PREDICTIVE MAINTENANCE & MACHINE LEARNING

A comprehensive and integrated vision – our Fleet Control Room

ilb
software & consulting

Daniele Bottazzi
Chief Commercial Officer – IB

SUMMARY

- IB Presentation
- Introduction to new technologies
- Predictive maintenance
- Fleet Control Room – IB Vision

1. IB Presentation

Who we are

The skilled and knowledgeable staff at IB provides systems and services for Maintenance & Operations improvements, with a special focus on technologies, methodologies and re-engineering of processes.

IB Company 115/115

Deployment software consultants 55/115

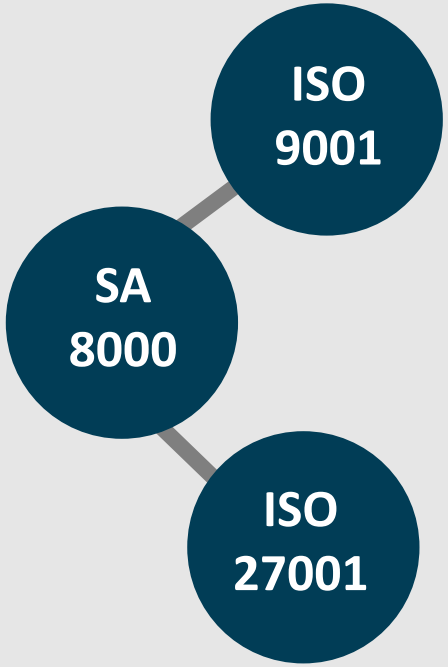
Software Developers 35/115

Certifications

CONTINOUS IMPROVEMENT

IB's Quality Management System integrates perfectly into the management system of a company, and aims to the maintain and fulfill quality requirements in compliance with all of the Labor and Environmental Regulations in force.

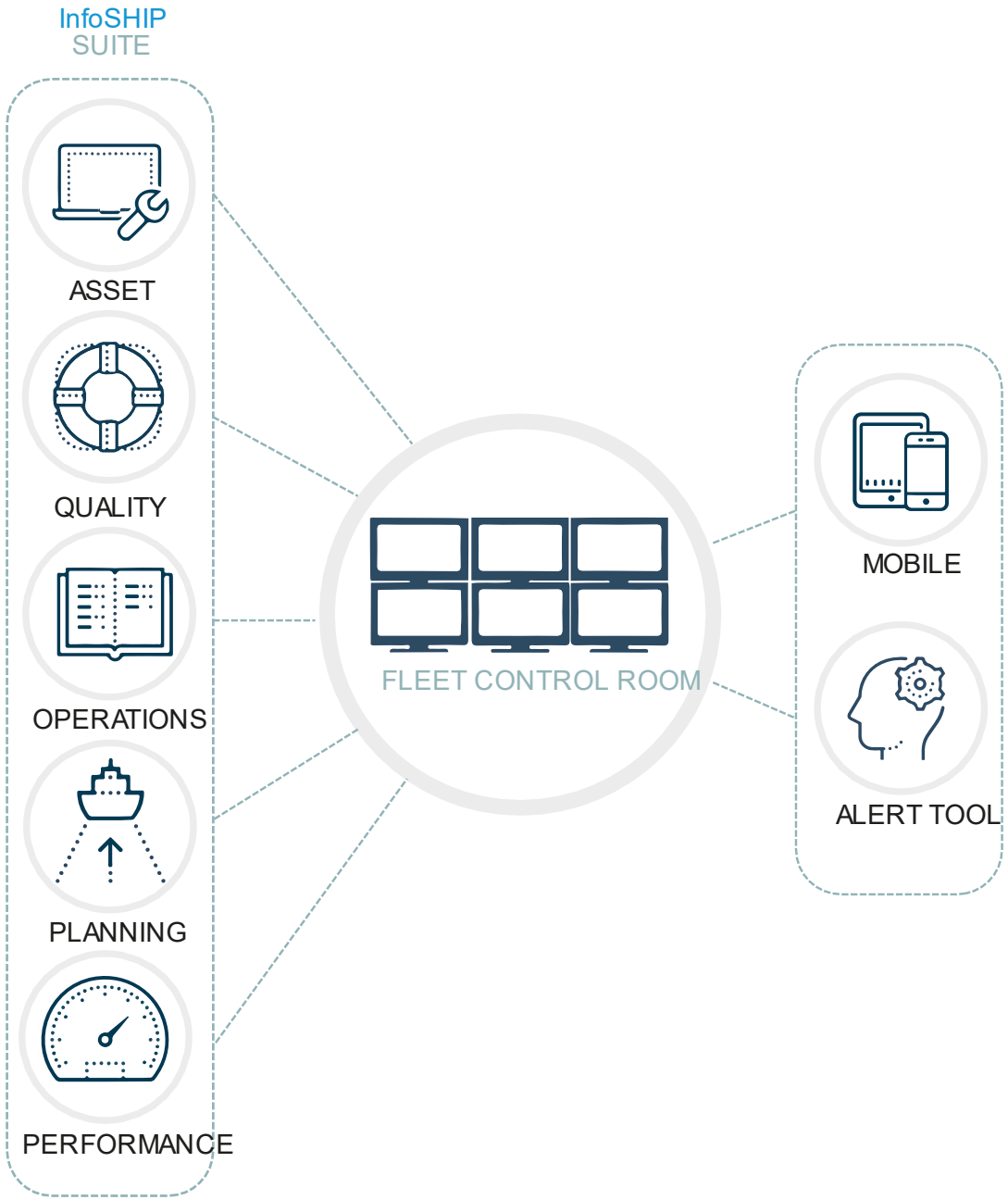
Since 2004, the standard of social responsibility & ethics, that lead us



1998 as the first ISO 9001 certification until obtaining in 2017 the new conformity ISO 9001: 2015

On June 2017, IB has awarded the prestigious ISO 27001 certification, which attests the company's commitment to information security at every level of the company.

InfoSHIP suite



Headquarters and IB Offices

FLORIDA
33327 Weston - USA
2900 Glades Circle, Suite 250
Ph: +1 305 998 2745

ITALY
16035 Rapallo (GE) - Italy
Via Cerisola, 37/2
Ph: +39 0185 273088

HONG KONG
Wanchai, Hong Kong
145 Hennessy Road
Hong Commercial Building, Room 28A, 23/5

2. Introduction to new technologies

Digitalization towards vessel operators

Milestones

- Advent of digital era is now
- Not only marine… all industries are impacted by this revolution (or evolution)

Slogans

- Artificial Intelligence
- Predictive Maintenance
- Machine Learning
- Digital Twin
- Internet Of Things (Iot)
- Etc.

Are those empty words or do they have any practical applicability?

Artificial Intelligence

What It Is

Artificial Intelligence is a collection of advanced technologies that allow machines to sense, comprehend, act and learn.
AI is adopted in several applications.

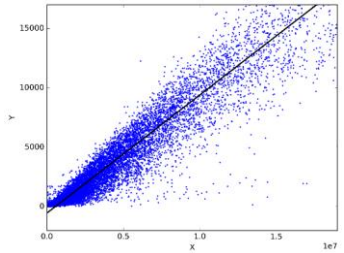

70


EE
15:17
What can I help you with?

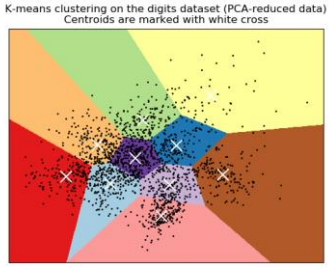
It is closer than it seems

Definitions

MACHINE LEARNING (ML) is a field of artificial intelligence that uses statistical techniques to give computer systems the ability to "learn" (e.g., progressively improve performance on a specific task) from data, without being explicitly programmed but using trained data sets.



Predicting a continuous-valued attribute associated with an object. E.g. Expected performances vs real-time performances. *Support Vecting Regressors, Lasso, etc.*

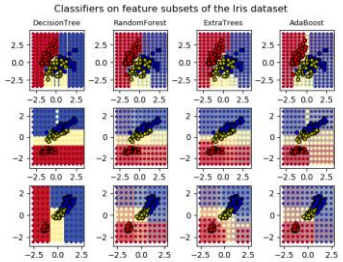


Automatic grouping of similar objects into sets. *K-means, mean-shift, etc.*

REGRESSION

CLASSIFICATION

CLUSTERING



Identifying which category an object belongs to. With Classification, the predicted output (class) is categoric, i.e. it can assume only few values. E.g. Component Failure probability: High, Medium, Low. *Support Vecting Machines, Random Forests, etc.*

Statistic learning

There are two different phases in automatic learning:

- **Training phase**: it is based on meaningful data sets; e.g. for hydrodynamic – after a drydock / propeller polishing, for thermodynamic – after an engine overhaul; → calculation of targets
- **Prediction phase**: from new data sets, computer can predict thanks to the models (physical or statistical).

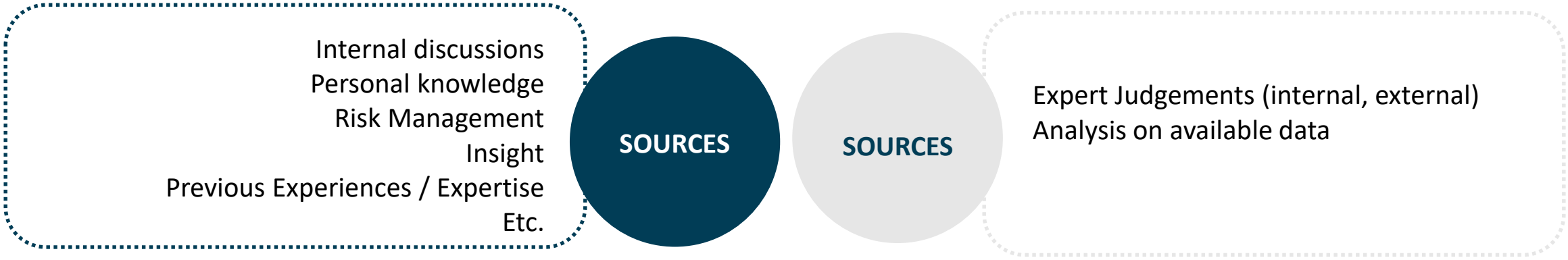
Two types of learning:

- **Supervised Learning**: The computer is presented with example inputs and their desired outputs, given by a "teacher", and th goal is to learn a general rule that maps inputs to outputs. As special cases, the input signal can be only partially available, or restricted to special feedback
- **Unsupervised Learning**: No labels are given to the learning algorithm, leaving it on its own to find structure in its input. Unsupervised learning can be a goal in itself (discovering hidden patterns in data) or a means towards an end

Why Machine Learning can help fleet operations?

Understand the conditions (considering the various variables which can impact the output) in order to take the proper **decision might be a very complicated duty**.

Typical approach is based on:



Taking in consideration possible constraints/obligations (economical, operational, compliance, contractual, etc.)

ML and, more in general, computer based systems, does not replace these activities, but, thanks to their computational power, can facilitate the decision makers to process the data and understand the conditions in order to provide them more precise/accurate/objective elements to take the proper decisions.

Example: is my ship consumption good?

E.g. Admiralty Coefficient $A = \frac{D^{2/3} S^3}{H}$.

Where S stands for Speed, H for power (horsepower) and D for Displacement

It is an empirical formula. It does not take in consideration for example:

- Sea state
- Wind State
- Currents
- Hull conditions
- Aging of equipment
- Bunker quality
- Navigation behavior
- Trim
- Etc.

Machine Learning is the only way to understand the performances in their steady conditions

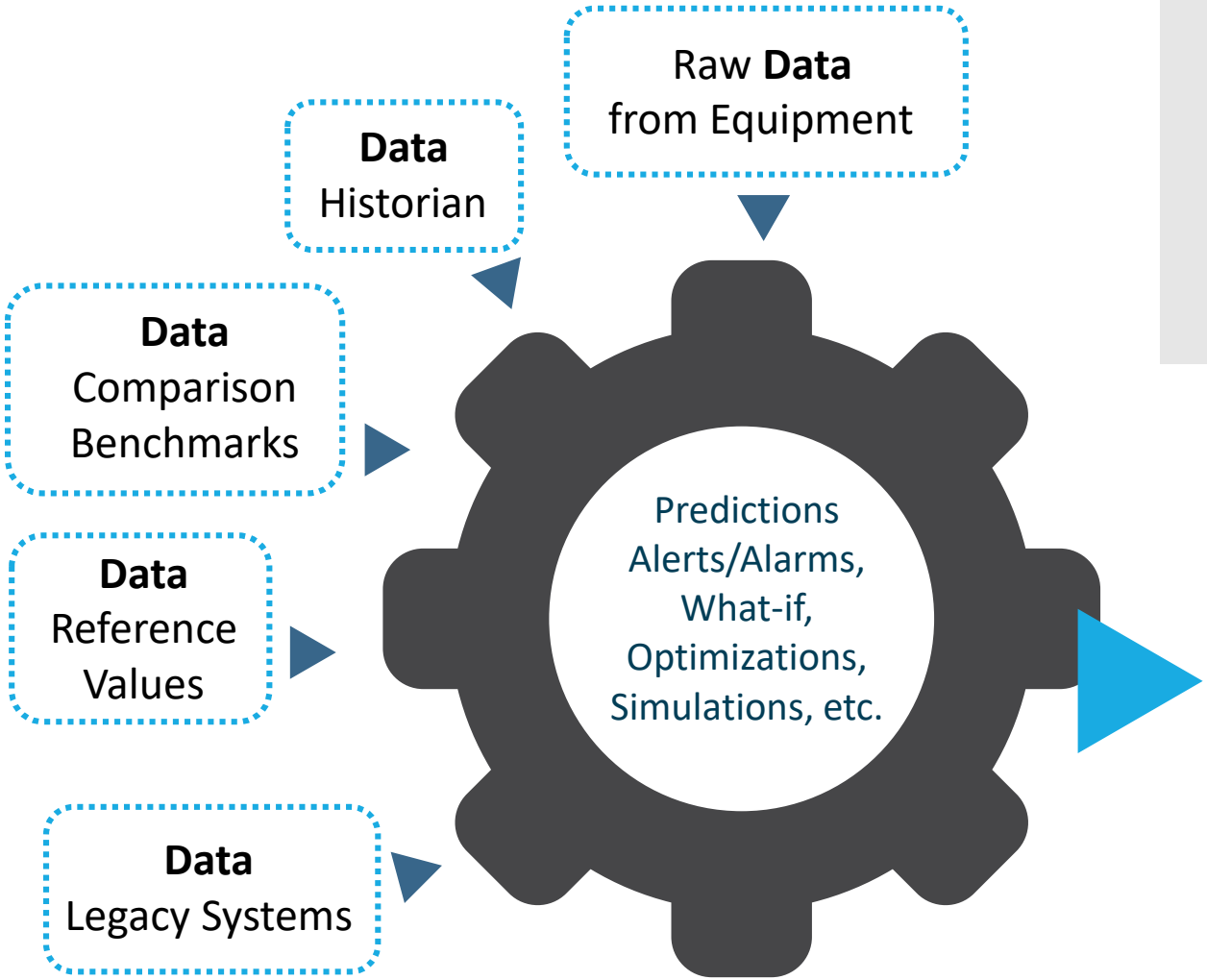
Data Availability

Data Storage

Data Standardization and harmonization

Data Reliability → Golden Rule: garbage in garbage out

Mandatory steps towards Artificial Intelligence



ARTIFICIAL INTELLIGENCE AND MAINTENANCE

Artificial Intelligence can be beneficial to maintenance for:

- Detect the early stages of a failure
- Predict when a failure will occur
- Calculation of equipment RULs (Remaining Useful Life)

DATA!!!

DATA RELIABILITY Crucial point

THREATS

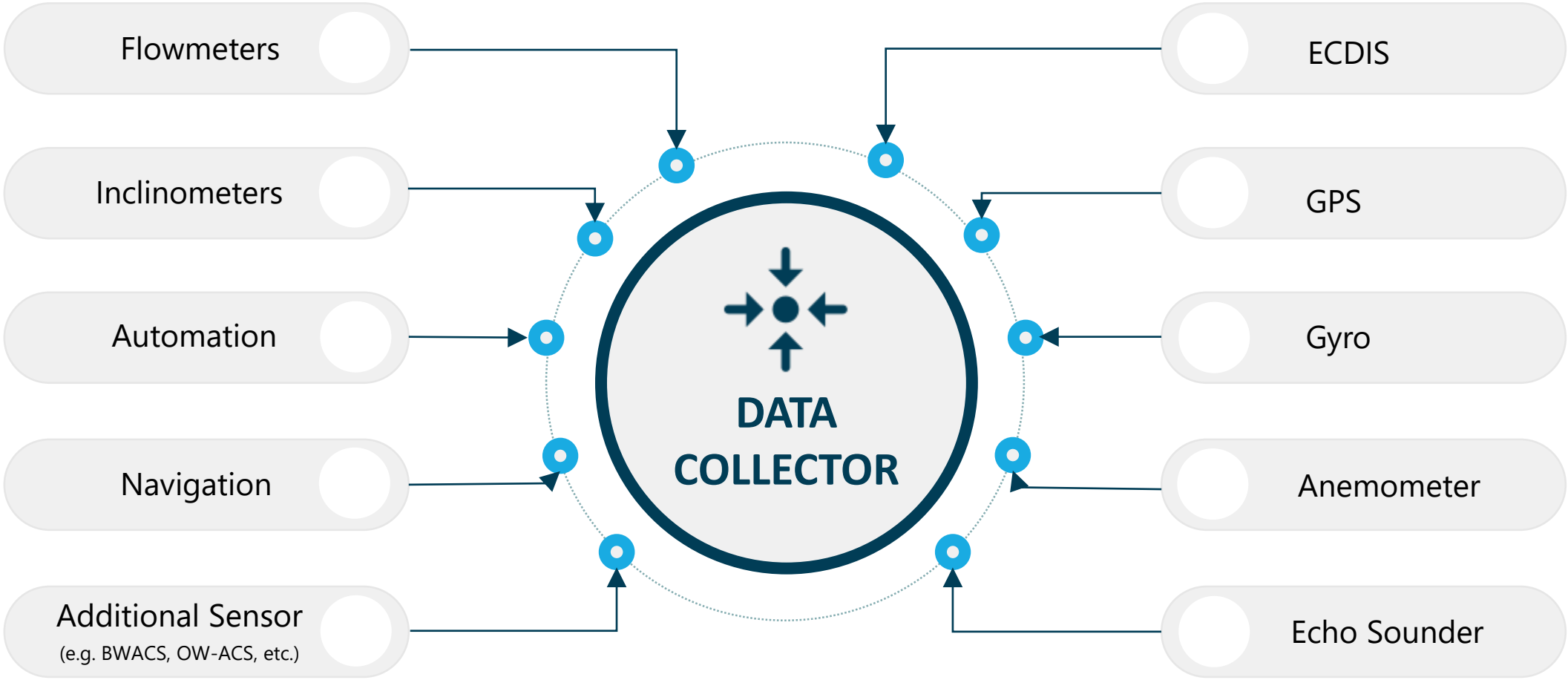
TECHNICIAN DATA (HUMAN CENTERED):

