

The development status of autonomous ships in MEGURI2040 and activities toward implementation in shipping

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Capt. Tomoyuki Koyama ¹⁾

Dr. Hideyuki Ando ²⁾



1) Japan Marine Science (NYK Group)

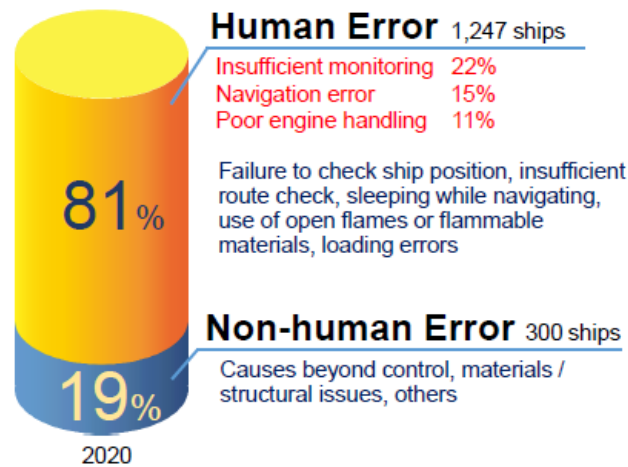
2) MTI (NYK Group)

Outline

- 1. Introduction on MEGURI2040 & DFFAS/DFFAS+ Project**
2. Risk assessment and verification in DFFAS+ Project
3. Summary

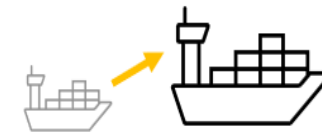
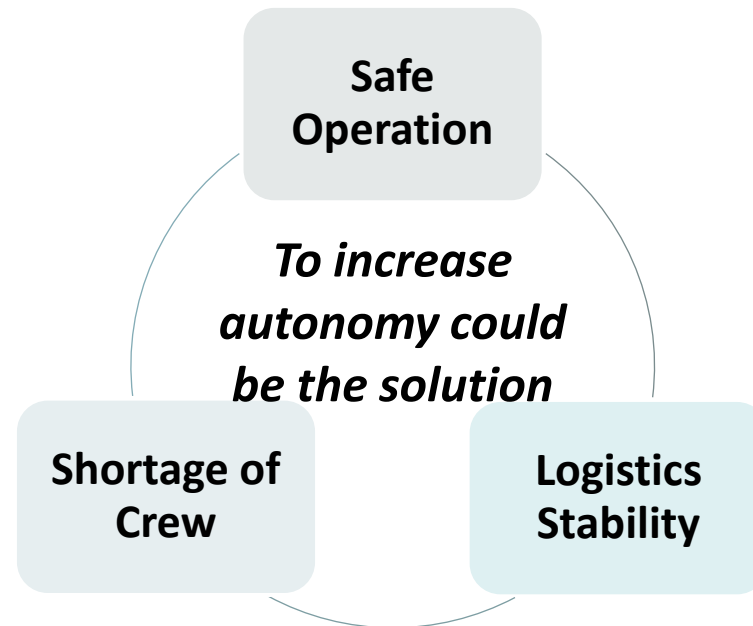
Why do we need Autonomous Ships?

Sustainability of shipping is fundamental for global economy

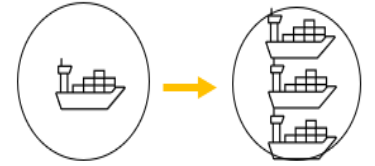


- ✓ Navigation accidents are caused mainly by **human errors (abt. 80%)**

- ✓ **Global seafarer shortage 8.8%**, highest ever
- ✓ **Shortage of seafarers** in Japan's domestic shipping (by 2040 there will be a 30% shortage of seafarers)



Bigger ships with smaller engines

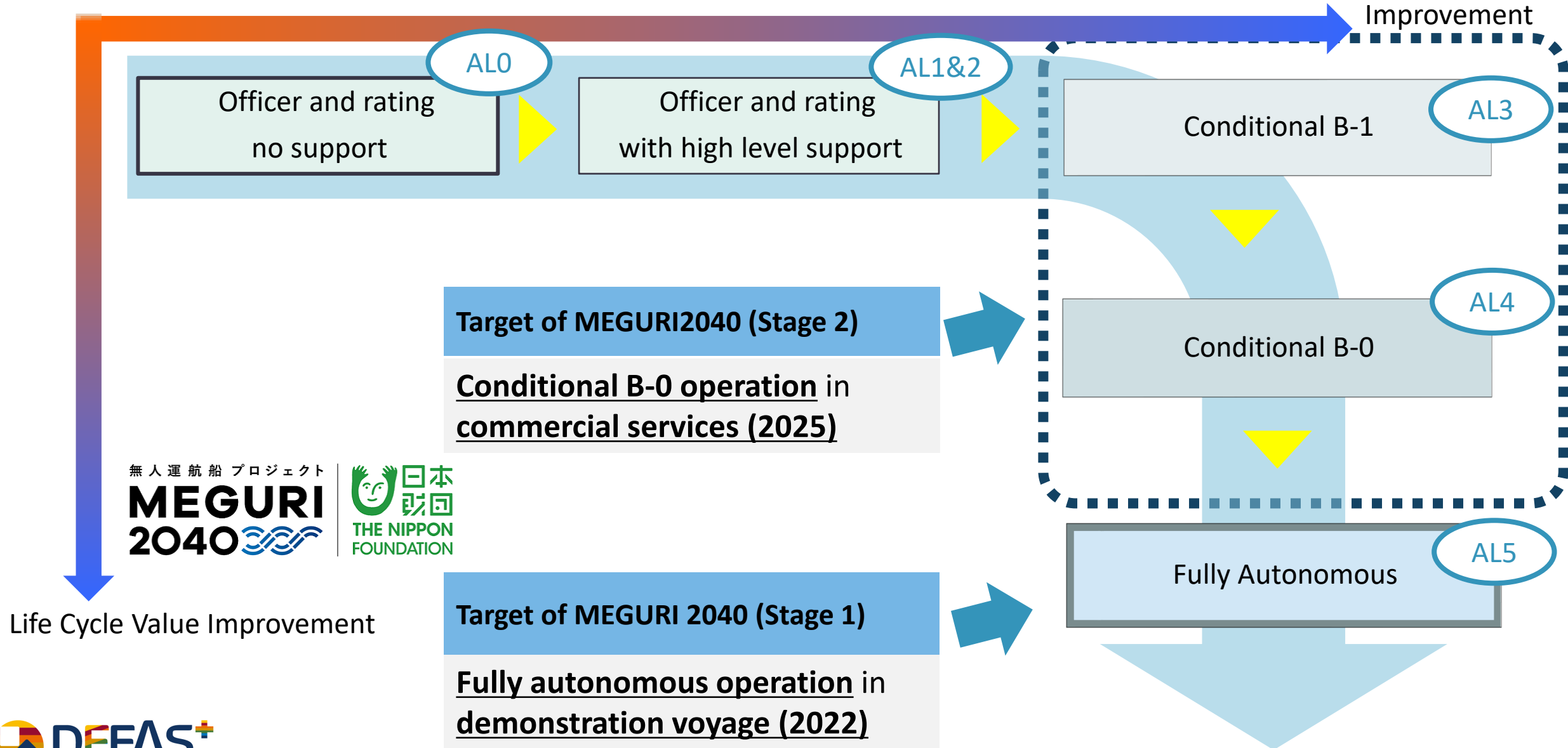


More congestions due to increased ships

- ✓ Reduced maneuverability in congested routes
→ **Early action** is important

- ✓ **Future increase in maritime transport demands in each region** (from trucks to shipping and trains)

