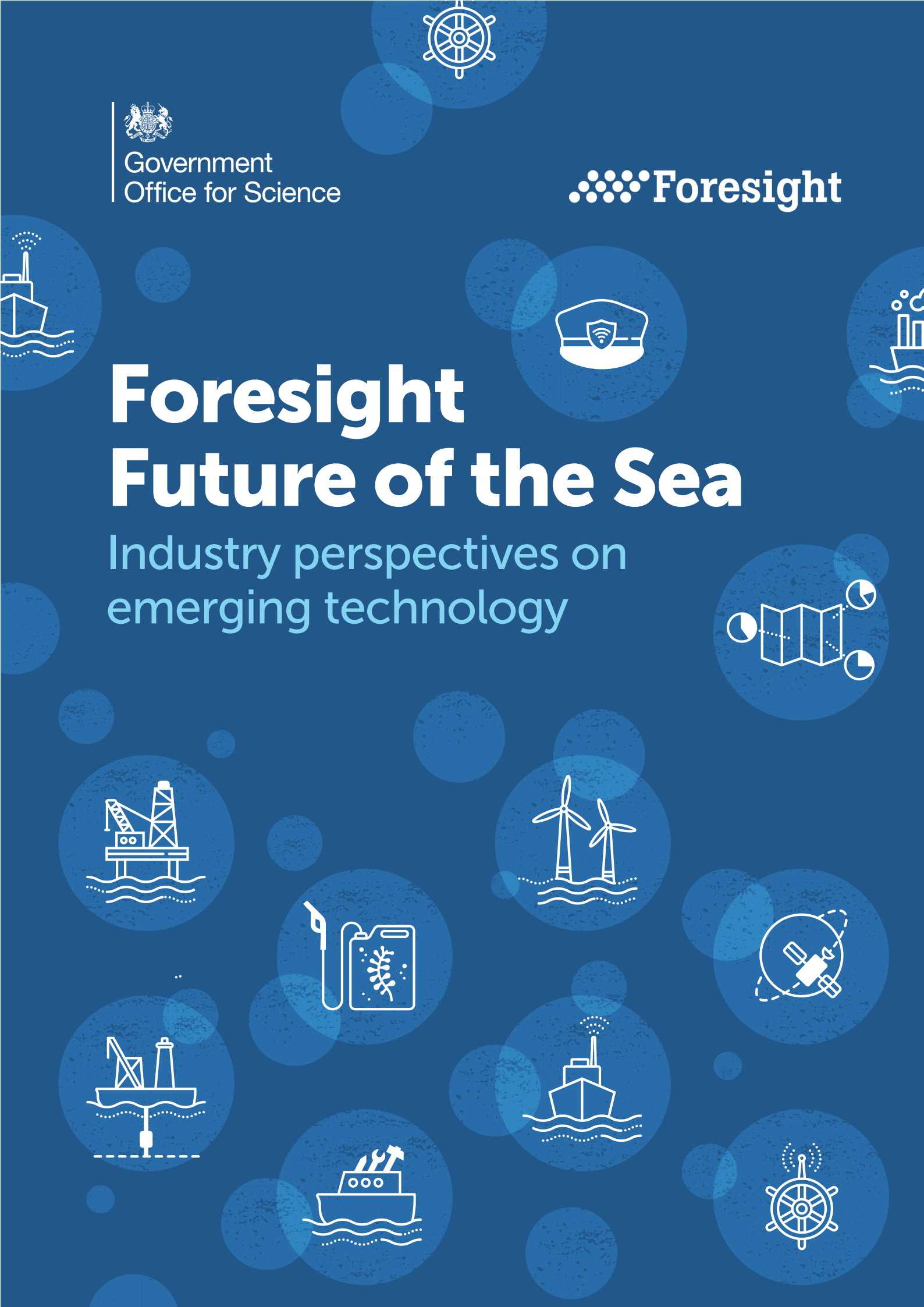
Government Office for Science

Foresight

Foresight Future of the Sea

Industry perspectives on emerging technology



Introduction

GO-Science's Foresight Future of the Sea project is looking at the important future trends, challenges and opportunities for the UK from the sea. This document reports the findings from interviews with 11 leading companies at the forefront of the development of the UK marine industry, each exploring an emerging trend or theme that will shape the future relationship between the nation and the sea. The document ends with an analysis of the specific challenges and opportunities for the UK that have been inferred from these interviews. A full report of the Future of the Sea project's findings will be published later in 2017.

The views expressed in this report are not those of the Government Office for Science, or HM Government.

