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Marine Robotics

Unmanned Autonomous Vehicles in Air Land and Sea
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Multiple autonomous vehicles at sea

Multiple coordinated robotics at sea

- Global awareness
- Heterogeneous coordination
- Interoperability
- Rules and regulations
- Non segregated space operation and human base operational infrastructure integration

Global awareness with heterogeneous autonomous vehicles

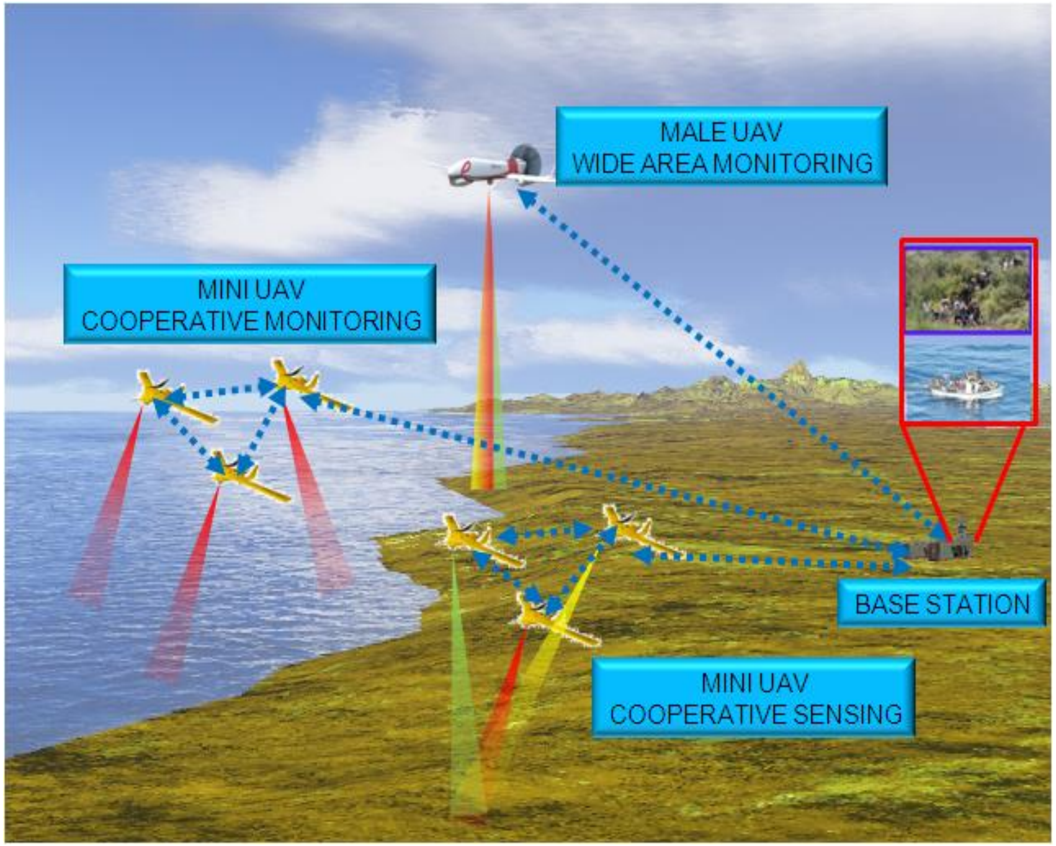
- Sunny project as an example
- Monitoring large scale environments
- Detect menaces preemptively
  - Vehicle characteristics
  - Vehicle behavior
  - Inter vehicle behavior

Tier 1 sees all without detail (radar, ais)

Tier 2 – sees details, heterogeneous

UAV configuration for awareness at sea

- Heterogeneous Airborne Surveillance Network
  - Two Tier Configuration
- Global Awareness
- Proximity Tracking
- Heterogeneous Sensor Configuration and Capacities
- Radar
  - MTI, SAR, ISAR Imaging
- Hyperspectral Camera
- EO and IR Gimbal
- AIS information
- Decentralized Data Fusion
- Learning



Sunny Advances

- **On board data processing**
  - **Processing of hyperspectral imaging in Real-Time**
  - **Processing of Maritime Moving Target Indicator Radar Data**

Perception

- **Development of multi-modal fusion**
  - **Decentralized data fusion between UAVs and SBS**

Sensor Fusion

- Exploitation and adaptation of mesh routing techniques
- Network topology control mechanisms

