Importance of fleet performance systems in energy efficiency

14/03/2024

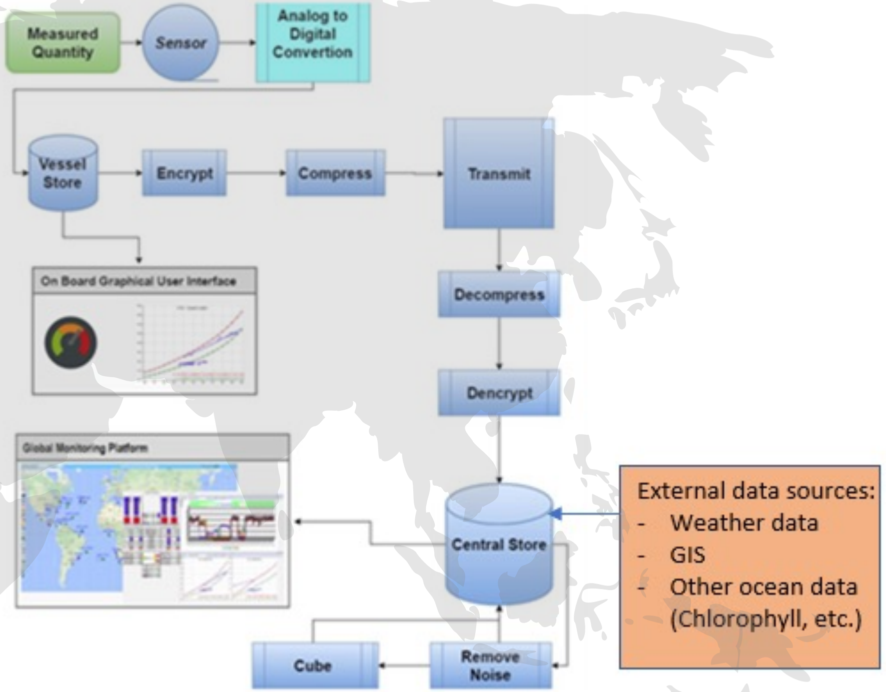
ANGELICOUSSIS GROUP

Fleet Performance Monitoring System

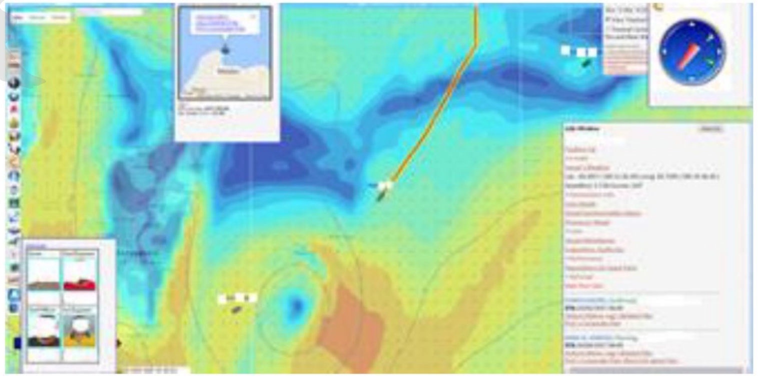
The fleet vessel performance monitoring system has been developed and is maintained by our team and our partner Infralabs Ltd in collaboration with Prof Ioannis Filippopoulos. The Platform fuses data from multiple sources, including onboard sensors, weather and satellite data, to support effective decision-making and trigger maintenance activities that minimize any deterioration in the fleet's energy performance, which includes:

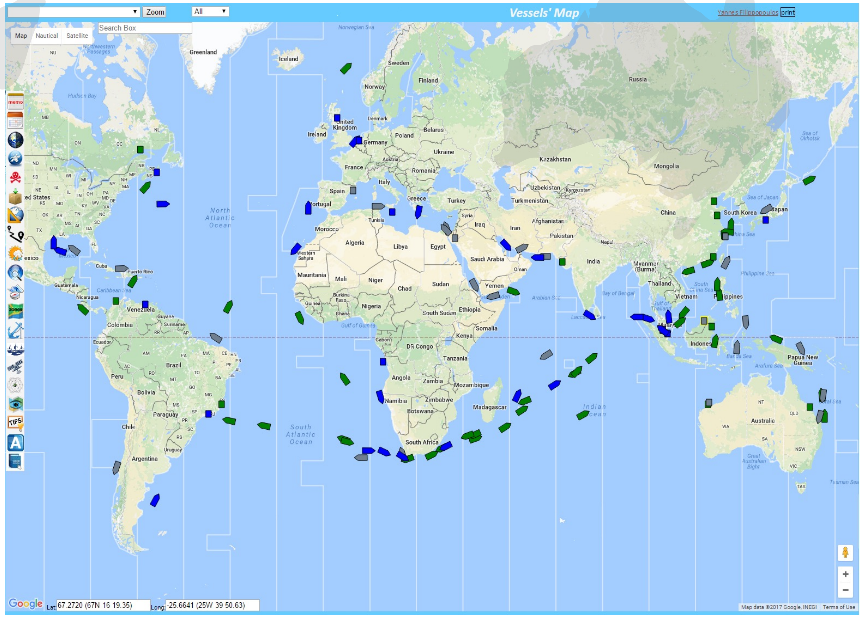
- Quantifying deviations in consumption against a baseline set during sea trials and shop tests for each vessel.
- Using analytics to select the anti-fouling paints that offer the optimal performance over the ships' docking period.
- Analyzing the data to minimize the changes in vessel power/rpm and optimize sailing efficiency.
- Deploying 'machine-learning' algorithms to select the optimum trim.
- Monitoring the electrical load to optimize diesel generator (DG) utilization

The vessel performance monitoring system shares the data and the calculations with several applications, including the Global Monitoring Platform, which shows all the vessels in the "real time".



infralabs
getting you to safe waters





Key vessel performance indices

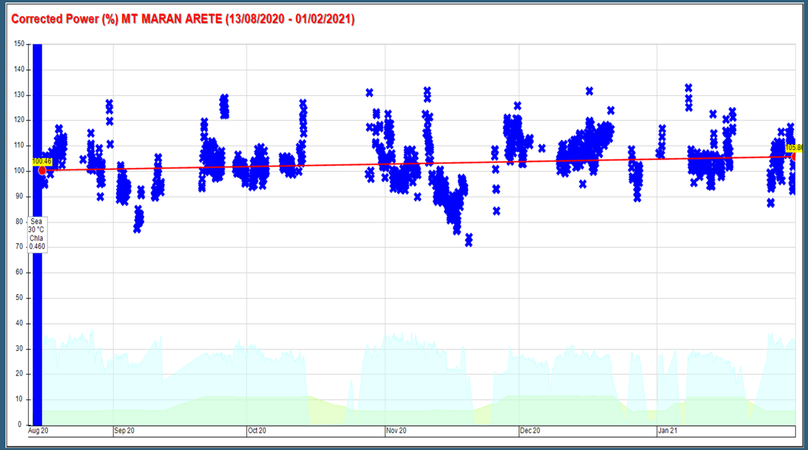
- For assessing the vessel performance, the following indices are used:

  - Power%, (or Resistance%)
  - SFOC%,
  - Excess Consumption.

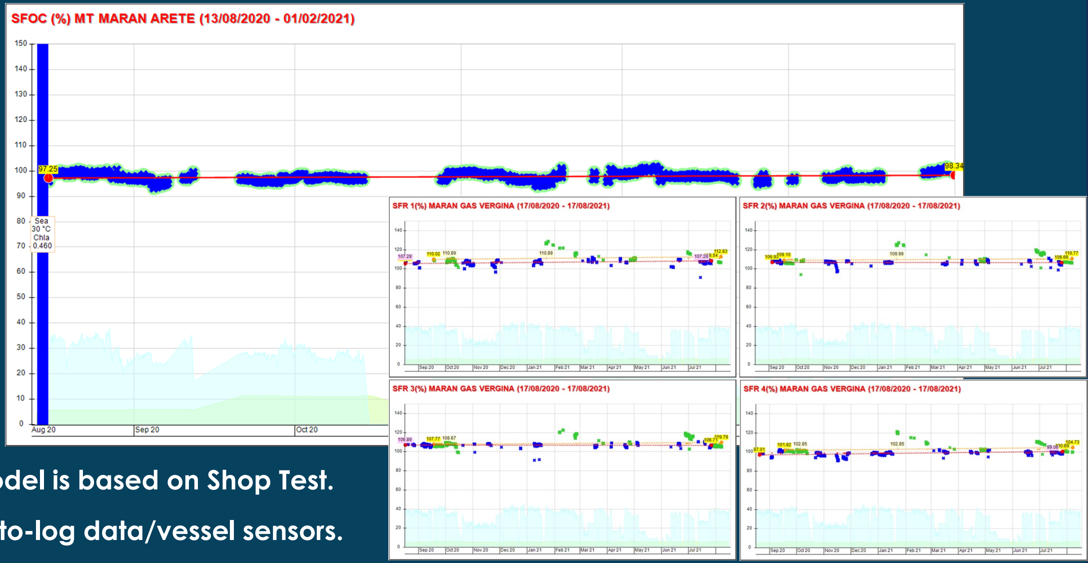
- Using the Excess Consumption, we quantify underperformance in t/day of fuel/gas against corrected sea trials / model tests.
- The source of the problem, i.e. hull & propeller on one side or engine on another could be identified using Power % and SFOC %.
- Any sensor errors could be detected by correlating Power % and SFOC%.

Power%

- Model is based on Sea Trials and Model Tests.
- Auto-log data/vessel sensors.
- Specific draught and speed as specified at any given point in time.
- Weather and currents correction based on satellite data
- Estimation of the clean hull and propeller power demand.
- Comparison of the model's prediction with the real time power measured and evaluate deviation.

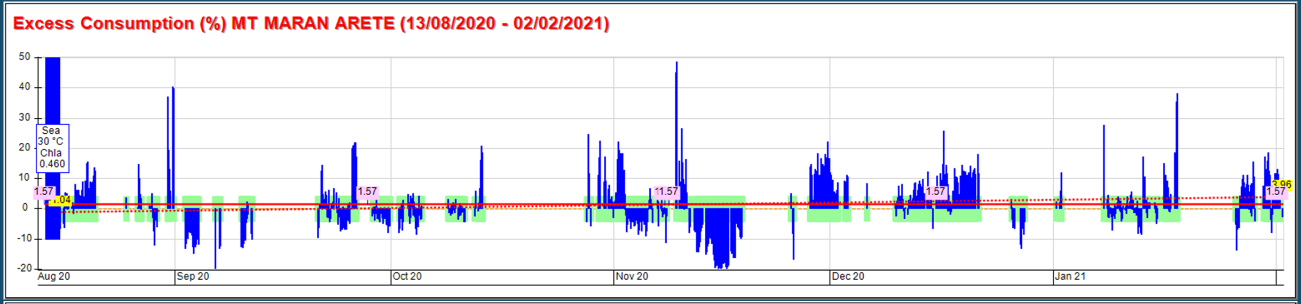


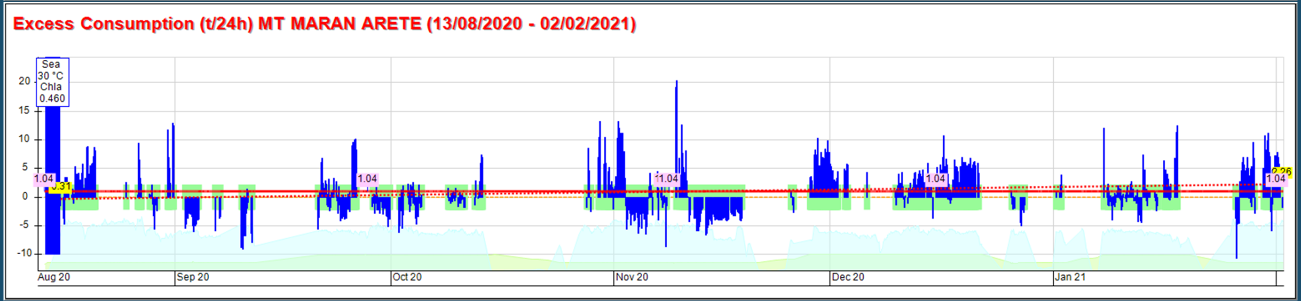
SFOC% - SGC%



- Model is based on Shop Test.
- Auto-log data/vessel sensors.
- Read shaft torque and fuel consumption.
- Correction for fuel/gas quality and LCV.
- Estimation of the expected SFOC/SGC%.
- Comparison of the model's prediction with the vessels SFOC/SGC, as calculated by the pair of vessels fuel/gas consumption, shaft power (and fuel quality).