Autonomous navigation roadmap and target of MEGURI2040 Stage 1&2



DFFAS Project in MEGURI2040 Stage 1

DFFAS (Designing the Future of Fully Autonomous Ship)

▶ Target

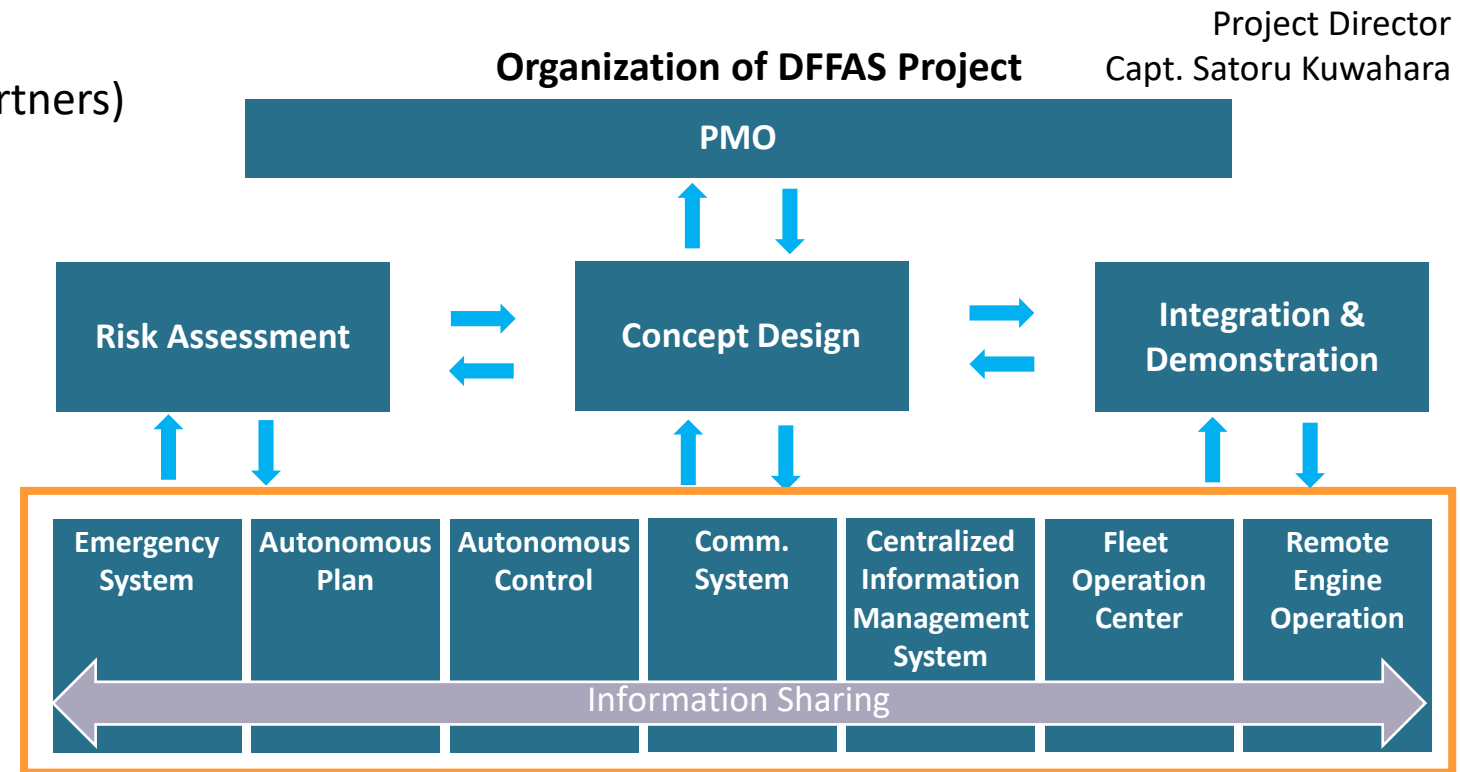
- Demonstration of fully autonomous ship navigation under MEGURI2040

▶ DFFAS consortium members & partners

- Consortium: 30 organizations (domestic)
- Total: 60+ organizations (including global partners)

▶ Schedule

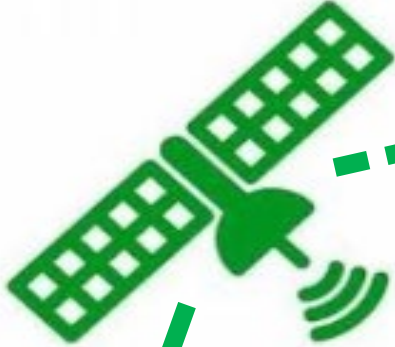
- Feb 2020 – Mar 2022 (abt. 2 years)



DFFAS System Overview



Telecommunication system
(3 satellites and 1 terrestrial communication line,
information management & control)



Land-based system
(land-based support functions)

DFFAS

DFFAS

Onboard system
(autonomous functions)



MEGURI 2040



Integrated Display Block
(ship information collection, monitoring & analysis)
(engine remote monitoring, control & anomaly detection)



Emergency Response Block
(remote operation function)

Results of DFFAS Project (2022)

Demonstration of fully autonomous functions in congested coastal routes in Japan

FOC
Makuhari

Port of Tokyo
Incl. Uraga Strait traffic route

Port of Tsu-Matsusaka
Incl. Irago Strait traffic route in Ise bay

Round trip
424 NM (790km)

