Green Ship Technology 2017
Copenhagen, Denmark

# Alternative approaches to monitoring - 'Digital Twin' of vessel performance -

24th March 2017


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MTI, NYK Group

# Outline

1. Introduction of NYK/MTI
2. IoT and Big data in NYK
3. Digital Twin
4. Digital Twin of vessel performance
5. Summary

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# NYK 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: 34,270 (as of the end of March 2016)
- Revenues: $ 22.7 billion (Fiscal 2015)

NYK Head Office in Tokyo

# NYK Fleet (as of the end of March 2016)

Containerships (including semi-containerships and others)
99 vessels / 5,820,781 DWT

Bulk Carriers (Capesize)
108 vessels / 21,248,606 DWT

Bulk Carriers (Panamax & Handysize)
269 vessels / 16,411,393 DWT

Wood-chip Carriers
47 vessels / 2,509,047 DWT

Cruise Ships
1 Vessel / 7,548 DWT

Car Carriers
119 vessels / 2,165,138 DWT

Tankers
68 vessels / 11,030,601 DWT

LNG Carriers
29 vessels / 2,176,681 DWT

Others
42 vessels / 695,974 DWT

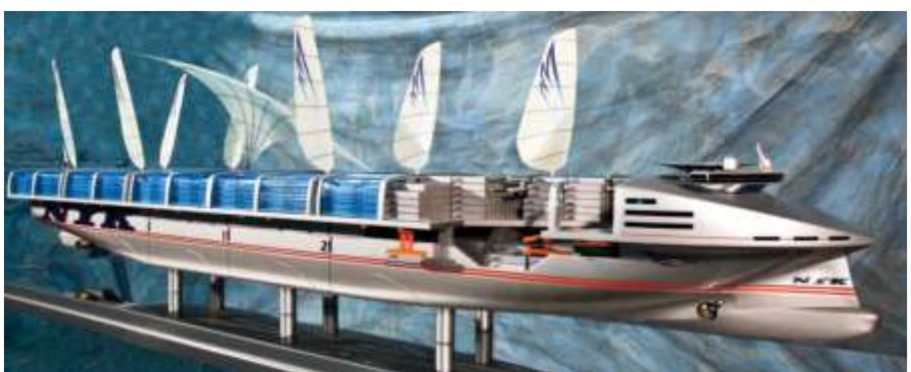
**782 vessels**
**62,065,769Kt (DWT)**

# MTI (*Monohakobi* Technology Institute)

- strategic R&D arm of NYK Line -

http://www.monohakobi.com/en/

- Established : April 1, 2004
- Stockholder : NYK Line (100%)
- Number of employees : 62 (as of 1st April, 2016)
- Location
  - Head Office : 7th Fl., Yusen Building, Tokyo, Japan
  - MTI CO.,LTD. SINGAPORE BRANCH, Singapore
  - MTI YOKOHAMA LAB (Transportation Environment Lab), Yokohama, Japan



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

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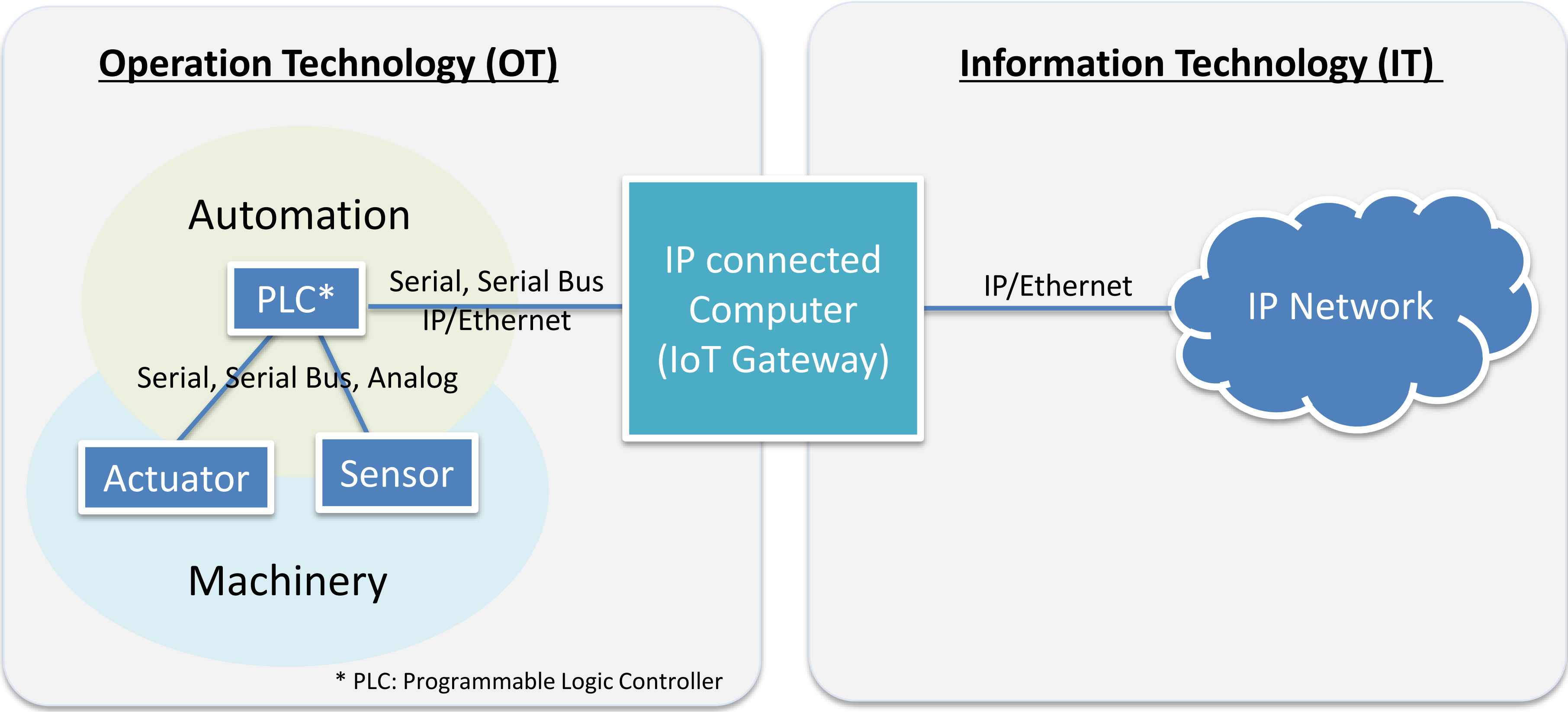
# IoT (Internet of Things)

