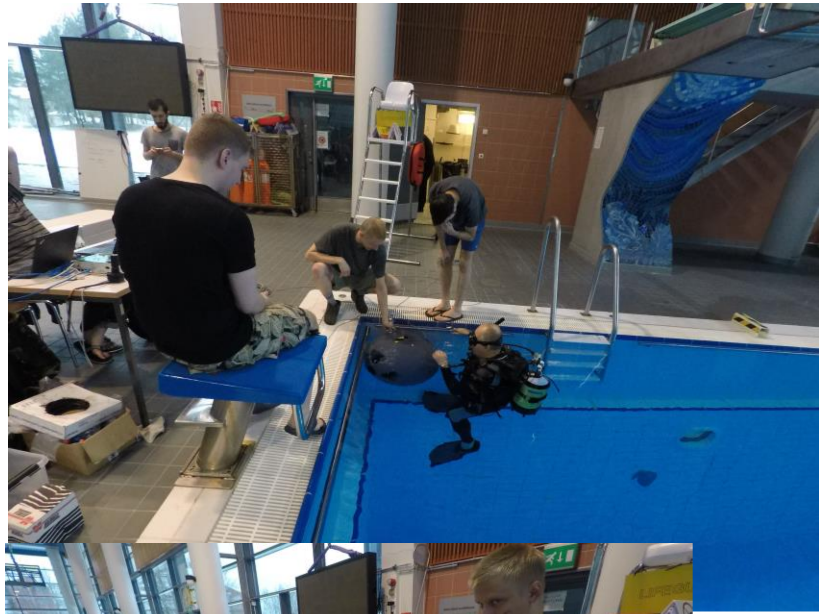


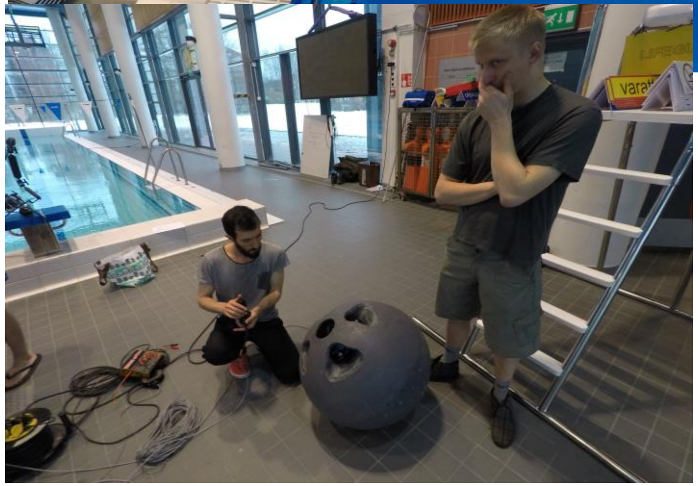




This project has received funding from the European Union's Horizon 2020research and innovationprogramme under grant agreement No 690008.

STABILITY TESTS IN POOL





Pool test video

- **Drag coefficient**: low level controls, energy consumption
- **Thrust force**: affects the efficiency
- **Hull strength analysis**: under 5MPa pressure
- **Ballast system**: changes the volume for buoyancy
- **Pendulum system**: changes gravity center for pitch
- **Pool test**: Acceleration vs horizontal thrusters
  Angle vs horizontal thrusters

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

BASIC INSTRUMENTATION

- Acoustic cameras
- Thrusters
- DVL (Doppler Velocity Log)
- Inertial navigation system
- Laser scanner
- Computer
- Batteries
- Integrated pressure hull

Components for functionality: navigation, control, autonomy, mapping, interpretation, evaluation

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

SCIENTIFIC INSTRUMENTATION

Selection of possible (feasible) methods:

Limitation: physics (environment), prices, time

Other limitations: size (weight, energy), attitude (continuous mov)

Selected devices:

pH and electrical conductivity measuring units

Magnetic field measuring unit (3 axes flux-gate sensors)

