IoT and Big data in shipping
– an approach of NYK Line -

23th September 2019

PRADS2019

Yasuo Tanaka , MTI

Outline

1. **Introduction**
2. IoT and Big data in Shipping
3. Autonomous Ship and system integration
4. What's more

What NYK/MTI is

NYK Corporate Profile

NYK LINE (NIPPON YUSEN KAISHA)

- NYK LINE (Nippon Yusen Kaisha)
  - 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

NYK Head Office in Tokyo

- Employees: 35,711 (as of the end of March 2019)

- Revenues: $ 21.8 billion (Fiscal 2018)

What NYK/MTI is

NYK Fleet (as of the end of March 2019)

NYK LINE NIPPON YUSEN KAISHA

Container ships (including semi-container ships and others)

63 vessels / 5,200,000 DWT

Bulk Carriers (Capesize)

105 vessels / 20,200,000 DWT

Bulk Carriers (Panamax & Handysize)

252 vessels / 15,392,000 DWT

Wood-chip Carriers

44 vessels / 2,382,000 DWT

Cruise Ship

1 vessel / 7,000 DWT

Car Carriers

118 vessels / 2,200,000 DWT

Tankers

56 vessels / 19,050,000 DWT

LNG Carriers

29 vessels / 2,209,000 DWT

Others

42 vessels / 701,000 DWT

710 vessels

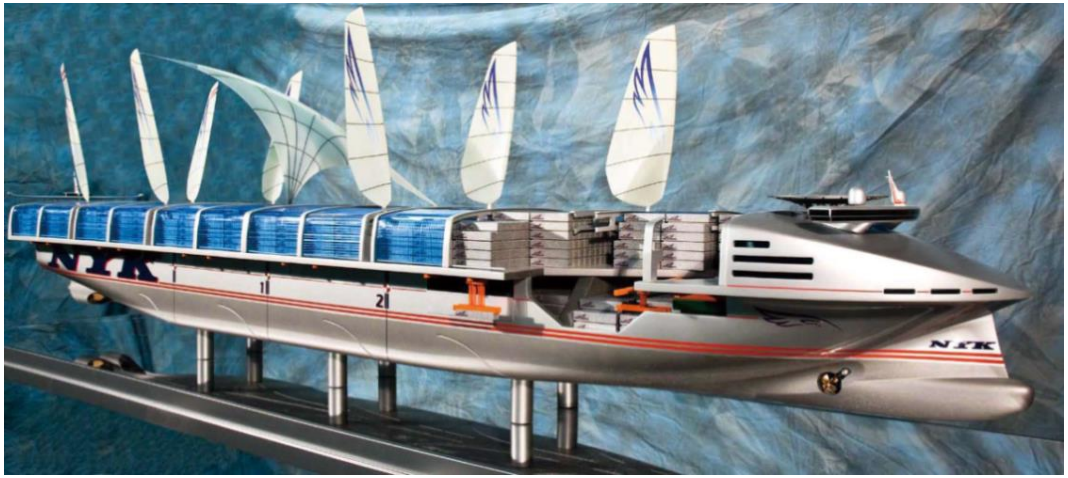
67,341 KT (1,000 DWT)

What NYK/MTI is

MTI Company Profile

- MTI is “Monohakobi (= quality transport) Technology Institute”
- Established : April 1, 2004
- Equity capital : JPY 99 million
- Stockholder : NYK Line
- Number of employees : 76 (as of 1st September, 2019)
- Head office : 2-3-2 Marunouchi, Chiyoda-ku, Tokyo, 100-0005, Japan
- URL : www.monohakobi.com/en/

Monohakobi Technology Institute



NYK SUPER ECO SHIP 2030 (Concept ship for the future 69% less CO2 emissions)

SINGAPORE BRANCH

- 1 Harbour
- Front Place #13-01
- HarbourFront Tower One
- Singapore (098633)

YOKOHAMA LAB

- (Transportation Environment Lab)
- 5-32-84, Sugita, Isogo-ku, Yokohama,
- Kanagawa, Japan

Monohakobi Technology Institute

NYK GROUP

Smarter ship and operation in NYK/MTI

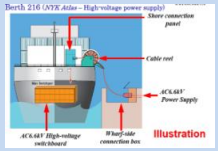
Now — Future

OIL — LNG — HYDROGEN

Ship (Hardware)

Wind Resistance Reduced
MT-COWL

Super Eco Ship 2050



Alternative Marine Power

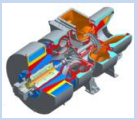
Super Eco Ship2030

30% Energy Saving PCTC

Measurement around propeller

Wind Power Generator
Andromeda Leader

Solar Panel
Auriga Leader



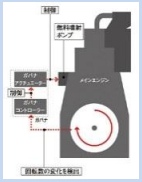
Hybrid T/C
Shin Koho

LNG-Fueled Tugboat
Sakigake

Innovative
Air Lubrication System
SOYO

LNG-Fueled PCTC
Delivery in 2016

Electronic Controlled Engine



Improved
Governor Controller

MT-FAST

Air Lubrication System
YAMATO, YAMATAI

Hybrid Electric Power Supply
Auriga Leader

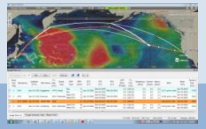
LNG Bunkering Vessel
Delivery in 2016

Operation (Software)

Monohakobi Technology Institute

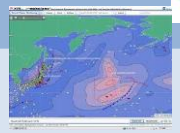
MTI Founded

NYK's own safety and Environment standard
NAV9000



Prediction of Current

Fuel Consumption Indicator
FUELNAVI

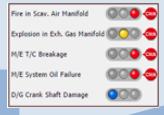


Integrated Operation Management System
NYK e-missions'

IBIS Project

IBIS Project
Onboard Broadband
NYK Satcom Project

LiVE
Operation Portal Site



Detection of Mach. Trouble with monitoring data

ShipDC &
IoS-OP

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

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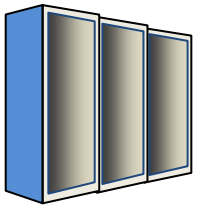
IoT platform of NYK

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

Onboard dashboard

VDR

Data Acquisition and Processing

Motion sensor

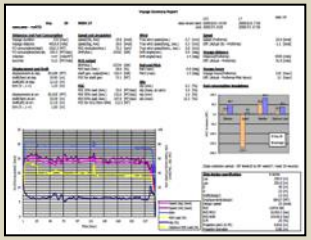
<Navigation Bridge>

<Engine Room & Cargo>

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

Integrated Automation System

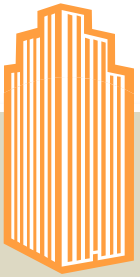
SIMS Monitoring & Analysis at Shore



Performance Analysis

- Long term analysis
- In service performance

Analysis



Operation Center (Tokyo, Singapore ...)

Shore Dashboard

- For operation
- For ship manager

Technical Analysis (NYK, MTI)

Ship performance in service

6000TEU Container Ship

Wave height 5.5m, Wind speed 20m/s

BF scale 8, Head sea @ Trans-Pacific (Oakland, US – Tokyo, JP)

@ engine rev. 55rpm

<**Calm sea** performance>

speed: 14 knot

FOC*: 45 ton/day

* FOC: Fuel Oil Consumption

<**Rough sea(BF8)** performance>

speed: **8 knot**

FOC: **60 ton/day**

Effecting factors

1. Weather (wind, wave and current), 2. Ship design (hull, propeller, engine), 3. Ship condition (draft, trim, cleanness of hull and propeller, aging effect)

