Monohakobi Technology Institute

NYK GROUP

G-NAOE
from 7th Nov. , 2024 Southampton, United Kingdom

Use of autonomous vessels and safety verification as a shipping company

MTI Co., Ltd.

Capt. Jun NAKAMURA

Outline

1. Introduction
2. Concept of Test Environment
3. How to Check Performance
4. Simulation Result & Summery

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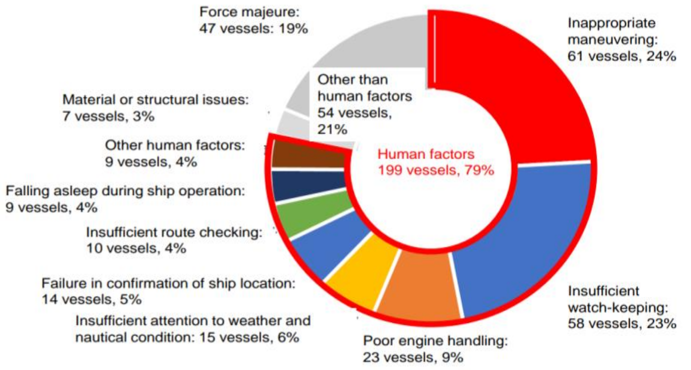
Why do we need Autonomous Vessel

Safe Operation、Shortage of seafarer、Competitive advantage



Source: Current status of marine accidents and countermeasures, Japan Coast Guard

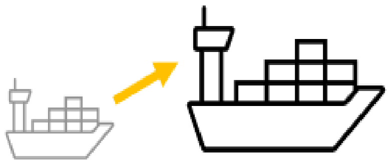
Navigation Accident is **Human error <u>about 80%</u>**

Safe Operation

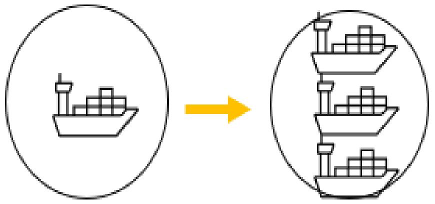
Value of Autonomous Vessel

Shortage of Crew

Competitive advantage



Bigger Vessel



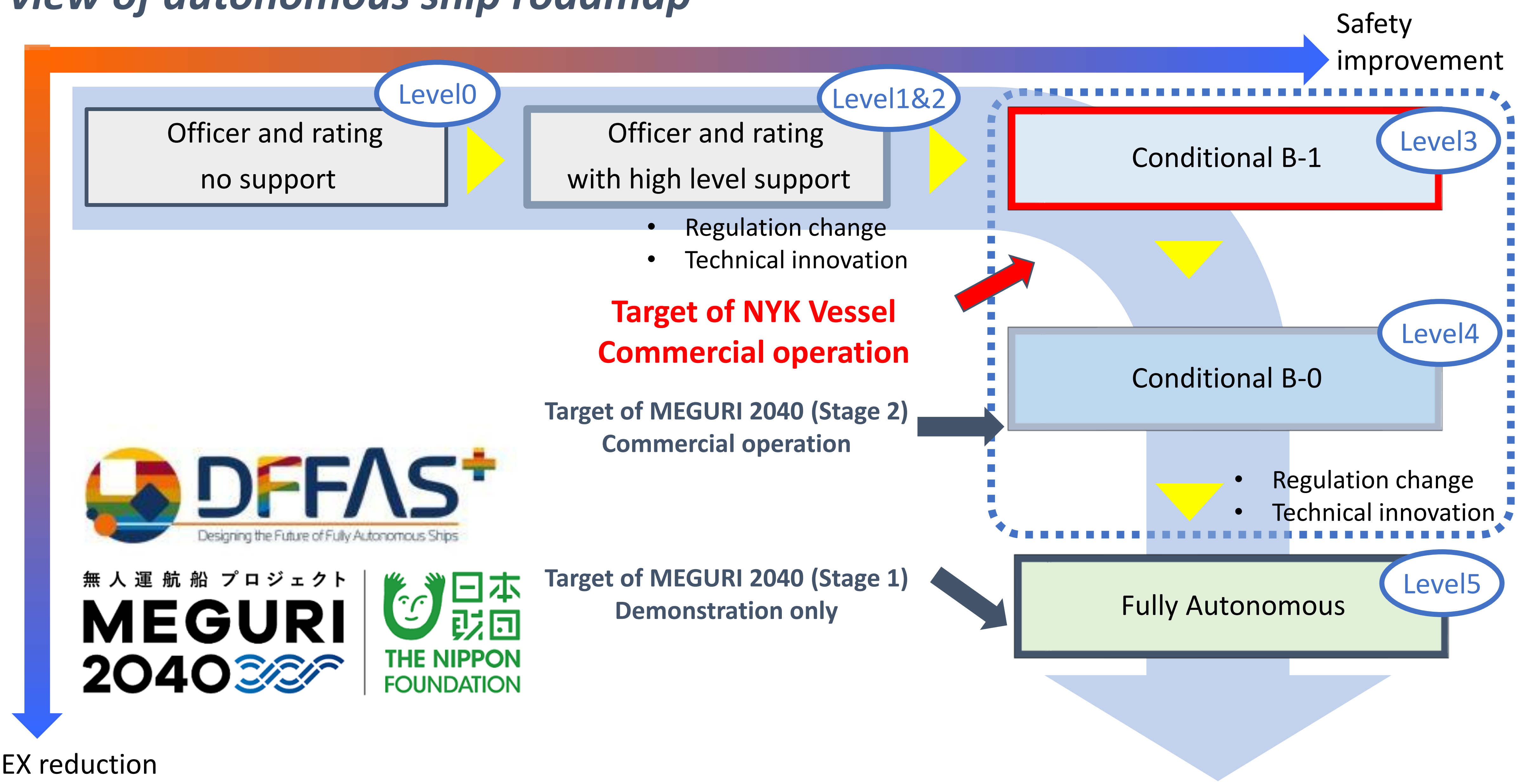
More congestion

Reduce Maneuverability
→**Early action** is important

- **Global seafarer shortage 8.8%**, highest ever
- **Eliminate the shortage of seafarers** in Japan
  (by 2040 there will be a 30% shortage of seafarers compared to today)

- Look out to other duty
  →Avoiding Trouble due to good maintenance
- Avoid additional cost due to big accident

Our view of autonomous ship roadmap



* Level 0-5, ONE SEA White Paper, Autonomous Ships Terms of Reference for Rule Development, 2022

Research partner of the NYK Group in the development of autonomous vessels

	Japan	Overseas
technological development	MEGURI2040 (53 Partners） Osaka Metropolitan University Hiroshima University Osaka University	SHI (Navigation System) ORCA AI（Image Recognition） DNV（Simulation technology）
Institutions, evaluation and verification.	Ministry of Land, Infrastructure, Transport and Tourism ClassNK Japan Ship Technology Research Association	ABS、DNV、BV LR（University of Warwick） University of Southern California ONE SEA

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・The development of open collaborative research systems that incorporate both domestic and international knowledge.

・Technology developed through open collaboration to become a global standard technology.

