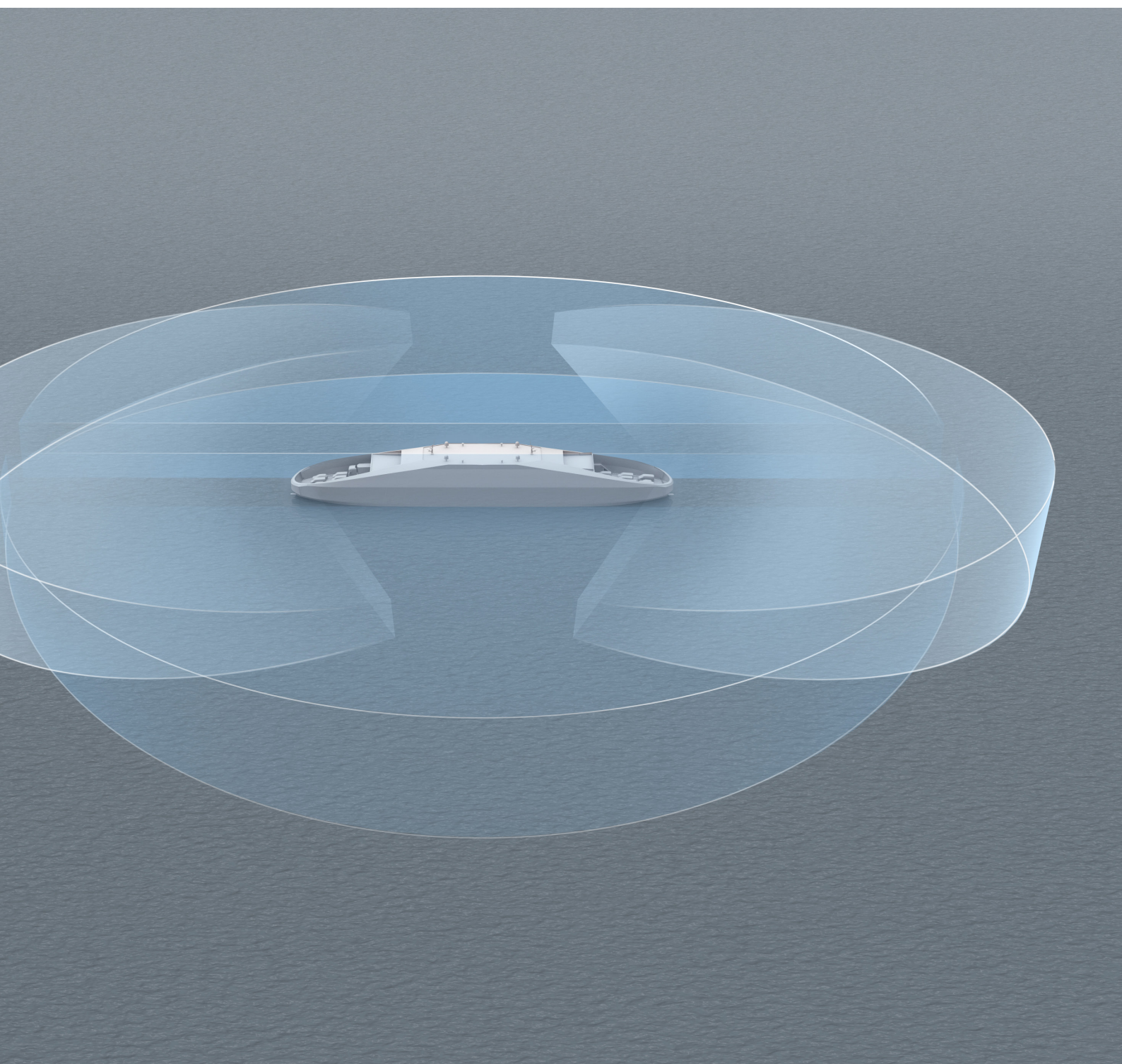

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B0 – a conditionally and periodically unmanned bridge

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“It is our intent to provide solutions to the current and near future fleet where technology is used alongside competent ship’s officers”

Abstract

The recent development in sensor technology, data analytics and computing power enables to increase the level of automation in ship navigation, steering and control. As a basic definition an autonomous vessel is not necessary unmanned but an unmanned vessel is, by default, autonomous to a high degree.

It is also important to make a distinct and clear difference between the technical readiness and capability of the vessel versus the status of usage of the vessel at any given time. In certain conditions, the crew onboard may be given the opportunity to change vessel operation from crew to machine operated.