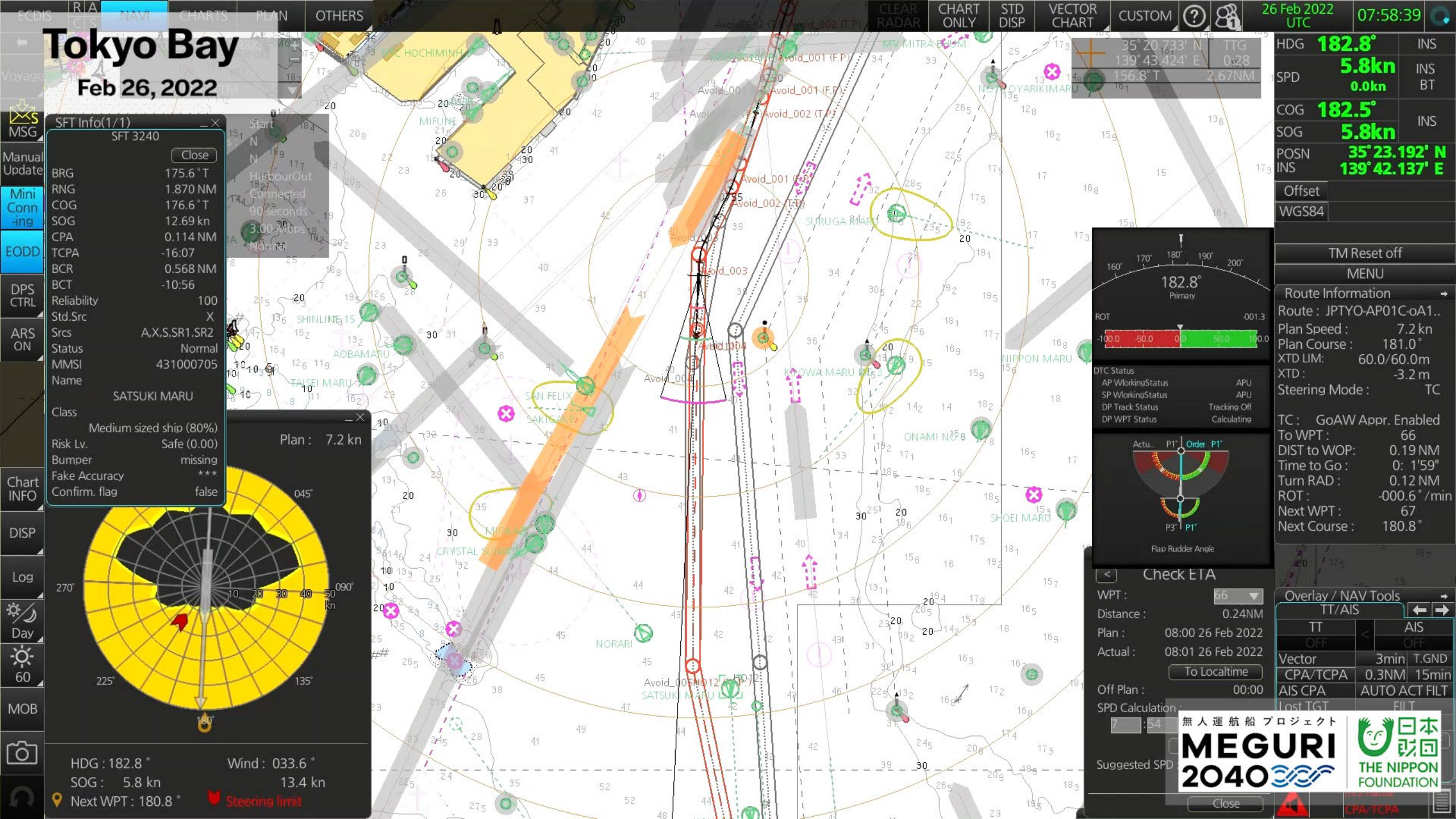
26-27 Feb 2022

28 Feb – 1 Mar 2022

Achieved 98.5% of fully autonomous navigation in the demonstration voyage

Containership "Suzaku", 749GT with fully autonomous functions






DFFAS+ Consortium for MEGURI2040 Stage 2

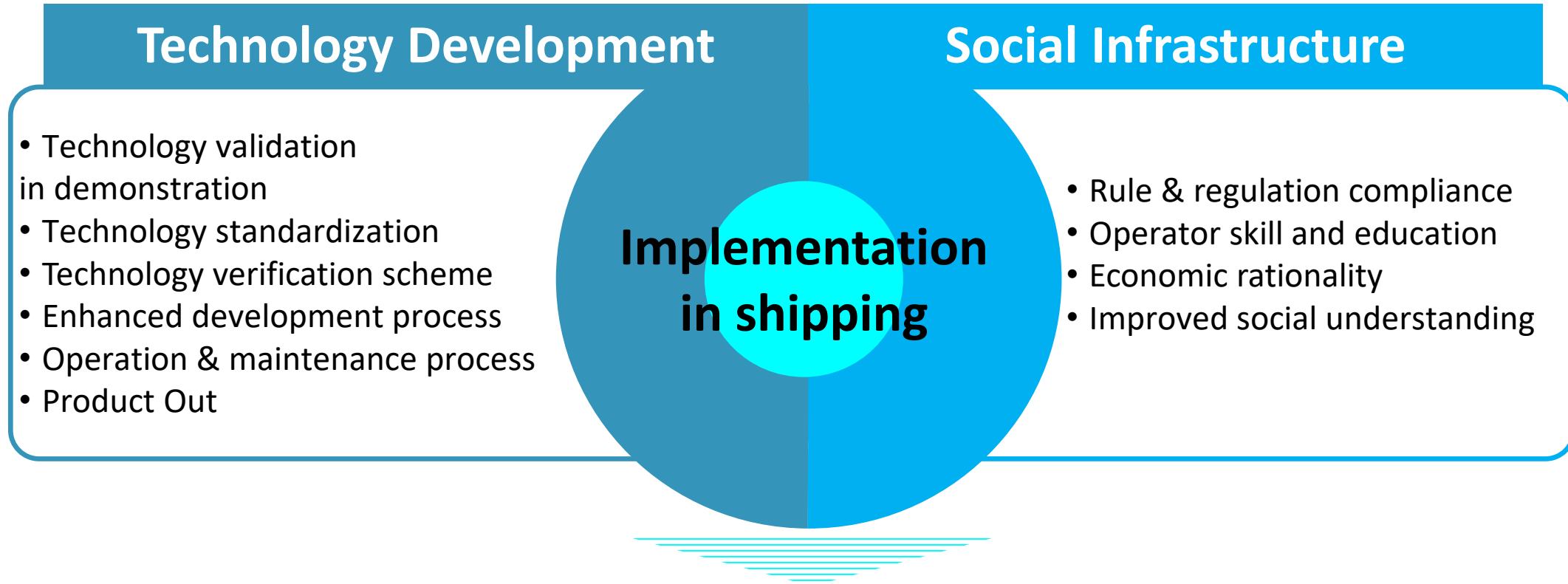
- In MEGURI2040 Stage 2, 53 companies form the DFFAS+ Consortium
- Project period: October 2022 to March 2026 (3.5 years)
- Total grants: 50 mil. USD granted from the Nippon Foundation



