APPG - The future of Ocean Technology

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Future of Ocean Technology Working Group

About the Scottish Association for Marine Science

The Scottish Association for Marine Science (SAMS) is one of the UK's oldest (founded 1884 by Sir John Murray) independent marine science organisations, delivering marine science for a productive and sustainably managed marine environment through innovative research, education, and engagement with society.

Based near Oban on the Scottish west coast, our marine research and teaching portfolio is diverse in topic and discipline, global in outlook, project locations and relevance, and delivered by the SAMS team with a can-do attitude, working in partnership with academic, business, government, industry, regulatory, voluntary and civic society colleagues.

SAMS is a charitable organisation (SC009206) and a Company Limited by Guarantee registered in Scotland (SC 009292) and operates two wholly owned subsidiary companies: SAMS Enterprise – a specialist marine consultancy – and SAMS Ltd. It is a partner of the University of the Highlands and Islands.

Questions:

1. **Are we currently experiencing an ocean technology revolution?**

Ocean technology has seen a steady **evolution** over the decades, embracing wider advancements in technology and engineering and deploying them to a marine environment to improve data capture, accuracy, volume and reach.

Revolution, however, is now required to ensure ocean technology can meet the growing demands and the sheer scale of data required to make headway in tackling escalating climate issues, all whilst being mindful of continually reducing the carbon impact of our own activities. **Funding**, Governmental and industry buy-in and investment in training & workforce is required to achieve a true revolution.

The Scottish Association for Marine Science (SAMS) has been using technology for ocean observations for at least the last 40 years. As an example, the Extended Ellett Line (named after SAMS oceanographer David Ellett (d. 2001)) is a series of measurements of the North Atlantic using static moorings and vessel-deployed sensors that has been continuously working since 1975.

In recent years, these observations are enhanced with remotely operated, robotic ocean gliders. In 2014 SAMS instigated the Scottish Marine Robotics Facility which now provides state-of-the-art testing and maintenance for ocean technologies for UK science. SAMS' location provides a natural infrastructure (deep, sheltered waters) for testing new technologies. SAMS operates ocean technologies including ocean gliders, autonomous underwater vehicles, remotely operated vehicles as well as innovative purpose-built autonomous aerial vehicles (aka 'drones') and autonomous surface vehicles.

SAMS has been at the forefront of novel technologies for marine monitoring, such as contributing to an early report to DEFRA highlighting the opportunities for monitoring the UK's Marine Protected Areas using robots (Wynn et al., 2012). Given this activity there has clearly been a slow revolution (over at least the last 10 years) in ocean technology. However, it is only recently that available technologies have become cheaper and much more reliable. Recent developments include the integration of different types of observing technologies (e.g., ARGO floats, gliders, remote sensing) into ocean circulation and hence climate models. The availability of existing and real-time data is producing much more accurate ocean models than have previously been possible.

2. What role can new ocean technologies play in mitigating and adapting to climate change?

Mitigation and adaptation require information. Ocean technology is key to understanding the ocean's response to climate change. Global Climate Models (GCM) are only as good as the environmental data that is used to calibrate, or 'tune' them. For our oceans, GCM's need parameters such as circulation, temperature, salinity, oxygen.

The UK needs **long term observations** of our oceans which require robust data from sustained monitoring stations. These data can be obtained from autonomous ocean gliders or static (fixed to the ocean floor) sensors. To provide improved observations these must be capable of obtaining continuous, highly accurate measurements and communicating that data back to the UK instantaneously. Challenges include ensuring enough of this technology is available in the UK and dramatically improving battery life to increase the endurance of these instruments.

For improved meteorological predictions the UK needs better 'live' data both from satellites and from atmospheric drones. Satellite, weather balloon and on-shore measurements continually synchronise weather-forecast models with reality. This maintenance of global atmospheric 'digital twins' has a decadal history.