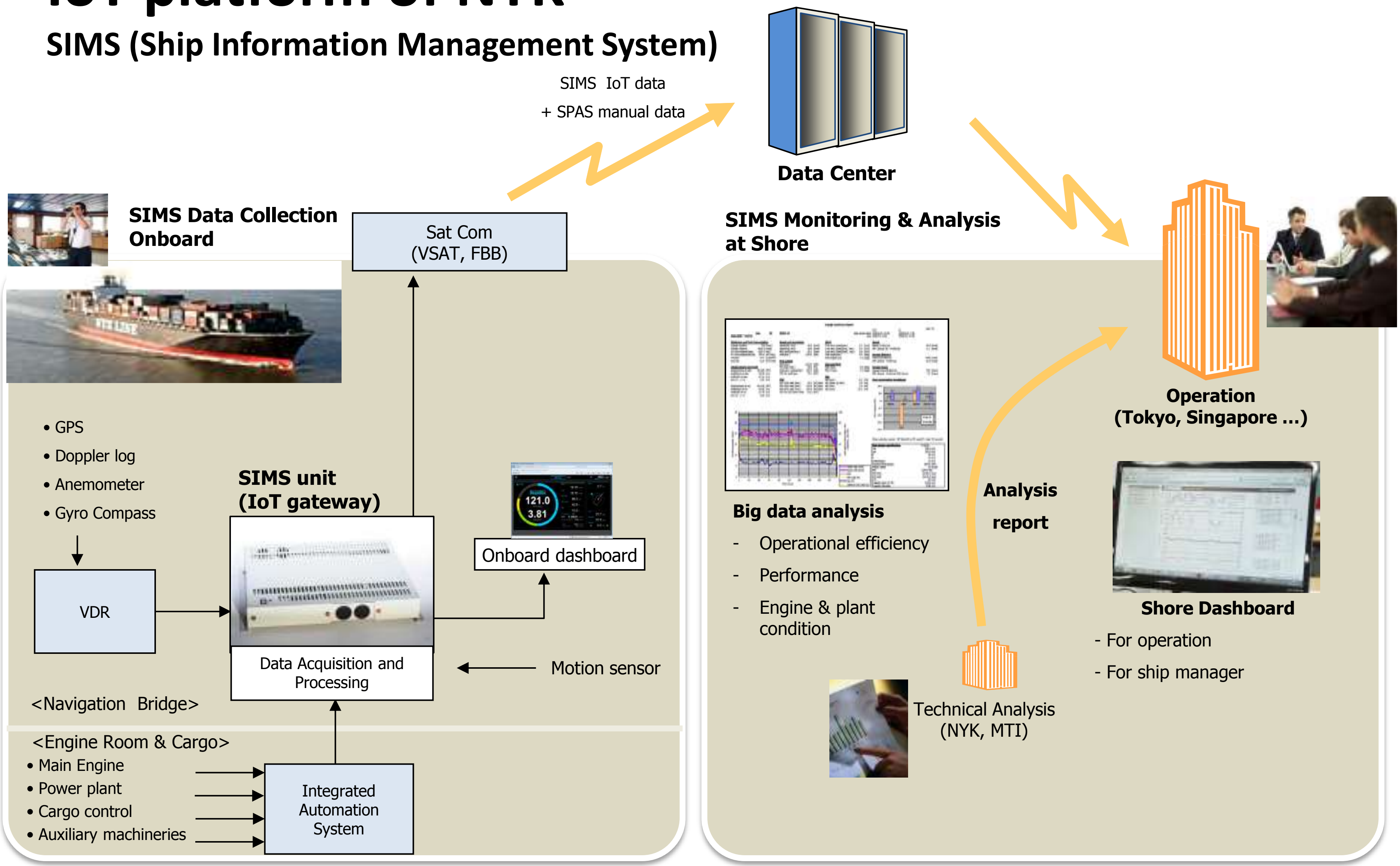



* PLC: Programmable Logic Controller

"Operation Technology (OT)" and "Information Technology (IT)" are to be bridged.
The era of "transparency" where user can access the field data.

