Search, identification and collection of marine litter with autonomous robots

SeaClear

https://seaclear-project.eu

D7.5

Dissemination and Exploitation report and business plan

WP7 – Dissemination and Exploitation

Grant Agreement no. 871295

Lead beneficiary: Subsea Tech

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1 R = Document, report, DEM = demonstrator, DEC = Websites, patents filing, etc. OTHER: Software, technical diagram, etc. ETHICS = Ethics

2 PU=Public, CO=Confidential, only for members of the consortium (including the Commission Services), CI=Classified, as referred to in Commission Decision 2001/844/EC.

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Disclaimer of warranties

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Definitions

- **Beneficiary:** A legal entity that is signatory of the EC Grant Agreement no. 871295.
- **Consortium:** The SeaClear Consortium, comprising the below-mentioned list of beneficiaries.
- **Consortium Agreement:** Agreement concluded amongst SeaClear Beneficiaries for the implementation of the Grant Agreement.
- **Grant Agreement:** The agreement signed between the beneficiaries and the EC for the undertaking of the SeaClear project (Grant Agreement no. 871295).

Beneficiaries of the SeaClear Consortium are referred to herein according to the following codes:

- **TU Delft:** Delft University of Technology.
- **DUNEA:** Regional Development Agency Dubrovnik-Neretva County - DUNEA.
- **Fraunhofer CML:** Fraunhofer Center for Maritime Logistics.
- **HPA:** Hamburg Port Authority.
- **SST:** Subsea Tech SAS.
- **UTC:** Technical University of Cluj-Napoca.
- **TUM:** Technical University of Munich.
- **UNIDU:** University of Dubrovnik.

Abbreviations

D&E: Dissemination and Exploitation
USV: Uncrewed Surface Vehicle
ROV: Remotely Operated Vehicle
LARS: Launching And Recovery System
EU: European Union
IFAC: International Federation of Automatic Control
ZDF: Zweites Deutsches Fernsehen (Second German National TV)
IAPH: International Authorities of Ports and Harbours
ESC: Exploitation Steering Committee
DoA: Description of Action
UAV: Unmanned Aerial Vehicle
MBES: Multi Beam Echosounder

Executive Summary

This deliverable is an updated version of the deliverable 7.1 Dissemination and Exploitation Strategy Plan which was submitted on 17/12/2020 at M12.

The first part is a report on Dissemination actions carried out along the project course, including the creation of the various promotion supports and the organisation or attendance to academic and industrial events. All actions were undertaken as per the DoA and dissemination KPIs exceeded expected results.

The second part is an updated version of the Exploitation strategy highlighting exploitable results, field of applications and targeted customers. A revised version of the business plan is presented taking into account feed-back from various potential end-users.

1. Introduction and objectives

Identifying the target groups, through dissemination actions, for the final implementation was one of the most important aspects to feed the exploitation plan. Without this information it would have been impossible to define a successful business model.

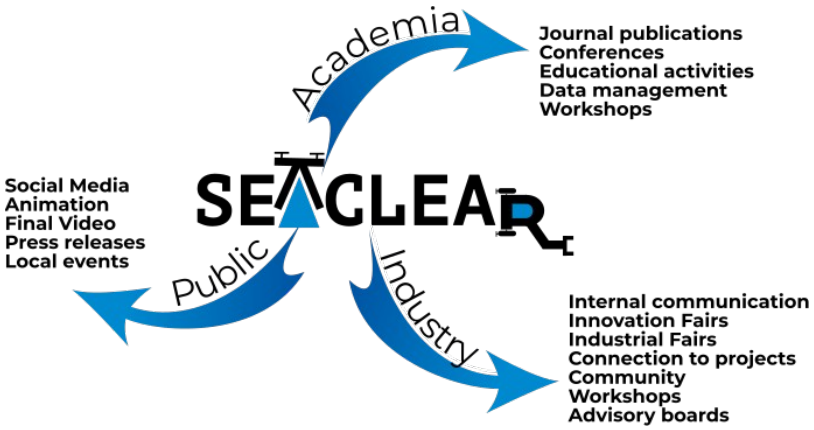
The exploitation plan and business model creation are explained more in detail in Section 3 but it is worthwhile mentioning here the identified target groups. They are important because they guided the dissemination activities and besides, a successful exploitation of the project results is the result of constant communication with the relevant target groups throughout the project. These targeted groups are:

- Environmental authorities
- Public conservation areas
- Tourism and hospitality actors
- Municipalities and local authorities
- Port authorities
- Marinas
- Hydropower management
- Water supply management
- Diving companies

The key objectives of SeaClear dissemination and exploitation (D&E) strategy were identified at the beginning of the project to be:

- To develop and implement a tailored dissemination plan for the project
- To raise public awareness throughout effective dissemination actions
- To guarantee broad dissemination of the project results to the relevant stakeholders
- To set-up and maintain an ambitious exploitation plan
- To build up the SeaClear community, involving relevant stakeholders and end-users

As such, three main dissemination segments were identified as presented in the figure below: **General Public**, **Academia**, and **Industry**. In the following 3 sections of this deliverable, we outline the dissemination activities that we undertook for each of these segments.



2. Dissemination report

2.1 General public dissemination

2.1.1 Project brand and visual identity

To increase the impact of the project, we decided to create a common brand and visual identity that would be used by all partners in all our means of communication. We did this during the early stages of the project to benefit from the investment in time early on. Having a common and consistent visual identity allows the audience to recognise the project easier, which assists in disseminating results in a more efficient manner. The actions undertaken for the brand and visual identity of the project are outlined in the following subsections.

One of the most important aspects of the visual identity is the creation of a logo. The logo was created during the proposal phase of this project and is visible in the figure below:

Figure 1: SeaClear logo

Along the same line, we created a set of templates that were used both for the internal communication of the project but also for some external documents created. This included a template for the deliverables and the presentations of the project.

2.1.2 Brochure

We designed a brochure to disseminate information about the project during conferences, outreach events, or any other events that members of the project participated. A preview of the brochure is visible in the figure below.

Figure 2: SeaClear brochure

2.1.3 Poster and roll-up

During the initial stages of the project, we created a poster for presenting the project. This was firstly used during our presence at the European Robotics Forum that was held in Malaga, Spain from 3rd to 5th of March 2020. The poster was targeted for an industrial/academic audience, and it presented the problem statement, the proposed solution of this project and the case studies that we are planning to examine. To target a more commercial/industrial audience, we also created a roll-up, with less written and more visual information. This presents in a visual manner the details of how the system works. Both the poster and the roll-up are visible in the figure below.

Figure 3: SeaClear poster and roll-up

2.1.4 Website

An especially important part of our dissemination efforts for the public has been our public website: https://seaclear-project.eu. A deliverable (D7.3) was submitted in the initial stages of the project, outlining the sections of the website, however the site was continually evolving during the project. At the first stage, the domain name was registered, and we populated the website with the basic information regarding the project.

During the project we constantly refined the structure of the website, with the final structure as follows:

About SeaClear: Two subsections belong to this section, one with information about the project and one about other related projects. The **About the project** page contains a public, readable abstract of the project together with an infographic describing the system visually. To help with understanding the components of the system, we created five explanatory videos that describe the surface vessel, the drone, the observation and collection ROVs, and finally the basket. To present the sequence of the developments of this project, we added a timeline with the milestones of the project. Upon reaching each milestone, a news item was linked from the respective element of the timeline. Finally, the **innovation statement** is present in this subsection.

Team: Includes firstly a list of partners, rendered graphically via their logos. Each logo links to a description of the partner, including their address and social media handles, and their role in the project. Furthermore, the members active in each partner are visible on this page. Upon clicking on each person, the visitor is redirected to a page dedicated to each member with short details about their expertise and role in the project. Secondly, the advisory boards are provided, with a photo and biography of each member when permitted and available. Finally, we created a page to advertise open positions for working within the project.

