2020

Guidance for Autonomous Ships

GC-28-E

KR

APPLICATION OF "GUIDANCE FOR AUTONOMOUS SHIPS"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to autonomous ships for which contracts for construction are signed or for which the application for Classification Survey is submitted to the Society on or after 1 July 2020.
2. The amendments to the Guidance for 2019 edition and their effective date are as follows;

Effective Date : 1 January 2020

CHAPTER 1 GENERAL

Section 1 General

- 107. has been amended.

Effective Date : 1 July 2020

CHAPTER 1 GENERAL

Section 1 General

- 103. 7 has been newly added.

CHAPTER 3 RISK-BASED APPROVAL

Section 2 Considerations when approving risk-based design

- 201. has been amended.
- 202. 3, 4 and 5 have been newly added and amended.

Section 3 Measures to reduce risk

- 301. 3, 4 and 5 have been newly added and amended.

CONTENTS

CHAPTER 1 GENERAL

Section 1 General

101. Background

1. Due to the development of various digital technologies and automation technologies, research and development on autonomous navigation technology that can recognize the surrounding situation and autonomously operate, logic system to make decisions, integrated sensor system, data communication function etc. are being conducted all over the world.
2. Considering the current status of the maritime industry and related information and communication technology development, autonomous operation can improve the safety and reliability of the maritime industry and enable efficient and economical operation of the ship.
3. While the maritime industry is becoming increasingly digitalized and automated due to development of information and communication technologies, the need to prevent or mitigate risks is also being identified by identifying new hazards as a result in advance.

102. Purpose

1. The purpose of this guidance is to ensure the safety and reliability of autonomous ships or systems and functions necessary for autonomous operation through risk assessment.

103. Application

1. This guidance provides key recommendations on the design or operation of systems that can be used to enhance ship autonomy at sea.
2. This guidance apply to autonomous ships on the surface of the water, not unmanned underwater vehicle.
3. The configuration of the autonomous system presented in this guidance can be changed according to the purpose of operation.
4. In applying this guidance, it is based on the satisfaction of all international conventions, national laws and domestic law of ports applicable to the ship, regardless of autonomous level.
5. Items not specified in this Guidance are to be in accordance with each relevant requirement of **Rules for the Classification of Steel Ships**.
6. Autonomous ships applying this guidance shall be certified for cybersecurity in accordance with the **Guidance for Maritime Cyber security System** and risk assessment shall be carried out in accordance with the **Guidance for Approval of Risk-based Ship Design**.
7. Equipment and systems that are additionally installed for the operation of autonomous ships shall be subject to cybersecurity type approval in accordance with the **Guidance for Type Approval of Maritime Cyber Security** and type approval in accordance with **Ch 3, Sec 23** of the **Guidance for Approval of Manufacturing Process and Type Approval, etc.** *(2020)*
8. Items not included in this Guidance may comply with ISO, IEC, KS or equivalent recognized standards by the appropriate consideration of the Society.

104. Definitions

The definitions of terms are to follow **Rules for the Classification of Steel Ships**, unless otherwise specified in this Guidance.

1. **"Autonomous Ships"** means ships that supports decision-making through the system and can be substituted by the system in whole or in part for the control and management of the ship.
2. **"Operator"** means a person engaged in the control and management of ships onboard or offshore.
3. **"Data Acquisition and Analysis systems"** means a system for recognizing the external conditions of

ships related to marine objects/ships and marine environment and the internal conditions related to ship operation/movement.

4. **"Autonomous Navigation Systems"** means a system that establishes a route plan and a steering plan for economical navigation and prevention of collision/grounding considering the internal and external conditions and controls the propulsion device and steering device of the ship in accordance with the established route plan and steering plan.
5. **"Communication Systems"** means systems involved in communication between information objects.
6. **"Outboard Support Systems"** means a system that monitors and controls the operational information of an autonomous ship.
7. **"Cyber security"** means activities or process, capability, etc. to assure confidentiality, integrity and applicability of the organization's assets and information contained in the assets.
8. **"Confidentiality"** means the property that information is not disclosed to system entities (users, processes, devices) unless they have been authorized to access the information.
9. **"Integrity"** means the property whereby an entity has not been modified in an unauthorized manner.
10. **"Availability"** means the property of being accessible and useable upon demand by an authorized entity.

105. Level of autonomy

1. The autonomy level can be classified according to the subjects performing the following functions. Table 1 shows the autonomy level of each function.
   (1) Data acquisition/analysis
   (2) Decision-making
   (3) Action

Table 1 Level of autonomy

Level of autonomy	Data acquisition/analysis	Decision-making	Action
AL 1	System / Operator	Operator	Operator
AL 2	System(1)	Operator(System)(1)	Operator
AL 3	System	System(Operator)(2)	System
AL 4	System	System(3)	System(3)
AL 5	System	System	System

(Notes)
(1) The system supports decision-making.
(2) Operator confirmation of decision-making is required.
(3) Operators are constantly monitored for decision-making and action.

2. Each autonomy level can be defined as follows:
   (1) AL 1: Data acquisition/analysis can be performed by the operator and the system, but decision-making and action based on the collected information are performed by the operator.
   (2) AL 2: Data is collected/analyzed by the system and decision-making and action are performed by the operator. The system supports operator's decision-making.
   (3) AL 3: Data acquisition/analysis, decision-making and action are performed by the system. However, the operator's confirmation of the decision-making by the system is required, and if the operator confirmation is not preceded, the decision-making is withdrawn. Operator's response is required when system failure occurs.
   (4) AL 4: Data acquisition/analysis, decision-making and action are performed by the system. The operator always monitors the information about the decision-making and action by the system. System responses to abnormal operating scenarios (system failures, etc.) are possible.

(5) AL 5: As a complete autonomous level, all functions such as data acquisition/analysis, decision-making and action are performed by the system and the operator monitors the emergency situation. System responses to abnormal operating scenarios (system failures, etc.) are possible.

106. Class notations

1. The scope and autonomy level of this Guidance for autonomous ships is basically made at the request of the owner, but is finalized through a risk assessment.

2. Autonomous ships to which this Guidance applies may be assigned notation at autonomy level of **105**, depending on the application of the autonomous system specified in **Ch 2**, **103**. **1** to **5**. For example, a ship with an autonomous systems as defined in **Ch 2**, **103**. **1** may be assigned "AL1".

3. For systems consisting of combinations of several subsystems, such as data acquisition system at autonomous level 1 (AL1), special features can be specified in addition to the notation. Example: AL1 (Ship operation/movement).

107. Equivalency

The equivalence of alternative and novel features which deviate from or are not directly applicable to the Guidance is to be in accordance with **Pt 1**, **Ch 1**, **104**. of **Rules for the Classification of Steel Ships**. *(2020)*

108. Modification of requirements

Since autonomous ships technologies are under development, the requirements of this Guidance may need to be supported by additional information and requirements, on a case by case basis. Designs that are not in compliance with this Guidance may be approved after evaluation by the Society, provided that it can be demonstrated that the design represents an equal or better level of safety.

Section 2 Operation Plan

201. General

1. The developer shall submit an operation plan for the ship.

2. The operation plan documents the owner's intention to operate the autonomous ship and the operational requirements for it, and shall specify at least the following information according to the purpose and function of the autonomous ship.
   (1) Operational information
      (A) Purpose of operation
      (B) Operation scope: Operating sea, sea conditions, conditions required for safe operation of the ship and the shipboard system (eg, communication network performance requirements and data quality requirements for communication systems)
   (2) System information
      (A) Level of autonomy
      (B) Modularization and configuration details
   (3) Hazard information
      (A) Operation scenario (normal/abnormal)
      (B) Hazards and mitigation measures

3. The operation plan shall specify the operation scope to ensure safe operation of the system or ship.

4. The system or ship shall operate only within the its operation scope. The ship shall be equipped with a device to check for deviations from all specified operation scopes and shall be recorded at all times during operation. Records shall be available at any time and shall be considered outside the specified operation scope if the recorded contents can not be verified.

5. The operation plan shall specify the possible hazards and their mitigation measures in the operational scenarios. Even if the system or ship is operated within the specified operation scope, if there is a situation that harms the safety of the ship due to risks not presented in the operation plan, the responsibility lies with the developers who have not reviewed the expected risk situations in the operational environment and have not prepared mitigation measures for them.

Section 3 Cyber security

301. General

1. The development of automated technologies based on information and communication technologies and the development of autonomous technologies are also increasing the cyber risk on the network. Especially for autonomous ships, such risks are further increased.
2. Systems and ships for autonomous navigation are required to prevent and detect such cyber threats in advance and to provide cyber security technologies to respond to cyber attacks. Therefore, on-board systems of autonomous ship shall be certified and maintained for cybersecurity in order to demonstrate the availability, confidentiality and integrity of the system.
3. The regulations related to cyber security shall be in accordance with the respective requirements of the **Guidance for Maritime Cyber Security System**. Additional considerations and requirements may be required if there are separate requirements in accordance with international regulations, such as IMO, in addition to the requirements of the **Guidance for Maritime Cyber Security System**, or where the Society is deemed necessary by the development of information technology and operational technologies.

