SEACLEAR

SEARCH, IDENTIFICATION AND COLLECTION OF MARINE LITTER WITH AUTONOMOUS ROBOTS

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INTRO/MOTIVATION

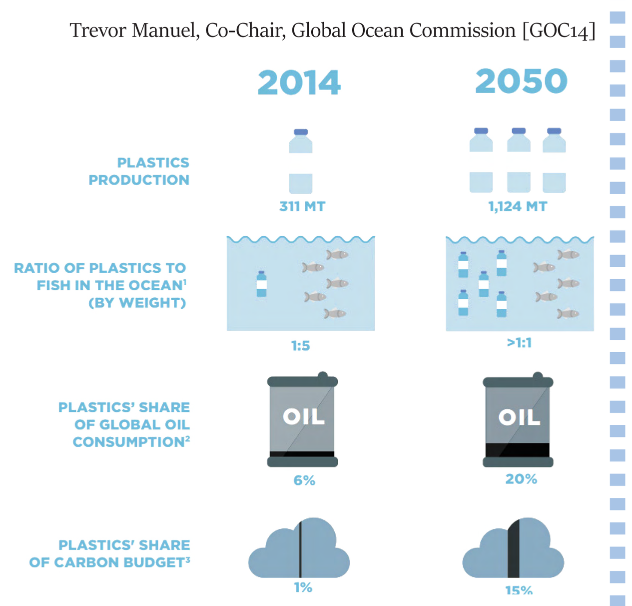
"We identified keeping plastics out of the oceans as one of our key proposals for action to advance ocean recovery[...]. The economic and environmental case is now clear - I therefore call on governments and businesses alike to take urgent action to capture the opportunity."

Trevor Manuel, Co-Chair, Global Ocean Commission [GOC14]

Today's oceans contain an estimated amount of 26-66 million tons of waste with approximately 94% located on the seafloor [E16], which has a negative impact on the marine environment and ecosystem. To contribute to resolving the pressing issue of marine waste, this project develops a solution of collaborative heterogeneous robots to detect and collect marine waste in situ within the water column and on the seabed.

The waste can then be transported on-shore and picked up/shipped/collected further to aferent recycling facilities. The final output of the project will be an experimental prototype with demonstrated behaviour in realistic case-studies (TRL 6-7).

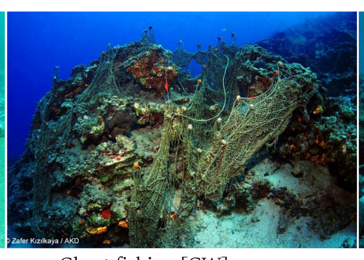
To bring the proposed output to the set TRL level, we as project partners, bring together the knowledge from marine technologies, control theory, robotics, motion planning, multi-agent collaboration, machine learning, pattern recognition and decision-making, embedded systems and sensors.



Forecast of plastics volume growth [WEF+16]

Different types of hidden marine waste:

Various seafloor waste [AW]



Ghost fishing [GW]

Plastic bags on the sea floor [ZW]

Floating hidden plastics [NC]

CASE STUDIES

Hamburg

The challenge lies in understanding the natural processes and using them sensitively to preserve the port. The port lies in the heart of the city of Hamburg and occupies almost one tenth of the area of the city touching a total of fourteen districts. These factors provide challenging conditions with a view to detecting, determining the origin and removing waste from the river Elbe in the port area.

In addition, there is the high turbidity of the water due to sediments that upstream into the port with every flood, making visual underwater detection of waste almost impossible. The heavy vessel traffic makes water-side waste collection even more difficult.

Some areas of the ports are designated for testing of autonomous vessels. The actual demo site will be selected in the course of the project in close coordination with the HPA harbour master. Against the backdrop of challenges above, we will deploy our robotic solution to evaluate its effectiveness. Given the water turbidity, we will pay particular attention to the quality of underwater mapping and classification as well, and evaluate the effectiveness of optical sensors.

A key point that we aim to answer is the extent to which the UAV surface map will help in locating underwater waste. Overall, the conditions in Hamburg are perfectly suited for the development of a practical, market-ready SeaClear product, since the technical requirements alone will present an endurance test for the envisaged solution.

