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The All-Party Parliamentary Group for the Ocean

The Ocean: Inquiry into the Future of Ocean Technology

January 2024

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Foreword

Sally-Ann Hart MP

Chair of the APPG for the Ocean

The ocean has long been a frontier of opportunity for exploration, cutting-edge research and scientific understanding, both in the UK and globally. Recent rapid advancements and capabilities of new types of ocean-based technologies are transforming the landscape of ocean research, leading to significant developments in the ways in which we observe, measure and predict changes in the ocean. As Chair of the All-Party Parliamentary Group (APPG) for the Ocean, I am pleased to see the productive developments and conversations about ocean technology and its huge potential, from industry, academics and Governments across the world. Policy collaboration, between the public and private sector, in this space is essential to ensuring the benefits of the ocean, and ultimately the need to protect it, are fully realised.

New technologies are already playing a crucial role in helping us understand the ocean. As the MP for the beautiful coastal community of Hastings and Rye, I recognise first-hand the importance of such developments. As highlighted in the APPG's first inquiry into blue carbon and ocean-based solutions to climate change, The Ocean: Turning the Tide on Climate Change[1], the ocean is key to regulating the global climate and thus, mitigating against, and adapting to, the effects of climate change. As highlighted in this previous report on blue carbon, the ocean occupies over 70% of the planet's surface area and produces around 50% of the planet's oxygen. The ocean absorbs over 90% of planetary heat caused by human activities and between 25-30% of all carbon dioxide emissions. In addition, and as will be explored in this report, ocean technology plays a crucial role in a number of other key areas including increasing biodiversity, providing more opportunities for renewable energy, ensuring higher quality and autonomous data collection and allowing for greater exploration and discovery of the deep ocean. The ocean also could provide vast potential living

1 APPG for the Ocean (2022) *'Parliamentarians call for blue carbon revolution to tackle climate change'*, available at: https://www.oceanappg.org/news-and-updates/parliamentarians-call-for-blue-carbon-revolution-to-tackle-climate-change

spaces in floating towns, cities, factories and infrastructure for people and facilities displaced from low-lying coastal regions by rising sea levels.

Ocean technology has the potential to revolutionise the ocean space. From the growing capabilities of autonomous vessels and the power of AI, effective marine renewables, sustainable blue carbon solutions and the potential of alternative green fuels to decarbonise the maritime industry, ocean technology is integral for the UK to achieve its science superpower status. However, a number of significant barriers currently prevent the full potential and benefits of ocean technology from being realised. Respondents to this inquiry cite a number of challenges the sector is facing which includes difficulties in scaling, sharing and acquiring new data, a lack of coordinated international collaboration and widening gaps in funding, grant opportunities and skills. Given that the UK is a leader of the Global Ocean Alliance and is committed to meeting ambitious net zero targets by 2050, there is a clear role for Government to play in facilitating this revolution to solidify the UK as a world-leading research hub of ocean technology and research.

On behalf of the APPG, we are grateful to all stakeholders who submitted evidence, both oral and written, to this inquiry and to all members of the APPG for their continued support for ocean issues in Parliament. Our report highlights the huge potential that ocean technology can bring to UK marine science, discusses the current challenges in developing and scaling ocean technology, and provides key recommendations to Government focused on improving data, international collaboration, leadership and funding.

Ocean technology is at a revolutionary point in its development, and it is therefore crucial that any ocean technology rollout, or funding for ocean technology development, is sustainable, long-term, and collaborative. In order to tackle our greatest global challenge – climate change – it is crucial that Government and industry work in concert to fully realise the power of ocean technology and its far-reaching potential to help us to better understand and restore the deteriorating global marine environment.

Executive Summary

The ocean is facing unprecedented challenges due to human activities and climate change. As a result, we are seeing well-documented rising sea levels, temperature changes and extreme weather events both in the UK and globally. However, amid these challenges, technology has emerged as a powerful tool to preserve and protect our oceans. With innovative advancements in data collection, autonomous vessels and artificial intelligence, marine renewables and blue carbon solutions, ocean technology is revolutionising the way we monitor, understand, and mitigate the impacts of climate change on marine ecosystems.

Ocean technology is crucial to shaping the future of the ocean and the UK, as an island nation with significant research centres and capabilities, is well-placed to be a global scientific leader in this space. Over the past decade, ocean technology has rapidly advanced, with significant developments in big data, autonomy, renewables, carbon capture and storage, and blue carbon. Such technologies are leading the transformation in the way in which we observe, measure and predict how the ocean behaves. They are equipping scientists with the necessary tools and capabilities to enhance our scientific understanding of the ocean.

Despite such progress, a number of significant barriers currently prevent the full potential and benefits of ocean technology from being realised. In light of this, and following the success of the APPG's first inquiry on blue carbon and ocean-based solutions, the APPG launched its second inquiry into the Future of Ocean Technology in May 2023. In order to fully understand our oceans and their incredible powers and capabilities, this inquiry sought to consider the significant and rapid technological advancements being made, examine the innovative and modern approaches to sustainable ocean technology and infrastructure and identify how government and industry can work collaboratively to ensure that the UK ocean technology sector can continue to flourish.

The call for written evidence ran between 19 May and 12 July 2023, and we were delighted to receive over 20 responses from key stakeholders. We were also delighted to hold two oral evidence sessions with leading scientists and industry representatives. The inquiry found that:

- We are currently undergoing a revolution in ocean technology, or at the very least, we are on the precipice of significant change. However, several barriers exist which are continuing to impact efficiency, uptake and progress. If not addressed correctly, these barriers will certainly impact the success and future of ocean technology.

- Previous attempts to regulate and drive investment in this space have been disjointed and lacking in ministerial direction, with the majority of marine science bodies and groups being disbanded and dissolved.

- There have been rapid technological advancements made in the ocean technology space, both in the UK and globally. From satellite technology to underwater vehicles, to buoys and gliders, growing investment in tidal and wind technology, powerful data sharing and blue carbon ecosystems such as mangroves, tidal marshes and seagrass habitats, technology is allowing us to build a fuller picture of the day-to-day workings of the ocean.

- There are several key challenges which are limiting the development and potential of ocean technologies from being fully realised. The most pressing and significant challenges relate to the limits on research, data and the use of current technology, lack of grants and sustainable funding, the need for improved international collaboration, a worsening skills shortage and lack of government attention.

- There is a clear role for the UK Government to play in driving technological innovation in the ocean space, by ensuring greater and long-term investment in ocean technology, tackling the widening funding gap and skills shortage and by supporting the sector and businesses in building international partnerships.

We are therefore calling on the UK government to establish a clear and comprehensive strategy and framework to foster research, development and innovation. The APPG makes the following key recommendations to Government:

1. **Establish and implement an overarching ocean strategy or a "strategic taskforce", overseen by a Minister for the Ocean.**
2. **Better and more sustainable, long-term funding for scientists carrying out ocean Research & Development.**
3. **Provide funding grants to cover the full cost of projects undertaken by universities and Independent Research Organisations.**
4. **Ocean companies to publicly collect and share data.**
5. **Support and develop guidance for UK companies looking to form international research partnerships.**
6. **Effectively harness the powers of AI for ocean research within an appropriate regulatory framework.**
7. **Government to review current consenting and marine licensing processes.**
8. **Government to provide cross-departmental support to oversee and develop a comprehensive regulatory ocean framework.**
9. **Government to support and work with industry to effectively address skills shortages through an "ocean skills roadmap."**
10. **Government to bring forward regulation on marine and maritime autonomy.**

Only through fostering innovation and the development of safe and efficient ocean technologies, can we understand the complexities of the ocean, and, in turn, mitigate and protect against the harmful effects of climate change.

Recommendations

1. Establish and implement an overarching ocean strategy or a "strategic taskforce", overseen by a Minister for the Ocean.

The majority of evidence submitted to the APPG's inquiry supports the need for an overarching ocean strategy to help the UK ocean technology sector to continue to grow and develop the necessary technological solutions to protect our ocean and mitigate against the harmful effects of climate change. This strategy should acknowledge the benefits and potential of current ocean technology solutions as well as set out plans to reform the UK funding and grants system to encourage further Research & Development (R&D) and support the required drive for global collaboration. Government should work with industry and scientists to develop this strategy supported by the establishment of a *"strategic taskforce"* made up of key ocean stakeholders, scientists, academics and government agencies. The APPG for the Ocean recommends that this strategy should be overseen by a specific Minister for the Ocean position in UK Government, a need also highlighted in the APPG's previous inquiry report into blue carbon and ocean-based solutions to climate change. The creation of such a position would ensure all ocean issues are at the forefront of the Government's environmental policy agenda.

2. Better and more sustainable, long-term funding for scientists carrying out ocean Research & Development.

Respondents cited a number of challenges facing the sector. Widening gaps in funding and lack of long-term funding opportunities were referenced in all evidence responses as being particular severe problems. Better long-term funding is needed to ensure the continued rollout of cutting-edge and innovative UK ocean technology. Funding is needed not just at the initial research and development stage, but also at the delivery and evaluation stages, in order to fully assess the effectiveness of new ocean technology. The APPG urges Government to play a key role in this process, working with industry to increase funding and identify a broader and longer-term approach to UK marine and ocean research, looking towards exemplary international funding structures such as those in the US, Norway and Canada.

3. Provide funding grants to cover the full cost of projects undertaken by universities and Independent Research Organisations.

Small and Medium Enterprises (SMEs) and universities are responsible for driving much of the scientific innovation agenda in the UK. This is due to the current funding and grants system which means the UK has a comparatively low number of Independent Research Organisations (IROs), with a large proportion of funding instead directed through universities. Subsequent cost pressures mean many universities and IROs are reliant on government grants, which are obtained through bodies such as ARIA, UKRI and Innovate UK. These bodies often fail to cover the full economic costs associated with undertaking research. The APPG recommends that UKRI, Innovate UK and ARIA funding grants should cover full costs for both universities and IROs undertaking innovative and high-quality ocean research and pilots, in order to ensure a level playing field and drive rapid technological advancements.

4. Ocean companies to publicly collect and share data.

Data sharing is a scientific norm and encourages more connection and collaboration between researchers, which can result in important new findings and scientific developments. Scientists across the world often seek to access and share findings across open data platforms. Ocean technology plays a crucial role in building a stronger evidence base of the ocean and climate change, with satellite and sensor technologies being able to measure changes in weather conditions and biodiversity. The APPG is therefore calling on Government to encourage and incentivise data sharing to ensure it is as transparent and streamlined as possible. Ocean data sharing should be FAIR (Findable, Accessible, Interoperable and Reusable) to ensure it can be shared and used for public benefit.

5. Support and develop guidance for UK companies looking to form international research partnerships.

International and strategic partnerships are essential to ensuring reliable findings and data. In the case of ocean research, it is fundamental, as the ocean has no boundaries or borders, making international collaboration crucial to unlocking new technologies and raising awareness for the role that the ocean plays in climate mitigation. The APPG would like to see the UK Government play a leading role in driving international ocean research collaboration by encouraging data-sharing and supporting UK SMEs build stronger international partnerships.

6. Effectively harness the powers of AI for ocean research within an appropriate regulatory framework.

The UK's AI industry is thriving, employing over 50,000 people and contributing £3.7 billion to the economy last year. If harnessed correctly, AI has the potential to revolutionise ocean science, advancing crucial data sharing practices, as outlined in recommendation 4, making large datasets more digestible and accessible and improving marine renewable technology. However, given concerns around public trust and current lack of regulation of AI products and services, the APPG is urging Government to ensure that any future AI regulation considers the development, maintenance and optimisation of ocean technologies.

7. Government to review current consenting and marine licensing processes.

Another significant barrier to emerging ocean technologies is a regulatory framework such as marine licensing. Inquiry evidence suggests that the current process is costly, complex and time-consuming, resulting in application delays of up to two years, which is having a detrimental impact on commercialisation and innovation for many of the SMEs in this sector. The APPG therefore is calling on Government to review the current consenting and marine licensing processes to address these delays.

8. Government to provide cross-departmental support to oversee and develop a comprehensive regulatory ocean framework.

An overarching Government strategy is needed to foster innovation and growth of the UK ocean technology sector. While Defra holds departmental responsibility, the new Department for Science, Innovation and Technology (DSIT), and the Department for Energy Security and Net Zero (DESNZ) can both support the growth of the future of ocean technology. The APPG is recommending that Government develop a centrally-coordinated approach to develop a comprehensive and robust regulatory ocean framework, which prioritises innovation and sustained environmental reporting.

9. Government to support and work with industry to effectively address skills shortages through an "ocean skills roadmap."

Inquiry responses highlighted the significant skills shortage within the marine and ocean sector, which is a major barrier to furthering any kind of ocean technology revolution. Responses set out that there is a lack of promotion and awareness of the variety of career options associated with marine science and research, from school-age up until university level. The APPG believes greater collaborative partnership between industry and Government is needed, through the development of an *"ocean skills roadmap"*, to tackle this skills shortage across educational, commercial and innovation sectors.

10. Government to bring forward regulation on marine and maritime autonomy.

There is a need to secure greater use of autonomous technology. Despite positive progress already made in this area, through digital innovation and the development of unmanned vessels, otherwise known as *'Marine Autonomous Systems'*, which are crucial ocean monitoring tools, regulatory measures are needed for the UK to lead the world in this area. Published in 2019, Maritime 2050 is an ambitious joint plan between Government and the maritime industry setting out how the UK will continue to be a world leading maritime nation, and presents the foundational regulatory framework required to support innovation. The APPG urges Government to bring forward the necessary legislative reforms as a priority to ensure the development of a comprehensive regulatory framework for autonomous and wider ocean technologies.

Background to the inquiry

The All-Party Parliamentary Group for the Ocean[2] was established in 2022 to provide a collective space in which all parliamentarians can support and promote ocean research and awareness, with a view to developing greater understanding of the ocean and its role in tackling significant challenges such as climate change, and to debate wider issues.

The APPG for the Ocean launched its first inquiry in June 2022 which focused on the ocean's role in climate change. At the time, the APPG welcomed discussions held at COP26 in 2021 on the urgent need to take action to mitigate climate change but felt an important resource in tackling climate change was overlooked in these conversations: the ocean. An often-overlooked aspect of the ocean is the positive and active role it plays in combating climate change and mitigating its dangerous consequences. The APPG's first inquiry report, entitled *The Ocean: Turning the Tide on Climate Change* considered the role that the ocean plays in both adapting to and mitigating climate change, including the significantly important role of blue carbon ecosystems. The APPG was delighted that many of the key recommendations made in the APPG's first inquiry into blue carbon and ocean-based solutions to climate change were echoed in the Government's Environmental Improvement Plan 2023. These recommendations included the establishment of three Highly Protected Marine Areas in English waters and plans between the Department for Environment, Food & Rural Affairs, (Defra) and the Department for Business, Energy & Industrial Strategy (BEIS) to *"address key questions including filling the evidence gaps that currently hinder inclusion of saltmarsh and seagrass habitats into the UK Greenhouse Gas Emissions Inventory"*. The APPG welcomed the Government announcement in July 2023 that the first three marine areas in England waters (Allonby Bay, North East of Farnes Deep, and Dolphin Head) received the highest level of protection for marine habitats and species and we look forward to seeing similar progress made in other areas.

Following the success of the APPG's first inquiry, the APPG launched its second inquiry into the Future of Ocean Technology. In order to fully understand our oceans and their incredible powers and capabilities, the APPG's view is that the Government must consider the significant and rapid technological advancements being made in the ocean science and technology space. If harnessed and regulated effectively, these new technologies have the potential to revolutionise our understanding of the ocean.