Important View for Autonomous Vessel as shipping company

Safety	Economic rationality	Reduce Workload
• Situation Awareness • Collison avoidance • Reduce Human error • Operation Design Domain (ODD)	• OPEX improvement • CAPEX impact	• Navigation Duty • Total working hours • Shift job (Nav.⇒Mentanance）

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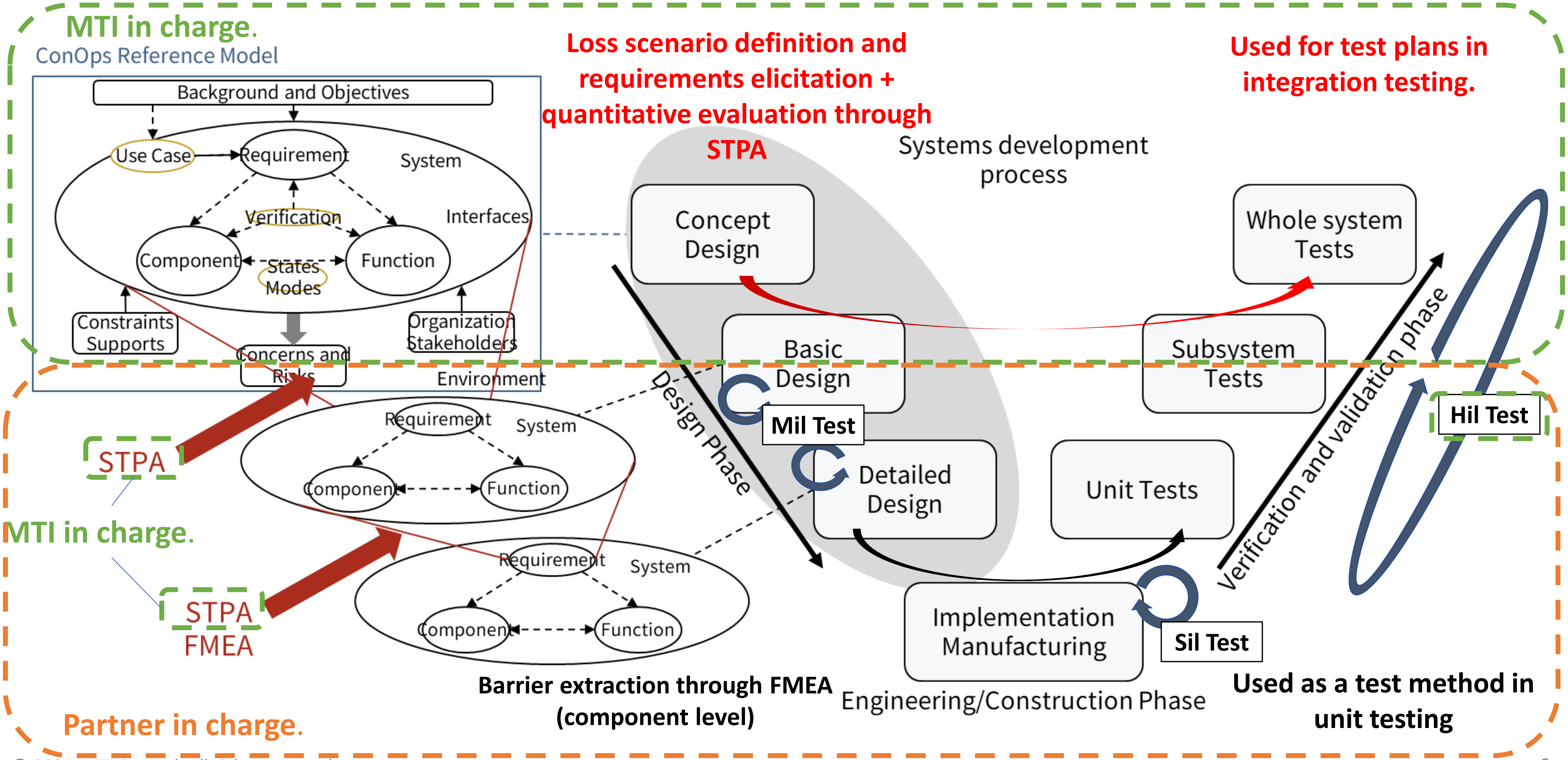
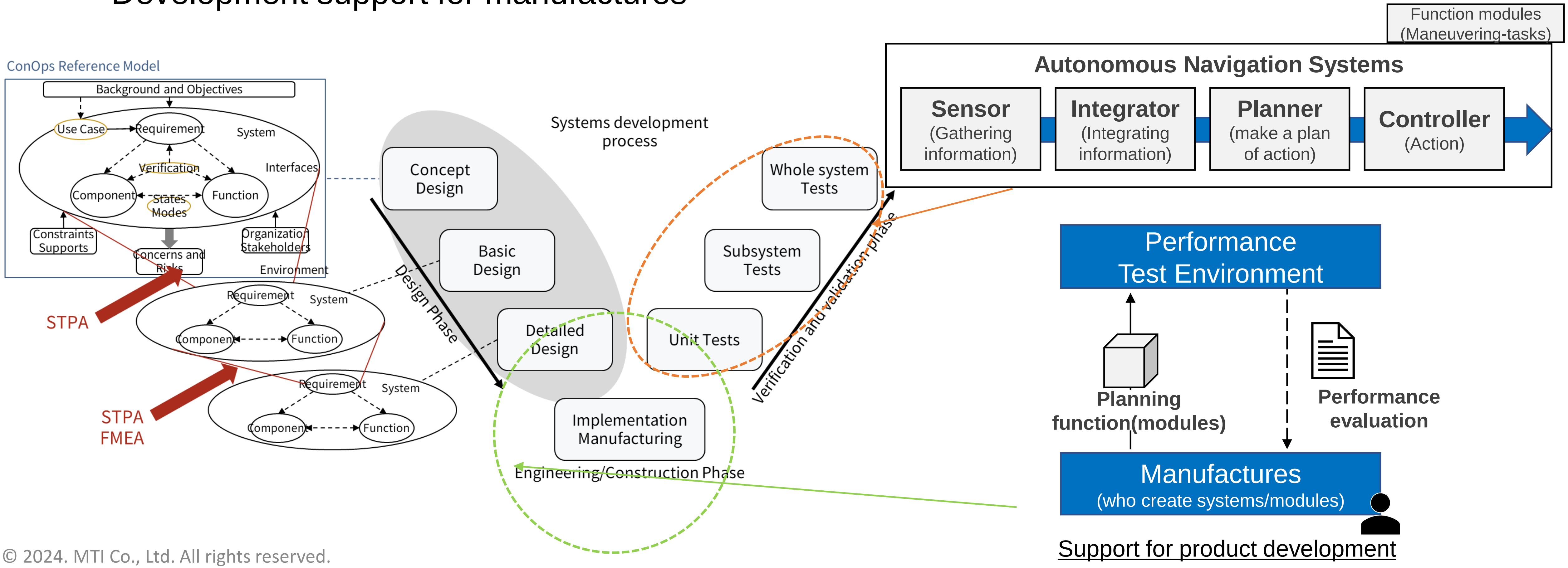
Our development process (V-model process)

