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Society of Maritime Industries · UK

Creating a Leading Edge

Accelerating Autonomous Assurance to Unlock the UK Opportunity.

January 2024

Society of Maritime Industries

(SMI) is the voice of the UK's maritime engineering and business sector promoting and supporting companies which design, build, refit and modernise ships, and supply equipment and services for all types of commercial and naval ships, ports and terminals infrastructure, digital technology, maritime defence and security, marine science and technology, maritime autonomous systems and marine renewable energy.

Background

Development of skill in autonomy is abundant in the UK, but there are barriers to unlocking this opportunity. Regulation has been slow to adjust to the pace of change and this is creating a certification gap, which could potentially undermine the UK's ability to maintain an edge in this domain. This report covers industry leaders' insights on the commercial and regulatory roadmap, the readiness for driving growth, and potential ideas for achieving safe and effective MAS operations by UK vessels and in UK waters.

Two workshops were carried out – 'Safe to Operate' and 'Operated Safely' – ensuring that viewpoints from both the Designers/ Builders and the Operators could be fleshed out and generate a common understanding of the challenges and collaborative solutions within the design and operational areas.

Key Takeaways

The following key points became evident and common across various stakeholders throughout the workshops:

A 'one size fits all' approach to the regulation of innovations such as autonomy will not work in this sector and instead, a proportionate goal-based and risk minimising regulation process should be developed.

Understanding the future of regulations is challenging. One solution to this is entering into action with boldness. We have seen evidence of this technique succeeding where companies have been bold and pushed the limits of regulations to get an autonomous capability in-theatre. We can also act on the precedent and build capabilities around what's been done successfully before.

Safety and risk assessment of marine autonomy is a crucial aspect which needs continual monitoring. Staying up to date with the latest best practices and lessons learned from real-world operations is vital in enhancing safety further. Some of the solutions identified included standardising safety case structures and formats to aid preparation, comparison and review and the possibility of providing a toolkit to support the development of these, recognising that the use of cross-domain assurance techniques was important but that this would bring new stakeholder groups into the marine industry. Operators needed flexibility in certification levels to allow for progressive trials and demonstrations of technology.

The operational concepts of MAS bring a requirement for high integrity software. The cost of developing or upgrading software integrity is exponentially higher and the skills vary from what is currently 'the norm' for Designers and Builders. Enacting a 'safe by design' approach is needed, utilising experience from other industries practised in functioning this way.

Training was another important factor that was brought up and currently there are no specific standards for autonomous vessels. These standards need to be developed alongside the technology and the regulations. Solutions suggested included the creation of a national piloting centre, and working with the MCA to develop training standards.

Operators thought that Designers/Builders needed clarification on the use case requirements, including information on client needs and potential use case mapping to support product development road mapping. Clear definition of operational life expectancy as well as upgrade and refit cycles to inform design decisions and through life support requirements (sometimes called ILS – integrated logistics support). The conversation should start with a clear and complete description and explanation of concepts of employment, use and operation. There should then be a clear link from the concept of operation to the user and system requirements.


Shipbuilding Enterprise
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Our Story
Our Vision
Level 1
Delivery & Impact
Level 2
Ecosystem Connectivity
What do Operators need from you?
(key challenges)
Modularity
Power (Space, weight, power)
Flexibility / Interoperability
need to take transitional approach to deployment
Clear advice on capability
Support elements
Design Authority

Findings

Challenges in designing and building 'safe to operate' autonomous systems:

Regulation

Designers/Builders are in a space where they typically lead, rather than lag, regulatory developments. Current regulations are seen to carry too much ambiguity, making them difficult to conform to correctly. There is a lack of clarity from international and flag state regulations filtering down. This presents multiple challenges – understanding what is required through retrospective application of new regulation when it is developed, and where regulatory barriers are identified in existing regulation constraining operational deployment. This means that Designers struggle to create design and production strategies for the near future, let alone for the longer term. One solution to this is entering into action with boldness. We have seen evidence of this work in the industry where companies have been bold and pushed the limits of regulations to get an autonomous capability in-theatre. We can also act on the precedent and build capabilities around what's been done successfully before.