This inquiry covers Great Britain, Northern Ireland and British Overseas Territories and examines the innovative and modern approaches to sustainable ocean technology and infrastructure. This includes aspects such as advancing developments in autonomy, the potential of marine renewable energy sources and blue carbon solutions to climate change and biodiversity loss. This could also include AI tools, underwater vehicles, sensors, data research platforms, and ocean-based energy generation solutions, including tidal, wave and offshore wind.

The APPG is grateful to all the stakeholders who shared their knowledge and expertise on the issue, and their views on how best the potential benefits that technology can bring to the ocean space can be fully realised. A list of the respondents to the call for evidence and the questions posed in the written evidence can be found in the Appendix.

2 APPG for the Ocean, available at: https://www.oceanappg.org/

Are we currently undergoing an ocean technology revolution?

Over the past decade, there has been a significant increase in technological advancements and innovations focused on the exploration, utilisation, and conservation of the ocean. In the race to find and scale solutions to tackle the worsening climate crisis, ocean technology has emerged as a growing industry within the ocean science community, with innovative businesses and products, scientific capability and investment at the forefront.

There is consensus across submissions to this inquiry that we are currently undergoing a revolution in ocean technology, or at the very least, we are on the precipice of significant change. According to a written submission from the National Oceanography Centre this revolution can be characterised within five key areas: *"big data, autonomy, renewables, carbon capture and storage, and blue carbon."*[3] Advances in technology in these areas are leading the transformation in the way in which we observe, measure and predict ocean behaviour, which can rightly be described as revolutionary.

The Society for Maritime Industries highlights that innovation in areas of rapid technological development is having far-reaching implications in the field of ocean science and technology, enabling us to *"observe the vast oceans in greater detail than previously possible."*[4] This is fundamental to being able to harness the power of ocean resources as sustainably as possible. The rise in demand for ocean research and technology, driven by climate change, sustainable fish harvesting, blue carbon, energy and defence, is *"a perfect storm capable of creating a new blue economy."*[5] Thus, the UK, as an island nation with significant research centres and resources, is very well-placed to harness these innovation opportunities to further the work of the ocean science community. In this context, the decision of the APPG to carry out an inquiry into the future of ocean technology is particularly timely.

Whilst significant technological progress is being made, it is important to note, as highlighted by the Plymouth Marine Laboratory in their inquiry response, that *"we can only manage what we can measure and understand, so future ocean technologies must probe further and deeper than traditional technologies have allowed."*[6] The current technology revolution therefore presents an unmissable opportunity to address our biggest challenges, *"such as those presented under the impacts of climate change; the biodiversity crisis; and energy and food security concerns"*, by embracing wider

Photo credit: Aaron Burden/Unsplash

3 Written evidence submitted by the National Oceanography Centre, July 2023

4 Written evidence submitted by the Society for Maritime Industries, July 2023

5 Ibid

6 Written evidence submitted by the Plymouth Marine Laboratory, July 2023

advancements in technology and engineering and deploying them within marine environments.[7]

Yet, the harnessing of such revolutionary technology does not come without its challenges and concerns. The UK Hydrographic Office notes that the ocean is still primarily *"an unknown frontier"* and technology is still not in a developed enough position to overcome the *"obvious reality that the ocean is vast, deep and always evolving."*[8] In order for any revolution in technology to be successful, it must be nurtured to succeed and bring about a truly sustainable future for the blue economy.

Therefore, this inquiry focussed on the five key areas of *"big data, autonomy, renewables, carbon capture and storage, and blue carbon",* as defined by the National Oceanography Centre, which are leading to developments in ocean technology and *"are actively changing and shaping the landscape of ocean research."*[9] The inquiry examined current innovation taking place across these key areas, studying examples and case studies of organisations at the forefront of this technological advancement. By considering the current landscape, the APPG is able to showcase some of the benefits and significant progress being made in this space. As well as identifying these benefits, the inquiry also considered the barriers that continue to negatively impact efficiency, uptake and progress. If not addressed correctly, these barriers will certainly impact the success and future of ocean technology, and thereby, have significant consequences for the future of the ocean itself, and diminish the UK's current standing as a world-leader in ocean and science innovation. Finally, the inquiry considered next steps and set out the recommendations in this report.

The current UK policy landscape

The UK's historical Marine Science and Technology (MST) policymaking has, until now, been characterised by a lack of focus. Over decades, various bodies have been established and subsequently dissolved, all broadly recommending a need for increased funding and better centralised research co-ordination. The Government's website indicates that the Department for Environment, Food and Rural Affairs (Defra) chairs a Ministerial Marine Science Group[10] which oversees the work of the Marine Science Co-Ordination Committee (MSCC) which is tasked to carry out a UK Marine Science Strategy written in 2010.[11] It is impossible to know, however, exactly what work this might consist of, given that the MSCC itself was dissolved in December of 2022. The last update report to the Ministerial Marine Science Group was written over 10 years ago,[12] suggesting that if the Government is indeed serious about central coordination of its marine science and technology ambitions, they have yet to make a compelling case for how they plan to go about it. Establishing a Minister for the Ocean with a remit to drive a refreshed strategy implemented in coordination between Government, research and industry stakeholders would surely help achieve this much needed focus.

Back in 1965, the Natural Environment Research Council (NERC) was formed with the mission of being the *"driving force for investment"* and is the largest funder of environmental science, which includes marine research, in the UK.[13]. However, in 1969, a review indicated that its intentions had not been

7 Ibid

8 Written evidence submitted by the UK Hydrographic Office, July 2023

9 Written evidence submitted by the National Oceanography Centre, July 2023

10 GOV.UK (2023), *'Ministerial Marine Science Group'*, available at: https://www.gov.uk/government/groups/ministerial-marine-science-group

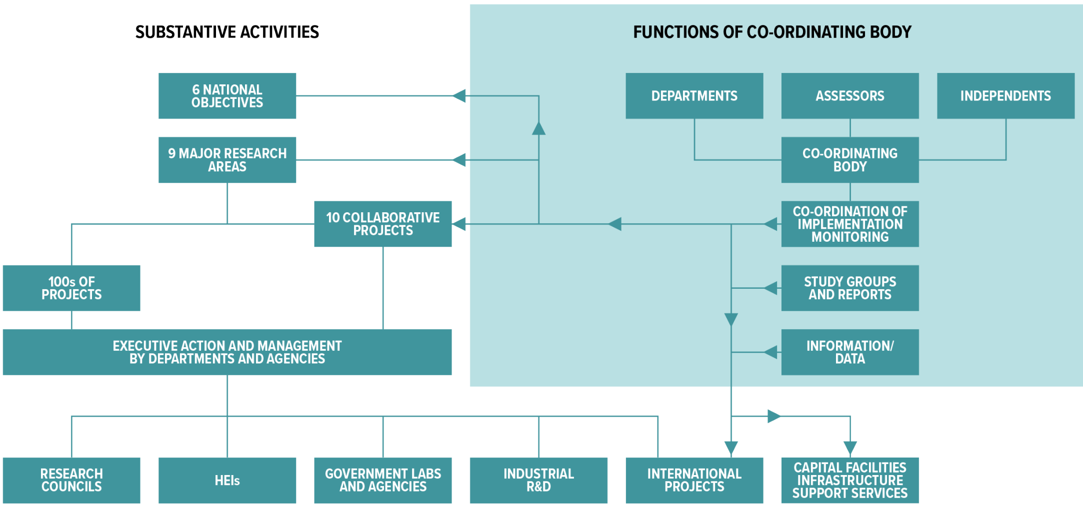
11 GOV.UK (2023), *'UK marine science strategy 2010 to 2025'*, available at: https://www.gov.uk/government/publications/uk-marine-science-strategy-2010-to-2025

12 GOV.UK (2013), *'Update report to the Ministerial Marine Science Group'*, available at: Ministerial-Marine-Science-Group-report-2013.pdf (publishing.service.gov.uk)

13 UKRI (2013), available at: https://www.ukri.org/councils/nerc/

fulfilled, particularly in relation to nature conservation and fisheries.[14] . In 1985, the House of Lords Science and Technology Select Committee conducted a review into MST. Throughout this period, some nine departments had some responsibilities for marine research and the committee asserted that the level of capability of MST in the UK was *"being run down"* almost across the board.[15] As highlighted by Leigh Storey, Associate Director of the Major Programmes Team at the Natural Environment Research Council in his oral evidence to the APPG, a report from this Lords Committee inquiry was published in 1986 and concluded that *"UK Marine research suffers from fragmentation, together with lack of funds"*. It specified that the main consequences of this were *"i) inadequate levels of funding; ii) lack of coordination of the national research effort, iii) absence of a forward-looking strategy as a framework for research; iv) failure to clarify the roles and responsibilities of bodies involve"*. Included in the Committee's total 64 recommendations were calls for increased funding, the establishment of a Marine Board with one of its councils to specifically focus on MST, a national marine strategy, and closer civil-military links.[16] When discussing the report, Committee member Baroness White asked, *"how can we make an intelligent choice when our current organisation for dealing with marine science and technology is so hopelessly fragmented and lacking leadership"*.[17]

Although the Government rejected the call to set up a Marine Board at the time, it did accept that *"a mechanism for greater co-ordination across the breadth of marine science and technology [was] required"*.[18] As such, the Co-ordinating Committee on Marine Science and Technology (CCMST) was established in 1988 *"to provide an essential framework for the basic, strategic and applied research priorities strongly linked to technological developments and industrial needs"*. The CCMST reported back in 1990 before being disbanded the following year. It recommended the framework below for how Government could oversee ocean research in the UK:



19

14 UK Parliament (1999), *'Marine Science and Technology POST 128 Report'*, available at: https://researchbriefings.files.parliament.uk/documents/POST-PN-128/POST-PN-128.pdf

15 UK Parliament (1986), *'Marine Science and Technology: Report'*, available at: https://api.parliament.uk/historic-hansard/lords/1986/apr/07/marine-science-and-technology-report

16 UK Parliament (1986), Lords Chamber debate, *'Marine Science and Technology: Report'*, available at: https://hansard.parliament.uk/Lords/1986-04-07/debates/a55a628e-4717-4e3d-922d-b406e98a237f/MarineScienceAndTechnologyReport

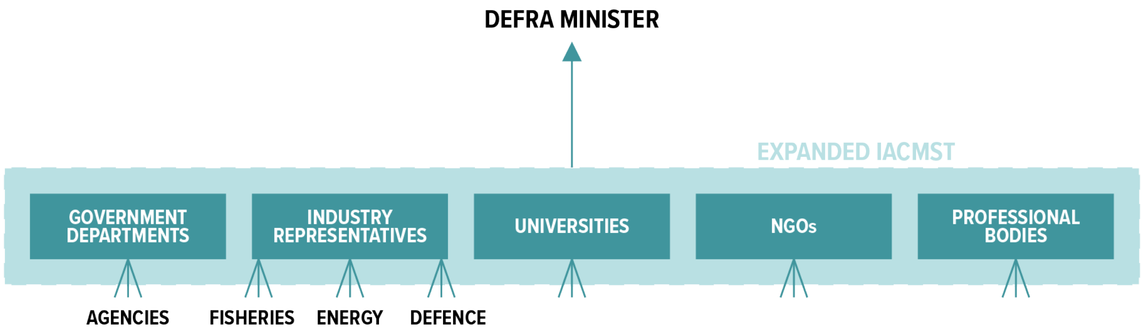
17 UK Parliament (1986), *'Marine Science and Technology: Report'*, available at: https://api.parliament.uk/historic-hansard/lords/1986/apr/07/marine-science-and-technology-report

18 UK Parliament (1986), *'Marine Science and Technology'*, written question, available at: https://hansard.parliament.uk/commons/1986-07-24/debates/6106fe7a-54b0-4c9f-9129-d1ea9ca77a43/MarineScienceAndTechnology

19 Inter-Agency Committee on Marine Science and Technology (2007), *'Investigating the oceans: an IACMST review'*, available at: https://www.foundation.org.uk/getattachment/76cfbed5-e5a8-4da7-bc56-9966b4c351e3/20071120_dalton.pdf

In its first and only report, the CCMST established that MST funding needed to be increased by £20-30 million.[20] Its objectives focused on environmental protection, the exploitation of natural resources, national defence, climate change, statutory sea obligations, and ocean technology. Regarding MST, it specifically argued for the need to develop and maintain a strong innovative industrial effort in order to compete in world markets. A later Science and Technology Committee report in 2007 described this proposal as *"laying the foundations of a comprehensive and coordinated approach to marine science and technology in the UK that would bring together government, academia, and industry"*.

Despite this, the Government in fact decided to narrow both the remit and membership of the body and replaced the CCMST with the Inter-Agency Committee on Marine Science and Technology (IACMST) in 1991. The Science and Technology Committee Review of the IACMST recognised that MST had been long under-served by the complexity of organisations involved in the coordination of funding and research, criticising *"the confusion"* over departmental responsibility for marine co-ordination and recommending that a single body should be created and report to Defra. Later, a 2007 review of IACMST ironically insisted that we *"cannot afford to go round the loop of the last 20 years again"* and recommended the below updated structure, with Defra Ministers having ultimate responsibility in overseeing MST:



Source[21]

The IACMST was replaced by the Marine Science Co-Ordination Committee (MSCC) in 2008, which itself was subsequently dissolved. While Defra notes on the Government's MSCC website that it remains *"committed to the coordination of marine science and to have a strong working relationship with the marine science community"*,[22] it is not clear how this is meant to be achieved, nor why its *"new approach"* which will involve teams *"focussed on marine science within government working alongside external advisory groups"* is likely to be any more effective than what came before it. As highlighted in this section, the number of different bodies that have been established and dissolved over the last 50 years has made it difficult to formulate a clear strategy for ocean technology.

