Towards the Seafarer of Tomorrow

Maritime Worker Competencies in the Autonomous Age

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Ongoing digitalization and automation developments in the maritime domain are increasingly enabling maritime operations to be monitored, controlled, and supported in distributed and remote locations at sea and on land. As maritime operations evolve, new and emerging technologies reorganize how work systems are designed, including the work tasks and demands of the people operating these systems. This requires a revaluation and update of what knowledge and skills current and future maritime operators will require, with the potential that operators of future ships and marine structures may never actually work or have experience at sea. Literature and research regarding autonomous ships has become much more prevalent in recent years and it is interesting to observe how the topics have evolved over time. While the initial writings were mostly on the technology (for example, Convention on the International Regulations for Preventing Collisions at Sea (COLREG) compliant software or digital twin engines), recently attention is being paid to the just-as-necessary non-technical skills. This is of interest as the shift away from "nuts and bolts" technology places more emphasis on the socio-technical aspects of highly automated and autonomous systems.

One of the first observations to make about autonomous shipping is that it is relatively lagging behind other modes of transportation in regard to automation, including road, rail, and air. The first autonomous vehicle was developed in 1995 and was able to navigate on its own but required a driver to accelerate and brake. In 2006 the first vehicle with "active lane keeping assist" entered the commercial market and over ten years ago the technology for fully autonomous vehicles existed. These vehicles have undergone millions of kilometres of road testing and have shown the potential for safe operation, yet they have not found large-scale adoption. As Cugurullo and Acheampong point out in their 2023 paper "Fear of AI," there exists a "… plethora of fears and concerns that our participants feel in relation to AI-driven cars" which are preventing general adoption of autonomous vehicles. In rail transport there are various examples of driverless trains in current operation, predominately found in urban transportation systems. The first was the Port Island Line in Kobe, Japan, consisting of a six-km-long system, which began autonomous operation in 1981. Since then, driverless trains have been adopted in many cities, although it should be noted that some still have human attendants on board. The mode of transportation that has the most prevalent level of automation is air. Airplanes have used commercial autopilot for decades. The need to land airplanes in poor visibility encouraged the development of auto-landing systems. Currently pilots are only necessary to taxi and take off and nearly all other parts of the journey can be done autonomously. However, this autonomous ability does not mean that aircraft operators are attempting to reduce the pilot complement.

While highly automated and autonomous technologies exist, being deployed across differing modes of transportation, the adoption of autonomous systems has been generally slow to materialize. Consequently, this will have repercussions for the shipping industry with the onboard mariner remaining integral to ship operation into the future. However, this does not mean that ships will continue to be crewed in the current manner and it is expected that crew sizes will reduce. The trend of reducing the number of seafarers on board ships, even while ship sizes and gross tonnage have increased, has been occurring since the 1960s. Technological advancements in shipbuilding and ship technologies have created an inverse relationship where gross tonnage and ship sizes have increased, while the number of seafarers required on board to successfully operate these ships has decreased. The more recent vision and work towards remote and autonomous surface ship operations can be viewed as another step in the natural progression of the decades-long trend of de-crewing ships and offshore structures, mainly in an effort to increase operational productivity and economic competitiveness.

Figure 1: A training program for the autonomous age needs to be effective. It should include foundational knowledge, practical skills development, and simulation.

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Although the overall goal and purpose of a system may remain the same (e.g., safe and efficient passage of a ship from point A to B), any new technological advancement or change introduced into an already established system can reorganize functions, tasks, and the overall organization of the people and processes to achieve the stated goal(s). In particular, from a human element perspective, automation has moved worker tasks from active, hands-on operations (e.g., actively navigating a ship, etc.) to increasingly more passive monitoring tasks of automated equipment and functioning (e.g., monitoring autopilot, responding to alarms, etc.). Humans are poor passive monitors of automated systems and increasingly complicated automation and operational systems can lack transparency, and thus operators do not have a full understanding of the underlying logic or decision-making of an automated system. Furthermore, as more tasks become automated, the tasks "left over" may increasingly be shifted from onboard ship personnel to shoreside personnel, a growing physical and perceptual disconnect between what is occurring at the sharp end of operations on board a structure at sea and the perception, comprehension, and projection of shoreside personnel and their decision-making may occur. This combination creates an interesting set of challenges for both future onboard and shoreside operator skill sets and training, as well as what and how remote operating centres (ROC) are designed and operated for maritime surface ships in order to best support overall system goals and the people involved in achieving those goals.