Demonstration in MEGURI2040 Stage 2

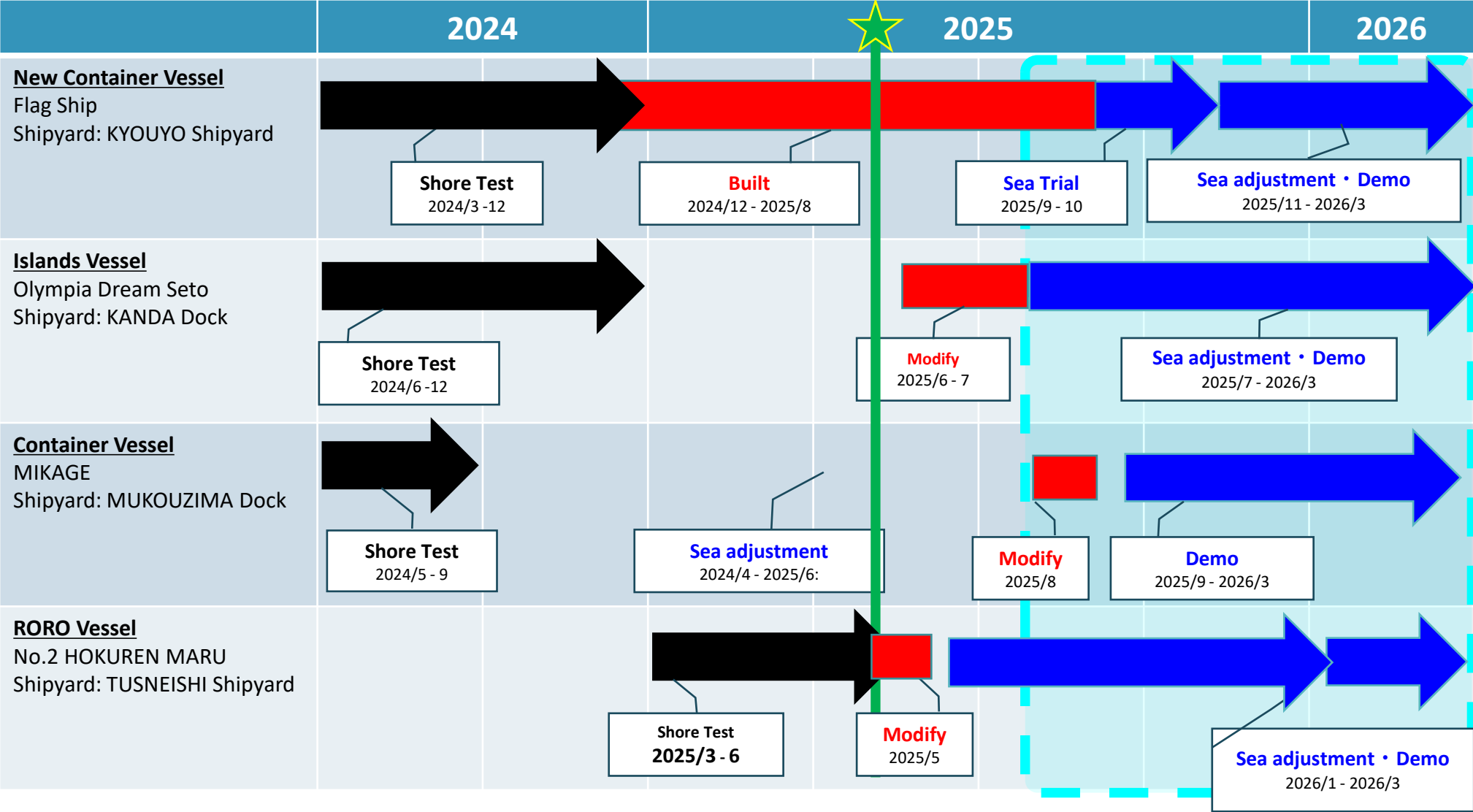
Demonstration of 4 autonomous ships in commercial operations with support from 2 Remote Operation Centers(ROC).

Period	Type, name, size & operation area	Ship	Companies
Nov 2025 - (5 months)	Newly built Container Vessel (about 7,800GT/Coasting area)	(Delivery in Sep 2025)	MTI (Lead) Ikous, Japan Marine Science, JMU, Furuno Electric, BEMAC, Tokyo Keiki, Nabtesco, Sunflame, Mitsui E&S Shipbuilding, Space Compass, JRCS, TerasakiElectric, NaikoMirai, WNI, EIZO
June 2025 - (9 months)	Island Vessel OLYMPIA DREAM SETO (942GT/ Smooth water area)		Japan Marine Science (Lead) Ryobi Ferry, Mitsui E&S Shipbuilding, Mitsubishi Shipbuilding, Furuno Electric
Oct 2025 - (6 months)	Container Vessel MIKAGE (749GT/Coasting area)		Mitsui O.S.K. (Lead) Imoto Lines, Furuno Electric, Mitsui E&S Shipbuilding
Sep 2025 – (a few voyages)	RO-RO Vessel No.2 HOKUREN MARU (11,413GT/ Limited major coasting area)		Kawasaki Kisen (Lead) Kawasaki KinkaiKisen, Japan Radio, YDK



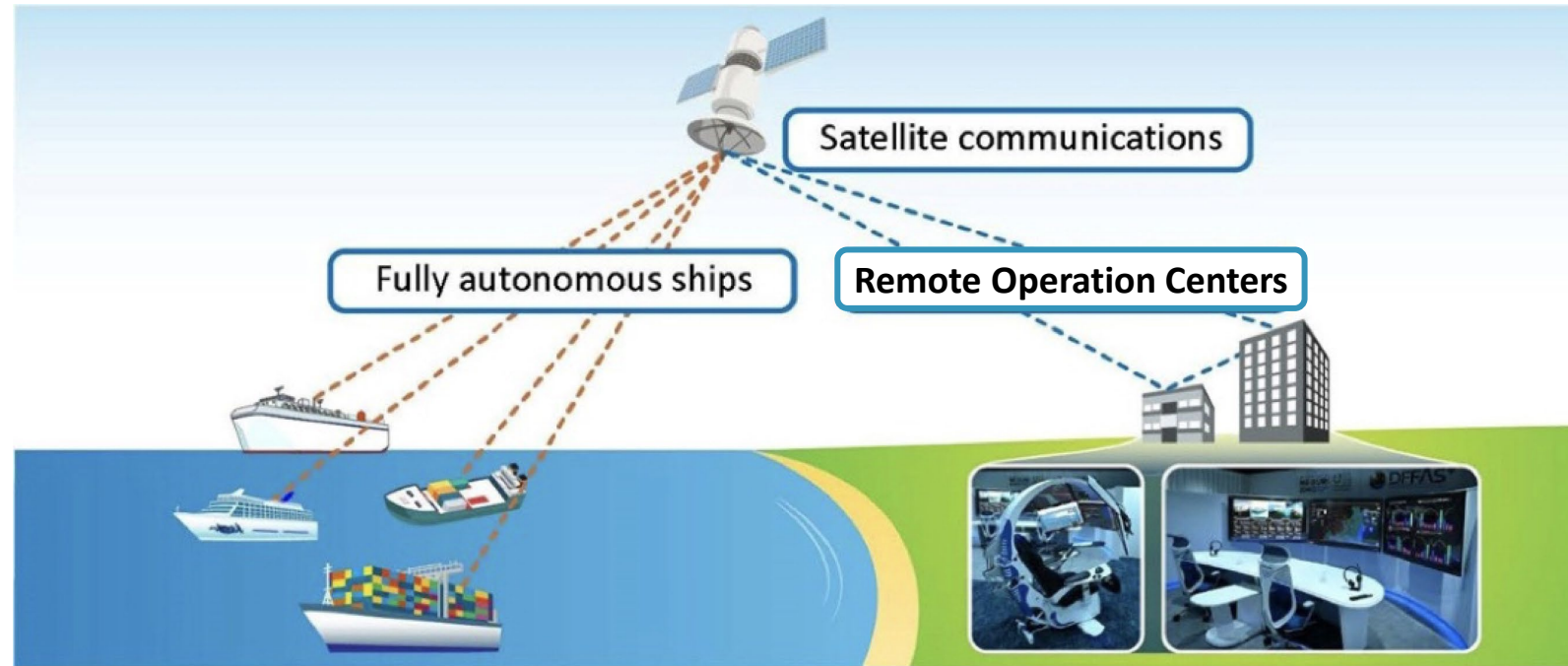
- Autonomous navigation demonstrations in commercial operations on various ship types (2 container ships, 1 passenger ship, 1 RoRo ship) will be conducted.
- Long term practical use of the autonomous navigation systems → Non-technical issues need to be considered, such as human-machine interface, comfortable work environment, crew familiarizations and trainings.

