Project Presentation

ROBUST

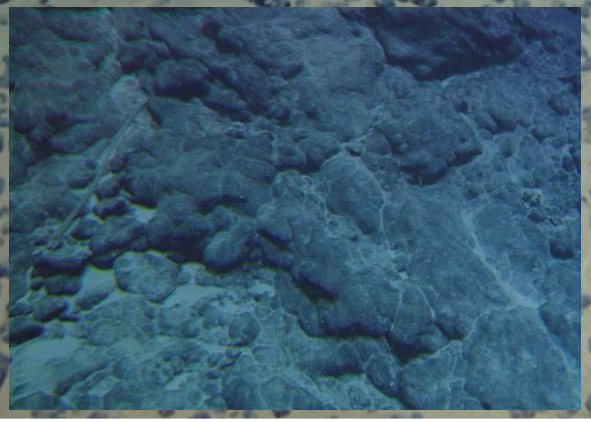
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690416

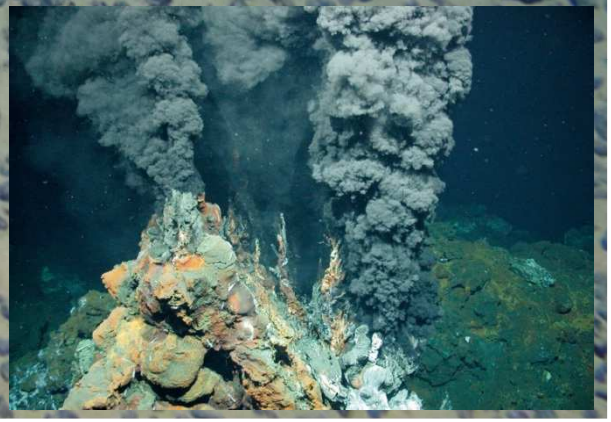
Layout

- Seabed Mining
- ROBUST at a Glance
- Methodology
- Technologies and Latest Developments

Seabed Resources

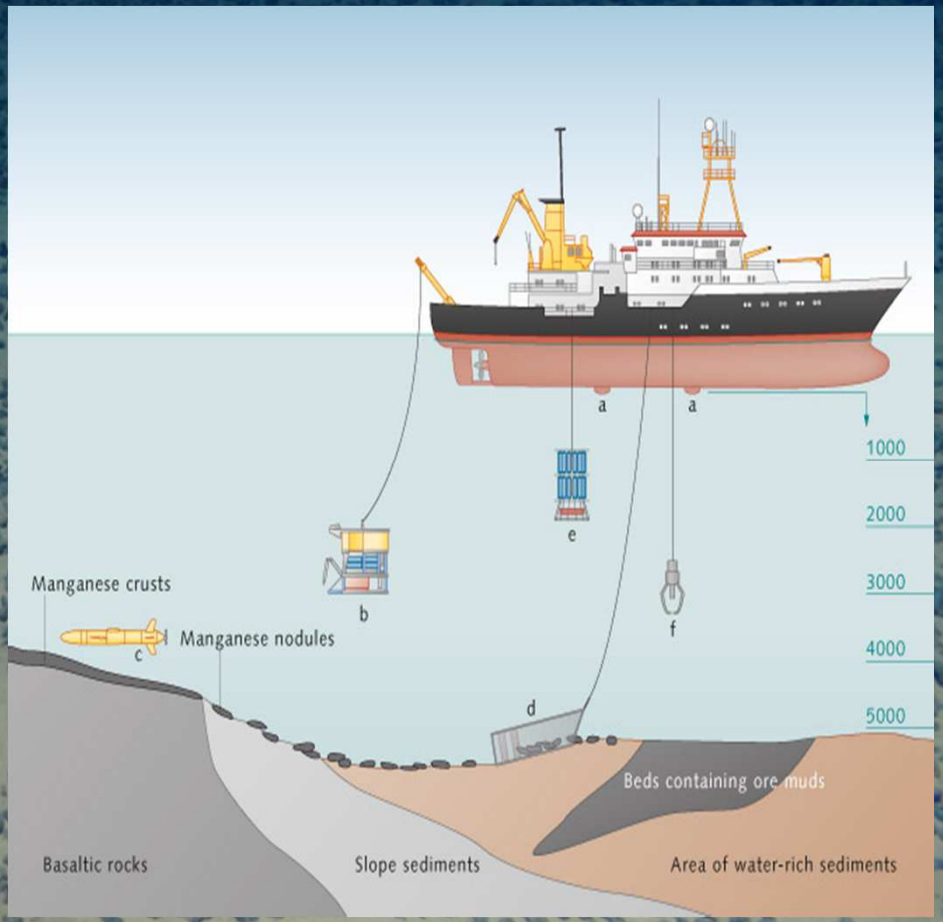
- **Manganese nodules** for which minerals are deposited around a nucleus over geological times
- **Cobalt crusts** accumulate when manganese, iron and a wide array of trace metals dissolved in water (cobalt, copper, nickel and platinum) are deposited on the volcanic substrates
- **Massive sulphides** are formed at hot springs on the sea floor (black smokers). They discharge minerals from the Earth's interior, forming chimneys that rise to several meters above the seabed





