Department for Transport

Technology and Innovation in UK Maritime: The case of Autonomy

A Maritime 2050 Route Map

January 2019

maritime 2050
NAVIGATING THE FUTURE

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Ministerial Foreword

From the sextant to the steam engine, our nation's rich maritime heritage has relied on our ability to identify and respond to major technological trends. Now, as we take stock of the sector as a whole, through our ambitious Maritime 2050 strategy, we can see that the maritime sector has reached a pivotal moment for technological development.

New technologies such as maritime autonomous systems can make the sector a cleaner, safer, more efficient place in which to work. They can improve how humans interact with machines and create new, high-value jobs around the UK. When coupled together with other developments, such as the digitisation of outmoded paper-based processes and the increasing use of data analytics, many of these new technologies will allow for a smarter maritime sector. It is also clear that these technologies have revolutionary potential, offering a challenge to traditional business models.

And, together with industry, the Government is ready to step up to that challenge. In February 2018 I was delighted to welcome over 80 representatives from industry to the Maritime Autonomy Futures Lab. This lab was the first time that such a broad range of stakeholders had been brought together to consider how the UK will remain a world-leader in the development of innovative maritime technology. That same evening the Transport Secretary, Chris Grayling, spoke of

the importance of a collaborative approach to achieving the best outcome for the UK maritime sector.

Building on a strong platform of engagement with industry, this route map, which complements the Maritime 2050 strategy, sets a pathway for how Government and the industry can work together to make the UK a world-leader in the development, manufacture, uptake, and use of maritime autonomy technologies.

Stakeholder Endorsement

"The Technology & Innovation in UK Maritime Strategy is incredibly important for the UK. It gives the industry, academia and Government some clear goals and plans and I have enjoyed working with the team at DfT at various workshops and reviews. They… spoke to a wide range of stakeholders and in the particular area of interest for L3 ASV, marine autonomy, they have reached some great conclusions and put forward some good plans. I look forward to helping deliver it and working with others in the industry to see how we can all grow."

Dan Hook, Senior Director – Business Development – L3 ASV

"BMT welcomes the policy recommendations on Technology and Innovation in the UK maritime sector produced by DfT in collaboration with the UK Maritime industry. These will enable the UK to continue to be a leading global supplier that contributes between £7.6bn and £13.8bn of direct gross value added (GVA) to the UK economy each year. In addition these recommendations demonstrate a clear commitment from Government in recognising the international competitive strength and value of the sector to the UK economy. We look forward to contributing to its implementation."

Guy Tomlinson, Capability and Strategy Director at BMT

"As an international organisation supporting all those working in marine technology, engineering and science, the IMarEST is very supportive of the initiative to develop the UK's strengths in maritime innovation. A platform where industry, government and business can work together will achieve so much more than any one of us could do alone and will stand us in good stead to lead on important issues such as green shipping, safety, autonomy regulation and meeting future skills needs."

David Loosley, Chief Executive, IMarEST.

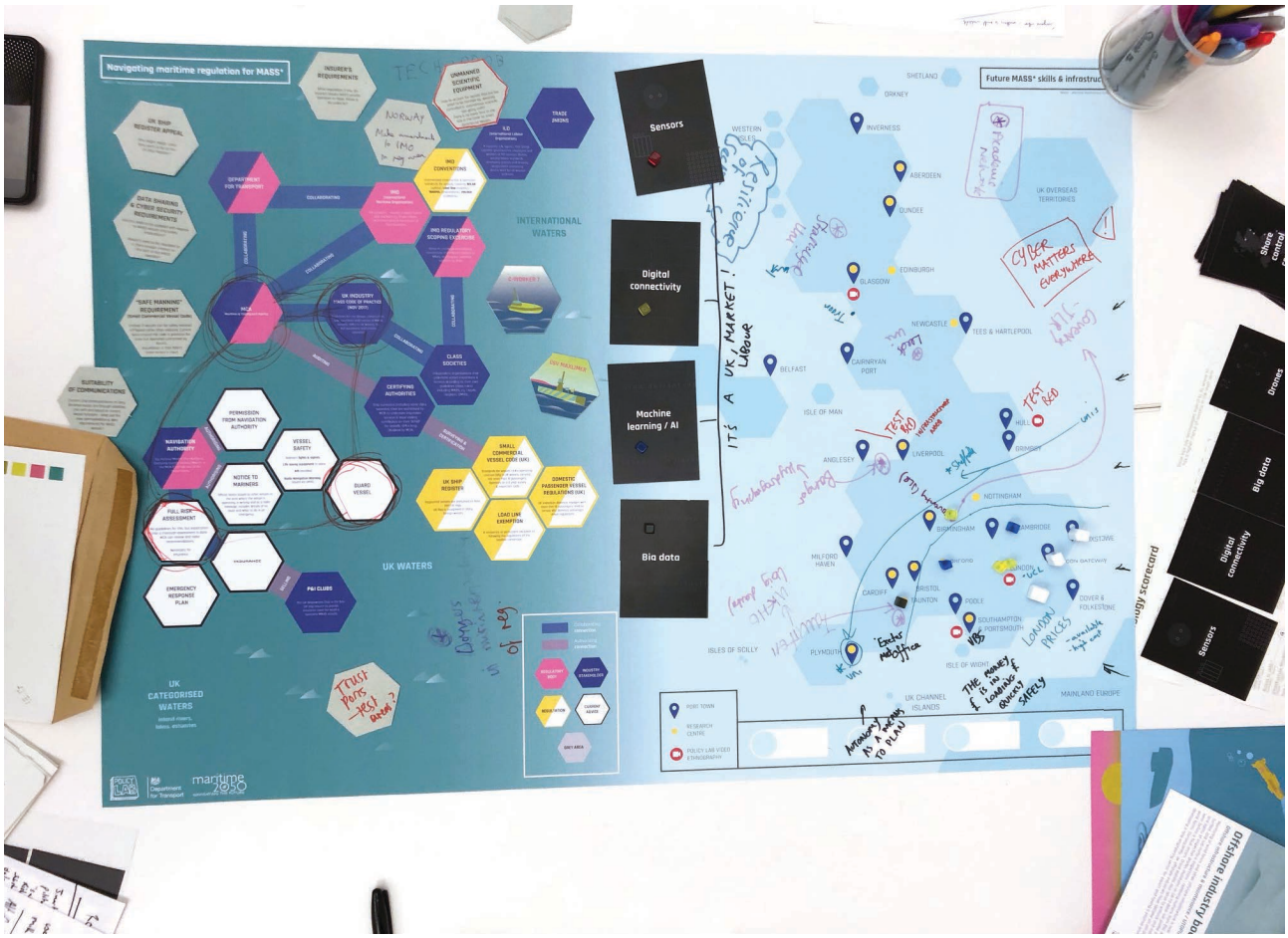
"The Department for Transport's partnership with Policy Lab has demonstrated exciting new ways of collaborating with industry experts and front-line staff to shape the future of maritime autonomy. The Lab's film ethnography explored the complex relationship between technology and human skills, whilst our "Futures Lab" applied speculative design and gamification approaches to generate fresh perspectives and innovative ideas. These open-policy making techniques have ensured that the recommendations better meet the needs of industry, whilst also providing a concrete road map from today's technologies into tomorrow's opportunities."

Dr. Andrea Siodmok, Deputy Director at Policy Lab, Cabinet Office.

Executive Summary

Introduction

1. This route map complements the ‘Technology’ theme chapter of the Maritime 2050 strategy. Maritime 2050 is an ambitious, long-term strategy to ensure that the UK remains a major maritime nation, providing a shared vision for Government, industry and customers and ensuring greater clarity for international parties and investors.



2. In the ‘Technology’ theme of Maritime 2050 there are four sections: Future Shipping; Smart Ports; Digitalisation; and Communication, Navigation and Exploration. These offer ambitious policy recommendations designed to keep the UK at the heart of innovation in maritime.

3. This route map, ‘Technology and Innovation in UK Maritime’, seeks to apply these recommendations to the specific case study of maritime autonomy. Maritime autonomy is a broad term describing how equipment operates and who it is operated by. Today, vessels are primarily operated by human crews. Advances in technologies such as sensors, data analytics, and machine learning, mean that in the future, vessels could operate with fewer crew on board. Robotics or algorithms could perform tasks to augment human capabilities. Alternatively, vessels could be completely unmanned, and instead ‘crewed’ from shore-based control centres. Another possible development is that vessels could operate entirely independently of any human operator, with decisions made entirely by the machine. To reflect this wide range of possibilities, Lloyds Register Foundation has developed a scale representing levels of autonomy, which ranges from ‘AL 0’ (no autonomy) to ‘AL 5’ (fully autonomous).[1]

4. Maritime autonomy and the technologies that enable it can bring great benefits to today’s maritime workforce if developed in a way that is sensitive to the workforce’s needs. Autonomous systems can augment human capabilities making the sector a safer place to work. Decision support provided to human crews by autonomous systems can improve high-level human performance. By carrying out dull, dirty, and dangerous jobs, autonomous systems allow humans to focus on making high-level decisions about the daily operations of the maritime sector. These new technologies also offer

[1] https://www.lr.org/en/latest-news/early-adopters-and-innovators-in-connected-assets-on-ships/

exciting opportunities for reskilling the existing workforce.

5. Maritime autonomy is part of a broader technological shift in the maritime sector that can be called smart shipping. Smart shipping is defined here as a technological pathway for the entire maritime sector. This pathway encompasses the automated, partly-digitised equipment of today, the remote operation of equipment, and the development of autonomous maritime systems, both at sea and onshore. Here, 'shipping' is understood in its broader sense, rather than just referring to seagoing vessels. This broad definition is used because new technologies will have the greatest impact when they are used holistically, as part of a wide-ranging approach that applies to the whole UK supply chain.

6. Maritime autonomy has been chosen as it incorporates many of the major challenges facing the sector today: safety, efficiency, skills, technology and infrastructure development, and the need for effective regulation. To reflect this, the route map has been developed in close collaboration with industry, laying the foundation for future productive joint efforts between industry and Government to ensure that, through its development of maritime autonomous technology, the UK remains a major maritime nation.

7. Using this case study, the Technology and Innovation in UK Maritime route map outlines how a number of the Maritime 2050 'Technology' theme's short and medium term recommendations will be implemented. The route map also illustrates where a number of Maritime 2050 'People' theme recommendations may be applied to this case study, though this theme will be explored in detail in its own separate route map. An illustration of the interdependencies between the two strategies is provided at page 12.

8. Together with industry, Government has identified five key themes for this route map:

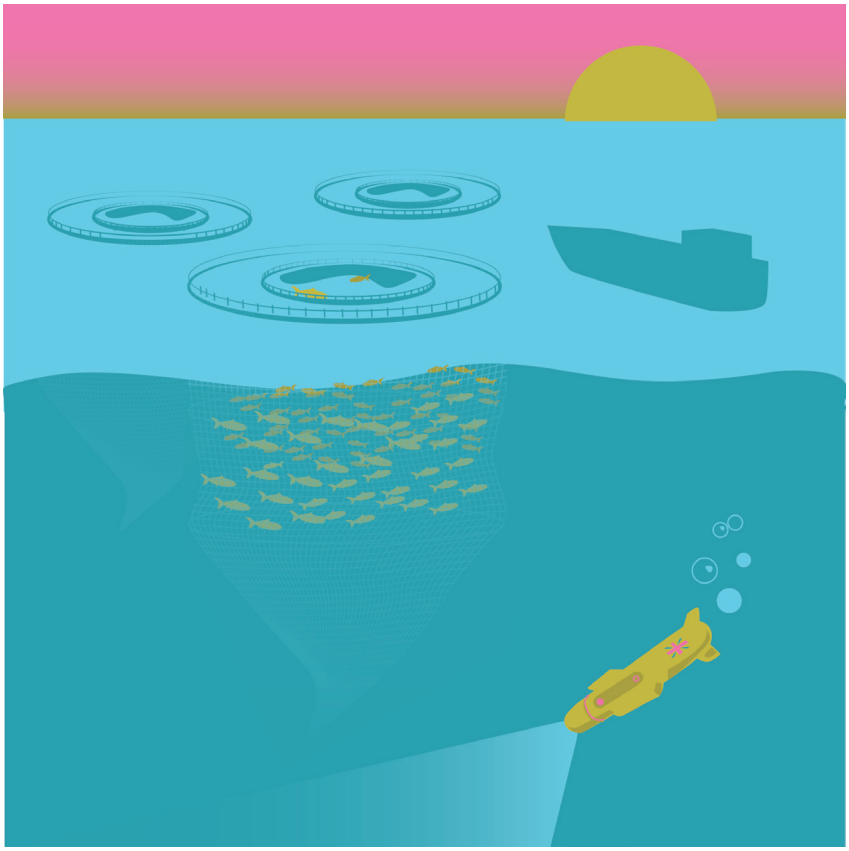
    - a Government vision to provide leadership and direction for industry;
    - ensuring that the physical, digital, and organisational infrastructure is in place for autonomous technologies;
    - supporting the development, use, and export of critical smart shipping technologies;
    - developing the skills base necessary for a technologically-enhanced maritime future; and,
    - regulating to create an open yet safe environment for innovative technologies such as maritime autonomous systems.