20 House of Commons Science and Technology Committee (2006-7), *'Investigating the Oceans'*, available at: https://publications.parliament.uk/pa/cm200607/cmselect/cmsctech/470/470i.pdf

21 Inter-Agency Committee on Marine Science and Technology (2007), *'Investigating the oceans: an IACMST review'*, available at: https://www.foundation.org.uk/getattachment/76cfbed5-e5a8-4da7-bc56-9966b4c351e3/20071120_dalton.pdf

22 GOV.UK (2023), *'Marine Science Co-ordination Committee (MSCC)'*, available at: https://www.gov.uk/government/groups/marine-science-co-ordination-committee

Progress in autonomy and marine renewables

Despite the lack of a coherent approach to marine science and technology at a ministerial level, one area where the UK is doing great existing work is in the field of marine renewables, and in offshore wind in particular. A number of responses to the APPG inquiry highlighted that the UK is the world leader in marine renewables and many also emphasised that current policies around offshore wind are highly commendable. For example, the European Marine Energy Centre noted that *"the Government should be applauded for setting a ringfence for tidal stream in AR4 of £20 million and maintaining this into AR5."*[23] (AR4 is the Allocation Round 4 of the UK's Contracts for Difference mechanism. AR4 was held in 2022, AR5 in 2023, and AR6 will be held in 2024). Likewise, the Blue Marine Foundation emphasised how the Offshore Wind Environmental Improvement Package, which is part of the Energy Act 2023 which received Royal Assent in October 2023, has further accelerated offshore wind.[24]

Another field in which Government is continuing to make steady process is ocean autonomy. The Department for Transport (DfT) has already made some welcome commitments to *'smart shipping'*, or autonomous vehicles.[25] In March 2023, the Transport Select Committee also stated that the Department should bring in new legislation to facilitate regulation that would enable companies to adopt remote-controlled vessels and autonomous ships to help them navigate and to assist crew. The Committee has made it clear that it wishes to provide the industry with greater certainty. The Chair, Iain Stewart MP, commented: *"like shore-side power, smart shipping technology will be crucial to ensuring the UK's sector can compete with the world*".[26] Similarly, the Government Office for Science highlighted in its *Foresight Future of the Sea* in 2018 that autonomy is, and will be, the *"single most important marine technological development".*[27]

The Maritime 2050 strategy (January 2019) and The Clean Maritime Plan, (June 2019) both produced by the Department for Transport (DfT), have set out the Government's ambitions for the maritime sector, with varying degrees of focus on modernising the industry and meeting net zero targets. The sixth section of Maritime 2050 looks at technology and explains that smart shipping will make the sector cleaner and safer; technology will create new high-skilled job opportunities; big data and AI will cut costs; and 3D printing could lead to a *'post-container'* society.[28] At the time of publication, Associate Director of NOC Innovations, Huw Gullick commented in the Transport Select Committee*'s press release on the Committee'*s report on the Government's Maritime 2050 strategy, that in order to "*take the industry forward*" regulation must "*catch up*" to drive ocean autonomy into its next stage.[29] The

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23 Offshore Energy (2023), *'UK government halves ring-fenced support for tidal energy in next renewables auction'*, available at: https://www.offshore-energy.biz/uk-government-halves-ring-fenced-support-for-tidal-energy-in-next-renewables-auction/

24 GOV.UK (2023), *'Energy Security Bill factsheet: Offshore wind environmental improvement package'*, available at: https://www.gov.uk/government/publications/energy-security-bill-factsheets/energy-security-bill-factsheet-offshore-wind-environmental-improvement-package

25 House of Commons Transport Committee (2023), *'Maritime 2050'*, available at: https://committees.parliament.uk/publications/34426/documents/189604/default/

26 UK Parliament Transport Committee (2023), *'DfT promises to sort muddle of maritime policies in response to major Transport Committee report'*, available at: https://committees.parliament.uk/committee/153/transport-committee/news/195900/dft-promises-to-sort-muddle-of-maritime-policies-in-response-to-major-transport-committee-report/

27 Government Office for Science (2018), *'Foresight Future of the Sea: A Report from the Government Chief Scientific Advisor'*, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/706956/foresight-future-of-the-sea-report.pdf

28 Department for Transport (2023), *'Maritime 2050: Navigating the Future'*, available at: https://assets.publishing.service.gov.uk/media/5e6a248786650c7272f4c59d/Maritime_2050_Report.pdf

29 UK Parliament Transport Committee (2023), *'Government should invest in maritime tech, cleaner fuels and workforce, Transport Committee says'*, available at: https://committees.parliament.uk/work/6555/maritime-2050-objectives-implementation-and-effects/news/194252/government-should-invest-in-maritime-tech-cleaner-fuels-and-workforce-transport-committee-says/

Clean Maritime Plan – which has been endorsed by the Chamber of Shipping, the Smart Green Shipping Alliance and the Institute of Marine Engineering, Science & Technology (IMarEST) – includes a plan for conversion technologies to transform energy sources, such as wind and solar, into forms of propulsion.[30] *It says that "the Government will also support clean maritime projects through its Transport Technology Research Innovation Grant (T-TRIG) programme"*.[31] Generally, UK policy in this area has made progress in recent years, in regards to certain types of renewables and other areas. There has also been greater acknowledgement from certain government departments of the benefits of autonomous technologies. However, more must be done across government to nurture the development of ocean technologies.

International Policy Context

No marine policy, including technological development, operates in a vacuum. At the UN Biodiversity Conference (COP15) in Montreal in 2022, the UK and roughly 190 other nations proudly signed up to the 30x30 agreement to protect 30% of the ocean by 2030. Moreover, the UN's Intergovernmental Conference's Treaty on Marine Biodiversity of Areas Beyond National Jurisdiction, also known as *"the High Seas Treaty"*, of which the UK has been a key leader in the last decade of negotiations, was signed in June this year and similarly made ocean protection and restoration a priority. The Treaty specifically recognises that *"the development and transfer of marine technology are essential"*.[32] International collaboration is also encouraging consideration of what our future ocean might look like. The G7 Future Seas Initiative, which the UK is a part of, has begun to look at new technologies such as digital twinning, which will become a crucial tool in future ocean mapping.

Finally, the international arena also provides space for comparison. The House of Lords Science and Technology Select Committee's 1986 report argued that *"it is undoubtedly true that the sheer level of funding for marine science and technology in this country, when measured against any of the international comparisons that have been made by this committee, is totally inadequate"*. Overall, it is fair to say that the previous policy landscape has failed to keep pace with technological advances in the ocean sector, particularly when compared to the international stage. However, international collaboration and the ongoing forward-thinking work of UK Government departments such as Defra and DfT suggest that significant technological progress is now being understood and considered by governments across the world.

30 Department for Transport (2023), *'Maritime 2050: Navigating the Future'*, Clean Maritime Plan, available at: https://assets.publishing.service.gov.uk/media/5d24a96fe5274a2f9d175693/clean-maritime-plan.pdf

31 ibid

32 United Nations General Assembly (2023), *'Draft agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction'*, available at: https://www.un.org/bbnj/sites/www.un.org.bbnj/files/draft_agreement_advanced_unedited_for_posting_v1.pdf

Emerging ocean technology solutions

Big Data

One major area that has seen significant and rapid technological progress in recent years is the ability to collect and observe different types of data. The ocean is a complex ecosystem and it is constantly evolving and not easily accessible, particularly when it comes to the deep sea. It requires a number of observation systems required to work in harmony, from satellite to underwater vehicles, to buoys and gliders, in order to create a full a picture as possible of the day-to-day workings of the ocean and its continuous and cyclical changes. Within data observation technologies, *'big data'* has come to the forefront and has been cited as the *"saviour"* of the ocean, due to the exponential growth of information technology and advances in ocean observatories.[33] Though there are few formal definitions of big data, there is a general perception that it is a blanket term for *" a large volume of information generated from complex and multiple data sources, which cannot be handled, analysed, stored, and shared with common tools."*[34] This is a particularly useful term when considering living environments such as the ocean, which covers 71% of the Earth's surface. The submission made by the National Oceanography Centre states *"we are now collecting more data on the ocean than ever before"*.[35]

The growth in big data is well reflected in new abilities to measure the growing impact of climate change. Although, the ocean is a very efficient carbon sink, it is also affected by climate change through ocean warming, acidification and de-oxygenation.[36] The Society of Maritime Industries submission notes that *"the technological revolution in ocean observation and measurement is playing a vital role in delivering the data, information and knowledge needed to inform this profound transition of the ocean economy in response to climate change."*[37] New ocean technologies are supplying much of the data, information and knowledge needed to inform adaptation, through their vital contribution to improved oceanographic, weather and climate prediction. Ocean technologies can also help in monitoring oceanic carbon sequestration, changes in sea temperatures and acidity levels, all of which can be used to measure the impact of our warming climate on the ocean.[38] Forecasting a range of possible future scenarios requires reliable data models to predict short and long-term impacts of climate change, which in turn require large datasets. Autonomous and robotic platforms can collect these vast datasets, thereby enhancing modelling and forecasting capabilities to measure and build the information required to mitigate and adapt to climate change.

For example, the rising temperature of the ocean over the last year has been widely documented. A recent article in The Guardian highlighted that in July 2023, the surface ocean temperature around the Florida Keys in the US soared to 101.19F (38.43C), which was a potential global record, highlighting the unprecedented extremes of rising ocean temperatures and compared them to that of a jacuzzi or

33 The Hill (2022), *'Can big data save the ocean?'*, available at: https://thehill.com/opinion/energy-environment/3766008-can-big-data-save-the-ocean/

34 *ICES Journal of Marine Science*, Volume 79, Issue 4, May 2022, Pages 975–986, https://doi.org/10.1093/icesjms/fsac059

35 Written evidence submitted by the National Oceanography Centre, July 2023

36 Written evidence submitted by the Society for Maritime Industries, July 2023

37 Ibid

38 Ibid

hot tub.[39] These temperatures were recorded by a water temperature buoy located in the waters off Manatee Bay at the Everglades National Park, according to US government data. Thus, the recording of such crucial, headline-making findings, which highlight the extremities of the climate crisis, would not be possible without advanced data capabilities.

The collection of such large datasets and its benefits are only now possible due to emerging technologies. A number of responses, including submissions from the Blue Marine Foundation, British Antarctic Survey, the Society for Underwater Technology, maritime surveillance company Sirius Insight and Plymouth Marine Laboratory highlight the importance of sensor and satellite technology in furthering ocean data monitoring. Professor Matthew Palmer of the Plymouth Marine Laboratory noted in his oral evidence that there is huge potential for sensor technology, which has grown both in terms of its diversity and its methods. His view is that this *'revolution'* is most evident in the *"rapid growth of data that comes from all of these, and other available technologies."*[40] Ocean sensors allow scientists to *"take high-quality, real-time measurements in remote parts of the ocean to better understand the world beneath the ocean surfaces."*[41] Oceanographic sensors can be adapted to measure a range of different metrics, such as *"light, temperature, sound, mass, or chemical species"*.[42] The rapid growth of sensor technology can be seen clearly in the development of different types of satellite and hyperspectral imagery. As defined by the marine conservation charity, the Blue Marine Foundation, satellites are simply machines that *"orbit the earth with sensors built in/attached."* Different types of satellites can vary, with differing sensors, spatial resolution abilities and speed, meaning there is no *'one-size-fits all'* approach within ocean technology. Satellites can support a number of different kinds of sensors, including hyperspectral imagery (a technique that processes images and information across the electromagnetic spectrum), sonar (sound), infrared, Synthetic Aperture Radar (SAR) and Light Detection and Ranging (Lidar) sensors, to name a few[43]. The most common use for satellite imagery in ocean habitats is to map and monitor changes in key ecosystems, in particular in mangroves, kelp and coral reefs. As outlined in the APPG's previous report into blue carbon solutions, these habitats are crucial to absorbing excess carbon in the atmosphere and so the measuring of changes in these ecosystems is vital for greater mitigation of climate change.

Satellite technology has progressed rapidly since the advent of Earth Observation satellites in the late 1970s.[44] Currently the collection of space-borne sensors measure a large range of oceanographic variables, including surface temperature, chlorophyll concentration and flow.[45] The British Antarctic Survey notes that *"continuity of satellite missions is vital"*, although measurements typically *"do not extend to the ocean interior",* meaning while they are not a replacement for ships and other vessels in ocean research, they can act alongside them.[46] In fact, sensor/satellite technology and big data is essential to ensuring a sustainable future for the UK ship and marine industry. The British Antarctic Survey raise that improved technology will mean that ship time could be optimised to encourage *"collaborative efforts and more streamlined approach to using fleets and deciding voyages, with onboard sensors being able to carry out increased monitoring work."* As this technology is further developed over the next decade, it will help reduce the carbon impact of research activities.

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39 The Guardian (2023), *'Florida ocean records 'unprecedented'* temperatures similar to a hot tub', available at: https://www.theguardian.com/us-news/2023/jul/25/florida-ocean-temperatures-hot-tub-extreme-weather

40 Oral evidence from Professor Matthew Palmer, Plymouth Marine Laboratory Lead for Environmental Digital Science, June 2023

41 Written evidence from the Blue Marine Foundation, July 2023

42 Ibid

43 Written evidence from the Blue Marine Foundation, July 2023

44 Written evidence submitted by The British Antarctic Survey, July 2023

45 Ibid

46 Ibid

Case study
Lidar mapping

Conservation non-profit Beneath the Waves[47] have teamed up with geographic information system (GIS) company Hexagon[48] and the Bahamian Government to put lidar to use in mapping sea grass meadows. With the help of AI mapping tools and satellite imagery, the lidar data was used to provide essential information on the meadows' carbon stocks, which are essential carbon sinks.

Photo credit: Benjamin L. Jones/Unsplash

Sonar Mapping is a technique to map the seafloor and subseafloor with sound waves.[49] Due to the seabed being the largest pool of carbon stock in the world, sonar technology has been *"utilised to map seabed sediment and estimate carbon stocks, particularly by measuring the changing nature of seagrass"*.[50] Scientists primarily use sonar to collect the necessary data to develop *"nautical charts, locate underwater hazards to navigation, search for objects impacting the seafloor like shipwrecks, and seabed mapping"*[51]. Sonar is effective in oceanography as sound waves travel farther in the water than radar and light waves can.[52]

47 Beneath the Waves (2023), available at: https://beneaththewaves.org/

48 Hexagon (2023), available at: https://hexagon.com/company/divisions/safety-infrastructure-geospatial

49 Written evidence from the Blue Marine Foundation, July 2023

50 Ibid

51 Ibid

52 NOAA Ocean Exploration (2023), available at: https://oceanexplorer.noaa.gov/technology/sonar/sonar.html

Case study
SWOT Satellite

The SWOT Satellite, launched by NASA and the National Centre for Space Studies, in partnership with the Canadian and UK space agencies, is a satellite designed to survey 90% of the Earth's surface, revolutionising the collection of Earth observation data. This data is vital for improving climate forecasting and weather patterns, as well as mitigating flood risks. SWOT-UK, co-led by the National Oceanography Centre, will spearhead this big data approach in the UK, covering the Bristol Channel and Severn estuary in partnership with the National Environment Research Council. The UK Space Agency has also provided £12 million of funding to US tech firm Honeywell, in order to route frequencies around the satellite which were previously unreachable.

Photo credit: Space X/Unsplash

In their submission to the inquiry, the UK Hydrographic Office, a *"world-leading centre for hydrography"* which specialises in data collection and analysis on ocean activity, acknowledges the effectiveness of *'high resolution optical and SAR satellites'*, which have been developed to include remote sensing features so data can be gathered quickly globally , which allows for better scientific collaboration and data sharing.[53] This technology is therefore particularly useful for monitoring and *"tracking the UK's*

53 Written evidence from The UK Hydrographic Office, July 2023

number of maritime research ships which are constantly out at sea".[54] Moreover, satellite data can be particularly valuable for informing responses to natural disasters as SAR can still collect data in spite of extreme weather conditions, while also operating at night. This allows for instant insight and can therefore be used to detect changing conditions that might impact the safe passage of rescue vessels. However, the UK Hydrographic Office does note *"this form of data collection is not yet sufficiently advanced to be the solution to mapping the remaining 75% of uncharted ocean."*[55] It is crucial to note the limits of current available technology when considering this *'revolution.'*

Furthermore, the Blue Marine Foundation identifies a number of other technologies allowing for more efficient seabed mapping - lidar, sonar and hyperspectral imagery. Lidar is a *"method of mapping the seabed using a pulsed laser to measure distances and create accurate 3D maps of the ocean floor"*.[56] The main use for lidar is in the mapping of the makeup of ocean habitats by measuring above ground or seafloor vegetation[57]. This is particularly beneficial as vegetation factors, like plant height and biomass, are important data points when estimating and measuring the ocean's carbon stocks.[58] Various lidar technology companies and projects have worked to map and subsequently estimate carbon stocks in *'mangroves, seagrass, tidal marsh, kelp and coral reefs'*, which are crucial natural blue carbon indicators for climate change.