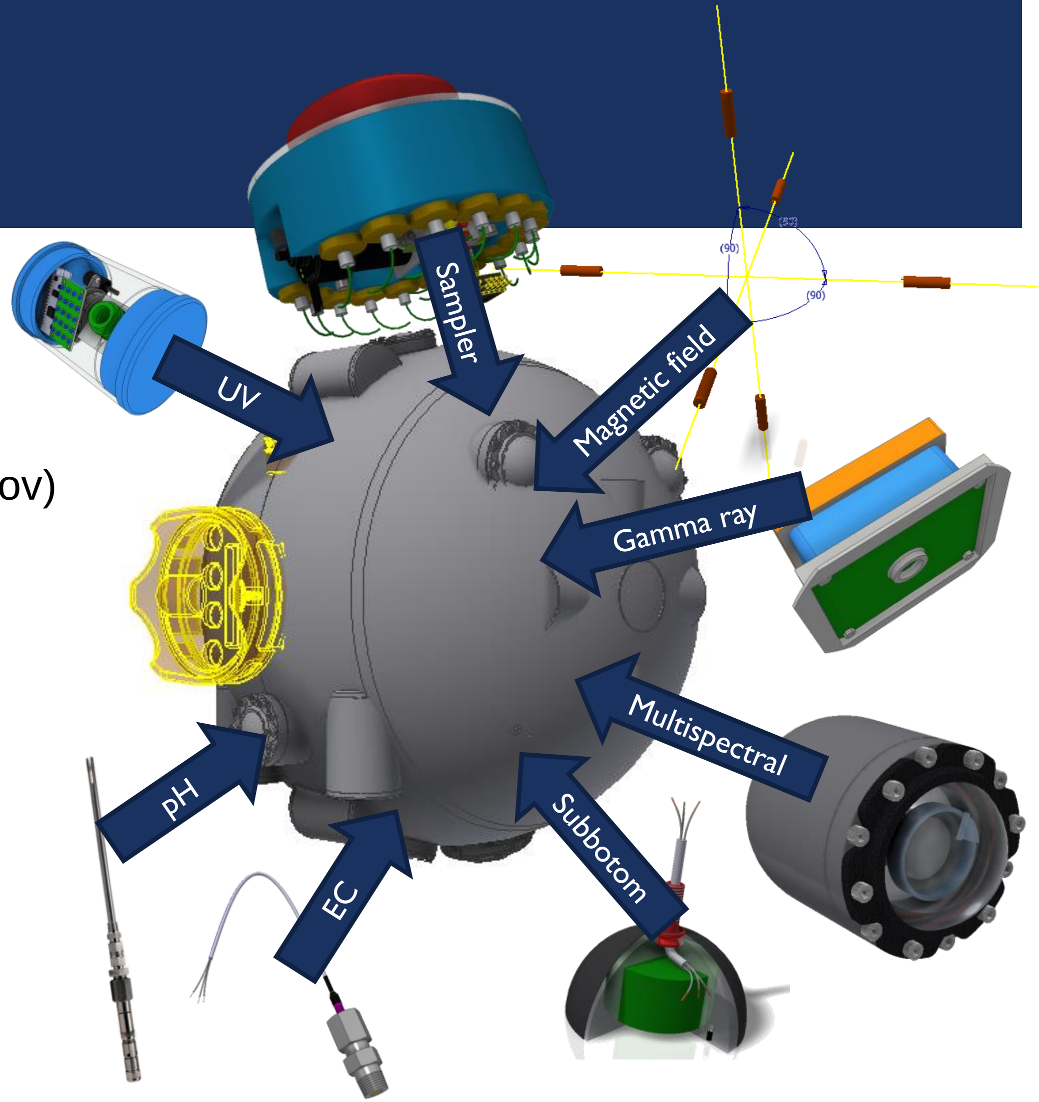
Natural (integral) gamma ray activity measuring unit