302. Application

1. If a communication network is established between the ship and the off-board support system, it shall be protected from unauthorized attack and data access.
2. A cybersecurity control system shall be in place to mitigate the risks of unauthorized attack and data access during the design, manufacture and installation of the ship system.
3. System security performance shall consider both normal and abnormal operating scenarios and shall consider the impact of system security failures on safety functions.
4. The applicable system security procedures shall mitigate the cyber security-related risks that may arise during the design, procurement, production, installation and commissioning of the system and at least take into account the following:
   (1) Risk management
   (2) Access control
   (3) Physical security
   (4) Incident response and recovery
   (5) Outside parties' security
   (6) Data security
   (7) Log management
   (8) Software development and testing
   (9) System management
   (10) Patch management
   (11) Encryption
   (12) Malicious code response
   (13) Network management
5. Ships with autonomous level 1(AL1) and autonomous level 2(AL2), in which communication networks between the off-board support systems are established, shall be certified for cyber security at least with CS1 determined through the risk assessment. And, ships with autonomous level 3(AL3) or above shall be certified by CS3. ⚓

CHAPTER 2 AUTONOMOUS SYSTEMS AND AUTONOMOUS SHIPS

Section 1 Configuration and Function of Autonomous Systems

101. Configuration of autonomous systems

1. The configuration of autonomous system presented in this guidance is shown in **Fig 2.1**.

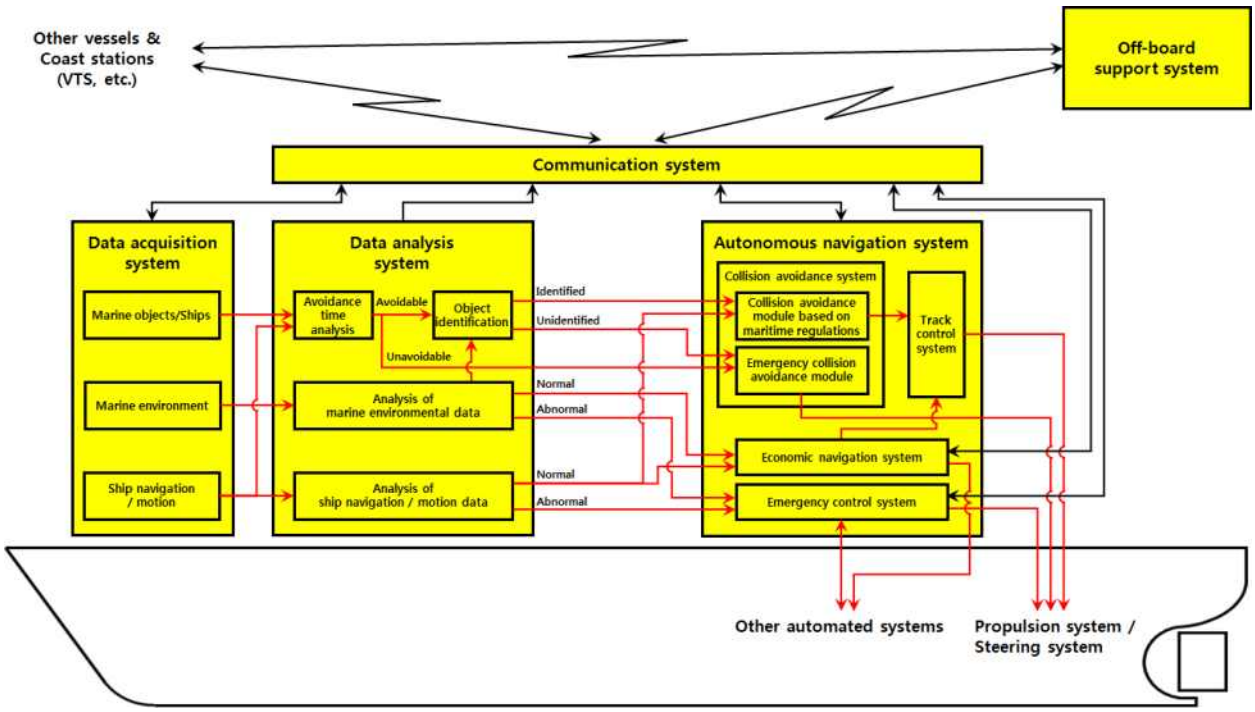

Fig 2.1 General configuration of autonomous system

102. Function of autonomous systems

1. Data acquisition and analysis system

(1) It is a system for recognizing the external situation of ships related to marine objects/ships and marine environment and the internal situation related to ship navigation/motion. It collects data from a number of data sources and integrates / analyzes them to provide operator or autonomous navigation system with results that can aid operational decision-making. The main functions of this system are as follows:

(A) After integrating and analyzing the external situation data collected through the marine objects/ships detection sensor module, it confirms the avoidance point, identifies the marine object or ship, and transmits the object identification result to the autonomous navigation system. If the object is not identified, alert the operator and deliver relevant information.

(B) It measures ship's navigation and movement information such as ship's position, direction, speed, inertia, etc., and analyzes the operation/motion status of the ship and delivers the sorted information to the autonomous navigation system (If the system is equipped with an economic ship routing system, the information is transmitted to the autonomous navigation system and the economic navigation system).

(C) It integrates and analyzes marine environmental (weather, wave height, etc.) data collected through the marine environment detection sensor module and delivers the analysis results to the economic navigation system.

(2) The subsystems of the data acquisition and analysis system are as follows.

(A) Marine objects/Ships detection sensor module (AIS, ARPA, radar, lidar, daylight camera, infrared

camera, etc.)
(B) Marine environmental detection sensor module (weather observation sensor, wave height sensor, echo sounding device, etc.)
(C) Position and navigation sensors (GNSS, gyro compass, etc.)
(D) Avoidance point analysis module
(E) Object identification module
(F) Marine environmental data integration/analysis module
(G) Ship navigation/motion data integration/analysis module

2. Autonomous navigation system

(1) It is a system that establishes route plan and steering plan for economical navigation and collision/grounding prevention considering the internal and external situation of the ship, and controls the propulsion device and steering device of the ship in accordance with the established route plan and steering plan and performs the following functions.
(A) Establishment of a collision avoidance path according to the maritime regulations based on the analysis results (avoidance time, avoidance object, ship navigation/motion status) through data acquisition and analysis system
(B) Manage predefined navigation plans and update them in real time as needed
(C) Control of propulsion and steering system to ensure safe and efficient navigation according to predefined navigation plan considering traffic condition (Traffic and marine environmental conditions if equipped with an economic navigation system)
(D) Alert the operator if the avoidance object is not identified in the data analysis system and avoid risk within the ship's operation scope if there is no response from the operator to the collision avoidance threshold according to the maritime regulations when related information is transmitted
(E) Avoid dangerous situation within the operation scope of the ship when an emergency danger situation (identification of a nearby colliding object) occurs
(F) Establishing the optimal route for economic operation considering the marine environment and the ship's navigation and motion status
(G) Ship control according to predefined procedures when detecting unusual movements
(2) The subsystems of the autonomous navigation system are as follows.
(A) Collision avoidance system
(B) Track control system
(C) Economic navigation system
(D) Emergency control system

3. Communication system

(1) It is a system involved in communication between information objects and performs the following functions.
(A) Transfer and share data between the ship and other ships
(B) Transfer and share data between the ship and coast stations such as VTS
(C) Transfer and share data between the ship and off-board support system
(D) Other distress communication
(2) The subsystem of the communication system may be configured as follows.
(A) LOS (line of sight) communication system
(B) Wireless communication system (VHF, UHF)
(C) Satellite communication system
(D) Short-range wireless communication system (W-LAN)

4. Off-board support system

(1) It is a system that monitors and controls the navigation information of autonomous ships and performs the following functions.
(A) Planning a voyage
(B) Autonomous system and navigation information monitoring
(C) Direct control of autonomous ship (if necessary)
(2) The subsystems of the off-board support system are as follows.
(A) Mission control computer
(B) Operation Control Panel
(C) Interface system

103. System configuration according to autonomy level

The autonomous systems required according to autonomy level of autonomous ship are as follows.

1. Autonomy level 1 (AL 1)

(1) Definition of autonomy level
  (A) Data acquisition and analysis: System and Operator
  (B) Decision-making: Operator
  (C) Action: Operator

(2) Ship characteristics: Ships equipped with a system for collecting data from multiple sources and integrating/analyzing them

(3) System configuration
  (A) Essentially required systems: Data acquisition and analysis system (systems with one or more of the functions specified in **102. 1** (1) (A) to (C))
  (B) Systems that may be required depending on operating characteristics
    (a) Communication systems
    (b) Off-board support systems

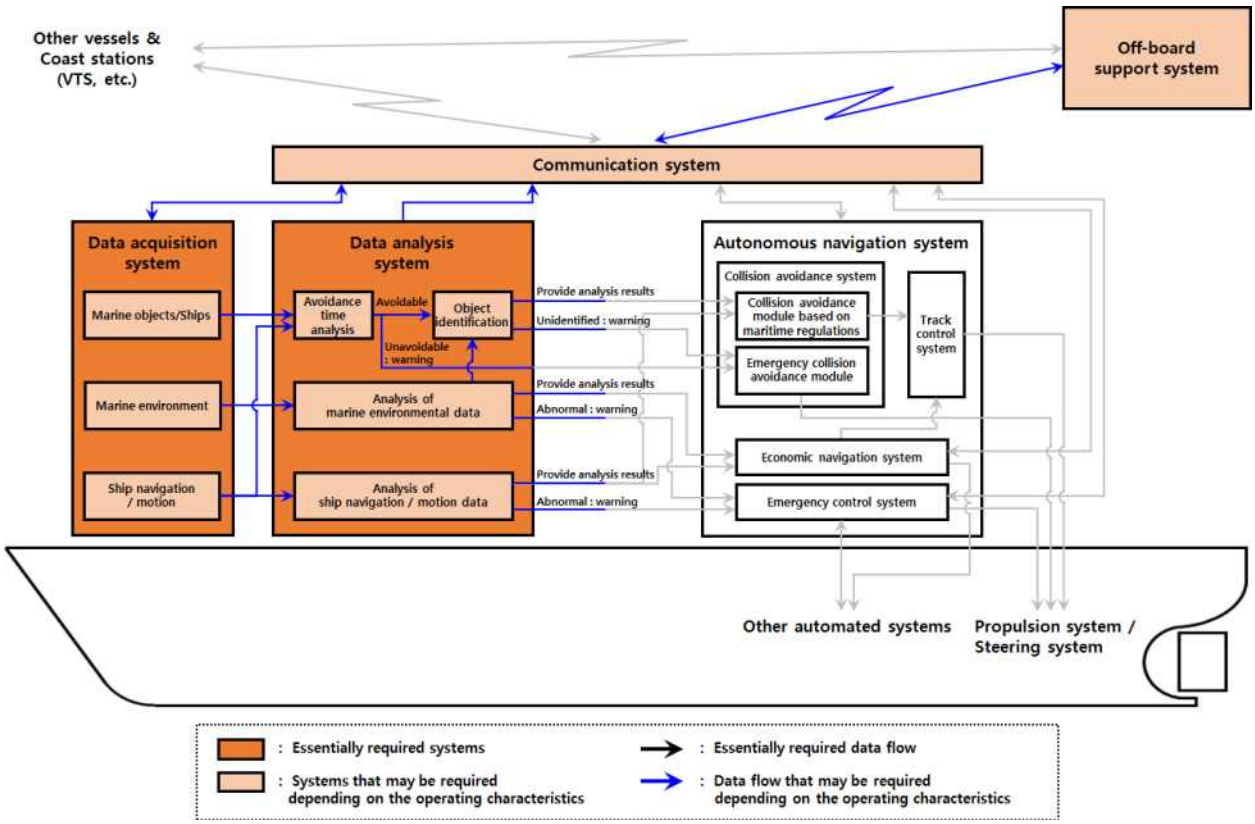

Fig 2.2 Autonomous system required for the ship of autonomy level 1 (AL1)

