Autonomous vessels – can the potential benefits be realised?

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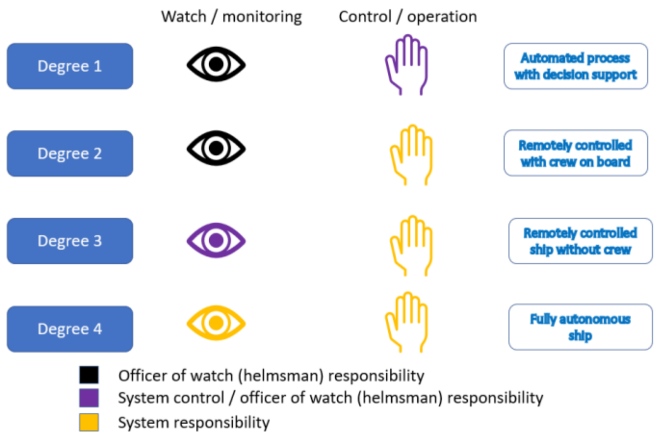
Between 80 and 90% of goods worldwide are quoted as being moved by ships as they can offer economic and efficient long-distance transport. Autonomous vessels provide potential advantages by reducing the impact on the environment, increasing safety, reducing costs, and addressing skills shortages. In 2019 it was estimated the market for autonomous shipping technologies was worth over $1Bn per year and growing. The challenges are to provide the necessary communications and associated regulatory regimes and obtain worldwide acceptance necessary for global operation. This paper considers what current solutions will support the realisation of autonomous vessels and challenges that will need to be addressed.

The maritime sector continues to pursue technical improvements to maintain safety improvements and ensure the maritime services can develop to meet changing operational requirements and deliver efficiency and environmental benefits, As such the IMO (International Maritime Organisation) has been updating the GMDSS (Global Maritime Distress and Safety System) instruments and the ITU addressing spectrum access and technical standards. In the case of Maritime Autonomous Surface Ships (MASS) the IMO has undertaken a regulatory scoping exercise to understand how existing instruments might apply and what changes may be necessary.

What is an autonomous vessel?

There are different levels of autonomy with degree 1 and 2 being feasible under the current ITU and IMO regulations.



Source: Avikus

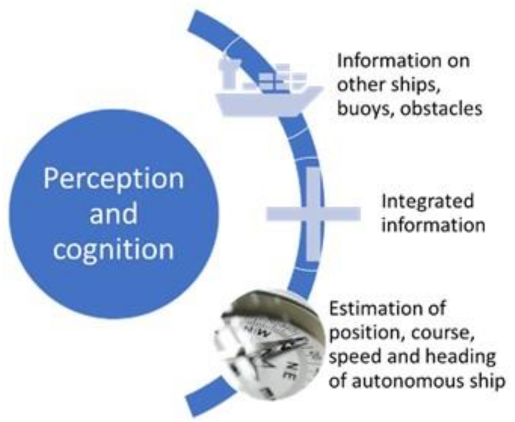
Degree 4 will involve operational decisions and monitoring, being made with no human intervention. Advantages of degree 4 autonomy are:

- There is no requirement for crew quarters or a bridge saving space that can be used for additional cargo,
- The routing / operation of the vessel is not constrained by the needs of crew so provides greater flexibility and opportunities to optimise routes and reduce operational costs as they arise,
- Can minimise emissions by altering course, speed etc. to take account of sea and optimum operation of the vessel.
- Removes the element of human error when making decision – in particular reducing risk of incidents at sea.
- Ideally suited for repetitive and dangerous tasks.

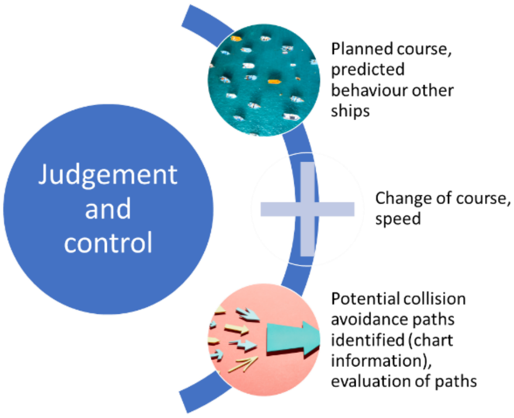
For some tasks it may be necessary to provide remote control of the vessel by a human located in another vessel or onshore at a control station. This might, for example, occur if the vessel responds to an emergency at sea.