Water sampler unit

Multi-spectral unit

UV fluorescence imaging unit

Sub-bottom sonar

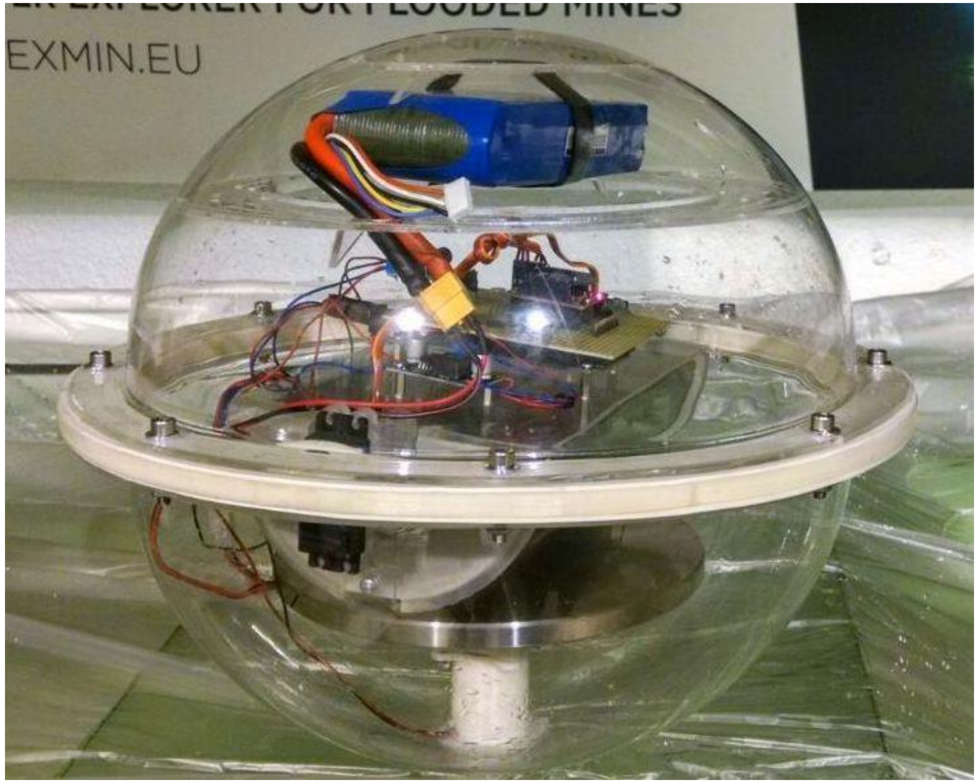


This project has received funding from the European Union's Horizon 2020research and innovationprogramme under grant agreement No 690008.

ATTITUDE CONTROL

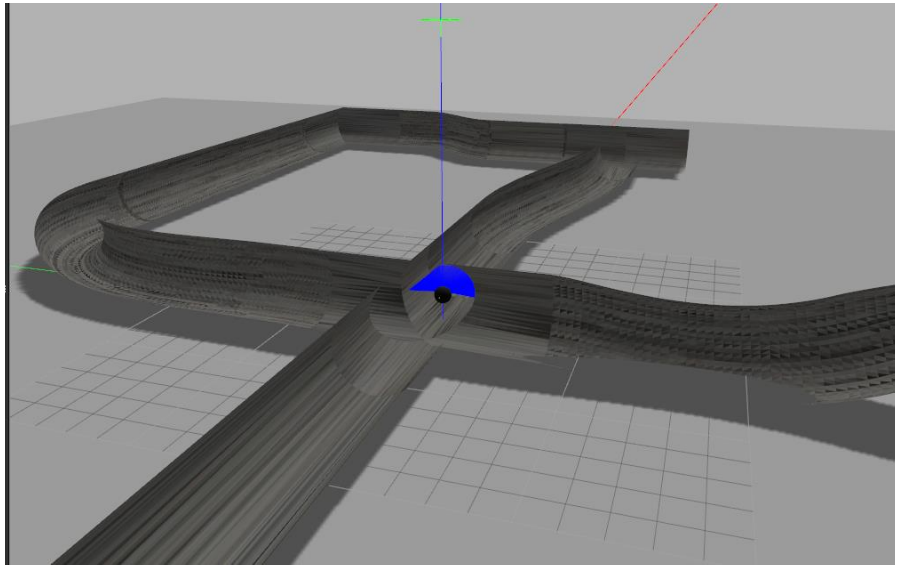
- First 1:2 scaled prototype (30 cm diameter)
- Test attitude mechanisms (open loop)
  - Pendulum for pitch control
  - Spinning disc for yaw control