Table 1. Company interviews

Company	Trend
Babcock	Reducing emissions to support global climate ambitions
Cammell Laird	Increasing demand for specialised shipbuilding
Lloyds Register	Alternative marine fuels and the ocean as a place for energy generation
Rolls-Royce	Remote controlled shipping
BAE systems	Affordability, security and autonomy
Gardline	Autonomy and data processing in surveying
ASV Global	Linking satellites and marine autonomous systems
Inmarsat	Increasing demand for satellite bandwidth
UK Seabed Resources	Emergence of deep sea mining
Shell	Growth of the decommissioning industry
DONG Energy	Development and integration of offshore wind power

Executive Summary

The UK's ocean economy is diverse. Industries from fishing to shipbuilding make significant contributions to the nation's manufacturing output, employment, tax revenue and exports. In the future those industries, transformed and supported by a range of new technologies, will be joined by opportunities in new sectors such as deep sea mining, autonomous marine vehicles, satellite applications and renewable energy.

Given the many opportunities the growing ocean economy presents to the UK, GO-Science's Foresight Future of the Sea project has been examining the changing role of technology in different ocean industries. To do this we canvassed the views of those most able to recognise the emerging trends, challenges and opportunities for the UK: those companies developing and deploying the technology in the marine environment. This report contains short interviews with leading industry figures giving their views on the most interesting technologies, their implications and the likely barriers to their realisation.

The ocean economy has always been a diverse landscape, and with the application of emerging fields of science and technology in new and existing industries, will become ever more so. What emerged from this consultation was a picture of some common drivers that will shape their collective future.

- The need to **reduce emissions** will be a major driver of **technological development** and innovation, affecting the design and powertrain of ships, driving the use of data analytics to improve efficiency, and influencing the technological solutions adopted by the seabed mining industry. Continuing decarbonisation of the energy grid will also offer ongoing opportunities in offshore wind, wave and tidal power.
- The **emergence of autonomous systems**, from unmanned ships to smaller vessels for deep sea mining and surveying, will also shape the industry's future. However, the speeds at which such technology will be adopted, and the impact it may have, remain uncertain. Many companies recognised that for autonomy to transform the sector, **improved data connectivity and extensive testing** are required.

The UK has a long history of ocean leadership, and a depth of engineering and communications expertise that can position us well to capitalise on the opportunities that these two key drivers and the accompanying technological change will present. These include the opportunity to: provide pilots and testbeds for new technologies, lead on the legal and regulatory innovations and to establish expertise in the new technical services needed to support technological innovation.

However, new innovation will require new collaboration, and the experiences collected here suggest that now is the perfect time for the different industries to come together to recognise their synergies, champion their collective potential and develop solutions that leverage their shared potential.

Reducing emissions to support global climate ambitions

Babcock is a leading global engineering support services organisation, delivering support to the marine defence, energy and transport sectors, in the UK and overseas. Babcock operates waterfront facilities in Rosyth, Faslane, Plymouth and Appledore.

Reducing emissions to support global climate ambitions

Perhaps the largest change that will impact the shipping industry as a whole over the next 10-30 years will be the need to reduce emissions to support global climate ambitions.

There is potential for the UK to be a world leader in this area, and investment in solutions that are attractive to regulators and operators could support this aspiration. As new Arctic sea routes begin to open, there may be increased environmental scrutiny on ships passing through these waters. Clean bunkering[1] solutions, scrubbers[2] and liquefied natural gas could help to alleviate harmful effects. Positioning the UK as a leader in clean fuel technology could therefore make us an attractive supplier for ship owners.

Melting Arctic ice will open new trade routes that could be used for increased trading between China and Europe. Ship routes through the Northeast Passage are over 2000 nautical miles shorter than routes through the Suez Canal, and require transit through the waters of many fewer countries. An Arctic route may therefore be lower risk and lower cost. At the rates of melt projected by the Intergovernmental Panel on Climate Change (IPCC), it is likely that within 10 years large cargo ships will be able to access the Northeast Passage for at least half of the year. The UK could be positioned to take advantage of this opportunity, for example, through developing port capacity in the Northern Isles.

The sea is crucial to the UK economy, with the large majority of our imports arriving by sea, yet we suffer from a certain 'sea blindness', overlooking our reliance on the oceans and lacking a joined-up approach to the maritime sector. By comparison, Singapore's Maritime and Port Authority has responsibility for encouraging economic growth, as well as national defence and awareness campaigns. The Netherlands has adopted industrial, academic and political strategies to recognise their maritime heritage and future.