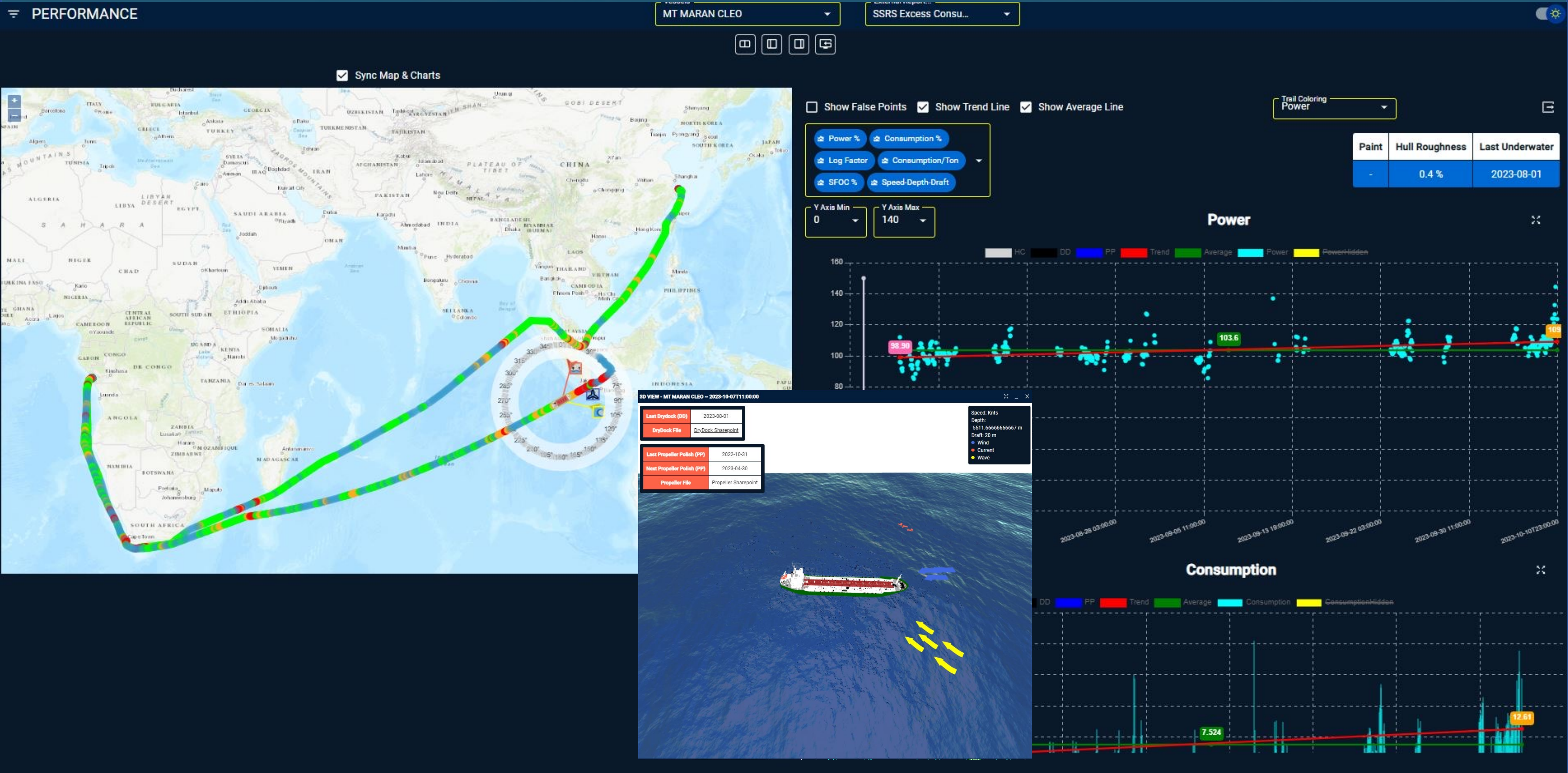
Excess. Consumption%





- Model is based on Shop Test, Model Tests and Sea Trials.
- Auto-log data/vessel sensors
- Combination of the two previous reports.
- Quantifies overconsumption.

New Platform

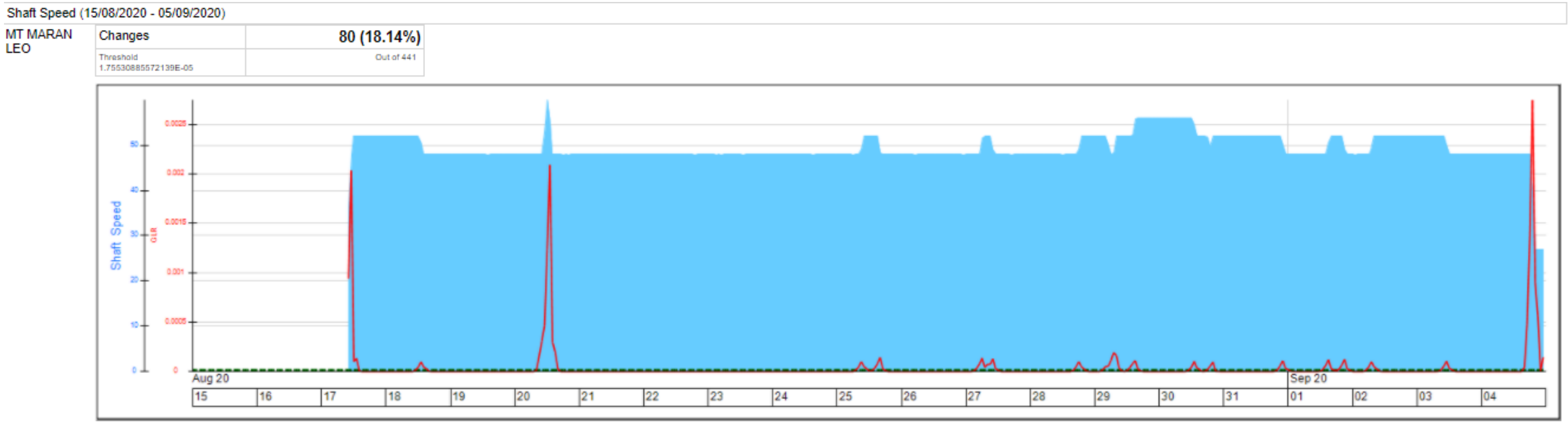



Stable Period Detection

STABLE PERIOD DETECTION

STABLE PERIOD DETECTION is applied on the input signals (RPM, power, speed, rudder angle, weather data, etc.)

- Having only the data from the stable periods of navigation is necessary for a reliable analysis.
- Data from the non-stable periods, such as speeding up or slowing down, maneuvering or the abrupt changes of the weather could lead to the wrong performance assessments.
- Implementation of the stable periods detection has reduced the scatter in the results and increased the reliability of the system.



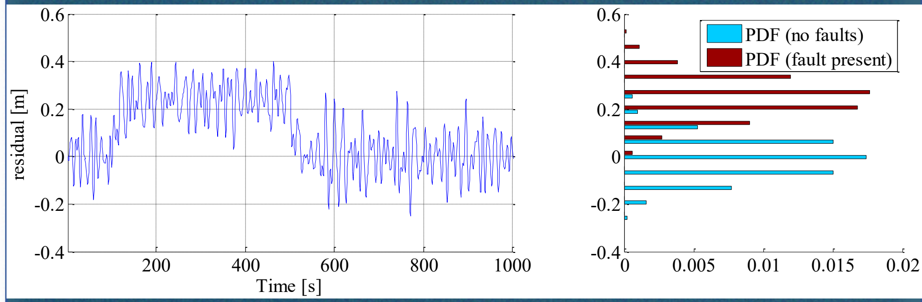
STABLE PERIOD DETECTION

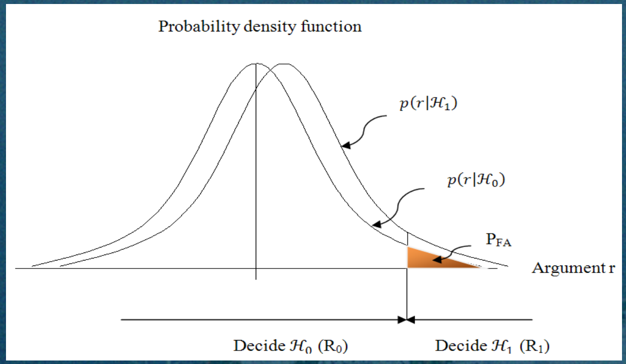
Standard change detection problem

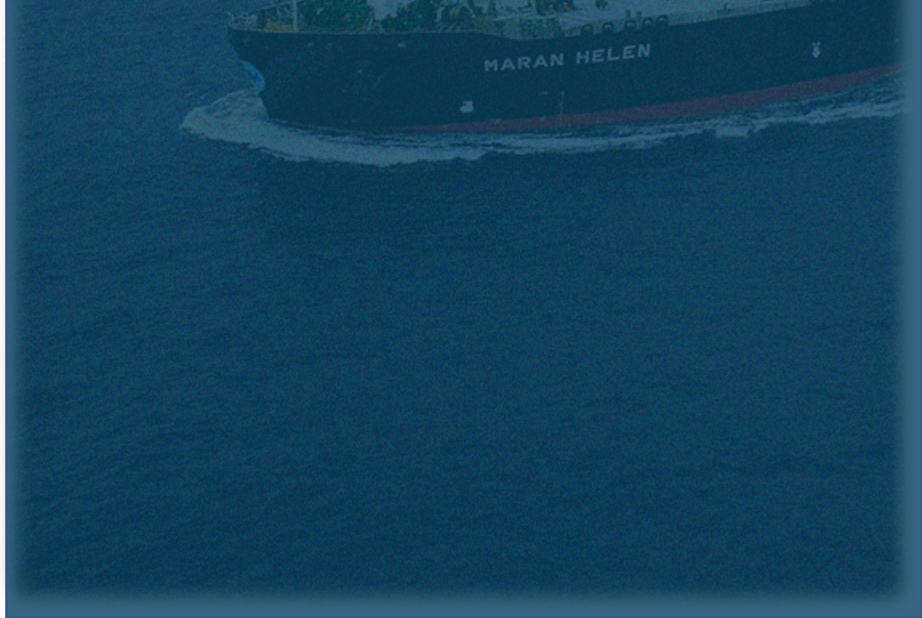
Condition 0 → Condition 1

Stable period detection problem

Condition 0 → Condition 1 → Condition 2 →







Solution- Adaptive GLR detector

- The detector is based on the change in probability density functions of the signals before and after the change.
- If the likelihood ratio is higher than a specific threshold value γ, then we assume that the change is present, otherwise the change is not present.
- After detecting the change, the adaptive GLR takes a new condition ***i*** (***i***>0) as the reference condition and it is triggered again.