DFFAS+ Project - Schedule



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The Key additional functions

Navigation

- New sensors
- Integrator
- Planner
- Controller

Machinery

- Abnormalities detection

ROC

- Voyage planning
- Engine & power plant remote monitoring

Others

- Status management
- Data recording
- Cyber security

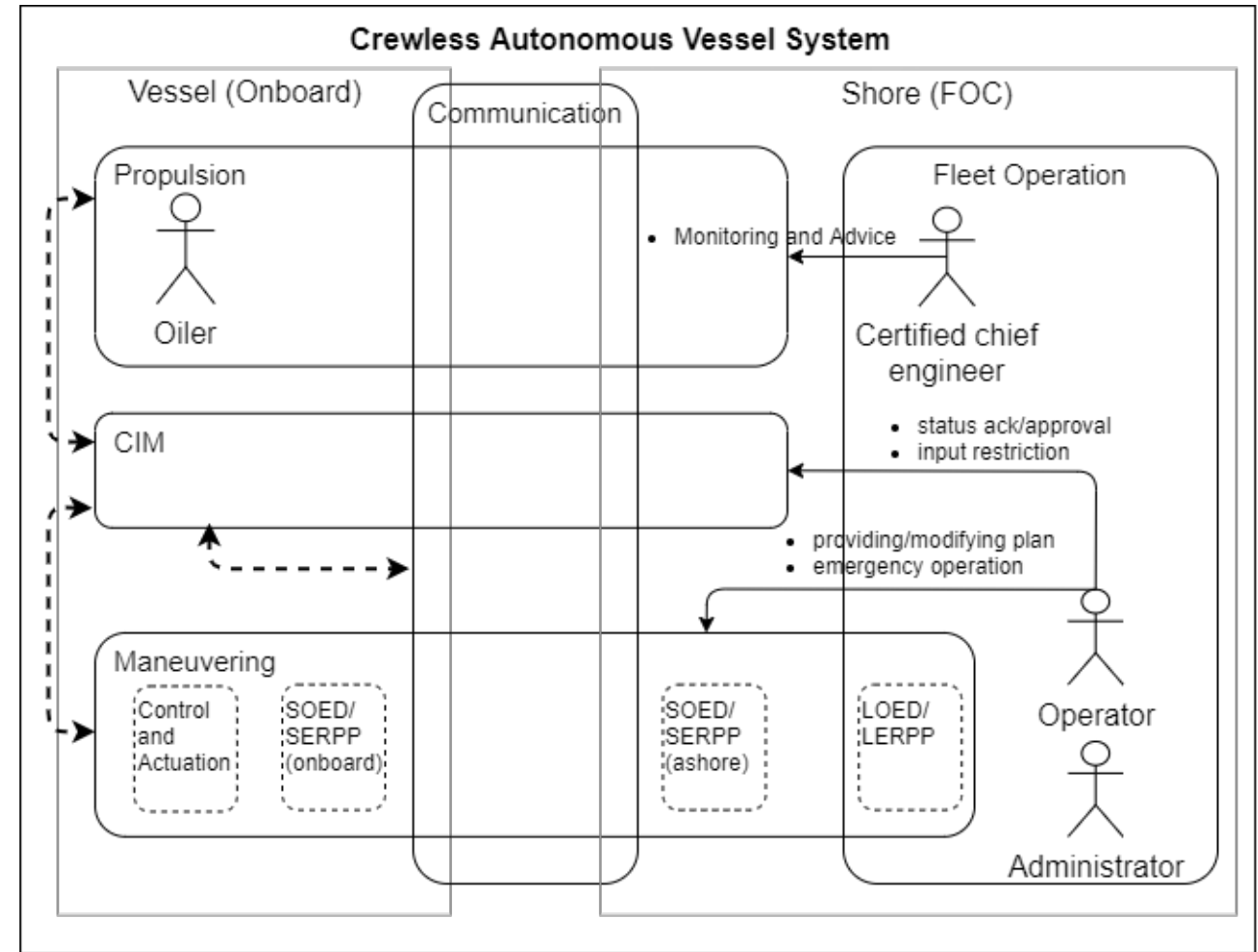
Definition of system requirements in ConOps

► Define Concept of Operations (ConOps)

- Master mariners and chief engineers, who are well versed in ship operations, define the ConOps in cooperation with engineers of manufacturers and system engineering specialists.
- For eliciting system requirements Model-Based Systems Engineering (MBSE) and risk assessment, such as STPA, are used.

► Key features of ConOps

- Ship specifications
- Who, When, What, How
- Operational Design Domain (ODD)
 - Environmental conditions
- Functional Requirements
- Rules and regulations



High level system concept description by using use case diagram

Navigation mode for classifying sea areas

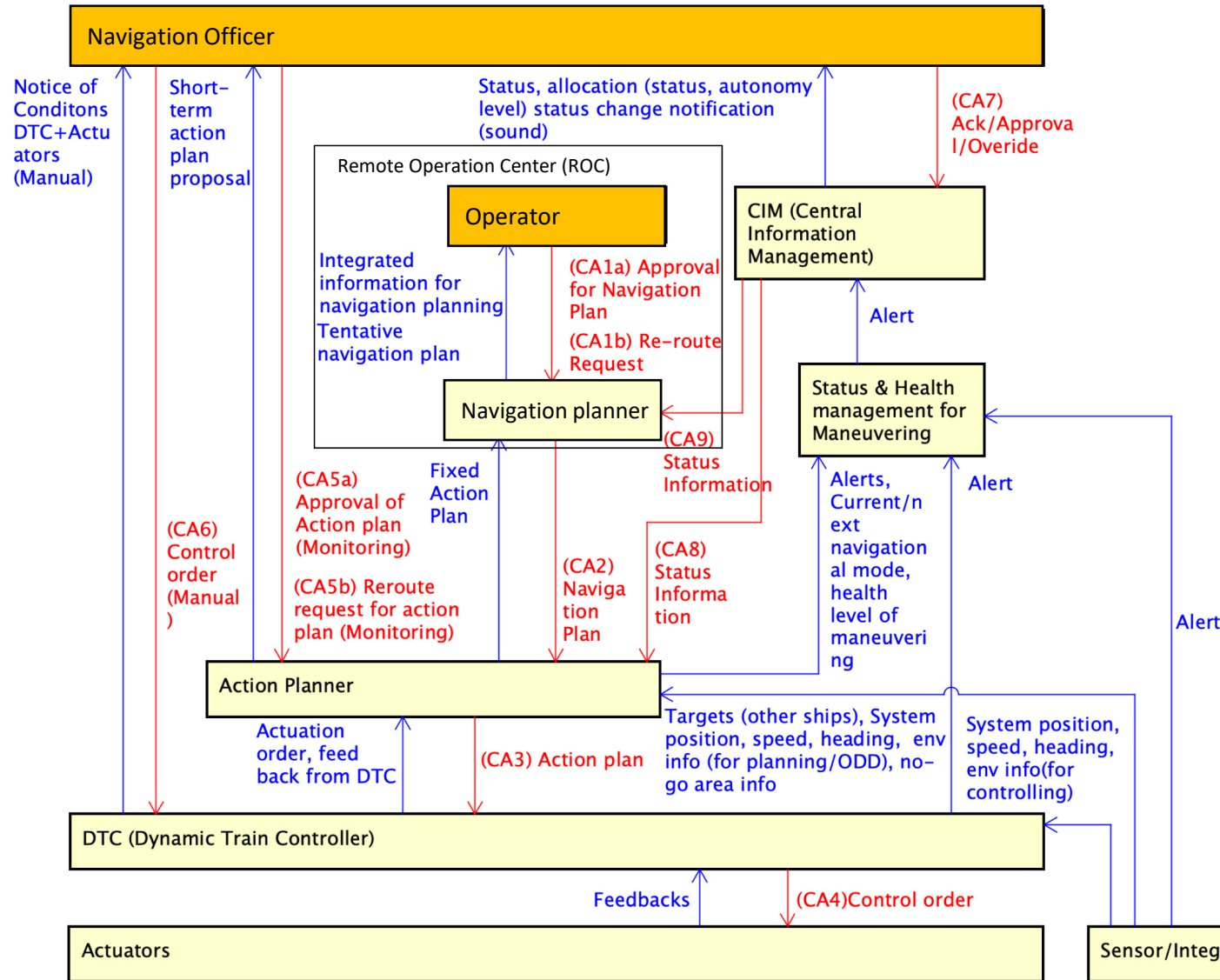
► System configuration could be different depend on navigation mode.

