Development of Supporting Technology for LNG Carriers

19th September 2019

Gastech

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MTI, NYK Group

Outline

1. Introduction of NYK/MTI
2. BOG (Boil Off Gas) simulation for LNGC
3. Total voyage support system for LNGC
4. Other works
   - ✓IoT Platform
   - ✓Cyber Security
   - ✓Autonomous Ship
5. Summary

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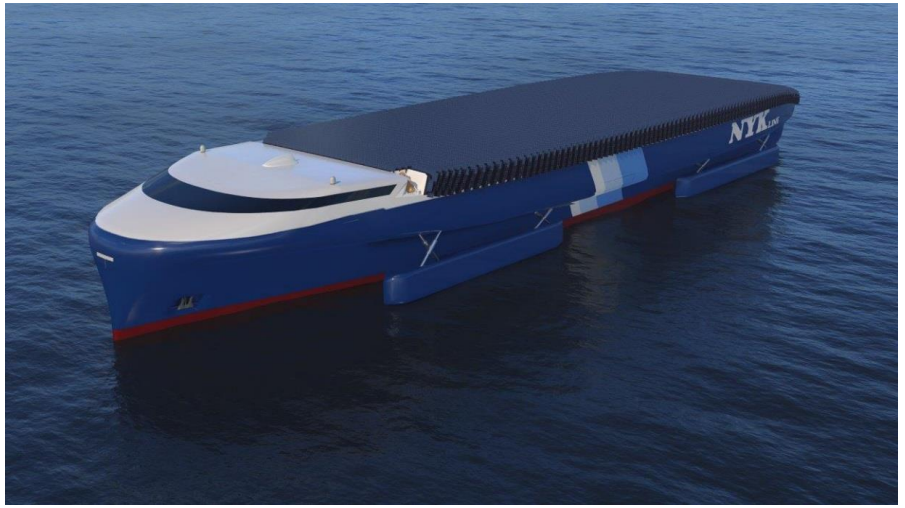
Corporate Profile

- 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
- 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

"Monohakobi (= quality transport) Technology Institute"

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



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Difficulty in LNGC operation

- ✓ BOG generation
- ✓ BOG used as fuel for propulsion
- ✓ “Cool Down Operation” before entering port
- ✓ Difference between loading amount and unloading amount

BOG simulation – cool down operation

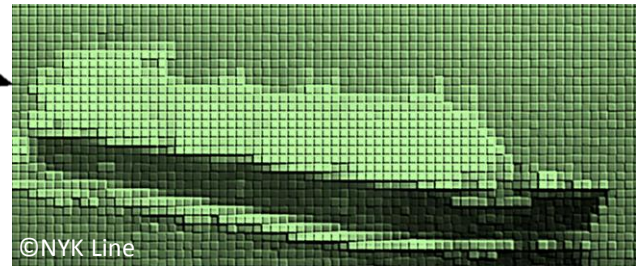
NYK Line

- MOSS type LNG Tank need to be cool downed around -110℃ at the equator of tanks, because of structural strength of the tanks.
- By pumping up heel LNG from the tank and spraying back into the tank, tank temperature goes down due to heat of vaporization.
- Large amount of BOG is generated by cool down operation

