Institute of Marine Engineering, Science & Technology

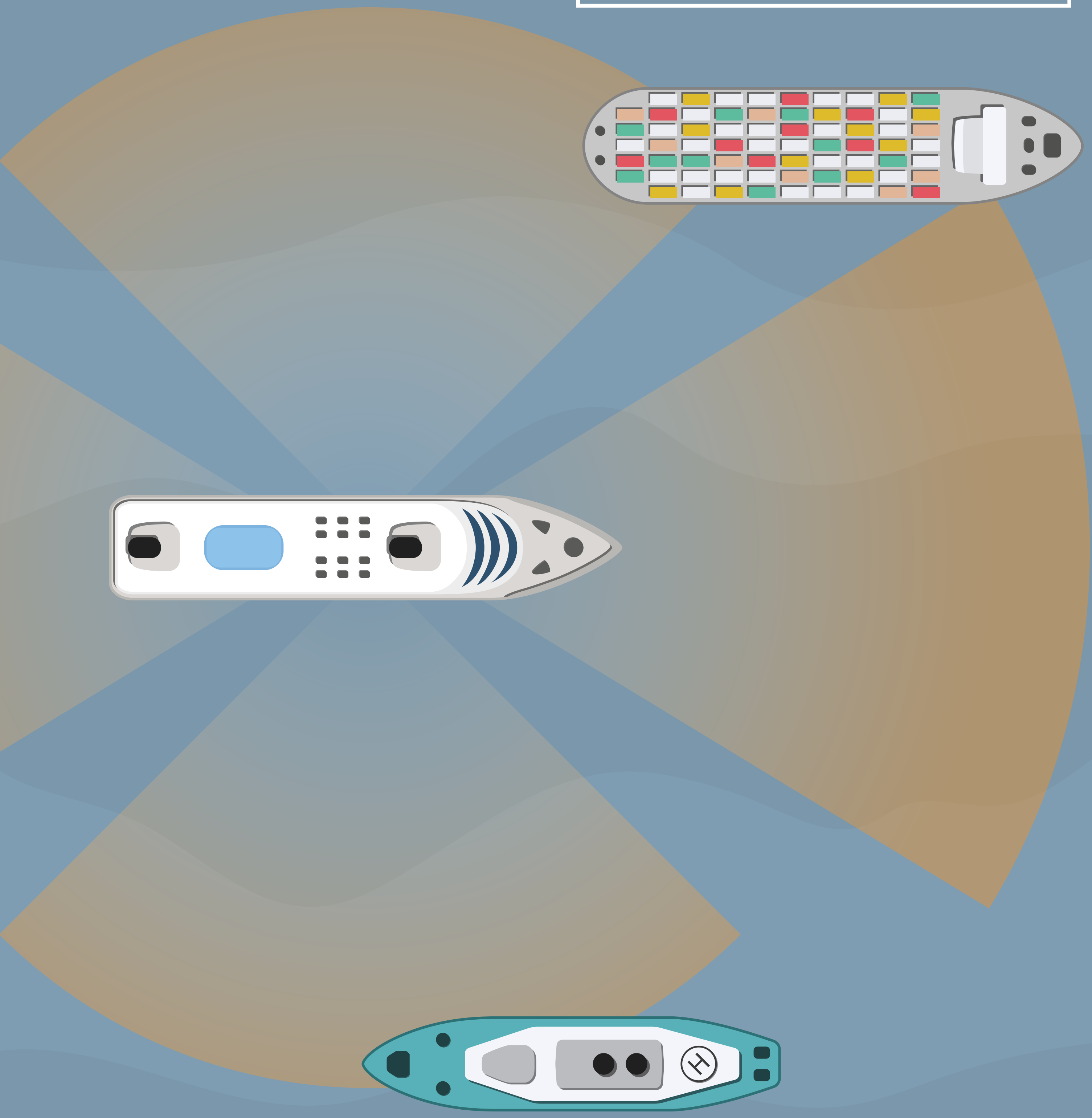
IMAREST

AUTONOMOUS SHIPPING

Putting the human back in the headlines

MANILA, PHILIPPINES – SEPTEMBER 2019

Anticipating changes to vessel systems, functions and future skills requirements as the shipping industry plots a course towards greater automation.



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INTRODUCTION

Seafaring in 2050 will bear scant resemblance to the occupation today. Those in charge of ships will possess and employ a wider range of skills – some of which probably don't exist yet. The working environment will be different too – it seems seafarers will spend far less time aboard ship than they do now.

What will bring about such a radical change in a role that has remained fundamentally unaltered since the beginning of the 20th Century? Within twenty years, automation, robotics and artificial intelligence will have advanced sufficiently that machines will be capable enough to carry out a lot of tasks currently performed manually by seafarers.

Where a human touch is still required, seafarers will likely work in something akin to partnership with machines, relying more heavily on their guidance and insight when it comes to making decisions. These decision support capabilities will lead to improved performance: as an individual, at a vessel level and a corporate level.