In-service ship performance model

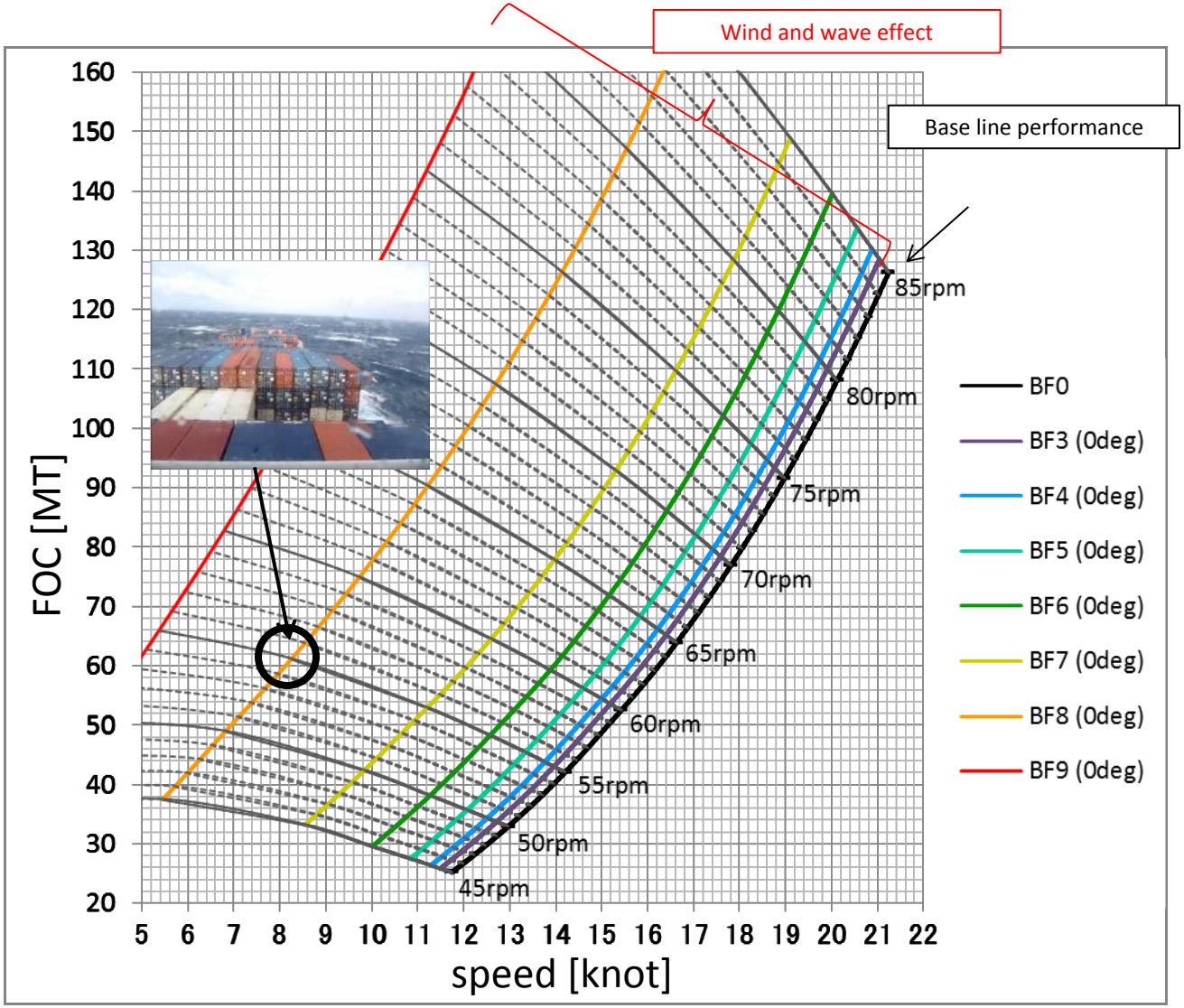
<Target vessel>
6000TEU Container
Draft 12m even

Sea condition

Beaufort scale

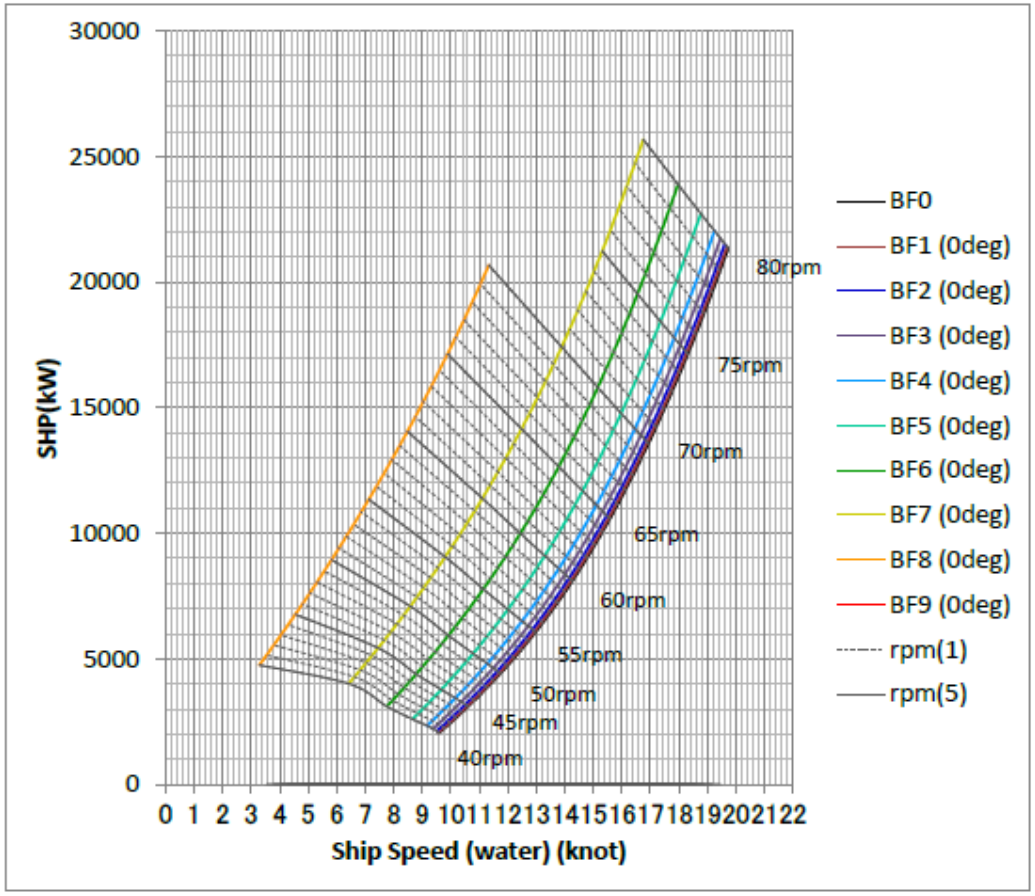
	wind speed (m/s)	wave height (m)	wave period (sec)
BF0	0.0	0.0	0.0
BF3	4.5	0.6	3.0
BF4	6.8	1.0	3.9
BF5	9.4	2.0	5.5
BF6	12.4	3.0	6.7
BF7	15.6	4.0	7.7
BF8	19.0	5.5	9.1
BF9	22.7	7.0	10.2