STABLE PERIOD DETECTION

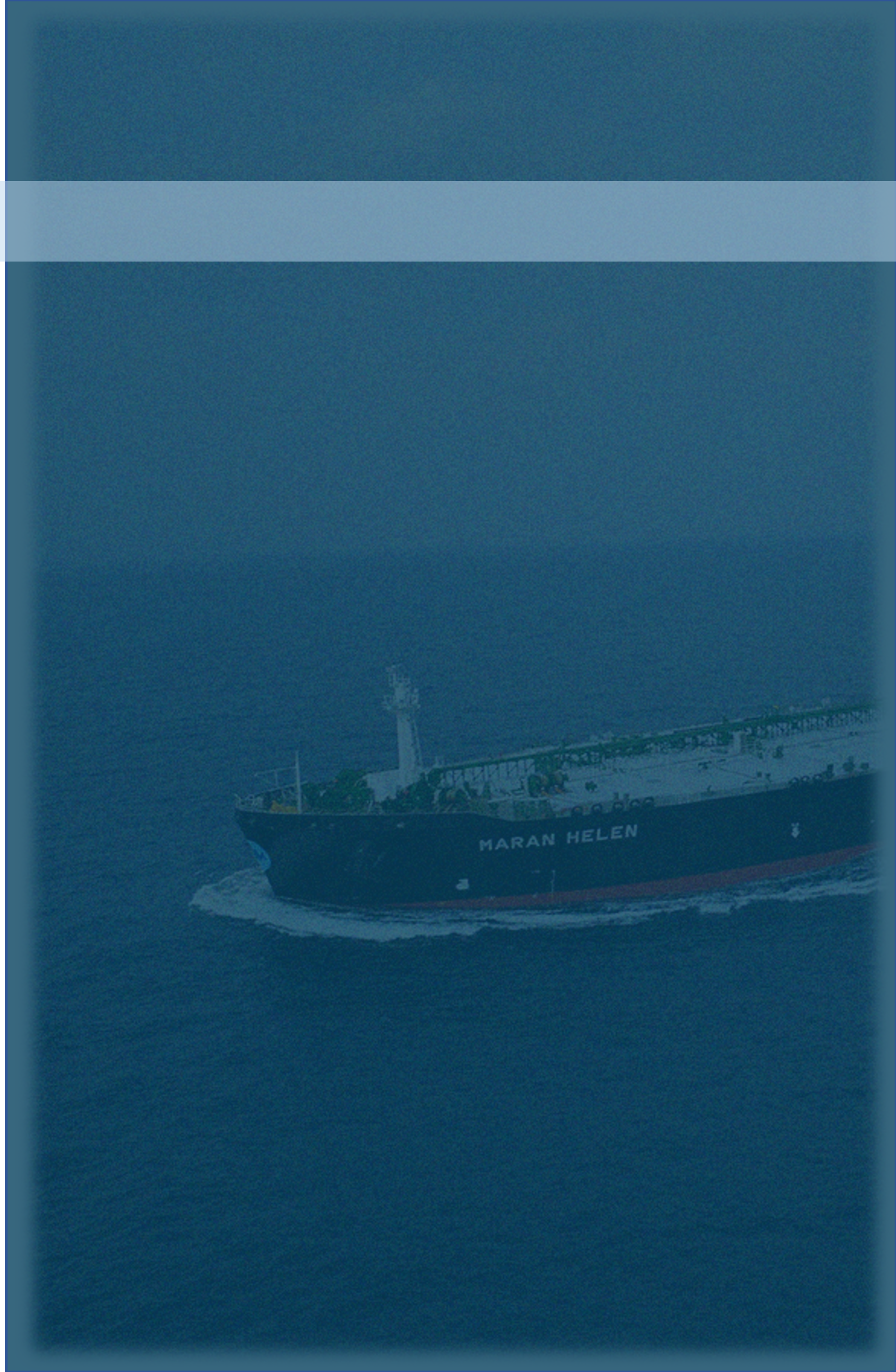
Adaptive GLR Detector - multiple decision functions

$$g_1(k) = \frac{1}{2\sigma^2} \max_{k-M+1 \le j \le k} \frac{1}{k-j+1} \left[\sum_{i=j}^{k} (r(i) - \mu_{01}) \right]^2 \xrightarrow{g_1(k) > h}$$

$$g_2(k) = \frac{1}{2\sigma^2} \max_{k-M+1 \le j \le k} \frac{1}{k-j+1} \left[\sum_{i=j}^{k} (r(i) - \mu_{02}) \right]^2 \xrightarrow{g_2(k) > h} \dots$$

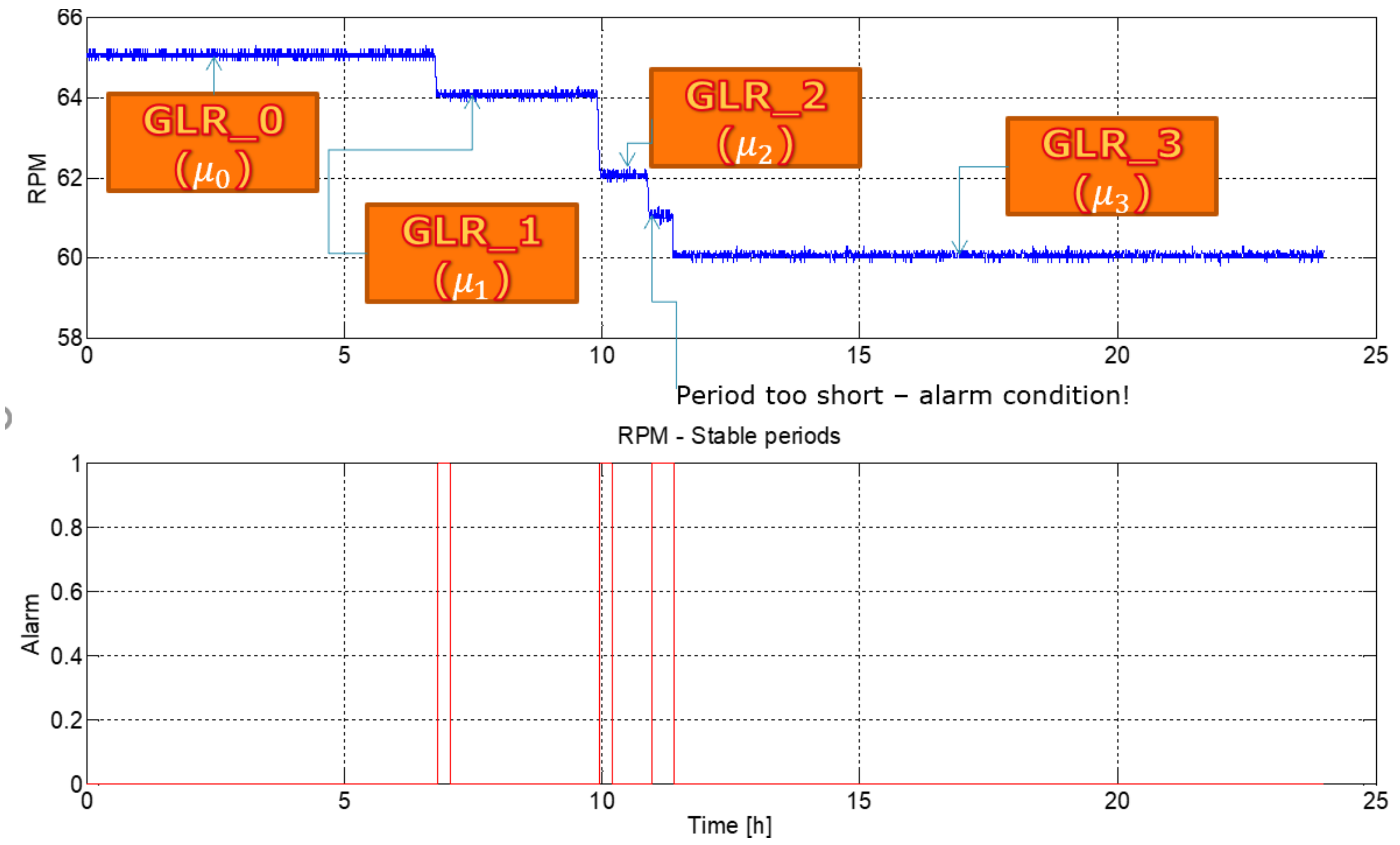
$$g_i(k) = \frac{1}{2\sigma^2} \max_{k-M+1 \le j \le k} \frac{1}{k-j+1} \left[\sum_{i=j}^{k} (r(i) - \mu_{0i}) \right]^2 \xrightarrow{g_i(k) > h} \dots$$

$$g_{number\ of\ alarms}(k) = \frac{1}{2\sigma^2} \max_{k-M+1 \le j \le k} \frac{1}{k-j+1} \left[\sum_{i=j}^{k} (r(i) - \mu_{0number\ of\ alarms}) \right]^2$$