Vision

9. Government wants the UK to be at the heart of a global maritime autonomy industry. The UK expects to be world-leading in the design, manufacture, uptake and use of smart shipping technologies, the associated skills base and the relevant regulatory framework. The UK should be the destination of choice for industry-leaders pursuing innovative projects and developing new technologies.

10. Working with industry, the Government will champion the development, testing, and adoption of new technologies. It will facilitate opportunities for collaboration, provide regulatory assistance, ensure safe testing environments, and support innovators seeking to develop smart shipping technologies.

11. Government will establish a Centre for Smart Shipping (CSmart) to oversee and implement, in collaboration with industry, the policies outlined in this route map. CSmart will act as the single point of contact for Government and industry and will provide oversight and coordination of Government's existing and future work on maritime technology and innovation in the maritime sector.



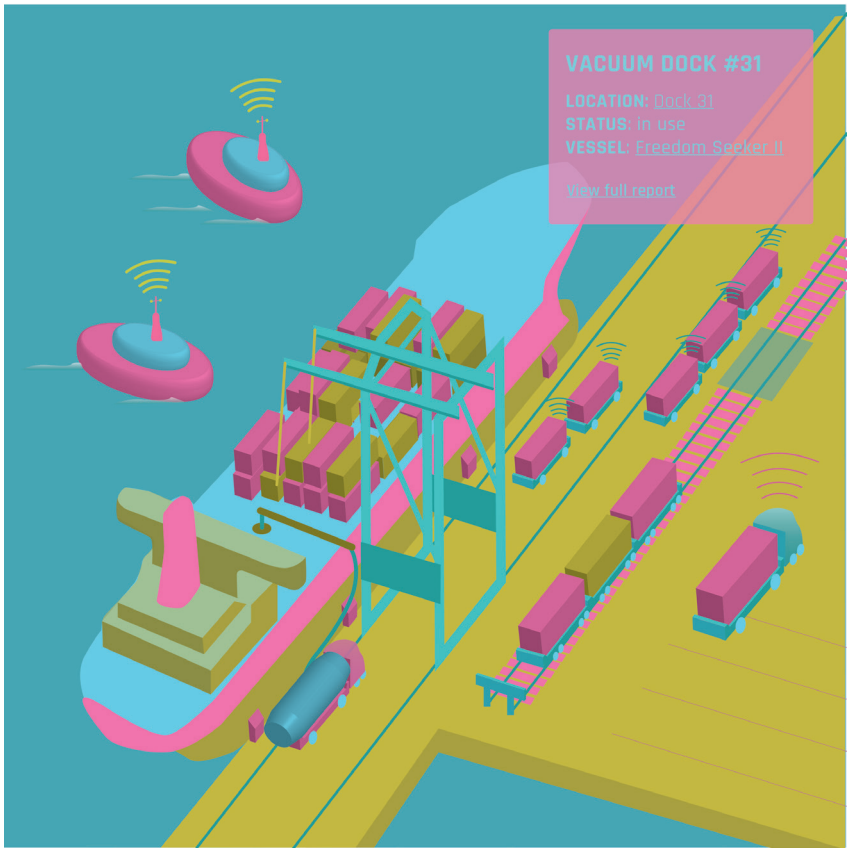
Infrastructure

12. Smart shipping's effectiveness will be severely limited if the infrastructure around vessels remains 'dumb'. The route map considers three main types of infrastructure: organisational, physical and digital.

13. Organisationally CSmart will oversee Government and industry efforts to develop and regulate smart shipping technologies.

14. Ports are critical elements of maritime infrastructure, and ideal locations for the development and testing of new technologies, as well as a clustering of expertise. The Government will work with industry to develop a UK Maritime Innovation Hub in a UK port. Such a hub could be an ideal location to pool expertise and manufacturing capabilities, and test maritime autonomous systems (both on land and on shore).

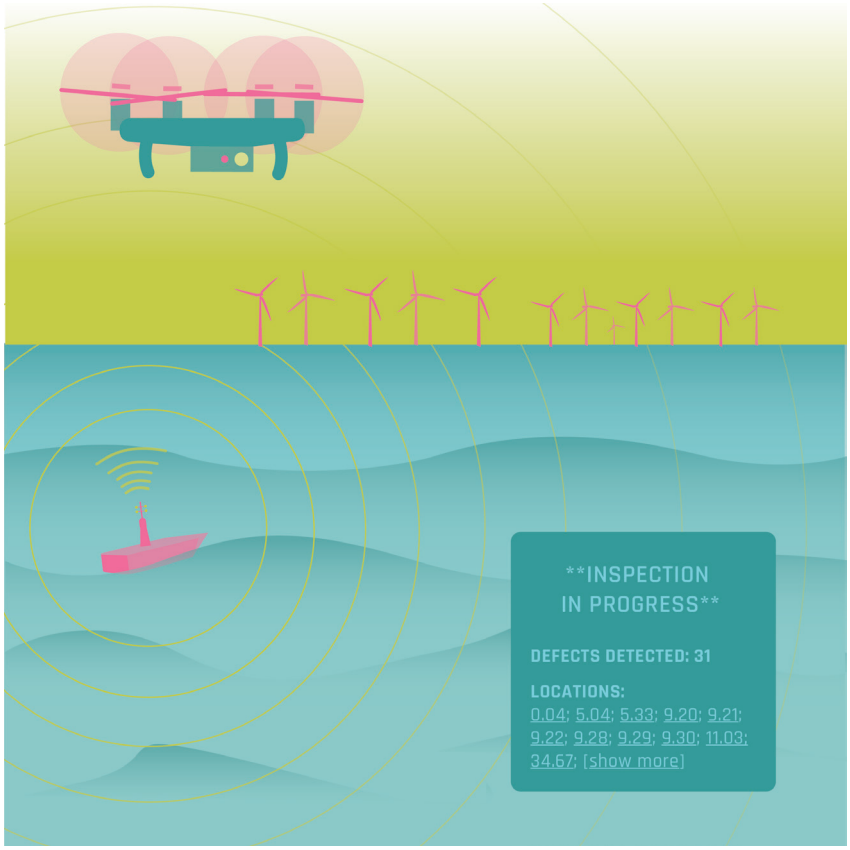
15. Shore-side control centres are another key piece of infrastructure for human operators to remotely control vessels or monitor the status of more autonomous systems. Government will work with industry to consider the establishment of a demonstrator shore-control facility to understand the implications of new maritime infrastructure such as shore control centres.



Technology

16. From its national vantage point, the Government can offer a useful perspective on the opportunities presented by innovative technologies within the maritime sector, helping to identify where these may bring broader benefits to the UK economy as a whole. Government can also play a role in helping commercialise UK research and development efforts, which can often fall into a so-called 'valley of death' between research and commercialisation[2].

17. Four technological trends are identified as key enablers for maritime autonomy with the potential to significantly impact the sector: the use of data and data analytics, the development of artificial intelligence (AI) and machine learning, advanced sensor technology, and improvements in robotics. All of these technologies have a far broader impact on the future of society beyond the maritime sector.



18. Government's role as a facilitator will be promoted with regular cross-sector networking events run through the CSmart. Collaboration with industry will be essential and

2 https://www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/inquiries/parliament-2010/role-of-the-private-sector/

realised through events such as ‘hackathon’-style events in which technologists and maritime sector professionals can come together rapidly develop appropriate technological solutions. Though these recommendations are provided in the context of maritime autonomy, they are designed to be broadly applicable to technology development.

19. To further support this aim Government will, with industry, consider the potential benefits of establishing a joint industry-Government business accelerator to support start-ups working on maritime technologies such as autonomous systems and help commercialise valuable British research and development.

People

20. Even with the development of remote operation and maritime autonomous systems, both on sea and at shore, people will remain at the heart of maritime. The Government seeks to retain the valuable experience of existing seafarers, ensuring that continuous education models are adopted to provide people with the essential skills for work in a technologically-advanced world.

21. The recommendations in our ‘People’ section seek to apply recommendations set out in the Maritime 2050 ‘People’ theme to maritime autonomy. To combat ‘sea

blindness' and promote the sector's attractiveness Government will raise awareness of the maritime industry in schools by having a single industry body overseeing a more coordinated cross-sector and in-school awareness and ambassador programme.

22. We will also task a single industry body with responsibility for bringing greater coherence and coordination to the promotion of maritime careers sector wide. To ensure that the existing workforce are prepared for the working world of tomorrow, Government will promote continuous learning and ensure that the latest technologies are used in maritime training.

23. To identify skills gaps and understand the future maritime workforce CSmart will feed into the Maritime Skills Commission, which will report on the current and future skills requirements for the sector every 5 years and ensure that maritime training is informed by industry need and technological development.

24. CSmart will also oversee a cross-sector mentoring programme between technologists and maritime sector workers to help ensure a transfer of knowledge. This will aim to ensure that technological opportunities are clearly understood, and that innovation can be targeted towards clear needs in the maritime sector.

Regulation

25. Maritime autonomy will require a radical new regulatory approach to meet the challenges of rapidly evolving technological change and its impact upon society. In this route map Government considers in particular one

aspect of this theme, by setting out how the UK will develop a domestic regulatory framework to enable the safe testing of maritime autonomous systems.

26. Government will establish a maritime innovation lab (MAR Lab) to pioneer innovative regulatory approaches to Maritime Autonomous Surface Ships (MASS). Led by the UK's maritime regulator, the Maritime & Coastguard Agency, MAR Lab will be responsible for developing a flexible and practical domestic regulatory framework to facilitate safe and innovative testing of vessels.

27. The availability of a wide variety of areas to safely test autonomous systems is essential for the development of the technology. Government will enable the safe testing of maritime autonomous technologies across a range of different environments and in different conditions.

28. In the longer term, the experience of MAR Lab will allow the UK to gather a body of evidence and expertise that can enable it to lead international efforts to regulate maritime autonomy at the International Maritime Organization (IMO).

Implementation

29. Recognising the rapid pace of technological change, this route map will be regularly reviewed by CSmart. Implementation of the policy pathway set out in this document will require continued close collaboration between industry and Government to ensure that the UK benefits from technological change. The policy recommendations in this route map are designed to advance the UK toward the ambitions outlined in Maritime 2050.

The Policy Pathway

30. To achieve our ambitious vision to place the UK at the forefront of the technological revolution in maritime, Government has identified a set of ten ambitions, spanning the topics of infrastructure, people, technology, and regulation.

Infrastructure

31. Establish a Centre for Smart Shipping (CSmart) to co-ordinate and implement Government policy on technology and innovation in the maritime sector, with a focus on autonomous technology. The Centre will have responsibility for implementing the policies outlined in this route map, and for providing support to industry-led flagship projects demonstrating the applications of innovative maritime technologies (particularly projects demonstrating the use of autonomous systems).

32. Collaborate with industry and academia to consider

establishing a demonstrator shore-control centre to help understand the implications of new infrastructure to support maritime autonomy.

33. Develop, with industry a 'UK maritime innovation hub' based within a UK port, for the collaborative development of innovative maritime technologies such as autonomous systems.

Technology

34. Explore the potential of a joint Government-industry business accelerator for maritime autonomy technology start-ups. This could be a dedicated facility providing advice to start-ups, helping them to grow and commercialise their technology and increase the UK's international appeal as a centre for innovation in maritime autonomy.

35. With industry, set a series of technological challenges to be tackled in 'hackathon'-style events, in which technologists will come together with industry to rapidly solve technological problems, including those related to maritime autonomy.

People

36. Ensure that the national Maritime Skills Commission, recommended in the M2050 People Theme assesses the current training requirements and future skills needs of the sector, in the context of major technological developments such as maritime autonomy.

37. Support the launch of an industry marketing campaign to promote the UK maritime sector in schools as an exciting and innovative place to work. Deliver this by working with industry to highlight the exciting career opportunities offered by the maritime sector, including the opportunities arising as a result of technological developments such as maritime autonomy.

38. Develop mentoring schemes between the maritime sector, technology experts from beyond the sector, and other professionals in industries facing similar challenges to encourage transfer of skills and people.

Regulation

39. Government will establish a maritime autonomy regulation lab (MARLab), for regulatory innovation in maritime autonomy. The lab will aim to encourage maritime innovation in the UK, helping create an

environment which attracts international companies to invest and test autonomous technologies here. The work of MAR Lab will be used to develop a domestic regulatory framework for maritime autonomy which will allow the UK to lead negotiations at the IMO to establish international regulations for maritime autonomy.

