R&D Activities of NYK toward Smart Shipping

5th December 2019

Hideyuki Ando, Senior General Manager, MTI (NYK Group)

NYK GROUP

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NYK LINE

- Head Office: Tokyo, Japan
- Founded: September 29, 1885
- Business Scope
  - Liner (Container) Service
  - Tramp and Specialized Carrier Services
  - Tankers and Gas Carrier Services
  - Logistics Service
  - Terminal and Harbor Transport Services
  - Air Cargo Transport Service
  - Cruise Ship Service
  - Offshore Service
- Employees: 37,820 (as of the end of March 2017)
- Revenues: $ 17.4 billion (Fiscal 2018)
- Fleet: 792 vessels(as of the end of March 2019)

MTI (R&D Arm of NYK LINE)

- Established : April 1, 2004
- Equity capital : JPY 99 million
- Stockholder : NYK Line (100%)
- Number of employees : 70 (as of 1st April, 2019)

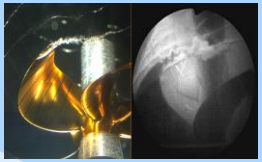
NYK/MTI's path toward smarter ship and operation

Now Future

OIL LNG HYDROGEN

Ship (Hardware)

Super Eco Ship 2050

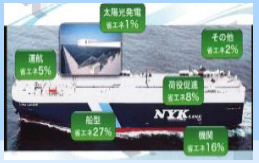


Measurement around propeller

Wind Resistance Reduced *MT-COWL*

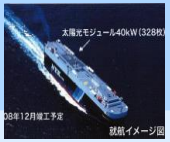
Alternative Marine Power

Super Eco Ship2030

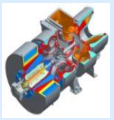


30% Energy Saving PCTC

Wind Power Generator *Andromeda Leader*



Solar Panel *Auriga Leader*



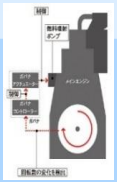
Hybrid T/C *Shin Koho*

Innovative Air Lubrication System *SOYO*

LNG-Fueled Tugboat *Sakigake*

LNG-Fueled PCTC Delivery in 2016

Electronic Controlled Engine



Improved Governor Controller

MT-FAST Energy Saving Device

Air Lubrication System *YAMATO, YAMATAI*

Hybrid Electric Power Supply *Auriga Leader*

LNG Bunkering Vessel Delivery in 2016

Operation (Software)

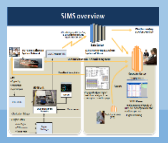
Monohakobi Technology Institute

MTI Founded

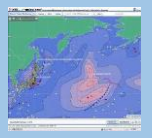
Fuel Consumption Indicator *FUELNAVI*

NYK's own safety and Environment standard *NAV9000*

Prediction of Current



SIMS Automatic onboard data collection system



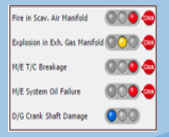
Integrated Operation Management System NYK e-missions'

IBIS Project

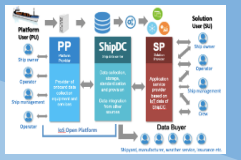
IBIS Project

Onboard Broadband NYK Satcom Project

LiVE Operation Portal Site



Detection of Mach. Trouble with monitoring data



ShipDC & IoS-OP

World First MASS Trial

2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

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Value creating digitalization in shipping

1. **Deep understanding of operating fleet and market**
2. **Optimized logistics and operations**
3. **Anticipation of failures**

Continuous learning ↑

↓ Continuous Improvement

4. **Incremental automation of ship functions**

5. **Monitoring fleet performance and improvement**

Better decisions

Pursuing total optimization of operation and ship

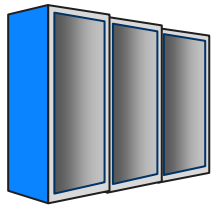
Safer, more consistent operations

Reference) McKinsey Company, How digital innovation can improve mining productivity, 2015
https://www.mckinsey.com/industries/metals-and-mining/our-insights/how-digital-innovation-can-%20improve-mining-productivity

IoT platform of NYK

SIMS (Ship Information Management System)

SIMS IoT data
+ SPAS manual data



Data Center

SIMS Data Collection Onboard

Sat Com
(VSAT, FBB)

- GPS
- Doppler log
- Anemometer
- Gyro Compass

SIMS unit (IoT gateway)

Onboard dashboard

VDR

Data Acquisition and Processing

Motion sensor

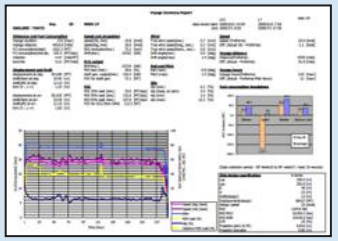
<Navigation Bridge>

<Engine Room & Cargo>

- Main Engine
- Power plant
- Cargo control
- Auxiliary machineries

Integrated Automation System

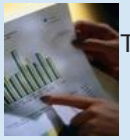
SIMS Monitoring & Analysis at Shore



Big data analysis

- Operational efficiency
- Performance
- Engine & plant condition

Analysis report



Technical Analysis (NYK, MTI)

Operation (Tokyo, Singapore ...)