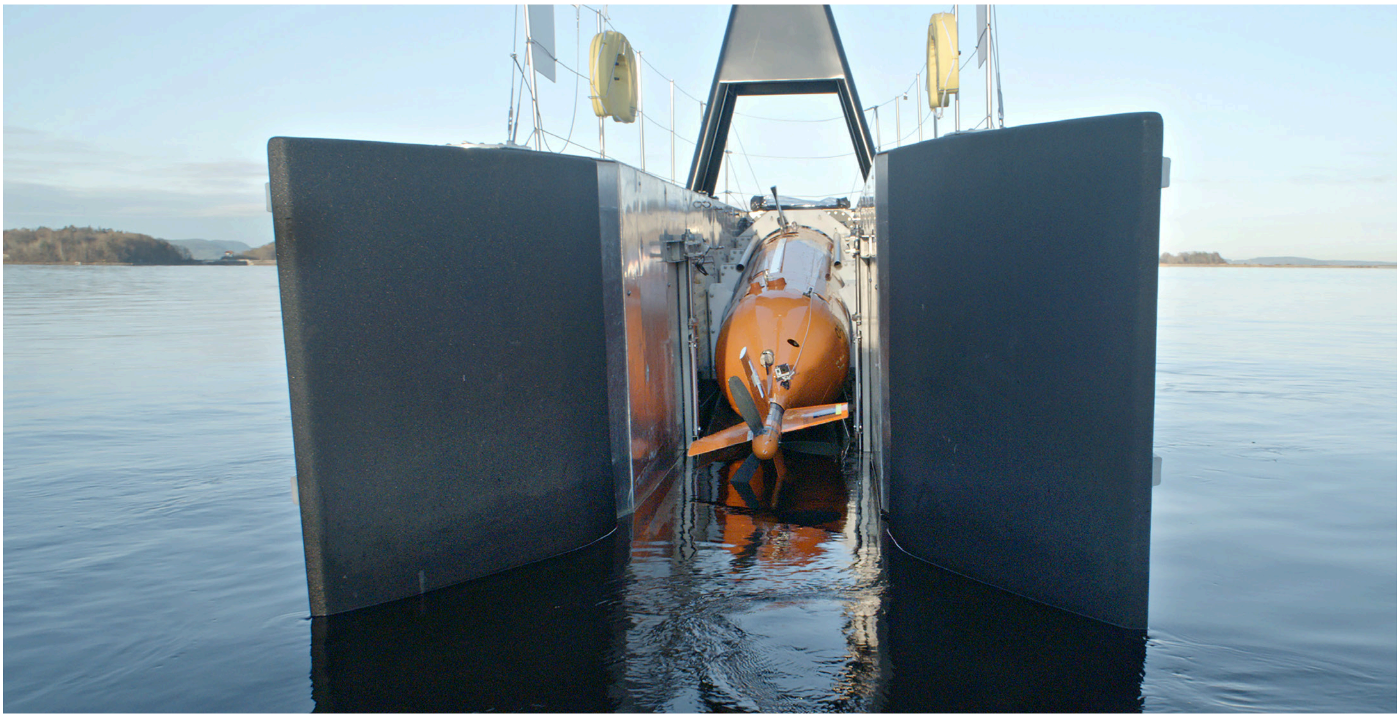
Where MAS are sold into an international market, the potential for a multitude of individual country specific domestic regimes is concerning and common approaches/ agreements are preferred.

No specific solutions were identified for this, but regulators should be sympathetic to these market challenges and in particular, consider scales of regulation appropriate to the size, risk profile, operational area and development/deployment status of MAS. Greater willingness to collaborate and top down direction has been seen to be successful in other markets.

It was noted that, when dealing with MAS, the variety of vehicles and systems that come under this banner are wide ranging in terms of size and capability. 'One size fits all' is not seen as an appropriate approach and it was suggested that an 'as low as reasonably practicable' (ALARP) approach is better suited. Some current regulations do not fit all vehicles and this blocks their route into the market. Adequate scoping of regulatory and technical standards is needed.

Safety and Risk Assessment

When talking about safety and risk, security also comes into the picture due to the reliance these systems have on digital systems (control software, data transfer, data recording, communication with a remote operating centre). If the MAS isn't secure, then safety can be impacted. There are challenges at the moment of understanding correct safety integrity levels and achieving these.



Traditional maritime systems tend to operate with low or medium integrity software, but the operational concepts of MAS bring a requirement for high integrity software. The cost of developing or upgrading this software is exponentially higher than what is currently 'the norm' for Designers and Builders. This is new for the industry and many companies are learning as they go and having to change systems retroactively, which is costly. Enacting a 'safe by design' approach is needed. The industry doesn't have many experts to provide understanding of the technology and what is needed to deliver safe and secure systems. However, there are other industries with great expertise in functioning this way, and one solution is to utilise the skills and experience from other areas.