STPA: Systems Theoretic Process Analysis
FMEA: Failure Mode and Effects Analysis



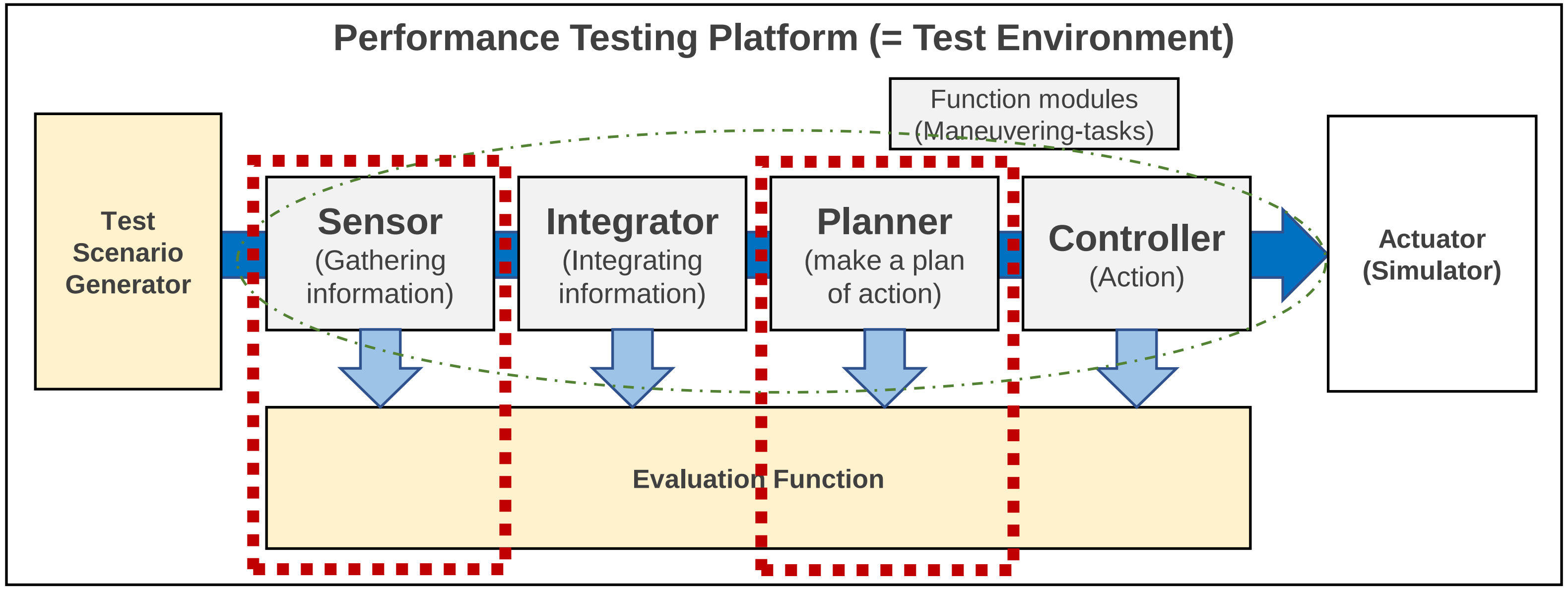
Concept of Test Environment for ANS(Autonomous navigation System)

- **Goal**
  - High-affinity with Model-Based Systems Engineering (MBSE)
  - Performance test connecting multiple modules
  - Development support for manufactures

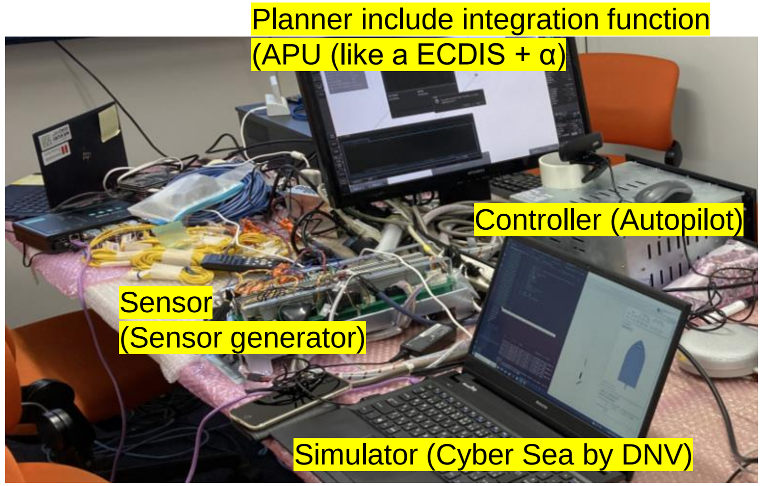


Test Environment for Autonomous Navigation Systems

- **Test environment will be able to:**
  - evaluated for each module
  - deliver MIL/SIL/HIL Simulation
  - change function models and Hull models



Test Environment Structure



Simulation Platform

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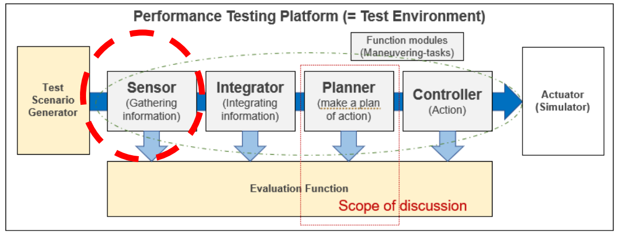
Evaluation Approach(Sencer)



Test Environment Structure

[Interface with Navigational equipment]

Information received from navigation equipment

Conformity of interface specifications

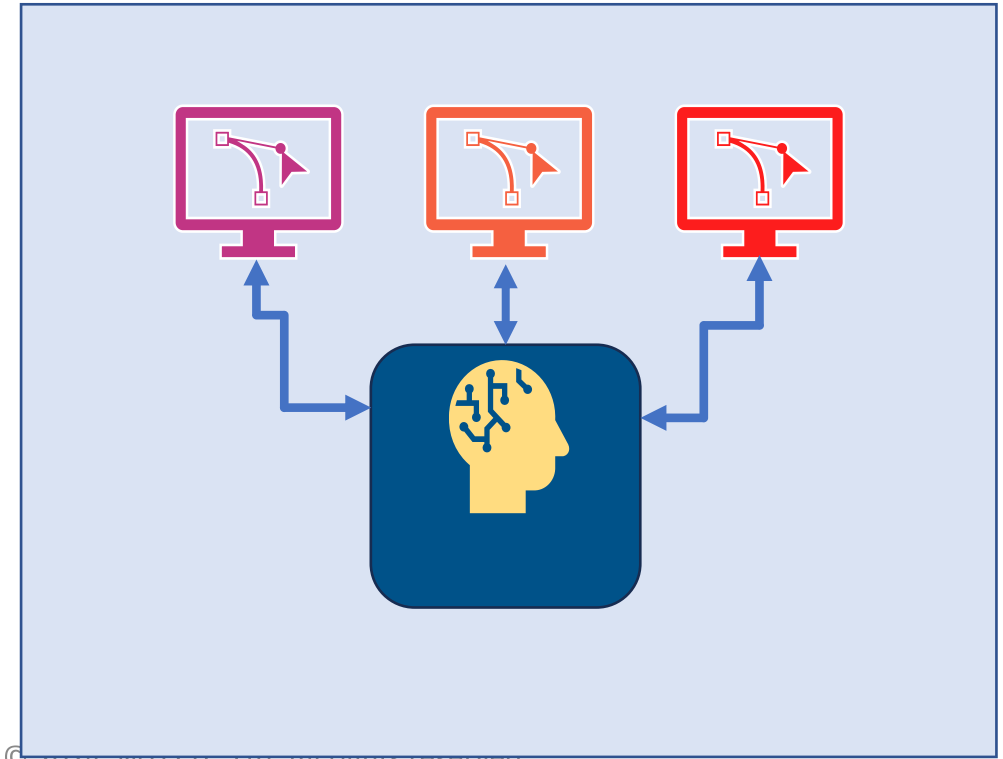
Review of the possibility of sentence collisions

