Gliders for Research, Ocean Observation and Management

Informations projet

GROOM

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Final Report Summary - GROOM (Gliders for Research, Ocean Observation and Management)

Executive Summary:
Underwater gliders are small and smart platforms, useful for long-term, multi disciplinary marine observations. Because of their remotely controlled navigational capabilities over long periods of time and the high spatial and temporal resolution of their measurements over the water column in near real-time, gliders have soon been identified to fill gaps left by the existing ocean observing platforms. Since the early European deployments in 2004, there has been a rapidly growing importance of these platforms for various science driven applications and for improving the capabilities of the ocean observing systems.

The objective of the GROOM project was the design of a new European Research Infrastructure to exploit the important potential of underwater gliders for the benefit of the European Research Area and of
European industries and citizens. GROOM aimed at defining the scientific, technological and organizational/legal features of a European glider capacity for research and sustained observations of the oceans, in line with the other European and international initiatives for marine in-situ observations.

The proposed infrastructure will include several glider facilities (“gliderports”) distributed across Europe, and a central facility to support coordination within the infrastructure and access to glider services. This central facility will also ensure coordination with glider organizations in USA, Canada, and Australia, and other stakeholders in a global context. This distributed architecture is the only way to maintain and operate a European fleet of gliders in European and foreign waters, in particular when it concerns sustained observations at the regional scale, which is an identified gap of the Global Ocean Observing System (GOOS).

The activity of the proposed Glider European Research Infrastructure within the “gliderports” is organized along five axes: mission planning and piloting, operations and maintenance, data management, sensor calibration and integration, public outreach. These five axes correspond to tasks on which the facilities will develop interoperability, cooperation and mutual benefit in the framework of a modular and cost-effective organization.

The Glider European Research Infrastructure has also been designed to complement the already existing European Marine Research Infrastructures like EuroArgo, EMSO and also EMBRC for the challenges faced by modern marine physical and biological observations. This infrastructure will also be the relevant entity concerning gliders for international coordinating organisations such as GOOS and Copernicus Marine and Environmental Service.

This Glider European Research Infrastructure can have a strong societal impact. It can be beneficial for both academic oceanographic research and operational oceanography systems on which a large number of marine activities now rely on. It can also foster the emergence of an industrial sector for marine environment and enhance economic activities and the development of SMEs in relation with the distributed infrastructure.

The GROOM project has shown the maturity of the existing glider facilities in Europe and of the present coordination which allows starting a roadmap toward an implementation of the Glider European Research Infrastructure. This implies an active participation of GROOM to the present evolution process of the European Marine Research Infrastructure landscape.

Project Context and Objectives:
The impacts of the ocean on the environment are a result of its storage capacity for heat, carbon and other substances as well as the degree to which it moves them around as a result of external physical forcing, internal dynamics, and biogeochemical cycles. The marine environment is overall a complex and turbulent system, characterized by strong interactions between physical, chemical, and biological processes. The study of these processes is difficult because there is a need to measure physical, chemical, and biological parameters simultaneously and the ocean is characterized by a high variability with significant variations over a wide range of spatial and temporal scales (<1km to 1000’s km horizontally; <1day to years, decades and more). At present, our predictive skill for ocean state and climate is mainly limited by our capacity to carry out a sufficient number (well distributed in time and space) of in-situ profiles to be able to
characterize the ocean variability from the surface to the bottom, to estimate with accuracy the distribution of heat, salt and other properties in order to predict the ocean evolution based on such an analysis.

A new answer to this problem has come from the technology of autonomous underwater gliders that small, intelligent, and cheap ocean observing platforms that can fill the gaps left by other observing systems. These new platforms have been designed to allow continuous and remotely commanded (via two-way satellite link) ocean measurements from the surface down to typically 1km depth at high horizontal and temporal resolution. They can be considered as a “steerable” version of the profiling floats that are deployed in the framework of Argo.

Glider activity in Europe has started in 2004 in the framework of the EU FP5 MFSTEP project and continued with the EU FP6 MERSEA project. Thanks to the creation of the European Gliding Observatories (EGO) group in 2006 and the support from the ES0904 COST Action started in 2010, the European glider activity developed through a scientific and technological animation that attracted the glider communities from Australia, Canada and the USA. In parallel, many national projects across Europe have focused on process-oriented studies with one or more gliders. As a result, small fleets of gliders have been formed in oceanographic institutions, whilst the technical and scientific skills to operate them and to use the large data fluxes collected by these platforms have started to grow in a distributed way.

Giders use a two-way communication system, are reprogrammable, and need periodic refurbishment. These aspects raise a large number of scientific and technological issues and there is a need to consider them in a research infrastructure framework, for the benefit of both fundamental marine research and operational oceanography.

The GROOM strategy is that significant progress will be achieved with a single entity for gliders and land facilities. Based on a number of distributed gliderports, this would allow a better scientific and technological coordination of the European resources, an harmonization of the procedures related to glider deployments, piloting and recoveries, a better definition of rules for access to the gliders, and a data management which is compliant with the international standards.

The objectives of the GROOM design study are to demonstrate that
1. a distributed architecture of “gliderports” around the European seas and overseas working in close coordination, is the required and cost-effective way to operate fleets gliders in combination with the existing observing systems,
2. such infrastructure is suitable to deploy, maintain and operate an array of several fleets of gliders continuously for operational monitoring and research,
3. such infrastructure can provide a world-class service to the research and environment monitoring communities.

Taking into account the existing frameworks for ocean observation and vision statements, the GROOM project work programme focuses on:
1. The integration of gliders into the existing global and regional/coastal ocean observing systems,
2. The Law of the Sea and maritime traffic issues that such platforms raise,
3. Research priorities to deliver new sensor capabilities for gliders,
4. The assessment of existing legal frameworks and existing Research Infrastructure (hereafter RI) entities for joint funding and management of the proposed RI,
5. Integration of the proposed RI in an international network of similar capacities, with the aim of an European leadership,
6. Use and adaptation of existing data management framework to gather and make available consistent and quality controlled datasets,
7. Exploiting the open access to glider data as an educational “window” on the oceans and their role in climate and marine resources.

The work in GROOM is organized in four scientific work packages (WPs) In addition to the project coordination and management (WP1 and WP6):
1. WP 2: Integration in the GOOS
2. WP 3: Scientific Innovation
3. WP 4: Targeted Experiments
4. WP 5: Observatory Infrastructure

Project Results:
I. WP2: INTEGRATION IN THE GOOS

The objective of WP2 was the analysis of the creation and maintenance of a sustainable glider component in Global Ocean Observing System (GOOS). An assessment of the potential contributions of the gliders to the GOOS has been carried out through the studying of the synergetic aspects of the joint operation of multiple in-situ GOOS components (e.g. Argo profiling and surface drifters, moorings, different types of ship based observations). The strategy was two-fold:

1. Studying the sampling characteristics (time/space/parameter) of the GOOS observing components under the requirements posed by the time/space scales of oceanic processes.
2. Performing observing system simulation experiments (OSSE) in order to assess the impact of glider data on the reconstruction of variable fields.

Moreover, being part of the GOOS requires sustainability (legal and financial). We therefore assessed whether the glider activity is in conformity with the public international law and whether the existing European legal framework for joint funding and management, in particular the so-called ERIC scheme, is suitable in its present form to fulfil the requirement of sustainability.