Table 4. Navigational mode used in DFFAS Plus project.

Navigational mode	Definition
Unberthing	Attitude control, unberthing operations
Leaving	Attitude control, speed control possible (speed: lower than upper limit at the operation and/or area)
Harbor Out	Track control, speed control possible (speed: from 0 knots to upper limit of the ship)
Coastal	Track and speed control possible if speed is above the operational minimum (avoiding auxiliary blower cycling) and below the ship's maximum
Ocean	Track control
Harbor In	Track control, speed control possible (speed: from 0 knots to upper limit of the ship)
Approaching	Attitude control, speed control possible (speed: lower than upper limit at the operation and/or area)
Berthing	Attitude control, berthing operations



Example) Control structure of the maneuvering subsystem



✓ Autonomous navigation statuses:

- ❑ Fully Autonomous
- ❑ Monitoring (by navigation officer)
- ❑ (normal) Track Control
- ❑ Manual operation.

✓ Control structure changes depend on navigation status, layer of control task, short- or long-term voyage planning, navigation mode, etc. To run risk assessment and to extract loss scenario, each case need to be considered.

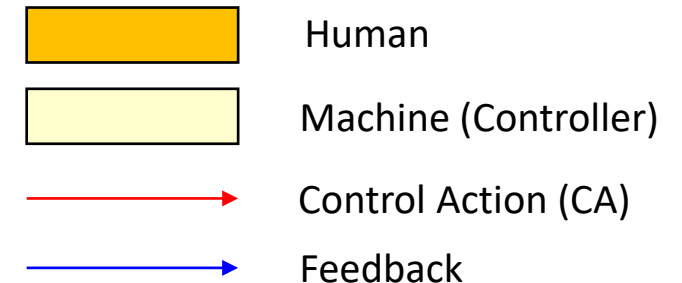


Image of loss scenario extraction by using STPA

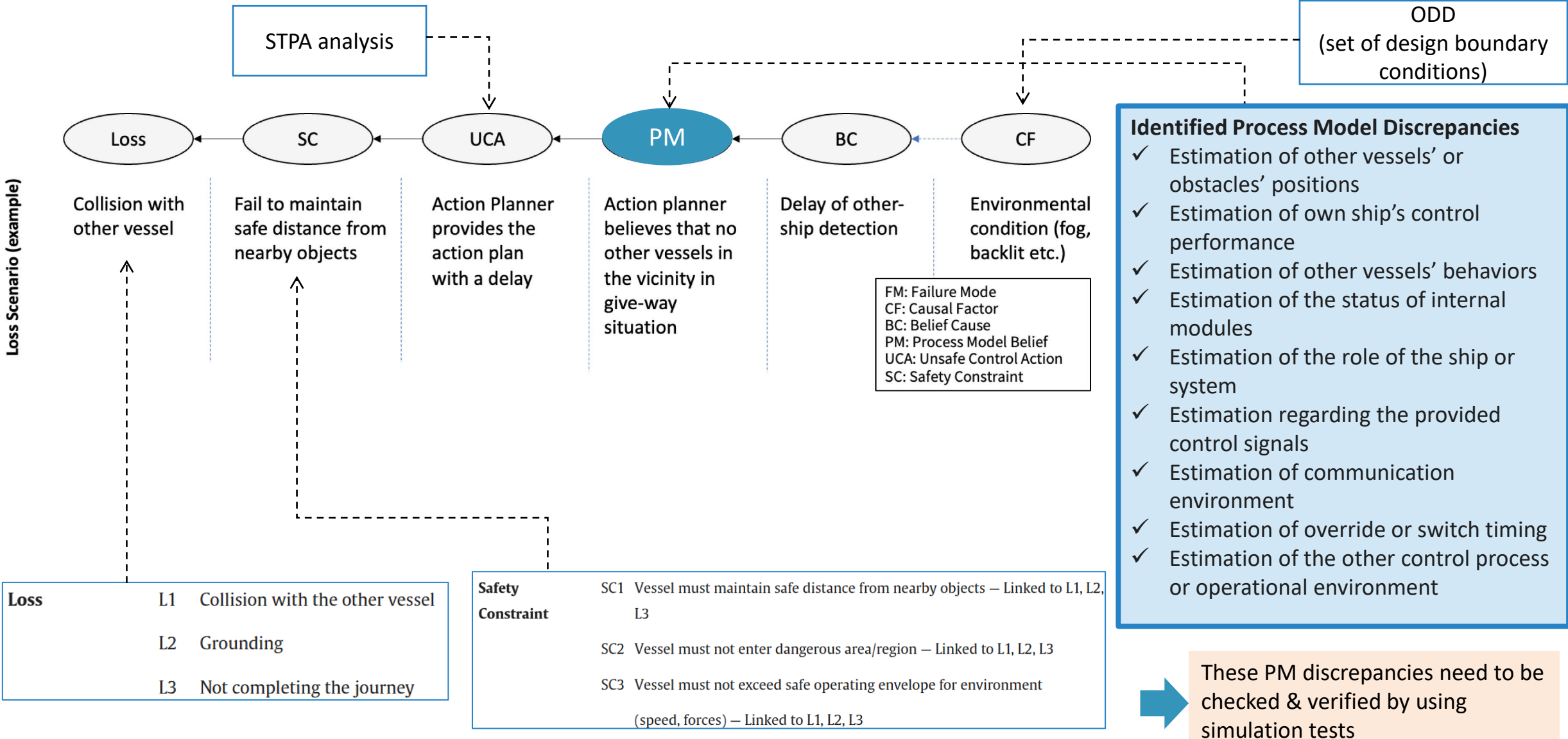
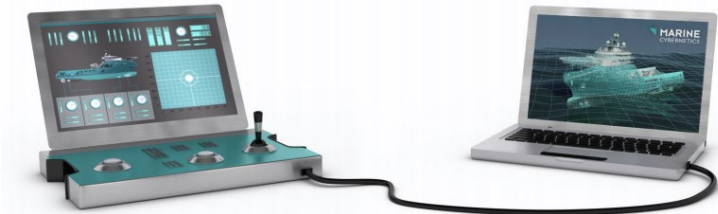
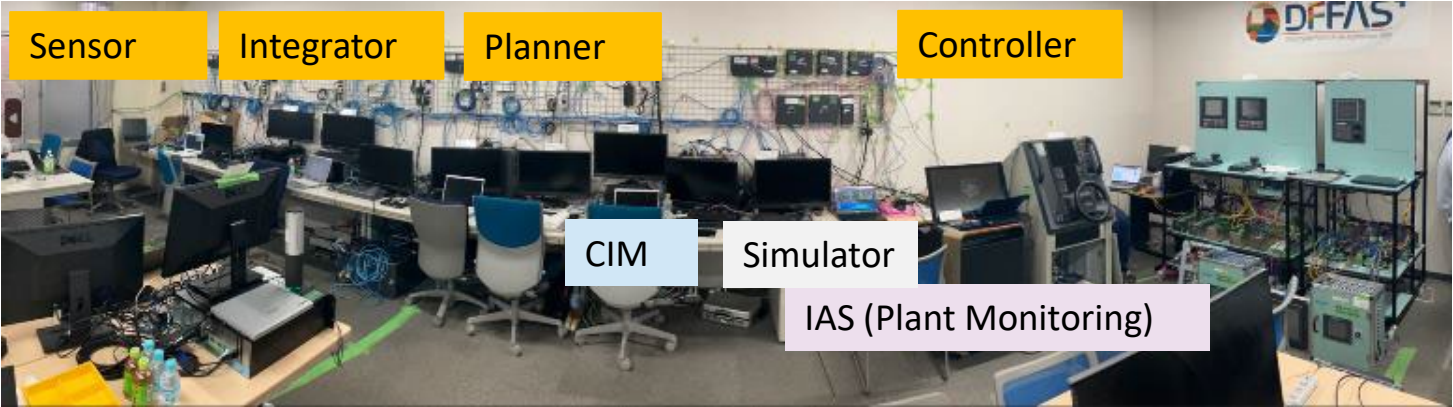