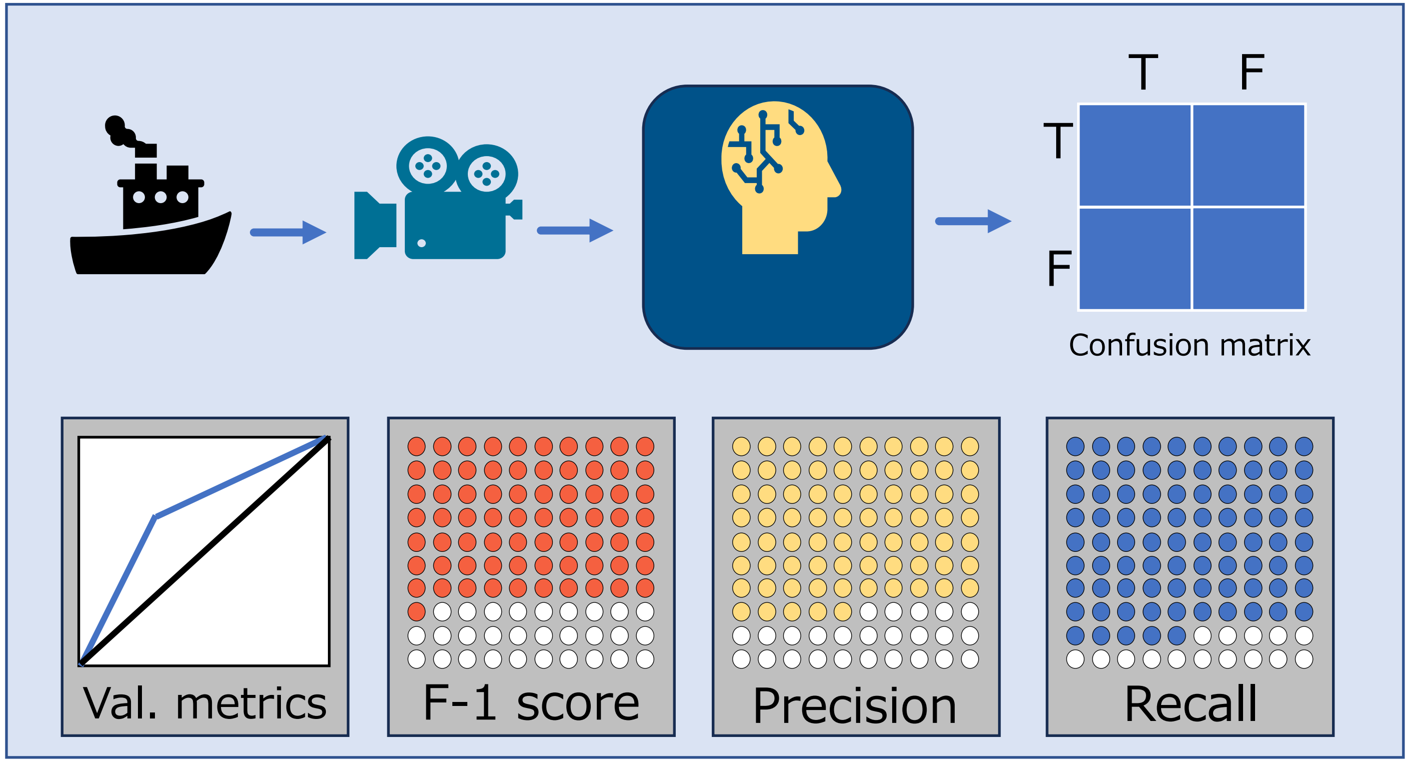
[Performance of camera Sencer]

Recognition rate of targets

Accuracy of labels for recognized targets

Accuracy of distance estimation (If available)





Evaluation Approach(Sencer)

[Performance of Camera Sencer]

Master/ Navigation Offer would like to know when and where the camera Sencer is available.

