

Underwater Intervention Missions



Pedro J. Sanz



“La Robótica Submarina y las Misiones de Intervención”

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Overview

1. INTRODUCTION
2. UNDERWATER INTERVENTION MISSIONS
3. CASE STUDY 1 → SAR Operations
4. CASE STUDY 2 → OFFSHORE Industry
5. CASE STUDY 3 → Cooperative Robots
6. LAST REMARKS

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UJI UNIVERSITAT JAUME I

Since 1991

- Students **14.000**
- Lecturers **1.400**
- Ratio Lecturer / student **10**

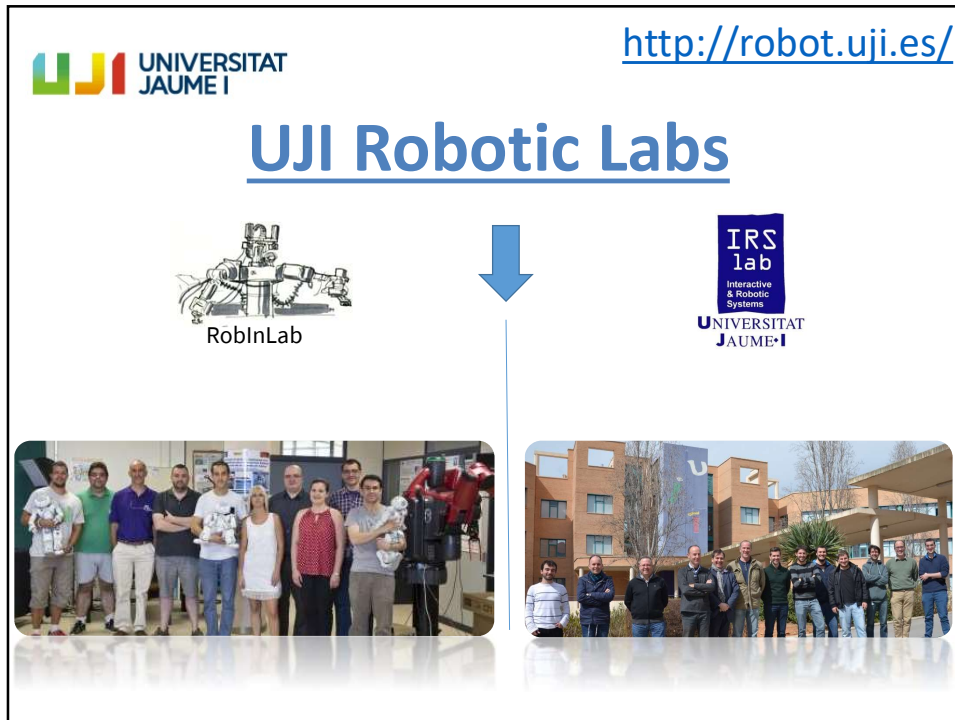
School of Technology and Experimental Sciences

Dep. of Comp. Science & Engineering

Castellón

The slide features a map of Spain with Castellón highlighted, an aerial view of the university campus, a night view of a building, a marina with sailboats, and a large modern building.

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UJI UNIVERSITAT JAUME I

<http://robot.uji.es/>

UJI Robotic Labs

RobnLab

IRS lab
Interactive & Robotic Systems
UNIVERSITAT JAUME I

The slide includes a line drawing of a robot, a blue arrow pointing down, and two group photos of people in a lab and in front of a building.

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UJI UNIVERSITAT JAUME I

<https://www.irs.uji.es/>

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IROs workshop
[ABOUT](#) [SPEAKERS](#) [PROGRAM](#) [POSTER SESSION](#) [CONTACT](#)

New Horizons for Underwater Intervention Missions: from Current Technologies to Future Applications

Madrid / Friday 5th October 2018
9:00 AM - 14:00 AM

MADRID 2018
IROs

<http://irosworkshop.marinerobotics.eu/>

Photo credit: Frederic Ouedrao and Teddy Segura/ROSM

 <p>Oussama Khatib Director of Stanford Robotics Lab, Stanford University, USA</p>	 <p>Antonio Pascoal Head, Oceans Thematic Area, LARSyS, ISR/LARSyS/IST-Univ. Lisbon, Portugal</p>	 <p>Gianluca Antonelli Professor of University of Cassino and Southern Lazio, Italy</p>	 <p>Sadao Kawamura Professor/Director of Ritsumeikan University, Kyoto, Japan</p>
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PI Sanz

UJI, 3 JUN 2019

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MIR

**MARINE &
MARITIME
INTELLIGENT
ROBOTICS**



With the support of the Erasmus+ Programme of the European Union



UNIVERSITÉ DE TOULON



UNIVERSITAT JAUME I



TÉCNICO LISBOA



NTNU

MIR – EMJMD IN MARINE AND MARITIME INTELLIGENT ROBOTICS
Erasmus Mundus Joint Master's Degree

<https://www.master-mir.eu/>





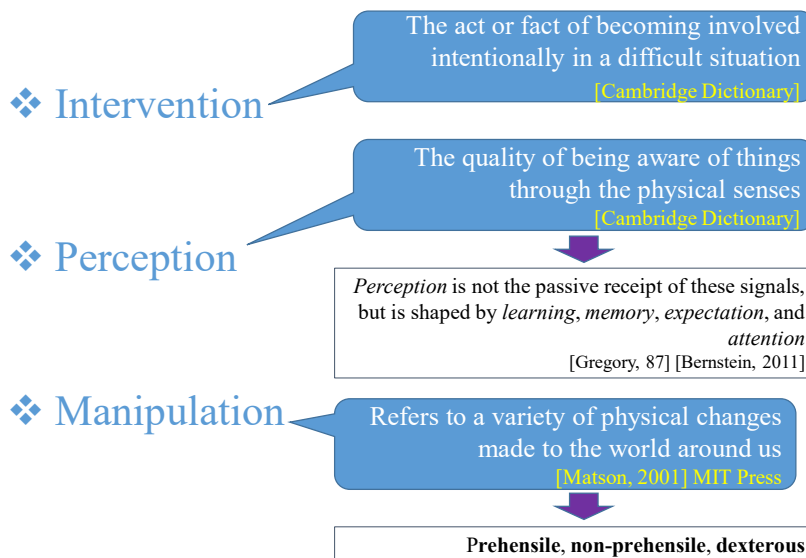
10

2. UNDERWATER INTERVENTION MISSIONS

1. Preliminary Concepts
2. A Taxonomy of Underwater Vehicles
3. State-of-the-Art and Evolution
4. Pros and Cons of ROV's and I-AUV's
5. Concerning Robotic Technology Progress

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Basic Concepts Revisited



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❖ *Example* “A UJI robot joins the SOS in the port of Castelló”

<https://www.elperiodicomediterraneo.com/sucesos/2021/06/06/robot-uji-suma-sos-puerto-52662330.html>

29/05/2021

SOS is a Morse code distress signal
(····· ———)
<https://en.wikipedia.org/wiki/SOS>

SeaBotix
ROV
vLBV200

6/06/2021

TELEDYNE SEABOTIX
Everywhere you look

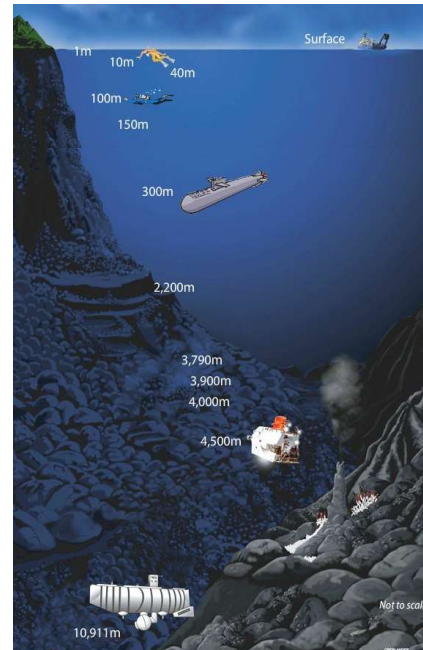
9/07/2021

“Found the body of the longshoreman who disappeared 41 days ago, when a ship capsized in the port of Castellón”

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Underwater Domain

- 72% of Earth surface covered by water
- 70% of world's oxygen comes from the oceans
- Oceans absorb 50% of all man-origin CO₂
- 80% of life on earth is underwater
- **95% of Oceans is unexplored**
- 90% of volcanic activity is underwater
- **Natural resources**
 - Minerals
 - Oil & Gas
 - Renewal energy
 - Fisheries
- **Science**
 - Marine forecast
 - Biology
 - Geology
 - Seismology
- **History**
 - Marine archaeology
- **Humanitarian**
 - Wreck rescue
- **Defence**
 - Mine countermeasures
 - Harbour surveillance