It is worth emphasising that greater reliance on automated systems does not mean that one day in the 2040s seafarers will be swept away and replaced by machines – and it is important we challenge this mistaken assumption. That said, the nature of the role will change. And it will get harder for individuals who ignore emerging requirements and adapt their skillsets accordingly to find a job.

It is impossible to predict and describe these new requirements exactly as the skills will be shaped by a combination of technological capability, organisational adoption and treatment by regulators. However we can make some broad-brush generalisations and educated guesses about how things will pan out based on the existing direction of travel.

The future of work lies in the incorporation of human performance with the machine, through timely identification, implementation and assimilation of new skills and ways of working. These new ways of working will demand a workforce that has a broader mix of transferable skills so that they can pursue different roles and new career routes as operational requirements evolve. It follows that curriculums must be developed to fulfil that requirement – and that this has to happen well in advance so that the industry and the institutions expected to foster these skills on the next generation of seafarers isn't caught short.

The IMarEST Marine Autonomous Surface Ship Special Interest Group (MASS SIG) is evaluating future skills requirements as automation becomes more widespread in the shipping industry. It wants:

- To work out the impact that the adoption of automation for specific ship functions will have on seafarer tasks, responsibilities, roles.
- To identify the areas of expertise needed to operate commercial vessels enhanced by remote and autonomous technology;
- To clarify succession planning requirements, workforce skills gaps and future training techniques.

As a springboard for this work, MASS SIG kicked off a series of workshops under the banner of "Remote and Autonomous Shipping – Putting the Human in the Headlines".[1] The first took place in Singapore in April 2018. The second event, held six months later in Manila, Philippines, aimed to pinpoint issues in future human-machine integration in the performance of the onboard functions required to operate a generic commercial vessel safely and efficiently.

Shipowners, operators, crewing managers, regulators and educators in attendance were asked to consider the changes likely to occur to onboard roles, firstly looking around 10 years ahead to 2030 and then around 30 years ahead to 2050. The event was designed to further the MASS SIG's understanding of the ways in which advances in automation technology could, and should, be assimilated into the shipping industry.

The findings presented in this report will help paint a more nuanced picture of the rationale for uniting the respective strengths and capabilities of human and machine and extent this will happen based on real-world needs and practicality. To make the results easier to digest, we present two imaginary vessels of the future, the *Horizon* built in 2030, and her sister ship, the *Succession* built in 2050.

This report presents the findings of this workshop, distilling the views of shipowners, ship operators, ship managers, regulators, and other stakeholders in attendance.

[1] hiip://www.imarest.org/policy-news/thought-leadership/1009-autonomous-shipping

ACKNOWLEDGEMENTS

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The event was led by Gordon Meadow, Daniel Ridgwell, and Adam Lewis of the IMarEST MASSSIG. We also thank the panellists for their time and insights to support this initiative.

The panel provided expertise, views and experience across the ship operation, management and ownership sectors.

PANELIST NAME	JOB TITLE	ORGANISATION
Mr George Ptaoulis	Crewing Manager	ABC Maritime
Mr Daniel Ridgwell	Principal Engineer/Autonomous Systems Capability Lead	BMT
Mr Roger Storey	Managing Director	CF Sharp Shipping Group, Singapore
Mr Tore Henricksen	President & Managing Director	Döhle Shipmanagement Phils. Corp.
Capt Roy Machart	General Manager	Peter Döhle Schiffahrts-KG
Mr Brian Phipps	Head of Crewing	Epic Gas Ltd, Manila
Mr Argyris Gkountaras	Crewing Manager	Global Seaways
Mr David Kelly	Director of Asia Pacific	Institute of Marine Engineering, Science & Technology (IMarEST)
Mr Adam Lewis	Head of Training & Operations	International Maritime Employers' Council Ltd (IMEC)
Capt Robert Fay	Senior Vice President Maritime Operations	International Registries Inc
Ms Joanna Sawh	Crewing Manager	K Line LNG Shipping
Mr Clark Arenas	Head, Manning Office, Marine HR, Fleet Management & Technology	Maersk Line
VADM Eduardo Ma R Santos, AFP (Ret)	President, IMarEST Philippines Branch	Maritime Academy of Asia & the Pacific (MAAP)
Gordon Meadow	Chair of the MASS SIG Founder and CEO – SeaBot XR	SeaBot XR
Glenn Mark Blasquez	Marketing Director	SIMS
Captain Fared Khan	Marine Director	Wallem Shipmanagement
RADM Bayani Gaerlan	President	Western Shipping Pte Ltd
Capt Alban Castellino	Head of Technical	Western Shipping Pte Ltd

HUMAN – MACHINE INTERFACE

According to the World Economic Forum report on the future of jobs, published in 2018, three key managerial challenges lie ahead. First, shifting the training of workers from prediction-related to judgment-related skills. Second, assessing the rate and direction of the adoption of artificial intelligence (AI) technologies in order to properly time the shifting of workforce training (not to early, not too late). And third, developing management processes that build the most effective teams of judgment-focused humans and prediction-focused AI agents.[2]

AI agents arrive at a time when people require stronger analytical and organisational skills, as well as the ability to listen, empathise, explain, advise, influence, and negotiate, all whilst navigating complex project systems. AI assistance should help to spot red flags hidden in the massive torrent of fast-moving data flows. The technology will also support the analysis of high-velocity big data while it's still in motion – before it is stored – to help people take immediate action on what's relevant and ignore what isn't.

