GROOM II

GLIDERS FOR RESEARCH, OCEAN OBSERVATION & MANAGEMENT : INFRASTRUCTURE AND INNOVATION

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Deliverable abstract

GROOM II is a H2020 European project whose objective is to design the future research infrastructure harnessing advantages of Marine Autonomous Systems (MAS). MAS open new possibilities to observe the Marine world, providing long term observation from the surface down to thousands of metres with a very small energy consumption and for a limited cost,. With the development of new miniaturised sensors, MAS now can measure parameters for ocean physics, chemistry and biology, which makes them useful in many sectors, from research, sustained observation and meteorology to industrial applications with fisheries and energy sectors.

Within the project, we are convinced of the capabilities of MAS and how it benefits for research and society, and strongly believe that a European Research Infrastructure will enable new possibilities and strengthen the position of MAS in Europe. The Research Infrastructure, as we

design it, will optimise the use of the platforms, allowing better observations for lower costs, develop the technology, the methodology and facilitate exchange of expertise, knowledge and instruments in Europe.

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List of Abbreviations

Argo	Scientific international programme for ocean observation using a fleet of robots
ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
EMBRC	European Marine Biological Resource Centre
EMODnet	European Marine Observation and Data Network
EMSO	European Multidisciplinary Seafloor and water column Observatory
EOOS	European Ocean Observing System
GOOS	Global Ocean Observing System
GROOM RI	GROOM Research Infrastructure
JERICO	Joint European Research Infrastructure of Coastal Observatories: Science, Service, Sustainability
MAS	Marine Autonomous Systems
MRI	Marine Research Infrastructure
R&D	Research & Development
WP	Work Package

1. Background and context

Underwater and surface Marine Autonomous Systems (MAS), in particular gliders, have become essential vehicles to carry scientific payloads for most environmental observations from the surface down to 6000 m and for activities supporting the blue economy. Their major advantages are being mobile, steerable, persistent and usable in large numbers and at relatively low costs. However, the distributed infrastructure required to exploit these assets must be able to meet different demands from research and monitoring of the marine environment to public service missions and industry needs, requiring customised payloads and operations. The rapid evolution of such technologies (robotics, artificial intelligence, sensors, big data) requires that the R&D resources offered by this distributed infrastructure continuously adapt to users' demands.

The complex hardware and information technology characteristics of such a distributed European infrastructure, optimising access to resources and R&D for gliders, were analysed during the GROOM-FP7 design study from the perspective of research and the Global and (future) European Ocean Observing System (GOOS & EOOS) needs. Since then, several "gliderports" have developed which have fostered a corresponding European industrial innovative sector.

GROOM II, building on its predecessor, will deliver the decision basis for an advanced Marine Research Infrastructure (MRI) that promotes scientific excellence, fosters innovation, supports the blue economy, builds industrial and public partnerships, and works towards helping achieve the common research and innovation mission for future Europe. The project will define the overall organisation of an infrastructure dedicated to ocean research and innovation, and maritime services supporting Blue Growth: GROOM RI.

This infrastructure will be a positive step against today's fragmented European landscape, aiding connections and synergies for the completion of the GOOS and EOOS.

2. Introduction

The ocean is a fundamental component of the global earth system influencing the global/regional climate, weather, ecosystems, living resources and biodiversity. The ocean plays a major role in many human activities including coastal protection, tourism, search and rescue, defence and security, shipping, aquaculture and fisheries, offshore industry and marine renewable energy. Ocean observation serves to better understand ocean functions and to meet the societal needs related to these activities.

However, the ocean is a very vast, variable and harsh environment that prevented it from being sampled at the right scales until the advent of underwater and surface Marine Autonomous Systems (MAS) as known as underwater gliders and other long range surface and subsurface vehicles. An extensive set of sensor payloads enables these MAS, operated in large numbers, to acquire key data from the marine environment. They have now become essential for a comprehensive observing of the open ocean and coastal environments, and support the blue economy, from the surface down to 6000 m.

3. Increasing need for oceanic research

3.1. Observing the ocean to understand its functions: a way to improve its protection

Better understanding of physical, biogeochemical, and biological ocean functions improves ocean and global prediction. This is tightly linked to various societal applications. The complexity of steps that lead to ocean knowledge include:

- Requirements setting process - why observe?
- Scientific approach - how to observe?
- Adequacy of observational elements - what to observe with?
- Data flow and data integration - how to unlock the observational potential?
- Data product creation, dissemination and co-design with users - how to integrate and communicate?

