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# Core Competency Development Pathways for Navigation Technology Students Oriented to the Staged Evolution of Autonomous Navigation in Intelligent Ships

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**Abstract:** The development of autonomous navigation in intelligent ships is reshaping the competency structure and occupational orientation of students majoring in Navigation Technology. Drawing on the IMO MASS Code and the China Classification Society Rules for Intelligent Ships (2026), this study examines five typical stages: automated assistance and decision support, remote control with crew on board, remote control without crew on board, autonomous operation with human-machine collaboration, and full-voyage autonomy with shore-based supervision. On this basis, a core competency development framework is proposed, consisting of stage evolution, job transformation, competency needs, and educational pathways. The study argues that, in addition to conventional seamanship, students should develop competencies in smart navigation equipment, remote control, autonomous navigation system supervision, human-machine collaboration, data analysis, shore-based operations management, and regulatory safety. Accordingly, pathways are proposed for reconstructing training objectives, optimizing the curriculum, reforming practical teaching, developing integrated teaching platforms, and improving competency-oriented assessment. The findings provide a reference for educational reform in Navigation Technology programs under the development of intelligent ships.

**Keywords:** Intelligent Ships; Autonomous Navigation; MASS Code; Navigation Technology; Core Competencies

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## 1. Introduction

Smart shipping is an important direction for the digital, networked, and intelligent transformation of the shipping industry. The development of autonomous navigation technology for intelligent ships is changing ship operation modes, maritime job profiles, and the competency structure required of navigation personnel. Traditional training in Navigation Technology has primarily addressed ship handling, route design, watchkeeping and collision avoidance, the use of navigational instruments, ship maneuvering, and ship safety management. As intelligent ships gradually acquire capabilities such as automated assistance, remote control, autonomous operation, and shore-based supervision, future work scenarios for Navigation Technology students will no longer be limited to the bridge. They will increasingly extend to shore-based remote-control centers, autonomous navigation monitoring platforms, smart shipping management platforms, and maritime supervision contexts[1].

The regulatory work of the International Maritime Organization (IMO) on Maritime Autonomous Surface Ships (MASS) indicates that the development of MASS involves ship design, remote operation, cybersecurity, risk assessment, human supervision, and shore-based oversight[2-4]. The China Classification Society (CCS) Rules for Intelligent Ships (2026) further refines functional requirements for intelligent ships, including visual enhancement, intelligent integration platforms, intelligent berthing and unberthing, intelligent bridge-area collision avoidance, and intelligent monitoring[5-7]. These developments suggest that future navigation personnel must not only master conventional navigational knowledge but also understand the operational logic of intelligent ships, identify smart-navigation risks, conduct remote monitoring and control, evaluate the outputs of autonomous navigation systems, and complete safety management and emergency response in complex navigation scenarios[8,9].

Current training models in Navigation Technology programs still rely primarily on conventional ship-handling competencies and seafarer certification requirements. Their response to job transformation and competency restructuring driven by intelligent ships remains insufficient. Course content related to intelligent ships, autonomous navigation, remote control, ship-shore communication, data analysis, and shore-based supervision is limited[10]. Practical teaching still relies mainly on navigation simulator training and shipboard practice, while new scenarios such as remote control, transfer of control, autonomous navigation state supervision, abnormal takeover, and shore-based operations management are inadequately covered. Assessment also tends to emphasize theoretical knowledge and single operational skills, while the integrated competency of students in intelligent navigation receives less attention.

Against this background, this study addresses the following question: What core competencies should Navigation Technology students develop under the staged evolution of autonomous navigation in intelligent ships, and how should education and training be adjusted accordingly? Rather than providing a broad discussion of talent cultivation under smart shipping, the study focuses on changes in students' future competency structures. It constructs an analytical framework of "stage evolution-job transformation-competency needs-educational pathways" to support educational reform in Navigation Technology programs.