0deg (wind, wave) – head sea



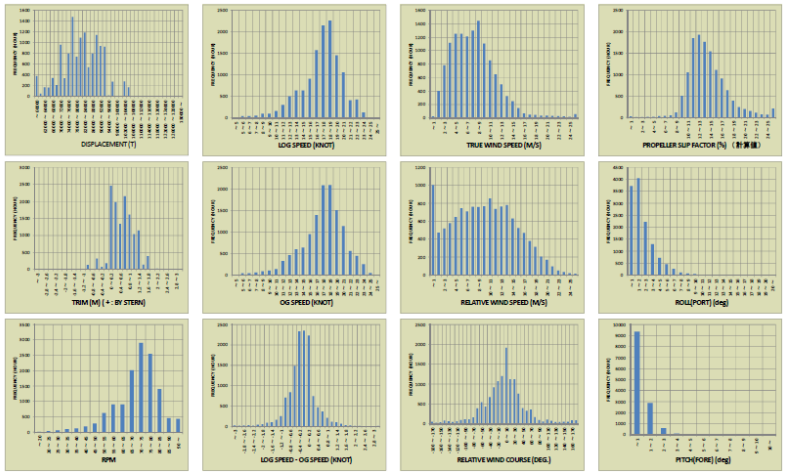
Estimation of seasonal sea margin

Ship performance model



Combine ship performance model with weather data to run simulations

Improve bad performance ship



23 % CO2 reduction was confirmed

Operational profile

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

Energy saving modification

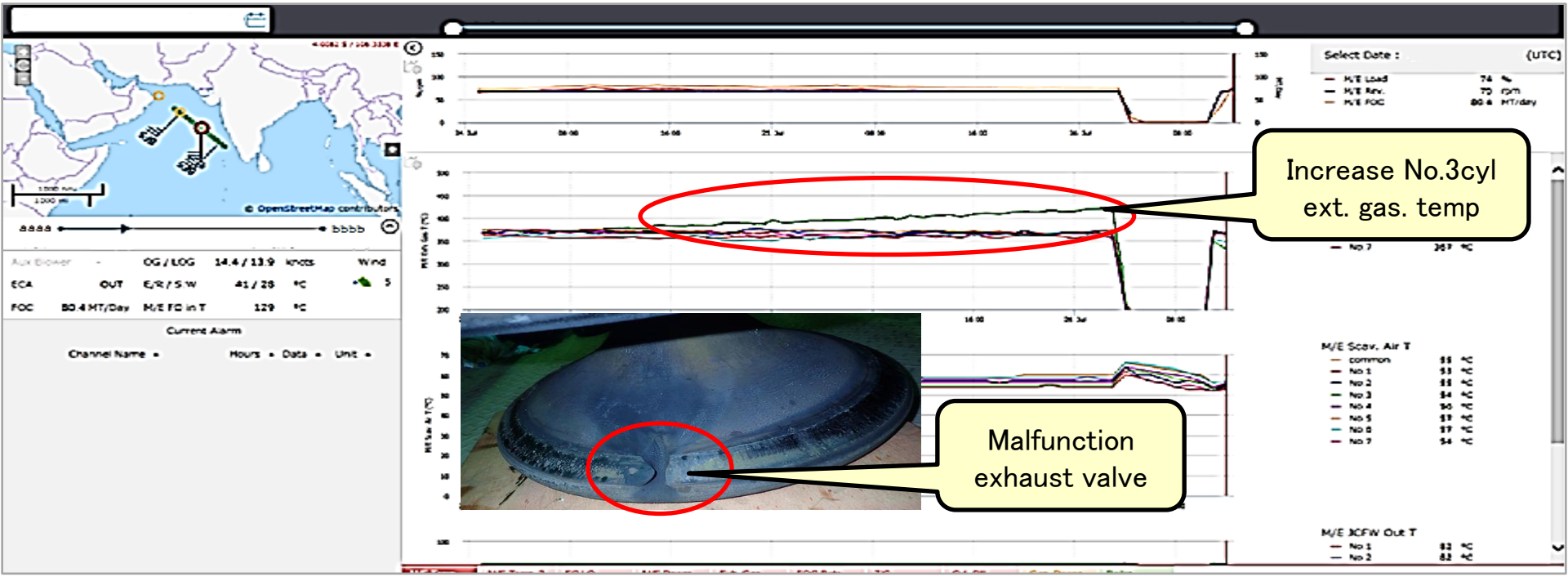
- Bulbous bow modification
- Install energy saving device (MT-FAST)
- Etc.

‘Digital Twin’ will be more used not only for energy efficiency but also for improving safety

Anomaly detection from IoT data

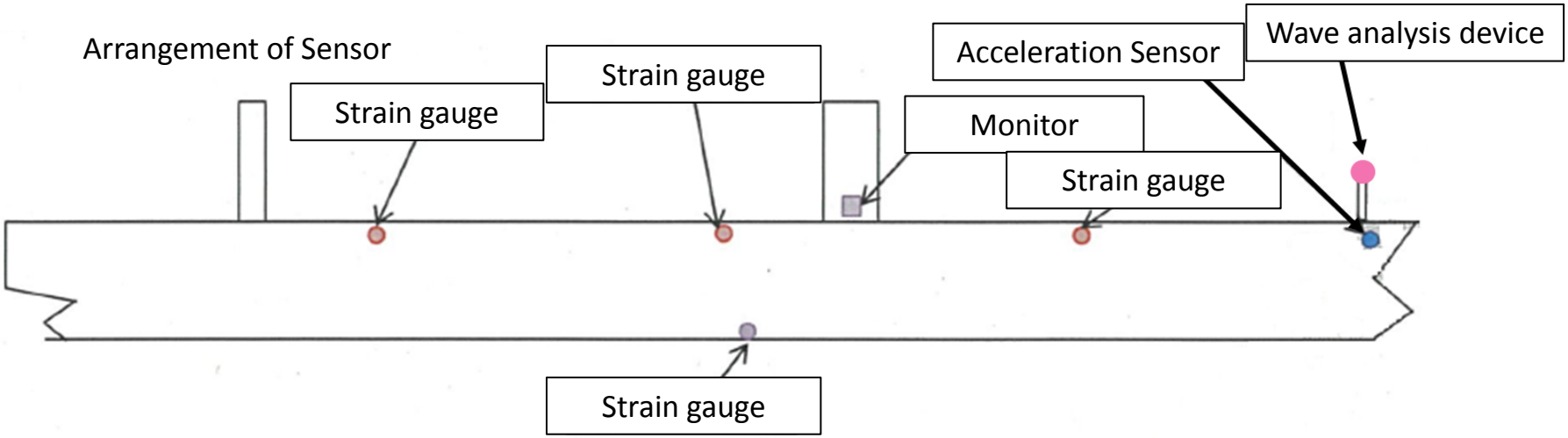
- Find trouble phenomenon in engine & power plants -

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 function by using the accumulated data.

Hull Stress Monitoring System



Hull Monitoring System Measurement data

×

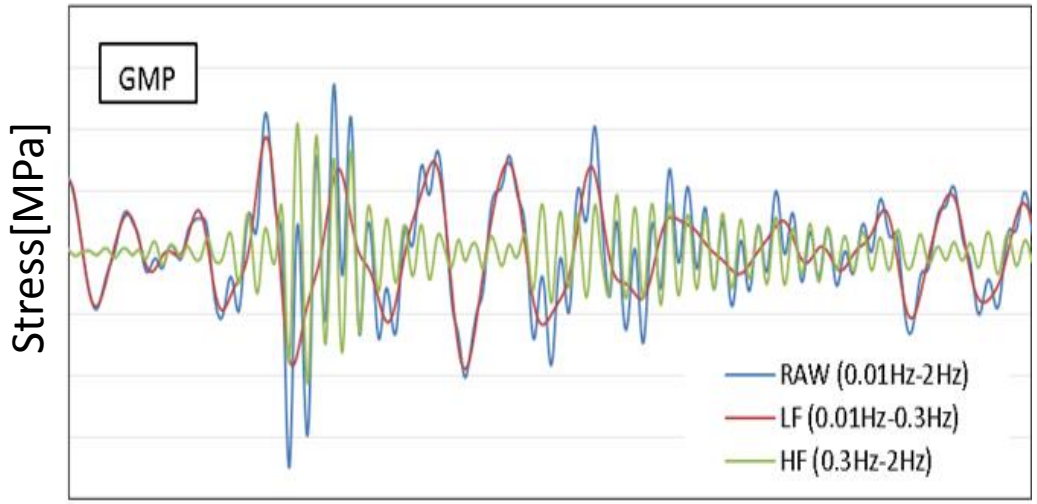
Operation/Environmental/ Loading Data

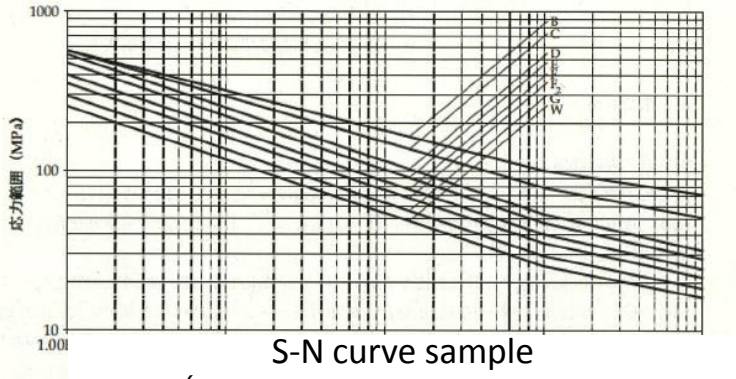
1) Estimation method of hull stress
2) Hull structure monitoring system in view of Ship Operator

1) This study was conducted as a part of the collaborative research project “Hull structure health monitoring of 14,000TEU large container ships” under the sup-port of the Ministry of Land, Infrastructure, Transportation and Tourism of Japan for i-Shipping operation.

2) This study was conducted as joint research by Japan Marine United Corporation, ClassNK, National Maritime Research Institute, Japan Weather As-sociation, NYK Line and MTI Co., Ltd.