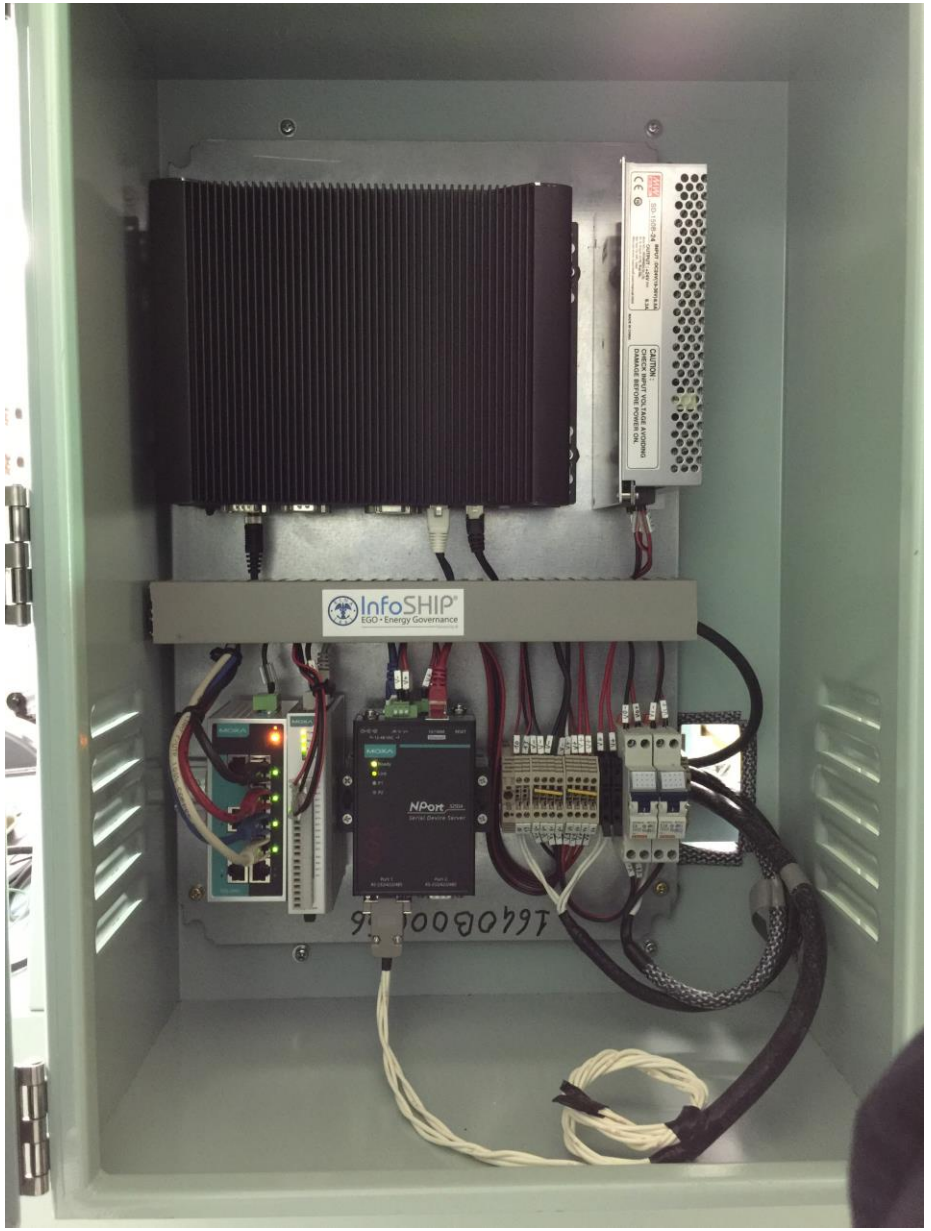
not homogeneous information, «poor» or useless, not properly encoded, no cross relations

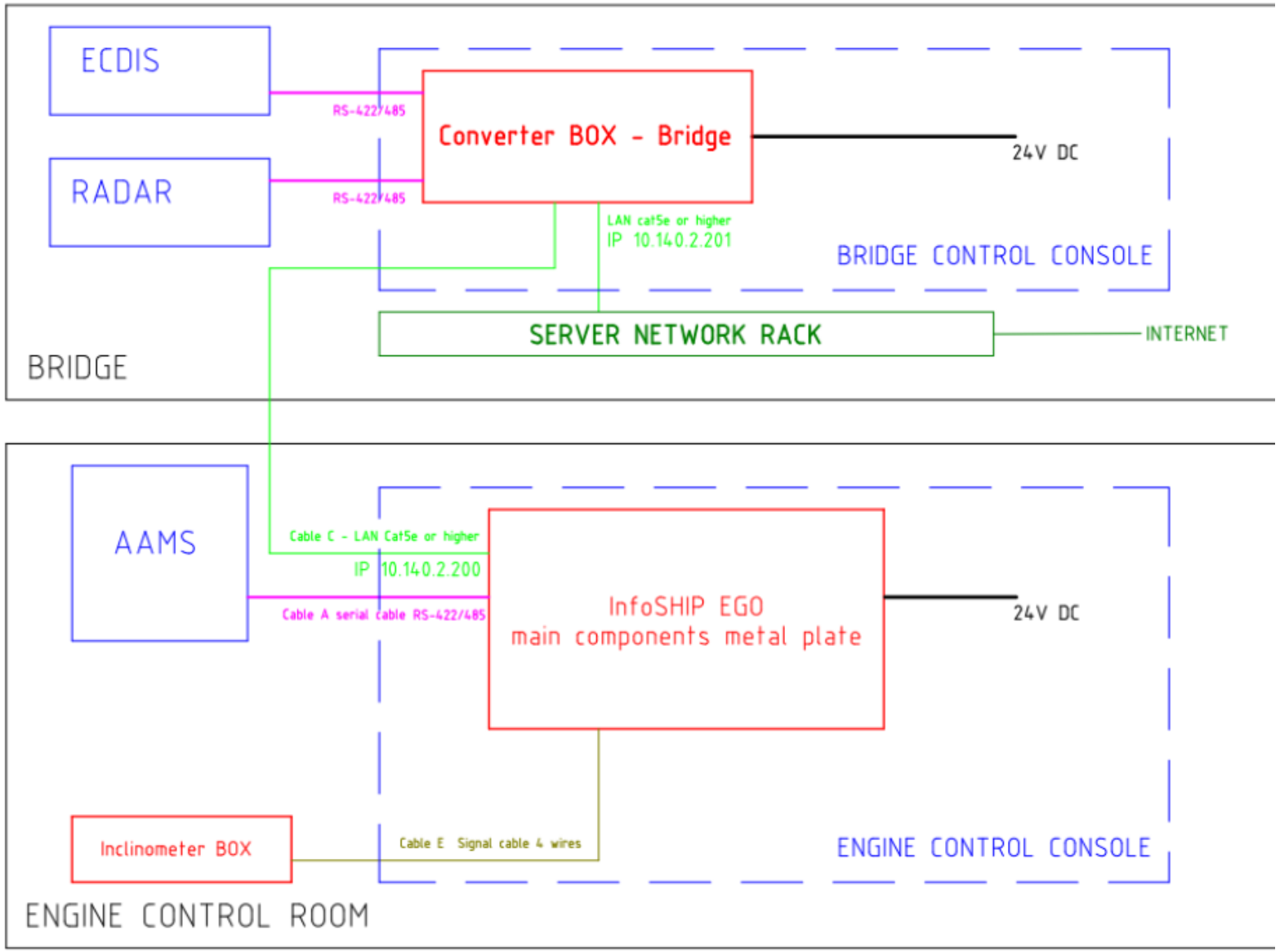
EQUIPMENT SENSOR DATA (AUTOMATION CENTERED):

Qualitative and quantitative poor information (availability, historian, no. of tags or sensors, lack of cross relation, sensors failures)

Vessel kit - Components




InfoSHIP
EGO - Energy Governance
NPort


ECDIS
RADAR
RS-422/485
RS-422/485
Converter BOX - Bridge
24V DC
LAN cat5e or higher
IP 10.140.2.201
BRIDGE CONTROL CONSOLE
SERVER NETWORK RACK
INTERNET
BRIDGE
AAMS
Cable C - LAN Cat5e or higher
IP 10.140.2.200
Cable A serial cable RS-422/485
InfoSHIP EGO
main components metal plate
24V DC
Inclinometer BOX
Cable E Signal cable 4 wires
ENGINE CONTROL CONSOLE
ENGINE CONTROL ROOM

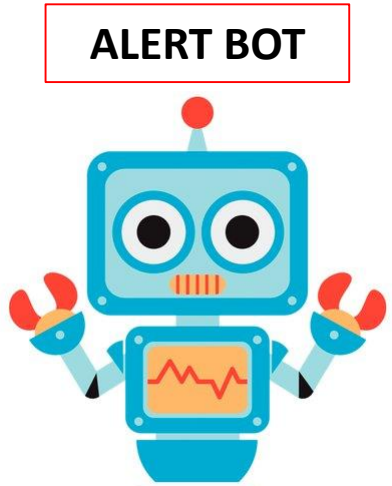
List of signals

NAVIGATION	Signal	Source (expected)	Expected Unit of measure
	Date and Time - ZDA	GPS	according to NMEA0183
	Geographic position - GGA or GLL	GPS	according to NMEA0183
	Track and ground speed - VTG	GPS	according to NMEA0183
	Heading - HDT	Gyro	according to NMEA0183
	Rate of Turn - ROT	Gyro	according to NMEA0183
	Water speed - VBW	Speed Log	according to NMEA0183
	Wind speed and angle/type - MWV	Anemometer	according to NMEA0183
	Depth below transducer - DBT	Echo Sounder	according to NMEA0183
	Waypoint(s) - WPT	ECDIS	according to NMEA0183
	Route - RTE	ECDIS	according to NMEA0183

AUTOMATION	Signal	Source	Expected Unit of measure
	Port Shaft RPM	Automation	rpm
	Stbd Shaft RPM	Automation	rpm
	Port Shaft Power	Automation	kW
	Stbd Shaft Power	Automation	kW
	Port Shaft Generator Status	Automation	boolean
	Stbd Shaft Generator Status	Automation	boolean
	Port Propeller Pitch	Automation	%
	Stbd Propeller Pitch	Automation	%
	Port Shaft Generator Power	Automation	kW
	Stbd Shaft Generator Power	Automation	kW
	Port Main Engine Status	Automation	boolean
	Stbd Main Engine Status	Automation	boolean
	Port Main Engine Load	Automation	%
	Stbd Main Engine Load	Automation	%
	Port Main Engine RPM	Automation	rpm
	Stbd Main Engine RPM	Automation	rpm
	Main Engine Fuel Consumption	Automation	t/h
	Main Engine Fuel in use MDO	Automation	
	Main Engine Fuel in use HFO	Automation	
	Draft aft	Automation	m
	Draft center port	Automation	m
	Draft center starboard	Automation	m
	Draft fore	Automation	m
	Boiler status	Automation	boolean
	Boiler fuel consumption	Automation	%
	DG 1 Power	Automation	kW
	DG 2 Power	Automation	kW
	DG 1 Status	Automation	boolean
	DG 2 Status	Automation	boolean
	DG Fuel in use (HFO, MDO, MGO etc.)	Automation	??
	DG Fuel Consumption	Automation	t/h
	Speed Through Water	Automation	Kn

AUTOMATIC DATA COLLECTION False positive mitigation– self quality check

3 levels of sensor value quality check:

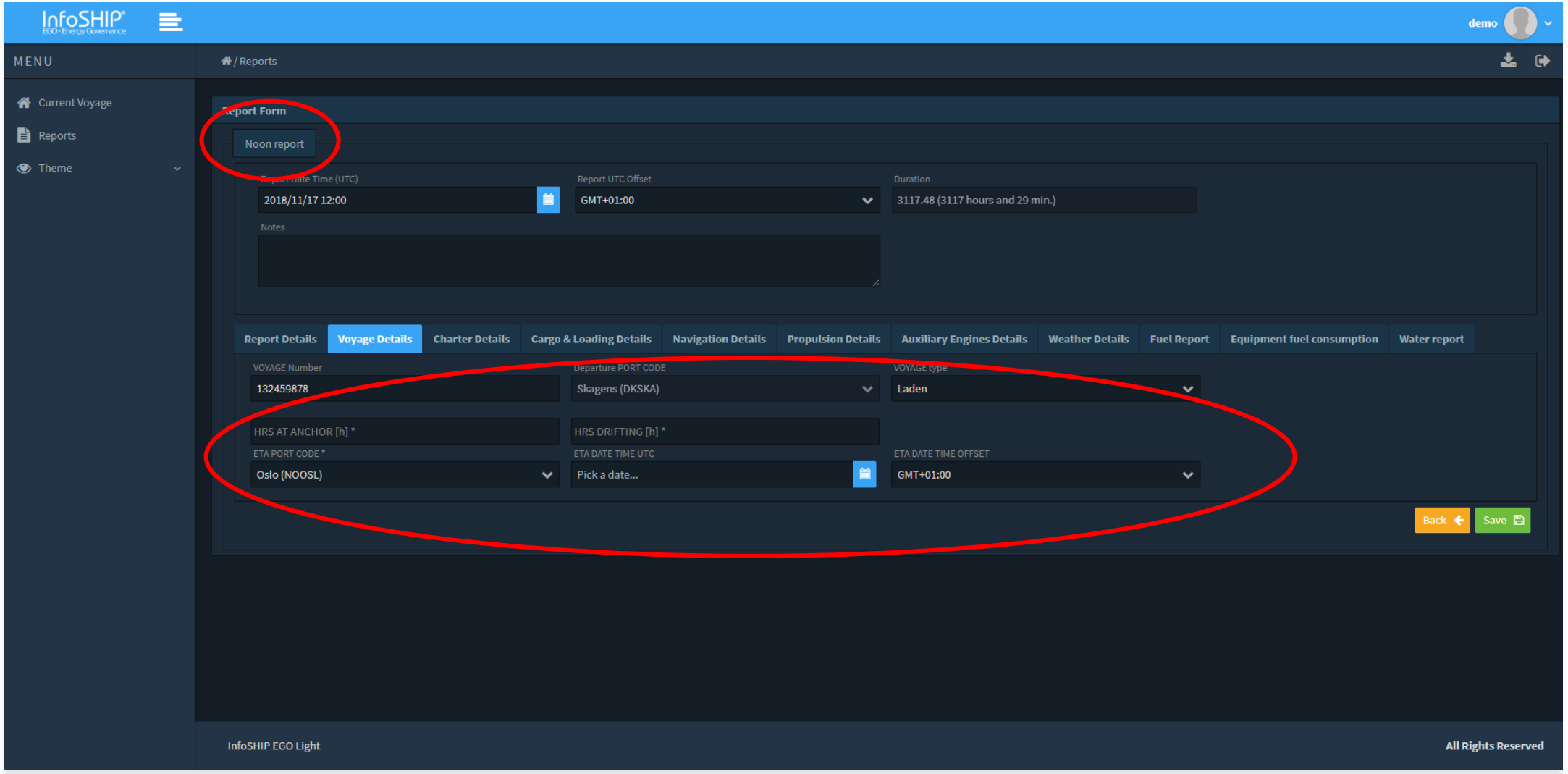


Signal Missing

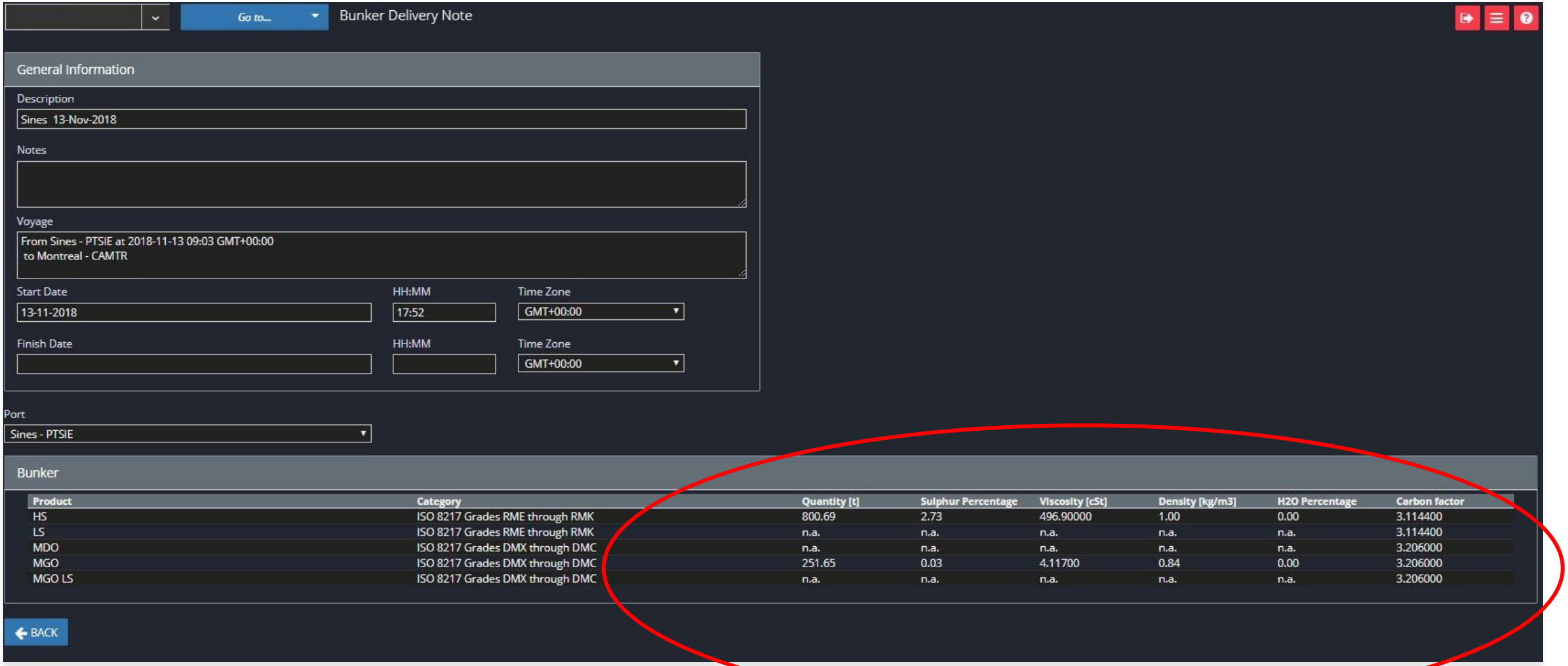
Signal out of Expected range

Specific controls
(e.g. STW – SOG > 5 knots)
--> 1 of the 2 sensors is not working properly

MANUAL DATA COLLECTION → OPERATION DATA



MANUAL DATA COLLECTION → OPERATION DATA



Product	Category	Quantity [t]	Sulphur Percentage	Viscosity [cSt]	Density [kg/m3]	H2O Percentage	Carbon factor
HS	ISO 8217 Grades RME through RMK	800.69	2.73	496.90000	1.00	0.00	3.114400
LS	ISO 8217 Grades RME through RMK	n.a.	n.a.	n.a.	n.a.	n.a.	3.114400
MDO	ISO 8217 Grades DMX through DMC	n.a.	n.a.	n.a.	n.a.	n.a.	3.206000
MGO	ISO 8217 Grades DMX through DMC	251.65	0.03	4.11700	0.84	0.00	3.206000
MGO LS	ISO 8217 Grades DMX through DMC	n.a.	n.a.	n.a.	n.a.	n.a.	3.206000

MANUAL DATA COLLECTION → CMMS

FULL OVERHAUL OF CYLINDER COVER, LINER AND PISTON

View | Edit | Print | Close | ...