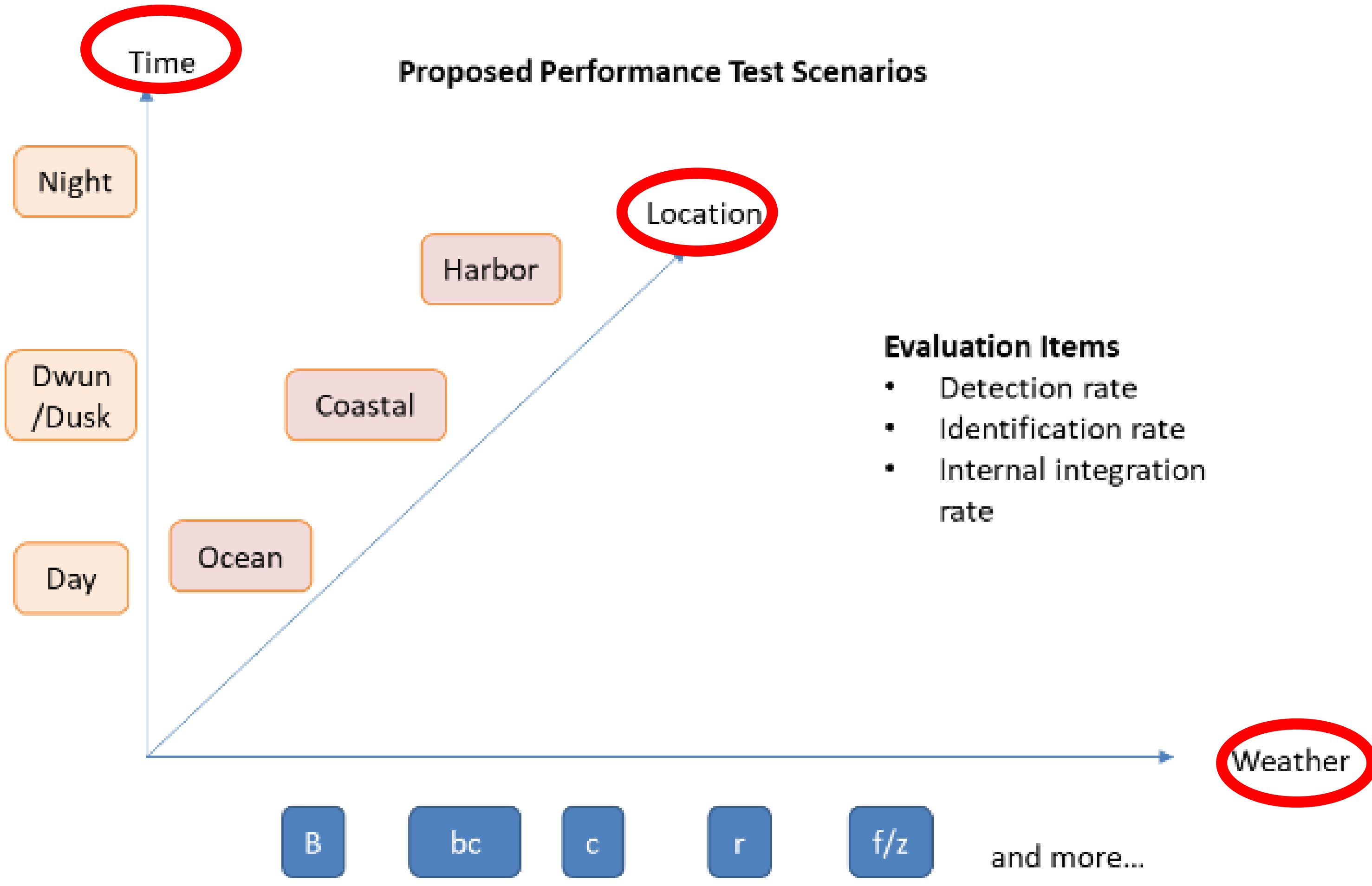
Assessment using 3-axis parameter

① Time

② Location

③ Weather

①Precision ②Recall



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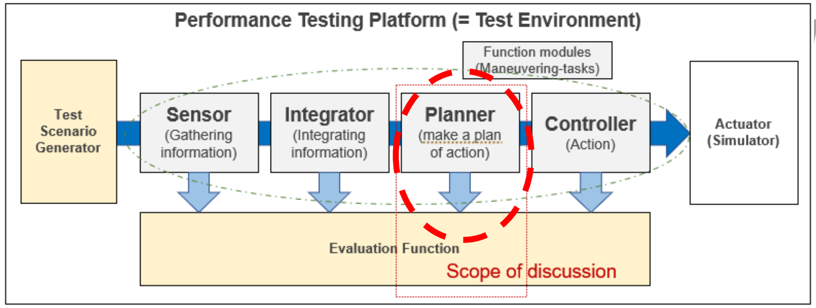
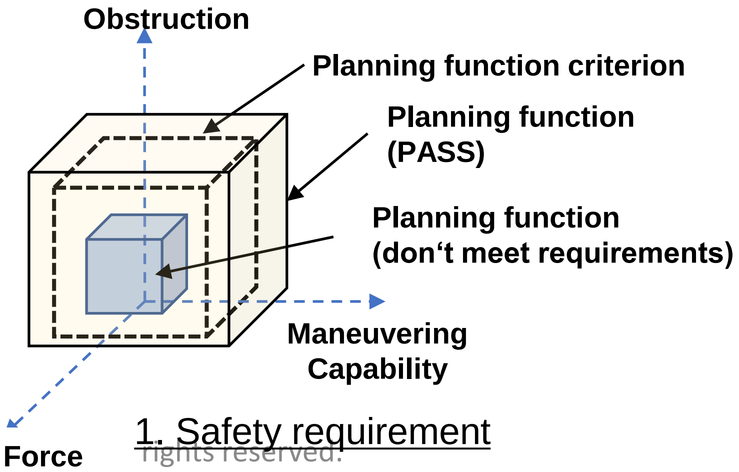
Evaluation Approach(Planner)

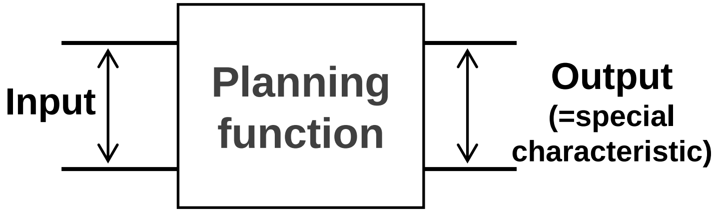


Test Environment Structure

- Approach (three steps)
  - 1st step: Definition of evaluation requirements for each modules
  - 2nd step: Consideration of validation methods
  - 3rd step: Testing and review
- Evaluation requirement
  - Assumptions: The planning function will pass the test if the following safety requirements
    - ✓ action plan in considering maneuvering
    - ✓ obstacle avoidance performance
    - ✓ Performance in the nature environment (wind, wave, current)

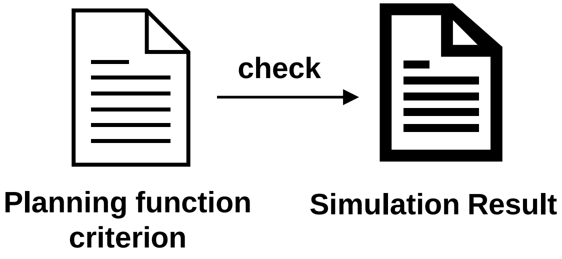


1. Safety requirement



What scenarios should be input?