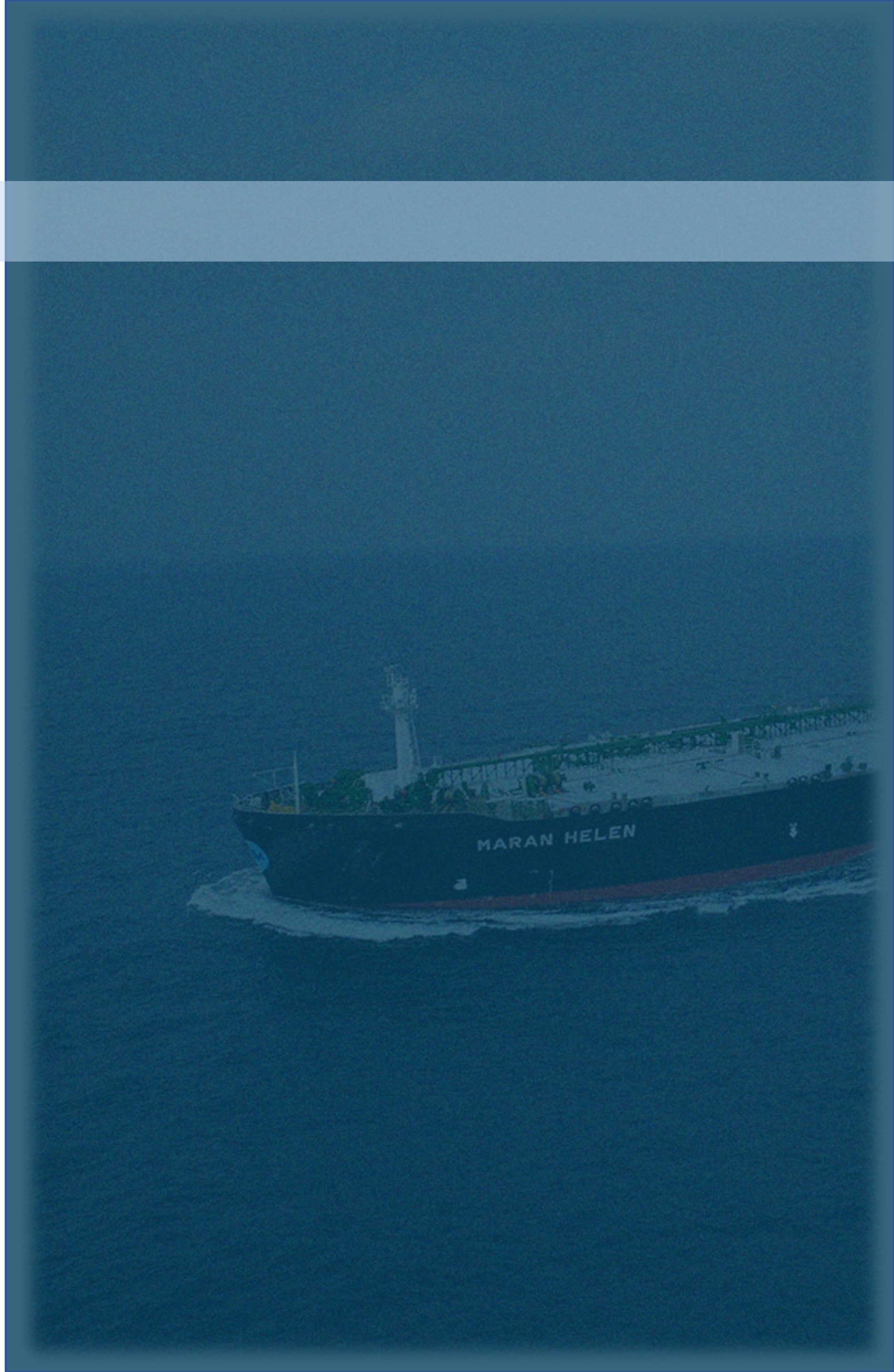


STABLE PERIOD DETECTION

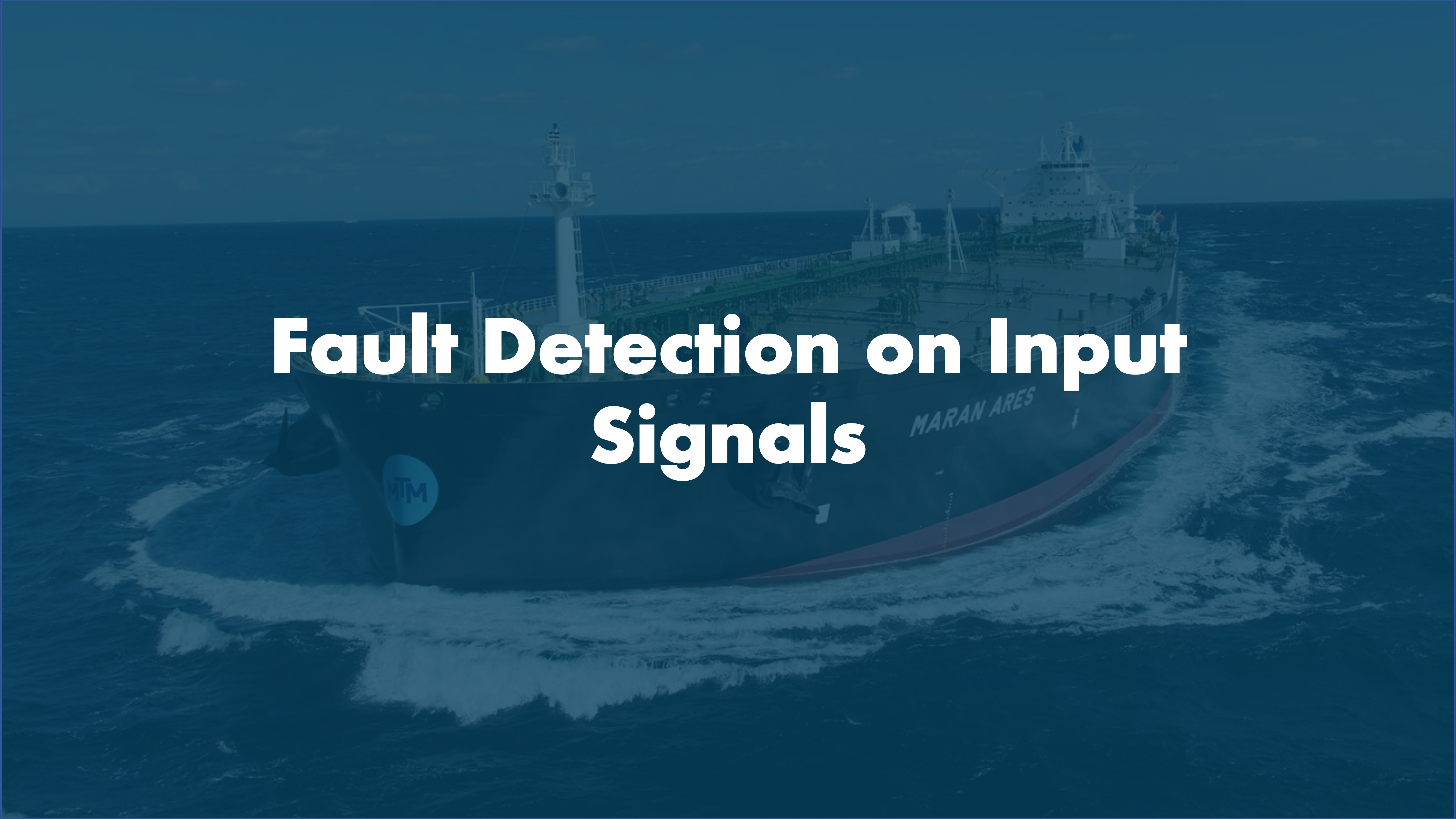
Adaptive GLR Detector - multiple decision functions



Detection of the stable periods on the RPM signal



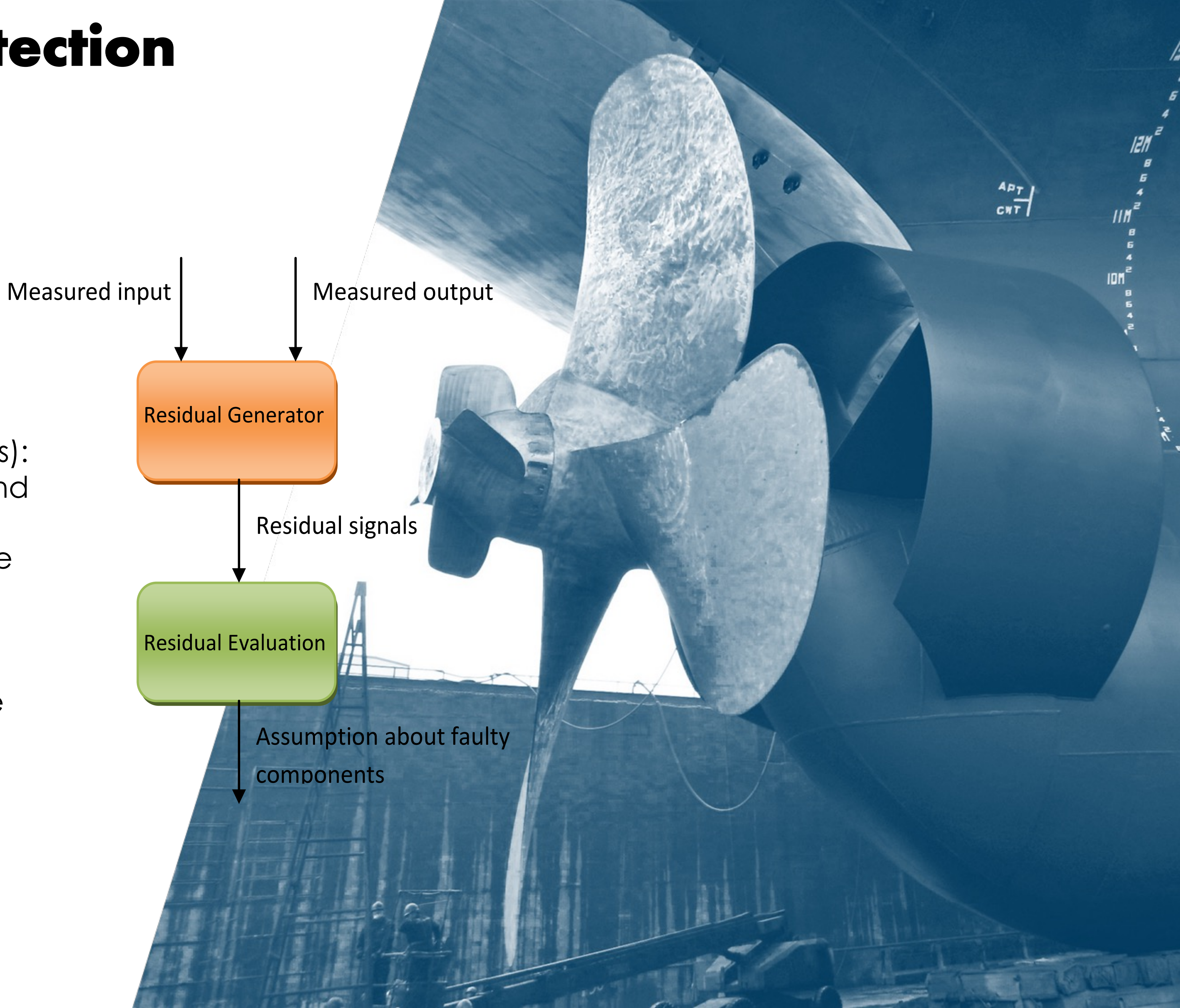
Fault Detection on Input Signals



Fault Detection

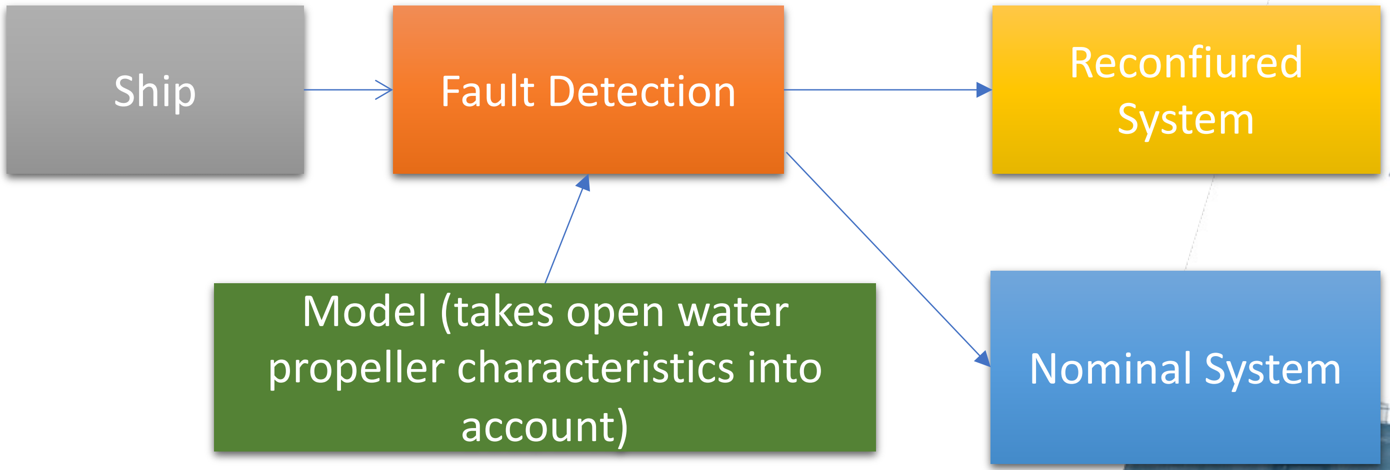
- A **fault** is something that changes the system behavior in a manner so that the system does no longer satisfy its purpose.
- Diagnostic steps:
  - ✓Fault detection,
  - ✓Fault isolation,
  - ✓Fault identification and fault estimation.