Updates: This has been one of the most active sections of the website, where we posted news about activities, participation to events, press releases etc. Each subsection is described separately next:

Updates/News: To make our website more engaging, we aimed to create a news item at least once a month. Each news item was accompanied with a relevant visual element, either a picture, a video, or a graphic. This helped capture the attention of the audience and explain more successfully the concepts. To ensure continuity, but also diversity in our news items, we devised a basic algorithm for eliciting news, where each month one of the partners contributed with a news item from their side. This algorithm was overridden whenever we had notable items to report at any given point in time. In total we have published 40 news items in the 46 months until the moment this report was written. At least three more news items are planned until the end of the project, one for the release of the Dubrovnik demonstration video, one for the closing of SeaClear, and one to direct the users to the website of the follow-up SeaClear 2.0 project.

Updates/Videos: Besides the explanatory videos produced for the *About SeaClear* page, we also produced several other videos about the trials and demonstrations during the project. These videos were featured in a dedicated subsection.

Updates/Events: A list of notable project events, such as workshops, research exchanges that members of the SeaClear project have attended or were organised as part of the project activities.

Updates/Press releases: This page featured all the press releases that were produced during the project.

Updates/Media kit: To assist journalists in reporting the project, and therefore increase the chances of having the project published in news outlets, we created a Media kit. This was in the form of a dedicated page that would feature a short and concise description of the project, funding information, quotes from the project leader, and various images and videos to be used freely. A list of existing media publications was featured. Finally, contact information and social media channels were provided.

Results: This section included relevant articles, dissemination material available for download, as well as papers and reports published by the consortium. A **Deliverables** section provides the publicly accessible deliverables that have been produced. A **Publications** section provides all the academic publications that were produced during this project, split into journal and conference publications.

A funding acknowledgement is given in the footer of each website page. A contact page is provided, together with a way to subscribe to the newsletter of the project.

The website served as a central channel of dissemination of news items, both in terms of developments within the project, but also in terms of participation to events or any project related publicity. The latest news items were featured on the front page of the project, to make the website more dynamic and up to date. A news archive is accessible through the top menu of the website.

Since December 2020, the SeaClear website has registered **26098 unique visitors**.

Finally, we are preparing a new page that will be available before the end of the project regarding the available modalities of business partnerships with the SeaClear project. This will help attract potential end-users even after the end of the project.

2.1.5 Animation

To explain the concept of the project, but also the role of each of its component in a more visual way, we produced an animation with a cartoonish but realistic design of the SeaClear system. This was the result of a collaboration with an external agency so that the result looks professionally.

The animation was featured on our social media channels with the occasion of the 'World Water Day' on March 22, 2021. To make it more accessible, we provided closed captions in 13 languages (Catalan, Croatian, English, French, German, Greek, Hungarian, Italian, Portuguese, Romanian, Slovak, Spanish, and Turkish).

To this day, the animation has had 9.4k views. It has been used extensively in events, press releases, media appearances, and presentations during the project. The video is currently featured on our YouTube channel[3] and depicted in Figure 4.

[3] https://www.youtube.com/watch?v=vC_sNOWLcsk&ab_channel=SEACLEAR1.0%262.0

Figure 4: YouTube animation video

2.1.6 Video production

Besides the animation, we also produced several other videos using real footage collected during tests, trials, and demonstrations. A separate effort was to produce explanatory videos for each component of the system, namely the USV, drone, collection and observation ROVs, and the basket. These videos were featured in the 'About SeaClear' page of our website and were going into more depth than the information provided by the animation.

Furthermore, we produced the following videos:

- A video on the comparison of the two test sites of SeaClear (Dubrovnik vs Hamburg)
- A video describing the basket prototype
- A video on the Launch and Recovery systems (LARS) of the USV
- Four videos for the Dubrovnik and Hamburg trials
- Two videos for the Dubrovnik and Hamburg demonstrations
- A video showcasing the SeaClear simulator, with explanations on how to use the system
- A final video covering the whole project history

In total, 15 videos were produced, and all are present on our YouTube channel. To enhance our visual identity, common style thumbnails were used for all the videos. In total, all the videos featured on the YouTube channel have had more than 20k views.

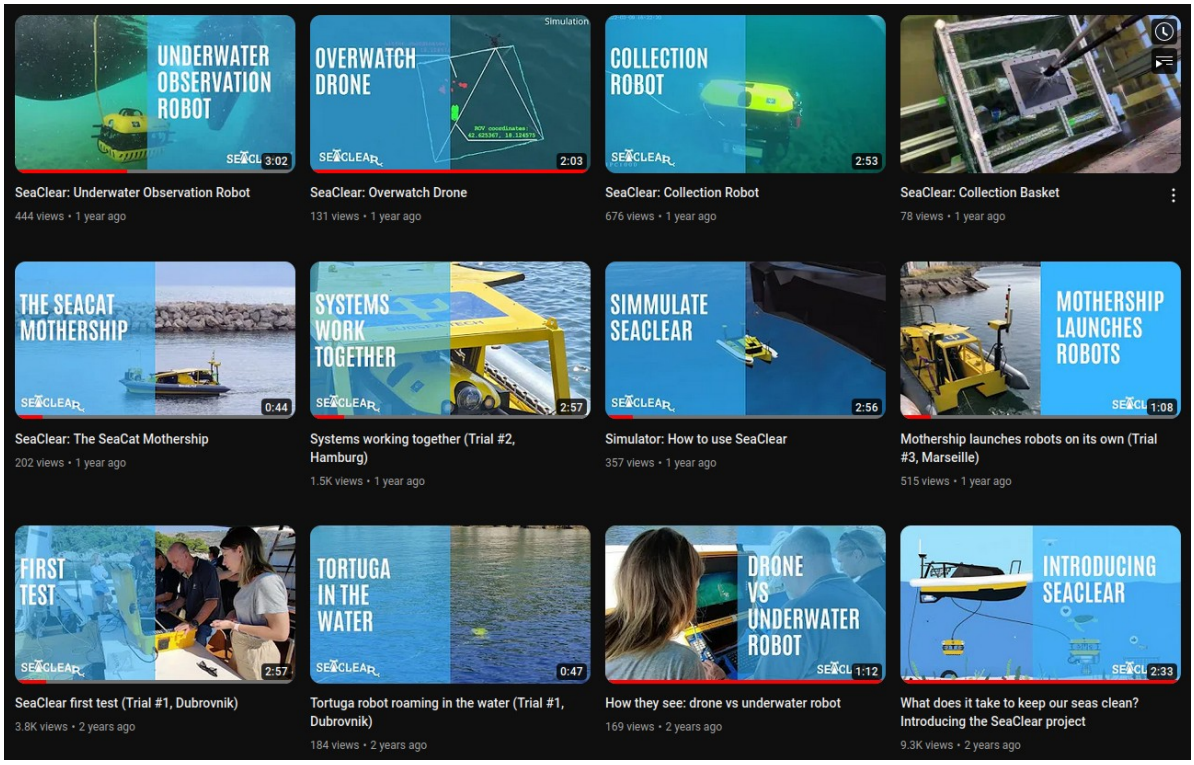


Figure 5: The various SeaCLear videos on our YouTube channel

2.1.7 Social media presence

From the very beginning of the project, our general public dissemination efforts were focused on social media channels. We created accounts on all major social media platforms as follows:

- Twitter (currently known as X): https://twitter.com/seaclearproject
- Facebook: https://www.facebook.com/SeaClearProject
- LinkedIn: https://www.linkedin.com/company/seaclear-project
- Youtube: https://www.youtube.com/seaclearproject
- Instagram: https://www.instagram.com/seaclearproject/

Initially, our dissemination strategy was to reproduce on all the platforms the news items that were featured on our website. We therefore had a low posting frequency of publishing updates on the social media channels. This was deemed ineffective to gain traction and followers, therefore we created a social media strategy to increase the frequency of our communication, and to target it better to the relevant stakeholders. The initial stage of the strategy was to identify relevant accounts to be followed, with the hope that some of these accounts would follow our project back and share further our posts. At the second stage, we devised a posting schedule so that we ensure continuity on our messages. When we did not have notable project updates to share, posts would be created to comment on environmental issues, events in the field, international days, or other projects' work.