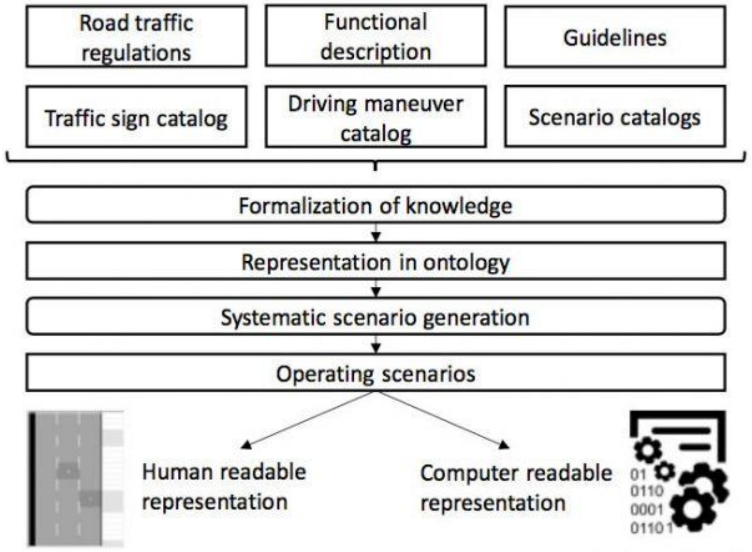
2. methods



3. Testing and review

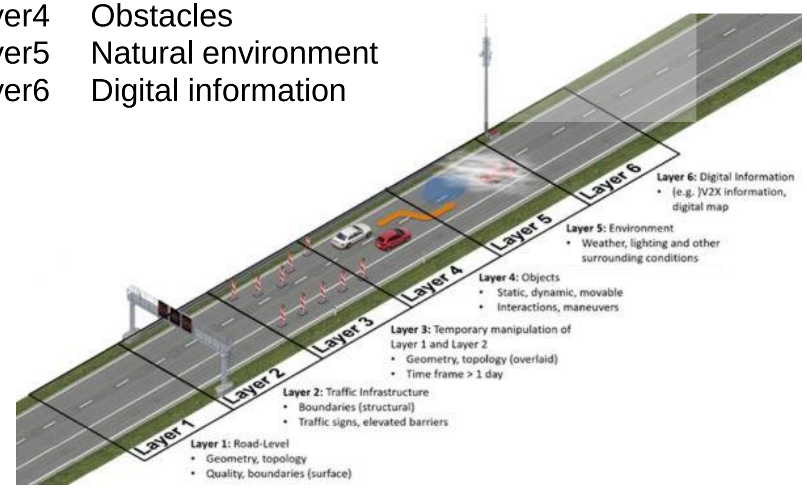
How to make an exhaustive scenario

- Consideration with reference to initiatives in the automotive
  - PEGASUS Project (Funded by the BMWi)
    - ✓Safety evaluation efforts based on test scenarios extracted from driving data
    - ✓Six-layer model for safety assessment scenario



Layering of Scenarios in “Vehicle”

Layer1	Road, Terrain
Layer2	Traffic signals, Traffic control
Layer3	Temporary restrictions
Layer4	Obstacles
Layer5	Natural environment
Layer6	Digital information



Layering of Scenarios in “Vehicle”

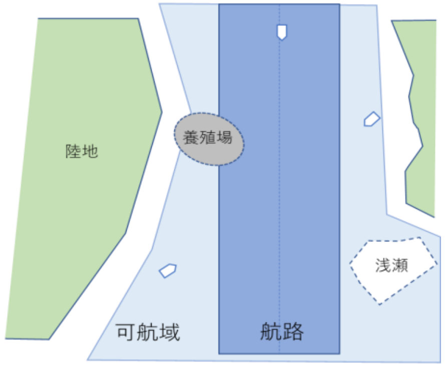
https://www.pegasusprojekt.de/files/tmpl/Pegasus-Abschlussveranstaltung/PEGASUS-Gesamtmethode.pdf

Embodiment of scenario components

- Scenario elements: organized based on the PEGASUSU Project’s six-layer model
- The natural environment (waves, wind, currents) has a significant impact on movement
  → Split layer five and add layer zero

Layer	Vehicle	Vessel
0	—	Natural environment (waves, wind, currents)
1	Road, Terrain	Navigable zone
2	Traffic signals, Traffic control	Road, Terrain
3	Temporary restrictions	Fish farms, Military training area, etc.
4	Obstacles	Obstacles (other vessels, structures on the water, etc.)
5	Natural environment	Natural environment (rain/fog/light, etc.)
6	Digital information	Digital information

Layering of Scenarios in “Vehicle”

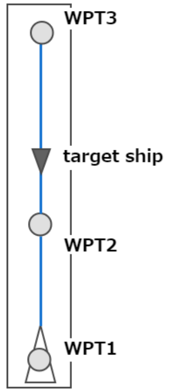


Layering of Scenarios in “Vessel”

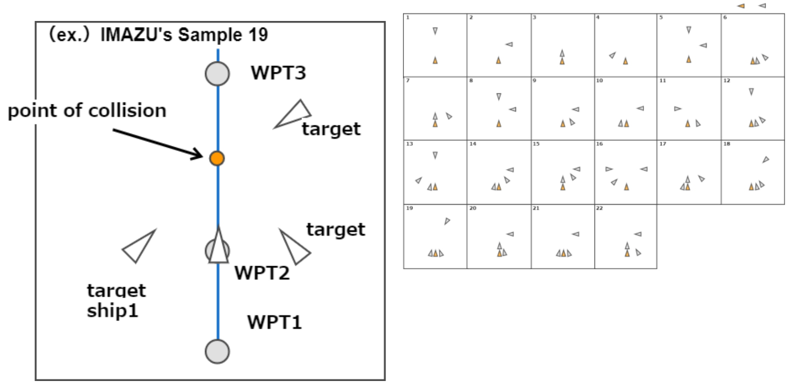
Test Scenario

- Define evaluation scenarios that replicate any navigational environment
- Define Phase 1~3 by check items
  → Check step by step (Ph1-> Ph2 -> Ph3)

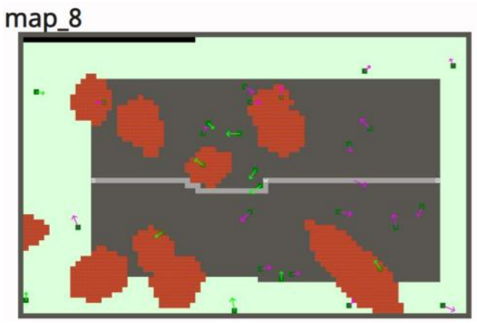
Phase	Scenario layer	Checklist
1	Layer 0	Is it possible to take into account maneuvering performance?
2	Layer 1-4	Is it possible to deal with simple collision patterns?
3	Layer 0-4	Is it possible to make appropriate avoidance suggestions under combined ph1,2 conditions.



Phase1 Scenario



Phase2 Scenario

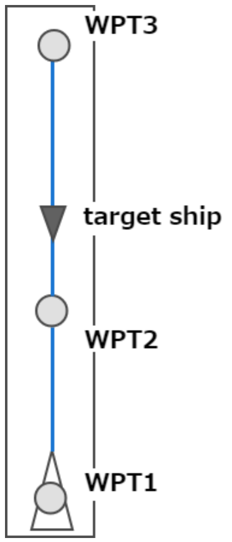


Phase3 Scenario

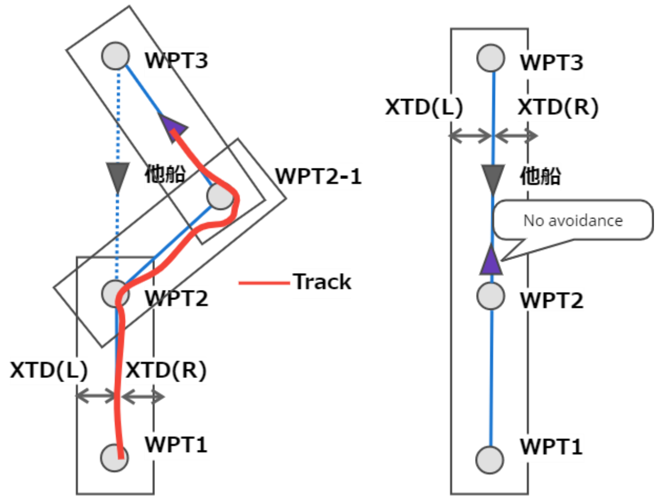
[1] H. Imazu: Research on Collision Avoidance Manoeuver (in Japanese). 1987
[2] Y. Cai, K. Hasegawa, "Evaluating of Marine Traffic Simulation System through Imazu Problem", 2013