The shipping industry has historically had a cultural resistance to innovation. To help to overcome this, the UK could take a fundamental look at the levels of innovation in maritime in comparison to other sectors such as aerospace and automotive, exploring how incentivising better integration between subsectors could help the UK to capture more of the future global growth in the marine and maritime sectors. A coordinated approach is needed.

GO-Science was speaking to Patrick Carnie, Strategy Director, Energy & Marine Technology, Babcock International Group.

1 Refuelling of ships
2 Air pollution control devices used to remove some particulates and/or gases from industrial exhaust streams

Increasing demand for specialised shipbuilding

Cammell Laird builds and upgrades scientific, military and commercial vessels, and produces ship platforms and integrates advanced technology into them for the marine environment. The company was founded in 1828 and is based on the River Mersey in Liverpool.

Increasing demand for specialised shipbuilding

Developments in scientific exploration, resource extraction and polar shipping routes will drive change in the requirements for ships operating in arctic conditions.

The UK does not compete in volume shipbuilding with countries such as China or South Korea any longer. However, a more-specialised, smaller-scale commercial shipbuilding industry has emerged in the UK and, as large production facilities are not required for building such bespoke ships, the UK is not disadvantaged in this field. Cammell Laird's forthcoming polar research vessel the *Sir David Attenborough* exemplifies a UK-built ship using cutting-edge technology that can function in arctic conditions.

Future shipbuilding will also be significantly impacted by environmental regulations. Ballast water treatment conventions and emissions targets are increasing the need for retrofitting and for new building designs; some new ships are now built to run on both traditional fuel oil and liquefied natural gas, a cleaner alternative fuel. Some manufacturers are examining the feasibility of battery and wind-powered ships. However, these developments are dependent on continuing legislation as, without higher oil prices, there is little incentive to develop cleaner power sources.

In order for the UK to grow its specialised shipbuilding industry, it must address a skills shortage. Pay can be lower than for comparable industries such as automotive, partly due to the historically low margins of the shipbuilding industry, and attracting enough engineering graduates is a challenge. Promotion of the UK's bespoke shipbuilding capabilities to other countries, using the UK's most technically-advanced ships as a launch pad for international orders, could help the UK compete in the global market.

GO-Science was speaking to Linton Roberts, Managing Director, Cammell Laird.

Alternative marine fuels and the ocean as a place for energy generation

Lloyd's Register is a global engineering, technical and business services organisation. Founded in 1760 as a marine classification society, Lloyd's Register now operates across many industry sectors, with some 9,000 employees based in 78 countries.

Alternative marine fuels and the ocean as a place for energy generation

A primary future challenge for the industry will be managing the carbon footprint from shipping.

Although some new vessels have been built to run on liquefied natural gas (LNG), this technology is broadly acknowledged as only an intermediate solution due to issues around methane slip (unintentional escape of unburned methane) and the energy required for liquefaction and transportation. Hydrogen has been proposed as a long-term solution, but is currently not synthesised in large enough quantities, although this technology may be commercially deployed by 2030.

The next few decades will likely see a decline in the activity of the UK oil industry supply chain. Offshore wind and other renewable energy industries have the potential to fill the gap in local economies, but only if a more UK-based supply chain can be established. Other, more niche, industries could also play a role; seaweed farming is a technology that has growth potential and is environmentally friendly.

The ocean will be used by increasingly diverse industries, as various forms of energy generation sit alongside deep sea mining, oil and gas exploration and fishing. These are opportunities but also pose challenges as the sea will become increasingly congested, particularly close to the shore.

The UK has strengths in soft skills and services, such as consultancy and insurance, and has a number of universities that are strong in marine research. Oceanography is a national strength, and could continue to provide a valuable research and skills base, but is likely to face increasing competition from Asian universities in the future.

GO-Science was speaking to Tom Boardley, Executive Vice President, Lloyd's Register.

Remote controlled shipping

Rolls-Royce are a global company providing power and propulsion systems to the marine, aerospace, energy and transport sectors. Seventy of the world's navies and over 30,000 commercial vessels use Rolls-Royce equipment, with a support network operating in 28 countries worldwide.

Remote controlled shipping

Unmanned ships present an exciting opportunity to transform the shipping industry in the next few years.

Autonomous technology is already being adopted, for example in the use of drones to inspect ships and wind farms, and in port operations. Rolls-Royce are working to develop fully autonomous and unmanned ships, with remotely controlled, unmanned coastal and harbour vessels expected by 2020, and the first fully autonomous unmanned ocean-going ships by 2035.