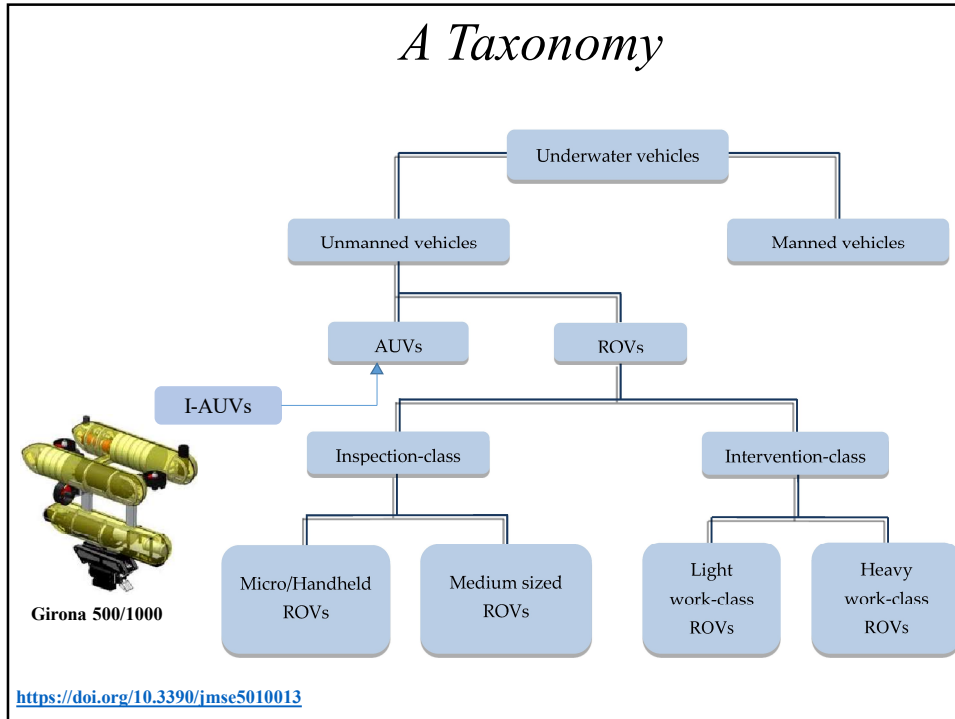


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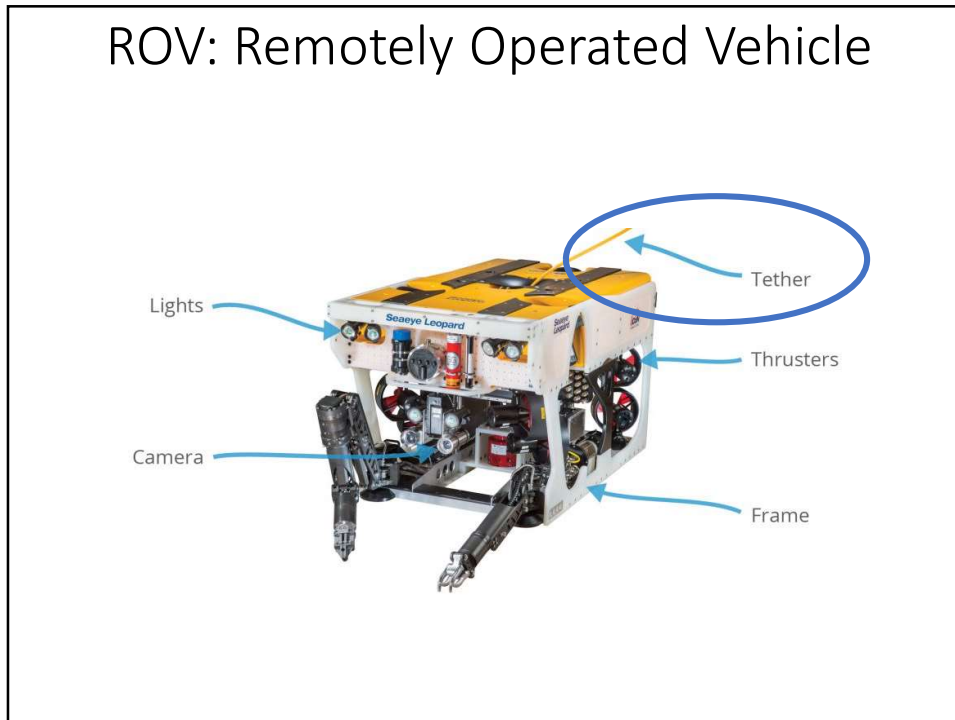
2. UNDERWATER INTERVENTION MISSIONS

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ROV: Remotely Operated Vehicle

subsea 7

Hercules Hydraulic Work Class ROV

- 3000m depth rating
- Neutrally buoyant
- Syntactic foam buoyancy
- 150-200 Shaft HP hydraulic power unit (3,000v)
- 8 Servo controlled hydraulic thrusters
- 2, 12 station solenoid valve packs
- Dimensions

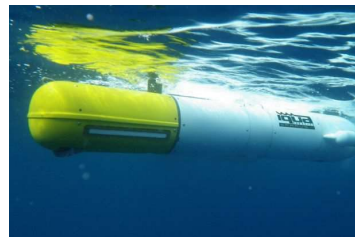
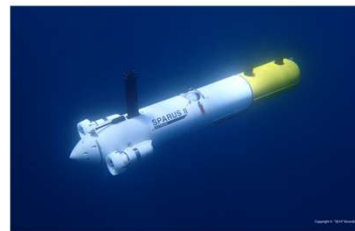
- Length	2400mm
- width	1850mm
- Height	2050mm
- Weight in air >3 Tonnes
- Pressure resistant control pod
- Fibre optic data and video communications
- CCTV & digital stills cameras
- Sonar, 3 axis fibre optic gyro, transponder
- 2 kW variable intensity lighting
- Auto heading and depth
- Pitch and roll control
- 3T through frame lift
- Electrical, data, and hydraulic expansion ports



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AUV: Autonomous Underwater Vehicle

SPARUS II (UdG / IQUA Robotics)



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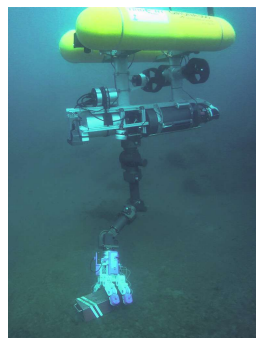
AUV: Autonomous Underwater Vehicle

Girona 500 (UdG / IQUA Robotics)

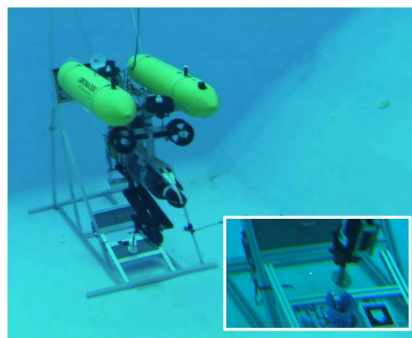


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I-AUV: Autonomous Underwater Vehicle for Intervention



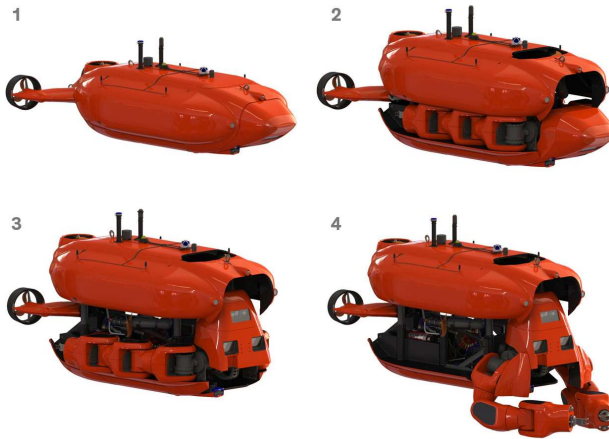
TRIDENT



TRITON

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New concept: *Aquanaut*



From Houston Mechatronics to
<https://nauticusrobotics.com/>

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New concept: *OceanOne*



King Abdullah University of Science and Technology and the *Stanford Robotics Lab*