Finally, the future organization of the glider component has been investigated and therefore the related financial model for a glider RI designed.

I.1. ANALYSIS OF THE GOOS IN-SITU COMPONENTS

The potential contribution of autonomous underwater gliders as a new sub-system for the GOOS was investigated in two steps. First, the existing in-situ components of the GOOS (profiling floats, surface drifters, moorings, research/commercial ships) are characterized in terms of their existing capabilities in sampling key physical and bio-geochemical oceanic processes. Then, as an independent measure for the
“interoperability” of gliders in the GOOS, 100 scientific publications that include data from glider campaigns were evaluated. These publications were categorized in respect to their linkage with other GOOS data. The main results are:

1. Gliders provide important complementary information to the existing in-situ GOOS in time, space, parameter and data access domains.
2. Most of the documented scientific applications operate in the transition regions between the open ocean and shelf seas.
3. Glider data is included for routine product generation (e.g. alerts, charts).
4. Process-oriented applications where gliders are important survey tools include local sampling of the (sub)mesoscale, sampling in shallow coastal areas, and emergency applications (e.g. oil spills).
5. Glider applications address investigations and monitoring of processes across multiple disciplines, making use of the wide range of available sensors.

Given the maturity of the glider community, the glider operations and the glider data flow, these results support the idea that a full implementation of gliders into the global ocean observing system is worth pursuing.

Two recommendations arise from these investigations to concretely implement gliders as a sustainable GOOS platform:

1. At a European level, the creation of a Glider European Research Infrastructure (hereafter GERI) to organize and optimize the use of gliders for sustainable observations is needed.
2. At an international level, the publication of an implementation plan at global scale for sustained observations with gliders is required.
3. Coordination with Joint World Meteorological Organization (WMO) and UNESCO’s Intergovernmental Oceanographic Commission (hereafter IOC) Technical Commission for Oceanography and Marine Meteorology in situ Observing Platform Support Centre (hereafter JCOMMOPS) is highly recommended.

I.2. OBSERVING SYSTEM SIMULATION EXPERIMENTS

The synergy between glider observations and models can be exploited through data assimilation using a variety of techniques from either the variational or sequential family. Data assimilation aims at optimally and recursively constrain the model by the observations.

The combination of models and observations through data assimilation enables to undertake OSSEs, which aim at assessing the impact of a given hypothetical dataset on the model solution. An OSSE is typically divided into four steps: i) generate a “nature” ocean model run, ii) simulate observations from the “nature” run, iii) assimilate these observations into a “perturbed” run, and iv) assess the impact on the model solution.

A few studies have reported the successful assimilation of real glider measurements into numerical models over the last few years. The assimilation was performed considering either threaded, vertical, or
averaged profiles over predefined spatio-temporal intervals. It appears that glider data are perfectly suitable for assimilation in numerical models.

By evaluating the impact of potential configurations of the observations, OSSEs are useful to design the optimal deployment of glider platforms in the ocean. Expected error reduction scores computed for different observing strategies can efficiently contribute to the design of observing glider networks in the GOOS.

Moreover, in the framework of the GOOS, glider platforms provide high-resolution observations along oceanic sections from which numerical ocean circulation models can take a large benefit. OSSE is only one aspect of the potential synergies between glider observations and numerical models.

More generally, the autonomous, controllable, cost-effective, long-duration and high-spatial-resolution sampling offered by glider platforms make them a very valuable source of information for the evaluation and improvement of numerical ocean circulation models. For example, glider measurements provide new insights into the mesoscale and submesoscale variability in the ocean, which can be used to validate the size and position of eddies and fronts as represented by numerical models. Repeated measurements collected along control sections allow accurately monitoring the presence and evolution of water masses and evaluating their realism in the model representation.

In addition, once in the water, the near real-time availability of glider measurements opens the possibility for further efficient operational feedbacks between models and gliders. While observations can constrain the model in real-time, model outputs might guide the position of future observations.

I.3. LEGAL ASPECTS OF GLIDER OPERATIONS IN EUROPEAN WATERS

The objective of the assessment was to set out the relevant legal framework and to assess and ascertain whether the envisaged activities of GROOM are conducted in conformity with public international law. As far as the applicable treaty law is concerned, the 1982 United Nations Convention on the Law of the Sea (UNCLOS) plays a key role. With regard to customary international law, it is important to note that the available State practice concerning the deployment and operation of gliders is not of a sufficiently uniform and universal scope. Currently, relevant customary rules are emerging. Yet the available State practice must be taken into account when interpreting the relevant treaty provisions.

GROOM is to be classified as marine scientific research (MSR), and GROOM gliders are to be considered as research equipment in terms of the international law of the sea as codified in UNCLOS. The deployment of GROOM gliders is only lawful if and to the extent to which it is done in conformity with UNCLOS requirements. This is particularly relevant if gliders are deployed within the EEZ of a foreign coastal State. As far as responsibility and liability are concerned, even though the research is formally conducted by the researching State, it is possible to hold the researching institutions responsible and liable for certain infringements. Against this background and in order to diminish the allegation of negligence by domestic courts, it is recommended that the deployment and operation of GROOM gliders is undertaken in line with accepted codes of conduct as published by, e.g. the Society for Underwater
Technology. That said, the special features of the devices deployed and operated within the framework of GROOM suggests the adoption of a specific code of conduct that should be drafted and, ultimately, submitted to the competent organizations such as the IOC by the project partners.

It is noteworthy that all glider activities outlined have the collection of data in common. However, the data collecting activities differ as far as the intent of the respective operators is concerned. In order to assign activities conducted within the framework of GROOM with respect to public international law, three categories of purposes for data collection have been identified and analysed:

1. Marine Scientific Research - Data collection for the purpose of MSR is conducted in order to enhance knowledge on the marine environment.
2. Hydrographic Survey - The objective of data collection for the purpose of hydrographic surveying is to be seen in the production of maritime charts that serve to enhance safety at sea.
3. Operational oceanography – Data collection for operational oceanography is conducted for the purpose of monitoring and forecasting.

At this stage of the assessment GROOM activities for the GOOS have to be ascribed to the category “operational oceanography”. This result would be in line with the prevailing view in legal doctrine concerning the deployment of unmanned research equipment such as drifters and gliders. In this respect, the chairman of the Third Committee of the Third United Nations Conference on the Law of the Sea, which ultimately led to the adoption of UNCLOS in 1982, stated that activities directed at the collection of meteorological relevant data “had already been recognized as routine observation and data collecting” and were thus to be considered as an activity “not covered by Part XIII of the negotiating text” which later became UNCLOS.

The responsibility of the research activities undertaken by GROOM has been analysed in order to understand whether or not it can be considered as activities undertaken by a competent international organization. If it is clear that GROOM Glider activities cannot be considered as research activities undertaken by a competent international organization (as EU cannot be considered as a competent international organization), it is helpful to point out that all research activities conducted under the umbrella of GROOM are not research activities undertaken by GROOM as a legal entity, but by the respective “national” partners of the GROOM consortium. However, glider deployment for the GOOS could be considered as activities undertaken by a competent international organization under the umbrella of a European Research Infrastructure Consortium (hereafter ERIC).