40. Government will continue to enable the safe testing of these autonomous and autonomy-supporting technologies around the UK, across a range of environments and in different conditions.

Table One: Policy Pathway Summary

Theme	Recommendation	Rationale
Infrastructure	Centre for Smart Shipping	Implementing policies in route map, co-ordinating industry and government activity
	Work with industry to develop a 'UK maritime innovation hub' based in a UK port	Creating a place to cluster expertise, develop and test new technologies like autonomy.
	Work with academia and industry to consider establishing a demonstrator shore-control centre	Understanding the implications of new infrastructure required for maritime autonomy
Technology	Explore the potential of a joint industry-government business accelerator for maritime technology start-ups	Supporting and growing business in the UK
	With industry, set a series of challenges to be tackled in hackathon-style events.	Bringing technologists and maritime sector professionals together to find appropriate technological solutions.
People	Ensure that the Maritime Skills Commission considers the impact of technological developments upon current and future skills needs.	Ensuring that the correct skills are available to operate new technologies and anticipate future needs
	Support the launch of an industry marketing campaign in schools showcasing the exciting opportunities offered by new technologies	Promoting the maritime sector and highlight skills needs.
	Develop cross-sector partnerships between maritime workforce, technologists, and those from other sectors.	Encouraging sharing of ideas, best practices, and personnel
Regulation	Establish a Maritime Autonomy Regulation Lab (MAR Lab)	Developing a world-leading domestic framework for testing autonomous vessels with a view to international leadership.
	Continue to enable the safe testing of autonomous systems	Encouraging innovators to come to the UK to test and develop autonomous systems.

Diagram Two: Timeline

	Short term	Medium term	Long term
Policy Priorities in TIUK route map *(bolded priorities are also in the relevant Maritime 2050 chapters)*	Centre for Smart Shipping Consider establishing a demonstrator shore-control centre Set a series of technological challenges to be tackled in 'hackathon'-style events Mentoring schemes between the maritime sector and tech experts from beyond the sector 'MAR Lab', for regulatory innovation in maritime autonomy Continue enabling the safe testing of these autonomous and autonomy supporting technologies	Joint Government-industry business accelerator for maritime autonomy start-ups **Promote the UK maritime sector in schools**	**'UK maritime innovation hub' based within a UK port** **Maritime Skills Commission reccommended in the M2050 People Theme**

Glossary

Artificial Intelligence (AI): A type of computer technology concerned with making machines work in an intelligent way, similar to the way that the human mind works.

Augmented Reality (AR): An artificial environment created through the combination of real-world and computer-generated data.

Automation: The use of methods for controlling industrial processes automatically, especially by electronically controlled systems, often reducing manpower.

Digitalisation: The use of digital technologies to change business practices and provide new sources of revenue.

Digitisation: To transcribe data into a digital form so that it can be directly processed by a computer.

Interoperability: The ability of a system or component to function effectively with other systems or components.

Machine Learning: A branch of artificial intelligence in which a computer generates rules underlying or based on raw data that has been fed into it.

Maritime Autonomy: The use of autonomous systems (including vessels, mooring systems, quayside cranes and other systems) capable of some level of operation and decision making capability without human crew – in the marine environment.

'MASS': Standing for Maritime Autonomous Surface Ships, MASS is the term used by the International Maritime Organization (IMO) for vessels that, to a varying degree, can operate independently of human interaction.

Remote Operation: In a maritime context, remote operation is the process of having a human operator, either on shore or a nearby vessel, controlling an unmanned vessel. Often described as maritime autonomy.

Sensor: Any of various devices designed to detect, measure, or record physical phenomena, as radiation, heat, or blood pressure, and to respond, as by transmitting information, initiating changes, or operating controls.

Smart Shipping: The increasing reliance on new technologies across the entire maritime sector. In particular,

smart shipping refers to a pathway that encompasses the automated and partly-digitised equipment of today, the remote operation of equipment, and partially and fully autonomous maritime systems, both at sea and onshore.

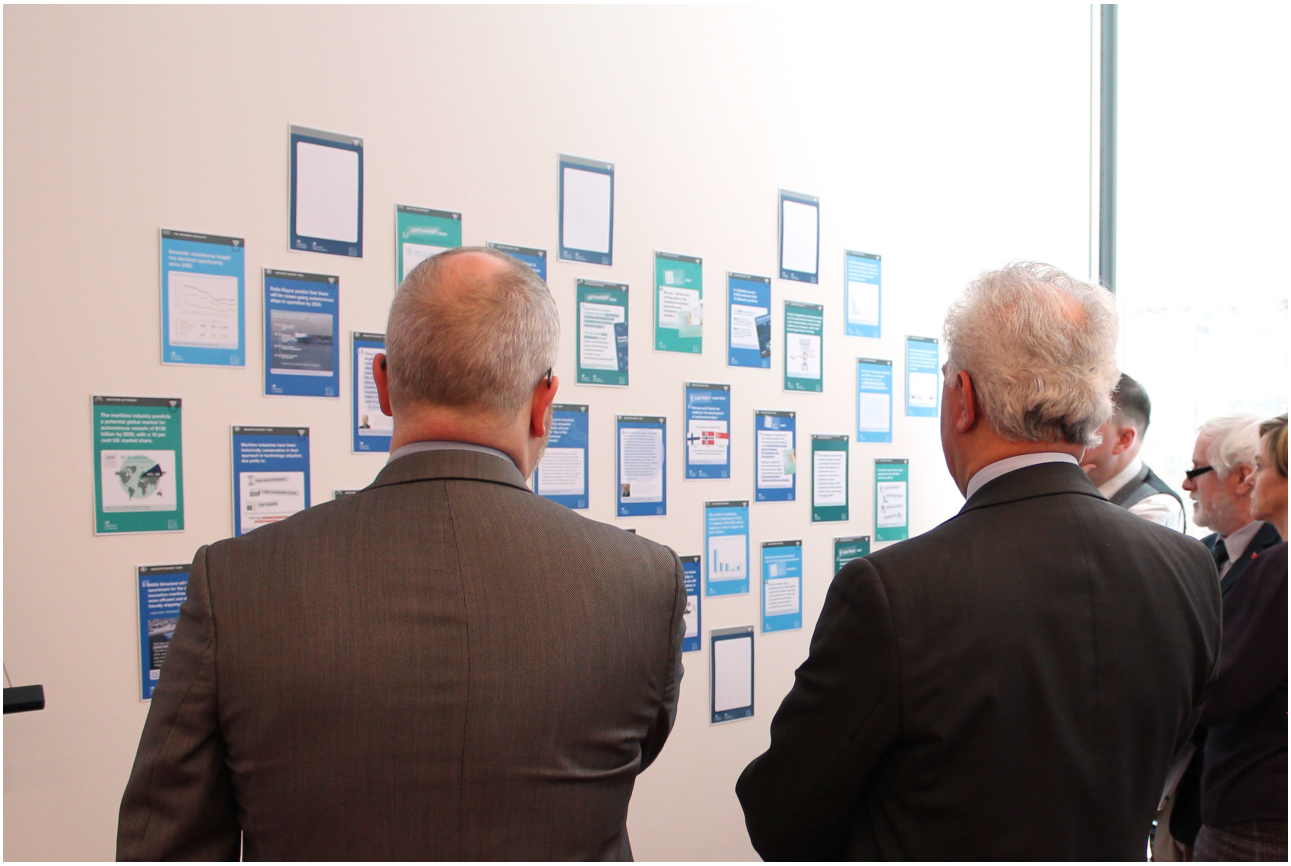
Technology-neutral: In this route map, a ‘technology neutral’ approach means that Government recognises that different technological solutions exist for different problems. There is no one size fits all approach.

Virtual Reality (VR): A technique by which a person, wearing equipment such as a headset or gloves, has the experience of being in an environment created by a computer, and of interacting with and causing changes in it.

Introduction

Context

41. The maritime sector is a critical part of the UK economy, and 95% of the UK's trade is seaborne[3]. In 2015, the sector directly contributed an estimated £14.5bn GVA and employed 186,000 people[4].At the same time, the world faces a 'fourth industrial revolution', as the rapid development of cyber-enabled, interconnected systems capable of increasingly sophisticated levels of autonomy leads to a reimagining of how individuals live and work. In recognition of the vital contribution of the UK maritime sector and the need to face this new future, the Government has launched its ambitious Maritime 2050 strategy.



42. Maritime 2050 explores how the UK can remain a major maritime nation by meeting the challenges of the long-term future and exploiting the opportunities that arise. The strategy provides a shared vision for Government,

3 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739789/port-freight-statistics-2017.pdf

4 https://www.maritimeuk.org/value/

industry, and customers to successfully navigate the journey to 2050 and beyond, ensuring greater clarity for international parties and investors. Maritime 2050 focuses upon seven key themes: 'The UK's Competitive Advantage', 'Technology', 'Trade', 'The Environment', 'People', 'Infrastructure', and 'Security'. This document is the route map for the 'Technology' theme of Maritime 2050.

43. The 'Technology' theme of Maritime 2050 is split into four sub-themes: 'Future Shipping', 'Smart Ports', 'Digitalisation', and 'Communication, Navigation and Exploration'. The theme is wide-ranging, setting out ambitious goals for growing innovation and technology in the UK maritime sector by 2050. This route map seeks to apply this broader approach to the specific case study of maritime autonomy.

44. Maritime autonomy refers to the use of autonomous systems (including vessels, mooring systems, quayside cranes and other systems) capable of some level of operation and decision making capability without human crew – in the marine environment. Maritime autonomy is a major emerging technology trend, it was identified in the Government's Foresight: Future of the Seas report as the single most important technological development in the maritime sector[5].Industry predicts a global market of $136bn over the next 14 years, with potential for the UK, with its strengths in this area, to have a 10% market share[6].

45. Maritime autonomy is part of a broader technological shift that includes the entire maritime sector – Smart Shipping. Smart Shipping encompasses the automated and partly-digitised equipment of today, the remote operation of equipment, and partially and fully autonomous maritime systems, both at sea and onshore. 'Shipping' here is used in its broader sense, to mean the transport of goods via vessel. This reflects the fact that new technologies will have the greatest impact when they are used as part of a wider system, a supply chain from door-to-door in which seaborne transport is only one of many 'maritime' elements.

46. Maritime autonomy is an ideal case study to explore the UK's approach to innovation and technological

5 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/706956/foresight-future-of-the-sea-report.pdf

6 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/706956/foresight-future-of-the-sea-report.pdf

development in maritime because it is a technology that cuts across the whole of the 'Technology' theme of Maritime 2050.

47. Given the focus on maritime autonomy, this route map focuses predominantly on taking forward further detail regarding the implementation of the short and medium term recommendations 'Future Shipping' and 'Smart Ports' sub-themes of the 'Technology' theme within Maritime 2050. These will build toward the longer term ambitions set out in the Maritime 2050 'Technology' theme. As well as setting out further detail regarding the 'Technology' theme of Maritime 2050, this route map also draws from ambitions set out in the 'People' theme. Relevant recommendations from these themes are outlined below (Figure 1 right).

Technology and Innovation in UK Maritime: The Role of Government

48. As the fourth industrial revolution spreads across the globe, technology development is moving at a rapid pace, with new frontiers being opened in areas such as robotics and AI, data analytics, and autonomous systems. These technologies have the potential to transform the way the world works, from business practices, to logistics, to social life. The maritime sector, as part of a connected network of global trade, is also affected by this rapid technological change. Future changes to the way vessels are designed and operated – as well as new, digitised, business practices – will re-shape the maritime sector as we know it today.

49. Maritime autonomy is one such change. Maritime autonomy is a broad term describing how equipment operates and who it is operated by. Today, vessels are primarily operated by human crews. Advances in technologies such as

Figure 1: Maritime 2050 Recommendations Relevant to Smart Shipping and Maritime Autonomy

Technology Theme

Future of Shipping

Short Term

Government and industry will deliver three flagship projects, developing technological proofs of concept and provide demonstrations of use cases for smart shipping.

Medium Term

UK will legislate for a domestic framework for autonomous vessels to attract international business and allow testing in UK's territorial waters.

Government will lead efforts to establish a new proactive and adaptive regulatory framework at the IMO.

Smart Ports

Short Term

Industry and government collaboration to find use cases and develop proof of concepts for new and existing technologies.

Medium Term

Government will work with industry to develop a 'Maritime Innovation Hub' in a UK port as a result of an open competitive process. The hub will bring together expertise, support technology development, and boost regional productivity.

sensors, data analytics, and machine learning, mean that in the future, vessels could operate with fewer crew on board. Robotics or algorithms could perform tasks to augment human capabilities. Alternatively, vessels could be completely unmanned, and instead 'crewed' from shore-based control centres. Another possible development is that vessels could operate entirely independently of any human operator, with decisions made entirely by the machine. To reflect this wide range of possibilities, Lloyds Register Foundation has developed a scale representing levels of autonomy, which ranges from 'AL 0' (no autonomy) to 'AL 5' (fully autonomous)[7]. To enable the development of maritime autonomy, broader changes will be required in the maritime sector, which will need to become generally 'smarter' in its use of technology.

