January 2020

ClassNK

Guidelines for Automated/Autonomous Operation on ships (Ver.1.0)

~Design development, Installation and Operation of Automated Operation Systems/Remote Operation Systems~

[English]

Introduction

In recent years, technologies such as sensing technology, AI and IoT have made rapid progress and are used in various fields. In the automobile field, research and development of automatic driving technology and demonstration experiments have been actively carried out by utilizing these technologies, and automatic driving technology for some functions such as brakes, accelerators, and steering has already been put into practical use.

In the field of ships, research and development of technology related to maritime autonomous surface ships (MASS) has been actively carried out in Japan and overseas with the aim of improving safety by preventing human error and improving working conditions by reducing the work load on crew members. The research stage is progressing to the development stage, and the demonstration experiment of technology related to MASS is being carried out mainly in Northern Europe. In Japan, MASS Demonstration projects have been launched, aiming for their practical application by 2025 together with the industry, academia and government.

It is expected that the design and development of technology related to MASS will be performed in various forms and concepts. The direction of the developments can be roughly divided into the following two ways. One is design and development aiming to save the number of crew members onboard unmanned ships or comparatively small ships with limited short navigation routes, and the other is design and development for partial automation of onboard tasks or remote support, mainly with the purpose of supporting the onboard operation of crew members. Although there may be some exceptions, the development of technology related to MASS along the former direction for coastal vessels and the latter for ocean going merchant vessels is expected to progress gradually.

Considering the current situation where design and developments of technology related to MASS are expected to be carried out based on various concepts, in March 2018, the Society issued the "Guidelines for Concept Design of Automated Operation/Autonomous Operation of Ships (Provisional Version)." These guidelines summarize the requirements to be considered for ensuring the safety of MASS, assuming that the design and development for the automated operation of ships are carried out under various forms and concepts. The safety of the technology related to MASS is to be confirmed not only in the design and development stage, but also in the onboard installation stage. Methods and procedures for maintenance and management during operation must be clarified as well. Based on this concept, the Society has newly compiled the requirements in each stage of design and development, installation, and maintenance management during the operation of technology related to MASS as "Guidelines for Automated/Autonomous Operation on ships ~Design development, Installation and Operation of Automated Operation Systems/Remote Operation Systems~", including the contents of the previously published "Guidelines for Concept Design of Automated Operation/Autonomous Operation of Ships (Provisional Version)". These guidelines will be reviewed as necessary in accordance with the progress of related technology development.

We hope these guidelines can contribute to the development and commercialization of technology related to MASS.

January 2020

Nippon Kaiji Kyokai (ClassNK)

Contents

Chapter 1 General

1.1 Purpose

-1. The Guidelines provide the requirements and procedures for verifying the functions of Automated Operation Systems (AOS) and Remote Operation Systems (ROS) which are used in ships or Remote Operation Centers (ROC), in each stage of design development (including concept design), installation, and operation (maintenance and management, etc.) of systems from the view point of securing the ship's safety.

1.2 Application

-1. The Guidelines are applicable to AOS or ROS which automatically or remotely operate some or all of the human decision-making processes (see **Fig. 1.1**), and are also applicable to ships that have these systems installed.

-2. Other than what is provided in the Guidelines, **Rules for the Survey and Construction of Steel Ships**, **Rules for the Surveys and Construction of Installations**, and relevant **Guidance** are to be applied when deemed necessary by the Society.

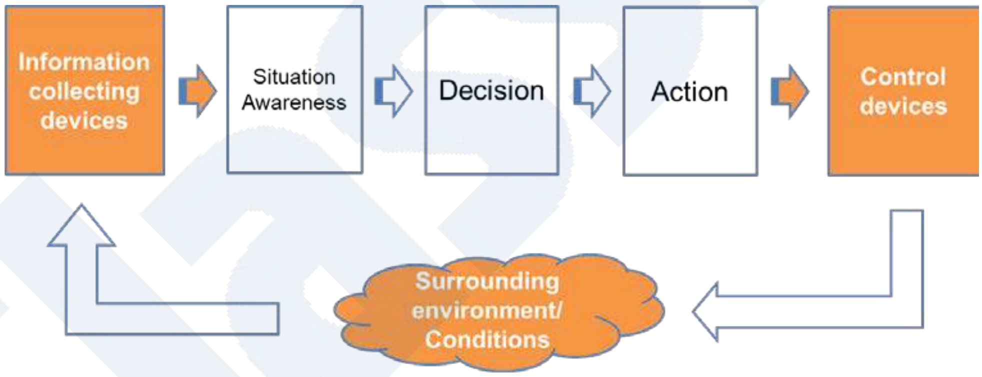

Fig. 1.1 Flow of decision-making process of person performing onboard operations

1.3 International Conventions, Domestic Laws and Regulations, etc.

-1. The Guidelines premise the satisfaction of all the international conventions, the laws and regulations of the flag state and the domestic laws and regulations of port states and so on, which are applicable to the ship in concern.

-2. Installation and use of AOS and ROS on ships or ROC are to be approved by the flag state and the relevant administration. In addition to the above, for trial operations such as sea trial, it may be necessary to obtain the approval of the coastal state in the test area.

1.4 Approval for Automated Operation System and Remote Operation System

-1. The AOS and ROS to which the Guidelines are applied should be approved by the Society according to the provisions of **Chapters 3 to 5 and 7** for each of the following stages in general. (See **Table 1.1** and **Fig. 1.2**.)

(1) System design development (See **Chapter 3**.)

(2) Installation of the system in ships or ROC (See **Chapter 4**.)

(3) Operation and maintenance management of ships in which the systems are installed. (See **Chapter 5**.)

-2. Class Notation will be affixed to the Classification Character of the ships installed with the AOS or ROS which meets the requirements of the Guidelines to identify the type of target task, the category of AOS or RCS and so on. The Society will confirm that the ship with Class Notation meets the requirements of the Guidelines at appropriate intervals.

Table 1.1 Approval for AOS and RCS

Stage		Object	Applicant	Type of Examination/Approval	Application
Design development	Concept design	Concept	Concept designer	AiP (Approval in Principle) (when requested)	Chapter 3*
	Basic design	System	System supplier	Type approval	Chapter 3*
Installation in ship or ROC	Ship design	Ship	System integrator	Plan approval	Chapter 4*
	Installation	Ship	System integrator	Survey onboard Class Notation	Chapter 4*
Operation and maintenance management		Ship	System owner	Maintenance of Class Notation	Chapter 5*

* For ROS, **Chapter 7** is also applied as appropriate.

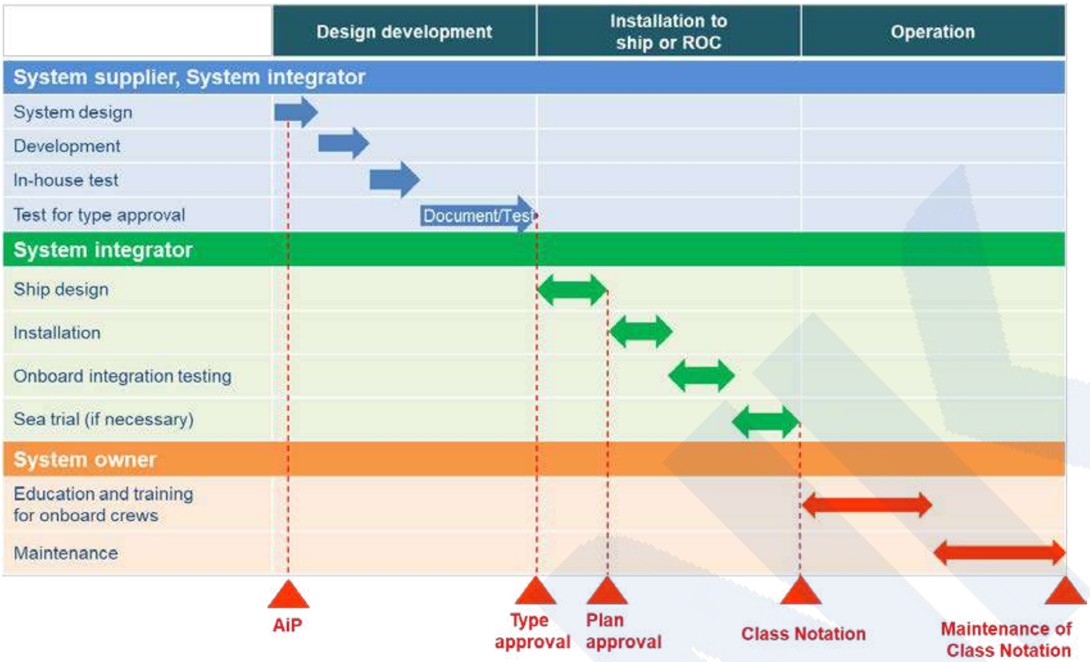

Fig. 1.2 Flow of approval of ACS and ROS

Chapter 2 Terms and Category

2.1 Terms

-1. The terms used in the Guidelines are specified in **Table 2.1**.