Table 1. Social media statistics

Platform	Followers/Visits	Posts	Impact
Website	26098	40	75 Newsletter subscribers
Twitter	171	614	47K total impressions
Facebook	26	299	6.7K page reach
Instagram	157	64	2.2K page reach
LinkedIn	961	217	1638 unique page visits last 365 days
YouTube	155	15	20K combined views

2.1.8 TV and radio appearances

During the project we have published 5 press releases as a consortium (with an extra, final press release planned on the occasion of the closure of the project). These press releases have attracted the attention of many media outlets resulting in numerous TV and radio appearances, in the forms of interviews, stories about the project etc. Some of these have been on prime-time TV, which resulted in significant publicity for the project and its developments. Below, we are listing some of the most notable media appearances:

- Horizon, The EU Research and Innovation Magazine — How robots and bubbles could soon help clean up underwater litter
- New Atlas — SEACLEAR project aims to robo-garbage-pick the ocean floor
- Interesting Engineering — Clearing the Seabed of Plastic with Autonomous Robots
- Springwise — Autonomous drones and vehicles collect rubbish from ocean floor
- Bild — Roboter sammeln Müll im Meer
- New Scientist — Delftse onderwaterrobots vissen zwerfvuil van de zeebodem
- National Geographic — Cercetătorii din Cluj lucrează la primul sistem robotic de curățare a deșeurilor de pe fundul oceanului

2.1.9 SeaClear cartoon concept

To engage with the younger generations and instil in them the need to protect our environment, we decided to design and distribute a cartoon describing our system. The idea is to distribute the cartoon to schools and teachers, so that they print it for their students and offer it as a comic creation activity. The students can colour the comic and add text on the text bubbles coming out of the SeaClear components or various forms of sea life. On the back page of the comic there is information about the project and a QR code that redirects students to a submission page hosted on our website. There, they can upload their design so that it is featured on our social media channels. The comic strip is presented in Figure 6: SeaClear cartoon below.

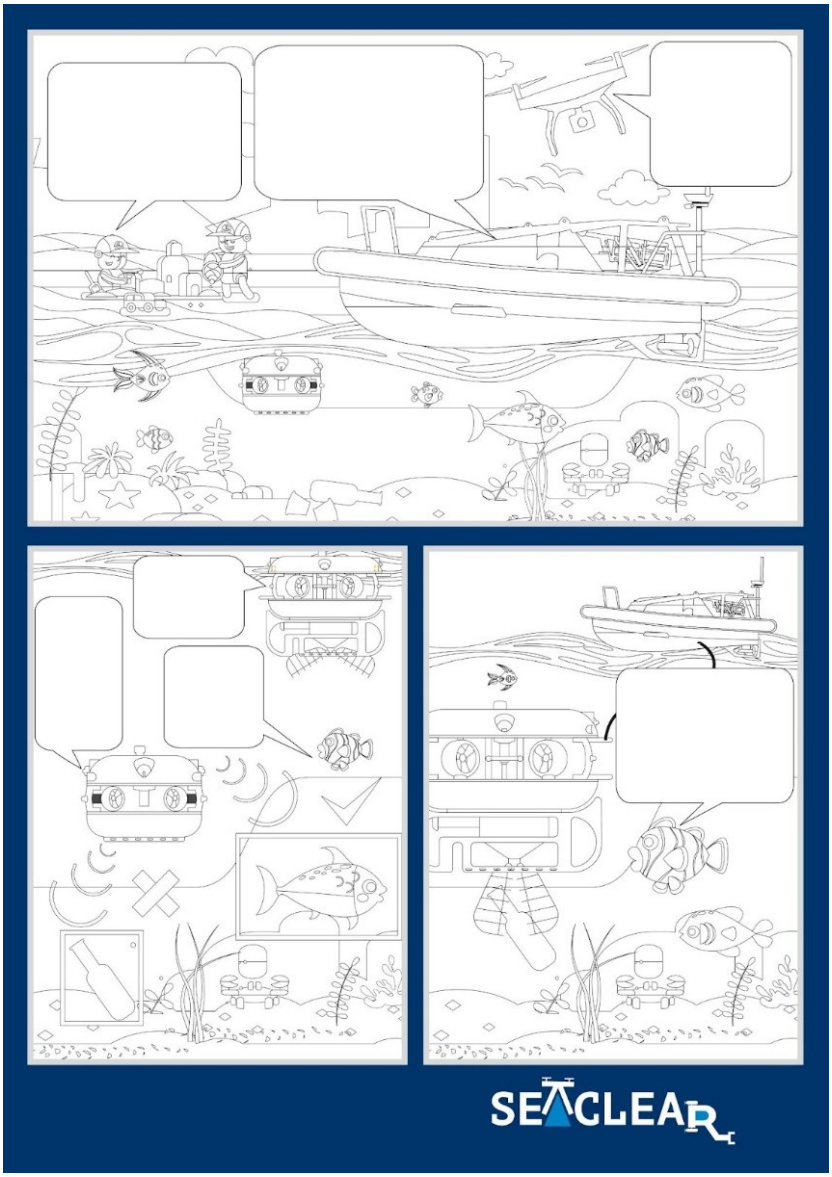


Figure 6: SeaClear cartoon

2.1.10 Educational kit for schools

Besides the comic strip material described in the previous paragraph, we have also prepared a more complete educational kit targeted at schools. The kit contains a presentation and a lecture plan which will allow interested teachers to understand the SeaClear system and develop further a comprehensive lecture. This could be adapted to the level and specific knowledge of the specific students. A certificate template is also available to award to students that have successfully completed the course. Finally, to disseminate this kit better, we have gathered teachers interested in the water pollution topic, and we constructed a database with possible contacts.

