The Robotic Seabed Cleaning Platform: An Underwater Cable-Driven Parallel Robot for Marine Litter Removal

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Servizi Tecnizi Srl, Italy

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MArinE Litter SusTainable RemOval and Management

www.maelstrom-h2020.eu

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EU H2020 project MAELSTROM: Smart Technology for Marine Litter Sustainable Removal and Management

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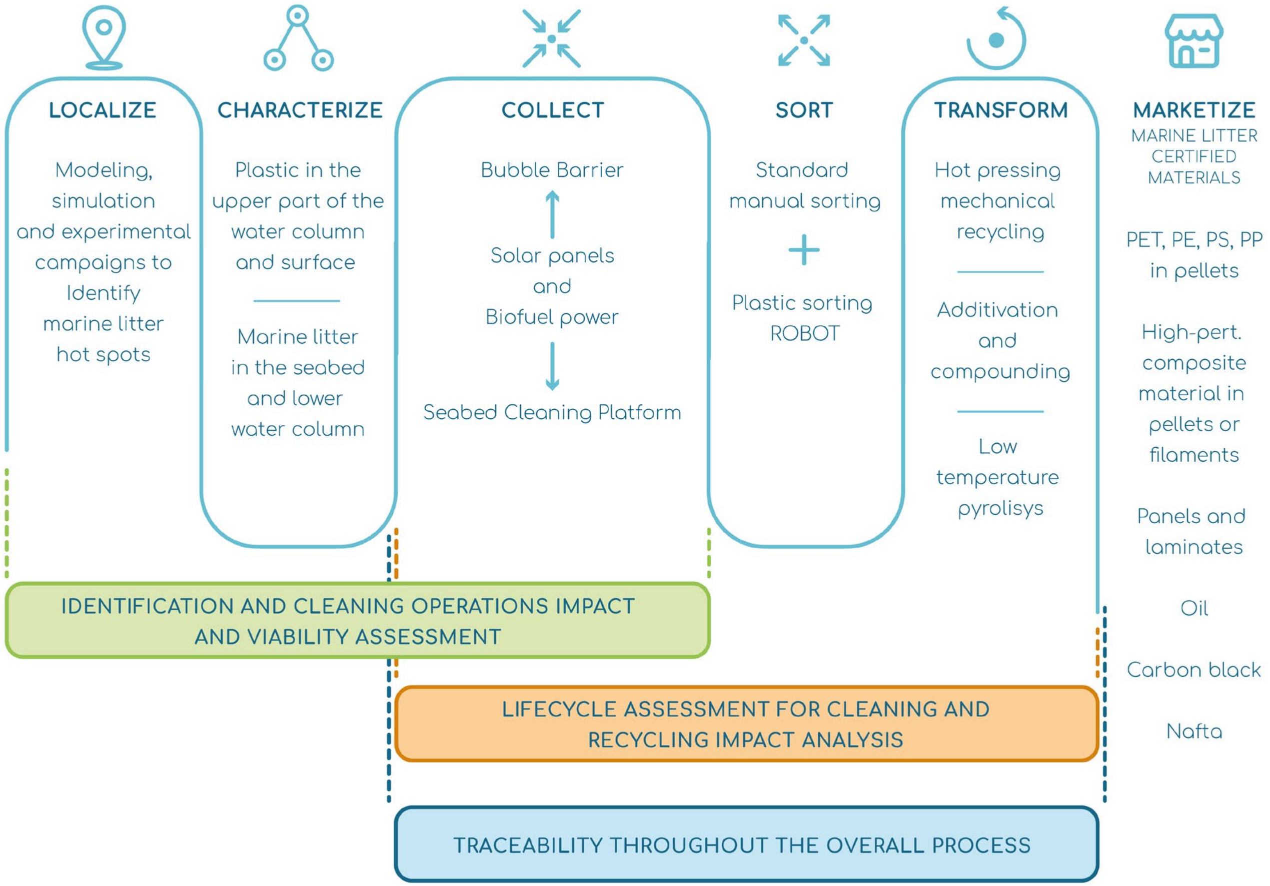
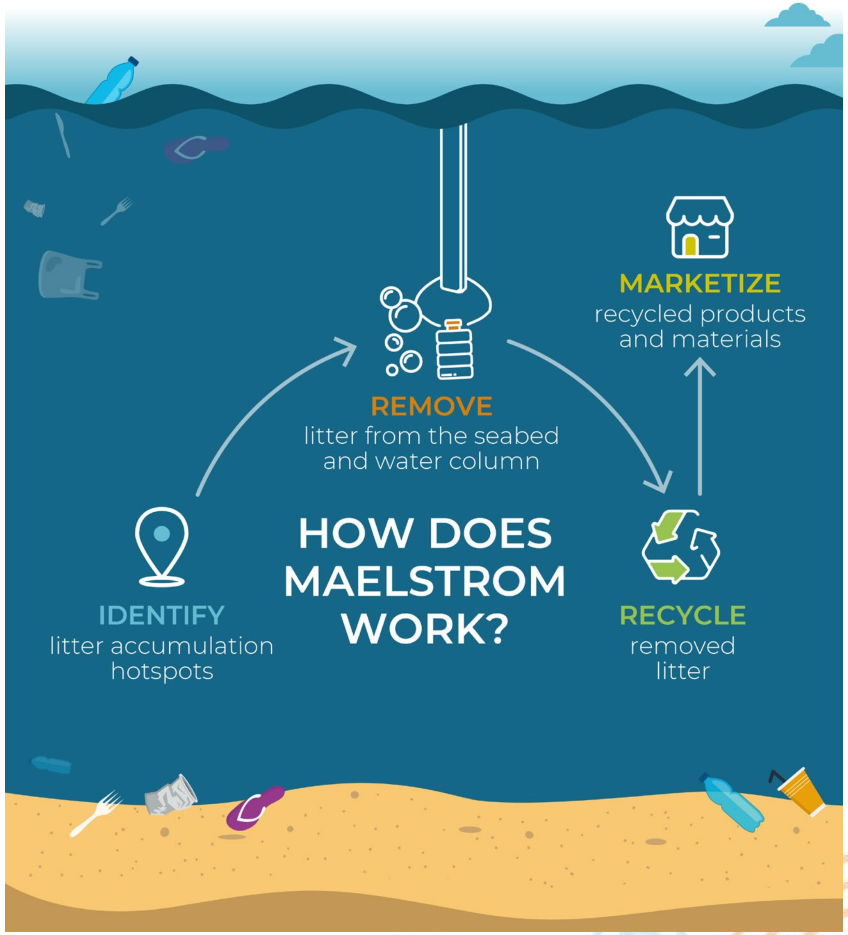
14 partners, 8 countries, coordination: CNR, Italy