Case study
Sonar technology

The Save Posidonia Project[59] *used a combination of sonar, drone technology, and SCUBA imagery to locate and monitor sea grass meadows in Ibiza. This data has been used to develop a sustainable tourism app to divert boats in the Mediterranean from anchoring on and potentially damaging the Posidonia Meadows, which are essential blue carbon solutions.*

The Blue Marine Foundation also highlights hyperspectral imagery as another *"developing technology which can capture information beyond the visibility of the human eye"*.[60] Hyperspectral sensors are deployed in a variety of ways, both above surface, by vessel, aeroplane or satellite, and subsurface, hand held by scuba divers, or Autonomous Underwater Vehicles. Hyperspectral imaging is particularly effective in identifying vegetation species and health. Vegetation species are identified by their *"spectral signatures"*, which can be measured in the way their structure interacts with light. Further information such as plant health, chlorophyll content and water content can also be captured by analysing these patterns.[61] The power of hyperspectral imagery also extends to species identification. The Whale and Dolphin Conservation charity highlight in their submission that traditional research methods (e.g. ships) are limited in geographical scope and often give imprecise estimates. Hence, little is known about the impact of human activity on cetaceans, which include whales, dolphins and porpoises. According to Whale and Dolphin Conservation, quantifying this impact is difficult, with most recent *"global calculations of cetaceans dying in fishing nets annually (300,000 p.a) being out of date and likely underestimated."*[62] However, new sensor technology can revolutionise this research and aid conservation efforts, as the use of such imagery can help *"track*

54 Ibid

55 Ibid

56 Written evidence from the Blue Marine Foundation, July 2023

57 Ibid

58 Ibid

59 Save Posidonia Project (2023), available at: https://www.saveposidoniaproject.org/en/

60 Written evidence from the Blue Marine Foundation, July 2023

61 Ibid

62 Written evidence submitted by The Whale and Dolphin Conservation, July 2023

cetacean migration, changes in abundance, distribution, routes, and patterns of behaviour".[63] Additionally, The Marine Conservation Society have long advocated for the introduction of Remote Electronic Monitoring on fishing vessels. This would transform our knowledge of fishing effort and catch, so enabling more sustainable quota allocations and better regulation of fisheries.[64] This would also allow scientists and governments to identify those responsible for unsustainable and illegal fishing activities, which continue to pose a major threat to marine life.

Looking to the future, should data collection continue to progress at such a rapid pace and high quality, a *"digital twin of the ocean"*[65] could be created, which would firmly revolutionise how ocean scientists and researchers observe and study the ocean. A digital twin is a *"realistic digital representation of a physical object or system that uses real-world data to monitor, simulate and predict behaviour."*[66] For the ocean, this would provide the ability to answer questions and provider greater certainty, vital when informing policy makers. In a practical sense, this could for example include the sitting of windfarms in the most appropriate location based on live big data feeds which will be developed as part of these *'real'* environments. Given these benefits, there is a growing effort among the ocean science community to make significant development progress in this area. The National Oceanography Centre in particular is supporting and leading much of the UK's work. Much has been done in recent months, including by the National Oceanography Centre, to consider next stages of digital twin development. A key societal aim, and a driving factor in the development of a digital twin ocean, is to *"predict how the physical and chemical ocean and its biological marine life will respond to climate change, how that response might alter its effectiveness in storage and sequestration of carbon, and the subsequent impacts on our society."*[67]

Autonomy

In order to deliver digital innovation, which as outlined in the previous chapter, is essential to any kind of technological revolution in the ocean space, greater autonomy is necessary. In this context, autonomy refers to unmanned vessels, otherwise known as *'Marine Autonomous Systems'* (MAS) which are transforming underwater operations. Ocean technology is now increasingly moving to such remotely-piloted vehicles,[68] which are delivering important knowledge in the race against climate change. The use of marine autonomy to collect data, provide environmental monitoring and measure the impact of activity in the ocean space, is therefore hugely significant. Despite the huge potential of autonomous technology, much more development and scale is still needed. The theme of autonomy was previously highlighted by the Government Office for Science, which set out that *"autonomy is likely to be the single most important marine technological development"*, bringing with it a range of challenges, including a need for *"better sensors, improved battery technology, electric propulsion technology, data transfer and inter-device connectivity"*[69].

The potential for autonomy is perhaps clearest in the development of MAS. Examples of MAS include satellites, gliders and auto submarines. These vehicles can work together to transmit large amounts of

63 Ibid

64 Written evidence submitted by The Marine Conservation Society, July 2023

65 Written evidence submitted by The National Oceanography Centre, July 2023

66 Ibid

67 Written evidence submitted by the Society for Maritime Industries, July 2023

68 Written evidence from British Antarctic Survey, July 2023

69 Government Office for Science (2017), *'Foresight Future of the Sea: Industry perspectives on Emerging Technology'*, available at: https://www.gov.uk/government/publications/future-of-the-sea-industry-perspectives-on-emerging-technology, [quoted in Government Office for Science, *"Foresight Future of the Sea: A Report from the Government Chief Scientific Adviser"*, 2018, pg 13]

data in near real-time, allowing scientists to accurately monitor and effectively tackle risks posed to the marine environment. In recent years, this technology has become more advanced and these vehicles are now capable of underwater surveillance duties.[70] These newer vessels have a range of capabilities.

The most well-known examples of MAS are Autonomous Underwater Vehicles (AUVs). AUVs are robot submarines, which are used to explore the world's oceans without a pilot or any tether. The National Oceanography Centre developed the UK's first AUV, Autosub-1, more than 25 years ago and since then, have developed a range of AUVs. These include Autosub 5 and Autosub Long Range, which can travel more than 10 times the distance of previous vessels. AUVs can reach distances and depths which cannot be reached by ship, *"exploring depths of up to or more than 6000 metres, with the ability to travel 95% of the ocean"*.[71] Perhaps the UK's most well-known AUV is *'Boaty McBoatface'*, famously awarded the name after a public vote. Autosubs used by the National Oceanography Centre can also collect data from remote parts of the ocean, and have a huge range of applications within the commercial sector – surveying *"disused oil and gas fields, monitoring Marine Protected Areas (MPAs), servicing wind turbines, or monitoring undersea cables",* which carry 95% of all internet traffic and financial transactions.[72] Furthermore, the National Oceanography Centre also has a fleet of around 40 gliders. These are smaller underwater robotic vehicles which can be used to measure a number of key ocean parameters crucial to building a strong database of the ocean, such as chlorophyll levels, temperature and salinity, which are then used for data analysis.[73]

Collectively, MAS are delivering important knowledge of the critical climatic and environmental changes occurring at the ocean/atmosphere boundary and in the ocean interior, especially concerning physical variables such as ocean temperature and salinity, but increasingly others such as carbon and Environmental DNA. The British Antarctic Survey , alongside national and international collaborators, are delivering much of this capability in the Southern Ocean around Antarctica, a key region experiencing extensive global climate and ecological impact.

Case study
The ARGO Network

The Global Argo Network is an integrated international effort to survey the world's oceans. Launched in 2000, its 3500 free-drifting floats are the catalyst for an exponential increase in knowledge concerning the Ocean's role in climate and weather forecasting. As part of this effort, new Biochemical (BCG) floats have been developed in order to significantly enhance the measurement capacity of the network, particularly in regard to ocean temperature and sea level rises. Work in the UK, led by the National Oceanography Centre and the British Antarctic Survey, is a critical and world-leading part of the global effort to deploy this technology. Fifteen floats were deployed in 2022 - the largest deployment of BGC floats to date. This technology, and the UK's role within its deployment, is testament to the UK's world leading potential in Oceanographic Climate Science.

70 Written evidence submitted by The National Oceanography Centre, July 2023

71 The National Oceanography Centre (2023), *'Autosubs'*, available at: https://noc.ac.uk/facilities/marine-autonomous-robotic-systems/autosubs

72 Ibid

73 The National Oceanography Centre (2023), *'Gliders'*, available at: https://noc.ac.uk/facilities/marine-autonomous-robotic-systems/gliders

Case study
Plymouth Smart Sound

Plymouth Smart Sound[74] *is a multi-million pound marine development platform supporting the design, testing and development of innovative marine products. The platform has over 1,000 square kilometres of authorised and de-conflicted water space that is amongst the most intensely sampled waters on the planet, offering a controlled environment for the meticulous testing of emerging ocean technologies and serving as a 'living laboratory'. This is complemented by fully integrated world-class onshore facilities, connected by a 5G marine communication network. Particularly, the Smart Sound has a focus on testing for autonomous AI controlled vessels. The 'Oceanus' currently in development will be the world's first ever long range AI powered research vessel, whilst the 'Mayflower', the world's first autonomous AI powered vessel was launched from Plymouth last year.*

Autonomy therefore has the potential to create huge opportunities for net zero operations at sea, with often smaller, lighter craft requiring lower power requirements than large vessels requiring a human presence on board. This can help reduce some of the costs associated with large ocean research voyages, as AUVs can stay out at sea for longer periods of time due to them being controlled remotely. It also reduces reliance on oil and other heavy fuels used to power ships. Leigh Storey of the Natural Environment Research Council, who gave oral evidence to the APPG, noted there are currently significant capacity issues within ocean research, but increases in autonomy could allow ships to conduct other types of research and increased autonomous systems could help offset this.[75] That being said, as Dr Helen Czerski, Associate Professor at University College London, highlighted in her oral evidence session with the APPG, the growth in autonomous technology does not remove the need for and importance of research ships and discovery voyages. In order for the ocean to be fully understood, scientists must continue to witness changes first-hand, with new technology on hand to support and process findings.[76]

Another aspect of autonomy which is central when considering the ocean technology revolution is the increased role of Artificial Intelligence (AI). The growth and potential of AI technology is well-documented. The UK's AI industry is thriving, employing over 50,000 people and contributing £3.7 billion to the economy last year.[77] Britain is home to twice as many companies providing AI products and services than any other European country and hundreds more are created each year.[78] Earlier this year, the Government launched the whitepaper *"AI regulation: a pro-innovation approach"* on the use of AI in the UK, to drive responsible innovation and maintain public trust in this revolutionary technology.[79] Professor Matthew Palmer stated in his evidence that when it comes to ocean science, AI is therefore a *"necessity not a choice."*[80] Evidence from the Plymouth Marine Laboratory outlines that realising the complexity of marine systems requires *"equally complex computational and software solutions."*[81] As

74 Written evidence submitted by Tim Fileman, Head of the Centre for Coastal Technologies at PML Applications Ltd, July 2023

75 Oral evidence from Leigh Storey, Associate Director, Major Programmes Team at the Natural Environment Research Council, July 2023

76 Oral evidence from Dr Helen Czerski, British physicist and oceanographer and Associate Professor at University College London, July 2023

77 GOV.UK (2023), *'AI regulation: a pro-innovation approach'*, available at: https://www.gov.uk/government/publications/ai-regulation-a-pro-innovation-approach

78 Ibid

79 Ibid

80 Oral evidence from Professor Matthew Palmer, June 2023

81 Written evidence from Plymouth Marine Laboratory, July 2023

ability to generate data grows so do the complexities of downscaling big data into more digestible and easy to use formats. AI thus presents opportunities to not just digest and analyse such data, but to provide more accessible platforms for a range of stakeholders and the public, ensuring better data transparency through greater access to information, which will help build coastal communities' connections with the sea. When considering the huge potential of AI, Professor Palmer gave members of the APPG an analogy of imagining a *"ChatGPT type tool that helps ocean scientists, policy makers, marine managers and coastal communities better understand what the ocean means to them, how they can better protect the ocean or sustainably manage their marine resources."*[82] Thus, future technology has the revolutionary potential to ensure further collaboration between industry and governments.

The Society for Maritime Industries response also notes that *"AI and software will certainly play a leading role in the development, maintenance and optimisation of ocean technologies."* For example, the Society for Maritime Industries highlights that AI has lots of applications within ocean technology and can be used to *"optimise the performance of wind farms, marine and tidal energy convertors."*[83] AI provides new tools that can hold significant amounts of data over large areas, such as floating or fixed wind turbines. This can then be used for analysing the environmental data required for offshore energy construction and operation. Importantly, as the Society for Maritime Industries notes, ocean technology AI is one of the few areas where these techniques can be *"additive rather than replacing existing methodologies."*[84] AI can enable greater predictive work, data analysis and monitoring. As emphasised by the UK Hydrographic Office, AI can take on much of the burden of data collection carried out by scientists. If perfected, AI can ensure *"that 24 hrs a day, 365 days a year, data can be continually collected by autonomous vessels at sea."*[85] This will revolutionise oceanography, marine conservation, climate studies, and renewable energy production.

Case study
Sirius Insight

Founded in 2016, Sirius Insight is a company that offers cost-effective and scalable AI driven solutions to modern maritime challenges such as maritime situational awareness and security. It is the only company of its kind globally. Maritime Surveillance AI allows for the swift and autonomous fusion of analysis and data from a wide array of sources and sensors, allowing for a comprehensive and un-interrupted maritime picture, at a fraction of the cost of patrolling. Such surveillance capabilities have a wide-ranging potential for defence and security, particularly with regard to critical national maritime infrastructure, allowing for constant and intelligent surveillance of off-shore wind farms, subsea pipelines and overseas cables. Furthermore, the technology has the capacity to detect vessel emissions, as well as ring-fencing protected maritime areas, allowing for a significant ecological utility.

82 Oral evidence from Professor Matthew Palmer, June 2023

83 Written evidence submitted by the Society for Maritime Industries, July 2023

84 Ibid

85 Written evidence by the UK Hydrographic Office, July 2023

Marine Renewables

The ocean sits at the centre of climate solutions, including new sources of clean energy. Otherwise known as marine renewables, this energy is created from the natural movement of water, encompassing waves, tides, and river and ocean currents. If harnessed correctly, marine renewables offer a long-term and sustainable alternative energy source to polluting fuels. If the UK hopes to meet ambitious net zero by 2050 targets, harnessing the power of marine technologies will be essential. New ocean technologies are therefore playing a vital role in mitigating the effects of climate change through decarbonisation, for example in the rapid development of offshore renewable energy. In their evidence, the Society for Underwater Technology states *"the rapid growth of the offshore renewable energy sector is an excellent example of the effectiveness of emerging sustainable ocean technologies."*[86]

The three main examples of marine renewable energy are offshore wind, tidal and wave technologies. Harnessing energy from these ocean technologies is being increasingly considered by a number of countries, from several small island development states to larger economies – such as the US, China and the UK. The National Oceanography Centre emphasises that *"the UK has some of the best natural resources in the world in the form of wind, wave and tidal power and we need to continually strive for the technology to harness these."*[87] For the renewables sector to succeed in this global challenge, new innovations and the scaling up of existing technologies will be key to driving the sector forward.

Responses noted that the potential to harness tidal and wave energy has improved rapidly. The European Marine Energy Centre's response highlighted the rapid development of marine renewable technologies. They operate the only accredited wave and tidal test centre for marine renewable energy in the world, which is based in Scotland. In particular, the European Marine Energy Centre highlights that *"the UK has a world lead in the deployment of tidal energy and is believed to have some 11GW of generating capacity in its waters."*[88] It is estimated that there are 100 Gigawatts of tidal energy available worldwide, meaning the UK possesses a sizeable amount of this energy power. Wave energy is the world's *"largest untapped source of energy"* with the Intergovernmental Panel on Climate Change (IPCC) estimating that the potential annual global production at 29,500 tidal watts per hour (Twh), which could provide clean electricity for over 500 million homes.[89] A written response from Wave Energy Scotland notes that the UK's Exclusive Economic Zone provides us with a *"large area of ocean suitable to produce electricity for the grid from wave energy devices."*[90] The wave energy technology currently being developed by Wave Energy Scotland, as instructed by the Scottish Government, could provide up to 20% of the UK's electricity demand by 2050, in line with net zero targets. Hence, the UK Marine Energy Council states in their response that *"the UK is currently the world-leader in marine renewables."*[91] Despite attempts to harness the powers of tidal energy, the industry largely stalled in 2018 when government support was withdrawn, with the Department for Business, Energy and Industrial Strategy rejecting proposals for a tidal energy scheme in Wales in 2018 due to it being deemed as too costly, which was criticised by the energy sector as a *"huge mistake"*[92]. However, with two devices being installed in Orkney in Scotland last year, there is renewed support for tidal technology.