Shore Dashboard

- For operation
- For ship manager

How shipping can utilize Big data and IoT
- Identify right issues to solve -

Identified issues

Optimum operation
- Fuel saving
- Reasonably minimized margin

Support business decision
- Tactical ship/fleet allocation

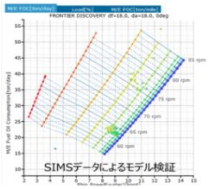
Safe operation

Big data

- IoT Data
- Report data
- AIS data
- Weather data

Analysis

Engineering knowledge
e.g. vessel performance



Data analytics & IT

Any useful data

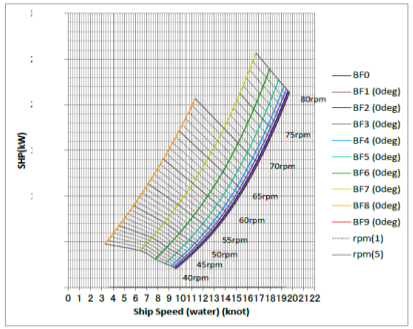
Operation data
- Schedule
- Route
- CB/HB
- AIS

Technical data
- Performance
- Sea trial
- Particular
- Paint

Market data
- Bunker cost
- Hiring cost
- Market

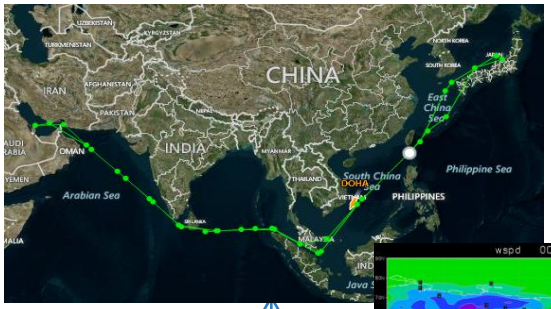
Commercial data
- Contract
- Fleet plan
- Owner info.

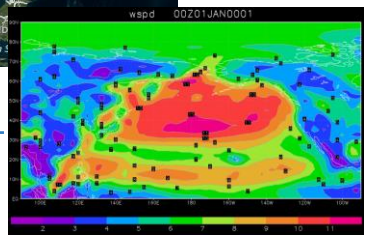
Understand seasonal operation risks



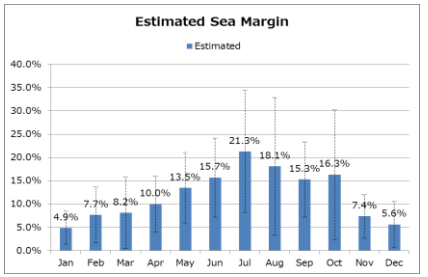
Ship performance model

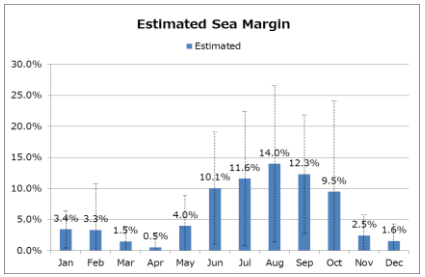
Service route





Voyage simulation with past weather data



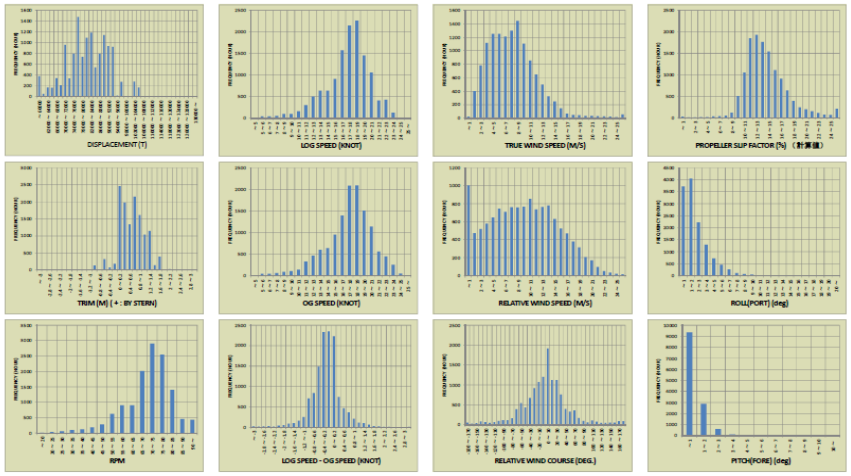


Estimation of
- Sea margin
- FOC and etc.

Combine ship performance model with weather data to optimize ship services

What is the issue?

Improve bad performance ship



23 % CO2 reduction was confirmed

Operational profile

- Speed, RPM, Power
- Draft, trim, displacement
- Weather
- Sea margin
- Etc.

