



# How Monitoring Systems can improve ship management and maintenance

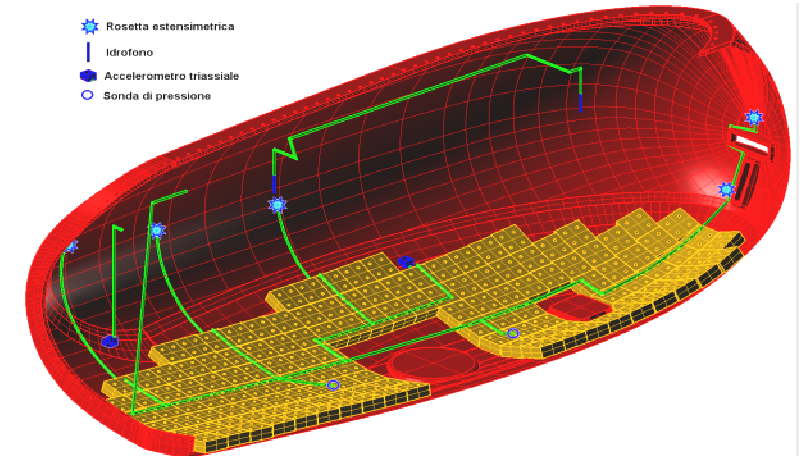
Napoli, 27/09/2018

Development, design, on-board installation, commissioning, management and data analysis of Monitoring Systems:

- in structural, acoustics, energetic or electric field
- for short- or long-term monitoring
- standard or customised

Main targets of a monitoring system:

- ✓ *assessment* of ship design and plant/structures "as built"
- ✓ *assessment* of ship operations and management
- ✓ *surveillance* of ship performance and structure
- ✓ *detection* of potential risks related to structure and and to cargo integrity and safety
- ✓ *feedback* on innovative/alternative solutions
- ✓ *resolution* of disputes with suppliers
- ✓ *data collection* to improve design of future ships
- ✓ *data collection* for basic and applied research
- ✓ *assessment* of critical issues and countermeasures identification
- ✓ *acquisition* of additional class notations by Registry





Fuel efficiency



**Maintenance**  
to Maintain, Keep, Preserve & Protect

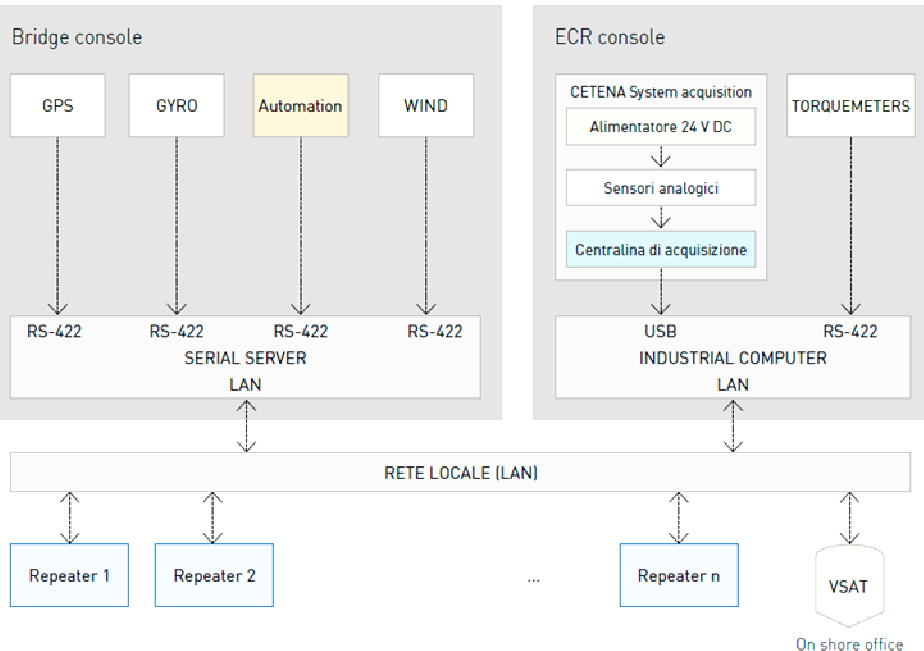


**Monitoring systems**



## PM&OTE - Performance Monitoring & Optimum Trim Estimator

- monitoring propulsive performances
- assessment of ship management in a fuel consumption perspective
- EEOI calculation in SEEMP perspective
- assessment of retrofit (re-blading, silicon paints, appendages, etc)
- dynamic trim optimisation: 2-4 % fuel saving
- performance index visualisation
- route optimisation with weather forecast