2. Autonomy level 2 (AL 2)

(1) Definition of autonomy level
  (A) Data acquisition and analysis: System
  (B) Decision-making: Operator (system support)
  (C) Action: Operator

(2) Ship characteristics: Ships equipped with a system to support operational decision-making within normal operating scenarios

(3) System configuration
  (A) Essentially required systems
    (a) Data acquisition and analysis system (system supporting autonomous navigation system functions)
    (b) Autonomous navigation system (collision avoidance module and/or economic navigation system in accordance with maritime regulations)
  (B) Systems that may be required depending on operating characteristics
    (a) Communication systems
    (b) Off-board support systems

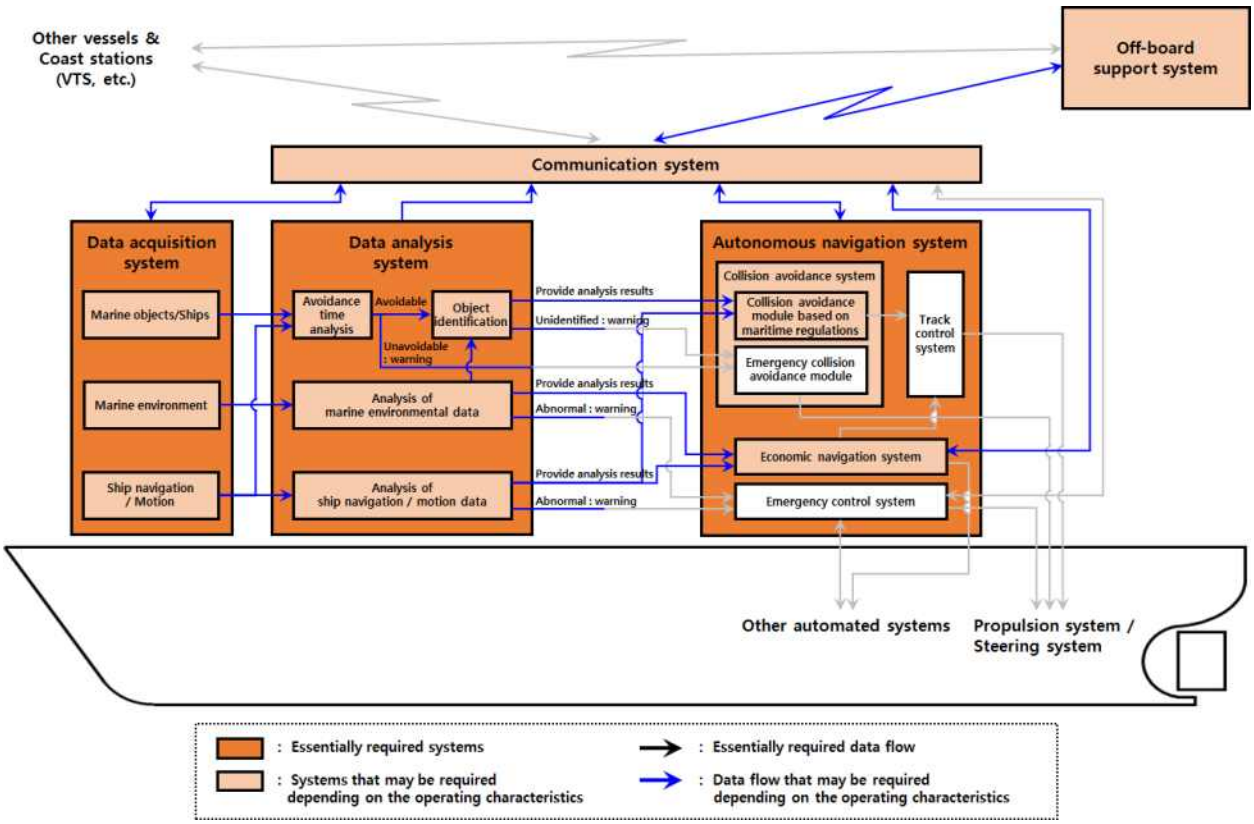

Fig 2.3 Autonomous system required for the ship of autonomy level 2 (AL 2)

3. Autonomy level 3 (AL 3)

(1) Definition of autonomy level
  (A) Data acquisition and analysis: System
  (B) Decision-making: System (normal operation scenario only / operator verification required)
  (C) Action: System (normal operation scenario only)

(2) Ship characteristics: Ships equipped with a system to support operational decision-making within normal operating scenarios (however, operator confirmation is required for decision-making, and if operator confirmation is not performed, the decision is withdrawn.)

(3) System configuration
  (A) Essentially required systems
    (a) Data acquisition system
      (i) Marine objects/ships detection sensor module
      (ii) Position and navigation sensor
    (b) Data analysis system
      (i) Avoidance point analysis module
      (ii) Avoidance object identification module
      (iii) Ship navigation/motion data integration/analysis module
    (c) Autonomous navigation system
      (i) Collision avoidance module in accordance with maritime regulations
      (ii) Track control system
  (B) Systems that may be required depending on operating characteristics
    (a) Communication systems
    (b) Off-board support systems

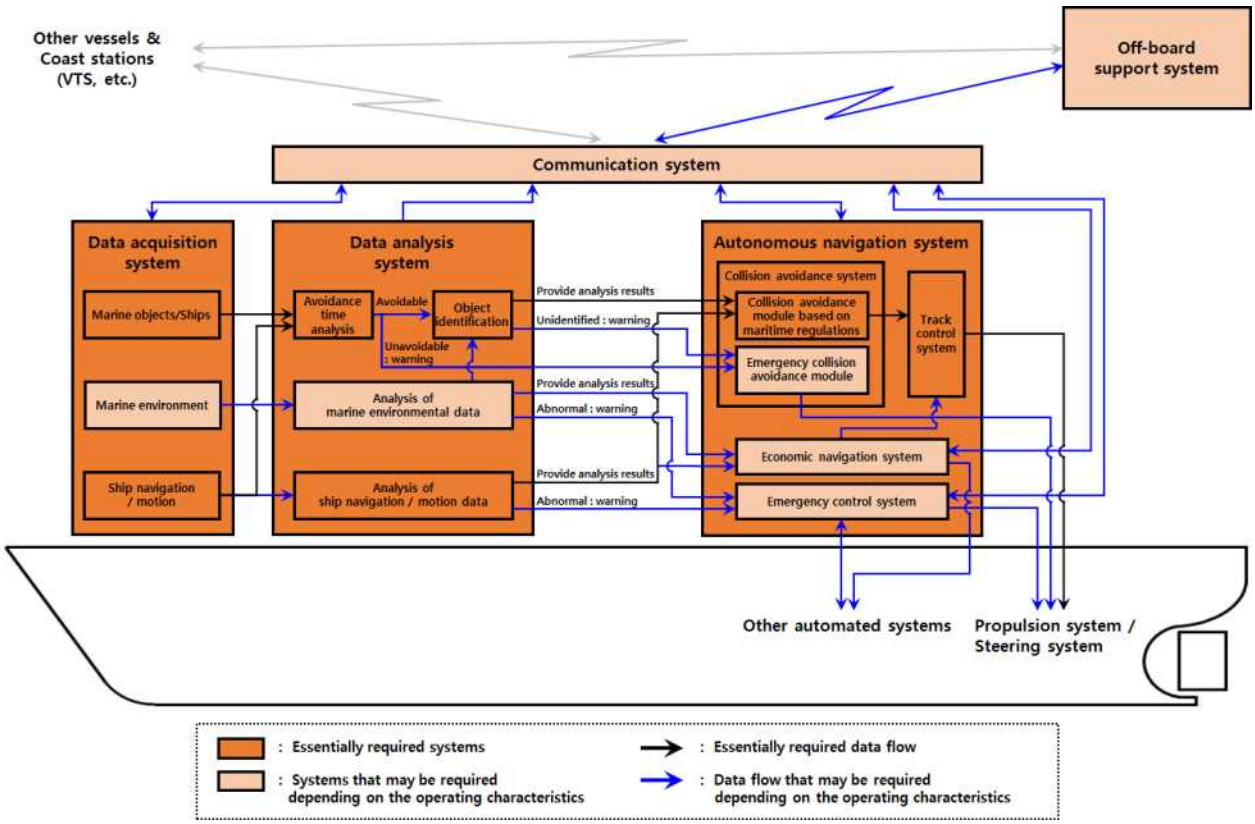

Fig 2.4 Autonomous system required for the ship of autonomy level 3 (AL 3)

4. Autonomy level 4 (AL 4)

(1) Definition of autonomy level
  (A) Data acquisition and analysis: System
  (B) Decision-making: System (operator monitoring)
  (C) Action: System (operator monitoring)

(2) Ship characteristics: Ships capable of autonomous operation under the conditions of operator monitoring (System-level response to abnormal operating scenarios (system failure, etc.): At the autonomous level, there is no need for boarding personnel, but a minimum number of people for monitoring/control can be boarded if there is no adequate communication system to monitor all decision making and execution information and to support remote control if necessary.)