## 2. Staged Evolution of Autonomous Navigation in Intelligent Ships and Its Training Implications

Autonomous navigation in intelligent ships will not be realized in a single step. It will evolve progressively from automated assistance and remote control to autonomous operation and full-voyage autonomy. Drawing on IMO's categorization of MASS autonomy and the intelligent functions specified in the CCS Rules for Intelligent Ships (2026), the development of autonomous navigation in intelligent ships can be summarized into five typical operating forms: automated assistance and decision support, remote control with crew on board, remote control without crew on board, autonomous operation with human-machine collaboration, and full-voyage autonomy with shore-based supervision. These stages differ in their operational characteristics, human responsibility boundaries, and competency requirements for Navigation Technology students[11].

### 2.1 Automated Assistance and Decision Support

The stage of automated assistance and decision support corresponds to the MASS category of automated processes and decision support. In this stage, crew members remain on board and undertake ship maneuvering, watchkeeping, collision avoidance, and safety management. Certain navigational processes are supported by automated equipment or intelligent navigation functions. Ship intelligence is mainly reflected in route and speed optimization, visual enhancement, collision warning, grounding warning, integrated information display, machinery condition monitoring, energy-efficiency management, and cargo management. Students should therefore develop an understanding of the basic principles of intelligent navigation equipment and decision-support functions while maintaining strong conventional navigational competencies. They should also be able to use intelligent equipment to improve navigational safety and operational efficiency[12,13].

### 2.2 Remote Control with Crew on Board

Remote control with crew on board corresponds to the MASS category in which the ship may be controlled from a remote-control station while personnel remain on board. The onboard personnel undertake state monitoring, local response, and emergency takeover. The key change in this stage is that the operational space of ship control expands from the bridge to a shore-based remote-control station. Students must understand ship maneuvering, collision avoidance, and watchkeeping rules, while also developing the ability to read remote-monitoring interfaces, conduct remote helm and engine control, judge ship-shore communication status, transfer control authority, and take over in abnormal situations[14-16].

### 2.3 Remote Control without Crew on Board

Remote control without crew on board corresponds to the MASS category in which the ship is controlled from a remote-control station or center and no conventional crew is carried on board. This stage is not equivalent to full autonomy, because ship operation still depends heavily on the monitoring, judgment, and control of shore-based personnel. Students need to shift from conventional shipboard operation toward remote-control and shore-based watchkeeping roles. They should master multi-source information monitoring, remote traffic-situation assessment, communication failure risk identification, shore-based command generation, and remote emergency response.

### 2.4 Autonomous Operation and Human-Machine Collaboration

Autonomous operation with human-machine collaboration represents a transition from remote control toward higher levels of autonomous operation. In this stage, the ship can autonomously perform route tracking, environmental perception, situation assessment, collision-avoidance decision-making, and motion control in specific navigation segments or scenarios. A remote-control station or shore-based supervisory team still conducts monitoring, confirmation, and necessary intervention. The core change is not the disappearance of human roles but the transformation of their functions. Navigation personnel gradually shift from direct operators to supervisors of autonomous navigation systems, human-machine decision-makers, and abnormal-takeover personnel[17].