Tasks | Meters | Attachments | Logistic | Purchases | History

Tasks

New Task | Link WR | DEFERRED | IN PROGRESS - RESTART | ON HOLD | COMPLETED | CANCELLED

TASK	DESCRIPTION	LOCATION	ROUTE	LAST WO	STATUS	PHASE
1	FULL OVERHAUL OF CYLINDER COVER, LINER AND PISTON	ME - Cylinder cover w/valves, piston and liner 01		12-01-2017	PLANNED	
2	FULL OVERHAUL OF CYLINDER COVER	ME - Cylinder cover w/valves, piston and liner 01		12-01-2017	PLANNED	
3	FULL OVERHAUL OF PISTON	ME - Cylinder cover w/valves, piston and liner 01		12-01-2017	PLANNED	
4	FULL OVERHAUL OF CYLINDER LINER	ME - Cylinder cover w/				

- PLANNED
- 22-09-2018 15:09:06 GMT+02:00
- 2018-RIG-PM-0092
- PLANNED MAINTENANCE
- Ship RIGEL
- CRITICAL
- ENGINE Department
- Location Downtime
- Location Failure
- ME - Cylinder cover w/valves, piston and liner 01

JOB INSTRUCTIONS

CHECK FOR BURNED GROOVES AT FUEL VALVE NOZZLE HOLES. WELD-UP IF REQUIRED.

CHECK LIST | ITEMS | TOOLS

TASK 2 FULL OVERHAUL OF CYLINDER COVER - FULL OVERHAUL OF CYLINDER COVER

Activity FULL OVERHAUL - Cylinder cover

Location ME - Cylinder cover w/valves, piston and liner 01 - 40020 - Cylinder Cover

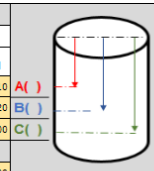
Measurement FULL OVERHAUL - GENERIC - Generic Full Overhaul

Date

- FULL OVERHAUL
- FULL OVERHAUL OF CYLINDER COVER, LINER AND PISTON
- ENGINE Department
- CHIEF ENGINEER

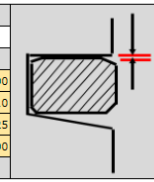
MEASUREMENT OF CYLINDER LINER

Measure point	Cylinder Number	1		2		3		4		5		6	
	Max allowable wear	Forward Ahead	Port Starboard	Forward Ahead	Port Starboard	Forward Ahead	Port Starboard	Forward Ahead	Port Starboard	Forward Ahead	Port Starboard	Forward Ahead	Port Starboard
A( )	320.80	320,000	320,050	320,010	320,040	320,030	320,020	320,060	320,000	320,070	320,080	320,100	320,010
B( )	320.50	321,000	320,650	320,000	320,650	320,400	320,500	320,150	320,030	320,045	320,600	320,100	320,020
C( )	320.30	320,100	320,100	320,100	320,100	320,000	320,000	320,000	320,000	320,000	320,000	320,000	320,000
Liner Temp.°C		24,00		21,00		20,00		24,00		22,00		23,00	



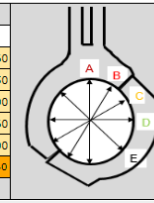
PISTON RING AND SCRAPER RING GROOVE CLEARANCE

Measure point	Cylinder Number	1	2	3	4	5	6
	Max clearance						
Piston ring Groove No.1	0.45	0,400	0,300	0,350	0,450	0,400	0,400
Piston ring Groove No.2	0.45	0,350	0,420	0,360	0,420	0,400	0,410
Piston ring Groove No.3	0.45	0,400	0,425	0,400	0,360	0,420	0,425
Scraper ring Groove	0.45	0,400	0,400	0,420	0,400	0,430	0,400



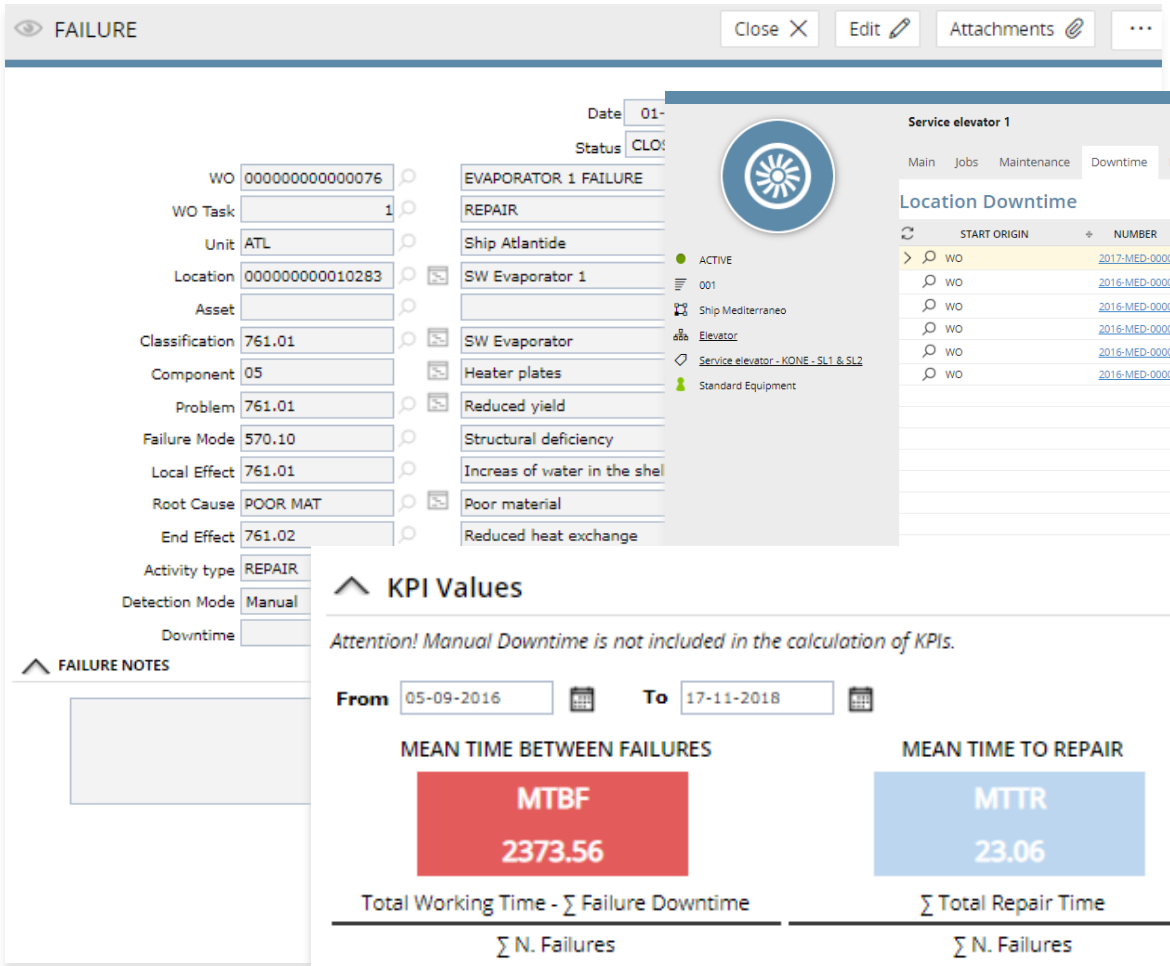
CONNECTING ROD OVALNESS

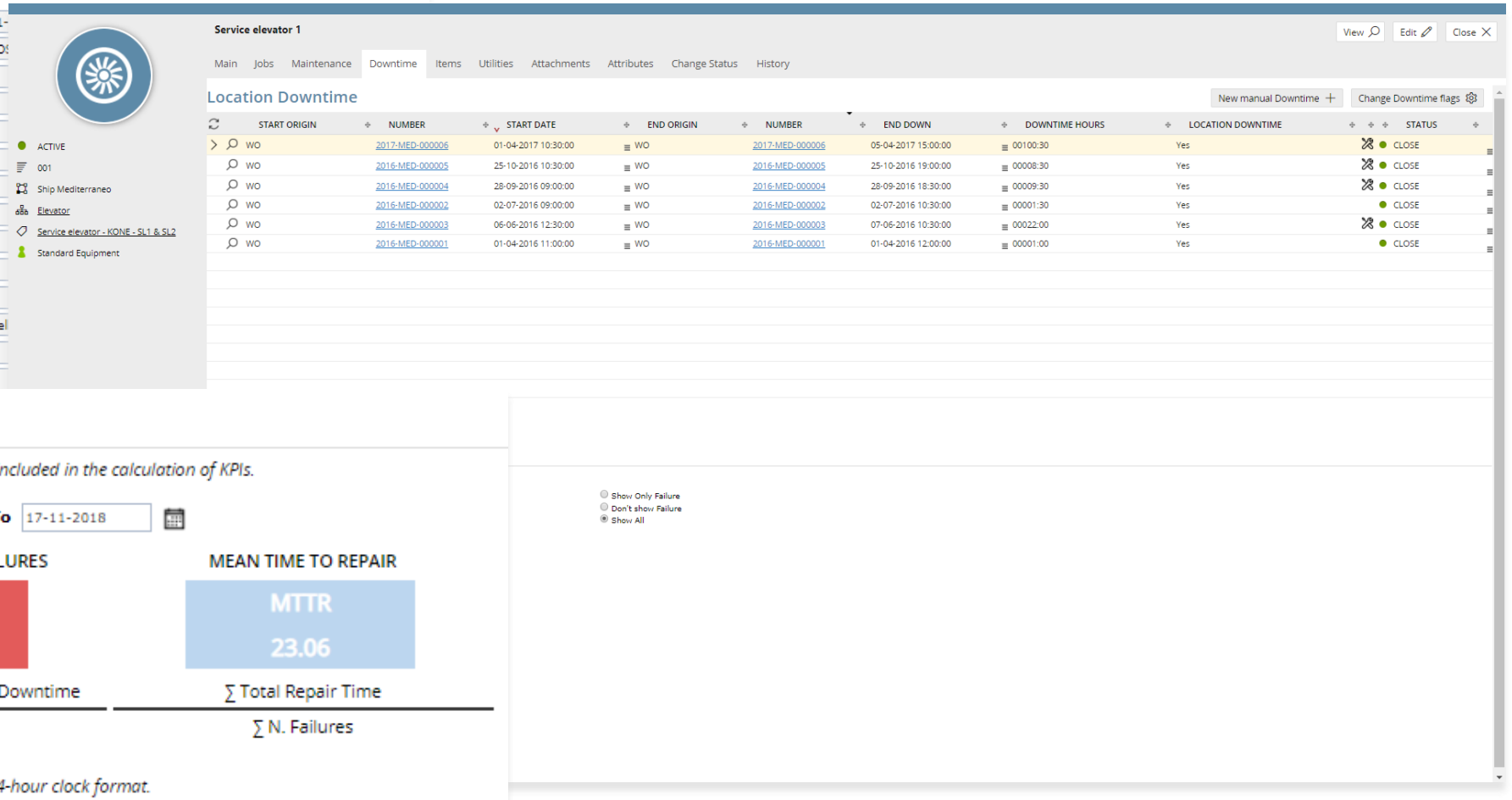
Measure point	Cylinder Number	1	2	3	4	5	6
A		324,950	325,000	324,060	324,960	324,000	324,960
B		324,950	324,950	324,200	324,200	324,080	324,950
C		324,200	325,000	324,200	324,200	324,060	324,200
D		324,950	324,950	324,060	324,950	324,080	324,960
E		324,200	324,950	324,500	324,200	324,080	324,200
Diff. between min/max	min/max 0.080	0,750	0,050	0,440	0,760	0,080	0,760



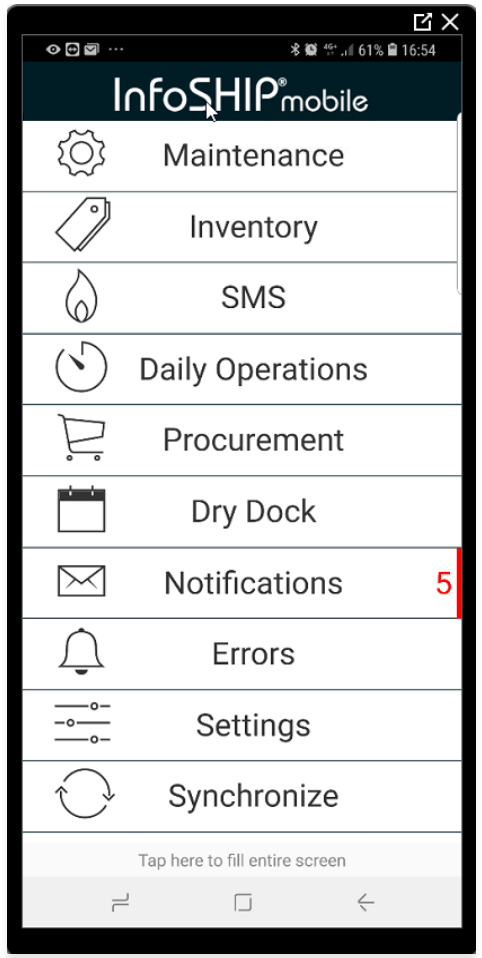
All measurements values should be stored in a db