The digitisation and automation of shipping will allow consistency of operations and improve safety, as human error is removed and unmanned ships lead to fewer people going to sea. Further, once life-systems are removed, a ship can be made smaller or have more room for cargo. Currently, most ships are made bespoke for the end-user to match their requirements, but with automation there can be increased modularisation and therefore reduced costs. The implementation of smart shipping will also reduce the need for ship brokers, as they will likely be replaced by a digital market place.

Rolls-Royce are already deploying technologies geared toward remote and autonomous operations. Situational software[3] has been adopted by some cruise ships to aid navigation in ports and ferries for auto-docking. Simulations and augmented reality are used for the safe manoeuvring of vessels and subsea cranes. Ship intelligence is used to monitor energy management, particularly on battery-powered vessels.

Norway and Finland are leading in the development of autonomous ships. However, the UK has been pro-active in addressing the regulation and legislative issues that automated shipping may bring. Introduction of funding streams for innovation and designated test zones, potentially in collaboration with Norway, Finland or Singapore, could strengthen the UK's position and business involvement.

GO-Science was speaking to Kevin Daffey, Director, Engineering &Technology, Marine, Rolls-Royce.

3 Situational software combines signals from multiple sources e.g. many radars to produce a single picture for maximum situational awareness.

Affordability, security and autonomy

BAE Systems provide technology-led defence, aerospace and security solutions. The company designs, manufactures and supports complex surface ships, submarines, torpedoes, radars, and command and combat systems.

Affordability, security and autonomy

Automation will allow ships to be smaller, simpler and cheaper, presenting an opportunity for the defence sector where affordability is a key challenge.

Automation also provides the opportunity to develop a new sector and skills base focused on 'off-board' control of autonomous systems.

The civil maritime sector is already taking advantage of automation, and it will soon be used in specialist defence functions such as mine clearance. Some sea-faring vessels will need to be at sea for days or weeks at a time, rather than being able to pull over or land within hours as with automated systems in the automotive and aerospace sectors. The associated safety and reliability implications of this may mean that uptake of marine autonomy will be slower than in other sectors.

Rather than a binary switch, automation will be implemented on a sliding scale, from systems working alongside humans, likely to happen relatively soon in ships and submarines, to complete automation, which remains some way off in the defence environment. The United States currently has a substantial lead in sea autonomy following considerable investment in the field.

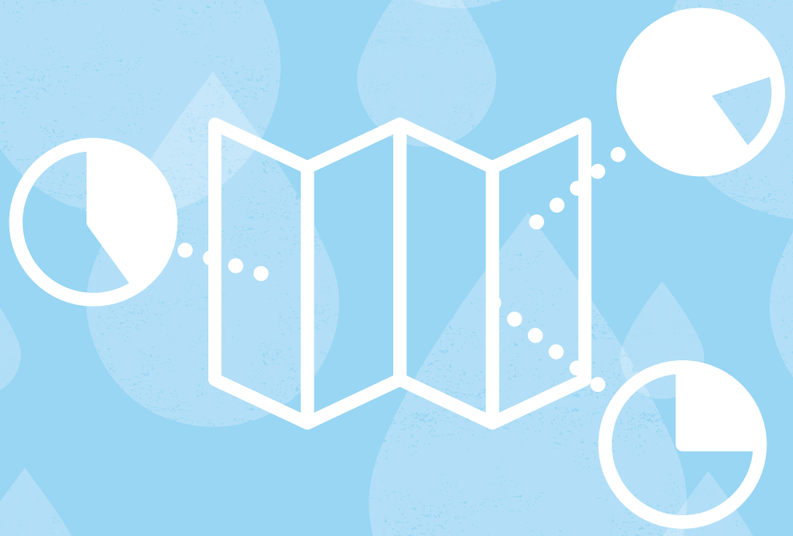
Several primary technology challenges must be overcome before autonomous vehicles can be used for defence at sea. These include the problems of power, reliable and secure communications, and assurance of cyber security. Vehicle safety is the primary concern and meeting the increasingly complex challenge of cyber security will require mechanisms to test and validate software effectively but at low cost. A legislative process allowing the insurance and licensing of the automated vehicles will facilitate industry development.

Attracting skilled employees remains a challenge for the defence marine sector, with specialists particularly required in the fields of data analysis, software, artificial intelligence, encryption and high-energy power.

Affordability will also be addressed by modular manufacturing of ship and submarine parts. The sector has been slow in introducing robotics to the manufacturing processes in comparison with others, but they can now use the lessons learned in these other industries to smooth the transition.

GO-Science was speaking to Duncan Scott, Head of Product and Engineering Strategy, BAE Systems Submarines.