Table 2.1 Terms

Terms	Description
Task	"Task" means functions of a ship consisting of related onboard operations and works.
Subtask	"Subtask" means the onboard operations and works which compose a task.
Decision-making subtask	"Decision-making subtask" means subtasks related to human decision-making, such as situation awareness, decision and action. The decision-making subtasks are executed based on external information and events acquired through sensors, etc. in general.
Computer system	"Computer system" means a system composed of software and hardware, which executes given functions.
System	"System" refers to a computer system or a combination of computer systems and humans.
Automated condition	"Automated condition" means a condition where computer systems take charge of execution of some or all of the decision-making subtasks which compose the target task.
Autonomous condition	"Autonomous condition" means a condition where all decision-making subtasks composing the target task are automated without limitations of ODD and fallbacks are also wholly automated.
Automated Operation System (AOS)	"Automated Operation System" means a system (a computer system or a combination of computer systems and humans) that automates some or all of the decision-making subtasks composing the target task.

Remote Operation System (ROS)	“Remote Operation System” means a system that allows remote operation of some or all of the decision-making subtasks that compose the target task.
Remote Operation Center (ROC)	“Remote Operation Center” means facilities or ships that have facilities that can perform remote monitoring and remote control.
Communication network	“Communication network” includes ship-shore communication, ship-ship communication and ship onboard communication.
Prerequisite specification for system installation	“Prerequisite specification for system installation” means the necessary minimum equipment required on a ship or ROC for installation of AOS or ROS so that they can work properly onboard. For example, the following is considered. - Means for collecting information required by AOS or ROS (information collection devices such as onboard sensors which are connected to AOS or ROS.) - Control devices to which output information is sent from AOS or ROS.
Operation Design Domain (ODD)	“ODD” means design range that AOS or ROS can work properly. For example, the following can be mentioned. - Geographical factors such as navigational areas - Environmental conditions such as day/night, weather, sea conditions, etc. - Ship’s traffic congestion degree - Outboard monitoring and support environment including port facilities (if applicable)
Fallback	“Fallback” means countermeasures to minimize risks when the AOS/ROS cannot work properly due to unpredictable events such as malfunctions of the AOS/ROS, cyber attack and so on. This includes countermeasures when the AOR/ROS has deviated outside of ODD.

Minimum Risk Condition (MRC)	"MRC" means a condition where the minimum functions are maintained which are necessary for the target task executions. For example, the MRC for a ship refers to the condition where the ship meets the minimum requirements for the task execution such as requirements of Classification Society and flag state requirements, i.e. conditions where seaworthiness is maintained. MRC must be maintained by fallback when AOS or ROS deviate from ODD.
Simulation Tests	"Simulation test" means a control system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.
Simulator	"Simulator" refers to an interactive simulator that enables various verifications and human training by reproducing the usage environment as much as possible for the task. This is also used for verification of human-machine interface.
System supplier	"System supplier" means a company that designs, develops, and supplies systems.
System integrator	"System integrator" means a company that integrates systems supplied by system suppliers into an integrated system and provides it. The system integrator at the stage of design development may be different from the system integrator at the stage of installation in a ship or ROC. The system integrator at the design development stage plays a role in integrating a number of subsystems as a system. The system integrator can also be a system supplier. The system integrator at the stage of installation in ships and ROC plays a role in integrating AOS and ROS into ships and ROC.

System owner	"System owner" means owner of a ship in which AOS or ROS is installed. The system owner can delegate part of the role as the system owner to the operating company of the ship, etc. System owner is also a contractor with system integrators and system suppliers.

2.2 Category for Automated Operation System and Remote Operation System

-1. For the purpose of identifying what kind of AOS or ROS is installed in the ship, Class Notation is affixed to the Classification Character of the ship in which the AOS or ROS is installed. In this case, after clarifying the target task to be automated or remotely controlled and the ODD, AOS or ROS is categorized based on the following four indexes:

(1) Scope of automation

(2) Scope of remote operation

(3) Fallback Executor

(4) Contents of ODD

-2. For categorizing AOS or ROS in the ship, basically the format shown in **Fig. 2.1** is to be used.

Task : ____________________

ODD : ____________________

____

____

____

		Executor	Location
Decision-making Subtask	Situation awareness		
	Decision		
	Action		
Fallback			

Fig. 2.1 Format for category of AOS or ROS

Chapter 3 Design development of Automated Operation System

3.1 General Concept

-1. It is assumed that this chapter is generally applied to system suppliers. The system supplier may advance the design development of AOS according to the requirements in this chapter in cooperation with the system integrator and the system owner as necessary.

-2. In general, AOS installed in ships is to be type approved in accordance with **3.3.** If it is desired to obtain an AiP (Approval in Principle) for the concept design of AOS prior to type approval, AiP can be performed by applying the requirements of this Chapter as appropriate, considering the content of the concept design.

-3. In the examination of type approval, it should be verified that the system is designed and developed appropriately so that the system is satisfied with its functional requirement specifications.

-4. The Society verifies the design of the system through document reviews and function verification tests.

-5. In addition to the confirmation for the safety of AOS during design and development, shop test items which are carried out before shipping are to be clearly defined in advance.

-6. When it is necessary to tune the AOS at time of installation in a ship due to the ship's specifications/particulars, the details on the tuning are to be clarified.

-7. **Rules for the Survey and Construction of Steel Ships**, **Rules for the Surveys and Construction of Installations**, and relevant **Guidances** are to be applied when deemed necessary by the Society.

3.2 Design and development of Automated Operation System

3.2.1 Design of Automated Operation System

3.2.1.1 Concept Design

-1. In designing AOS, the following basic elements for ensuring safety are to be clarified.

(1) Target of Automated Operation on a Ship

- (a) The target task to be automated is to be clearly defined.
- (b) All of the subtasks which compose the target task are to be clearly defined.
- (c) Decision-making subtasks are to be distinguished from other subtasks among the subtasks composing the target task.

(2) Division of Roles between Humans and Automated Operation Systems

- (a) The division of roles between humans and AOS is to be clarified.
- (b) In case that the execution transfers of the subtasks from computer systems to humans and/or from humans to computer systems are designed in AOS, appropriate processes are to be established so that the execution transfers will not affect safety. These processes are

to include the time for the execution transfer, and means and procedures that the human to whom the subtask is transferred can respond properly for the execution of the subtask.

(c) As deemed necessary, appropriate processes are to be established on the execution transfer between the target task to be automated and other tasks.

(3) Prerequisite specification for system installation

(a) The necessary specifications on the usage environment of AOS are to be clarified for the ship in which AOS is installed.

(b) The above specifications include the types of information input to the AOS, the specifications of information collection devices such as sensors connected to the AOS and the specifications of control devices to which the AOS output information.

(c) When it is necessary to tune the AOS at time of installation in a ship due to the ship's specifications/particulars, the details on the tuning are to be clarified.

(4) Operational Design Domain (ODD)

(a) The ODD of the AOS is to be clearly defined. In addition to geographical condition, weather and sea conditions, traffic congestion degree, outboard monitoring support environment including port facilities might also be considered as ODD.

(5) Fallback

(a) The process of fallback is to be clarified and it is to be also ensured that the fallbacks are sufficiently executed when the AOS cannot work properly due to unpredictable events such as malfunction of the AOS, cyber attack and deviation from ODD.

(b) If there is a means that can return to the ODD when AOS deviates from the ODD, the return means are to be clarified.

(c) Fallback executor is to be clearly defined.

(d) Actions to be taken should be clearly defined in advance in the case that no requested responses are taken by the fallback executor in case of fallback. The effectiveness of the actions are to be confirmed during risk assessment.

(6) Human Machine Interface (HMI)

(a) The information concerning AOS is to be notified to related persons including the crews, persons for operation support and so on. The related persons are also to be clarified.

(b) The interface is to be designed based on appropriate standards for human-centered design.

(7) Cyber security

(a) Appropriate measures for cyber security are to be established.

(b) At minimum, the following is to be included in the measures.

i) Management procedures for cyber security

ii) Countermeasures against occurrences of cyber attacks

(c) Refer to the Society's "Guidelines for Designing Cyber Security Onboard Ships", "Cyber

Security Management System for Ships (Requirements and Controls)” and “Guidelines for Software Security” as necessary.

(8) Reliability of Computer Systems

(a) The computer systems are to be designed in accordance with appropriate standards.

(b) The computer systems used for AOS are to be designed so as to perform the required function sufficiently.

(c) Maintenance procedures for the computer systems are to be established.

3.2.1.2 Function requirement specifications

-1. The system supplier has to create the functional requirement specifications taking into account the basic elements for ensuring safety specified in **3.2.1.1-1**.

-2. The need for self-diagnosis functions is to be considered taking into account the features of the AOS.

3.2.1.3 Risk Assessment

-1. Risk assessment approaches are to be properly applied to confirm the system’s safety in the design works of AOS.

-2. When conducting a risk assessment, basic elements for ensuring safety specified in **3.2.1.1-1** should be included in the scope of consideration as much as possible.

-3. In particular, relationships between the "ODD" where the AOS works properly, "fallback" to minimize the risk when deviating from the ODD, and the "MRC" that is the minimum ship conditions to be maintained are important points in verifying the safety of the AOS. It should be verified as much as possible that the relationship of these three items is properly considered and designed.

-4. In the risk assessment, the event scenarios that require “fallback” should be considered as much as possible.

-5. Refer to **Chapter 6** for how to conduct a risk assessment.