Communications

- Active Learning
  - Learning from detection history

Learning

- Enable efficient human feedback
  - Human Target Validation

Control

Platforms

- Tier 1 - Portuguese Air Force Antex

- Tier 2 - Tecnalia

Altus - Ouranos

Altus-Etheras

Platforms Specifications

UAVS Specifications				
Payload Size	To be customized during integration	-	-	-
Payload Volume	-	20000000 mm3	-	-
Payload Weight	30Kg	10Kg	3-4Kg	4-9kg
Power	*(Depends on the batteries/generator configuration)*	80W	50W	*(Depends on the batteries/generator configuration)*
Length	3.30m	2.30 m	2.94 m	2.6 m
Rotor diameter/wingspan	6 m	3.3 m	2.52 m	2.2 m
MTOW	100 Kg	21,5 Kg	90 Kg	33 kg
Endurance	6-8 h	4h	1 h	50min-2h
Max. Airspeed	150 Km/h	100-130 Km/h	370 Km/h	70 Km/h
Max. Altitude	13000 ft.	10000 ft.	19685 ft.	4000 ft.
Operational range (link)	40 Km *(Can be extended)*	50 Km	100 Km	20 km
Video link range	40 Km *(Can be extended)*	50 Km	100 km	20 km
Take off distance	100 m (max.)	70 m	*Catapult Launch*	*Vertical Take off*

Sensors per Platform

- Tier 1

  - Radar

  - AIS

On-board Processing
Keep Target(s) Tracks:
• Track ID
• history of {time, position, velocity, uncertainty position and uncertainty velocity}
• Associated AIS information
• Crop of the SAR image
• Shape descriptors
Sends to the SBS:
• Periodic Track Records information (MTI)
• CROP SAR on request
• Periodic message of on-board data processing status