This paper presents a concept of B0 – conditionally and periodically unmanned bridge – which enables more efficient utilization of vessel crew, reduction in fatigue and increases safety by enabling an unmanned bridge provided that certain conditions are met. It also reviews the main tasks of the crew at the bridge and elaborates the benefits of B0 concept.

A review of the regulatory background that will either require amendment or a demonstrated equivalent or better status with the appropriate use of technology to enable B0 operations. The technology requirements and implications are discussed in the last section of the paper.



The officer of the watch

A Deck Officer assigned with the duties of watch keeping and navigation on a ship's bridge is known as the Officer of the Watch (OOW). While keeping a watch on the bridge he/she is the representative of the ship's master and has the total responsibility of safe and smooth navigation of the ship. The captain of the vessel when on bridge and has assumed "the conn" has the status of OOW in this context.

The OOW is also in charge of the bridge team, which is there to support him or her in the navigation process. The OOW is also responsible to ensure that the ship complies with COLREGS and is operated with the utmost safety under all conditions. The main duties of the OOW can very broadly be defined as: navigation, watch keeping and radio watch.

The examples below comprise a generalized approach to the duties of the OOW on bridge. Key rules could be grouped into the following:

- check navigational equipment in use at regular interval of time;
- prepare, execute and monitor a safe passage plan;
- to ask for support whenever required;
- contact the master when need arise; and,
- not leave the bridge unattended during the assigned watch.

In more details the OOW will routinely perform the following actions:

The OOW must check the position for personal situational awareness and verifying (and reverifying) to ensure the best possible "mental picture" of the operation is formed. The previous positions affect the future position and therefore, in order to maintain maximum accuracy of the plot, is by necessity an iterative process. When starting or finishing the watch it is crucial that the communication when changing watches cover all relevant information. This is due to the fact that navigation of the vessel is by nature dynamic and all conditions at any given time affect the ship.

Even in the 21st Century, following the working and the reliability of the ship's compasses is still required as is the operation of the depth sounder. This is done in order to have as precise a window within which the errors can be made good, particularly in poorly charted areas such as the Antarctic. Should a gyrocompass fail, GNSS¹ will in most cases provide location data but will affect the autopilot if no other redundant systems are available.

Rule 5 of COLREGS² puts special emphasis on lookout and states that "**Every vessel shall at all times maintain a proper lookout by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.**" This is further emphasized when the vessel operates in restricted visibility (Rule 19 of COLREGS) wherein the role of the lookout man is paramount.

The radio watch (GMDSS³) watch is crucial to the safety of all and must be maintained on the stipulated frequencies as per regulations. Whether or not information received affects the ship immediately is not the primary task but to determine if it affects the ship.

When applicable and the OOW should ensure other members of the bridge team are alert and awake at all times. During times when the Engine Control Room is in unmanned operation, the OOW may also send another bridge team member to inspect the machinery rooms to ensure that all is well.

¹ Global Navigation Satellite System. A navigational system that utilizes Satellites to determine the ship's position. The American GPS, or Global Positioning System, is one system available to GNSS but other systems such as GLONASS from Russia, Galileo from the EU, the Chinese BeiDou are also in use. More regional systems are coming on line.

² International Maritime Organization, Convention on the International Regulations for Preventing Collisions at Sea, 1972

³ Global Maritime Distress and Safety System. Onboard, this generally includes Emergency position-indicating radio beacons (EPIRBs), NAVTEX, Satellite Communications, High Frequency Radio as well as Search and Rescue Transponders.

B0 Benefits

Although the number of crew, especially in oceangoing cargo vessels has decreased during the last decades, at least one person on the bridge is required regardless of the conditions. While this is very much justified in situations where the ship is approaching other ships or areas where more traffic is anticipated, crossing an ocean in very good and clear conditions can lead to a situation where the OOW is on the bridge for the entire work shift without touching any equipment or doing anything but looking at radar screens and outside the window making sure that there is nothing out there. This can cause mental fatigue with an associated loss of alertness and can lead to a situation where a human reacts too late to an event which could have been anticipated significantly earlier if the OOW would have been more alert during the situation.

Enabling a better quality of rest during good conditions when there is no need for major navigation actions has an impact on crew alertness and decreased fatigue when approaching coastal areas or routes which have traffic. The B0 concept enables the crew to use the time during the work shift more freely to tasks which will keep them more alert and increase the wellbeing at work. Moreover, at least for the majority of the crew, the working hours during the ocean crossing voyage could be closer to normal office hours. Together, this will most likely increase the safety of navigation in areas where manned bridges would be required.