Development of BOG simulator

Actual Operation Data by IoT

Improve ac curacy



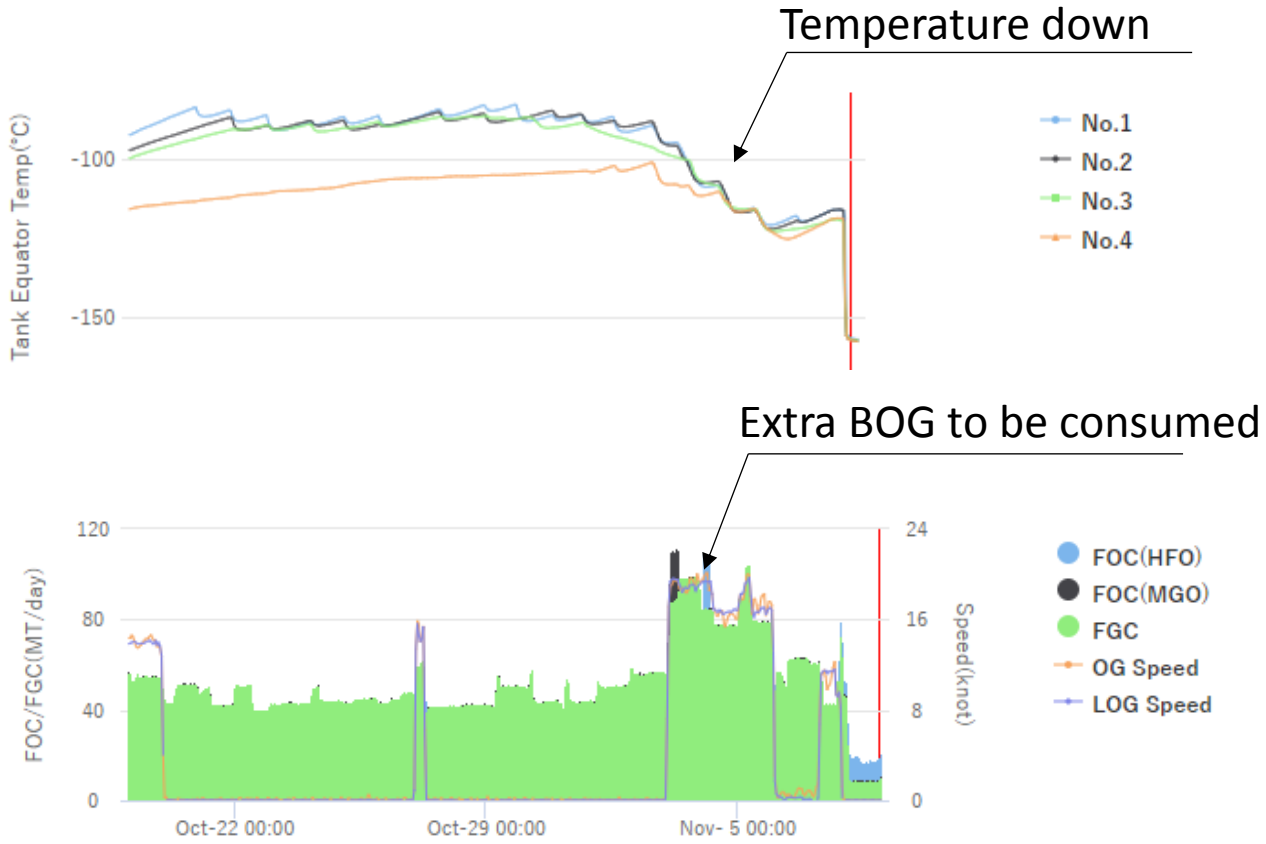
Data to input

- Tank Particular
- Initial Condition
- Environmental Data
- Vessel Motion
- Demand for Propulsion
- Cool Down Operation Plan

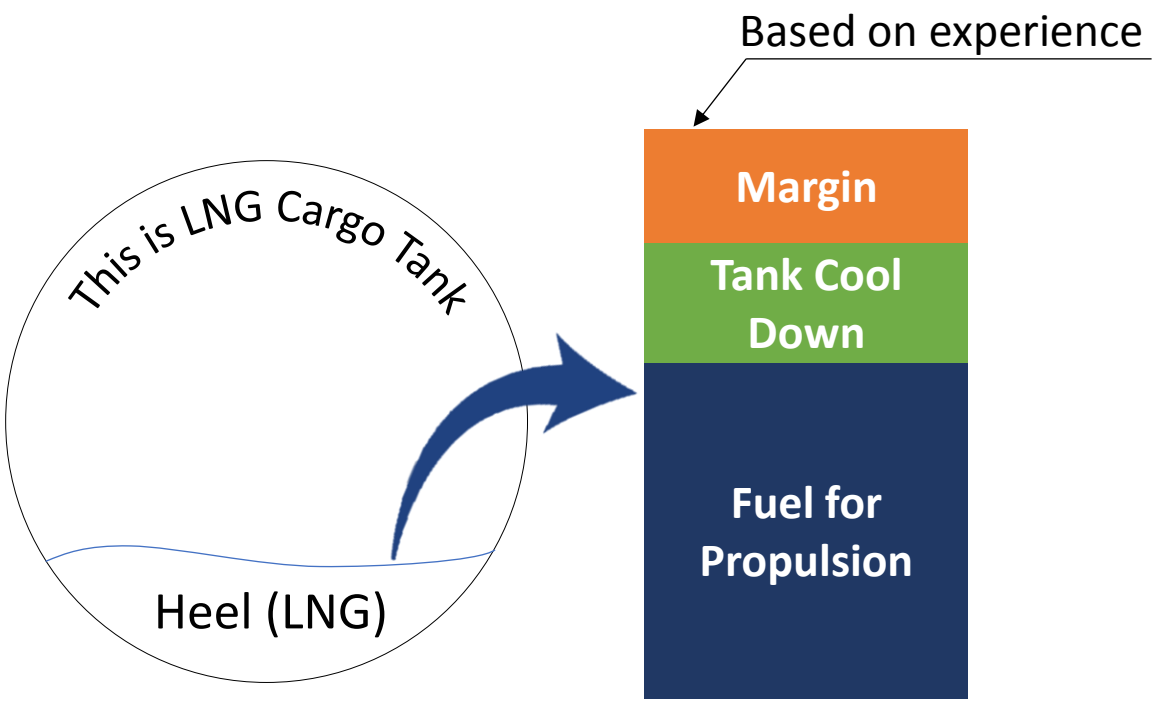
Chemical Process Simulation

CHEMCAD by Chemstations

BOG simulator – example of cool down operation

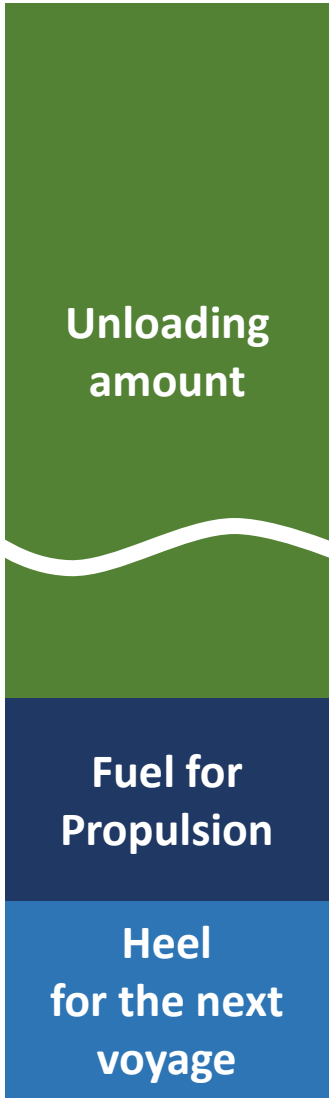


BOG simulator – for optimizing heel amount



- Heel is necessary for propulsion and tank cool down operation
- LNG for Tank Cool Down can be simulated by using BOG simulator
- Fuel for Propulsion can be simulated by using voyage simulator
- Heel amount can be properly estimated by using the simulators