2.1.11 SeaClear infographic

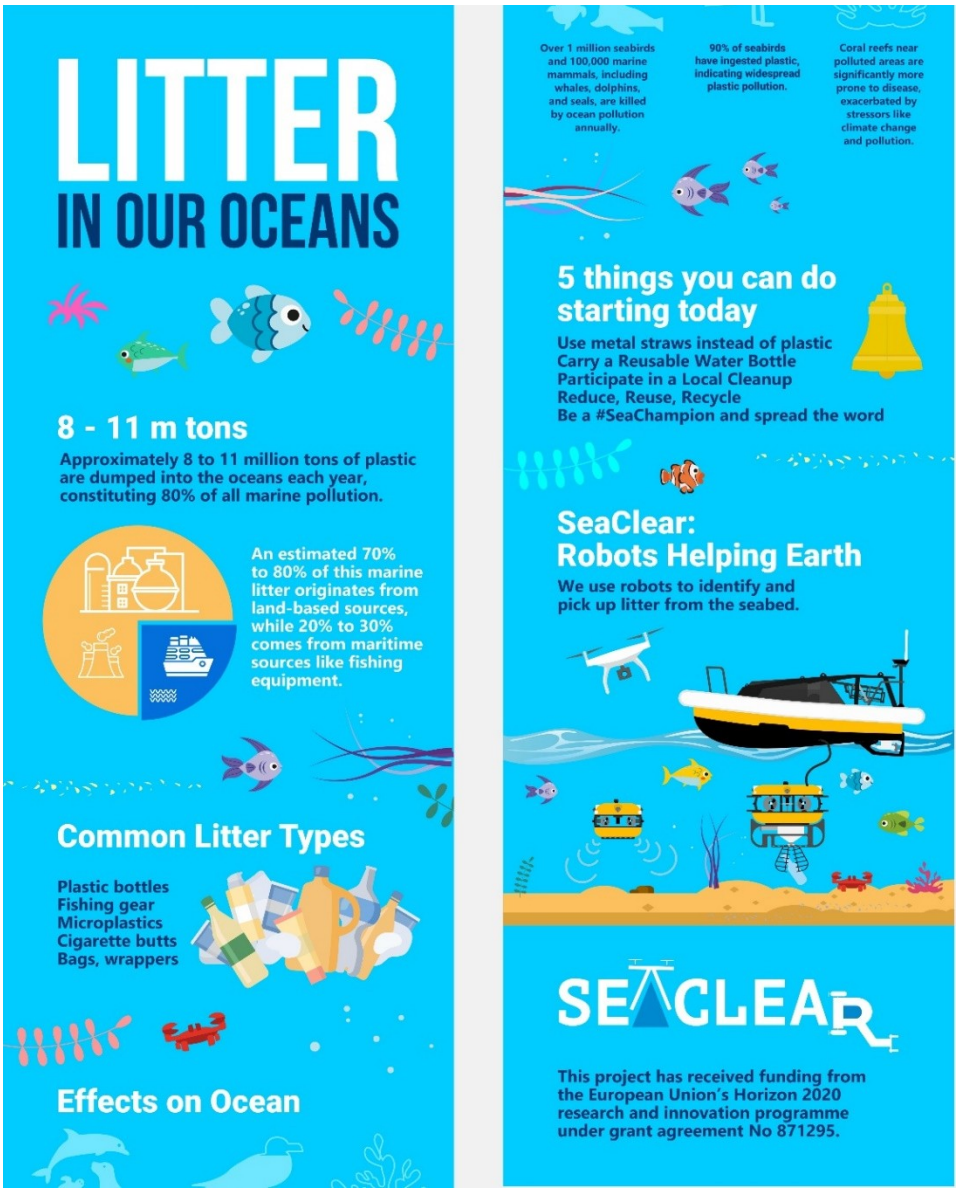


Figure 7: SeaClear infographic

To complement the comic strip and the educational kit, we have also created an easy-to-use infographic, on the topic of marine litter. The infographic is visible on the Figure 7 above (reshaped as a two-column figure to fit the page).

2.1.12 SeaClear demonstrations

A key aspect of the SeaClear project has been the public demonstrations either of the components or of the whole system itself. This has been accomplished both through participation in various events, but also through our own main public demonstrations at the two test sites of the project (Hamburg and Dubrovnik).

The first public demonstration of the full system took place on the 8th of June 2023 at the port of Hamburg. During this demonstration we showcased the abilities of the system to locate the underwater robots, navigate autonomously, and detect litter. Several key stakeholders have been invited to observe the demonstrations, and discussions were held with each of the bodies involved to gather the feedback of the potential end-users of the system. This included the Port of Hamburg's Harbor Master, the Port strategy, Environmental department, the Port authority, technical division and more. Besides internal bodies, journalists were also invited to cover and report upon the demonstrations. Most notably, the demonstrations were covered by ZDF, which gathered footage for their program called 'Plan B'. The SeaClear project was featured on the respective program during their September episode[4].

The second public demonstration of the full system took place on the 12th of October 2023 in Dubrovnik. The full pipeline, from system deployment, through litter detection and mapping, to collection and deposition in the basket, was demonstrated for the first time in the same location. During this second demonstration, the research team together with EU evaluators were on-board the main operations vessel, while the media and local-authority representatives were on-board a second boat following the action. Underwater live streams were available on both ships, together with explanations of what is happening at each stage. This allowed journalists and evaluators to understand and better follow the steps taken for underwater litter detection, mapping, and collection.

The day after the demonstration, on the 13th of October, the final SeaClear conference took place at the University of Dubrovnik. The event, titled: "SeaClear: Smart Robots and Human Hearts—for Clean Oceans", welcomed press, local authorities, researchers, and students, to disseminate the results of the SeaClear project. The work package leaders shared their experiences with robotic litter collection from the ocean floor, and lessons learned during this project.

2.1.13 Participation to public-oriented events

To capture more of the general public attention, partners of the project also participated in several science events. For example, SeaClear was present at two editions of the "European Researchers' Night", in the 2021 and 2022 editions at Cluj-Napoca, Romania and in the 2022 and 2023 at

[4] https://www.zdf.de/gesellschaft/plan-b/plan-b-intelligente-lebensretter-100.html

Dubrovnik, Croatia. We demonstrated the algorithms for litter search that were developed in the project. In parallel, the technology videos were used as additional material for explaining the concepts in a visual manner.

The collection ROV (Tortuga robot) of the SeaClear system also took part in a scientific exhibition called "Neue Sammlung", which was installed at the Pinakothek der Moderne in Munich. The exhibition opened on the 14th of July 2022, and lasted until January 15th 2023, during which time the Tortuga robot was exhibited. Next to the robot, we placed a QR code with a redirection to our website. During the 6 months of the exhibition, 1514 people have visited our website through the QR code. Also the SeaClear project was featured in the art exhibition on November 25th at the Sponza palace in Dubrovnik, Croatia as part of the Days of creative and cultural industries.

The SeaClear overall system had a stand at the ITS event that took place in October 2021 in Hamburg, Germany. Besides showcasing the latest features tested, a mock-up of the collection ROV has been displayed for interaction with the public. Within the Homecoming event, which took place in Hamburg on September 2022, SeaClear was present at the stand and shared the intermediate results with the visitors.

2.2 Academic dissemination

The main objective of SeaClear academic communication was to distribute SeaClear knowledge and outcomes to the academic and research community. Audience included faculty, scientific and industry researchers, and students.

This objective was achieved by academic communication and exploitation of results in five forms:

- Articles in scientific periodicals and journals
- Communication in scientific conferences (with, or without, associated papers)
- Organization of workshops.
- Creating new, and updating existing teaching materials with content resulting from the project.
- Creating PhD, MSc, and BSc projects related to SeaClear.

The overall strategy of academic dissemination is presented in the figure below.

Each of these communication forms are reported in the following subsections.

2.2.1 Journal publications and conference participation

The KPI for academic publications was set to 32 articles, resulting in an average of 8 publications per year. Naturally, fewer publications appeared in the first two years of the project, with the main bulk of articles being published in the second half of the project. Currently we can report 32 published/accepted articles (11 journal and 21 conferences), and 4 articles that were submitted for publication. This is a total of 36 articles that were produced during this project, which exceeds the original target. Furthermore, we are currently in the preparation phase of a final publication describing the complete SeaClear system. All articles are on topics related to the goals of the project and have an appropriate acknowledgment to the funding source. Open access is available for all the articles. The details for the journal and conference publications are provided in two following tables at Annex 1.

2.2.2 Workshops

Besides presenting the work described in the research articles, members of the SeaClear team have organised/participated in various workshops at several scientific conferences. More specifically, we have organised workshops in the following venues:

- **Reinforcement Learning and Machine Learning for Control**: Open Invited Track at the 6th IFAC conference on Intelligent Control and Automation Sciences
- **Innovative Technology for searching, identifying and recovering marine debris**: Technical session at the 7th International Marine Debris Conference
- **Learning for Multi-Robot and Networked Systems**: Open Invited Track at IFAC World Congress 2023
- **SeaClear: search, identification and collection of marine litter with autonomous robots**: Tutorial session at the European Control Conference 2023

The detailed description and impact of these workshops are further detailed in the separate, dedicated deliverable D7.4.

2.2.3 Educational activities

Another key aspect of academic dissemination has been the inspiration and preparation of the future generations of researchers, through various educational activities. This activity was undertaken by the academic partners of the project, and it has materialised in different forms.

First and foremost, we have included students in the research activities of the project through Bachelor and Master thesis proposals. The topics were drawn from the actual research questions of this project which allowed the students to get relevant and valuable research experience. At least 3 Master and 4 Bachelor thesis projects were completed during the last four years.

8 PhD theses have been developed during this project, and they are scheduled to be defended after the end of the project.

Furthermore, lecture notes were updated to reflect the information obtained from the project. For example, a new lecture was introduced on Underwater Robotics Modelling and Control, as part of the Robotic Systems Control, taught at the Automation Department of UTC. Additionally, we delivered several guest lectures from one partner to another, to exchange teaching information and techniques. This has been the case at least 4 times during the project, with a guest lecture delivered twice from TUM towards UTC (Lecture on Advanced Control Techniques of Robot Arms), once from UTC towards TUM (Underwater Robot Modelling and Control), and from TUD towards UNIDU (Hydrodynamic Imaging with Artificial Intelligence)

2.3 Industrial and end-user dissemination

2.3.1 Connection to other projects

Due to its nature, the SeaClear project had many opportunities to connect to other actions or projects, either in the robotics domain or on the litter detection and collection part. We pursued such connections either through common organisation of workshops, knowledge and expertise sharing, or simply by exchanging social media contacts.