86 Written evidence from the Society for Underwater Technology, July 2023

87 Written evidence from the National Oceanography Centre, July 2023

88 Written evidence provided by The European Marine Energy Centre, July 2023

89 Ibid

90 Written evidence from Wave Energy Scotland, July 2023

91 Written evidence provided by the UK Marine Energy Council, July 2023

92 The Guardian (2018), '*'Huge mistake'*: Britain throwing away lead in tidal energy, say developers', available at: https://www.theguardian.com/environment/2018/jun/19/huge-mistake-britain-throwing-away-lead-in-tidal-energy-say-developers

Case study
Orbital Marine Power's O2 in Orkney

Manufactured in Dundee and then installed in Orkney in 2021, Orbital Marine Power's O2 is the world's most powerful tidal turbine. The 74m long turbine is expected to operate in the waters off Orkney for the next 15 years with the capacity to meet the annual electricity demand of around 2,000 UK homes and is powered by grid connection at the European Marine Energy Centre. The project has led to the creation of green jobs throughout both the construction and operation of the site and is estimated to have contributed £370 million (GVA) to the UK economy, 71% of which was accrued in Scotland, thus providing both high national returns and sustainable, regional growth.

Photo credit: Maxwell Andrews/Unsplash

The European Marine Energy Centre outline that marine renewables can also *"have a key role in a secure and cost-effective net zero energy system."*[93] Research by the University of Edinburgh has found that deployment of just under 13 Gigawatts of marine energy will reduce energy costs, with an annual saving of over £1 billion for UK households.[94] This is significant as marine energy emits no carbon, making it one of the most sustainable alternative energy types. According to the European Marine Energy Centre, the manufacturing and deployment of the equipment will be decarbonised due to overall net zero decarbonisation shifts, as will the vessels to be used to deploy and maintain the equipment: marine energy therefore provides a *'non-fossil'* energy source. If this potential is exploited and adequately supported marine energy would therefore be effective in supporting energy security. Tidal stream energy has already provided over 60Gigawatts per hour of clean electricity to the UK energy system.

Furthermore, the UK Marine Energy Council highlights in their response that marine renewables work well with other types of renewable energy, mainly offshore wind. Marine renewables are very effective at decarbonising offshore activity. This is being demonstrated by Mocean's Renewables for Subsea Power (RSP) project. Wave energy can support offshore wind projects, as they operate best in water around wind turbines. With both energy types working in harmony, this can make such projects more cost effective. The Council is therefore advocating for the co-location of these two renewable assets, as *"wave and wind is a clear example of two technologies that when deployed together will deliver mutual benefits to the project developers and make efficient use of network assets. Waves can be harnessed 3-8 hours after the energy*

93 Written evidence provided by The European Marine Energy Centre, July 2023

94 Ibid

is initially harnessed by wind farms."[95] A study by Offshore Wind Consultants found that co-locating wave and wind would reduce total costs for the combined projects by 12%. [96]

Case study
Mocean's Renewables for Subsea Power (RSP) project

Mocean's Renewables for Subsea Power (RSP) project emphasises the payoff from harnessing marine renewables to power underwater technological innovation. By connecting an ocean battery to a wave energy converter produced by Mocean, the demonstration has highlighted the cost-efficiency, reliability, and ease of powering subsea equipment with renewable wave power. The £2million demonstrator project, led by EMEC and WES, have been deployed in the seas off Orkney and have now begun a minimum four-month test programme where they will provide low carbon power and communication to infrastructure such as subsea controls and underwater autonomous vehicles.

In addition, new marine renewables look set to play a vital role in enabling carbon dioxide removal through making possible options for marine carbon capture and storage and marine carbon dioxide removal.[97] While there have been debates over the long term benefits and sustainability of carbon capture projects, a submission from Steve Hall, Fellow of the Institute of Marine Engineering states that *"carbon capture and storage will help buy time to decarbonise the economy"* during this transition period to net zero[98]. The National Oceanography Centre's response outlines that the *"ocean offers huge opportunities to store carbon under the seabed. Technology has a fundamental role to play in making the technology viable, and crucially in identifying carbon leakage."*[99] In 2022, the National Oceanography Centre led a world-first study off the coast of Scotland which showed that any leakage from a carbon storage reservoir can be detected and measured through new ocean technologies[100]. Without these kinds of assurances, which can only be delivered through technology, public support for carbon capture might be reduced.

Case study
Carbon capture and leakage

A groundbreaking study by the National Oceanography Centre in 2022 found that carbon storage in the deep ocean may be considerably less permanent than previously assumed, raising questions about the role the ocean may play as a carbon sink in the future. Having found that any leakage of carbon from a storage reservoir could be detectable and quantifiable thanks to new technologies, it is hoped that this North Sea study will form the scientific foundation of public trust in carbon capture as a valuable mitigation technique during the process of decarbonisation.

95 Written evidence from UK Marine Energy Council, July 2023

96 Wave Energy Scotland (2023), *'Wave and Floating Wind Energy: Opportunities for Sharing Infrastructure Services and Supply Chains'*, available at: https://www.waveenergyscotland.co.uk/media/1471/o-lo-r10-031956-r02-final-report.pdf

97 Written evidence from Society for Underwater Technology, July 2023

98 Written submission from Steve Hall (Saltwater Steve), June 2023

99 Written submission by the National Oceanography Centre, July 2023

100 National Oceanography Centre (2022), *'New paper shows potential for safe storage of carbon dioxide offshore'*, available at: https://noc.ac.uk/news/new-paper-shows-potential-safe-storage-carbon-dioxide-offshore

Blue carbon solutions

When considering the rapid development of ocean technology, it is crucial to consider the role of the ocean itself. As highlighted in the APPG's previous inquiry into blue carbon solutions, discussions on the ocean and climate change can wrongly refer to the ocean as a passive participant. Dr Helen Czerski in her oral evidence highlighted the important role the ocean itself plays in climate mitigation. She stated that the ocean is *"an anatomy made up of component parts."* In this sense, it can be regarded as its own *"physical machine."*[101] For example, the Gulf Atlantic Stream results in pockets of cold water inside warm water and vice versa.[102] The Gulf Stream, which is a warm current in the Atlantic, is a crucial natural temperature monitor, carrying warm water northwards towards the north pole, where it then cools, becomes denser and sinks, and then flows back southwards, a process which is essential to the earth's climate system. These temperature changes are essential to predators choosing where to hunt due to these different ecosystems. The ocean relies on such predictors to maintain vital ecosystems, yet recent research shows a slowdown in Gulf currents due to climate change, which could cause temperatures to rise even further.[103]

Blue carbon and ocean-based solutions thus have a significant role to play in combating climate change. The ocean is the largest carbon sink in the world, absorbing between 25-30% of all carbon dioxide emissions caused by human activity. Without the ecosystem the ocean provides, the Earth would be much warmer than it is at present, as highlighted by the Society for Maritime Industries in their response as *"climate change's biggest moderator by far is the ocean."*[104] Understanding the ocean at a much finer temporal and spatial scale will be critical to modelling uptake of CO2 and other changes. As defined in the APPG's previous report *The Ocean: Turning the Tide on Climate Change*[105], blue carbon, as the name suggests, relates to ocean-based carbon sinks, where-in the ocean plays an active role in providing carbon capture solutions.

Therefore, technology has an important part to play in enhancing ocean solutions. The Blue Marine Foundation response acknowledged that blue carbon ecosystems, such as mangroves, tidal marshes and seagrass habitats, are a recognisable climate change solution, which is exactly why they must be restored and protected. The response noted that several national governments have already included blue carbon ecosystems within their National Determined Contribution, as part of the Paris Climate Agreement.[106] To strengthen these commitments, ecosystems such seagrass meadows and kelp forests, must be better understood. New ocean technology can enable increase in understanding through more effective mapping and monitoring. If this is carried out in the right way, *"technology could enable a new level of investment in marine conservation and restoration projects and provide national governments with a greater understanding of their marine natural capital assets."*[107]

A written response from UK seaweed farming and processing company SeaGrown outlines how technology could enhance blue carbon solutions as *"nature-based technology could transform the levels of sustainable marine biomass (seaweed) being produced in the UK and overseas."*[108] Seaweed farming creates sustainable feedstock for industries such as biodegradable plastics, human food, animal feed and many other novel sectors such as textiles.

101 Oral evidence from Dr Helen Czerski, July 2023

102 Ibid

103 The Guardian (2021), *'Climate crisis: Scientists spot warning signs of Gulf Stream collapse'*, available at: https://www.theguardian.com/environment/2021/aug/05/climate-crisis-scientists-spot-warning-signs-of-gulf-stream-collapse

104 Written evidence submitted by the Society for Maritime Industries, July 2023

105 APPG for the Ocean (2022) *'Parliamentarians call for blue carbon revolution to tackle climate change'*, available at: https://www.oceanappg.org/news-and-updates/parliamentarians-call-for-blue-carbon-revolution-to-tackle-climate-change

106 Written evidence from The Blue Marine Foundation, July 2023

107 Ibid

108 Written evidence from SeaGrown, July 2023

Case study
Seagrown

SeaGrown's specialised seaweed farming technology is boosting the levels of sustainable biomass in our waters. The farming apparatus has allowed seaweed to grow for two consecutive winters in harsh conditions in the North Sea with wave heights of 13m, without the use of any additional water, power, chemicals or land. In addition to offering a habitat for wildlife and various uses in food and textiles, the seaweed then absorbs excess nutrients, nitrogen and, crucially, CO_2 at 2-3 times the rate of onshore woodlands, playing an important role in mitigating climate change.

In order to reach net zero, the quantity of carbon dioxide taken from the atmosphere and stored in natural solutions must increase just as the carbon dioxide emissions must decrease. By protecting and rewilding ecosystems in our ocean, blue carbon stores will have increased capacity and ability to store carbon. New ocean technologies are therefore essential to supporting the protection of marine and blue carbon ecosystems. The inquiry response provided by Scottish aquaculture technology company ACE Aquatec highlights a number of ways technology can support protection and conservation of blue carbon habitats, including through *"coral propagation and replacement activities to boost biodiversity near degraded reefs."*[109] ACE Aquatec note that, in turn, this will *"support, support local ecosystems, bring increased tourism to coastal communities and establish community-led programmes."*[110] Technology is thus revolutionary in the sense it can enhance not just our natural habitats but also our coastal communities, bringing significant tourism and economic opportunities to UK regions.

Photo credit: National Oceanography Centre

109 Written evidence from ACE Aquatec, July 2023

110 Ibid

Case study
ACE Aquatec FaunaGuard

ACE Aquatec's FaunaGuard system protects oceanic wildlife from the risks associated with offshore construction by transmitting patterns of safe levels of underwater sound to deter mammals and fish from the site, creating a temporary exclusion zone to protect animals from physiological harm. Unlike other acoustic deterrent devices (ADDs), FaunaGuard has been designed and tested for specific species, making it kinder and more effective.

Furthermore, technologies such as Environmental DNA (eDNA) monitoring may offer the ability to increase our knowledge of the location and behaviours of marine species, but it is again important to note this technology is very much in the early development stage. eDNA refers to *"DNA released by living things into their environment"*.[111] This encompasses all marine life, from bacteria to whales, and can be found in mucus, faeces, and other material. While DNA can be analysed from other sources, such as soil and air, in marine environments water samples are used. eDNA has the benefits of being *"non-intrusive"*, thereby increasing the chance of collecting data from less seen and shyer organisms.[112] It can be used to *"detect species, monitor changes to biodiversity such as changes to seagrass and kelp blue carbon habitats and in fisheries management"*.[113] eDNA has the potential to be a key part of monitoring Marine Protected Areas.

Case study
Blue Marine Foundation and the Solent

The Blue Marine Foundation's Solent Seascape Project involves monitoring biodiversity using data from eDNA, released by animals and organisms into the surrounding water. This allows any uplift in biodiversity to be quantified and traced, and can be paired with habitat mapping and machine learning to better predict species behaviour and inform the management of ecosystems, including of MPAs.

The National Oceanography Centre highlights that *"blue carbon is an area that is gaining huge amounts of attention – from policy-makers, the science community, commercial organisations and the public too. But this is a controversial and contested space and science is needed to explore the viability and risks of these proposed solutions."*[114] With growing interest in blue carbon on a national and international stage, with it being a key discussion point at COP27 and COP28, a number of large-scale research projects are currently being undertaken. For example, some technology companies are developing projects to extract carbon dioxide from surface water, a process known as 'ocean or marine geoengineering'. Although there is still much research needed in this area, such technologies could have the potential to remove CO2 at the scale required to meet the goals of the Paris Agreement. However, as Dr Helen Czerski [115]rightly highlighted in her oral evidence, the power of the ocean itself must always be protected first and foremost. The APPG is committed to continuing to raise the profile of blue carbon amongst parliamentarians, stakeholders and the wider public and shining a spotlight on this area of research, and what needs to be done to support it.

111 Written evidence by Blue Marine Foundation, July 2023

112 Ibid

113 Ibid

114 Written evidence from the National Oceanography Centre, July 2023

115 Dr Helen Czerski oral evidence, July 2023

Other solutions

Ocean technology also has wider applications, particularly within the transport sector. The decarbonisation of transport is an essential part of achieving net zero, with major industries from aviation and shipping to road vehicles all playing their part in the shift away from diesel fuels. ACE Aquatec emphasise that technology is crucial to ensuring the efficient use of green transport.[116] The European Marine Energy Centre has also diversified their work and research into green hydrogen, which will be important to creating cleaner energy and transport systems.[117]

The maritime sector presently accounts for about 2.8% of all global greenhouse gases emissions, mainly due to its rapid growth, dependence on carbon-intensive bunkers, and the sheer size of its business (more than 80% of world trade by volume is transported by sea).[118] The National Oceanography Centre state that *"alternative fuels for shipping will drive technologies, and the design of ships themselves."*[119] Ocean technology and the objectives of green shipping are intrinsically linked. The National Oceanography Centre are currently trialling the use of HVO fuel (Hydrotreated Vegetable Oil) in their major research ships, with RRS James Cook this autumn, and with the RSS Discovery into 2024/5. Both will help inform future hybrid fuel options for the ships, including their replacement as part of the UK's National Shipbuilding Strategy[120]. The use of shore power facilities will also become essential by allowing ships to *'plug in'* when in berth to take power from the grid rather than use their engines, which will inform the future of greening port cities. However, as the National Oceanography Centre notes in their response, limitations on grid capacity have been highlighted in Southampton, with limits on the number of ships able to plug in at any one time.[121] Infrastructure investment is clearly necessary to develop this further across the UK.

The above examples, which cover more than five major UK industries and areas of infrastructure, therefore highlight the huge benefits and potential of ocean technology. Such technologies are currently transforming our oceans and marine ecosystems. It is the role of industry and governments globally to continue to realise these benefits, both scientifically and economically, whilst recognising and working to overcome any limitations.