To date, the relationship between the man and machine, for the shipping industry has centred on industrial automation. However, the advent of AI through cognitive computing means that the adoption of the AI agent will provide decision support technology which can accelerate and augment human decision making in real time.

The drive toward new ways of working and the reasoning for greater remote or autonomous operations is not unique to shipping. The foundations for change are laid down through concepts such as Industry 4.0.[3] While these new paradigms provide a solid theoretical foundation in justifying the removal of the repetitive, dull, unhealthy and sometimes dangerous tasks that people might currently undertake, there are practical implications for the shipping industry. *Autonomous Shipping: Putting the Human Back in the Headline* highlighted that the next stage in the voyage towards the more remote and autonomous ship and the use of AI technology is in identifying the tasks that humans would be better handing to the machine and looking how that handover would enable the industry to meet business goals and to make operations safer and more efficient. Establishing the complexity in the performance of onboard functions which might benefit from further adoption of AI technologies will enable progress.

Machines can already see, hear, speak, learn, read and write. For cognitive computing, however, the big question is can machines understand? According to Schabenberger[4], human mimicking of tasks can be accomplished in four ways:

- **Self-learning** means the system receives initial instructions, but after that it pretty much learns on its own based on the data you continue to feed it.
- **Machine-learning techniques** automate model building to iteratively learn from data and to find hidden insights without being explicitly programmed where to look.
- **Specific, human-like tasks** means the system can classify and understand objects and recognize human languages, but the tasks it performs are highly specialized. A system that is designed to drive your car cannot change the main engine oil or repair a broken chair.
- **In an intelligent way** describes how the system is able not only to understand input such as text, voice or video, but also to reason and create output consumable by humans.

It is irrelevant which method is used to build future automation technology because in each case the system

[2] The Future of Jobs Report2018: hiip://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf
[3] Industry 4.0 - The fourth industrial revolution: hiips://www.i-scoop.eu/industry-4-0/
[4] Schabenberger: hiips://www.sas.com/en_gb/insights/articles/big-data/executives-guide-to-cognitive-computing.html

must be taught. Therefore, for the shipping industry the starting point for automating functions and tasks is in capturing the human's current tacit knowledge in the performance of duties; this must be understood before the technology can be fully developed. Using this iterative process will provide the flexibility and agility to quickly assess progress to determine whether an alternate approach is warranted for each onboard function.

The roundtable brought together the experts from the shipping industry to add to the body of knowledge in understanding operations from a real-world perspective, mapping the complexity in the performance of the onboard functions required to operate a ship. The objective was to capture, track and evaluate future changes to seafaring roles, measuring the impact to the specific functional requirements currently performed by personnel during the shipping industry's voyage in automation to 2030 and 2050. Understanding the rate and direction of change is essential if we are to change the focus of workforce training to protect against skills gaps. In turn this will shed light on potential future skills gaps; providing greater insight on the consequences for future ship operations onboard and ashore.

"The starting point for automating functions and tasks is to capture the tacit knowledge of human seafarers who currently operate vessels. This must be understood before the technology can be fully developed."

THE ROUNDTABLE

The panel examined the likely future status of reliance on human skills versus reliance on machines in performing operational tasks usually undertaken by the marine engineering crew. Two high level themes were used: 1) ship system and operational requirements; and 2) ship voyage status (see Table 1). Due to time constraints, the roles normally undertaken by deck officers and other crew were not examined.

THEMES

Ship System and Operational Requirement	Ship Voyage Status
Propulsion System	Cold Ship to Port Standby
Supporting Ship Systems	Port Standby to the Commencement of Manoeuvring
Performance and Efficiency Monitoring	Manoeuvring for Commencement of Passage at Sea
Safe Evacuation of Personnel	Commencement of Passage-at Sea (Full Away)
General Administration	Emergency Response
Failure Diagnosis	Alongside / Anchorage
Physical Maintenance	
Condition Based Monitoring	

Table 1: **shows the ship system and operational tasks (left hand column) and the ship voyage status (right hand column) that were considered by the panel**

Whilst there are a number of definitions of levels of autonomy in shipping being developed and discussed the panel used the Human and Machine Interface Status (HAMIS) framework developed by the MASS SIG (see Figure 1) to identify which functions and tasks in 2030 and which in 2050 would require a high reliance on human skills (i.e. little automation and lots of human intervention) and which might be replaced by a machine learning capability (i.e. no need for a human intervention).