Energy saving modification

- Bulbous bow modification
- Install energy saving device (MT-FAST)
- Replace propeller
- Engine de-rating

Modifications were conducted on 40 ships

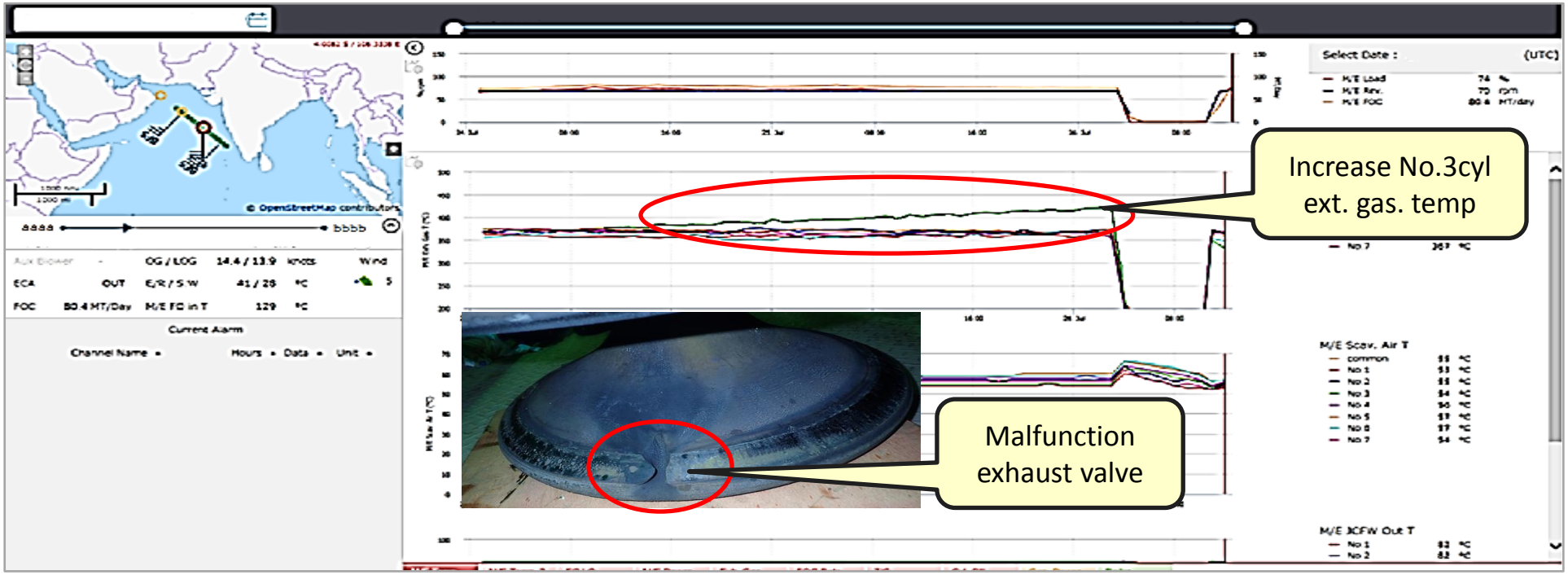
Data and simulations played important roles to optimize ship design

What is the issue?

Anomaly detection from the collected data

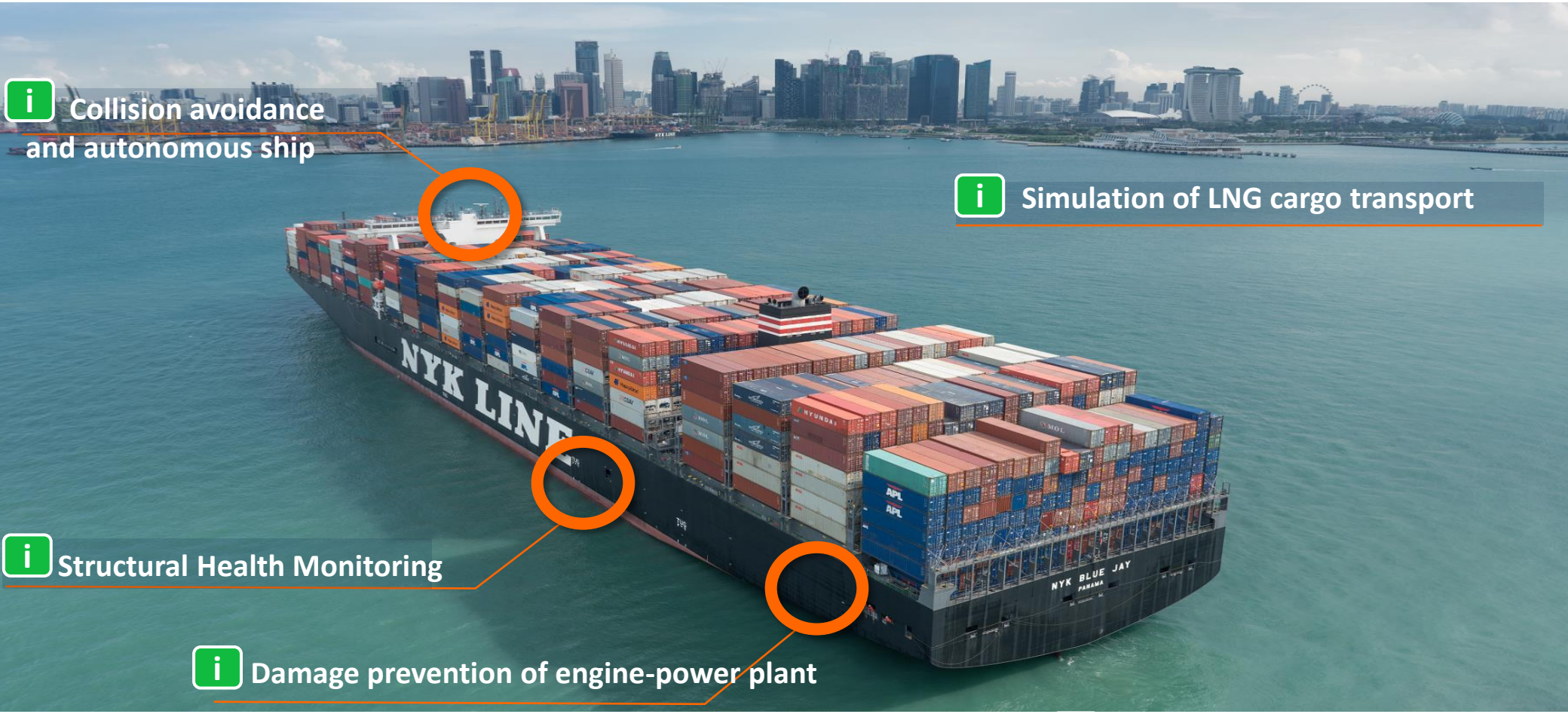
- Find trouble phenomenon from the IoT data -