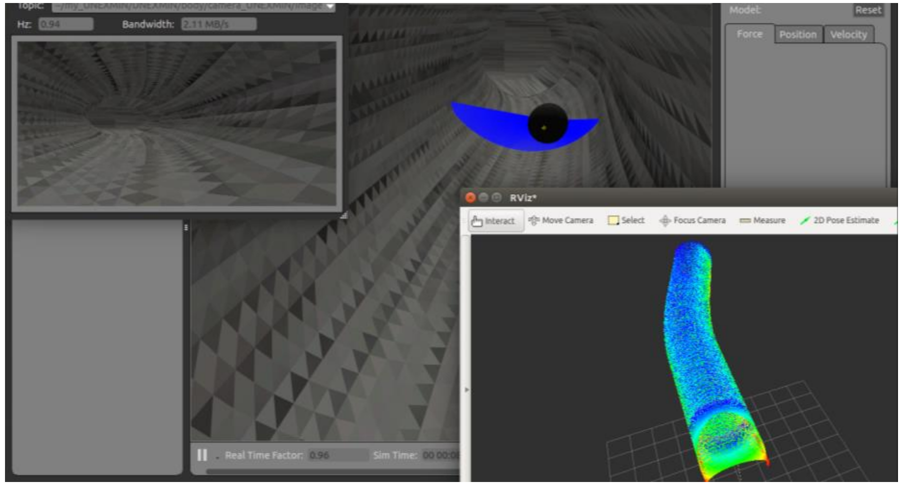
- Second scaled prototype with UX-1 manifolds system under construction
  - Pendulum for pitch control
  - Thrusters for yaw control



NAVIGATION

- Analysis of possible scenarios started already
- Creating virtual environment (in GAZEBO) for GNC simulations under development





POST-PROCESSING AND DATA ANALYSIS

- Data standards defined
- Database structure defined
- Database management system and import data file formats and content defined for navigation and sensor subsystems
- Core point-cloud modelling and visualisation coding completed and demonstrated
- Data conversion requirements agreed

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

STAKEHOLDER MOBILISATION

- Objectives:
  - The identification of Stakeholders
  - To map, **understand** and process **Stakeholder views and requirements**
  - Collection and analysis of Stakeholder requirements for creating an initial specification of UX-1
  - Creation of **detailed stakeholder database** as well as a **database of flooded mines** (including contact details with ownership status) that will serve afterwards as a starting point for the commercial exploitation of the technology
  - **Adaptation of the robot design to Stakeholder needs** and try to develop day-to-day working contacts with future customers.

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

INVENTORY OF FLOODED MINES

Task objective: An on-line, public access inventory of potential target mines in Europe will be created

- focus will be on mines that cannot be surveyed by any other mean due to complex typology or a range of depth that is below the range of scuba divers (max 50 m)
- metallic minerals will be of primary importance, but others also
- existing databases will be reviewed (PROMINE & Minerals4EU) **- DONE**
- missing data will be collected from mine authorities covering at least 24 countries - **DONE**

Task timeline:

Step 1: Define relevant categories in the data collection template (October 2016) **DONE**
Step 2: Data collection (start November 2016 – May 2017) **DONE**
Step 3: Data compilation and preparation (June-July 2017) **DONE**
Step 4: Inventory online (October 2017) **IN PROGRESS**
Step 5: Deliverable 5.4 ready (December 2017)