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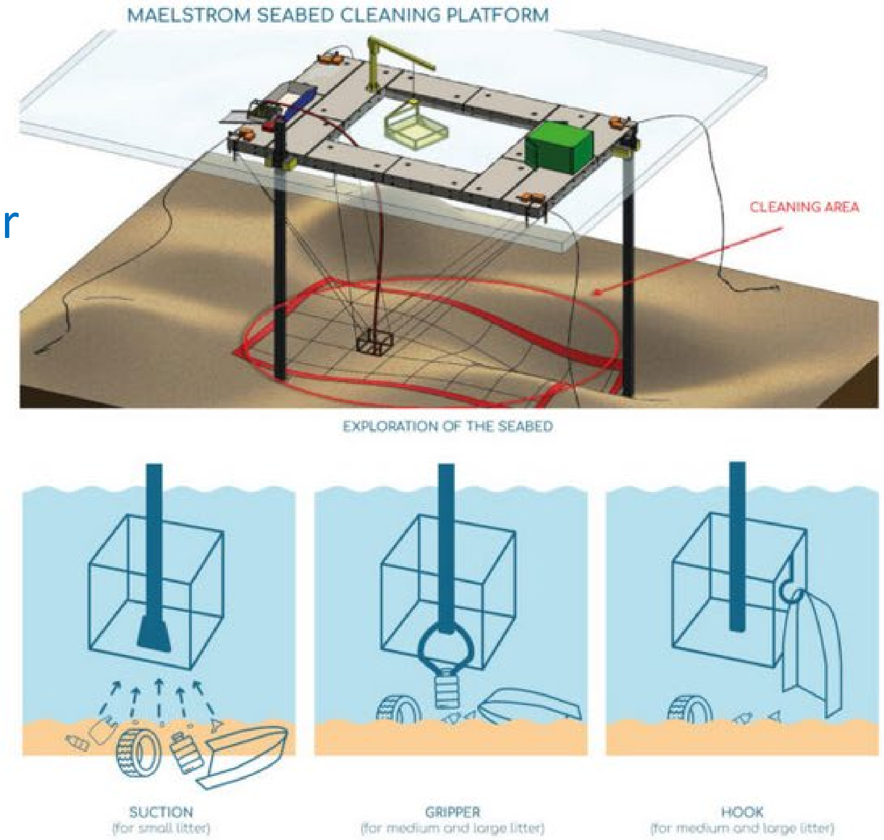
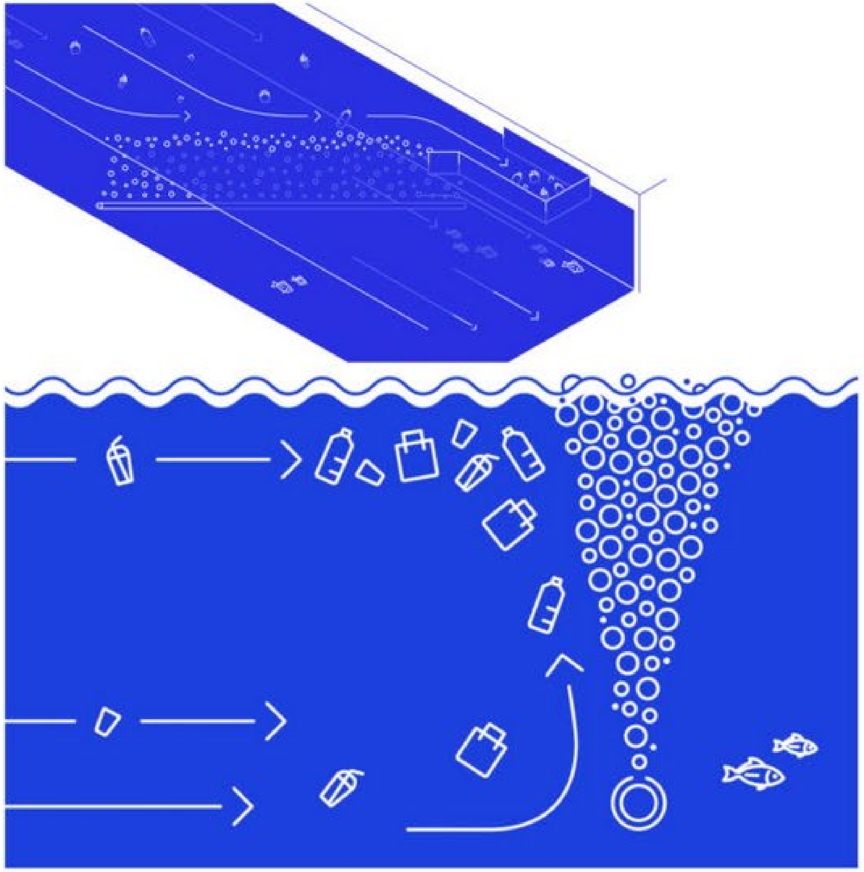
MAELSTROM: Two different systems for marine litter removal