116 Written evidence provided by ACE Aquatec, July 2023

117 Written evidence provided by The European Marine Energy Centre, July 2023

118 UNCTAD (2022), *'Roadmap to decarbonize the shipping sector: Technology development, consistent policies and investment in research, development and innovation'*, available at: https://unctad.org/news/transport-newsletter-article-no-99-fourth-quarter-2022#:~:text=The%20maritime%20sector%20presently%20accounts,volume%20is%20transported%20by%20sea).

119 Written evidence from the National Oceanography Centre, July 2023

120 GOV.UK, Ministry of Defence (2022), *'Refresh to the National Shipbuilding Strategy'*, available at: https://www.gov.uk/government/publications/refresh-to-the-national-shipbuilding-strategy

121 Written evidence from the National Oceanography Centre, July 2023

Key challenges

There are several key challenges limiting the development and potential of ocean technologies from being fully realised. The most pressing and significant challenges relate to the limits to research, data and current technology, lack of grants and sustainable funding, the need for international collaboration and a worsening skills shortage combined with a lack of government attention.

Current data and research limits

A potential barrier to new technology in the area of marine science research is risk appetite. In her oral evidence Emma Johnson of the Society for Maritime Industries highlighted that lack of trust around some ocean technologies, in particular AI, has led to concerns around data safety.[122] Public confidence in AI technology remains low and it is clear more must be done to address such concerns. The British Antarctic Survey states that the *"reliability of autonomous technologies remains a key concern for more widespread adoption. It is estimated that only around 50% of current AUV missions are fully successful. Trust in autonomous systems is a bottleneck."*[123] Another risk associated with autonomous platforms is around whether platform data can be fully recovered, particularly during times of technological difficulties, which would prove challenging when trying to study the deep ocean, which is more difficult to access. This kind of data collection also requires high power which current battery capacity cannot cover. The British Antarctic Survey argues that scientists will therefore be naturally cautious to commit to autonomous measurement solutions until they can be guaranteed to produce reliable data, which can then be shared and peer-reviewed. This kind of trust needs to be built over time as part of a planned transitions to MAS, rather than simply enabling MAS provision. In other words, according to British Antarctic Survey the *"if you build it, they will come" approach is not sufficient."*[124]

The current issues around autonomous technology are part of the wider limitations around big data. A number of responses warn that such large datasets are incredibly complex to scale, making it difficult to share. As highlighted above, the lack of current open data sharing platforms available to cope with rapid technological developments is also a limitation to building a full picture of the ocean. The vastness of the ocean itself and its remoteness, make actually acquiring new data a significant concern. Professor Palmer argued that there is a need to reinforce the ethos of *"measure once, use many times"*[125] by promoting good and collaborative data management and strategic investment in future sustainable ocean technologies that meet the need of multiple stakeholders.

Furthermore, another limitation is around the consenting process to undertake ocean research. The European Marine Energy Centre outlines in their response that UK consenting processes are holding back delivery of tidal stream projects. For example, in Scotland the consenting process can take, at a minimum, 4 years, and often longer.[126] Consent is required in order for a research project to be eligible

122 Oral evidence from Emma Johnson, Director of MST and MAS Groups at Society of Maritime Industries, June 2023

123 Written evidence from the British Antarctic Survey, July 2023

124 Ibid

125 This ethos is the title of the Marine Environmental Data and Information Network (MEDIN) business plan for 2019–2024. MEDIN's vision is that all UK marine data is findable, accessible, interoperable and re-usable (FAIR), to increase the understanding of our marine environment and support the sustainable development of the blue economy. The title has been adopted as a label of *'good ethos'* across the ocean research space.

126 Written evidence provided by The European Marine Energy Centre, July 2023

to access grant and revenue support. However currently relatively small-scale marine energy projects are required to go through the same consenting process as large-scale offshore wind farms, despite onshore and offshore projects being two very different project areas. UK consenting agencies also do not have the capacity to respond in a timely manner to applications. EU consenting review approval times are around 3 months, compared to the waiting time of 12 months for the UK. This will have an impact on international competition, as some organisations may look for project approval in Europe instead due to shorter wait times.

Another significant barrier to emerging ocean technologies is the regulatory framework such as that of marine licensing. The current process is considered *"time-consuming, expensive and bureaucratic"*,[127] resulting in applications taking up to 2 years to process, which will make any small to medium sized company's commercial operation extremely challenging. As an example, SeaGrown referenced they are regularly approached by prospective seaweed farmers from all over the UK for assistance in setting up new seaweed farms. However, only a tiny proportion of these approaches ever reach a successful conclusion, largely due to the *"onerous Marine Licensing procedure."*[128] The current Maritime and Coastguard Agency (MCA) Regulations in the UK present a challenge for the operation of newer technologies such as autonomous vessels and AI.[129] These regulations have been designed to *"ensure maritime safety and the specific requirements and characteristics of autonomous technologies"*.[130] To prevent the further spread of uncertainty and frustration around limitations for innovators in the UK, MCA must carry out detailed engagement with industry experts to consider how the necessary deployment of autonomous vessels can work within a regulatory framework which effectively addresses the unique challenges and conditions associated with MAS. In doing so, this can help identify the necessary modifications or new regulations that will *"enable the safe and efficient operation of these advanced maritime systems in UK waters".*[131] This proactive approach will not only foster innovation and attract investment but also ensure that the *"UK remains a leading hub for autonomous technology development and deployment."*[132]

127 Written response from SeaGrown, July 2023

128 Ibid

129 PML Applications written evidence, July 2023

130 Ibid

131 Written evidence by Society of Maritime Industries, July 2023

132 Response from PML Applications, July 2023

Relatedly, an additional identified barrier is *"lock in"*, where established ways of working simply become the norm because they are the ones known to work.[133] Lock-in can be both technological and institutional and acts as a barrier to innovation. For example, scientists or bodies might come to rely on certain technologies as they produce data comparable and easier to share with other countries/groups, or there may be external factors such as scientific or political leaders/experts who might favour more traditional approaches, thus impacting innovation. This can act to effectively lock out the development of new technologies, due to high costs or lack of associated research, which potentially presents missed opportunities for the powers of ocean technology. Similarly, breaking these causes of *"lock in"* requires in-depth planning, as opposed to simple rollout of MAS. The National Oceanography Centre are calling for greater *'openness'* regarding data to combat these associated challenges. There must be greater commitment to be *"sharable and accessible"*, which has a huge role in delivering *"necessary and sustainable actions to ensure the environment is protected"*.[134] Ships and large research companies must be *"incentivised"* to share such data, by making it a key feature of licensing agreements, which is an important underpinning for innovations and a spur to develop new technologies.[135]

In his oral evidence, Professor Matthew Palmer highlighted that another key limit within ocean technology research is the combination of high costs with a lack of accessibility to current technology, which he noted has led to a kind of lack of *"democratisation of ocean discovery",* whereby only organisations and businesses with significant financial backing can access innovative and cutting-edge technologies. Professor Palmer told the APPG that *"things simply need to be cheaper, or suitably supported to allow easy access and use of new technologies for the vital ocean research that the planet depends upon."* Better access will also enable the types of *"fail-fast, learn-fast frameworks"* that help drive innovation and invention in other sectors, but that are simply not currently available to the ocean research community.[136] Despite this, there are currently few systems which are fully available and developed enough to provide the full datasets required to provide an accurate monitoring picture of the ocean. This signifies one of the most complex problems in furthering ocean technology: Research and Development. We must therefore *"build the trust in new technologies, by providing the technologies that ocean science needs."*[137] Costs for access to new and emerging technologies must also be reduced to ensure scientists can carry out appropriate risk assessments which are integral in using new technologies.

The National Oceanography Centre argue that *"only by maximising the impact of emerging technologies can the UK become a science superpower."*[138] A few inquiry responses have welcomed the creation of the Advanced Research & Invention Agency (ARIA). Announced by Government in February 2021 and sponsored by the Department for Science, Innovation and Technology, ARIA is a R&D funding agency designed to complement and amplify the UK's world-class research ecosystem. However, ARIA currently has no specific focus on funding for ocean research and science. The National Oceanography Centre's submission calls for ARIA to work with other key government bodies in the space such as UK Research and Innovation (UKRI) to *"develop plans to remove barriers (such as risk appetite) to new observing technologies being adopted rapidly into ocean science."*[139] This could be done for research projects that might otherwise be considered too risky, on account of the level and complexity of technological innovation, which would also help scale such research further and drive the *'innovation'* necessary for the UK to be considered a scientific superpower.

133 Response from British Antarctic Survey, July 2023

134 Written evidence from the National Oceanography Centre, July 2023

135 Ibid

136 Oral evidence from Professor Palmer, June 2023

137 Ibid

138 Written evidence from the National Oceanography Centre, July 2023

139 Ibid

International collaboration

Many of the tools, platforms, sensors, software and IT architecture have value partners across government, industry and academic sectors but it is *"inefficient and severely limiting"*[140] that these sectors often experience little incentive to collaborate. Emma Johnson noted that in order to fully unlock technologies and its potential, *"fostering international cooperation could help garner support."*[141]

As with any kind of research, international and strategic partnerships are essential to ensuring reliable findings and data. In the case of ocean research, it is fundamental, as the ocean has no boundaries or borders. In his oral evidence, Leigh Storey highlighted how international collaboration is crucial to the work of NERC.[142] Leigh Storey also noted international coordination will always be key for further ocean technologies. For example, NERC has supported NASA over the last few years in the collecting and receiving of satellite data. Moreover, NERC worked with the Royal Netherlands Institute for Sea Research to develop Marine Facilities Planning[143], a joint data-sharing platform designed to share marine facilities. It is now used by almost every research ship in the world. Leigh also stated that in order to ensure such international collaboration can continue, coordination and support at a higher Government level is needed. Furthermore, NERC are currently in talks with the US Government about regulation and authorisation of scientists travelling abroad to do research and to use new technologies in US waters. However, currently any scientist looking to carry out research in international waters requires diplomatic approval. He made the point that if the people carrying out the actual research need approval then surely the same must be applied to new and emerging technologies. It is clear more work is needed to consider international regulation of ocean technologies and encourage open and collaborative data sharing across countries, to create open data platforms for a wide range of ocean variables.

The Whale and Dolphin Conservation make the point that *"even where new methods are proven, they need to be scaled up, and to be used in combination and applied through international cooperation."*[144] Most of the climate impacts facing the ocean take place offshore and in areas beyond national jurisdiction. Many populations are vulnerable to actors and potential disasters from more than one country, due to shipping and fishing taking place across international waters. Therefore, the new historic agreement adopted by the UN, the Biodiversity Beyond National Jurisdiction (otherwise known as the High Seas Treaty) and agreed in June 2023 after decades of negotiations, is crucial to securing the international cooperation required to ensure effective protection of more than two thirds of the global oceans. It is essential that the UK play a leading role in ensuring its recommendations are adopted by all UN nations in the coming years.

International frameworks and partnerships are crucial to ensuring technological innovation. Wave Energy Scotland has pioneered the development of an international standard for ocean energy technology that sets out a number of performance metrics that determine the technology maturity.[145] The international community, driven by the International Energy Agency Ocean Energy Systems Technology Collaboration Programme (IES-OES), has also developed the IEA-OES Evaluation and Guidance Framework for Ocean Energy Technologies.[146] This document supports both public and private investors to deliver effective funding programmes and carry out efficient evaluations of the effectiveness of emerging wave and tidal technologies. The Framework has already been adopted by a

140 Response from British Antarctic Survey, July 2023

141 Emma Johnson oral evidence, June 2023

142 Leigh Storey oral evidence, June 2023

143 Marine Facilities Planning (2023), available at: https://www.marinefacilitiesplanning.com/about

144 Written evidence from The Whale and Dolphin Conservation, July 2023

145 Written evidence by Wave Energy Scotland, July 2023

146 Ocean Energy Systems Technology Collaboration Programme (2023), available at: https://www.ocean-energy-systems.org/about-us/#:~:text=The%20Ocean%20Energy%20Systems%20Technology,OES)%20was%20launched%20in%202001

number of funders, including Wave Energy Scotland and the US Department of Energy. Continued adoption by governments and funders of such programmes in the UK and beyond is crucial to maximise technology and all it has to offer, ensuring promising technology is up to appropriate and internationally supported standard, which is crucial to any technology revolution being successful and having real long-term impact.

Thus, there are a number of ways in which a lack of international collaboration could damage the future development of UK ocean technology. In their response, Sirius Insight note that as they have been unsuccessful in developing partnerships internationally, they are now seeing few funding opportunities for important international maritime situational awareness activity. The National Oceanography Centre stress that in order for continued successful international collaboration, *"the UK must overcome the temptation for short-term, transactional engagement with international partners when contributing to the science and technology solutions required for the global challenges of our time."*[147] It is crucial that the UK is seen *"as a good global citizen and long-term partner,"*[148] particularly when it comes to capacity development and data-sharing efforts with countries across the Commonwealth and beyond. The UK's science and technology strategy demands a *"broader, longer-term approach to research funding and infrastructure investment"*, which also takes into account the role of international partnerships.[149]


Photo credit: National Oceanography Centre

147 Written evidence from the National Oceanography Centre, July 2023

148 Ibid

149 Ibid

Funding and grants

When it comes to key future challenges, every response received by the APPG cites concerns around funding and future investment as the primary barrier in revolutionising ocean technology. Such is the disparity between investment and funding within the ocean sector that this gap is often referred to as *"the valley of death"*[150], which will trap promising technologies in a limbo if left unaddressed. The UK Hydrographic Office highlight that, as a global system, the ocean receives significantly less funding than other major sectors. Only 2% of Official Development Assistance funding globally is spent on the oceans, even though the ocean has a significant impact on climate issues and crises taking place both at sea and on land.[151]

Firstly, responses make a clear case that there is a need for overall funding for innovative ocean science and technology to be increased. Failure to secure this increase risks the UK falling behind its European and international counterparts. The UK Government's rejoining of Horizon Europe is an important step forward in this process, but more must be done to further scientific investment. The Government's Horizon announcement was welcomed. The large grant opportunities provided by Horizon are essential to furthering ocean technology development. The National Oceanography Centre argue that *"additional funding for research and development will always deliver returns on investment"*.[152] Although they welcome the government's pledge to increase R&D investment to 2.4% of GDP by 2027, in order to *"truly embrace the 'science superpower' narrative, substantial*", more sustained and secure funding is needed, as R&D spending in the UK is currently 30% below the OECD average and nearly half the rate of the US and Germany[153]. In order to compete internationally in marine science, increased and sustainable investment will be key in the coming years. The European Marine Energy Centre also warns that, as proved by the London School of Economics, the UK is in a race against countries like Canada, China, France, and the US to fully capitalise on the economic opportunities which innovative ocean technologies like tidal stream and wave energy can provide.[154] However, projects in these countries are currently being delivered with upwards of 80% of UK supply chain capacity.[155] Thus, the Society for Maritime Industries conclude that *"as a developed country, the UK comparatively invests the least in the development of ocean technologies."*[156]

Responses from the Society of Maritime Industries and Society for Underwater Technology, as well as The National Oceanography Centre, refer to the US, Canada, and the EU, all of which have large programmes directed towards connecting new ocean technologies with their commercial application across the blue economy. In particular, funding from the US Inflation Reduction Act and the Canadian Ocean Supercluster programme are cited as exemplary ways in which the UK Government could be fostering ocean science innovation. The present Canadian initiatives in this area (the Centre for Ocean Ventures and Entrepreneurship (COVE) COVE Ocean – Centre for Ocean Ventures & Entrepreneurship[157] and the Canadian Ocean Supercluster[158]) are outstanding examples of how government can drive ocean technology innovation, support local businesses and start-ups, all while ensuring Canada remains a global ocean leader. The US Government has also developed a number of initiatives and partnerships to further ocean technology innovation. In October 2023, the US Department for Energy announced $36 million in funding for eleven

150 Written evidence from The Whale and Dolphin Conservation, July 2023

151 Written evidence by The UK Hydrographic Office, July 2023

152 Written evidence from the National Oceanography Centre, July 2023

153 The Royal Society (2022), *'Investing in UK Research and Development'*, available at: https://royalsociety.org/topics-policy/projects/investing-in-uk-research-development/

154 Written evidence provided by The European Marine Energy Centre, July 2023

155 Ibid

156 Written evidence by Society of Maritime Industries, July 2023

157 COVE Ocean (2023), available at: https://coveocean.com/

158 Canada's Ocean Supercluster (2023) available at: https://oceansupercluster.ca/

innovative projects across eight states to accelerate the development of new technologies for marine carbon dioxide removal capture and storage. Projects include developing underwater optical sensors and lasers, seabed monitoring tools and improving autonomous vehicle and glider technology.[159] The National Oceanic and Atmospheric Administration, part of the US Department of Commerce, oversees the National Oceanographic Partnership Programme (NOPP) which facilitates partnerships between Federal agencies, academia, and industry to advance ocean science research and education. Since 1997, NOPP has funded over 200 projects that address ocean and climate science, climate adaptation change, education, economic development, quality of life, and national security.[160] The UK Government should work with industry in like manner, funding bodies to seek to replicate such exemplary international funding programmes to keep a pace with rapid international developments in ocean technology.