### 2.5 Full-Voyage Autonomy and Shore-Based Supervision

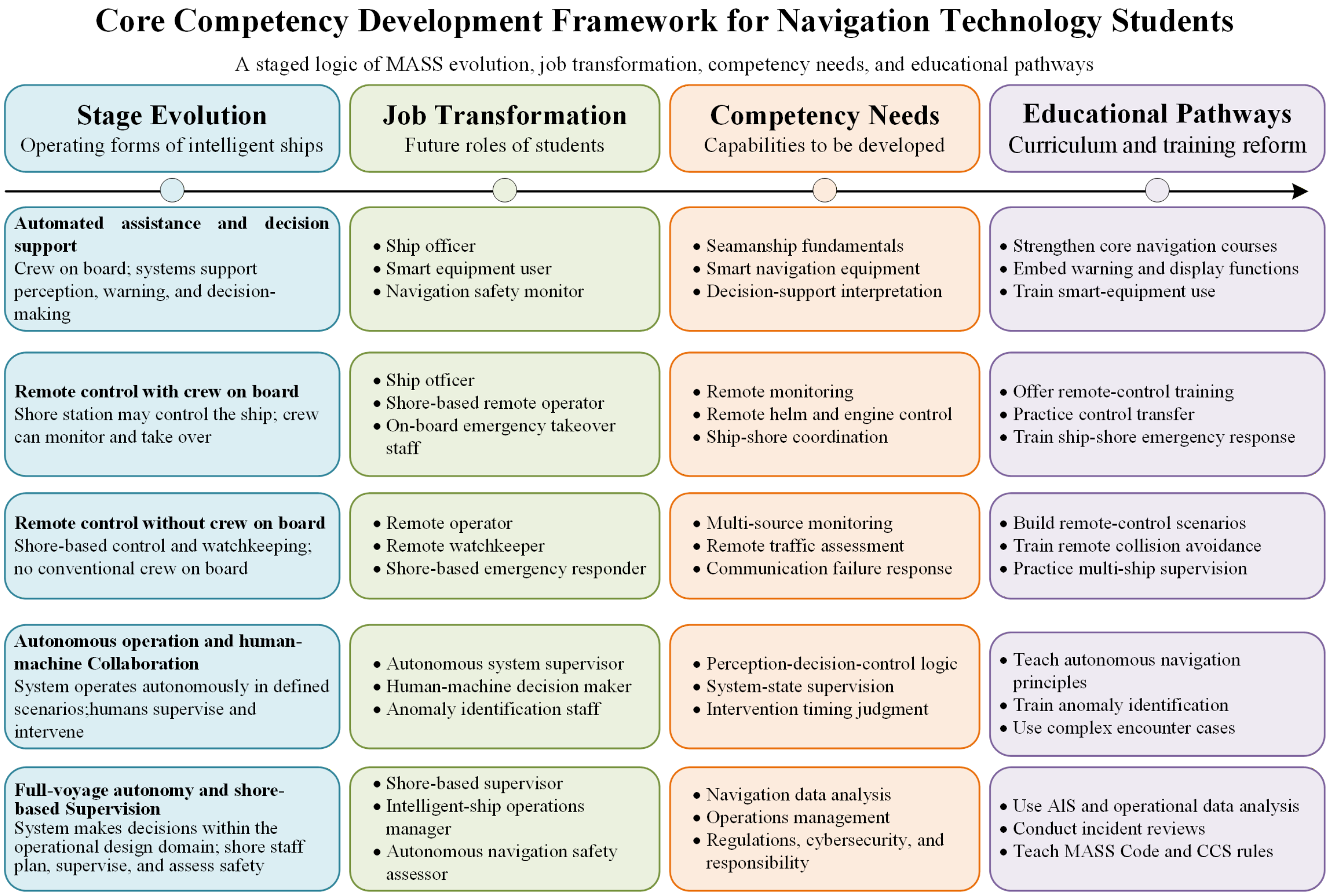
Full-voyage autonomy with shore-based supervision corresponds to the MASS category of fully autonomous ships and represents a higher level of intelligent ship operation. In this stage, the ship can make decisions and determine actions autonomously within its operational design conditions. Human roles shift further from direct control and real-time intervention toward mission planning, operational supervision, safety assessment, incident review, and responsibility management. Students should use navigational knowledge to judge whether the operation of an autonomous navigation system is safe, compliant, and reliable[18-21]. They should develop competencies in data analysis, regulatory interpretation, cybersecurity awareness, and integrated safety management.

## 3. A Core Competency Development Framework Based on Stage Evolution, Job Transformation, Competency Needs, and Educational Pathways

### 3.1 Logic of Framework Construction

The development of autonomous navigation in intelligent ships changes the future job roles of Navigation Technology students and reshapes the core competencies they should acquire. Based on the relationship between the development stages of intelligent ships and future job transformation, this study constructs a core competency development framework for Navigation Technology students. The framework consists of four layers. The first layer is stage evolution, referring to the progression from automated assistance and decision support to remote control, autonomous operation, and shore-based supervision. The second layer is job transformation, in which future roles expand from ship officers and watchkeepers to smart navigation equipment users, remote-control operators, autonomous navigation system supervisors, human-machine decision-makers, shore-based supervisors, and intelligent-ship operations managers. The third layer is competency needs, including conventional seamanship, understanding of smart navigation equipment, remote-control ability, autonomous navigation system supervision, human-machine collaboration, data analysis, and regulatory safety literacy. The fourth layer is educational pathways, through which these competencies are developed by reconstructing training objectives, optimizing curricula, reforming practical teaching, developing teaching platforms, promoting university-industry collaboration, and improving assessment mechanisms[22-24].

