

ABS  
ADVISORY ON  
AUTONOMOUS  
FUNCTIONALITY





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# FOREWORD

The development of autonomous functionality in the marine and offshore industry has gathered pace in recent times.

The objective of this Advisory is to shed light on the journey to autonomy, bring to attention major considerations affecting autonomous development and to provide a framework and structured process to guide stakeholders in the application of autonomous functionality.

This Advisory is organized in the following manner:

**Section 1 – Introduction** provides an overview of the drivers and challenges of autonomous development.

**Section 2 – Automation vs Autonomy** provides the background to the term “autonomous” and details the progression of the categorization of functions from smart to semi-autonomous and autonomous.

**Section 3 –Autonomous Framework** introduces the Smart to Autonomous framework which is a goal-based framework to guide the implementation of autonomous and remotely-controlled functions.

**Section 4 – Concept of Operations** details the importance of the development of a Concept of Operations document.

**Section 5 – Remote Control and Operations Centers** details the role and importance of Remote Control and Operations Centers which will play a critical human-in-the-loop role for autonomous operations.

**Section 6 – Flag State and Port State Engagement** provides a brief on the roles of the Flag States and Port States and the importance of engaging them in autonomous development projects.

**Section 7 – IMO MASS Regulatory Scoping Exercise** provides a brief on the Maritime Autonomous Surface Ships (MASS) Regulatory Scoping Exercise on-going at the International Maritime Organization (IMO).

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## SECTION 1 - INTRODUCTION

The desire and drive to improve operations and automate the work performed onboard ships and offshore units is not new. With the rapid technological advancement which has taken place in the recent decades, the autonomous and remote functionality to aid, assist, or augment crew capabilities is being tested and evaluated in multiple marine and offshore sectors.

Autonomous technology is not a singular technology. It is a result of the convergence in the advancement of various technologies such as:

- improved sensors and imaging technology,
- improved connectivity within the vessel and from the vessel to shore,
- improvement in data management and analytics, and
- development of machine learning and artificial intelligence tools

While there is growing interest in autonomous technology in the marine and offshore sector, it is currently being used in multiple applications in naval vessels and underwater vehicles.

Multiple maritime countries have identified autonomous shipping as a game changer and disruptor with potential to deliver value to their economies as maritime and offshore transitions into a new digitalized and sustainable future. These countries are investing in Research and Development (R&D) in this sector, setting aside sea areas for trials and test-bedding activities and are actively engaging the industry to craft the future framework for the incorporation of autonomous functionality for vessel operations. They see the following as drivers which encourage the focus in development of autonomous functionality:

- **Enhanced safety:**

Functions incorporating both smart and autonomous functionality are being designed to augment and assist the operators in performing their tasks and thus have the potential to reduce or eliminate human error in operations. For simple and routine tasks, safety can be enhanced by having these tasks automated.

- **To retain and attract talent into the maritime workforce:** [1] [2]

A skilled and dynamic workforce is key to the development of a thriving maritime sector. Unfortunately, with a changing workforce, the maritime and offshore industry is facing challenges in attracting sufficient talent. This problem is compounded in some developed economies that face the problem of an aging population.

Autonomous and remote technology, which provides the possibility of reduced crewing and the locating of personnel onshore allowing them to monitor and control multiple assets would therefore look to be an attractive value proposition.

- **Economics:**

The implementation of autonomous technology and functions brings about the possibility of reduced crew numbers. For fully autonomous vessels or offshore units, operations may be able to be carried out without any presence of humans onboard. This will result in reduction of operational expenses.

However, this may be somewhat offset by onshore expenses for operation centers or portside logistic and maintenance activities.

- **Design Improvement:**

Autonomous functionality has the potential to bring about a paradigm change in the design of ships and offshore units. A portion of space onboard ships and offshore units today are designated for crew accommodation and habitability support systems. With the reduction of accommodation facilities and systems, it will optimize ship and offshore unit designs. As a result, more space and resources can be allocated for the primary objective of the ship or offshore unit.



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Nonetheless, the road to autonomy will not be straightforward and is lined with challenges. This journey mirrors the challenges faced by other industries when faced with disruptions brought by digitalization.

The current discourse on autonomous functionality will be linked with unmanned operations. However, this is a misconception. It is incorrect to equate an autonomous ship or offshore unit with an unmanned ship or offshore unit. As this document will explain, autonomy focuses on the functions which enable the operations of a marine or offshore unit. An unmanned ship will definitely require autonomous or remotely controlled features. However, an autonomous ship or offshore unit need not necessarily be unmanned.

The development of autonomous functions and vessels does not preclude the presence of humans onboard vessels. There is the possibility of reduced manning onboard vessels. Nonetheless, apart from the offshore sectors and some specialized vessels, the industry is not contemplating the total absence of humans onboard vessels. Regardless of manning levels, human/machine interaction should be evaluated for all autonomous systems to address safety concerns even if only temporarily manned.

The challenges in allowing autonomous functionality in operations are multi-dimensional. They include:

- **International rules and regulations:** [3]

The United Nations Convention on the Law of the Sea (UNCLOS) and IMO instruments revolve around the premise that vessels are operated by humans onboard. Presently, the key instruments related to the design, construction and operation of vessels for example SOLAS, MARPOL, COLREG, STCW and ISM Code would appear to disallow the operations of autonomous vessels.

The potential for fully autonomous vessels where there will be no human or reduced human presence onboard ships challenges the core premise with which IMO instruments are built.

- **Maritime legal regime:** [4]

Similarly, the maritime legal regime is constructed around the premise that vessels are operated by humans onboard. The departure from this construct will have an impact on seaworthiness obligations, safe manning levels, the duties of the shipmaster, and compulsory pilotage.

- **Readiness of the maritime eco-system:**

Introduction of autonomous vessels would disrupt the well-established interaction and interfaces between vessels and coastal states. This would be more acute in busy port waters.

- **Marine Insurance:**

Majority of the claims today are caused by human errors which is the basis of setting requirements by P&I Clubs for their members. Autonomous systems and associated liability will need to be determined.

- **Maritime operations chain:**

The onset of autonomous development will affect the entire chain in maritime operations and will require the industry to have a detailed re-look into the following:

- Design of vessel or unit
- Operational procedures
- Software and equipment reliability
- “Rules of the Road”
- Responsibilities of the various actors in the chain
- Interactions between port and vessel
- Logistical support
- Response to distress at sea

- **Societal acceptance:** [5]

Similar to discussions on autonomous cars or aircraft, the adoption of autonomous vessels will also depend largely on society’s acceptance and willingness to utilize them. Would society be comfortable with placing their trust in ships which are not directly controlled or at minimum whose autonomous functions are overseen by humans not physically present onboard the vessel?

The reduction or even possible elimination of the presence of crew onboard autonomous vessels will also invite questions regarding loss of jobs and the future of the seafaring workforce. If we transition to an autonomous future, would this herald the loss of seafaring skills and how would this impact the safety of shipping in the future? These are all difficult questions.

The development of autonomous functionality presents the industry with a unique opportunity for advancement. Historically, developments in the industry have taken place in a stepwise manner and at times as a knee-jerk reaction to safety incidents.