(3) System configuration
  (A) Essentially required systems
    (a) Data acquisition system
      (i) Marine objects/ships detection sensor module
      (ii) Marine environment detection sensor module
      (iii) Position and navigation sensor
    (b) Data analysis system
      (i) Avoidance point analysis module
      (ii) Avoidance object identification module
      (iii) Marine environment data integration/analysis module
      (iv) Ship navigation/motion data integration/analysis module
    © Autonomous navigation system
      (i) Collision avoidance module in accordance with maritime regulations
      (ii) Emergency collision avoidance module
      (iii) Track control system
      (iv) Economic navigation system
      (v) Emergency control system
  (B) Systems that may be required depending on operating characteristics
    (a) Communication systems
    (b) Off-board support systems

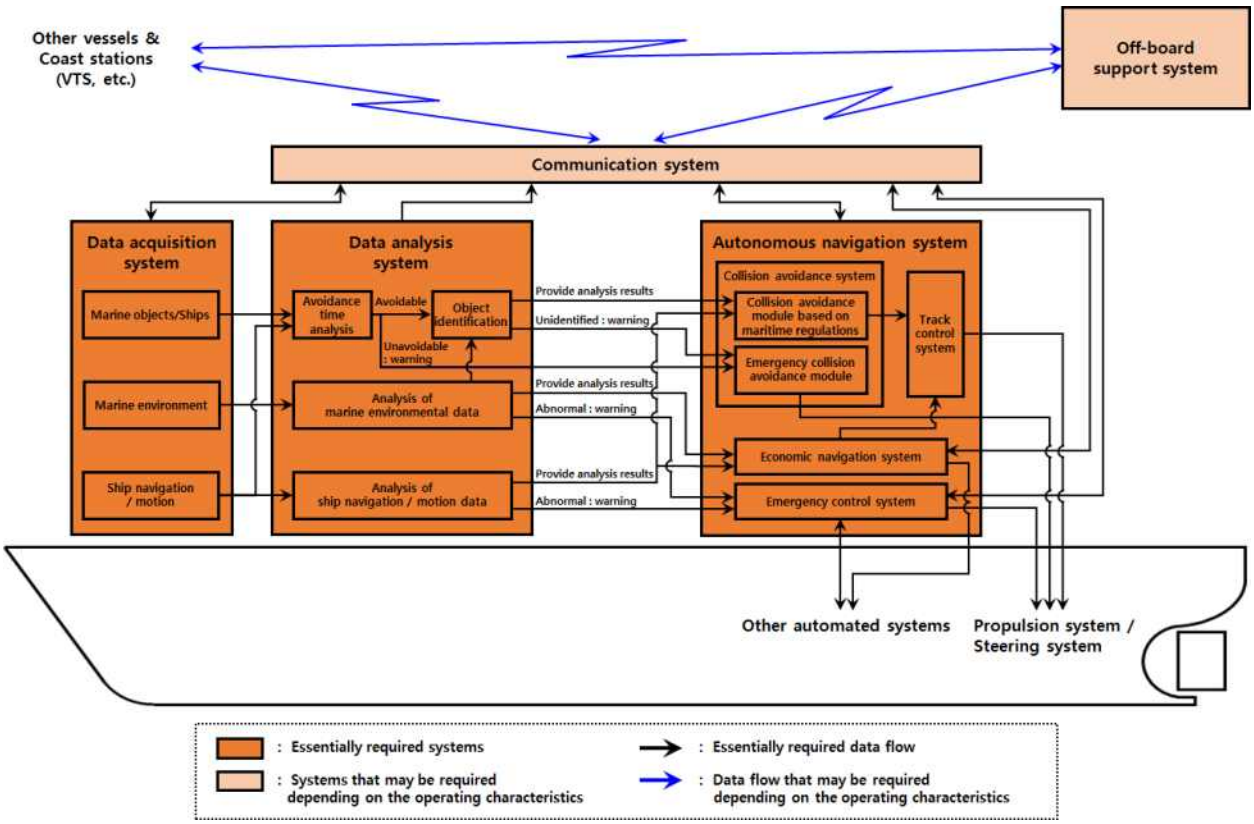

Fig 2.5 Autonomous system required for the ship of autonomy level 4 (AL 4)

5. Autonomy level 5 (AL 5)

(1) Definition of autonomy level
  (A) Data acquisition and analysis: System
  (B) Decision-making: System
  (C) Action: System

(2) Ship characteristics: Ships capable of autonomous operation (Operator in off-board support system monitors emergency situations)

(3) System configuration
  (A) Essentially required systems
    (a) Data acquisition system
      (i) Marine objects/ships detection sensor module
      (ii) Marine environment detection sensor module
      (iii) Position and navigation sensor
    (b) Data analysis system
      (i) Avoidance point analysis module
      (ii) Avoidance object identification module
      (iii) Marine environment data integration/analysis module
      (iv) Ship navigation/motion data integration/analysis module
    (c) Autonomous navigation system
      (i) Collision avoidance module in accordance with maritime regulations
      (ii) Emergency collision avoidance module
      (iii) Track control system
      (iv) Economic navigation system
      (v) Emergency control system
    (d) Communication systems
    (e) Off-board support systems

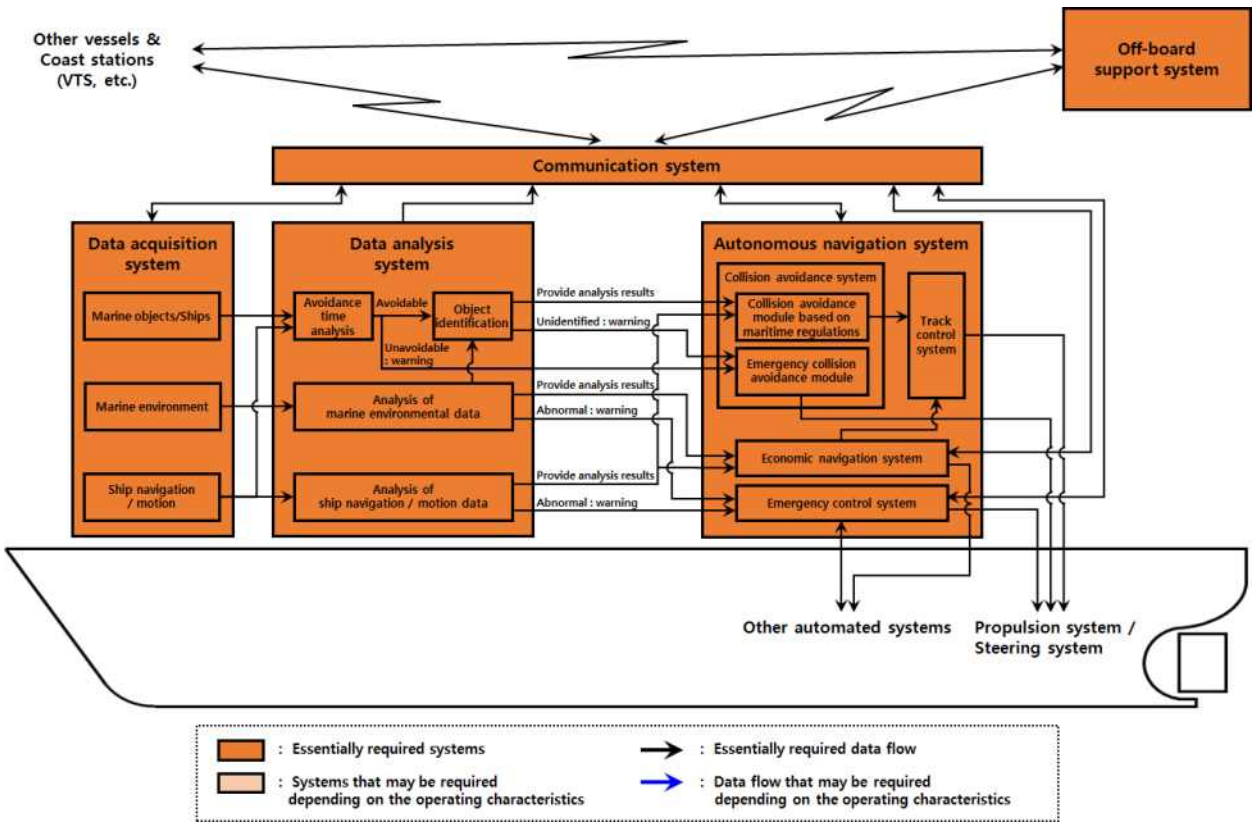

Fig 2.6 Autonomous system required for the ship of autonomy level 5 (AL 5)

Section 2 Requirements for Autonomous Systems and Autonomous Ships

201. Basic requirements for autonomous ships

1. Autonomous ships shall be operated within the safe operation scope specified beforehand, and system reliability and safety shall be ensured within the range.

(1) An autonomous system shall be designed with all safety hazards reasonably predictable for safe operation.

(2) It shall be designed to cope with major defects or safety-related emergencies and shall be designed in such a way that the effects on a single fault are eliminated.

2. The responsibility for the autonomous ship operation procedures shall be clarified and properly reviewed and monitored.

(1) The responsibility for the operator shall be specified and officially assigned.

(2) When transferring control of autonomous ships to internal or external personnel, the relevant responsibilities shall be clearly allocated and officially assigned in accordance with the procedures specified beforehand.

3. A autonomous ship shall be equipped with a voyage data recorder(VDR) that stores data on the ship's internal and external conditions.

(1) The stored data may include the following information.

(A) Internal system status monitoring (fault indication, subsystem operation status, etc.)

(B) Data communication with external system

(C) Situation recognition sensor data (radar, observation camera data, etc.)

(D) Decision-making (avoidance action, speed change, etc.)

(E) Performed functions (activated system, activated warning signal, etc.)

(2) To save memory, data storage in VDR can be adjusted as a circular storage method that saves recent data while sequentially deleting old files. When using the circular storage method, the VDR shall be able to store the data record of sufficient time that the post-operation analysis is not problematic even if the old data is sequentially deleted, and the accident data shall not be deleted.

4. Ships on which persons are on board shall comply with all codes and conventions involved.

5. It shall comply with all relevant provisions of the International Convention adopted by IMO or local laws. If necessary, the exemptions or equivalent solutions shall be expressly approved by the Administration.