Dubrovnik

Within this Dubrovnik case study, the aim is to illustrate the effectiveness of the SeaClear system as a tool for supporting sustainable tourism and aquaculture and as a comparison to traditional methods of cleaning marine waste. Additionally, due to high transparency of Adriatic sea, within this case study we will have a perfect opportunity to demonstrate the usefulness of aerial robots in marine waste mapping.

We are planning to set two demo sites: one at Lokrum and the other at Mali Ston. The demo sites will be selected taking into consideration the following criteria: a minimum length of 100m in order to allow a fixed 100-metre stretch to be surveyed; they will be characterized by a low to moderate slope (~1.5–4.5°); they will have a clear access to the sea (not blocked by breakwaters or jetties); they will be accessible to survey teams throughout the year; they will ideally not be (or will be for comparison) subject to cleaning activities.

Furthermore, the selected areas will be situated in the vicinity of ports or harbours, river mouths, coastal urban areas, tourism destinations; and in relatively remote areas. Surveys will be carried out at intervals of three months in autumn (mid-September – mid October), winter (mid-December – mid-January), spring (April), summer (mid-June – mid-July). We will deploy our robotic solution and evaluate its overall effectiveness, but also exploiting the clear water to focus in particular on litter mapping and classification from visible-light cameras.

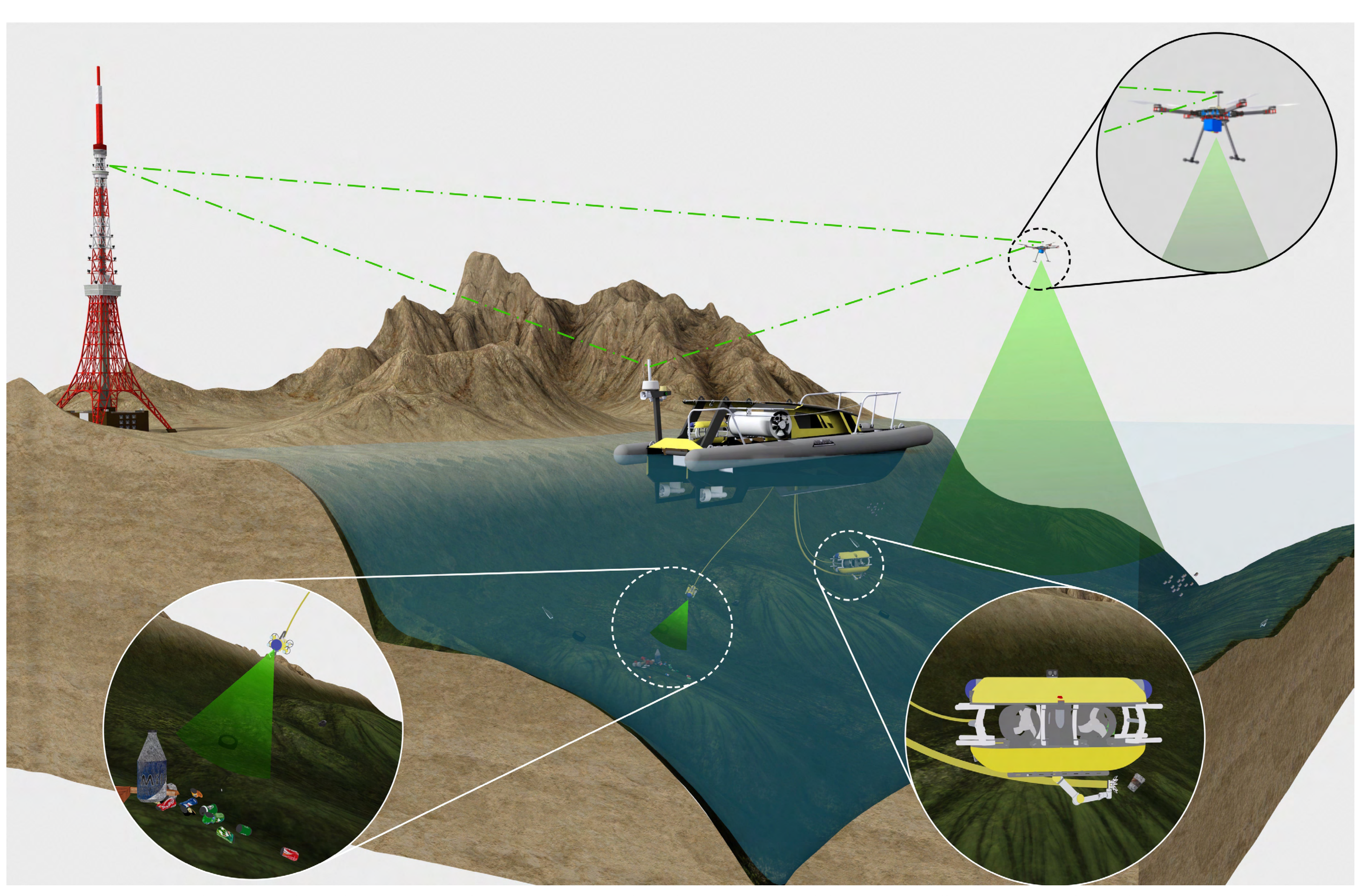
SEACLEAR SYSTEM