Autonomous operation requirements

Autonomous operation is based on perception and cognition, and judgement and control as shown below.



The starting point is knowing the location and course of the autonomous ship and how this relates to other ships, buoys and obstacles (situational awareness). This data is provided by a number of sensors, systems etc. and integrated to provide a "picture" of the situation that may or may not require action by the autonomous vessel.

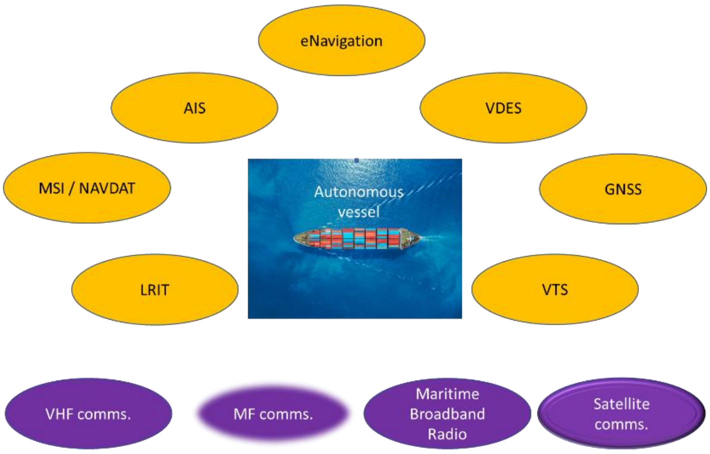


Without autonomy the bridge will determine the necessary action, for example change of course, based on the planned course, expected actions of other ships according to the Laws of the Sea and experience. An autonomous ship will undertake a similar judgement and identify potential collision paths, determine the most appropriate and take the necessary action.

What maritime radiocomunications services are needed?

To achieve the vision of autonomous vessels it will be necessary to put in place the necessary systems and protocols for ship to ship, ship to shore and shore to ship communications to provide for safety related data, accurate positioning, reporting / monitoring and control.

There are already existing and planned services that may be used many of which already have access to spectrum and are required under the GMDSS.



Automatic Identification System (AIS) that provides for information exchange between ships and ships to shore including the vessel identity, size, position, speed and course. This allows the relative position of ships and shore to be monitored and, for example, appropriate action taken to avoid collisions. AIS operates autonomously so there is no need for intervention to obtain the necessary data. It primarily uses two dedicated channels in the VHF band (161.975 MHz and 162.025 MHz) and has now been installed on the majority of commercial vessels.

eNavigation is intended "to meet present and future needs of shipping through harmonisation of marine navigation systems and supporting shore services". For example it will provide integration and presentation of information received in graphical displays

Long Range Tracking and Identification (LRIT) provides for "the global identification and tracking of ships to enhance security of shipping and for the purposes of safety and marine environment protection". Reports are transmitted at regular intervals, for example every 6 hours, from the ship to a shore Data Centre via a satellite link. LRIT is currently only available to Governments and national administrations.

Vessel Traffic Services (VTS) monitor vessels' movements based on AIS and Radar data and will allow the ship traffic on sea routes to be managed. VTS is established by harbour and port authorities to provide:

- Information service,
- Traffic organisation service, and
- Navigational assistance service.

VHF Data Exchange Systems (VDES) will support communications and positioning data but also new services such as e-navigation and facilitate autonomous shipping. In addition to AIS and AMS (application specific messages) it will include satellite communications (LEOs) to provide high speed two way data exchange on a global basis not just in coastal areas served by VHF frequencies.