50. Today's maritime sector faces a number of challenges and sources of market failures. It is a complex sector, with many discrete stakeholders with their own business practices and incentives who act as part of a larger supply chain. Therefore, whilst there is a recognition that technological change could bring a benefit across the sector, split incentives at times lead to a reluctance on the part of any one individual link in the chain to invest. Similarly, the global nature of the maritime sector and the nature of maritime trade, with low margins and long equipment life-cycles, can be a barrier to long-term investment in innovative technologies. On a more fundamental level, the maritime environment contains a number of unique safety challenges, for example, the need for pilots to board large vessels by rope ladder, fatal risks associated with mooring vessels to the quayside, and harsh conditions at sea.

51. Drivers for the adoption of technology

7 https://www.lr.org/en/latest-news/early-adopters-and-innovators-in-connected-assets-on-ships/

People Theme

Maritime Workforce

Short Term

Raise awareness of the maritime sector in schools by having a single industry body overseeing a more coordinated cross-sector in-school awareness and ambassador programme.
Maritime Skills and Promotion

Long Term

Government aims to establish a Maritime Skills Commission reporting the existing and future skills needs of the maritime industry on a 5-yearly cycle. This can be used to inform the maritime training curriculum and keep it up to date with the evolving needs of the industry.

could include: requirements for certain standards of equipment or digital provisions; commercial needs of shipowners and other customers driving demand for automation and smart logistics systems;, and the increasing sophistication of a cyber-security threat from which older industrial control systems, which are common in the sector, are particularly vulnerable.

52. Technologies such as maritime autonomous systems have the potential to help address many of these challenges in different ways. This route map does not seek to identify any one particular challenge and then steer technological solutions toward it. Instead it seeks to identify how Government can work with industry to facilitate an environment of innovation in UK maritime, providing the right conditions for the market to innovate to fix the problems it identifies.

Technology and Innovation in UK Maritime: the Approach

53. In developing this route map, Government has worked closely with industry, ensuring engagement with major stakeholders from across the maritime sector[8]. Beginning with a large 'Maritime Autonomy Futures Lab' in February 2018, over 80 industry representatives were invited for a day of innovative, interactive exercises to establish how industry and Government could work together to maximise the benefits of autonomous systems in the maritime sector. Targeted stakeholder engagement was then conducted through small workshops and face-to-face interviews.

54. Industry responses to this engagement have identified the key areas of focus for Government and industry as vision and leadership, infrastructure, skills, technologies, and regulation. Those themes form the scope of this route map:

- A **vision** for maritime autonomy in the UK
- Development and future-proofing of UK **infrastructure** for maritime autonomy;
- The **skills** requirements for maritime autonomy;

8 This approach was informed by the Government Office for Science 'Futures Toolkit' and the Cabinet Office Policy Lab https://www.gov.uk/government/publications/futures-toolkit-for-policy-makers-and-analysts, and https://openpolicy.blog.gov.uk/category/policy-lab/.

- Creating a culture of innovation to help develop the **technologies** which will shape the sector and allow the development of maritime autonomy;

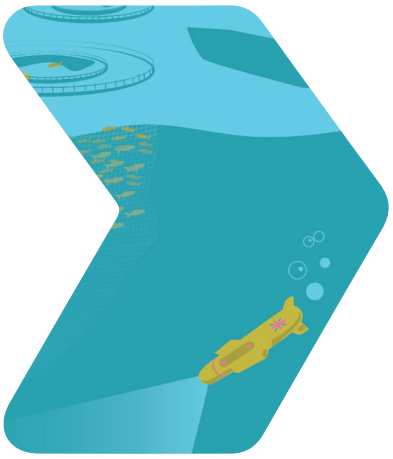
- The **regulatory environment** for maritime autonomy and associated technologies.

Vision

Our Vision for Maritime Autonomy in the UK

55. Government's vision is for the UK to be at the heart of a global maritime autonomy industry. The UK should be world leading in the design, manufacture, uptake and use of maritime autonomous systems and the associated regulatory framework.

56. Working with industry, the Government will champion the development, testing, and adoption of new technologies. Government will facilitate collaboration opportunities, provide regulatory assistance, ensure safe testing environments, and explore how best to support to innovators seeking to test out maritime autonomous systems and other smart shipping technologies.



57. The Government will act as the centre around which a wide variety of innovative expertise can form to find successful, profitable smart shipping solutions, such as maritime autonomy, to major national and global logistics problems.

58. Through active promotion and rigorous standards, Government wants the UK to become the destination of choice for developers and manufacturers of maritime autonomous systems as well as innovators looking to test this technology.

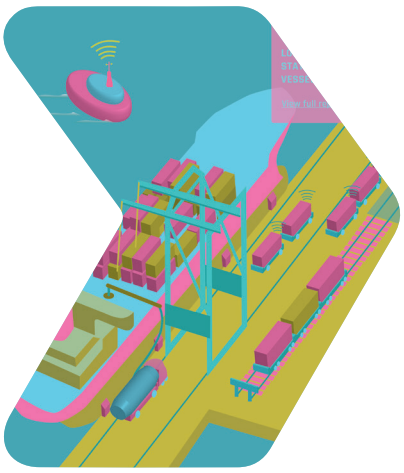
59. UK businesses will become the exporters of choice for the vital hard technologies and soft skills needed to make the maritime autonomy revolution a reality. Government will support industry in making these changes happen.

60. The purpose of this route map is to set out how Government and industry will work together to achieve this ambitious vision.

The Policy Pathway

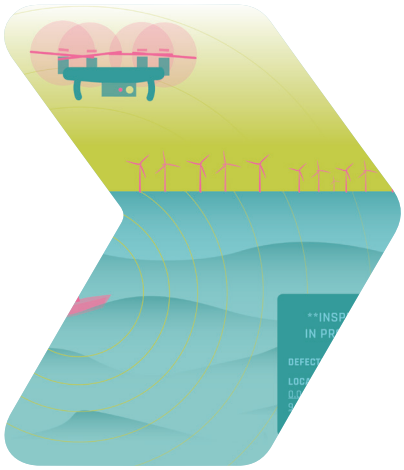
61. To achieve our ambitious vision to place the UK at the forefront of the technological revolution in maritime, Government has identified a set of ten ambitions, spanning the topics of infrastructure, people, technology, and regulation.

Infrastructure



1. Establish a Centre for Smart Shipping (CSmart) to co-ordinate and implement Government policy on technology and innovation in the maritime sector, with a focus on autonomous technology. The Centre will have responsibility for implementing the policies outlined in this route map, and for providing support to industry-led flagship projects demonstrating the applications of innovative maritime technologies (particularly projects demonstrating the use of autonomous systems).

2. Government will work with industry and academia to consider establishing a demonstrator shore-control centre to help understand the implications of new infrastructure to support maritime autonomy.



3. Government and industry will work together to develop a 'UK maritime innovation hub' based within a UK port, for the collaborative development of innovative maritime technologies such as autonomous systems.

Technology

4. Explore the potential of a joint Government-industry business accelerator for maritime autonomy technology start-ups. This could be a dedicated facility providing advice to start-ups, helping them to grow and commercialise their technology. It would aim to increase the UK's international appeal as a centre for innovation in maritime autonomy.

5. With industry, set a series of technological challenges to be tackled in 'hackathon'-style events, in which technologists will come together with industry to rapidly solve technological problems, including those related to maritime autonomy.

People

6. Ensure that the national Maritime Skills Commission, recommended in the M2050 People Theme assesses the current training requirements and future skills needs of the sector, in the context of major technological developments such as maritime autonomy.

7. Support the launch of an industry marketing campaign to promote the UK maritime sector in schools as an exciting and innovative place to work. Deliver this by working with industry to highlight the exciting career opportunities offered by the maritime sector, including the opportunities arising as a result of technological developments such as

maritime autonomy.

8. Develop mentoring schemes between the maritime sector, technology experts from beyond the sector, and other professionals in industries facing similar challenges to encourage transfer of skills and people.

Regulation

9. Government will establish a 'MAR Lab', for regulatory innovation in maritime autonomy. The lab will aim to encourage maritime innovation in the UK, helping create an environment which attracts international companies to invest and test autonomous technologies here. The work of MAR Lab will be used to develop a domestic regulatory framework for maritime autonomy which will allow the UK to lead negotiations at the IMO to establish international regulations for maritime autonomy.

10. Government will continue to enable the safe testing of these autonomous and autonomy-supporting technologies around the UK, across a range of environments and in different conditions.

Diagram One: Maritime 2050 and Technology and Innovation in UK Maritime Relationship

Chapters in the Maritime 2050 Strategy - *DfT's Long term vision*

Technology	People	Environment	Trade	Infrastructure	Security & Resilience	UK competitive advantage

TIUK report - *Top 10 Policy Priorities (bolded priorities are also in the relevant Maritime 2050 chapters)*

Vision

Infrastructure	Technology	People	Regulation
1. Centre for Smart Shipping	4. Joint Government-industry business accelerator for maritime autonomy start-ups	**6. Maritime Skills Commission reccommended in the M2050 People Theme**	9. 'MAR Lab', for regulatory innovation in maritime autonomy
2. Consider establishing a demonstrator shore-control centre	5. Set a series of technological challenges to be tackled in 'hackathon'-style events	**7. Promote the UK maritime sector in schools**	10. Continue enabling the safe testing of these autonomous and autonomy supporting technologies
3. 'UK maritime innovation hub' based within a UK port		8. Mentoring schemes between the maritime sector and tech experts from beyond the sector	

Infrastructure

Introduction

Differing Infrastructure, Differing Needs

61. Changes in in the fundamental physical, digital and organisational facilities of the maritime sector will be needed for the operation of maritime autonomous systems. To deliver the maximum possible benefit to the UK from maritime autonomy, and smart shipping more generally, infrastructure will need to be adapted and upgraded.

62. Longer term ambitions for the UK's maritime infrastructure are explored in the 'Infrastructure' theme of the Maritime 2050 strategy. This section focuses specifically on the infrastructure required to implement maritime autonomous systems.

63. Key to understanding the development of the infrastructure for maritime autonomy is the recognition that maritime is an integral part of the UK's broader supply and logistics chains. As the Government's study of England's port connectivity has shown, the efficiency gains that smart shipping brings can only be realised if there is a smarter landside supply chain connected to the UK's ports[9]. This section considers the infrastructure needed to facilitate a supportive environment for autonomous shipping in three spheres: organisational infrastructure; physical infrastructure; and, digital infrastructure.

Organisational Infrastructure

64. Creating a supportive environment for the development of maritime autonomy requires effective organisational collaboration between industry and Government.

65. Government will support this co-ordination and collaboration through a national centre of excellence for smart shipping which combines, draws upon, or oversees the work of existing bodies. This Centre for Smart Shipping (CSmart) will also be responsible for implementing some of the policy proposals outlined in this strategy, which will be reviewed regularly.

9 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/710030/transport-infrastructure-global-future-a-study-england-port-connectivity.pdf

66. CSmart will adopt a cross-sectoral approach to transport policy in line with the recommendations of the UK's National Infrastructure Assessment and the Government's 'Transport Infrastructure for our global future: A Study of England's Port Connectivity'.[10]

67. CSmart will also learn lessons from the aerospace industry to better understand how to commercialise British research and development capability in the maritime sector. It will help support and promote UK maritime innovators by ensuring that maritime autonomy is included in the Government's award-winning GREAT Britain campaign.