Autonomy and data processing in surveying



Gardline Marine Sciences is a global company that carries out surveys in the marine environment for scientific, environmental and industrial uses. Gardline also provides offshore geotechnical services in energy, engineering and telecommunications.

Autonomy and data processing in surveying

Autonomy will be the most exciting technology for marine industries over the next few decades, allowing cheaper and more efficient data acquisition.

However, to make use of the huge amount of data that autonomous vehicles will allow us to collect, more infrastructure will be needed to backhaul it to the shore.

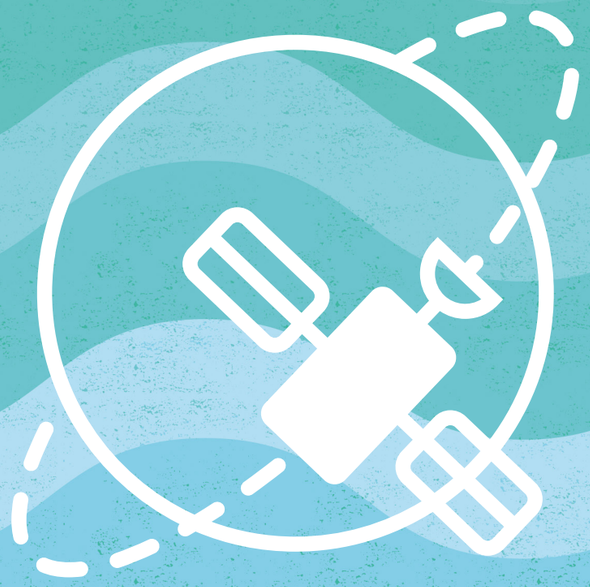
The scale of data processing required will be extensive; survey completion will be much faster, but producing a cohesive picture from the data will be challenging. It will become increasingly important for organisations to share the data they collect. To date the industry has been willing to share data collected, but in future this may need to become a requirement rather than voluntary.

The UK has many of the relevant skills for autonomy already, but they reside in bespoke areas across the sector with little coordination. In the near future there is likely to be a large skills gap in marine industries as a whole; the recent decline in the oil price resulted in the loss of senior staff while simultaneously reducing opportunities for new graduates.

The UK is a leader in autonomy innovation; however it must improve its ability to bring innovations to market and to build awareness with potential users about the opportunities new technologies represent. Seabed mapping is a good example of an activity where encouragement of the UK private sector would help to build a global lead in marine autonomy technology.

GO-Science was speaking to Phil Durrant, Managing Director, Gardline Environmental.

Linking satellites and marine autonomous systems



ASV Global is a US/UK company specialising in the design, building, operation and maintenance of autonomous unmanned surface marine systems. The company operates a 24,000 sq. ft. design, build, maintenance and operations facility in Portsmouth.

Linking satellites and marine autonomous systems

Linking autonomous marine vehicles with satellites is the key to beyond-line-of-sight operations, and efficiently transferring to land the data collected at sea will be crucial for industry development over the next few years.

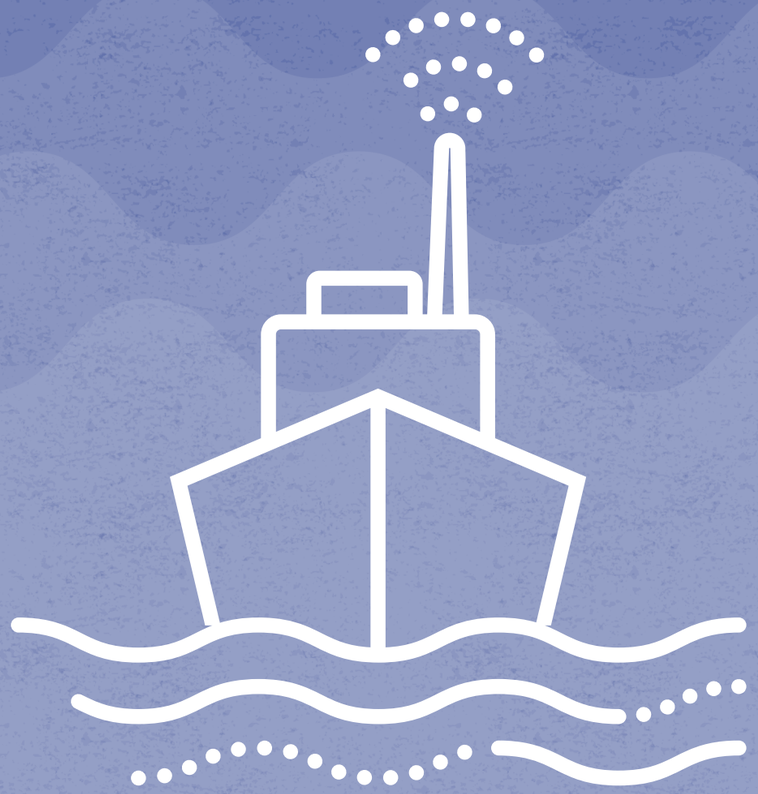
When manned ships or platforms are no longer needed within transmitting distance of autonomous systems, data acquisition will become much cheaper. The technology for unmanned marine vehicles to feed high bandwidth data via satellites is currently in the field-trial stage. These systems are not yet rugged enough for full deployment in field conditions, but are being used to carry out some scientific research. It may take around three to five years for the systems to become market-ready.