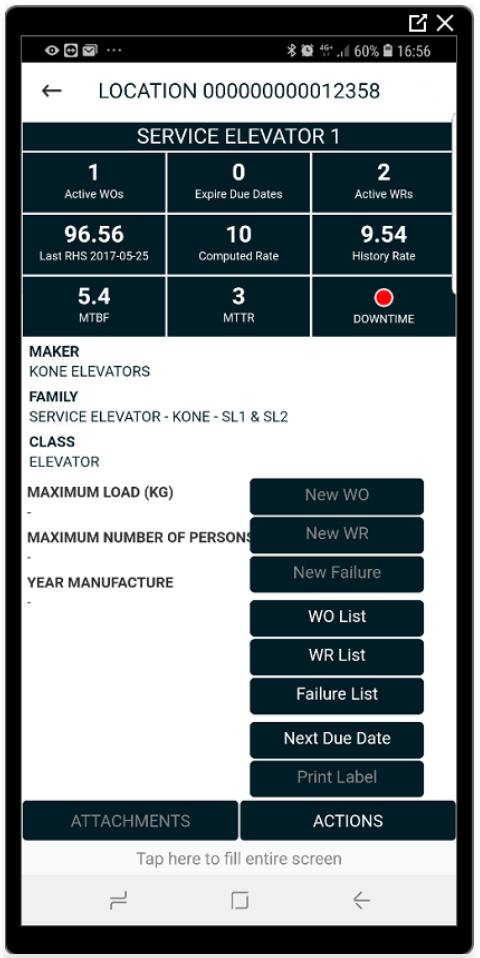
MANUAL DATA COLLECTION → CMMS

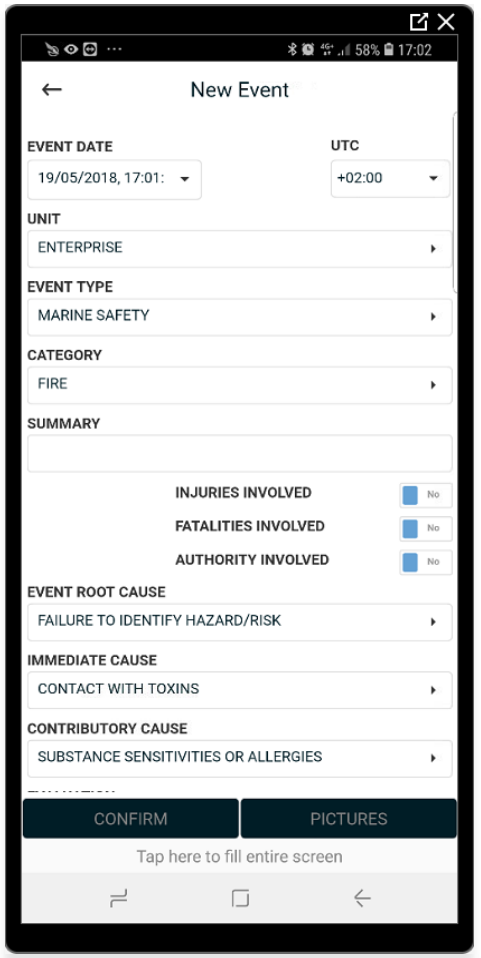




MANUAL DATA COLLECTION

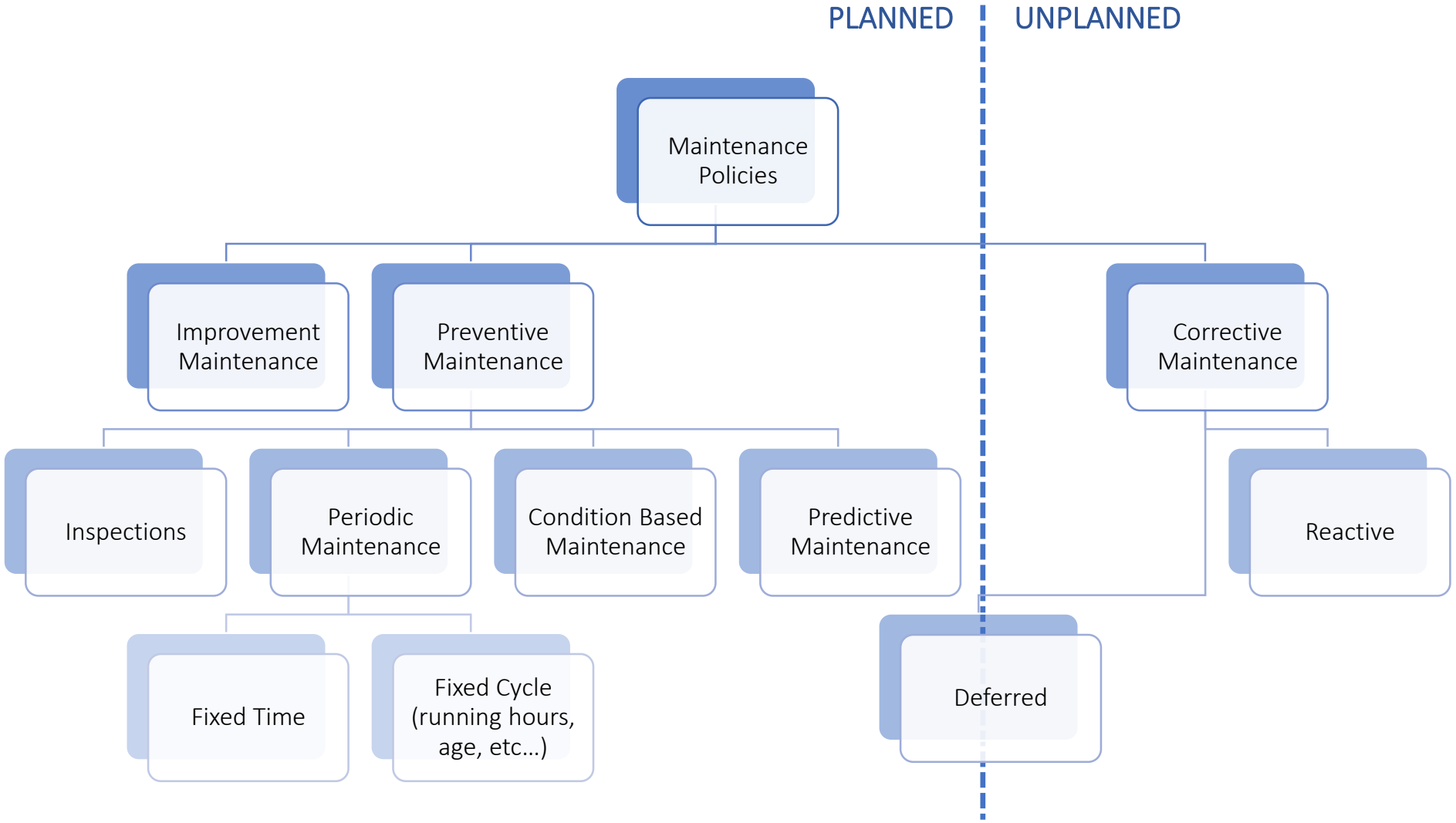


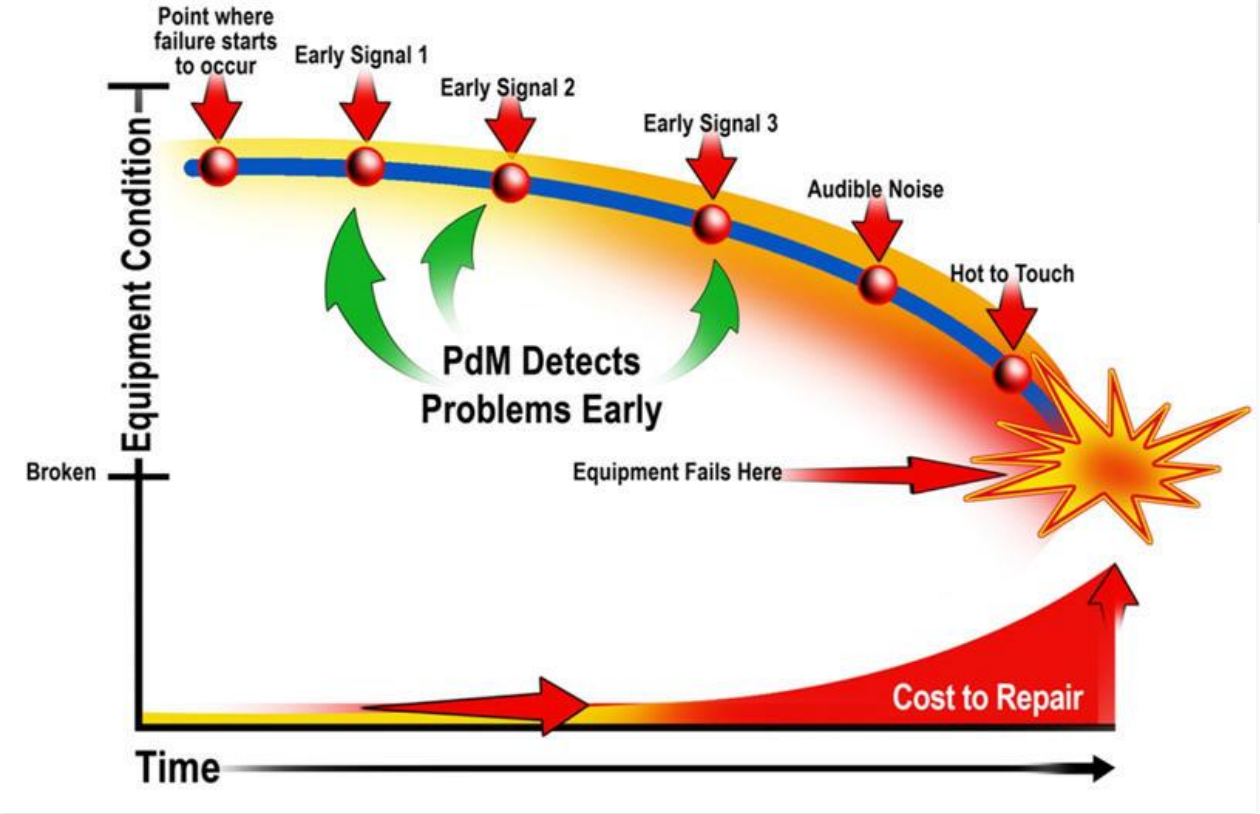




3. Predictive Maintenance

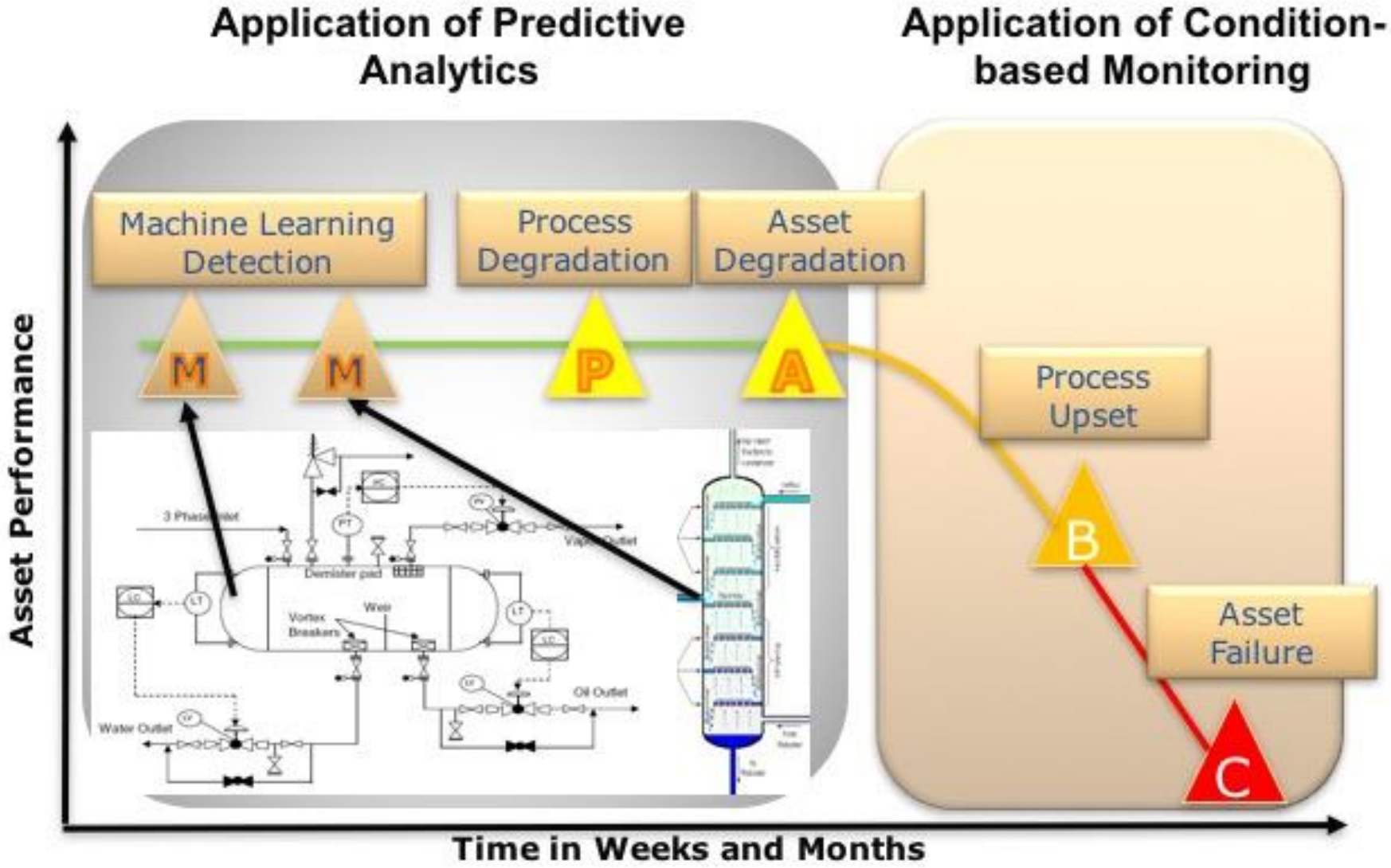
Definition


PLANNED
UNPLANNED
Maintenance Policies
Improvement Maintenance
Preventive Maintenance
Corrective Maintenance
Inspections
Periodic Maintenance
Condition Based Maintenance
Predictive Maintenance
Reactive
Fixed Time
Fixed Cycle (running hours, age, etc…)
Deferred



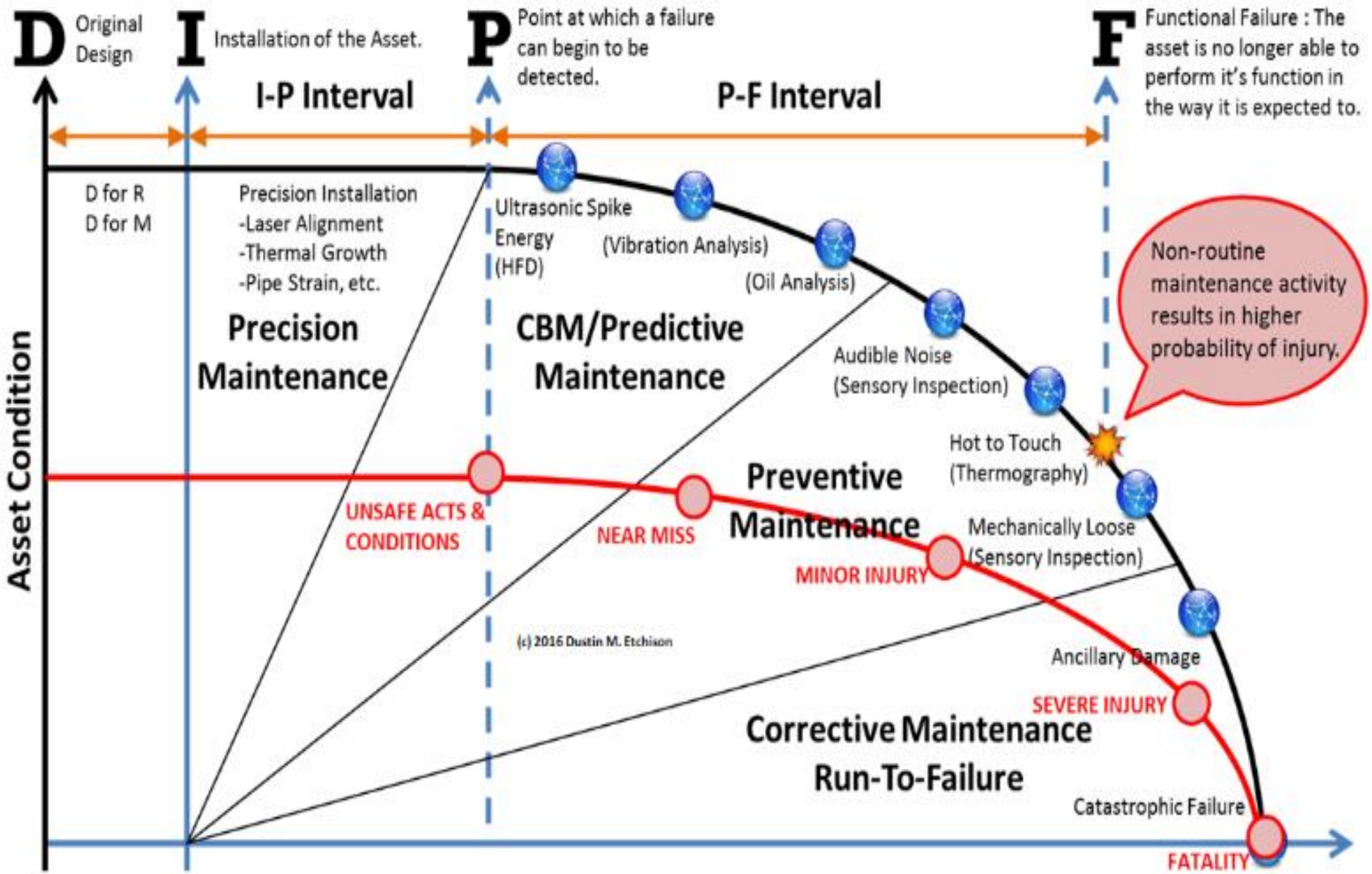
PREDICTIVE MAINTENANCE

Predictive maintenance (PdM) techniques are designed to help determine the condition of in-service equipment in order to predict when maintenance should be performed.

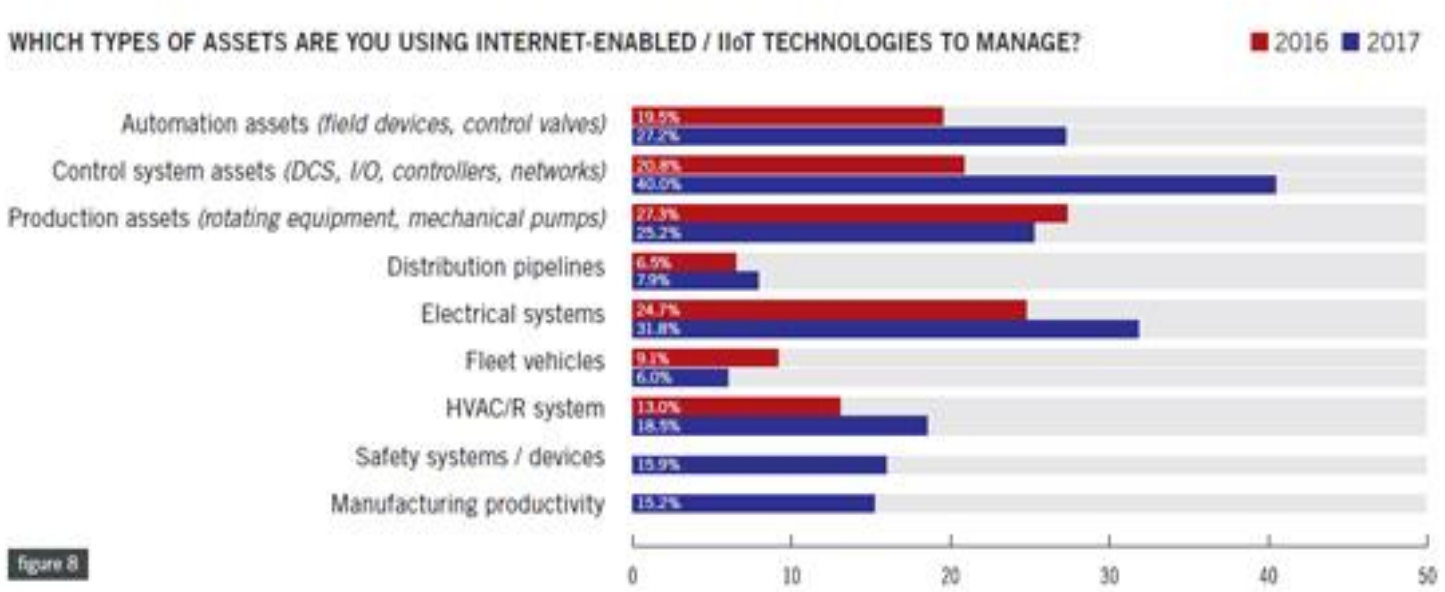

Application of Predictive Analytics
Application of Condition-based Monitoring
Machine Learning Detection
Process Degradation
Asset Degradation
M
M
P
A
Process Upset
B
Asset Failure
C
Asset Performance
Time in Weeks and Months

Predictive maintenance techniques

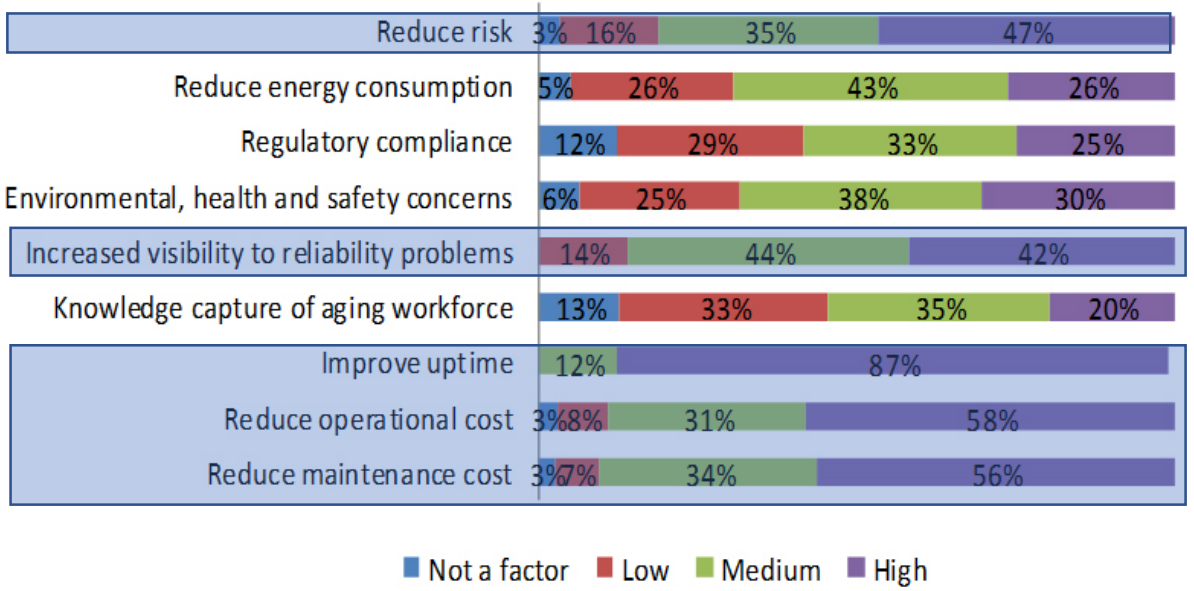
- Vibration monitoring
- Oil Analysis
- Infrared
- Corrosion
- Ultrasonic
- Acoustic
- Maintenance Techniques (RBI, RCM, FMEA, etc.)
- Condition Monitoring in EAM/CMMS
- Predictive Software Modeling


D
Original Design
I
Installation of the Asset.
P
Point at which a failure can begin to be detected.
F
Functional Failure : The asset is no longer able to perform it's function in the way it is expected to.
I-P Interval
P-F Interval
Asset Condition
D for R
D for M
Precision Installation
-Laser Alignment
-Thermal Growth
-Pipe Strain, etc.
Precision Maintenance
Ultrasonic Spike Energy (HFD)
(Vibration Analysis)
(Oil Analysis)
CBM/Predictive Maintenance
Audible Noise (Sensory Inspection)
Hot to Touch (Thermography)
Non-routine maintenance activity results in higher probability of injury.
UNSAFE ACTS & CONDITIONS
NEAR MISS
Preventive Maintenance
MINOR INJURY
Mechanically Loose (Sensory Inspection)
(c) 2016 Dustin M. Etchison
Ancillary Damage
SEVERE INJURY
Corrective Maintenance
Run-To-Failure
Catastrophic Failure
FATALITY

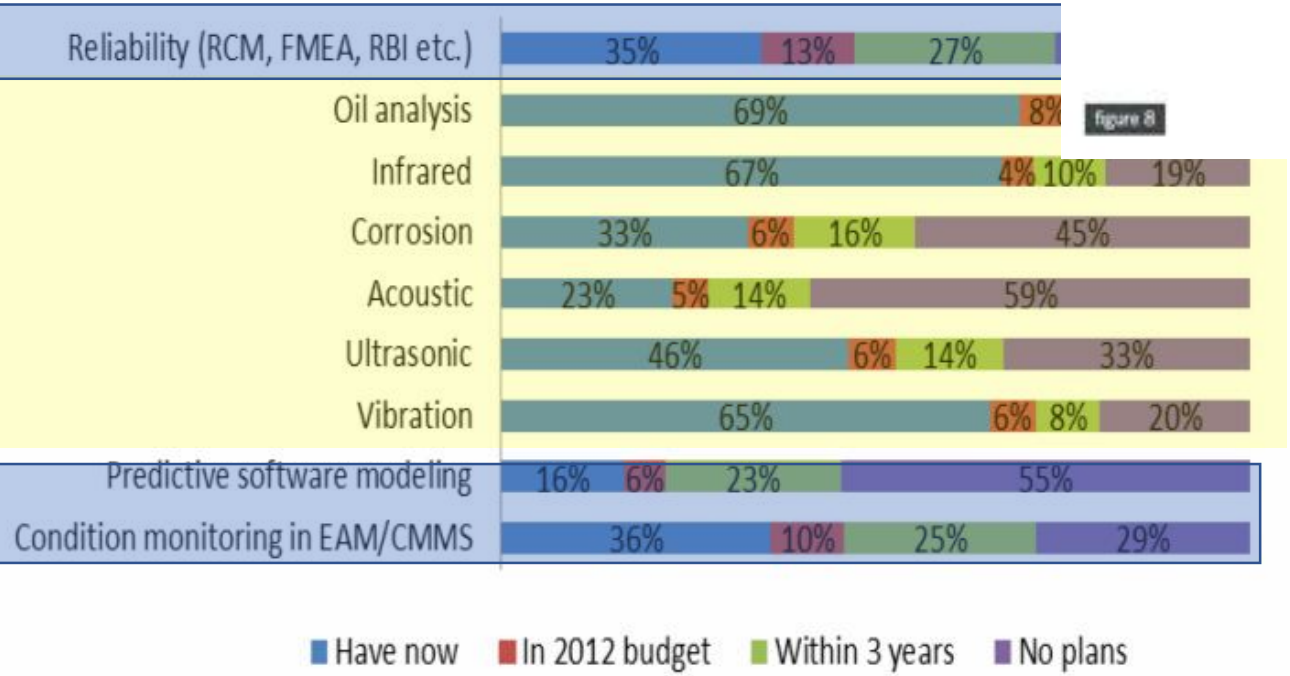
Predictive maintenance techniques evolution



Rate the drivers for deploying predictive maintenance(PdM) solutions



What PdM technologies do you deploy?