Physical Infrastructure

Understanding Infrastructure Needs

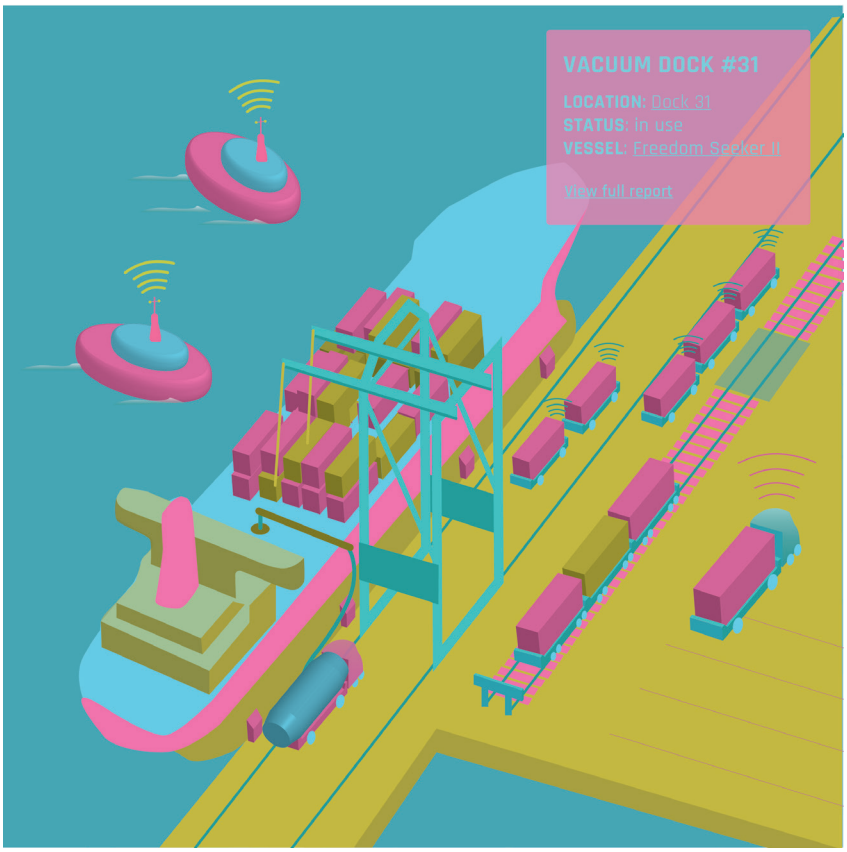
68. New maritime autonomy technologies will require the development of new physical infrastructure. This could include docking facilities within ports, power generation facilities, communications networks, and shore control centres for remotely-operated vessels. Through CSmart, the Government will work with the sector to understand these infrastructure needs.

10 https://www.nic.org.uk/wp-content/uploads/CCS001_CCS0618917350-001_NIC-NIA_Accessible.pdf, and https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/710030/transport-infrastructure-global-future-a-study-england-port-connectivity.pdf

69. Government will also work with industry to better understand the technological, legal and regulatory implications of this new infrastructure. Shore control centres, locations from which vessels are remotely operated or, if autonomous, monitored, will be key to unlocking the potential of smart shipping. Government will work with industry and academia to consider establishing a prototype shore-control centre for remote and autonomous shipping to understand the implications of the new infrastructure that will be required to support maritime autonomy.

The Role of Ports in Maritime Autonomy

70. Ports are the linchpin of our maritime infrastructure, the gateways for the UK's global trade. In the first quarter of 2018 alone, UK major ports handled 112 million tonnes of freight[11]. Ports are fixed locations with infrastructure that has a high cost and a long life-cycle, so the UK's ports need to make decisions now that will future-proof them against developments in maritime autonomy.



71. The effectiveness of autonomous vessels will be diminished if ports are 'dumb'. With the use of innovative

11 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/715517/port-freight-statistics-january-to-march-2018.pdf

technologies – such as sensor-enabled pieces of equipment that can 'speak' to each other (the internet of things), robotics, automation, and digitised freight procedures – ports will become safer, more efficient, and more profitable.[12]

72. Ports represent ideal testing locations for novel autonomous technologies and supporting smart shipping technologies, both on and off the water. As well as providing a unique physical space for the testing of equipment, they are regulated environments and multimodal logistics hubs. Ports also offer opportunities to create clusters of expertise drawing upon innovative ideas from within and beyond the sector, as well as the chance to develop smarter supply chains. All port operators have a responsibility to operate their harbour safely and so will have a role to play in the development and testing of maritime autonomous systems.

73. Government will therefore work with industry and academia to work together to develop a 'UK maritime innovation hub' in a UK port. This innovation hub could be a physical location providing office and meeting space. It will generate opportunities for networking across sectors, nurturing fruitful industry partnerships thus helping to develop UK expertise in maritime autonomy research and development.

Digital Infrastructure

74. As well as the organisational and physical infrastructure, maritime autonomy can only work within a complex digital infrastructure.

75. There are many ways for increased digitalisation to make shipping easier and more efficient: paperless bills of lading, e-certificates, smart contracts using distributed ledger systems such as blockchain, improved connectivity, and robust intelligent systems both on-board and onshore. Many of these technologies are currently being trialled, both in the UK and internationally. Further detail on these is set out below in the technology section of this route map.

76. Increasing digitalisation, however, will increase the need for vigilance around threats to cyber-security. A smarter

12 Hamburg Port Authority, 2015, Energieeffizienz und Smart Energy, http://www.hamburg-port-authority.de/de/smartport/energy/Energieeffizienz/Seiten/default(Standard).aspx.; http://transport.sia-partners.com/20160930/internet-things-transportation-port-hamburg-case-study; https://www.cisco.com/c/dam/en/us/products/collateral/se/internet-of-things/port-of-hamburg.pdf

and more connected maritime sector is one which is more vulnerable to costly cyber-attacks, such as the 2017 'NotPetya' attack which cost Maersk at least $300m.[13] In recognition of this growing concern among the industry, the Department for Transport issued cyber security guidance for vessels in 2017.[14]

77. Through the CSmart, the Government will continue to work with the security services and law enforcement agencies such as the National Cyber Crime Unit to consider how to ensure maritime connectivity remains robust and resistant to damaging cyber-attacks.

Our Ambition

- Establish a Centre for Smart Shipping (CSmart) to co-ordinate and implement Government policy on technology and innovation in the maritime sector, with a focus on autonomous technology. The Centre will have responsibility for implementing the policies outlined in this route map, and for providing support to industry-led flagship projects demonstrating the applications of innovative maritime technologies (particularly projects demonstrating the use of autonomous systems).

- Collaborate with industry and academia to consider establishing a demonstrator shore-control centre to help understand the implications of new infrastructure to support maritime autonomy.

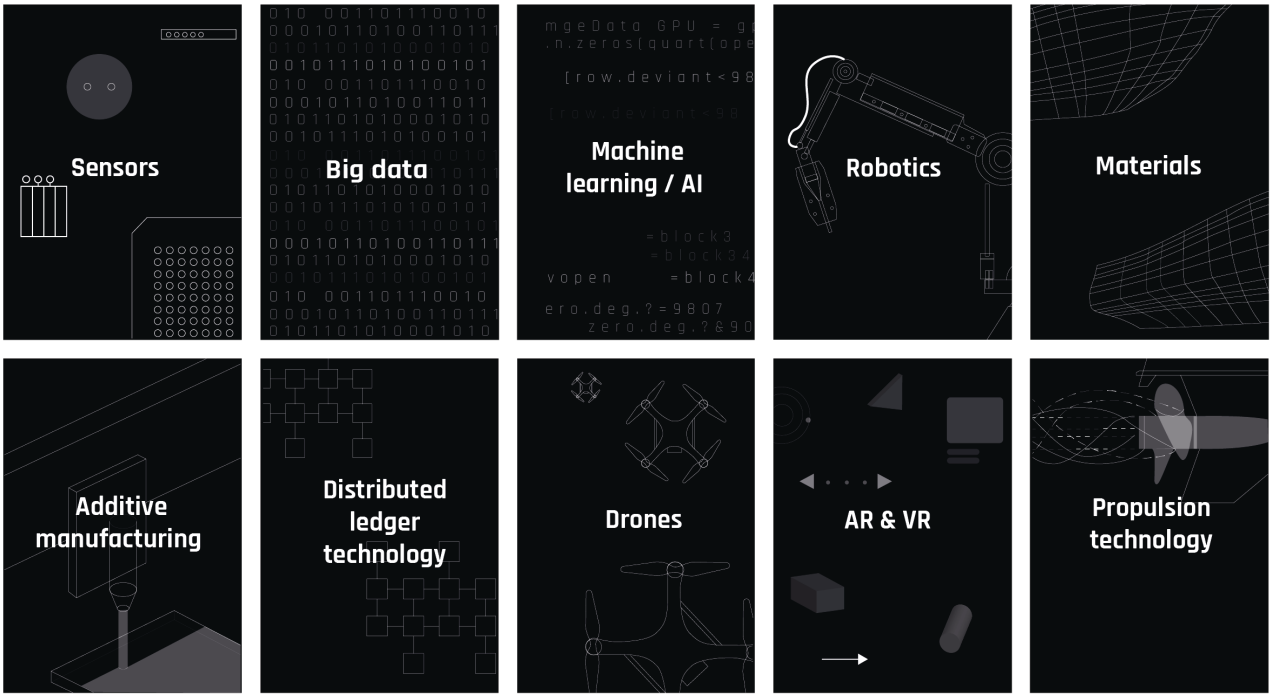
- Develop, with industry a 'UK maritime innovation hub' based within a UK port, for the collaborative development of innovative maritime technologies such as autonomous systems.

13 http://www.ics-shipping.org/docs/default-source/resources/safety-security-and-operations/guidelines-on-cyber-security-onboard-ships.pdf?sfvrsn=16 and; https://www.scmagazine.com/notpetya-attack-totally-destroyed-maersks-computer-network-chairman/article/739730/.

14 https://www.gov.uk/government/publications/ship-security-cyber-security-code-of-practice

Technology

Introduction: Top Technological Trends for the Maritime Sector



78. The UK has a world-leading technology sector, which is growing rapidly. The digital sector alone contributed £130.5bn to the UK economy in 2017.[15] The development of maritime autonomous systems will bring significant new business opportunities for UK innovators, with industry estimating that the UK can have a 10% market share in a global maritime autonomy market worth $136bn within the next fourteen years.[16]

79. The Government has played a central role in supporting the development of British research and development across the economy. An important part of this role is, for instance, the ability of Government in bridging the so-called 'valley of death' between research, development and commercialisation. In the UK this role is played by organisations such as the Catapults and the UK research councils as part of UK Research and Innovation. There is a strong foundation of government support for the development of maritime autonomy, with the National

15 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/759707/DCMS_Sectors_Economic_Estimates_2017__provisional__GVA.pdf

16 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/706956/foresight-future-of-the-sea-report.pdf

Environment Research Council (NERC) investing £17m in the development of autonomous systems in 2017.[17]

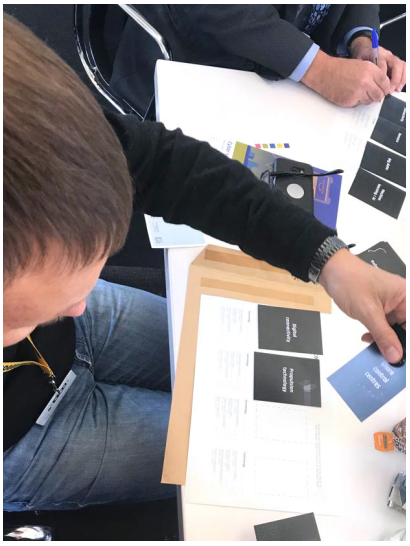
80. The Maritime 2050 strategy considers how Government can work with industry to support innovation in UK maritime. It does so with the objective of promoting world-class research to increase productivity and create high-skilled jobs, in line with the Government's Industrial Strategy. This chapter of the route map illustrates how those ambitions can be delivered in the case of maritime autonomy.

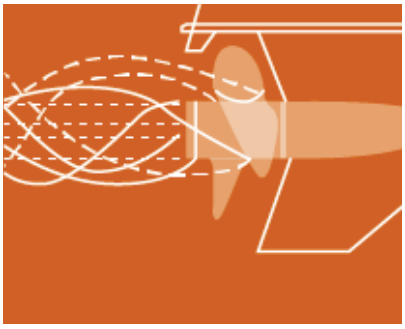
81. It explores the potential of the four most important future technologies or technological trends that will facilitate the transition to maritime autonomy, as identified by industry consultation. It offers technology-neutral policy recommendations to support the research, development, and commercialisation of innovative technologies in UK maritime as well as the marinisation, where appropriate, of other potentially beneficial technological developments.

82. Digital connectivity and shore control centres were two of the most important technologies to enable maritime autonomy identified by our stakeholders. These technologies are viewed as the foundation of an effective, connected maritime sector. They are essential for the remote, autonomous operation of vessels and equipment. In recognition of this, these topics have been identified as critical infrastructure and are covered in the infrastructure section.

83. Propulsion technologies were identified as another important technology. As set out in the Maritime 2050 strategy, the UK aims to be at the forefront of the global transition towards 'zero-emission shipping'. Such a transition is being stimulated by the development of international agreements to limit emissions of both greenhouse gases and air quality pollutant emissions. In April 2018 the IMO committed itself to a reduction in greenhouse gas emissions of at least 50%, and in 2020 it will introduce a sulphur cap on the global fleet.