3.2.2 Development of Automated Operation System

3.2.2.1 Organization and process for design development of Automated Operation System

-1. The system supplier is required to satisfy the following requirements.

(1) Upgrading of the AOS and handling of bugs should be generally performed by the system supplier throughout the lifecycle of the AOS.

(2) Appropriate quality system regarding software development and testing and associated hardware such as ISO 9001 taking into account ISO 90003 are to be operated.

(3) The system supplier is to have the ability to ensure and verify the reliability and validity of software and hardware that make up the AOS. The reliability and validity of software are to be verified by simulation tests.

(4) The system supplier is to have the ability to plan various test programs, e.g. functional

verification tests, shop tests before shipping and system integration tests and so on. The test plans for system integration tests carried out at the time of installation in ship may be prepared in cooperation with the system integrator for the installation of the system in ship.

-2. The development of AOS should be based on the following.

(1) Appropriate standards such as IEC 61508 and ISO 26262

(2) For software in AOS, the development process as illustrated in **Fig. 3.1** or a similar development process recognized by the Society to have equivalent reliability.

(3) The requirements for the hardware in AOS are as specified in **3.1-7**.

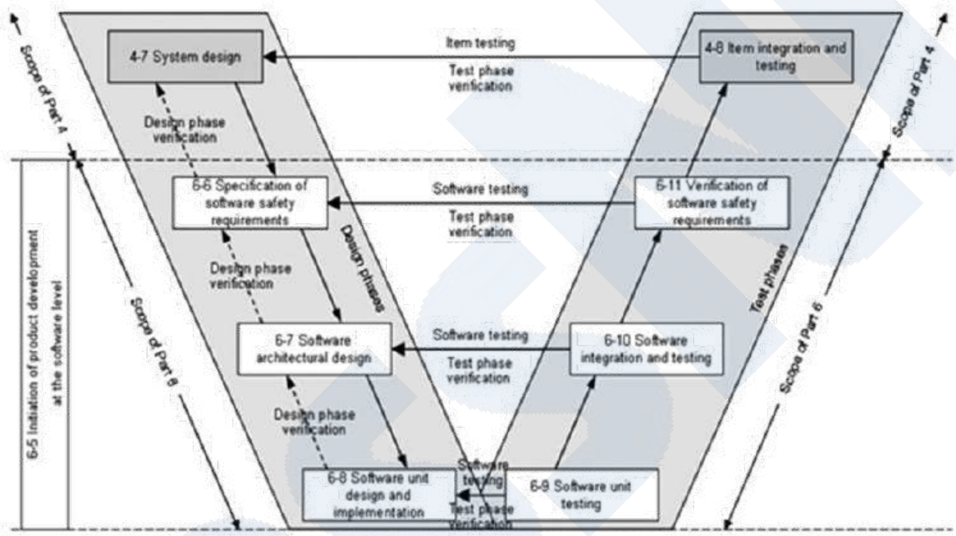

Fig. 3.1 Software development process (example) (Source: ISO 26262)

3.2.2.2 Function confirmation test

-1. A function confirmation test shall be performed to verify that the developed AOS satisfies the functional requirement specifications created at the time of design development.

-2. The function confirmation test may be a test devised by the system supplier. The Society may require additional function confirmation tests, depending on the results of the document review specified in **3.3.1**.

-3. For the function confirmation test, methods such as simulation should be used effectively according to the features of the AOS.

-4. The items of the function confirmation test are to include at least the following. Test items should be added as appropriate based on the results of the risk assessment.

(1) The AOS works properly

(2) The software and the hardware control interaction and function properly each other.

(3) The software composing the AOS can take proper actions in the case of system malfunctions

3.3 Type approval for Automated Operation System

3.3.1 Document examination

-1. For the purpose of evaluating the validity of the design, the following documents are to be reviewed.

(1) Design concept and functional requirement specifications

(2) Results of risk assessment

(3) System and process for design and development of the AOS (This is for confirmation that the system supplier has the appropriate quality control ability and that the design and development are performed in an appropriate process.)

(4) Results of the functional confirmation test

3.3.2 Functional verification test required by the Society

-1. The Society requires functional verification tests under the conditions specified by the Society, taking into account the expected operational environment conditions and disturbance conditions, etc. based on the document examination in **3.3.1**.

-2. The system supplier is required to submit test plans for the functional verification tests in **3.3.2-1** to the Society for approval.

-3. The functional verification tests are to be performed in the presence of the Surveyor.

-4. Depending on the features of the AOS, especially an AOS for maneuvering tasks, expert judgment might be necessary to evaluate its effectiveness. In particular, evaluations based on actual experiences can be considered useful for the confirmation of the safety of the AOS including human involvement, e.g. separation distance during evacuation maneuvering, start of evacuation, and handover from the automatic evacuation function to the crew and so on. For this reason, if the Society deems it necessary, a test using a simulator might be required.

-5. When conducting tests by a simulator, at least the following items are to be included as verification items.

(1) Validity of interaction with humans (execution transfer from system to onboard crew)

(2) Response of AOS under worst-case environment that cannot be verified on actual ship

(3) Response of the AOS on situations/scenarios where there are few experience opportunities in the actual sea area

(4) Effectiveness of fallback for AOS

3.4 Documents for type approval of the Automated Operation System to be submitted

-1. The following documents are to be submitted to the Society for type approval of AOS.

(1) Application for type approval

(2) Functional requirements specification of AOS

(3) Results of risk assessment

(4) Documents related to the design and development system (quality system related)

(5) Documents related to the design and development process

(6) Result of function confirmation test

(7) Various test plans (function verification test, shop test before shipping, system integration test onboard, etc.)

(8) Other documents deemed necessary by the Society

-2. The functional requirements specification for the AOS should include the following contents.

(1) Functional requirements for AOS

(2) System architecture that gives an overview of the AOS

(3) Overview of the automation algorithm

(4) Types of data input to the AOS, e.g. sensors that are assumed to be connected

(5) Output target of the signal from the AOS (control devices, etc.)

(6) Documents clearly defining the task to be automated and the subtasks which comprise the task to be automated, including distinction of decision-making subtasks and other subtasks

(7) List of subtasks to be automated

(8) Documents clearly defining the division of roles between humans and the AOS. The documents are to include diagrams showing the composition and interrelationships between subtasks.

(9) Documents explaining the execution transfer process in AOS, in the case where execution transfers of subtasks are considered between the Computer System and human. The documents are to include considerations on the time required for the execution transfer, and the means and procedures that the person to whom the subtask is transferred can respond properly in the execution of the subtask.

(10) Documents clarifying the ODD of AOS

(11) Documents clarifying the fallback process

(12) Documents presenting the cyber security measures, if the Society deems it necessary, including the network logical configuration diagram

(13) List of Reference standards

Chapter 4 Installation of Automated Operation System in the Ship

4.1 General

4.1.1 General Concept

-1. It is supposed that this chapter is generally applied to the system integrator. The system integrator may cooperate with the system supplier and system owner with respect to the contents specified in this chapter, as necessary.

-2. It is presupposed that the AOS that has been approved in accordance with **Chapter 3** will be installed in the ship.

-3. This chapter describes the items to be confirmed and the requirements to be satisfied when installing the AOS in the ship as well as the procedure for obtaining approval for the individual ship. Specifically, it is confirmed that the connection and integration of related equipment and sensors with the AOS are properly conducted, as well as that the AOS works properly and performs the required functions, through document examination and system integration test.

-4. When it is necessary to tune the AOS due to the ship's specifications/particulars, it is required that these tunings have been properly performed based on **3.1-6**.

4.1.2 Flow to installation in the ship

-1. The following procedures are to be followed when installing AOS that has been approved in accordance with **Chapter 3** in a ship.

(1) Obtain approval for individual ship design (Plan approval)

(2) Risk assessment for installation in the individual ship

(3) Implementation of system integration test onboard

4.2 Approval for individual ship design (Plan approval)

4.2.1 General

-1. In obtaining approval for the individual ship design, it is to be shown that the basic elements for ensuring safety described in **3.2.1.1-1** are also satisfied in the ship.

4.2.2 Risk Assessment

-1. The risk assessment for installation of the AOS in the ship should be carried out based on the hazards related to the linkage between the ship and the AOS.

-2. In particular, the following hazards should be remarked and necessary measures should be taken to ensure the safety of the ship in which AOS is installed.

(1) Risks caused by human machine interface (HMI)

(2) Malfunction of sensors and control devices connected to the AOS

(3) Effects of the AOS on other systems in the ship

(4) Cyber security

(5) Flaws on operations of the AOS, including forgetting to update related software or verifying the validity of responses in the event of an emergency

-3. Risk assessment can be omitted as appropriate if the risk of installing the AOS in the ship can be sufficiently grasped, such as when the AOS has been installed on similar ships in the past. In this case, documents that justify omitting the risk assessment shall be submitted. The documents are to include the following items **(a)** and **(b)**:

(a) Equivalence with previous risk assessments regarding operating conditions and environmental conditions of ships

(b) Validity of adopting the same risk measures as in previous risk assessments

-4. Refer to **Chapter 6** for how to conduct a risk assessment.

4.2.3 Documents to be submitted for plan approval for individual ship design

-1. At least the following drawings or documents are to be submitted to the Society.