From a Gartner Group Research

Predictive Maintenance Measurement of Effectiveness

- Vibration monitoring
- Oil Analysis
- Infrared
- Corrosion
- Ultrasonic
- Acoustic
- Maintenance Techniques (RBI, RCM, FMEA, etc.)
- Condition Monitoring in EAM/CMMS
- Predictive Software Modeling

FEEDBACKS FROM FIELD
SYSTEMIC APPROACH
CROSS REFERENCE

Maintenance policy evolution – from PMS to Prescriptive

Analytics are **essentials** for a predictive maintenance adoption.

- **DESCRIPTIVE ANALYTICS** is the failure root cause detection. Diagnosis identifies the «**patterns of behaviour**»
- **PREDICTIVE ANALYTICS** permits to build a model able to forecast **when** something will fail.
- **PRESCRIPTIVE ANALYTICS** automates the **actions** to prevent the failure or malfunction.

MACHINE LEARNING can support all aforementioned cases.

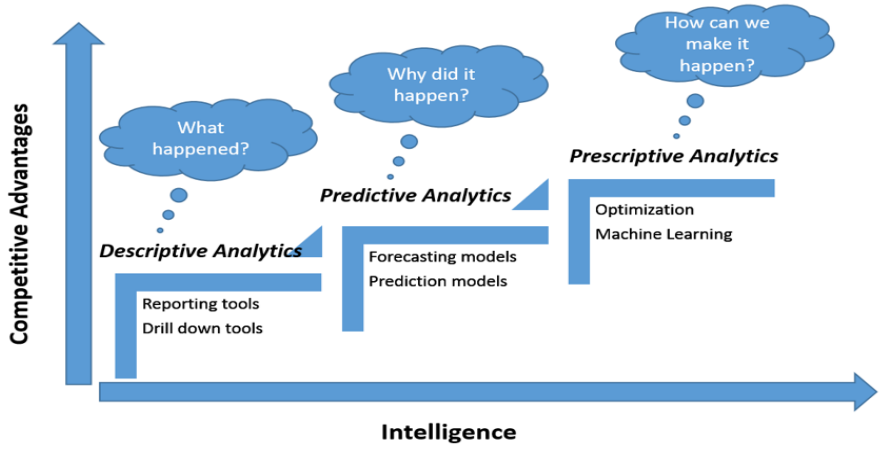
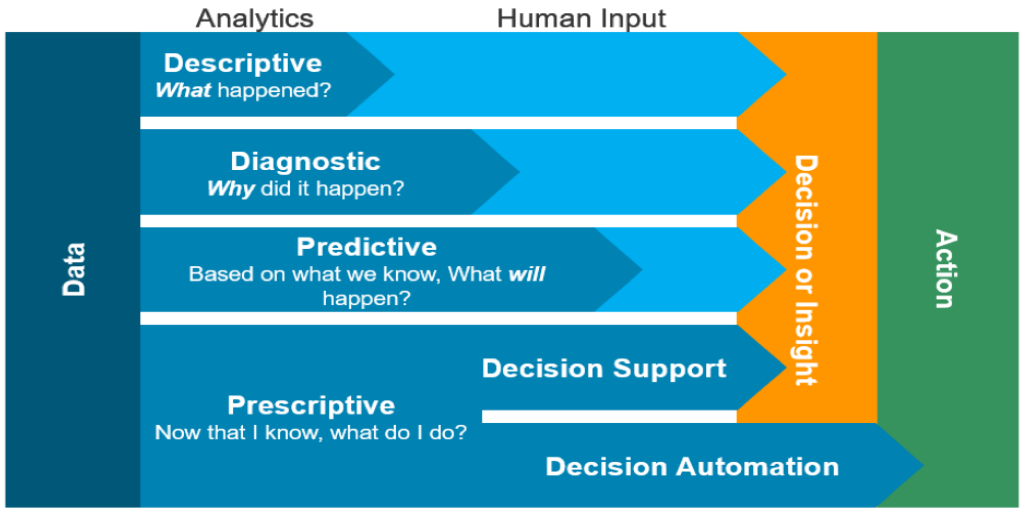


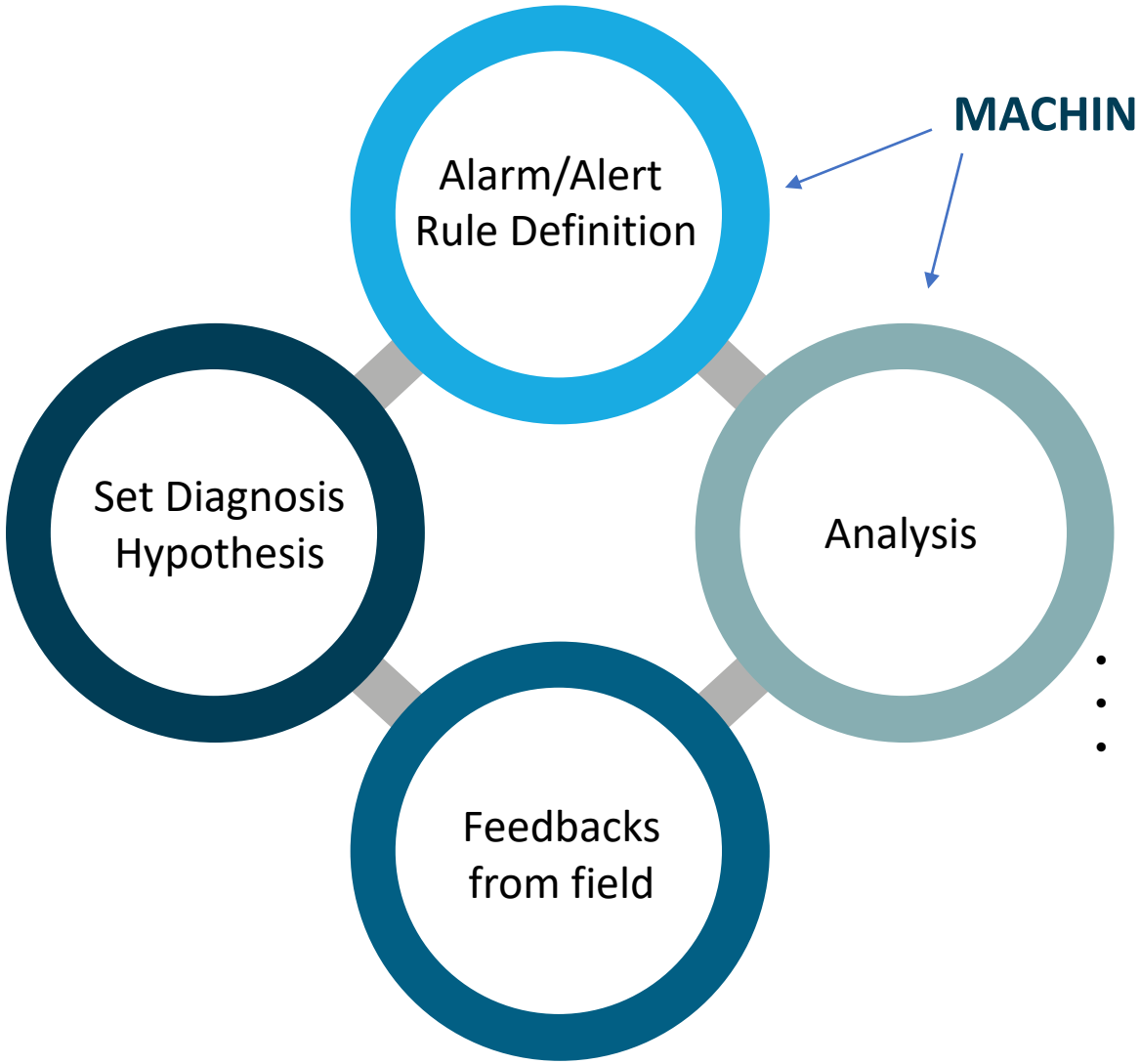
Figure 1- Evolution of Analytic Models



Adapted from Gartner Report July 2015

4. Fleet Control Room
IB vision

Alarm / Alert definition



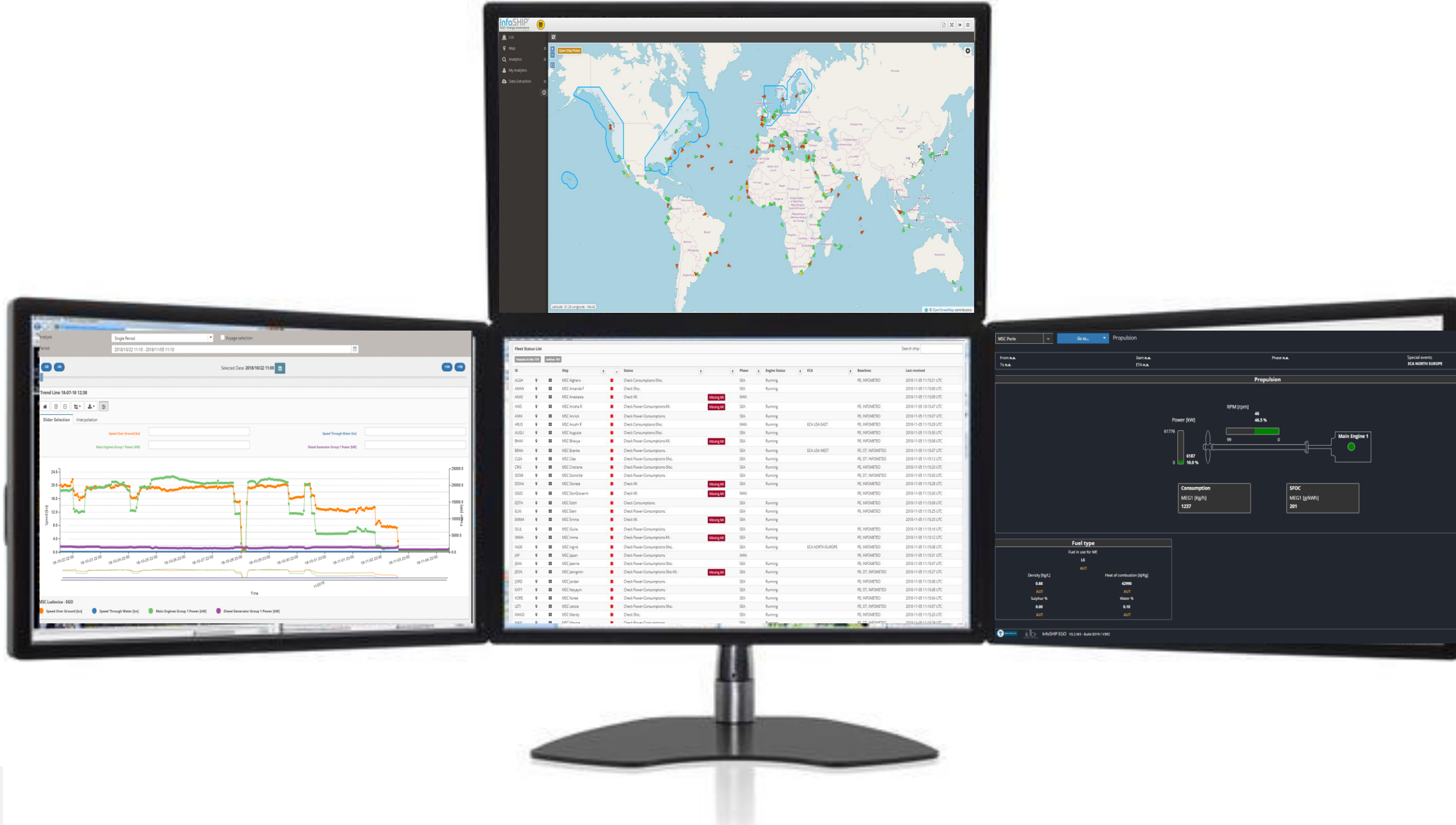
MACHINE LEARNING

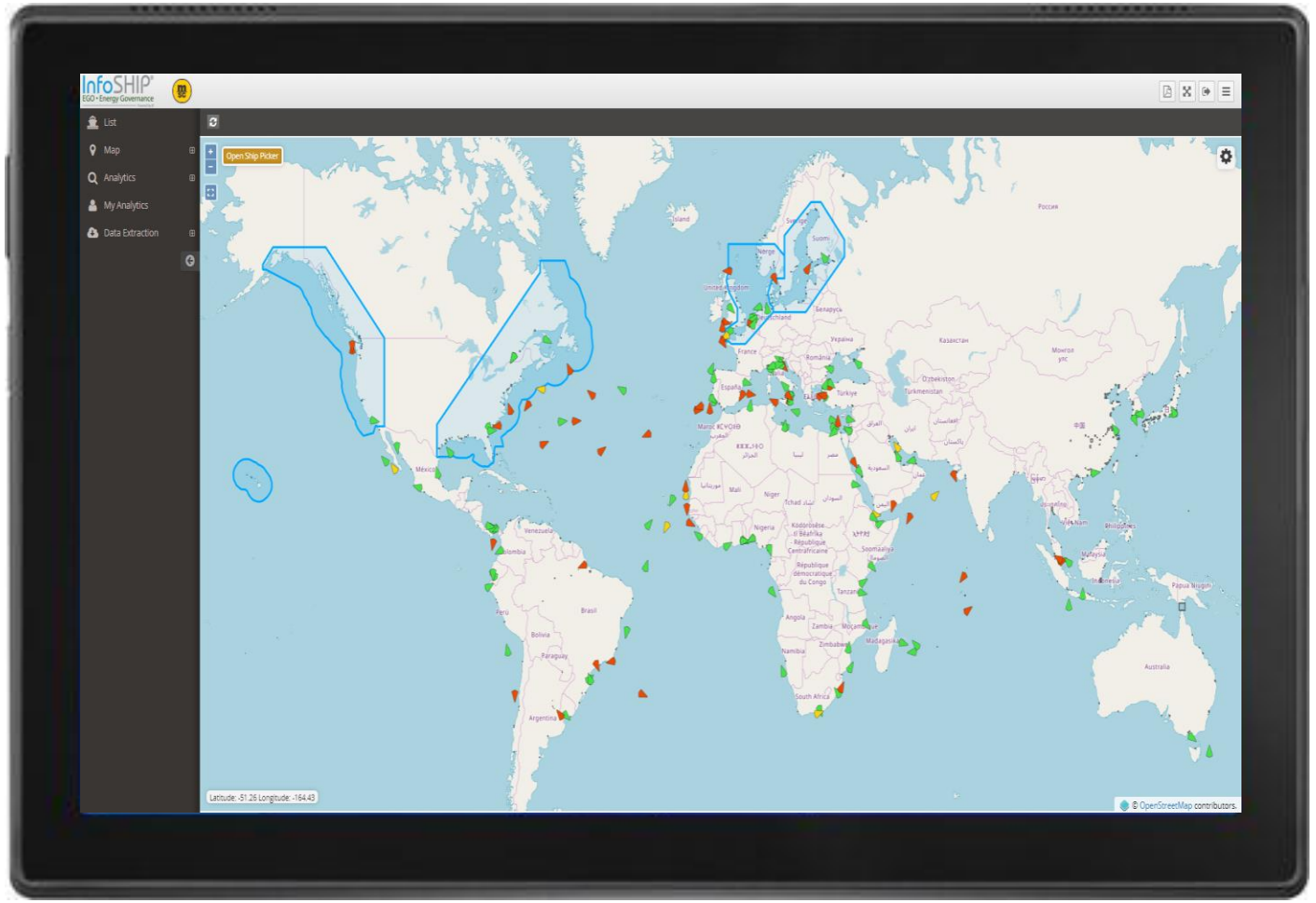
Every cycle adds new alarms/alerts rules more sophisticated reducing the no. of diagnosis hypothesis per each alarm

Theoretically trend to 1
(Pure determinism)

- Revision of thresholds
- Cleansing of Diagnosis Hypothesis
- Adjust data sources (add sensors, add information, etc.)

The primary scope is to have **less people** in front of monitors looking at data they don’t really care, but **ask the computer to drive the analysis** according to the conditions and provide precise duties to crew personnel


InfoSHIP
Open Ship Picker
Trend Line 18-07-18 12:38
Fleet Status List
MSC Perle
Propulsion
Power [kW]
RPM [rpm]
Main Engine 1
Consumption
MEG1 [Kg/h]
1237
SFOC
MEG1 [g/kWh]
201
Fuel type
Fuel in use for ME
LS
InfoSHIP EGO


InfoSHIP
EGO • Energy Governance
List
Map
Analytics
My Analytics
Data Extraction
Open Ship Picker
Latitude: -51.26 Longitude: -164.45
© OpenStreetMap contributors.