84. To help achieve the goal of zero emissions shipping the Government has convened the Clean Maritime Council, which met for the first time in October 2017. The Council comprises experts from industry and academia. It will advise on the development and implementation of a Clean Maritime Plan to be published in 2019. The Plan will explore the role technology can play in reducing





17 https://nerc.ukri.org/funding/available/capital/mas/

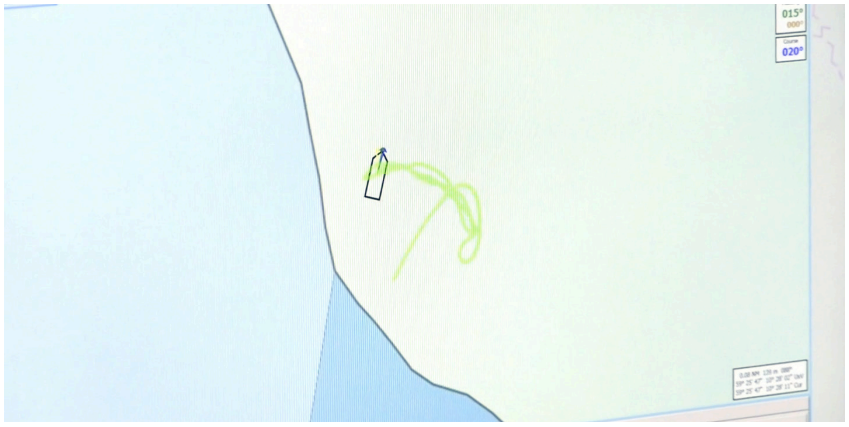
environmental impacts and building clean growth opportunities for UK business.

85. Aside from those technologies mentioned above, the most popular enabling technologies chosen by industry experts were: Sensors; Big Data; AI and Machine Learning; and Robotics. These technologies are inter-dependent, working together as part of a physical and digital 'ecosystem' which will facilitate the development of maritime autonomy. For instance, the data gathered by sensors can be used to develop machine learning algorithms, or inform repairs which may be carried out by robots.

Sensors

Sensor Technology Across the Economy

86. A 'sensor' is a broad term for any device used to measure the physical environment (e.g. weather conditions) in which equipment operates, or to measure the condition of the equipment itself.



87. Sensors are being applied in across the UK economy to great effect.They are, for instance, critical to the operation of high-tech environments such as 'smart cities'. Here, a range of sensor-equipped devices are connected to each other by wireless internet connections. They gather, analyse, and share data to improve services such as waste collection and emergency service response times in a system known as the 'Internet of Things' (IoT).

88. In the UK, many companies are developing sensor technology. The UK is home to centres of excellence in sensor development such as 'Sensor City' in Liverpool. Sensor City, backed by the Government, is a hub for start-ups and existing companies developing sensors and 'Internet of Things' solutions.[18]

18 https://www.sensorcity.co.uk/

Sensors in Maritime

89. In the maritime sector, UK-based companies such as BAE Systems, Chelsea Technologies Group and Thales Group are actively developing maritime sensor technology. Where innovative sensor development is not being considered with maritime applications in mind there is potential to explore the 'marinisation' of this technology.

90. Sensors are a foundational technology of maritime autonomy. They allow for the gathering of the data that allows autonomous systems to operate. Autonomous and remotely operated equipment requires sensors to monitor visibility, weather, the location and condition of equipment. Advanced sensors, combined with machine learning algorithms, can allow autonomous systems to recognise and interact with other equipment in the maritime environment (such as vehicles or berthed vessels at a quayside, or other vessels at sea).

Data

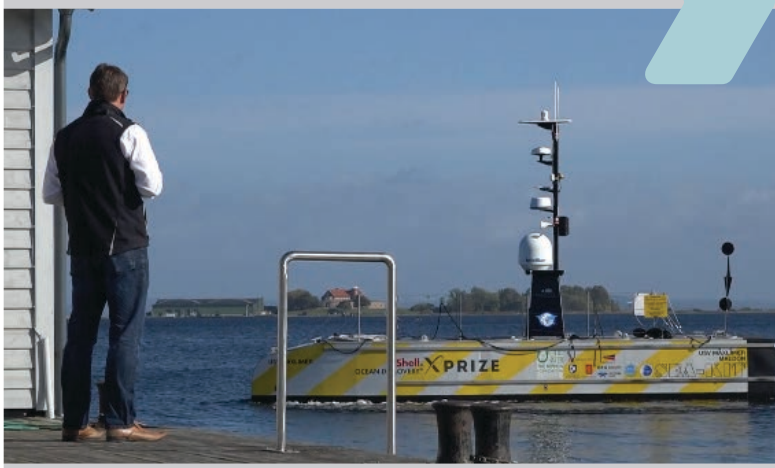
Big Data Across the Economy

91. Data is the information, particularly facts and numbers, collected to be examined, considered, and used to help decision-making. Companies now collect and store huge volumes of data, which is increasingly becoming one of the world's most valuable commodities.[19] The sheer volume of data now available is astonishing, and in 2015, Lloyds Register Foundation estimated that there will be a 4,300% increase in annual data generation by 2020.[20] These huge volumes of data, which are hard to process using traditional techniques and

19 https://www.economist.com/leaders/2017/05/06/the-worlds-most-valuable-resource-is-no-longer-oil-but-data

20 https://www.lr.org/en/insights/global-marine-trends-2030/global-marine-technology-trends-2030/

Shell Ocean Discovery XPrize



Testing Hushcraft's remote operated and fully autonomous vessel

The Shell Ocean Discovery XPrize is a global competition to advance the development of marine robotic technologies in order to access and illuminate the deep ocean environment. Of the 9 grand final teams one, Team Tao, is based in the UK and another – the international GEBCO-NF Alumni team – is using an autonomous vessel (SEA-Kit) designed and operated by a British company, Hush Craft Ltd.

In November 2018, the SEA-Kit vessel completed a 32-hour seabed mapping mission. The vessel, controlled from a land station, successfully launched a smaller autonomous vessel, followed it as it conducted a mission at 1000-4000m, and then recovered it, all whilst completely unmanned and complying with existing collision regulations (COLREGS).31

applications, are known as ‘big data’.

92. Data analytics (or ‘big data analytics’) is the process of analysing data to uncover patterns, market trends, and other important information. The use of big data is already transforming the world’s societies and economies today, a trend that is set to accelerate in the near future.[21]

93. The UK possesses one of the world’s strongest and most developed data analytics sectors. The UK’s data analytics industry is estimated to be worth £241bn by 2020, with a 177% growth predicted over the next 5 years.[22] Data can be held in ‘data centres’, large groups of networked computer servers upon which data is remotely stored. With its well-developed data centre and cloud computing infrastructure, the UK has the largest data centre market in Europe. Many significant global companies such as the New York Stock Exchange store their European data in UK data centres.[23]

Big Data in Maritime

94. In the maritime sector specifically, there are many potential applications of data and data analytics, which will facilitate the development of autonomous technologies. In order to operate effectively, autonomous vessels will require large amounts of environmental, performance, and location data. At the same time, shore control centres will require large amounts of data to allow human operators of remote and autonomous vessels to make effective decisions about the day-to-day operations of fleets of vessels and cargo handling equipment.[24]

95. Data-driven, sensor-equipped autonomous vessels could perform in-voyage or predictive maintenance, autonomously, reducing the frequency of costly stops in dry-dock. Autonomous vessels using machine learning algorithms and vast datasets to analyse complex maritime environments could lead to a growing confidence in the capabilities and safety benefits of remote and autonomous operation.

21 https://www.weforum.org/agenda/2017/09/the-value-of-data/
22 https://invest.great.gov.uk/industries/technology/data-analytics/
23 https://www.ft.com/content/251f9418-e6ce-11df-8894-00144feab49a
24 https://oceandiscovery.xprize.org/prizes/ocean-discovery/articles/Meet-The-Teams-of-the-Shell-Ocean-Discovery-XPRIZE-Part-2; https://oceandiscovery.xprize.org/prizes/ocean-discovery/articles/meet-the-teams-of-the-shell-ocean-discovery-xprize-part-3; https://www.linkedin.com/pulse/xprize-mission-benjamin-simpson/

AI and Machine Learning

AI and Machine Learning Across the Economy

96. Artificial Intelligence (AI) and machine learning are interlinked technologies. AI refers to the attempt to build machines capable of intelligent behaviour. Stanford University defines machine learning as 'the science of getting computers to act without being explicitly programmed.'[25] Machine learning is the foundational technology behind autonomous systems.

97. AI development in the UK is well advanced compared to other countries and it is estimated that AI may add £630bn to the UK economy by 2035.[26] Major global AI companies such as Deepmind, Swiftkey, and Babylon Health, as well as a large number of AI start-ups are based in the UK. In 2018 the Government and industry committed to grow the industry through the AI Sector Deal.[27]

AI and Machine Learning in Maritime

98. In the maritime sector, AI and machine learning will be essential to the further development of remotely operated and autonomous systems. At present many purportedly 'autonomous' vessels are in fact remotely operated, with few showing true artificial intelligence. Effective AI and machine learning algorithms will enable vessels and cargo handling equipment to operate safely on their own, with minimal human intervention.

99. AI and machine learning could also be used to assist the future maritime workforce, even in the context of an increasingly autonomous sector. For instance, seafarers undertaking maintenance on board vessels can use AI to understand when to most effectively and economically perform maintenance, machine learning algorithms can be used by human crews to analyse larger datasets providing performance and environment gains to vessels, and insurance professionals assessing complex claims can draw upon data collected and analysed by the AI of autonomous systems.

25 https://www.wired.co.uk/article/machine-learning-ai-explained
26 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/652097/Growing_the_artificial_intelligence_industry_in_the_UK.pdf
27 https://www.gov.uk/government/publications/artificial-intelligence-sector-deal/ai-sector-deal

Robotics

Robotics Across the Economy

100. A robot is a machine capable of carrying out a series of complex actions automatically. Robots exist at varying levels of sophistication. This ranges from machines providing human augmentation, to fully autonomous systems. Robots can be used for a wide variety of tasks, including assembly and repair, inspection, and exploration. Robotics is the branch of technology that deals with the design, construction, operation, and application of robots. Robotics can play an important role in increasing productivity and improving safety.

101. We welcome the UK robotics industry's updated RAS strategy, which outlines an approach to address barriers to growth and plans to realise the potential benefits of up to £183.6bn over the next 10 years[28].

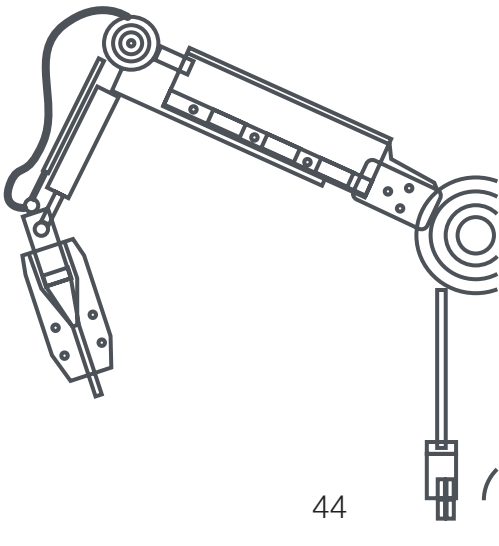
Robotics in Maritime

102. In the maritime sector, robotics technologies are already used in ports, through automated gantry cranes and other cargo handling equipment. Robots are particularly suited to harsh and extreme marine environments. They can remove the need for dull, dirty, and dangerous jobs in the maritime sector.

103. The UK-RAS network has not yet considered potential maritime applications for robotics technologies. CSmart will work with UK-RAS to consider the potential marinisation of new robotics and autonomous systems technology being developed by UK researchers.

Government and Technology Development

104. As set out above, the Government recognises the potential of new technologies to facilitate maritime autonomy. However, this route map takes as its assumption that industry, rather than the Government, is best placed to determine the exact uses to which such technological developments are put. As such, rather than favouring specific technologies, this route map aims to set out broad measures that will create an environment in which the market can drive innovation to facilitate maritime autonomy. The following policy priorities are therefore technology neutral.



28 RAS2020

- Mindful of this, the two key ambitions set out in this section are designed to support innovation and development of technology across maritime, including technologies that will facilitate the use of autonomous systems.

- It is important for industry to understand its technology needs, and to work with technology developers to consider where technologies such as maritime autonomous systems can solve problems. One way, for example, that expertise can be brought from outside industry to find appropriate technological solutions is the 'hackathon' model. Originating in computing, a 'hackathon' involves a large group of people coming together to engage in collaborative computer programming. This idea could also be applied more broadly to consider how autonomous systems could solve challenges set by industry. CSmart, with industry will host a series of 'hackathon'-style events to bring technologists to the sector.

107. At the same time, there is a wider recognition in the UK that more can be done to develop and commercialise Britain's world leading research and development. One way to do this could be to provide support for maritime technology start-ups working on developments such as autonomous systems. Business accelerators can provide opportunities for mentoring, structural resources, and capital that start-ups need. CSmart will work with industry to consider the potential benefits of establishing a business accelerator for maritime technology start-ups.