We believe that when alerted of an upcoming navigational danger, the bridge team will be more alert than when the situation is slowly building up over time.

The regulatory framework

In general, the legal instruments applying to the maritime industry are a range of laws and conventions, both international and national, that govern the ships and their related operations. The majority of maritime conventions are issued by a specialized UN agency located in London called the International Maritime Organization. To provide more detailed application of the conventions, the IMO issues conventions such as SOLAS, STCW, MARPOL. The IMO has no direct enforcement powers, rather this is typically enforced by authorities in the member countries following local ratification of the conventions. The operations on the practical level are surveyed by specialized maritime classification agencies with the mandate of IMO and flag states. Currently the approved classification societies are members of IACS and globally recognized as guardians of the rules.

High levels of autonomy already defined today such as conditionally unmanned machinery spaces are typically not applied to vessels carrying passengers. We see that this will probably also be the case for periodically unmanned bridges. However, the technology used will greatly help any vessel operating with any levels of autonomy and manning.

The possibility to safely operate the vessel without direct, continuous and active supervision of the master, or the person who has the delegated responsibility, will likely require a fundamental revision of the legal system. In the first stages the change will probably affect some aspects of the construction of the bridge and the operations in open waters with clearly defined requirements for conditions to apply.

Jurisdiction

One of the central rules to understand is the jurisdiction of the states' rights and obligations to regulate the maritime industry. The main body of rules is the UN convention from 1982 on the Law of the Seas (UNCLOS).

Bridge visibility

The International Convention for the Safety of Life at Sea (SOLAS) Ch. 5, req. 22, defines the

required construction of the bridge. The most important aspect is the visibility outside the windows of the bridge. From the main conning position, the vessel must have 225 degrees visibility with a view of the sea surface not "obscured by more than two ship lengths, or 500 m, whichever is the less, forward of the bow to 10° on either side under all conditions of draught, trim and deck cargo. When going towards unmanned bridges, these requirements need to be met by a virtual line of sight.

Competence in watchkeeping

STCW¹ defines conditions for the required crew on bridge and in what conditions the status is accepted. The principles of the typical crew on the bridge and the operating conditions are described below.

Bridge status	Required crew on bridge	Conditions
B3	OOW, lookout, helmsman	Special conditions
B2	Officer of the watch, lookout	Night, good conditions
B1	Officer of the watch	Day, good conditions

The B0 concept outlines the general conditions on when it could be possible to enable transferring the monitoring responsibility from the OOW to a machine for a certain period of time.

In order to maintain the command hierarchy, B0 needs to be linked in engine room status. OOW/Captain is legally responsible of the ship and in case Unmanned Engine Control Room status is lost, he/she needs to do the decision when it is safe to revert back to E0 and B0. Therefore, E0 or UMS² notation is linked to B0. When the engine room has E0 status, there needs to be alarm system which provides alarms for bridge and chief engineer. As part of the risk management of B0, smart filtration of alarms with regards to propulsion or escalation of unanswered alarms, will need to apply.

¹ International Maritime Organization, International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 2010

² Unmanned Machinery Space. A notation where systems are in place to allow the ship to operate without engineering personnel on 24 hour shifts in the Engine Control Room. Used interchangeably with E0.

Conditions for B0

General conditions for B0

The general conditions for B0 are described in the table below. The principle is that the weather conditions are good, visibility clear, technical status should correspond to E0/ UMS, no fixed objects visible in the forward sector nor any vessels visible with a CPA and TCPA ¹ below certain values. In addition, there should be no radio traffic. If these conditions apply, the OOW work in B1 situations nowadays is to monitor the radar, look outside the window and make sure that nothing is to be done. It is proposed that during these situations the OOW could leave the bridge unmanned.

Condition	Definition
Maximum continuous duration of B0 status	The maximum continuous duration of B0 status is T_{B0} hours after which an OOW needs to go to the bridge and verify the conditions of the B0.
E0 status (technical readiness)	The engine room status needs to technically conform to E0. This does not mean that there cannot be crew in the engine room, but conditions for the E0 engine room status need to be fulfilled in order to be able to have B0 status for the bridge.
Open sea	No fixed objects or shallow water in a sector ($\pm\alpha_{B0}$ degree) in direction of heading on radar or in the voyage plan within R_{B0} NM
Deep waters	Deep open waters with no known navigational hazards. Depth criteria to be linked to the draught of the ship.
Distance to other vessels	TCPA for all other vessels $>$ $TCPA_{B0}$ h with CPA $>$ CPA_{B0} NM
Distance to any vessel or object on radar	No other vessels or fixed objects should be anywhere around the vessel within the minimum range of B0 R_{min} .
Other vessels in sight	No other vessels in sight with visual observation
Weather conditions	Good visibility (visibility range with respect to speed), low sea state, no ice