(1) System architecture in the ship

(a) Documents which clarify the relationship between the AOS and other systems onboard the ship

(b) The sensors and navigation equipment used are to be clarified.

(2) Operation Design Domain (ODD)

(a) Documents which demonstrate that the ODD at the time of type approval is applicable even in the ship

(b) If there are any differences from the prerequisites for type approval, these differences are to be clarified and it is also required to verify that these differences are acceptable for the ship by using appropriate methods such as risk assessment.

(3) Risk assessment results

(4) User manual (for reference)

(5) Documents on software version control related to the AOS

(6) Others deemed necessary by the Society

4.3 System integration test onboard

4.3.1 General Concept

-1. The Society verifies that the AOS works properly on the ship as confirmation that installation work has been completed correctly.

-2. Based on the results of the examinations through plan approval in **4.2,** onboard tests are to be carried out in the final environment integrated with all other devices and/or systems that interact with each other, and the following items are to be confirmed.

(1) Function as designed

(2) System safety in case of internal and/or external failures of the AOS

(3) Presence of possibilities of interactions with other systems operating onboard is to be confirmed. When possibilities are considered, it is to be confirmed that the interaction does not affect the safety of the ship.

(4) When it is necessary to tune the AOS due to the specifications of the ship, the tunings are to be performed appropriately.

-4. The tests are to be conducted in the presence of the Surveyor.

-5. Prior to conducting the tests, the necessity of both the preparatory explanation to the flag state government and the coastal states in the test sea area as well as their approval are to be considered in advance, and appropriate action is to be taken if necessary.

4.3.2 Confirmation test in actual operation (Sea trial)

-1. In consideration of the feature of the AOS, if the Society deems it necessary, a confirmation test in actual operation is required.

-2. The tests are to be conducted in the presence of the Surveyor.

4.3.3 Documents to be submitted for system integration test onboard

(1) Test plan

(2) Other documents deemed necessary by the Society

Chapter 5 Operation of Automated Operation System

5.1 General

-1. It is assumed that this chapter is generally applied to the system owner. The system owner may cooperate with the system supplier and/or system integrator with respect to the contents specified in this chapter, as necessary.

-2. Explanatory documents for the AOS (including user manuals) are to be prepared for the people involved in the automated/autonomous operation of the ship including the onboard crews, and these explanatory documents are to be available onboard.

-3. The explanatory documents are to include at least explanations on the contents of the basic requirements for ensuring safety described in **3.2.1.1-1** as well as the outline and functions of the AOS.

-4. Appropriate training for the onboard crews to learn the AOS operation is to be provided as necessary.

-5. Procedures for the operation of AOS including the following are to be established.

(1) Maintenance management of the AOS, including necessary procedures for maintenance and management of the software and the hardware, procedures for ensuring traceability in software changes and updates and recording methods at least

(2) Procedures related to the matters specified in **3.2.1.1-1 (5)** and **(7)**

(3) Education and training for onboard crews

-6. All software changes and updates must be implemented in accordance with the procedure in **5.1-5. (1)**.

-7. If making any changes that might affect the reliability and safety of the AOS, the changes should be approved by the Society in advance. At that time, documents that clearly indicate the procedure for the changes including change method, execution and verification together with reasons are to be submitted to the Society.

Chapter 6 Risk Assessment

6.1 General Concept

-1. Sufficient verifications are to be carried out to prevent predictable failures on various operation scenarios in automated/autonomous operation of the ship. From this viewpoint, risk assessment can be very useful as a method for evaluating the safety of AOS.

-2. When performing a risk assessment for AOS, the assessment on risks caused by “automation” is to be the basis.

-3. The risk assessment for AOS and the ship installed with AOS can be based on the relative comparison with risks of the conventional ships without AOS installation.

-4. This chapter describes the timing and method of risk assessment for AOS.

6.2 Timing of risk assessment

-1. In general, risk assessment for AOS should be performed at the following stages.

(1) Design and development stage (when type approval is obtained)

(2) Installation in the ship

6.3 Method of risk assessment

6.3.1 General method of risk assessment

-1. The general flow of risk assessment is shown in **Fig. 6.1**.

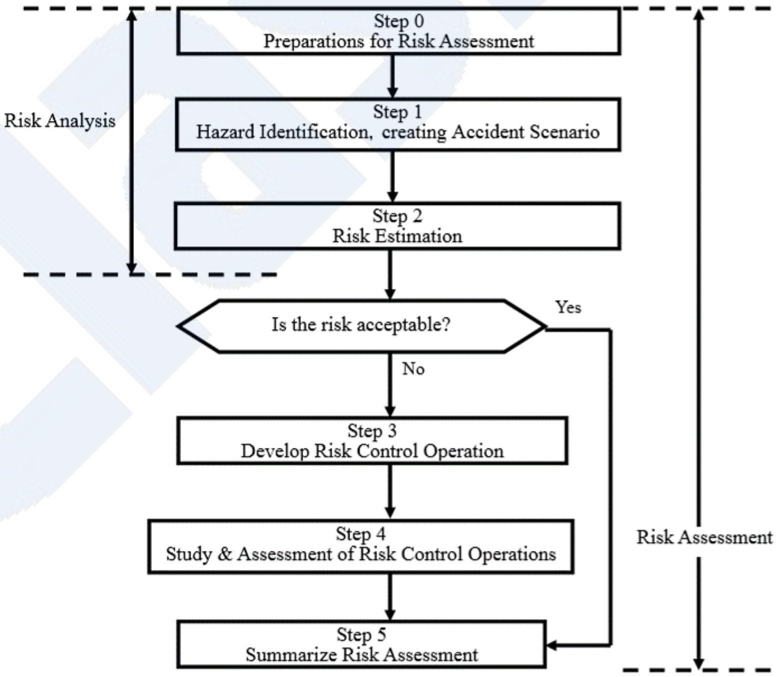

Fig. 6.1 General flow of risk assessment

-2. In conducting the risk assessment, refer to the following standards and guidelines as appropriate, in addition to the "Risk Assessment Guidelines" issued by the Society.

(1) IMO MSC-MEPC.2 / Circ.12 (FSA Guidelines)

(2) ISO / IEC 31010

(3) ISO / IEC 27005

6.3.2 Risk assessment performed during design and development

-1. In situations where the specifications of the ship are not finalized, it is not realistic to perform a risk assessment assuming all situations during operation. Therefore, the risk assessment performed at the time of AOS development can be primarily based on the risk assessment of the AOS itself with primary focus on extraction of hazards. When risk control measures for such hazards are affected by the specifications of the ship, the risk assessment can be just an extraction of these hazards when developing the system. Risk control measures for such hazards should be verified by appropriate methods at the time of risk assessment performed during AOS installation in the ship.

6.3.3 Risk assessment performed during installation in the ship

-1. In the risk assessment performed during installation in the ship, it can be premised that the risks come from the AOS itself have been already verified at the time of system development, and risk assessment can focus on the risks associated with linkage between the ship and AOS.

-2. In particular, it is necessary to identify hazards to be considered for the followings and take necessary risk control measures so that the safety of the ship can be ensured.

(1) Risks caused by human machine interface (HMI)

(2) Malfunction of sensors and control devices connected to the AOS

(3) Effects of the AOS on other systems in the ship

(4) Cyber security

(5) Flaws on operations of the AOS, including forgetting to update related software or verifying the validity of responses in the event of an emergency.

-3. In cases where it is relatively easy to identify potential hazards such as when the task to be automated by the AOS is maneuvering or docking and congested sea areas, night navigation, poor visibility, etc. are not included in ODD, it may be acceptable to omit risk assessment.

6.4 Examples of hazards to be considered

-1. The examples of hazards to be considered are shown in **Table 6.1**, taking the case where the task to be automated is "maneuvering" as an example.

Table 6.2 Examples of hazards to be considered

Hazard	Examples of hazards, taking the case where the task to be automated is "maneuvering"
Changes in the external environment	Bad weather, poor visibility, appearance of congested vessels, etc.
	Unexpected behavior of other ships
Failure of AOS and related equipment	Loss of signal from information collection devices
	Deterioration of reliability or stability of information from information collection devices
	Failure of related equipment in the AOS
	Software bug in AOS
	Inappropriate tuning of parameters according to the ship's specifications (e.g. the maneuverability of the ship is not correctly reflected in the AOS)
	Power loss of AOS or related equipment
	Inappropriate human machine interface (HMI), e.g. it is difficult to understand the reason for issuing an alarm, or there is not enough time to execute transfer from the AOS to a human
	Improper interface between the AOS and other systems such as differences in situation awareness range, differences in kinetic performance models, mismatched parameters, system failures, poor communication, etc.
Failure of the fallback executor	Poor physical condition or dozing, etc. of the officer in charge of a navigation watch
Cyber attack	GNSS spoofing, AIS spoofing, etc.
	Jamming to RADAR, etc.
	Unauthorized access/hacking to AOS and related systems
	AOS or related systems infected with malware
Emergency occurrence	Severe hull damage Malfunction of ship equipment such as rudder, radar, etc. Fire or pirate invasion * Regarding the above, it is acceptable to just confirm that the significance of the result at the time of occurrence does not increase compared to those of the conventional ships. It is not required to take measures to reduce the frequency of these occurrences compared to the conventional ships.