Maritime Safety Information (MSI) / NAVDAT provides higher data throughput than NAVTEX and supports the digital broadcasting of navigation, safety and security related data between shore and ships. Messages sent include navigational and meteorological warnings, search and rescue, VTS traffic information, tides and currents and meteorological forecasts and local information. NAVDAT operates at 500 kHz (MF band) on a 10 kHz channel or in the HF bands.

Global Navigation Satellite Service (GNSS) provides the means of accurately locating the position of a ship to a high degree of precision such as needed for autonomous operation. There is a constellation of satellites that transmit signals providing positioning and timing signals to GNSS receivers that use the data to determine the receiver location. There are four core global satellite navigation systems; GPS (US system), GLONASS (Russian Federation), Beidou (China) and Gallileo (European Union).

Communications will be an essential part of realising autonomous vessels. VHF will play a key role for coastal voyages as will satellite, in particular for offshore (oceanic) voyages. MF communications are likely to be replaced by satellites over time.

Maritime Broadband Radio (MBR) operating in the 5.8 GHz range[1], although not part of GMDSS or other systems specified in the SOLAS convention, will be able to provide broadband communications links (around 10 Mbit/s) for ships and fixed installations engaged in offshore activities. MBR will enable the transmission of operational, navigational and administrative data, updating of chart data, messaging and live video from cameras for potential ranges greater than 45 kms by using highly dynamic beamforming and adaptive power control.

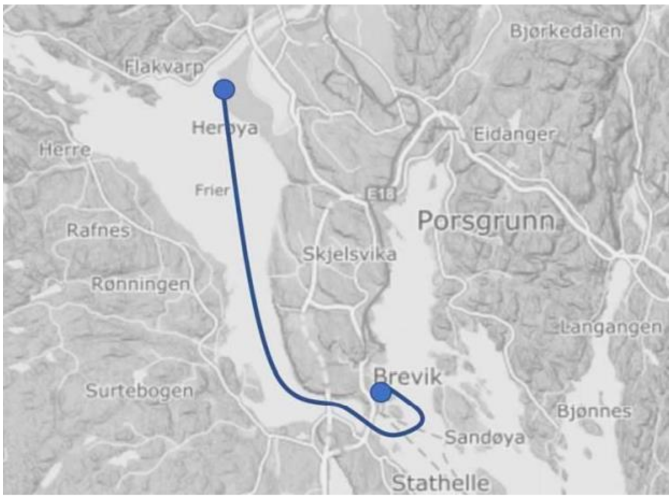
Developments and Trials

Trials of unmanned ship operation have already started and extensive testing will be essential to ensure autonomous vessels can meet the necessary safety, control, monitoring, management and operational requirements. In the EU operational guidelines for trials of MASS[2] have been developed. They are not mandatory but support trials "in designated testing environments (test areas and/or ship safety zone/s), in the interest of the protection of human life, maritime safety, security and the environment".

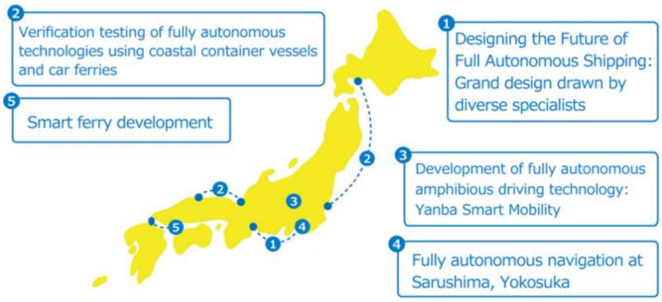
Examples of trials include:

In Norway Kongsberg Maritime is providing key enabling technologies, such as sensors and integration. for a fully electric and autonomous container ship – the YARA Birkeland. The ship has a small capacity (120 twenty foot containers) and has a detachable bridge that can be removed when ready for autonomous operation. It is equipped with radars, AIS, daylight camera detectors and pan tilt zoom systems with daylight camera and infrared sensor that provide situational awareness and maritime broadband radio and GSM for connectivity and communication. The ship operates between Heroya and Brevik with the route being monitored by the VTS in Brevik.