Traffic situation	Clear of traffic in the forward sectors (45 degrees to port & starboard of planned track)
Special operating area	B0 cannot be entered in known high traffic areas, VTS areas or any areas which also prevent E0 operation.
Radio monitoring	Radio monitoring needs to be arranged by having a solution that can repeat / stream the radio communication remotely to the crew and all radio traffic needs to be provided for the crew as recorded messages which the crew need to confirm that they have listened within predefined time either by having a mobile device or going physically to the bridge to confirm the receipt of messages.
Monitoring equipment status	The monitoring and diagnostic equipment should be on and functioning properly.
Navigation equipment status	The navigation equipment and the backup equipment should be functioning properly.
Automatic Identification System monitoring	AIS system needs to be on and there needs to be alarm based on AIS data if other vessels enter to the range when B0 status cannot be maintained anymore.
OOW call alarm	There needs to be a dedicated OOW alarm that will alert the designated OOW or is sounded in public rooms, bridge, cargo offices and appropriate cabins.
Deadman alarm	Should the deadman alarm not be reset within a predefined time, the call should be escalated to the Captain and Chief Engineer.

Distance and time considerations

The conditions for B0 are heavily dependent on range with respect to distance and time. How far are the other ships? When considering the B0 status, one needs to take into account not only the speed of the own vessel but the others as well.

¹ Closest Point of Approach & Time to Closest Point of Approach. A calculation to evaluate the risk of collision between a ship and another object, where the distance between the two will be at its minimum and when that will be.

In general, radar range can be considered to be up to 96 nautical miles. A target at this range will be reached in six hours and 24 minutes if the vessel is sailing at 15 knots.

However, if the other vessel is also sailing at 15 knots, the time when the vessels meet naturally be half the time (three hours and 12 minutes).

There are several ways to define the criteria. For example, one can use fixed values for each criterion or those can be made dynamic to be based on vessel S_{vessel} , maximum allowed reaction time T_{max} . The maneuvering capabilities of the vessels can be factored in also.

The table below presents proposed values for the B0 conditions and explains the reasoning behind those values.

Criterion	Proposed values	Reasoning
T_{max}	1 h	Getting to the bridge, max 15 min and max 45 min to adjust possible darkness and to assess the situation properly
R_{max}	96 NM	Maximum range of the radar (if radar onboard has smaller maximum range, that should be used instead)
R_{min}	10 NM	Range inside which there cannot be any other objects or vessels on radar, on map or other sensing systems, and there cannot be shallow water anywhere within this range.
T_{B0}	$R_{\text{max}} / S_{\text{vessel}} - T_{\text{max}}$ h	The higher the vessel speed is, the smaller the maximum continuous duration of B0 status can be. It is proposed that the bridge can be left unmanned to time that will give minimum one hour time before the vessel has reached the boundary of the visible range of the radar when the B0 status started. If the vessel speed is e.g. 15 KN, maximum continuous duration of B0 status, $T_{\text{B0}} = 96 / 15 - 1 = 5 \text{ h } 24 \text{ min}$. With speed 10 KN, the value becomes $T_{\text{B0}} = 96 / 10 - 1 = 8 \text{ h } 36 \text{ min}$

TCPA	1 h	Depending on the combined vessel speeds
TCPA_{B0}	$T_{\text{max}} + \text{TCPA}$	The maximum allowed time to get onboard and adjust to the possible darkness plus the limit to the time of the closest point of approach.
CPA_{B0}	1 NM	Has to be adjusted to the speed in relation to time to react
$\pm\alpha_{\text{B0}}$	$\pm 45^\circ$	No traffic within the forward sectors of the planned track.
R_{B0}	96 NM	Time to close the distance at 15 knots is similar to that of a normal watch. Allows for appropriate time to gain situational awareness.