Overall, the SeaClear project got connections to the following projects:

- MARLESS project
- INNOVAMARE project
- BLUEfasma project
- RoboVaas project
- RAPID project
- AMUCAD project from EGEOS GmbH
- BASTA Project from GEOMAR
- Ocean Technology Campus
- Hamburger Klimawoche
- Seabin project from Nports
- Marispace-X
- The Ocean Cleanup
- The Seacleaners
- Venice Lagoon Plastic Free
- MAELSTROM project
- eSEA Marine
- Global Partnership on Plastic Pollution and Marine Litter

2.3.2 Events participation

Since the industry represents a significant segment of the potential stakeholders of the SeaClear system, we arranged to participate in various Innovation and Industrial fairs. This has been possible mainly during the second part of the project, due to the restrictions imposed regarding the CoVID-19 pandemic. Partners of the project have participated in the following industrial events:

- European Robotics Forum 2020, at Malaga, Spain
- ITS Congress Hamburg 2021
- SMM Hamburg 2022
- HomeComing Hamburg 2022
- Euromaritime Marseilles 2022
- Munich AI 2022
- Euronaval Paris 2022
- A.I. Society / Automatica 2022
- Bavarian Europe day (science fair)
- Ocean Business Southampton 2023
- FOWT Nantes 2023
- Seanergy Paris 2023

Furthermore, in this regard we also organised open days at the headquarters of Subsea Tech in Marseilles, where the SeaClear system was demonstrated to over 70 interested industrial participants.

Finally, one of the most notable participations to an industrial event has been the World Ports Conference of 2022, organised by the International Authorities of Ports and Harbours. At the gala session of the event, the organisers granted several awards. The IAPH 2022 sustainability award in the 'Environmental care' category was granted to the SeaClear project for its support to the 'World Port Sustainability Program'.

3. Exploitation and business plan

3.1 Exploitation strategy

To elaborate and support the exploitation plan, an Exploitation Steering Committee (ESC) was set up in September 2022. This committee was managed by SST with a representative from each consortium partner.

The nominated partners were:
Coordinator:
Yves Chardard, SST
Members:
Ivana Palunko, UNIDU
Claudia Hertel-ten Eikelder, HPA
Bart De Schutter, TU Delft
Levente Tamas, UTC
Hatem Sultan, TUM
Iva Pozniak, DUNEA
Cosmin Delea, Fraunhofer

ESC meetings were held each quarter from November 2022 till December 2023 (5 meetings).

Concrete results of the ESC actions were the preparation of the list of exploitable results, the identification of potential customers and the search of other fields of exploitation besides litter cleaning. These lists are presented in the following chapters.

As planned in the DoA, all project partners have been involved in the exploitation efforts with individual actions summarized below. Such actions have been started during the project course and will be continued after the project completion.

The two end user partners (HPA and DUNEA), having no exploitable technical results, have specific exploitation plans within their own domain of interest (port cleaning and tourism).
Subsea Tech as the sole industrial partner and hardware manufacturer will apply the system in other domains than litter collection such as marine renewable plants inspection and environmental studies.

The academic partners, besides the potential with external stakeholders, will mostly exploit the results for their own education and research purposes.

The summary of each individual partner exploitation strategy is presented hereafter:

HPA: The Port of Hamburg is connecting with other ports worldwide to build a chain of intelligent ports – chainPORTs. The chainPORT initiative is a multilateral partnership of the world's leading ports. Its members are committed to the exchange of knowledge, innovation and the promotion of strategic topics. Via the chainPORT initiative, HPA provides SeaClear with global access to a great variety of ports and port operators, and thus, help develop a sustainable business model and thereby increasing the potential for a successful establishment in the global maritime industries market.

DUNEA focuses on stakeholder mobilisation and participation for the use case of Dubrovnik Neretva County, including all relevant sectors of the area (scientific, tourism, relevant government units and county institutions, decision makers, environmental NGOs, fisheries sector, educational institutions) for awareness raising of marine litter issues. This will give a clear picture of local community needs concerning waste management, focusing on marine litter issues.

Subsea Tech, as an industrial SME specialized in the operation and the sale of marine and underwater robotics systems, conducts a direct valorisation of the SeaClear results, widening its present scope of applications and contributing to the delivery of new unmanned systems capable of automated target detection, classification and collection. Subsea Tech is already deeply involved in harbour infrastructures inspection and environmental monitoring campaign. The SeaClear concept which allows to clean-up seabed litter is a definite and significant added value to the present services offer. Other main areas of valorisation are the inspection of marine renewables plants and the monitoring of marine and underwater environment. Subsea Tech has already offered these cleaning services as part of concrete call for tenders in France, Scotland, Germany and Japan with respectively EDF, SSE, RWE and OYO companies. It is interesting to note that all these cleaning campaigns are related to the construction and exploitation of offshore wind farms.

As an academic institute, **TU Delft** plans the exploitation at the educational and research level, through inclusion of the SeaClear results in the field of cooperative control, multi-source data classification, and hybrid robot control as well as the SeaClear case studies and demonstrators in both advanced MSc and PhD courses and lecture series targeting practitioners in the life-long learning framework. In addition, to further the SeaClear research, MSc students will be actively involved in the project through MSc thesis projects.

Fraunhofer focuses on bridging the gap between science and industry, thus actively pursuing exploitation at both industrial and scientific level. Through past and present research projects, most of which have been conducted in a national or EU framework, Fraunhofer can draw on its extensive partner network of maritime stakeholders with various backgrounds, e.g. in navigation, industry, administration and science to propose innovative maritime services to monitor and reduce marine pollution. In addition, Fraunhofer aims to involve working students in the project activities, thus complementing the knowledge acquired at university with practical problems that need to be solved

with innovative thinking Nonetheless, students are welcomed to complete Bachelor or Master Theses within the field of marine robotics.

UTC targets exploitation in research (e.g. via importing the novel mapping algorithms developed in related applications with communicating robots) and education. The new results from SeaClear will be included in advanced graduate courses at UTC; and we will involve students at all levels (BSc, MSc, and PhD) in the research. Beyond these immediate goals, their higher-level education objective is to form students sensitive to the ecological challenges of today's society and increase awareness of these challenges among young researchers at our university and in our network.

TUM focuses on exploitation at educational and academic levels. TUM considers high-quality cutting-edge education is the key for Europe's global competitiveness in the field of service robotics. Through the lectures and coursework closely approximating the progress of SeaClear from a control-systems perspective, we offer a prime opportunity for students to learn the state-of-the-art technology of field-robotic, service-oriented applications in unstructured and dynamically challenging environments and improve their chance for a job in industry or in research. Furthermore, we will offer topics for research theses at Bachelor/Master/PhD levels to advance further on the success of SeaClear.

UNIDU will exploit SeaClear results at the research and educational level, by including the field of cooperative control, multi-source data classification and mapping in both actively involving MSc and PhD students in the project. Also considering the SeaClear case studies and demos through courses and lecture series, UNIDU interdisciplinary team (i.e., electrical engineers, mathematicians, marine biologists) will target practitioners in the life-long learning framework.

3.2 Exploitable results in addition to the complete system

As a concrete action of the ESC, a list of exploitable results in addition to the complete system has been established. The table below shows these results which can be exploited on a stand-alone basis, together with the corresponding partners:

Partner #	Partner	Exploitable results
1	TU Delft	Multi-sensor system for underwater detection and classification of seabed objects
3	CML	Web- and Console applications for commanding waterborne robots (USVs, ROVs, AUVs)
5	SST	USV + ROV for offshore underwater inspection works USV supported ROV LARS system (Tortuga and mini Tortuga) USV + Captive drone (for extended aerial inspection or surveillance)

6	UTC	Modular system for mapping, detection and navigation assistance with USV/UAV
7	TUM	ROV grippers and Suction systems
8	UNIDU	USV + Captive drone (for extended aerial inspection or surveillance)

Table 2: List of exploitable results

As can be seen in the table above, they are numerous stand-alone potential products (or services) that can be exploited individually by each nominated partner. It is expected however, as mentioned in the previous chapter, that the academic partners will focus on research and education purposes while SST will attempt to transform this potential in actual products or services sales.