The main goal of the **Se**arch, Identific**a**tion and **C**ollection of Marine **L**itt**e**r with **A**utonomous **R**obots - **SeaClear** - projectproject is to develop a collaborative, heterogeneous multi-robot solution engaged in collecting marine waste. Our solution will be the first that uses autonomous underwater robots for cost-effective marine litter collection.

This goal will be reached by bringing together state-of-the-art technologies from the fields of machine learning, sensing, manipulation, aerial and marine technologies and by building a stable and reliable system capable of tackling a highly disputed social, economic and environmental issues, namely ocean pollution.

In SeaClear's vision, a group of interconnected unmanned aerial and waterborne vehicles with specialised sensory equipment and/or end-effectors, running complex digital image processing algorithms, reliably connected to a data exchange network, and interfaced by an interactive web-based application, are working together towards autonomously fulfilling the task of cleaning marine litter in a predefined coastal area. Multiple robots will be employed to efficiently handle the tasks happening at different timescales (mapping, classification, collection). This disruptive concept has the potential to improve maritime safety and human health, to overcome one of the greatest effects of humans (that is, ocean pollution), to reduce costs for a multitude of maritime stakeholders and to help local economies regain their tourism potential.

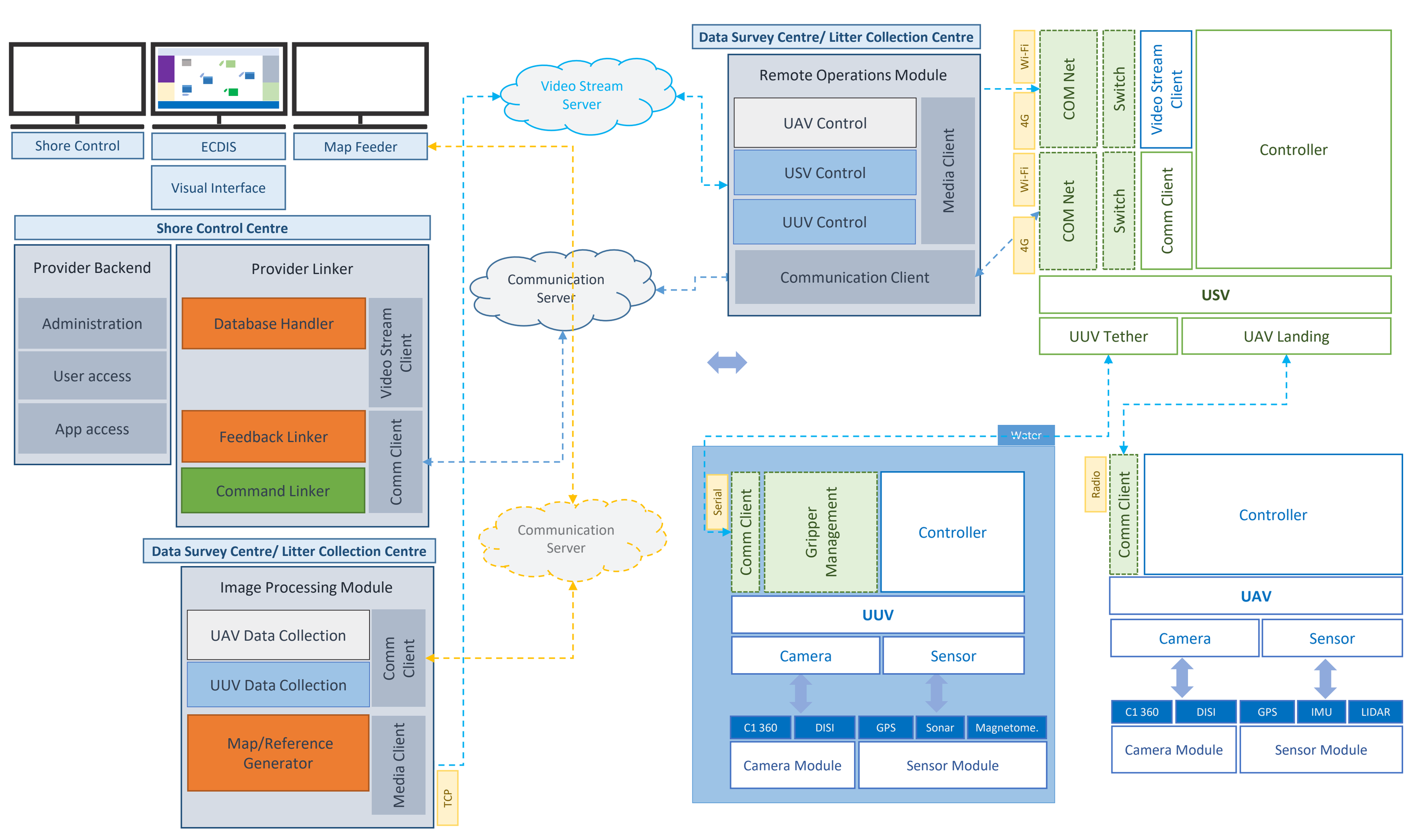
The aerial and underwater images gathered by the survey robots will be post-