Current Seabed Mining Technologies

- Echo sounders – profile of the sea floor (a)
- ROVs equipped with cameras and grabbing arms – produce images and collect samples (b)
- AUVs – equipped with echo sounders and various sensors, various hours autonomy (c)
- Dredges towed behind the ship – collecting larger samples (d)
- Multirosettes – water samples at different depths measuring physical and chemical parameters (e)
- Grab samplers – individual bottom samples, including small boulders, equipped with cameras for underwater orientation (f)



Seabed Mining Needs

- Seabed 3D mapping in a quick and efficient manner
- Mineral identification found in the mining sites
- Exploration technologies need to be:
  - Cost effective
  - Environmentally friendly (non intrusive)

ROBUST at a Glance

- **ROB**otic s**U**b**S**ea exploration **T**echnologies
- 48 month project, starting in February 2016
- Project funded by EC under H2020-SC5-2015 (Topic: New sustainable exploration technologies and geomodels)

ROBUST at a Glance - Consortium

ROBUST at a Glance - Objectives

- To develop technologies which will allow in-situ material identification (Mg nodules):
  - Laser based in-situ element identification using the Laser Induced Breakdown Spectroscopy (LIBS)
  - Seabed 3D mapping using an AUV robotic vehicle which will identify the target through 3D mapping of the terrain and position the LIBS in order to perform the scanning

Methodology

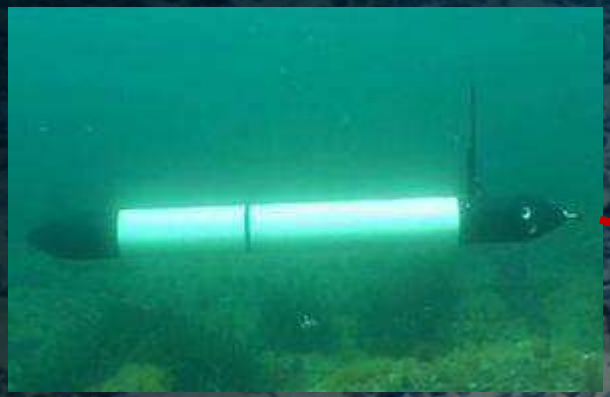
- Use of existing AUV technology in order to develop a vehicle with advanced control capabilities
- Equip AUV with 3D sea bed mapping and individual target identification and measurement technologies
- Equip AUV with a manipulator which will bear the LIBS probe
- The LIBS system will be developed for 6000m operations.
- Deep sea LIBS operation will be simulated using a 600bar pressure chamber.
- The LIBS probing head and umbilical cord will al be designed and tested in real environment using the GEOMAR-ROVKiel 6000
- A two mission scenario is foreseen, where the first will encompass the 3D mapping, the target identification and volume measurement, and the second the LIBS scanning
- Lastly, a suitable location will be selected for trials of the full ROBUST technologies at 200-300 m depth, using real mineral resources