Designers/Builders identified challenges around the understanding of risk associated with novel technologies, not only associated with the introduction of MAS but also the combination of MAS and Net Zero Fuels, such as hydrogen, opportunities for improved safety through the removal of risk to people onboard were not able to be realised due to misconceptions of risk. In particular, the questions 'what is safe' or 'what is safe enough' don't have clear answers and safety engineering may need reframing in terms of a revised understanding of risk. Similarly, the use of existing small boat standards, which assume an increased risk (to life) in an offshore environment, does not recognise that this presents a decreased risk (to life) for MAS.

Other engineering challenges identified relate to the need to achieve greater reliability and provide redundancy, but there is struggle in establishing these requirements with reference to the Operator's needs and the need for them to consider the through-life non-functional requirements and not just the functional requirements. Solutions to this include establishing the risk profiles associated with certain types of vessels and operational profiles and considering whether the creation of alternative categorisation of operational areas might allow for more appropriate regulation/requirements definition.

Training and Crewing Standards

Training standards and crewing requirements are not yet ready for autonomous systems and need development. It was recommended that, as for technical regulations above, these should be risk specific depending on the vessel type/size/capability/operational concepts. One particular challenge at the moment is the availability of suitably qualified and experienced personnel (SQEP) across the industry. It was observed that there are enough SQEP Designers and Builders but a lack of SQEP Operators, and this is particularly challenging for smaller companies with smaller budgets for recruiting and upskilling those employees. Smaller companies using maritime autonomous systems are struggling to create an employment model that works for them. For example, they may have weeks of no operations (needing zero Operators) followed by weeks of 24/7 continued operations (needing many Operators working in shifts).

“One particular challenge at the moment is the availability of suitably qualified and experienced personnel (SQEP) across the industry.

A solution was suggested of having a form of national piloting centre which could have three functions: one being providing certified training, one being a service which provides qualified personnel for companies to sub-contract, and the last being a hireable facility to host operations, a remote operating centre facility, for companies which don't have the budget to build their own. This 'national piloting centre' would need to provide specific services which meet particular standards so that any company could create their systems to interface with the centre (the infrastructure, types of Operator available, standard interfaces for Operators to use). A government body such as the Maritime and Coastguard Agency (MCA) could set out the requirements for providing this service and signoff 'recognised organisations' who meet the criteria. Companies with ROCs/training services/SQEP Operators would be able to become a recognised organisation for this service and sell this as a new offering. This has the potential to provide new revenue paths for organisations, and make their people, equipment and infrastructure more efficiently utilised.

The inclusion of crewed/uncrewed operating modes mainly results in sub-optimal design solutions and therefore, constrains the appropriate application of MAS technology, in particular, this is driven by the requirement to comply with manned regulations and the arrangements required to house and support people when onboard.

It is recognised that there are requirements for appropriate manned/unmanned, crewed/uncrewed, limited manning (i.e. short-range operations) and restricted manning (i.e. alongside operations), but these should be appropriately considered and their impacts on vessel design understood. Concessions should be possible within manned regulations to accommodate these alternative modes without undue restriction.

Trials Areas

The MCA have deliberately taken a permissive approach to vessel trials around the UK coast, however, it is possible that this may have constrained the industry by preventing permissive trials within controlled areas. In particular the use of instrumented test ranges for trials and evidence generation to support sensor certification, calibration and navigational control trials is seen as being a critical requirement. Similarly, the use of designated marine ecosystems with locally provided communication networks, interface standards and support infrastructure is seen as something that may allow for more seamless and effective MAS deployment, for example, in a windfarm development area or local port environment. The solution identified for this is for the MCA and other flag state regulators to consider the designation of waters for MAS development trials in which full compliance with regulations might be relaxed in favour of a progressive certification approach under controlled trial conditions. Likewise, the promotion of active marine ecosystems and the identification and provision of systems to support MAS deployment is something that could be encouraged, particularly where large-scale offshore development is taking place.

Communication

Communications are still a challenge, especially in the underwater space, although this is a well-known problem and there are projects underway looking to provide solutions. One solution is to have good communications in congested waterways, such as the 5G seen in Plymouth Marine Laboratory's Smart Sound.

Ship to ship communications were also discussed: the question of how autonomous vessels use VHF and the emergency channel has not yet been overcome, but it's believed that speech and artificial intelligence technology could enable communications between an uncrewed and crewed vessel, AIS is likely to be more heavily relied on by autonomous systems.