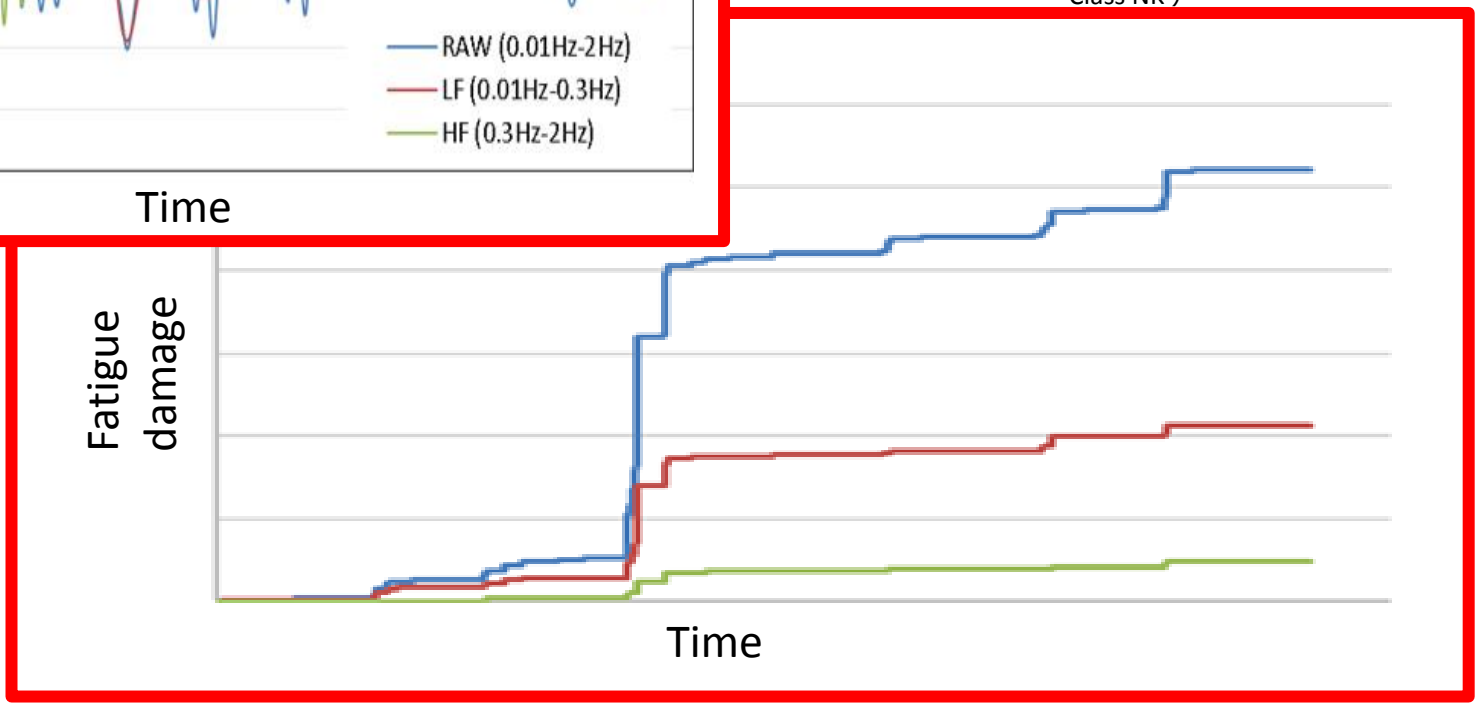
Assessment of Fatigue Damage





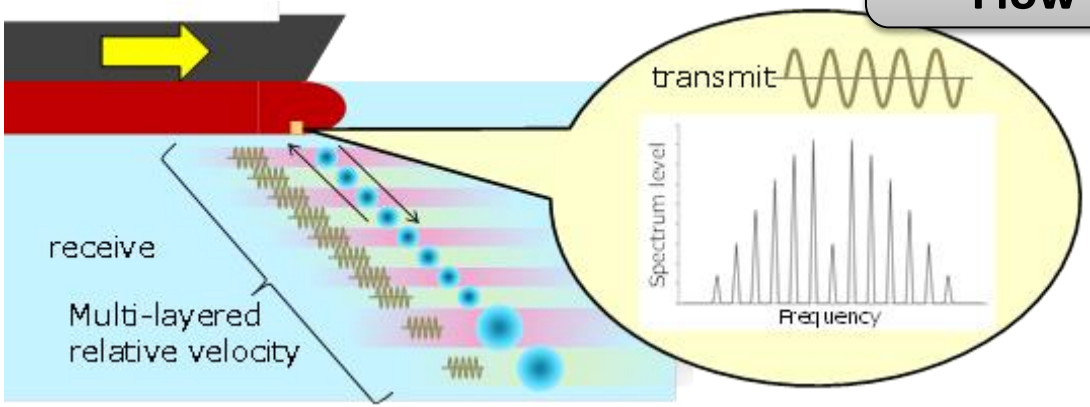
S-N curve sample

Source（Rules for Building and Classing Steel Vessel of Class NK）



Multi-Layered Doppler Sonar (MLDS)

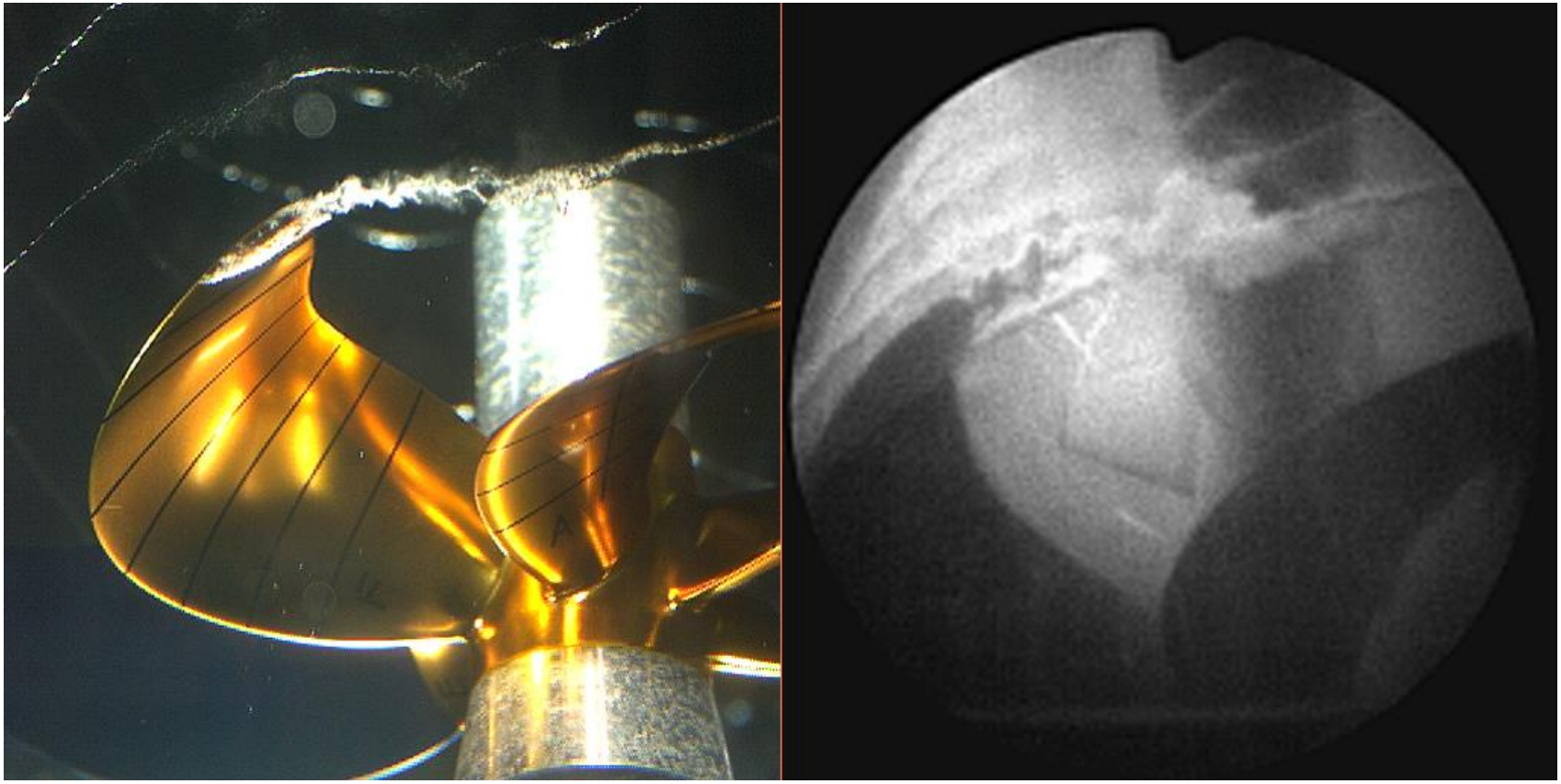
For measurement of Flow velocity at Stern