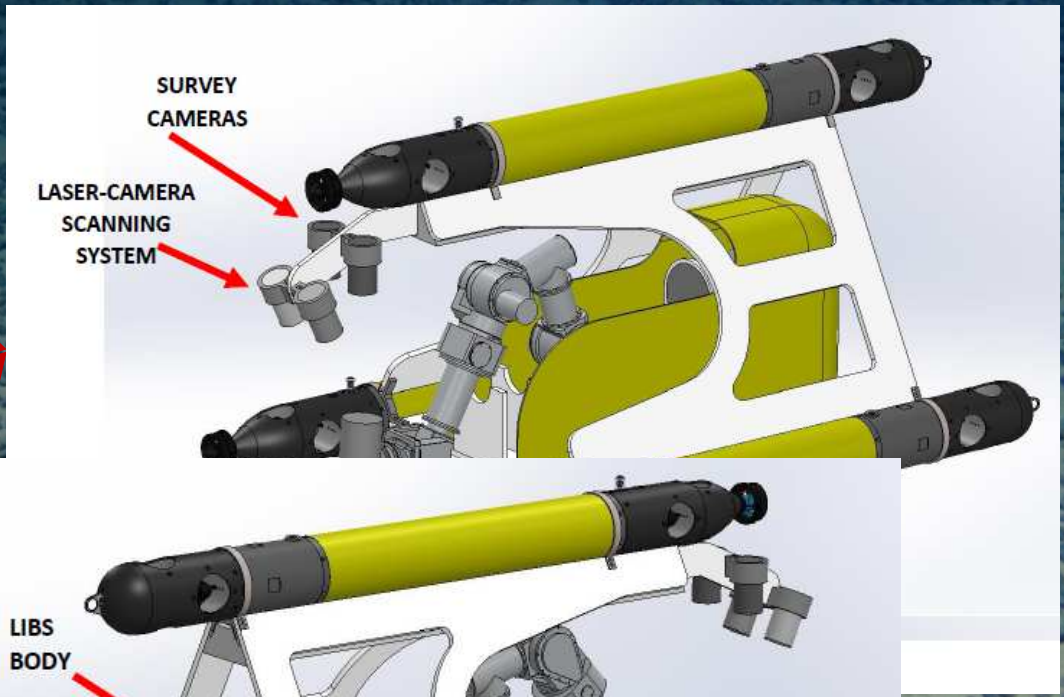
Technologies

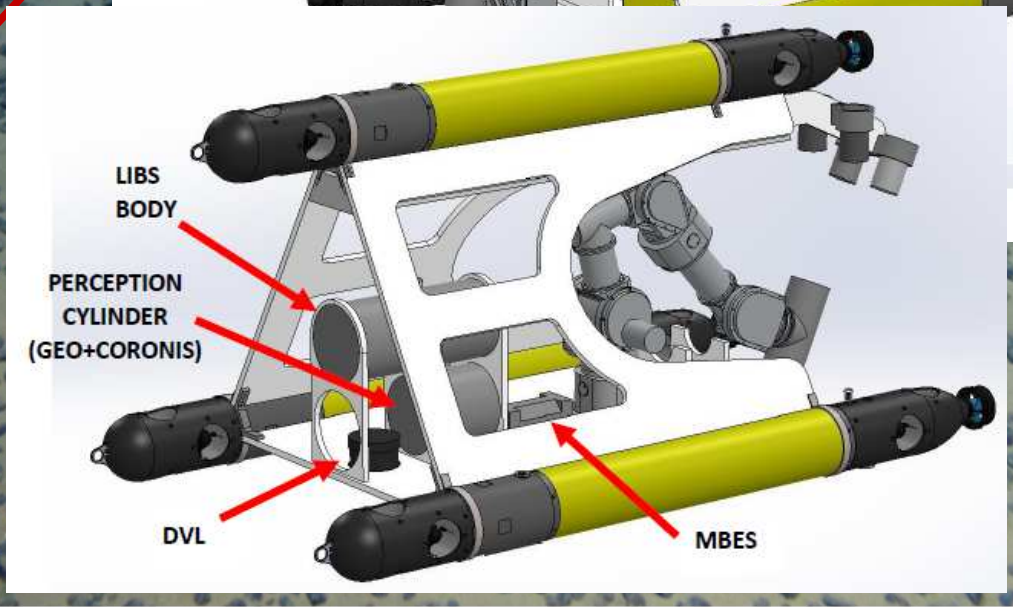
- AUV with hovering capability
- AUV manipulator system for carrying and placing the LIBS on the target
- AUV movement and manipulator synergy during LIBS scanning
- The mapping of the Area of Interest by AUV
  - General Mapping
  - Target localization
  - Target identification
  - Target volume and structure estimation
- Laser Induced Breakdown Spectroscopy

