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

UNEXMIN PROJECT – AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

LUIŠ LOPES & UNEXMIN CONSORTIUM
REAL-TIME MINING CONFERENCE
AMSTERDAM, THE NETHERLANDS
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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
WHERE DO UNEXMIN COME FROM?

UNEXMIN: Underwater Explorer for Flooded Mines

New sustainable exploration technologies and geomodels

Ensuring the sustainable supply of non-energy and non-agricultural raw materials

UNEXMIN
- Geosciences
- Engineering
- Sustainability

Geoscientific data
- Water geochemistry and other environmental analysis
- Identification of geological structures
- Recognition of mineralogy and mineralized areas

Spatial data
- 3D imaging of tunnels and other underwater environments
- Identification of artefacts

Applicability

Information about mineral deposits and new exploration scenarios

New information to better understand Earth’s processes

Underwater exploration in unsafe areas

Risk assessment for natural hazards

Environmental monitoring

Offering supporting data to other fields

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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
"… 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
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

OUTPUTS

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“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.”

CHALLENGES

- Explorer structural design for robustness and resilience
- Data processing and evaluation
- Autonomous operation and supervision
- Localization, navigation and 3D mapping
- Guidance, propulsion and control
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 developers

Technology exploitation

Stakeholders
WORK STRUCTURE

- WP1: Robotic functions validation
- WP2: Scientific design and adaptation
- WP3: Autonomy for mine exploration and mapping
- WP4: Multi-robot platform development
- WP5: Stakeholders mobilisation
- WP6: Post-processing and data analysis
- WP7: Demonstration/Pilots
- WP8: Dissemination, technology transfer and exploitation
- WP9: Project coordination and management
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
STABILITY TESTS IN POOL

- **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
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

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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
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
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.
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)
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
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 World 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

Nobody has seen for 160 years

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

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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
THE FUTURE OF UNEXMIN

Offering service with the developed equipment

- Further develop the existing instruments / sensors
- Develop new instruments
- Open-source platform for customer 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…
THANK YOU!