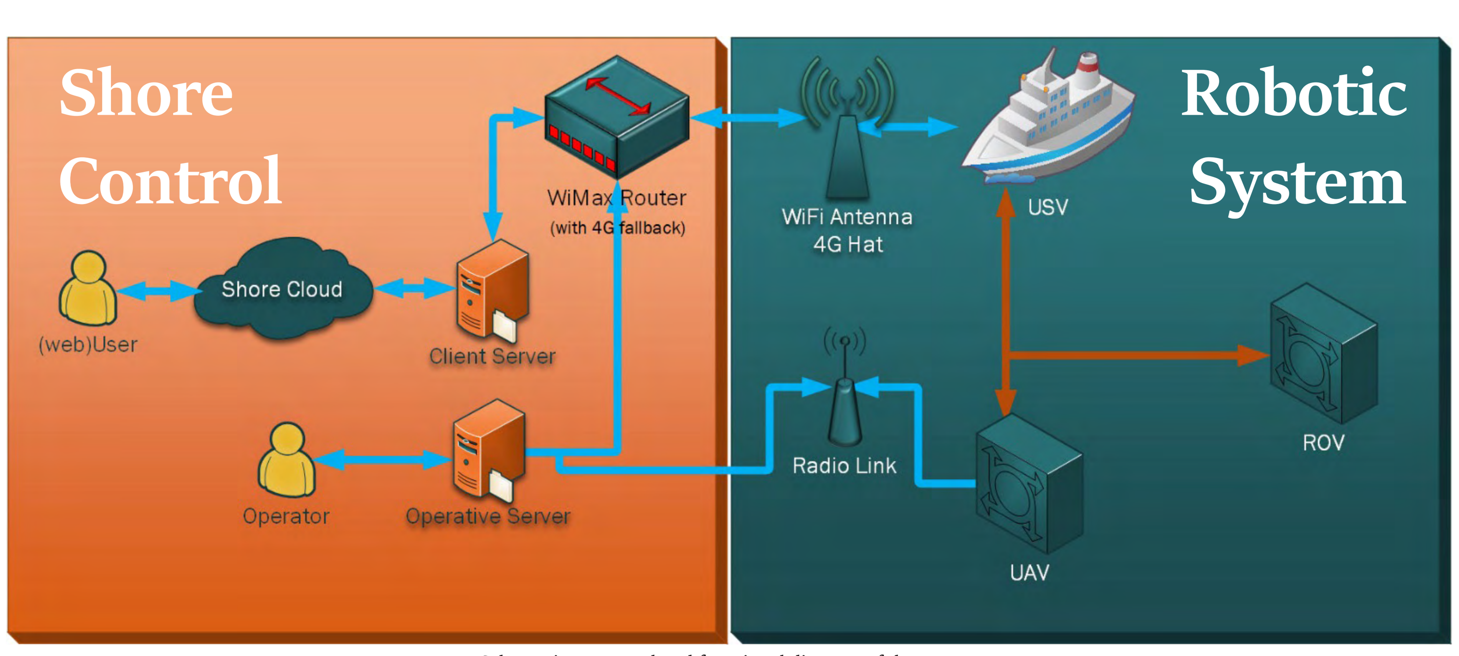
The proposed SeaClear concept with SeaCat USV, Guardian observation UUV (left), Tortuga collection UUV (right) and UAV