Technologies - AUV

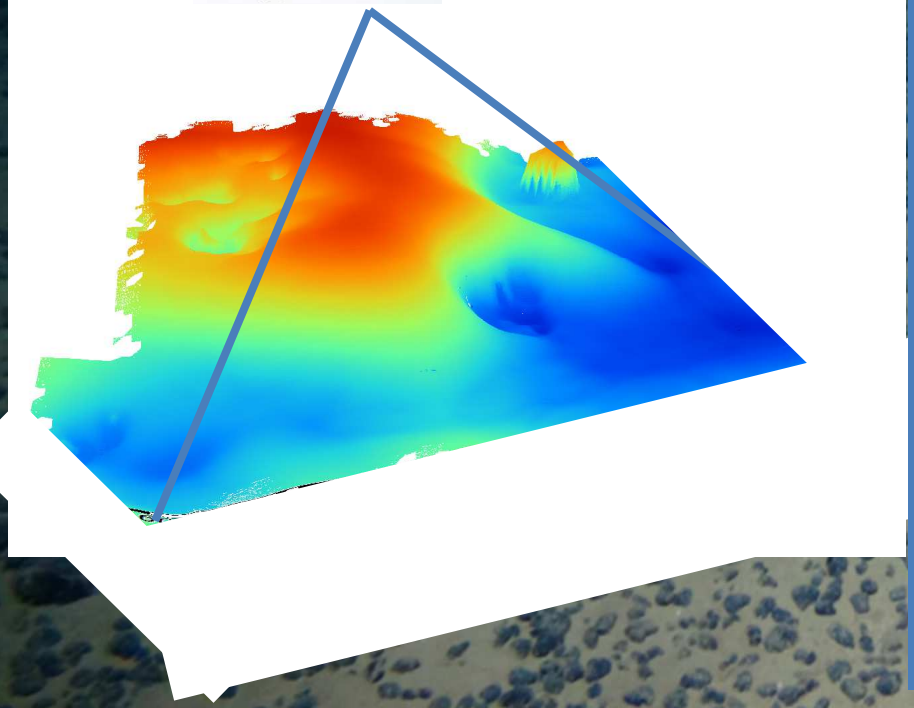
Modular Design Using FOLAGA Vehicles



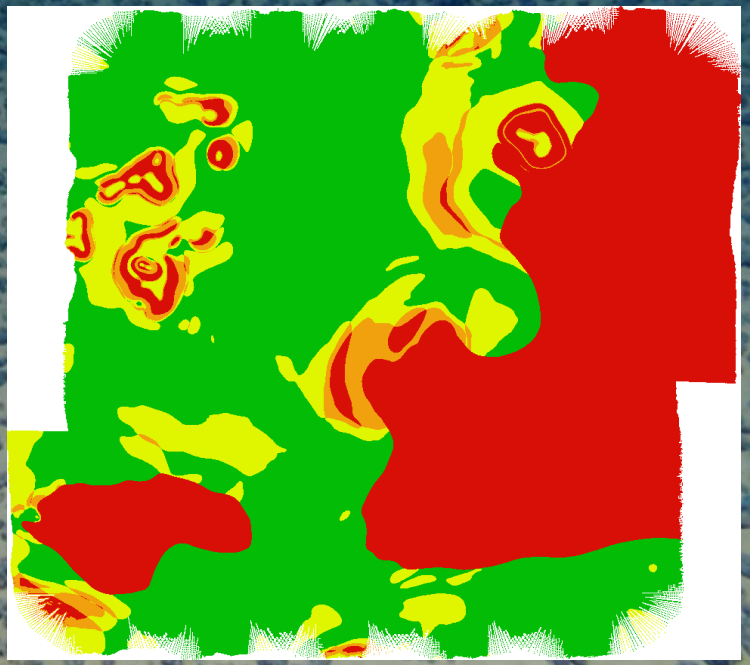




Technologies – Acoustic Based Mapping



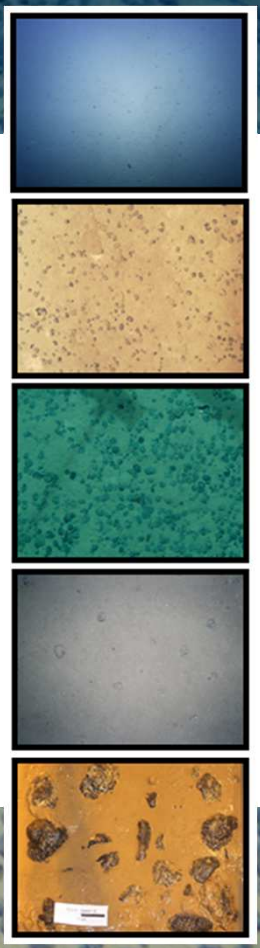
Determine likely nodule areas, based on statistics (backscatter, bathymetric derivatives) + geological knowledge