While this chain is simple in outline, the steps are complex in implementation and execution. It is applicable for “observing for research” and “observing for application and monitoring” “Ocean observing value chain” UNESCO 2012).

3.2. The ocean observing value chain: a need for cooperation

Because the ocean observing value chain is not executed by any one entity or organisation, its success relies on the coalescence of various sub-processes. Therefore, it is of critical importance that local coordination activities are established for these subprocesses. A coordinated research institute can facilitate the subprocesses to optimise their operation and thus further contribute to the ocean observing value chain.

There are a wide variety of international and European programmes which aim at overseeing ocean observing systems.

4. Marine Autonomous Systems (MAS) as new, cheaper, more efficient devices to observe the ocean

4.1. Marine Robotics : a wide variety of technologies

Developed in the 1980s and 1990s, when ocean observation relied mainly on expensive and punctual expeditions using research vessels, underwater gliders were designed to be small, intelligent, mobile and affordable.

Underwater gliders have reached a mature state and are routinely operated by many institutes and agencies. Typically, gliders profile from the surface to the seabed and back during a cycle that lasts between half an hour to six hours. They travel at speeds around 0,5 knots, even in extreme weather conditions and can stay at sea multiple months. They can even be deployed for a year with a survey track extending over thousands of miles.

Nowadays, marine robots are widely used for ocean observation, marine research, and increasingly by private companies. The demand is growing on par with the rapid evolution of marine robotics and sensing technologies. More recently, autonomous surface vehicles (ASV) have started to boom and complement AUVs with surface measurements.

ASV and AUV are one same group, the so-called Marine Autonomous Systems (MAS). Interest in MAS primarily resides in their payload. Sensors on gliders measure various variables.

4.2. MAS contribution for Science and Society

MAS can go places the research vessels can't access. They can go under the ice and through storms. Hence, its data improves hurricane forecast and has led to major results in weather forecasting, climatology and ocean state estimates.

Ocean observation data is also useful to a wide variety of stakeholders such as fisheries, pollution agencies, search and rescue, industrials and so on. Services have already been developed and demonstrated. Yet, they are not often used. GROOM II addresses this issue and explores new applications of gliders. Lastly, the consortium takes into consideration developments in miniaturised sensor systems and artificial intelligence as well as emerging markets.

5. About the GROOM II project

5.1. Who are we?

The EGO (Everyone's Gliding Observatories) network was launched by several teams of oceanographers, interested in developing the use of gliders for ocean observations and willing to set up a strong glider community. EGO was first composed of scientific teams from France, Germany,

Italy, Norway, Spain, and the United Kingdom and EGO stood for “European Gliding Observatories” for a while but it is now more appropriate to call it “Everyone's Gliding Observatories”, as colleagues from Australia, Canada, South Africa and USA, from academia or industry, have joined this open community.

The EGO acronym was chosen because gliders are among the first intelligent marine robots. Dedicated to oceanography, they do react to their environment. In line with Asimov stories, the EGO acronym suggests that gliders will probably develop some kind of personalities as their intelligence will increase.

This idea of this glider group emerged in October 2005 and since then, collaborations have been developing. Experiments with international fleets of gliders have been carried out and EGO Workshops (including “Glider Schools”) are organised every year or so to present and discuss both scientific and technological issues.

We intend to facilitate glider experiments through networking and support within the EGO community. We collect information about the worldwide glider activity, references, tutorials, technical notes and links, and we support the development of software related to gliders. Our goal is to share the efforts needed by glider data collection as a community, and support the dissemination of glider data in global databases (like Coriolis Data Center) in real-time and delayed mode for a wider community.

In 2010, a core group from the European EGO groups launched two projects, GROOM FP7 and EGO COST Action (see section Projects), to progress toward the creation of an actual European Research Infrastructure for underwater gliders. And some years later, the GROOM II project consolidates these first initiatives that now also include other types of marine autonomous vehicles.