202. Basic requirements for autonomous systems

Each autonomous system shall perform the functions described in **102.**, and the following basic requirements shall be satisfied when performing the functions.

1. Data acquisition and analysis system

(1) The external conditions related to collision and environment and the internal conditions related to the operation and motion of the ship shall be properly recognized for safe operation of the autonomous ship, and the analyzed results should be communicated to the autonomous navigation system or operator with sufficient time to be safely processed.

(A) Data collected from the sensors shall be appropriately converged / analyzed and presented to the operator to avoid overloading the information that could degrade the accuracy of the ship's condition / situational awareness.

(B) Data storage shall be appropriate to the amount of data collected. Procedures shall be provided for deleting unnecessary or outdated data and recovering to a normal state when the capacity is exceeded.

(2) The marine objects/ships detection sensor module shall be able to identify obstacles and track moving or stationary objects.

(A) The sensor module can be applied as a combination of various sensors depending on the mission and operation scope of autonomous ships. In addition to the sensor devices installed on the ship, the necessary information can be obtained through other sensor devices installed in the base station or other places.

(B) When using the information collected by the AIS, operational limits such as 'Uncertainty of ship information by user input method', 'Restrictions on radio wave transmission range and

visible path', and 'update frequency of AIS ship information' shall be considered.

(3) Sensor shall be designed to withstand the operating environment.

(4) Marine objects/ships detection sensors with autonomy level 3 (AL3) or higher, where the system-initiated action is performed, shall be able to detect all limits of the operating range such as reduced visibility.

(5) The ship navigation / motion data shall include the ship's motion information and location information.

(6) If there are a marine environmental data integration/analysis module and/or a ship navigation/motion data integration/analysis module, a warning shall be issued to the operator when the operational limits are approached. If an emergency control system is installed, the information shall be forwarded to the autonomous system so that predefined safety procedures can be carried out when the operational limit are exceeded.

(A) For ships with an autonomy level 4 (AL4) or higher in which the system makes decision-making and action and whose crews do not embark on the maintenance work due to system failure, it shall be possible to collect and analyze information on the operational status and soundness of the main engine, auxiliary engine and shafting, and visual monitoring shall be provided with one or more CCTV systems. The results collected and analyzed shall be transmitted, recorded and documented in a format suitable for verification by the off-board support system operator.

(7) Ships equipped with an economic navigation system shall independently collect marine environmental data from their own sensors. Accumulated data such as wind speed and wave frequencies are provided to the off-board support system and can be used to support the future economic operations.

2. Autonomous navigation system

(1) The autonomous navigation system shall properly control ship and equipment in accordance with the software embedded in the off-board support system and/or the commands of the off-board support system.

(2) The operator shall be able to control the autonomous navigation system at any time.

(3) The navigation plans shall be established taking into account the waypoints, the turning angle and the speed of safety, and shall be defined and updated at any time by the operator.

(4) If the ship is equipped with a track control system, it shall notify the operator of any departure from the planned route, and an alarm shall be issued when the deviation exceeds the specified limits. The tolerance of deviation shall be set according to the navigational situation (navigation the open sea, marine traffic volume, etc.) to avoid the risk of information overload to the operator.

(5) Operational factors(navigation speed, etc.) for all operational scenarios shall be set taking into account the operation scope of each autonomous system.

(6) In the case of no complete autonomous operation of the navigation and berthing/leaving within the port, control shall be transferable to the onboard operator or the operator in off-board support system.

(7) Automatic avoidance technique, based on navigational regulations (COLREG, etc.) applicable to existing ships for all identified ships in the vicinity and appropriate ship maneuvering, shall be applied to autonomous navigation systems equipped with collision avoidance module based on maritime regulations.

(8) Navigation plans shall be established to avoid extreme environments when equipped with an economic navigation system and a track control system, since safe operation of ship may be difficult by the system in the event of heavy weather.

(9) Ship equipped with an emergency collision avoidance module shall perform appropriate avoidance maneuver if a near collision situation is identified. The avoidance maneuver may follow the following procedure.

(A) Deceleration

(B) Prediction and Estimation movement of obstacles

(C) Departure from initial ship path

(10) If the system can not find a solution to the collision avoidance for the ship with an autonomy level 4 (AL4) or higher in which the system makes decision-making and action, a predefined safety procedure shall be carried out.

(11) Ships equipped with an economic navigation system shall be capable of performing the following functions.

(A) Comparing and evaluating the weather data collected by the ship with the received weather

forecast
(B) Estimation of current and future weather conditions according to the ship's voyage plan through the above data combination
(C) Perform route optimization according to route optimization criteria, taking into account the estimated weather conditions and the stability and maneuverability of the ship

(12) Ships equipped with emergency control systems shall be able to manage in a reliable way situations that could potentially threaten the safety of the ship.
(A) If an abnormal condition affecting the operation is identified, it should be possible to automatically restore to a safe situation or at least automatically mitigate damage based on a predefined algorithm. Abnormal condition affecting the operation means that it is in an environment where normal operation is not possible from analysis results(marine environment, ship navigation/motion status) through data acquisition and analysis system, when the ship navigation/motion status are determined to be abnormal, or when a serious system error is detected through other automation systems which may affect the operation.

(13) For ships with an autonomy level 4 (AL4) or higher in which the system makes decision-making and action and whose crews do not embark on the maintenance work due to system failure, the system should be designed to be resilient to errors.

(14) For ships with an autonomy level 4 (AL4) or higher in which the system makes decision-making and action and whose operators do not embark, if the connection between the ship and the off-board support system breaks beyond the predefined time, a predefined safety procedure shall be carried out. The safety procedures may include the followings.
(A) Operator's manual control attempt
(B) Slow operation to the next waypoint
(C) Maintain current position
(D) Operation to previous waypoint

3. Communication systems

(1) Communication lines are to be have adequate coverage, bandwidth, and reliability to safely control autonomous ships and autonomous systems, and data quality is to be adequate for autonomous levels and functions required under normal and predictable abnormal conditions.
(A) The communication network capacity, reliability, availability, maintainability, safety and security performance required under normal conditions and predictable abnormal conditions are to be considered.
(B) The performance of the communication network is to be take into account the variability and vulnerability of wireless data communications, personal data communications, and the public data communications utilized.
(C) The communication network structure is to be provide adequate resilience to interference, performance degradation, and failure.
(D) In order to prevent communication errors between the outboard support systems and the ship (or between multiple ships), a secure data management protocol is to be developed and the data link is to be properly encoded and encrypted to prevent interference.
(E) If a failure occurs in the external communication, a backup procedure for transmitting the important data is to be executed. In the event of a failure, automatic switchover between the main communication path and the backup path is to be made, and an alert is to be provided to the operator. Independent communication systems are to be used as the main path and backup path respectively.
(F) A transmission control means for confirming the completion of data transmission by applying a cyclic redundancy check or an equivalent acceptable method are to be designed and provided. If corrupted data is detected, it is to be limit the number of retries to maintain the total acceptable response time.

(2) Required communication network performance requirements and data quality requirements are to be defined in the operation plan.

(3) During remote control, the outboard operator is to be able to recognize the communication latency that causes a delay between the control action and the actual ship response. The wait time is to be continuously displayed during operation and is to alert the operator if the wait time exceeds the predefined limit.
(A) Control feedback If a new command is issued before the loop cycle is completely processed, a control error may occur between the entities. Therefore, the communication protocol should be designed in consideration of this and the operator should be informed of the information about the control loop feedback time and the appropriate system response The shortest in-

terval information should be provided.

(4) The type of data and the interval and amount of transmission periodically provided to the outboard support systems are to be appropriately changed when the control mode is changed (for example, autonomous operation → remote control). Where necessary, traffic-intensive situations in coastal waters such as ports are to be able to provide maximum availability and minimum latency using land-based communications networks.

(5) All data is to be identified by priority and the transmission software is to be designed taking into account the priority of the data.

(A) Warnings for systems that provide start-up, control, emergency signaling, or safety functions are to be precede other data in all operating modes of the system and are to be clearly distinguished.

(6) Functions that must operate continuously to provide essential services that rely on wireless data communication links are to have alternative means of taking action within an acceptable time frame.

(7) The network is to detect the failure of the link itself and detect a data communication failure at the node connected to the link. Appropriate warning notifications are to be provided when detecting communication faults.

(A) If the operator does not embark on board as a ship with an autonomous level 4(AL4) or higher that the system is to make decisions and implement, a predefined safety procedure is to be carried out if an unexpected fatal loss or failure occurs in the communication line.

(8) Radio waves emitted from communication lines are not to be interfere with other systems, and radio waves emitted from other systems are not to be interfere with the performance of communication lines.

(9) The communication systems are to be designed to allow access only to authorized personnel.

(10) The transport protocol is to conform to recognized international standards. Satellite communication providers are to be recognized by the International Maritime Satellite Organization(IMSO).

(11) Communication networks and systems are to comply with the following international standard requirements:

(A) IEC 61850-90-4, Network engineering

(B) IEC 61162, Maritime navigation and radiocommunication equipment and systems - Digital interfaces

(C) IMO MSC.252 (83), Performance Standards for Integrated Navigation Systems (INS)

4. Outboard support systems

(1) Information related to data collection and analysis is to be provided to outboard operators for safe navigation and efficient functioning of autonomous ships.

(2) If the operator does not embark on board as a ship with an autonomous level 4(AL4) or higher that the system is to make decisions and implement, the followings are to be considered.

(A) Function to control the autonomous ships gainst possible dangerous situations during operation is to be provided.

(B) Operators are to be able to reprogram the autonomous ship's mission and control it at any time.

(C) Means of communication with the other decision-making bodies (eg, VTS, port authorities, shipping companies, etc.) participating in the operation of own ship and autonomous ships are to be provided.

(D) It is to be able to respond to requests from other ships using wireless communications or video signals.

(3) It is to be established appropriate control transfer procedures to prevent control confusion among multiple operators. And, in principle, ensure that no more than two control are exercised at the same time.