<https://www.youtube.com/watch?v=p1HmgP9l4VY>

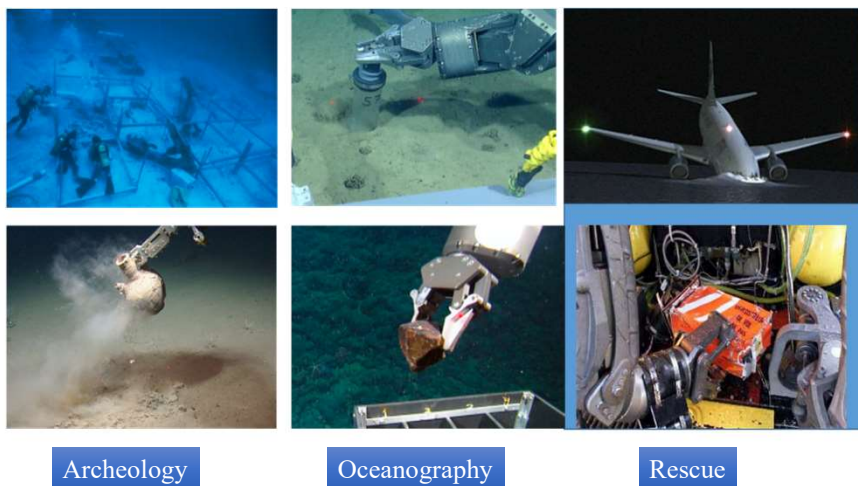
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2. UNDERWATER INTERVENTION MISSIONS

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Underwater Intervention in Action



Common problems: "Search and Recovery"; "Select and Sampling"; "Inspect and Repairing"

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❖ SoA Intervention
Work Class ROV's

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❖ SoA Intervention
Work Class ROV's

“Prestige” sinking and oil spill (2002)

To the rescue →


3.850 m depth

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SAR Operation Example

The Black Box Recovery Problem

Crashed Aircraft

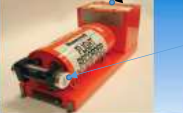




A flight data recorder (**black box**) is an electronic device employed to record instructions sent to any electronic systems on an aircraft.

Black Box

Underwater Locator Beacon Pinger

→ Limits: 30/40 days; 1/2 km









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Flight Data Recorder of flight AF 447* found at 3,980 m depth (May 2011)

* Disappeared over the Atlantic on 1 June 2009

It was raised and lifted on board the ship *Ile de Sein* by the Remora 6000 ROV







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The search was targeted in an area of about **10.000 square kilometers**

Approx. 30 M \$ (three missions)

❖ SoA Intervention

Work Class ROV's

A team led by the [Woods Hole Oceanographic Institution](#) operating full ocean depth [autonomous underwater vehicles](#) (AUVs) discovered, by means of [sidescan sonar](#), a large portion of the debris field from flight AF447



Phoenix's Remora ROV Specifications


General Weight in Air	900 kgs dry
Weight in Water	Neutral
Dimensions Length:	1.7 m
Width:	1.0 m
Height:	1.2 m
Maximum Operating Depth	6,000 m

Vehicle Description

Propulsion	25 hp electro-hydraulic
Thrusters	4 x Axial / lateral thrusters 2 x Vertical thrusters
Manipulators	2 x Hydro-Lek six function, rate controlled

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1. Localization
2. Recovery
3. Legal Process (judicial seal)

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AF 447
May 2011 Search and Recovery of AF 447

Inspiring Motivation for TRIDENT European Project



TRIDENT

Marine Robots and
Dexterous Manipulation for
Enabling Autonomous
Underwater Multipurpose
Intervention Missions



(ICT-248497)

(May 2011 was the 1st Annual Project Review)



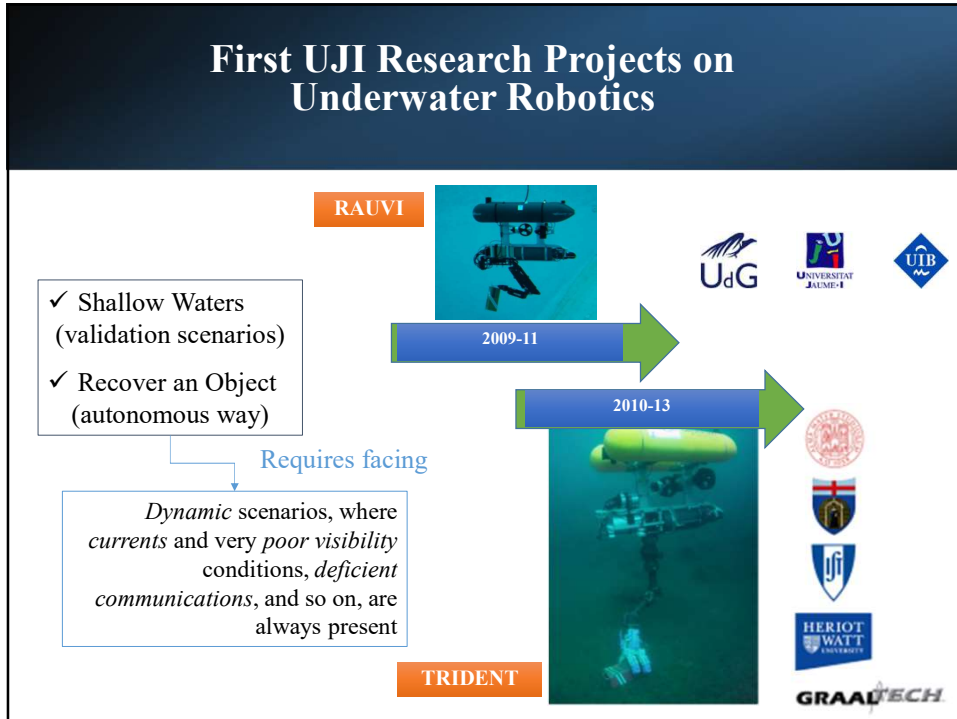
The *search and recovery* of a *black-box mockup* was used as a final proof of concept