# IoT platform of NYK

## SIMS (Ship Information Management System)

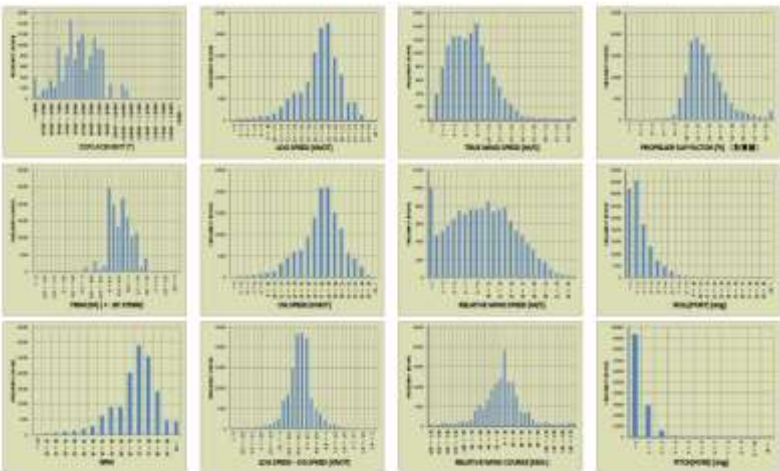


# Potentials of utilizing IoT and Big data in shipping

| Role | Function | Example applications |
|---|---|---|
| **Ship owner** | Technical management | • Safety operation<br>• Condition monitoring & maintenance<br>• Environmental regulation compliance<br>• Hull & propeller cleaning<br>• Retrofit & modification |
| | New building | • Design optimization |
| **Ship operator** | Operation | • Energy saving operation<br>• Safe operation<br>• Schedule management |
| | Fleet planning | • Fleet planning<br>• Service planning<br>• Chartering |

Other partners in value chains, such as cargo owners, shipyards, equipment manufacturers, and class societies, have also interests in ship IoT data to improve their operational efficiency.

# Energy saving hull modification



**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.

# Utilize IoT in shipping

**Target**

- Prevent unpredicted downtime (**owner**)
- Reduce maintenance cost (**owner**)
- Energy efficiency in operation (**operator**)

**Measure**

- Condition monitoring
- Big data analysis
- Support service engineer
- Intelligent machinery
  - Self diagnostics

**Change way of working !**

# NYK/MTI's R&D activities for digitalization

- Open collaboration with industry partners -

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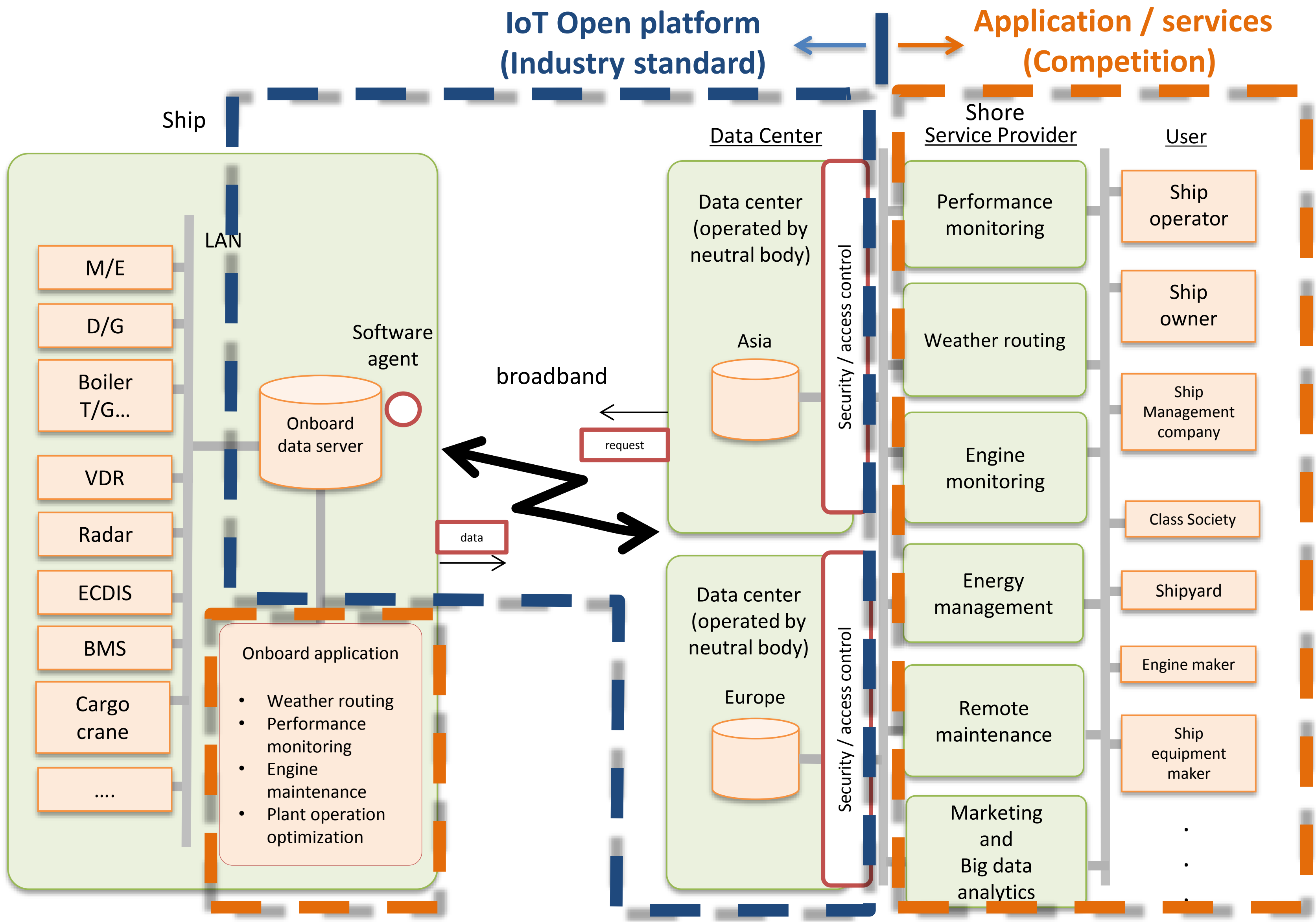
i-Shipping: Japanese government funding projects Ship IoT for safety (2016-2020)