(4) In the event of system failure, hearing and visual alerting are to be provided to the operator and warnings presented to the equipment under autonomous/remote control are to be clearly distinguishable and categorized according to the type of response required of the crew and outboard operators.

(5) An outboard operators with decision-making authority over the operation are to have the appropriate qualifications for the ships subject to support and are to have access to at least the same level of information as the crew.

(6) The control systems are to be designed to reflect human factors. Control devices are to be easily identifiable and are to be arranged in a logical manner reflecting their function, manner of operation and their importance. The following considerations are to be considered when designing

an outboard support systems.
(A) The appropriate number of autonomous ships that operators can safely control.
(B) Maintain control connection with autonomous ships and, when control connection is broken or damaged, maintain proper operation and notify it appropriately
(C) Communication loss and recovery function
(D) Data logging function
(E) Login and password authentication, machinery or software upgrade function
(F) Automatic safeguard function to prevent unauthorized use of autonomous ships by third parties

203. Other requirements

1. An autonomous systems are to be safely operated by an appropriate number of qualified and experienced staff.

(1) The organization and size of the operational team are to be determined so that autonomous ships can be deployed, operated and retrieved, or fully countered based on relevant knowledge and experience in predictable emergency situations.
(2) The required training completion, and the appropriate level of qualification, proficiency, experience and health status are to be confirmed for all operational scenarios, including safety and technical issues.
(3) The system operators are to have sufficient operational or service experience with the controlled ships of the same class.
(4) Direct/indirect communication between team members is to be considered.
(5) Instructions for the control, operation and maintenance of the autonomous ships are to be provided to the operators.

2. Structural arrangements are to be made to ensure safe access to the structural and installation equipment/systems during autonomous ship's maintenance.

3. A preventive maintenance systems are to be introduced if the crew is not aboard to carry out maintenance work due to a system failure as a ship with an autonomous level 4 (AL4) or higher that the system makes decisions and executes.

(1) The systems are to be able to carry out corrective actions to prevent malfunctions according to the result of the condition evaluation of the machinery.
(2) The systems are to be able to identify the required pre-orderable spare parts and transmit the relevant information to the operators.

Section 3 Approval procedure of autonomous ships

301. General

1. The general approval procedure for autonomous ships is shown in **Fig 2.8**.

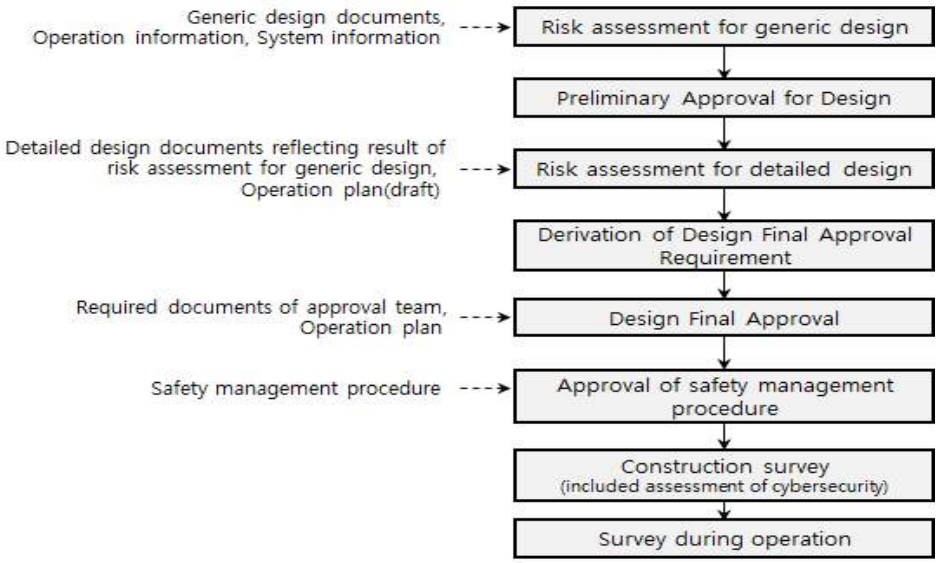

Fig 2.8 The general approval procedure for autonomous ships

302. Approval procedure

1. Risk assessment for generic design

(1) The developer is to submit to the approval team of Our Society the generic design document including the document stating operational information and system information specified in **Ch 1, 201. 2** of these Guidance.

(2) The approval team is to establish a risk assessment plan with the developer based on the generic design document, operational information and system information. The risk assessment plan is to include, at a minimum, the following:
- (A) Main interest risk definition and corresponding risk assessment criteria
- (B) Hazard identification work plan (including method and scope)
- (C) Hazard analysis and evaluation work plan (including method and scope)
- (D) Work plan (including method and scope) for generic design related experiments, calculations, analysis, simulations, etc.
- (E) List of functional requirements condition and safety requirements condition (draft)
- (F) Items of assumption, exemptions and restrictions

(3) The developer evaluates the risk according to the risk assessment plan under the supervision of the approval team. The following considerations are to be taken into account when assessing risk. And the relevant work processes and results are to be documented.
- (A) Identified risk factors, the frequency and magnitude of each risk factor
- (B) Identifiable safety devices included in the design
- (C) Risk model for quantitative risk analysis
- (D) References, assumptions, uncertainties, sensitivity, etc.
- (E) Comparison of the calculated risk level with the evaluation criteria
- (F) Risk control measures and risk reduction levels
- (G) Items requiring additional risk analysis, testing, calculation and analysis, simulated testing, etc.
- (H) Cautions for construction and operation

(4) The approval team reviews the rationality and appropriateness of the risk assessment process and results based on the risk assessment plan.

2. Preliminary Design Approval

(1) The approval team is to review the feasibility and safety level of the generic design to determine whether a design preliminary approval certificate is issued.
(2) Design preliminary approval does not guarantee final design approval.

3. Risk assessment for detailed design

(1) The developer submits the detailed design document and operation plan(draft) reflecting the risk assessment result of the generic design to the approval team.
(2) The approval team identifies additional or detailed design information and modified design content as compared with the generic design, and establishes a risk assessment plan with the developer based on the operation plan. The key considerations in establishing a risk assessment plan are the same as those for establishing a risk assessment plan for a generic design, but the functional requirements and safety requirements for approval are to be further elaborated.
(3) The developer evaluates the risk according to the risk assessment plan under the supervision of the approval team, and documents the related work processes and results.
(4) The approval team reviews the rationality and appropriateness of the risk assessment process and results based on the risk assessment plan.

4. Derivation of Design Final Approval Requirement

(1) The approval team draws up the final design approval requirements based on the risk assessment plan and the results of the generic design and the detailed design. The design final approval requirements are to include, at a minimum, the following:
(A) possible risk categories and risk assessment criteria
(B) Rational basis for limitations and restrictions applied to risk analysis
(C) Requirements to meet the assumptions and conditions applied for risk calculation
(D) Requirements for the successful functioning of the safety device and the risk control means
(E) Requirements to achieve the target function of the design.
(F) Verification work to demonstrate the fulfillment of the above requirements, if necessary.
(2) The items listed in the final approval requirements are drafts of survey requirements related to construction and operation.

5. Design Final Approval

(1) The developer submits the operation plan and all documents requested by the approval team for issuance of the design final approval certificate.
(2) The approval team determine the suitability of the design for the final approval requirements of the design and review the feasibility and safety level of the entire detailed design or the target design to determine whether a design final approval certificate shall be issued.
(3) The design final approval certificate is the basis for the construction of the design subject and the start of production.

6. Approval of safety management procedure

(1) The developer shall draw up the survey requirements during manufacture and operation on the basis of the safety devices, risk control measures, precautions and restrictions identified in the final approval process of the design and document the safety control procedure sufficiently reflecting the contents of the relevant inspection requirements And submit it to the approval team for approval.
(A) The requirements of construction Survey is to ensure that the safety level of the design, which has been approved by the final approval during the construction and manufacturing of the ship, is maintained sufficiently without deterioration. In general, it includes completion test and various test for autonomous systems software and hardware, system interoperability test between each autonomous systems, and survey requirements for sea trial.
(B) During the operation, the survey requirements are to ensure that the safety level of the design, which has been proven by the final approval in the course of providing the intended service, is maintained without deteriorating the level of safety.

7. Construction survey

(1) Survey is to be carried out in accordance with the construction survey requirements set forth in the safety management procedures for system manufacturing and shipbuilding.
(2) During the construction survey, a cyber security evaluation according to Ch 1, 301. and 302. of this Guidance is to be carried out.
(3) If the design content and assumptions identified in the design final approval procedure are

changed at the construction stage and the ship's risk is affected, the relevant risk are to be re-interpreted and reassessed at the discretion of the approval team. The contents of survey requirements and safety management procedures may be revised according to the results.

8. Survey during operation

(1) The ships are to be operated in accordance with the operation plan.
  (A) The ships are to be operated in accordance with the operational purpose indicated in the operation plan.
  (B) The ships are to be operated within the operation scope as specified in the operation plan.
  (C) The ships are to be operated in accordance with the operational scenario presented in the operation plan.
  (D) All risk situations occurring during operation are to be identified in advance under the normal and abnormal operating scenarios presented in the operation plan, and mitigation measures are to be appropriately prepared for them.

(2) The survey are to be carried out in accordance with survey requirements during operation set out in the safety management procedure.

(3) If the design content and assumptions identified in the design final approval procedure are changed at the construction stage and the ship's risk is affected, the relevant risk are to be re-interpreted and reassessed at the discretion of the approval team. The contents of survey requirements and safety management procedures may be revised according to the results.

302. relevant test

The tests required for autonomous systems and autonomous ships are to be in accordance with the safety management procedure for the ships in question. In general, the following tests may be required and repeated tests may be required to verify the consistency of the test results.

1. Software test

The software constituting the autonomous systems are to be approved according to the standards deemed appropriate by the Society. The relevant test procedures and maintenance procedures are to be reviewed during the risk assessment of the generic design and detailed design, and it is to be included in the survey requirements and safety management procedure for the ships in question.

(1) It is to be confirmed that the software development work has been performed according to the procedures defined by the software manufacturer and agreed upon in the approval team.

(2) The software modules of the application software are to be tested individually and then integration test is to be carried out.