I.4. LEGAL FRAMEWORK FOR JOINT MANAGEMENT OF A EUROPEAN GLIDER COMPONENT

As far as can be seen, the concept of ERIC is the only relevant framework of joint funding and management that is suitable to be considered as the basis for a sustainable (i.e. permanent and efficient) European glider infrastructure. The EU itself acknowledged that ERICs shall serve to fulfil long-term and sustainable purposes. In recital 9 of EC Regulation 723/2009, it stated that the research infrastructure “should help to safeguard the scientific excellence of Community research and the competitiveness of the Communities economy, as based on medium-term to long-term forecasts, through the efficient support of
European research activities.” The pertinent requirements to be fulfilled are laid down in the aforementioned Regulation.

In case of successful application, the respective ERIC is to be considered as an international organization, i.e. a form of organization, which is commonly used for the realization of long-term enterprises. The main advantage is to be seen in the fact that the requirements for lawfully deploying and operating gliders are significantly simplified between the States participating in the ERIC. As ERICs have the status of international organizations, all activities undertaken within their framework are automatically attributable to them. In particular, States that are members of an ERIC are deemed to have authorized the deployment and operation of gliders within their Exclusive Economic Zones.

It should be noted, though, that no special funding exists for ERICs. As far as the financial perspective is concerned, the benefit of establishing an ERIC is limited to the application of a common system of value added tax, and to exemptions from some of the requirements that are applicable to the award of public work contracts, public supply contracts and public service contracts.

I.5. FINANCIAL MODEL FOR A GLIDER COMPONENT IN THE GOOS

Two levels of organization based on the tasks shared through the European Infrastructure and their respective financial models have been studied:

1. The low level of European integration where the glider community maintains and develops best practices (deployment, sensor calibration and integration, maintenance), data management and international collaborations, which mainly need a glider coordination action. This level of organization would only need a financial consortium agreement to support extra costs related to the coordination tasks. However, among other limitations, such a low level of organization is not convenient for the management of sustained lines in the GOOS.

2. The high level of European integration where many tools, product and services are shared and accessible through the research infrastructure. This “modular organization” based infrastructure shall ensure the maintenance of endurance lines for the GOOS with a dedicated fleet of gliders distributed in gliderports. This level of integration deserves to be identified in the ESFRI roadmap to reach the objectives of being the European glider component of the GOOS.

By GROOM ending, the glider community is facing two options based on the level of tasks, tools and services that will be integrated into the future infrastructure: ESFRI process or a less formal community based initiative. The choice of the future organization and its related financial model will depend on the capacity of the community to be endorsed by ministries for long term national commitments in the framework of the respective national policies for Research Infrastructures. Following the ESFRI process, it is highly recommended to implement the infrastructure for a sustained contribution to the GOOS, as well as for research and marine management applications.

The financial model designed for a glider component in the GOOS is mainly inspired by this ESFRI joining process. In that framework, financial maturity and sustainability are major issues.
Financial maturity has been studied through the analysis of the evolution of funding over the past couple of years. Stability of the investment from 3 key countries (Spain, United Kingdom and France) has been identified. Other countries have long term projects and give already good perspectives to structure their investments around national facilities (Cyprus, Greece, Italy and Norway). The overall funding from these key countries is already at a very reasonable level. Overall, financial maturity has been reached or is achievable, and the main issue is now sustainability. This study highlighted the crucial need for consolidating national long term funding commitments on glider activities, except for few partners who have already managed to get such commitments.

A roadmap relying on well identified milestones (European projects, ESFRI update, national agendas ...) has been set up for a coherent and cooperative approach for the implementation of the infrastructure and its sustained financial model (see attached GERI_Roadmap.pdf).

II. WP3: SCIENTIFIC INNOVATION

The first focus of this WP was on the potential offered by gliders to perform mesoscale and submesoscale studies in order to make progress in the understanding of the marine processes. To address the multidisciplinary character of that problem, our analysis concerned a comprehensive list of innovative sensors that will allow to measure new parameters that are needed, in particular for biology. The second important aspect, addressed in the WP, is related to the overall data management that can provide quality checked free accessible data from a unique data centre with standard procedures. A third task was focused to the outreach activities and the capacity building through the transfer of knowledge and expertise to new users and students.

II.1. NEW CONTRIBUTIONS OF GLIDERS TO MARINE RESEARCH

Over the past few years, numerous scientific experiments involving gliders have been carried out in order to better understand the physical and biological interactions at mesoscale and submesoscale in the ocean. These processes still represent a challenge for oceanographers. Gliders equipped with several sensors provide data with exceptionally high spatial and temporal resolutions (vertical ~ 1 m and ~few seconds; horizontal ~ 1 km and few hours) to investigate mesoscale and submesoscale variability in frontal and coastal regions. These biogeochemical and physical data at high resolution provide adequate materials to study the physical, chemical and biological processes and interactions as these small scales. This can be exemplified by some relevant process studies carried out during GROOM which have been published in excellent scientific journals:

1. In the Alboran Sea, gliders gave evidence of phytoplankton patches steered down to near 200 meters by frontal dynamics resulting in the subduction of water from the dense side of a front. In the Balearic Sea, the vertical hydrographical structure of an eddy was sampled at high resolution by gliders and showed
small-scale interleaving of different water masses. Such processes seem to be ubiquitous in the Mediterranean Sea and have a crucial role for the vertical fluxes of matter and energy in the ocean.

2. In the North-western Mediterranean Sea, the important role of submesoscale coherent vortices for the transport of intermediate and deep waters has been demonstrated by the use of gliders in the framework of repeated sections. Their origin and formation could have been identified, as well as their impact for the heat and salt transport toward the whole basin and for the wintertime ventilation processes. About half of the intermediate and deep waters circulate in the cores of these eddies and this has a significant impact on the general circulation and the biogeochemical cycles.

3. In the Peruvian Upwelling System, a past glider mission has shown the importance of submesoscale processes in the upwelling front which was further investigated with a seven gliders experiment. This swarm experiment was carried out with adaptive sampling and showed density compensated salinity filaments at about 150 m depth related to lateral eddy stirring of the background salinity gradient. Closer to the surface, however, non-density compensated salinity and oxygen intrusions reaching well below the mixed layer could be also seen.

4. In the North Atlantic, a one-year occupation of the Porcupine Abyssal Plain (PAP) site was designed to assess the role of submesoscale processes in restratifying the upper ocean. The resulting observations showed the rapid deepening and restratifying of the mixed layer into details, as well as the signature of Mediterranean water subsurface eddies crossing the site.

5. In the Weddell Sea, for the first time, three Seagliders were deployed in order to survey the continental shelf and slope to assess the spatial and temporal variability of the water masses and the Slope Front. Intrusions of small subsurface lenses of warmer water across the Slope Front were observed.

6. In the Baltic Sea, the first glider expedition coupled with a R/V survey, while showing the feasibility of a glider deployment in such complex coastal environment, succeed to map small eddies with diameter of only 10-20 km.

Among others, these experiments to study physical processes at the mesoscale and submesoscale and their biogeochemical implications have highlighted the added value of the glider technology for multidisciplinary observations at high resolution.

Complementary, an important review of the physical, chemical and biological sensors was made to assess the maturity of the multiple sensors already used on gliders. This review shows a wide range of technology readiness level for the sensors. Three categories of sensors have been identified:

1. already implemented sensors;
2. sensors mature for implementation with a small modification;
3. prospective sensors.