processed in a centralised unit, called Data Survey Centre. This unit comprises complex algorithms for digital image processing (see Algorithms below), through which accurate 3D maps of the analysed volumes can be built. The output of this unit consists of a list of targets that represent actual pockets of marine litter or hotspots with high litter density. In order to achieve this, the centre makes use of two modules, the Image Processing Module, responsible for processing the multimedia data and the Remote Operation Module for controlling the UVs.

The Litter Collection Centre is responsible for managing the UVs in the waste collection phase. As the actual pockets of litter are online updated, using the detection UUV, before actually being collected the by collection UUV, this unit also uses the aforementioned two modules. The core difference is that in this phase, an initial map of litter is already existing, thus it needs to be updated, rather that recreated and the USV is expected to be commanded in a seakeeping mode, rather than in maneuvering mode.



Detailed structural and functional diagram of the system



Schematic structural and functional diagram of the system

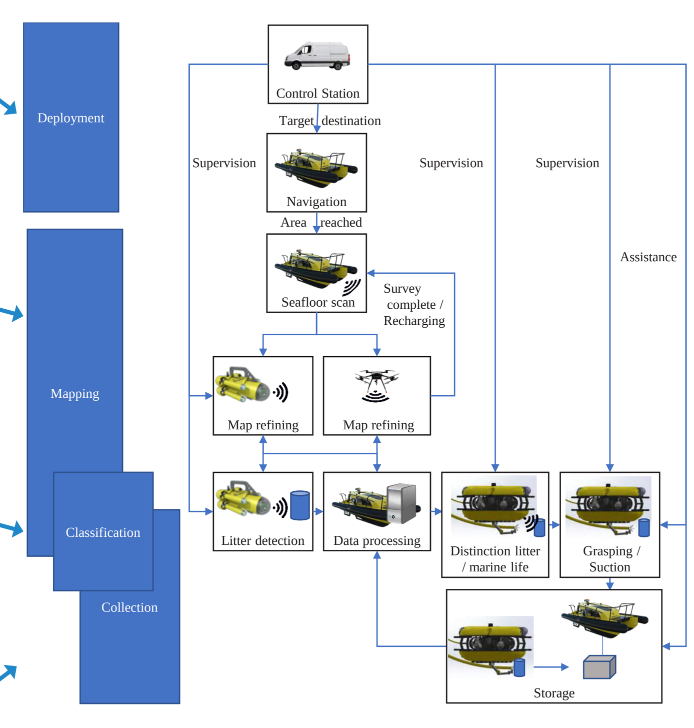
ROBOTICS/ALGORITHMS

Deployment of the system: The SeaClear system will be deployed in litter-rich spots identified in the use case scenarios with the USV acting as a carrier for an Unmanned Aerial Vehicle (UAV) and two Unmanned underwater vehicles (UUVs). The USV will host local processing units dealing with global navigation, image processing (detection, classification), seabed mapping (aerial + underwater) and coordination control of the UUVs.

Mapping: Once the destination is reached, the USV will first survey the work area with a multibeam bathymetry sonar to produce a 3D map of the seabed, before deploying the observation UUV and the UAV. The USV will then be in "follow-up mode" controlled by the observation UUV navigation. The UAV will survey the area in front of the USV. UAV video will be transmitted to the main processing unit on the USV for creating the aerial density map with object detection/classification if images allow (depending on ambient light, surface water conditions, water turbidity, etc.).

