
Please see Glossary at end for explanation of acronyms

Impacts and benefits

1. What are the potential applications for autonomous vehicles?
   There are a wide range of applications for Maritime Autonomous Systems (MAS) above (UAV), on (USV) and beneath (UUV & ROV) the sea surface. This expanding market impinges on a wide range of maritime applications such as marine science and hydrographic survey, offshore resource exploitation, maritime transport and defence and maritime security operations. By way of example, but not exclusively, MAS impacts on oceanography, offshore oil/gas, offshore renewable energy, deep-sea mining, fishing and aquaculture and underwater asset management.

2. What are the potential user benefits and disadvantages from the deployment of autonomous vehicles?
   Unmanned Vessels are persistent; they can go to previously unattainable places in the world’s oceans, seas and inland waters; they are significantly more cost effective than manned vessels in certain circumstances; they reduce risk to humans and are not subject to human weaknesses; they can relay real time data to control stations ashore or afloat. Autonomy is currently a complementary capability to manned systems; they could be vulnerable to cyber interference and ensuring devices are adequately protected is a current focus for system designers.

3. How much is known about the potential impact of deploying autonomous vehicles in different sectors?
   The maritime learning curve is exponential and the potential impact is highly significant. USV, UUV & ROV and UAV are all in current use but it is the dawn of a new era at sea. Whilst most current vessels are relatively small, major companies such as Rolls-Royce are investing very large sums into the development of large USV for future commercial use.

4. How much is known about public attitudes to autonomous vehicles?
   There is a growing awareness of the potential for MAS. This spreads from academic institutions, through commercial R&D and production organisations, to owners and operators of both manned and unmanned vessels, as well as being a highly debated topic in all international and national bodies, notably the International Maritime Organisation (IMO). There have been several successful deployments of MAS which have generated significant and positive public interest, an example has been the MASSMO deployments organised by the National Oceanography Centre. The UK MAS Regulatory Working Group has published an industry led Code of Conduct* for surface MAS to assist in the generation of best practice and to demonstrate a responsible approach to the development and utilisation of MAS technology.

A copy can be downloaded from [http://www.ukmarinealliance.co.uk/content/masrwg-code-conduct](http://www.ukmarinealliance.co.uk/content/masrwg-code-conduct)
5. **What is the scale of the market opportunity for autonomous vehicles?**
   A recent survey of market opportunities conducted by the MAS Council (a new interest group within the Society of Maritime Industries (SMI)) has identified the increasing number of UK companies engaged in MAS. This includes academic institutions, distributors, equipment and platform manufacturers, system integrators, service companies and naval architects. The survey suggests annual turnover in MAS applications is £200 million, of which around 25% is export related. This is expected to rise to £500 million by 2020. Estimates put the global market for MAS at $136bn over the next 15 years. 500 people are currently working in the UK on MAS activities and this is expected to double in the short to medium term. Maritime opportunities were highlighted in the RAS 2020 Robotics and Autonomous Systems strategy paper but not covered in detail.

Creating an enabling environment

*Research and development*

6. **Is the scale of current and planned demonstration facilities for autonomous vehicles sufficiently broad and ambitious?**
   This is a new venture in the maritime environment and facilities are growing by the day but are not yet matching the rising demand being identified. Government initiatives at all levels certainly need to become broader and more ambitious. Currently only around 30% of the UK’s seabed within the exclusive economic zone (EEZ) is mapped. The Department for Business, Innovation and Skills (now Business, Energy and Industrial Strategy) and Maritime & Coastguard Agency in partnership with The Crown Estate and Department for Environment, Food & Rural Affairs have produced a report examining the economic benefits of mapping the remaining 70% and it is recognised this could only be economically delivered by autonomy.* A government sponsored project to undertake this work over, say, 10 years would encourage industry investment in the technologies required to deliver this and accelerate the industry’s ambition with attendant export potential.