Case） M/E (Main Engine) No.3 cylinder abnormal exhaust gas temperature



1. Visualization of data
2. Analysis by domain experts (marine engineer) . Accumulate cases.
3. Implement automatic anomaly detection functions by using accumulated cases.

NYK/MTI R&D projects for safer operation
- open collaboration with industry partners -



i Collision avoidance and autonomous ship

i Simulation of LNG cargo transport

i Structural Health Monitoring

i Damage prevention of engine-power plant

MLIT Ministry of Land, Infrastructure, Transport and Tourism

ClassNK

i **i-Shipping(Operation):**
Japanese government funding R&D projects – IoT for safety (2016-2020)
Joint research with ClassNK

Contents

Our activities toward Autonomous Ships

Our objective

- Improve Safety (reduce the number of accident)
- Reduce workload (new approaches for future crew shortage)

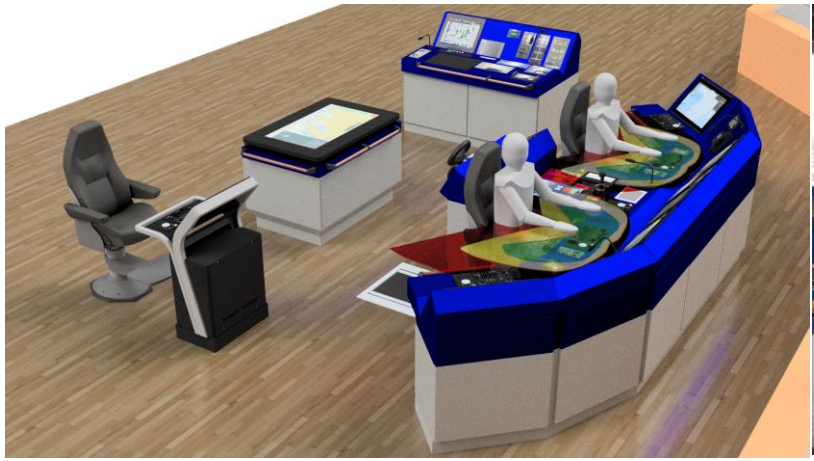
What do we need ?

- Advanced support by computer systems (fully utilizing computer power) = Complement human operations
- At the same time, **PPTO** (**P**eople, **P**rocess, **T**echnology and **O**rganization) is important

How to approach ?

- User-centric … Involvement of experienced captains with know-how, skills & experiences to lead projects to the right direction
- Continuous improvement … identify the right issues to solve and improve step-by-step (bottom-up approach)
- Open collaboration with best partners

Manned-Autonomous Ship

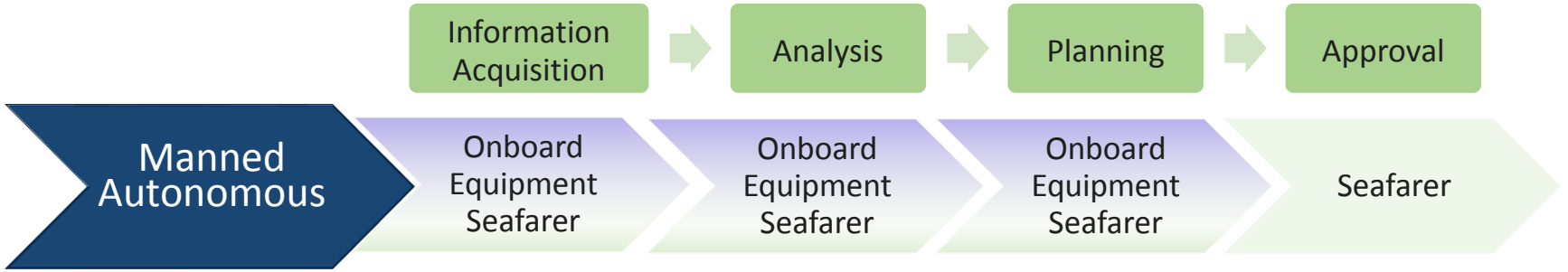


Provided by Japan Radio Co. Ltd.