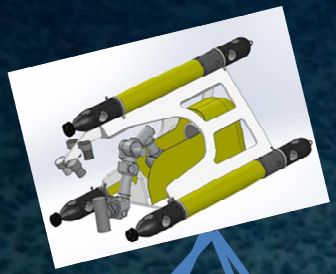
Green: likely
Red: unlikely

Technologies – Vision Based Mapping

Different nodules appearances

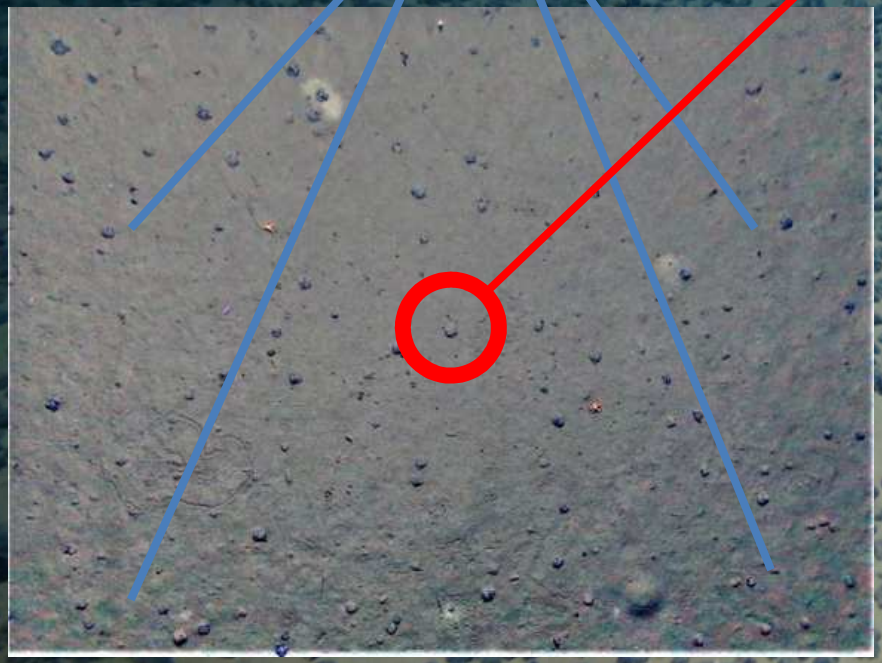


Technologies – Vision Based Mapping

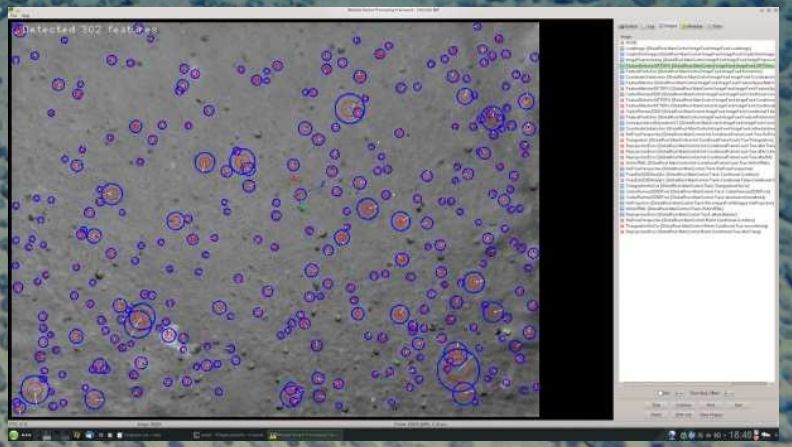


Visual Station Keeping While Sampling

Target Nodule for LIBS



