

**Marine Board
Transportation Research Board
of the National Academies.**

“Autonomous Ships, Vehicles, and Shipping”

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Scope of “Autonomous” needs clarification

Lloyd’s Register: Defines six levels of autonomy:

- Levels 1 to 3 on manned ships for decision support
- Levels 4 to 6 for unmanned remote/autonomous control

Shipboard departments and functions may operate under different levels of autonomy.

Two different regulatory authorities:

- National regulation for domestic trades.
- International regulation by IMO for international trade.
- Each area has different operating environments.
- Different technical and regulatory issues.

Questions

- No clear answers to the questions posed by the concept of large unmanned ships in long haul international trade.
- Projects underway that may lead to the operation of small unmanned ships under controlled conditions in national waters under national regulation.
- Can it be scaled up to large ocean going ships with complex navigation and engineering systems operating for extended periods of time in remote waters?
- Answers are speculation based on individual or corporate opinion often influenced by bias as to their interests or goals.

Difficult to believe an unmanned ship can provide an equal or higher level of safety than a conventional manned ship.

A remote operator will be limited in the situational awareness needed for appropriate decisions to only the information presented on displays.

The displays present filtered and processed information provided by sensors and electronic equipment provided through a communication link. It is a complex interconnected and integrated system subject to multiple anomalies and errors.

Validating the accuracy of information on displays on a manned ship is by checking the presentation on the display screens against real world observation. A remote operator lacks this primary means of validating the accuracy of the information displayed.

Interaction between manned and unmanned ships

Collision regulations (COLREGS) only govern a two ship situation with standardized rules when in sight of each other.

COLREGS did not contemplate unmanned ships and will need to be revised. What the obligations and responsibilities will be between manned and unmanned ships is unknown.

With multiple ships or confined waters restricting maneuvering there is a need for communications and mutual agreement between ships to manage traffic.

Ships operating in high traffic areas need to deal with a dynamic marine environment with unexpected events. Communication between ships is critical.

Regulatory issues

National level - each nation may adopt laws or regulations for their territorial waters according to their national interests and acceptance of risk. As navigable waters are under Federal jurisdiction it is assumed that an Act of Congress would be needed to enable the USCG to promulgate regulations.

International level – IMO has a proposal on its agenda to adopt a Work Plan to scope needed revisions to regulations. It is anticipated it will be a 8 to 10 year project with an unknown outcome.

We will still need bilateral or multilateral agreements between flag States and port States to permit foreign flag ships in international trade to operation in territorial waters

Port Practices

We don't believe autonomous ships will alter U.S. port practices in the foreseeable future.

It is expected that if, or when, unmanned ships come into service they will take onboard navigating and mooring personnel for arriving and departing ports.

But, given the exponential growth of technology and its applications it is problematic to foresee much beyond twenty years.

Security

- Ship systems are now protected from cyber threats by isolation from external access.
- Primary concern is cyber security of the remote control communication link which has access to the command and control systems.
- Hacking could lead to malicious interference with the operation of the systems, or
- The more serious threat of terrorist gaining control of the ship to use it as a destructive weapon.

Traffic management

- VTS does not directly control the movement of ships.
- VTS provides information to persons onboard controlling the ship.
- Traffic management is a responsibility of the persons onboard.
- In high traffic areas it is essentially a complex self organizing system dependent upon communications between the ships.
- Problematic as to how an unmanned ship remotely controlled, possibly by an operator in a foreign Shore Control Center, could participate in such a system.

Human element challenges

- The challenge will be determining the appropriate combination of technology and human involvement to provide safe, efficient and reliable shipping.
- Technology is best at monitoring systems and managing low level repetitive operations in a controlled environment.
- Humans are best at interpreting complex situations and higher level decisions requiring experience, judgement and innovation in a dynamic environment that is complex and unpredictable.
- A system that has the humans monitoring the equipment and technology making the decisions has the appropriate roles reversed.

Human element challenges

- The remote operators will not have the same situational awareness of the weather and sea state and its impact on the ship as an onboard crew.
- Nor will they have the close familiarity with all ship board systems operating at different levels of autonomy as determined by the ship owner's business plan.
- They will also lack the same level of motivation as an onboard crew that has the ship under their feet as both a home and a means of survival, rather than a remote blip on a screen.

Human element challenges

- Information overload is even now a problem with manned ships requiring the setting of priorities to prevent distractions from a focus on essential information.
- On a manned ship the real world is always there to bring you back to reality from the blizzard of information on the display screens. That option will not be available to an operator limited to remotely monitoring a ship's systems.
- Humans are not good at monitoring displays for long periods. It can cause complacency and lack of engagement with developing situations. Leading to “shock and startle” when the unexpected occurs.

Major Issues

The issues which have been identified include:

- The degree of redundancy and robustness in technical, navigational and engineering systems;
- The quality of the software and algorithms;
- Cyber security and the reliability of the communications system;
- The risks in mixed manned and unmanned traffic;

Major Issues

- The situation awareness of the remote operator limited to data from sensors.
- The reliability of the sensors and systems in harsh environments.
- System failure in remote areas.
- Security and environment issues and concerns.

Major Issues

- Responsibility and Liability issues;
- Training and competency of the shore-based remote control personnel;
- Regulatory constraints under IMO and UNCLOS and the obligations of flag States and ships;
- The cost and interaction with mooring personnel and port services now performed by ships crew;

Major issues

- The cost of delays and having maintenance and minor repairs done by high wage labor while in port, rather than by low wage ships crew;
- The cost of infrastructure and personnel for shore based remote control and monitoring systems.
- Whether Shore Control Centers are private or governmental organizations, and authority of Shore Control Centers.