Information on scientific and environmental interests, and on the technology (accuracy/size/energy consumption/connection) of the sensors, as well as on the existing methods available to measure the variables concurrently, shows a great potential of gliders for research and management.

II.2. DATA FLOW AND PROCESSING
The main goal of Task 3.2 was to define and start implementing a dedicated data management system for gliders in Europe that:

1. provides a unique access point to the European gliders;
2. improves the data coherency in terms of format, quality, processing chain (clearly documented);
3. sets up a capability able to serve both operational (within a few hours) and research (best quality after calibration and validation) users.

Such a system has to be coherent with what is under development at the international level for gliders (IMOS in Australia, IOOS in USA) and interoperable with data management system of other networks (Argo, OceanSITES) or IODE standards (SeaDataNet/EU, QUARTOD/USA, GOSUD, GTSPP). An agreement was soon reached in terms of organisation of the data management activities (who does what, data flows in real time and delayed mode, data format, real time QC and post-recovery procedures).

The overall data management system which is targeted is schematized in the attached GERI_Data_Management.pdf.

Then, a large meeting gathering most of the Glider data managers in Europe assessed the achievements regarding the setting up of the DAC/GDAC (Data Assembly Centre / Global Data assembly Centre) (see figure) data management system and the agreement on Near Real Time Quality Check procedures for the current core parameters. Products from this work are now becoming routinely used:

1. A glider data format has been defined and described in the user’s manual V1.0 (http://www.coriolis.eu.org/Observing-the-ocean/Observing-system-networks/EGO-gliders/EGO-Glider-data-management).
2. A matlab real-time processing chain was specified, developed between CMRE, IFREMER and BODC and delivered to GROOM partners in spring 2014, (except for the QC part that is still under development).
3. The procedure to distribute glider data on GTS in TESAC format was documented by BODC. UK is working with WMO partners on a BUFR template for glider and Argo data and this will be the solution in the future.
4. Recommendations for automatic real time QC for Temperature, Salinity, Oxygen, Chlorophyl-a are now available and well documented. Delayed mode QC for the different variables is in progress. Issues are more complex here and working groups per parameter have been set up to continue after the end of the GROOM project.

The data flow is schematized in the attached GERI_Dataflow.pdf.

II.3. CAPACITY BUILDING AND TRAINING, OUTREACH

Substantial efforts were engaged by the different institutes for the promotion and dissemination of the glider activities. A lot of materials explaining the role, functioning and usefulness for the global ocean observing system with gliders (and other marine robots) to young audience, general public and decision makers have been produced in order to explain and to increase the acceptability of such new robotic
technologies for ocean sciences, monitoring and management. The outreach material and actions have been specifically focused toward several public (the young audience, undergraduate and graduate students, technicians, future scientists, general public and stakeholders) to offer clear views on the interest of the glider activities depending on the expectation of these various audiences. These actions include among others:

1. A week long science exhibition with online activities aiming at attracting the wider public including academic and school teachers/students.
2. An extensive web-based communication to reach out several audiences. Internet for robots such as gliders is perfectly suited for communication on this technology and its scientific applications.
3. Conferences, courses and workshops for general public, scientific audience and students to build additional opportunities for knowledge transfer, training and exchanges.

Essential information on glider technology and on the project is available online or in form of flyers, brochures, videos and also fake gliders which have been widely exposed in several exhibitions and scientific museums. This information can be summarized in “key messages”:

1. Gliders are autonomous and used to observe the ocean interior.
2. Gliders ideally explore coastal areas and regional seas.
3. Gliders contribute to research and monitoring activities.
4. Gliders as part of an integrated Ocean Observation System.
5. Gliders to address societal issues such as coastal management.

The encouraging feedback during open house events or science exhibition confirmed that the direct contact with the public is important and beneficial. It surely gives very helpful indications that allow evaluating the best outreach activities and means to better communicate and give information to the general public. There is a strong will of the partners to cooperate on outreach. The coordination of these activities in the framework of a Research Infrastructure offers very good perspectives and cost-effectiveness.

III. WP4 TARGETED EXPERIMENTS

Work Package 4 aimed to assess existing (or already planned) glider missions, to design and execute new targeted marine field experiments and demonstrated the exciting new possibilities for the infrastructure. The original intention was a dialogue this work package and the others on the definition of some GROOM standards by trying to follow them in the field to test their usefulness and efficacy. The WP was organised through 3 Tasks:

1. Task 4.1: Endurance lines. The aim of this task was to assess the capacity of the glider technology with GROOM standards to support endurance lines in the Regional Ocean Observing Systems.
2. Task 4.2: Fleet Missions. The deployment of fleets of gliders is critical for the future of process studies.
The goal of this task was to assess the current capacity for fleet deployment and test a prototype glider fleet mission planning tool.

3. Task 4.3: Synergies with other platforms. An important aspect of the glider platforms is their complementarities with other platforms. The objective of this task was to test the multi-platform and multi-sensors deployment considering float, moorings, acoustic experiment and new sensors.

III.1. ENDURANCE LINES

Here ‘endurance lines’ refer not only to gliders attempting to repeatedly occupy hydrographic sections, but also to virtual moorings where a glider maintains station at one location to provide a time series comparable to a mooring. Emphasis was placed in this Task on pushing the boundaries of what could be achieved with gliders; testing the limits of potential ocean observing systems using gliders. Gliders are able to support a growing number of oceanographic sensors and there is considerable interest in the use of gliders as a platform for sustained observations. For example, deployments were undertaken in regions infested with sea ice; such deployments are inherently risky but the scientific reward is high, and the alternative options for an ocean observing system are non-existent. Successes in occupying repeat sections in regions such as the Mediterranean amply demonstrated that the glider has now come of age as a proven tool for ocean long term observations. Trials of using gliders to replace moorings showed great potential as well as areas for future development.

The major part of this Task entailed synthesizing information from partners about the sustained missions they were undertaking as contributions to GROOM. It notes the strengths and weaknesses of existing sustained observing systems and clearly identifies both the opportunities and challenges for glider technology.

Here are the conclusions of this synthesis:

1. The primary motivations for using gliders for sustained observations were:
   1.1. To provide more frequent sampling than is possible with available ship-time or budget.
   1.2. To obtain data with higher spatial resolution.
   1.3. To obtain data in real-time for data assimilation and for increased data security.

2. The advantages of using gliders:
   2.1. Increased spatial resolution (compared to sampling form ships).
   2.2. Real-time data.
   2.3. More frequent sampling.
   2.4. Better near-surface sampling than can be obtained form moorings.

3. The disadvantages of using gliders:
   3.2. Additional resources required.

In addition, we consider the potential for gliders to replace or complement ships or moorings as a platform...
for existing long-term observation programs. 11 campaigns are summarized in which GROOM partners undertook trials of gliders within monitoring programs. We note that gliders are able to make complementary measurements that are not possible with other platforms, such as high-spatial resolution, and so can add significant value to on-going sustained observations from ships or moorings.

The use of gliders is most successful when:

1. Gliders are able to completely replace other platforms.
1.1. There is easy access to deployment and recovery sites close to shore and when it can be made from small vessels and there is no need for a research vessel
1.2. When it is only required to sample the upper 1000m.