Autonomous development will affect cross-functional systems and requires in-depth examination into operational procedures and its effect on the wider ecosystem. This will require the industry to examine its operating procedures and philosophy.

In addition, the increased reliance on cyber physical systems will lead to a paradigm shift in the industry’s approach to safety and expand its focus beyond the traditional hull, mechanical and electrical areas. In order to understand the reliability and robustness of cyber physical systems, this will require Verification and Validation (V&V) techniques beyond the traditional approaches.

Through this, the vision is that the industry will be better able to utilize and apply advanced technology safely and emerge as one with increased safety, efficiency and sustainability.

## SECTION 2 - AUTOMATION VS AUTONOMY

It is important to define and categorize the different applications for autonomy versus the traditional application of automation in the marine and offshore industry. Automation systems including control, alarm and monitoring have been applied in the industry for decades. The industry has mature and well-established requirements related to electrical, hydraulic, computer-based systems and equipment for control, monitoring, alarm and safety systems.

Automation is the automatic control and operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labor. These are normally routine or repetitious tasks under predefined conditions. It is important to also define “automatic control” as the means to control via predetermined orders without action by the operator. These systems are prevalent in the marine and offshore industry. Examples include automatic synchronization function on electrical switchboards and the automatic starting/stopping function of standby pumps.

Autonomy is different in that it requires a quality of self-governance and freedom from external control or influence. Rather than only predefined actions, the system can choose from the best or most appropriate option and not just follow a predetermined algorithm or script.

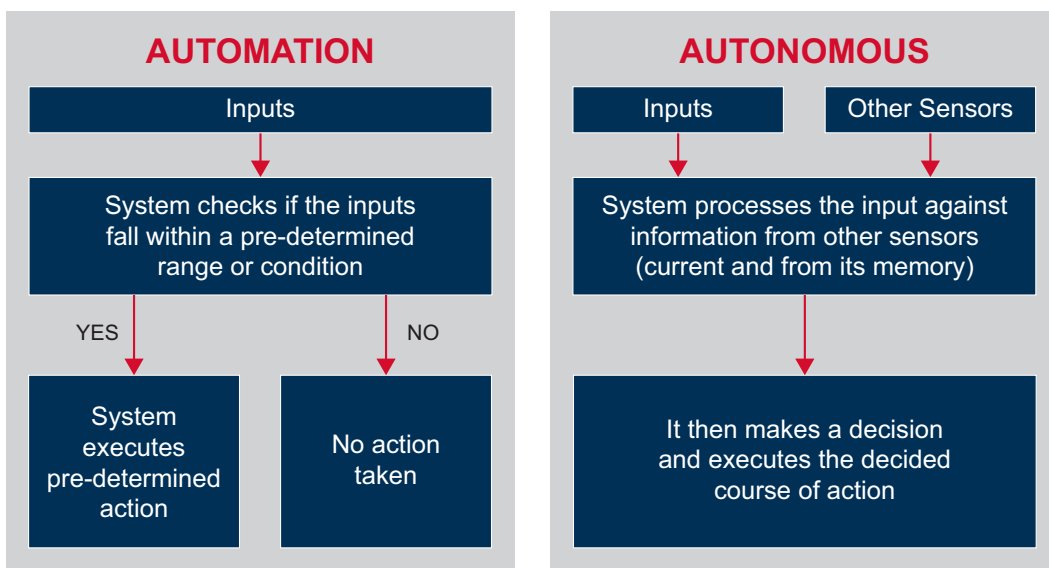


Figure 1 - Automation vs. Autonomous

Automated systems play a key role in future autonomous functionality. While operating within a predetermined scope, advanced automated systems can have the appearance of autonomy.

The autonomous decision-making and action determination will be required when the automation system has exceeded its predefined scope.

### OPERATIONAL DECISION LOOP

In order to investigate, reveal and clarify the concept of autonomous functionality, we will need to look to the thought processes of humans when undertaking a task. Parasuraman, Sheridan & Wickens has proposed a simple four-stage model of human information processing as follows:

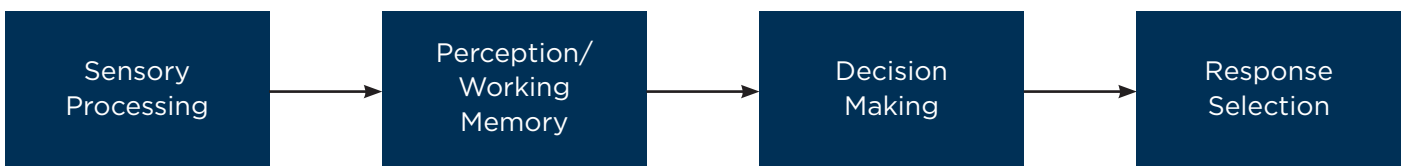


Figure 2 - Simple Four-Stage Model of Human Information Processing [15]

This can be summarized to the following operational decision loop.

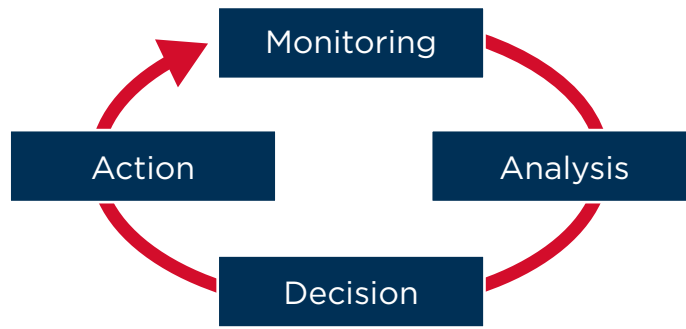


Figure 3 - Operational Decision Loop

**Monitoring** is the process of the human observing operations by measuring and collecting parameters.

**Analysis** is the human understanding the concept and orientating to the current operational scope. He or she analyses the information gathered in the monitoring stage based on his or her knowledge, experience and skills.

**Decision** is the stage where the human considers possible options. He or she then makes a decision on the most appropriate course of action.

**Action** is where the human consciously carries out the decision made in the earlier step.

Where machines are involved in operations, the spectrum ranges from Smart to Semi-Autonomous and Autonomous.

System Autonomy Levels		Integration and Application to Decision Loop			
		Monitoring	Analysis	Decision	Action
1	Smart	M	M	H	H
2	Semi - Autonomous	M	M	H/M	H/M
3	Autonomous	M	M	M	M
Notes:					
1. H - Human, M - Machine					

Table 1 - Autonomy and Operational Decision Loop

Smart systems are systems which augment human capabilities by assisting during the Monitoring and Analysis phases. A smart system may make recommendations, but the final decision rests with the human operator.

With semi-autonomy, the system can choose from multiple options in both pre-defined and unexpected scenarios. Once the decision is made, the system or human needs to follow up with appropriate actions to achieve the intended objective. These actions can be taken by the human, a combination of human and system, or solely executed by system automation.

An autonomous system or function will be one where all four steps in the operational decision loop will be carried out by machines. The role of humans in such systems will be supervisory with the option to intervene and override the actions being carried out by the system.

