Ship Intelligence

Marine

Rolls-Royce

Autonomous ships
The next step

Autonomous shipping is the way forward in the maritime industry with Rolls-Royce leading the way in its development

> **"Autonomous shipping is the future of the maritime industry. As disruptive as the smartphone, the smart ship will revolutionise the landscape of ship design and operations"**
>
> **Mikael Mäkinen, President, Marine**

Sensing the environment: The same image as seen by using different sensors. From left to right: radar, high definition camera and infrared. Each provides different outputs with individual benefits. These would be combined to a single output using sensor fusion to reveal an understanding of the surroundings shown in the image on the far right.

Revolution

For the smart ship revolution to become a reality a number of critical questions need to be answered

What technology is needed and how can it be best combined to allow a vessel to operate autonomously, miles from shore?

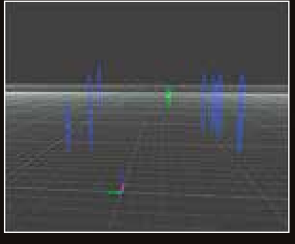
How can an autonomous vessel be made at least as safe as existing ships, what new risks will it face and how can they be mitigated?

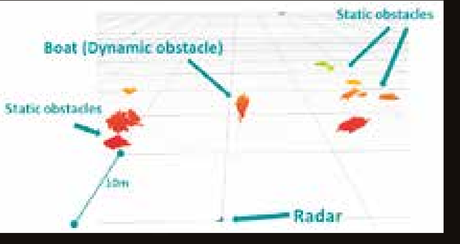
What will be the incentive for owners and operators to invest in autonomous vessels? Are autonomous ships legal and who is liable in the event of an accident?

The Rolls-Royce led, Advanced Autonomous Waterborne Applications Initiative (AAWA) will answer these questions. Funded by Tekes (Finnish Funding Agency for Technology and Innovation) the project brings together leading international maritime businesses and top Finnish universities (details of which can be found on the back page).
The project has examined the current state of the maritime industry and what can be learnt from other industries – from aviation's drones and driverless cars to the smartphone. It is now exploring the current state of understanding of the technological, safety, legal and economic aspects of remote and autonomous operation.
The results will inform the specification and preliminary designs for a proof of concept demonstrator by the end of 2017 and a remote controlled ship in commercial use by the end of the decade.

Technology.

A ship's ability to monitor its own health, establish and communicate what is around it and make decisions based on that information is vital to the development of autonomous operations





The need is to develop a set of electronic senses that inform an electronic brain and allow the vessel to navigate safely and avoid collisions. The AAWA project is exploring three areas:

1. Sensor fusion

Sensor technology is well developed and found in many forms of autonomous vehicle operation, most notably cars where competing developers have prioritised differing technologies.

The AAWA project has explored the contribution different sensor technologies make in providing a vessel or its remote operators with an accurate perspective on the vessel's surroundings at all times and in all conditions.

Looking at different types of radars, high definition visual cameras, thermal imaging and LIDAR the project has concluded fusing multiple sensor inputs provides the best results. The main question is not can this be done? It is how to combine these technologies in the most cost efficient way considering the challenges of the maritime environment.

Finding the optimum way to combine the different sensor technologies in a range of operating and climatic conditions will be the subject of a series of tests at sea in 2016.

2. Control algorithms

Navigation and collision avoidance will be particularly important for remote and autonomous ships, allowing them to decide what action to take in the light of sensory information received. The decision algorithms behind this need perfecting, as it requires an interpretation of maritime rules and regulations. This leads to interpretation challenges for the programmer.

The development of control algorithms for autonomous vessels will be a gradual and iterative process and subject to extensive testing and simulation.

3. Communication and connectivity

Autonomous vessels will still need human input from land, making connectivity between the ship and the crew crucial. Such communication will need to be bidirectional, accurate, scalable and supported by multiple systems – creating redundancy and minimising risk. Sufficient communication link capacity for ship sensor monitoring and remote control, when necessary, has to be guaranteed.

The project is exploring how to combine existing communication technologies in an optimum way for autonomous ship control. We have created a simulated autonomous ship control system which will be connected to a satellite communications link as well as land based systems. This will allow us to explore the behaviour of the complete system.

Safety and Security.

The operation of remote and autonomous ships will need to be at least as safe as existing vessels if they are to secure regulatory approval, the support of ship owners, operators, seafarers and wider public acceptance.

Remote and autonomous ships have potential to reduce human-based errors, but at the same time may modify some existing risks as well as create new types of risk. These circumstances and possible remedies will need to be explored.

The marine industry has some experience on systematic and comprehensive risk assessments. However, when new, emerging technology is involved, new knowledge, wider and deeper understanding of new and changed risk (with a variety of known and unknown hazards) is needed; guided by research to lead us to new approaches the project is exploring.

Cybersecurity will be critical to the safe and successful operation of remote and autonomous vessels. The project will identify and adapt current best practice from a range of industries for application in the marine environment.

The results will be used to make recommendations to regulators and to classification society and other AAWA Partners to support development work for creating the first set of standards for remote and unmanned vessel operation.

Legalities.