Monohakobi Technology Institute

NYK GROUP

# Open platform for maritime industry



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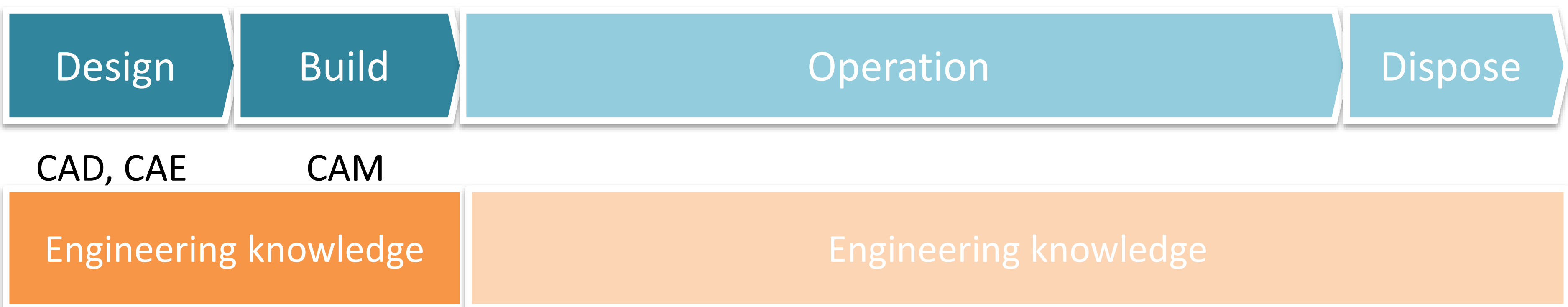
# Engineering knowledge, simulations and tools have been used for design and production




- Designers and engineers consider life cycle value of products
  - Manufacturability, usability, maintainability, disposability …

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

Design → Build → Operation → Dispose

CAD, CAE — CAM

Engineering knowledge

- Designers and engineers may provide engineering services to support operations
- IoT allow designers and engineers to access field data
- Operational efficiency will be improved by integrating existing good culture and engineering knowledge.

# Digital Twin

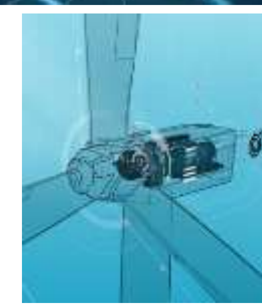
**An approach of Product Lifecycle Management(PLM) to extend computer-based engineering capabilities to operations**

**Real**
**(Product, Plant…)**

**IoT data** →

← Operation support services

**Virtual**
**(3D model, engineering simulation)**




Reference)

1. http://www.gereports.com/post/119300678660/wind-in-the-cloud-how-the-digital-wind-farm-will/
2. Michael Grieves, Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management (English Edition), 2012

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# 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**

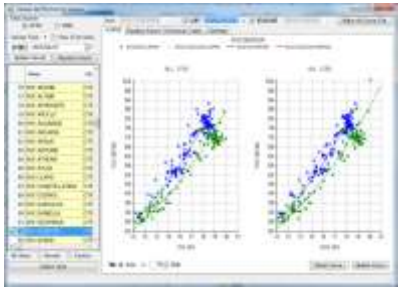
FOC: **60 ton/day**

**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)

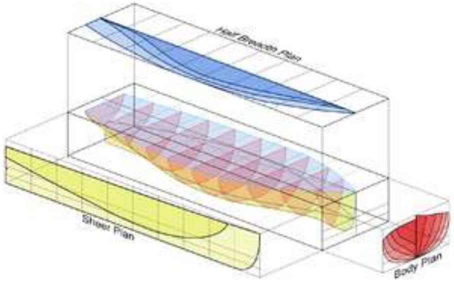
# Model of vessel performance in service

1. **<u>Long term analysis</u>**
   – Degradation of hull and propeller



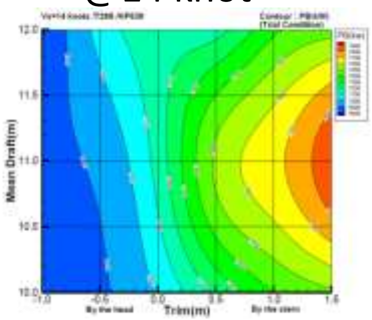
2. **<u>Draft and trim effect</u>**
   – Tank test, CFD or estimation from IoT measurement data