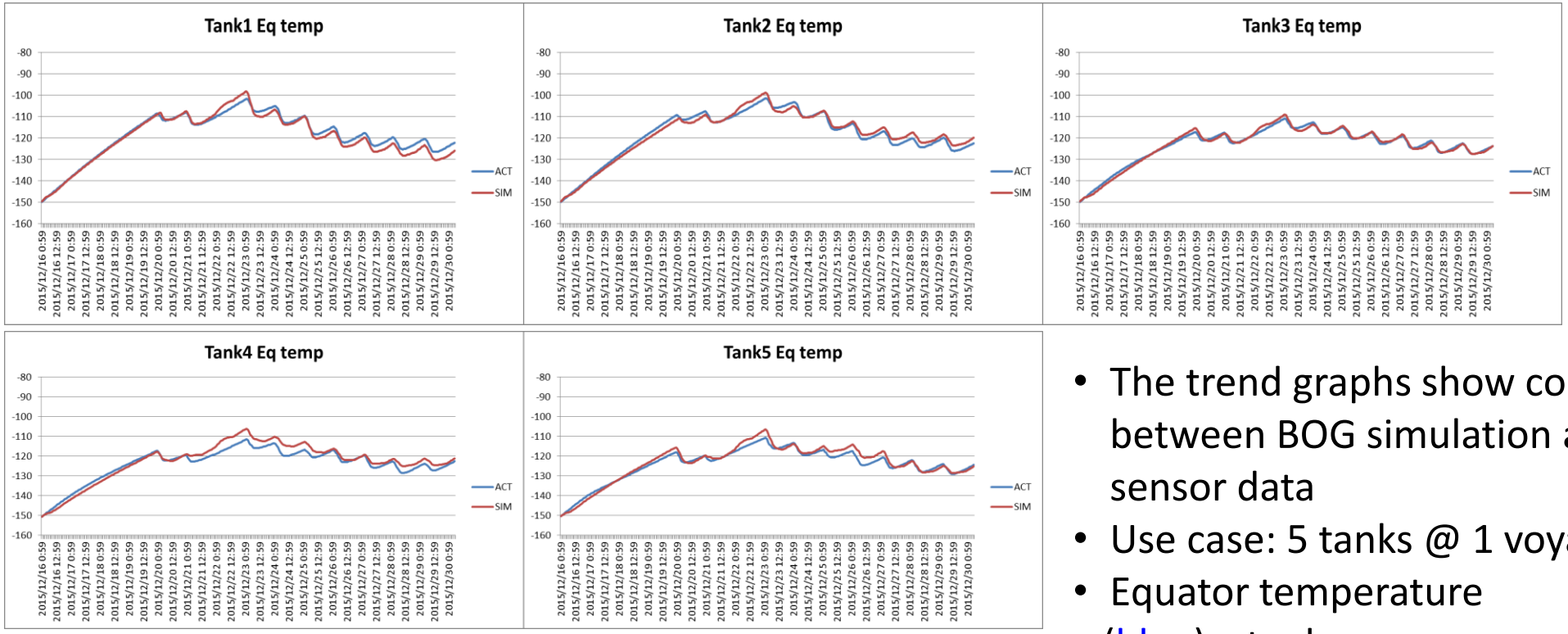
BOG simulator – for estimation of unloading amount



- To predict unloading amount needs proper estimation of Fuel for Propulsion and estimation of Heel amount for the next voyage
- Fuel for Propulsion can be simulated by using voyage simulator
- Heel for the next voyage can be also simulated (as described in the previous slide)

BOG simulator – simulation example 1

Tank condition (Equator temperature)