*UK National Seabed Mapping Programme – Scoping Study dated 30 March 2016

7. **Is the Government doing enough to fund research and development on autonomous vehicles, and to stimulate others to do so? Should it be doing more to coordinate UK actions?**
   Investment has already taken place through a joint Innovate UK/Dstl MAS competition (£5 million) and through a number of NERC programmes, particularly with the National Oceanography Centre. However, much more is needed in all areas from academic institutions through company R&D to the various companies producing all elements and systems required to maintain a UK lead in the international field and ensure the MAS industry reaches its full potential. Co-ordination is a vital part of success and no more so than with this emerging technology. The MAS Steering Group, the UK MAS Regulatory Working Group and the newly formed MAS Council of SMI are working closely together
to direct and address the full spread of requirements. Clear ministerial responsibilities are needed to ensure effective co-ordination across the spectrum.

8. **How effective are Innovate UK and the CCAV in this area?**
Innovate UK has been a driving force to date through its Robotics and Autonomous Systems Special Interest Group (RAS SIG) but CCAV has not yet made its mark in the maritime environment.

9. **Is the environment for small and medium-sized enterprises (SMEs) working in this sector sufficiently enabling?**
The environment is right, but is not uniform across the UK being dependent on whether or not the LEP, say, identifies marine as a major economic generator, and it is questionable whether it is sufficiently enabling. This inquiry needs to explore in some detail what is being done and how UK industry can be supported in both the home and export markets.

**Real world operation**

10. **Will successful deployment of autonomous vehicles require changes to digital or physical infrastructure?**
There will be a need for a significant development of the infrastructure needed to support MAS. Autonomous vessels require secure and reliable communications in all bands and there will be a need to develop new facilities ashore (and afloat) which can control these vessels on a global basis and to exploit the data which they produce. As mentioned under question 6, if the government were to treat the mapping of the UK’s EEZ (an ‘Ordnance Survey’ of the seabed) as a major infrastructure project, this could accelerate developments in MAS.

11. **How might a move from current levels of highly automated vehicles to their extensive deployment best be managed? What do you see as the key milestones?**
This is a complex question as the answer varies when addressing the needs of the current, relatively small, surface vessels or identifying the needs of larger commercial shipping when these vessels become operational. The answer also varies for the more established underwater vessels (both UUV and ROV) and UAV working in support of maritime operations. Transformative change is not inevitable in the UK given the maturity of the existing solutions and aversion to risk. Autonomous vehicles are best exploited within a suitable system; a directed framework of operational studies will inform system and technology definition and so increase the probability of transformative change.

Technology roadmaps have been prepared which have identified the following key milestones:
- Supervised autonomy
- Information architecture standards
- Full individual autonomy
- Swarm autonomy

12. Does the Government have an effective approach on data and cybersecurity in this sector?
   The effective management of marine data in the public domain is fragmented although there are major efforts to improve the situation. In terms of wider maritime operations, cost effective satellite capacity will be required across all maritime sectors to fully exploit the capabilities of autonomous vessels and devices as they traverse the oceans and help to increase the market adoption rate. Furthermore, this is where effective cybersecurity to protect the assets and their data will be essential and there is still much work to be done. Therefore, the inquiry must highlight that a fully co-ordinated and effective approach to data handling and movement, with increasing resilience and defence against cyber-attack, is one of the greatest challenges to maintain confidence in the technology’s integrity. This must be made a priority for government policy and funding.

13. Are further revisions needed to insurance, regulation and legislation in the UK to create an enabling environment for autonomous vehicles?
   There will be a number of requirements for revisions in all these areas which are being addressed by the MASRWG. These will include updates to the four IMO Instruments (Collision Regulations, Marine Pollution, Safety of Life at Sea and Standards of Training, Certification and Watchkeeping for Seafarers), which are being co-ordinated through the Maritime & Coastguard Agency. An information paper has already been forwarded to IMO highlighting what the UK is doing and efforts are underway to build international consensus for the UK approach. A further paper will be raised to IMO for MSC.98 in 2017 to initiate the necessary revisions. Following publication of the Code of Conduct (see Q4 above), the MASRWG is preparing a Code of Practice for completion early in 2017. All relevant UK authorities and companies are engaged in this process, including classification societies and insurers.