The Smart-to-Autonomy levels are based on the human-system level of interaction in the processes of data handling, decision-making and execution. It is summarized as follows:

Manual	No system augmentation of human functions. The system offers no or limited assistance, and a human must make all decisions and take all actions.
Smart	System augmentation of human functions. The system provides passive decision support, in the form of health and condition anomaly detection, diagnostics, prognostics, decision/action alternatives, and/or recommendations.
Semi-Autonomy	Human augmentation of system functions. System operation builds upon a smart foundation and is governed by a combination of system and human decisions and actions.
Full Autonomy	No human involvement in system functions. The system makes decisions and takes actions autonomously. Humans are out of the loop and perform a supervisory function. They will have capability to intervene and override actions made by the system.

Table 2 - Smart-to-Autonomy Levels

This development of autonomous functionality is a progression from increasing levels of automation. Sheridan's levels of automation which arose from research into human-machine interaction forms the baseline in the development of autonomy levels.

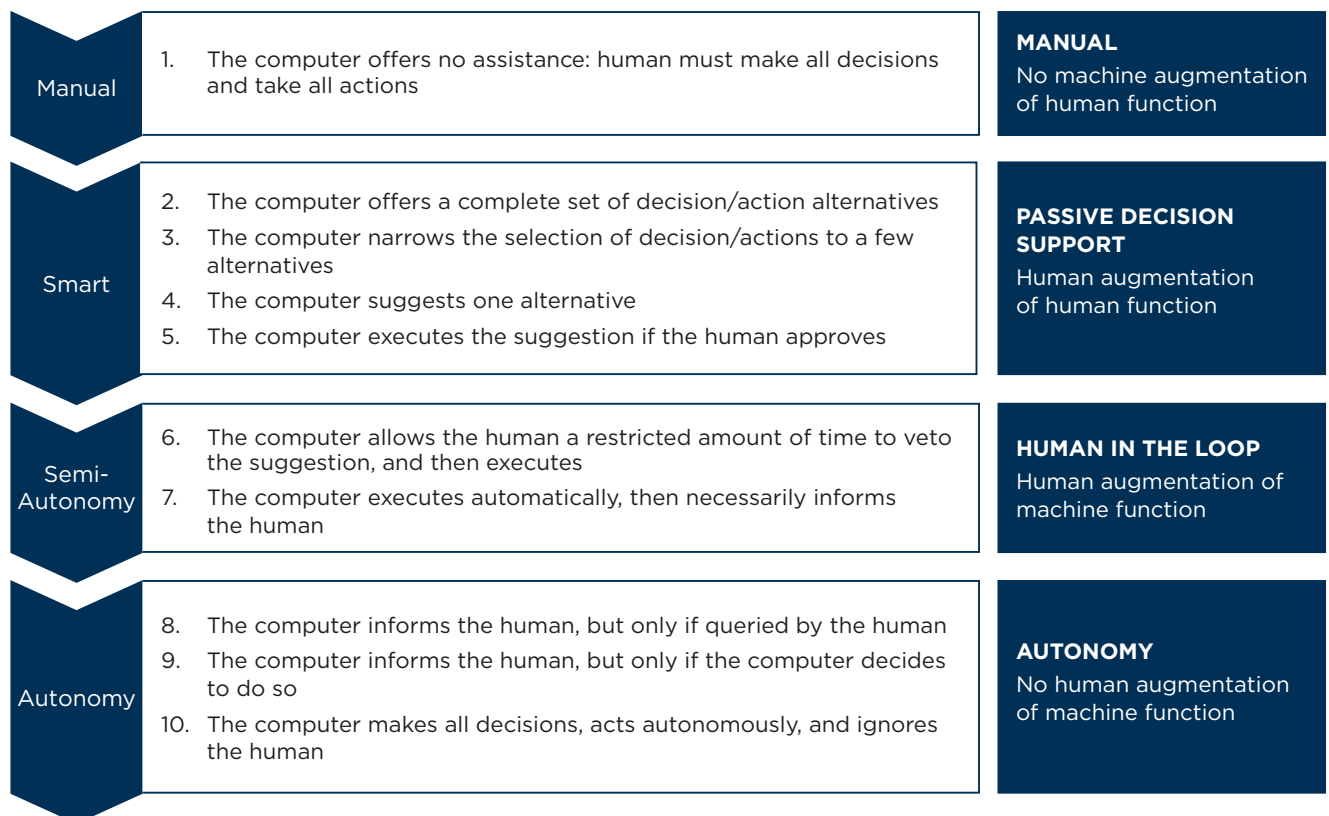


Figure 4 - Sheridan's Level of Automation [6]

Multiple organizations have defined levels of autonomy. The development of useful levels of autonomy for the offshore and marine industry will need to recognize the diverse nature of tasks and functions onboard offshore and marine assets.

## SECTION 3 – AUTONOMOUS FRAMEWORK

Over the course of the last century, regulations in the marine and offshore industries have developed and evolved into the generally prescriptive body of rules which we have today. While there has been enormous engineering and technological progress, the systems onboard have largely remained the same. Ships will have a propulsion system, a navigation system, an electrical power generation and distribution system, piping and cargo handling systems to support the onboard machinery. Offshore units will have an electrical power generation and distribution system, piping systems to support the onboard machinery as well as drilling or process systems, depending on the unit's function.

Rules and regulations are written revolving around these onboard systems. The rules and regulations prescribe requirements pertaining to the design, engineering, performance and maintenance of these systems.

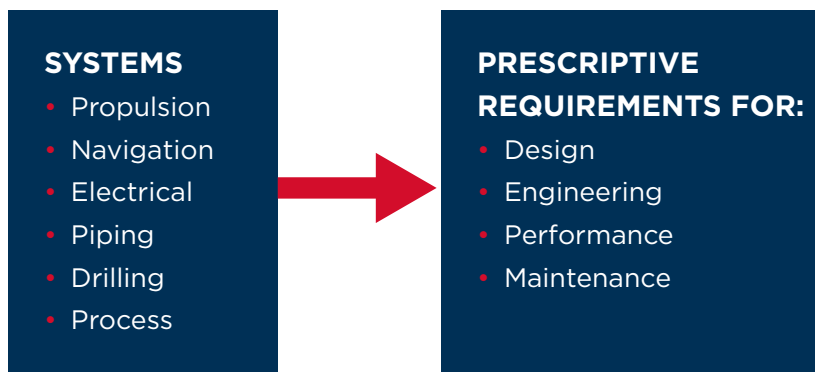


Figure 5 - Traditional Model of Regulations

In the age of digital transformation, disruptors will appear when there is an opportunity for improvement in the functional or operational aspects which can be addressed by digital technologies. This new inverted model elevates the importance of the functional and operational aspect. The system's design and engineering is to support its functionality. The regulatory model will need to adapt to focus on the safety of operations.