Improper operation	Forgetting to update charts, atmospheric information, related software, etc. Misinformation
	Incorrect input of setting data and initial input data to the AOS, e.g. navigation plan data, reference values for evacuation determination, etc.
	Lack of proficiency and understanding of the AOS users, e.g. cannot understand the meaning of alarms, unsuitable use environment of AOS, etc.
	Replacement of related equipment with equipment that is not compatible with the AOS

Chapter 7 Remote Operation System

7.1 General

7.1.1 Scope

-1. This chapter is applied to Remote Operation Systems (ROS), ships installed ROS and Remote Operation Center (ROC) equipped with ROS.

-2. Remote operation is roughly divided into two types, remote monitoring and remote control.

7.1.2 General Requirements

-1. The information and actions to be monitored or operated remotely are to be clarified and shared by the parties concerned with correct understanding.

-2. The type and degree of information to be provided to the parties concerned are to be clarified according to the tasks for remote monitoring and remote control.

-3. The executing parties of remote operation are to be clarified. The executing parties of the remote operation are to have the ability and knowledge to execute the remote operation for the task to be remote operated. The Society will confirm that the abilities and knowledge of the executing parties are appropriate as necessary.

-4. Authority and responsibility for final decision-making regarding remote operations of the ship are to be clarified in advance.

-5. The communication network for remote monitoring and remote control are to be able to appropriately perform the necessary data communication in terms of time and quantity.

-6. Appropriate measures as fallback are to be taken to ensure the safety of the ship when communication during remote monitoring or remote control becomes insufficient.

-7. For ROS, **Chapters 3** to **6** of these guidelines are to be applied as appropriate, taking into account the specifications of the ROS.

7.2 Risk Assessment

-1. Appropriate measures are to be taken to ensure the safety of the ship by extracting hazards related to remote monitoring and remote control through appropriate risk assessment method.

-2. Examples of hazards to be considered are shown below.

(1) Poor communication between the ship and ROC

(2) Oversight during remote monitoring or mistake during remote control

(3) Cyber attacks

7.3 Remote Operation Center

-1. Appropriate equipment is to be provided according to the content of remote monitoring and remote control to be performed.

-2. The facilities used are to have sufficient reliability.

-3. If the Society deems it necessary, items related to ROC are also subject to examination.

7.4 Relationship between remote monitoring and remote control and crew onboard

-1. The relationship in the decision-making process (situation awareness, decision and action) for the remote operation between the ROC and the crew onboard are to be clarified.

7.5 Ability of remote operator engaged in remote monitoring and remote control

-1. Remote operators engaged in remote monitoring and remote control at ROC are to have the necessary knowledge, experience, and abilities to appropriately perform their assigned tasks.

【Appendix】

Guidelines for Automated/Autonomous Operation on ships

〜Design development, Installation and Operation of Automated Operation Systems/Remote Operation Systems〜

Explanation

Contents of Appendix

A1 Basic Concept of the Guidelines

A1.1 Design and development of Automated/Autonomous Operation on Ships

It is expected that the design and development of automated/autonomous operation on ships will be performed in various forms and concepts. The direction of the developments can be roughly divided into the following two ways. Although there may be some exceptions, the development of automated operation technology along the former direction for coastal vessels and the latter for general merchant vessels is expected to progress gradually.

- Design and development aiming to save the number of crew members onboard or unmanned ships for comparatively small ships with limited short navigation routes
- Design and development for partial automation of onboard tasks or remote support, mainly with the purpose of supporting the onboard operation of crew members onboard

Considering the current situation that design and developments of Automated Operation Systems (AOS) and Remote Operation Systems (ROS) on ships are expected to be carried out based on various concepts, it might be inappropriate to set normative requirements uniformly in order to secure the safety of AOS and ROS. The purpose of the Guidelines is to define the common basic requirements for the safety of AOS and ROS on ships with various designs so that the designs and developments are carried out with adequate and sufficient considerations on safety.

A1.2 Scope of Automation and Remote operation

When a ship is considered to be one plant system, onboard operations can be classified into various functions such as “navigation”, “propulsion”, “power management”, “cargo management” and so on. These functions can also be subdivided into several operations and works. In the Guidelines, a certain group of these operations and works is defined as a “task”, which can be a subject for automated or remote operation. Accordingly, the grade and content of the task differ depending on the subject, scope and degree of the automation or remote operation.

For example, in case that the operations related to “navigation” are automated, the task to be automated is “navigation”. On the other hand, when the operation to be automated is only the “watchkeeping”, which is a component of “navigation”, “watchkeeping” is the task to be automated.

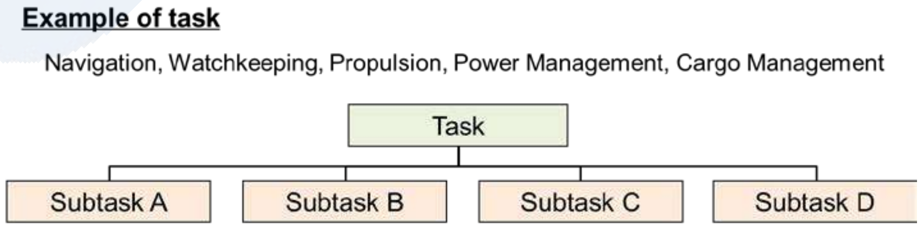

Fig. A1.1 Task and Subtask

In the Guidelines, the case where all the operations (subtasks) which compose the task are automated with no limitations of ODD is termed “autonomous condition”. Therefore, among the ship with autonomous tasks, there might be large differences in the degree and condition of “autonomous”. It is important to clearly define the tasks to be automated for identification of automated operation.

Among the subtasks, a subtask that covers human decision-making processes such as “situation awareness”, “decision”, and “action” of humans are defined as the decision-making subtask. The Guidelines are applicable when some or all of the decision making subtasks are automated. It is considered that the existing rules for automation and remote operation may be applicable to the cases where subtasks other than the decision-making subtasks are automated.

For example, if the requirements are clearly specified in existing rules, such as the Heading Control System (HCS) and Truck Control System (TCS), the existing rules are to be applied.

Examples of related rules;

- Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use (Part 7)
- Rules for Automatic and Remote Control Systems / Guidance
- Rules for Navigation Bridge Systems / Guidance
- Rules for Preventive Machinery Maintenance Systems / Guidance
- Rules for Integrated Fire Control Systems
- Rules for Hull Monitoring Systems
- Rules for Centralized Cargo Monitoring and Control Systems / Guidance
- Rules for Safety Equipment / Guidance
- Rules for Radio Installations / Guidance, etc.

A1.3 Task and Automated Operation System/Remote Operation System on board

The Guideline considers tasks onboard to be at the highest level in the system configuration. As shown in Fig. A1.2, there are various tasks onboard. Some tasks are supported by a system composed of multiple sub-systems (sub-system groups), while others are supported by only one system. In some cases, the system is completely automated by a computer system, and in other cases persons are incorporated as part of the system. Further, systems performing different tasks may cooperate indirectly through information exchanges and so on. As described above, the tasks onboard fulfill their functions while various systems are involved in a complicated manner.

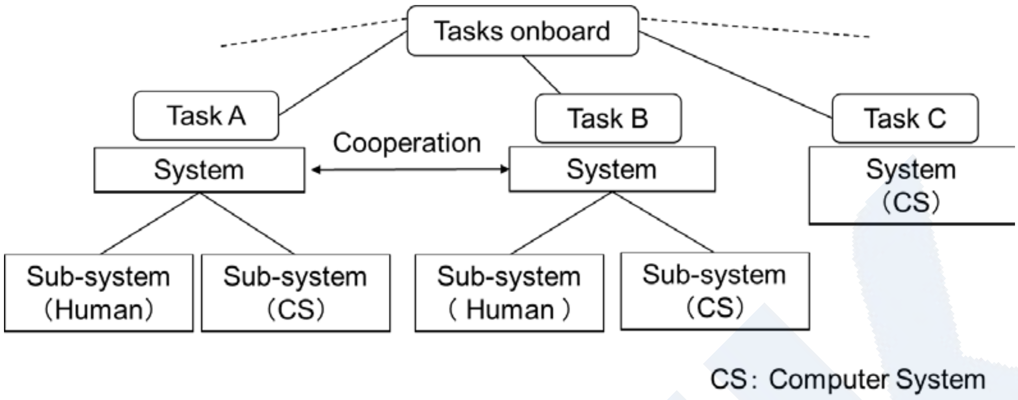

Fig. A1.2 Tasks onboard and System

The Society is of the opinion that some parts of the decision-making processes that have been performed by humans as parts of the system will be gradually automated or remotely operated. **Figure A1.3** shows an example of AOS. It shows both the cases where the AOS is applied in the system (task) layer and where the AOS is applied in the sub-system (subtask) layer.