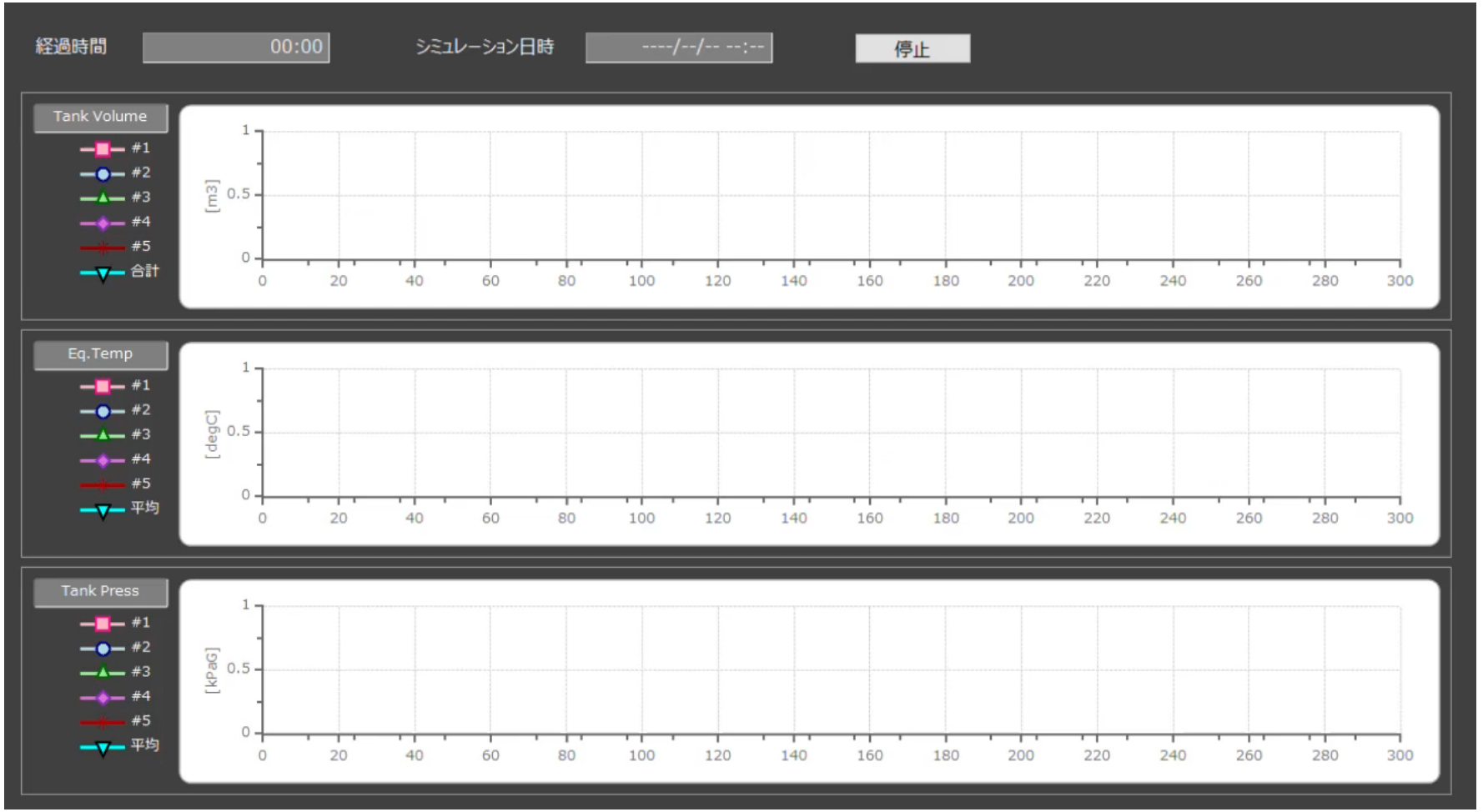


- The trend graphs show comparison between BOG simulation and actual sensor data
- Use case: 5 tanks @ 1 voyage
- Equator temperature
  (blue)actual
  (red)simulation

azbil

BOG simulator – simulation example 2

e.g. Equator temperature, volume and pressure



azbil

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Total LNGC voyage support system

Contribution to Safety & Efficiency

Fleet Operation

LNG Trading

Ship Management

Smart Navigation

R&D

- Voyage Simulator
- BOG Simulator
- Sloshing Risk

Chart

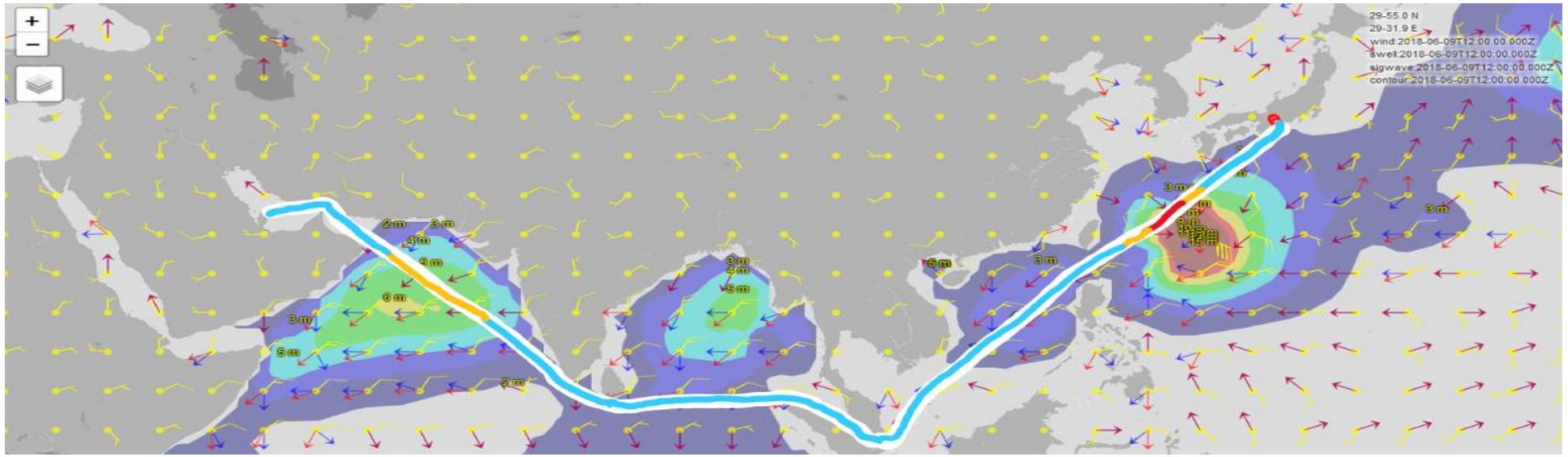
etc.