In the ocean context, added complexity and inherent opacity of seawater to satellites has delayed the development of the oceanic “digital twin” until this decade. Combining both twins into an operational, coupled ocean-atmosphere model will rely on ‘responsive robotics’, which are designed to be deployed to make additional measurements where the model, *itself*, assesses that there is problematic uncertainty in the twins’ validity. This ‘targeted data assimilation’ will evolve this decade and revolutionise the accuracy of predicting weather and ocean health for, e.g., off-shore wind, near-shore aquaculture, fisheries, storms, and flooding. In addition, climate adaptation and mitigation will require a better understanding of Harmful Algal Blooms (HABs) which can impact food safety in the UK. Although there is no evidence linking an increase in HABs to ocean warming; there is a requirement for increased monitoring as the global aquaculture industry expands.

3. Assess the effectiveness of emerging sustainable ocean technologies.

Compared to large research vessels, **autonomous platforms** with a low-carbon impact, like gliders, can provide new perspectives for ocean science. For example, they have had a transformative effect on our ability to observe climate-related ocean circulation patterns. They observe the ocean currents and conditions in regions of complex geography, which traditional (ship-based or moored) observing platforms are ineffective.

However, while these technologies augment the observations gathered by traditional means, they are **not currently able to replace them**. The accuracy, precision, and continuity provided by moored platforms remains essential for understanding the ocean’s role in climate. Furthermore, ship-based observations remain essential for quality controlling and calibrating data from all other platforms. Platforms such as gliders, ARGO floats have depth and geographic limitations including battery endurance and investment to reach full potential.

A recent review (McGready et al., 2023) outlines the effectiveness of new technologies for monitoring MPAs. The diversity of technology provides a wide range of observations but also highlights the challenges. A recent project in the North Sea examined the impact of carbon capture and storage on the seabed by using combined biogeochemical sensors with AUV measurements.

4. Outline key methods for sustainable ocean technologies.

Affordability and widespread **availability** of technology has been the key to recent advances in understanding our oceans. The ability of a project or institute to employ a variety or a spectrum of instruments, many ‘off the shelf’ instruments have enabled diverse observations across a wide geographic area to be obtained.

Notable examples are the recent advances in biogeochemical sensors (e.g., nutrients) helping to quantify carbon in our oceans. These data can be used to refine our understanding of the oceanic carbon-cycle. In addition, as mentioned previously, algal bloom forecasting has benefitted greatly from technology such as the SAMS OpitCAL and Imaging Flow Cytobot allowing real time monitoring of phytoplankton species. The capability of gliders in observing marine heatwaves as they happen was recently demonstrated as a SAMS glider in the North Atlantic monitored the recent record sea surface temperatures.

Sustained ocean observations are essential in providing the 'long view' of our oceans and inshore waters. SAMS has a long-established inshore monitoring station in the Firth of Lorn Observatory (FOLO) but presently lacks the funding to ensure a sustainable long-term future. Further offshore, the North Atlantic is monitored by ocean gliders which previously used large oceanographic research vessels to obtain the measurements. Investment in UK ocean gliders can limit the pressure on expensive and polluting, UK research vessels. Additionally, a network of ocean hydrophones (some already existing for defence) could be used to monitor the presence and behaviour of marine mammals. In summary there is an opportunity, with investment, to instrument the seas in an intelligent and dynamic way.

5. **If there is enough funding and support for research to develop new technologies?**

Technology is expensive. Whilst there is much that can be achieved from off-the-shelf sensors and equipment the **UK lacks funding for training and testing** of new technologies. We are not leading in terms of operational capability, specifically the people with the skills required to build, test, and operate these technologies. In addition, there needs to be investment in onshore technology – to develop the ability for data storage and analysis, IT, people, and training.