Source) Yonezawa et al, "Improvement of Measuring Accuracy of Ship's Speed through Water by using MLDS", HullPIC2018,2018

- **Familiar as Speed log**
- **Easy to install**
- **Low cost**

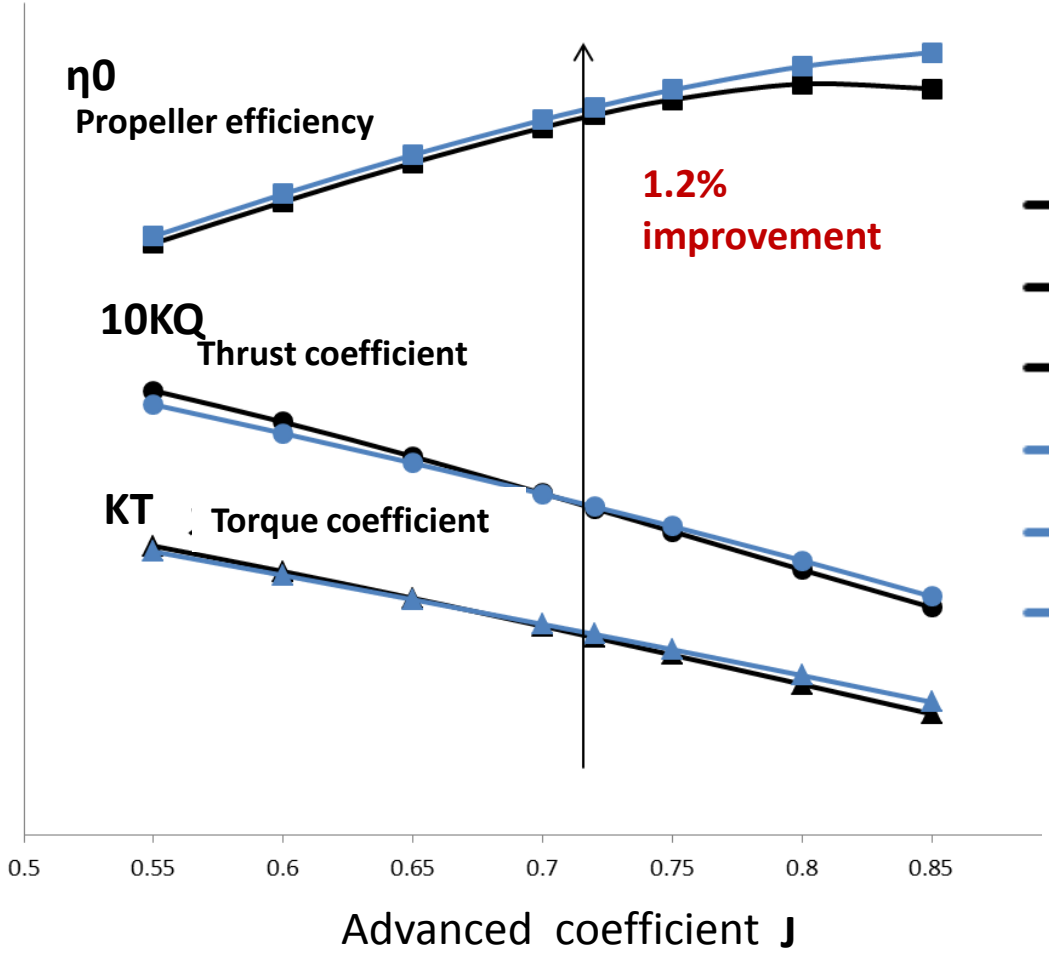
Observed cavitation



<u>Similar to model test cavitation pattern</u>

→It implies that the assumed inflow was a good estimate

Feedback to the subsequent vessel



KT(Previous propeller)

10KQ(Previous propeller)

η0(Prevuous propeller)

KT(New propeller)

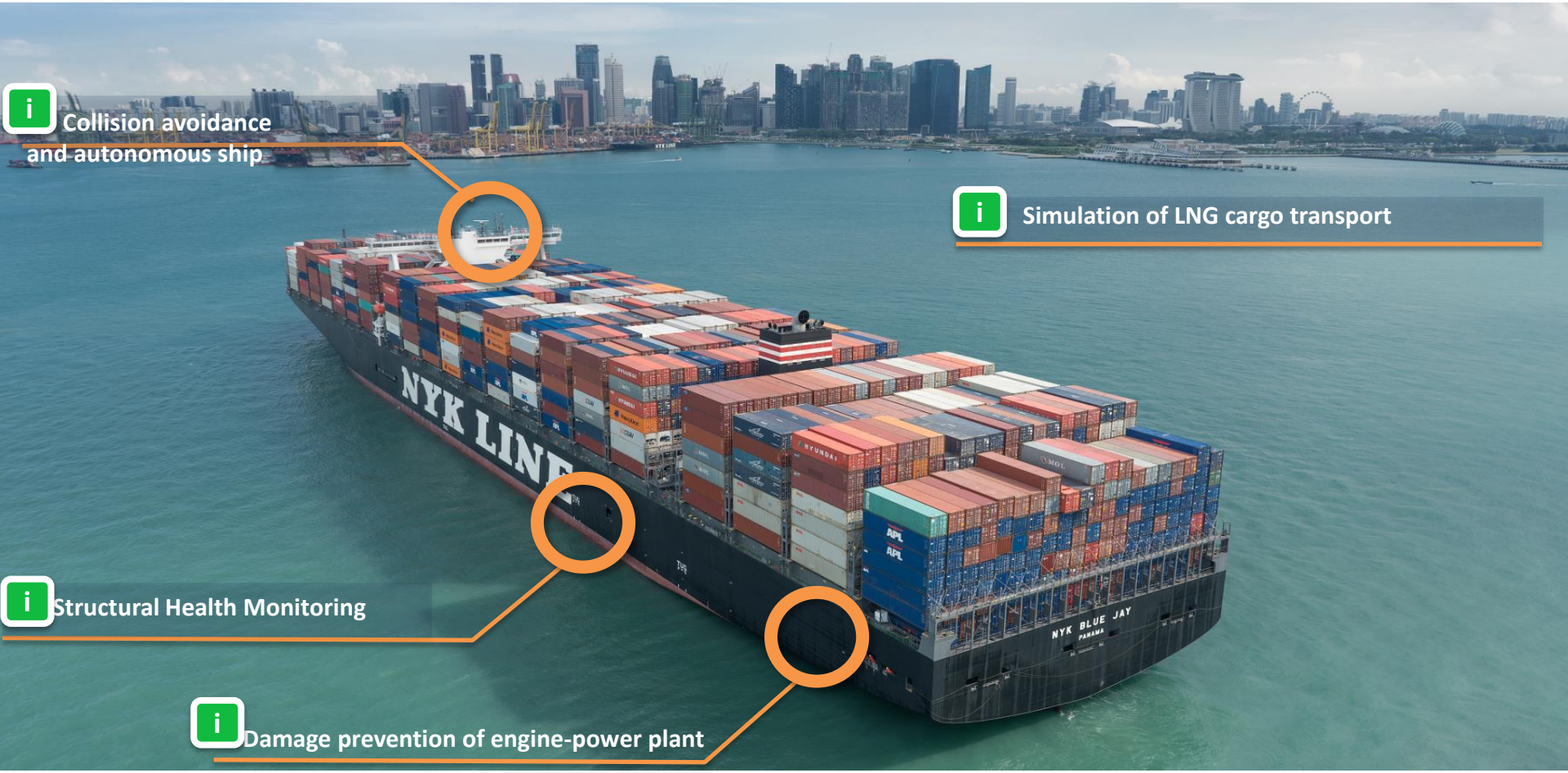
10KQ(New propeller)