AL3

- Cyber access for autonomous/ remote monitoring and control
- onboard permission required
- onboard override possible

- Advanced support system … additional functions to assist cognitive process of human operator based on existing navigation system
- Autonomous operation under approval of human operator



Reference：1) Lloyds Register, “Current and Emerging Cyber Risks facing Maritime Industries”, European Maritime Cyber Risk Management Conference, London, June 2017

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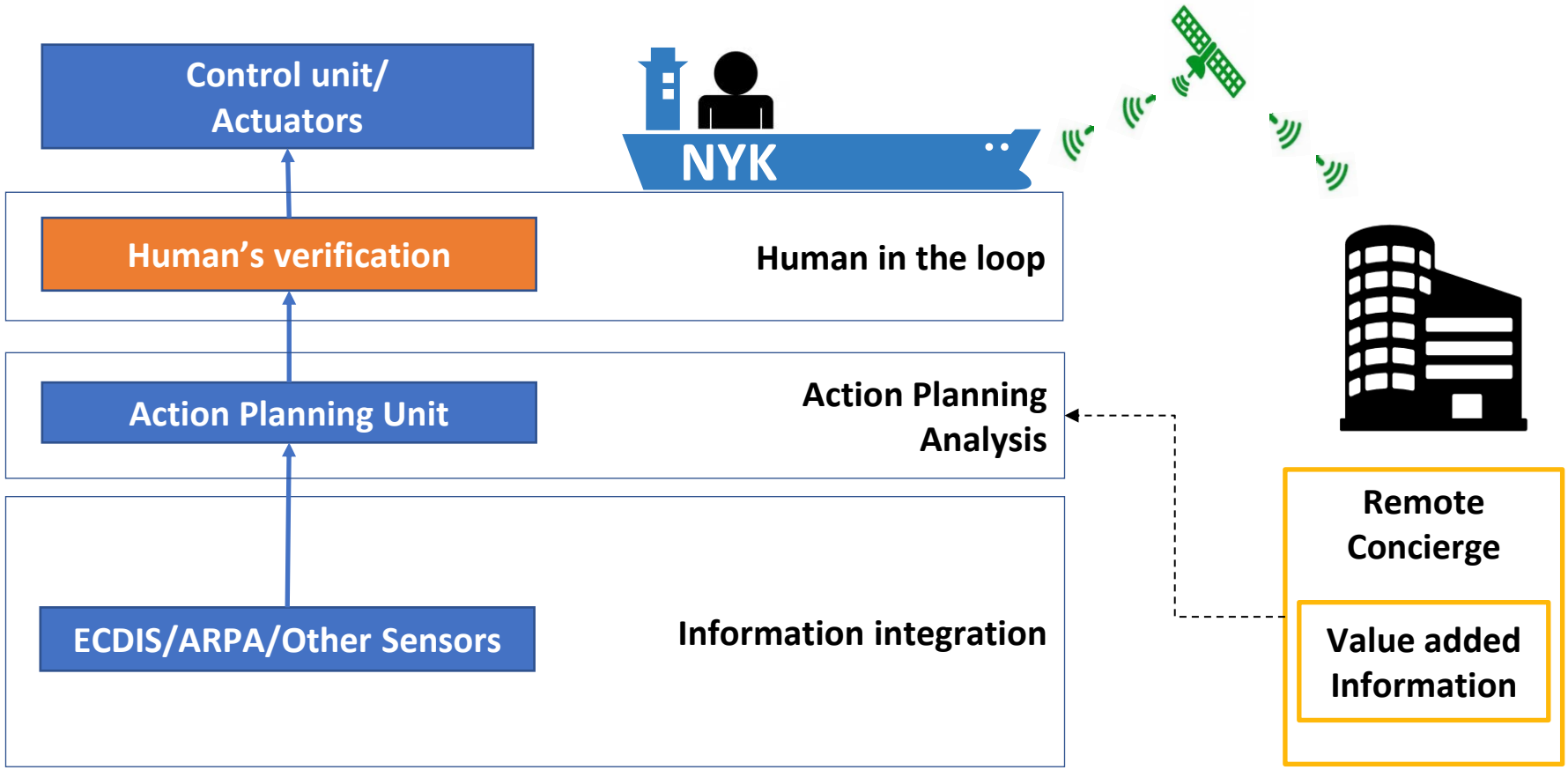
Concept of Action Planning System (APS)

- NYK group aims to define a manned-autonomous system framework as ***Action Planning System (APS)*** and to clarify requirements for APS through open collaboration.