High level alerts ready “off the shelf"

- Sfoc
- Propulsive power (ship is requesting more power than expected)
- Propeller slip
- Consumption
- No. of dg running compared to optimum
- Trim
- Speed optimization
- Hull Degradation
- Emerging propeller (propeller is not fully submerged)
- Engine performance degradation
- Engine overhaul effectiveness
- Voyage schedule effectiveness
- Bad weather impact on ship route
- Charter contract clauses

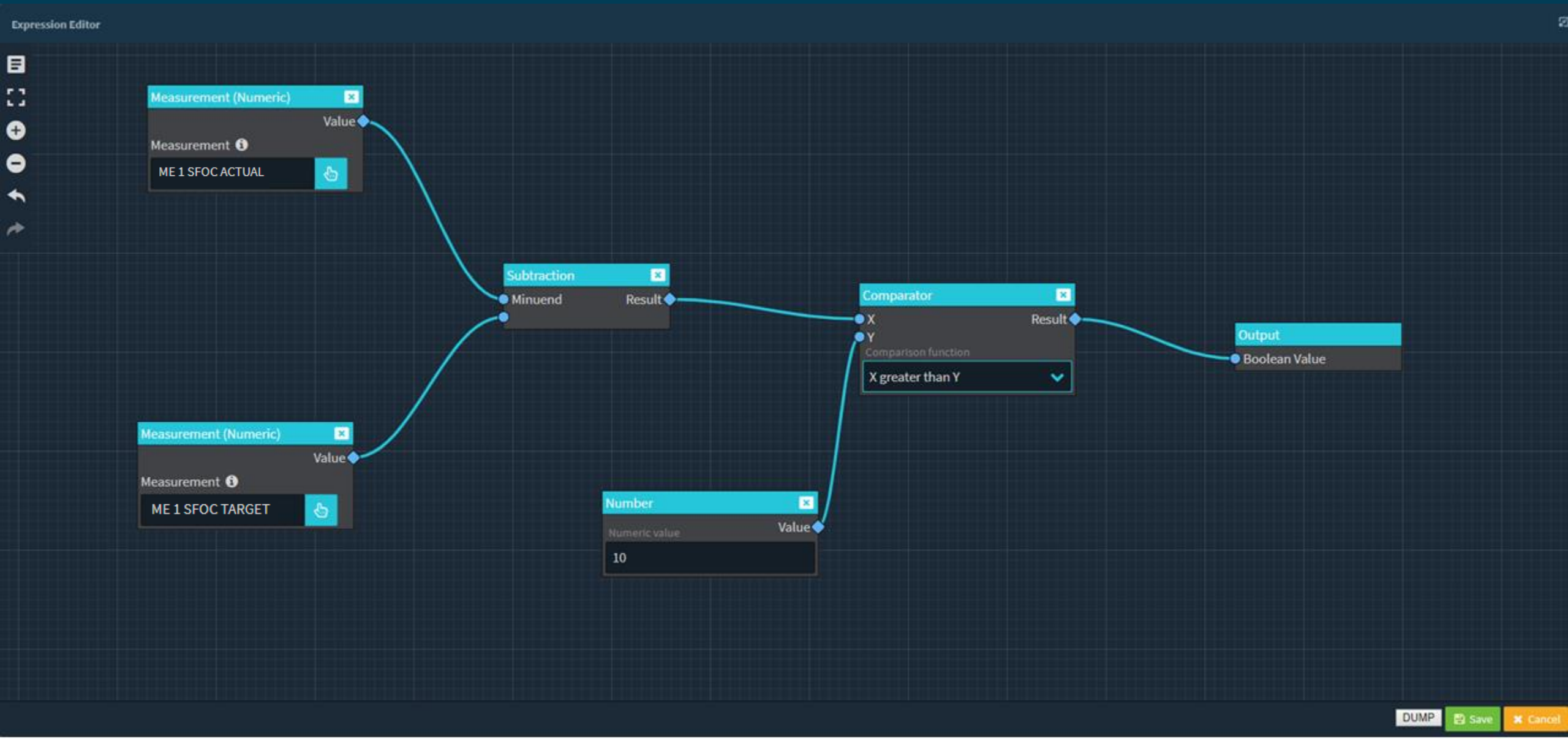
EXAMPLE – SFOC OVER THRESHOLD

SFOC DEFINITION: It stands for Specific Fuel Oil Consumption and represents one of the most important indicators for the health and efficiency of the engine.

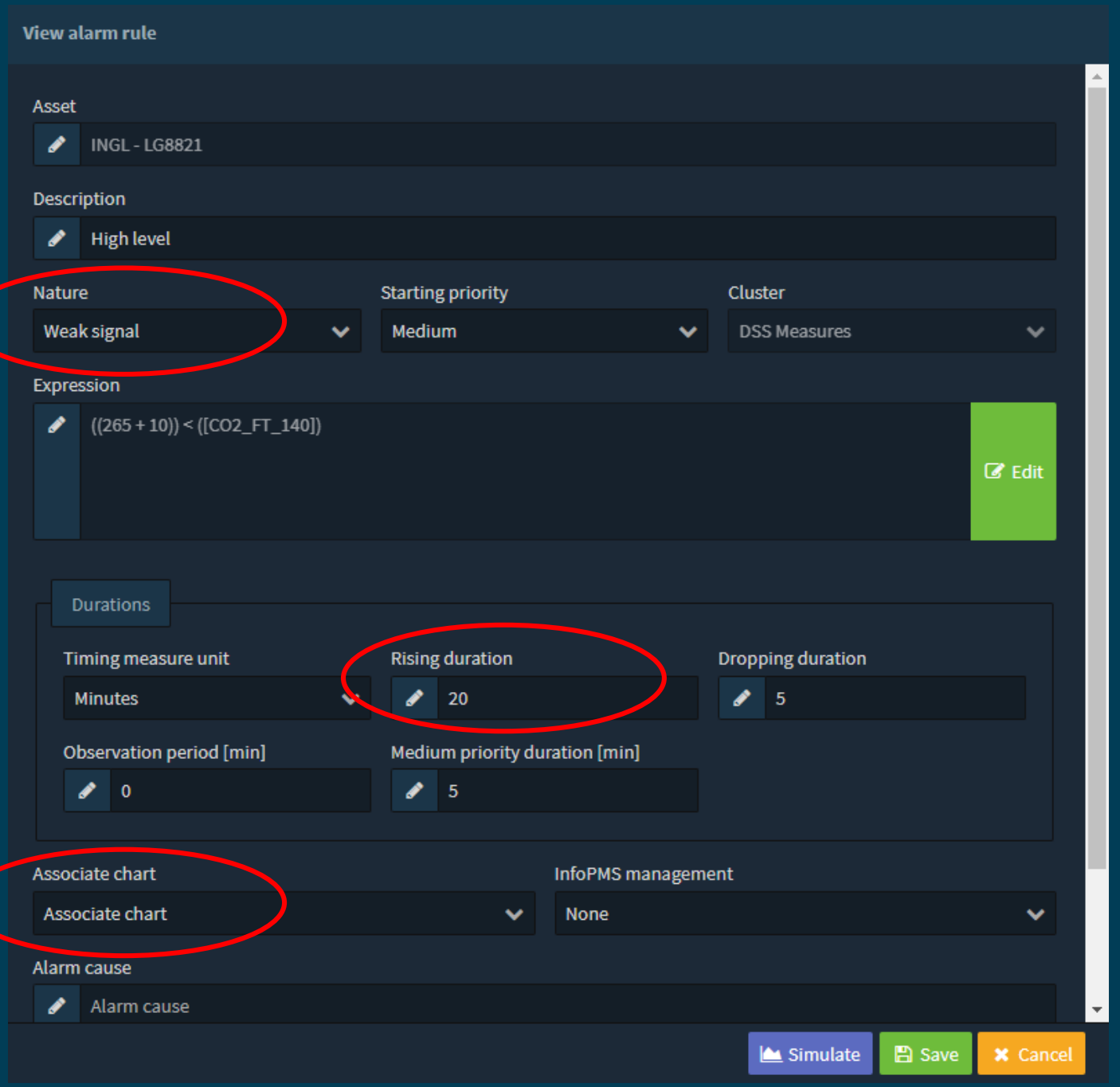
SFOC (g/kwh) = Mass of fuel consumed per hour / Power developed in kW

ALERT RULE: if my current SFOC is greater than the target (calculated by a Machine Learning Regressor Real Time) by 10 points for more than 20 minutes in steady conditions, then alert.

ALARM RULE

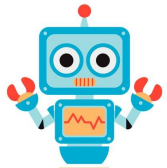

Expression Editor
Measurement (Numeric)
Value
Measurement
ME 1 SFOC ACTUAL
Subtraction
Minuend
Result
Comparator
X
Y
Result
Comparison function
X greater than Y
Output
Boolean Value
Measurement (Numeric)
Value
Measurement
ME 1 SFOC TARGET
Number
Numeric value
Value
10
DUMP
Save
Cancel

ALARM RULE


View alarm rule
Asset
INGL - LG8821
Description
High level
Nature
Weak signal
Starting priority
Medium
Cluster
DSS Measures
Expression
((265 + 10)) < ([CO2_FT_140])
Edit
Durations
Timing measure unit
Minutes
Rising duration
20
Dropping duration
5
Observation period [min]
0
Medium priority duration [min]
5
Associate chart
Associate chart
InfoPMS management
None
Alarm cause
Alarm cause
Simulate
Save
Cancel

DIAGNOSIS HYPOTHESIS DEFINITION

EXAMPLE

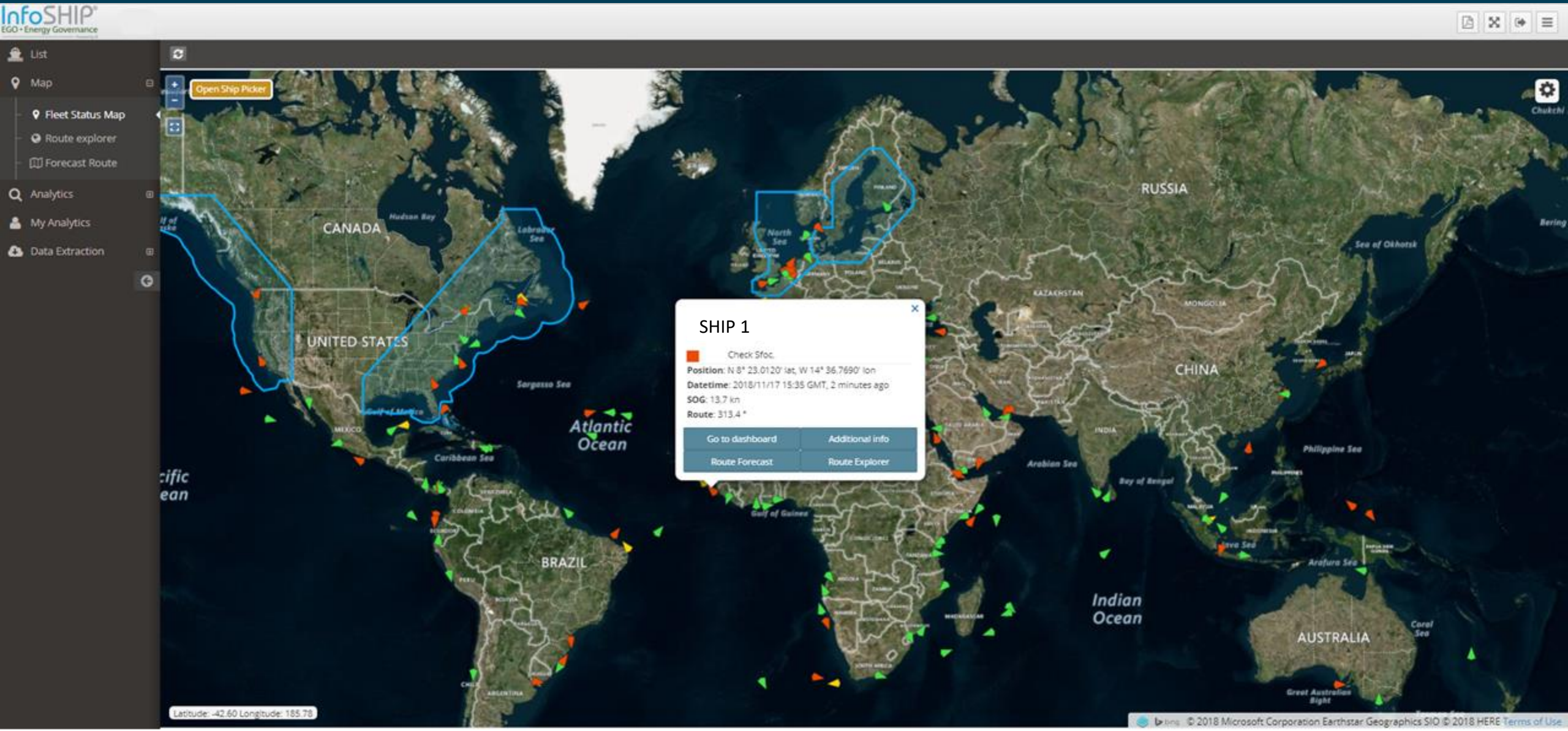


ALERT BOT

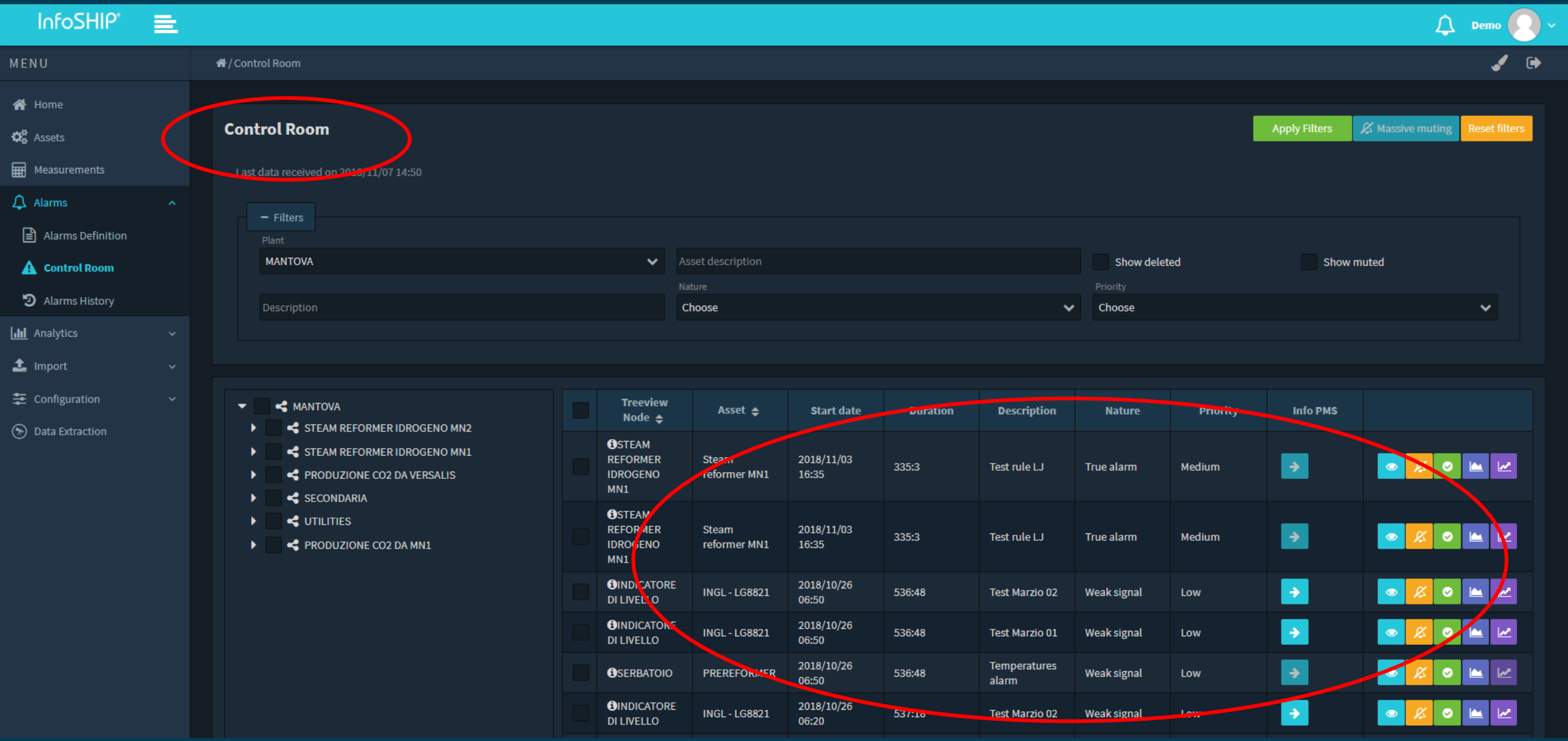
ROOT CAUSE ANALYSIS

PRELIMINARY CHECK	1st Level	2nd Level	n Level	CHECK
• Check current ship position and activity • Fuel manual inputs • Check source data signals • Check sister ships for common issue	• Maintenance issue • Equipment issue • Procedure issue	• Maintenance last jobs • Maintenance planned • Lubrication • Turbine • Compressor • Cylinder head • Missing or wrong data …	• Maintenance done on engine parts • Planned maintenance on engine parts • Lubrication system setup • Contaminated lube oil • Dirty turbine blades • Exhaust gas leaking • Waste gate setup • Compressor filter cleaning • Valve leaking • Gasket issue • Fuel data issue	• Shore: Check Last Maintenance Reports • Shore: Check Planned Maintenance • Ship: Check Lube System Setup • Shore: Check Lube Oil Analysis • Ship: Check Lube Oil Filters • Shore: Check Performance • Ship: Clean Procedure • Ship: Visual Check • Ship: Check Parameters • Shore: Check Last Done • Ship: Check Filter Status • Shore: Check Performance • Ship: Visual Check • Shore: Check Fuel Analysis

DISPLAY ALERTS OVER THE MAPS



ALERT / ALARM CONTROL ROOM



TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
SCATTER SFOC [g/kWh] 200	ENGINE PERFORMANCE DIAGRAMS	NEXT PLANNED JOB on 15/11/2018
SISTER SHIPS COMPARISON	FUEL TECH DATA Manual Inputs OK	RUNNING HOURS 5671 47% TO OVERHAUL
DIAGNOSIS HYPOTHESIS	LUBE OIL ANALISYS OK	SIMILAR EVENTS on SISTER SHIPS
SHIP ACTIVE ALERTS 12	WATER ANALISYS OK	FEEDBACK AND ROOT CAUSE

TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
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SHIP ACTIVE ALERTS 12	WATER ANALISYS OK	FEEDBACK AND ROOT CAUSE

Consumption per Hour [kg/h]