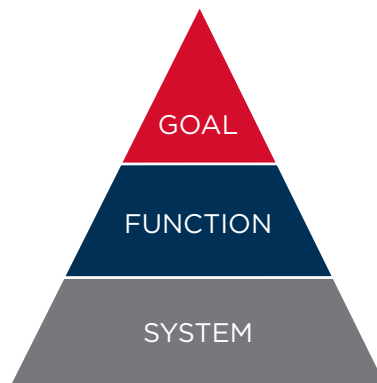


Figure 6 - New Model of Regulations

This section describes a goal-based framework for autonomous functionality requirements. This framework is based on the *IMO Generic Guidelines for Developing IMO Goal-Based Standards (MSC.1/Circ. 1394)* to guide the implementation of autonomous and remotely controlled functions.

Goal Based Standards (GBS) as defined by the above-mentioned IMO Circular are:

*"High-level standards and procedures that are to be met through regulations, rules and standards for ships. GBS are comprised of at least one goal, functional requirement(s) associated with that goal and verification of conformity that rules/regulations meet the functional requirements including goals." [7]*

The ABS approach to autonomous development builds upon the key principles established in the following publications:

- ABS Guidance Notes for Smart Function Implementation
- ABS Guide for Smart Functions for Marine Vessels and Offshore Units
- ABS Guidance Notes on Review and Approval of Novel Concepts
- ABS Guidance Notes on Qualifying New Technologies

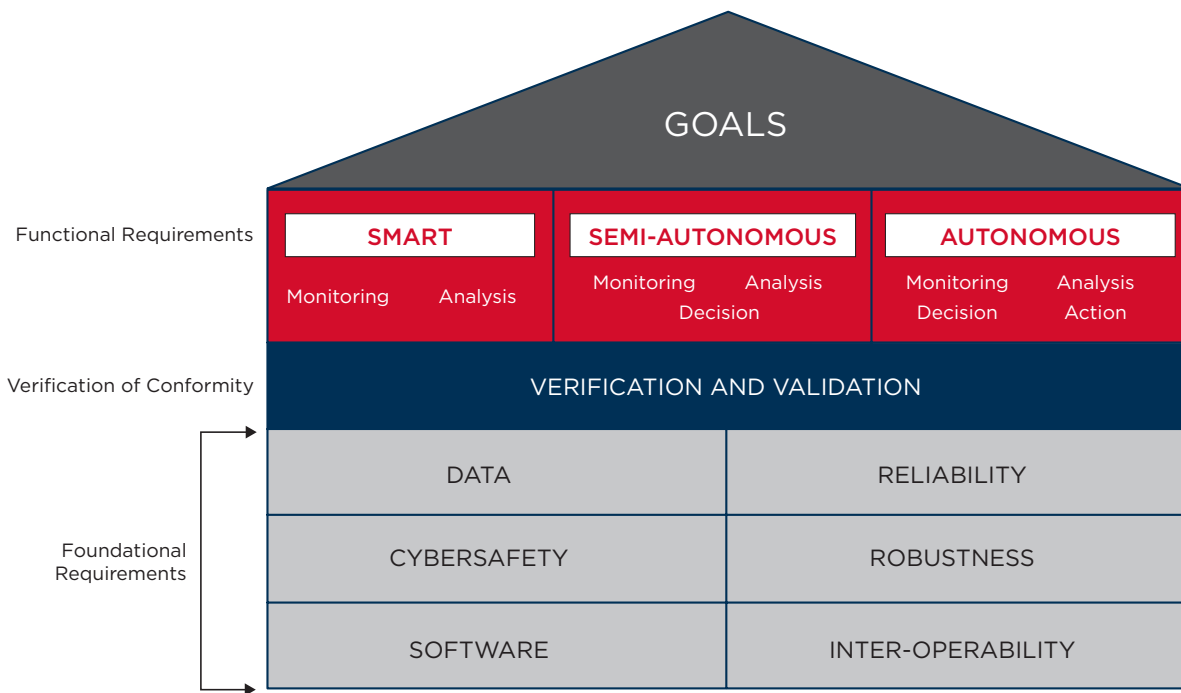


Figure 7 - Smart-to-Autonomous Goal Based Approach

## GOALS:

Goals are high-level objectives to be met. They should address the issues of concern and reflect the required level of safety. In the implementation process during the development of autonomous vessels, the over-arching goals would be that the autonomous functionality is to be **designed, constructed, operated and maintained for its planned mission safely, reliably and predictably.**

## FUNCTIONAL REQUIREMENTS:

Functional requirements provide the criteria to be satisfied in order to meet the goals. Autonomous functions being implemented to meet the goals for autonomous vessel development can be categorized into: smart, semi-autonomous or autonomous. This categorization is dependent on the functions' coverage of the different stages in the operational decision loop.

Functional requirements are to be developed based on experience, an assessment of existing regulations, and/or systematic analysis of relevant hazards.

## VERIFICATION OF CONFORMITY:

Verification of conformity establishes the method and criteria to demonstrate and verify that the function's specifications and implementation conforms to the goals and functional requirements and addresses the safety of the operation of the vessel or unit. A verification plan should be developed followed by subsequent initial and continued validation that the goals and functional requirements are met. The function's risk level, assigned due to its potential function failure or under-performance, forms the basis for setting the required criteria for the verification and validation process. A risk assessment will help map to requirements in existing standards and Rules or determine the need for additional requirements. Safety of the vessel and risk expand beyond just the asset, crew or humans on board, but also to the maritime community that interacts with the vessels.

Recognizing that the functions being introduced today are new and will not be covered easily by traditional conventional requirements and regulations, the framework is supported by Verification and Validation principles laid out in the ABS *Guidance Notes on Qualifying New Technologies* and the ABS *Guidance Notes on Review and Approval of Novel Concepts*.

## FOUNDATIONAL REQUIREMENTS:

The technologies being implemented on autonomous vessels will be highly reliant on connectivity and software. Underpinning the framework will be the foundational requirements established in the ABS Rules, Smart Guide and CyberSafety and Software series of publications. These foundational requirements, focusing on functionality, quality, security and integrity of the data, cyber security, software integrity, reliability, robustness and inter-operability, are to support operational functions including, monitoring, analysis, decision making and action taking.

This framework is scalable. It can be applied by itself to a single autonomous function or system. For more complex functions or for the development project of a fully autonomous vessel with multiple functions and systems, it can be scaled up with multiple functions/systems forming system goals and subordinate goals (sub-goals) which feed into and support an over-arching goal.

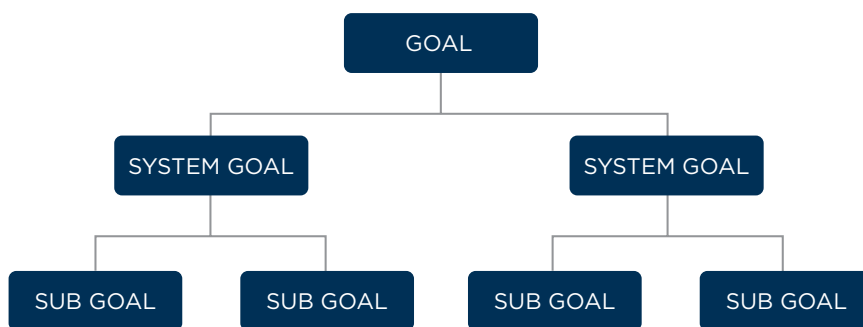


Figure 8 - Scalability of Goal-Based Framework

## RISK ANALYSIS:

Risk analysis is an essential element for assessing component, system and system of systems impact of autonomous operations. Risk assessments and reliability studies at the early or conceptual phases are part of the foundation for creating satisfactorily robust systems, determining requirements and any additional areas to address during design.