5.2. Where are we?

Currently, the scientific community faces the challenges of sustained ocean observation and world-class services with these platforms. To help sustain, and fully benefit from the existing glider infrastructures and sound expertise in European countries, a distributed Research Infrastructure (RI) is critically required. Consequently, the GROOM II project has started with the following core objectives :

1. Design the legal and organisational elements of a future GROOM RI.

2. Demonstrate its added value for research, ocean observing, innovation and blue economy.

3. Disseminate, exploit results and seek support for the implementation of a GROOM RI.

GROOM II is funded by the European Commission under the Horizon 2020 programme. The project started in October 2020 and ends in September 2023. Its consortium consists of 14 European partners from 12 countries, including large national marine research organisations and technological platforms, universities, and private companies.

5.3. What do we aim for?

GROOM RI Vision : Be the European Research Infrastructure harnessing the advantages of Marine Autonomous Systems (MAS) to provide high-quality ocean observation data and services for the benefit of society, enabling scientific excellence and moving towards net-zero activities.

GROOM RI Mission : This European Research Infrastructure integrates national infrastructures for Marine Autonomous Systems (MAS) to provide access to platforms and services to the broadest range of scientific and industrial users, as well as other ocean observing RIs. It maintains a unique centralised provision of cyber-infrastructure, data and knowledge for the optimised use of MAS to study climate and marine environments, and to support operational services and the blue economy.

6. What will the GROOM RI offer?

GROOM II community is developing a set of Use Cases to better understand how to link the services, the strengths of a distributed RI and the capacities of different nodes and partners. The following Use Cases are a way to develop a concrete, coherent and shared understanding of what GROOM RI will offer, how it will do it, and for who. Each Use Case explains a specific capacity of the RI. It corresponds to the external services that GROOM RI will provide. The following list is non-exhaustive and the presented Use Cases are still subject of the discussion.

UC1 - MAS Contribution to Forecasting efforts

Rationale: Improving operational forecasts with data from MAS enabling collaborative cross country observations to improve ocean forecasts at European level, dramatically increasing observational and forecasting capabilities with minimum increase of the carbon footprint.

Potential users: National Met Offices and Mercator Ocean (Met Office, CMEMS, EMODNet physics, …)

The GROOM Offer: To optimally perform these activities the users need to dynamically re-task MAS operations at sea, and with the current state of technology that retasking will need to go through human pilots. GROOM will develop and maintain a digital infrastructure to allow emerging complex piloting activities like this, minimising human supervision of MAS with the introduction of automation and AI. The centralised digital infrastructure approach will also allow plug-and-play activities from the different nodes, enabling consistent transnational utilisation of MAS if required. Currently, institutions will need to develop and deploy bespoken workflows to do those collaborations between MAS operators and forecast developers.

To enable these activities, GROOM must develop a framework that enables interoperability at all levels:

- Data gathered by MAS platform and coming from any RI member will be in standard formats that are useful for the end-users.
- Data quality at the minimum level required to do assimilation
- A close loop to enable automatic re-tasking of the MAS platforms from the models.

UC2 - MAS Contribution to the regulatory Monitoring of Biodiversity and Biogeochemistry

Rationale: Fulfilment of national obligations around statutory monitoring.

Potential users: Agencies from European nations with the mandate to do the monitoring.(EMODNet Chemistry, EMDONet Biology, ICOS, LifeWatch, ICES, OBIS, EuroOBIS, UN Decade of the Ocean actions, UN SDG 14, …)

The GROOM Offer: European countries have the mandate to perform monitoring of biodiversity on the European seas.These activities while mandatory are sometimes very expensive and difficult to sustain. GROOM will :

- Design a system towards net zero observations
- Develop and maintain a catalogue of services and capabilities provided at national level allowing European users and stakeholders to identify providers that could perform the monitoring for them.
- Develop a light touch framework to facilitate international access to the services.
- Monitor the emerging monitoring requirements to act as a catalyst in lobbying for the development and integration of new sensors.
- Consistent outputs across providers and European seas. This includes FAIR data and consistent reporting by the MAS operators.

UC3 - MAS Contribution to Discovery Science

Rationale: Provide the entry point for European scientists in need of observations performed with MAS.

Potential users: Any scientist applying to EU funding.

The GROOM Offer: Facilitate and broker access to established national MAS facilities to European scientists. GROOM will:

- Design a system towards net zero observations
- Help to develop new data workflows and tools that facilitate the scientific uptake of data coming from MAS
- Develop and maintain a catalogue of services and capabilities provided at national level allowing European scientists to identify providers and partners to be part of EU grants
- Develop a light touch framework to facilitate international access to the services

- Monitor the emerging scientific requirements to act as a catalyst in lobbying for the development and integration of new sensors
- Consistent outputs across providers
- Assure high quality data, promoting the adoption and development of international best practices

UC4 - MAS CONTRIBUTION TO THE GOOS, GCOS, OTHER INTERNATIONAL INITIATIVE (UN DECADE)

Rationale: Provide the European MAS contribution to the GOOS.