Test Scenario: Phase1

- Check point
  - Is it possible to take into account maneuvering performance?
- Confirmation Method
  1. Appearance of target ship on the route
  2. Control the timing of the appearance of target ship
  3. Verify avoidance action (simulation and review)



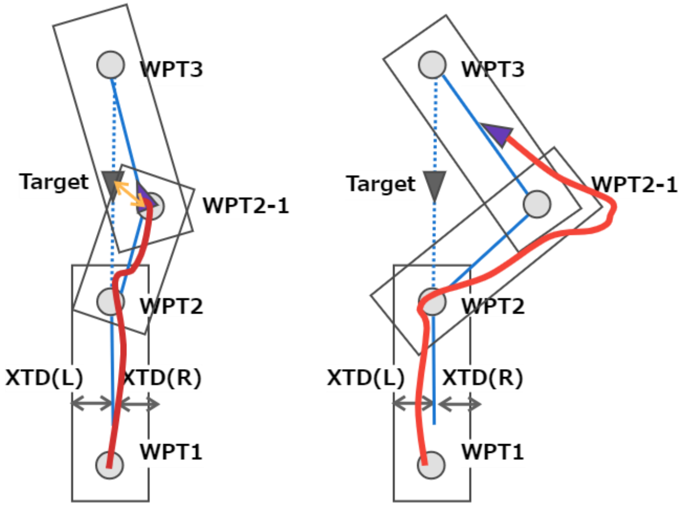
Phase1 Scenario



Avoiding navigation in XTD

Give-up notice

PASS
(Criteria for acceptance)



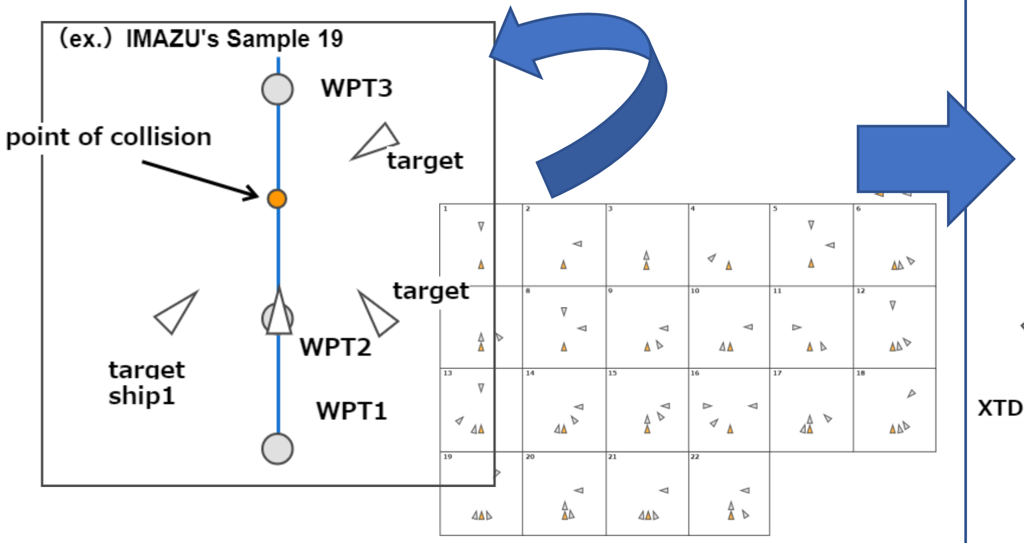
Intrusion into FBA of other vessels

Out of XTD

FAIL

Test Scenario: Phase2

- Check point
  - Is it possible to deal with simple collision patterns?
- Confirmation Method
  1. Reproduce Imazu's pattern (pattern 1~22)
  2. Verify avoidance action (simulation and review)



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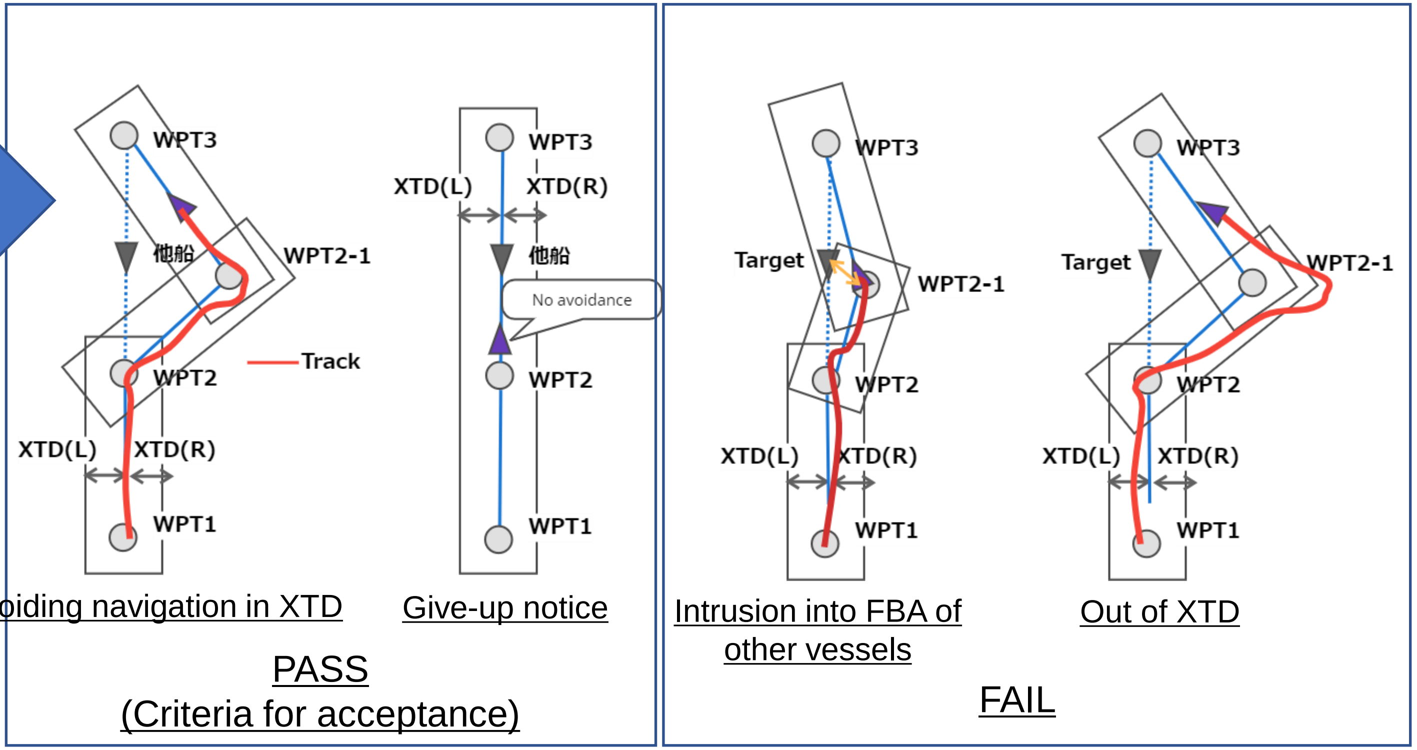
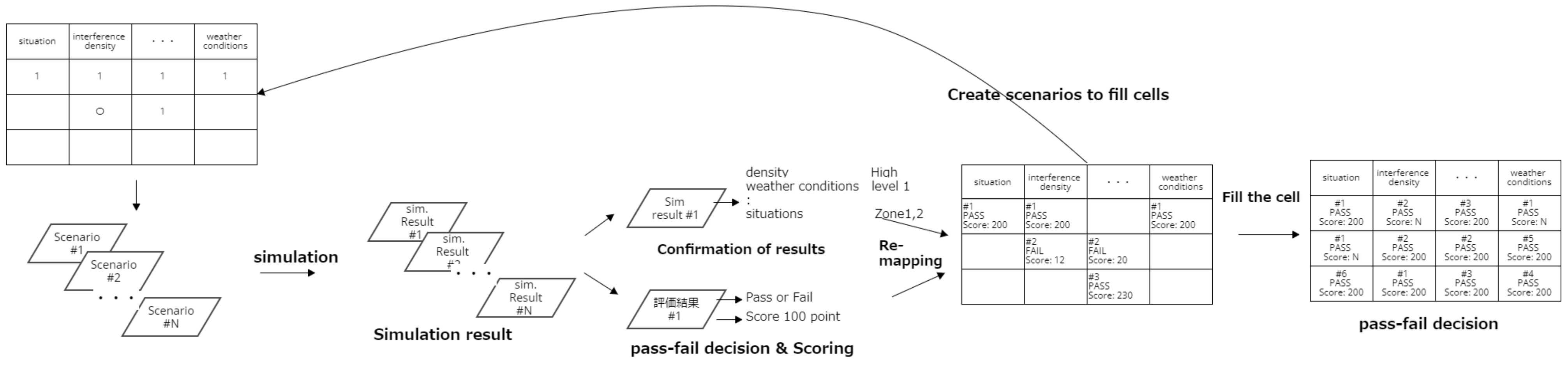