Underwater CDPR: Robotic Seabed Cleaning Platform
Developed by TECNALIA and CNRS-LIRMM as an upgrade of the CoGiRo cable robot used in industrial plants

Bubble Barrier
A system to intercept plastic pollution in rivers before it reaches the ocean

Shallow water





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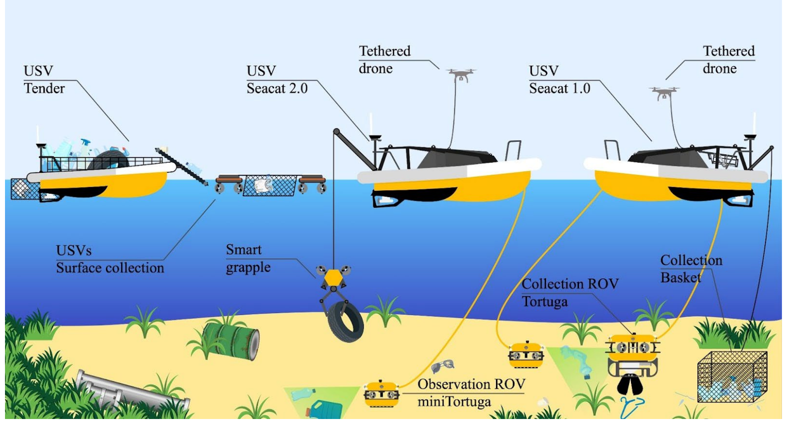
State of the art

Existing solutions for removal of marine litter

- Removal of floating pollution

- Removal of underwater litter



SEACLEAR

SeaClear project (EU H2020): Aims at deploying a system consisting of an unmanned surface vehicle, an unmanned aerial vehicle, a small ROV and a larger ROV

Robotic Seabed Cleaning Platform: Capable of efficiently removing relatively large and heavy objects

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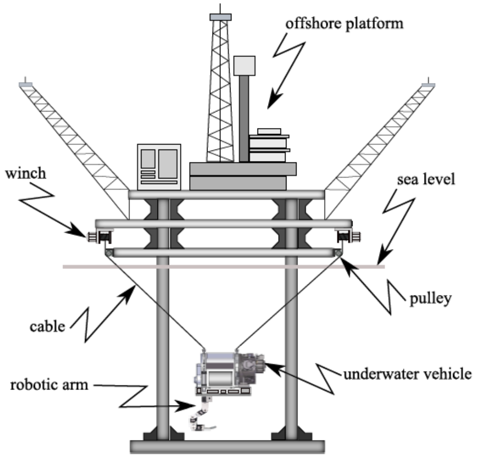
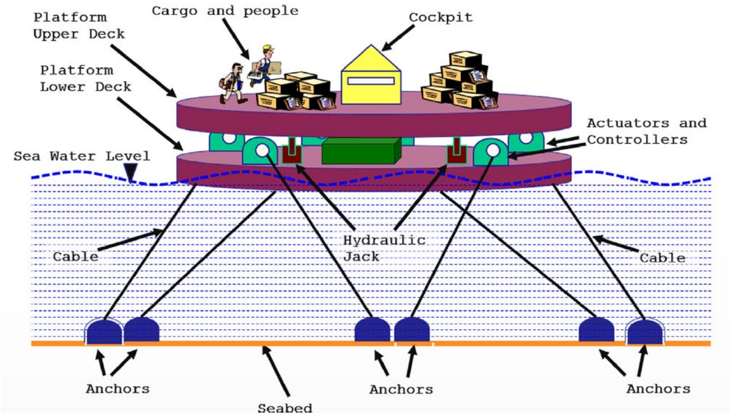
State of the art