track image features, visual odometry

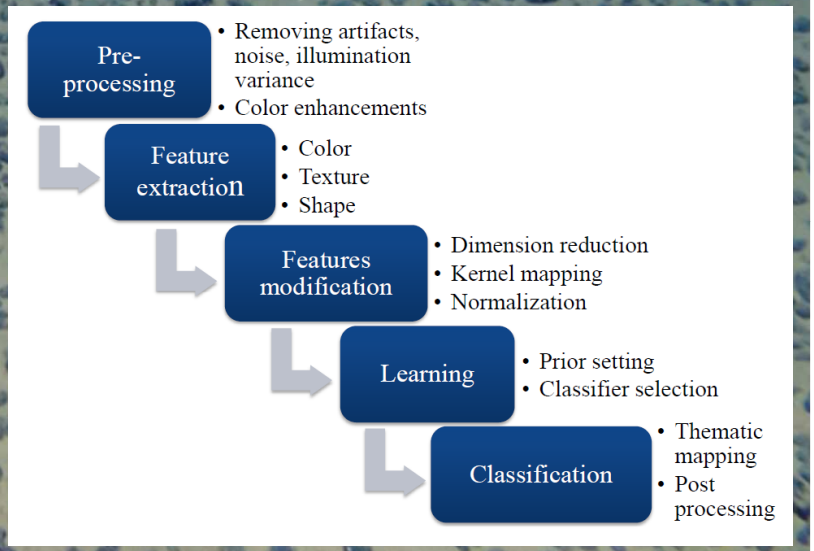


Technologies – Vision Based Mapping

Monocular camera

Real Time Navigation System

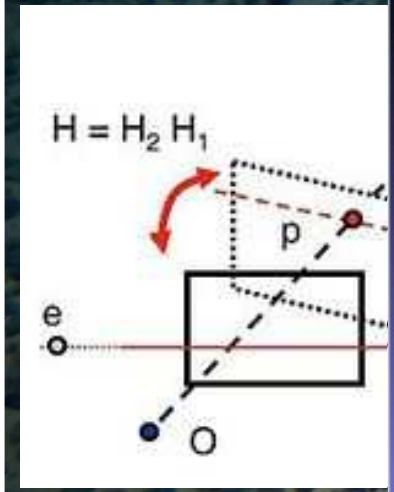
Mn-nodule detection

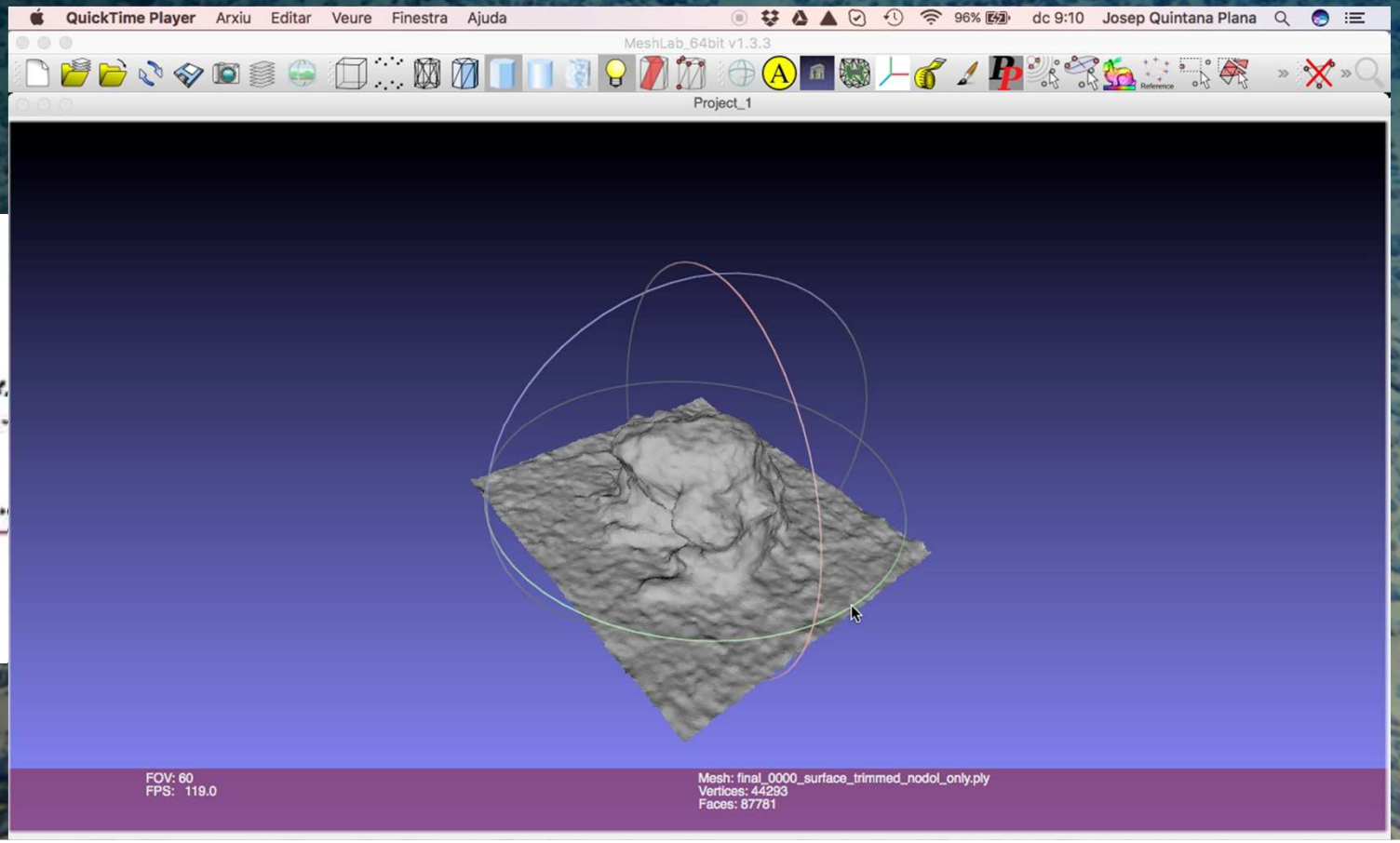


Technologies- Vision Based Mapping

Stereo camera