2. The types of sustained observation for which gliders are particularly well suited:
2.1. When real-time data is required. Whilst there are other possibilities for the telemetry of data, gliders are very effective when data is needed in real time.
2.2. On the continental slope and shelf where Argo data are rare.
2.3. When near-surface data is needed. Such measurements are difficult to make with moored instruments.

Moreover, this task highlights the issues that need to be overcome in order for gliders to realize their full potential in sustained observation program:

1. Increased depth capability would enable more applications.
2. Increased endurance. The greatest benefit from using gliders is achieved when the need for ships is eliminated.

Building upon this synthesis a summary of the usefulness and relevance of the GROOM standards has been produced. These standards are currently considered by GROOM to be normally desirable in glider deployments. We recognize that there are circumstances in which it may not be possible or even desirable to apply such standards. The GROOM standards are not meant to hinder or put off scientists who are planning glider campaigns and should be considered as best practise.

We aimed to summarize the application of a minimal set of standards that developed over the projects initially in other WPs. These "standards" should not be fixed as expectations and technical requirements change over time. Therefore everyone was asked to evaluate one example of their own glider campaigns, and feed-back information that might help in future to further refine the GROOM standards.

A snapshot of what GROOM partners actually do in their glider deployments was produced in order to define a set of standard procedures for operation of European gliders across institutions and countries. What is outlined is a summary of the applications of standards to selected deployments of gliders during the GROOM project. They cover aspects such as data quality control and accessibility, sensor calibration, device handling and interoperability, legal aspects. It shows an impressive homogeneity that has been achieved in the execution of glider mission across the European institutions and the maturity of the network in operating as a joint infrastructure. It also identifies where GROOM standards may need to be
III.2. FLEET MISSIONS

One particular aspect of the GROOM design study was to investigate the best methods for deploying large numbers of gliders together, using numerical methods to design the optimal survey design. Trial glider deployments were undertaken to test and critically evaluate the fleet operation techniques designed in the other Work Packages. The task involved planning, executing and reviewing fleet missions. At the time of writing the GROOM proposal, a ‘fleet mission’ was taken to be one with more than 2 gliders at the same time. It is noteworthy that one of the final GROOM glider campaigns, the REP14 mission in the Mediterranean in 2014, was a simultaneous deployment of 12 gliders of 3 different types. This is an example of the advances that the GROOM design study has stimulated.

The scientific objectives of a fleet deployment determine its framework and constraints. In order to ensure successful missions, the development of tools taking them into account is a necessary and on-going task. Hereafter, we will refer to a generic name for such tools: “mission planning tools.” A mission planning tool allows optimizing the mission of a glider, or a fleet of them, taking into account constraints like currents, bathymetry, satellite data, GCM outputs, maritime traffic, power available, and duration of the mission. It consists of a glider simulator, which could be very basic like a home-made linear extrapolation in space and time for the next surfacing of a glider or a battery discharge model, or very complex with a full 3D flight simulator in a GCM. It is connected to the glider data and configurations and to additional information. The planning tool simplifies the piloting of the gliders by taking into account various constraints.

We have tested the tool developed in WP5 (deliverable D5.6) by CMRE providing forecasts for glider trajectories using a numerical ocean forecast and a risk analysis (probabilities of failures, collisions, bad buoyancy range). We assess here this is a very useful tool to plan a glider (fleet) mission by considering risks and environmental predictions that can also provide an optimization of a glider network (adaptive sampling framework). It takes as parameters: target depth, duration of the mission, glider speed, currents, target density. Minor problems were identified and will be corrected by the authors of the package. During the GROOM-REP13 exercise, this tool was successfully coupled with the monitoring and automation system of CNRS (GFCP), showing the effectiveness and robustness of a software that is distributed and modular. In parallel, the leader-follower approach was developed in the context of tidal environments, like the North Sea.

GROOM has proven that an approach based on a number of services distributed in a few partners and coordinated at the European level is the way forward. Each service was managed by an expert team and could be combined with the others by just defining standard interfaces. This is very valuable in terms of software maintenance and possible evolutions of the system. The modularity is the guarantee that such a system can be adapted according to the various science needs and foster the integration of more and more services in the future. Finally, the modularity has the advantage that it allows each service to be provided by a network which can increase the efficiency and robustness of the system with the smallest degree of redundancy.
Relatively few partners use mission planning tools for their gliders today, even though most of them can see their advantages. The reason is that the required resources (manpower, computers) to set up an operational system for that are quite significant. The investment that it could represent at the individual level is considered by each partner together with the expected advantages of using such tools. Because of the priorities made by each partner, the general picture in Europe is that a few partners have developed mission planning tools to use them in the field and in particular in the framework of multi glider experiments. Various aspects have been considered by these pioneer teams but none could manage to tackle all of them. There is clearly a need to organize the access to such tools as services in an infrastructure framework that would be beneficial to all partners and users.

III.3. SYNERGIES WITH OTHER PLATFORMS

The final task of WP4 was to test synergies with other platforms. This mainly included purchasing and deploying new sensors to extend the repertoire of glider measurements. This Task also includes an appraisal of using acoustics for glider navigation and data transfer as was trialed by a GROOM partner in Fram Strait.

The assessment of new sensors proceeded through close collaboration with Work Package 5. Results are devoted to a presentation of in-situ trials of new sensors for underwater gliders carried out in the framework (but not exclusively) of the GROOM consortium. The main common denominator between the selected experiments is the use of one or more gliders. Otherwise, the experiments have different purposes:

1. Trials presenting sensors acquiring new parameters (i.e. rarely or never used on other platforms).
2. Trials presenting amelioration of existing sensors, using, for example, new measurement techniques.
3. Trials presenting tests of sensors already implemented on other platforms, although still not used on gliders.

The sensors tested span from physics to biogeochemistry and the trials are conducted by research laboratories (i.e. no commercial tests are presented), although, often, manufacturers are directly involved. To organize the assessment, a form was developed and submitted to people involved in a planned GROOM activity concerning new sensor tests. The aim was to highlight the added value of the field trial for ocean science, and to share the expertise with a large audience.

Here are the sensors tested and discussed:

1. ADCP (Acoustic Doppler Current Profiler), CTD (Conductivity, T°C, Depth), Weather Station.
2. Acoustic sensor
3. Partial Pressure of Carbon dioxide (CO2) and methane (CH4)
4. CTD (Conductivity, Temperature, Depth)
5. Nitrate (NO3-)
6. Waves
7. Zooplankton biomass
8. Chlorophyll fluorescence and particulate backscatter.
This report will obviously quickly become out of date, as new sensors are designed, manufactured and tested. This is an extremely fast-moving area of marine sciences. A good deal of commercial expertise and scientific research is being brought to bear on the challenges of miniaturizing sensors for the marine environment suitable for use on gliders and profiling floats. Nonetheless this deliverable is a very valuable resource for all in the glider community when deciding whether to invest the time and money in integrating a new sensor into their glider.

Another part of this task was to assess the potential and difficulties of using acoustics as a component of a glider-based ocean observing system. The use of acoustics for navigating gliders to inaccessible locations, such as beneath sea ice, is a particularly challenging task that few groups have attempted. Indeed the GROOM community showed great foresight in including this task in the Work Packages. This work describes the experiences of in situ trials of navigating gliders under the ice using acoustics in Fram Strait from 2008, initially during the summer and then during autumn. The RAFOS receptions have been analyzed. It gives extremely valuable indication for the future glider deployments under the ice. In conclusion, this deliverable offers a valuable appraisal of the state-of-the-art in acoustic navigation of gliders. This technology has been led by US colleagues, but it is clear that there is a great deal of potential to extend this work, and GROOM offered the ideal means of developing this expertise in Europe.