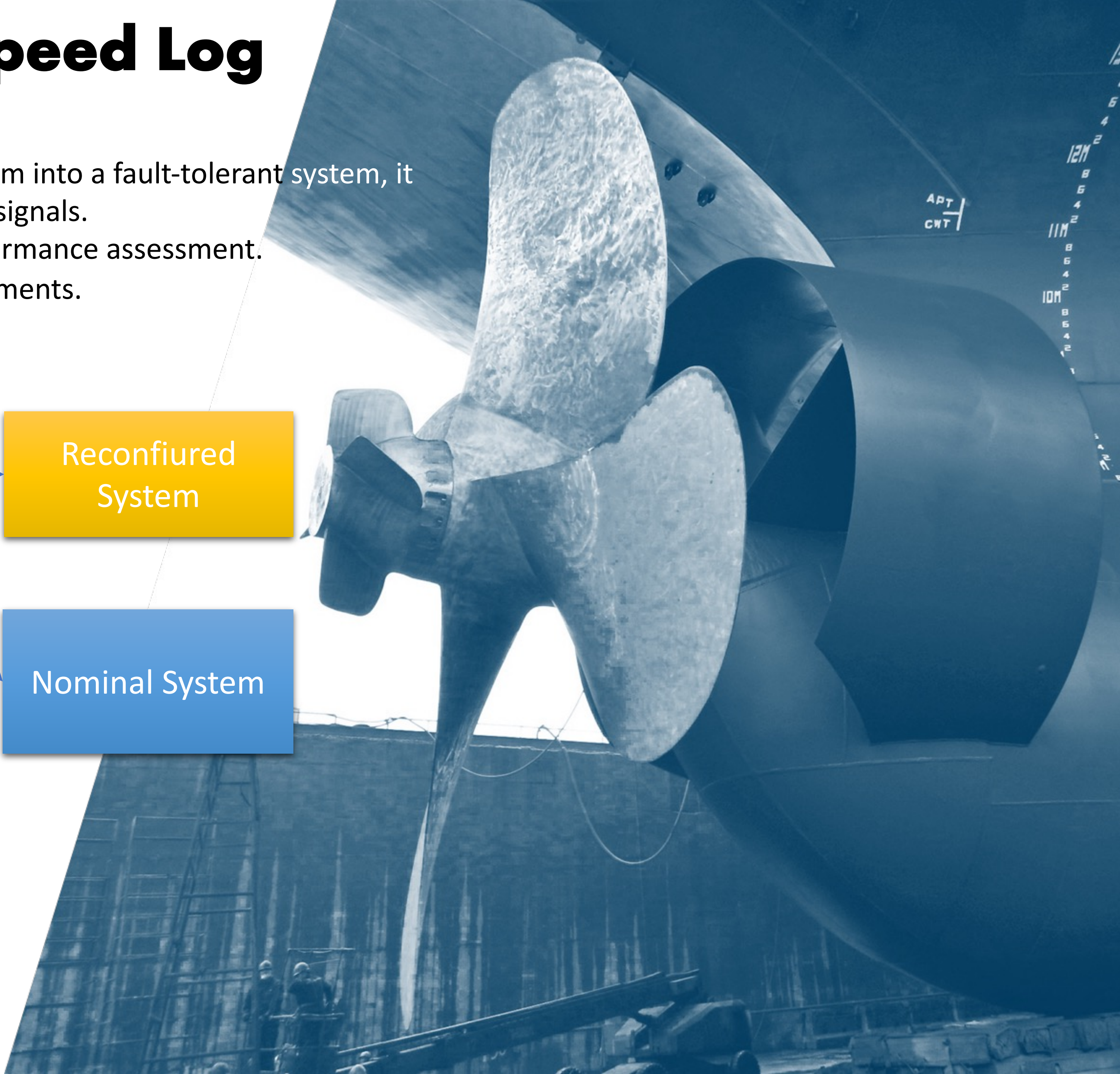
- Diagnostic algorithms (two components):
  - ✓Residual generation: The model and the I/O pair are used to determine residuals, which describe the degree of consistency between the system and the model behaviour.
  - ✓Residual evaluation: The residual is evaluated in order to detect, isolate and identify faults.



Fault Detection on Speed Log

- In order to transform a conventional performance system into a fault-tolerant system, it is necessary to perform fault diagnosis for all the input signals.
- Speed is one of the most important inputs for the performance assessment.
- Speed log could give in some cases erroneous measurements.

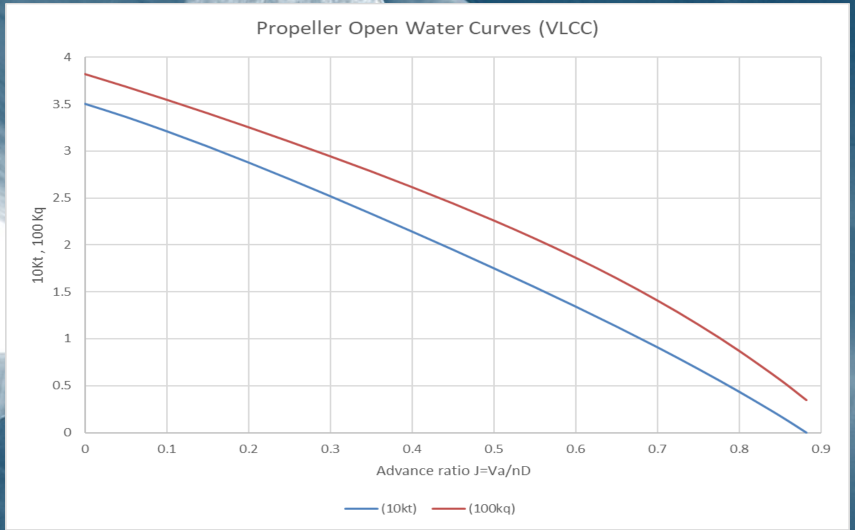


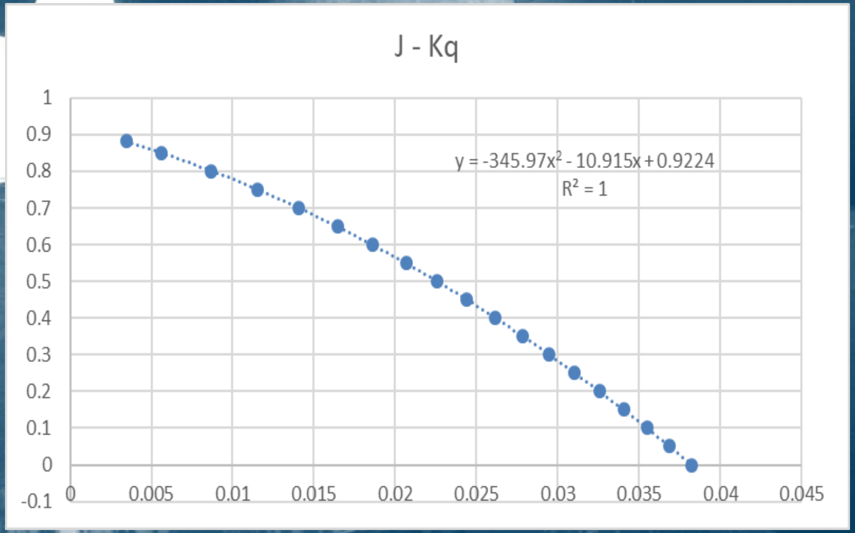


Fault Detection on Speed Log

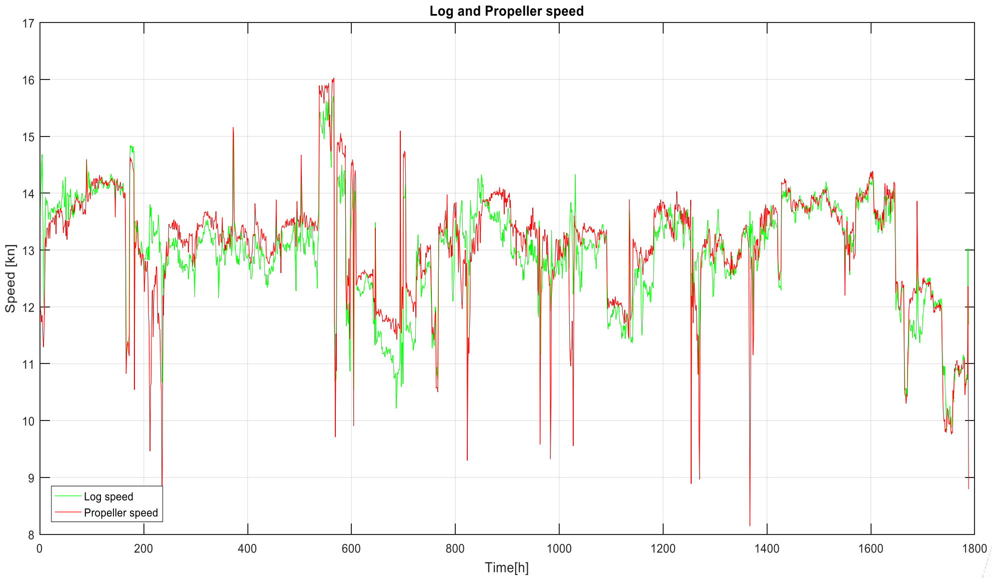
- Thrust coefficient, $K_T = T/\rho n^2 D^4$
- Torque coefficient, $K_Q = Q/\rho n^2 D^5$
- where:
- *T*- propeller thrust
- *Q*- propeller torque
- *ρ*- sea water density
- *n*- revolution per minute
- *D*- propeller diameter

$$J = c_1 K_Q^2 + c_2 K_Q + c_3$$





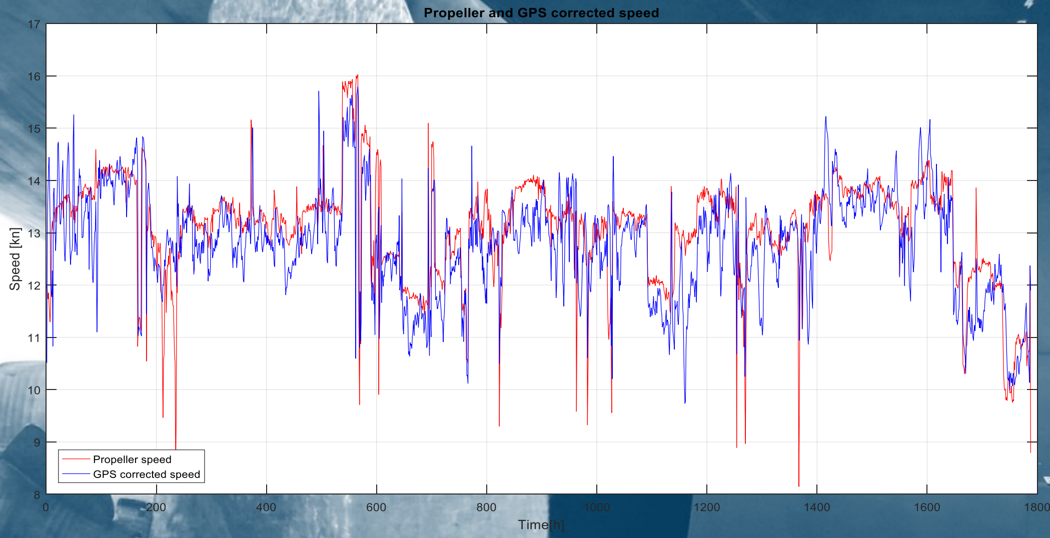
Speed Graphs

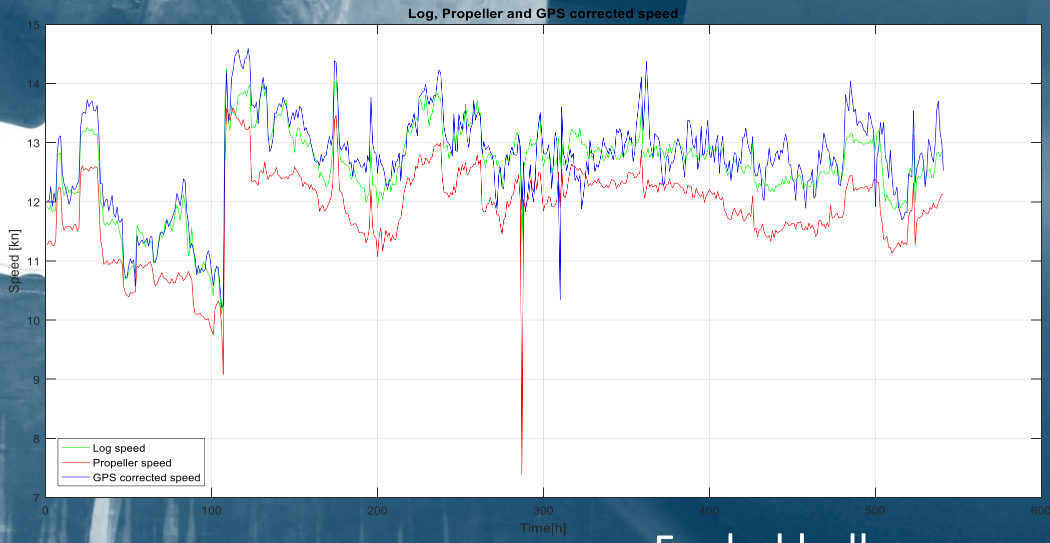


$$V_{PROP}=JnD/(1-w)$$

TABLE I. VLCC WAKE FRACTION

speed [kn]/draught [m]	9.705	20.8	22.5
10	0.333	0.278	0.265
12	0.337	0.281	0.267
14	0.3398	0.283	0.269
15	0.341	0.284	0.27
16	0.342	0.284	0.271
17	0.343	0.285	0.272