Sensors per Platform

- Tier 1

  - Radar

  - AIS

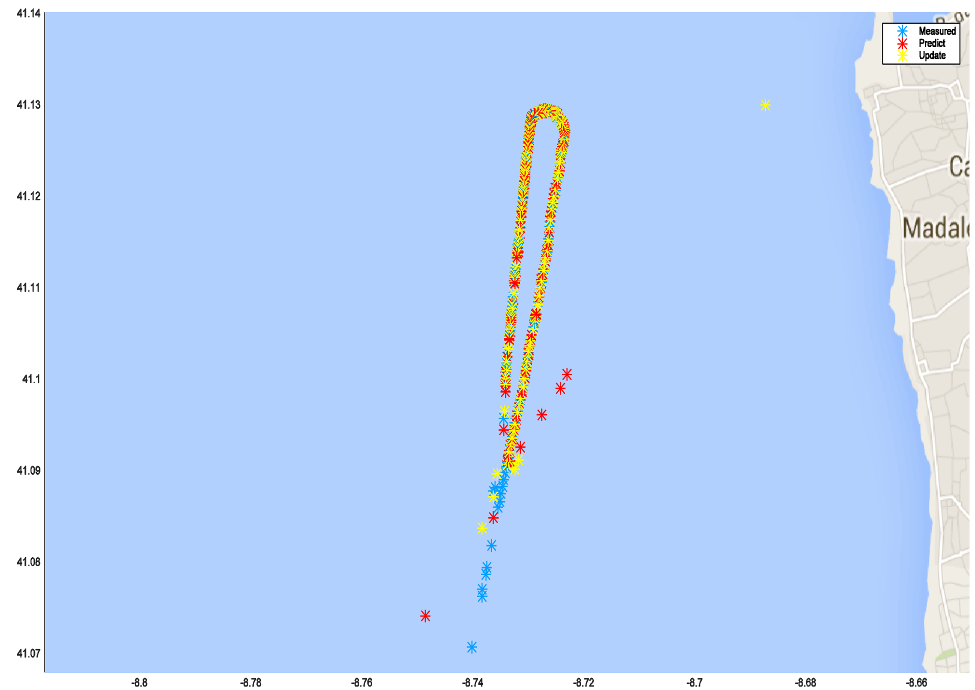
Radar Target Detection

Sensors per Platform

- Tier 1
  - Radar

  - AIS

AIS Kalman Tracker

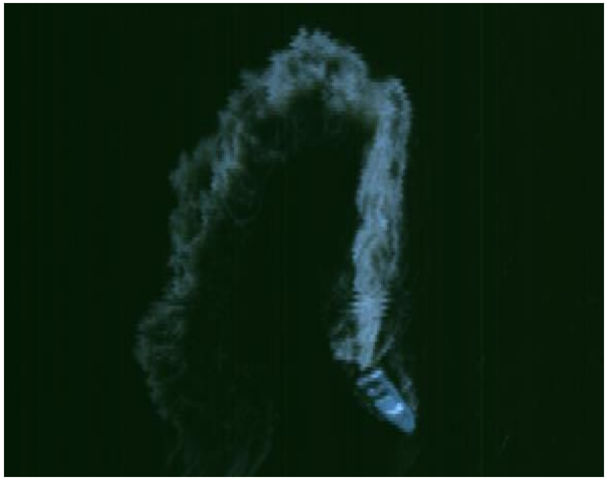


- Tier 2

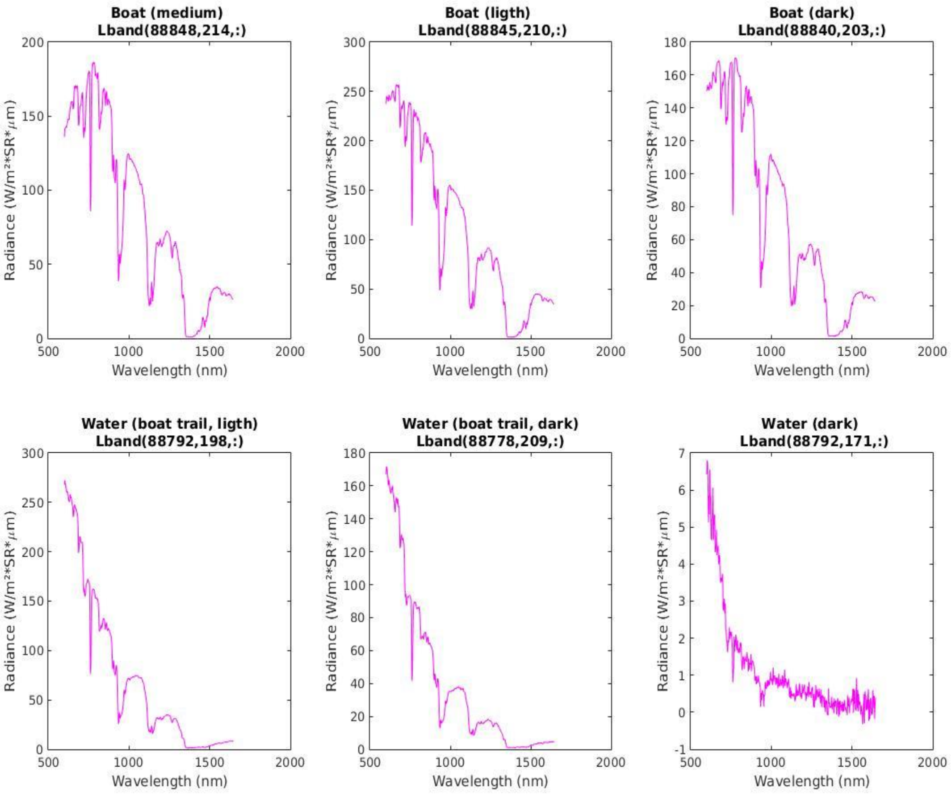
  - Hyperspecral

Sensors per Platform

- Tier 2
  - Hyperspectral



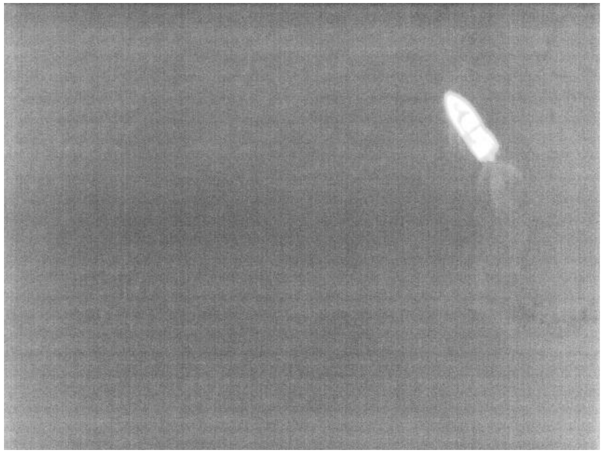
Waterfall image



Sensors per Platform

- Tier 2

  – Gimbal E/O IR



Interoperability and coordination of multiple autonomous robots at sea

- Standard UxV interoperability frameworks
  - Stanag, JAUS
- Frameworks for interoperable development
- Mission management (fleet)
- Integration with man operated infrastructure