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3. CASE STUDY 1

SAR OPERATIONS
Research Projects: RAUVI, TRIDENT

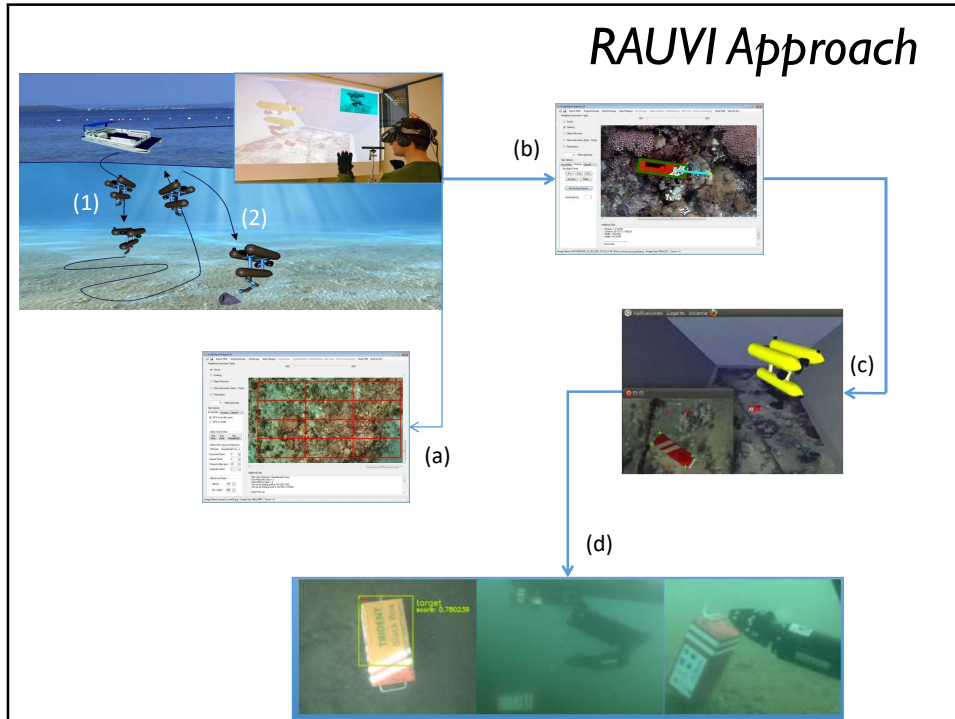
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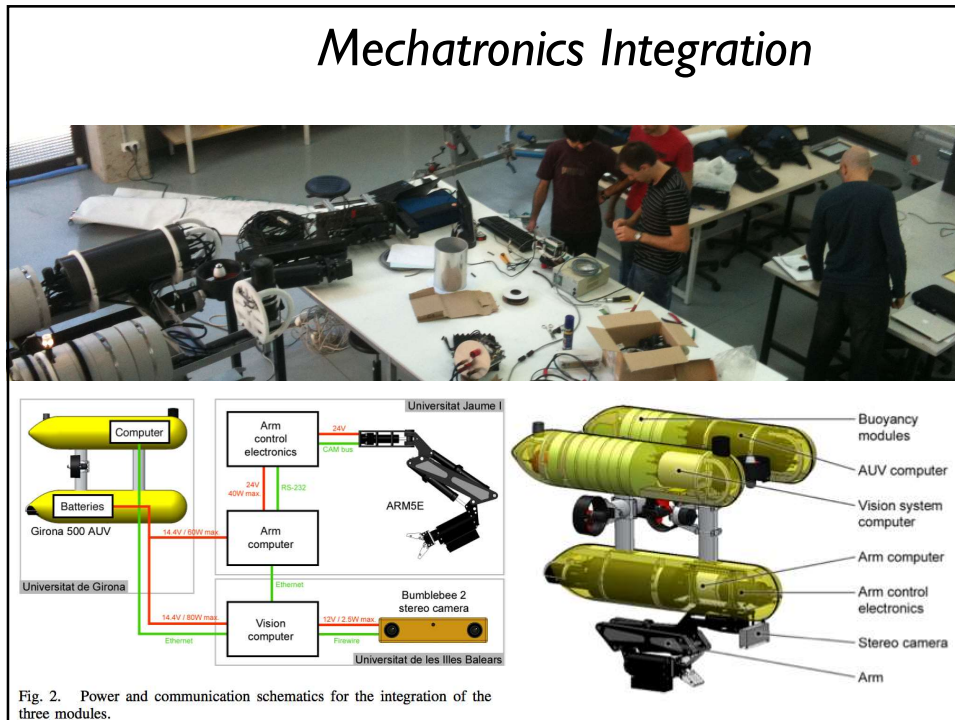
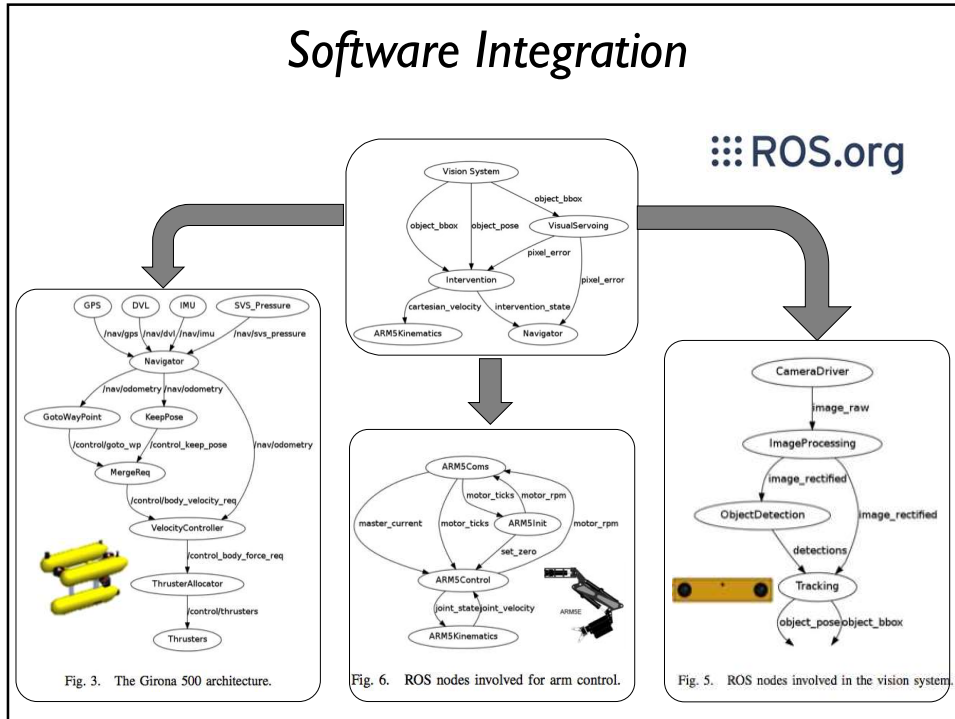


Fig. 2. Power and communication schematics for the integration of the three modules.


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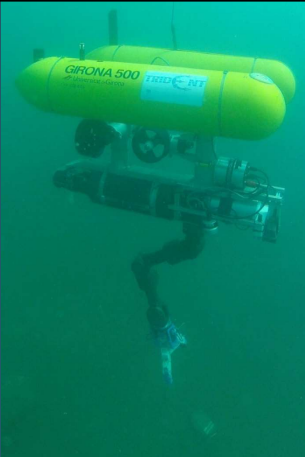

TRIDENT

An European Project Targeted to Increase the Autonomy Levels for Underwater Intervention Missions




Pedro J. Sanz, Pere Ridao, Gabriel Oliver, Giuseppe Casalino, Yvan Petillot, Carlos Silvestre, Claudio Melchiorri, Alessio Turetta





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TRIDENT

Marine Robots and
Dexterous Manipulation for
Enabling Autonomous
Underwater Multipurpose
Intervention Missions












SEVENTH FRAMEWORK
PROGRAMME

2010-13


(ICT-248497)

TRIDENT – Marine Robots and Dexterous Manipulation for Enabling Autonomous Underwater Multipurpose Intervention Missions
<http://www.irs.uji.es/trident/>




- 
Universitat Jaume I de Castellón (Spain)
 Dr. Pedro J. Sanz
 Multisensory Based Manipulation Architecture
- 
Universitat de Girona (Spain)
 Dr. Pere Ridaó
 Navigation and Mapping
- 
Universitat de les Illes Balears (Spain)
 Dr. Gabriel Oliver
 Visual/Acoustic Image Processing
- 
Università di Bologna (Italy)
 Dr. Claudio Melchiorri
 Mechatronics System and Control
- 
Università di Genova (Italy)
 Prof. Giuseppe Casalino
 Floating Manipulation
- 
Instituto Superior Técnico (Portugal)
 Dr. Carlos Silvestre
 Single and Multiple Vehicles Control
- 
Heriot Watt University (United Kingdom)
 Dr. Yvan Petitot
 Vehicles Intelligent Control Architecture
- 
Graal Tech (Italy)
 MSc. Andrea Caffaz.
 Electromechanical design of the arm

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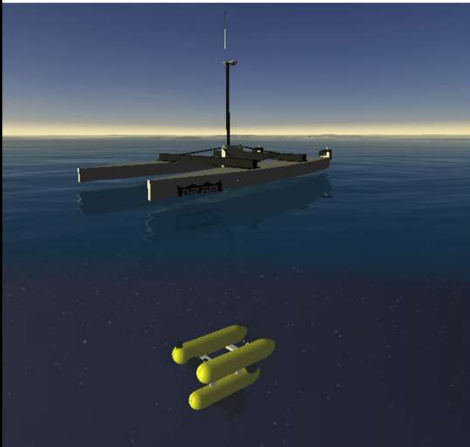
TRIDENT


Marine Robots and
Dexterous Manipulation for
Enabling Autonomous
Underwater Multipurpose
Intervention Missions



SEVENTH FRAMEWORK
PROGRAMME

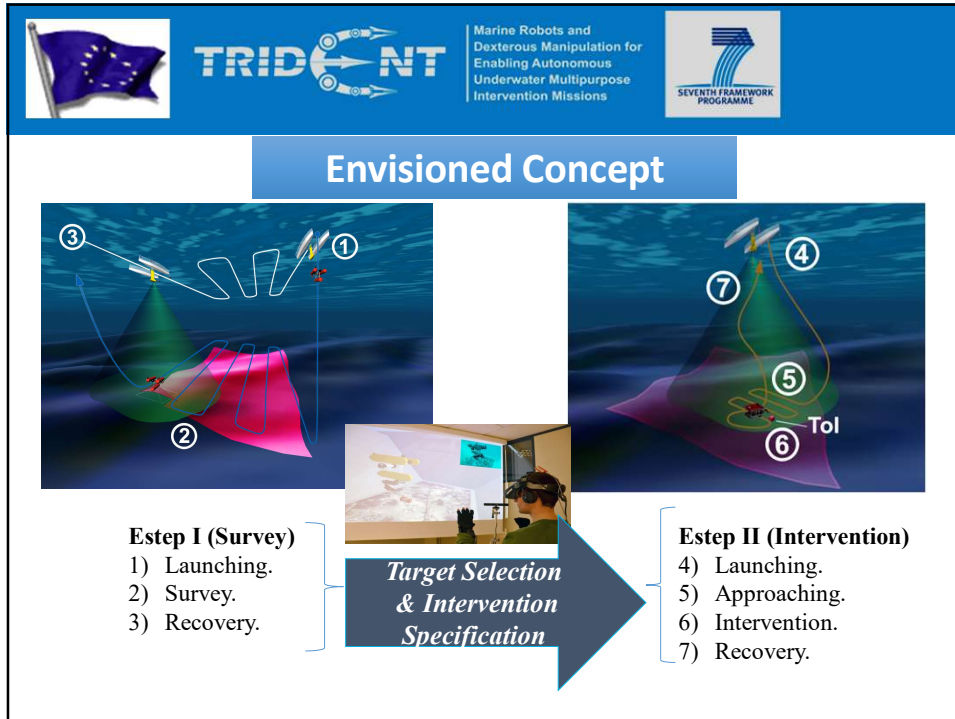
Robotic Tandem for Multipurpose Intervention Missions





