This presentation looks at the current state of underwater inland and near-shore mining at INESC TEC and has much relevance in the future of deep-sea mineral exploitation.
Underwater mining

- **Efficient underwater mining technology**
  - H2020 Societal Changes 5 (Raw Materials) RIA
  - 2015-2018
  - 17 partners, 9 countries
  - 12.4 M€
  - INESC TEC Role: Positioning, navigation and awareness system, support AUV, LIBS sensor

- **Robotic Exploration of flooded mines**
  - H2020 Societal Changes 5 (Raw Materials) RIA
  - 2015-2018
  - 13 partners, 7 countries
  - 4.8 M€
  - INESC TEC Role: Robot development, navigation, mapping
Coral
Sustainable Ocean Exploitation: Tools and Sensors

Apoio NORTE2020 através do Fundo Europeu Desenvolvimento Regional e do Fundo Social Europeu
Mining History

• Need to know some details of the underground mining as well as the open cut mining
• In particular whether block or sub-level caving has been used

Source: H. Hamrin, Guide to Underground Mining Methods and Applications
Inland Submerged Mining (Concept Prototype)

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477
¡VAMOS! overview...

Modular Launch and Recovery Vessel

Dewatering Facilities

HROV

Underwater mining vehicle

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477.”
¡VAMOS! Underview...

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477"
VAMOS! virtual view...

allowing remote operation at night and in turbid water.
Mine planning views...
Positioning of launch and recovery vessel...
Landing the mining vehicle...
Concept design MV (after WP2)
Hybrid Satellite AUV/ROV

- Preliminary mine survey
- Detailed localized mapping
- Operations support
  - "Other view" assistance
  - Realtime mapping
- Multiple laser structured light systems/cameras
- 3D Multibeam sonar
- Redundant full 6DOF control
- Custom inverted USBL/ SBL positioning
- High precision INS system
- DVL sonar
- Pressure tolerant batteries
- Docking station
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477
Multi-sensor navigation system

Hybrid SBL and iUSBL system for enclosed mines

Development of a Laser based structured light system scanner

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477
**Key challenge**
Enable real-time monitoring **boosting sensitivity** and establishing robust calibration protocols. *(double pulse configurations and gas assisted sampling)*

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477.
PNAS system diagram incl HROV
### EXAMPLES OF SIZES / VOLUMES NAVIGATION SENSORS

<table>
<thead>
<tr>
<th>Sensor Description</th>
<th>Weight (g)</th>
<th>Volume (L)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multibeam (5kg) / Acoustic camera (17kg)</td>
<td>17000</td>
<td>15.75</td>
<td>50</td>
</tr>
<tr>
<td>INS</td>
<td>700</td>
<td>0.46</td>
<td>10</td>
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<tr>
<td>DVL</td>
<td>1000</td>
<td>1.16</td>
<td>3</td>
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<tr>
<td>Pressure sensor</td>
<td>400</td>
<td>0.10</td>
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</tr>
<tr>
<td>Acoustic modem</td>
<td>1000</td>
<td>0.30</td>
<td>30</td>
</tr>
<tr>
<td>Cameras + Lens 8</td>
<td>4000</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Laser (8 a 12) ref 10</td>
<td>3000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lights 8</td>
<td>1600</td>
<td></td>
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</tr>
<tr>
<td>CPU, SSD, interfaces</td>
<td>1500</td>
<td></td>
<td>60</td>
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<tr>
<td>Electronics (BMS, Energy management and distribution, synchronization, trigger)</td>
<td>500</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>30700</td>
<td>17.77</td>
<td>193</td>
</tr>
</tbody>
</table>
EX. 60CM DIAM / NAVIGATION SENSORS

- Acoustic camera
- Forward Looking Sonar
- Acoustic modem
- Lasers
- Cameras
- CPU
- INS
- DVL
EX 60 CM DIAM. NAVIGATION SENSORS
Coral Research Questions

• Explore the effectiveness of robotic technologies and solutions to achieve lower cost and more efficient, exploration and environmental impact monitoring;

• Provide advanced understanding of biogeochemical processes in deep sea ecosystems;

• Develop innovative technologies and methodologies to assess the resilience and biodiversity of deep sea ecosystems under mining extraction;

• Identify potentialities on new biotechnological applications of deep sea organisms;

• Develop a framework and guides for risk and impact assessment for sea floor exploitation;

• Develop modelling tools in support of risk assessment scenarios;

• Develop legal instruments framed in EU regulation to foster an effective management of sea floor resources.
From the surface to the deep

TURTLE – Hybrid robotic landers

- Robotic Autonomous Deep sea lander
- QREN, National funds
- 1 M€
- 1400Kg, 1000m prototype
- Efficient ascend/descent
- Long term presence at sea bed

Mission planning (EDA)

- AUV mission planning for mine countermeasures
- EDA – European Defence Agency
- 5 Partners, 5 Countries
- 1 M€
Transport
Long-term presence

radio data communication

permanence at surface for insitu maintenance or battery recharging

multiple efficient ascents/dives

long term ocean floor data gathering
Repositioning
Sea tests
Other projects (complementary technology)

- EEA Grants
- 2015-2016
- 0.3 M€
- Underwater energy transmission
- Underwater RF communications

- EEA Grants
- 2015-2016
- 0.3 M€
- Long range maritime communications
- Broadband communications in marine environment
- Surface and underwater internet access
Short range communications

- Propagation of RF waves in seawater is well suited for short-range broadband communications
  - A 100 MHz carrier suffers a 30 dB attenuation for each 10 cm of propagation
- Based on Wi-Fi radios using sub-GHz frequencies
Wireless power transfer (WPT) in the underwater environment

Wet mateable connectors are problematic:

- Needs to be plugged-in
- Pins are exposed to seawater,
- Suffers from fouling and corrosion

A wireless connector has been proven to be a better choice.

- Limits the size of inductors to approx. 16 cm of diameter
- AUV can dock in near contact (< 5 cm distance)
Thanks