ICARUS Maritime Scenario

- Large scale disaster at sea
  - Large number of victims on the water
- Fixed wing UAVs
  - Large area survey / situation assessment
  - Victim location on the water
- Unmanned rescue robot capsules
  - Mobile life-rafts
  - Guided to the victim vicinity
- Transport USVs
  - Fast access to location
  - Deploy survival capsules
  - Support rescue operations, local area survey
- Short range VTOL UAVs
  - Local victim localization
  - UCAPs guidance support

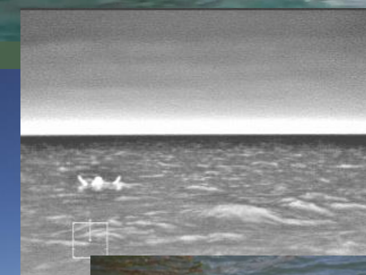
Assets

- INESC
  - Unmanned Capsule
  - ROAZ ASV
- Calzoni U-Ranger
  - Manned / unmanned autonomous
  - 7m length, aluminum hull
  - Max speed 40 kts

Field missions

- REP 2012
  - Data collection
- REX 2013, 2014
  - UCAP validation, deployment system
  - Radar processing
  - Victim detection
- Field tests at CMRE – La Spezia
  - U-Ranger sensor suite integration
- UAV integration tests (CMRE, La Spezia)
- Final sea demonstration Jul /2015 Alfeite, Portugal