- 3 DOF ASC
- 4 DOF AUV
- 7 DOF MANIPULATOR
- 3 FINGER DEXTEROUS HAND

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 Marine Robots and Dexterous Manipulation for Enabling Autonomous Underwater Multipurpose Intervention Missions
 




TRIDENT

FINAL EXPERIMENTS



 Port de Sóller, Mallorca (Spain)
 1st - 5th October 2012

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 Marine Robots and Dexterous Manipulation for Enabling Autonomous Underwater Multipurpose Intervention Missions
 








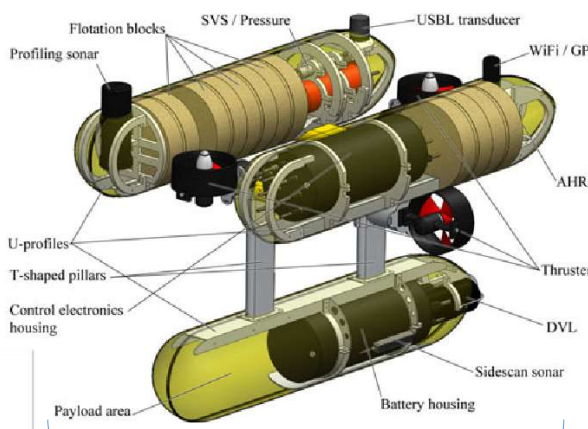



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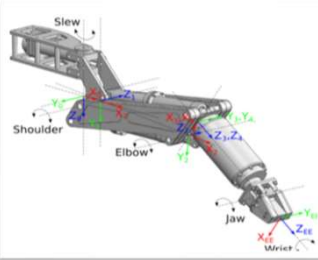
❖ I-AUV's: The Mechatronics



I-AUV
Configuration for
RAUVI Project



Girona 500
<https://iquarobotics.com/>



Arm5E
ECA/CSIP

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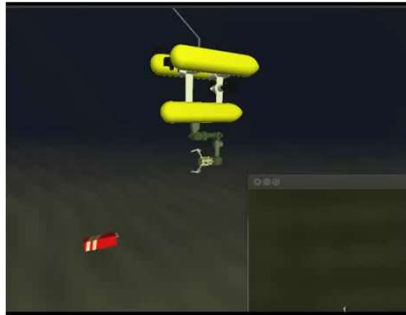
❖ I-AUV's: The Software

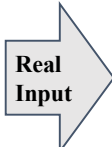
UWSim

A software tool for visualization and simulation
of underwater robotic missions

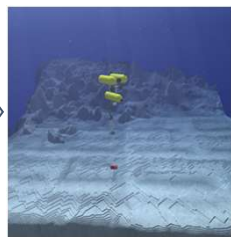
<http://www.irs.uji.es/uwsim>

- Real information gathered on experiments can be used to create and improve realistic scenarios
- These scenarios allow researchers to develop algorithms in a much more realistic environment avoiding oversized complexity

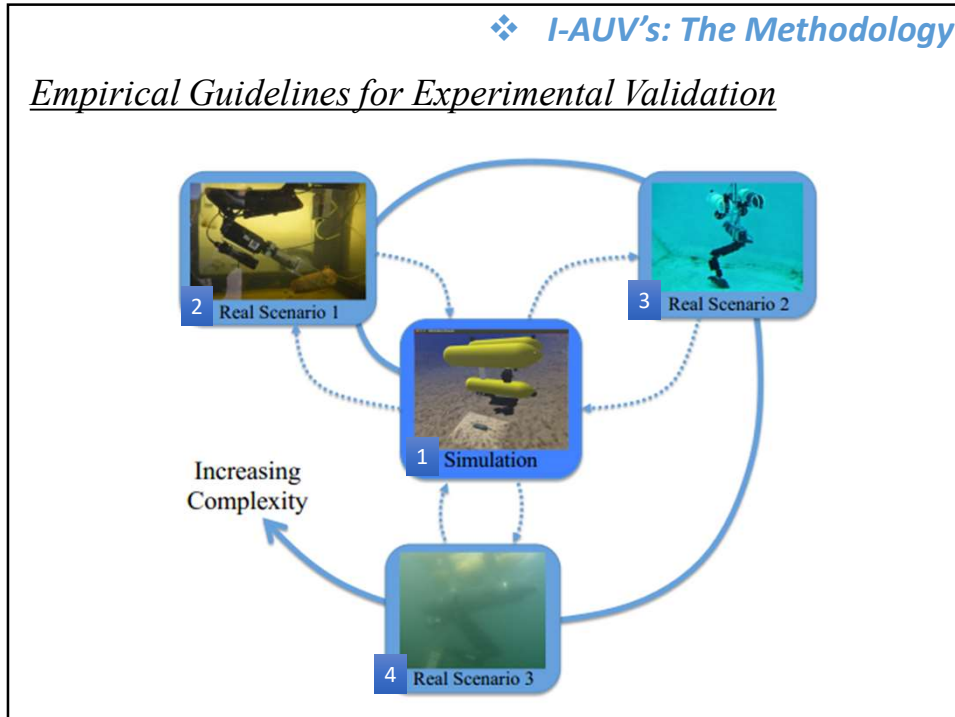




**Real
Input**



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4. CASE STUDY 2

OFFSHORE Industry
Research Project: TRITON


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2012-14



GOBIERNO DE ESPAÑA



MINISTERIO DE CIENCIA E INNOVACIÓN

TRITON

Multisensory Based Underwater
Intervention through Cooperative
Marine Robots

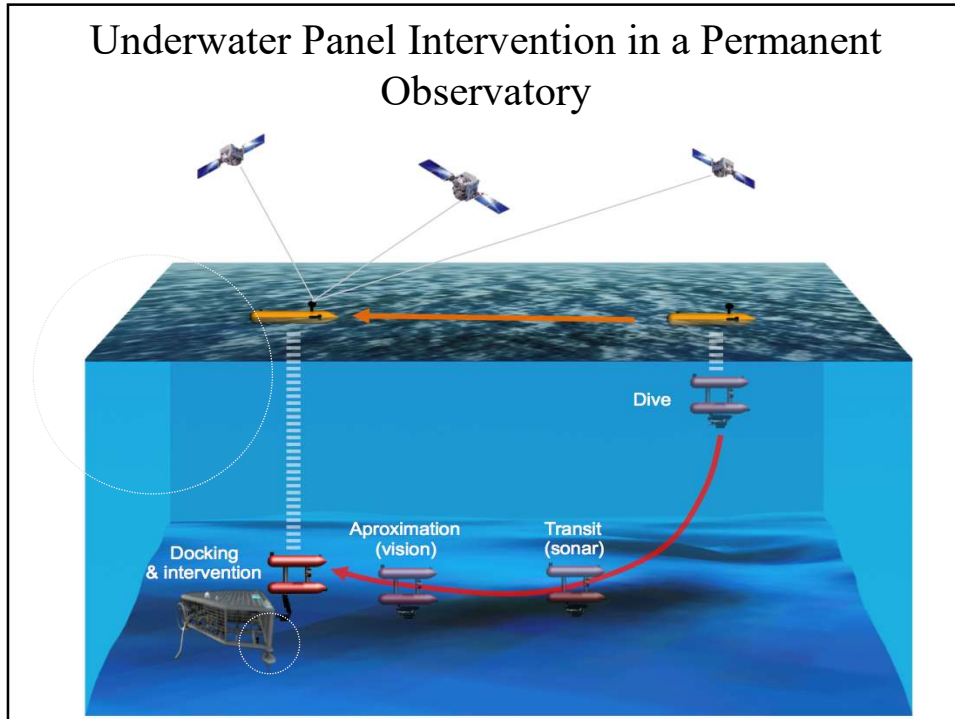
“Approaching the technological transfer”