Operation

Data Analytics

Based on automatically collected data

Concept of voyage simulator



Vessel performance model

Marine weather

Voyage schedule and route

…

INPUT

voyage simulator

as calculator

Speed

Fuel consumption

Vessel motion and sloshing risk

…

OUTPUT

Vessel performance in rough sea

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

Vessel performance in different weather condition

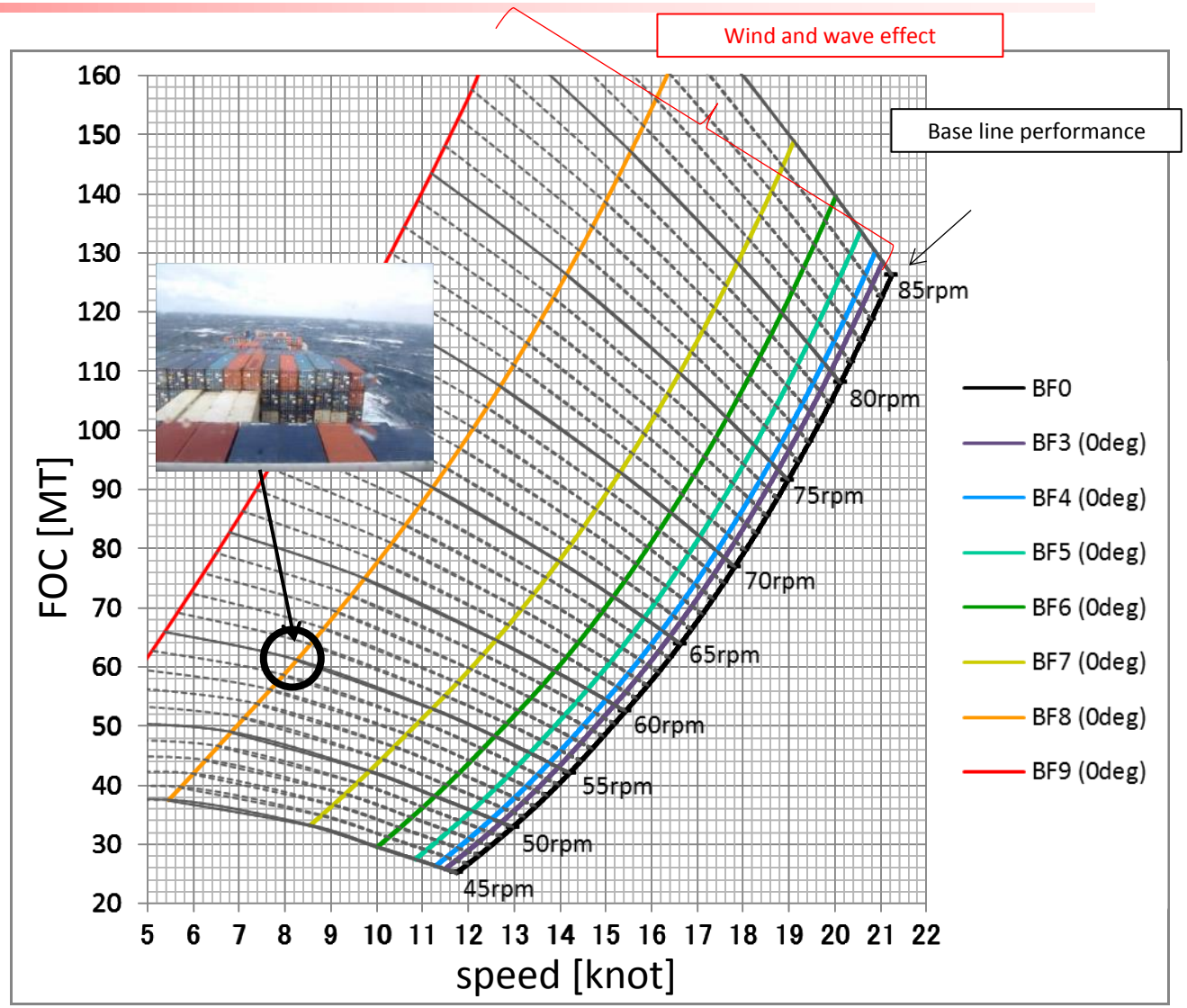
Ship performance in service

<Target vessel>
6000TEU Container
Draft 12m even

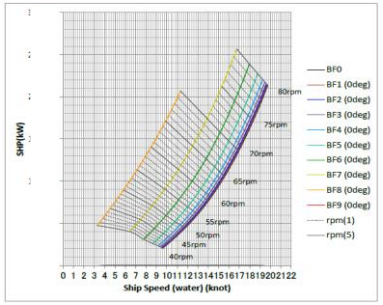
Sea condition

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

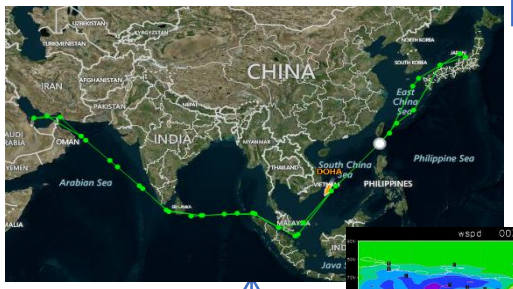


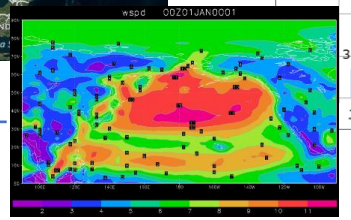
Voyage simulator – weather effects in fuel consumption