3620.0

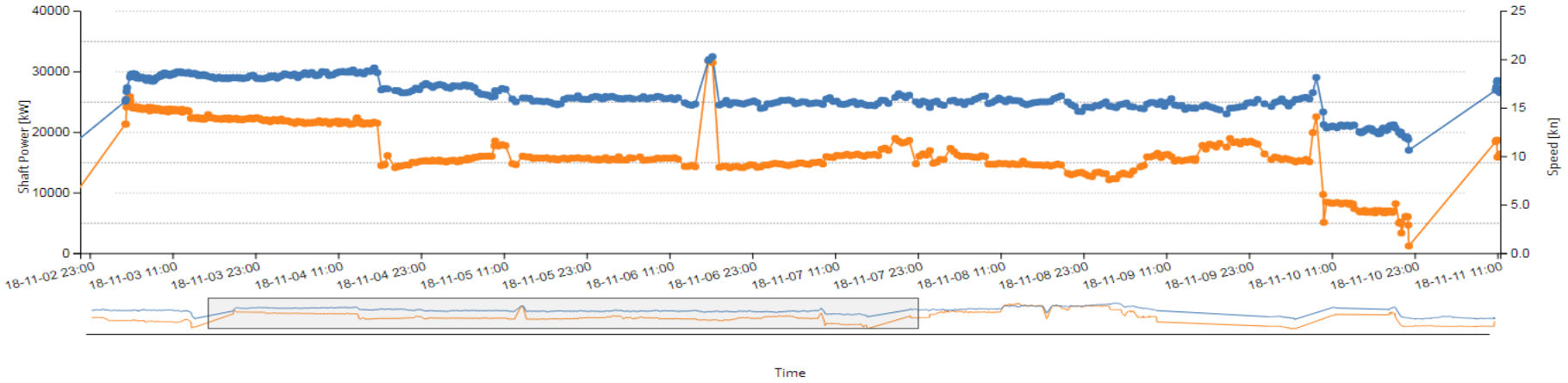
Me Fuel Consumed [t]

529.16

Steaming Time [hh]

146.25

Speed vs Power



EGO

Shaft power

Speed Over Ground [kn]

Shaft Power [kW]

18156.07

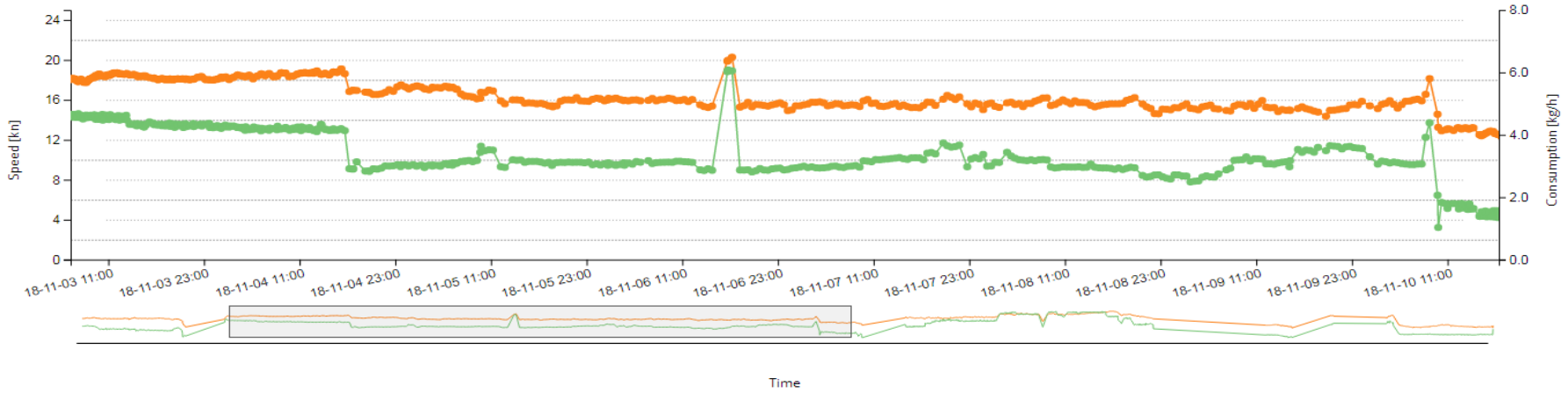
Main Engine group SFOC Current [g/kWh]

200.83

Shaft MCR

38.28

Speed vs Consumption per Hour



EGO

Speed Over Ground [kn]

ME Consumption

TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
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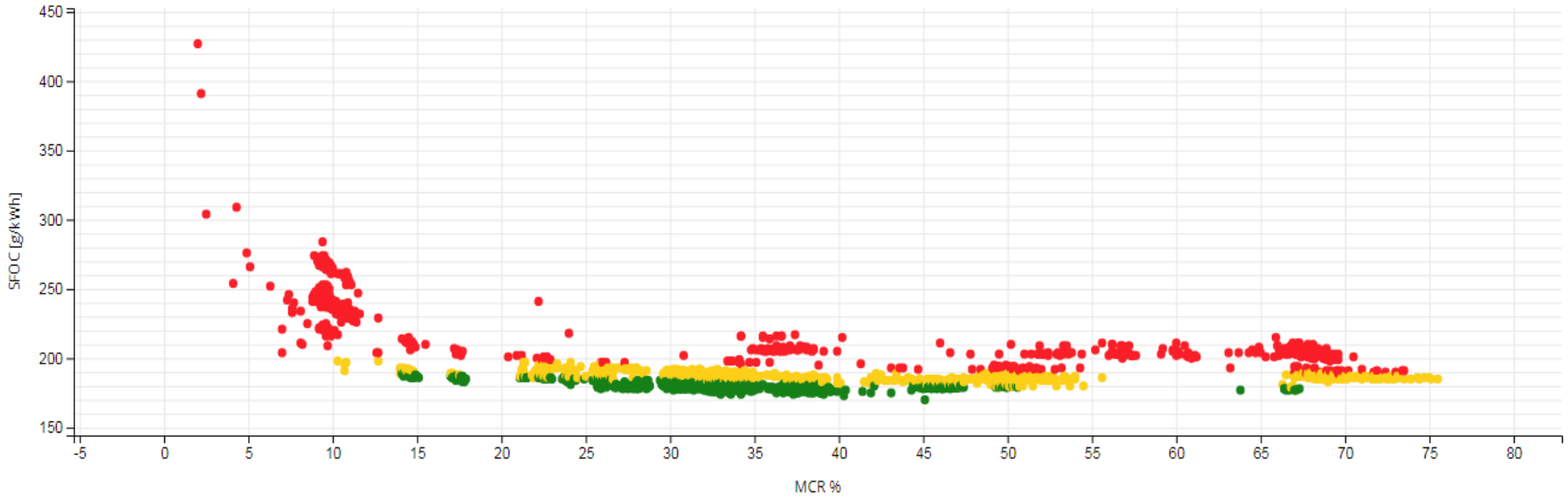
SHIP ACTIVE ALERTS 12	WATER ANALISYS OK	FEEDBACK AND ROOT CAUSE

Analysis: Single Period — Voyage selection

Period: 2018/11/01 10:20 - 2018/11/19 10:20

SFOC



EGO

Consumption per Hour [kg/h]
3620.0

Me Fuel Consumed [t]
529.16

Steaming Time [hh]
146.25

Shaft Power [kW]
18156.07

Main Engine group SFOC Current [g/kWh]
200.83

Shaft MCR
38.28

TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
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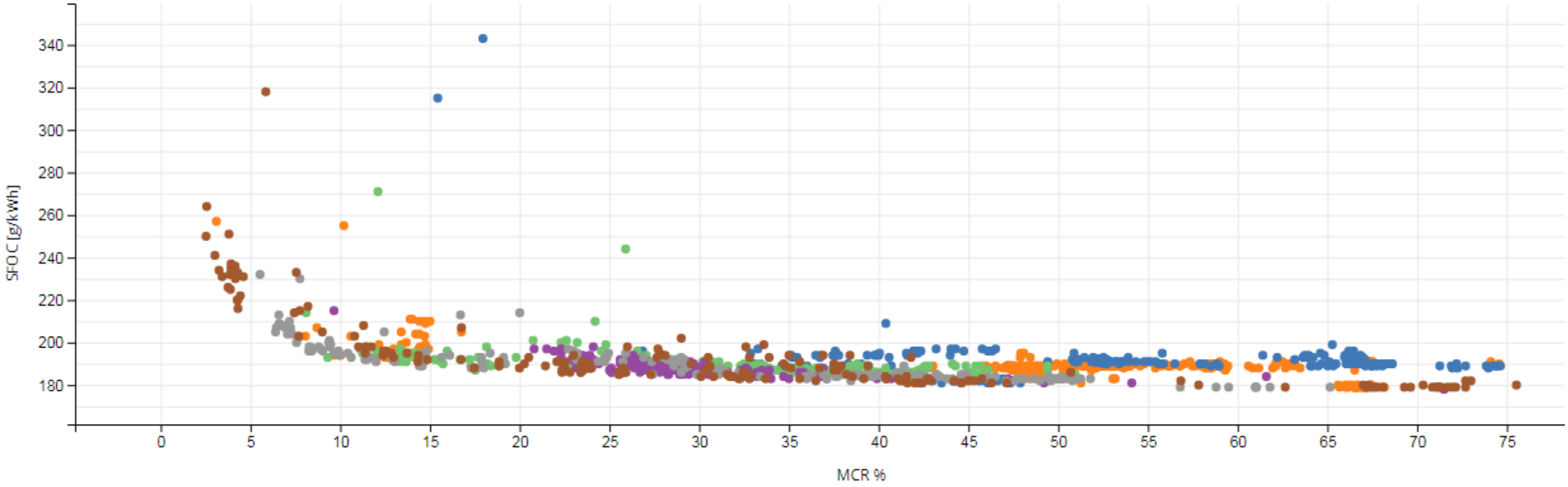
SFOC


SFOC [g/kWh]
340
320
300
280
260
240
220
200
180
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
MCR %
EGO - SHIP 1
EGO - SHIP 2
EGO - SHIP 3
EGO - SHIP 4
EGO - SHIP 5
EGO - SHIP 6

TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
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SCAVENGE AIR RECEIVER

Temp [°C]	Press Ind [bar]
45.3	1.8

THRUST BEARING

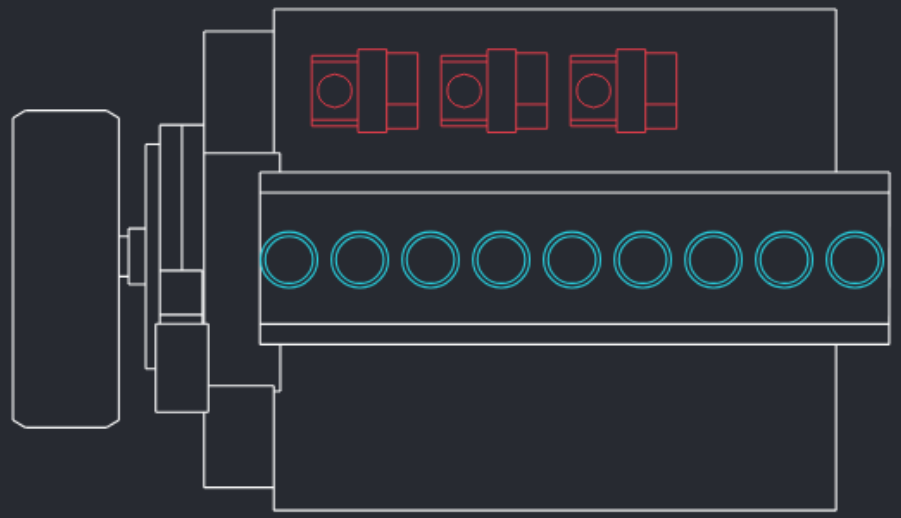
Radial Temp [°C]
44.2

FUEL OIL

Inlet Temp [°C]	Inlet Press [bar]
137.4	7.5

SHAFT BEARINGS

No1 Inter Shaft Bearing Temp [°C]	54.2
No2 Inter Shaft Bearing Temp [°C]	53.2
No3 Inter Shaft Bearing Temp [°C]	53.9
S/T Bearing Temp Fwd [°C]	48.4
S/T Bearing Temp Aft [°C]	37.4



T/C EXHAUST GAS TEMPERATURE

No1	
Inlet [°C]	Outlet [°C]
355.4	231.8
No2	
Inlet [°C]	Outlet [°C]
354.4	130.9
No3	
Inlet [°C]	Outlet [°C]
360.4	236.3

EXHAUST GAS OUTLET TEMPERATURE

No1 [°C]	No2 [°C]	No3 [°C]
322.4	324.2	317.8
No4 [°C]	No5 [°C]	No6 [°C]
317.8	307.0	315.5
No7 [°C]	No8 [°C]	No9 [°C]
312.1	307.6	324.2

CRANK PIN BEARING TEMPERATURE

No1 [°C]	No2 [°C]	No3 [°C]
48.7	48.4	48.8
No4 [°C]	No5 [°C]	No6 [°C]
48.7	48.4	48.8
No7 [°C]	No8 [°C]	No9 [°C]
48.7	48.4	48.8

MAIN BEARING TEMPERATURE

No1 [°C]	No2 [°C]	No3 [°C]
FWD 49.4	FWD 53.9	FWD 53.2
AFT 54.2	AFT 53.2	AFT 53.2
No4 [°C]	No5 [°C]	No6 [°C]
FWD 49.4	FWD 49.4	FWD 53.0
AFT 54.4	AFT 53.9	AFT 50.6
No7 [°C]	No8 [°C]	No9 [°C]
FWD 49.7	FWD 50.6	FWD 54.2
AFT 53.0	AFT 48.9	AFT 49.4

CROSSHEAD BEARING TEMPERATURE

No1 [°C]	No2 [°C]	No3 [°C]
FWD 48.1	FWD 48.6	FWD 48.3
AFT 46.6	AFT 46.8	AFT 47.0
No4 [°C]	No5 [°C]	No6 [°C]
FWD 48.4	FWD 48.1	FWD 48.5
AFT 46.8	AFT 46.3	AFT 47.2
No7 [°C]	No8 [°C]	No9 [°C]
FWD 48.9	FWD 48.5	FWD 48.1
AFT 46.8	AFT 47.5	AFT 46.6

TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
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CHECK THE ROOT CAUSE ANALYSIS / FAULT TREE TO DETECT POSSIBLE INSIGHTS

PRELIMINARY CHECK	1st Level	2nd Level	n Level	CHECK
• Check current ship position and activity • Fuel manual inputs • Check source data signals • Check sister ships for common issue	• Maintenance issue • Equipment issue • Procedure issue	• Maintenance last jobs • Maintenance planned • Lubrication • Turbine • Compressor • Cylinder head • Missing or wrong data …	• Maintenance done on engine parts • Planned maintenance on engine parts • Lubrication system setup • Contaminated lube oil • Dirty turbine blades • Exhaust gas leaking • Waste gate setup • Compressor filter cleaning • Valve leaking • Gasket issue • Fuel data issue	• Shore: Check Last Maintenance Reports • Shore: Check Planned Maintenance • Ship: Check Lube System Setup • Shore: Check Lube Oil Analisys • Ship: Check Lube Oil Filters • Shore: Check Performance • Ship: Clean Procedure • Ship: Visual Check • Ship: Check Parameters • Shore: Check Last Done • Ship: Check Filter Status • Shore: Check Performance • Ship: Visual Check • Shore: Check Fuel Analisys

TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
SCATTER SFOC [g/kWh] 200	ENGINE PERFORMANCE DIAGRAMS	NEXT PLANNED JOB on 15/11/2018
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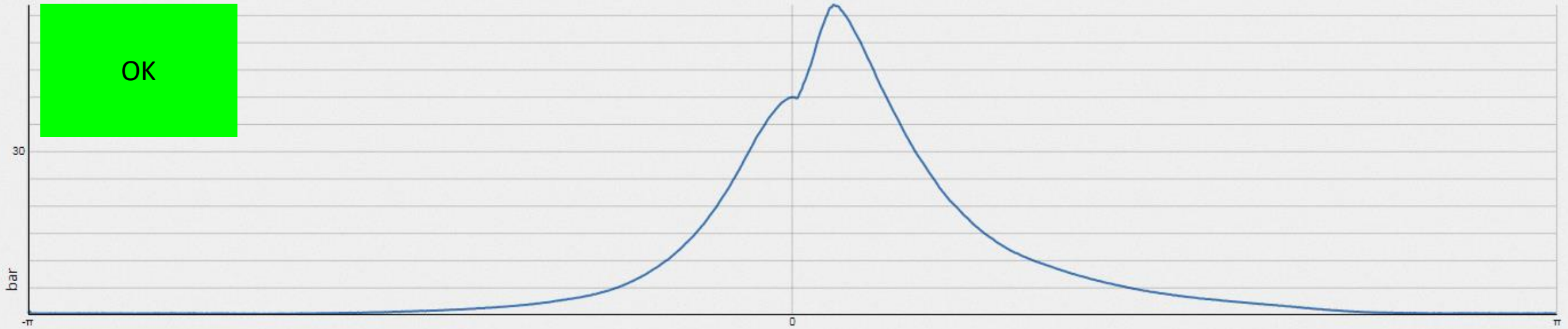
DIAGNOSIS HYPOTHESIS	LUBE OIL ANALISYS OK	SIMILAR EVENTS on SISTER SHIPS
SHIP ACTIVE ALERTS 12	WATER ANALISYS OK	FEEDBACK AND ROOT CAUSE

Cylinder : 3

Revolution : 4

OK

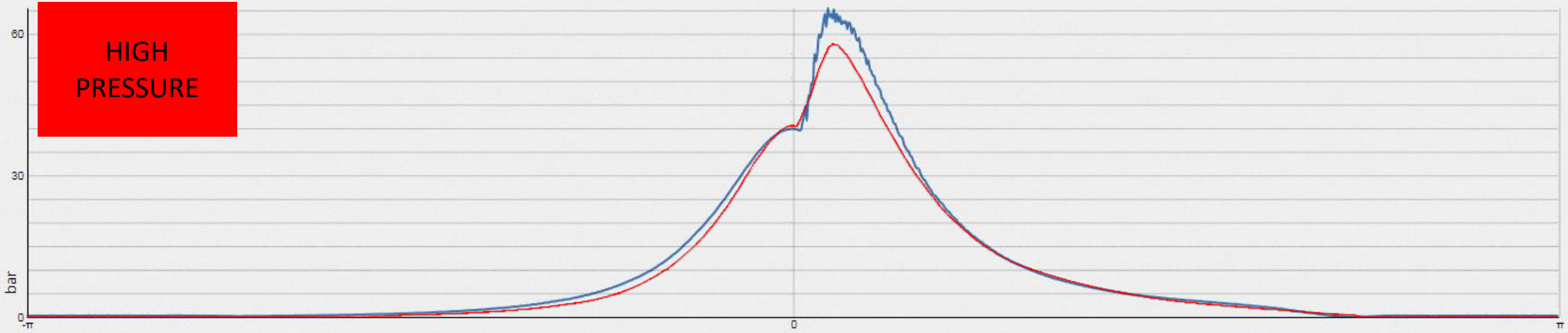


Measures	Average values
Angle of the first measurement point [radian]:	-3.1360877
Average p(i) for cylinder 3 [bar]:	6.44804
Average p(comp) for cylinder 3 [bar]:	36.74504
Average p(max) for cylinder 3 [bar]:	56.35149
Average p(scav) for cylinder 3 [bar]:	0.21903701