Exp. Validation Scenario

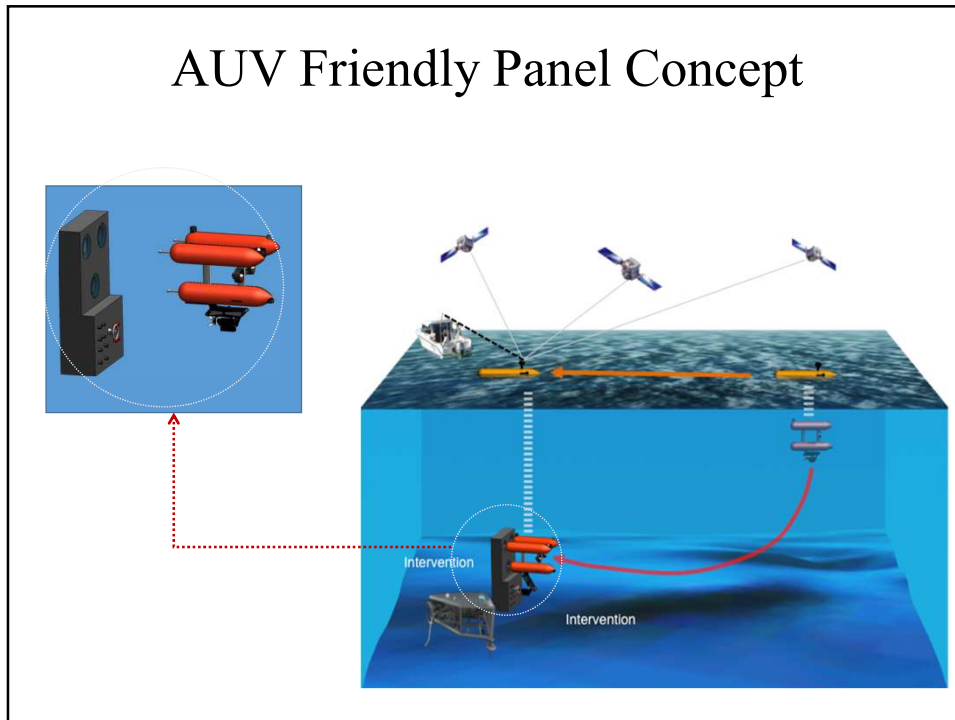
➔

“Intervention on a Panel”

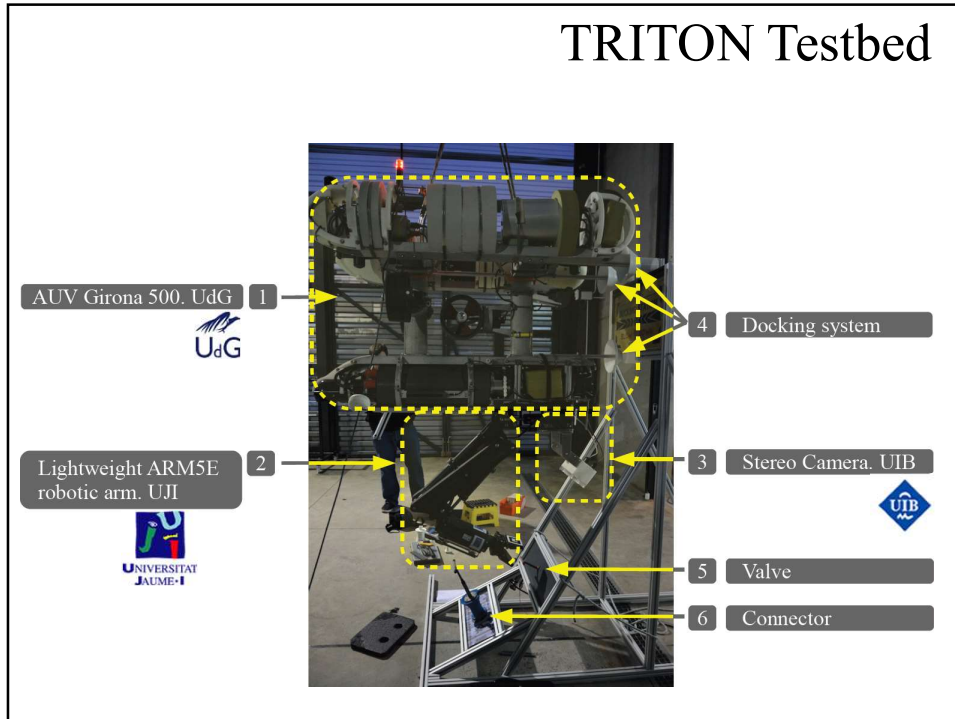
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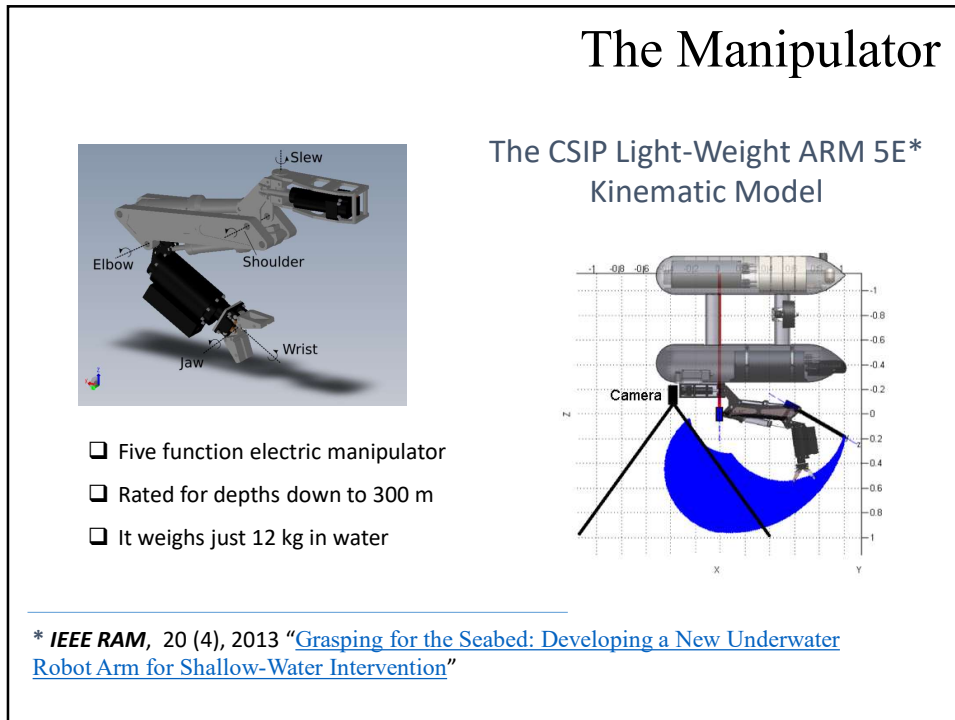
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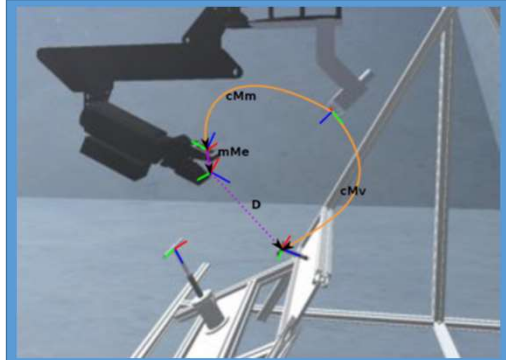