The next table is a list of potential applications for the SeaClear system and sub-systems beyond litter cleaning which have been established during the ESC meetings with all the partners, with a priority ranking based on the actual potential. Each application is rated with a H (High) which means high potential due to similarity with litter collection or use of complete system, M (Medium) for applications where part of the system would have a clear use but with alternative solutions, L (Low) for application where there is existing proven competition with no obvious added value for the SeaClear system.

#	Application	Potential	Comments
1	Sample collection	H	Detection and collection of shells, archaeological artefacts or any valuable items on the seabed
2	UXO detection and classification	H	Detection and collection of unexploded ordnances (UXOs)
3	Offshore wind farm inspection	H	Inspection of underwater and above water parts of offshore wind turbines with unmanned system
4	Forensics	H	Detection and collection of crime scene evidence
5	Search & Rescue	H	Detection and collection of drowned bodies
6	Marine parks monitoring	H	Above and below water surface surveillance and monitoring
7	Fish farm monitoring	M	Fish farms already well equipped with specific instrumentation. Could supplement existing systems
8	Underwater cable inspection	M	Would require improving system seaworthiness
9	Underwater archaeology	M	Limited opportunities and needs ultra delicate handling
10	Divers' assistance	M	
11	Surface oil spills	M	Mostly for surveillance with USV + UAV
12	Bathymetry	M	USV + MBES for large areas in auto navigation mode
13	Critical sites surveillance	M	USV + dedicated surveillance sensors
14	Vessel hull inspection	L	High competition from dedicated ROV systems

15	Bridges inspection	L	Competition with divers, specifications not well adapted
16	Big aquariums clean-up/inspection	L	Observation ROV only, cleaning system to be designed
17	Underwater movies	L	Requires high end camera systems
18	Underwater reforestation	L	Small market, requiring specific tooling.

Table 3: List of potential SeaClear applications other than litter cleaning

Future communication actions will be directed first to application fields with highest ranking. Some of them have been started with meeting and demonstrations organised for MRE plant developers, Navy officials and UXO specialists.

Finally, the last table below gives a list of the targeted customers that will be contacted as from 2024, based on the results obtained during Hamburg and Dubrovnik demonstrations in 2023. These potential customers have been selected by each partner in their respective country and contacts have already been made, including demos like for example at the Calanques National Marine Park near Marseilles in September 2023. A pitch deck has been prepared and sample slides are attached in paragraph 3.5

Partner #	Partner	Potential customers (3 to 5)
1	TU Delft	Wadden Sea (+ tourist board) Port of Rotterdam Veerse Meer (nature reserve)
2	DUNEA	ACI Marina Croatia CROMARIS (mariculture)
3	CML	L3Harris Technologies Inc. CHCNav Ltd. SatLab Geosolutions AB Saab Seaeye Ltd Hempel GmbH Kongsberg Gruppen (Maritime) ASA
4	HPA	City of Hamburg/ Municipal Cleaning taking care of Lake Alster & Canals cleanings Fire Department Wilhelmshaven - Initial search & rescue E-Scooter service providers Tier/ Voi/ Bolt / Lime German Federal Bureau of Aircraft Accident Investigation Hamburg Wasser
5	SST	Harbour of Marseille Calanques national marine parc (Cassis) Cap Corse national marine parc (Corsica) Port Vauban (Antibes marina) Harbour of Sète

6	UTC	Water company from Ro
7	TUM	City of Hamburg/Municipal Cleaning taking care of Lake Alster & Canals cleanings Stadtwerke München
8	UNIDU	Harbour of Dubrovnik Mljet national park Croatian Mountain Rescue Service Dubrovnik Fire department

Table 4: List of targeted customers for presentations and demonstrations in 2024

3.3 Business model

There is no change to the initially proposed business model.

The consortium has the capacity to perform all tasks from components purchase and fabrication to assembly and marketing.

The business model remains simple but efficient: the developers (in green) supply their components to the final integrator (in brown) which looks after worldwide marketing and sales supported by its own distributors and agents' network.

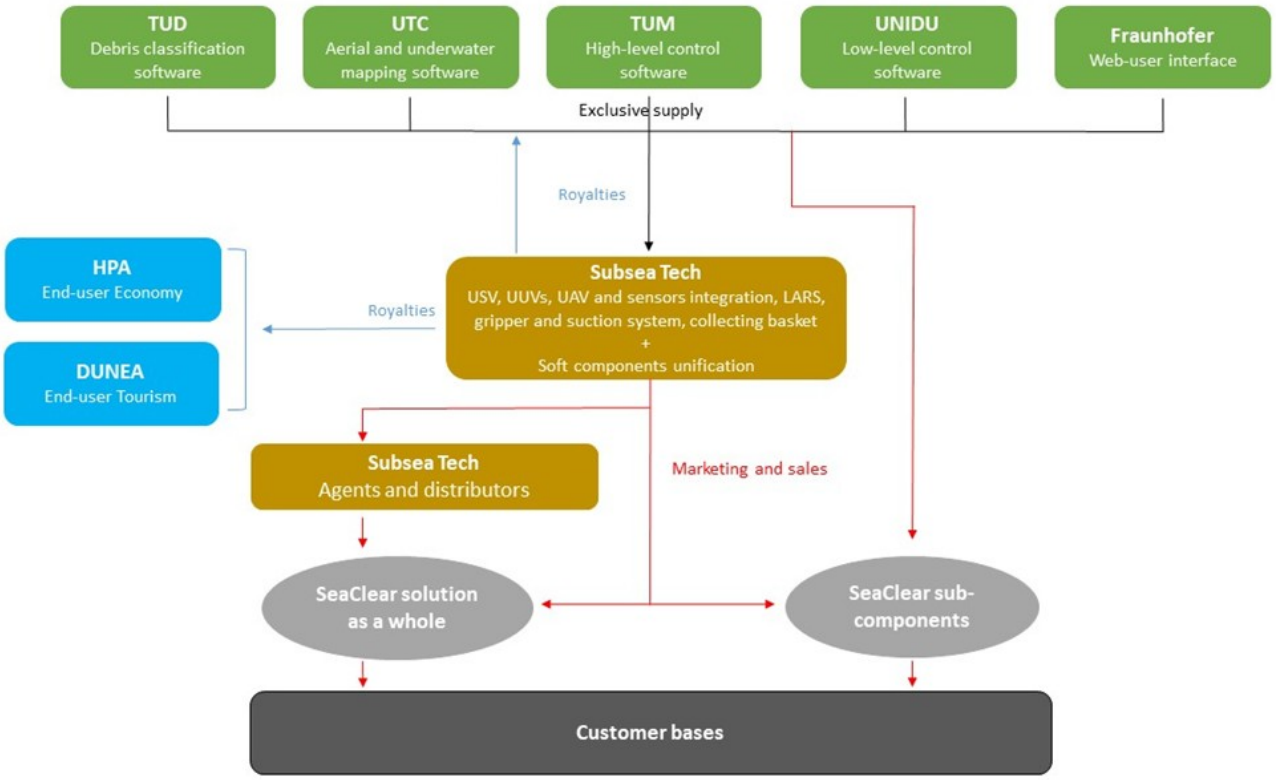


Table 5: SeaClear business model

The developers and other non-manufacturing partners (in blue) are compensated though a scheme of royalties, based on results input into the system.

We aim at keeping the overall royalties' level at around 30 k€ for each sold unit. This amount will be spread between partners as per the following scheme:

- TUD: 16% - TUM: 16% - UTC: 16% - UNIDU: 16% - Fraunhofer: 16% - HPA: 10% - DUNEA: 10%

The developers keep the possibility to market and sale their own generated IP without relying on Subsea Tech or its distribution network. In that case, no royalties are to be paid to any other partner.