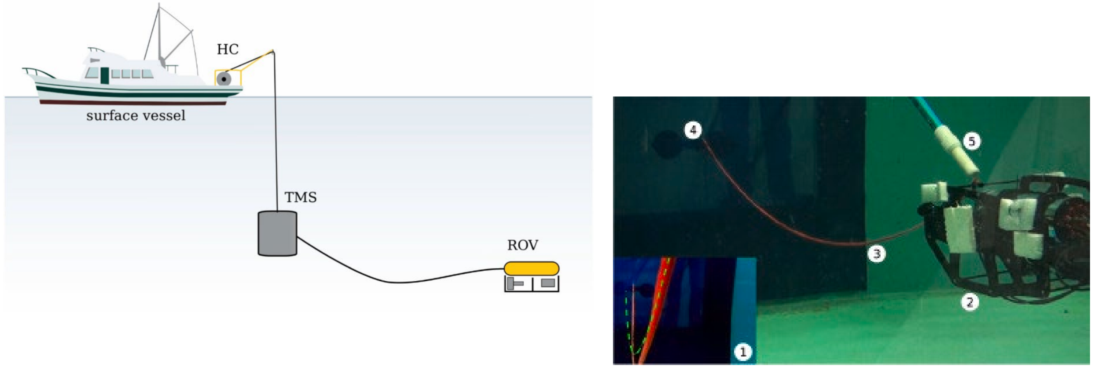
Few previous works on marine and underwater CDPRs



El Ghazaly et al, 2015



Horoub et al, 2018



Laranjeira et al, 2020

To the best of our knowledge: No prototype and experiments of an underwater CDPR reported in the state of the art

El Ghazaly, G., Gouttefarde, M., Creuze, V.: Hybrid cable-thruster actuated un- derwater vehicle manipulator systems: A study on force capabilities. In: Proc. IEEE/RSJ Int. Conf. Intelligent Robots and Systems (IROS), 2015.

Horoub, M., Hassan, M., Hawwa, M.: Workspace analysis of a gough-stewart type cable marine platform subjected to harmonic water waves. Mechanism and Machine Theory 120, 2018.

Horoub, M., Hawwa, M.: Influence of cables layout on the dynamic workspace of a six-dof parallel marine manipulator. Mechanism and Machine Theory 129, 2018.

Laranjeira, M., Dune, C., Hugel, V.: Catenary-based visual servoing for tether shape control between underwater vehicles. Ocean Engineering 200, 2020.

Viel, C.: Self-management of the umbilical of a ROV for underwater exploration. Ocean Engineering 248, 2022.

Sacchi, N., Simetti, E., Antonelli, G., Indiveri, G., Creuze, V., Gouttefarde, M.: Analysis of hybrid cable-thruster actuated ROV in heavy lifting interventions. Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2022.

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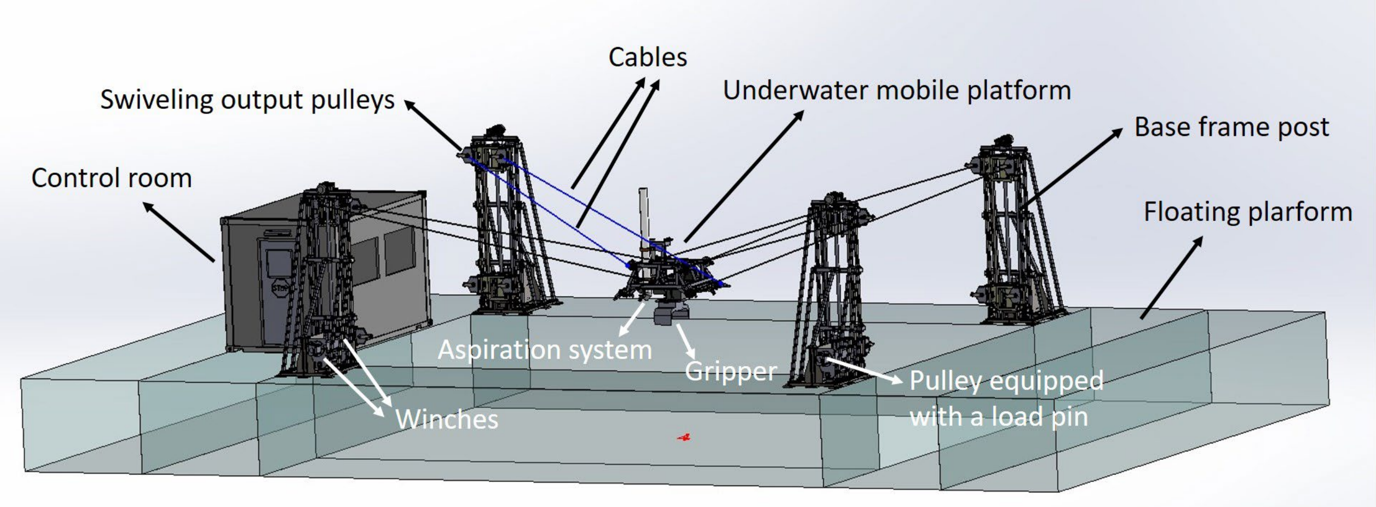
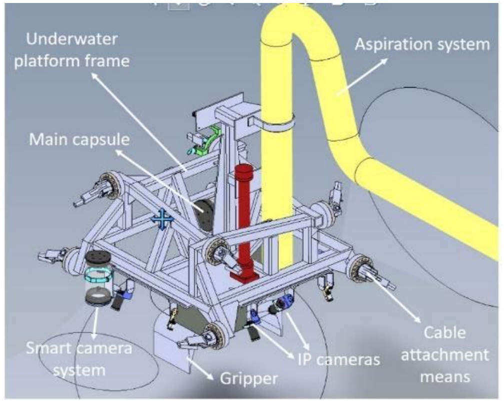
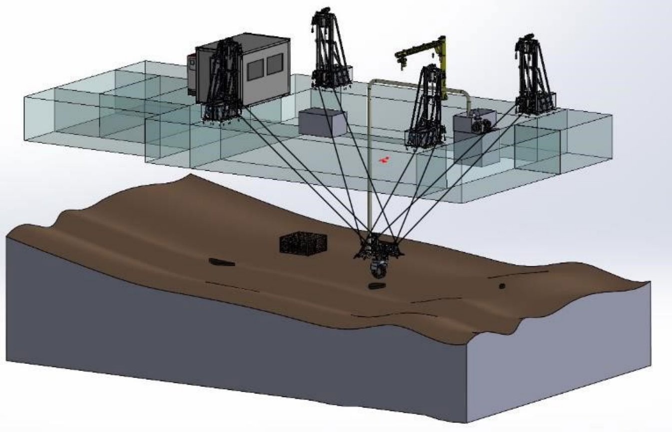
Overall Description – Robotic Seabed Cleaning Platform