Table 7
Sample loss scenarios from STPA.

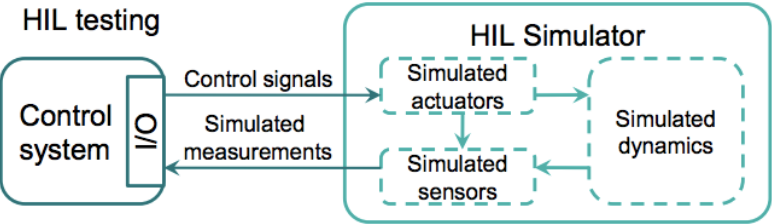
LSID	UCA	Context	Process Model	Belief Cause	Causal Factor
3P1-1	Action Planning Module provides an action plan to approach other ships and/or land to DTC (Drive Train Controller), leading to a distance close to other ships and/or land [SC1]	Other ships, obstacles and/or land are around own ship	Action Planning Module does not recognize other ships or land around the own ship, or recognize in a different position	The ship's position and attitude information deviates from the true value (Process model variable: Own ship - Position)	Failure/performance reduction of own ship sensors and communication routes (not detected)
3P1-2	Action Planning Module provides an action plan to approach other ships and/or land to DTC (Drive Train Controller), leading to a distance close to other ships and/or land [SC1]	Other ships, obstacles and/or land are around own ship	Action Planning Module does not recognize other ships or land around the own ship, or recognize in a different position	The position and attitude information of other vessels deviates from the true value, or the information of other vessels is missing (Process model variable: Other ship)	Reduced sensor performance due to environmental change, aging deterioration (fog, heavy rain, etc.)

HIL(Hardware In the Loop) test arrangement

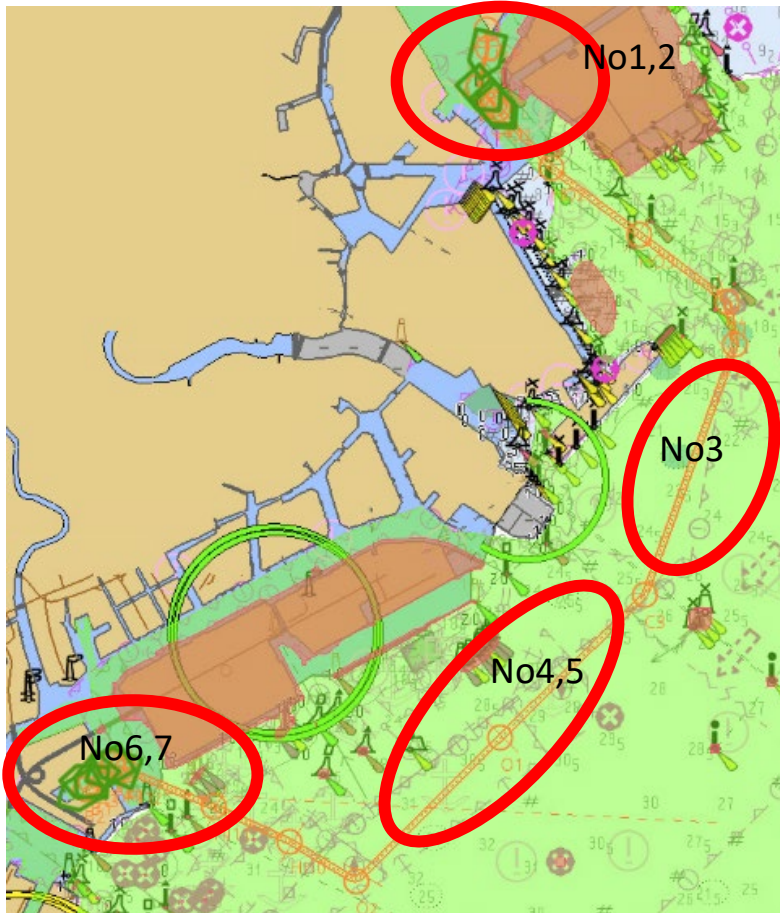


Control system
(Autonomous Navigation System)

simulator



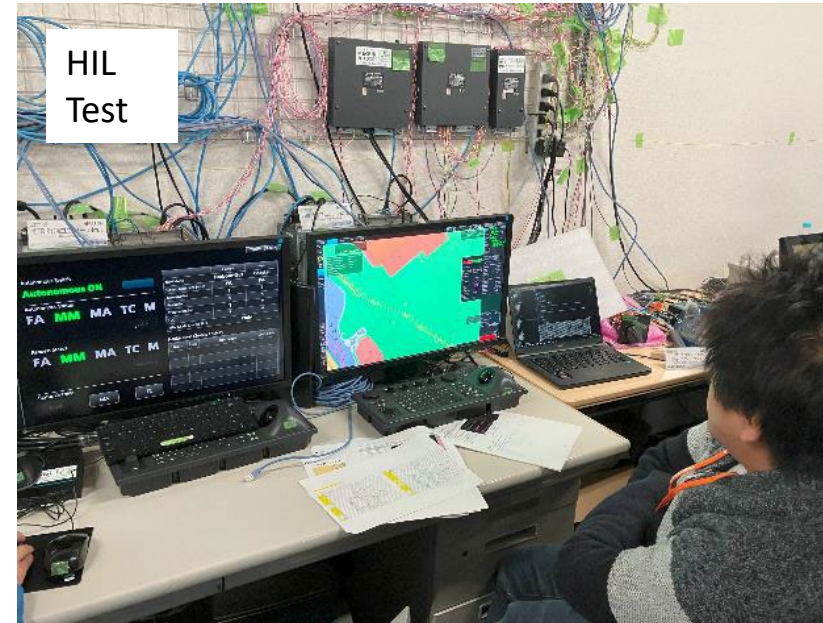
Courtesy) DNV, CyberSea



1. Preparation for navigation
 1. Route transfer from shore
 2. Thruster preparation, offshore route optimization, route monitoring, etc.
2. Maneuvering away from shore
 1. MMS operation
 2. Autonomous navigation start
 3. DTC control Engine/navigation coordination (automatic thruster shutdown)
3. Evasive maneuvers
 1. Normal avoidance (FA/MA)
 2. Fallback
4. Abnormal occurrence
 1. APU stop (equipment running TCS)
 2. 1 GPS unit stopped → 2 GPS units stopped → MRM/MRC operation
5. ODD
 1. EODD over (wind/waves/currents)
 2. Passage of watch area
6. Shore arrival operation
 1. Engine/navigation coordination (automatic thruster start)
 2. Automatic application of berthing route
 3. DTC berthing (including End Of Track control)
 4. End of autonomous navigation → MMS maneuvering
7. Completion of navigation