Our Ambition

- Explore the potential of a joint Government-industry business accelerator for maritime autonomy technology start-ups. This could be a dedicated facility providing advice to start-ups, helping them to grow and commercialise their technology and increase the UK's international appeal as a centre for innovation in maritime autonomy.

- With industry, set a series of technological challenges to be tackled in 'hackathon'-style events, in which technologists will come together with industry to rapidly solve technological problems, including those related to maritime autonomy.

People

Introduction: Keeping the Human in the Loop

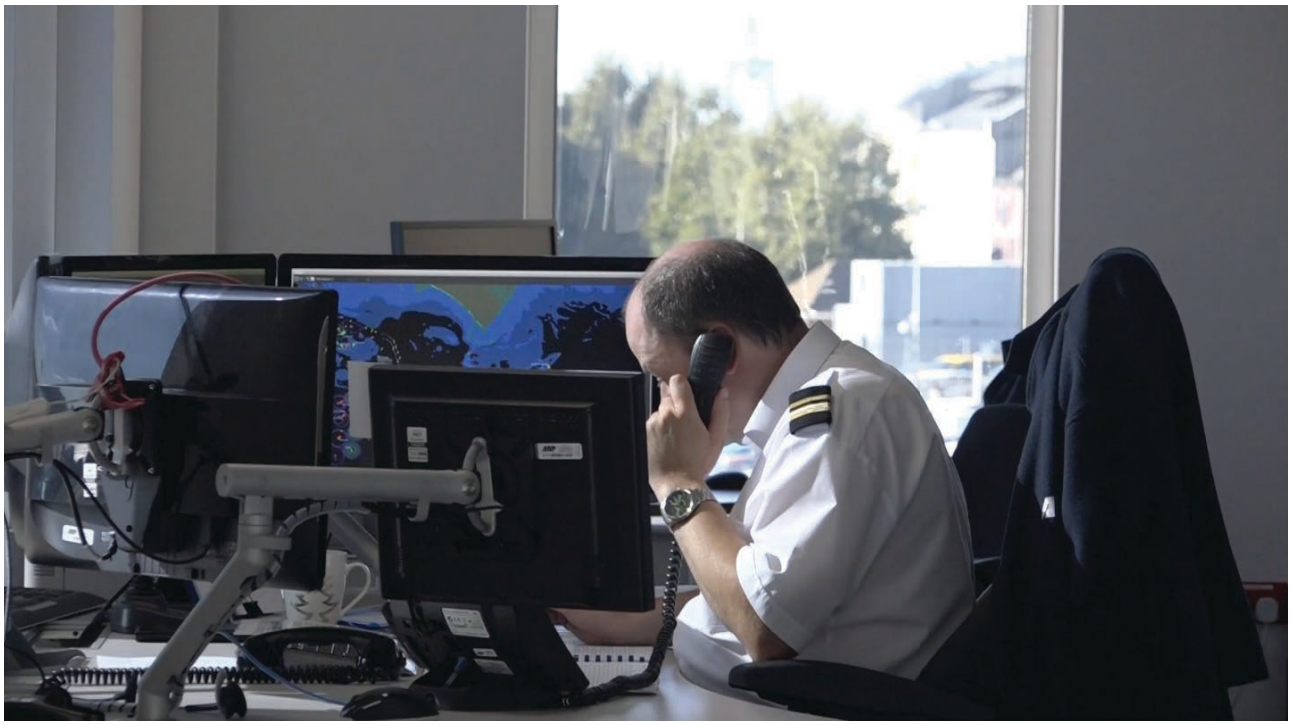
108. People remain at the heart of the maritime sector's journey towards and maritime autonomy. At the Maritime Autonomy Futures Lab in February 2018, representatives from across the maritime sector stressed the need to place people at the centre of technology and innovation policy.

109. There is a degree of concern within some parts of the maritime workforce about new technological trends such as maritime autonomy. A survey by IMarEST (Institute of Marine Engineering, Science and Technology) found that nearly 50% of UK seafarers are worried about the impact of autonomous shipping, and around 20% of industry professionals believe that technologists do not fully understand the requirements of industry.[29]

110. However, a human-centred approach to technology and innovation policy may enable the development of new technologies as a 'force multiplier', augmenting and improving the capabilities of human operators whilst limiting exposure to a range of dull, dirty, dangerous roles. Technology has the potential to help people do their jobs more safely and efficiently, for example, by removing the need for people to enter confined spaces on board vessels. These benefits will only be realised if people are allowed to develop the right skills and given access to the right training.

29 https://www.imarest.org/policy-news/thought-leadership/1009-autonomous-shipping

111. The shipping industry has embraced significant technological change before. Many tasks which used to be carried out manually, such as fire control and navigation, have been automated to some degree for decades. Rather than always necessarily leading to job losses, this technological can often change the nature of work. It can create new, skilled opportunities in the development, operation, and maintenance of this technology.



112. Maritime autonomous systems could radically reshape the future maritime workforce, potentially leading to upskilling and better paid jobs.[30] The increasing use of technology within the sector could lead to more flexible working and more shore-based operations, helping to ease the mental and physical strain of long, isolating periods of time at sea.

113. Smart shipping technology could also offer opportunities for improved training of the maritime workforce, to adapt to new careers. The UK has a global pedigree in maritime training. Institutions such as the Warsash Maritime Academy, Glasgow Maritime College and Fleetwood Nautical Campus train world-class seafarers. As these institutions increase their use of new technologies such as augmented and virtual reality (AR and VR), the UK could take the lead

30 https://www.imarest.org/policy-news/thought-leadership/1009-autonomous-shipping/file

in supplying highly-skilled professionals to the global maritime workforce. It could also use this technological advantage to lead on international regulation for the training of seafarers.

114. This considers the interaction of maritime autonomous technologies with people, particularly people as users of technology. In response to industry feedback, it sets out a people-centred smart shipping policy around four themes:

- the need to attract new talent into the maritime sector;
- ensuring that the existing maritime workforce is adequately; prepared for an increasingly technological and automated future;
- understanding what skills the future maritime workforce will need; and,
- the need to introduce new technology in a way that is sensitive to societal concerns and attitudes.
- It does this within the context of the Government's wider strategy on maritime and people, as set out in Maritime 2050.

Maritime 2050: People

115. The 'People' theme of Maritime 2050 outlines ambitious policy recommendations for the sector, and this chapter considers how some of those proposals might be applied in the specific case study of maritime autonomy (see Figure 2 right).

116. In Maritime 2050, the Government recommended the creation of a Maritime Skills Commission, which will report on the current and future skills requirements for the sector on a 5-yearly cycle. The work of this commission will be informed with input from the CSmart.

Attracting New Talent: Combating Sea Blindness

117. As set out in the 'People' theme of Maritime 2050, the maritime sector suffers from the effects of societal 'sea blindness': though the maritime sector is vitally important to the UK economy, there is a tendency for it to be overlooked by the general public, few of whom are familiar with or directly engaged in the sector's day-to-day operations.

118. Sea blindness is also likely to impact on the development of maritime autonomy in the UK maritime sector. The UK's position in the global maritime autonomy market be shaped in part by the availability of people with appropriate technology skills. In order to facilitate the development of autonomy, therefore, the UK maritime sector will have to be better at recruiting new entrants. The actions below on sea blindness and the attractiveness of maritime careers, which have been set out in Maritime 2050, are also therefore applicable to this route map.

119. More broadly, the Government

Figure 2: Maritime 2050 People Theme Recommendations Relating to Smart Shipping and Autonomy

Maritime Workforce

Short Term

Raise awareness of the maritime sector in schools by having a single industry body overseeing a more coordinated cross-sector in-school awareness and ambassador programme.

Task a single industry body with responsibility for bringing greater coherence and coordination to the promotion of maritime careers sector wide.

Long Term

Government aims to establish a Maritime Skills Commission, bringing existing leading maritime skills experts together to report on the existing and future skills needs of the industry on a 5-yearly cycle, to inform the maritime training curriculum and keep it up to date with the evolving needs of the sector.

remains committed to the support of STEM (Science, Technology, Engineering and Mathematics) educational projects, seeking to inspire interest in STEM-based careers on offer within the sector, both now and in the future. In turn, this will help the growth of the maritime sector, which is currently hindered by the lack of graduates and technicians with relevant qualifications. Action in this area may be particularly helpful to attract new entrants into the field of maritime autonomous technologies.

120. Industry must continue to raise awareness of career opportunities in the sector. The shifting nature of skill-sets means that it is critical to attract people at an early age, and new technological trends such as maritime autonomy can open up new career opportunities to people with diverse backgrounds and skillsets.

121. To co-ordinate cross-sector awareness in secondary schools, a single industry body will devise a marketing campaign and an 'ambassador programme' making use of best-practice examples in developing lesson plans and resources aligned with the natural curriculum.

Preparing the Existing Workforce: Developing Lifelong Learning

122. The maritime sector of the future will require different skillsets, which creates wide-ranging educational challenges for the existing maritime workforce. In particular, the Maritime 2050 People theme highlighted the need for continuous learning as current maritime roles evolve in light of technological advancements.

123. The introduction of innovative new technologies should not simply replace the existing knowledge of experienced people. The challenge for industry will be introducing a culture of continuous learning and

professional development, ensuring that its people are skilled and confident using new technologies.

124. Government will play an active role in ensuring that the sector is linked with the technologists and futurists who will play an ever-increasing role, alongside existing seafarers, in shaping the future skills landscape of the sector.

The Future Workforce: Understanding Future Skills Needs

125. To help unlock the potential of technological change, Government, industry and academia should form partnerships to better understand skills gaps and needs as technologies such as maritime autonomous systems advance. These partnerships should draw upon cross-sector and cross-governmental efforts to understand the 'future of work'.

126. These partnerships will be overseen by CSmart. This will complement the work of the Maritime Skills Commission which will inform the future maritime training requirements and ensure that it is kept up to date with the evolving needs of the industry.

Technology and Society: Encouraging Societal Acceptance

127. The introduction of new technologies such as autonomous systems could bring disruptive change and uncertainty, in any sector. Though much work has been done on the acceptance of autonomous vehicles in built-up city areas, there have been fewer attempts to test autonomous vessels on the world's oceans. It will be important to ensure that, as new technologies such as maritime autonomous systems are tested, we gain a better understanding of the broader societal concerns surrounding their adoption.

128. Members of today's maritime workforce are understandably concerned about the impact of autonomous vessels. Many remain unconvinced that increased automation on-board ships will create a safer industry. There is also a feeling that technology is being advocated for technology's sake, rather than as a solution for a genuine problem.

129. Understanding and addressing these concerns is an important responsibility for Government and

industry. At the same time, direct contact with maritime professionals will help technologists to better understand user needs and the potential maritime applications for new technology.

130. There are also potential benefits to the sharing of knowledge and experience across different sectors. Other transport modes such as rail, aviation, and roads, also face challenges related to societal adaptation to the future of mobility and better integration of transport networks.

131. To encourage this sharing of knowledge and experience, CSmart will work with the maritime and technology sectors to establish a series of mentoring schemes in which members of the existing maritime workforce, trainees and future maritime workers will be matched with workers from other industries, such as automotive and aerospace, along with technologists and futurists.

132. These schemes will facilitate the spread of best practice across industry and the workforce. At the same time, technologists will benefit from an immersion within a crucial industrial sector, creating new business opportunities and a people-centred approach to the development and introduction of new technologies.

Our Ambition

- Ensure that the national Maritime Skills Commission, recommended in the M2050 People Theme assesses the current training requirements and future skills needs of the sector, in the context of major technological developments such as maritime autonomy.