IV. WP5 OBSERVATORY INFRASTRUCTURE

GROOM Work Package 5 “Observatory Infrastructure” consists of four tasks, which have all completed successfully. The first task, “Ground segment description” has succeeded on collecting a large volume of information on the existing facilities and practices related to glider activity in Europe to provide the basis for the future infrastructure. Another task “Glider payload assessment” has described existing mission-tested sensors, prototypes currently under testing, sensors in the development phase, as well as variables for which sensors will be needed within 5-10 years. It also lists sensor characteristics, reviews calibration and intercomparison approaches currently in use, as well as maintenance, biofouling and performance details and issues. Finally, it describes protocols for sampling, sample analysis, and intercalibration: a major contribution to the development of GROOM standards and recommendations. Work on the third task “Mission planning and analysis” has produced interesting results for collecting input from MyOcean (such as predicted currents) and from AIS (Automatic Identification System) for ships and calculating the risk of glider mission failure. Empirical information based on recently-collected GROOM partner glider flight statistics has also been incorporated. The most advanced version of the software developed in this task calculates the optimal set of mission tracks for a fleet of gliders. Finally, the last task in WP5 “Estimated setup and running costs” has compiled cost information from partners based on their activities in previous years using a survey developed and published at the beginning of the project.

IV.1 GROUND SEGMENT DESCRIPTION
This task is concerned with drafting a document describing the ground segment as part of the total glider infrastructure. It identifies where and how the current landscape of glider infrastructure can be developed to enhance the efficiency and output, and identifies the different roles the various aspects of the infrastructure can play.

Early on in the project a questionnaire was sent out to all participating partners and its response served as the basis of the detailed description of the state-of-the-art laboratory hardware and field tools. In addition to hardware systems, software systems play a vital role in glider ports, ranging from management of glider fleets, piloting and data visualising to mission planning. Important software systems developed in Task 5.3 and elsewhere are considered in this deliverable.

IV.1.1. THE GLIDER PORT

An important result of the deliverable is the definition of the “glider port” concept and the description of its components. A glider port is defined as the infrastructure required operating underwater gliders and managing the gathered data. The infrastructure contains several aspects that contribute to the overall task of glider operation.

The five main roles are summarised as

1. hardware operations and maintenance,
2. data management,
3. mission planning and piloting,
4. hardware calibration, integration and testing, and
5. public relations.

Most glider ports did not and could not implement all aspects but it became evident that gliderports could and should complement each other. The glider activities are organized as a community since the creation of EGO and the level of networking between glider ports in Europe has increased enormously, making major advances in terms of understanding of the needs, tool developments and data management, but also reducing duplication and improving efficiency.

IV.1.2. GLIDER PORT ORGANISATION

As part of a network of glider ports, each glider port may be organised according to a different model. The deliverable defines glider port models on the institutional level, national or regional level, SME level and the European level. The centralisation of core components (at a national level) allows processes to be organised more efficiently and to evolve to a higher level of sophistication, but this might also increase the levels of complexity. There is no “best” model, and the preferred implementation depends on the institute's policy and (national) political commitment.
IV.2. GLIDER PAYLOAD ASSESSMENT

This task aimed at evaluating glider observation capabilities and recommending new ones. Specifically, its goals included:

1. The assessment of the predominantly-measured parameters and the sensors used for them
2. Space, power, communication requirements
3. A review of newer and recommended sensors
4. The compilation of best practices, including lab and field calibration, intercalibration, and comparison protocols.

Work for this task began by the circulation of questionnaires to academic and industry partners. The questionnaires aimed to collect primary information about unpublicized sensors and practices, or the addressing of gaps in information that exist in the technical and scientific literature. The compiled information was quickly formulated into two deliverables.

The first deliverable, D5.2 “Sensors for gliders: existing, under development, and future sensors,” consists of an inventory of sensors and their characteristics/technical specifications, especially those that impact glider payload, i.e. power requirements, weight, and size (dimensions), relying on published documentation, as well as the surveying of the glider community at-large including users and industry partners. A total of 37 sensors are described, divided into three development/readiness categories:

1. Developed, mission-proved, commercially available sensors for gliders: OS-TRL 4 or TRL 9 or Development status I (25 sensors);
2. Prototypes and sensors in development for gliders: OS-TRL 2-3 or TRL 5-7 or Development status III (3 sensors);
3. Readily adaptable sensors for glider use: OS-TRL 2 or TRL 4 or Development status IV (10 sensors);

D5.2 provided the technical information on which several other GROOM deliverables, most notably the all-encompassing D3.5 based their evaluation of current and future payload progress.

The second deliverable, D5.3 “Glider missions and sensor use” describes the two main parts of the report:

1. Mission procedures
   1.1. Glider inspection and preparation, mission planning, deployment
   1.2. Operation
   1.3. Data management
   1.4. Recovery
   1.5. Compass calibration
   1.6. Pressure verification
   1.7. Endurance
   1.8. Battery handling
2. Sensor procedures
2.1. CTD
2.2. Dissolved oxygen
2.3. Optical properties – general comments
2.4. Chlorophyll a fluorescence
2.5. CDOM fluorescence
2.6. Turbidity/backscatter
2.7. Current
2.8. Photosynthetically available radiation
2.9. Zooplankton presence/abundance
2.10. Turbulence

While the main text discusses each of these components in detail, a Best Practices summary table at the beginning of the report lists them and assigns each one of three recommendation levels:

1. “strongly recommended” - fundamental/important/widely-used;
2. “Recommended” - feasible, improve performance and usability; and
3. “Suggested” - (mostly sensors) improve data utility/applicability.

These levels acted as an initial guide to describe “GROOM Standards” and are expected to be a legacy of this project. They were evaluated for their usefulness and applicability in WP4, and were not to be necessarily applied universally in the same way, but they are useful in that they identify main issues that current and future glider ports and the entire research infrastructure must address.

IV.3. MISSION PLANNING AND ANALYSIS

In this task, ideas on how to optimally sample the ocean using gliders were explored from a variety of standpoints. First, from a scientific standpoint, it is often the case that a particular ocean variable is of primary importance and should be measured as accurately and completely as possible to capture the relevant phenomena. In particular, areas of high variability must be sampled more frequently and at higher spatial resolution. In this sub-task (D5.4 Optimal sampling design methods for North Atlantic/Arctic and Mediterranean Sea), methodology was developed to produce optimal sampling strategies for a network of gliders. Besides optimizing the path, it was also possible to examine different launch points (glider ports) in order to minimize the expected observation error even further. Other parameters and depths could be used as the optimizing criterion as well. A second way in which one might consider a glider mission optimum is that it is exposed to the smallest risk possible. In this sub-task (D5.5 Environmental conditions and glider mission risk assessment tool), a software package was developed which collects input from MyOcean (such as predicted currents) and from AIS (Automatic Identification System) for ship positions and calculates the risk of glider mission failure. Empirical information based on recently-collected and published GROOM partner glider failure statistics have also been incorporated. The most advanced version of the software developed in this sub-task (D5.6 Prototype glider mission planning system) calculates the optimal set of mission tracks using the methodology of D5.4 for a fleet of gliders and near-real time forecasted ocean state statistics and calculates the associated risks using the methodology of D5.5. This software tool was integrated with an automated piloting system operating at DT-INSU, France.
and tested during the REP-13 experiment (see D4.5).