CAD views of the Robotic Seabed Cleaning Platform





- 6-DOF mobile platform driven by 8 cables in a suspended configuration similar to the one of the CoGiRo CDPR
- Four base frame posts secured to a floating platform (floating barge)
- Routing pulley (close to the winch) equipped with a load pin to measure the cable tension
- The mobile platform can move down in the water below the floating barge which has a rectangular hole (inner pool)
- Aspiration system and a gripper are installed on the CDPR underwater mobile platform

Gouttefarde, M., Collard, J.F., Riehl, N., Baradat, C.: Geometry selection of a redundantly actuated cable-suspended parallel robot. IEEE Trans. on Robotics 31(2), 2015.

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Design and calibration – Robotic Seabed Cleaning Platform

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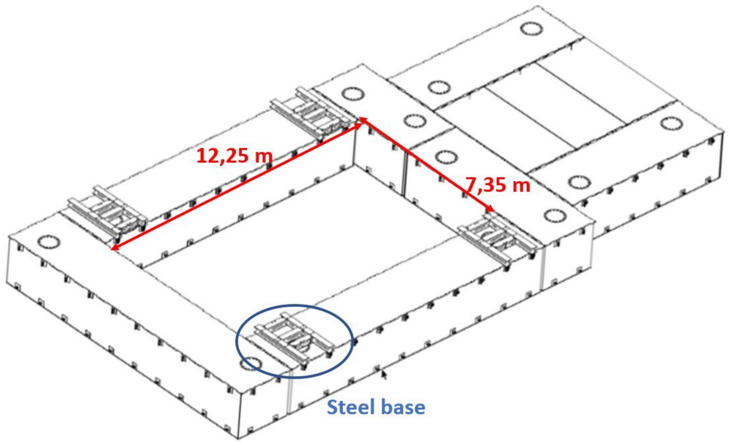
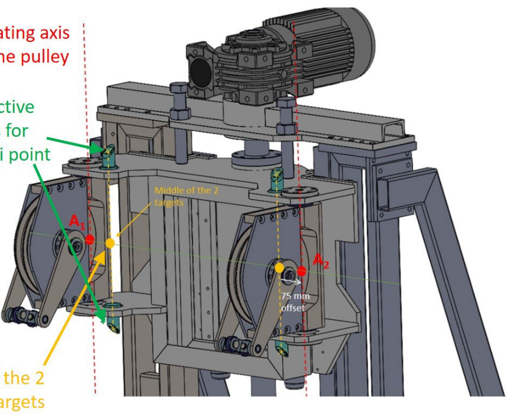
Post

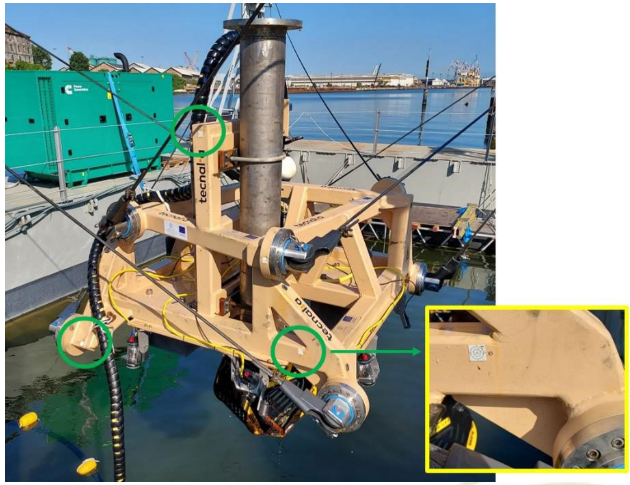
Floating barge



Calibration: Determination of the positions of the points Ai from the target measurements



Underwater mobile platform



- Components have been designed to be used in harsh outdoor maritime environment
- Size of the floating barge to reach between 15 to 20 m operation depth
- Metallic posts with the swiveling output pulleys on a vertical carriage to move the pulleys from an upper (parking) to a lower (working) position
- Underwater mobile platform: Steel welded structure, protected by a marine resistant paint
- Geometric calibration with the help of a total station measuring the positions of reflective targets

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Sensors – Robotic Seabed Cleaning Platform