Test Scenario: Phase3

- Check point
  - Is it possible to make appropriate avoidance suggestions under combined ph1,2 conditions.
- Confirmation Method
  1. Organize parameters relevant to avoidance (i.e., create scenario axes)
  2. Make scenarios based on scenario axes
  3. Simulation
  4. Re-mapping and scoring of function simulation results to scenario axes
  5. Review (Is the scenario exhaustive?, Are all scenarios passed?)



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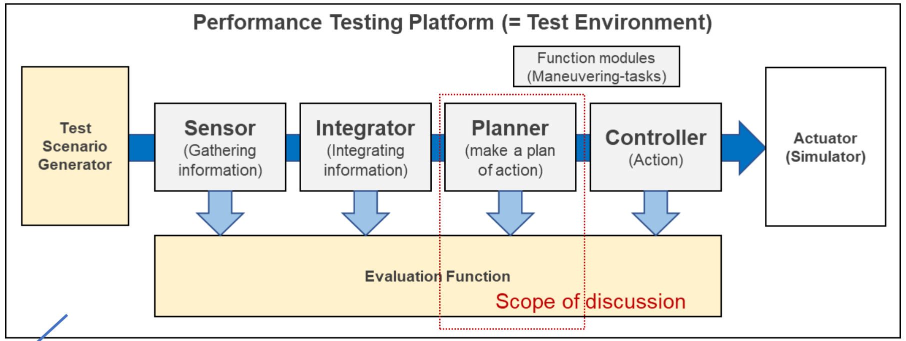
Simulation Result: Simulation Platform

- We confirmed that:
  - TCS function by autopilot (software)
  - Speed controller function by speed pilot (FMU)
- **Realization of MIL/SIL/HIL Simulation**

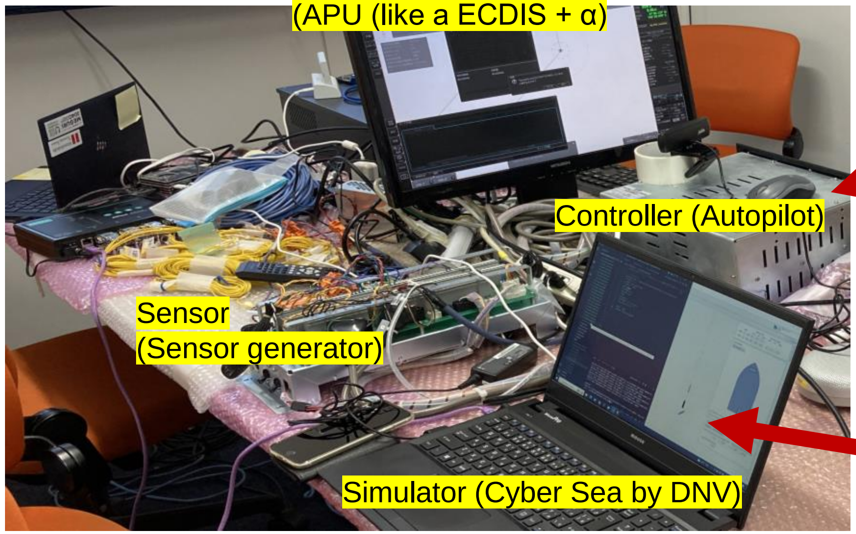


Test Scenario Generator

Scenarios

Evaluation Function

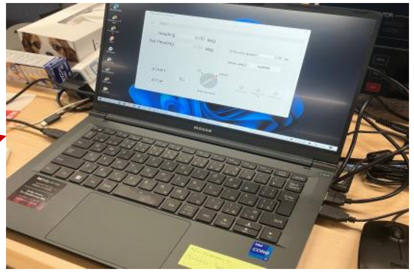
Sim.Result



Simulation Platform

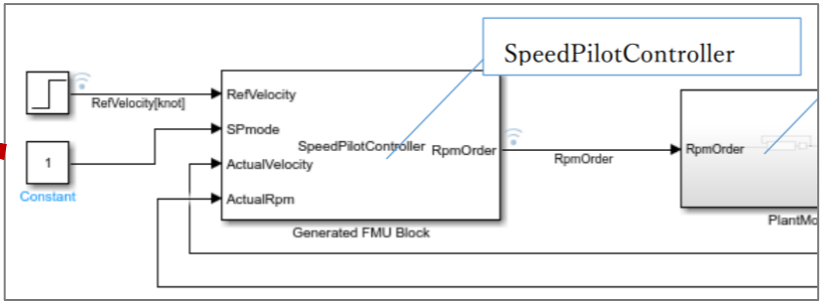
Test Environment

Exchange



Autopilot function (software)

Import



Speed pilot function model (FMU)

Summary

- For the social implementation of autonomous vessels, the NYK Group is working **in open collaboration** in technology development, standards and rules support.
- NYK is committed to developing, evaluating and verifying better autonomous navigation systems **to achieve safe and efficient operations.**
- In terms of the evaluation of autonomous navigation systems, work is being undertaken in particular on **the evaluation of the camera image recognition and collision avoidance algorithms**, which are new technologies, and eventually an evaluation of the entire autonomous navigation system will be carried out.