System Calibration → Dense Point Set Creation → Volumetric Measurements

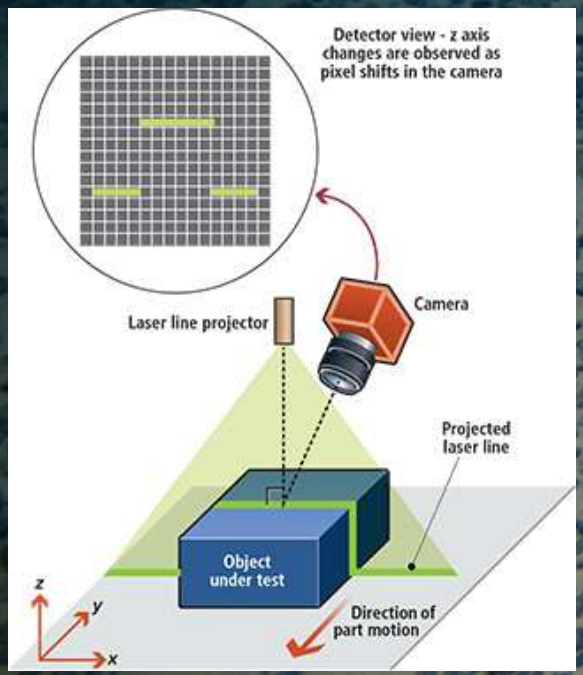


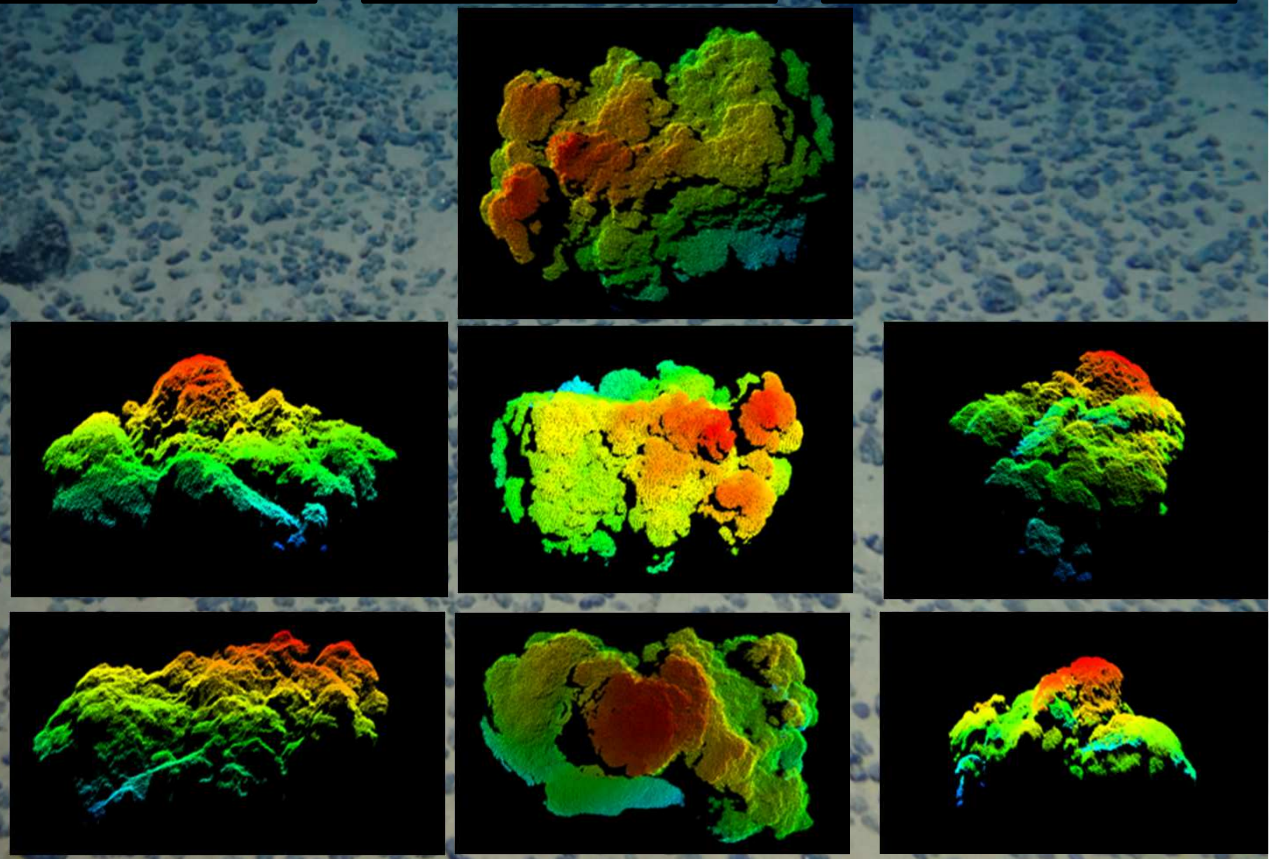


Technologies – Vision Based Mapping

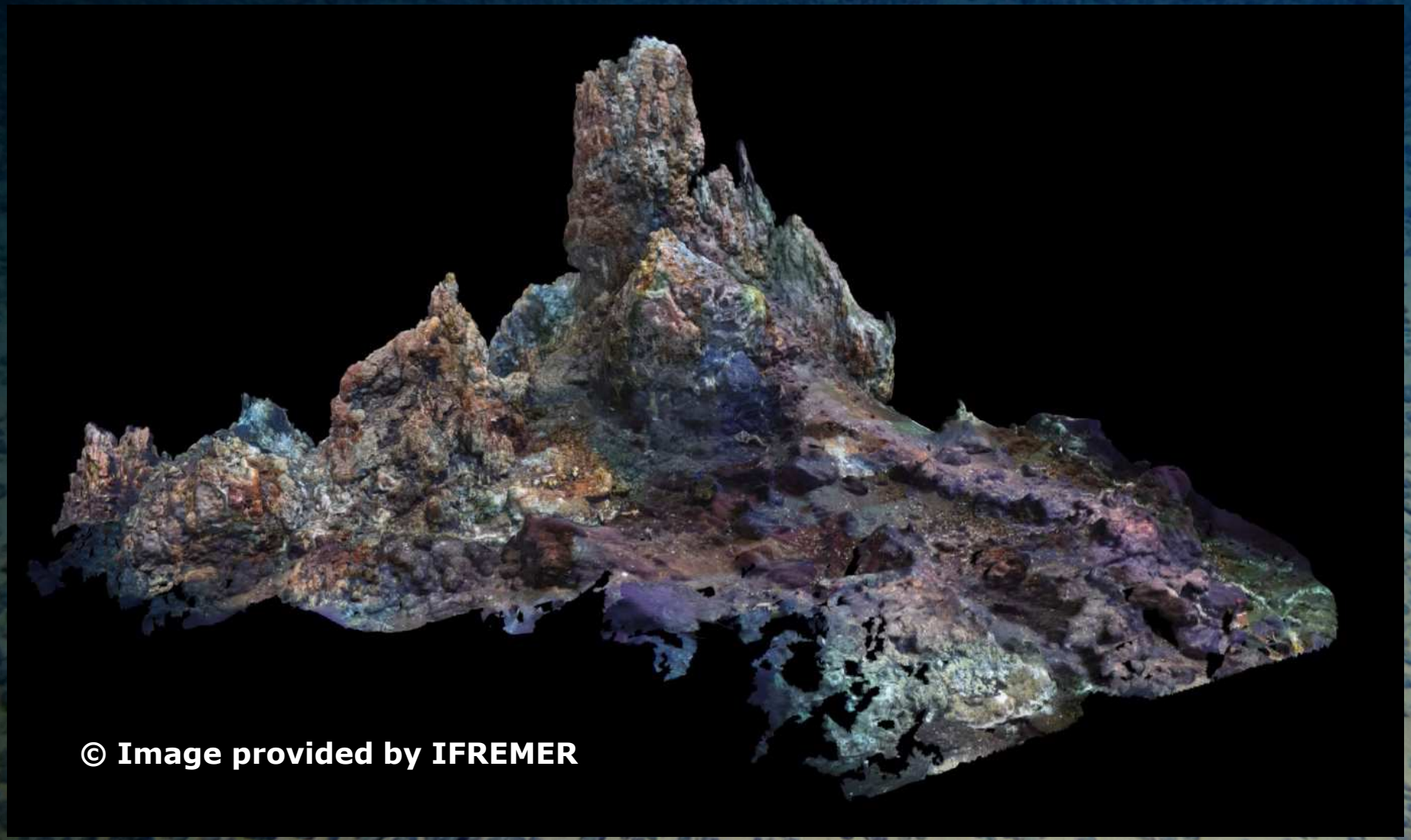
Laser scanner

Project a single strip of laser light → Line Detection → Triangulation → Volumetric Measurements