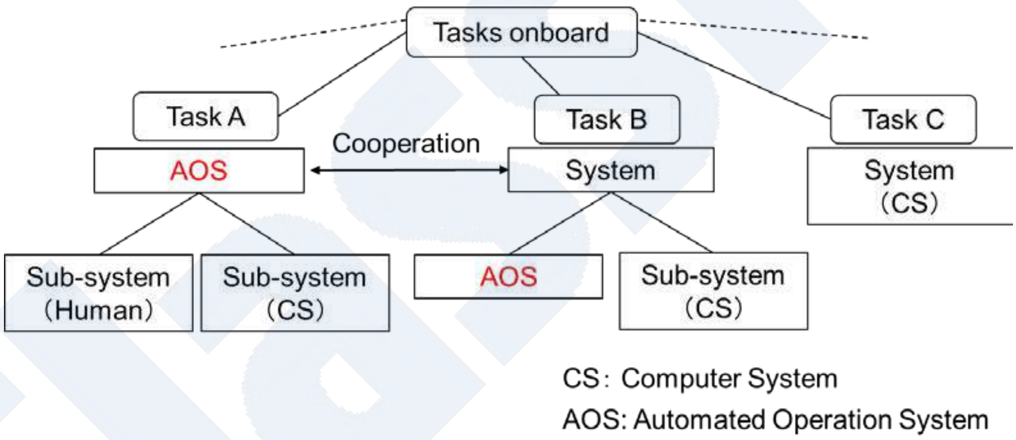

Fig. A1.3 Tasks onboard and Automated Operation System (AOS)

A1.4 Related laws and regulations

Regardless of the scope, extent, and degree of automation or remote operation, the Guidelines premise the satisfaction of all the international conventions, the laws and regulations of the flag state and the domestic laws and regulations of ports of call and so on, which are applicable to the ship. If there is a need to flexibly apply these conventions, laws and regulations, approval from the flag state is to be obtained in each case.

A1.5 Ensuring safety in automation and remote operation in decision making process

In designing automated/autonomous operation on the ship, the most important points for ensuring safety are considered as below.

- The task to be automated is to be clearly defined.
- All of the subtasks which compose the task to be automated are to be clearly defined, and the division of roles between humans and computer system that execute these subtasks is to be clarified.
- In remote operation, regardless of either the execution of the subtasks from outside the ship, i.e. ROC are made by computer system or by human, the division of roles and relationship between the ROC and the crew onboard is to be clearly defined. Moreover, in cases where remote operation at ROC is executed by both human and computer systems, the division of roles and relationship between the human engaged in remote operation and the computer systems executing remote operation are also to be clarified.
- The ODD of the AOS/ROS is to be clearly defined.
- Fallback executor when AOS or ROS deviates from the ODD is to be clearly defined.
- The task, scope, division of roles, and relationship between humans and computer systems related to the AOS or ROS are to be shared among all parties involved in automated/autonomous operation.

In addition, the Guidelines provide important requirements for safety design of automated remote operation, such as “Human Machine Interface (HMI)”, “cyber security”, “reliability of computer systems” etc. (See Fig. **A1.4**.)

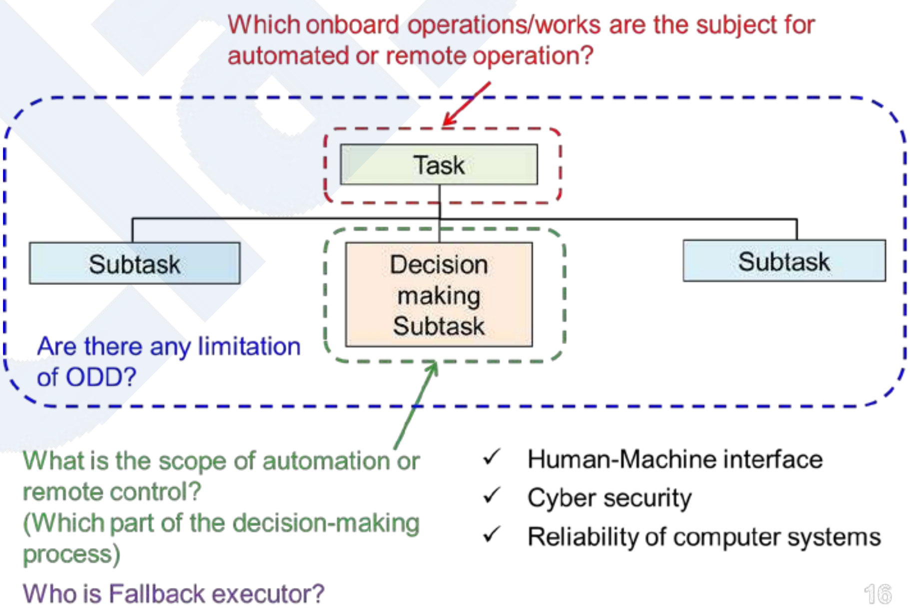

Fig. A1.4 Summary of basic elements related to safety

A1.6 Remote Operation

Since the possibilities are expected that remote operation technology will be adopted in the development of automated/autonomous operation technology, the basic requirements for adopting remote operations are specified in **Chapter 7**. **Fig. A1.5** shows a conceptual diagram related to remotes operation.

Although it can be considered that automated technology and remote operation technology are essentially different from one another, some concepts such as ODD and fallback can be applied commonly for both automated operations and remote operations.

The execution of the decision making subtask by remote operations can be performed both by humans and by computer systems. The society considers that when the computer systems execute remote operations, that cases can be basically verified by combining the requirements for AOS specified in **Chapters 3 to 6** of the Guidelines and characteristics unique to the remote control systems. On the other hand, when the subtask is executed by remote control by humans, the requirements of the AOS might not be always applicable. In this case, the requirements will be appropriately determined for each case.

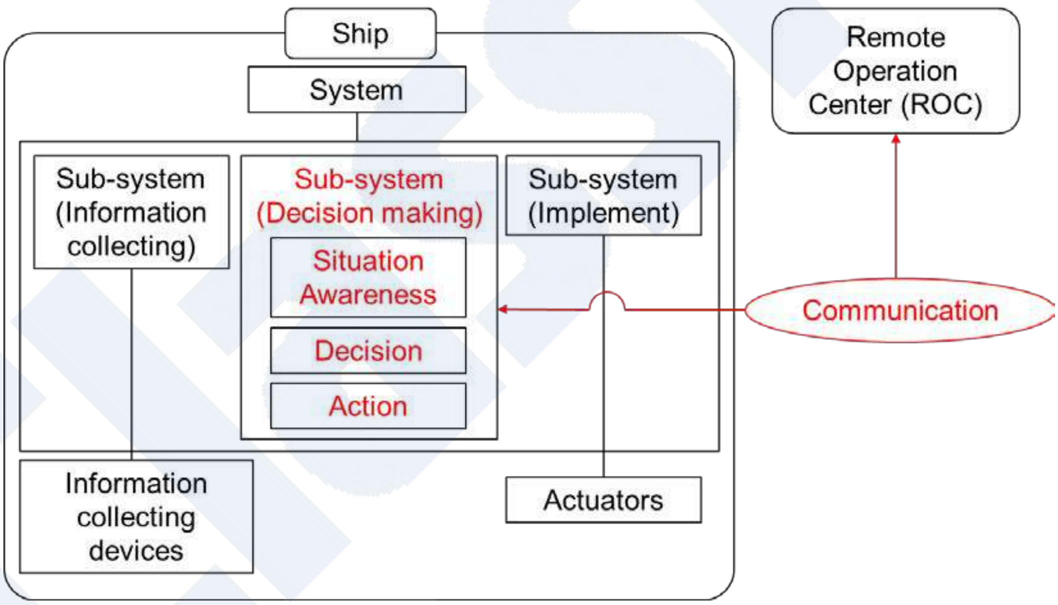

Fig. A1.5 Conceptual diagram related to remote operation

A2 Explanation of terms

Some of the terms used in the Guidelines are descripted with reference to terminology of driving automation of automobiles. In addition, words such as "system" and "function" have a wide range of meanings, so on the terms used in the Guidelines, efforts were made to clarify the meanings in **Chapter 2** as much as possible.

To assist in understanding the meanings of the terms in the Guidelines more clearly, some of the terms are explained with examples.

A2.1 Task

A certain group of onboard operations that is a subject of automated operation is called a “task”. “Tasks” differ depending on the subjects, extents, and degrees of automated operations in consideration. The type of “task” is the subject of automated operation decided based on the designer’s intention.

A2.2 Subtask

The roughness of content, grade, and grouping etc. of the subtasks which compose a task also differs depending on the task to be automated/remotely operated. Depending on the design, the same onboard operation may be the task to be automated, or may become a subtask which composes the task.

A2.3 Decision-making subtasks

“Subtasks related to human decision-making”, which is mentioned in the term of “decision-making subtasks” in **Chapter 2** of the Guidelines, basically indicates the subtasks such as responding to external disturbance factors related to execution of subtask by the process of “situation awareness, decision, and action”.

Control to operate according to preset normative rules and achieved goals is not considered to be related to the “human decision-making” used in the Guidelines.

A2.4 Automated Operation System (AOS)

In the Guidelines, in **Chapter 2**, “a system that automates some or all of the decision-making subtasks that compose a task” is descripted as AOS. **Fig. A2.1** shows a conceptual diagram of the AOS. As an example, case 1 is a case where the computer system (CS) is responsible for situation awareness only, case 2 is a case where situation awareness is shared between the computer system and humans, and case 3 is where the computer system is responsible for all decision-making process, situation awareness, decision and action.