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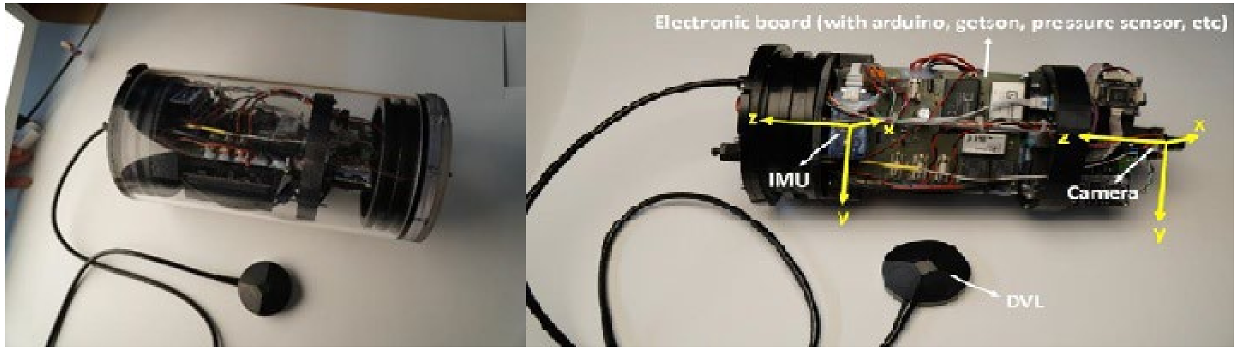
The Robotic Seabed Cleaning Platform in Venice lagoon



The waterproof underwater capsule of the smart camera system (left) and the smart camera system description with reference frames fixed to it (right)

- Sensors on the floating barge: Pressure sensor (atmospheric pressure) and two RTK GPS to estimate the position and orientation (around the vertical axis) of the floating barge
- Sensors on the underwater mobile platform:
  - 5 IP cameras for the human operator to see the surrounding of the underwater mobile platform (in relatively clear water)
  - Camera used for visual servoing (to approach litter)
  - Depth sensor (pressure)
  - IMU to measure the orientation of the underwater mobile platform
  - A Doppler Velocity Log (DVL): A hydro-acoustic sensor to measure the distance of the mobile platform to the seabed

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Control System – Robotic Seabed Cleaning Platform

- Pilot (human operator) uses estimated underwater mobile platform pose as well as the cameras located on the mobile platform to drive the underwater mobile platform using a joystick
- Simple control based on Inverse Kinematics
- Previously obtained bathymetry map of the seabed environment allows one to identify “hotspots” where underwater litter may be located

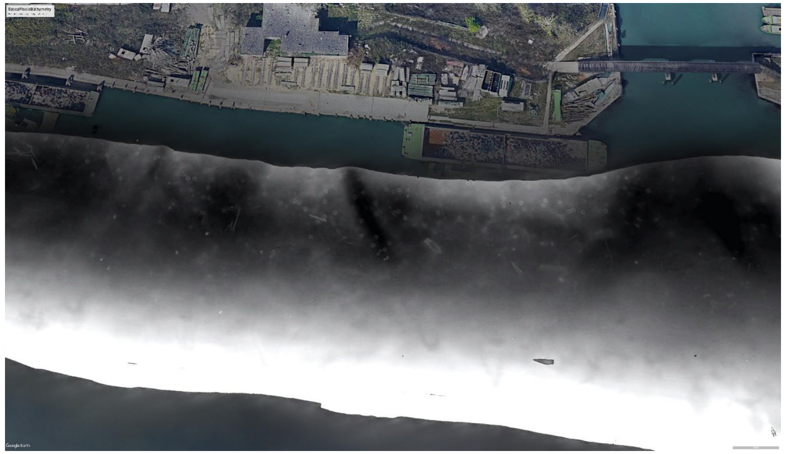
Human-Machine Interface (HMI) of the CDPR

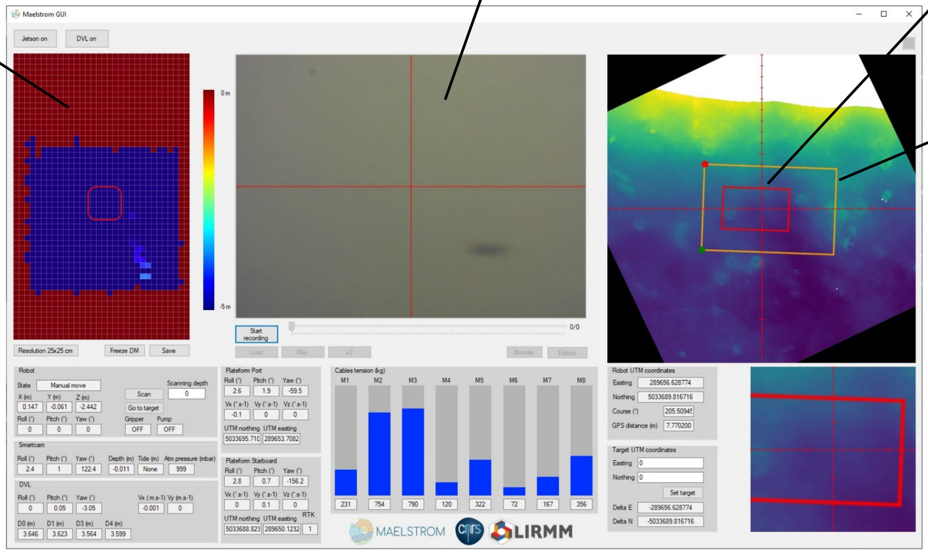
Image from the camera for visual servoing (highly turbid water)