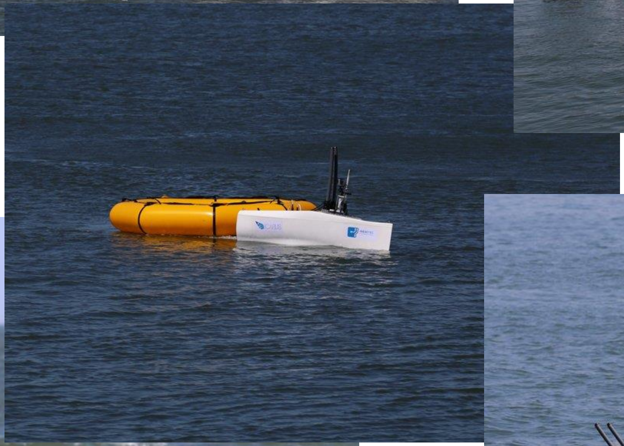






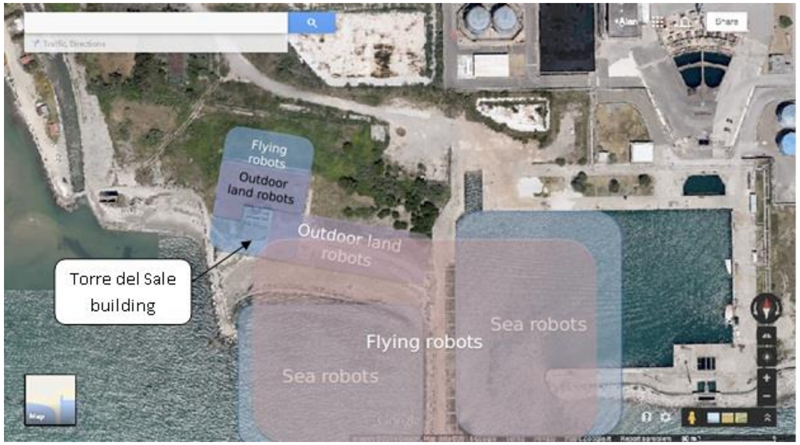


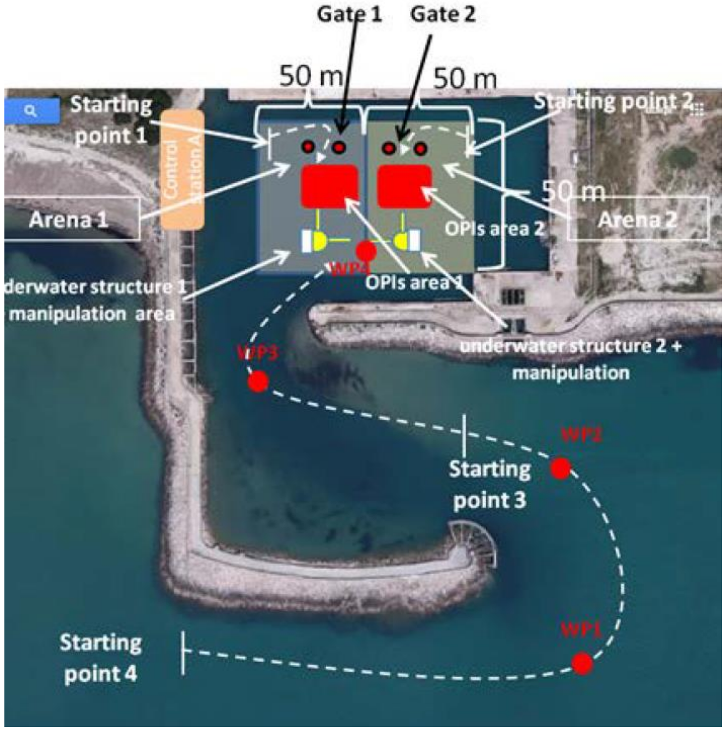
Sea demonstration trials



euRathlon

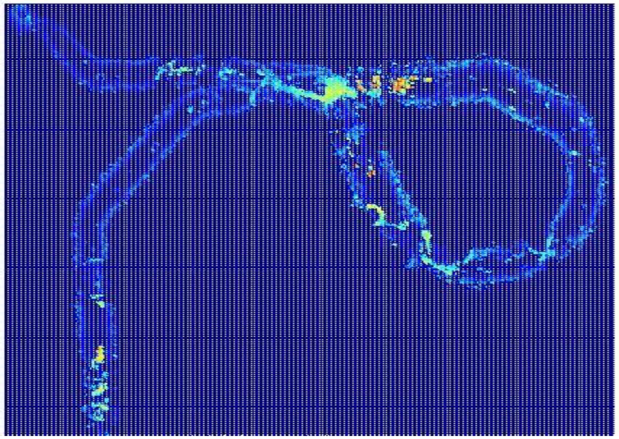
- Fukushima inspired disaster scenario
- Air, Sea and Land Cooperating robotics
- Missions
  - Underwater pipe inspection
  - Search for missing workers
  - Navigation and environmental survey
  - Leak localization and stopcock open/closing
  - Grand Challenge with cooperating robots performing all tasks in sea land and air
- Piombino, Italy, Sep. 2015