Function of APS

The APS targets the decision-making support necessary for seafarers to maneuver vessels and has the following three specific functions.

1. **Anti-collision and anti-aground support:** formulate and present an action plan to prevent collision and aground during voyage. The parameters for the analysis can be different depending on the area (open ocean, coastal area, congested area, or waterway).

2. **Approach support:** formulate and present an action plan for stopping and restarting the boat, e.g., anchoring, berthing, and mooring.

3. **Docking and undocking support:** formulate and present an action plan for docking/undocking including position and attitude adjustment by using various actuators such as main engine, rudder, thruster, and tug's support. This function is the same as the approach support mode for a ship with a docking and undocking capability of its own.

ODD (Operational Design Domain) of APS

The ODD for APS is roughly defined as follows. Since onboard seafarers validate the action plan from the system, those who handle APS should be required to have appropriate competences.

1. **The geographic and weather condition are acceptable enough** that ships can be controlled by the system, which refers to the standards for other navigation instruments, such as the Dynamic Positioning System, etc.

2. **The system behaves correctly**, i.e., information is correctly displayed on the monitor, and the results are validated by human judgment.

3. **Integral and reliable information including human manual function can be obtained** for situation assessment and action planning.

Definition of APS status

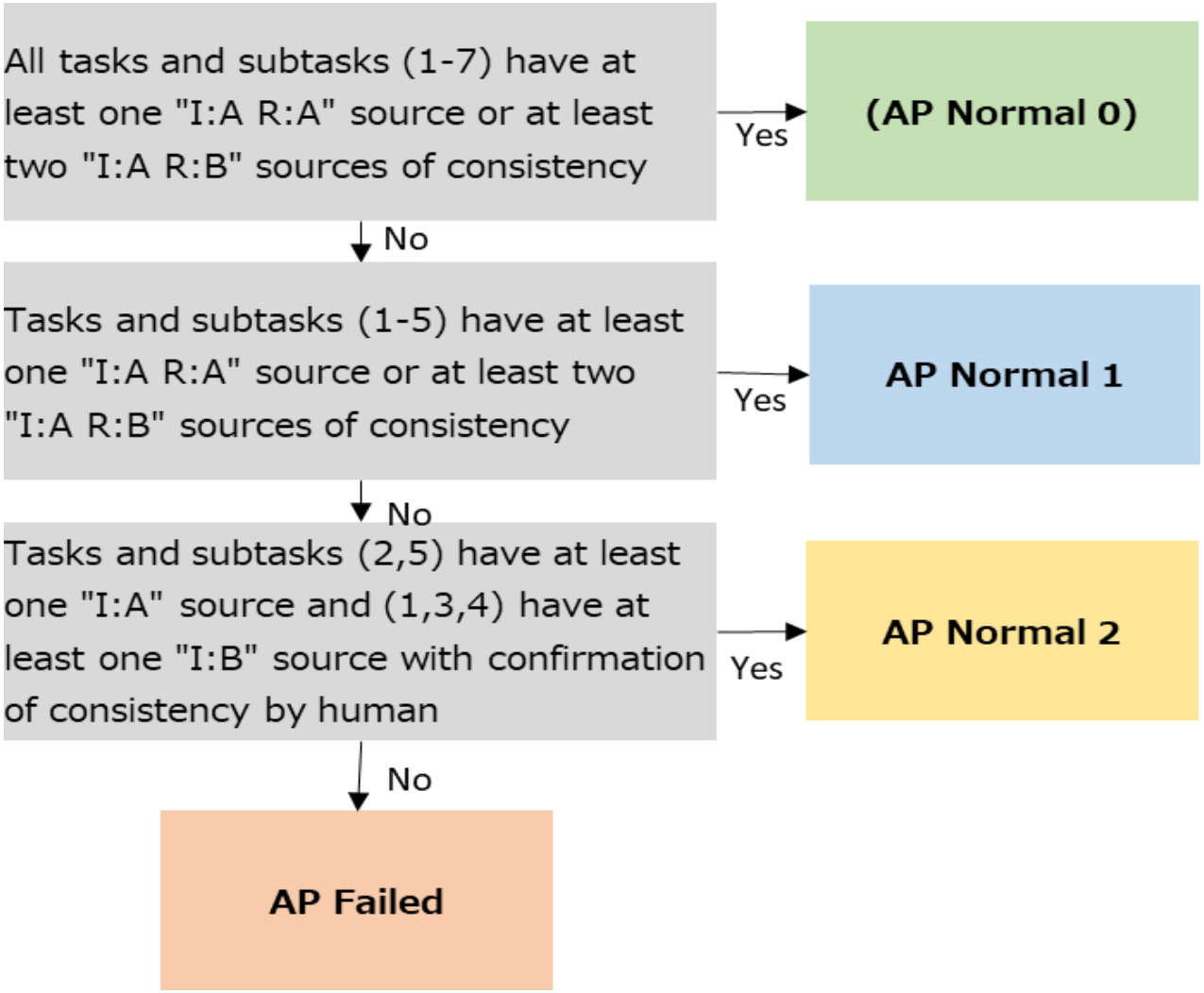
Table 3. Definition of APS status.