Safe working zone (no cable collision)

Depth map built with the DVL measurement

Bathymetry map example





Bathymetry map centered on the inner pool of the floating barge (by means of RTK GPS measurements)

Experiments in Venice (September 2022) – Cleaning campaign

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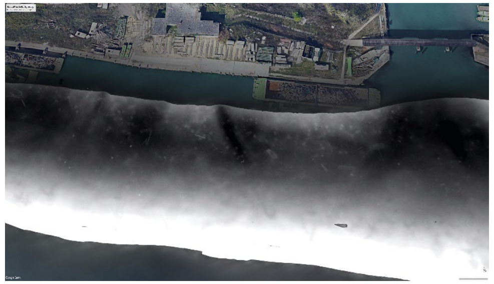
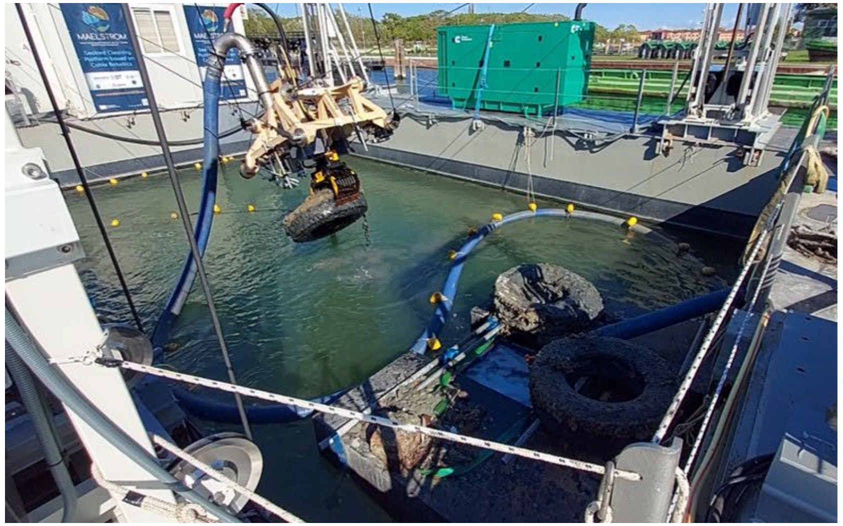
The Robotic Seabed Cleaning Platform moved by a tugboat to a cleaning spot



Bathymetry map



The Robotic Seabed Cleaning Platform removing a tire from the water (left) and various litters collected by the RSCP during the cleaning campaign in Venice lagoon

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Video of the experiments in Venice – Cleaning campaign

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Thanks for your attention

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Workspace in various operating conditions

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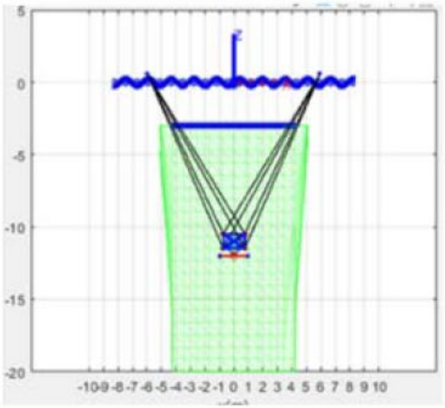
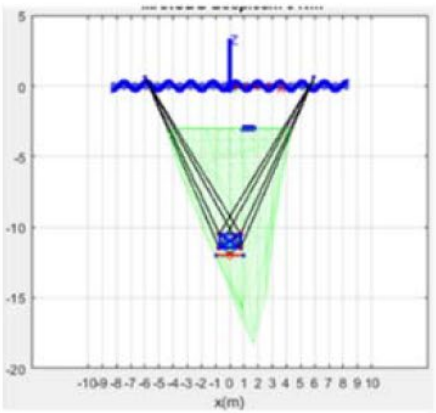
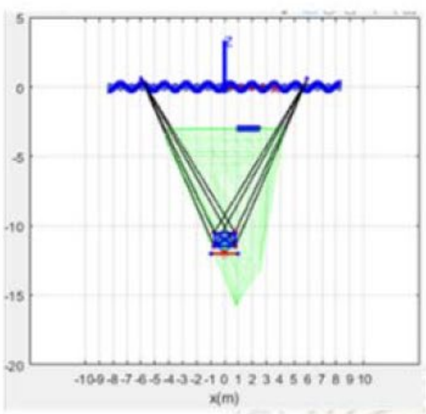
Teórico
WK(20m): 8m x 5m (aprox)
WK(15m): 8m x 5m (aprox)
WK(10m): 9m x 5m (aprox)
WK(4m): 10m x 5m (aprox)



F=494N equiv to 0,6m/s
WK(20m): 0
WK(15m): 1m x 1m (aprox)
WK(10m): 4m x 2m (aprox)
WK(4m): 8m x 4m (aprox)



CDG +60cm desp
WK(20m): 0
WK(15m): 0
WK(10m): 4x2 (aprox)
WK(4m): 6m x 4m (aprox)



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MARINE LITTER REMOVAL TECHNOLOGY