2. Completion test of autonomous systems

An autonomous systems composed of several devices are to be tested for effectiveness by performing an integration test after completion of the configuration. For example, in the case of a data acquisition and analysis system that is integrated with various sensors, it is necessary to verify that the entire system is working properly by performing a completion test on the integrated system as well as individual tests on each sensor.

(1) The roles and responsibilities for integrating systems, equipment and components, the integration procedures, and the point at which verification is performed is to be defined in the safety management procedure.

3. Onboard test

It is to be confirmed that it is working as close to actual as possible after installation on board. And it is to be confirmed that a predefined safety system is working effectively in case of system failure or danger.

4. Interworking test for autonomous systems

Through the interworking test between the autonomous systems installed in the ship, it is to be check whether the data transfer between the systems and the performance of the functions are correct. This test may be included in the sea trial.

5. Sea trial

It is to verify that the system is operating effectively for the autonomous ships operating within the operation scope and risk presented in the operation plan through the sea trial. ⚓

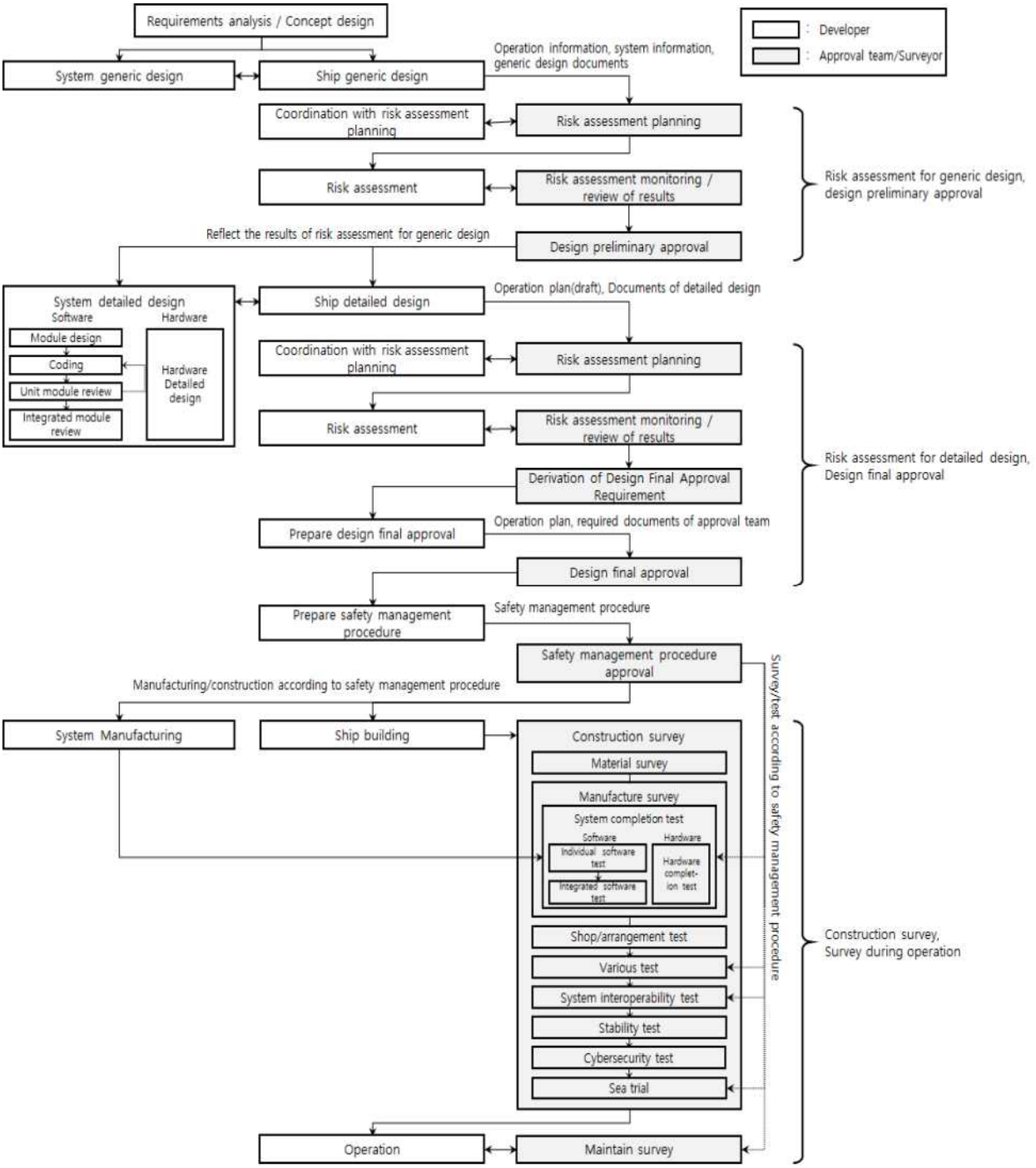

Fig 2.9 The general approval procedure for autonomous ships(Detail)

CHAPTER 3 RISK-BASED APPROVAL

Section 1 General

101. General of Risk-based approval

1. Prescriptive regulations which is based on empirical knowledge is difficult to apply to the unprecedented novel concept design and may sometimes restrain the level of innovation that is feasible in design.
2. An essential prerequisite for widespread use of novel concept design is a predictable and reliable process of submitting and approving the design making full use of latest risk assessment tools and techniques. Risk-based Approval is the approval of such risk-based design.
3. Prescriptive regulations prescribe each requirement for certain components, systems or functions of the whole ship. Risk-based design may deviate from all or part of such prescriptive requirements and there may be different levels of approval depending on how deviate from the prescriptive requirements.
4. Prescriptive regulations prescribe each requirement for certain components, systems or functions of the whole ship. Risk-based design may deviate from all or part of such prescriptive requirements and there may be different levels of approval depending on how deviate from the prescriptive requirements.
5. In a risk-based approval process, the approval basis is to be defined based on the submitted design in terms of risk, and design analysis and review of result are to be carried out according to the approval basis. Therefore, in a risk-based approval process, the approval basis is to be newly defined wherever the design is modified.
6. The relevant provisions of risk-based approval are subject to the respective requirements of the **Guidance for Approval of Risk-based Ship Design.**

102. Applications

1. The design of the ship subject to the **Guidance for Approval of Risk-based Ship Design** is as follows.
   (1) Designs of ships and ship systems which intend to apply novel concept and non-proven technology which can not directly apply existing regulations.
   (2) Designs which intend to apply a equivalent or alternative at higher level of existing regulations.
2. The risk-based approach and the risk-based approval process defined in this Guidance may be applicable to all area related to ship design, but are not limited to specific technical, regulatory field.
3. The risk-based approval process is to take into account relevant risk which can occur during the whole life cycle in course of design, construction, operation and dismantling.
4. When applying this Guidance, substitution of design measures to reduce risk with operational or procedural measures is not permitted. Design measures are to take priority over operational or procedural measures.
5. For successful application of this Guidance, all stakeholders are to exchange their opinions from the start of design to final approval through continuous mutual discussion.

Section 2 Considerations when approving risk-based design

201. General *(2020)*

The risks associated with the safety and emergency situations of autonomous ships due to failure and damage to the ship's internal systems, external sudden environmental changes or natural disasters are as follows.

(1) Movement/liquefaction/release of cargo
(2) Fire and Explosion
(3) Immersion/sinking
(4) Conflicts
(5) Blackout
(6) Bad weather
(7) Bad visibility
(8) Complex marine environment
(9) Unidentified object
(10) Marine pollution
(11) Dangerous goods leakage

202. Considerations when approving risk-based design *(2020)*

A risk assessment is to be address all possible risk factors that may be potentially attributable to an undesirable event or accident. General risk factors that take into account the functional aspects of autonomous ships may be presented as follows:

1. Security

The risks for security-related cyber attacks or physical intrusion from outside are as follows.

(1) cyber attacks
  (A) Unauthorized software installation including malicious code
  (B) Unauthorized modification of data or software
(2) physical intrusion
  (A) Unauthorized entry from outboard
  (B) Passengers accessing the onboard system

2. Communication

The risks associated with systems of the autonomous ships, the Outboard Support Systems, the GPS or the satellite, as well as the communication between autonomous ships and other autonomous ships or general ships are as follows.

(1) Failure to connect with outboard support systems
(2) Connection failure with GPS, satellite, etc.
(3) Connection failure between ships
(4) Decrease in communication quality
(5) Data
  (A) Wireless communication data loss
  (B) Data transmission cycle
  (C) Communication information error

3. Hull structural safety

The risks for hull structural safety as floats are as follows.

(1) Drainage
  (A) Seawater ingress through hatch covers
  (B) Malfunctions of bilge well level switch due to trash in the well
  (C) Negligence of crew on bilge alarm
  (D) Blockage of bilge well due to trash in cargo hold
  (E) Failure of general service pumps or bilge pumps
  (F) Failure of bilge well suction valves
  (G) AMS(alarm monitoring system) failure
(2) Weight control
  (A) Inattention or misjudgement of crew
  (B) Failure of fuel oil level gauging system
  (C) Failure of loading computer
  (D) Failure of ballast water system

4. Cargo

The risks for cargo of the autonomous ships as follows.

(1) Cargo storage
  (A) Failure of power supply for reefer container(failure of transformer, disconnection between socket and plug, breakage of socket and plug)
  (B) Failure of reefer container controller and refrigerator

(2) Cargo safety
  (A) Leakage of flammable or explosive cargo
  (B) Leakage of toxic cargo
  (C) Flooding in cargo holds

5. System

The risks for system of the autonomous ships as follows.