3. **<u>Wind and wave effect</u>**
   – Theoretical calculation

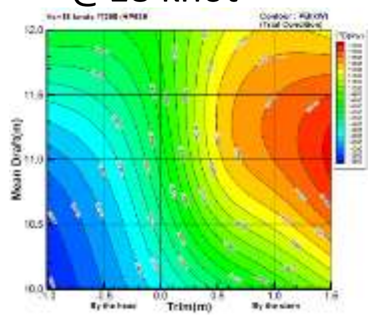


# Continuous model to represent discrete performance data – draft and trim

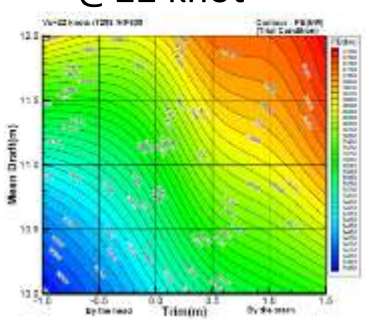
@14 knot

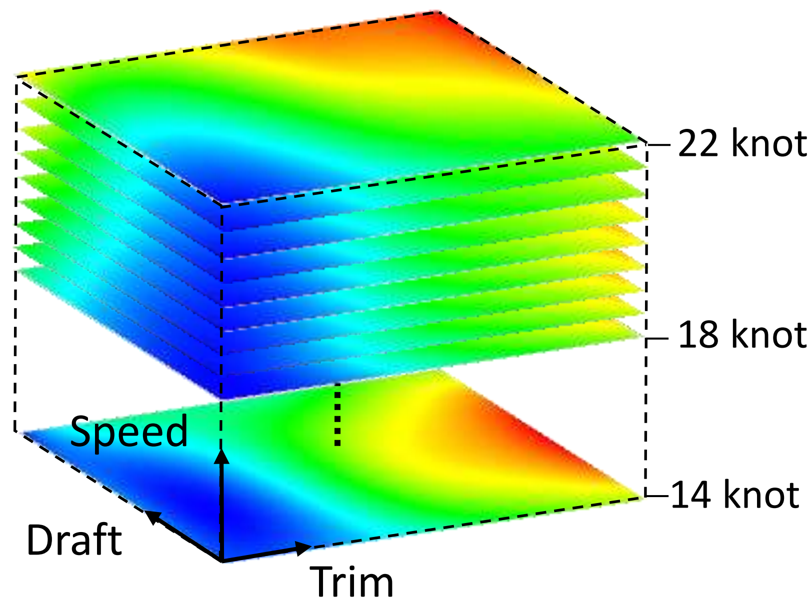


@18 knot



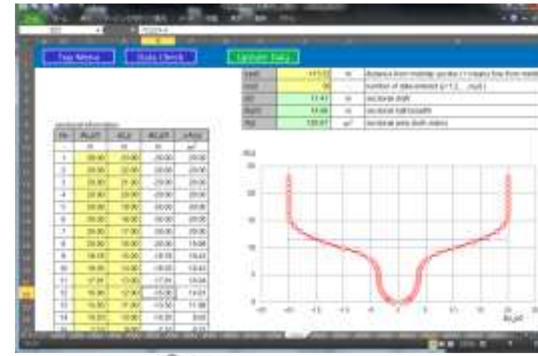
@22 knot

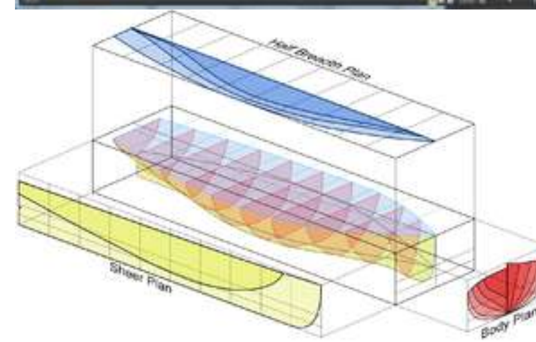





Extend 3-dimensional B-spline volume to multi-dimensional volume to represent continuous data (Joint research with AIST)

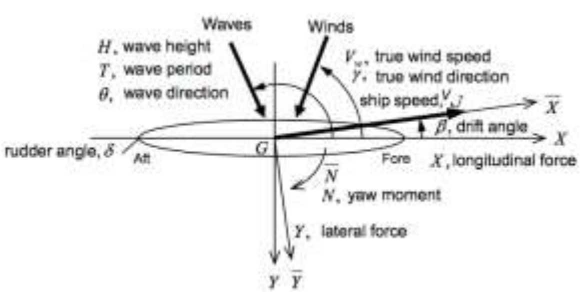
# Theoretical estimation of wind and wave effect (Joint research with NMRI)






**Considered forces and moments**

1. Resistance in still water
2. Hydrodynamic forces and moments
3. Propeller thrust
4. Rudder forces and moment
5. Wind resistance
6. Added resistance in short crested irregular waves




$$X = X_0(V_S) + X_D(\beta) + (1-t)X_P(N_P, V_S) + X_R(\beta, \delta) + X_A(V_r, \gamma_r) - R_{AW}(V_S, \beta; H, T, \theta) \quad (27)$$

$$Y = Y_D(\beta) + Y_R(\beta, \delta) + Y_A(V_r, \gamma_r) \quad (28)$$

$$N = N_D(\beta) + N_R(\beta, \delta) + N_A(V_r, \gamma_r) \quad (29)$$

Reference) M. Tsujimoto, et.al,: Development of a Calculation Method for Fuel Consumption of Ships in Actual Seas With Performance Evaluation, ASME 2013 32nd International Conference on Ocean, Offshore and Arctic Engineering(OMAE),2013