There are several separate committees addressing the lack of clarity on legislation around the use of unmanned vehicles at sea, which is currently hampering industry and investors. A 'doctrine of equivalents' is required to supplement current legislation. Across the sector, skills availability is an issue. Recruiting people with the programming, software development and systems engineering skills is sometimes challenging and the UK faces strong international competition for the talent.

The sector generally receives less attention than others. There is Government support for established marine technology companies; however more support for start-ups would be beneficial. In particular, investing in a technology's end-use is critical to ensure that it is developed to provide solutions to real-world problems.

GO-Science was speaking to Dan Hook, Managing Director, ASV Global.

Increasing demand for satellite bandwidth



Inmarsat is a global mobile satellite communications company with a history steeped in maritime communications. The company owns and operates 11 satellites flying in geostationary orbit above the Earth, and is headquartered in London.

Increasing demand for satellite bandwidth

Satellite communications are the critical enabler of the era of smart shipping into which the maritime industry is sailing.

Driven by a fundamental shift from scarce and expensive commodity to plentiful, value-driven resource, enhanced connectivity will unlock the potential of the connected ship, enabling the adoption of new tools and technologies by ship owners and ship managers and provide modern crews with shore-based internet speeds.

The opportunities that flow from the connected ship are numerous and constantly expanding. At the highest level, a greater degree of visibility on vessel and cargo position and performance produces tangible metrics that can be shared with customers and other stakeholders.

At the operational level, there are numerous OPEX (operating expenditure) benefits that derive from better communications. The most popular include monitoring of the main engine and associated systems to derive vessel performance data.

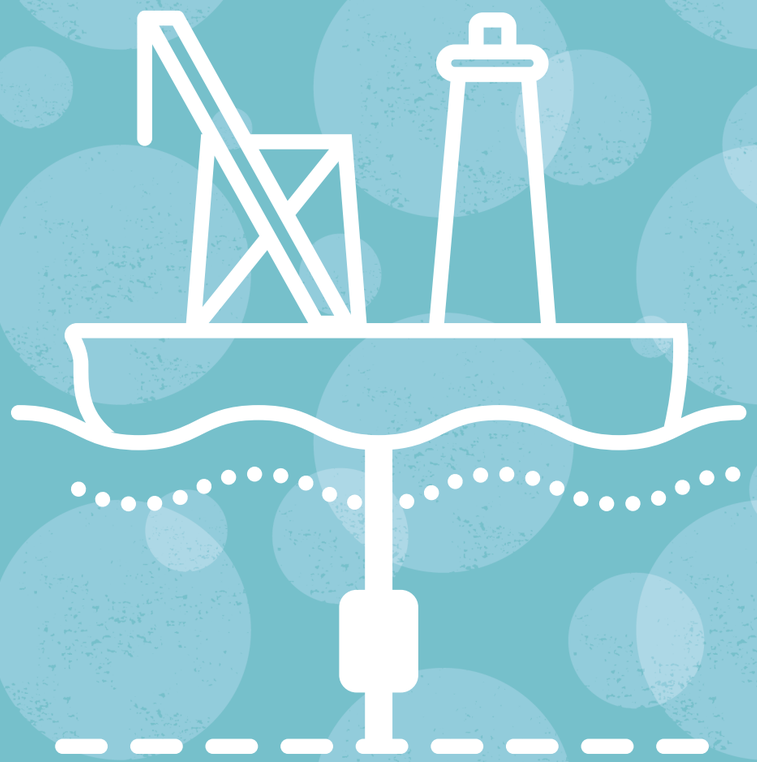
The use of applications such as passage planning and weather routeing for optimal sailing can also contribute to a profitable voyage. Greater availability of bandwidth also plays a key role in bridge procedures, whether for navigation and situational awareness or security of physical and cyber assets.