The HAMIS Framework is colour coded as follows:

- **Blue:** Indicating high to medium onboard human skills reliance
- **Red:** Indicating low reliance on human skills but human onboard
- **Green:** Indicating supervision moved offboard or ashore to tasks becoming fully autonomous

HUMAN AND MACHINE INTERFACE STATUS	ROLE OF ENGINEER PER MACRO LEVEL TASK	LOCATION OF ENGINEER OR OPERATOR
HAMIS LEVEL 1	High reliance on human skills: little autonomy and lots of human adjustment or intervention	Onboard
HAMIS LEVEL 2	Medium reliance on human skills: information collection is automated but fed to a person making decisions	Onboard
HAMIS LEVEL 3	Low reliance on human skills: the ship takes care of functions and tasks i.e. it can be left to itself for certain amount of time and follows rules. Onboard presence still required. Human crew still needed to perform certain tasks.	Onboard
HAMIS LEVEL 4	The ship takes care of itself for a certain amount of time and has learning capability. Operation is watched over by supervisor who only intervenes when necessary	Offboard
HAMIS LEVEL 5	Ship has full functional performance with decisions made through marine learning capability and no need for any person at any stage	Offboard

Figure 1: Human and Machine Interface Status (HAMIS)

Based on real world complexity in the performance or management of each of the systems, functions or tasks and voyage status listed in Table 1 panel members voted via an anonymous online polling system on the extent to which they believed, for the ship of 2030 and the ship of 2050, reliance would be placed in the hands of the human versus the extent to which this would pass to the machine. Voting was based on the assumption of cargo carrying vessels engaged in international and transoceanic voyages rather than smaller ships restricted to shortsea passages.

Key questions were also addressed in supporting discussions.

- Independent of time-line, which tasks and functions must remain in situ and why?
- With a focus on the years 2030 and 2050, which tasks and functions must remain in situ, which can be performed remotely, and which will likely have become obsolete?
- Based on real world practicality, what is the likely level of human reliance compared to machine assistance?

The poll results are summarised in Figures 2 to 15 across the following pages. Figures 2 to 7 show the views from the panellists for the ship of 2030 (the *Horizon*) and of 2050 (the *Succession*) for the ship systems and operational requirements and Figures 8 to 15 show the views from the participants for the *Horizon* and *Succession* for different stages of a voyage.

SHIP SYSTEMS AND OPERATIONAL REQUIREMENTS

Propulsion System

Horizon 2030 – In relation to the propulsion system, based on their experience around three-quarters of panelists felt that by 2030 there would be a medium to low reliance on onboard human physical skills and that an onboard presence would still be required. Based on current technological trends, it seems to the panel that functions will continue to undergo further automation. However advances in AI will lead to more sophisticated approaches to data collection and trend analysis. The role of the person will be to clarify as well as rectify, with the roles increasingly moving to a person making decisions based on solutions and recommendations.

Succession 2050 – Most of the panel (92%) felt that the functions related to propulsion would be moved offboard by 2050 and that a ship could be left to itself for a certain amount time with some level of learning capability. Nearly half the panel felt that the function would still need to be watched over by a supervisor who could be called upon when necessary whilst the others felt that the ship would have fully functional performance with decisions made through marine learning capability and no need for any person at any stage whilst the equipment was in operation.

The panel felt that there is a requirement for propulsion systems to be looked at from an operational as well as regulatory perspective due to the rapid change in technology in propulsion systems (electrical and hybrid propulsion, for example). It was also felt that it would be possible to get to HAMIS 4 sooner than 2050 were there to be a greater focus on automation of certain technologies rather than a complete focus on unmanned systems. By 2050 the panel agreed that it is likely the propulsion system and associated tasks could be overseen from the shore on certain ship types, as is the case in the aviation industry, where large volumes of data on airplane engine performance is transmitted in near real-time to ground centres around the world to identify potential problems and act (remotely) accordingly. However, the panel was split on the question of whether a human would need to be in the loop as more than half considered that by 2050 there will still be a requirement for human intervention at a supervisory level at some point. This was regardless of the available technology and regulatory framework.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	14%	0%
2: MEDIUM HUMAN RELIANCE	36%	0%
3: LOW HUMAN RELIANCE	36%	8%
4: HIGH MACHINE RELIANCE	14%	46%
5: FULL MACHINE RELIANCE	0%	46%
TOTAL	100%	100%

Figure 2: **Percentage of panel believing that propulsion system functions will be carried out to each HAMIS level of autonomy**

The panel considered whether cost would be a barrier to the adoption of automation with regards to propulsion systems. There was a sense that as technology develops the costs of equipment and its implementation will fall, thus contributing to a reduction in human involvement in the process of ship propulsion. Technology that is being adopted in the automotive industry to contain units within the engine that in turn require less human involvement will almost inevitably be adopted by other transport sectors including the shipping industry. However, it must be noted that in the case of shipping the engine is not simply about enabling propulsion.

Supporting Ship Systems

Horizon 2030 – Even as soon as 2030 the panel felt that with regards to supporting systems (any infrastructure, components or subsystem used on a generic ship as operated and maintained by the engineering department) there is likely to be a low reliance on human skills but almost two-thirds of the panel considering that the human would still be required to perform a range of tasks.