Fouled hull

Residuals

$r_1 = STW - V_{PROP}$

$r_2 = STW_{COM} - V_{PROP}$

$r_3 = STW_{COM} - STW$

where:
STW – speed through the water

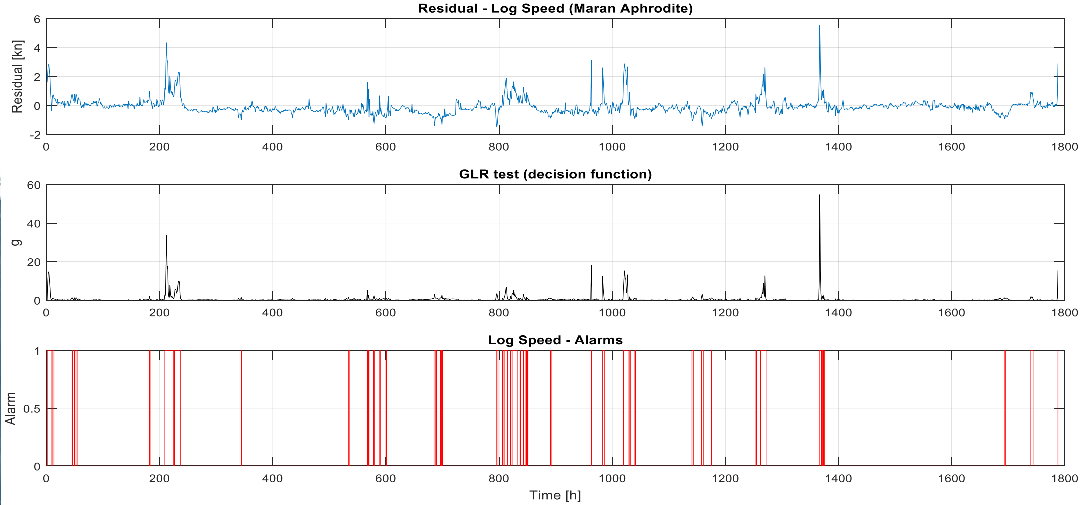
STW_{COM} – speed through the water calculated from the speed over ground *SOG* and weather data for sea current

V_{PROP} – vessel speed calculated with the propeller absorbed torque, RPM, wake fraction and propeller open water diagram

fault on *STW* (f_1), fault on STW_{COM} (f_2), and fault on V_{PROP}

TABLE I. FAULT SIGNATURES

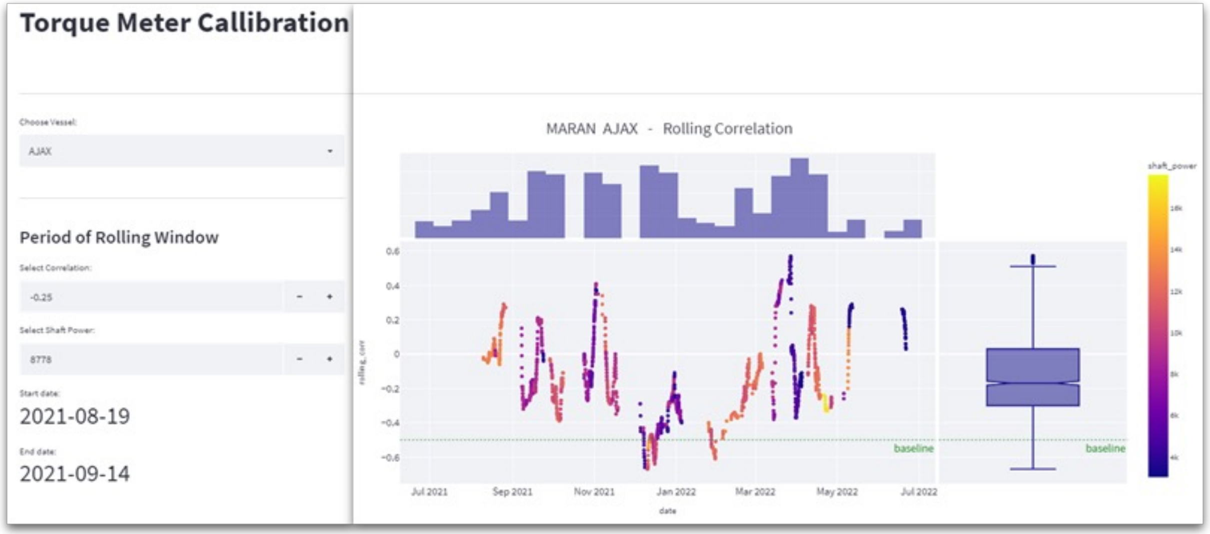
residual / fault	*f1*	*f2*	*f3*
r_1	*1*	*0*	*1*
r_2	*0*	*1*	*1*
r_3	*1*	*1*	*0*
	i	*i*	*i*



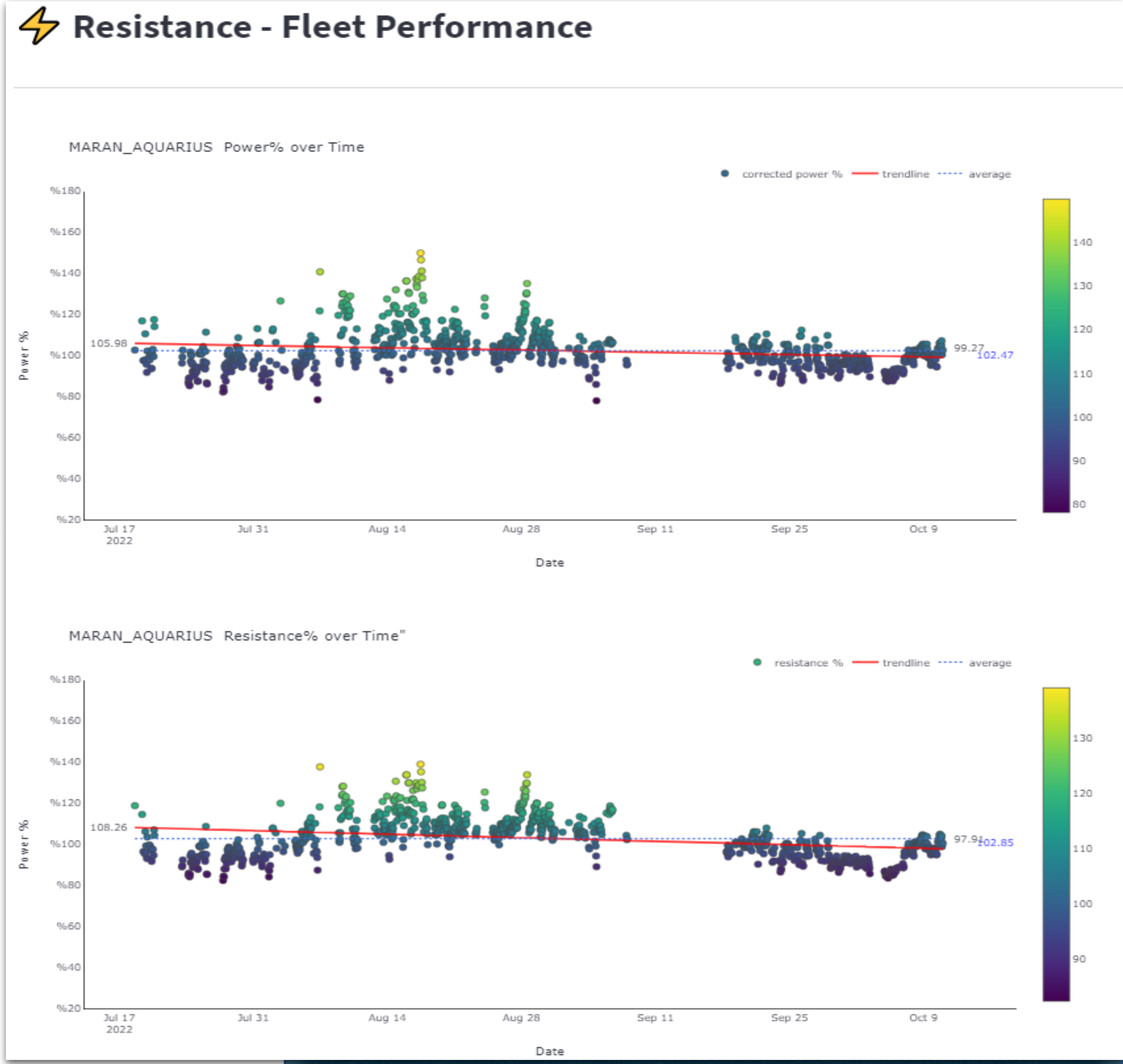
Other Features

Torque Meter Fault Detection

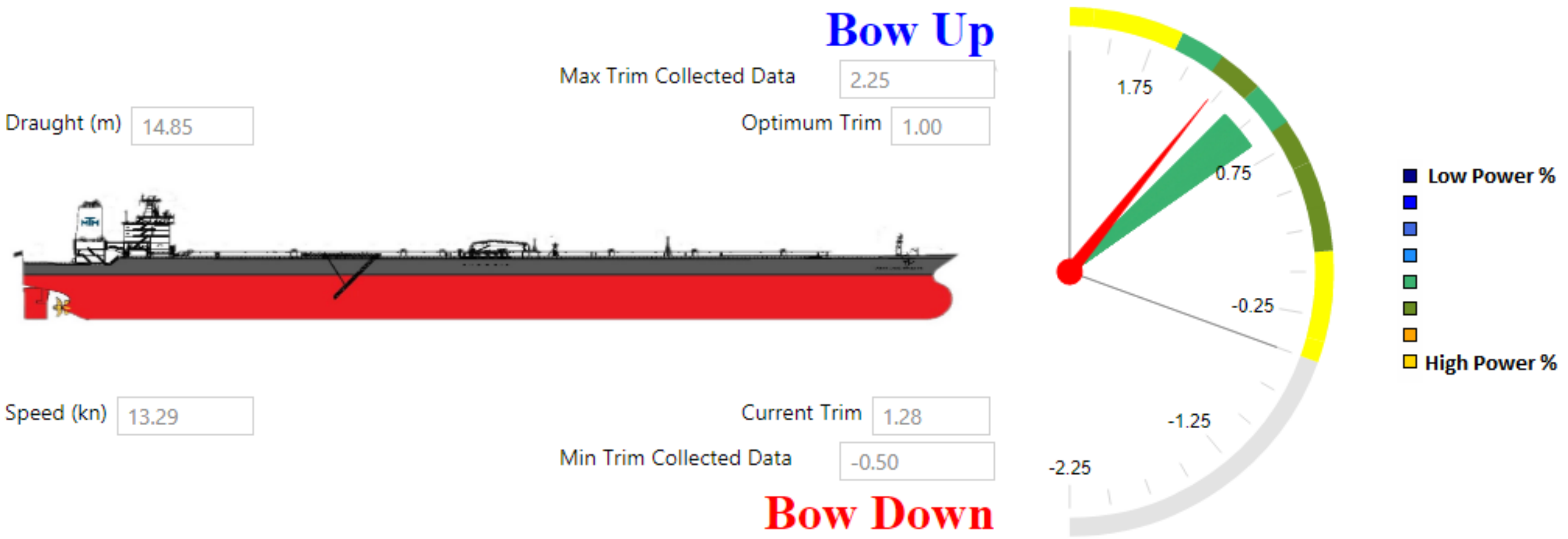
- The torque meter fault detection report correlates SFOC% and Power% to detect periods of negative correlation which indicate erroneous torquemeter measurements.
- This feature of the report enhances the data quality and the overall reliability of the measurements and corresponding results.