*Figure1: Core competency development framework for Navigation Technology students based on stage evolution, job transformation, competency needs, and educational pathways.*



**Core Competency Development Framework for Navigation Technology Students**

A staged logic of MASS evolution, job transformation, competency needs, and educational pathways

| **Stage Evolution**<br>Operating forms of intelligent ships | **Job Transformation**<br>Future roles of students | **Competency Needs**<br>Capabilities to be developed | **Educational Pathways**<br>Curriculum and training reform |
|---|---|---|---|
| **Automated assistance and decision support**<br>Crew on board; systems support perception, warning, and decision-making | • Ship officer<br>• Smart equipment user<br>• Navigation safety monitor | • Seamanship fundamentals<br>• Smart navigation equipment<br>• Decision-support interpretation | • Strengthen core navigation courses<br>• Embed warning and display functions<br>• Train smart-equipment use |
| **Remote control with crew on board**<br>Shore station may control the ship; crew can monitor and take over | • Ship officer<br>• Shore-based remote operator<br>• On-board emergency takeover staff | • Remote monitoring<br>• Remote helm and engine control<br>• Ship-shore coordination | • Offer remote-control training<br>• Practice control transfer<br>• Train ship-shore emergency response |
| **Remote control without crew on board**<br>Shore-based control and watchkeeping; no conventional crew on board | • Remote operator<br>• Remote watchkeeper<br>• Shore-based emergency responder | • Multi-source monitoring<br>• Remote traffic assessment<br>• Communication failure response | • Build remote-control scenarios<br>• Train remote collision avoidance<br>• Practice multi-ship supervision |
| **Autonomous operation and human-machine Collaboration**<br>System operates autonomously in defined scenarios;humans supervise and intervene | • Autonomous system supervisor<br>• Human-machine decision maker<br>• Anomaly identification staff | • Perception-decision-control logic<br>• System-state supervision<br>• Intervention timing judgment | • Teach autonomous navigation principles<br>• Train anomaly identification<br>• Use complex encounter cases |
| **Full-voyage autonomy and shore-based Supervision**<br>System makes decisions within the operational design domain; shore staff plan, supervise, and assess safety | • Shore-based supervisor<br>• Intelligent-ship operations manager<br>• Autonomous navigation safety assessor | • Navigation data analysis<br>• Operations management<br>• Regulations, cybersecurity, and responsibility | • Use AIS and operational data analysis<br>• Conduct incident reviews<br>• Teach MASS Code and CCS rules |

## 3.2 Relationship between Stage Evolution and Job Transformation

Under different degrees of autonomy, ship operating characteristics and human responsibility boundaries differ, and the future jobs of students change accordingly. Table 1 summarizes the relationship between stage evolution and job transformation.

*Table 1. Relationship between the staged evolution of autonomous navigation in intelligent ships and job transformation.*

| Stage evolution | Main operating characteristics | Future job transformation of students |
|---|---|---|
| Automated assistance and decision support | Crew remain on board; systems support perception, judgment, and decision-making. | Ship officers, smart navigation equipment users, navigation safety monitors. |
| Remote control with crew on board | Shore-based control is possible; onboard personnel can monitor and take over. | Ship officers, shore-based remote operators, onboard emergency takeover personnel. |
| Remote control without crew on board | Shore-based control is used; no conventional crew are carried on board. | Remote operators, remote watchkeepers, shore-based emergency response personnel. |
| Autonomous operation and human-machine collaboration | Systems operate autonomously in specific scenarios; humans supervise and intervene when necessary. | Autonomous navigation system supervisors, human-machine decision-makers, anomaly identification personnel. |
| Full-voyage autonomy and shore-based supervision | Systems make decisions autonomously; shore staff undertake mission planning, supervision, and safety assessment. | Shore-based supervisors, intelligent-ship operations managers, autonomous navigation safety assessors. |