At the remote operation centre the following is undertaken voyage planning, emergency and exception handling, condition and operational monitoring and surveillance of the ship and surroundings.



Japan has been very active in the developing and testing of initiatives related to autonomous vessels as advantages are of particular relevance (e.g. shortage of crew due to aging population). For example MEGURI2040[3] is a fully autonomous ship navigation project launched by The Nippon Foundation in 2020. The figure below shows the five different projects for which new equipment, systems, technologies and frameworks were being developed in November 2021. The aim was to undertake tests by the end of March 2022.

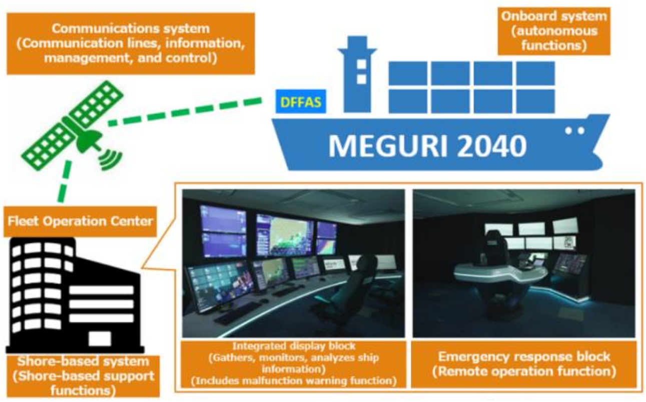


Source: Nippon Foundation

In one trial under MEGURI2040[4] a fully operational autonomous ship operated between Tokyo Bay and Ise Bay – a distance of

[1] See ETSI technical standard EN 303 276
[2] guidelines_for_safe_mass.pdf (europa.eu)
[3] The Nippon Foundation MEGURI2040 Fully Autonomous Ship Program | The Nippon Foundation (nippon-foundation.or.jp)
[4] NYK Group Companies Participate in Trial to Simulate the Actual Operation of Fully Autonomous Ship | NYK Line

790 kms. The system consisted of three primary components as shown below - these are navigation ship side, shore side support and communications and information exchange between ship and shore. There is also a fleet operations centre that tracks the ship and can take over control if necessary.



Source: NYK

Challenges

There are a number of challenges that need to be addressed before fully autonomous vessels can be realised:

- **Reliable communications** between ships and ship and shore that can support the necessary services and data capacity. Satellite communications will become increasingly important to provide the necessary data transmission in sea areas A3 and A4 where the VHF band cannot provide coverage and MF and HF bands may not be sufficiently reliable.
- **Redundancy** of communications solutions to ensure the necessary high level of availability and ability to override ship manoeuvres remotely in case of, for example, safety issues.
- **Security** of communications is an important consideration. Awareness of cyber security is currently low in the maritime community and existing navigation systems are vulnerable to attacks and ships can be ideal targets for extortionists as they can carry containers reaching values of several hundred million dollars. Already ships are increasingly reliant on exchange of information between ship and shore, and this opens up new opportunities for the attackers as well as special purpose data exchange systems used only by ships. GNSS receivers can be jammed, spoofing can lead to incorrect positions and corrupted data can lead to inappropriate avoidance manoeuvres and increased risk of collisions.
- Access to sufficient and appropriate **spectrum** as obtaining further spectrum for maritime services is difficult, as evidenced for other services. It may be necessary to refarm some older systems, introduce new channel plans rather than seeking further spectrum at future World Radio Conferences.
- Development of **open equipment standards** necessary for a global market and to ensure necessary testing undertaken to ensure safety standards are met.
- What are the implications of **non GMDSS** ships that are not autonomous?
- How to support **emergency situations** such as responding to vessels in distress.

Conclusions

It is clear that some degree of autonomy will be introduced over the coming years as systems and services are becoming available but the vision of fully autonomous vessels will require global adoption and changes to existing maritime regulations – there is currently no way of exempting human surveillance for vessels covered by GMDSS. It will be important to follow developments and address security and spectrum issues before they become significant challenges.