Using B0

When entering the B0 status, the OOW needs to perform procedures to make sure that the navigation equipment are ok, monitoring systems are ok and alarm systems to call OOW automatically to the bridge are ok. Therefore, at a minimum, the following tests and activities need to be performed:

- Test procedures for navigation equipment
- Checklist of critical operations and functionalities
- Check the alarms and related internal ship-board connectivity
- Check that B0 conditions hold and there are no vessels or fixed objects in radar or in the voyage plan within the B0 range R_{B0}
- Record the event, checklist and conditions of entering to the B0 status on the ship logbook

Alarm hierarchy

In case there is an alarm that will cause loss of E0 status, an engineer and OOW will be alerted to return to their respective places of duty. That will cause loss of B0 status. The principle is that an engine room alarm which will cause loss of E0 status, will always cause a need for the OOW to go to the bridge. Depending on the severity of the alarm, the captain might be called as well. Therefore, the alarm hierarchy related to engine room alarms is as follows:

E0 status alarm -> engineer, OOW -> Captain

In case there is an alarm which causes loss of B0 status, OOW will be commanded on duty. That will not cause loss of E0 status by default. Therefore the alarm hierarchy related to bridge alarms is as follows:

B0 status alarm -> OOW -> Captain

When the B0 status is deactivated due to a B0 status alarm, the OOW will decide if there is a need to call the captain to the bridge and possibly the duty engineer to the engine room. However, in case E0 status remains untouched, the B0 status alarm will not automatically cause loss of E0 status.

Requirements for technology

In order to maintain the B0 status, the B0 conditions need to be monitored by means of technology. There should be at least two independent means for all measurement and situational awareness technologies.

Monitoring and diagnostics of all navigation sensors and equipment

In order to leave the bridge unmanned for a period of time, monitoring and diagnostic equipment for critical equipment such as navigation equipment is required. Currently this is an OOW task, but in a B0 situation, there needs to be a system which can monitor the status of the navigation equipment, such as the error of gyrocompass, radar performance or stability of the GNSS.

Provide equivalency to lookout by means of technology

Regulations require people to look out the window due to the fact that for safe operation, one cannot rely only radar. The basis for the B0 bridge is to provide continuous visibility from the bridge with cameras and possibly other sensors which offer equivalent field of view and range as a human can have with a bare eye. A requirement to in all situations to have two independent sources of information to support the machine line of sight maintaining the B0 watch should be stated. This technology could also alleviate the challenges of night time operations. Additional technologies with Infrared technology (cameras and lights) This can be achieved by either having night cameras operating on IR wavelengths as well as appropriate IR lights, or recognizing other traffic based on lights and normal daytime cameras.

In case there is no human operator performing the lookout function, in order to provide equivalency for the SOLAS Ch. 5, req. 2, there needs to be automated target identification and classification. ABB is currently deploying technology that is already combining camera and sensor data supplying an algorithm which performs classification of the targets, currently alongside bridge staff.

A system that recognizes and identifies land from camera data and continuously monitors that from the video stream. If land is seen in the horizon in the forward sector, the B0 condition needs to be terminated.

Arrangement of audio microphones at the bridge and outside the vessel to provide means to sense audible signals, as well as an analysis solution that is able to recognize exceptional noise from the environment.

Clear sectors

In order to keep the B0 status, one needs to monitor that there are no other vessels or any fixed obstacles within R_{B0} NM on the voyage plan or the radar, no other vessels of which TCPA and CPA values are above the conditions of B0. In addition, there is a minimum safety distance inside which there should be nothing on any sensor system or on the nautical chart. There needs to be at least two independent means of monitoring of the B0 range to make sure that there is no other traffic which would end the B0 status.

This requirement could be met by monitoring the radar to ensure CPA & TCPA values remain above B0 prerequisites, potential AIS analysis and assessment of the electronic charts. Together these data sources currently inform the OOW and bridge team of their real time situation.

Automatic recording & confirmation of reception of radio messages

Usage of machine learning to manage situations where no radio watch is kept could stream the critical messages directly to the OOW with a confirmation and acknowledgment via the bridge or a mobile device.

Portable, mobile or remote monitoring onboard

The OOW needs to have immediate access to the navigation, radar, camera and other relevant sensor data during B0 status, in at least a similar method as current E0 or UMS systems inform the Engineers today of the alarm that is triggered.

Conclusions

We are in no doubt that this is a complex concept from both regulatory and cultural aspects.

However, the industry is now at a point where (according to BIMCO) the pipeline of competent seafarers is significantly smaller, the technology is maturing rapidly yet safety of our crews, cargo and ships still remains paramount as it has for millennia. It is our intent to provide solutions to the current and near future fleet where technology is used alongside competent ship's officers in order to improve decision making with a timely assessment.

It is the nuances of ship operation that still requires human crews today, even as we see an increasing number of ships being more Electric, more Digital and more Connected than ever before.



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