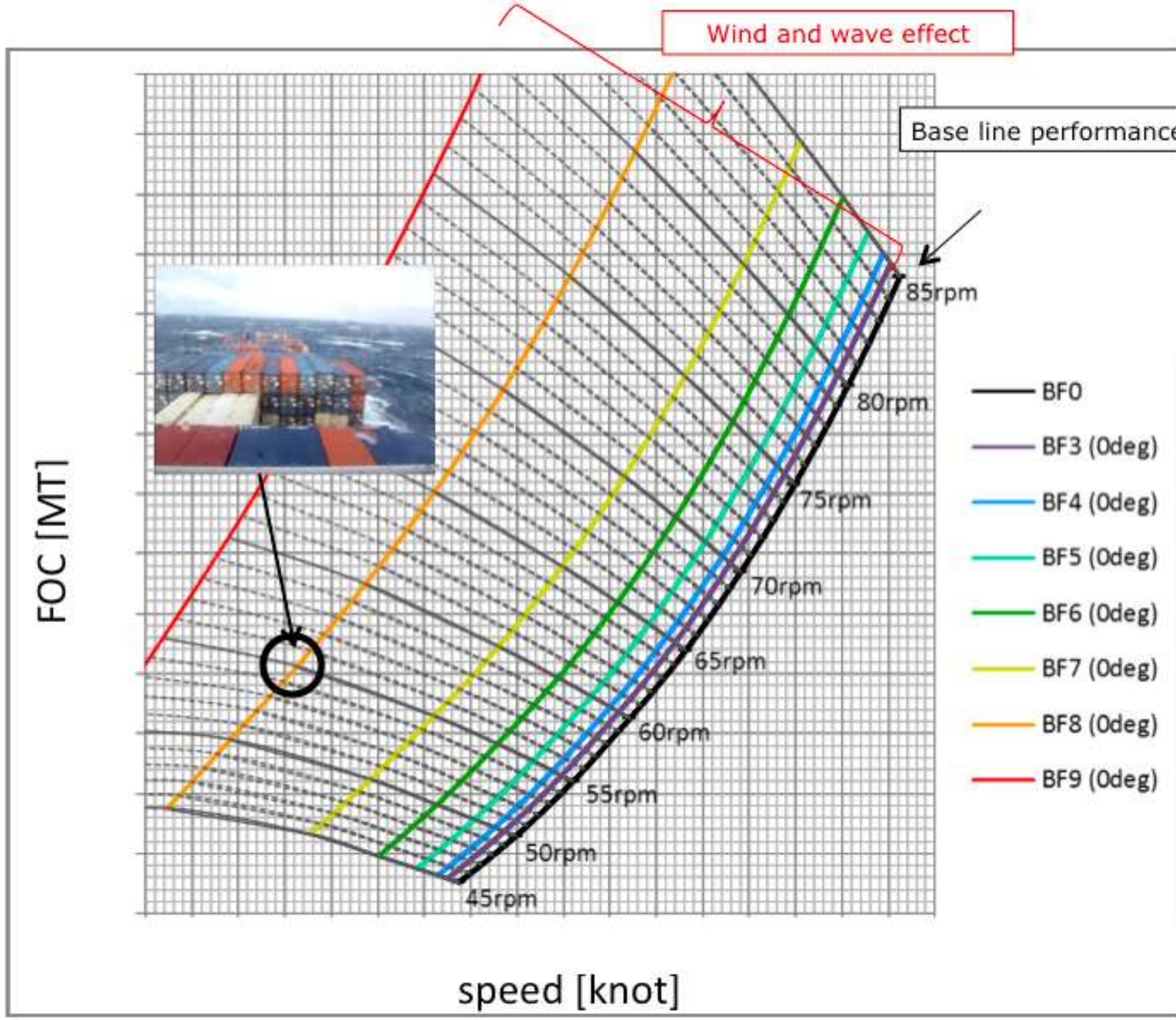
# In-service ship performance model

<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 |

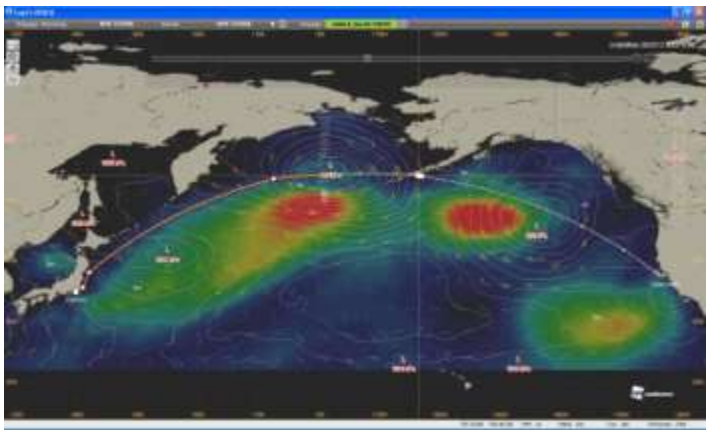
0deg (wind, wave) – head sea