Status	Target	Definition
AP Normal 0	Fully autonomous navigation	It has highly reliable information and planning algorithms to carry out all tasks. Human approval can be skipped in usual situations. It does not apply to the current APS, but it is assumed to be available for achieving automation only with machines in the future.
AP Normal 1	Manned autonomous navigation	It has reliable information to carry out tasks till action planning. Human intervention and additional actions other than verification and approval of navigation plans are unnecessary.
AP Normal 2	Manned autonomous navigation	To maintain all tasks to be executed with high accuracy, part of the input information is missing, or some tasks depend on the manual inputs by human only.
AP Failed	NA	A state in which some or all the information sources of tasks are missing, and it is impossible to present an appropriate analysis and action plan even if a human adds and/or modifies information.

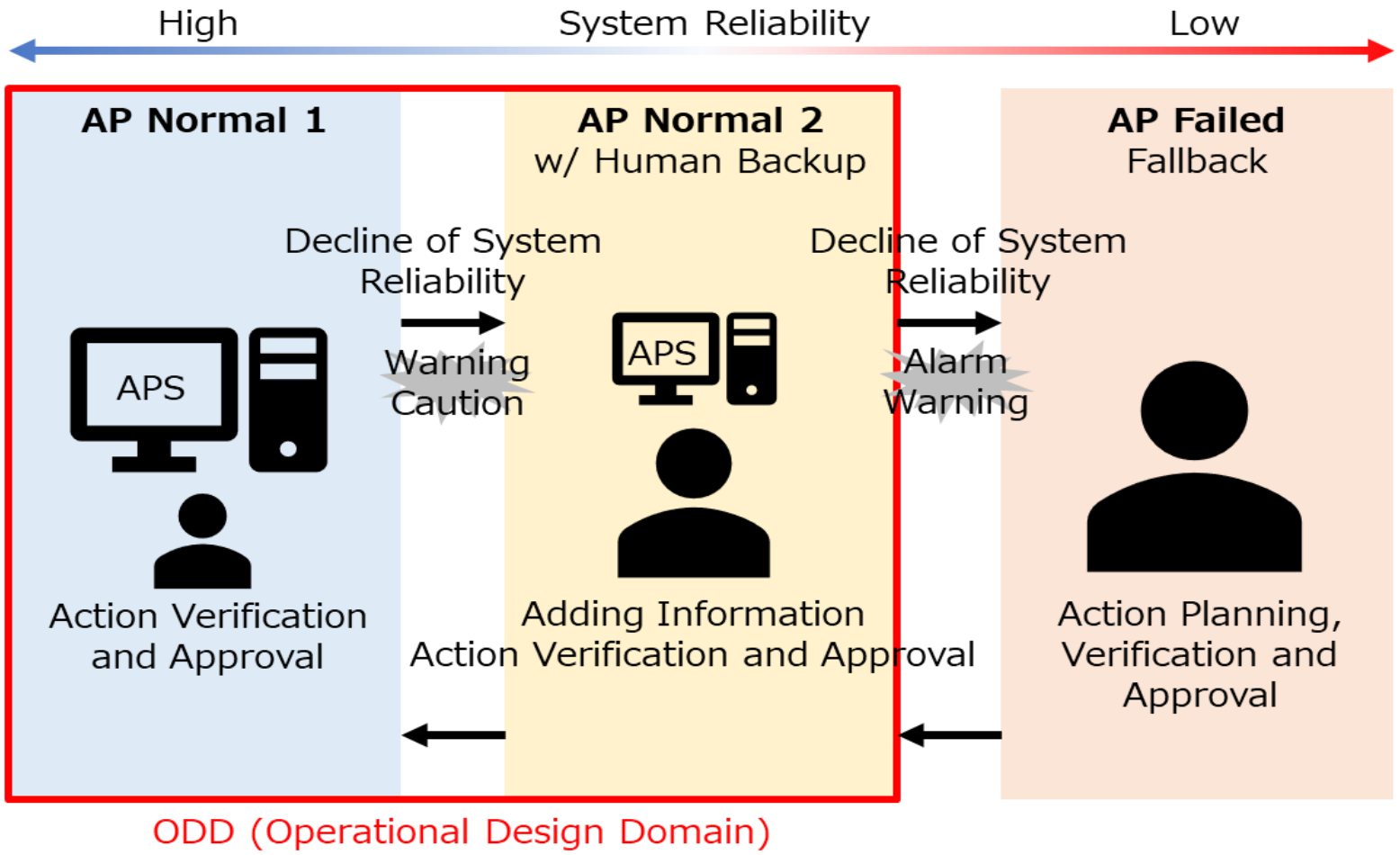
ODD

Fallback

Criteria for determining APS status



APS Status Transition



Risk assessment to check relative safeness (HAZID, FMEA)