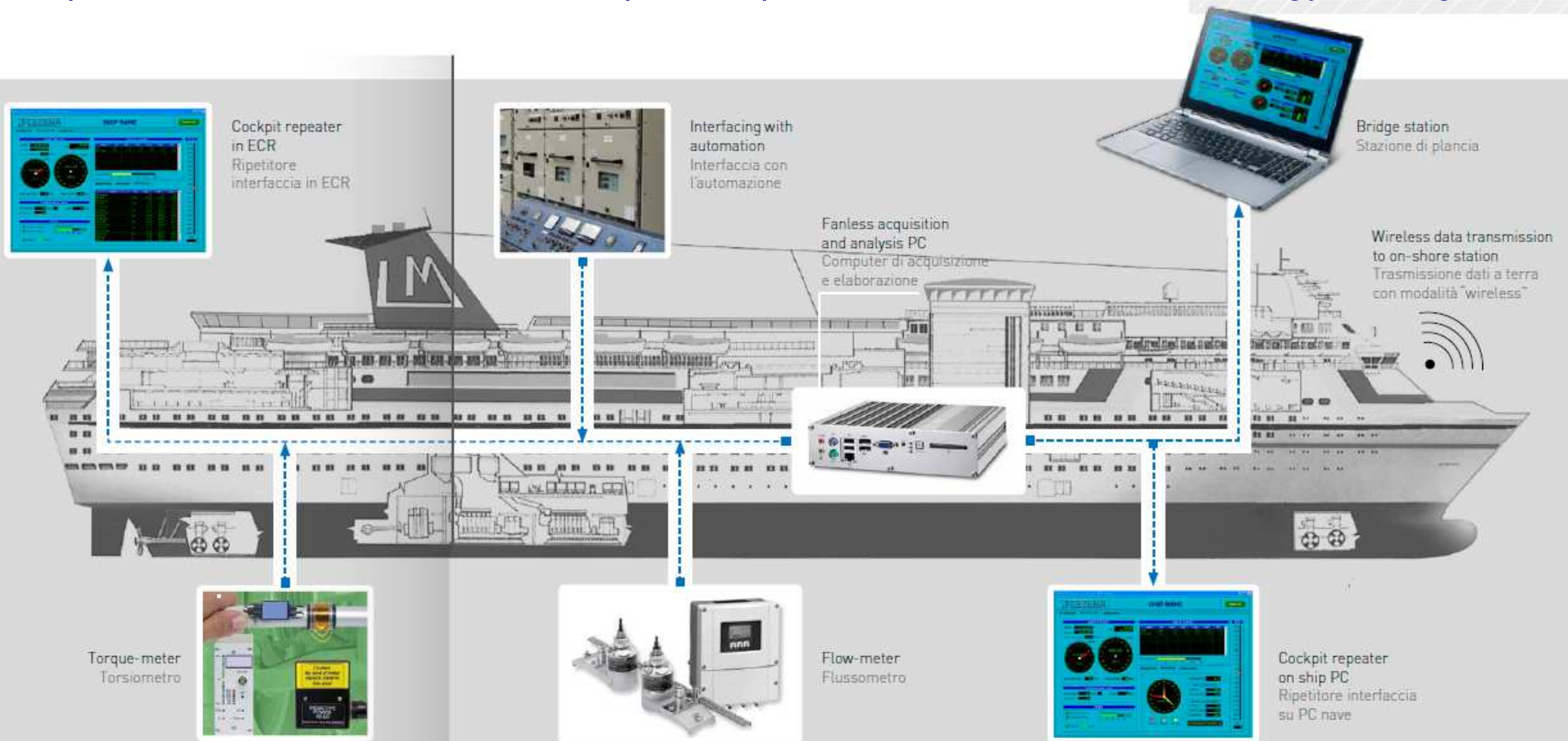
- ✓ Low installation impact
- ✓ Interface with: torquemeters, flowmeters, ship automation and navigation systems, wave radar
- ✓ Acquisition of dedicated sensors (high-precision inclinometers) to monitor dynamic trim