Succession 2050 – The panel were unanimous that the management of the ships supporting systems would be moved offboard with the majority feeling that the function would be watched over by supervisor who could intervene when necessary. This judgment was based on ongoing changes to the requirements from subsystems as well as the potential for complete redesign of systems to support greater autonomous and remote operations.

The panel felt that a shift towards increased automation onboard vessels for the supporting ship systems was seen as logical. With this in mind the panel envisaged that the roles and responsibilities of deck and engine functions will become increasingly blurred as technology becomes more integrated into ship systems.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	0%	0%
2: MEDIUM HUMAN RELIANCE	22%	0%
3: LOW HUMAN RELIANCE	64%	0%
4: HIGH MACHINE RELIANCE	14%	71%
5: FULL MACHINE RELIANCE	0%	29%
TOTAL	100%	100%

Figure 3: **Percentage of panel believing that control of supporting ship systems will be carried out to each HAMIS level of autonomy**

> “The roles and responsibilities of deck and engine functions will become increasingly blurred as ship systems grow more integrated.”

SHIP SYSTEMS AND OPERATIONAL REQUIREMENTS

Performance and Efficiency Monitoring

Horizon 2030 – Two-thirds of the panel felt that much, if not all, of the function of monitoring ship performance could be moved offboard by 2030 with a supervisor in the loop who would step in to make decisions when necessary.

Succession 2050 – Nearly all the panel felt by 2050 with regards to performance and efficiency monitoring the ship would have full functional performance with decisions made through marine learning capability and no need for any person at any stage.

A complete reduction in onboard human reliance and the potential to remove the human from the loop entirely by 2050 for performance and efficiency monitoring was seen as one of the most likely outcomes of increased automation and machine learning. This is because machines will be increasingly able to monitor themselves due to advances in sensor technology.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	0%	0%
2: MEDIUM HUMAN RELIANCE	14%	0%
3: LOW HUMAN RELIANCE	22%	0%
4: HIGH MACHINE RELIANCE	64%	7%
5: FULL MACHINE RELIANCE	0%	93%
TOTAL	100%	100%

Figure 4: **Percentage of panel believing that performance and efficiency monitoring will be carried out to each HAMIS level of autonomy**

Safe Evacuation of Personnel

Horizon 2030 – When it comes to the safe evacuation of personnel the panel believes that by 2030 there will still be a high reliance on human skills: little adoption of autonomy and lots of human adjustment or intervention

Succession 2050 – Nearly 80% of respondents felt that technology would progress sufficiently enough so that the safe evacuation of any personnel onboard a vessel could be undertaken through offshore supervision and by using automated technologies onboard.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	62%	14%
2: MEDIUM HUMAN RELIANCE	15%	0%
3: LOW HUMAN RELIANCE	23%	7%
4: HIGH MACHINE RELIANCE	0%	56%
5: FULL MACHINE RELIANCE	0%	23%
TOTAL	100%	100%

Figure 5: **Percentage of panel believing that functions related to evacuation will be carried out to each HAMIS level of autonomy**

Up to 2030 it was not felt likely that the human could be removed from the loop when it came to safe evacuation of personnel. While technology could be used to support this activity (such as using drones to send spare parts to the engineer or crew onboard or 3D printing to manage any issues that might lead to an evacuation under other circumstances) there was a view that keeping the human in the loop to have oversight and make decisions in parallel with technology was the best way forward to assure the safety of personnel. Looking further ahead to 2050, the question whether a crew member needing evacuation would be familiar with newly emerging solutions such as escape drones. The overall view was that they would adapt and incorporate technology proven to support the saving of life at sea as it develops.

Examples were discussed by the panel where technology could have potentially been used to mitigate accidents. For example, could a computer have made a better decision than the human in cases such as the grounding of the Costa Concordia? Elevating technology in the decision-making process will require social acceptance and a roadmap for integration within current personnel at sea. It is currently accepted that machines can indicate danger via alarms for example when getting too close to the shore but can humans accept computers making the final decision?

For automation to be accepted in the evacuation of personnel a change to the SOLAS convention would be required. For example, the ship's Master is the only one allowed to issue the call to abandon ship. Whilst the panel felt that it likely that this function could and probably would become autonomous, it was agreed that the industry shouldn't consider removing the responsibility from a Master. Someone still needs to be in overall control.

SHIP SYSTEMS AND OPERATIONAL REQUIREMENTS

Administration

Horizon 2030 – More than half the panel felt that by 2030 the ship could take care of the majority of the onboard administration functions i.e. paperwork and documentation. However, the remainder were split between the requirement for human intervention with more than one-third still feeling there would need to be a human onboard to undertake administrative tasks.

Succession 2050 – 100% of respondents felt that technology would progress sufficiently enough so that that the administration workload associated with shipping would be semi to fully autonomous by the year 2050 and entirely offboard.