- As part of the demonstration project in Japan under MLIT program -

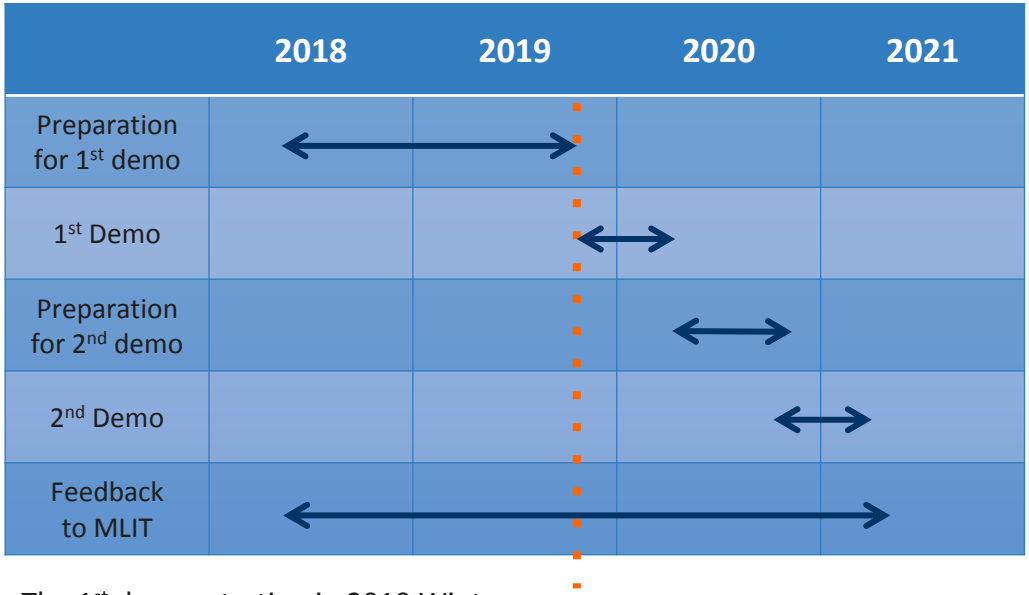
		Criticality / Freq scale	Extremely remote 5000隻で20年に1回の頻度	Very remote Once per 10 years per 1000 vessels	Remote Once per year per 1000 vessels	Seldom Once per year per 100 vessels	Resonably probable Once per year per 10 vessels	Probable Once per year per vessel	Frequent Once per month per vessel
			1	2	3	4	5	6	7
Conventional Ship	Minor	1							
	Moderately serious	2							
	Serious	3							
	Major	4	F1-common A1.1, B2.3	F2-common A3.1, A4.3, A3.3, B2.2, B3.2 D1.1, D2.1, F1.2, F1.4, F1.5	F3-mitigation A4.1, A4.2, B1.2, E1.1, E2.1, E2.2, E3.1, E3.2 F3-common A3.2, C1.5, E4.2, F1.3	F4-mitigation C1.2, C1.3, C1.4, C2.1, C3.1, C3.2, D1.2, D1.3, D3.1, D4.1			
	Exceptional	5							
Ship with APS	Minor	1		F2-new risk A2.1	F3-new risk F1.6				
	Moderately serious	2							
	Serious	3							
	Major	4	F1-mitigation C3.2 F1-common A1.1, B2.2 F1-new risk A1.2, A2.2, B1.1 B2.3, B3.1	F2-mitigation A4.1, A4.2, B1.2, E1.1, E2.1, E2.2, E3.1, E3.2 F2-common A3.1, A4.3, A3.3, B2.1, B3.2 D1.1, D2.1, F1.2, F1.4, F1.5 F2-new risk E4.1, F1.1	F3-mitigation C1.2, C1.3, C1.4, C2.1, D1.2, D1.3, D3.1, D4.1 F3-common A3.2, C1.5, E4.2, F1.3				
	Exceptional	5							

Blue：risk mitigated

Red: new risk

Demonstration Project in Japan under MLIT program

- Objective: Demonstrate APS concept
- Target ship: Tug boat of Shin-Nippon Kaiyosha
- Period: 2018 – 2020
- Project members: company name (role)
  1. MTI (project coordinator/concept design)
  2. JMS (project coordinator/simulator)
  3. NYK (project coordinator/ship owner)
  4. IKOUS (ship owner)
  5. Furuno Electric (navigation equipment)
  6. Japan Radio (navigation equipment)
  7. Tokyo Keiki (navigation equipment)
  8. BEMAC (DPS)
  9. Keihin Dock (shipyard)
  10. Mitsubishi Shipbuilding (engineering)
  11. Sky Perfect JSAT (satellite communication)
  12. NTT DoCoMo (4G/5G network)
  13. NTT (system provider)
  14. Niigata Power Systems(propulsion)
  15. ClassNK (verifier)
  16. NMRI (risk assessment)



The 1st demonstration in 2019 Winter
The 2nd demonstration in 2020 Winter

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Summary

Manned-Autonomous Navigation as a waypoint

Manned autonomous navigation can be positioned as a “technological waypoint” towards fully autonomous and remotely controlled navigation.