## 3.3 Relationship between Job Transformation and Competency Needs

Job transformation is ultimately reflected in changes in the competency structure. Ship officers rely primarily on navigational fundamentals, ship maneuvering, and collision-avoidance competencies. Remote-control operators require remote monitoring, ship-shore communication, and transfer-of-control competencies. Autonomous navigation system supervisors require knowledge of the perception-decision-control process and the ability to judge the rationality of system outputs. Shore-based supervisors and safety assessors require data analysis, operational management, risk assessment, understanding of regulations and standards, and cybersecurity awareness. These requirements can be summarized into seven core competencies: conventional seamanship, understanding of smart navigation equipment, remote control and transfer of control, autonomous navigation system cognition and supervision, human-machine collaboration and abnormal response, data analysis and shore-based operations management, and regulatory safety and comprehensive literacy.

### 3.4 Relationship between Competency Needs and Educational Pathways

Competency needs must be translated into implementable educational pathways. Conventional seamanship depends on foundational courses such as navigation, ship maneuvering, watchkeeping and collision avoidance, and navigational instruments. Understanding of smart navigation equipment depends on teaching content related to visual enhancement, collision warning, grounding warning, and integrated information display. Remote-control competency depends on training in shore-based control, remote watchkeeping, transfer of control, and emergency takeover. Autonomous navigation system cognition depends on courses in intelligent ships, autonomous navigation principles, and the perception-decision-control process. Human-machine collaboration depends on semi-autonomous navigation scenarios, anomaly identification, and manual intervention training. Data analysis and operations management depend on AIS data analysis, log analysis, equipment state data analysis, and incident review. Regulatory safety and comprehensive literacy depend on education related to the MASS Code, intelligent-ship rules, COLREGs, STCW, cybersecurity, data security, and engineering ethics[25,26].

The key function of the framework is to transform the development trend of intelligent ships into executable educational reform tasks. Stage evolution answers how ships may operate in the future; job transformation answers what roles students may undertake; competency needs answer what students should master; and educational pathways answer how programs should organize courses and training. This progressive logic helps avoid a reform plan that remains at the level of slogans and enables curriculum design, practical projects, and assessment methods to focus on specific competencies.

*Table 2. Correspondence among core competencies, course support, and practical training.*

| Core competency | Key supporting courses | Practical training content |
|---|---|---|
| Seamanship and equipment understanding | Navigation, ship maneuvering, navigational instruments, introduction to intelligent ships. | Route design, radar observation, interpretation of intelligent warning information. |
| Remote control and ship-shore collaboration | Ship-shore communication, remote-control technology, intelligent integration platform. | Shore-based control, transfer of control, response to communication abnormalities. |
| Autonomous navigation system supervision | Principles of autonomous navigation, intelligent perception, collision-avoidance rules. | System-state monitoring, judgment of collision-avoidance decisions, manual intervention. |
| Data analysis and operations management | Navigation data analysis, smart shipping safety management. | AIS data analysis, incident review, operational risk assessment. |
| Regulatory safety and comprehensive literacy | MASS Code, intelligent-ship rules, cybersecurity and data security. | Regulatory case analysis, responsibility-boundary discussion, teamwork tasks. |

## 4. Core Competency Structure for Navigation Technology Students in the Context of Intelligent Ships

### 4.1 Seamanship and Understanding of Smart Equipment

Foundational navigational ability remains the basis of intelligent-ship talent development. The development of intelligent ships does not reduce the importance of conventional seamanship. Students can judge whether the outputs of smart navigation equipment or autonomous navigation systems are reasonable only when they understand ship motion, navigational environments, collision-avoidance rules, and maneuvering limitations. This competency includes navigation, ship maneuvering, watchkeeping and collision avoidance, route design, electronic chart application, radar observation, AIS interpretation, ship positioning, and emergency response. At the same time, students should understand the functions of smart navigation equipment and decision-support systems, including visual enhancement, integrated information display, collision warning, grounding warning, and route and speed optimization[27,28].