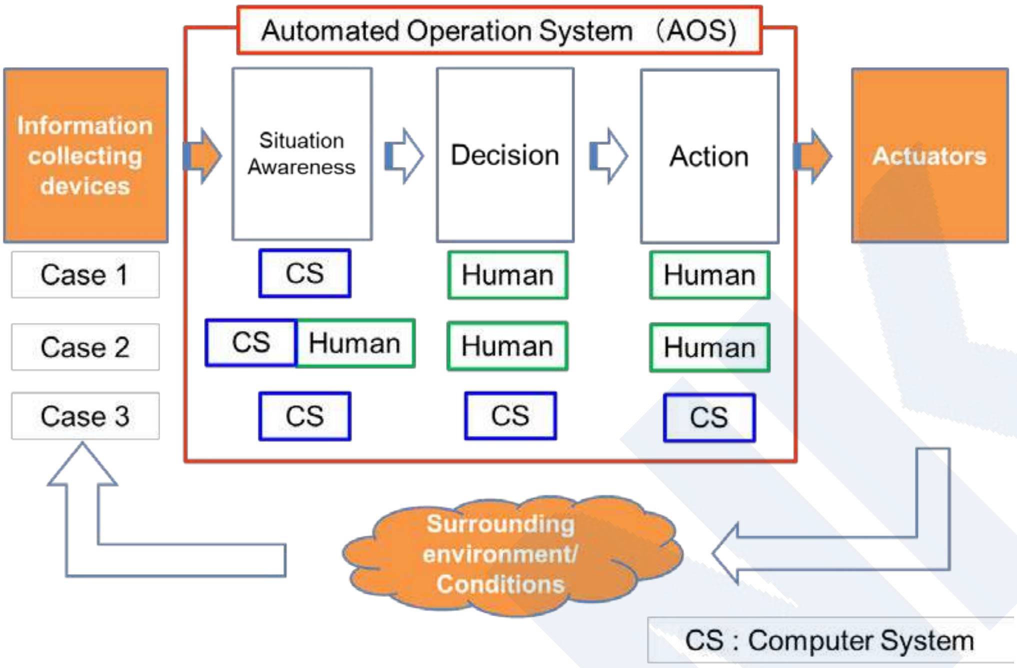

Fig. A2.1 Conceptual diagram of the Automated Operation System (AOS)

A2.5 Remote Operation System (ROS)

In the Guidelines, in **Chapter 2**, “a system that allows remote operation of some or all of the decision-making subtasks that compose a task” is descripted as ROS. It also includes systems that allow remote execution of tasks related to the functions of the onboard system, e.g. modification of the system.

A2.6 ODD, MRC and Fallback

The three terms ODD, MRC and fallback are of particular importance in the Guidelines. First, **Figure A2.2** shows a conceptual diagram of the relationship between the ODD and the MRC. Operation of the AOS and ROS is based on the premise that the state of the ship is in the MRC. Fallback is an action to keep the state of the ship in the MRC when the AOS or ROS fails or deviates from the ODD, not an action of returning the state of the ship from the MRC to the ODD. In addition, in the Guidelines, a state where seaworthiness is lost due to serious hull damage and/or failure of ship’s equipment and machineries is considered as the state in which the ship has deviated from the MRC.

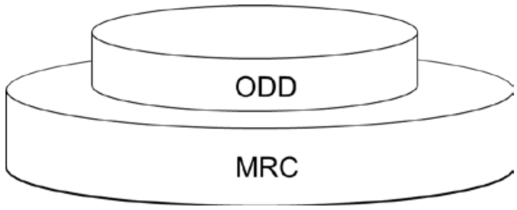

Fig. A2.2 Conceptual diagram of the relationship between the ODD and the MRC

Figure A2.3 shows a simplified example for the ship whose navigation is automated. In order to sort out the issues, the ODD is simply assumed to be only used in the open sea, and the fallback is assumed to be executed by the officer in charge of a navigation watch. If the ship sails in the open sea (ODD inside), AOS is functioning normally, but if the degree of traffic congestion exceeds the calculation limit of AOS (e.g. entering a congested sea area), it has deviated from the ODD. In this case, the officer in charge of a navigation watch executes fallback (e.g. switching from AOS navigation to manual navigation) to keep state of the ship in MRC. Then, when the ship goes out of the congested sea area and back to the open sea, it becomes possible to start AOS navigation. On the other hand, if the AOS fails, the officer in charge of a navigation watch has to execute fallback and maintain state of the ship in the MRC. However, in this case, return to the ODD cannot be achieved unless the AOS is repaired.

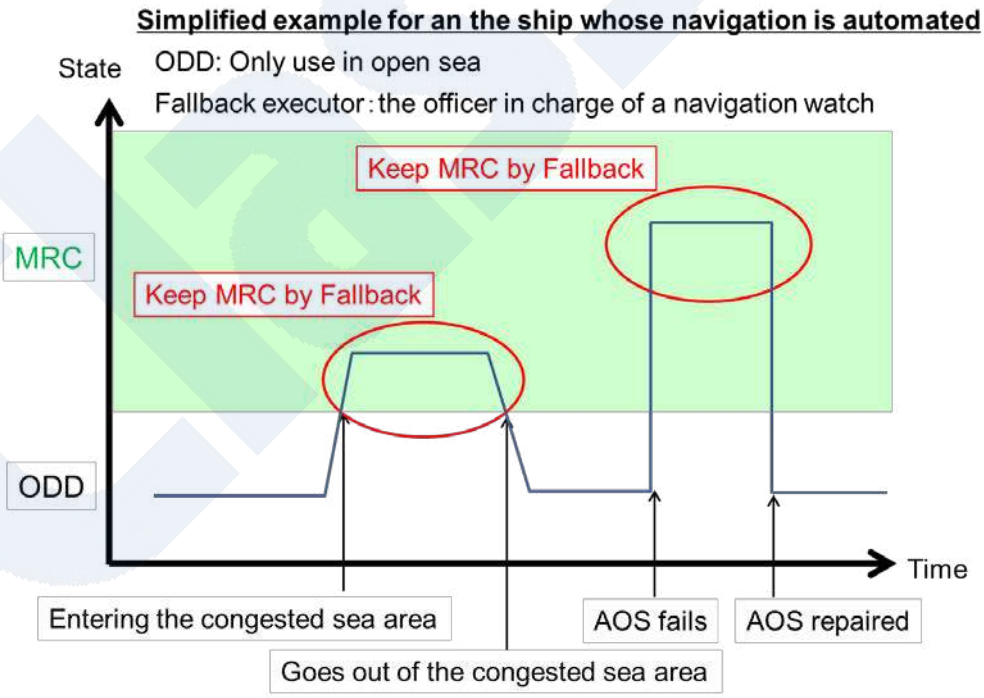

Fig. A2.3 Simplified example for the ship whose navigation is automated

As mentioned in **Chapter 6** of the Guidelines, it is enough to take risk mitigation measures to keep the state of the ship in the MRC when conducting risk assessment in AOS and ROS. It is not required to consider measures to reduce the frequency of occurrence of ships falling outside the MRC and the significance of the results compared to the conventional ships.

A2.7 System Supplier and System Integrator

Since system suppliers must have the ability to design, develop, and supply AOS, it is assumed that multiple companies will form a consortium and share their functions. In that case, it is necessary to clarify the ultimately responsible company for the Society (to whom the certificate of type approval is issued).

As described in **Chapter 2**, it is considered that system integrators will have roles in two stages, the design development stage and the installation stage. In any case, the more complex the system to be developed, the greater the need. In this case, it is important for the system integrator to carry out the system integration in cooperation with the system supplier and the system owner.

Figure A2.4 shows a conceptual diagram showing the relationship between the system supplier and the system integrator at the design and development stage. In **Fig. A2.4**, a system integrator integrates sub-systems supplied by multiple system suppliers into one AOS. In this case, the system integrator can also be the system supplier of the AOS/ROS.

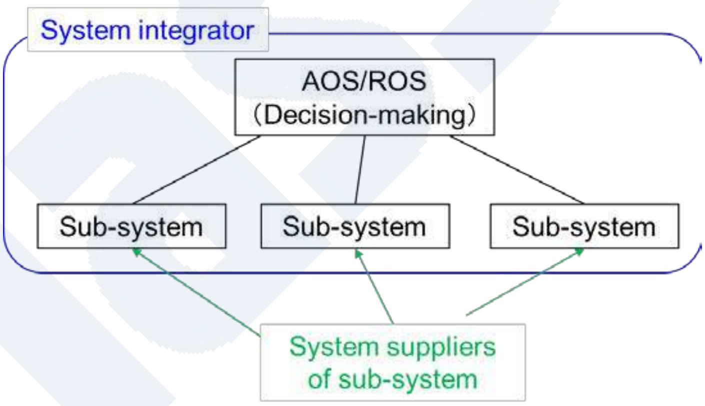

Fig. A2.4 Conceptual diagram showing the relationship between the system supplier and the system integrator at the design and development stage

Figure A2.5 shows a conceptual diagram showing the relationship between the system supplier and the system integrator at the installation stage. It is intended for installation on both ships and ROC. As shown in **Fig. A2.5**, when a task is composed of three subtasks A to C, and each system is supplied by a different system supplier, the system integrator needs to integrate these three systems when they are installed to the ship or ROC. Also, subtask B is composed of an AOS and other sub-system, and these integrations may be performed at the time of installation. If the system integrator of subtask B is different from the system integrator of the task, the system integrator of the task needs to cooperate with the system integrator of subtask B to proceed with the system integration.