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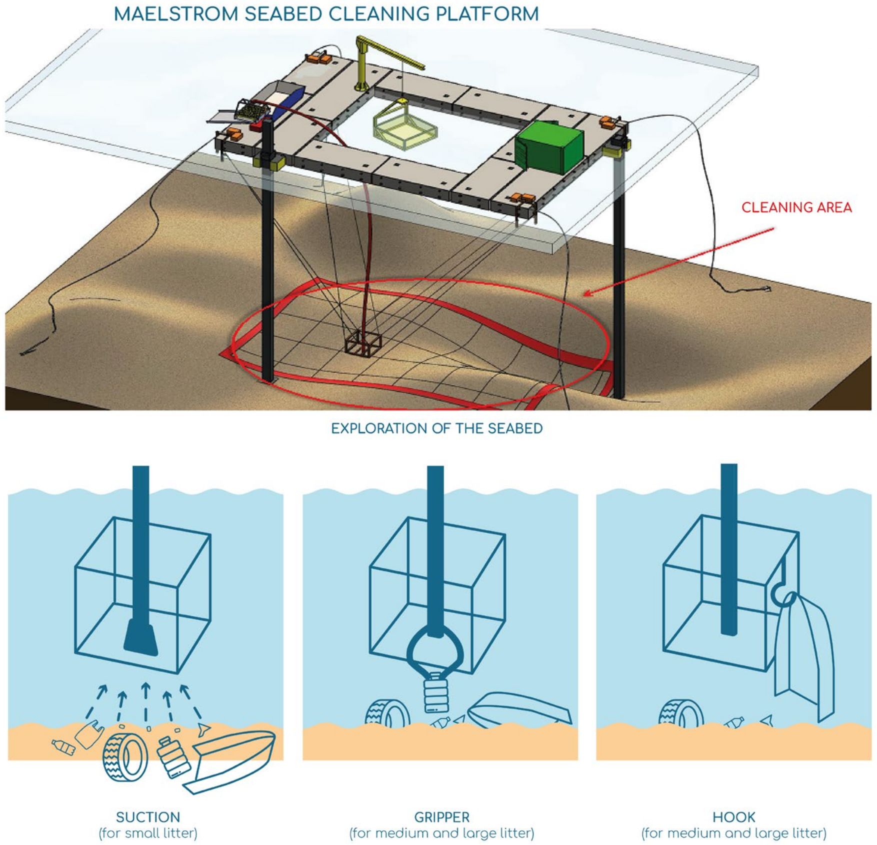
WP3 – SEABED AND LOWER WATER COLUMN CLEANING TECHNOLOGY: CABLE-BASED ROBOTIC PLATFORM



ATTIVITA' DI PULIZIA DEI FONDALI A PARTIRE DALL'ESTATE 2023

SO2

Marine litter removal from seabed
and both lower and upper water column

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SEABED CLEANING PLATFORM in the Venice Coastal Area, Italy

FROM DESIGN TO REALITY

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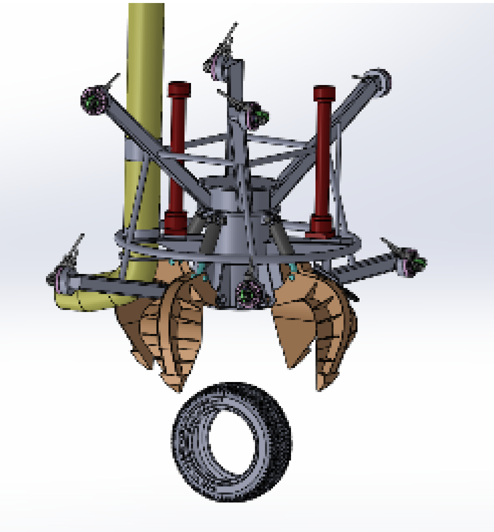
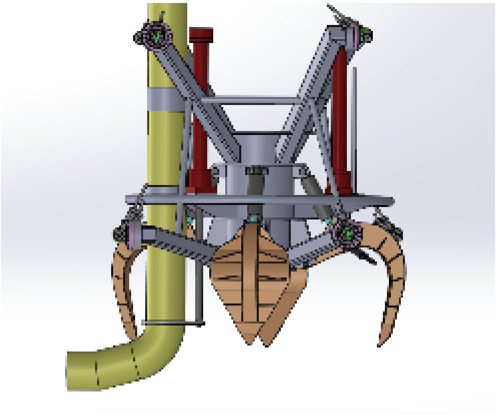
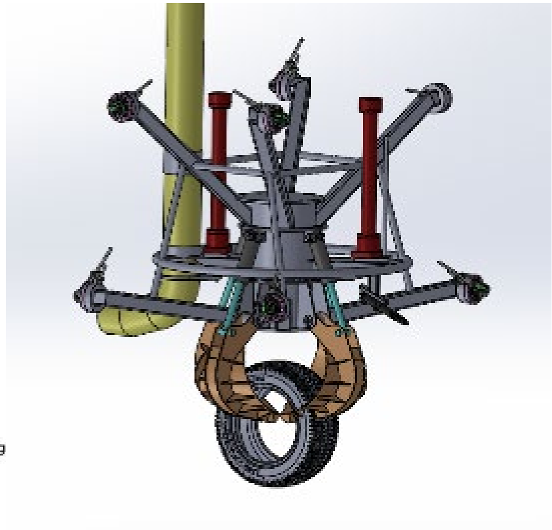
Underwater mobile platform



A gripper and an aspiration system





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