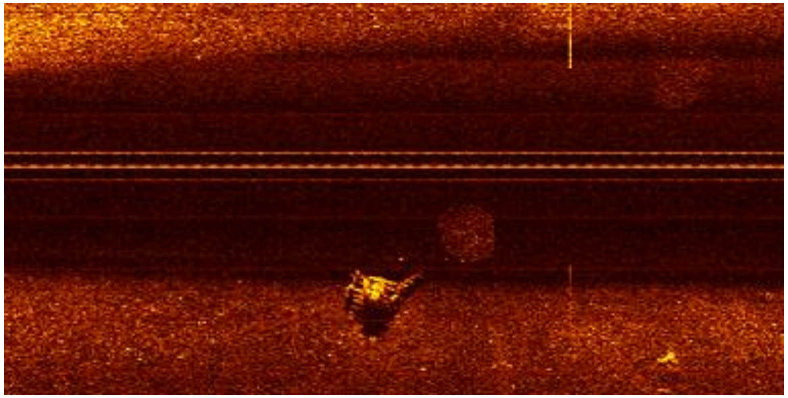


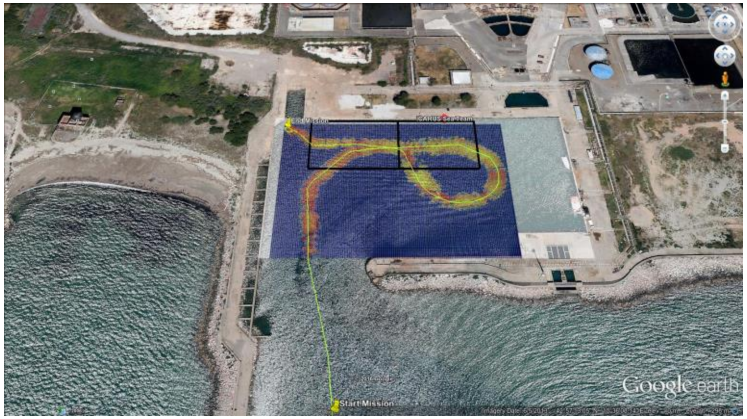


Environment survey and mapping

- ROAZ USV performs initial survey
- Relevant points of interest are detected
- Bathymetry from multibeam sonar data
- Sides scan sonar info provides imaging and target assessment
- Navigation accuracy <10 cm and 0.05º in attitude
- Environment assessment data available in realtime
- Initial realtime statistical analysis (20cm grid) to provide data for AUV mission planning, and deploy







Autonomous AUV deploy

- MARES AUV deploy at predefined location
  - AUV efficient transport to location of interest
  - Extending AUV underwater autonomy
  - AUV mission support

- Complex multi-robot missions
  - Ex: Wide search followed by detailed underwater investigation

- Deploy of OTUS Aerial Robot from ROAZ USV
  - Allowing for aerial overview in search and rescue missions
  - USV can act as a mobile base for UAV
  - Tested at euRathlon but not used in the competition trials

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Emerging applications and current challenges

Emerging applications

- Autonomous intervention tasks – “cut the cord to ROVs”
  - Autonomous intervention in sensitive areas: offshore oil industry, submarine cable handing
  - Higher level of mission abstraction
- Fisheries and biological studies
  - From the periodical survey to long term presence
  - New applications in adaptive sampling
- Equipment transport and positioning to deep sea
- Offshore aquaculture support
  - Surveillance
  - Monitoring

Emerging applications

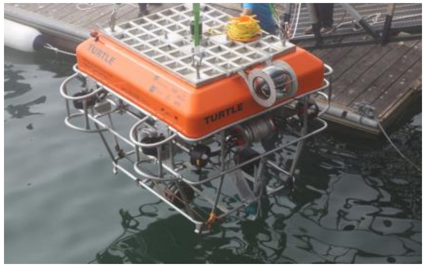
- Underwater mining
  - Deep sea sustainable mining
  - Flooded land mines (exploration and exploitation)
- Long term autonomous security applications and surveillance
- Mass disaster search and rescue support

INESC TEC driving objectives for Marine Robotics

- **Going deeper**
- **Extended autonomy**
- **Safety**
- **Sustainability**
- **Harsh and complex environments**

Research towards these goals

- Sensing & Perception
- Multi-robot cooperation
- Distributed navigation
- System development
- Energy and communications at sea



INESC TEC – Robotics and Autonomous Systems

ICARUS – Air, sea and land search and rescue
FP7
24 partners,
10 countries,
17.5M€

Safety

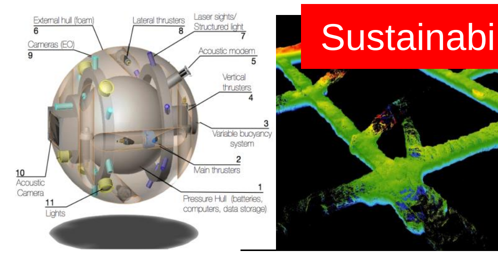
SUNNY- Unmanned Aerial Border patrol,
FP7,
18 partners
10 countries,
13M€

Stay longer

VAMOS – Underwater mining exploitation
H2020
17 partners,
9 countries,
12.4M€

Sustainability

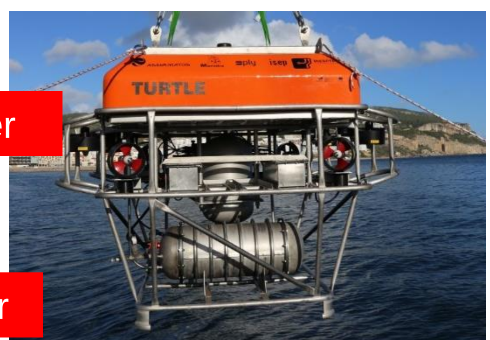
UNEXMIN - Underwater exploration and mapping
H2020,
13 partners,
7 countries,
4.8 M€