Furthermore, the lack of ocean-related funding is evident when compared with other major UK industries, such as aerospace, automotive and defence. The Norwegian Defence Research Establishment has invested significant sums in ocean technology for defensive purposes, which as Leigh Storey highlighted, is a key additional application of AUVs. This has resulted in collaborative projects and growth of Norwegian-based marine technology company Kongsberg Maritime[161], who have successfully commercialised the resultant technologies and become world-leaders in mine sweeping, securing hundreds of millions of USD return on investments. Their website states this would not have been possible without *"close co-operation"* between The Royal Norwegian Navy, research, industry and end user.[162] It is essential that similar R&D support structures are adopted in the UK, which will ensure increased revenue for the UK blue economy.

As well as increased overall funding, how the current funding system works, and subsequent grants are allocated must also be considered. The National Oceanography Centre highlight that, when compared to other European countries, the UK has a comparatively low number of independent research organisations (IROs), with a large proportion of funding instead directed through universities.[163] This is because of how the current funding system works. Small and Medium Enterprises (SMEs) and universities are therefore responsible for driving much of the scientific innovation agenda in the UK. However, due to the huge cost pressures on universities, they are *"heavily reliant on match funding via government grants"*.[164] These grants are mainly obtained through bodies such as the UKRI and Innovate UK and UKRI funds both universities and Independent Research Organisations (IRO) at 80% of the full economic costs (FEC) of undertaking research. However, countries such as Germany and the US have a greater proportion of IROs. Such plurality in institutions undertaking research leads to a *"richer, more innovative science ecosystem."*[165] Sir John Kingman, outgoing Chair of UKRI, commented in 2021 that *"the funding system should not artificially favour any one institutional form over another…Research council grants currently cover only 80% of full cost…The funding system should, operate a level playing-field, promote plurality and make high-quality research financially viable*[166]*."* The National Oceanography Centre

159 US Department of Energy (2023), *'DOE Announces $36 Million To Advance Marine Carbon Dioxide Removal Techniques and Slash Harmful Greenhouse Gas Pollution'*, available at: https://www.energy.gov/articles/doe-announces-36-million-advance-marine-carbon-dioxide-removal-techniques-and-slash

160 US Department of Commerce (2023), *'National Oceanographic Partnership Program (IWG-NOPP)'*, available at: https://www.noaa.gov/ocean-science-and-technology-subcommittee/national-oceanographic-partnership-program

161 Kongsberg Maritime (2023), available at: https://www.kongsberg.com/maritime

162 Kongsberg Maritime (2023), *'In-depth Cooperation'*, available at: https://www.kongsberg.com/es/kmagazine/2013/3/depth-cooperation/

163 Written evidence from the National Oceanography Centre, July 2023

164 Ibid

165 Ibid

166 The British Academy, Sir John Kingman (2021), *'Reflections on his time as UKRI chair'*, available at: https://www.thebritishacademy.ac.uk/events/sir-john-kingman-reflections-on-his-time-as-ukri-chair/

argues that the UK funding system places IROs at increased financial risk, due to this funding shortfall, causing them to be subject to *"mission drift (focusing on commercial research and abandoning or restricting basic research bids to UKRI) or are taken over by universities."*[167]

Furthermore, funding available from organisations such as Innovate UK for new R&D are *"minimal and highly competitive"*[168] and cannot keep apace with the increasing number of innovative SMEs entering the UK ocean sector. SMEs are struggling to access long term sustainable funding, which as outlined above, is due to a lack of IRO funding, meaning these businesses are competing for limited funds. For example, while ACE Aquatec has developed the bulk of its product range off the back of similar grant funding, they describe this process as *"extensive and complex."*[169] Wave Energy Scotland and Society of Maritime Industries also note in their responses that there is currently no official funding for when a project finishes to support the commercialisation of this new technology, which is essential to making

Photo credit: Luca Bravo/Unsplash

167 Written evidence from the National Oceanography Centre, July 2023

168 Written evidence by ACE Aquatec, July 2023

169 Ibid

products and software readily available and scalable. This is instead left to company owners and often results in them *"looking to sell the company in order to raise funds."*[170] For example, Wave Energy Scotland has over the last 9 years distributed £50 million of R&D funding to the development of wave energy technology through its competitive development programme, with viable wave technologies from developers Mocean energy and AWS Ocean Energy. However, both companies now require significant additional funding for commercialisation and to deploy the technology in pre-commercial arrays before it becomes investable.[171] This is in contrast to other European funding systems, with countries such as Norway ensuring that projects are formulated within a *'pyramid structure'*, whereby *"lower projects deliver to high level projects so that the technology developed is not wasted."*[172]

Available funding is therefore *"scattered too widely and not joined-up"* which risks future technology struggling to make any real commercial and economic impact.[173] Some responses also outline a lack of funding for certain types of technology such as sensor development, seabed mapping and blue carbon solutions such as regenerative aquaculture. Leigh Storey commented that ensuring *"sustained investment"* to build skills, technology and knowledge is a major difficulty.[174] This has resulted in what British Antarctic Survey identify as a *"cautious attitude"* in many funding schemes, meaning that *'high-risk/high-reward projects'* often associated with emerging ocean technology do not receive the necessary grants, resulting in *"low demand, slow uptake and reduced research funding."*[175] This lack of long-term funding also applies to people as well as technology, with a lack of funding for long-term technical posts, which are essential to driving development. If the UK wants to be at the forefront of new ocean technologies then long-term investment (i.e., capital investment, operational spend) is needed. For example, NERC has sustained funding for research ships over the last 10 years and invested more than £2 million in technological upgrades. However, NERC's funding has been *"flat since 2013"* due to the impact of inflation.[176]

The UK has the potential to be a *"world leader"* in the development and application of ocean technologies, however there must be solutions to tackle outlined funding and uptake challenges. The National Oceanography Centre recommend that in order to address the IRO funding gaps, the UKHI could offer grants and funding to research institutions at *"100% full economic cost"*.[177] Equally, they recommend examining whether IROs could be eligible for UKHI quality-related (QR) funding, which is currently only available to UK universities and is awarded based on research quality. In order to address the issues around funding and risks associated with *'newer, less developed technologies, newer bodies such as ARIA could be looking at developing grants based on innovation and future technology potential for 'high risk high reward'* ocean technologies[178]. Moreover, responses from UK Marine Energy Council and Steve Hall suggests that funding does not just have to come from grants but could also be in the form of tax relief for R&D projects. UK Marine Energy Council advises that the Government should align its tax regime with net zero, by replicating what is being provided for investment for increased oil and gas in the North Sea, into emerging technologies such as renewables. By providing capital allowances or alternative tax credit for investment from qualifying entities into marine and ocean projects, the UK can *"accelerate the industries' growth."*[179]

170 Written evidence by Society of Maritime Industries, July 2023

171 Written evidence from Wave Energy Scotland, July 2023

172 Written evidence by Society of Maritime Industries, July 2023

173 Ibid

174 Leigh Storey oral evidence, July 2023

175 Written evidence from British Antarctic Survey, July 2023

176 Leigh Storey oral evidence, July 2023

177 Written evidence from the National Oceanography Centre, July 2023

178 Ibid

179 Ibid

Skills shortage

The UK Hydrographic Office estimates that the global maritime or *"blue economy"*[180] will be worth $3.2 trillion by 2030, highlighting the sector'*s growing economic value.* [181] *Looking at just those companies directly involved in the design, build, manufacture and support of vessels, the former Department for Business Innovation and Skills (BEIS) (now split into the Department for Business and Trade (DBT), the Department for Energy Security and Net Zero (DESNZ) and the Department for Science, Innovation and Technology (DSIT)) estimated total sales at £7.6 billion a year, contributing £3.1 billion*[182] *to the economy. The blue economy industry and the associated highly-skilled jobs are essential to the UK economy and the UK*'s coastal communities in particular.

Despite the huge economic benefits that the blue economy brings to the UK, there remains a significant skills shortage within the sector, which is acting as a brake on the ocean technology revolution. Plymouth Marine Laboratory state that this growing skills shortage is *"already providing bottlenecks and inefficiency in technology development, deployment, support and data management."*[183] In order to fully realise and make use of new ocean technologies in the future, increased steps must be taken to ensure the next generation of ocean science technologists. In their response, the Society of Maritime Industries warned that *"competing maritime economies have already taken significant leaps forward and, without decisive government action, the UK is in danger of becoming a follower rather than a leader in this sector."*[184] They note that *"recruitment of skilled engineers and technicians into the ocean technology sector is difficult"*, and so there is a need in the UK for greater recruitment efforts amid an ageing workforce within the sector.[185]

The British Antarctic Survey note that it is *"important to invest now in skills enhancement for existing and future marine scientists to ensure there are sufficient trained specialists to capitalise on new data approaches."* Increased training is essential to creating an *"equitable, diverse and inclusive marine science community"* fit for the future.[186] In her oral evidence, Emma Johnson highlighted that from industry's point of view, there is a significant shortage in engineers and more must be done to prompt the importance and applications of STEM subjects at school. She noted that Maritime UK are currently doing good work promoting STEM subjects in schools and showcasing their application to jobs in the ocean sector - it's about *"getting awareness at an early age that this huge sector exists"*. Professor Matthew Palmer echoed these comments, once again highlighting that *"attracting people with highly transferable skills"* must be a key priority for both industry and the Government. Reponses indicate that there is a need for a more *"scientifically literate workforce"*[187] in the UK and more must be done to encourage young people to consider a career in ocean technology, to study appropriate subjects at schools and universities, and have experienced mentors, trainers and tutors available to aid career transitions across the ocean sector.

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*

180 Emma Johnson Oral evidence, June 2023

181 UK Hydrographic Office (2019), *'How the UKHO is supporting the Blue Economy'*, available at: https://ukhodigital.blog.gov.uk/2019/04/05/how-the-ukho-is-supporting-the-blue-economy/

182 Institute of Maritime Engineering, Science and Technology (2023), *'Mitigating the skills gap in the maritime and offshore oil and gas market'*, available at: https://www.imarest.org/reports/683-mitigating-the-skills-gap-in-the-maritime-and-offshore-oil-a-gas-market-1/file

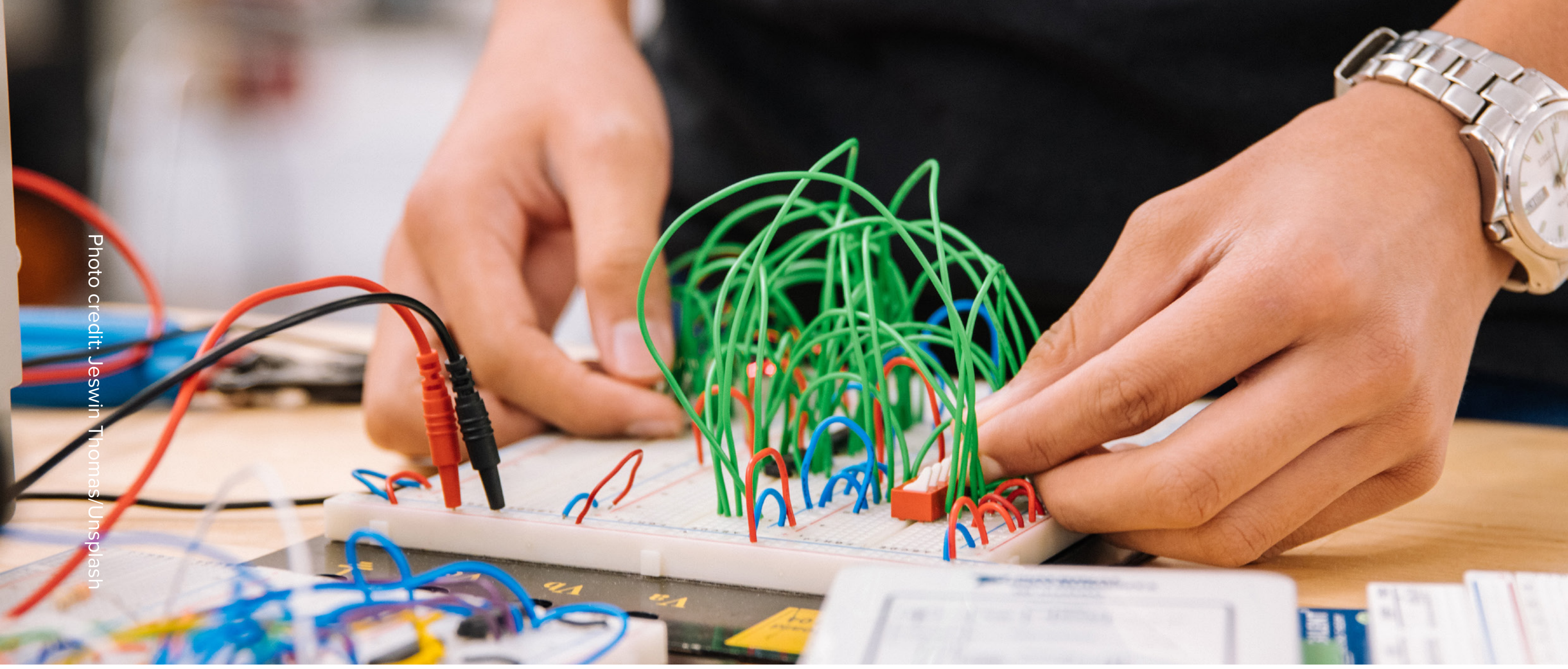
183 Plymouth Marine Laboratory written evidence, July 2023

184 Written evidence by Society of Maritime Industries, July 2023

185 Ibid

186 Written evidence from British Antarctic Survey, July 2023

187 Written evidence provided by Scottish Association for Marine Science, July 2023



to apprenticeships."[188] There is significant competition from the commercial sector, who can offer more competitive salaries, which is driving talent away from research institutions looking to fund projects in ocean technology. Thus, 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."*[189] Increased use of AI techniques can help to some extent. For example, a recent Scottish Association for Marine Science (SAMS) seabed survey of a wind farm using an AUV collected 11,000 seabed photographs per hour of robotic survey. A person would take a considerable length of time to process this data, however increased AI technology means that multiple autonomous platforms can more easily record this large dataset. This reduces the *'manpower'* for *"basic piloting tasks"* (i.e., the ones that can be automated), but does requires more manpower for developing the hardware and software required for automation of such platforms[190]. It is clear that there is still a very clear role for people within the technological revolution, which will create new kinds of jobs. However, they must receive the appropriate training to deal with new technologies, much of which is currently not available or properly promoted.