The customer bases have been progressively build based on data collected through the dissemination activities and through extensive prospect research in accordance with the market and business segment description.

The production price is built up from the information given by each partner involved in the supply of parts and services for the final product. Partners supplied items are considered free of charge for the integrator.

3.4 Updated business plan

Note: Figures of costs and revenues have been removed from this chapter as their confidential aspect was not compatible with a public document. They are available on the original document.

Based on the contacts with the numerous stakeholders met during the project course and the various discussions during the ESC meetings, the business plan has been updated to estimate the potential revenues and expenses related to the exploitation of the SeaClear system both as a product and as service.

To establish the business plan, a computation of the SeaClear system costs has been elaborated, taking into account the detailed costs of each sub-system and sensors. These costs are presented in the table below (see also the note at the start of this section):

Component	Unit cost
Vehicles	
SeaCAT USV	
Tortuga (collecting ROV)	
Mini-Tortuga (observation ROV)	
UAV + winch	
Communication and shore control	
Vehicles sensors	
Multibeam echosounder	

Multibeam imaging sonars (x2)	
Positioning system	
Hard sub-components	
LARS system Tortuga	
LARS system Mini-Tortuga	
Gripper and suction device	
Collecting basket	
Integration works	
Tests and delivery	
Factory Acceptance Tests	
Sea trials	
Training	
Packaging (20' container)	
Total production cost	
Overheads and marketing costs (25%)	
Royalties for software	
Total costs	
target sales price	
Net result	

Table 6: SeaClear components costs and sale price

With a direct cost of XXX €, a standard XX% for overhead and a provision of XX k€ for royalties, the total cost reaches XXX € which gives a XX% result with a sale price of XXX €.

For the service contracts, the cost calculation is made by adding the equipment amortization, the operators cost, the system maintenance and the consumables. If we assume an 80-day annual operation (standard for work boats) over 10 years, the day rate of the system is XXX/ (80 x 10) = XXX €/day, to which we add the operators at XXX €/day (all-inclusive with food, transport and accommodation) and 5% of purchase cost per year for maintenance, i.e. (XXX*0.05/80) = XXX, we get a total day rate of XXX €/day that we round up to XXX €/day to cover mob/demob costs at each work site.

The plan has been issued for the 10 coming years and it will be updated and extended on a yearly basis to reflect the actual market response.

The top part of the business plan presents the revenues split in two main activities: product sales and service contracts. It is expected that the first revenues will be generated by the service contracts provided with the existing SeaClear system, system which will also be used for demonstrations as many potential customers are in demand of trialling the system before committing on purchase.

We can see form our initial marketing campaigns that there is a strong interest in the marine renewables industry, and especially in the offshore wind farms projects as many development projects now include mitigation measures against environmental impacts such as litter cleaning in the farm area.

After 2 to 3 years of service contracts, we expect to be able to sell complete systems on a regular basis, hardware and software, to service companies eager to develop seabed cleaning activities in their respective regions/countries in response to local or national authorities' demands. These targeted customers would be primarily diving companies willing to switch from divers supported to unmanned operations.

The following assumptions have been made to build the plan and are referred to in the table:

(1) industrialization expenses: XXX k€ spent in year 1 and amortized over 5 years

(2) Production overheads: X% of production direct costs (plant amortiz., management, safety/quality and manufact. profit)

(3) Production costs cover both fabrication and services costs

(4) Marketing and commercial costs: X% of production costs

(5) Production and marketing costs in year 1 are fixed costs to set up production line and carry out marketing/commercial activities

(6) Royalties amount XX k€ to be shared between partners

This business plan does not take into account taxes and therefore the net result shall be considered as indicative only.

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Revenues (k€)										
Products sales (per market segment)	Number of units									
Ports	0	1	1	1	2	1	2	2	2	
Central and local authorities	0	0	1	0	1	1	0	1	2	
MRE plants	0	1	0	1	1	2	2	1	2	
Protected areas	0	0	1	0	1	0	1	2	1	
Civil infrastructures	0	0	0	1	0	1	1	2	2	
Total units	0	2	3	3	5	5	6	8	9	
Unit sale price (k€)										
Total products revenues										
Services sales (per market segment)	Number of days									
Ports	10	40	50	50	55	60	70	75	80	
Central and local authorities	0	25	30	30	40	50	50	55	60	
MRE plants	10	20	30	35	40	45	50	60	70	

Protected areas		20	25	30	40	45	50	60	65	70
Civil infrastructures		0	10	25	40	50	60	65	70	75
Total days	0	40	120	165	195	230	265	295	325	355
day rate (k€)										
Total services revenues										
Total revenues (k€)	**0**									
Expenses (k€)										
Variable costs/unit										
Number of units sold										
Cost of units sold										
Number of days sold										
Cost of days sold (60% of revenues)										
Total direct cost										
Industrial. expenses amortization (1)										
Production Overheads (2)										
Total production cost (3)										
Marketing/commercial costs (4)										
Royalties for partners (6)										
Total sales and production costs (4)										
Net profit/loss (k€)										
Cumulated profit/loss (k€)										
Net profit/loss (%)										

Table 7: Updated Business Plan

The profit percentage increase with years as sale prices in this simulation follow an increase of 4% year while the costs only increase by 3%. In fact, purchase costs increase can be limited thanks to quantities increase which allow to negotiate purchase prices.

3.5 Communication materials for exploitation

To facilitate communication with potential end-users of the system, we have created:

- a **marketing brochure**, different from the public-communication brochure of Section 2, has been developed; one page of this brochure is illustrated in Figure 8.
- a business **pitch-deck** has been developed, to have a starting point for business communication; example slides are illustrated in Figure 9.

Figure 8: Example page from marketing brochure

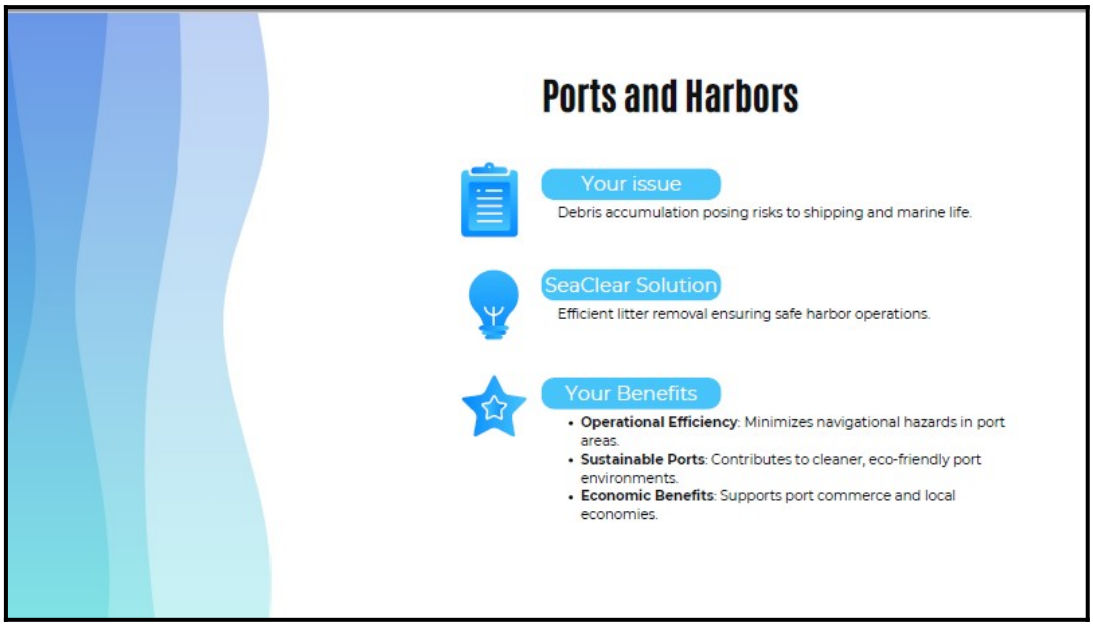


Figure 9: Example slides from the business pitch-deck: title slide and the ports-and-harbors use case slide

4. Summary and concluding remarks

Dissemination tasks of all kinds as per the DoA have been widely undertaken to promote the SeaClear concept throughout European countries, with all partners highly involved, especially in their respective countries.