Risk assessment is the process of gathering data and synthesizing information to develop an understanding of the risks involved. To gain an understanding of the risk of an operation, one must answer the following three questions:

- i) What can go wrong?
- ii) How likely is it?
- iii) What are the impacts?



Figure 9 - Elements of Risk Assessment

Qualitative answers to one or more of these questions are often sufficient for making good decisions. However, for more detailed information and understanding, quantitative risk assessment methods (QRA) may also be used.

The risk assessment process consists of four basic steps:

- i) Hazard identification,
- ii) Frequency assessment,
- iii) Consequence assessment, and
- iv) Risk evaluation

The level of information required will vary based on the function, system and related operations. In some cases, after identifying the hazards, qualitative methods of assessing frequency and consequence are satisfactory to enable risk evaluation. In other cases, a more detailed quantitative analysis is required. The risk assessment process is illustrated in the below figure:

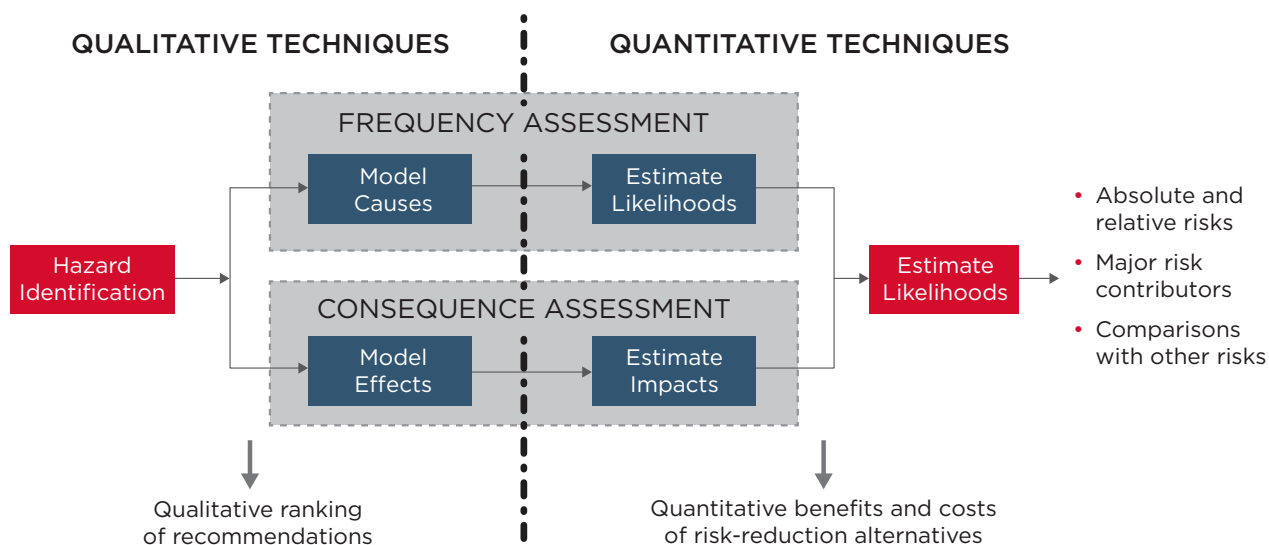


Figure 10 - The Risk Assessment Process

There are many different analysis techniques and models that have been developed to aid in conducting risk assessments. Some of these methods are summarized in the below figure:

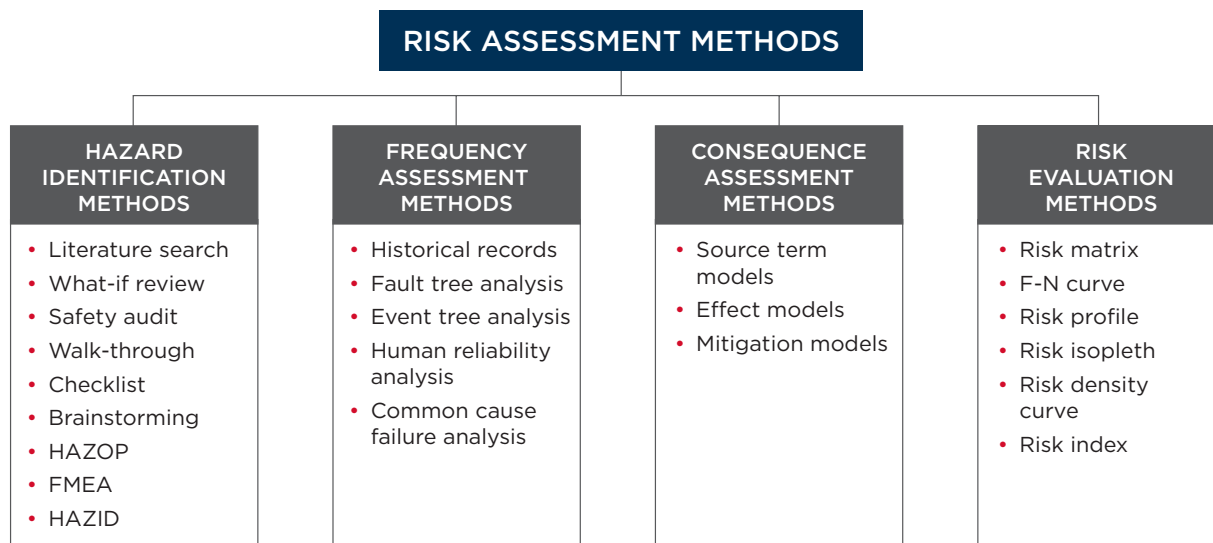


Figure 11 - Overview of Risk Assessment Methods

A key to any successful risk analysis is choosing the right method (or combination of methods) for the system, function or operation at hand.

Further guidance on Risk Assessment methods can be found in the following ABS references:

- ABS Guidance Notes on Review and Approval of Novel Concepts
- ABS Guidance Notes on Qualifying New Technology
- ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries
- ABS Guidance Notes on Failure Mode and Effects Analysis (FMEA) for Classification
- ABS Guide for Smart Functions for Marine Vessels and Offshore Units

Risk analysis supplements existing prescriptive requirements, allows the evaluation of alternative methods and helps verify that the design principles and intent of applicable Regulations are met, thereby providing an equivalent level of safety. In all cases, the requirement of specific risk assessments will be based on the intended design of the autonomous functionality and its impact on the systems it supports and overall safety of the asset and operations.

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## SECTION 4 - CONCEPT OF OPERATIONS

It is crucial that planning for the operations of remote control and autonomous vessels and units be carried out early in the design phase with as much details as possible and involving all relevant stakeholders. This is to be carried out in the preparation and development of a Concept of Operations (ConOps) document.