> Other traditional aspects of crewing a ship, such as 'ships papers', documents which are required to be held onboard a vessel, will need to have their requirements reconsidered, but there are many ways that correct documentation could be held digitally onboard or at a ROC, and many of these traditional functions have a digital alternative.

Challenges in safely operating autonomous systems:

Assurance 'Safety Case'

Operators felt that the challenges to safely operating autonomous systems related to the development of an assurance 'safety case' and the acceptance of this by the Regulators and in some instances, third parties like insurers or clients. Specifically, this related to an understanding of how this should be structured, whether this should be standardised and how to manage the dependencies between the 'safe to operate' and 'operated safety' elements. The challenge of achieving proportionality in the assurance process is made difficult by the small nature of many systems, utilising non-standard, non-marine or non-industrial components, but in some cases with the complexity of onboard systems or functions only found on larger vessels, all whilst ensuring that the human-machine interface was safe and sustainable. When interacting with Designer/Builders, Operators noted a challenge around the inflexibility of some CONOPS, the need for the management of change associated with this and varying mission profiles and a lack of awareness of how this might impact the assurance artefacts. Understanding product maturity, product development stages and establishing trust and confidence in the technology were associated with this.

Some of the solutions identified included standardising safety case structures and formats to aid preparation, comparison and review and the possibility of providing a toolkit to support the development of these, recognising that the use of cross-domain assurance techniques was important but that this would bring new stakeholder groups into the marine industry (and conversely challenge existing marine stakeholder groups) and that this would potentially require new ways of working with regulators and an upskilling of the industry. Assurance needs to be proportional and based on risk but should provide for both structure through the use of prescriptive requirements and flexibility through the use of goal-based requirements/processes; it should be progressive and use a mix of process audit and product inspection techniques to support certification. Importantly, Operators needed flexibility in certification levels to allow for progressive trials and demonstrations of technology in order to understand its capabilities, test use cases and market to potential clients within commercial settings.

Defining Acceptable Performance

A key challenge is establishing the “bar”, the acceptable criteria and performance. There are different interpretations of this challenge, for instance, clearly defining acceptably safe for regulator certification through to winning hearts and minds across broader stakeholders. People can have a tendency to trust other people over machines. Modern sensors outperform human perception and yet they attract a lot of scrutiny. The prevailing view is that the machine should demonstrate equivalent, if not better, performance than the human. There is however a lack of means to assess and quantify human performance tailored to maritime e.g. navigational situation awareness. Several issues complicate the challenge further. Human performance is not fixed but varies between individuals, tasks and contexts.

Further, autonomy itself varies in nature, for example, with different levels of human/machine control and remote/in-situ Operator monitoring. Any transition from human-in-the-loop to fully autonomous will require a leap in assurance approach that is yet to be understood. Responsibility and therefore, liability for incidents and accidents arising from unsafe events is still an issue to be satisfactorily resolved. Mitigating the actions of malicious or nefarious actors further complicates circumstances; also, an end-to-end treatment is needed, for example, steps downstream of sensor data, e.g. data processing, interpretation and decision-making. An overarching challenge is that maritime differs from other transportation sectors in the variety of roles and operational areas that must be accommodated.

A potential solution to efficient assessment and demonstration of safety is multi-fidelity testing environments from simulation, to trial ranges to open sea. Where feasible, learning should be read-across from other domains such as self-driving cars and the nuclear industry. Safety of road transport has a more cluttered, congested and faster moving environment to contend with, yet driver assistance technologies have been gaining traction for some time. Onboard sensors and processing could be better utilised to ensure reliable operation. Equipment health data and AI allow for powerful prognostics to anticipate faults and failures. This in turn, could be used to constrain a vessel's operation envelope to reflect any predicted performance shortfall and remain safe. Data generally, where it pertains to safe operation should be shared across stakeholders for all to benefit. A potential solution to enable the adoption of increasing autonomy at sea is to enforce constraints such as imposing AIS position signalling, dedicated sea lanes for uncrewed vessels and their specific marking.

> However, an international agreement is required for this and will require compelling market economics. A consistent approach to fail-safe or last-resort measures might also help, with emergency stop capability and "not in command" signalling.