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

UNEXMIN DISSEMINATION CHANNELS AND MATERIAL

- Website developed and continuously updated
- Blog (News in the website – 2 per month)
- Brochures (First in 7 languages; Second in development)
- Press releases
- Documents (images, deliverables, presentations)

available for download

- Social Media: Twitter, Facebook, LinkedIn, Youtube

www.unexmin.eu

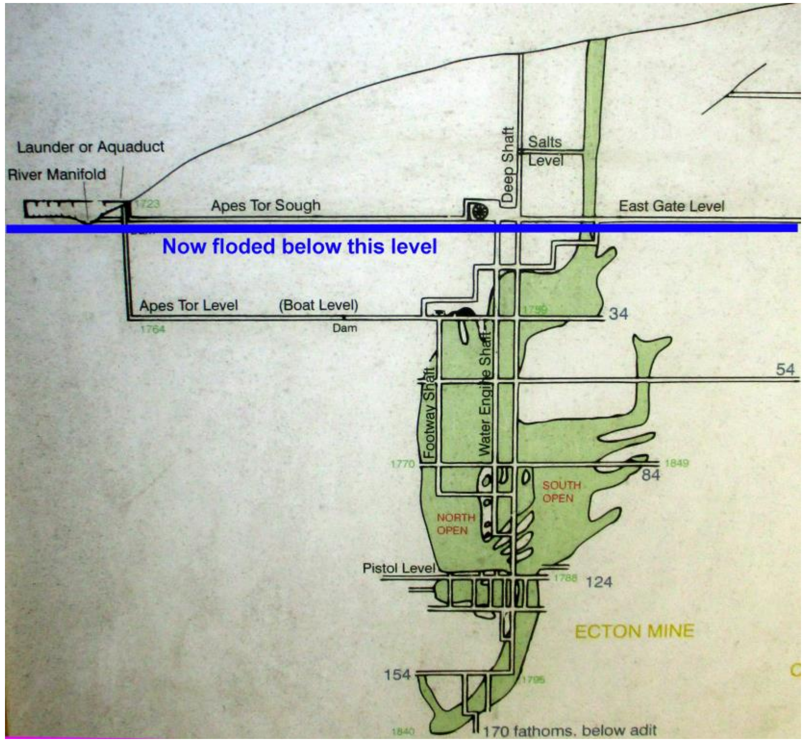
UNEXMIN

DEMONSTRATION, PILOTS

- **Kaatiala, Finland (mid-2018; first prototype)**
  - Pegmatite mine
  - Open-pit and small underground part
  - Robot recoverable by divers
- **Idrija, Slovenia (late-2018)**
  - Mercury mine
  - UNESCO Word Heritage site
- **Urgeiriça, Portugal (early-2019)**
  - Uranium mine
  - It is completely flooded
  - Water level 12–20 m below surface
- **Ecton, UK, mid-2019; multi-robotic platform)**
  - Cu – (Zn-Pb) mine (MVT)
  - National monument site