It was considered that administration tasks were primarily linked to the connectivity of monitoring systems and the recording of outputs. The panel felt that as we move to a more integrated shipping industry the "Internet of Things" will have greater influence on administration with a significant shift from 2030 to 2050 as the reliance of humans in the loop reduces.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	8%	0%
2: MEDIUM HUMAN RELIANCE	8%	0%
3: LOW HUMAN RELIANCE	22%	0%
4: HIGH MACHINE RELIANCE	54%	29%
5: FULL MACHINE RELIANCE	8%	71%
TOTAL	100%	100%

Figure 6: **Percentage of panel believing that control of administrative functions will be carried out to each HAMIS level of autonomy**

Physical Maintenance

Horizon 2030 – Around half the panel felt that there would be a medium reliance on human skills with regards to physical maintenance tasks. Technology will continue to progress steadily through innovation in maintenance trending and condition-based monitoring through the use of AI and sensors. This will reap tangible benefits in terms of equipment longevity. It was still felt that data collection would be further automated, but still fed to a person making decisions who could then act appropriately. Nearly all the panel felt that a human would need to be onboard even if the ship was taking care of some functions and following rules.

Succession 2050 – 100% of respondents felt that technology would progress sufficiently enough so that any requirements for physical maintenance on a generic ship would become an offboard monitoring function and that the vessels would see much more significant gaps in the need for recurring physical maintenance.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	7%	0%
2: MEDIUM HUMAN RELIANCE	33%	0%
3: LOW HUMAN RELIANCE	53%	0%
4: HIGH MACHINE RELIANCE	7%	73%
5: FULL MACHINE RELIANCE	0%	27%
TOTAL	100%	100%

Figure 7: **Percentage of panel believing that control of maintenance functions will be carried out to each HAMIS level of autonomy**

The panel felt that maintenance tasks generally vary according to the ship owner's perspective where traditional maintenance costs are allocated against the business model. If the ship is a disposable asset to be used for 3-5 years and then sold, the levels of maintenance will likely differ to those ships being retained for the longer term. It could be argued therefore that owners of vessels holding on to vessels may find the idea of maintenance free vessels, attractive even if the upfront investment was significantly higher.

Whilst technology to reduce maintenance is being rapidly adopted in other sectors such as the automotive industry the majority of ships are built as cost effectively as possible. For example, in the automotive industry there has been a pronounced shift towards making cars less likely to require serious maintenance or repair through the use of onboard computers to monitor performance and to raising alerts of any faults. However, ships are exposed to a much harsher operating environment than typical consumer road vehicles making maintenance a significantly greater consideration as well as a significant burden on profits. The panel felt that ship design would have a greater impact than technology and there is likely to be a change to a more modular approach to ship design in the longer term, resulting in a significant reduction in the need for ongoing physical maintenance. The long-term aspiration for the panel was, of course, that ships would one day be as close to maintenance free as possible.

SHIP SYSTEMS AND OPERATIONAL REQUIREMENTS

> “Our attitude to machines has undergone a radical shift. In the past, if a car or radio or something broke down you would fix it - or call someone who could. Today, you simply purchase a new one. Similarly, I envisage ships will be modular and will simply replace parts that break down rather than fix them.”

In the past it was common for ships to go into dry dock every two to three years, but today that interval has increased to five years likely due to increased reliability of the ship systems. However, the panel felt that, irrespective of what is above the waterline, since a ship is built with the propulsion system under the water, the dry docking will always be required. Factors affecting the propulsion system and hull such as biofouling and corrosion which might require replacement coatings for example can realistically only be carried out in dry dock. That said, design changes or improvements in paints for example may further extend the time between dry dock visits.

SHIP VOYAGE STATUS

Cold Ship to Port Standby

Horizon 2030 – Three-quarters of the panel felt that during this stage of a voyage there would be a medium to low reliance on human skills. Data will be collected automatically but fed to a person making decisions but also that the ship itself might take care of some functions. I.e. it could be left to itself for a certain amount of time and follow rules. A quarter of the panel felt that some functions would start to move to the shore.

Succession 2050 – 100% of the panel felt that technology would progress sufficiently enough so that taking a ship from cold to port standby could be undertaken from shore- with only a third believing a human would be required to supervise.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	0%	0%
2: MEDIUM HUMAN RELIANCE	64%	0%
3: LOW HUMAN RELIANCE	14%	0%
4: HIGH MACHINE RELIANCE	22%	31%
5: FULL MACHINE RELIANCE	0%	69%
TOTAL	100%	100%

Figure 8: **Percentage of panel believing that control of ship cold-start functions will be carried out to each HAMIS level of autonomy**

The panel confirmed that at present the preparation of the engine from cold start to port standby is a fairly routine exercise for the 2nd or 3rd engineer. However, certain types of engines require more intervention and this may become more common if complexity in engines increases. For example, as advances are made in engine technologies to reduce Greenhouse Gas Emissions.