HIL Test Summary

- Term : Sep. 2024 ~ Mid. Feb. 2025
- Total Test Days : 3days x 10times = 30 days
- Operation time : about 300 hours
- Test Items : 333 items
 - Confirmed 295 items
 - Other items will be confirmed at onboard tests
- Remarks :
 - Briefing to captains and chief engineers on autonomous navigation systems.
 - Interviews with captains and navigators on human-machine interface.



Master of the new built ship

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Roadmap for the goal-based MASS code and EBP

SESSIONS OF MSC	WORK PLAN
MSC 110 (June 2025)	<ul style="list-style-type: none"> - Consideration of the outcome of the MASS-CG, established at MSC 108 - Further develop the non-mandatory MASS Code - Update this road map
MASS-ISWG 4 (2nd half 2025)	<ul style="list-style-type: none"> - Further develop the non-mandatory MASS Code
MSC 111 (May 2026)	<ul style="list-style-type: none"> - Consideration of the outcome of MASS-ISWG 4 - Finalization and adoption of the non-mandatory MASS Code - Invite relevant sub-committees to review the non-mandatory Code - Update this road map
MSC 112 (December 2026)	<ul style="list-style-type: none"> - Develop a framework for an Experience-building phase (EBP) post adoption of the non-mandatory MASS Code
MSC 1XX (2028)	<ul style="list-style-type: none"> - Commence development of the mandatory MASS Code, based on the non-mandatory Code and result from the EBP and review conducted by the relevant sub-committees, and consider amendments to SOLAS (new chapter) for the Code's adoption
MSC 1XX	<ul style="list-style-type: none"> - Adoption of the mandatory Code (latest 1 July 2030 for entry into force on 1 Jan 2032)

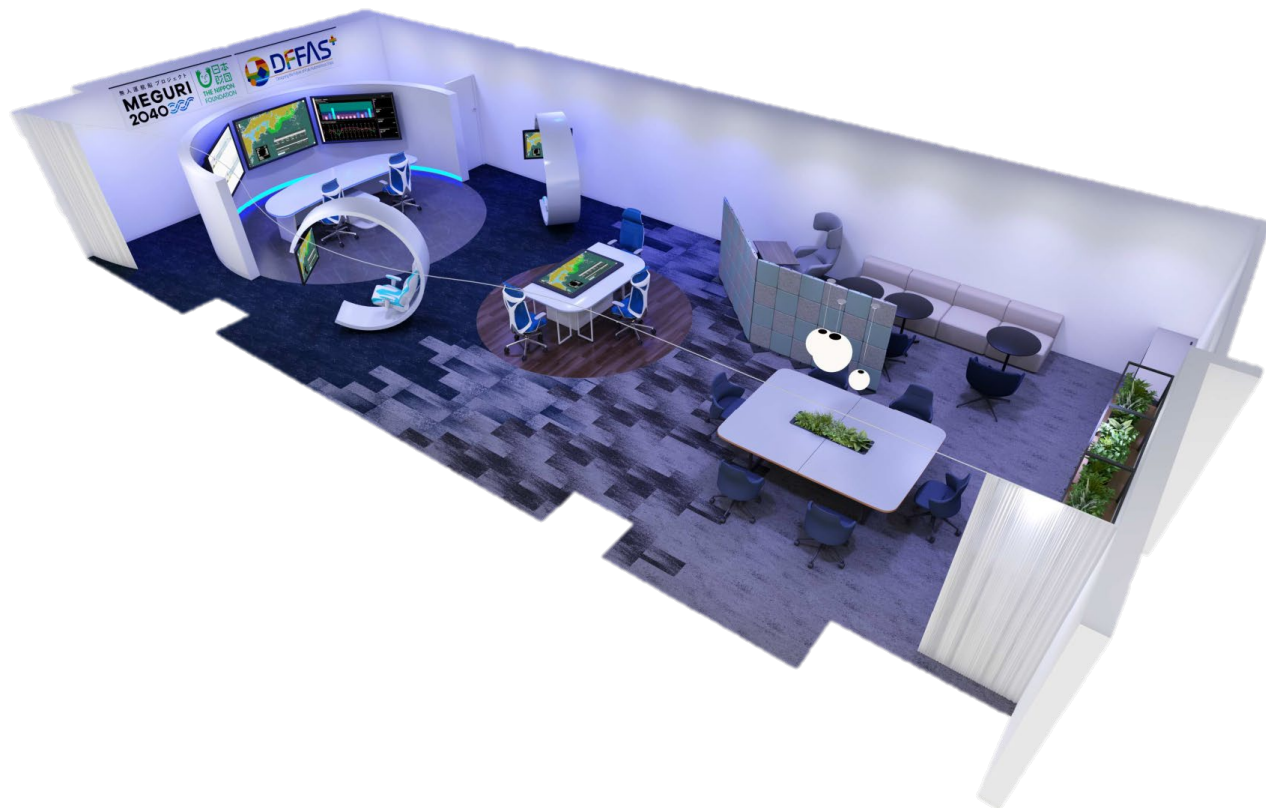
- The target of finalization and adoption of the non-mandatory MASS Code is MSC 111 in May 2026
- A framework for experience-building phase (EBP) will be developed in MSC 112 in December 2026



NYK group intends to accumulate experience and data through demonstrations in EBP.

- ✓ To improve technology, education, process and organization for coming the MASS mandatory code
- ✓ To share experiences with IMO MSC and other stakeholders to proceed implementation of autonomy in shipping.

- ▶ In MEGURI2040 Stage 1, we successfully completed a demonstration voyage of DFFAS in 2022 and are currently advancing the DFFAS+ project as Stage 2 for demonstration in this year.
- ▶ The DFFAS+ project aims to introduce autonomous navigation systems into shipping and is currently preparing for several months long demonstration in commercial services.
- ▶ The DFFAS+ project employs a new risk analysis method STPA based on system control structure and analyze loss scenario that failure potentials lead to accidents. Simulation tests, onboard tests and monitoring after delivery will be conducted based on the analyzed failure potentials.
- ▶ Going forward, we believe it is essential to transparently and openly share with legal experts the types of errors that developers anticipate during system development, in order to advance the realization of a safer autonomous system in shipping.



Source: DFFAS+ CONSORTIUM

無人運航船プロジェクト
MEGURI
2040



Thank you for your listening.