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Intervention Approach



System Frames and Transformations

- *open/close* a valve
- *plug/unplug* a “hot-stab” connector

$$cMe = cMm * mMe$$

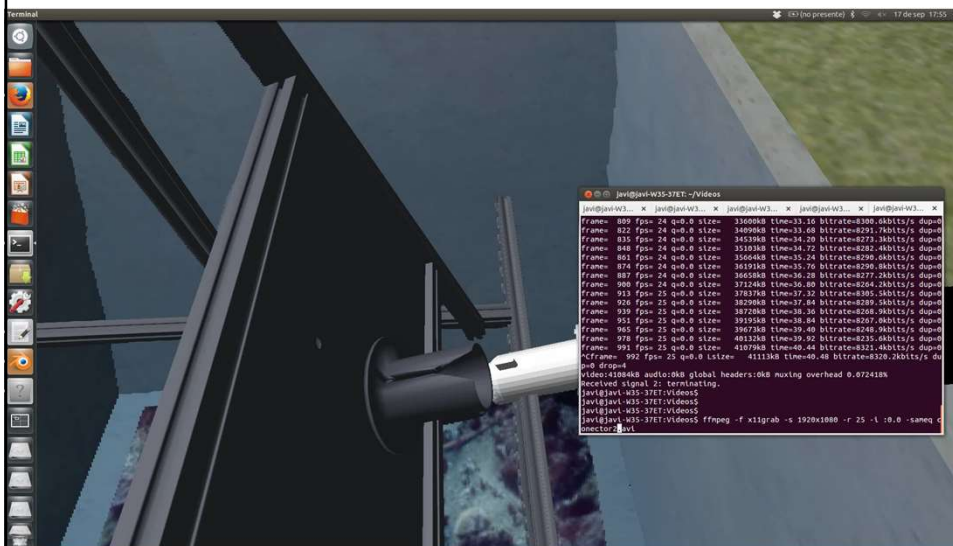
$$bMc = bMe * (cMe)^{-1}$$

$$eMo = eMb * bMc * cMo$$

- Initialization of the Visual Kinematic Controller
- Detection of the object to Manipulate
- Manipulation
 - Open/Close the Valve
 - Plug/Unplug the Hot-Stab Connector

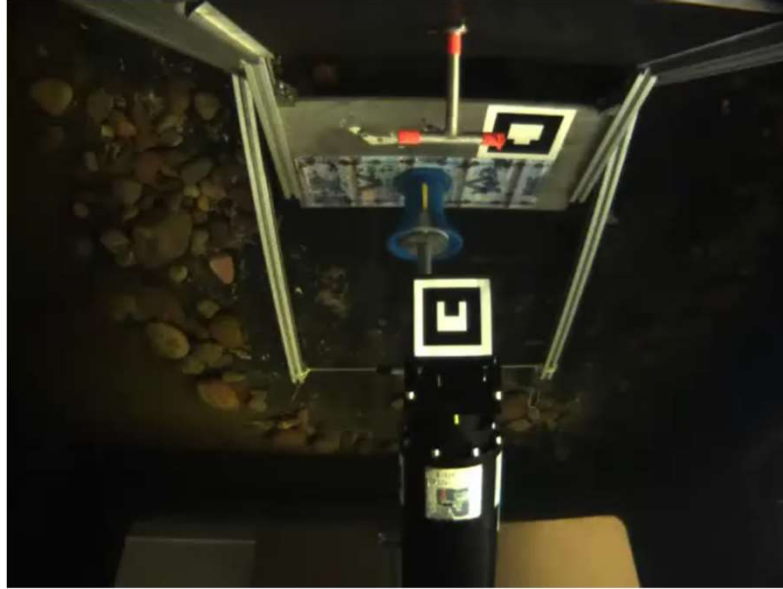
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Simulation Results



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Water Tank Experiments



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Sea Trial



TRITON

Intervención Submarina mediante Robots Marinos Cooperativos y Percepción Multisensorial

AUTONOMOUS UNDERWATER INTERVENTION

Docking & Intervention



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Universitat de Girona





Universitat de les Illes Balears

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5. CASE STUDY 3

ROBOTIC COOPERATION
Research Projects: MERBOTS, TWINBOT




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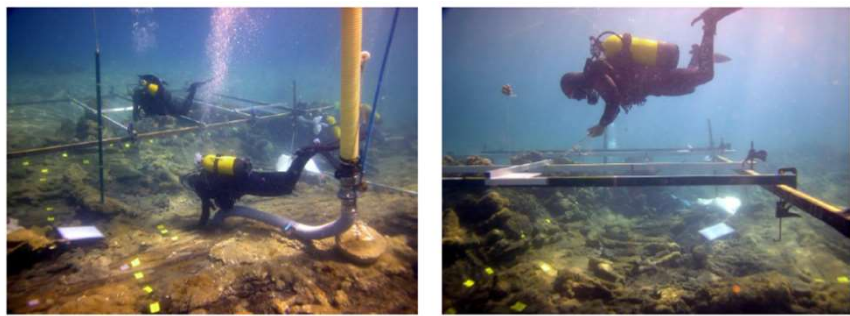
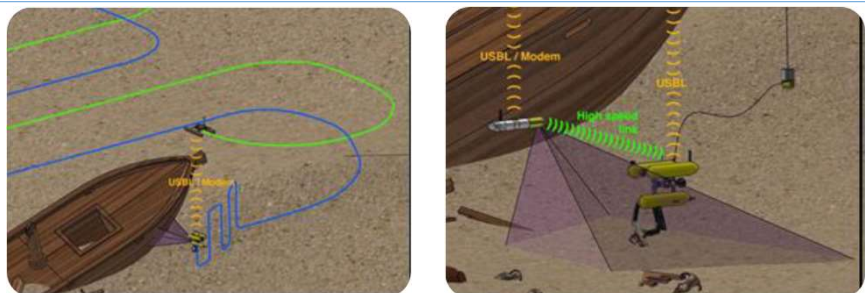


MERBOTS (2015-18)
 (DPI2014-57746-C3)

Multifunctional coopERative marine roBOTS for Intervention DomainS



	 U <i>d</i> G	 UNIVERSITAT JAUME I	 UIB
Sub-Project name	ARCHROV DPI2014-57746-C3-3-R	MERMANIP DPI2014-57746-C3-1-R	SUPERION DPI2014-57746-C3-2-R
Project coordinated by			
IP1	Pere Ridao (Partner UdG)	Pedro J. Sanz (Partner UJI, Coordinator)	Gabriel Oliver (Partner UIB)
IP2			
	Marc Carreras	Raül Marín	Alberto Ortiz

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❖ *The Envisioned Concept*

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❖ *M6. Cooperative intervention at sea (Sant Feliu harbor)*

MERBOTS

Sea Trials


27-31 March 2017
Sant Feliu de Guíxols



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de les Illes Balears



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de Girona



UNIVERSITAT
JAUME I


<https://www.youtube.com/watch?v=1xECxNb0-dQ>

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New GUI for underwater intervention missions

Enabling semi autonomous manipulation (H-ROV)

GUI in the market



Ongoing GUI



Real time

Simulation

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TWIN ROBOTS FOR COOPERATIVE UNDERWATER INTERVENTION MISSIONS – TWINBOT (2018-20)





DPI2017-86372-C3

Spanish Program for Research, Development and Innovation Oriented to the Challenges of Society

Extended deadline of 9 months: **30 SET 2021**

“Inspired on the European Proposal”



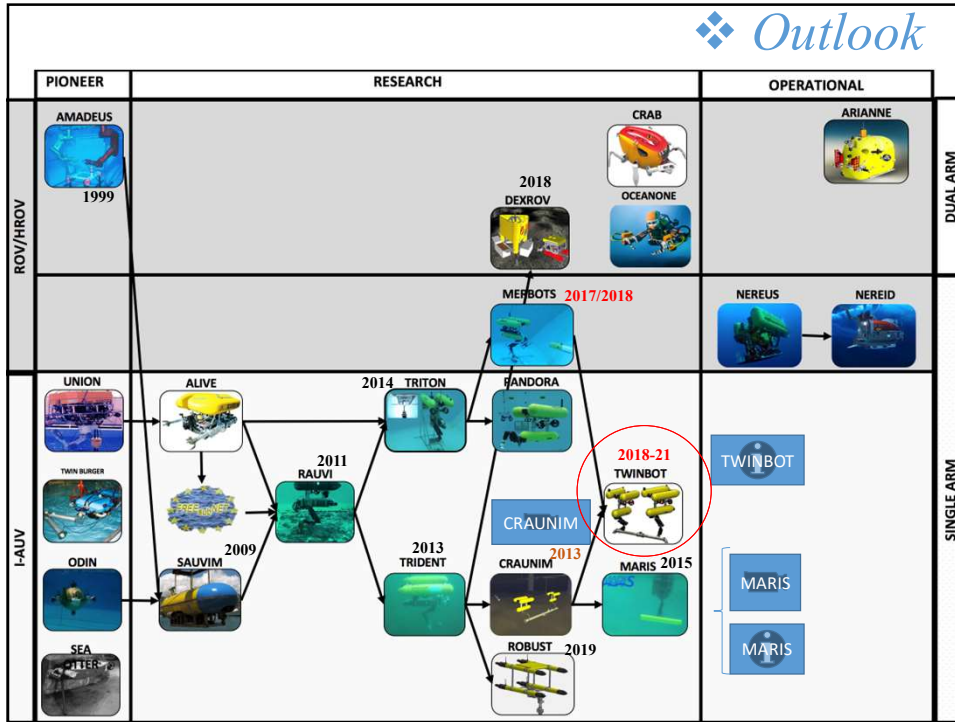


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Cooperative Transportation

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

“Simulation vs Water Tank”