Currently, when a vessel or unit is delivered by the builder, the owner typically takes control of the asset, deploys its crew and with it, its operating instructions, protocols and procedures. The vessel or unit with its new crew onboard moves into its operational phase governed by operating protocols and procedures shaped by norms and conventions guided by the existing maritime regulatory framework and centuries of seafaring and offshore experience. The roles and responsibilities of all stakeholders in the ecosystem has been carefully crafted and are generally well understood.

The introduction of remote control and autonomous vessels and units will require a paradigm shift from this current state. The potential for fully autonomous operations without direct human control will negate the established command and control hierarchy onboard vessels and upend the established interaction protocols in the ecosystem. This is further complicated by the various possibilities of operating configurations.

A Concept of Operations (ConOps) document is a document describing the characteristics of a proposed system from the viewpoint of an individual who will use that system. Generally, its main aim is to define the planned operating modes (seagoing, port operations, piloting, anchor/mooring, distress/emergency, transiting, drilling or producing) and to lay out its operating philosophy.

The content of the ConOps is to include but not limited to the following:

- i. Operational Envelope - Intended Area of Operations and Details/Limitations/Restrictions
- ii. Defined Planned Voyage and Operation Phases with supportive Methods of Control
- iii. Autonomous Approach - System Mapping by Method of Control/Operational Phase/Autonomy Level
- iv. Operational environment and its characteristics [8]
- v. Major system elements and the interconnection among those elements [8]
- vi. Interfaces to external systems or procedures [8]
- vii. Capabilities, functions/services and features [8]
- viii. Operational risk factors [8]
- ix. Performance characteristics [8]
- x. Provisions for safety, security, integrity and continuity of operations in emergencies [8]
- xi. Logistics requirements [8]
- xii. Operational procedures

The ConOps would need to take the holistic view of the operations of the vessel or unit and its autonomous function(s).

This includes the operation of the onboard systems. With a task or multiple tasks being performed by the autonomous function(s), how are they being carried out? What is the inter-dependency and impact of these functions on the other systems onboard the vessel? Will the crew onboard understand the workings of these functions and do they know the remedial steps which they ought to take in case a failure occurs?

This consideration is not to be limited to the autonomous functions or systems and its related interfacing systems only. The vessel or unit is to be considered in its entirety. At a minimum, this would include consideration of the vessel's or unit's arrangements, structures and equipment details. For example:

1. In the case of an unmanned vessel, there is no captain to minimize wave impacts. What is the effect of this on the vessel's accelerations and structural loads?
2. With the reduction or absence of crew, what would be the impact on the operational robustness of the systems and vessel/unit? Would increased redundancies be necessary?
3. Do we need to consider different arrangements in case the vessel goes deadship and needs to be boarded?
4. With reduction of crew, will all planned and unplanned maintenance be able to be carried out? Will this impact equipment design?

The issues identified have to be considered in conjunction with the framework outlined in Section 3.

The external interactions between the autonomous vessel or unit and functions with its surrounding maritime ecosystem will also need to be detailed in this document. This is especially important for functions with external interactions for example the autonomous navigation function. How does the autonomous system behave and react when it meets other vessels, which for the foreseeable future will be a conventional manned vessel? How does the autonomous system communicate its intention to other vessels or the port VTS (Vessel Traffic Service)?

A key difference in the operation of remote control and autonomous vessels and units is its increased dependency on its supporting systems and connectivity to Remote Control and Operations Centers providing shore-based supervision, monitoring and some measure of remote control. The ConOps needs to also take this into account and study in-detail the roles and responsibilities of the Remote Control and Operations Center.

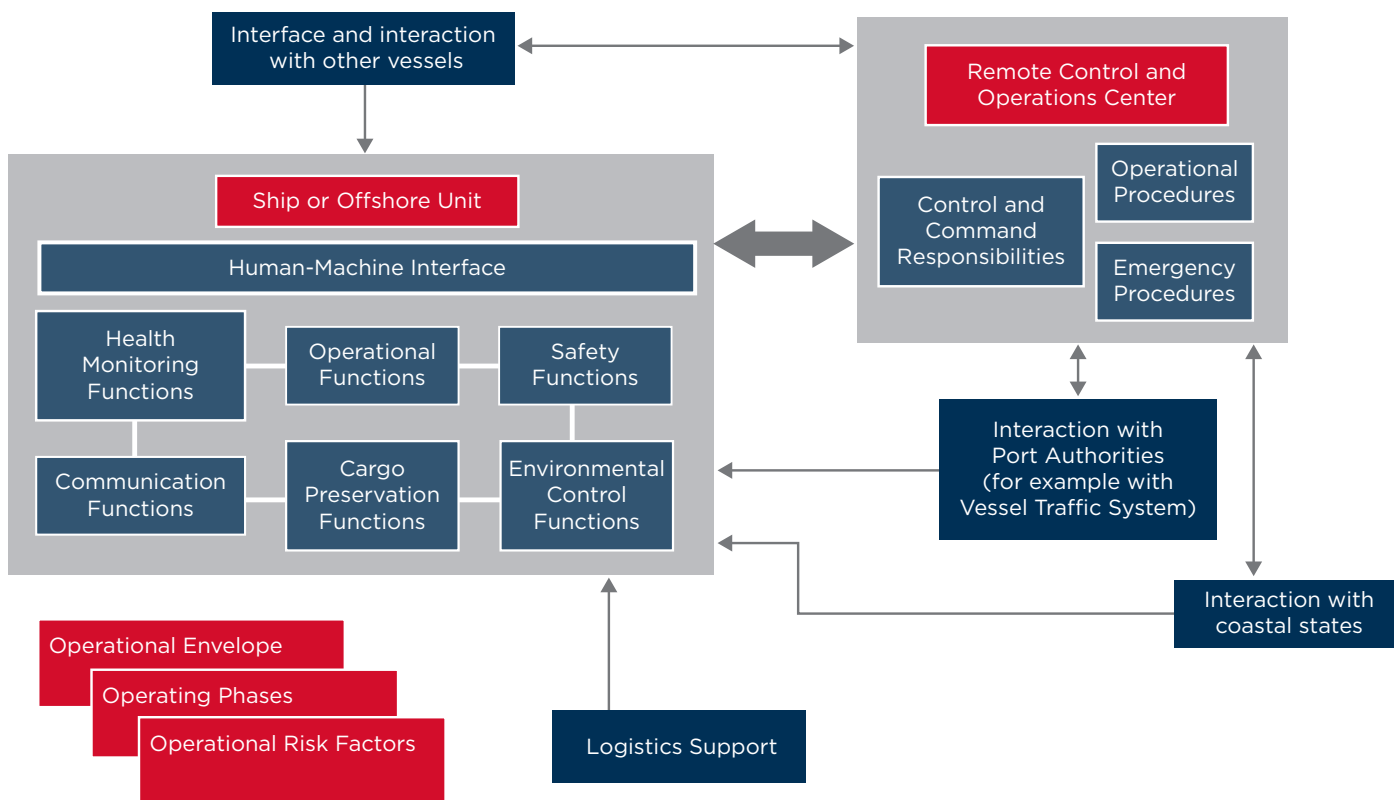


Figure 12 - Considerations for the Development of a Concept of Operations Document

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## SECTION 5 - REMOTE CONTROL AND OPERATIONS CENTERS

While the aim of autonomous development is the enabling of systems onboard vessels and units to operate itself without human input and control (with or without the presence of humans onboard), it is highly likely that these systems will be supported by shore-based supervision, monitoring and remote control. Thus, a critical concept arising from the development of autonomous vessels and units will be the establishment of Remote Control and Operations Centers where they will be monitored by humans in these centers.