Inmarsat operates a fleet of satellites to provide a global communications network capable of enabling a digital transformation of the maritime industry. This technology aims to solve the ‘bandwidth bottleneck’ at sea by delivering internet access and associated innovative applications to vessels at sea.

Clustering of UK maritime technology companies could really accelerate the development and innovation of the sector and bring large economic benefits. For example, Norway has already developed a maritime technology hub which enables innovation through collaboration of a cluster of marine technology businesses.

GO-Science was speaking to Rob Myers, Senior Director, Maritime Market Development, Inmarsat.

Emergence of deep sea mining



UK Seabed Resources is a UK-based subsidiary of Lockheed Martin Corporation, a global company which specialises in the development, integration and sustainment of advanced technology systems, products and services for the maritime, aerospace and defence sectors.

Emergence of deep sea mining

Seabed mining technology presents a future UK development opportunity.

Advances in autonomous harvesting machinery technology will centre on the extraction of minerals at depth, while minimising environmental disruption. The UK is well placed to take a lead in the industry, due to its skills base and experience, including in North Sea oil and gas extraction.

There are three types of deep sea deposits – cobalt crusts, polymetallic sulphides and polymetallic nodules. UK Seabed Resources is primarily interested in the last. The current challenges are both regulatory and technical, and notably the emerging environmental regulations may shape the technical solutions. While these regulatory, technical and environmental challenges, as well as infrastructure investments, will need to be addressed for successful development of seabed mining, in the longer term it is expected that such mining will be a viable alternative to active terrestrial sources.

To date, UK Seabed Resources' exploration activities have been in international waters, specifically the Clarion Clipperton Zone in the Pacific, rather than national exclusive economic zones (EEZs), while other contractors have looked at EEZs, e.g. the Cook Islands. It is currently unknown whether the UK's EEZ contains mineral deposits of sufficient value and density to attract commercial seabed mining operations. However, mineral extraction within the UK's EEZ would be theoretically possible if surveying indicated sufficient density of minerals. Currently, the UK does not have an established mineral processing industry, and although the cost of transportation is marginal, if plants were to be based in the UK, they would need deep water port access and low-cost energy.

Seabed mining and similar oceanic activities will require maritime autonomous systems that are increasingly reliable, as these vessels will operate in harsh environments for long periods of time, and sensors that are increasingly sensitive. Increased use of autonomous vehicles will also drive the demand for increasingly sophisticated and resilient space-based communications and navigation technology for communication, control and data retrieval from these vessels. The satellite communications sector would benefit from increased investment in the UK, including the potential for development of vertical launch capability. Additional challenges will be in regulations for controlling such craft, and development of supporting infrastructure for autonomous vessel operation.

GO-Science was speaking to Chris Williams, Head of Government Affairs, UK Seabed Resources and Mike Mansergh, Head of Strategic Engagement, Maritime, Lockheed Martin.

Growth of the decommissioning industry

Shell is an integrated energy company that provides around 13 per cent of the UK's total oil and gas production. Their headquarters are in the Netherlands.

Growth of the decommissioning industry

The current low oil prices represent an opportunity for the UK to invest in and progress technology in decommissioning of oil and gas platforms.

The decommissioning of offshore structures in the North Sea is an opportunity to grow the skillset required in the UK. These skills will be both exportable and transferrable to civil nuclear decommissioning. However, decommissioning technology is not being pioneered by the UK currently, in part because the industry requires investment on a scale which is not generally seen in the UK. Safety in decommissioning will be also critical; better risk modelling and forecasts will be needed to ensure dangerous procedures are carried out during the lowest risk period.

Offshore wind is also a growing industry and, with the largest offshore wind capacity of any country, the UK is well placed to take a lead in this sector. However currently the technology is largely coming from Denmark and Germany. As the most-ideal locations for offshore wind farms are used, wind turbines will need to be installed in deeper water. This will drive technological developments which may allow new UK players to enter the market.

The shipping industry is attracting fewer people, and those that do enter generally have less practical experience, despite having good degrees. Instead, experienced senior people are being brought in from other countries. Exposing students to shipbuilding, and giving them multidisciplinary foundations would help fill these skills gaps. Similarly, more work with universities on the integration of automation into whole systems would be useful to provide doctoral students and academic researchers in this area. Currently, there are very few centres of excellence for systems engineering and there needs to be more investment in systems engineering. Moving forward, academia and industry need to collaborate closely on these types of courses.

GO-Science was speaking to Katherine Trauth, Global Lead on LNG Marine Fuels, Tech Development and Shipbuilding Projects; Stephen Bowring, Global Discipline Head, GM Civil, Structural and Offshore Engineering; Alison Brown, MetOcean Tech Lead, Shell.