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SMART SOUND
European Union
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How can Operators and Designers work more closely together – from the Designer/builder perspective:

Engineering Expectations

The current cost expectations for delivering autonomous systems are unrealistic and customers do not have a full enough understanding of the cost and time involved in creating these systems. In particular, customers don't realise how bespoke some of the systems they require are, and the cost and time implications of developing systems with different capabilities. Some of the customers for these vessels are unconventional and focused on ocean technology or very specific operations. In terms of available flexibility, large vessels with a hangar for payloads can have these payloads switched out and the vessel re-rolled for a different capability quite easily, but for smaller vessels, a change of capability often means a complete redesign or a different vehicle altogether. These vehicles are not yet in mass production, so costs are naturally higher. The Designers and Builders also don't have a full picture of Operator/customer needs into the future and therefore can't develop their production to prioritise bases designs or standardisation, which would lower cost.

Often Designers and Builders are given ambiguous concepts of use (CONUSE), operational profiles and roadmaps for future uses, or the specifications they are working to were written with a crewed solution in mind.

There have been actions that have degraded trust over the years, such as vehicles being made badly and vehicles being used incorrectly/in an unsafe manner. These issues could be eased by the development of clearly defined CONUSE documents, as well as building trust between design/build and the Operator/customer. Feedback and usage reports from the Operators to the Designers/Builders would be of benefit to all, as issues or bugs in the systems could be designed out for improvements in future vehicle hardware or software patches. Another solution would be to create a form of quality accreditation for Designer/Builders to show they are competent at delivering capable and safe vessels, this accreditation could be given by a class society.

Platform: Demands from Operators in relation to Designers/Builders related to the provision of Space, Weight and Power (SWaP) and the flexibility or modularity within the platform to accommodate a range of payloads with the ability to re-role throughout a vessel's life. In particular, there were challenges around meeting stability requirements for these payloads and understanding the operating conditions for these as well as the ultimate survivable conditions.

The short lifecycle of OT (operational technology) compared to standard marine technologies meant that ongoing maintenance and modification of MAS would be required through-life and system architectures would need to be open and transparent to support this. The integration of Operator supplied or specific equipment into platform-based systems also caused challenges through disruption to existing design solutions and tried and tested architectures.

Equipment: Designers/Builders noted that the launch and recovery of payloads, and in some cases, the need to launch and recover the MAS itself, as well as for it to tow or be towed, presented significant challenges; this also included the need to host other autonomous systems (i.e. UAV or UUV) and to act as a host or relay hub for these. Other challenges included matching the payload operational conditions to the platform operational conditions and ensuring that the specific mission requirements were appropriately matched to the MAS architecture – for example smaller MAS in particular, are designed for specific mission types and are less able to be re-rolled due to SWaP constraints – this may require multiple MAS solutions.

Deployment: Designers/Builders identified that, in most cases, design solutions had to accommodate transitional deployments of MAS technology. Therefore designs may need to evolve to allow for progressive acceptance. This was based on a requirement to ensure minimal additional training burden and the use of familiar or similar technologies, processes and interfaces. What might be an optimal solution, or one based on a clean sheet of paper, may need to be balanced against the Operators ability to resource and operate the system using existing personnel and platforms. Clear identification of operational roles and responsibilities was required as it was noted that the introduction of MAS did not always reduce manning requirements but did require alternative personnel functions. Similarly, clear information on MAS capabilities was required to ensure that Operators understood the limitations (and opportunities) provided by the MAS and were then able to ensure its appropriate deployment and successful benefit realisation.

Support

There is a need to have a clear understanding of the through-life support package, particularly because the design authority is likely to remain vested in the Designer/Builder and through-life upgrades, repairs and updates are unlikely to be easily achievable by the Operator. Ongoing dialogue and support between the Designer/builder and the Operator are necessary to ensure the maintenance of the safety case that underpins the safe deployment of the MAS. Clarity on what the support package should contain and how it should be delivered is something that should be discussed and agreed upfront to ensure that supportability was considered as a design requirement and deliverable.

Sales model

One observation from the Designers/Builders was that customers are reluctant to invest in this technology, but the only way to reap the benefits of autonomy is to strive forward and invest in its development. Designers/Builders have a view that 'fortune favours the bold' and customers who are bold in their plans and investments are being rewarded with more efficient/greener/safer operations. Designers/Builders developing innovative models of sale was also discussed.

Awareness of Requirements

Designers/Builders felt that the Operators and end users lacked sufficient awareness of their own requirements regarding MAS and industries' capabilities to achieve these. This was a case of being able to match problems to solutions and come to a common understanding of capabilities and benefits that could be realised through the appropriate use of MAS. Later discussion identified that in some cases, the Operators were also struggling to 'sell' the concept of MAS to their clients and that some offshore contract opportunities prevented the use of MAS through standardised job specifications based on the use of ships. A solution to this might be to convene more industry wide discussions to allow for the mutual creation of use cases for MAS, which matched service requirements with MAS technologies in a way that allowed for appropriate deployment and development of the technology.


