Japanese MASS R&D Projects and Approaches for Ensuring Safety

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Trials for the development of MASS

- Since 2018, MLIT has conducted the first MASS trials in Japan.
  - In 2018: simulation testing to collect data for safety validation
  - In 2019: checking simulation data against the actual ship testing data
  - In 2020: development of safety guidelines for MASS design, as well as actual ship testing

**Remote Control Function**

Players:
- Oshima Shipbuilding Co., Ltd.
- MHI Marine Engineering, Ltd.

Players:
- MTI Co., Ltd.
- ClassNK
- BEMAC Corp.

**Autonomous Operation Function**

Players:
- Oshima Shipbuilding Co., Ltd.
- MHI Marine Engineering, Ltd.

**Auto Berthing & Un-Berthing Function**

Players:
- Mitsui E&S Shipbuilding Co., Ltd.
- Tokyo University of Marine Science and Technology, etc.

Realizing phase-II* MASS by 2025

*generally corresponding to the Degree 1 MASS
MEGURI 2040 Fully Autonomous Ship Program

- Demonstration tests of fully autonomous navigation for coastal shipping
- Promote innovation in Japan’s logistics, economy and social platforms

| Designing the Future of Full Autonomous Ship (DFFAS): Grand design drawn by diverse specialists | Autonomous navigation in a congested sea area (roughly 500 ships pass each day), using a container ship "SUZAKU". |
| Verification testing of fully autonomous technologies using coastal container vessels and car ferries | Autonomous navigation under rough weather and sea condition together with mooring operations by a drone, using a container ship "Mikage". Autonomous navigation in long distance of 750 km over about 18 hours, using a large car ferry "Sunflower Shiretoko". |
| Fully autonomous navigation at Sarushima, Yokosuka | Autonomous navigation (automated navigation from departure to berthing), using small passenger ship "Sea Friend ZERO". |
| Smart ferry development | Autonomous port berthing and unberthing using turning and reversing maneuver as well as autonomous navigation under high-speed (up to 26 knots), using a large car ferry "SOLEIL". |
Risk Assessment for MASS Trials

- Interim guidelines for MASS trials (MSC.1/Circ.1604) requires risk assessment prior to MASS trials.
- Specific methods or procedures of risk assessment for MASS trials are not prescribed in those guidelines.
- NMRI supported each consortium to conduct risk assessment to ensure safety of MASS trails in MEGURI 2040 Program.

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Risk Analysis Procedure Document

- Outcome of NMRI’s supporting works for risk assessment
  - Ensuring safety of MASS trials
  - Improving safety of autonomous ship systems

- Knowledge from the works

- NMRI developed a Procedure Document for Risk Analysis on Autonomous Ships.

- It has been referred to in Safety Guidelines for MASS published by MLIT.

- It will contribute to reduce a burden on developers and certifiers, and facilitate MASS R&D and commercialization.

Examples of types of hazards presented in the Procedure Document

<table>
<thead>
<tr>
<th>Classification</th>
<th>Types of hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>External conditions</td>
<td>• Rough weather</td>
</tr>
<tr>
<td></td>
<td>• Poor visibility</td>
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<tr>
<td></td>
<td>• Congested sea area</td>
</tr>
<tr>
<td></td>
<td>• Unexpected behavior of other ships</td>
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<tr>
<td>Failure of automated system or related system</td>
<td>• Loss of signals from sensors</td>
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<tr>
<td></td>
<td>• Disorder of hardware of automated system</td>
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<tr>
<td></td>
<td>• Bugs of software of automated system</td>
</tr>
<tr>
<td></td>
<td>• Loss of power in automated system</td>
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<td></td>
<td>• Inappropriate HMI</td>
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</tbody>
</table>
Safety Evaluation Method using Simulation

- NMRI decided to use a scenario-based approach to ensure comprehensiveness of test scenarios.