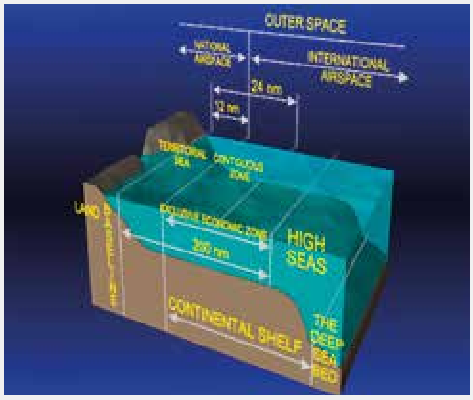
Where in the world an autonomous vessel is operating and whether it is remote controlled or autonomous will have a significant impact on the rules applied to it

A vessel's voyage is covered by a range of national, international and private legal frameworks. To further complicate matters, maritime law does not anticipate the development of remote or autonomous ships. This presents many ambiguities. For example, does a ship's master or crew necessarily have to be on board the ship?

For remote controlled and autonomous shipping to become a reality we need efforts at all regulatory levels. The legal challenges of constructing and operating a demonstration vessel at a national level need to be explored, while simultaneously considering appropriate rule changes at the IMO.

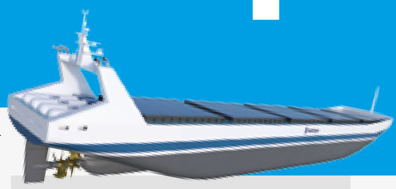
Questions of liability for autonomous ships are subject to national variations, but generally it seems that there is less need for regulatory change in this field. What needs to be explored, however, is to what extent other liability rules, such as product liability, would affect traditional rules of maritime liability and insurance in the field of autonomous shipping.

Legislation can be changed if there is a political will. The AAWA team plans to continue researching this element of the law, and to propose solutions, throughout the program. In the end, however, the necessary regulatory actions at national and international level need to be taken by governments.



ABOVE: legal frameworks to govern the operation of autonomous vessels will need to be set at national and international levels

Next steps...



2020	2025	2030	2035
Remotely operated local vessel			
Reduced crew with remote support and operation of certain functions	Remote controlled unmanned coastal vessel	Remote controlled unmanned ocean-going ship	Autonomous unmanned ocean-going ship

Unmanned ships will most likely start with local applications

The next two phases of AAWA utilise the findings from the first phase. Phase II includes:

• the development and testing of specific technological solutions for autonomous operations using both simulators as well as tests at sea across a variety of environmental conditions

• research to understand the changed and new risks (a variety of known and unknown hazards) presented by new and emerging technology, building on the marine industry's experience of systematic and comprehensive risk assessments, to develop new approaches;

• exploring the legal challenges of constructing and operating a demonstration vessel at a national level whilst simultaneously considering appropriate rule changes at the IMO. We need efforts at all regulatory levels for remote and autonomous shipping to become a reality;

• exploring stakeholder views of remote and autonomous shipping to establish cost and revenue models of autonomous operation for different ship types.

Rolls-Royce envisages a remotely operated local vessel being the first stage and in operation by 2020

The outcome of Phase II will be the technical, legal and safety specifications for a full-scale demonstrator.

Phase III aims to produce a full-scale commercial demonstrator, subject to funding.

Embedding smart ship equipment into an existing vessel is the first step along the Rolls-Royce roadmap to a fully autonomous intelligent ship. The company envisages a remotely operated local vessel being the first stage and in operation by 2020. By 2025 the company hopes to have a remotely operated autonomous vessel in international waters.

Five years later the company hopes that autonomous ocean-going vessels are a common sight on the ocean. As time goes on, such ships will become ever more intelligent and capable of more advanced autonomous operation.

Economics

Remote and autonomous ships have the potential to redefine the maritime industry and the roles of the players in it with implications for shipping companies, shipbuilders and maritime systems providers, as well as technology companies from other (especially the automotive) sectors.

Attractive Benefits

Remote and autonomous shipping is increasingly being explored by the maritime industry. Discussions with the industry have identified direct cost-reducing benefits and other indirect benefits.

Direct benefits are often listed at a vessel level:

- More efficient use of space in ship design
- More efficient use of crew and their skills
- More efficient use of fuel.

Indirect benefits occur at company and network levels in the shipping sector. Remote and autonomous shipping allows improved optimization of operations and processes. For example, optimizing processes or operations based on real-time data enables economies of scale at fleet and company level as well as reducing the likelihood of human errors, contributing both to safety and service quality. In terms of the shipping sector, autonomous shipping will recast the roles and reorganize the division of work.

The AAWA team sees that these indirect benefits are the key to gaining long-term competitive advantages from autonomous shipping. The industry now needs to start searching for assignments where an autonomous ship pays off exceptionally well.

Industry Disruption

A transition to remote-controlled and autonomous vessels will also have an impact on shipping, its resources and management. This transition will affect not only the technology-related operations, but will lead to changes in the way the shipping business operates. New kinds of capabilities will be required and some actors may find their roles changed. Global companies' logistics chains are likely to become more integrated and adaptable using the whole fleet in an optimum way.

Ongoing digitalization and autonomous technologies will create new services already along the way towards autonomous shipping. Some of these services will support existing market players and some will allow new players to enter the market. For example, in the automotive sector the self-driving car has been seen as an opportunity not only by traditional car manufacturers, but also by entrants from other technology sectors.

REDEFINING SHIPPING

Advanced Autonomous Waterborne Applications (AAWA) partners

Company	Input
Rolls-Royce	System Integration and Automation Control
Deltamarin	Ship Design
Inmarsat	Satellite Communications Technology
DNV GL	Classification and regulatory guidelines
NAPA	Software house providing solutions for ship design and operation

Universities	Input
Aalto / VTT (Technical Research Centre of Finland)	Safety and Security
Tampere University of Technology / University of Turku	Technology Research
University of Turku	Business Aspects
Åbo Akademi / University of Turku	Legal Aspects

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