### 4.2 Remote Control and Ship-Shore Collaboration

Remote control changes the way operators acquire information, assess risks, and execute commands. Students need to master shore-based remote-monitoring interface interpretation, remote helm and engine control, route tracking, ship-shore communication status assessment, analysis of communication delay, remote collision avoidance, transfer of control, and emergency takeover. Remote control should not be regarded as simply moving the bridge to shore. It involves changes in information perception, control chains, responsibility allocation, and emergency response processes. Teaching should therefore emphasize risk judgment under incomplete information, communication delay, limited visual feedback, and insufficient control feedback.

### 4.3 Autonomous Navigation System Supervision and Human-Machine Collaboration

Autonomous navigation systems usually involve environmental perception, situation awareness, risk assessment, path planning, collision-avoidance decision-making, motion control, and state monitoring. Students should understand the relationships among these processes and be able to judge system states and outputs. This competency addresses whether students can effectively supervise an intelligent navigation system. In complex encounter situations, students should be able to determine whether a collision-avoidance action generated by the system complies with collision-avoidance rules, satisfies safe-distance requirements, and avoids creating new traffic conflicts[29]. When system alarms, communication interruptions, target-recognition errors, or increasing control deviations occur, students should be able to judge whether manual intervention is required.

### 4.4 Data Analysis and Shore-Based Operations Management

Full-voyage autonomy and shore-based supervision place higher demands on data analysis. Students should be able to understand and analyze AIS data, navigation logs, equipment state data, alarm records, remote-control records, and in3cident data. Through data analysis, they can conduct operational status assessment, risk-trend judgment, efficiency analysis, and incident review. Shore-based operations management includes multi-ship monitoring, mission planning, route operation tracking, shore-ship collaborative dispatch, abnormal-event response, and navigational safety management. Future Navigation Technology graduates may work for smart shipping platforms, remote-control centers, maritime supervision agencies, and shipping companies. Data analysis and operations management will therefore become essential capabilities for adapting to new positions.

### 4.5 Regulatory Safety and Comprehensive Literacy

The development of intelligent ships involves the application of collision-avoidance rules, the responsibility of the master, qualification requirements for remote operators, management of shore-based control centers, cybersecurity, data security, system reliability, and engineering ethics. Students should develop awareness of regulations, safety, responsibility, and risk. This competency includes understanding the MASS Code, intelligent-ship rules, COLREGs, and STCW requirements; recognizing cybersecurity and data-security risks; understanding responsibility boundaries in intelligent-ship operation; and collaborating with professionals in naval architecture, communication engineering, control engineering, artificial intelligence, and safety management.

## 5. Major Deficiencies in Current Training for Navigation Technology Students

### 5.1 Insufficient Response of Training Objectives to Future Job Transformation

Current training objectives in Navigation Technology programs mainly target conventional ship officers, navigational watchkeepers, and ship management personnel. They emphasize ship handling, navigational safety, watchkeeping and collision avoidance, and ship management, but give insufficient attention to emerging roles such as remote-control operators, autonomous navigation system supervisors, shore-based supervisors, intelligent-ship operations managers, and autonomous navigation safety assessors. As a result, students may be prepared for conventional bridge work but insufficiently prepared for new tasks involving remote control, human-machine collaboration, smart equipment interpretation, and shore-based supervision.

### 5.2 Insufficient Support for Intelligent-Ship Content in the Curriculum

Existing curricula are mainly organized around navigation, ship maneuvering, collision avoidance, navigational instruments, ship management, and seafarer competency examinations. Content on intelligent ships, autonomous navigation, remote control, ship-shore communication, data analysis, cybersecurity, and smart shipping management remains insufficient. Although some courses cover electronic charts, radar, AIS, and navigational instruments, they often focus on equipment use rather than multi-source information fusion, intelligent warning, automatic decision-making, human-machine interaction, and remote-control processes.

### 5.3 Weak Connection between Practical Teaching and Intelligent-Navigation Scenarios

Practical teaching in Navigation Technology programs mainly relies on navigation simulators, ship-handling training, and shipboard practice. Training content is concentrated on bridge operation, route planning, encounter avoidance, radar observation, and watchkeeping procedures. Scenarios involving remote control, transfer of control, autonomous navigation state supervision, perception anomaly identification, manual takeover, and shore-based supervision are comparatively insufficient. In the operating environment of intelligent ships, students need to make judgments under multi-source information, multiple interfaces, multiple tasks, and uncertain conditions. Conventional bridge-centered training cannot fully cover the complex scenarios required by future positions.