Part of the problem lies with **lack of investment** in grass roots organisations priming the talent of the future, in schools and the quality and consistency of career-focussed STEM learning, and pathways to apprenticeships. For research organisations, there is huge competition from the commercial sector, who can offer significantly higher salaries, which takes talent away from projects whose outcomes can be shared for the good of the entire sector. Generally, as much of the technology developed for the marine industry can be cross disciplinary, (for example, sensors used to measure oxygen can be used in numerous marine environments and onboard a wide range of vehicles and instruments) investment can provide rewards across a wide diversity of projects and sectors.

Simple investment in equipment does not always lead to a step-change in use or is not immediate in terms of scientific rewards. Platforms (vehicles), instruments (sensors) and observations (data) all require resource and capacity to reap dividends. Platforms need investment in education and training, in engineering, instruments in research and development and data in information technology and artificial intelligence or machine learning.

6. What are the current barriers for emerging ocean technologies, including those which enable marine science research, as well as marine and ocean-based renewable energy technologies?

Without doubt **training, and skills** are needed at the grass-roots level (schools and universities). Since 2018 SAMS has offered a BSc in Marine Science degree with an option for students to specialise in Oceanography and Robotics. This programme aims to train and inspire undergraduates in ocean technology and to develop numeracy skills. Students study marine instruments and data, robotics and learn about programming. However, many students do not have the basic maths and computing skills before joining the programme. Clearly there is much work to still to do.

As stated earlier, the UK produces very few ocean instruments (the exceptions being the National Oceanography Centre's Autosub and the commercial vehicle EcoSub). In contrast, France is offering low-cost effective ocean robots. Also, **UK maritime law** is slow to catch-up with developments in technology. An example is the legality and legislation surrounding autonomous surface vehicles. It is still unclear on the legislation required to operate these vehicles in UK inshore waters.

SAMS is currently developing a '**Scientific Robotics Academy'**, providing training for schools, and bringing in engineers to understand the needs of the environmental sciences. Both Autonomous and Net Zero equipment are being developed for pure commerce; and this equipment is reliable and robust, but rarely easily adaptable to the style of 'bolt on instruments' that science needs. UK "Technology Hubs" (for example here at Oban Airport) must focus on long-term Climate and Net Zero innovation, not just commercial gain for investment. The SAMS Scientific Robotics Academy focusses on bridging the gap between scientific needs and engineering capacity by pushing engineering forward: needs 'innovation' bridging support. In general, new technology tends to be driven by topical issues, i.e., developing equipment or sensors that address ocean heatwaves or microplastics. We need a more coordinated approach whereby we allow technologies to evolve rather than rapidly changing course in an attempt to address the latest challenge. **Multifaceted collaborative working** such as this, which straddles educational, commercial and innovation sectors, need both Government advocacy and funding.

Research councils do not fund the use of ocean technologies in the same way they fund ship time. Ship time is funded directly by UK Government and so is not costed into proposals, but all costs associated with, for example glider observations come from individual project budgets (e.g., lithium batteries, refurbishment between missions, paying onshore glider pilots). Importance of new technology is not reflected in the level of funding from the research councils, which puts those trying to push the barriers of innovation at a distinct disadvantage.

Finally, funding and investment across all these areas is crucial. Often funding can be piecemeal – which stifles the essence of invention, and the need to test, fail and repeat - or targeted to specific objectives which don't always represent genuine scientific needs – for example, driven by public or commercial interests. Government advocacy to ensure that private funding (i.e., impact investors, industry funding, commercial and individual philanthropy) becomes not only normalised but led solely by the science, is also crucial.

7. What is the impact of AI and software on future ocean technologies?

Skilled operators will always be required in ocean science. At present, capacity, resource, investment in training, and remaining competitive against the demand of the commercial sector continue to be a barrier to enabling faster development. AI and advanced software are essential especially in analysing and processing the large datasets that can be collected. For example, a recent SAMS seabed survey of a wind farm using an AUV collected 11,000 seabed photographs per hour of robotic survey. A human operator would take a considerable length of time to process these data. **Future ocean technologies need AI**, or at least more automation, to increase their scale. Single-platform operations have been normal in the past. We are now working towards fleet deployments, where multiple autonomous platforms can be operated with coordination. This reduces the 'manpower' for basic piloting tasks (i.e., the ones that can be automated), but requires more manpower for developing the hardware and software required for automation (of piloting, visualisation, etc). Clearly there is still a need for people, just with different skills.