Integration with on board systems:

- acquisition of signals and information through ship net
- cockpit available to Officers on all ship's computers and on onshore to Energy Manager



Cockpit available to Officers on all ship's computers and on onshore to Energy Manager

PM-OTE Repeater - v.5.4.1 - (C) 2009-14 MGA

# CETENA

## SHIP NAME

POWER OFF

OPTIMUM TRIM | DATA COLLECTOR | MANUAL INPUT

### NAVIGATION DATA

Latitude: **44°22.3514' N** Time: **18.43.45**  
 Longitude: **8°58.3721' E** Date: **05/03/2015**  
 Course over Ground: **134.2** [deg] Heading: **132.1** [deg]

Speed: **20.4** [kn]

Water speed (Log): **0.0** [kn] Speed threshold: **0.0** [kn]

### ANALOG CHANNELS

| Signal     | EU  | Max   | Min   | Avg   | Med   | Std  |
|------------|-----|-------|-------|-------|-------|------|
| Rollio     | deg | -0.20 | -0.20 | -0.20 | -0.20 | 0.00 |
| Beccheggio | deg | -0.92 | -0.92 | -0.92 | -0.92 | 0.00 |

ACQ buffer [%]: **80**

### ENVIRONMENTAL DATA

Wind direction: **0.0** [deg] Depth: **0.0** [m]  
 Wind speed: **0.0**

### SYSTEM

No data from NAV.  Remote HDD [%]: **75**  
 No data from E,C,R.     
 Poll Data  Record

### TORQUEMETERS | WAVE RADAR | OTHER SIGNALS

#### ASSE SN

Speed [RPM]: **120.9** Power [kW]: **18721**  
 Torque [kNm]: **1725**

68% ONLINE

#### ASSE DR

Speed [RPM]: **120.9** Power [kW]: **20891**  
 Torque [kNm]: **1686**

75% ONLINE

### OPTIONAL VOYAGE DATA - DEPARTURE

GENERAL - DRAFT AND TRIM

Voyage ID: **123** Displacement: **20150** [t]  
 Captain: **Captain name** Draft forward: **6.75** [m]  
 Chief Engineer: **Chief name** Draft aft: **6.65** [m]

SEA CONDITION

Sea state: **5 Rough** Wave direction: **270.0** [°]  
 Wave period: **7.0** [s]

BUNKER

H.F.O. Density: **950** [kg/m<sup>3</sup>]  
 Ref. Temperature: **0.0** [°C]  
 Sulfur percentage: **0.0** [%]

PAYLOAD

Cargo tons: **6500** Linear meters: **0**  
 Passengers no.: **800** TEU no.: **0**