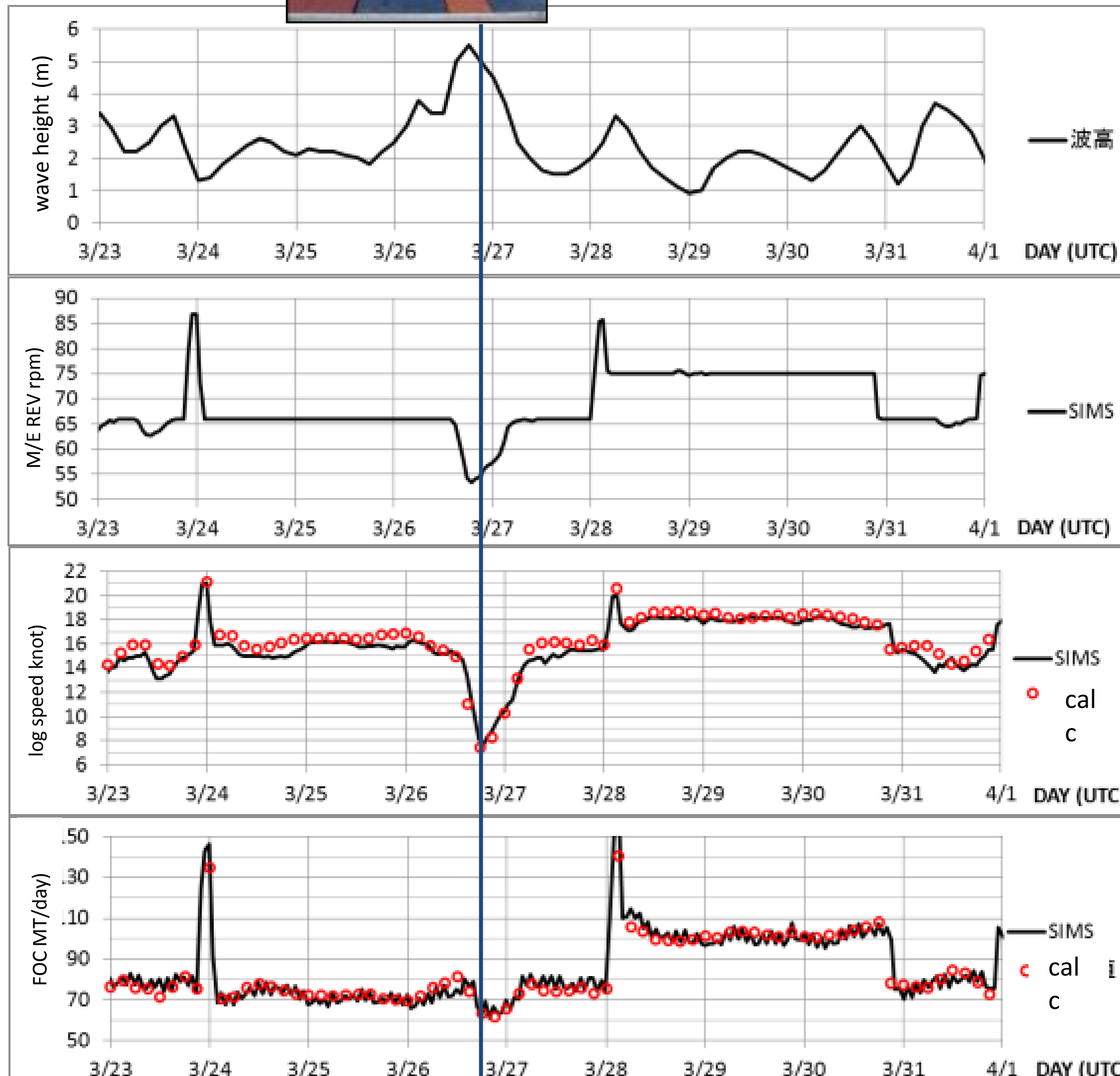


# An example of model valid

6000TEU 2012/3/21 - 4/1

Voyage : OAKLAND-TOKYO



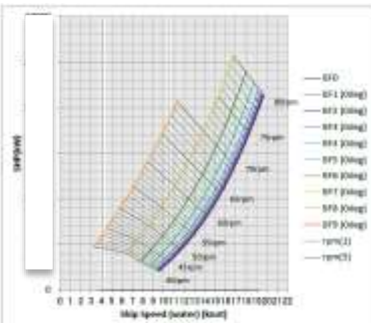



Accuracy of vessel performance model was confirmed.