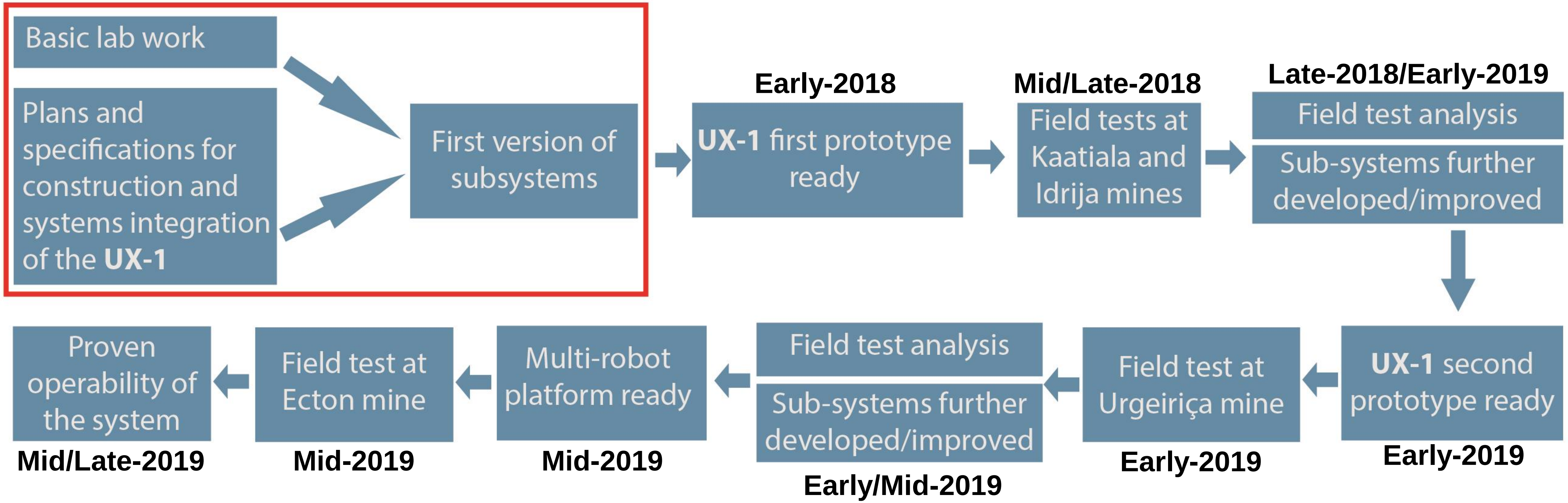
Testing in real life conditions with increasing difficulty in mine layout, geometry and topology