Development and integration of offshore wind power

DONG Energy is the global leader in offshore wind power, having made the successful transition from oil and gas. They are also an energy supplier to industrial and commercial markets. They are headquartered in Denmark but the UK is currently their primary market for offshore wind power production.

Development and integration of offshore wind power

One of the biggest challenges for the large-scale deployment of offshore wind is storage and integration.

While the grid electricity system can absorb the 18GW of capacity that will be installed over the next decade, the longer-term opportunity to significantly expand the role of offshore wind in the UK's power generation mix will depend on developments in demand-side response (DSR) and energy storage. Government will have an important role in driving innovation in these areas.

If the UK wants to remain a leader in wind energy, it needs to consider how to integrate wind power to the grid and how to maintain a resilient grid when a larger share of the power comes from non-dispatchable sources.[4] Alongside this major challenge are specific innovation challenges that include growing the size of turbines, new types of foundation and the industrialisation of some parts of the supply chain.

It is probable that fixed-platform wind may serve the majority of available UK future capacity; however floating platform technology might be expected to play more of a role in a number of emerging offshore wind markets outside NW Europe, where water depths are greater. As a leader in offshore wind, the UK is well placed to drive the technologies needed in these new markets and the associated supply-chain offer. Decommissioning and repowering[5] of wind farms as the sector matures will also become increasingly important, and one where the UK can take the lead if its supply chain is ready to meet this challenge.

Academic research and early technology readiness levels in this field are UK strengths; however we have historically been less successful at commercialisation of research. Improved signposting of innovation routes, for example as targeted by the new Innovation Hub, will go a long way to simplifying a process that is currently hard to navigate, and Government could consider what steps might more expediently bring innovation to market. For example, eco-port hubs could be developed to support not only offshore wind farms but also innovation, commercialisation and manufacturing. In this way the supply chain, entrepreneurs and innovators are co-located and supported.

GO-Science was speaking to Benj Sykes, Vice President and UK Country Manager, DONG Energy Wind Power and Phil Ford, Lead Stakeholder Advisor, DONG Energy UK.

4 A non-dispatchable source of electrical energy is one that cannot be turned on or off in order to meet fluctuating electricity demands.

5 Repowering refers to measures that improve the efficiency and capacity of wind farms by retrofit of the latest technology.

Challenges and opportunities for the UK's ocean economy

These interviews highlight a range of technology and business trends that will shape the future of the marine and maritime industry. From these we can infer a number of challenges and opportunities for the UK.

Challenges

- The **industries are fragmented**. This results in difficulties commercialising and reducing the costs of innovations, and risks the sector as a whole being less than the sum of its parts.
- The **industries have been historically conservative** in their approach to technology adoption, due partly to long asset lifetimes, high investment costs and low margins; this may constrain penetration rates of new technology in future. This is a concern when maximum benefit will come to countries who lead or are early adopters of disruptive technologies.
- The industry perceives a persistent **'sea blindness'** or lack of recognition of the industry's importance to the UK economy.
- Increasing automation and uptake of new technologies will **require new skills in the marine workforce** and the UK must ensure skills supply meets these changing demands. The industry will continue to compete with the automotive and aeronautical sectors for skilled graduates, and faces a struggle to attract talent if it cannot increase the range and depth of employment opportunities.

Opportunities

- **New trading routes, new resources and increasing demand for commodities and services** as the population grows will present trading, infrastructure and processing opportunities.
- A strong services sector means that the UK is well placed to take **a leading role on legal and regulatory innovation**, for example in emissions reduction legislation.
- Automation is a major interest area, but uncertainty persists over deployment timeframe and eventual industry impact. The UK could show leadership through **pilots and dedicated areas of technology experimentation**, as seen in car automation development.
- Increasing uptake of automation will also lead to opportunities in **high-value technical services** on new platforms and the need to more fully consider connectivity in the oceans.
- Technological improvements may increase demand for **high-tech specialist technology and ships**. This presents an opportunity for the UK where there are existing strengths and a skills base in bespoke technology and ship building.
- Data transfer is currently a constraining factor and the **development of satellite bandwidth and capability to process large amounts of data**, are expected to be major growth areas.

Collectively the UK has many engineering and business strengths in the ocean economy. These have multiple overlaps, but the industry has historically struggled to articulate its value as a coherent and integrated sector. Sectoral coordination, considering the potential synergies between different industries, could reap benefits in realising economies of scale, planning and pooled expertise. The GO-Science Foresight Future of the Sea project will seek to establish how this improved coordination can be achieved.