While the concept of Remote Control and Operations Center with continuous connectivity to vessels or units may be a new one in maritime operations, Remote Operations Centers have been in use in other industries such as mining, defense, petroleum, refinery, utilities and aerospace industries [9]. The factors driving the use of Remote Operations Centers are similar to the ones which are driving the current discussions of the advent of autonomous operations in the marine and offshore industries:

- **Increased safety** [9]:  
By keeping people out of harm's way
- **Overcome the shortage of manpower and expertise** [9]:  
These industries face similar manpower challenges to the maritime industry where the field locations are located either offshore or in very remote locations and these jobs do not appeal to the current workforce. By centralizing the operational control of multiple facilities in one location, these industries are able to maximize the productivity and impact of their personnel.
- **Reduction in costs** [9]:  
Similarly, remote operations centers bring significant cost reduction benefits due to the increased productivity. Additionally, the cost of personnel working offshore or in remote locations would be higher than one working in a remote operations center.

Experience from remote operations centers in the other industries shows that they will contribute the following additional benefits [9]:

- Improved communication between front-line operators and the management chain
- Sharing of expertise due to the centralization of personnel from different disciplines
- Enables the collection and analysis of operational data

The introduction of Remote Operations and Control Centers in the maritime industry can build upon the experience gained in other industries. However, the challenge for our industry is that it combines all the traits of the Remote Operations Centers in those diverse industries and it will also need to deal with challenges unique to the maritime environment. Autonomous operations in the marine and offshore industries will have to deal with:

- The monitoring and operations of heavy machinery in a dynamic, unpredictable and harsh marine environment
- Operations in an un-sanitized and un-controlled environment together with various actors exhibiting different characteristics: conventional manned ships and small vessels such as leisure vessels
- A highly regulated industry
- Difficulty in obtaining reliable and sufficient data connection at sea
- Greater environmental impact arising out of any incident



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The Remote Control and Operations Center will play a critical role in the control and monitoring loop of autonomous operations. The functions which it may be called upon to perform will be diverse:

- Voyage planning of all aspects of the autonomous vessel for example setting of navigation waypoints and the configuration of the vessel's machinery
- Monitor the progress of the voyage
- Maintain situational awareness
- Health monitoring of onboard machinery and vessel's hull/structure
- Respond to anomalous and emergency situations
- Communicate with and share information with ports or coastal states when in their waters for example liaising with a port's VTS (Vessel Traffic Service) system
- Communicate with surrounding vessels
- Control transitions between operating modes

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## SECTION 6 - ENGAGEMENT WITH FLAG STATE AND PORT STATE

The United Nations Convention for the Law of the Sea (UNCLOS) assigns the obligation to ensure safety at sea with regards to the construction, equipment and seaworthiness of ships to the Flag States. Flag States carry out this responsibility by utilizing a certification and inspection regime in accordance with IMO rules and regulations to govern vessels flying its flag. In practice, a portion of this work is then delegated to the Classification Societies acting on their behalf.

Port States have broad jurisdiction over vessels in its ports or domestic waters whether they be foreign or domestic vessels. For foreign vessels visiting its ports, Port States have inspection powers to inspect and enforce compliance of these vessels to the applicable IMO regulations. For domestic vessels plying its ports and country's domestic waters only, generally, they are not required to comply to IMO regulations. However, these vessels will have to comply with domestic regulations which are administered by the Port States.

Where autonomous functions intended to be used onboard vessels are used only to augment and assist the crew's duties, this would likely be allowed under the existing rules and regulations.

However, autonomous functions which will perform tasks mandated by current regulations for example an autonomous navigation system performing the duties of a Look-Out as required by COLREG (International Regulations for Preventing Collisions at Sea 1972) will present a challenge as this would be in conflict with the regulations. In most cases, the current rules and regulation will not allow the use of such autonomous functions.

As such, engagement with the vessel's Flag State and/or Port State will be necessary and crucial. In most cases, the designer would need to demonstrate to the relevant authorities that the safety level of the proposed autonomous function is equivalent to that when the task is being carried out by humans. An exemption from the affected regulation(s) would most likely be needed.

Various Flag Administrations recognize this conundrum. If we were to apply the existing rules and regulations, development of autonomous functionality and vessels would be unachievable. In order to encourage innovation, some Flag Administrations have shown flexibility and are working with industry.

Additionally, the increased reliance and transfer of some control to Remote Control and Operations Centers raises interesting questions on the regulatory requirements. The possibility of a vessel being navigated and controlled from a Remote Control and Operations Centers in a location other than the Flag State raises questions as to the laws or regulation which would apply to these centers. New instruments and rules would need to be written to regulate the conduct of the Remote Control and Operations Centers.

## SECTION 7 - IMO MARITIME AUTONOMOUS SURFACE SHIPS (MASS) REGULATORY SCOPING EXERCISE

Taking note of the development of Maritime Autonomous Surface Ships (MASS) in the industry, the International Maritime Organization (IMO) recognizes the need for the IMO to be proactive and to take a leading role in this development.

In this regard, a proposal to undertake a Regulatory Scoping Exercise to determine how the safe, secure and environmentally sound operation of MASS might be introduced in IMO instruments was accepted at the 98th session of the Maritime Safety Committee meeting (MSC 98) in February 2017 [10].

To facilitate the process of the Regulatory Scoping Exercise, the degrees of autonomy are organized as follows [11]:

- **Degree one: Ship with automated processes and decision support:**  
Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
- **Degree two: Remotely controlled ship with seafarers on board:**  
The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- **Degree three: Remotely controlled ship without seafarers on board:**  
The ship is controlled and operated from another location. There are no seafarers on board.
- **Degree four: Fully autonomous ship:**  
The operating system of the ship is able to make decisions and determine actions by itself.

It has to be noted that these degrees of autonomy were established with the purpose of guiding the discussions during the Regulatory Scoping Exercise. The IMO has not decided that these degrees will be used in any future instrument related to MASS and they may well change in the course of future development of MASS regulations.

The Regulatory Scoping Exercise will be carried out in two steps. At the first step, IMO instruments will be reviewed to identify and determine instruments which will apply to MASS and if the instrument needs to be amended to be adapted to MASS operations. Once the first step is completed, the second step will be conducted to analyze and determine the most appropriate way of addressing MASS operations. At this step, detailed discussions will take place to determine if the existing instruments are required to be amended or new instruments need to be developed to address MASS operations [11].



The final report arising from this Regulatory Scoping Exercise is scheduled to be submitted to the 102nd session of the Maritime Safety Committee meeting (MSC 102) in May 2020 [11].