η0(New propeller)

Apply new propeller with 1.2% higher efficiency to the subsequent vessel in the series

Utilizing IoT data for safer operation

- Open collaboration with industry partners -



MLIT Ministry of Land, Infrastructure, Transport and Tourism

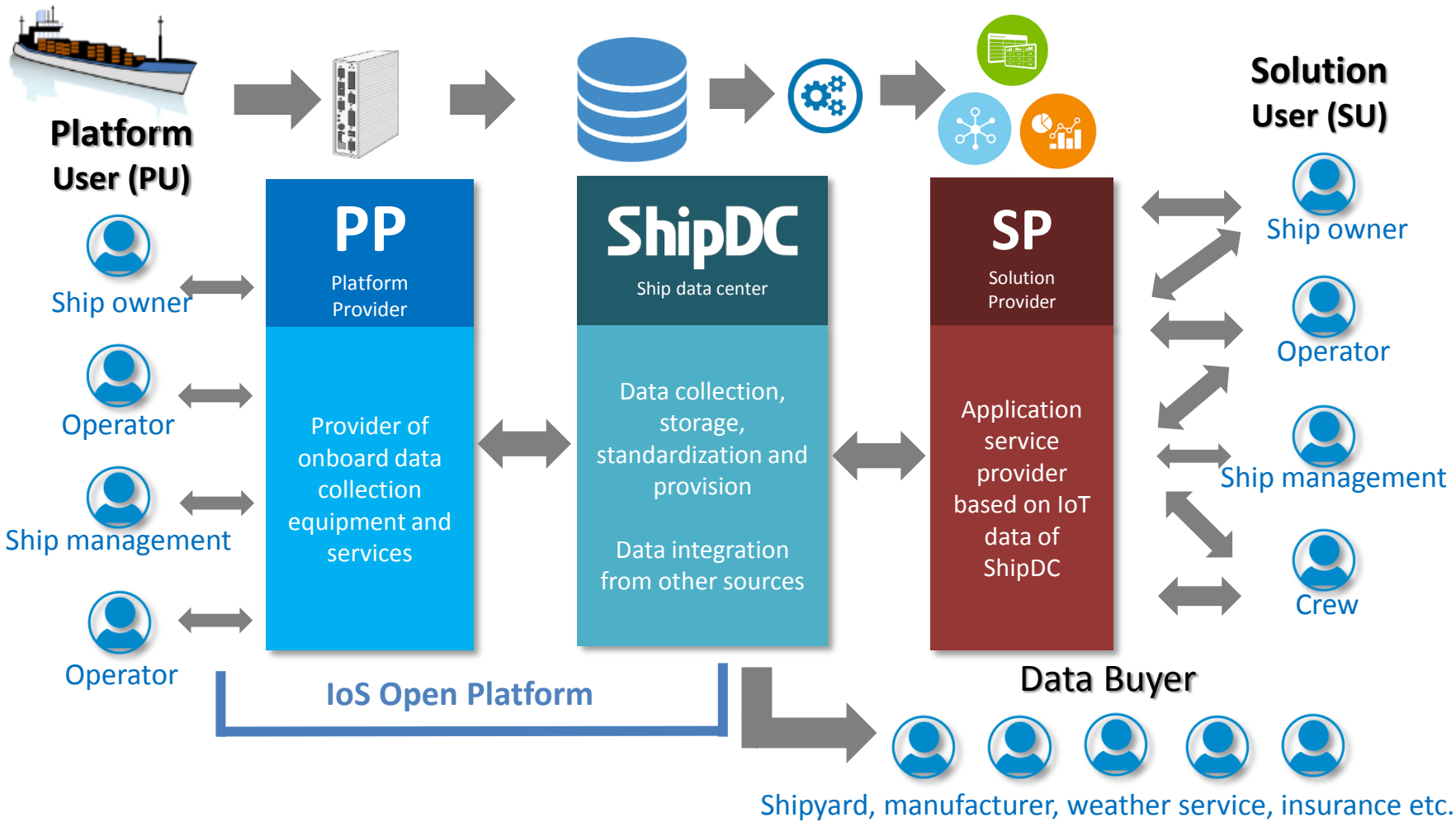
ClassNK

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

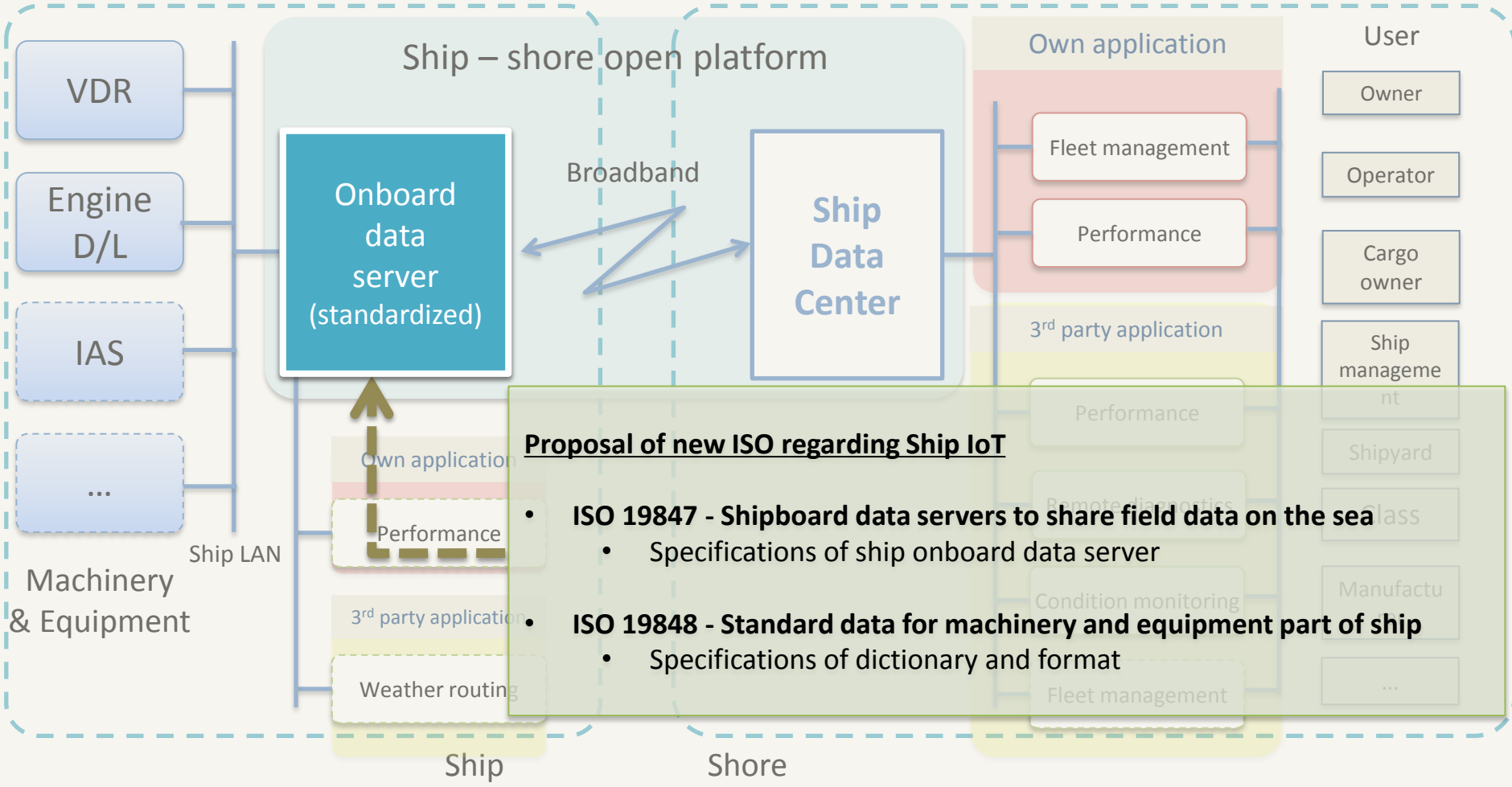
Internet of Ships (IoS) Open Platform

ShipDC

Roles are defined and each player provides their expertise on the Internet of Ship(IoS) platform. Data governance and business rules have been built by IoS OP Consortium under ShipDC.