### 5.4 Insufficient Assessment of Integrated Competencies

Existing assessment methods mainly include theoretical examinations, operational tests, course assignments, and internship evaluations. Assessment content tends to focus on knowledge mastery and single operational skills, while remote-control ability, human-machine collaboration, system supervision, abnormal response, data analysis, and regulatory safety literacy are insufficiently reflected. Education oriented to intelligent ships should place greater emphasis on students' integrated judgment in complex scenarios rather than merely testing whether a student has mastered a specific operation.

## 6. Development Pathways Oriented to the Staged Evolution of Autonomous Navigation in Intelligent Ships

### 6.1 Reconstructing Training Objectives for Future Positions

The objectives of Navigation Technology programs should be expanded from training conventional ship officers to cultivating interdisciplinary maritime professionals for intelligent-ship operation. Students should develop conventional seamanship, understanding of smart navigation equipment, remote-control ability, autonomous navigation system supervision, human-machine collaboration, data analysis, and shore-based operations management. Training objectives may be organized into three levels. The foundational level emphasizes conventional competencies such as navigation, ship maneuvering, watchkeeping and collision avoidance, navigational instruments, and ship management. The intelligent level emphasizes smart equipment understanding, remote control, autonomous navigation system cognition, and human-machine collaboration. The management level emphasizes shore-based supervision, data analysis, safety assessment, and smart shipping management.

## 6.2 Developing a Curriculum System Integrating Seamanship, Intelligent Technology, Regulations, and Operations Management

Curriculum reform should be oriented toward students' future core competencies. The seamanship module should include navigation, ship maneuvering, collision avoidance, navigational instruments, ship management, route design, and navigational safety, thereby maintaining the disciplinary foundation of Navigation Technology. The intelligent technology module should include introduction to intelligent ships, principles of autonomous navigation, intelligent perception, ship-shore communication, remote-control technology, intelligent integration platforms, intelligent berthing and unberthing, and intelligent bridge-area collision avoidance. This module helps students understand operating mechanisms and typical functions of intelligent ships. The regulatory module should include the MASS Code, intelligent-ship rules, COLREGs, STCW, cybersecurity, data security, responsibility allocation, and engineering ethics. The operations management module should include navigation data analysis, smart shipping safety management, autonomous navigation risk assessment, incident review, shore-based supervision practice, and smart shipping platform application. These modules support students in adapting to shore-based supervision and intelligent-ship operations management positions.

### 6.3 Establishing a Staged and Progressive Practical Teaching System

Practical teaching should correspond to the staged evolution of autonomous navigation in intelligent ships and form a progressive training system. Training in automated assistance and decision support should emphasize the use of smart navigation equipment, interpretation of integrated information displays, visual enhancement, collision-warning response, and grounding-warning judgment. Training in remote control with crew on board should emphasize shore-based monitoring, remote helm and engine control, ship-shore collaboration, transfer of control, and onboard emergency takeover. Training in remote control without crew on board should emphasize remote watchkeeping, multi-source information monitoring, communication failure judgment, remote collision avoidance, remote emergency response, and multi-ship supervision. Training in autonomous operation and human-machine collaboration should emphasize monitoring of autonomous navigation states, judgment of collision-avoidance decisions, perception anomaly identification, decision anomaly identification, manual intervention, and abnormal takeover. Training in full-voyage autonomy and shore-based supervision should emphasize mission planning, operations supervision, navigation data analysis, safety assessment, incident review, and smart shipping operations management.

### 6.4 Building an Integrated Virtual-Physical Teaching Platform for Intelligent Ships

Teaching platforms are essential for supporting core competency development. Navigation Technology programs may build integrated virtual-physical teaching platforms for intelligent ships by combining navigation simulators, remote-control consoles, electronic charts, AIS data, radar displays, visual perception modules, autonomous navigation simulations, ship-shore communication simulations, abnormal-takeover training, and smart shipping management modules. Such platforms should support three functions. First, they should support conventional navigation training, including ship maneuvering, route design, watchkeeping and collision avoidance, and emergency response. Second, they should support intelligent-ship training, including remote control, intelligent monitoring, autonomous collision avoidance, intelligent berthing and unberthing, and bridge-area collision avoidance. Third, they should support comprehensive assessment through records of students' operation processes, risk judgments, takeover timing, and task completion results.