Poll Data

Manual input data

Sea state data

### TORQUEMETERS | WAVE RADAR | OTHER SIGNALS

Wave height [m]: **4.2**

PEAK WAVE PARAMETERS

Period [s]: **-999.9**  
 Direction [deg]: **-999.9**

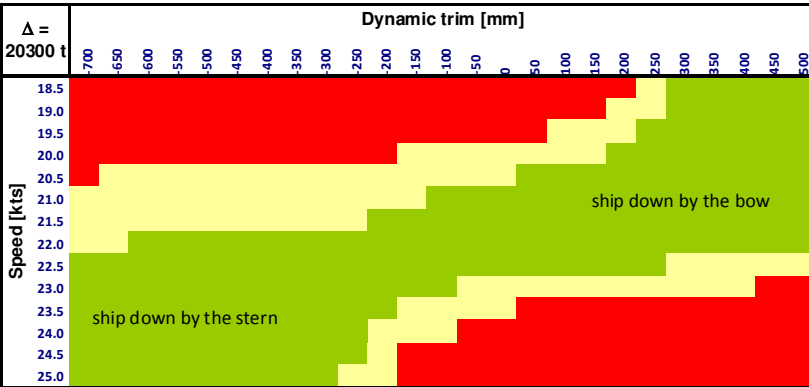
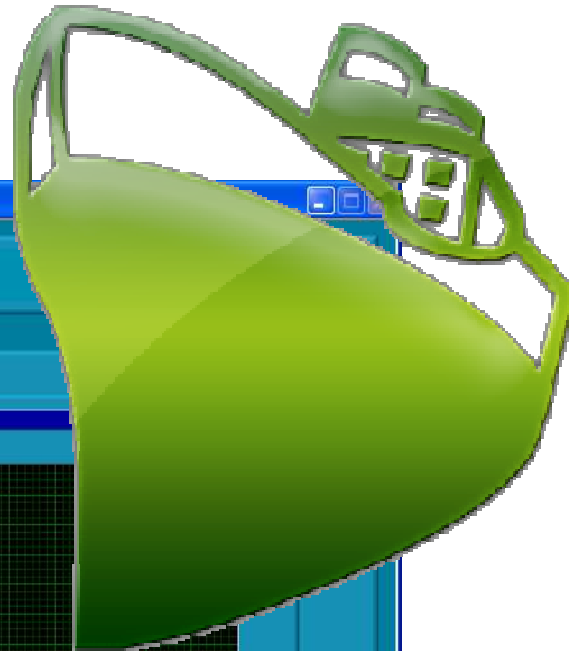
AVERAGE WAVE PARAMETERS

Period [s]: **7.0**  
 Direction [deg]: **273.5**  
 Spread [deg]: **-999.9**

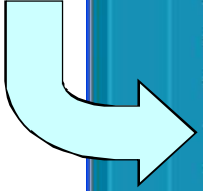
Wave dir.  Wind dir.  Ship hdg

Invalid data from wave radar

# Dynamic Trim optimisation as a function of ship speed and displacement

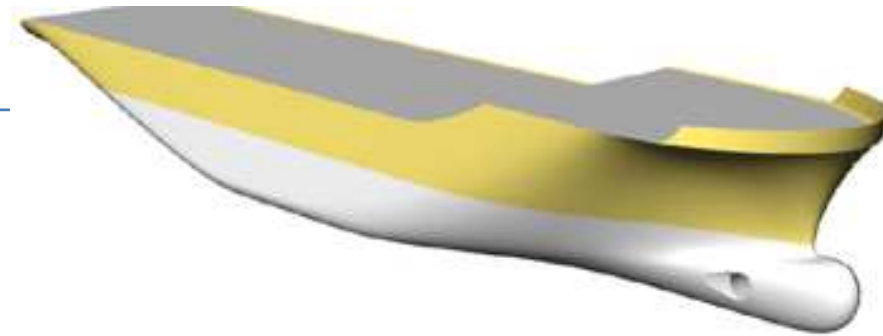
Embedded info on % of fuel saved as a function of speed, trim and displacement



The **DSS** shows how to trim the ship to save how much fuel

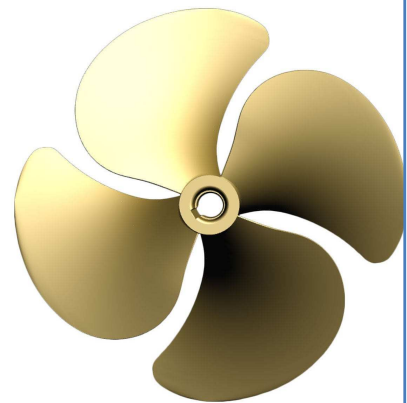


## Basic hull and propeller performance indicators



Hull and propeller performance refers to the relationship between the condition of a ship's underwater hull and propeller and the power required to move the ship through water at a given speed. Measurements of changes in ship specific hull and propeller performance over time make it possible to indicate the impact of hull and propeller maintenance, repair and retrofit activities on the overall energy efficiency of the ship in question.