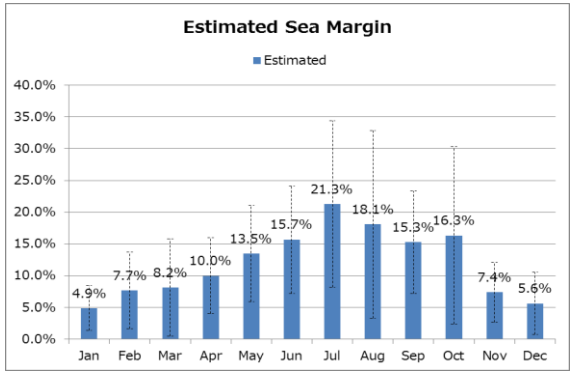
Ship performance model

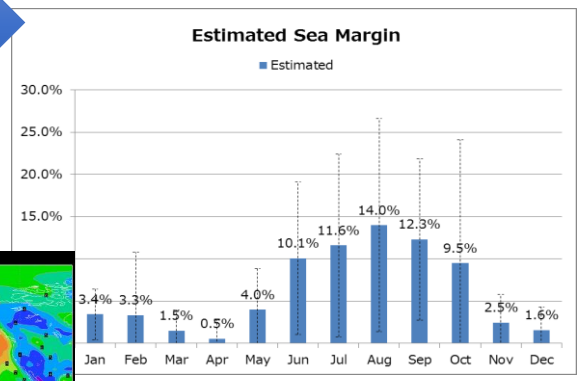
Service route





Voyage simulation with past weather data





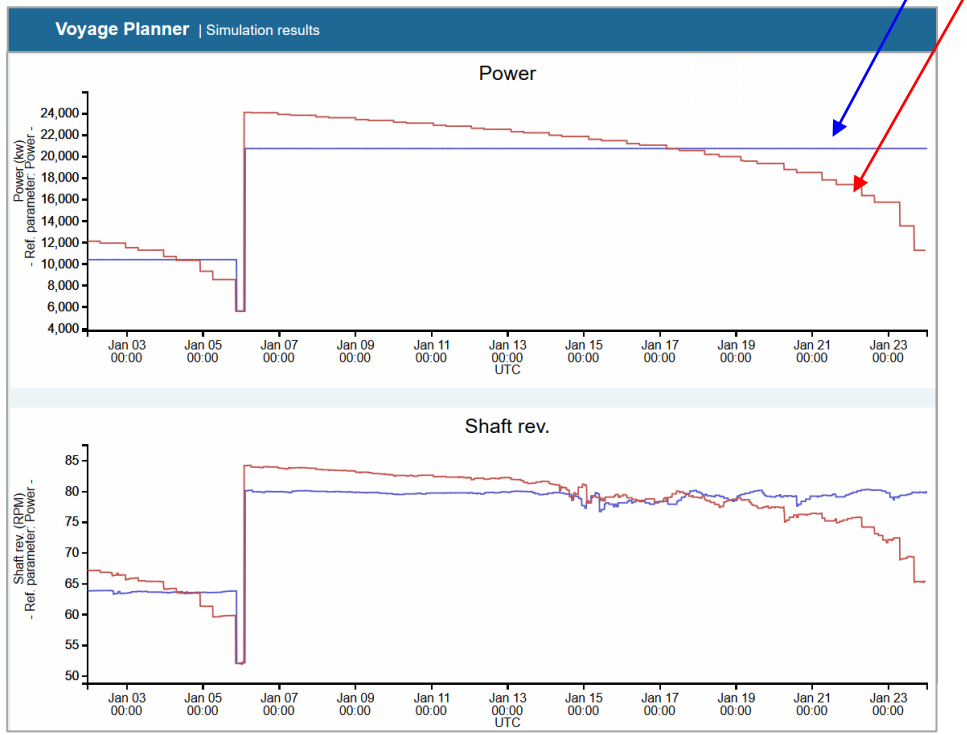
Estimation of
- Sea margin
- FOC and etc.

Combine ship performance model with weather data to optimize ship services

Voyage simulator – practical optimization of voyage

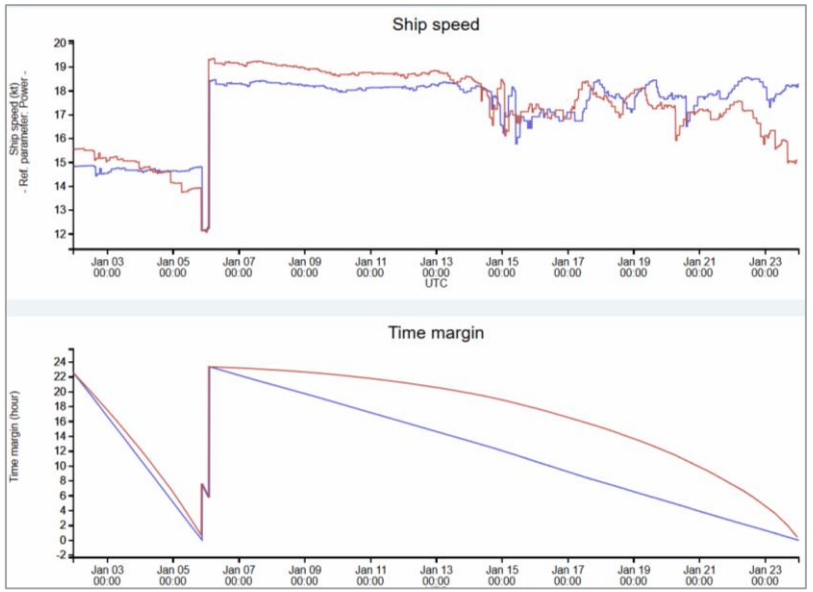
- **Constant power**
- **Speed plan considering risks, such as uncertainty of weather forecast and schedule changes**