### 6.5 Promoting University-Industry Collaboration and Scenario-Based Teaching

The cultivation of intelligent-ship talent requires support from industry resources. Universities may cooperate with shipping companies, intelligent-ship enterprises, classification societies, maritime administrations, port and waterway management authorities, and equipment developers. Industry partners can provide cases of remote-control platforms, intelligent-ship testing, autonomous navigation function verification, maritime supervision, and smart shipping operational data. Project-based and case-based teaching can be adopted around tasks such as remote control of ships entering port areas, collision avoidance by semi-autonomous ships in complex encounter situations, emergency takeover under communication interruption, risk judgment during intelligent berthing and unberthing, and intelligent collision avoidance in bridge-area waters. These cases help students understand future job requirements in concrete scenarios.

### 6.6 Improving Competency-Oriented Assessment Mechanisms

Assessment mechanisms should shift from single knowledge-based assessment toward integrated competency assessment. Assessment content may include foundational navigational knowledge, smart equipment interpretation, remote-control ability, autonomous navigation system supervision, complex-scenario risk judgment, abnormal takeover, data analysis, regulatory understanding, and teamwork. Assessment methods may combine theoretical examinations, simulation training, case analysis, project tasks, scenario exercises, and comprehensive defenses. For remote-control ability, assessment may focus on interface interpretation, control commands, judgment of communication abnormality, and takeover timing. For human-machine collaboration, assessment may examine whether students can judge the rationality of outputs from the autonomous navigation system. For data analysis, assessment may examine whether students can conduct operational status analysis and incident review based on navigation data and abnormal records.

### 6.7 Strengthening Faculty Capacity and Teaching Resources

The implementation of core competency development also depends on faculty capacity and teaching resources. Teachers in Navigation Technology programs need to continually update their knowledge of intelligent ships, autonomous navigation, remote control, smart shipping platforms, and related regulations and standards. Universities can enhance teacher' understanding of intelligent-ship operating scenarios and their ability to transform such scenarios into courses through enterprise practice, classification-society training, maritime supervision research, research project participation, and interdisciplinary team building. In addition, smart shipping case libraries and scenario libraries should be developed. These libraries should cover remote control, complex encounters, intelligent berthing and unberthing, bridge-area collision avoidance, communication interruption, perception anomalies, manual takeover, and shore-based supervision, thereby providing stable support for classroom teaching, simulation training, and comprehensive assessment.

## Conclusion

The development of autonomous navigation in intelligent ships is changing the competency structure of Navigation Technology students. Drawing on the IMO MASS Code and the CCS Rules for Intelligent Ships (2026), autonomous navigation in intelligent ships can be summarized into five typical stages: automated assistance and decision support, remote control with crew on board, remote control without crew on board, autonomous operation with human-machine collaboration, and full-voyage autonomy with shore-based supervision. Different stages correspond to different job roles and competency needs.

Based on the analytical framework of “stage evolution-job transformation-competency needs-educational pathways,” the training of Navigation Technology students should be extended from conventional ship handling and watchkeeping toward smart navigation equipment understanding, remote control, autonomous navigation system supervision, human-machine collaboration, data analysis, shore-based supervision, and intelligent-ship operations management. This framework links the development trend of intelligent ships, future job requirements, and educational reform pathways, preventing navigation education reform from remaining at a merely macro-level discourse.

In response to the future development of intelligent ships, Navigation Technology programs should reconstruct training objectives, develop a curriculum integrating seamanship, intelligent technology, regulations, and operations management, establish a staged and progressive practical teaching system, improve integrated virtual-physical teaching platforms, promote university-industry collaboration and scenario-based teaching, and form competency-oriented assessment mechanisms. These pathways can enhance students' ability to adapt to autonomous navigation in intelligent ships and provide support for the cultivation of interdisciplinary maritime professionals in the context of smart shipping..

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