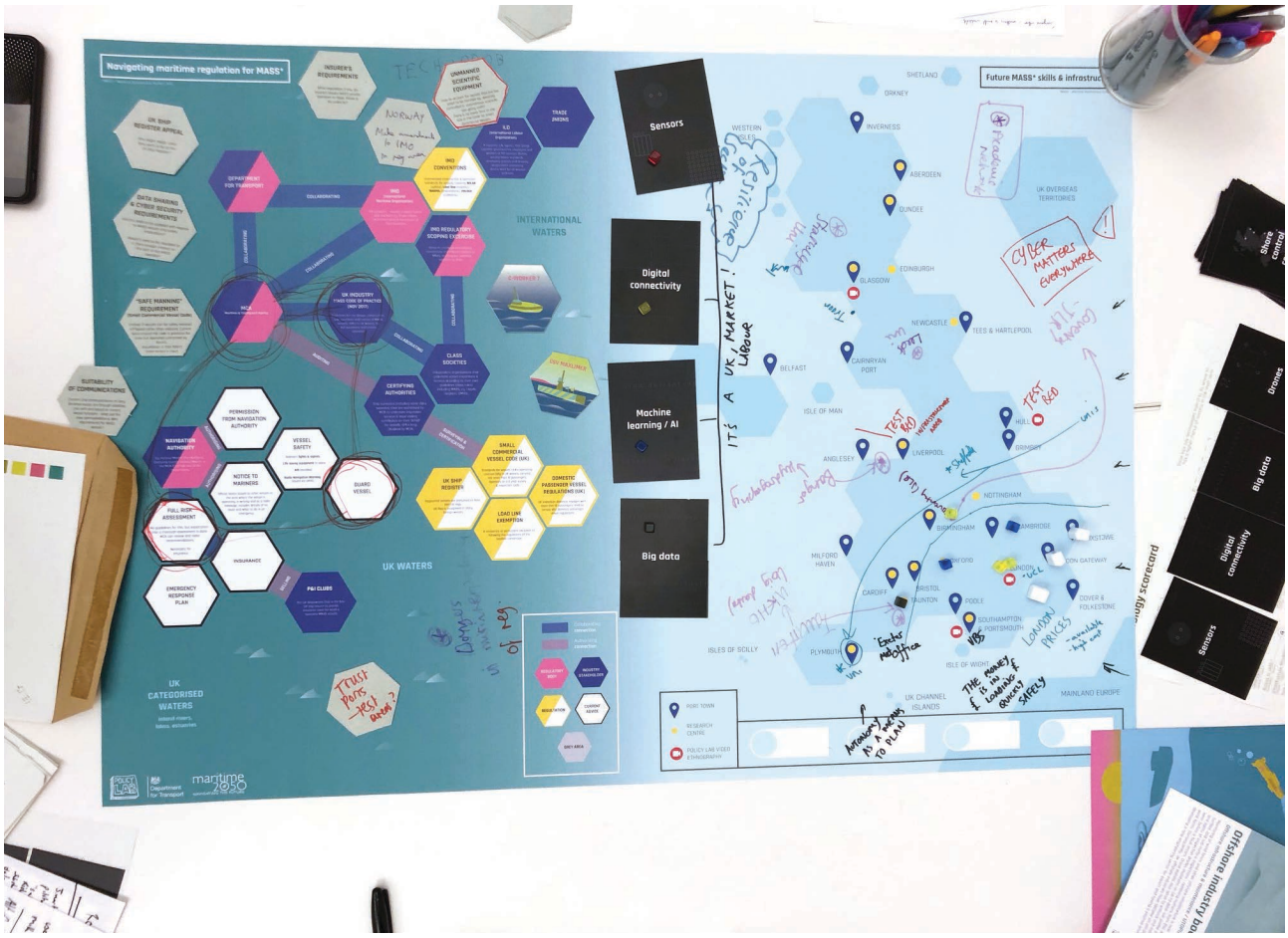
- Support the launch of an industry marketing campaign to promote the UK maritime sector in schools as an exciting and innovative place to work. Deliver this by working with industry to highlight the exciting career opportunities offered by the maritime sector, including the opportunities arising as a result of technological developments such as maritime autonomy.

- Develop mentoring schemes between the maritime sector, technology experts from beyond the sector, and other professionals in industries facing similar challenges to encourage transfer of skills and people.

Regulation

Introduction: Mapping the Regulatory Landscape

133. The effective operation of autonomous technology requires introduction of, and compliance with, a set of agreed standards for the safe operation of equipment, at the both domestic and international level. Industry has identified regulatory challenges as a major barrier to the development of maritime autonomous systems. The development of maritime autonomy will have wide-ranging regulatory implications, including for land-based infrastructure, the collection and use of data, cyber security and the future maritime workforce.



134. Similar regulatory challenges are also being raised by the rapid development of technology in other transport modes. The Law Commission, for instance, is currently reviewing the regulatory framework for the safe deployment of automated vehicles in the UK on behalf of the Centre for Connected & Autonomous Vehicles (CCAV).

135. This section considers how the Government may create the correct regulatory regime to support the development of maritime autonomy, particularly Maritime Autonomous Surface Ships (or MASS). MASS refers specifically to autonomous vessels that travel on water rather than beneath it and does not cover Unmanned Underwater Vehicles (UUVs), many of which also contain remote or autonomous capabilities.

136. The regulation map below encapsulates the broader regulatory environment as it stands today, including the organisations and activities operating within it and their interdependencies. (see next page)

137. To support the development of the diverse range of craft and vessels increasingly wishing to use autonomous systems, and the pace at which change is happening, it is important to have a flexible regulatory framework that encourages these advances. The Maritime and Coastguard Agency (MCA) is taking a range of regulatory approaches to support these developments. Regulation must be considered at both the domestic and international level.

138. The trialling of autonomous systems in the UK is currently focused on autonomous vessels under 24 metres which are being tested in UK territorial waters. Internationally, projects are being undertaken to develop larger autonomous vessels to operate on coastal routes and international voyages. Reflecting today's environment, this section focuses upon how to ensure the right regulatory framework for the testing and development of autonomous vessels under 24 metres. It is expected that larger autonomous vessels will be increasingly trialled and developed in future.

Domestic regulation

139. Recognising the need for clarity and confidence, the UK Government will develop a domestic framework to support the safe use of autonomous vessels in UK waters. Government will also work with industry to understand the future regulatory requirements around shore-based infrastructure, data and cyber security.

140. Developing a world-leading domestic regulatory framework for autonomous technologies will create an environment which attracts international companies to invest in the development of autonomous technologies in the UK. The framework will be flexible and practical, advising operators and developers to ensure the safe

Navigating maritime regulation for MASS*

*MASS = Maritime Autonomous Surface Ship

IHO
(International Hydrographics Organization)

The IHO ensures that the world's seas, oceans and navigable waters are properly surveyed and charted.

ILO
(International Labour Organization)

A tripartite U.N. agency that brings together governments, employers and workers of 187 member States, setting labour standards, developing policies and devising programmes promoting decent work for all women and men.

TRADE UNIONS

DEPARTMENT FOR TRANSPORT

COLLABORATING

IMO
(International Maritime Organization)

174 members - includes member states and and NGOs eg. Trade Unions, IACS (International Association of Class Societies).

IMO CONVENTIONS

International construction & operation standards for vessels, covering **SOLAS** (safety), **Load-line** (stability), **MARPOL** (environment), **COLREG** (collisions).

UNCLOS
(United Nations Convention on the Law of the Sea)

International agreement that defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources.

DEPARTMENT FOR ENVIRONMENT, FOOD & RURAL AFFAIRS

COLLABORATING

COLLABORATING

IMO REGULATORY SCOPING EXCERCISE

Remit to review all international conventions and industry barriers to MASS, and propose potential solutions by 2020.

INTERNATIONAL WATERS

MCA
Maritime & Coastguard Agency

UK INDUSTRY
MASS CODE OF PRACTICE (NOV 2017)

Guidelines for the design, construction, safe operation and control of MASS vessels <24m in UK waters, for full autonomy and remote operation.

COLLABORATING

MINISTRY OF DEFENCE

AUDITING

COLLABORATING

CLASS SOCIETIES

Independent organisations that undertake vessel inspections & surveys according to their own guidelines (class rules) including MASS, eg. Lloyds Register, DMVGL.

CERTIFYING AUTHORITIES

Ship surveyors (including some class societies) that are authorised by MCA to undertake inspection surveys & issue coding certificates on their behalf for vessels <24m long. (Audited by MCA).

SURVEYING & CERTIFICATION

PERMISSION FROM NAVIGATION AUTHORITY

AUTHORISING

NAVIGATION AUTHORITY

Eg. Harbour Master, Port Authority, Dockyard, Queens Harbour Master, or the MCA if outside any of the above areas.

AUTHORISING

NOTICE TO MARINERS

A Notice to Mariners advises mariners of important matters affecting navigational safety, including new hydrographic information, changes in channels and aids to navigation, and other important data. They provide essential, up to date information and advice to those navigating within the UK's area of jurisdiction.

VESSEL SAFETY

Relevant **lights & signals**.

Life saving equipment in place.

AIS installed.

Radio Navigation Warning issued via UKHO.

GUARD VESSEL

SMALL COMMERCIAL VESSEL CODE (UK)

Standards for vessels <24m operating commercially in UK waters, carrying not more than 12 passengers. Operates on a 5 year survey & inspection cycle.

UK SHIP REGISTER

Registered vessels are presumed to have met UK regs.
UK flag is recognised in many foreign waters.

DOMESTIC PASSENGER VESSEL REGULATIONS (UK)

UK vessels on domestic voyages with more than 12 passengers need to comply with domestic passenger vessel regulations.

LOAD LINE EXEMPTION

A temporary or permanent exclusion to following the regulations of the loadline convention.

FULL RISK ASSESSMENT

No guidelines for this, but expectation that a thorough assessment is done - MCA can review and make recommendations.

Necessary for insurance.

INSURANCE

Hull & Machinery insurance

Hull & Machinery insurance provides physical loss or damage insurance for a ship's hull, any propulsion machinery and equipment used for activities such as cargo handling.

EMERGENCY RESPONSE PLAN

SELLING

P&I CLUBS

The UK Shipowners Club is the first UK ship insurer to provide insurance cover for small & specialist MASS vessels.

UK WATERS

TRAINING COLLEGES

Institutions must ensure new and existing seafarers have the latest skills and knowledge of emerging regulatory and safety requirments

UK CATEGORISED WATERS

inland rivers, lakes, estuaries

Collaborating **connection**

Authorising **connection**

REGULATORY BODY

INDUSTRY STAKEHOLDER

REGULTATION

CURRENT ADVICE

GREY AREA

POLICY LAB

Department for Transport

maritime 2050
NAVIGATING THE FUTURE

testing and operation of vessels and technology. It will also allow for the proactive adaptation of regulations using innovative methods to keep pace with technological developments.

141. In the short term there will be a focus on remotely-operated vessels which are already emerging into the market. Regulatory reviews for remotely-operated vessels will provide the foundations for subsequent regulatory developments needed for fully autonomous vessels to operate in UK waters.

142. In parallel with the development of this framework, Government, working with academia and industry, will establish an innovation lab, the Maritime Autonomy Regulatory Lab (MAR Lab) for Maritime Autonomous Surface Ships. The Lab will work with CSmart to provide an environment to discuss regulatory proposals and vessel testing with stakeholders, identifying regulatory gaps and legislative barriers to further the development of autonomous vessels in UK waters.

143. Where legislative barriers to the development of autonomous ships are identified Government will work with industry to adapt current regulatory approaches or identify appropriate solutions. A flexible regulatory framework for domestic smart ships will:

- Advise operators and developers so as to ensure the safe testing and operation of vessels and technology, and

- Proactively adapt regulations using innovative methods to keep pace with technological developments.

144. As a key part of the development of this framework Government will continue to enable the safe testing of these smart shipping technologies around the UK across a range of environments and in different conditions. Allowing testing across UK waters means developers can test technologies in the appropriate maritime environments, reducing overall risk.

145. Government will continue to provide pragmatic advice to stakeholders testing autonomous and remotely-operated vessels in UK waters. All aspects of testing autonomous vessels will be discussed on a case-by-case basis to ensure the action taken is appropriate to the vessel being tested. These discussions will support the regulatory developments needed for the long-term operation of MASS in UK waters.

International

146. The experience and evidence gathered during the development of a domestic regulatory framework will give the UK an edge in negotiations at the IMO as it seeks to set an example for international regulations on maritime autonomy.

147. Government will be an international leader in the development of autonomous shipping regulations. The UK will continue to be an active member of the IMO regulatory scoping exercises on MASS. Government will be active participants at relevant IMO working and correspondence groups.

148. Government will work with like-minded IMO members to develop strong positions supporting progress towards the safe and environmentally sound operation of MASS. It will ensure current IMO discussions remain focused on the identification of regulations and guidelines that need changing to allow the operation of MASS internationally.

149. Government will work with IMO members to make appropriate regulatory changes to enable the international operation of MASS. Government is open-minded as to the form these changes may take. Where possible Government will consider the appropriateness of enabling operation within the current regulatory options, such as equivalents or alternative design arrangements.

150. Government will support the development of guidelines for the testing of autonomous vessels to ensure international tests of larger MASS can take place. The UK will work with international partners to use guidelines for testing to facilitate international test voyages for both remotely-operated and fully autonomous ships.

151. As international discussions progress, Government will take appropriate action to further develop the domestic regulatory framework for the introduction of internationally agreed regulatory developments for larger autonomous ships.

Our Ambition

- Government will establish a ‘MAR Lab’, for regulatory innovation in maritime autonomy. The lab will aim to encourage maritime innovation in the UK, helping create an environment which attracts international companies to invest and test autonomous technologies here. The work of MAR Lab will be used to develop a domestic regulatory framework for maritime autonomy which will allow the UK to lead negotiations at the IMO to establish international regulations for maritime autonomy.

- Government will continue to enable the safe testing of these autonomous and autonomy-supporting technologies around the UK, across a range of environments and in different conditions.