Potential users: IPCC, G7 priorities, UN Decade of the Ocean actions, World Ocean Database (National GOOS initiatives, EU GOOS contributors)

The GROOM Offer: GROOM will help to design and implement a fit to purpose system to provide sustainable net zero MAS observations to the GOOS. The system will complement the ARGO array, filling the gaps in coverage and capability. This will contribute to the uptake of MAS operations during the decade of the Ocean. GROOM will monitor and collaborate with initiatives like the UN sustainable development goal 14, CoastPredict, OceanPredict and DITTO, the need of high quality targeted observations will be required. The GROOM RI will develop the system to provide observations coming from MAS, and an interoperable framework to integrate current and emerging MAS platforms on a close feedback loop to be utilised by those UN activities.

UC5 - MAS CONTRIBUTION IN RESPONSE TO EMERGENCY SITUATIONS

Rationale: Provide the tools to quickly respond to emergency situations with MAS platforms.

Potential Users: Governments (monitoring agencies, coastal observatories)

The GROOM Offer: GROOM will generate a solution to fast respond to emergency situations (spills, volcanic eruptions, etc.) deploying MAS platforms from different partners providing:

- A high level command platform that will allow governments and others to collaboratively to retask the MAS fleet
- Fast deployment of bespoken data products to make the best decisions on the emergency situation
- The framework to share assets on the field minimising the time to deploy and operate them
- Interoperability and transparency with other initiatives responding at the same time, maximising collaboration

7. Produce relevant and high quality data to observe and understand the marine world

7.1. The need for Fair data of Essential Ocean Variables

Understanding the ocean is vital yet impossible to measure extensively. That's why the GOOS promotes the sustained measurements of Essential Ocean Variables, which are a collection of ocean properties selected in a way so as to provide the best, most cost-effective suite of data that enable quantification of key ocean processes. They are selected based on their Relevance, Feasibility and Cost effectiveness and fall into four categories - physics, biogeochemistry, ecosystems and cross-disciplinary. This sustained observation will, *in fine*, help mitigate climate change, improve meteorology and weather prediction and monitor ocean health.

In order to provide useful measurements of these variables, the data must be FAIR (findable, accessible, interoperable and re-usable). The FAIR principle is promoted by the European Commission in order to ensure the quality of the data. Oceanographic community is strongly contributing to provide this FAIR data, whatever technique was used.

7.2. The potential of Gliders

Although gliders are relatively "slow" samplers, this is not an impediment to providing sampling capability at key space and time scales for the global observing system. Primarily focused on measuring physical variables, recent technological progress allows MAS to embark on a more diverse payload. Development of smaller and more energy efficient sensors enlarge the possibilities of MAS. There also has been a lot of progress in developing such sensors for gliders, for example, fluorometers for measuring phytoplankton have been in development for a long-time and the BIOGLIDER project, funded by Martera, integrates echosounder and a vision profiler onto gliders, enabling access to biological variables on the first 1000 m of the water column.

Nowadays, MAS data are used for many applications in ocean physics, chemistry and biology. Ocean numerical modelling and forecast activities already benefit from these data. MAS can go straight into storms and hurricane and underwater gliders can navigate under the ice, accessing vastly under-sampled areas, so data can improve hurricane intensity forecast models and has led to major results in ocean forecasting, weather forecasting including hurricane intensity, climatologies, and state estimates.

But Glider deployments are challenging because they must be managed in real-time throughout their deployment with the two-way communications needed for active piloting by the different operating teams. Glider technology requires a high level of expertise on the scientific and technological aspects in order to effectively operate the vehicles.

7.3. The impact of GROOM

Coordinating the MAS actions in Europe will help centralise the efforts already put in place. OceanGliders shares best practices, requirements, and scientific knowledge needed for glider operations, data collection and analysis and most of OceanGliders partners are part of GROOM II project. Data management requires metadata and its description, storage, and access. One of the benefits of coordination will be improved and sustained quality control of glider data.