The APPG acknowledges evidence calling for training and skills at school and university levels to showcase the marine and environmental sciences, to allow rapidly-developing sectors like ocean technology to continue to grow. 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 develop the necessary data and numeracy skills. Students have the option to study marine instruments, data, robotics and programming. However, SAMS have noted that many students do not have the *"necessary basic maths and computing skills required for such study before joining the programme."*[191] In addition, SAMS is developing a *'Scientific Robotics Academy'*, providing training for schools, and bringing in engineers to platform the environmental sciences, in an attempt to try to *"bridge this current gap"* between scientific needs and engineering capacity. From their work to help address this skills gap, SAMS argue 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."*[192] This requires *"multifaceted collaborative working"*[193] which straddles educational, commercial and innovation sectors, and greater partnership from Government and industry.

188 Ibid

189 Ibid

190 Written evidence from Scottish Association for Marine Science, July 2023

191 Ibid

192 Ibid

193 Ibid

Government leadership and action

The majority of responses state that when it comes to the Government's role in supporting the development, implementation and progress of ocean technologies, there is a *"lack of long-term, strategic and joined-up thinking"*[194] and more must be done to support future ocean technology projects.

Firstly, there is a role to play for Government to nurture and support a *'public-private partnership'* with industry and the ocean science community. In their response, the Society of Maritime Industries argue that Government needs to *"reach out to those conducting ocean science technology research across the whole R&D community."*[195] As identified in this report, there are a number of key bodies, such as UKRI, and specifically Innovate UK, who have funded ocean technology projects which have been essential in building a database of the ocean. NERC is also currently working on a Future Marine Research Infrastructure programme which strongly advocates for the application of new ocean technology to ocean science.[196] Wave Energy Scotland welcomes the support the Government is giving to the acceleration of offshore wind renewable energy projects by legislating for the *'Offshore Wind Environmental Improvement Package'* within the Energy Bill.[197] However, this is not only applicable to offshore wind energy generation and could be harnessed in the potential expansion of broader technologies. Likewise, Wave Energy Scotland highlights that there is opportunity for Government to further engage with the ocean technology sector more broadly, to fully understand opportunities for investment and growth.[198] Government must work as closely as possible with project leads and executive management across leading organisations to fully understand the kind of support packages that are required for each specific area of technology development.

Alongside this, as established in the previous data and funding/grants section, Government should look to offer directed and open funding calls to support an array of cutting-edge research, from the development of new data platforms to addressing wider challenges, such as those posed by developments in sensors, data collection and AI/overall standards. Such funding should be sizeable, sustainable and not simply one-off grants. Crucially, the application process must be easy to understand. Emma Johnson noted that *"it is widely recognised that further funding and support are required to fully unlock the potential of these technologies."*[199] Encouraging private-public partnerships, fostering innovation ecosystems, and enhancing international cooperation could help to secure necessary funding and support. The catalyst effect of government funding calls is significant and could help connect the industrial and commercial cycle required to fund, develop and sell ocean technology.

Furthermore, Government should be supporting the acceleration of ocean technology development publicly by setting an expectation that businesses should seek to use ocean technology when safe and appropriate to do so. Dr Helen Czerski rightly made the point that any new type of ocean infrastructure will not work until new technologies are properly tried and tested. Any infrastructure that is developed to remove or store excess carbon must be supported by scientific research. She added that infrastructure is not just about *"funding machines"*, but also *"funding the science and people"* to ensure that these technologies can work as effectively and safely as possible.[200] The UK community has great strengths in various sectors (IROs, universities, industry etc), and a central strategy and Government commitment to promote innovation and coordinated investment across these will generate optimal returns. This is being delivered by Defra across a range of environmental issues and should be reproduced in the ocean sector.

194 Written evidence from the National Oceanography Centre, July 2023

195 Written evidence by Society of Maritime Industries, July 2023

196 Leigh Storey oral evidence, July 2023

197 Written evidence from Wave Energy Scotland , July 2023

198 Ibid

199 Emma Johnson oral evidence, June 2023

200 Dr Helen Czerski oral evidence, July 2023

For example, as highlighted by the Blue Marine Foundation, following a recent successful campaign led by EODEX and Alford Technologies, promoting the use of low-order detonation techniques in sensitive marine environments, to ensure marine life such as whales and dolphins are not harmed, Defra published a *"joint interim policy statement"* setting out their recommendations whilst further evidence is collected on best possible techniques.[201] Such commitment could be replicated across the ocean technology sector to address risk-impact and ensure impact on the marine environment is kept to a minimum whilst using and promoting innovation. There is therefore a clear role for Government in overseeing ocean technology development and ensuring businesses and companies developing and promoting such technologies take the necessary steps, safety precautions and are held accountable with appropriate checks and balances.

While Defra must continue to take a leading departmental role, the importance of the ocean must be better highlighted across other departments. The technology capabilities and skills developed within ocean research can be applied across many major industries and are relevant to other Government departments, as reflected in the Department for Transport and the Transport Select Committee's work around autonomous vehicles. In particular, respondents were asked to consider how the new Department for Science, Innovation and Technology (DSIT), and the Department for Energy Security and Net Zero (DESNZ) can best support growth into the future of ocean technology. There is a key role for DSIT to play within this space, especially in the area of Carbon Capture, Utilisation and Storage (CCUS) and how the *"highly contentious issue of carbon leakage"* can be addressed.[202] Autonomous underwater vehicles could be a crucial tool for DSIT in addressing this significant issue, due to their ability to travel along a pipeline to detect and fix leakages. It is also essential that DSIT promote the importance of open data to ensure actions within it are sustainable, and the environment is protected. Whilst recognising the existing good work of organisations such as MEDIN and The Crown Estate to centralise geospatial data, the UK Hydrographic Office would welcome further exploration into the *"manipulation and storage infrastructure"* for big data, and to investigate what additional mechanisms could be used to "require more datasets to be centrally registered or stored.[203]

The Department for Energy Security and Net Zero now holds the responsibility for achieving the Government's ambitious targets to increase offshore wind fivefold to 50GW by 2030. It is therefore imperative that Government holds this Department to account to ensure they are working closely with British businesses at the forefront of wind and wave technology, as this will be key to ensuring ambitious carbon reduction targets are met. Beyond the Department for Energy Security and Net Zero, autonomy could play a role in surveying oil and gas pipelines, and telecommunication cables located at the bottom of the ocean, which have been highlighted as something which may be under threat from natural disasters and hostile nations[204]. For example, in the Netherlands, companies which win a windfarm contract have to make data available, therefore helping companies, governments, the science community and the public to better understand the ocean.[205] Both departments must work together to make this kind of data-sharing with industry possible in the UK.

The majority of responses also argue that there is certainly a clear role for the Government to play in nurturing a skills revolution in order to harmonise with a technological one, as identified in the previous section. For example, Plymouth Marine Laboratory's response notes a *"lack of sustained funding opportunities for skills that support capital investments are a critical part of that problem."*[206] Although funding solutions do exist, it is primarily independent research institutions, such as Plymouth Marine Laboratory and the National Oceanography Centre, that provide access for the UK marine research

201 Written evidence from Blue Marine Foundation, July 2023

202 Written evidence from the National Oceanography Centre, July 2023

203 UK Hydrographic Office written evidence, July 2023

204 Written evidence from the EMEC, July 2023

205 Written evidence from the National Oceanography Centre, July 2023

206 Written evidence from Plymouth Marine Laboratory, July 2023

Photo credit: National Oceanography Centre

community to ocean technology required to deliver high-quality ocean research. As highlighted in the submissions from such organisations however, their limited size and multiple work-streams present continual challenges to meet the shortfall that government-directed funding typically provides. This means these *'centres of excellence'* for marine research and technologies are therefore *"forced to pay to engage with many of the available technology innovation calls or are financially prevented from doing so."*[207] This is clearly having an adverse effect on developing innovation and is an *"inefficient approach to maximising the returns from previous R&D investments."*[208]

Enabling innovation through increased funding mechanisms is crucial to attracting young people to start a career in ocean and marine science. The UK's major ocean science institutions must have access to the funding and resources necessary to promote the benefits of working in such a fast-paced and developing industry, from an early age. In line with this, the APPG supports industry's calls for the Government to develop a closer working relationship with the ocean and marine sectors, in order to understand and develop a kind of *"skills roadmap"* seen across other departments like DfT, to ensure that the UK's blue economy can rely on a robust skills pipeline into the future.[209] Government and industry must work together in addressing the skills shortage in the ocean sector through increased education and training opportunities.

Overall, an overarching Government strategy is needed to foster innovation and growth of the UK ocean technology sector. The National Oceanography Centre notes this could be overseen by a Minister for the Ocean, a Government role that the APPG has long been calling for.[210] In order to retain diversity and foster innovation, with different organisations bringing different ways of working and thinking, a *"centrally-coordinated strategy"* will ensure *"optimal cross-fertilisation of ideas and overall direction of travel"*.[211] Responses submitted by the European Marine Energy Centre and UK Marine Energy Council have called for the establishment of a kind of *"strategic taskforce"* to realise *"tidal and wave energy potential."* However, the APPG would argue this taskforce could cover the whole ocean research space, considering the roles of data, AI, autonomy, energy and blue carbon. As noted in these responses, the taskforce could

207 Written evidence provided by The European Marine Energy Centre, July 2023

208 Ibid

209 Written evidence by Society of Maritime Industries, July 2023

210 Written evidence from the National Oceanography, July 2023

211 Written evidence by British Antarctic Survey, July 2023

still follow the model of the *'Offshore Wind Industry Council'*[212] and would work to bring industry and government together to address the barriers and implement solutions required to realise the potential of ocean technology and encourage the ocean research sector to thrive. Following the Government's recent disbandment of the Marine Science Coordination Committee whose remit was to *"bring together the principal public investors in marine science to tackle cross Departmental issues"*, it therefore could not be timelier for a government-wide strategy and implementation plan.

The breadth of evidence from stakeholders quoted in this inquiry highlights the revolutionary technology currently available and that still being developed by the ocean and marine sector. However, it is clear, in both the oral and written submissions to this inquiry, that there is a need for greater support, awareness and funding for emerging ocean technology solutions. As highlighted by the findings of this report, ocean technology has the potential to transform the way we understand and study our oceans, while simultaneously promoting scientific excellence, innovation and developing more sustainable energy and fuel alternatives crucial to net zero targets. Promising new technologies are therefore vital to saving and protecting our oceans and its habitats. Industry and Government must work more collaboratively to ensure the shared goals of scientific research and innovation can be realised and that the UK remains at the forefront of world-leading and groundbreaking ocean research. The APPG has listed several key recommendations below which we believe should be urgently accepted and acted upon by UK Government.

Recommendations

1. **Establish and implement an overarching ocean strategy or a "strategic taskforce", overseen by a Minister for the Ocean.**

2. **Better and more sustainable, long-term funding for scientists carrying out ocean Research & Development.**

3. **Provide funding grants to cover the full cost of projects undertaken by universities and Independent Research Organisations.**

4. **Ocean companies to publicly collect and share data.**

5. **Support and develop guidance for UK companies looking to form international research partnerships.**

6. **Effectively harness the powers of AI for ocean research within an appropriate regulatory framework.**

7. **Government to review current consenting and marine licensing processes.**

8. **Government to provide cross-departmental support to oversee and develop a comprehensive regulatory ocean framework.**

9. **Government to support and work with industry to effectively address skills shortages through an "ocean skills roadmap."**

10. **Government to bring forward regulation on marine and maritime autonomy.**

212 Written evidence from European Marine Energy Centre and UK Marine Energy Council, July 2023

Conclusion

The final question the APPG asked respondents to consider was *'where can ocean technology go next?'* In the context of the ocean technological revolution, there is huge potential and vast opportunity in the coming years for the UK as a world-leader to further develop and fine-tune its ocean technology capabilities. Responses outline how technology has the potential to revolutionise the ocean space, with cleaner, smaller vessels replacing large polluting ships213; advanced AI214 and autonomous vehicles which can reach the unknowns of the deep sea215; real-time open data to better engage people with the ocean216 and enable greater sea awareness217; and the creation of a space where innovations, such as in battery technologies, can help inform other sectors such as automotive and aviation. In a very real sense, the opportunities are endless. However, such opportunities can only be fostered through strong industry partnerships, joined up research approaches, collaboration and robust and fair funding systems, all of which must be overseen by Government. Dr Helen Czerski highlighted to the APPG that the ocean is not an empty pond, it is a physical engine that gives us the foundation of our world, a theme which must be central to ensuring good practice and the development of technology which only seeks to support our natural habitats and not damage them further. As highlighted by the National Oceanography Centre, the ocean is a *"collaborative space across sectors and industries"* and only *"collaboration between technology, industry and government can ensure ambitions are truly fulfilled."*218 Ultimately, ocean technology has the power and potential for the UK to achieve its science superpower status, but it must be properly harnessed, funded and regulated, to ensure research innovation and excellence remains at the heart of UK marine science.

213 Written evidence from the National Oceanography, July 2023

214 Written evidence from Saltwater Steve, June 2023

215 Written evidence from the National Oceanography, July 2023

216 Written evidence provided by Scottish Association for Marine Science, July 2023

217 Written evidence from Sirius Insight, July 2023

218 Written evidence from the National Oceanography, July 2023

Appendices

List of written evidence inquiry questions:

1. Are we currently experiencing an ocean technology revolution?

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

3. Assess the effectiveness of emerging sustainable ocean technologies.

4. Outline key methods for sustainable ocean technologies.

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

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?

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

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?

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

10. Where can ocean technology go next?

List of organisations and representatives who submitted written and oral evidence to the inquiry:

- ACE Aquatec
- Blue Marine Foundation
- The British Antarctic Survey
- Dr Helen Czerski, Associate Professor at University College London
- Dr Matthew Palmer, Plymouth Marine Laboratory Lead for Environmental Digital Science
- Emma Johnson, Director of MST and MAS Groups at Society of Maritime Industries
- European Marine Energy Centre
- Leigh Storey, Associate Director of the Major Programmes Team at the Natural Environment Research Council
- Marine Conservation Society
- The National Oceanography Centre
- Plymouth Marine Laboratory
- Scottish Association for Marine Science
- SeaGrown
- Sirius Insight
- Society for Underwater Technology
- Society of Maritime Industries
- Stephen Hall CMariSci FIMarEST
- Tim Fileman, Head of The Centre for Coastal Technologies, PML Applications
- UK Hydrographic Office
- UK Marine Energy Council
- Wave Energy Scotland
- Whale and Dolphin Conservation

APPG for the Ocean

All-Party Parliamentary Groups are informal groups of Members of both Houses with a common interest in particular issues. The views expressed in this report are those of the group. Tendo Consulting Ltd are funded by the National Oceanography Centre to act as the Secretariat to the APPG.

The APPG for the Ocean was founded to provide a collective space where all parliamentarians can support and promote ocean research and awareness, to develop greater understanding of the ocean and its role in tackling challenges such as climate change, and to debate wider issues.

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