Cylinder : 12

Revolution : 3

HIGH PRESSURE

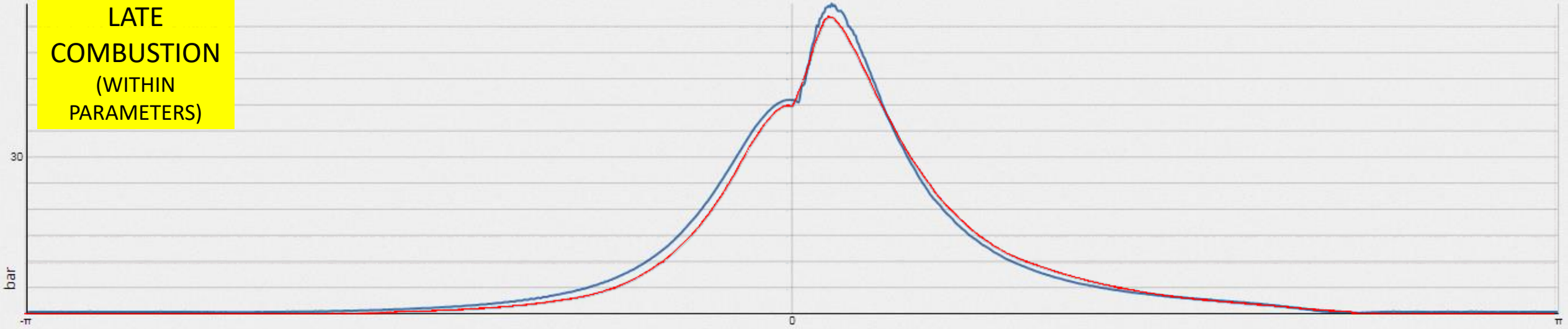


Measures	Average values
Angle of the first measurement point [radian]:	-3.1405103
Average p(i) for cylinder 12 [bar]:	6.1890993
Average p(comp) for cylinder 12 [bar]:	40.048145
Average p(max) for cylinder 12 [bar]:	64.2832
Average p(scav) for cylinder 12 [bar]:	0.21903701

Cylinder : 5

Revolution : 1

LATE COMBUSTION (WITHIN PARAMETERS)

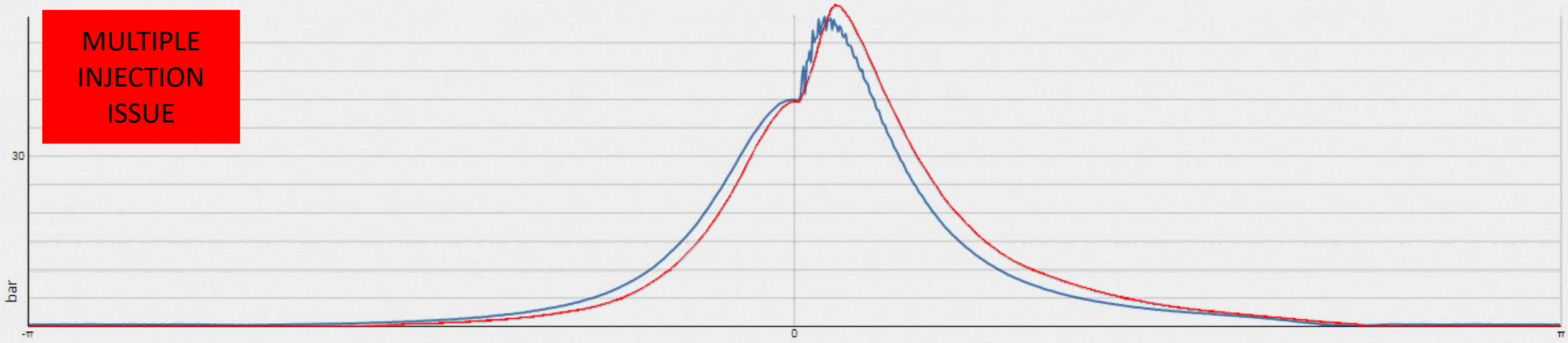


Measures	Average values
Angle of the first measurement point [radian]:	-3.1359284
Average p(i) for cylinder 5 [bar]:	4.772541
Average p(comp) for cylinder 5 [bar]:	41.29923
Average p(max) for cylinder 5 [bar]:	58.20893
Average p(scav) for cylinder 5 [bar]:	0.21903701

Cylinder : 9

Revolution : 3

MULTIPLE INJECTION ISSUE



Measures	Average values
Angle of the first measurement point [radian]:	-3.137665
Average p(i) for cylinder 9 [bar]:	3.730032
Average p(comp) for cylinder 9 [bar]:	40.356007
Average p(max) for cylinder 9 [bar]:	53.20826
Average p(scav) for cylinder 9 [bar]:	0.21903701

TREND POWER [kW] 18156 CONS [t/h] 3.62	ENGINE PARAMETERS ANALISYS	PREVIOUS JOB DONE on 15/09/2018
SCATTER SFOC [g/kWh] 200	ENGINE PERFORMANCE DIAGRAMS	NEXT PLANNED JOB on 15/11/2018
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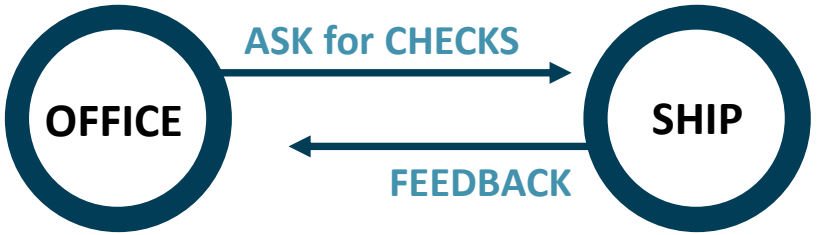
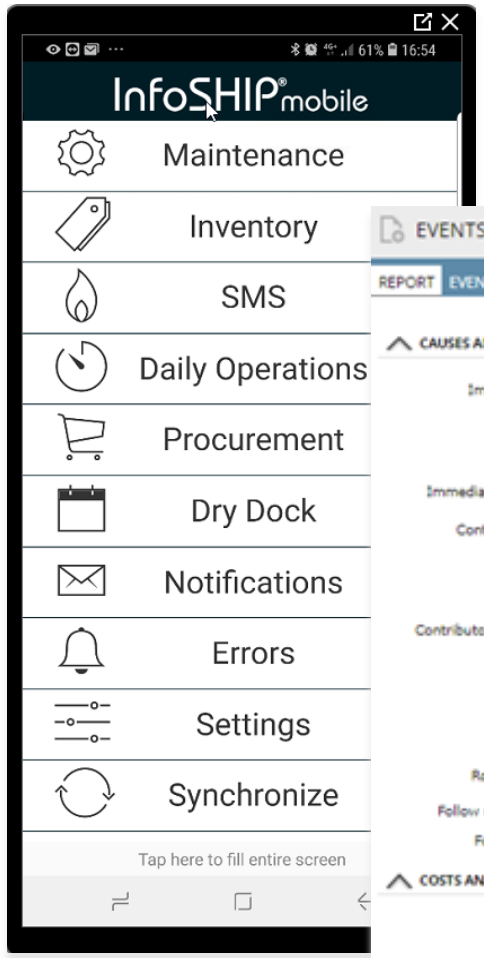
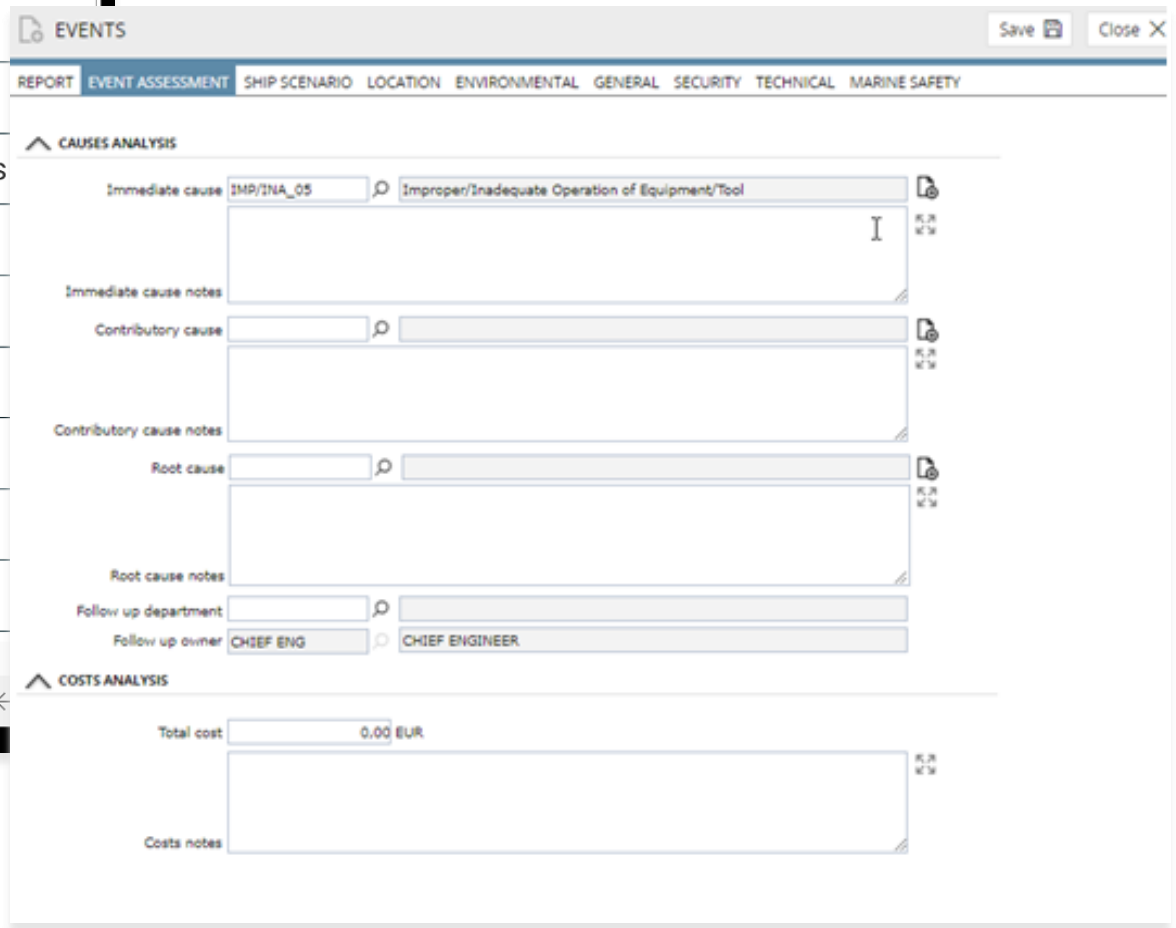
SHIP ACTIVE ALERTS 12	WATER ANALISYS OK	FEEDBACK AND ROOT CAUSE



1. The office defines the checks needed by the crew on board
2. Streamlined activation of check internal procedures
3. Integrated mobile tool available to crews
4. The crew perform the checks and gives feedback to the office
5. The root cause is identified, recorded into the system and available to detect similar events



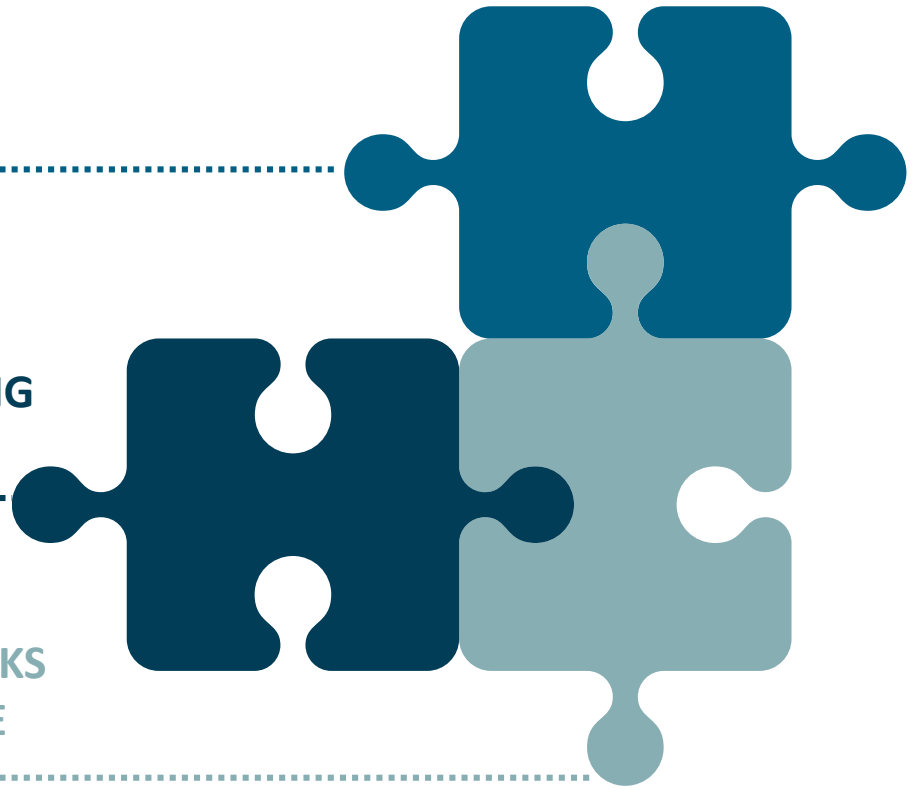


Approach shall be multi skill

DOMAIN EXPERTS
ENGINEERING
PHISICAL MODELS

MACHINE LEARNING
DATA SCIENTISTS

ON FIELD FEEDBACKS
HUMAN EXPERTISE

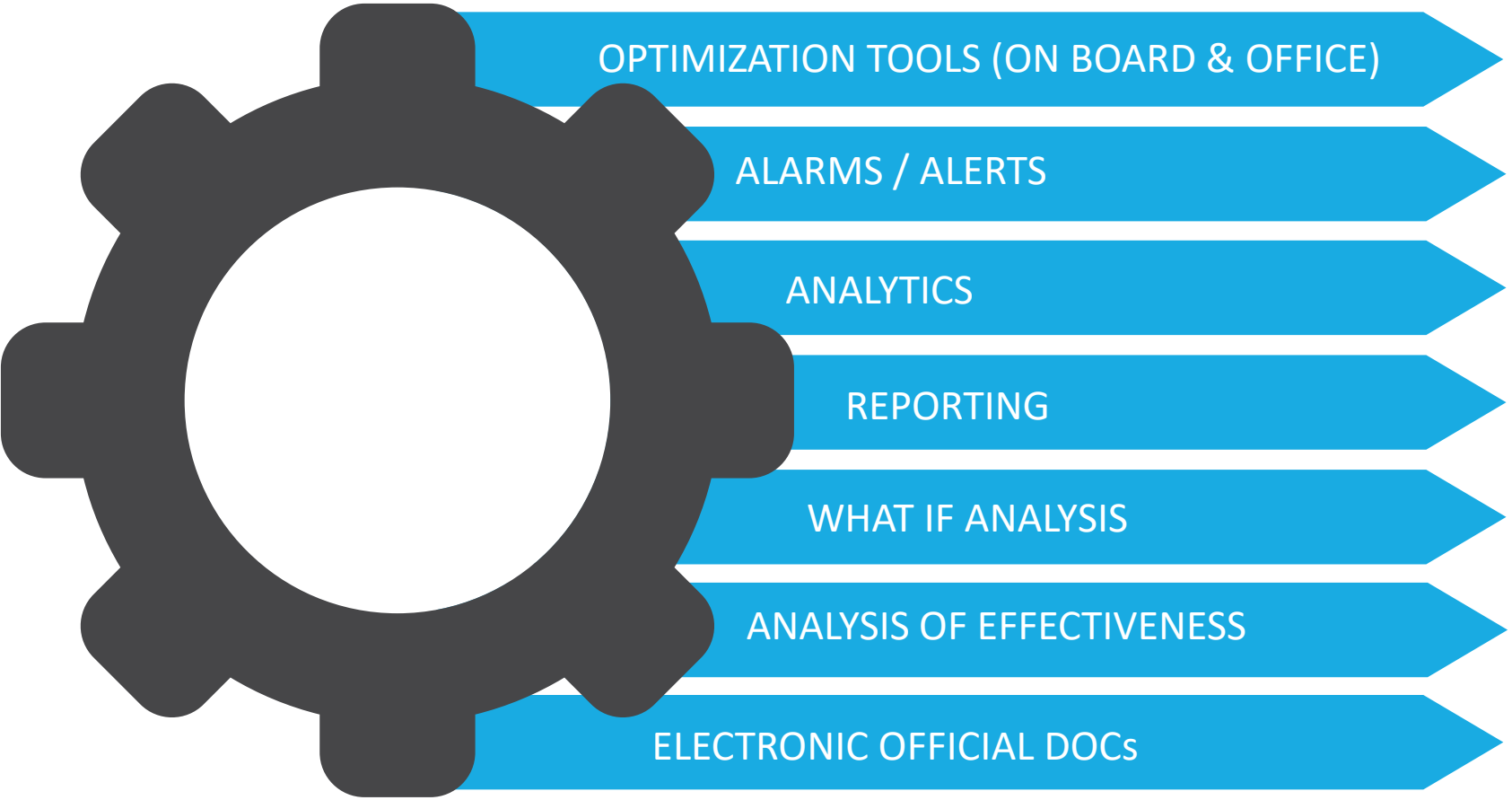


Key words which have influenced our development road map

- Independency from equipment manufacturers, class societies, in general big operators which technology represents not a core business
- Cloud vs on premises. No marriages that force customers to be linked to 3rd parties.
- 1 remote control for multiple components (performance, energy, procurement, logistics, maintenance, compliance, operations, etc.)
- Smooth adoption - Step by step introduction (no all in)
- Usability both on new and existing ships
- Scalability according to client size in terms of functionalities and hardware architecture. Let everyone access new technologies
- Enhance the analysis with the utilization
- Data collector designed to be open to acquire any kind of signal (digital, analog) with plug & play connectors for the market standards (NEMEA, Modbus, OPC, etc.) and/or proprietary standards (Kongsberg, ABB, etc.)

Fleet Control Room

- Stock
- Logistics
- Procurement
- Budget & Cost Control
- Event & Incident mngt
- Risk Assessment Control
- Documentation (designs, 3d Models, Monographies, etc.)
- Analytics
- Route / Speed Optimization
- Predictive Maintenance
- Oil Record Books (Logbooks)
- Bunker
- Consumptions
- Vessel Positioning (past & forecast routes)
- Trim Optim
- Meteo
- Voyage Reports
- PMS



MONITORING & PROACTIVE DECISION SUPPORT SYSTEM

Enable customers to build their data connections and rules

“Data connections and the added value they bring represent the future client treasury”

Expertise + new technologies

- Raw or elaborated data acquisition
- Data processing
- Machine learning
- Data mining
- Artificial intelligence

Conclusions – Attention points

- Holistic approach – no data silos but data correlations - differential diagnosis
- Mixed utilization of data driven and experience driven approach
- Adoption of robust systems – all data sources concur to knowledge management and decision making with harmonized and meaningful data
- Artificial intelligence / machine learning smart introduction
- Attention to provide the right tools to various operators / decision makers (crew, tech ops, management)

Why IB

Wide coverage of data domain: from performance data to maintenance / administrative data

Source of data: from automatic collection (Modbus, opc, nemea, etc.) to transactional / manual inputs (database) info

INFOSHIP Software Suite: Availability of «ready to use» specific software modules (PMS, Procurement, Energy, etc.)

No limitations for its applicability to some specific equipment / manufacturer, but access to all plants/vendors

Alarm rule definition tool and **fleet control room**

Super powerfull Analytics tool (big data!!)

Hardware and software independency

“The best way to predict your future is to create it.”

— **Abraham Lincoln**