IV.4. ESTIMATED SET UP AND RUNNING COSTS

The report about costs resulting from the survey compiles this information and indicates the “spending habits and trends” for the glider community, which is important in evaluating the possible funding models for the future glider infrastructure. It became clear that a wide variety of operating modes both at administrative and scientific levels exists. This made it difficult to make general conclusions, but does point out order of magnitude costs and the need for a future glider infrastructure. At a practical level, this information also helps new users to make plans when considering glider operations at the institutional level.

Potential Impact:

I. IMPACT OF THE GROOM DESIGN STUDY

The overall expected impact of GROOM was to contribute to the technological development capacity and scientific performance of marine observations in European Seas and global ocean by the establishment of a Research Infrastructure dedicated to gliders. For that, GROOM has provided a conceptual design of a distributed Gliders European Research Infrastructure (hereafter GERI) in conjunction with other marine platform for research, marine observations and applications for the management of the marine environment that is illustrated by attached figure GERI_Modular_Organization.pdf.

It shows an artistic view of the future GERI. This will be a network of facilities operating gliders in different areas of the world while coordinated by the central facility of the GERI in the centre, which would be the entry point to GERI users. Facilities are distributed geographically and different in terms of 1) personnel (scientists/engineers/technicians) and equipment (buildings; pools of gliders, possibly of different types; workshops; computers and communication facilities; access to sea via small/medium/large ships) and 2) developments of the five aspects of the glider activity, as suggested by the different sizes of the inner coloured boxes (yellow, orange, red, green, blue). This figure illustrates the interoperability and modular organization concepts that emerged from the GROOM design study. The GERI will provide world-class services, tailored to the needs of the users. Each specific task associated with each aspect of the glider activity that must be carried out for a user of the GERI will be done by a dedicated and expert group of coordinated facilities.

This design for a GERI is of particular relevance now for policy bodies at the European level (e.g. ESFRI, JPI Oceans) for establishing plans and roadmaps for the overall design of Marine Research Infrastructures of European interest as well as at the National level where the component of the distributed RI are located and operated.

This overall impact of GROOM can be detailed as follows.

I.1. CONSOLIDATION OF THE FRAGMENTED INFRASTRUCTURE INTO ONE COHERENT SYSTEM
While useful for the design of the future GERI, several GROOM results have already been implemented by the partners, reducing the discrepancy between the existing GROOM partners’ glider infrastructures and more widely with similar infrastructures in the world. For example, the general agreement on a global data management system (WP3) has been sealed by all partners with the signature of a MoU. All partners now allocate resources to implement this data flow and data standards in their day to day activity, which allows having a good overall monitoring of the glider activity at sea and which guarantees the real time data availability in a GDAC like Coriolis in France.

Another achievement which results in less fragmentation is the perspective of a glider component in the GOOS. Being part of the GOOS implies to be identified as a coherent entity at the international level and WP2 widely contributed to this. Moreover, the clarification about the legal aspect of the glider activities (WP2) with respect to the international law is also an essential element for a coherent RI benefiting to the GOOS. As a result, most of the glider “endurance lines” operated by the partners are now well sustained and are part of well established observing systems.

The shape of the future GERI is based on two important concepts that emerged from the GROOM design study and are the core elements of the future infrastructure: the “modular organization” concept and the “gliderport” concept. Both concepts are based on the resources of the individual national infrastructures and the possible organization of the data and work flow within a GERI by sharing and providing access to all the resources. This also includes an optimal management of the gliders themselves. Every member of the infrastructure can now use these clearly defined concepts to make progress in its own implementation being thus in line with the future GERI.

I.2. INCREASING THE SCIENTIFIC BENEFIT FOR USERS OF THE INFRASTRUCTURE BY PROVIDING A HIGH LEVEL SERVICE

Due to the complexity of the glider technology, maximizing the scientific benefit can only be achieved with adequate protocols and standards, adequate data distribution system, interoperability of components ... During GROOM, standards and best practices for deployment, calibration, recovery have been defined in order to simplify the access to the glider technology. They are progressively being adopted by GROOM partners. As a matter of fact, the “modular organization” concept already allows access to tools and services developed by the different expert teams in the “gliderports” and across “gliderports” for many technical tasks required to operate gliders and exploit the results. In particular, access to the “mission planning tools”, which will be one of the pillars of the future research infrastructure, is already possible for GROOM partners but also external users. This tool includes artificial intelligence methods to exploit the high level of interactivity allowed by the “intelligence” of the glider technology.

At this stage, only a more structured organization can guarantee an efficient access to these resources. The “modular organization” concept (see deliverable 1.10) includes a series of mechanisms to make these resources accessible to the public through a central access point that shall be managed by the GERI.

I.3. PROVISION OF A RATIONALE TO INCLUDE THE GERI INTO A COHERENT ENSEMBLE OF...
SIMILAR MARINE RESEARCH INFRASTRUCTURES (HEREAFTER MRIS)

Marine Research Infrastructures (hereafter MRIs) are now being developed in Europe for other marine platforms – such as fixed point observatories, profiling floats, research vessels, ferryboxes ... – which benefits to the GOOS and the future European Ocean Observing System (hereafter EOOS) but also for biological observations by marine stations.

Although GROOM conclusion highlights the need for increasing reliability and endurance of the glider technology, the overall organization of the GERI will allow implementing gliders as a full Global and Regional Ocean Observing Systems (hereafter GOOS/ROOSs) component. As a first action, coordination with the Joint Technical Commission for Oceanography and Marine Meteorology in situ Observing Platform Support Centre (JCOMMOPS) to map the glider activity worldwide has already started. Synergies with other platform-oriented MRIs have been identified. In particular, the large number of new sensors that gliders can carry and the analyses of several deployments performed during GROOM lead to the conclusion that gliders are perfectly suited to fill the gaps left by other MRIs such as EuroArgo, FIXO3/EMSO (Fixed-point Open Ocean Observatories / European Multidisciplinary Seafloor and water column Observatory).

Complementing the GOOS and EOOS with a glider component is a goal that the glider community can now reach thanks to the GROOM project. In most of the ROOSs, gliders are already or will complement and fill the gaps of the existing observations at the right space and time scales. The Copernicus Marine Environment Service will take full benefit of this additional flux of data, in particular at the regional scale, as gliders provide in particular missing information on the open ocean-coastal zone transition region.

I.4. DESIGN SOLUTIONS TO MAKE GLIDERS OPEN TO ALL MARINE DISCIPLINES FOR FRONTIER SCIENCE

State of the art sensors and future ones, including their readiness level, have been analysed for that. Extensive and comprehensive information about the current and future scientific payload of the gliders and deployment capacity for any external users is now available. For example, acoustics shows a great potential for behavioural ecology studies.

The development of coordinated multi-glider experiment with such sensor payload is a perfect example of the new capacity offered by glider to access simultaneously the essential parameters of a whole marine ecosystem. In fact, within the multiplatform approach paradigm for marine observation, gliders allow to conduct completely new types of in-situ experiments to make considerable progress in the understanding of marine processes. Thanks to gliders, marine biologists and ecologists will have soon access to a facility to fully map at the right resolution entire pieces of the marine ecosystems from the surface to the bottom. Only a GERI with a “modular organization” can provide the right tools to make such performances routinely accessible to all disciplines.