Developing Standard Operating Procedures, sharing best practices and building capacity and training within the European community is vital to develop well executed operations, good use of the instruments, and finally good data management. Partners in the project believe that structuring the community around a RI dedicated to MAS will lead to better apprehend the complexity of the platforms and better control the whole data value chain leading to better data for the benefit of the GOOS.

8. Interactions with industrial partners

Developing an Industry Advisory Group for Marine Autonomous Systems IAG-MAS aims to develop systematic and sustained interactions between the glider science community and the ocean industry. IAG-MAS identifies and advances industry/science priorities for innovation in developing new glider products and applications. This innovation will lead to new knowledge, technologies and services that must be transferred to the market, typically via SMEs, in order to advance safe, responsible, and effective commercial operations.

IAG-MAS, brings together leaders from over 20 organisations that specialise in manufacturing marine autonomous platforms and marine sensors as well as maritime service providers. Our group unites professionals with considerable technical, commercial, and manufacturing expertise in the marine autonomous system space – from AUV fleet operators to marine surveyors to environmental monitoring data scientists and maritime security executives.

This advisory group will be gathered during the project duration to:

- build collaboration & trust between industrial & national/EU both scientific & technical stakeholders
- identify & advance priorities for innovation in developing new MAS (products & applications)
- share ideas about a cooperative framework between GERI providers and users

The IAG-MAS workshops will produce a set of inter-related outcomes for the emerging research infrastructure:

- to identify emerging applications relevant to MAS that need large scale coordination to be properly addressed

- to identify and design a framework of cooperation between the private sector and the marine research infrastructures (here it is good to show that we are sharing with other like JERICO, EMSO, ...) with a focus on MAS
- feedback (on the designed framework) from the IAG-MAS/GROOM consortium will be communicated to the European Commission and national stakeholders in marine observation.

9. Challenges

The strategic set up for the GROOM RI shall ensure that complex hardware and information technology provide optimised and universal access to its resources and R&D, and a seamless integration into the Global and future European Ocean Observing Systems (GOOS and EOOS). GROOM RI leverages from the national RIs that developed in Europe over the past decade, and from the long-lasting coordination initiated in Europe and globally. GROOM RI is establishing the organisational and legal bases for the RI with an adequate business model, able to offer services to users from the academic world, governmental and non-governmental entities, and private companies.

As a formal entity, the GROOM RI will ensure cooperation, coordination, integration, and simplification to provide world-class glider services. This new glider infrastructure will connect scientists and industry with other oceanographic platform operators and marine system integrators to capture high value ocean data for society. The collective membership of GROOM RI will provide ocean and data services, guide technological development, best practices, frontier science and process studies, and facilitate international scientific and industrial cooperation.

10. Expected outcome

GROOM RI WILL:

Be a fit-for-purpose infrastructure that:

A) facilitates and harmonises access to MAS services,

- acting as a common voice in connection with global efforts (GOOS, EOOS, ENVRI community, etc…),
- co-designing common strategy, setting priorities, etc…,
- mapping user requirements, creating external partnerships, and strengthening cooperation.

B) operates MAS for the benefit of:

- high level marine research,

- national met-offices, WMO, Copernicus, EMODNet and other communities involved in marine environmental management, providing required in-situ observations to improve operational models,
- other observing platform operators in the coastal and offshore ocean (Euro-Argo, EMSO, EMBRC, JERICO),
- Blue Growth and Blue Economy (promote Blue Growth by creating new knowledge, technologies and services, focusing on social impacts and engaging with local and regional stakeholders).

Deliver performant services by:

A) providing efficiency and economy of scale

- integrating, facilitating and harmonising MAS activities within Europe,
- developing a coherent organisation with exchange of world-class services between the infrastructure nodes,
- developing shared / common IT infrastructure and data management system,
- assessing legal aspects of operations and infrastructure use,
- progressing toward net-zero operations.

B) being the leader in MAS technology development,

- monitoring the emerging requirements, acting as a catalyst in lobbying for the development and integration of new sensors and data value chain,
- developing EU standards for mission planning and piloting, as well as for the preparation, maintenance, deployment and recovery of the MAS,
- supporting training & capacity building and mechanisms for joint glider operations in the European glider community.

Ensure high quality data production and good access to data through:

A) developing shared best practices and training for MAS operations, data collection, processing and dissemination,

B) developing EU standards for sustainable data management systems,

C) enabling a centrally managed dialog between data providers and data management systems to enable FAIR Data.

11. GROOM II Factsheet