Moving towards 2050 there are elements of preparing the engine for port standby mode which could be handled remotely; such as monitoring. However, even if the process could be fully automated, regulation as it currently stands may not allow it. For example, there may still be a regulatory requirement for someone to visually check the preparation of the vessel in areas such as steering gear and propulsion system, temperature of fuel, air in the system, and, seaworthiness – seaworthiness being the key aspect here to ensure the vessel is safe for departure. However, it was pointed out a key difference between aviation and shipping is that planes do not have engineers onboard anymore and airworthiness is checked by ground staff with the pilot and cabin crew performing further checks onboard.

SHIP VOYAGE STATUS

Port Standby and Commencement to Maneuvering

Horizon 2030 – Even by 2030 three-quarters of the panel felt that the tasks required from going from port standby to maneuvering could be performed offboard with the ship undertaking many of the functions itself. More of the panelists felt this section of the voyage could be done from ashore compared to the task of moving from cold to port standby.

Succession 2050 – 100% of respondents felt that technology would progress sufficiently enough so that, as with cold to port standby this would be a stage of the voyage that could be managed offboard-with the majority believing it would not require any human intervention.

Reduced reliance on human crew up to 2030 was particularly interesting in this case. Shipping companies will need to assess the cost-benefit of having someone onboard versus someone ashore. For example, the Chief Engineer upon commencement to maneuvering is already on the bridge in many cases (and thus not in the engine room) as they are monitoring all the ship systems including the propulsion system. So, whilst today there still are engineers in the engine room there are already examples of how the Chief Engineer is able to monitor the equipment semi-remotely with currently available technology.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	0%	0%
2: MEDIUM HUMAN RELIANCE	0%	0%
3: LOW HUMAN RELIANCE	26%	0%
4: HIGH MACHINE RELIANCE	74%	33%
5: FULL MACHINE RELIANCE	0%	67%
TOTAL	100%	100%

Figure 9: **Percentage of panel believing that vessel standby and maneuvering preparations will be carried out to each HAMIS level of autonomy**

> “Even today chief engineers are able to leave the engine room and monitor equipment semi-remotely from the bridge.”

Maneuvering for Commencement of Passage at Sea

Horizon 2030 – 80% felt that there would be a low reliance on human skills with regards to maneuvering. The ship should be able to take care of this function but would need to follow specific rules with an onboard presence still required and a human still performing certain tasks. However, 20% felt that there was some potential for more tasks to be moved to shore control with a human undertaking a supervisory role.

Succession 2050 – Again, 100% of the panel felt this could be managed from ashore with an equal split between whether a human would be needed in a supervisory capacity or whether there would be fully functional performance of the ship with decisions made through machine learning capability and no need for a person at any stage.

Some of the panel expressed views that maneuvering to commencement of passage-at-sea (including pilotage) will still require crew onboard until 2030, at the very least. However, it was suggested that the Chief Engineer may not be required to remain onboard for the full voyage and could disembark with the pilot, though this would be highly problematic on a ship working in the spot market.

In the longer term, the role of an engineer as we know it today may become redundant when it comes to ship operations whilst in the nearer future the engineers would not necessarily have to remain on board a vessel for the duration. What is more likely however, is that by 2050, in terms of roles, the industry would see the split between the deck and engine tasks onboard beginning to disappear – with these roles likely to become amalgamated. Norway, France and Holland are already delivering dual tickets to accommodate for this in the future.

The panel felt that, in addition to new skills, workers will perform tasks using a more integrated set of skill sets, and that the industry should communicate the need for this change to educators and training providers in order to allow them to begin to plan for the future.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	0%	0%
2: MEDIUM HUMAN RELIANCE	0%	0%
3: LOW HUMAN RELIANCE	80%	0%
4: HIGH MACHINE RELIANCE	20%	46%
5: FULL MACHINE RELIANCE	0%	54%
TOTAL	100%	100%

Figure 10: **Percentage of panel believing that maneuvering for commence of passage will be carried out to each HAMIS level of autonomy**

SHIP VOYAGE STATUS

Commencement of Passage-at Sea (Full Away)

Horizon 2030 – Around two-thirds of the panel felt that whilst a ship was on its passage at sea by 2030 many of the functions could be managed offboard with a supervisor at a shore facility or onboard another vessel. The remainder of the panel were split between whether passage-at-sea could be fully automated by 2030 or whether a human would be needed on board.

Succession 2050 – As with other stages of voyage the panel felt that this could be managed offboard with three-quarters of the panel feeling this stage of voyage could be fully automated with decisions made through machine learning.

During passage-at-sea the panel felt that it was possible to operate a vessel without engineers on board. However, the picture is not as simple as just undertaking a journey from A to B. For example, in order to comply with regulations under MARPOL (and other Conventions such as the Ballast Water Management Convention) there is a need to undertake tasks and perform duties on board that currently require an engineer. As such, the automation of technologies and processes that allow for compliance with environmental and other Conventions must be considered in parallel to automation of ship propulsion systems, navigation systems etc. Marine Engineers will likely still be needed to perform maintenance tasks, but potentially on systems that include a lot more automation than is currently available.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	0%	0%
2: MEDIUM HUMAN RELIANCE	0%	0%
3: LOW HUMAN RELIANCE	19%	0%
4: HIGH MACHINE RELIANCE	69%	25%
5: FULL MACHINE RELIANCE	12%	75%
TOTAL	100%	100%

Figure 11: **Percentage of panel believing that commence of passage (full-away) will be carried out to each HAMIS level of autonomy**

This will call for a different set of maintenance skills. As new ships come out of shipyards, more and more automation will be incorporated. LNG-powered and other vessels adopting alternative fuel and propulsion systems are going to be very different ships than those we see and operate today and the voyage maintenance requirements are still unknown.