I.5. PROVISION OF PLANS AND ROADMAPS FOR A FUTURE GERI
The assessment of the existing legal and financial models against the scientific and technical requirements of a GERI and the actual capacity of the GROOM partners to interact with their European and national stakeholders to make progress toward a common agenda is a major impact of the GROOM design study.

The consensus is that a loose network of glider Research Infrastructures distributed across Europe, while guaranteeing a certain level functionalities, is not enough to manage the complex organization needed to exploit the wide potential of gliders and to make it accessible to a wide range of users across the European Research Area. Since most of the countries have already chosen a model based on one or two national RIs to manage their gliders, the European Research Infrastructure Consortium (hereafter ERIC) framework appears to be the adequate one. It can best guarantee the GERI functionalities regarding to the requirements of EOOS and GOOS as well as regarding excellence in marine research. The financial maturity and sustainability of the members of the future GERI have been assessed and found to match the essential requirements for joining the ESFRI process.

As an overall impact of the project, the roadmap to implement and run the future GERI has been proposed by GROOM (see attached GERI_Roadmap.pdf). This roadmap is based on the present financial model and legal status of the national components and their current national and/or institutional commitments in glider activities. Based on the existing roadmaps in Europe for Marine RIs and on-going H2020 projects, the glider roadmap to establish a European RI runs from 2015 to 2020 with clear milestones and deadlines. Afterward, the glider RI could be fully operationally operated.

I.6. BLUE GROWTH AND THE GLIDERS

Besides the benefits coming at the European level from the added value of gliders to the future EOOS and to the Copernicus Marine Environment Service, and their related industrial activity, the potential for industrial partnership strongly relies on the technological capacities available in the “gliderports”. Established “gliderports” can now bring together scientists and technicians from various disciplines which have in turn fostered the creation of clusters of excellence including SMEs. These “gliderports” have allowed SMEs to develop when they offered services for glider operation (maintenance, deployment …) or proposed to further develop gliders and their sensor payloads. There are already some good examples of fruitful public-private interaction for some GROOM partners thanks to the vicinity of the research institution and the “technology parks” hosting these SMEs.

The exemplary quality of such cooperation is demonstrated by the recently accepted H2020 BRIDGES project (Bringing together Research and Industry for the Development of Glider Environmental Services). To progress toward a glider technology better suited for industry needs (greater depths, “service oriented” approach …), some GROOM partners complemented by European SMEs in relation with some “gliderports” located in marine technological districts (Southampton, Toulon) have proposed this project to the H2020 in the Blue Growth focus area. BRIDGES will develop deep and ultra-deep gliders and new sensors for frontier science, improved monitoring, and responsible exploitation of the marine environment with fit-to-purpose glider services to the oil and gas and the deep sea mining industries.
BRIDGES is the clear demonstration that the know-how developed by GROOM has produced the appropriate innovation ecosystem with research institutes and industries, which is one of the main roles of European RIs.

II. MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION OF RESULTS

Dissemination activities within GROOM were meant to ensure synergies and to build close links between the project and all relevant stakeholders and end-users. Standard channels (peer review journal, scientific and technical conferences, websites (see below) ...) have obviously been operative for that and for the dissemination of the project results. However, dedicated activities with the relevant stakeholders and also specific outreach activities were developed during GROOM.

II.1. STAKEHOLDERS OPEN FORUM ACTIVITIES

Because of the nature of a Design Study project in the fast evolving context of MRIs in Europe, we organized the Stakeholders Open Forum. This Forum was constituted by all actors that could be relevant to the project, such as similar projects, SMEs, European, regional and national authorities, associations, competitiveness cluster, etc. Stakeholders were classified in four main categories: Non European partners such as US/IOOS (Integrated Ocean Observing System), other European projects for Marine Research Infrastructures (MRIs), such as I3 (Integrated Infrastructures Initiatives), ESFRI projects in preparatory phase, policy makers in the fields of MRIs such as national and European official bodies, international bodies like IOC/UNESCO, and other public stakeholders like marine/maritime clusters and finally SMEs active in the field of expertise covered by the proposal.

GROOM succeeded to participate to several workshops and meeting which these stakeholders to promote and make progress with its agenda. For example, during the course of the project, concrete activities with international and European bodies (IOOS, IMOS, EuroGOOS, JCOMM ...) have started. GROOM participated to a JCOMM Observations Coordination Group (hereafter OCG) meeting which was the first concrete opportunity for GROOM to assess the requirements for the glider community to be recognized as a GOOS component.

GROOM was clearly identified as the main entity to make progress for a glider component in the GOOS. Regarding European needs for the roadmap toward EOOS, maintaining GROOM momentum after the end of the project is essential and a glider Task Team in EuroGOOS has been recently established for that.

Participating to major international events was a suited opportunity for GROOM to make the project much more visible and to shape a lot of contacts already established during previous meetings. After all dissemination activities carried in 2012 and 2013, the communication skills of the GROOM project in early 2014 were much higher with an extensive address book resulting in particular from a fruitful participation to OI’14 in London in March 2014. Our objective at OI’14 was to showcase the project to companies and key stakeholders which all use to attend the OI series. This was also an opportunity to contact new
companies and stakeholders relevant to our activities. For example, an in-depth contact was established with the Brazilian PROOCEANO company, one of the first private companies being able to operate gliders to service the Oil and Gas industry.

The main overall result of these dissemination activities is that GROOM has proven that coming at a European level is feasible and is the way forward to capitalize the technological, scientific and industrial potential of this technology in Europe. “Gliderports” are becoming centres of excellence for research and training by gathering SMEs and research institutions, while giving birth to an actual European industrial sector.

II.2. OUTREACH ACTIVITIES

In order to transfer expertise and knowledge on glider technology, on glider scientific use and glider data applications, the GROOM partners have engaged outreach activities including specific educational actions. The GROOM project focused on specific dissemination targets like new users and students (“capacity building”) as well as on outreach activities dedicated to a wider public and especially to young people. GROOM summarized its essential information on glider technology and on the project with “key messages”. These are available online, with flyers, brochures or other written and illustrated materials.

Most partners have chosen a web-based communication to reach out the non-specialist audience. However, aiming to attract the school teachers/pupils and academic/students public, and taking advantages of the good “communications skills” that smart robots such as gliders actually offer, some GROOM partners have also organized open house science exhibition with several online activities. Partnerships with high schools have been developed resulting in activities organized in common between teachers and GROOM scientists for this young audience.

Although GROOM objectives here were not to coordinate ocean education issues in general, the interest among GROOM partners for such outreach activities as an integral part of the infrastructure is a real one. As a result, collaborations are now on-going between the partners. The ocean sciences and education communities know the benefits of the public outreach sector that is to create a public awareness of the role of scientific discovery in society and to foster innovative collaborations to disseminate knowledge. Sharing efforts and resources, development of common evaluation methods, networking with similar initiatives worldwide, such as the COSEE organization (www.cosee.org) to ultimately lead to a structured outreach activity for ocean sciences within the infrastructure itself certainly deserves consideration for the future GERI.

List of Websites:
http://www.groom-fp7.eu