Arising from this exercise, a Draft Interim Guidelines for MASS trials have been submitted to the 101st session of the Maritime Safety Committee meeting (MSC 101) in June 2019. These guidelines take a holistic view of MASS operation and considers the operation of MASS in association with its surrounding maritime environment [12].

Concurrently, the ISO (International Organization for Standardization) is developing the terminologies related to automation of MASS. This work to be produced by the ISO will be tabled at the 102nd session of the Maritime Safety Committee meeting (MSC 102) for consideration and will feed into the Regulatory Scoping Exercise. [13] [14]

The result of the Regulatory Scoping Exercise will lay the foundations and inform the IMO on the next steps to be taken in developing instruments pertaining to the design and operations of MASS. It has to be noted that requirements for MASS will not be ready at the conclusion of the Regulatory Scoping Exercise in May 2020. There is still some way to go in the development of MASS regulations at the IMO.

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## CONCLUSION

This advisory covered the background on autonomous functionality as well as the Smart to Autonomous Framework which is supported by the development of a Concept of Operations document which will be specific to the application. It is also highly likely that autonomous vessels or units will have remote support whether in the form of a supervision, monitoring, and/or control. As we continue through autonomous functionality implementation, there will be necessary interaction with IMO, Flag and Port state entities.

### REGULATORY FRAMEWORK

Implementation of autonomous functionalities cut across various domains which are affected and governed by separate regulatory instruments. In order to accommodate them, the regulatory framework will need to be set up holistically to enable autonomous operations. Stepwise or piecemeal amendments to existing instruments will not be ideal to advance the development of autonomous functionalities. Against this backdrop, the IMO's Maritime Autonomous Surface Ships (MASS) Regulatory Scoping Exercise is a necessary first step toward autonomous operations in the marine sector.

The regulatory regime in the offshore industry differs slightly. Compared to the marine sector, it is less prescriptive and more goal-based. With the over-arching goal of safety of operations, it has to be demonstrated that the safety of operations is maintained with autonomous functionalities working alongside humans.

### SUPPORTING INFRASTRUCTURE

A key difference between autonomous functionalities and current conventional operations will be the increased reliance on supporting infrastructure external to the ship or offshore unit. Existing infrastructure (for example data connectivity) will need to be enhanced and upgraded. Services which are not yet in existence today will need to be developed to support autonomous operations. The growth of these supporting infrastructure is intertwined with progress in the other two factors (Regulatory Framework and Industry Adoption).

New rules and requirements will have to be drafted to regulate these supporting infrastructure. On the other hand, investment into and growth of these services will only be economically viable if the number of industry adopters of autonomous functionalities reach a critical mass.

### INDUSTRY ADOPTION

The key link in the development of autonomous functionalities, as in any other new technology, would be adoption by the industry. Push factors leading the industry to consider implementation of autonomous functionalities will be if these functions can improve the economics of their operations. Industry will not consider technology for technology's sake.

The industry has to be convinced that these autonomous functionalities make economic sense and be assured that it operates at a level of safety which is equivalent with or an improvement on the current level.

The development of autonomous functionalities is ongoing and rapidly evolving. Made up of different moving parts coupled with the complicated environment around vessel operations, active involvement and collaboration from all stakeholders is necessary for the successful and safe implementation of autonomous functions.

# LIST OF ABBREVIATIONS

1.	COLREG:	Convention on the International Regulations for Preventing Collisions at Sea, 1972
2.	ConOps:	Concept of Operations
3.	FMEA:	Failure Mode and Effects Analysis
4.	GBS:	Goal Based Standards
5.	IMO:	International Maritime Organization
6.	ISO:	International Organization for Standardization
7.	ISM Code:	International Safety Management Code
8.	MASS:	Maritime Autonomous Surface Ships
9.	MSC:	Maritime Safety Committee
10.	QRA:	Quantitative Risk Assessment
11.	R&D:	Research and Development
12.	SOLAS:	International Convention for the Safety of Life at Sea, 1974
13.	STCW:	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
14.	UNCLOS:	United Nations Convention on the Law of the Sea
15.	VTS:	Vessel Traffic Service
16.	V&V:	Verification & Validation

# RELATED ABS DOCUMENTS

1. ABS Guide for Integrated Software Quality Management (ISQM)
2. ABS Guide for Smart Functions for Marine Vessels and Offshore Units
3. ABS CyberSafety Series Guides and Guidance Notes: Volume 1 to 7 (CyberSafety™)
4. ABS Guidance Notes on Smart Function Implementation
5. ABS Guidance Notes on Qualifying New Technologies
6. ABS Guidance Notes on Review and Approval of Novel Concepts
7. ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries
8. ABS Guidance Notes on Failure Mode and Effects Analysis (FMEA) for Classification

## REFERENCES

- [1] Singapore Maritime Institute, "Singapore R&D Roadmap 2030 - Maritime Transformation," Singapore, 2019.
- [2] Department for Transport, United Kingdom, "Technology and Innovation in UK Maritime: The case of Autonomy," 2019.
- [3] Comite Maritime International, "CMI International Working Group Position Paper on Unmanned Ships and the International Regulatory Framework," 2018.
- [4] L. Carey, "All Hands Off Deck? The Legal Barriers to Autonomous Ships", CML Working Paper Series, No 17/06, August 2017, <http://law.nus.edu.sg/cml/wps.html>
- [5] G. Meadow, D. Ridgwell and D. Kelly, "Autonomous Shipping - Putting the human back in the headlines," Institute of Marine Engineering, Science & Technology, Singapore, 2018.
- [6] T. B. Sheridan and L. W. Verplank, "Human and Computer Control of Undersea Teleoperators," 1978.
- [7] *IMO MSC.1/Circ.1394 - Generic Guidelines for Developing IMO Goal-Based Standards*, International Maritime Organization, 14 June 2011.
- [8] *ISO/IEC/IEEE 29148 - Systems and software engineering - Life cycle processes - Requirements engineering*, 2018.
- [9] C. T. Farrelly and L. R. Records, "Remote Operations Centres - Lessons from Other Industries," in *Australian Mining Technology Conference*, October 2007.
- [10] *IMO MSC 98/23 - Report of the Maritime Safety Committee on its Ninety-Eighth Session*, International Maritime Organization, 28 June 2017.
- [11] *IMO MSC 100/WP.8 - Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS) - Report of the Working Group*, International Maritime Organization, 6 December 2018.
- [12] *IMO MSC 101/WP.8 - Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS) - Report of the Working Group*, International Maritime Organization, 12 June 2019.
- [13] *IMO MSC 101/24 - Report of the Maritime Safety Committee on its 101st Session*, International Maritime Organization, 12 July 2019.
- [14] International Organization for Standardization, "ISO/AWI 23860 - Ships and marine technology - Terminology related to automation of Maritime Autonomous Surface Ships (MASS)," [Online]. Available: <https://www.iso.org/standard/77186.HTML?browse=tc>. [Accessed 22 January 2020].
- [15] R. Parasuraman, T. B. Sheridan and C. D. Wickens, "A Model for Types and Levels of Human Interaction with Automation," *IEE Transactions on Systems, Man and Cybernetics - Part A: Systems and Humans*, vol. 30, no. 3, May 2000.

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