However, by 2050 the panel felt that it was inevitable that there is less reliance on humans in the process.

Emergency Response

Horizon 2030 – As with evacuation of personnel the vast majority of the panel felt that by 2030 this is still a function that requires a human presence on-board. Whilst there may be a role for automation of information gathering there remains a need for a human to act in a supervisory and decision making capacity.

Succession 2050 – Three-quarters of the panel felt that emergency response could be managed offboard and a quarter felt that it could be a fully automated process. However a similar number felt that a human should still be onboard in a supervisory capacity.

Greater automation may result in an engineer performing less 'engineering' tasks. Instead, their focus will shift to emergency prevention and maintenance. This evolution has already begun with unmanned systems notifying the engineer about a potential emergency before it occurs. This is consistent with advances in the automotive industry where, if a modern car senses something is wrong with a system, it simply stops to prevent any more damage being done. However, this doesn't mean the car is able to repair itself and engineering intervention is then required.

Remote repair may not be feasible option in the case of physical failures, such as cracked pipes or loose fittings, which if left untended could pose a significant risk to the environment. The ability to prevent and clean up, for example, any spills or apply contingency measures must still be available.

A key consideration is where the responsibility lies in the event of an emergency. Even if the reliance on humans on-board is lessened the remaining crew or offboard personnel will still need to be well trained and need to know what to do in an emergency.

It was also noted, that increasing reliance on technology will result in increased exposure to cyber security threats which is something the industry needs to look at in a lot more detail.

HAMIS	2030	2050
1: HIGH HUMAN RELIANCE	0%	0%
2: MEDIUM HUMAN RELIANCE	36%	0%
3: LOW HUMAN RELIANCE	50%	19%
4: HIGH MACHINE RELIANCE	7%	54%
5: FULL MACHINE RELIANCE	7%	27%
TOTAL	100%	100%

Figure 12: **Percentage of panel believing that emergency response will be carried out to each HAMIS level of autonomy**

CONCLUSION

In the years to come automation will become increasingly pervasive in vessel operation. As advances in artificial intelligence and machine learning find their way into more and more ship systems, it is inevitable they will alter the role of seafarers: their tasks, responsibilities and required skills. And these effects will impact every stage of a typical voyage. It is highly likely that a subset of tasks currently performed at sea will move to land and be carried out from shore-based facilities.

There was however the clear reminder that there are well appreciated challenges of integrating autonomy that still need to be resolved including but not limited to the regulatory framework; responsibilities and liabilities and the assurance of safety and environmental protection.

A widely recognised risk across the maritime sector is that the numbers of people both entering and being retained in a sea-going career are dwindling. The perception remains that any means to reduce reliance on crew will be welcomed as will the opportunity to sell shipping as a high technology, exciting career.

Whilst it was recognised that the capital expenditure of integrating technologies will be initially high the costs of procurement will eventually reduce and with it take up will increase. Ultimately, of course, this will result in a noticeable reduction in operational expenditure.

With the industry embracing such revolutionary changes, the need to shift traditional mentalities and operating profiles is recognised. This is encouraging and demonstrates that the sector is committed to this shift. To facilitate a more intimate human-machine interface a shift in roles and therefore skills is also recognised. In the short term, this is likely to be seen by merging traditionally separate roles.

The shift to increasing automation and to offboard tasks identified in this roundtable is likely to be replicated and reflected across the maritime sector, with a possible exception of highly-complex specialist carriers. However, all this being said there still remains a need to retain human interaction in the loop even by 2050. It may not be a case of less seafarers just seafarers in 2050 having very different roles from today.

> For the foreseeable future, autonomous systems will remain unable to make critical decisions based on sound judgement. So, the challenge lies not in teaching humans to trust machines, but providing them the skills and competencies to know when to stop trusting and overrule them.

WHAT NEXT?

The IMarEST will continue to undertake activities that look at how increasing adoption of automation in the shipping industry affects human performance.

This roundtable and this subsequent report focusses on the engineering aspects of ship operation and a complementary piece of work is currently being planned to gather input from a deck/navigation perspective.

Once this new piece of work has been completed, the IMarEST's MASS Special Interest Group will seek to benchmark current workforce knowledge and skills against the future requirements for knowledge and skills based on identified changes to the operational working environment.

Humans are and will always be essential in keeping the shipping industry ticking over. However, the changing nature of roles and duties presents a variety of safety concerns. This report has sought to highlight what is arguably the most significant challenge: how will humans and autonomous systems work together.

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