“VR for the guidance of underwater robots”

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TWINBOT: Autonomous underwater cooperative transportation


March 2021 · *IEEE Access* PP(99):1-1
 DOI: 10.1109/ACCESS.2021.3063669


<https://ieeexplore.ieee.org/document/9367135>


Cooperative Transportation

Authors:

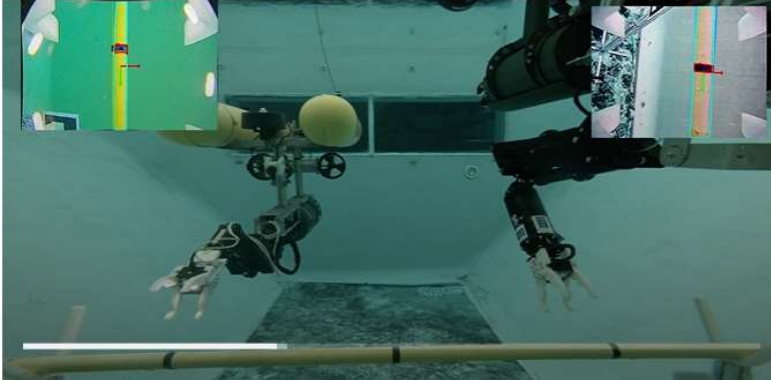
 **Roger Pi**
 Universitat de Girona

 **Patryk Cieslak**
 Universitat de Girona

 **Pere Ridao**
 Universitat de Girona

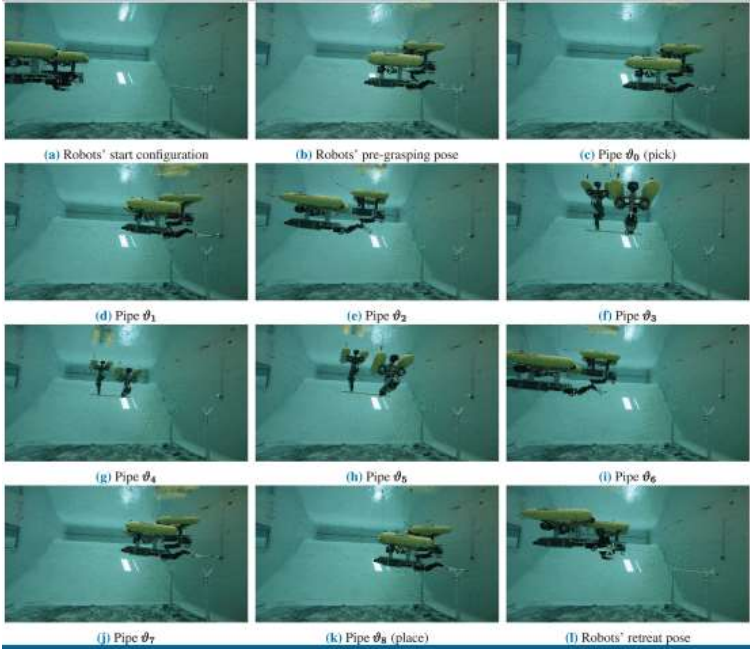
 **Pedro J Sanz**
 Universitat Jaume I

<https://ieeexplore.ieee.org/document/9367135>



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Mission Sequence in the Water Tank



(a) Robots' start configuration

(b) Robots' pre-grasping pose

(c) Pipe ϕ_0 (pick)

(d) Pipe ϕ_1

(e) Pipe ϕ_2

(f) Pipe ϕ_3

(g) Pipe ϕ_4

(h) Pipe ϕ_5

(i) Pipe ϕ_6


(j) Pipe ϕ_7

(k) Pipe ϕ_8 (place)

(l) Robots' retreat pose

<https://www.youtube.com/watch?v=epnU4v3Hz44>

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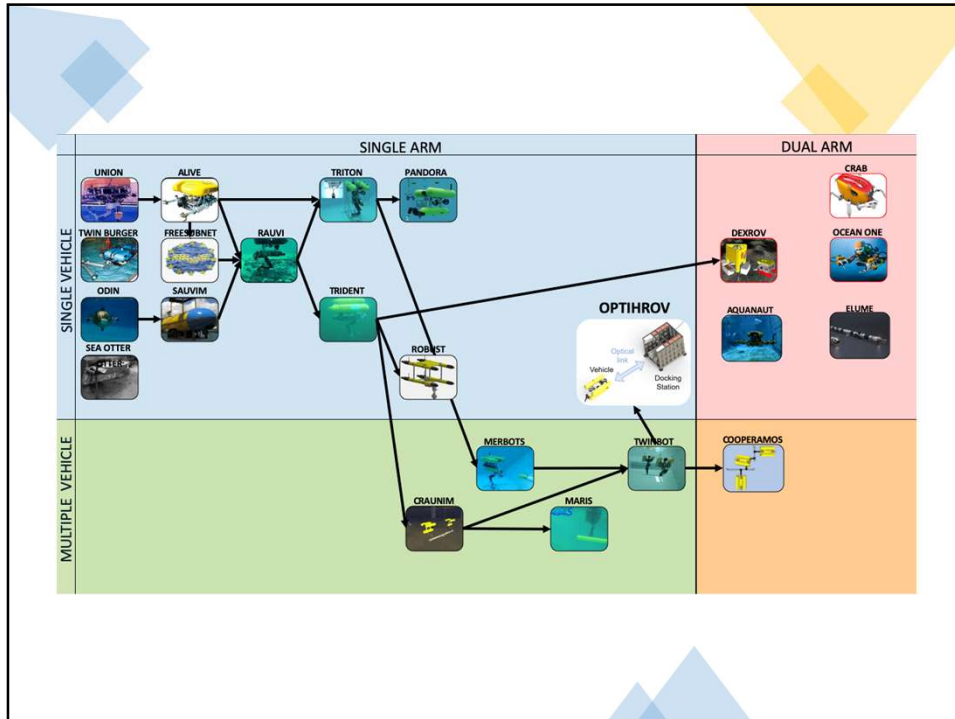
6. LAST REMARKS

- 6.1. Ongoing Research Activities (COOPERAMOS, OPTHIROV)
- 6.2 Synergies with other Contexts (Aquaculture, Nuclear Industry)

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6.1. Ongoing Research Activities (COOPERAMOS, OPTHIROV)

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(1/09/2021 a 1/09/2024)

COOPERative Resident robots for Autonomous ManipulatiOn Subsea COOPERAMOS



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Proyectos I+D+i para la realización de «Prueba de Concepto»

OPTIHROV
 “Optically Linked Hybrid Autonomous/Remotely Operated Vehicle”

(1/12/2021 a 30/11/2023)

Proof of Concept Demonstration

- In Lab Technology Validation (TRL 4)
- Validation/Demonstration in a Relevant Environment (TRL 5-6)

Logos: MINISTERIO DE CIENCIA E INNOVACIÓN, Financiado por la Unión Europea NextGenerationEU, Plan de Recuperación, Transformación y Resiliencia, AGENCIA ESTATAL DE INVESTIGACIÓN

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6.2 Synergies with other Contexts (Aquaculture, Nuclear Industry)

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MICINN/GVA
ThinkInAzul



GENERALITAT
VALENCIANA

Aquaculture

The Department of Innovation (GVA) and the Spanish Ministry of Science and Innovation are *co-funding* a multidisciplinary research project of *excellence* in *Marine Sciences -ThinkInAzul-* to reduce the effects of *climate change* on the conservation of the *marine environment* and *aquaculture* production.




GVA-THINKINAZUL/2021/037

JELLYFISH

“Towards a Sustainable Precision Aquaculture based on Robotics, Artificial Intelligence and low-cost Sensors”

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European
Commission

Horizon 2020
European Union funding
for Research & Innovation

El-Peacetolero

Grant agreement ID: 945320
Start date: **1 September 2020**
End date: **31 August 2024**

“Embedded Electronic solutions for Polymer Innovative Scanning Tools using Light Emitting devices for diagnostic Routines”

Funded under
H2020-Euratom-1.

Overall budget
€ 3 652 170


EU contribution
€ 2 999 236

Coordinated by
SORBONNE UNIVERSITE

France

(8 Partners)

UNIVERSITAT JAUME I DE CASTELLON
EU contribution
€ 149 985



“IRS-Lab diseñará tres prototipos robóticos para diagnosticar el estado de los polímeros de tuberías industriales en el aire y en el agua”

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Underwater Intervention Missions



Pedro J. Sanz



“La Robótica Submarina y las Misiones de Intervención”