Sustainability

Complex environment

TURTLE – Robotic autonomous deep sea lander
QREN
4 partners
1.3M€



Go deeper

Stay longer

MARES – Hovering modular AUVs
National funds, International contracts
1 M€

Go deep

Autonomy

TURTLE Robotic Autonomous Deep Sea

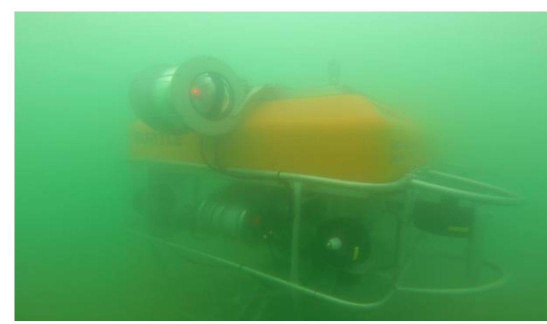
Stay longer

Go deeper

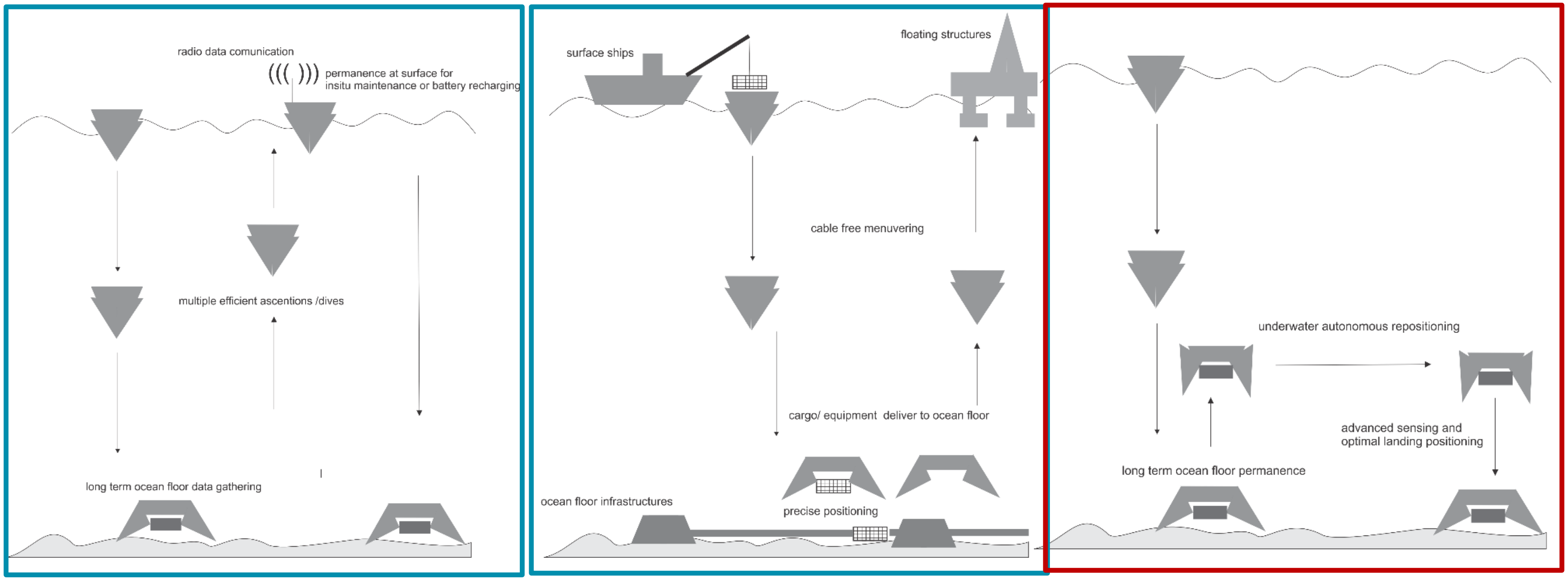
- New system for new function

- Hybrid AUV/ Lander concept
  - **Long term permanence** at sea bottom
  - **Autonomous positioning**

- Robotic lander
  - VBS based ascent/descent
  - LBL/USBL positioning
  - Long term permanence at bottom
  - 1.4 Ton
  - 8 Kwh Pressure tolerant batteries