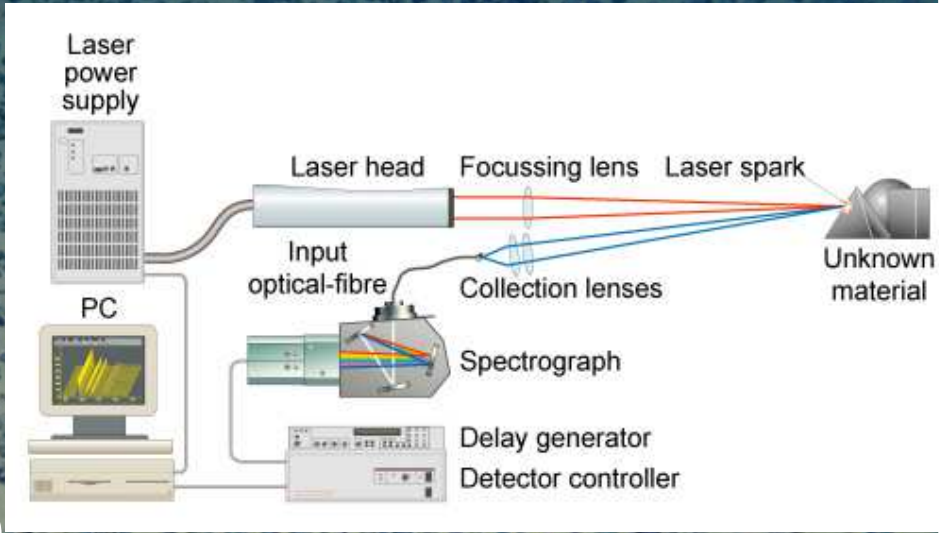
Technologies – Vision Based Mapping



© Image provided by IFREMER

Technologies - LIBS

- Optical non-contact technique for in-situ chemical analysis
- Its principle:
  - Laser beam is focused onto the sample surface to generate a plasma
  - Plasma emits light
  - Light guiding to the spectroscope
  - Quantitative analysis of the emission of atomic lines (spectra)



Source: http://www.appliedphotonics.co.uk/Libs/about_libs.htm

Technologies - LIBS

Analysis results

	Atlantic manganese nodule	Pacific manganese nodule	Massive sulfide
Image of sample			
Electron microscope image			

Chemical element	
C – Carbon	6.
O – Oxygen	3(
Na – Natrium	0.
Mg – Magnesium	1.
Al – Aluminum	3.
Si – Silicium	8.
S – Sulfur	-
P – Phosphor	0.
Mo – Molybdenum	0.
Cl – Chlorine	0.
K – Potassium	0.
Ca – Calcium	1.
Ti – Titan	0.
Mn – Manganese	1(
Fe – Iron	3(
Co – Cobalt	0.
Ni – Nickel	0.
Cu – Copper	0.
Zn – Zinc	0.

Identification of emission lines of Zn, Cu

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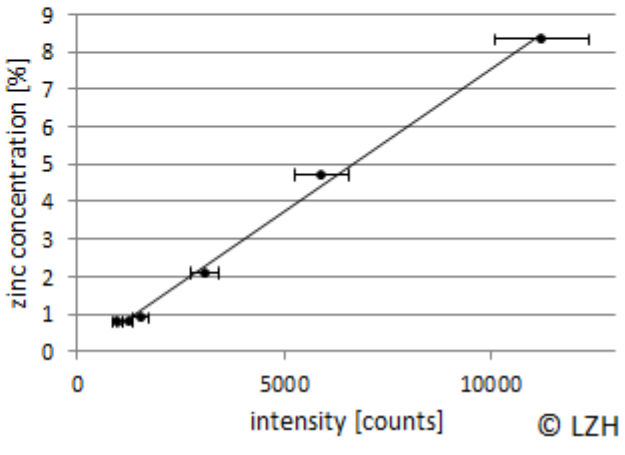
Calibration



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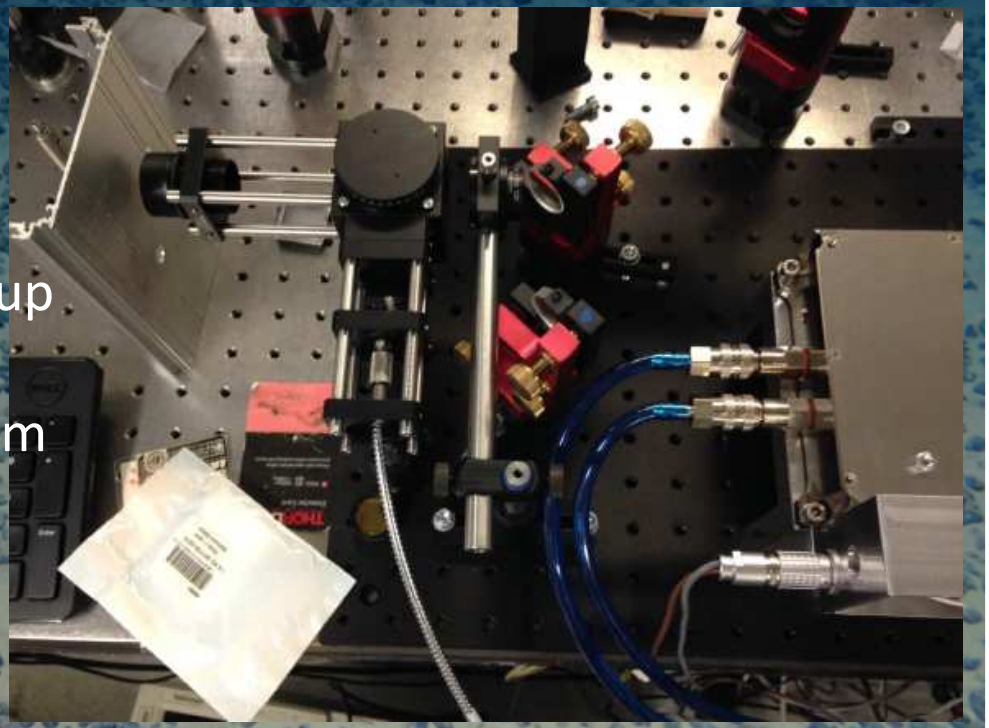
Technologies- LIBS

- Laser system set up ready and tested in atmospheric conditions



- The next steps:
  - Test in shallow water
  - Test in a pressure chamber (up to 650 bars)
  - Test on ROV at 4000 to 6000m for LIBS validation
  - Test on AUV at 300 m, for ROBUST validation


Thank you
Any questions?
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