Classification of debris type: In this step the observation UUV is tasked with refining the map and detecting debris. With the fused data fed into previously trained classification algorithms, the map is updated with information on the location and the type of debris. Based on this information the collection UUV can decide how to approach the task of collecting waste.

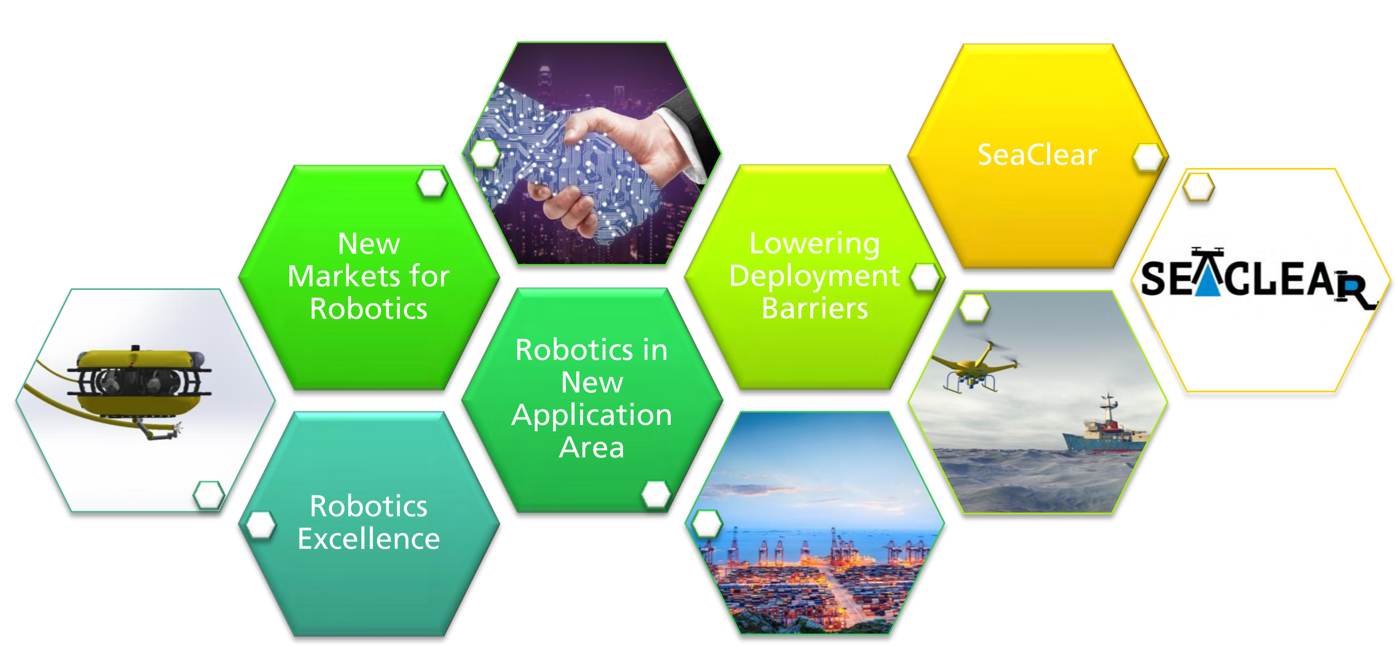
Collection of the debris: In the last step the collector UUV, equipped with a special manipulator, will transfer litter to the USV storage unit. The UUV will distinguish in situ between debris and marine life to prevent unnecessary harm and achieve highly targeted litter manipulation. Particles smaller than the hose diameter will be sucked directly into the storage unit using a pump installed on the USV. Larger objects will be handled by a gripping device surrounding the suction device entry.



Detailed functional view of the system

Footnotes:
[E16] https://www.eunomia.co.uk/reports-tools/plastics-in-the-marine-environment/
[AW] https://www.projectaware.org/update/european-seafloor-survey-reveals-depth-marine-litter-problem
[NC] https://www.ncl.ac.uk/press/articles/archive/2018/09/plastics/
[ZW] https://zerowasteeurope.eu/2013/06/good-plastics-bioplastics-and-greenwashing/
[GOC14] Global Ocean Commission. "From Decline to Recovery: A Rescue Package for the Global Ocean", report, 2014
[WEF+16] World Economic Forum and Ellen MacArthur Foundation, "The new plastics economy: rethinking the future of plastics", 2016

IMPACT



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