Total FOC in voyage
Actual: 961 MT
Calculation: 969 MT

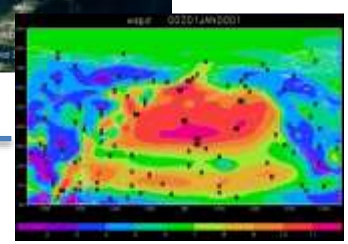
# Sea margin estimation

## - Example of LNG carrier -

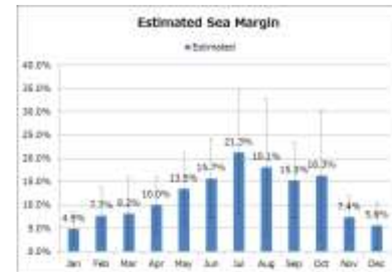


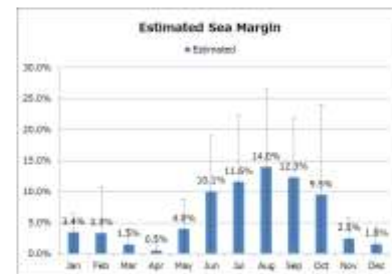
Ship performance model

Service route

Voyage simulation with past weather data



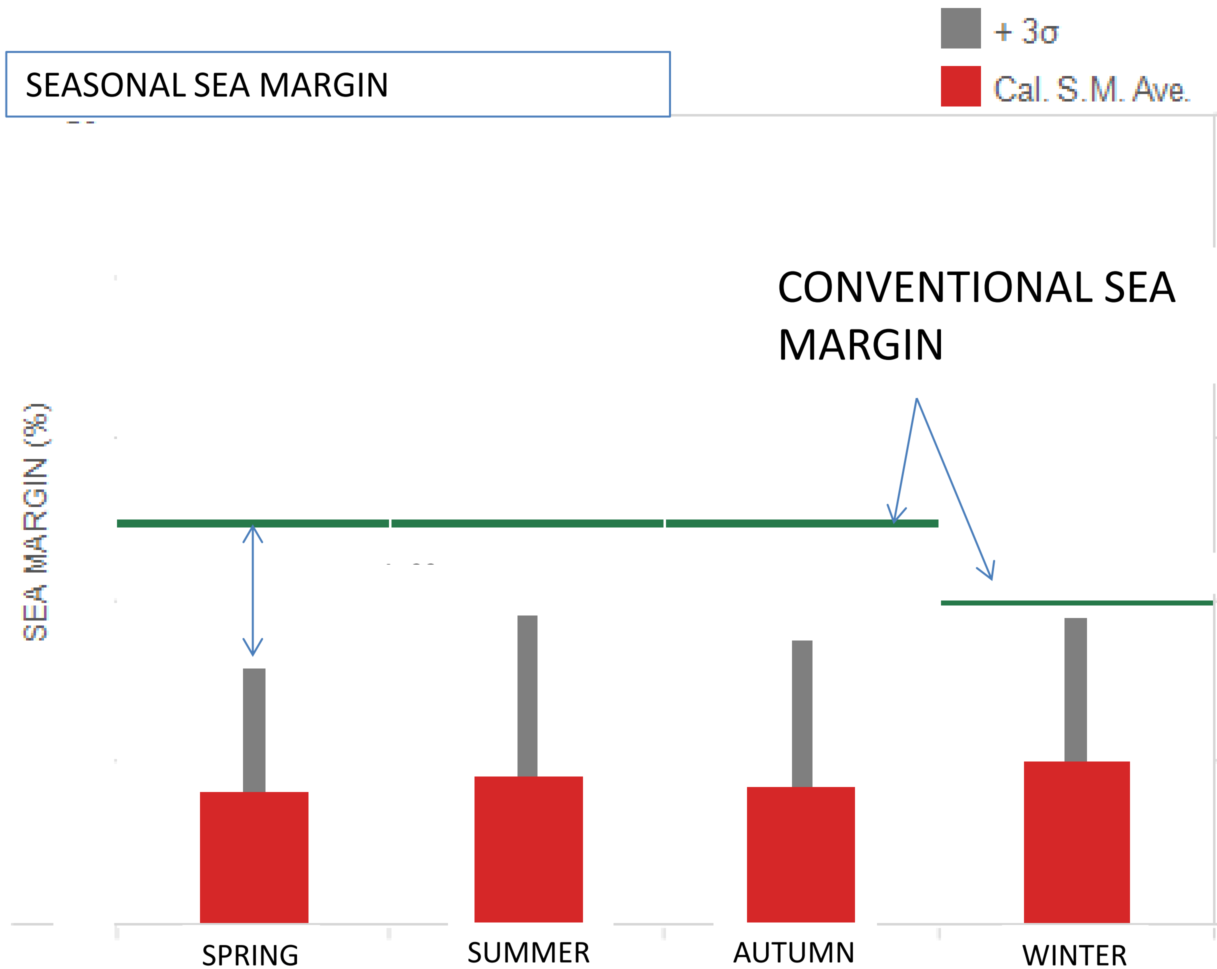




Estimation of

- Sea margin
- FOC and etc.

Combine ship performance model with weather data to optimize ship services

# Sea margin estimation
# - Example of cape size bulk carrier -




Simulation results show conventional sea margins are much larger than required for some routes

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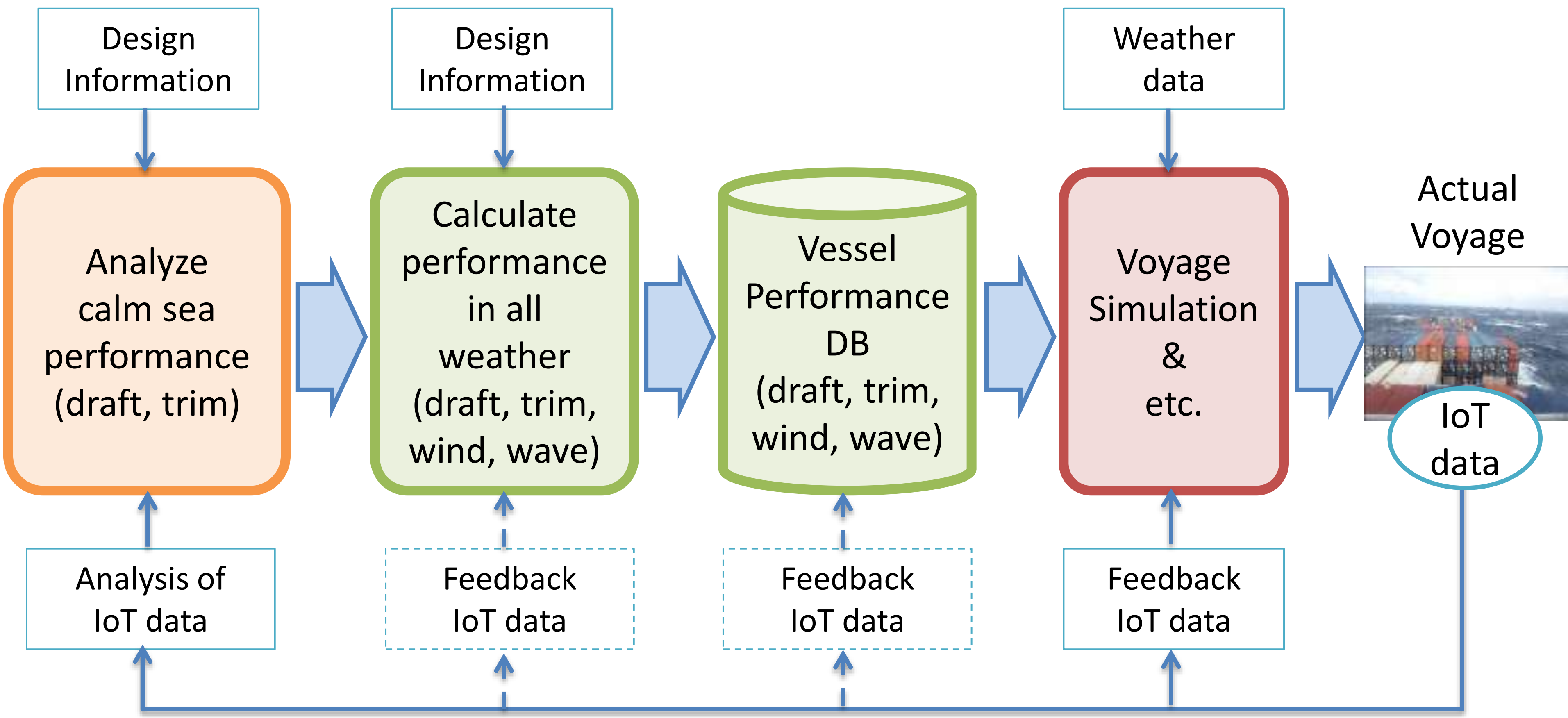
# Flow of vessel performance analysis and usage




The future challenge would be how to feedback these knowledge and experience to ship design

# Thank you very much for your attention