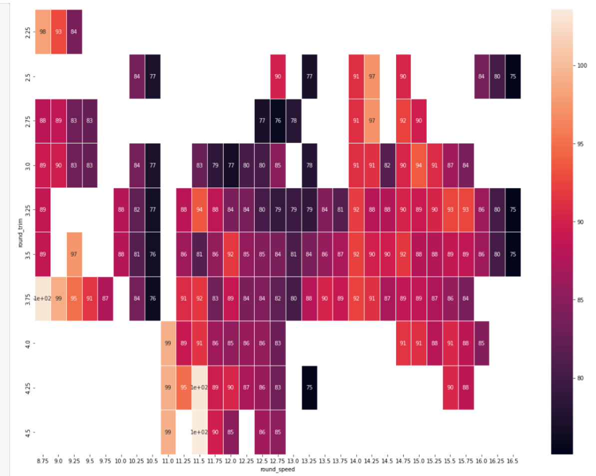
Resistance %

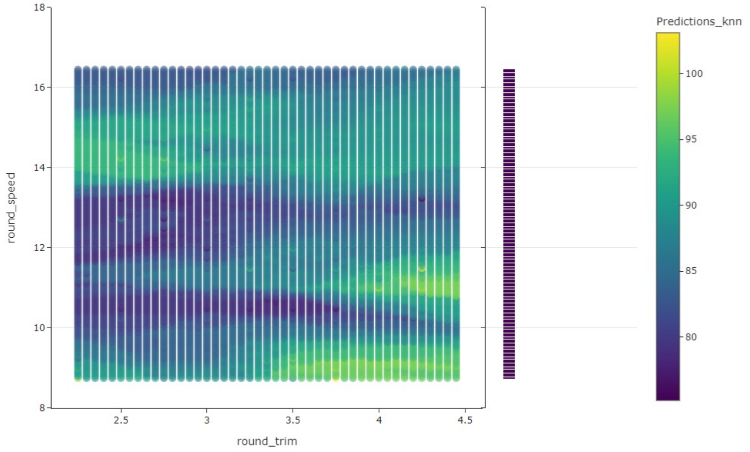


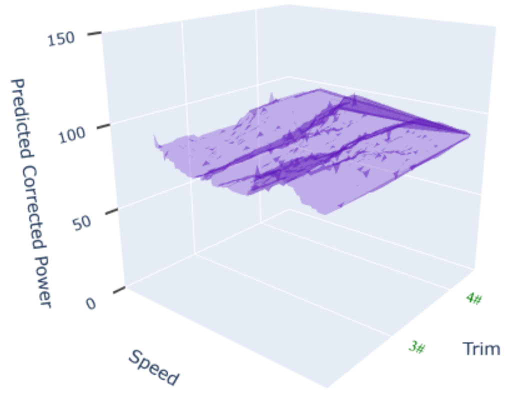
Optimum Trim



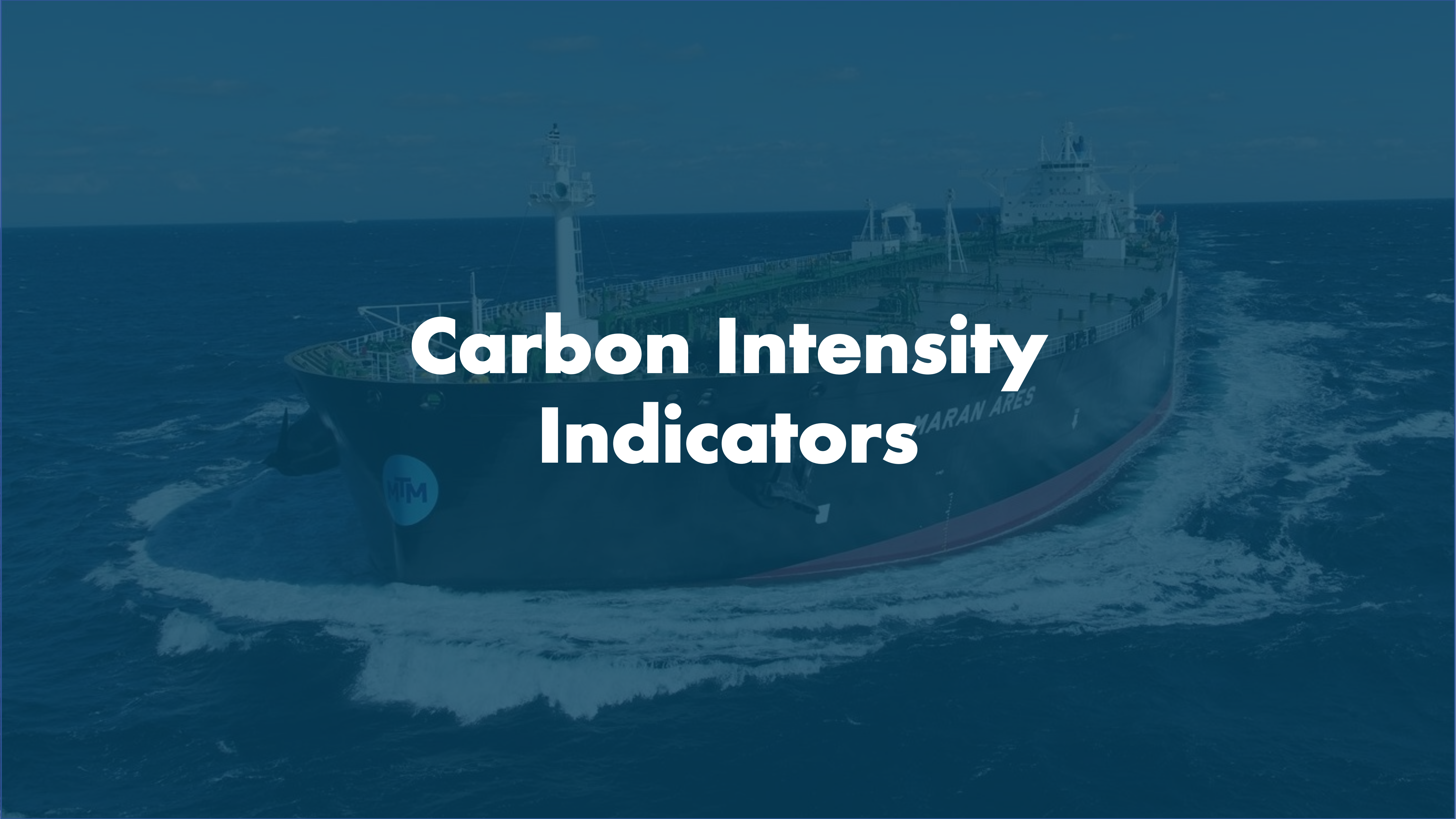
- In-house developed trim optimization software based on dynamic trim and machine learning.
- The trim optimization software utilizes live data of draught, trim and the corresponding Power% per measurement to establish the optimal trim-speed combinations for a specific draught.





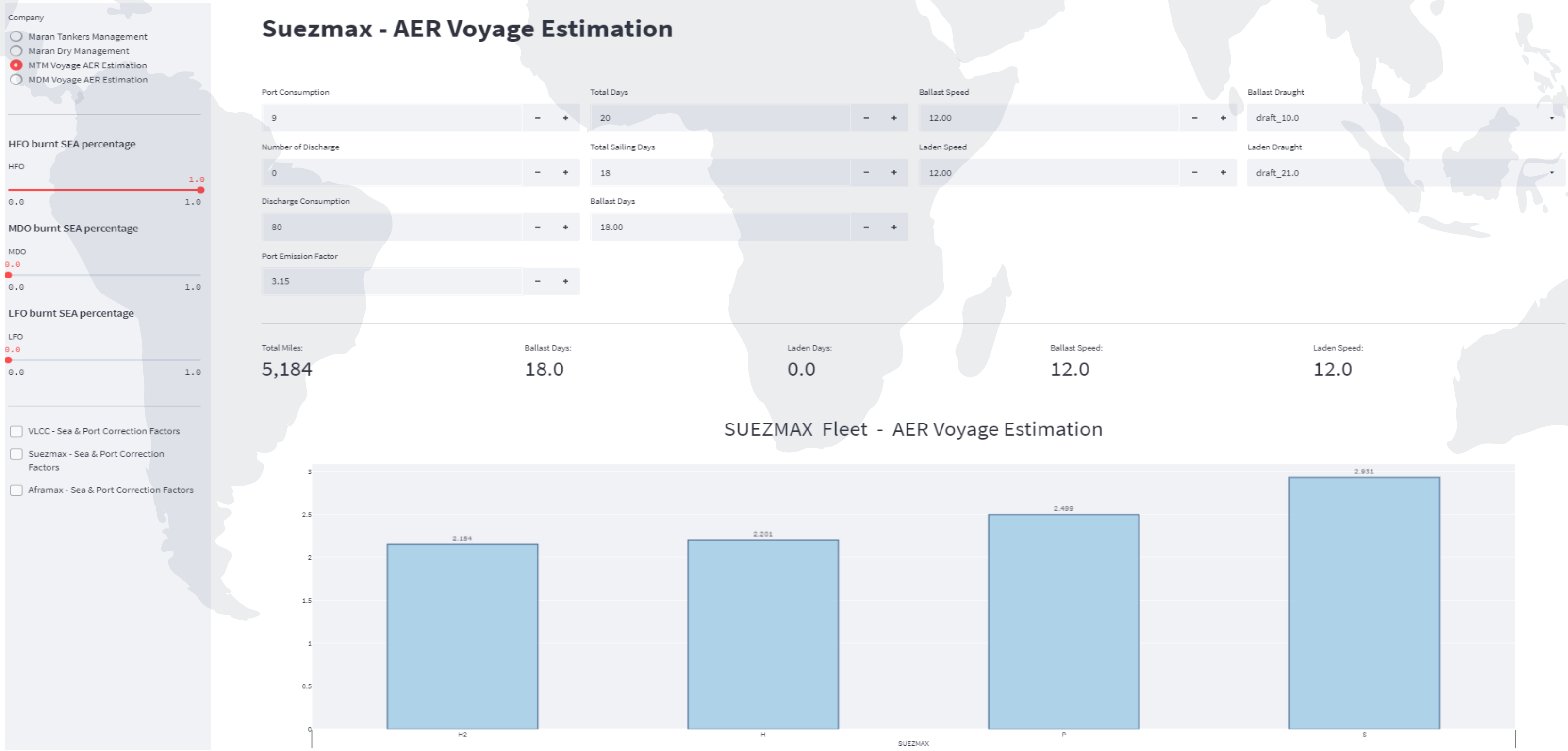


Carbon Intensity Indicators



CII voyage estimation

- The automated web report for the CII prediction considers the operational profile selected by the user and simulates the CII results.
- A single leg, or a combination of legs can be selected.
- The tool can be used to assess the effect of any future legs to the vessel's final CII score, to determine the maximum speed that allows a good CII rating and to compare different vessel classes for the same operation.