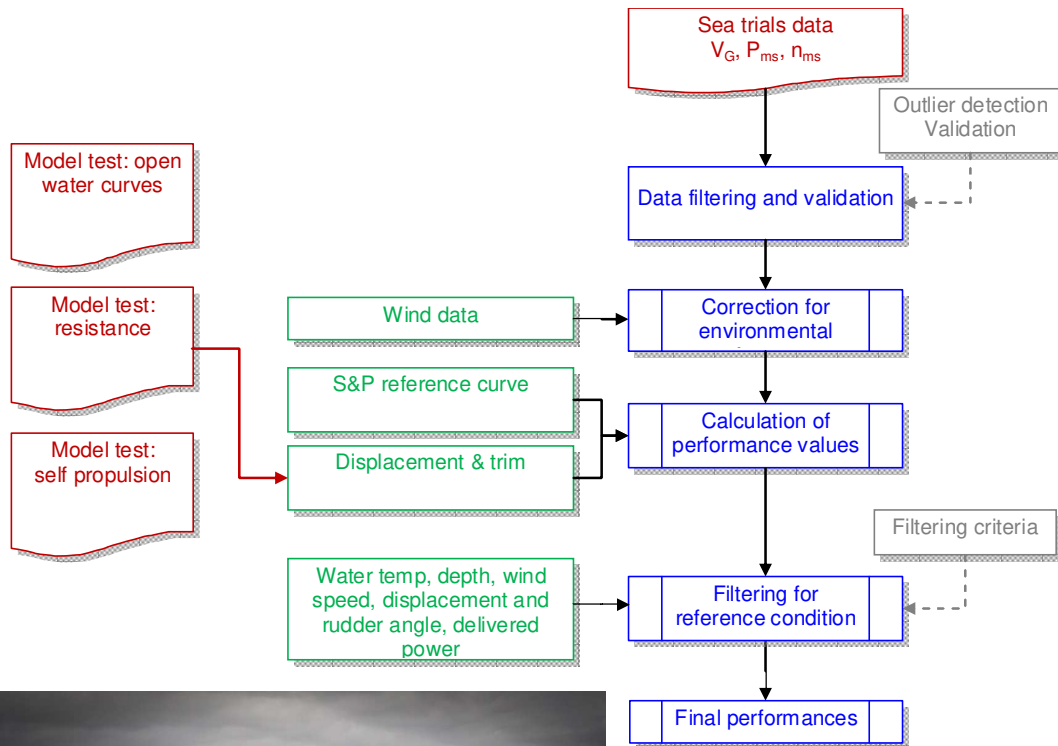
| Performance indicators (PI)  | Definition   |
|--|--|
| <b>Dry-docking performance:</b><br>Determining the effectiveness of the dry-docking ("repair" and/or retrofit activities)  | Change in hull and propeller performance following present out-docking (evaluation period) as compared with the average from previous out-dockings (reference periods).  |
| <b>In-service performance:</b><br>Determine the effectiveness of the underwater hull and propeller solution (including any maintenance activities that have occurred over the course of the full dry-docking interval) | Average change in hull and propeller performance from a period following out-docking (reference period) to the end of dry-docking interval (evaluation period).          |
| <b>Maintenance trigger:</b><br>Trigger underwater hull and propeller maintenance, including propeller and/or hull inspection   | Change in hull and propeller performance from the start of the dry-docking interval (reference period) to a moving average at a given point in time (evaluation period). |
| <b>Maintenance effect:</b><br>Determine the effectiveness of a specific maintenance event, including any propeller and/or hull cleaning  | Change in hull and propeller performance from before (reference period) to after a maintenance event (evaluation period).  |