The human component of a ROC will require new and modified skills; however, it also introduces an opportunity for more specialized personnel and operations. For example, cargo operations and monitoring were the responsibility of the crew during transit; however, as operations move to shoreside it would make sense to have a specialist monitoring the cargo. This specialist would not be distracted by ship operations and could concentrate on only the cargo. While the shore-based operator may not need to be concerned as much about some aspects of ship operations, there will be other areas which will become more critical. What specifically this information is will evolve as autonomous ships enter service, but we can create a broad framework for a training program based on what has been effective (Figure 1). To begin, the foundation knowledge must be provided

Table 1: Training program for mariners. SMS=ship management system. BRM=bridge resource management. ROC=remote operating centre.

Level	Suggested Courses and Program Overview			
Knowledge	Sensors 101	Autonomous SMS	Cybersecurity	Legal/Regulatory
Practical Skills	Sensor Operation	BRM	Ship Handling	Enhanced Emergencies
Simulation	Simulation exercises in ROC			

for the skills beyond what was learned in the normal course of being a mariner. The next step is that this knowledge is applied to allow practical skills to develop. The final step is to bring these skills together during simulated operations. In concrete terms, a training program might look like Table 1.

To begin with, a mariner would need to know about new and different sensors and information sources. In addition, they would need to be aware of emergency procedures and legal requirements. Finally, cybersecurity will have important implications for remote ship operators. From this basic knowledge, we can start to build up their skills. The knowledge of sensors helps them operate and build situation awareness in the ROC. The ship management system, legal, and cybersecurity aspects will allow them to adapt to emergencies and, of course, simulation with ship handling will be critical. All of this can be brought together in ship simulation exercises administered in ROC training.

ROCs will have to support the personnel and their work tasks, and thus is dependent upon an array of variables related to the capabilities of the system – how it is organized and its goals, including operational environment (e.g., location, traffic, weather, etc.), type of ship, type of cargo, uncrewed or reduced crewing on board. Over the past several years, differing concepts have been proposed for how remote operations and ROCs are to be implemented, with the necessity that uncrewed ships are at least as vigilant and safe as a crewed ship. However, there remains no formal guidelines or recommendations on the design or composition of ROCs for maritime surface vessels. There are several examples, spanning from conceptual plans to real-world implemented ROCs and equipment, that have been proposed or are in early implementation ranging from single ship control and monitoring to multi-ship fleet management. However, questions remain on the design requirements to both establish and maintain ROC personnel situation awareness across differing control and monitoring paradigms, including level of automation/autonomy in which a ship is operating or number of vessels managed per operator. Furthermore, the system configuration and human machine interface perspective, including supporting automation transparency for highly automated systems, require further consideration and development.

Current ROC examples typically resemble a combination of current bridge equipment (e.g., radar, conning, ECDIS, CCTV view of ship surroundings) and an instructor station for navigation simulator training (e.g., provides an overview of the simulator exercise, ship(s), and environmental parameters of the scenario). However, this may not be reflective of all operational paradigms, particularly when it comes to scaling remote operations from single to multiple vessels. Furthermore, differing inputs and communication channels between personnel on board and shoreside, perceptual and ship-sense support for shoreside operators, or digital twinning may be necessary to support situation awareness of sharp-end operations and optimal decision-making in planning, executing, and monitoring operations.

In moving forward with the further implementation of uncrewed and autonomous surface shipping, the development of both the ROCs (as a built environment and the equipment therewithin) and operator skill sets (and by proxy, education and training programs to meet the defined learning outcomes) will require co-development in concert with one another. There will likely not be a one-size-fits-all model for autonomous shipping as a "single" operational paradigm (and by extension ROCs and their operators) but rather highly differentiated approaches for how de-crewed, uncrewed, highly automated, and autonomous surface vessels are monitored and controlled. A multidisciplinary approach is required for the successful implementation and operations of differing forms of autonomous shipping models wherever evolving technological development is driving change within these complex socio-technical systems.

Further Reading

Bainbridge, L. [1983]. *Ironies of automation*.
Cugurullo, F. and Acheampong, R.A. [2023]. *Fear of AI: an inquiry into the adoption of autonomous cars in spite of fear, and a theoretical framework for the study of artificial intelligence technology acceptance*.
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Strauch, B. [2017]. *Ironies of automation: still unresolved after all these years*.
Tenold, S. [2019]. *Bigger and bigger: shipping during the golden age, 1950-73*.
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