The highly ambitious research topics of SeaClear project and the large public awareness about the issues of marine pollution have helped to reach a large number of people in academic and industrial communities but also an amazing number of standard citizens.

Although the SeaClear system is still in need of typical software and hardware enhancements for rolling out a commercial version, that can meet the robustness and efficiency needs of the industry, it is now fully operational in relevant environments and some very advanced discussions with highly interested potential customers should result in the first cleaning campaigns as soon as 2024.

Now, with the follow-up SeaClear2.0 project, we anticipate further breakthroughs in the intersection of robotics, artificial intelligence, and marine conservation, which will further increase SeaClear system efficiency. Here we want to dive deeper and for bigger marine litter elements. We expect that the newly enhanced SeaClear system will have reached TRL9 by 2024 with further development and added capabilities in the following years.

No direct competing system allying similar performances and compactness have been identified yet, but SeaClear shall open the door to a new generation of sea going robotic system capable of tackling of marine litter pollution from inland to offshore water and operating on a commercial basis. The journey started in Hamburg and in Dubrovnik has set sail towards a cleaner, healthier future for our oceans, guided by the promising beacon of technological advancement and more social responsibility.

5. Annex 1: Academic publications

Table 5.1 Journal articles

Nr.	Title	Journal	Status	DOI
1	Koopman operator dynamical models: Learning, analysis and control	Annual Reviews in Control	Published	https://doi.org/10.1016/j.arcontrol.2021.09.002
2	The Quadrature Method: A Novel Dipole Localisation Algorithm for Artificial Lateral Lines Compared to State of the Art.	Sensors	Published	https://doi.org/10.3390/s21134558
3	Deep Learning for Object Detection and Segmentation in Videos: Toward an Integration with Domain Knowledge	IEEE Access	Published	https://doi.org/10.1109/ACCESS.2022.3162827
4	Diffeomorphically Learning Stable Koopman Operators	IEEE Control Systems Letters	Published	https://doi.org/10.1109/LCSYS.2022.3184927
5	Cooperative Control of Uncertain Multiagent Systems via Distributed Gaussian Processes	IEEE Transactions on Automatic Control	Published	https://doi.org/10.1109/TAC.2022.3205424
6	A Simulator and First Reinforcement Learning Results for Underwater Mapping	Sensors	Published	https://doi.org/10.3390/s22145384
7	Online learning control for path-aware global optimization with nonlinear mobile robots	Control Engineering Practice	Published	https://doi.org/10.1016/j.conengprac.2022.105228
8	Safe trajectory tracking for underactuated vehicles with partially unknown dynamics	Journal of Geometric Mechanics	Published	https://doi.org/10.3934/jgm.2022018

9	Numerically efficient H∞ analysis of cooperative multi-agent systems	Journal of the Franklin Institute	Published	https://doi.org/10.1016/j.jfranklin.2022.09.013
10	Optimistic planning for control of hybrid-input nonlinear systems	Automatica	Published	https://doi.org/10.1016/j.automatica.2023.111097
11	Application of Hamilton-Jacobi-Bellman equation/Pontryagin's Principle for Constrained Optimal Control	Journal of Optimization Theory and Applications	Accepted	
12	3D exploration-based search for multiple targets using a UAV	Springer Journal of Intelligent Robotic Systems	Submitted	
13	The SeaClear System: A Multi-robot Solution for Autonomous Cleanup of Marine Debris on the Seabed		In preparation	
14	Entanglement Definitions for Tethered Robots: Exploration and Analysis		In preparation	
15	SeaClear Dataset: Detection and Segmentation of Marine Debris in Shallow Waters		In preparation	

Table 5.2 Articles in conferences with proceedings and peer review

Nr	Title	Venue	Status	DOI
1	Path-aware optimistic optimization for a mobile robot	60th IEEE Conference on Decision and Control	Published	http://dx.doi.org/10.1109/ CDC45484.2021.9683546
2	Distributed Learning Consensus Control for Unknown Nonlinear Multi-Agent Systems based on Gaussian Processes	60th IEEE Conference on Decision and Control	Published	http://dx.doi.org/10.1109/ CDC45484.2021.9683522
3	Extended Kalman filter for payload state estimation utilizing aircraft inertial sensing	2021 Aerial Robotic Systems Physically Interacting with the Environment	Published	http://dx.doi.org/10.1109/ AIRPHARO52252.2021.9571038
4	Underwater robot pose estimation using acoustic methods and intermittent position measurements at the surface	2022 IEEE International Conference on Automation, Quality and Testing, Robotics	Published	http://dx.doi.org/https://doi.org/10.1109/ AQTR55203.2022.9802002
5	3D Object Recognition using Time of Flight Camera with Embedded GPU on Mobile Robots	18th International joint conference on Computer Vision, Imaging and computer graphics theory and applications	Published	
6	MPI Planar Correction of Pulse Based ToF Cameras	2022 IEEE International Conference on Automation,	Published	http://dx.doi.org/10.1109/

		Quality and Testing, Robotics		AQTR55203.2022.9802059
7	Recovering the 3D UUV Position using UAV Imagery in Shallow-Water Environments	2022 International Conference on Unmanned Aircraft Systems	Published	http://dx.doi.org/10.1109/ICUAS54217.2022.9836195
8	Mixed Use of Pontryagin's Principle and the Hamilton-Jacobi-Bellman Equation in Infinite- and Finite-Horizon Constrained Optimal Control	International Conference on Intelligent Autonomous Systems	Published	
9	A simple path-aware optimization method for mobile robots	6th IFAC Symposium on Telematics Applications	Published	https://doi.org/10.1016/j.ifacol.2022.08.001
10	Structure-Preserving Learning Using Gaussian Processes and Variational Integrators	Proceedings of The 4th Annual Learning for Dynamics and Control Conference	Published	https://proceedings.mlr.press/v168/brudigam22a.html
11	Exploration-Based Search for an Unknown Number of Targets using a UAV	6th IFAC Conference on Intelligent Control and Automation Sciences	Published	https://doi.org/10.1016/j.ifacol.2022.07.614
12	Beam-Based Tether Dynamics and Simulations using Finite Element Model	6th IFAC Conference on Intelligent Control and Automation Sciences	Published	https://doi.org/10.1016/j.ifacol.2022.07.624

13	Towards Data-driven LQR with Koopmanizing Flows ⋆	6th IFAC Conference on Intelligent Control and Automation Sciences	Published	https://arxiv.org/pdf/2201.11640.pdf
14	Next best view estimation for volumetric information gain	6th IFAC Conference on Intelligent Control and Automation Sciences	Published	https://doi.org/10.1016/j.ifacol.2022.07.625
15	Numerically Efficient Agents-to-Group H∞ Analysis	10th Vienna International Conference on Mathematical Modelling MATHMOD	Published	https://doi.org/10.1016/j.ifacol.2022.09.095
16	Learning the Koopman Eigende composition: A Diffeomorphic Approach	2022 American Control Conference	Published	http://dx.doi.org/10.23919/ ACC53348.2022.9867829
17	Hand-Crafted Features for Floating Plastic Detection	IEEE/RSJ International Conference on Intelligent Robots and Systems, 2022	Published	
18	Multi-Agent Exploration-Based Search for an Unknown Number of Targets	22nd IFAC World Congress	Published	https://doi.org/10.1016/j.ifacol.2023.10.206
19	Koopman Kernel Regression	Advances in Neural Information Processing Systems 2023	Accepted	

20	Active search and coverage using point-cloud reinforcement learning	27th International Conference on System Theory, Control and Computing	Presented	
21	Towards establishing an automated selection framework for underwater image enhancement methods	OCEANS 2023	Published	http://dx.doi.org/10.1109/ OCEANSLimerick52467.2023.10244710
22	Two-Channel Extended Kalman Filtering with Intermittent Measurements	IEEE American Control Conference 2024	Submitted	