Nobody has seen for 160 years



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

UNEXMIN WORKFLOW



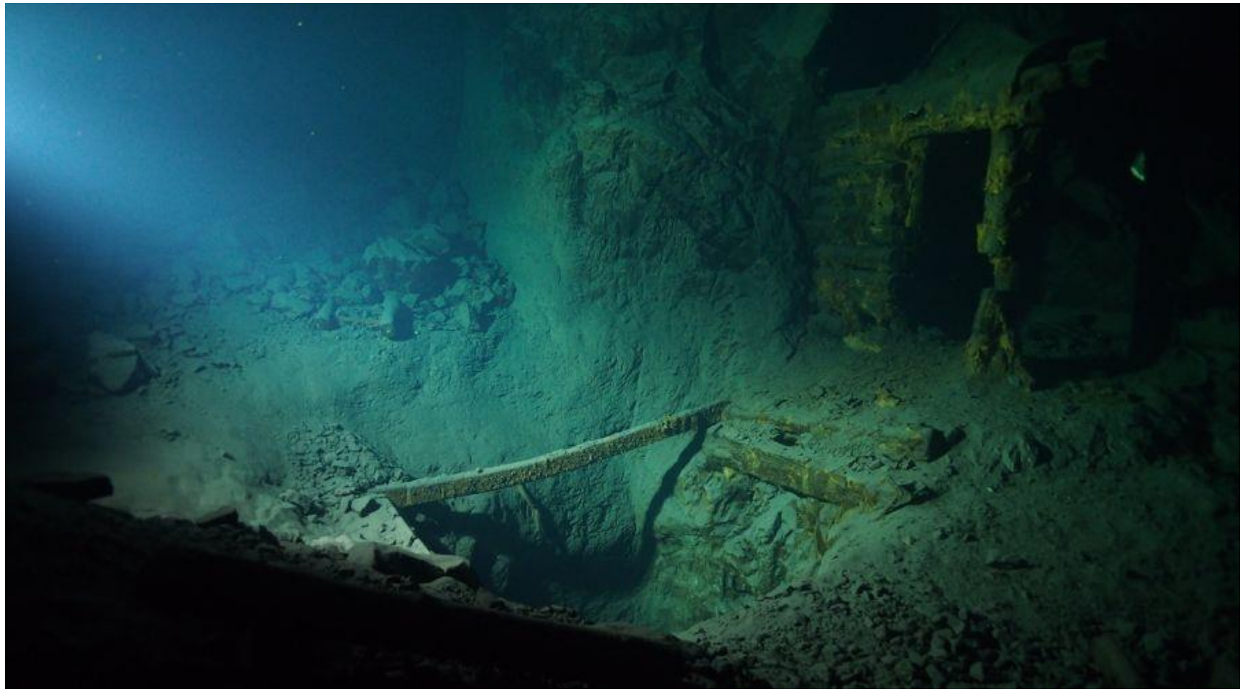
UNEXMIN

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

APPLICABILITY

- **Raw materials exploration**
  - Early stage of exploration (after sampling; before drilling)
  - Proper calculation of reserves

- Water reservoirs
- Pipeline investigation
- Cavity measurement (salt mines)
- Cave system exploration
- Cultural heritage sites
- Rescue
- Ship-wrecks
- Ect…



FURTHER USE

- **Partial utilization of the technology**

- Sensors / instruments for regular and other underwater mining
  - Exploration, selective mining, innovative commodity processing
- Robotic control (automatic operation)
- Multi-robot platform adaptation
- Post-processing, data evaluation software
- Inventory of flooded mines

- Space applications

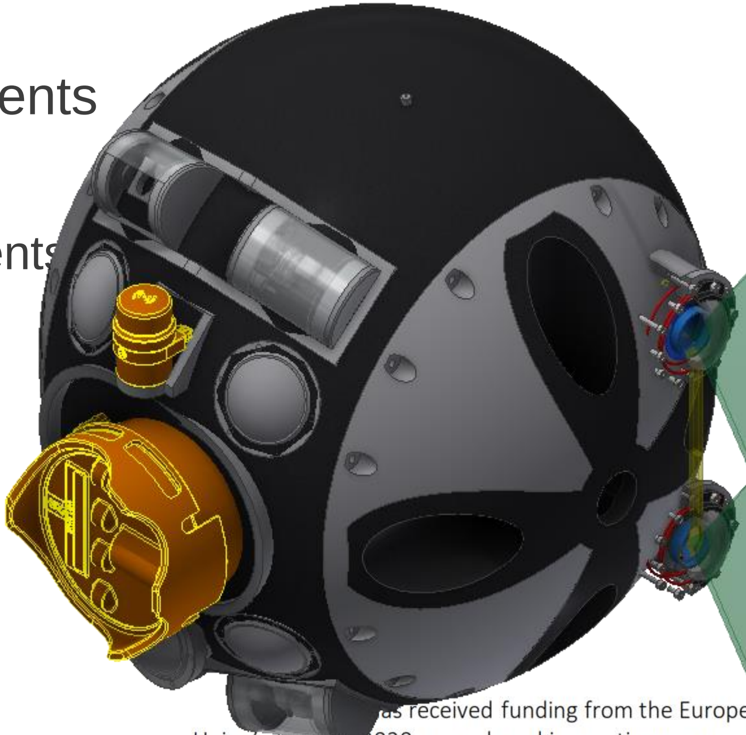
UNEXMIN

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

THE FUTURE OF UNEXMIN

Offering service with the developed equipment

- Further develop the existing instruments / sensors
- Develop new instruments
- Open-source platform for costumer developed instruments
- Modification of the UX-1 series
  - Long-range version, more batteries vs. scientific instruments
  - Ect…
- UX-2 series: sampling / drilling
- Other directions of development:
  - Bigger depth capability
  - Longer mission range
  - Smaller version for more confined spaces
  - Ect…



as received funding from the Europea
Union's Horizo 2020research and innovationprogramme
under grant agreement No 690008.

THANK YOU!

UNEXMiN

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