Power



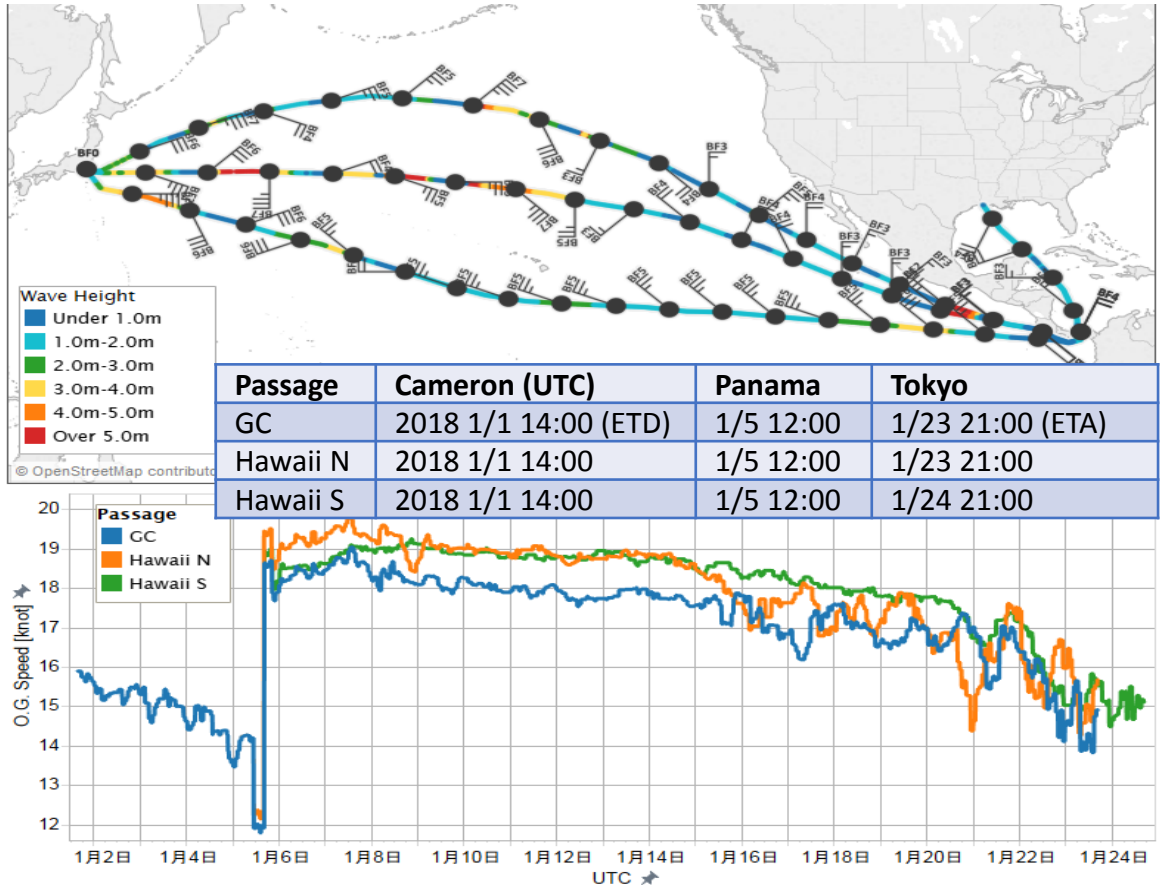
RPM

Ship speed



time margin

Voyage simulator – example of route comparison



Passage	Cameron (UTC)	Panama	Tokyo
GC	2018 1/1 14:00 (ETD)	1/5 12:00	1/23 21:00 (ETA)
Hawaii N	2018 1/1 14:00	1/5 12:00	1/23 21:00
Hawaii S	2018 1/1 14:00	1/5 12:00	1/24 21:00

Great Circle (GC) is the most efficient route but the rough sea condition is expected. Hawaii S. route is one day longer but calm condition and FOC is smaller than Hawaii N.

GC	Atlantic	Pacific	Total
Hours (h)	92	433	525
Distance (mile)	1,365	7,521	8,886
FOC (MT)	326	2,430	**2,756**

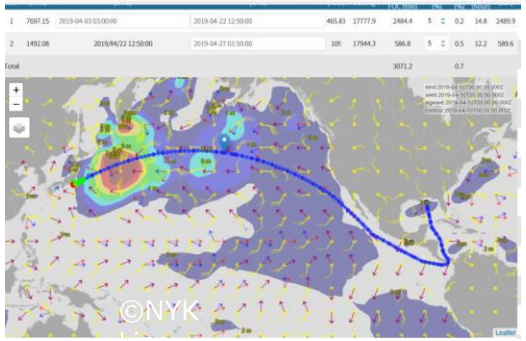
Hawaii N	Atlantic	Pacific	Total
Hours (h)	92	433	525
Distance (mile)	1,365	7,787	9,152
FOC (MT)	326	2,794	**3,120**

Hawaii S	Atlantic	Pacific	Total
Hours (h)	92	457	549
Distance (mile)	1,365	8,220	9,585
FOC (MT)	326	2,694	**3,020**

Combination of voyage simulator & BOG simulator

- Fuel consumption
- Vessel motion

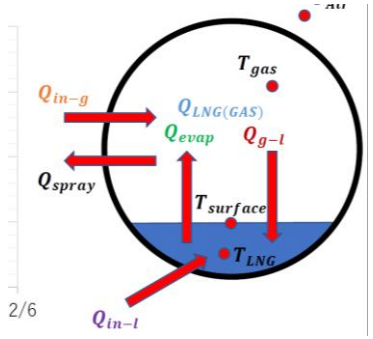
Voyage simulator

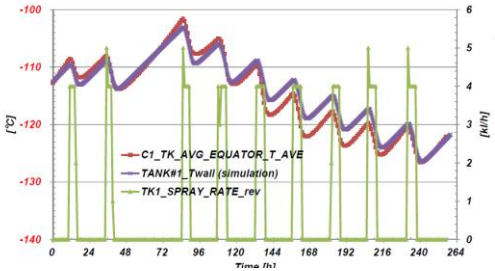


Combination

- BOG generation
- Cool Down operation

BOG simulator

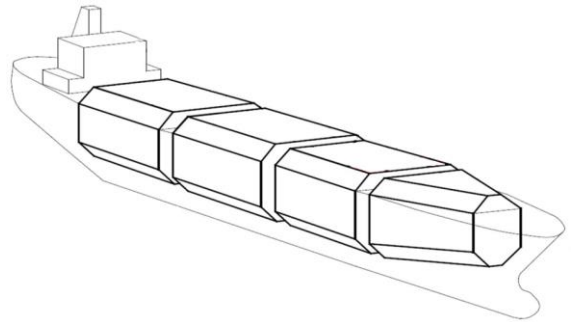




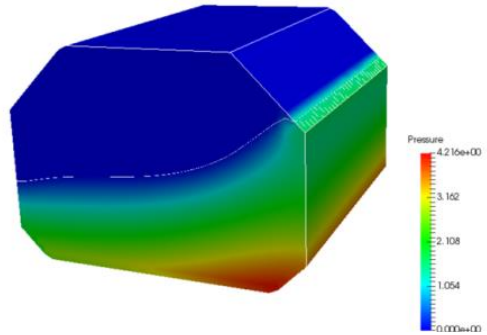
Voyage planning considering with Cool Down operation

Evaluation of tank damage risk by sloshing

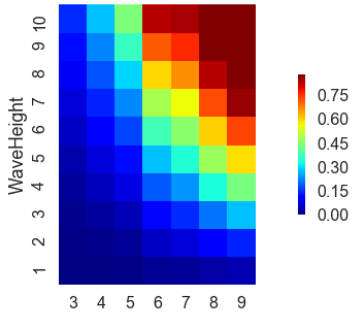
1. Vessel motion (response) analysis
   - Method: Strip theory
   - Calculation cases : All loading conditions
   - Result: Vessel motion response in 6DOF



2. Impact pressure analysis
   - Method: Finite Difference Method (FDM)
   - Calculation cases : All filling levels and ship motions
   - Result: Vessel motion response in 6DOF



3. Sloshing risk evaluation
   - Method: Comparing structural deformation with thresholds
   - Calculation cases : Coupling cases of the above 2 steps
   - Result: Sloshing risk chart Tp (wave period) – Hs (wave height)