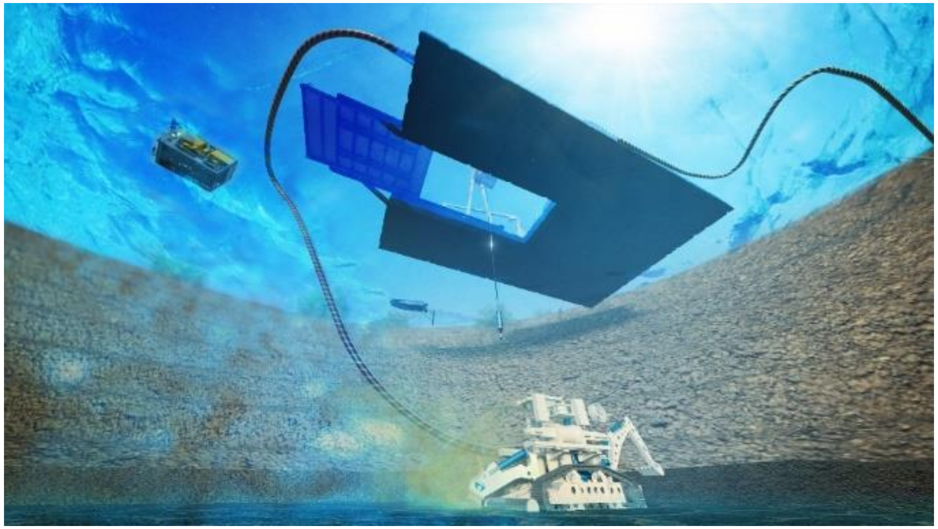


Robotic Deep Sea Lander



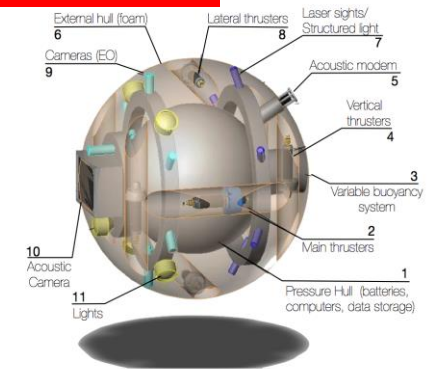
VAMOS - underwater mining exploitation

- Efficient robotic underwater mining system
- High precision navigation and mapping of a changing environment
- Real time wireless operations autonomous support
- Turbidity, noise
- In situ mineral analysis – LIBS sensor

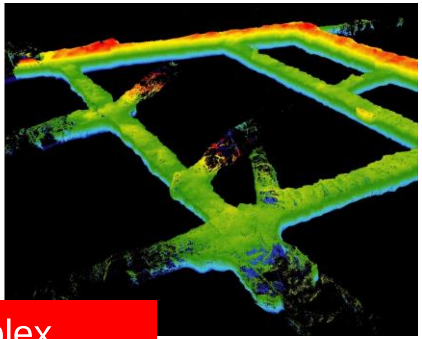


UNEXMIN

Sustainability



- Exploration of flooded underground mines
- Extreme environment for navigation
  - Visibility issues
  - Precise control
  - Unstructured with hazardous obstacles
- In-situ mineral information gathering
- Severe limitations on robot design



Complex environment

Autonomy

Current challenges in underwater robotics?

System design

- “Do the same or more with less”: *less support, less human involvement, less power, less money*
  - Reduce the size
  - Reduce de power
  - Reduce operational constraints
  - Do more- autonomy

Current challenges in underwater robotics?

Planning and coordination

- Work with others / work with man
- Higher level of abstraction in mission definition
- Failure resiliency and autonomy reliability

Current challenges in underwater robotics?

Control

- Manipulation
  - Autonomous intervention
  - Dexterous manipulation

- New challenging scenarios
  - Surf zone
  - High sea states – for specific applications (ex: rescue)

Current challenges in underwater robotics?

Perception

- Tackle difficult environments:
  - Turbid waters (mining, outfall plumes)
  - Very unstructured environments – "see and percept" (flooded gallery mines, underwater caves, debris areas
- Detailed 3D environment mapping
  - quality perception for new tasks, "see underwater what is not seen is now"
- New sensing instruments and insitu technology
  - Raman
  - LIBS,
  - microplankon DNA analysis …

Current challenges in underwater robotics?

Navigation and mapping

- Long term navigation without infra-structuring – terrain based navigation
- High precision/accuracy in mapping and navigation (particular applications such as realtime 3D modeling in mining or dredging)
- Semantic mapping
- Navigate/survivability in challenging environments – “go where robots don’t go”