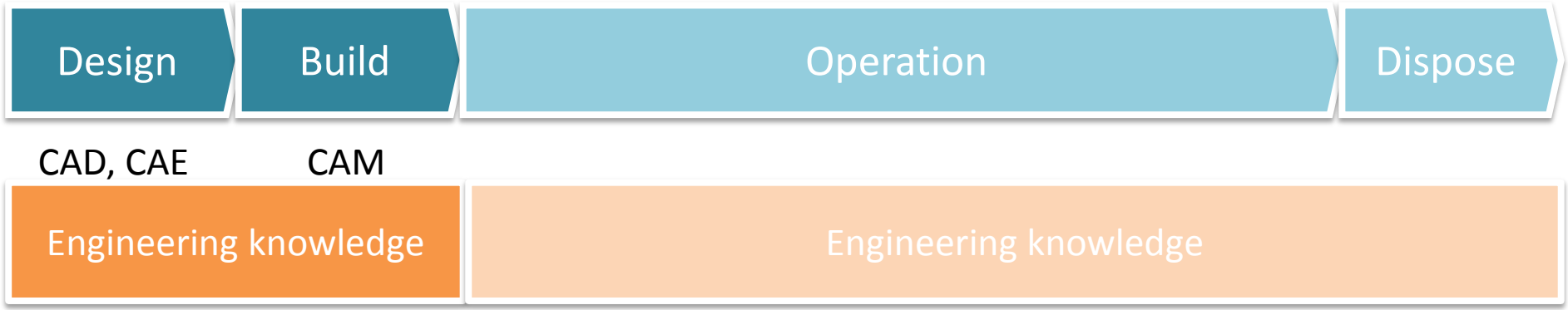
Standardization activities of Ship IoT platform
(SSAP3: Smart Ship Application Platform 3 Project by JSMEA)



JSMEA: Japan Ship Machinery and Equipment Association

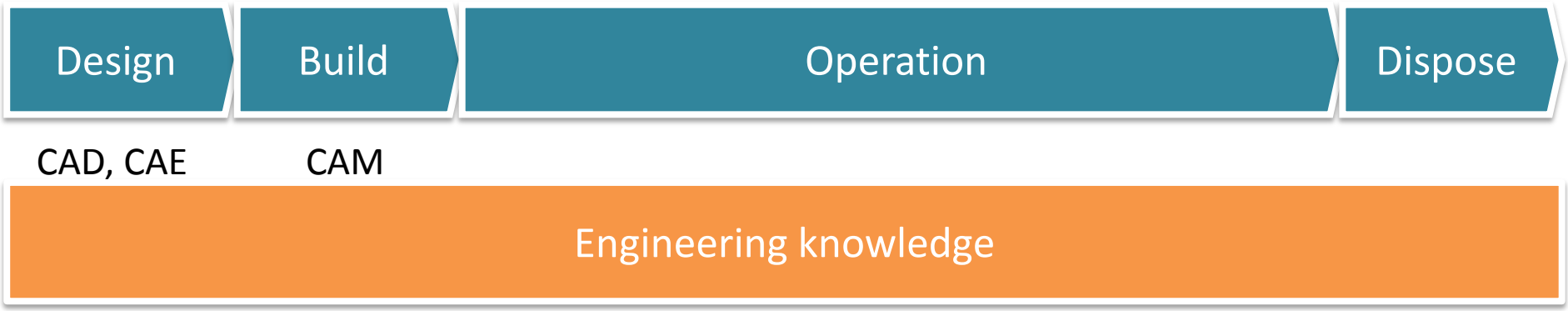
Before IoT:

Engineering knowledge, simulations and tools have been used for design and production



- Designers and engineers consider life cycle values of products only at design stage
  - Manufacturability, usability, maintainability, disposability …

Era of IoT:
Engineering knowledge, simulations and tools are now demanded through life cycle of products



- **Operation optimization** with engineering knowledge
- Feedback of operation data to product design for **design optimization**

Pursuing total optimization of operation and product design

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Approach to advanced automation of ships

ex) Automation level (AL1 – AL5) by Lloyds Register

AL0	AL1	AL2	AL3	AL4	AL5
• No cyber access	• Manual cyber access	• Cyber access for autonomous/ remote monitoring	• Cyber access for autonomous/ remote monitoring and control • onboard permission required • onboard override possible	• Cyber access for autonomous/ remote monitoring and control • onboard permission not required • onboard override possible	• Cyber access for autonomous/ remote monitoring and control • onboard permission not required • onboard override not possible

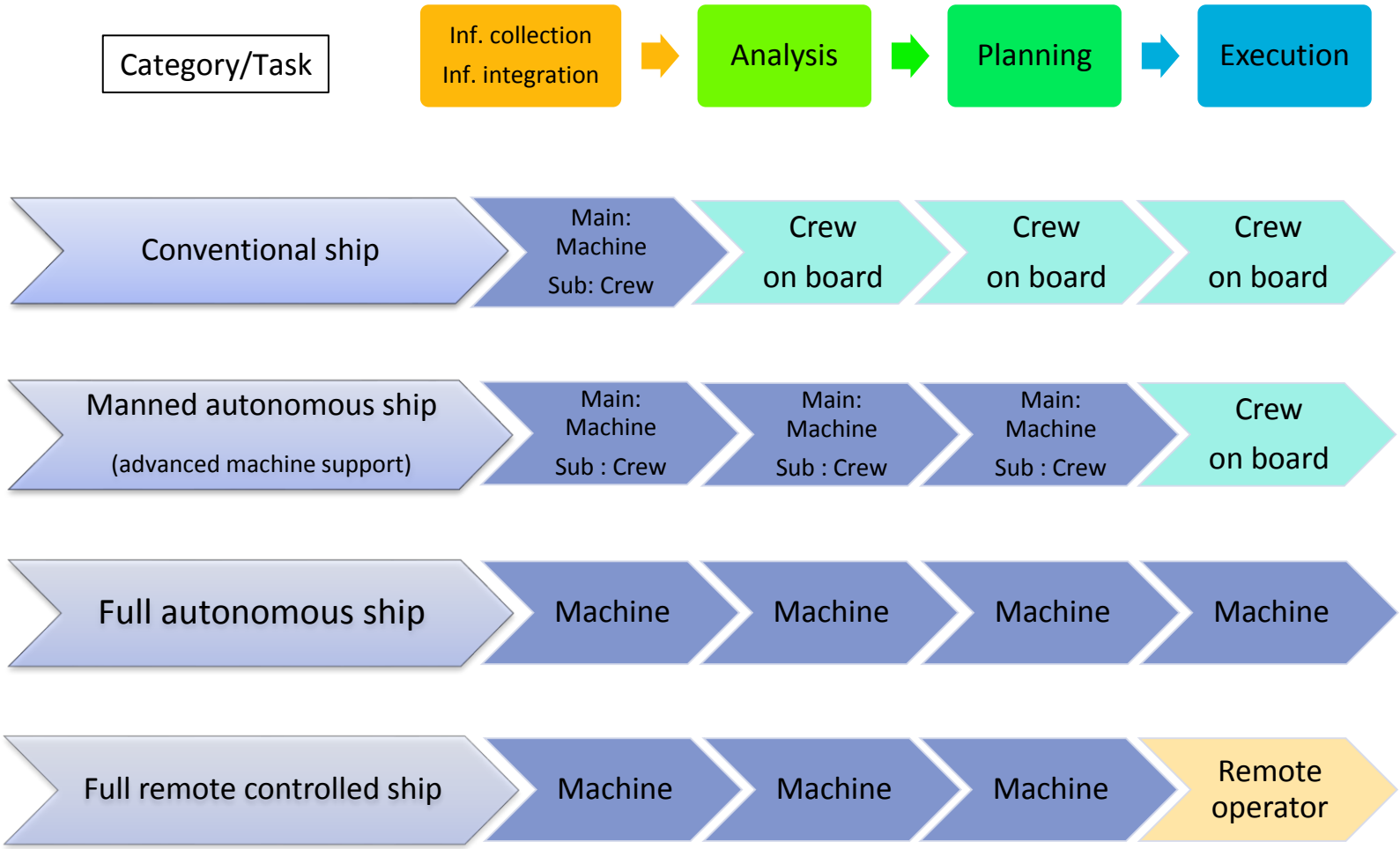
Reference) Edward Fort , Global Head of Engineering, Lloyds Register, "Autonomous ships – LR approach" January 2018

Example of subject onboard systems

- Propulsion and steering
- Power generation, management and distribution
- Navigation and communication
- Ventilation and chilled water
- Cargo and ballast management
- Fuel, lubrication and other ancillaries
- Fire fighting and emergency systems
- …

The advanced automation will proceed as per each machinery system, depending on the importance level of each system and on the progress in automation-technology levels.