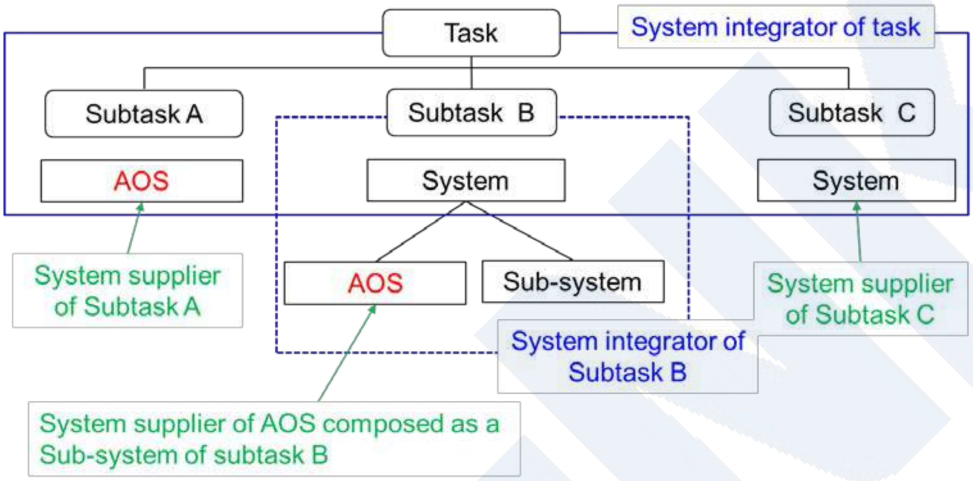

Fig. A2.5 Conceptual diagram showing the relationship between the system supplier and the system integrator at the installation stage

A3 Category of Automated Operation System and Remote Operation System

In the Guidelines, Class Notation will be affixed to the Classification Character of the ships installed with the AOS or ROS. The purpose is to be able to identify what kind of AOS or ROS is installed in the ship, by clarifying the tasks to be automated/remotely operated and ODD, and categorizing the system based on the following four indexes,.

(1) Scope of automation

(2) Scope of remote operation

(3) Fallback Executor

(4) Contents of ODD

Examples of categorizing the scope of automation, the scope of remote operation, and the fallback executor are shown in **Table A3.1** to **Table A3.3**. Although these are arranged individually to make it easier to grasp the concept, in practice, automation and remote operation may be combined. For reference, **Table A3.4** shows a matrix of combinations of typical systems that are currently considered. Theoretically, there may be cases where “humans execute all subtasks, and the computer system execute fallback”. However, careful consideration is needed as to whether it is technically feasible. In addition, the location of fallback execution may be onboard or at ROC.

In practice, it is necessary to evaluate the security of the AOS or ROS, especially for the combination of the above-mentioned scope of automation, scope of remote operation, and fallback executor, with comprehensive consideration for the size of the task and the content of ODD. For this reason, the system characteristics (combination of automation, remote control, and fallback) can be assumed to be various cases, and only typical combinations are illustrated at the present stage in order to flexibly handle according to actual situations.

It should be noted that the category/identification using the above four indexes means the category/identification of the tasks to be automated or controlled remotely, not indicating the absolute level or degree of automation or remote operation. It is extremely important to clarify the tasks to be automated or remotely operated in order to make stakeholders' recognition accurate.

Table A3.1 Example of categorizing scope of automation

Category	The feature of system	Scope of automation (Executor of decision-making subtasks)
0	Humans executes all subtasks	Humans
I	Computer systems execute some decision-making subtasks	Computer systems and humans
II	Computer systems executes all subtasks	Computer systems

Table A3.2 Example of categorizing scope of remote operation

Category	The feature of system	Scope of remote operation (Location of execution of decision-making subtasks)
0	Crew onboard execute all subtasks	Crews onboard
I	Some decision subtasks remotely executed	Partly executed at ROC
II	All decision subtasks remotely executed	All executed at ROC

Table A3.3 Example of categorizing Fallback executor

Category	The feature of system	Scope of automation (Executor of decision-making subtasks)
0	Human executes Fallback	Humans
I	Fallback execution is shared between humans and computer systems.	Computer systems and humans
II	Computer system execute fallback	Computer systems

Table A3.4 Example of combination of Automated Operation System, Remote Operation System and Fallback

The feature of system	Category			Scope of automation/ Scope of remote operation				Fallback executor	
	Automation	Remote operation	Fallback	Onboard ship		ROC			
				Human	CS	Human	CS	Human	CS
Humans executes all subtasks and Fallback	0	0	0	◎	-	-	-	◎	-
	0	I	0	○	-	○	-	◎	-
	0	II	0	-	-	◎	-	◎	-
Computer systems execute some decision-making subtasks. Human executes Fallback.	I	0	0	○	○	-	-	◎	-
	I	I	0	○	-	-	○	◎	-
	I	I	0	-	○	○	-	◎	-
Computer systems execute all decision-making subtasks. Human executes Fallback.	II	0	0	-	◎	-	-	◎	-
	II	I	0	-	○	-	○	◎	-
	II	II	0	-	-	-	◎	◎	-
Computer systems execute all decision-making subtasks and Fallback.	II	0	II	-	◎	-	-	-	◎
	II	I	II	-	○	-	○	-	◎
	II	II	II	-	-	-	◎	-	◎

Notes) ROC: Remote Operation Center

CS: Computer System

A4 Other supplementary explanation

A4.1 Relaxation of examination for approval

If the AOS is newly developed by combining sub-systems whose reliability has already been confirmed, the combination is mainly examined for approval. In this case, review of the sub-system can be reduced or omitted as appropriate when the Society accepts that the reliability of the sub-system has already been sufficiently confirmed. If the combination of sub-systems changes and a significant difference is found in the change, re-examination for the difference caused by the new combination is to be examined for approval to the new combination.

A4.2 Self-diagnosis function

The self-diagnosis function is described in **3.2.1.2-2** of the Guidelines. This assumes a function similar to that provided by an automatic collision prevention assistance device (ARPA). However, in the case of AOS or ROS, it is difficult to request the function in a unified manner, and it is also difficult to set uniform requirements for the degree of the self-diagnosis function at this stage. Therefore, the necessity and degree of the self-diagnosis function should be determined on a case-by-case basis.

A4.3 Test plan for system integration test onboard planned during design development

In **3.2.2.1-1 (4)** of the Guidelines, system suppliers are requested to prepare test plans for system integration tests to be carried out when installing systems on ships or ROC. The system integration test at the time of installation is performed by the system integrator at the installation stage, but it may be difficult for the system integrator alone to plan test items in order to confirm that the system is properly installed. From such a viewpoint, it is intended to ensure that the system is properly integrated by listing at least the items to be implemented after installation from the perspective of the system supplier on the system design and development stage.

A4.4 Functional verification test designated by the Society

The purpose of the functional verification test specified by the Society is to finally confirm that the developed system satisfies the functional requirement specifications, and the following viewpoints are considered important.

- Whether the system can read input data correctly
- Is the system algorithm reliable
- Whether the output data is correctly transmitted to the target device
- Whether the basic elements for ensuring safety described in **3.2.1.1-1** are satisfied, especially Human Machine Interface (HMI)

A4.5 Confirmation test in actual operation (Sea trial)

For example, when the tasks related to ship maneuvering are to be automated, if the Society recognizes the necessity to confirm the reproducibility in actual operation after reviewing the results of simulation tests and simulator verification conducted during system development, a confirmation test in actual operation is required. Since the specific test method needs to be coordinated with the flag state and the coastal state in the test area, test plan for confirmation test in actual operation should be decided after consultation between the system integrator and stakeholders including the Society.

A4.6 Response to emergency occurrence

Emergency occurrence is listed in **Table 6.1** as an example of a hazard to be considered in the **Chapter 6** of the Guidelines. An emergency here refers to a state deviating from the MRC as shown in **A2.6**, such as damage to the hull, failure of marine equipment, etc.

In operating AOS and ROS, it is necessary to clarify in advance the response to emergency occurrence, for example, whether to continue using the AOS or ROS, to cancel their operation immediately, or to ask the Captain to judge according to the situation, etc. The validity of the AOS or ROS response to emergency occurrence is to be verified during risk assessment.

A4.7 Risk assessment for remote control systems

The risk assessment of the ROS is specified in **7.2** of the Guidelines. When performing a risk assessment for ROS, the assessment for risks from "remote operation" is to be fundamental. In the Guidelines, "poor communication", "oversight or mistake", and "cyber attack" are mentioned as typical viewpoints peculiar to remote operation. On the other hand, as described in **A2.5,** there might be cases where ROS is used for remote execution of works related to the functions of the onboard system, e.g. modifying the system onboard. In such cases, if the communication is interrupted in the course of the modification work of the system onboard, or if a different modification is performed by mistake, there is a possibility that the ROC will not be able to perform subsequent operations. In addition, there is a possibility that the crew onboard cannot technically respond and resolve such situation. These cases can be considered as a hazard unique to remote operation. This is deeply related to the way of fallback in remote operation, and it should be noted that the validity of fallback may be particularly important when conducting a risk assessment of a ROS.

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