(1) Propulsion
  (A) Torque generation or control
    (a) BMS failure
    (b) ECS failure
    (c) ECU failure
    (d) Failure of engine internal sensors for condition monitoring
    (e) Failure of internal components of main engine
    (f) Excessive vibration
    (g) Fire accidents in engine room
  (B) Propulsion power generation(transfer)
    (a) Shaft damage
    (b) Shaft bearing damage
    (c) Stern tube sealing damage
  (C) Auxiliary machinery system for propulsion
    (a) Fuel oil supply system failure
    (b) Engine cooling system failure
    (c) Engine lubrication system failure
    (d) Air supply system failure
    (e) Boiler failure
    (f) Turbo charger failure
    (g) Failure of scrubber or SCR
    (h) Fire accidents in engine room

(2) Steering
  (A) Steering force generation
    (a) Rudder damage or deformation
  (B) Rudder angle control
    (a) Hydraulic power pump failure
    (b) Hydraulic locking due to solenoid valve failure (in case of valve control type steering gear hydraulic system)
    (c) Hydraulic locking due to torque motor failure (in case of torque motor type steering gear hydraulic system)
    (d) Hydraulic oil leakage
    (e) S/G control system failure
    (f) Damage of S/G control system electric cables
    (g) Failure of HCS module in the autopilot
    (h) Failure of power supply to S/G control system, hydraulic pumps, etc.
  (C) Rudder angle monitoring
    (a) Repeat back unit failure
    (b) Rudder angle indicating system failure

(3) Electric power system
  (A) Power generation
    (a) Generator failure
    (b) Generator controller failure
    (c) ICMS failure (power failure)
    (d) RPM pick-up sensor failure
  (B) Power distribution
    (a) Electrical problems on main switchboard (e.g., short circuit, electric leakage, etc.)

(b) Component failure of main switchboard
(c) Ingress of water into main switchboard
(d) Failure of distribution boards
(e) PMS failure
(f) Damage on cable sheath
(C) Power storage
(a) Battery performace decrease due to aging
(b) Failure of battery discharge board
(c) Overcharge of battery
(d) Failure of ICMS's UPS system
(4) Autonomous system
(A) IT system failure
(B) Sensor failure
(C) Actuator failure
(D) System network failure
(E) System update failed
(F) Interface between operator and system
(a) Operator mistakes
(G) System integration
(a) Interfaces between subsystems and components
(b) Unauthorized modification of data or software
(H) Control crosstalk
(a) Unexpected remote activation
(I) Electromagnetic interference
(J) Hazardous Equipment
(K) Maintenance

6. Outboard Support Systems

The risks associated with outboard support systems are:
(1) A person's mistake in remote control / maintenance
(2) Qualifications and training of land personnel
(3) Fire
(4) Intrusion from the outside
(5) Cyber attack

Section 3 Measures to reduce risk

301. Measures to reduce risk *(2020)*

Measures to mitigate or mitigate risk factors for autonomous ships may be presented as follows.

1. Security

It is to be satisfy the applicable requirements of the **GUIDANCE FOR MARITIME CYBER SECURITY SYSTEM**.

2. Communication

(1) Redundancy for communication links or equivalent means is to be considered.
(2) The system is to be equipped with equipment capable of detecting GPS, satellites, and communication errors between ships. If a communication error is detected, the ship is to be able to take appropriate action according to the predefined algorithm.
(3) The operators of the outboard support systems are tobe able to respond appropriately to other ships communications to the autonomous ships while monitoring the radio channel appropriately.
(4) Standards for data management is to be provided.

3. Hull structural safety

(1) Where hatch covers are to be installed, hatch covers with high reliable weathertight performance are to be installed.
(2) Level gauges are to installed with high reliability level type rather than a floating type for bilge wells.
(3) Where bilge wells are installed at the bottom of the hold, bilge wells are to be installed at several places in the hold.
(4) Safe navigational guidance are to be provided, taking account of the cargo hold flooded.
(5) It is to be stored in real time and transmitted to shore for information on alarms and suction valves status related to bilge.
(6) The ballast water treatment system is to operated automatically.
(7) Loading computer which can cover the ballast water control scenarios based on fuel oil consumptions during voyages is to be provided.
(8) Automatic evaluation system on the variations of stability and hull girder moment followed by fuel consumption are to be provided. Evaluation data is to be stored in real time and transmitted to shore.
(9) HMS(Hull Monitoring System) and FMS(Fatigue Monitoring System) for real-time monitoring of hull structure is to be installed.
(10) Highly reliable sensors are to be installed in HMS and FMS.
(11) Hull structural stability assessment system is to be based on HMS and FMS measurement data.
(12) Autonomous navigation system, which decides the ship's heading angles and speeds and execute commands, based on the structural safety evaluation results and current ship operating data, is to be installed.
(13) HMS and FMS measurement data is to be stored in real time and transmitted to shore.
(14) Robust and seamless data transmission is to be ensured in wireless networks.
(15) Cybersecurity is to be ensured for data transmission and reception.

4. Cargo

(1) Where cargo temperature control is required, reliable remote temperature control and power supply systems are to be installed.
(2) A system is to be installed to automatically assess the condition of the cargo.
(3) Cargo status information is to be stored in real time and transmitted to shore.
(4) Where cargo containing toxic are stored, safety manual to enter the cargo holds is to be provided.
(5) CCTVs are to be installed on the deck to recognize thermal images.
(6) Equipment installed inside the cargo hold (e.g. ventilation fans, fixed fire extinguishing system, fire detection alarms, CCTV, bilge systems, etc.) is to be remotely controlled from outside the ship.
(7) Cargo hold monitoring data (eg CCTV, fire/smoke detection, cargo hold vent signal, deck condition, etc.) is to be stored in real time and available for transmission on shore.
(8) Autonomous evaluation and response system for a fire/explosion accident is to be provided.
(9) Robust and seamless data transmission is to be ensured in wireless networks.
(10) Cybersecurity is to be ensured for data transmission and reception.

5. System

(1) Propulsion and auxiliary system
  (A) Equipment related to the propulsion and auxiliary system is to be considered redundant or equivalent.
  (B) The performance of the main engines is to be compared and evaluated using two separate data sets that were measured independently.
  (C) The function to emergency stop the propulsion and auxiliary system remotely from the shore is to be applied.
  (D) The condition of main engine and auxiliary system is to be automatically diagnosed and self-recovery and emergency response is to be available.
  (E) Measurement data relating to the operation of main engines and auxiliary system are to be stored in real time and transmitted to shore.
  (F) Detailed inspection of the main engines is to be carried out at each entry.
  (G) Regular monitoring, sophisticated safety assessments and emergency response are to be possible for engine room.
  (H) The engine room layout design and the fire extinguishing system is to be developed, taking into account the engine room unmanned.
  (I) Application of an electric propulsion system may be considered.
  (J) Robust and seamless data transmission is to be ensured in wireless networks.
  (K) Cybersecurity is to be ensured for data transmission and reception.

(2) Steering
  (A) A function that a rudder of ship automatically returns to its neutral position when the S/G control system fails or S/G failure alarm occurs is to be applied to the S/G control system.
  (B) Operation data of the steering gear is to be collected onboard and transmitted to onshore (e.g., rudder angles, running signal, deviation alarm, etc.).
  (C) Rudder, autopilot and ECDIS system are to be considered redundant or equivalent.
  (D) The steering gear control and hydraulic system are to be provided with fault detection, self-diagnosis and automatic recovery of the system.
  (E) The steering system is to be equipped with an automatic collision avoidance system.
  (F) CCTV is to be installed inside the steering room to visually check the steering angle.
  (G) Steering angle transmitters are to be installed to facilitate repair or replacement in case of failure.
  (H) Steering angle transmitters are to be redundant.
  (I) The suitability assessment function for the steering angle is to be applied.
  (J) Robust and seamless data transmission is to be ensured in wireless networks.
  (K) Cybersecurity is to be ensured for data transmission and reception.

(3) Electric power system
  (A) Redundancy or equivalent measures for power management system is to be considered.
  (B) The design is to be considered to allow the ship to propel at least with an emergency generator.
  (C) New cable layout design is to be considered with engine room unmanned.
  (D) Operational record data for generators and generator control is to be stored in real time and available for transmission to on shore.
  (E) Operational record data for power management system is to be stored in real time and available for transmission to on shore.
  (F) Consideration is to be given to using battery(or fuel cell) power at main engine start-up.
  (G) Where an electric propulsion system is applied, the design of a suitable power management system and a large energy storage system are to be considered.
  (H) The risk of fire and explosion in the electric propulsion system is to be reviewed.
  (I) High reliability cables with electromagnetic shielding is to be used.
  (J) Consideration is to be given to new cable layout design that can enhance the performance of the main cable's penetrations and minimize the number of penetrations.
  (K) The application of the trunking system to the bus bar is to be considered.
  (L) Distribution operational data and fault records of major distribution equipment (MSBD, distribution board, PMS) are to be stored in real time and available for transmission to the shore.
  (M) Robust and seamless data transmission is to be ensured in wireless networks.
  (N) Cybersecurity is to be ensured for data transmission and reception.

(4) Autonomous system
  (A) Redundancy or equivalent means for systems of autonomous ships is to be considered.

(B) Safety operating instructions, including emergency procedures, are to be established in case of system malfunction and equipment failure. The system status is to be monitored during system operation.
(C) The operator's job scope is to be minimized when autonomous ships are designed. The degree of automation is to be defined to minimize the actions required of the operator. Once the scope of the operator's work has been determined, a method of providing the operator with the necessary information to make the decision and take action is to be provided. Control functions simulation for predefined levels of automation and operator feedback is to be done at the design stage. Appropriate training courses are to be developed to provide and maintain essential operational skills for operators.
(D) Information on the control loop feedback time and the shortest interval between commands, taking into account the appropriate system response, is to be considered.
(E) It is to be establish appropriate control transfer procedures and ensure that no more than one control is formed at the same time.
(F) It is to be identify the strength and safety levels expected for the magnetic field and establish safety guidelines at the level of expected strength.
(G) Safety guidelines are to be established so that the risks associated with the equipment can be controlled through detailed risk analysis and design characteristics.
(H) Safety guidelines related to operation, maintenance, repair, and receipt are to be established.
(I) Robust and seamless data transmission is to be ensured in wireless networks.
(J) Cybersecurity is to be ensured for data transmission and reception.

6. Outboard support systems

(1) Education plan formulation and qualification standards for land personnel are to be prepared.
(2) Safety guidelines are to be established to minimize or prevent predictable hazards. ⚓

GUIDANCE FOR AUTONOMOUS SHIPS

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