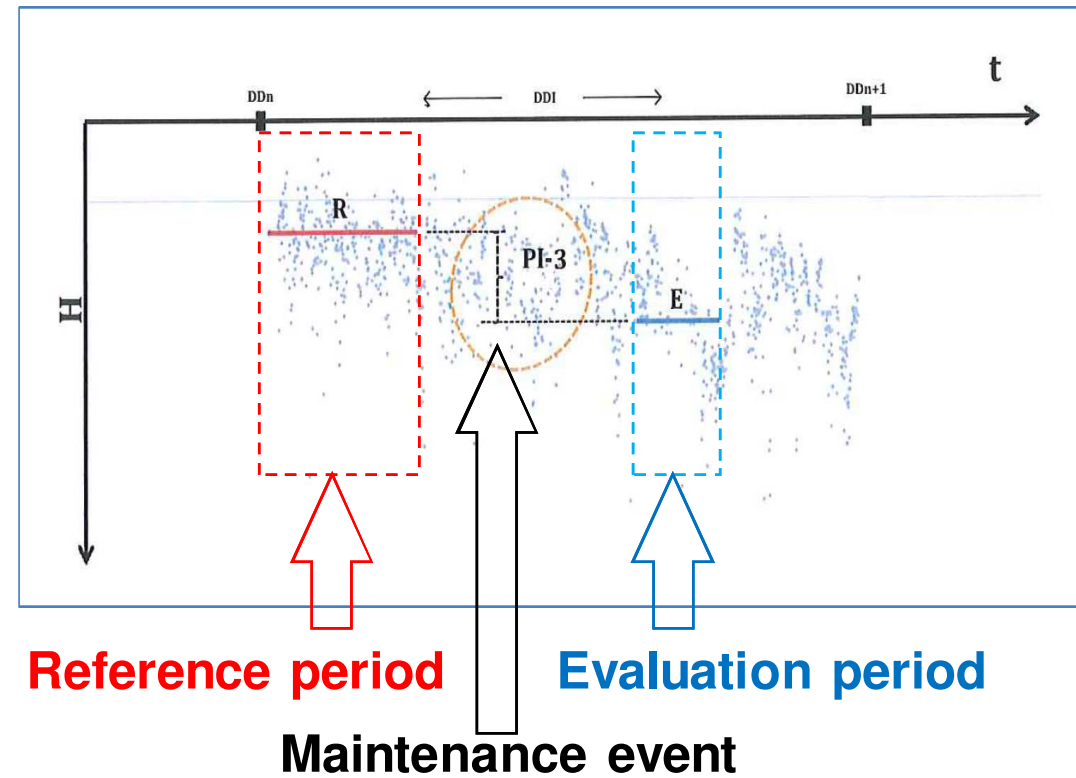


## Basic hull and propeller performance indicators:

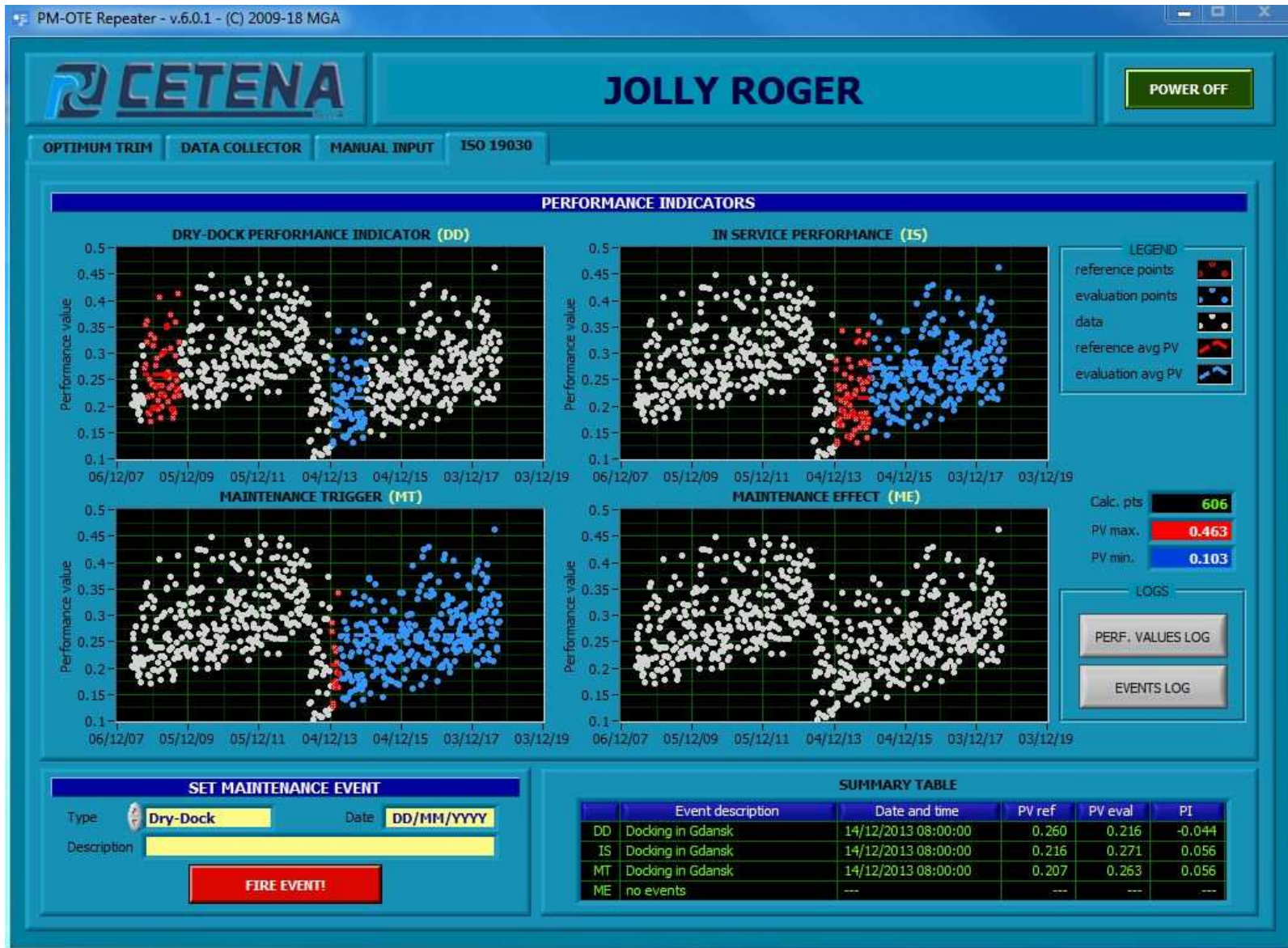
- acquired power/speed data are corrected to be referred to standard environmental conditions (ISO 19030 / ISO 15016)