CII : Definition & Methodology

The **attained annual CII** of an individual ship has the following key points:

- It is applicable to all ships above 5,000 GT.
- Is calculated as the ratio of the total mass of CO_2 (M) emitted, to the total transport work (W), undertaken in a given calendar year.

$$CII_{attained} = \frac{CO_2 Emissions}{DWT \cdot Distance}$$

The **required annual CII** of an individual ship has the following key points:

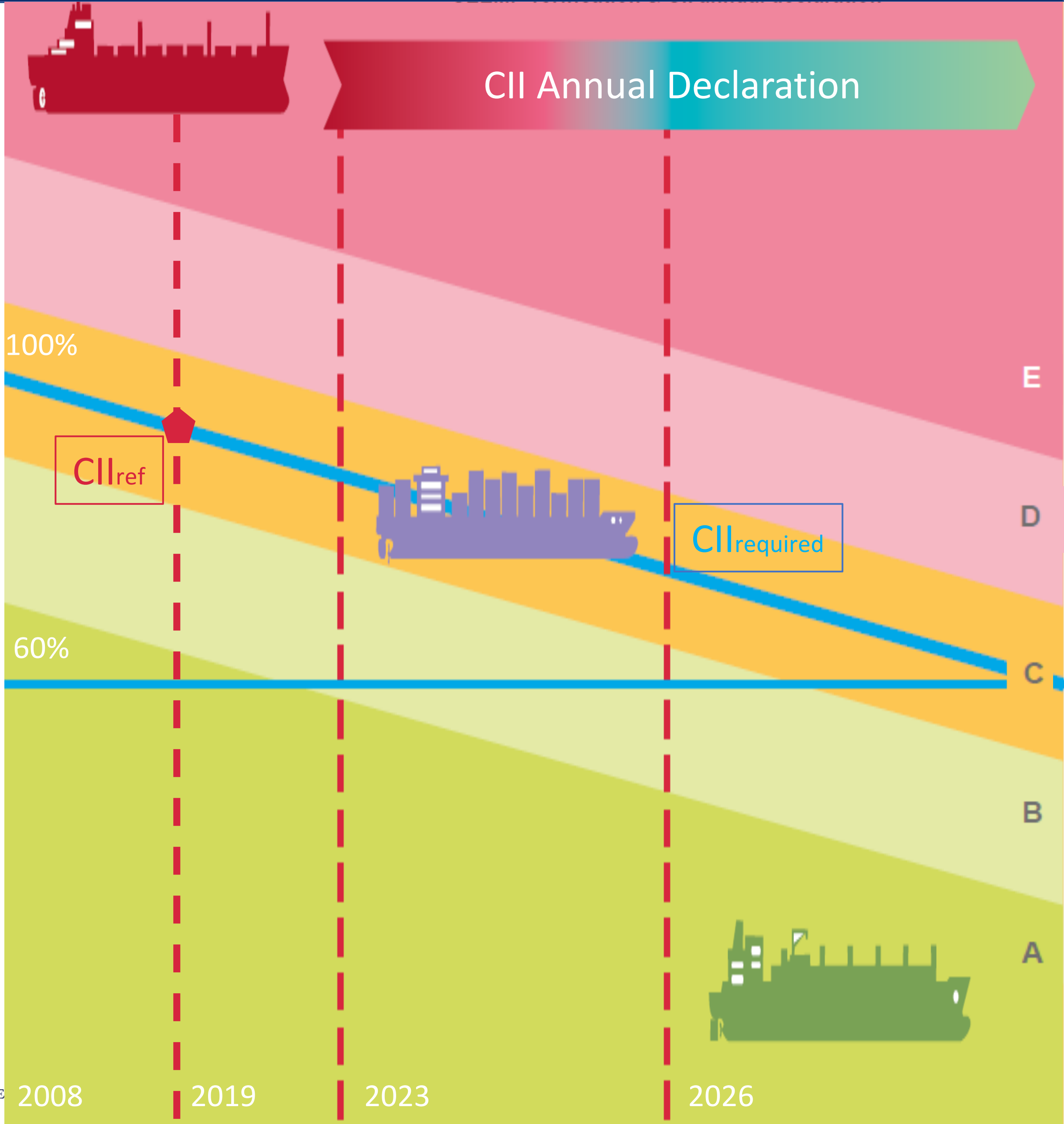
- The ships are to achieve a required operational energy efficiency (required CII) in accordance with the carbon intensity indicator (CII) reduction factor.

$$CII_{ref} = a \cdot Capacity^{-c}$$

- capacity is either vessel's DWT or GT or a specific value, it is specified based on ship type.
- a and c are parameters estimated through median regression fits, taking the attained CII and the capacity of individual ships collected through IMO DCS in year 2019 as the sample.

$$CII_{required} = \frac{1 - Z}{100} \cdot CII_{ref}$$

- Z: annual operational carbon intensity reduction factor



Sources:
Reducing Ship Emissions: IMO EEXI & CII/SEEMP, Bureau Veritas, June 2021

CII monitoring

Pengerang, Indonesia

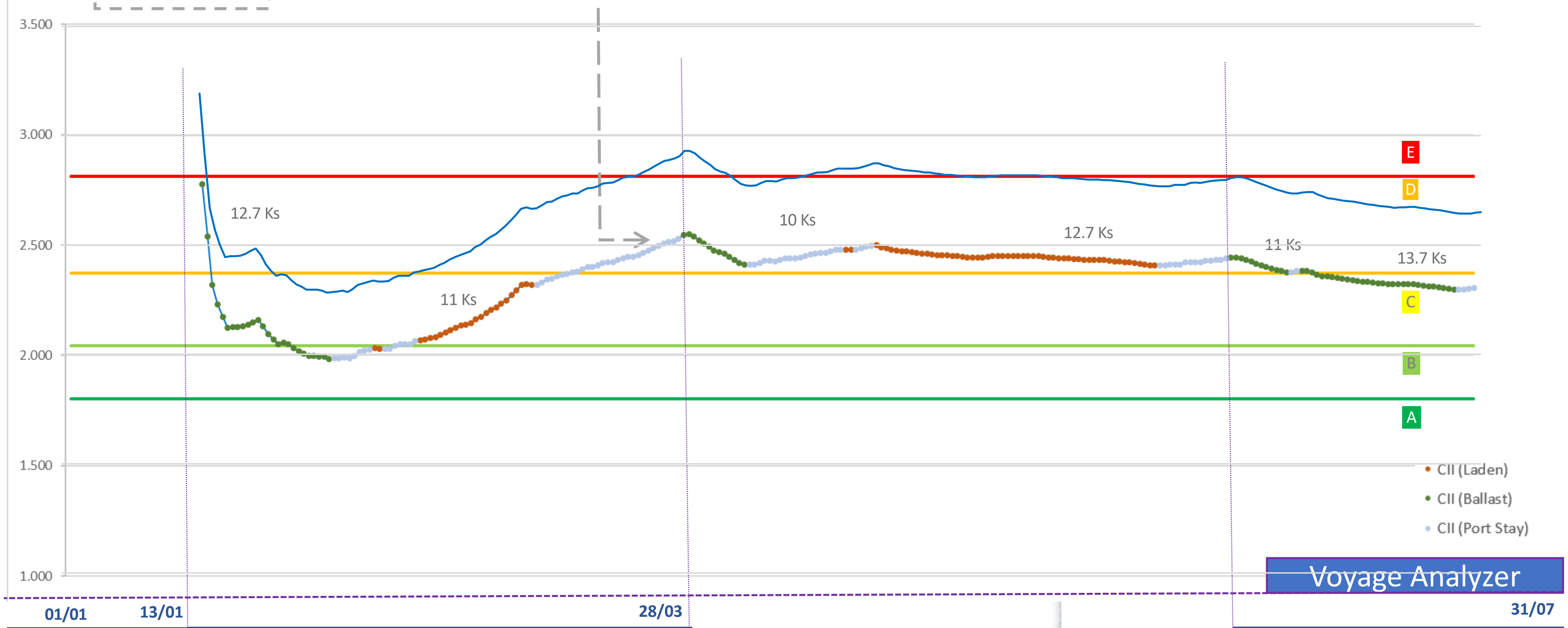
- Port Stay: 15 days
- Ops: Discharging
- Comments: Fist days of the calendar year, no voyage distance was measured, as a result CII value cannot be calculated

Canaport, Canada

- Port Stay: 18 days
- Ops: Discharging
- Vessel was waiting using scrubbers

Overall CII Trajectory

- Vessel's rating went from a D to C, following a long ballast voyage



TIANJIN > RAS TANURA > PENGERANG	PENGERANG > BONGA TERMINAL > EGINA FPSO > CANAPORT (ST.JOHN)	CANAPORT (ST.JOHN) > CORPUS CHRISTI > OFFSHORE CORPUS CHRISTI NO.1 (TSA) > YOSU	YOSU > ACU > RIZHAO > NINGBO

TIANJIN > RAS TANURA > PENGERANG

- Voyage No: 020
- Charterer: .
- The reporting year started with the port stay at Pengerang.

PENGERANG > BONGA TERMINAL > EGINA FPSO > CANAPORT (ST.JOHN)

- Voyage No: 021
- Charterer:

CANAPORT (ST.JOHN) > CORPUS CHRISTI > OFFSHORE CORPUS CHRISTI NO.1 (TSA) > YOSU

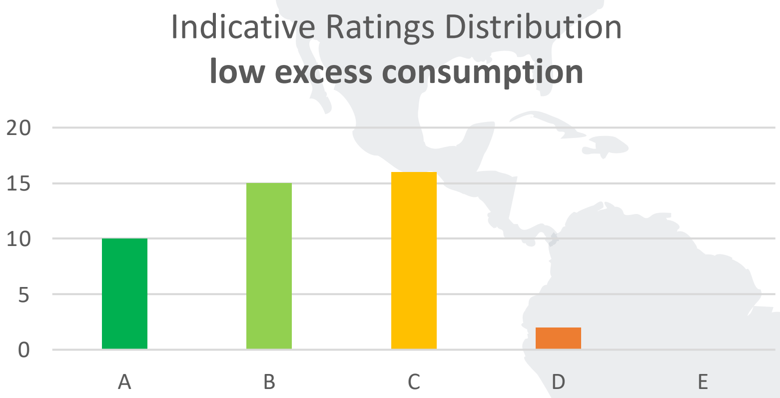
- Voyage No: 022
- Charterer: .
- Analysis considers the period until the port stay at Singapore.

YOSU > ACU > RIZHAO > NINGBO

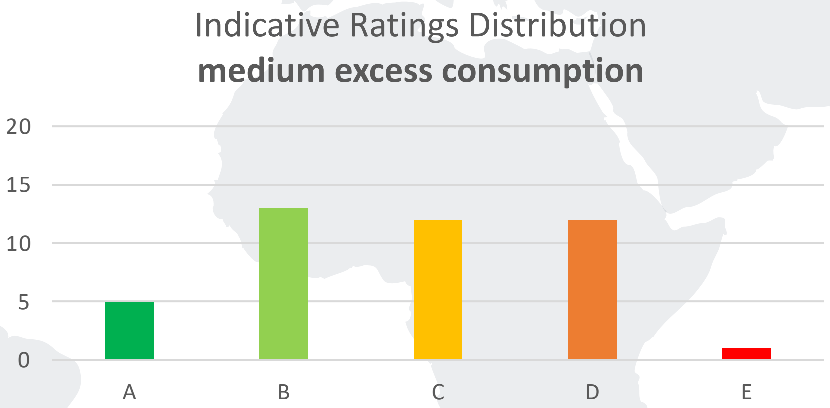
- Voyage No: 023
- Charterer: .
- Analysis considers the period until the port stay at ACU.

Effect of Excess Consumption on CII & emissions

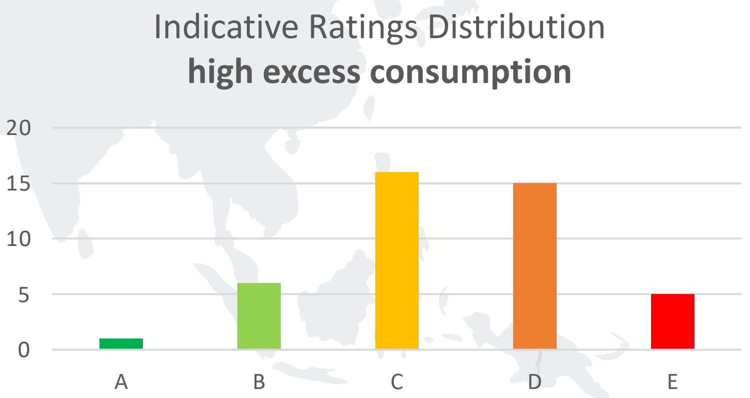
Example Fleet with well managed excess consumption:



Example Fleet with typical excess consumption:



Example Fleet with high excess consumption:



THANK YOU

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MTM
MARAN TANKERS MANAGEMENT INC.

MGG
MARAN GAS MARITIME INC.

MDM
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MARANUK
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MARAN ASIA PTE LTD.

FMS
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