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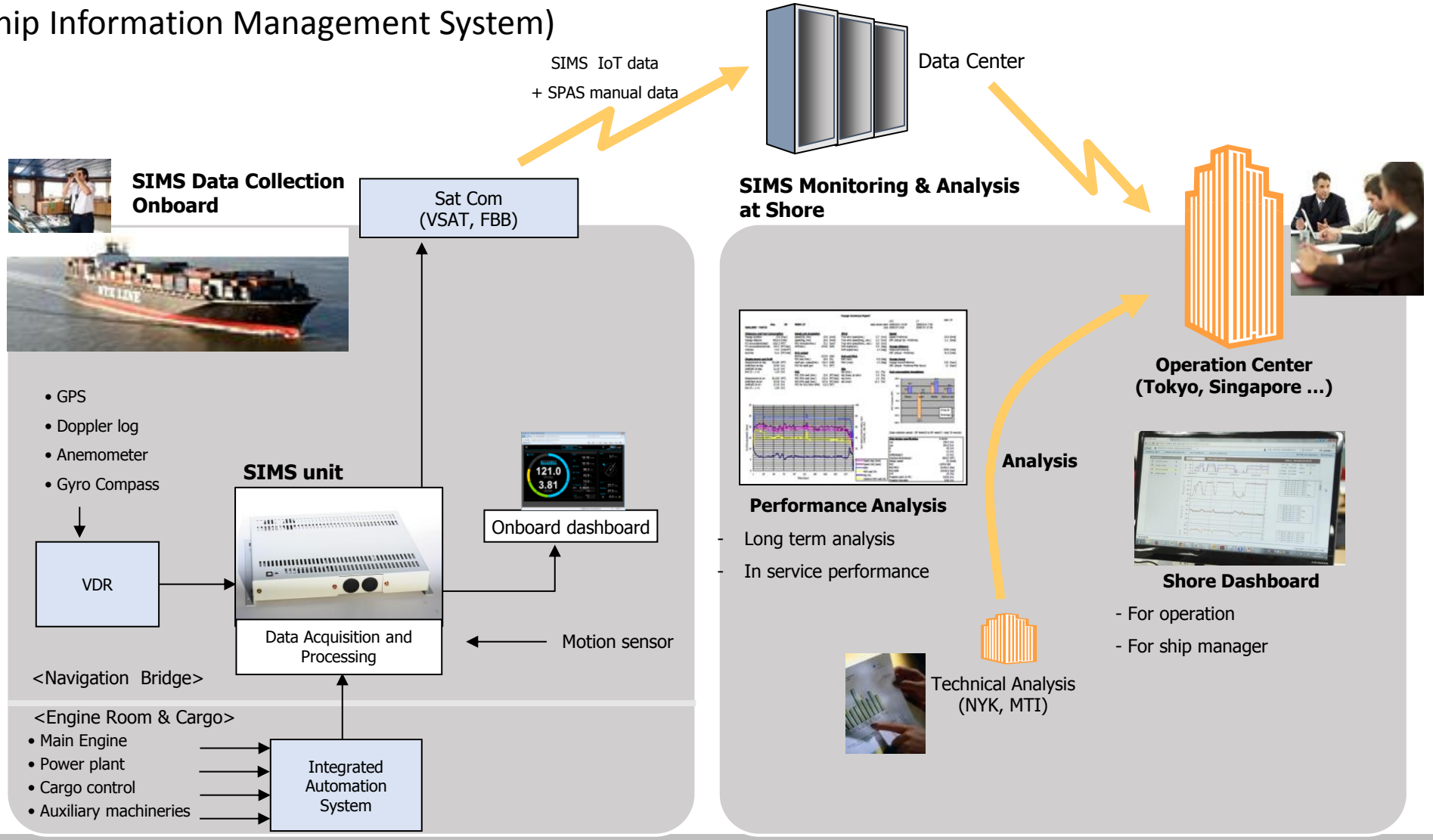
IoT platform of NYK

SIMS (Ship Information Management System)



Cyber Security and Cyber Resilient Ship

Both of security by design and security management in operation are important

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

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

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

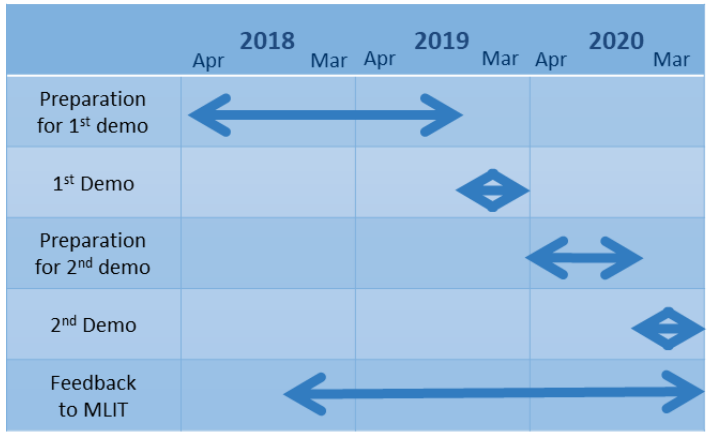
- **NIST Framework and 800-53** – computer security policies, procedures and guidelines
- **ISO 27001/2** – ISMS: Information Security Management System

Collaboration with industry partners

- Objective: Demonstrate APS concept
- Target ship: Tug boat (Wing Maritime Service Corp.)
- 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)

Autonomous Ship Demonstration Project in Japan

Demonstrations in 2019 Winter (the 1st demo) and 2020 Winter (the 2nd demo) are the targets.



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Summary

- Development of operation simulators for LNG Carrier such as BOG simulator and voyage simulator undergo.

- By integrating these simulators as a total voyage simulator, safe and economical LNGC operations will be supported. At the same time, it may provide benefits to LNG trading businesses.

- At the same time, R&D for IoT platform, cyber security and autonomous ship technologies are ongoing to enhance further safety and efficiency together with global industry partners.

Thank you very much for your kind attention