Machine learning has been a significant breakthrough and can be used to identify species or features and provide a statistical assessment of large photographic data sets. Data visualisation is increasingly important in providing new perspectives on the oceans and engaging a new generation of ocean scientists. Photogrammetry (the development of 3D visuals from photographs) has now becoming widely used for science, commerce and by the public. Wreck sites can be viewed as a 3D rotating digital image – something that would not have been possible 10 years ago. 3D seabed visualisation is also increasingly used to view predictions of offshore wind and cable route sites. SAMS is currently combining film footage from a remotely operated vehicle and 'trained' AI software to accurately measure the biological growth on subsea structures, informing decisions such as decommissioning in the oil and gas sector.

8. How can the new Departments for Science, Innovation and Technology, and for Energy Security and Net Zero, best support growth into the future of ocean technology?

It is indisputable that ocean technology has made great strides over the last decade. **Technology coupled with software** has enabled the oceans to be investigated in more detail and in hard to access environments. DSIT can assist in the **revolution**

by bringing scientists, technicians, and developers together to tackle the scientific and economic challenges that the UK faces (e.g., offshore wind, aquaculture, tidal developments, understanding habitat change and the impacts of warming oceans, pollution and microplastics) and by shaping the funding landscape to best meet the needs of those working within ocean technology.

9. **Do you feel that the Government is doing enough to support future ocean technology projects? What action would you like them to take?**

UK Government needs to **invest in both technology and people**. Technology that will be future-proof, durable and possess the ability to interface and communicate across a wide variety of platforms. It needs to support schools and universities to promote and deliver numerate, scientifically literate, and imaginative teaching.

10. **Where can ocean technology go next?**

Ocean **technology can help meet the challenges facing the oceans**. For example, autonomous vehicles might be able to operate in a fleet or ‘swarm’ to provide simultaneous data from a wide geographic area. Applications such as this can help map the ocean seabed or provide high-resolution data coverage of impacts such as algal blooms or oil spills. **Engaging people with our oceans** is important. Enabling real-time data via the internet, ‘citizen science’ gives people access to technology (the ‘internet of things’) to investigate the oceans from their own homes. Community science projects could use low-cost technology (e.g., mini remotely operated vehicles) to investigate their coastal environments. Better **industry-science partnerships**; starting from a position of trust, can deliver mutual goals. We need **simpler legislation** for developing technologies, allowing wider access to the ocean for small-scale robotic projects. Under-ice technology can be used to investigate glaciers and sea ice. **Miniaturisation** of existing sensors will enable measurements to be taken by smaller much more portable vehicles and instruments. **Autonomous vehicles** that can operate much **deeper** with **longer** lasting batteries can provide access to the deep sea. Exploring and understanding the deep-sea is a vast frontier that requires significant investment in technology. However, we do not yet fully understand the deep-sea, and are far from being able to exploit this hostile environment (e.g., for mining). The average ocean depth is 3,500m only accessible to a few UK research ocean robots. **Communication** with deep-sea vehicles is a problem – how can we provide real-time large bandwidth communication with autonomous vehicles in deep-water? Meanwhile, surface vessels must transition to **cleaner energy**, either hydrogen or electric power. How can the UK research fleet transition to a low carbon impact. The development of large autonomous, cleanly-powered surface vessels is possible as has been seen with the experimental development of autonomous commercial ships.

Wynn et al., (2012) Investigating the feasibility of utilising AUV and Glider technology for mapping and monitoring of the UK MPA network. DEFRA MB0118 National Oceanography Centre, Southampton. 244pp.

McGready et al., (In Press) A review of new and existing non-extractive techniques for monitoring marine protected areas. Frontiers of Marine Science