- Scenario Creation
  - Normal Scenarios

  - Disturbance-scenario-based approach

  - Coverage of Scenario Space

  - Functional Requirements
  - ODD Taxonomy
  - Regulations

  - Scenario Space

  - Item Definition

  - Normal Scenario

- Critical Scenarios
  - There are critical risk factors derived from maneuvering among the normal scenarios.
  - system-derived critical risk factors such as failures, malfunctions.
  - emergency measures such as fallbacks.

Disturbance-scenario-based approach

- NMRI proposed a method for making disturbance scenarios considering the sub-tasks of navigation tasks.
- Each navigation task is decomposed into perception, judgement, and control sub-tasks, and scenarios are created based on the disturbances corresponding to each subtask.

<table>
<thead>
<tr>
<th>Sub-tasks</th>
<th>Perception</th>
<th>Judgment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbance</td>
<td>Perception disturbance</td>
<td>Traffic disturbance</td>
<td>Ship motion disturbance</td>
</tr>
<tr>
<td>Sensors:</td>
<td>radar, camera, GPS, etc.</td>
<td>Encounter situation,</td>
<td>Mechanical disturbances acting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>geographical conditions and the behavior of other ships etc.</td>
<td>on the hull due to weather, sea conditions, loading conditions, etc.</td>
</tr>
</tbody>
</table>

In February 2022, MLIT has compiled points to consider at designing, installing and operation phases of MASS and published *Safety Guidelines for MASS*

**Example of contents of the guidelines**

**Points to consider at the designing phase of MASS**
1. Defining Operational Design Domain (ODD)
2. Human Machine Interface (HMI) settings
3. Smooth transition measures for crews to maneuver in the event of Automated Operation System (AOS) failure
4. Installing of recording devices
5. Ensuring cyber security
6. Ensuring an operating environment to perform the evasion and auto (un-)berthing function
7. Ensuring an operating environment to perform remote control function
8. Identification of important parameters of AOS
9. Conducting risk assessment
10. Preparation of manuals, etc. for AOS
11. Prompt notification and response when AOS malfunctions are discovered
Overview of the points to consider for MASS

**Design**
- Defining ODD
  - It is necessary to define an ODD for each AOS in accordance with the performance and usage of the individual MASS or AOS
- HMI setting
  - It is necessary to have a function to enable crews to easily and reliably recognize information about judgements made by the AOS
- Ensuring cyber security
  - It is necessary to prevent unauthorized access to the AOS from outside, unauthorized communications shall be blocked by firewalls or other means
- Compliance to laws and regulations

**Installation**
- Documents to be provided for MASS
  - AOS manuals should be kept in a location that is easily accessible for review by the crews using the AOS
- Ensuring cooperation between AOS and other equipment and facilities
  - It shall be confirmed through connection tests, etc., that the equipment and devices that make up the AOS are properly connected

**Operation**
- Implementation of system integration tests on board
  - The soundness of the relevant system, etc., shall be confirmed by actually operating the AOS
- Prevention of misuse of AOS during operation
  - Important operations should be performed by crew members who are proficient in handling the AOS
- Maintenance management of AOS
  - It is necessary to properly manage the version of the AOS, and to confirm that interoperability with the info collection devices etc., is not impaired when the version is changed
- Implementation of appropriate ship maneuvering using AOS
  - Crews who are proficient in the operation of the AOS must be properly assigned
- Ensuring cooperation between AOS and other equipment and facilities

**Compliance to laws and regulations**
Conclusions

- This presentation introduced Japanese MASS R&D Projects and Approaches for ensuring safety.
  - Trials for the development of MASS by MLIT
  - MEGURI 2040 Fully Autonomous Ship Program by the Nippon Foundation
  - Risk assessment prior to demonstration tests by NMRI
  - Scenario-based Safety evaluation method with simulators by NMRI

- Japan would like to continue to contribute to development of IMO regulations including the MASS Code to ensure safety of MASS.
Thank you for your attention!

This presentation is prepared in cooperation with the following organizations.
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