14. What, if any, ethical issues need to be addressed in the substitution of human judgement in the control of vehicles by algorithms and Artificial Intelligence?
   This aspect should not be underestimated in the maritime domain as with others, particularly in their command and control systems. Cultural change and full use of available technology are pivotal to the success of maritime autonomous vessels, as is the shift of emphasis for the requirement for experienced mariners both afloat and increasingly ashore. Whilst this may be seen as a potential roadblock, it should be emphasised that this is not the case. The inquiry could consider how risk tolerability and acceptance should be addressed to capitalise on the potential safety benefits offered by autonomous systems whilst not imposing overtly stringent requirements on the adoption of new technologies.

Wider governance

15. What does the proposed Modern Transport Bill need to deliver?
   No comment at this stage.

16. How effective is the UK’s education system in delivering people with the right skills to support the autonomous vehicles sector?
As with any emerging technology there is immense scope for students to start developing awareness and both skills and knowledge from the youngest age. There are requirements for young people to be part of the technology development and the operation of autonomous vessels. Input to schools and university curricula is at an early stage, as is the general motivation to become part of such an exciting world with the career opportunities it now presents. Government initiatives and incentives will be a welcome and essential part of this process. The development of MAS is a good example of where the modern engineer needs a wide scope of understanding covering mechanical, electrical and software skills.

17. Is the Government’s strategy and work in this area sufficiently wide-reaching? Does it take into account the opportunities that autonomous vehicles offer in a wide range of areas, not just on the road?
It is true to acknowledge that air and automotive vehicles currently attract the most publicity, both positive and negative. Many still believe that autonomous developments in the maritime world are still embryonic or have just not been exposed to it yet. This is not correct and therefore the strategy must be seen as not yet wide-ranging enough and increased emphasis on maritime issues is a real opportunity and crucial to the overall development of MAS.

18. What are the implications of exit from the European Union for research and development and the autonomous vehicle industry in the UK? Are specific actions from the Government needed to support or protect the autonomous vehicles sector in the short term or after the terms of Brexit have been negotiated?
It is too soon to analyse the implications of exit from the EU although the maritime market is global. Whilst there may be short-term impacts in Europe, the maritime industry in the UK is sufficiently well balanced and advanced to withstand them from both technological and operational standpoints. It is essential that the UK keeps ahead of its competitors and is seen to be taking the lead in ensuring that autonomous vessels, and the systems which make them competitive and effective, can operate safely wherever there is a need across the world.

Maintaining the competitive edge in technology requires strong government engagement. EC funding through HORIZON 2020 has supported research and development on a range of MAS projects which have benefited UK based consortium members. Alternative funding sources will need to be established, post-Brexit, to avoid impacting on the UK’s ability to stay at the forefront of technology in the sector.

21 October 2016

GLOSSARY

CCAV Centre for Connected and Autonomous Vehicles
Dstl Defence Science and Technology Laboratory
EEZ Exclusive economic zone
IMO International Maritime Organisation
LEP Local Enterprise Partnership
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<th>Abbreviation</th>
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<tr>
<td>MAS</td>
<td>Maritime Autonomous Systems</td>
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<td>MAS RWG</td>
<td>Maritime Autonomous Systems Regulatory Working Group</td>
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<td>MASSMO</td>
<td>Marine Autonomous Systems in Support of Marine Observations</td>
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<td>MSC</td>
<td>Maritime Safety Committee of the IMO</td>
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<td>NERC</td>
<td>Natural Environment Research Council</td>
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<td>RAS SIG</td>
<td>Robotics and Autonomous Systems Special Interest Group</td>
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<td>SMI</td>
<td>Society of Maritime Industries</td>
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<td>UAV</td>
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<td>USV</td>
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<td>UUV</td>
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