FUGRO

How can Operators and Designers work more closely together – from the end user/Operator perspective:

Use Case

Operators thought that Designers/Builders needed clarification on the use case requirements, including information on client needs and potential use case mapping to support product development road mapping. Clear definition of operational life expectancy as well as upgrade and refit cycles to inform design decisions and through life support requirements (sometimes called ILS – integrated logistics support).

The conversation should start with a clear and complete description and explanation of concepts of employment, use and operation, as this is the foundation for a shared understanding of the fundamental need being addressed. It's useful if these drill into specifics of what, why, how and where but also broader implications such as those beyond autonomy, for instance reliability. The area of deployment will bring different regulatory and legal stipulations that again must be shared (e.g., UK, Middle-East, Asia-Pacific). There should then be a clear link from the concept of operation to the user requirements and on to the system requirements. These requirements must be high-quality, so unambiguous and measurable, for example. A sharing of the underlying context to the military capability to which the MAS contributes is useful and this could, for example, be framed by the so-called Defence Lines of Development (DLoDs).

With a valuable perspective, suppliers should get deeply involved in the definition of requirements. So, understanding the basis and rationale for the user need and translating and interpreting these to system requirements, both functional and non-functional.

Safety Case

It was apparent that there was a need for a clear contractual delineation of responsibilities for safety case inputs, specifically around 'safe to operate' aspects and the documentation required to evidence these; this would require recognition of the link that the Operator played between the Designer/builder and regulator and the need to ensure that regulatory requirements impacting design were communicated, particularly to support assurance. One challenge noted was the differences between the Operational Domain (OD) ('the world'), the Operational Design Domain (ODD) (the Designer/Builders CONOPS) and the Target Operational Domain (TOD) (the Operators CONOPS) and the need to understand how to manage or minimise the differences between the ODD and TOD in order to ensure vessels were appropriately matched to the required tasks and the whether sufficient flexibility should be provided to allow for multiple mission types or whether it was better to use different platforms for different jobs.

Further to similar themes discussed elsewhere was the need to understand the assurance artefacts required from the design/build space and how these related to the operational safety case; clarity on responsibility and delegation to third parties, like Class, was necessary. Specific evidence related to legacy development or assurance processes was discussed as being necessary to support the safety case and the need to ensure that the process of development was documented and assured as appropriate to support future certification.

Prescriptive Standards

In time, there may be value in prescriptive standards of, e.g. build and performance, that could be pointed to. Mutual agreement on the timing and nature of the scope and requirements freeze is paramount. Agility to change and adapt is in practice limited by commercial arrangements. A trade body was called for that could take a lead on proposing benchmark standards for MAS. A distinctive "kite stamp" of assurance might then result in broad stakeholder support and trust, as per the food standard "Red Tractor" labelling. Standards might comprise basic but consistent turnkey capability at different autonomy levels and potentially definition of a central open architecture or backbone for different autonomy "bolt-ons".

Equipment

Operators thought that Designers/Builders could provide better clarity around the segregation (and integration) of systems onboard, particularly regarding the dependencies between 'mission' or 'vendor' supplied equipment and vessel systems and how these supported the use of autonomy. This would assist with understanding the wider challenge around the flexibility of the design space and the available parameters which could be changed or altered, as well as the ownership of equipment risk.

Open and early conversation on cost implications of potential/likely capability increments would help to contain scope creep. Given its evolving nature, the supplier should strive to inform and educate the Operator on the capability and limitations of the technology and its operational implications.

Management of Risk

The shared management of risk was discussed, both with regard to ensuring that this was proportionate and also with regard to understanding the transfer of residual design risk to the operational space as well as operational mitigations that might be invoked in the design space (and vice versa). The risk needed to be identifiable and manageable. Although already good practice, given the evolving nature and adoption of autonomy technology, there should be an embedded culture and unwavering focus on sharing risk understanding and safety know-how.

Conclusion:

There is the need to have wider industry discussions around use cases and the need to rationalise the MAS solutions for these into 'risk profiles' that can be used to streamline proportionate regulation. There is also a case to be made for more permissive trials/operational areas to allow for more efficient development/ deployment.

What leapt out from the above discussions was a need and desire for an intimate and collaborative relationship between the Operator and supplier as a basis for success. It would be helpful if this extended through life and beyond entry into service, with constructive lessons and insight being passed back for continuous improvement.

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