Typical category of MASS (Maritime Autonomous Surface Ship)



Assessment of MASS（Deep sea vessel）

	Conventional ship	Manned autonomous ship (advanced machine support)	Full autonomous ship	Full remote controlled ship
Incident risk	Base	+	+	+
Workload	Base	+	+	+
Cyber risk	+	−	−	− −
Total reliability	Base	+	−	−
Cost	Base	+	−	− −

Remarks

1. **Using heavy fuel may not be suitable for ascertaining reliability of MASS.**
2. **Current essential elements such as international rules / industrial standards / insurances, have not covered some aspects of MASS.**

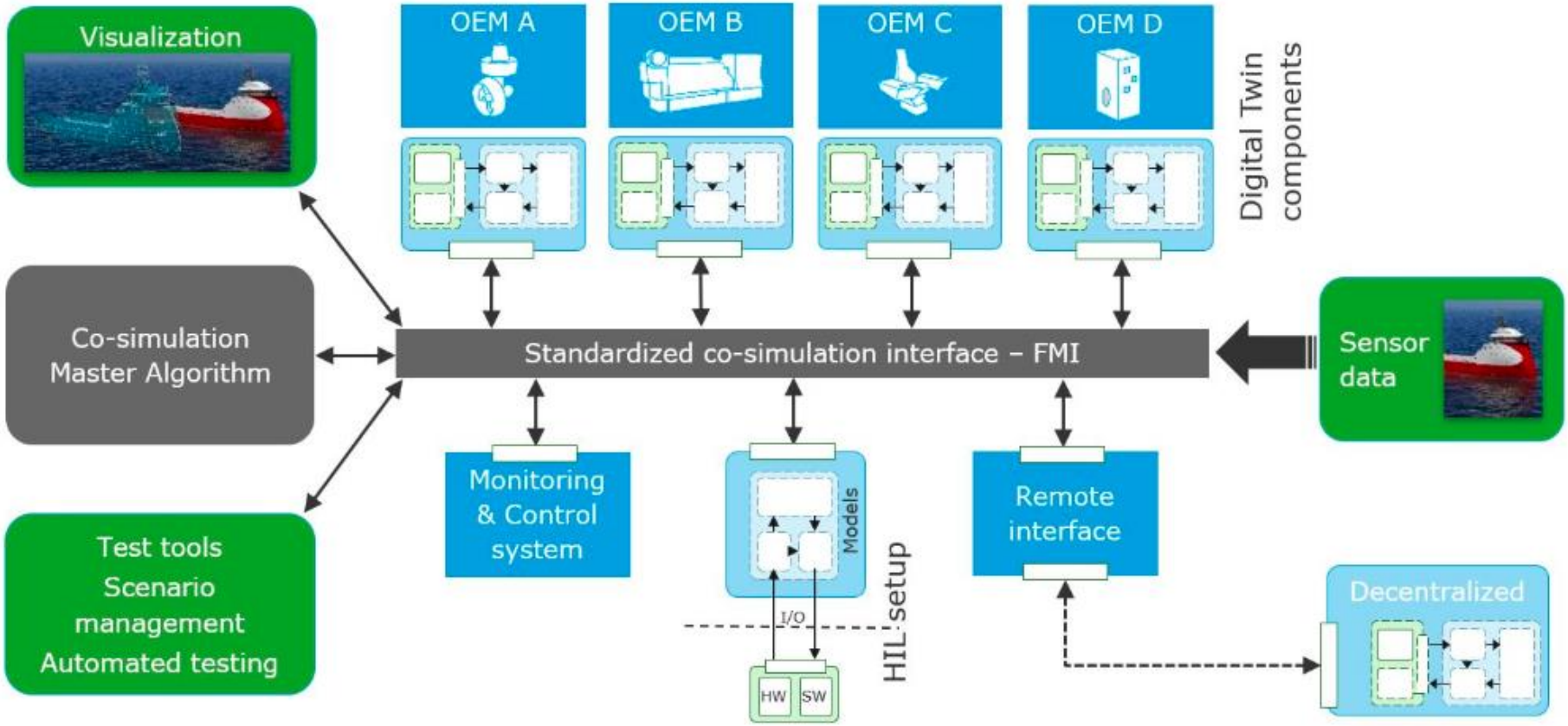
Participate in Open Simulation Platform (OSP) JIP

https://www.dnvgl.com/feature/open-simulation-platform-osp.html
https://opensimulationplatform.com/

- DNV-GL, Rolls-Royce, SINTEF Ocean and NTNU leads the Joint-Industry-Project
- Open source simulation platform for design, construction and oeperation.

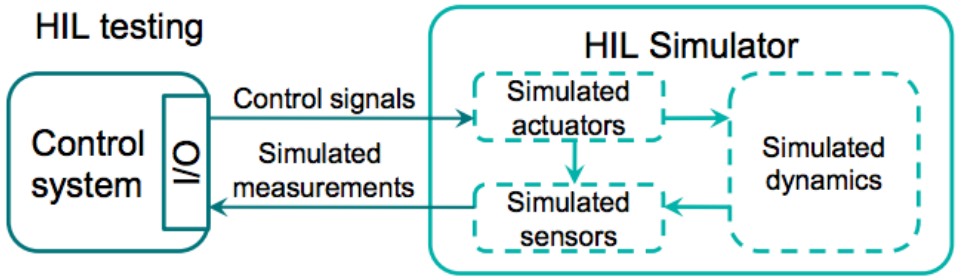
OSP Architecture

The Open Simulation Platform Architecture



Software Quality & Reliability

Highly automated system requires more & more reliability of software. To develop, design and approve efficiently, simulation-based test environment become more indispensable.



Source) DNV-GL Marine Cybernetics Advisory

https://www.dnvgl.com/services/hil-testing-concept-explanation--83385

Cyber Security

Cyber risk management will need to be implemented. Protection of Industry Control System is crucial

The Guidelines on Cyber Security onboard Ships - Version 3, BIMCO – Nov 2018

Cyber security guidelines in shipping

- **IMO, MSC (98)** – Cyber risk management onboard ships should be included in SMS as of 1 Jan 2021 (Jun 2017)
- **BIMCO** – the guidelines on cyber security onboard ships – version 3 (Nov 2018)
- **ABS, DNV-GL, LR, BV etc.** – Guidelines and notations of cyber security onboard ships (2016)
- **IEC 61162-460** – Safety and security standards for navigation and radio communication equipment
- **IACS** Maritime Cyber System Recommendations (MCSR)

Cyber security guidelines

- **NIST Framework and 800-53** – computer security policies, procedures and guidelines
- **ISO 27001/2** – ISMS: Information Security Management System

Source) BIMCO
https://www.bimco.org/products/publications/free/cyber-security

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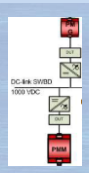
Future ship concept toward zero emission

NYK SUPER ECO SHIP 2050

CO2 emission ▲ 100%

67% reduction of necessary energy for propulsion (comparing to ships built in 2014)

Solar ~ 9%



Power distribution < 1%

Heat recovery ~ 15 %

Reduction in auxiliary power demand ~ 7%

- VFD
- Crew related
- Lower machinery demand
- Lighting

Propulsion ~ 9%

Prime movers ~ 19%

Resistance ~ 37%

- Light weight material
- Hull optimisation
- Super structure optimization
- Hull cleaning

Key R&D items for 2030

- **Electrification**
- **Research for Fuel Cell**
- **Hull & propulsion**
- **Digitalization**

NYK Maritime Museum & Hikawamaru (Sightseeing)

●The NYK Maritime Museum

1993 The NYK Maritime Museum was founded in Yokohama.

2003 The Museum removed to the location of NYK Yokohama building.

●NYK Hikawa Maru

1930 Hikawa Maru was put into service on the Japan-Seattle Line.

1960 She retired from services, and was moored at Yamashita park in YOKOHAMA.

2008 She was reopened to the public after renovating and redecorating.

Thank you very much for your attention