- corrected data are comparable
- performance indicators can be built

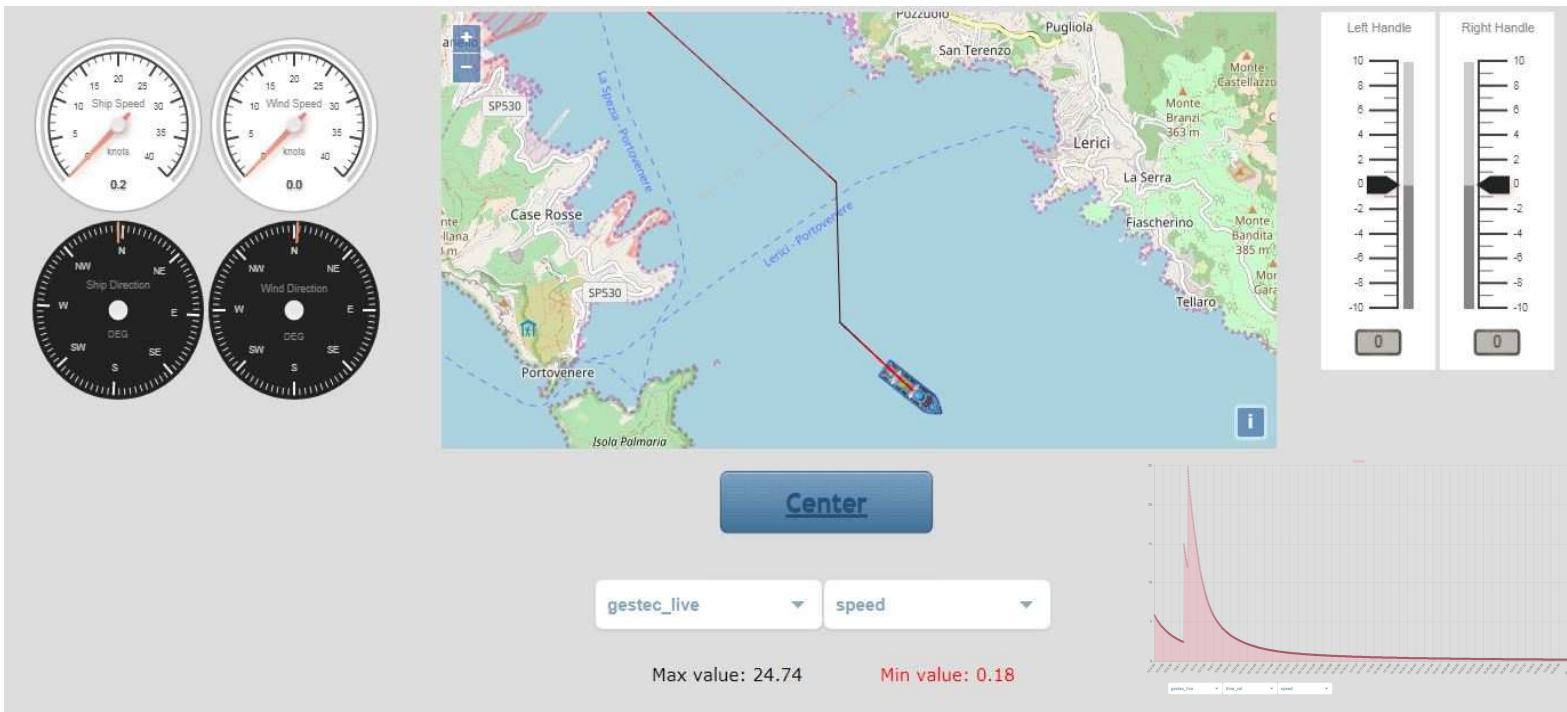
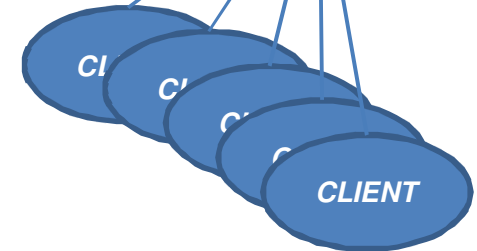
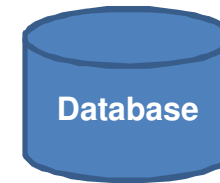


# On-line basic hull and propeller performance indicators



## On-line visualisation and analysis of ship performance

- Real-Time map
- Ship position, route, performance data
- Reconfigurable real-time updated gauges
- Colour-indication of performance / KPI on route





# How the ship is operated? Is the actual way the best one?

Cetena S.p.A. - Data Collector Analysis - v.2.6.4 2011-16 - MGA

Ship name

Data folder: D:\PMOTE Data Valid trips: 29/30

| Departure | Date       | Time  | Arrival | Date       | Time  | Nav.  | Displ. |
|-----------|------------|-------|---------|------------|-------|-------|--------|
| PORT 1    | tue 29 dec | 20:16 | PORT 2  | wed 30 dec | 00:17 | 4:00  | 20180  |
| PORT 2    | wed 30 dec | 22:49 | PORT 3  | thu 31 dec | 07:30 | 8:40  | 20120  |
| PORT 3    | thu 31 dec | 14:47 | PORT 4  | sat 02 jan | 04:43 | 37:56 | 20340  |
| PORT 4    | sat 02 jan | 16:06 | PORT 2  | mon 04 jan | 01:32 | 33:26 | 20300  |
| PORT 2    | mon 04 jan | 05:04 | PORT 1  | mon 04 jan | 09:29 | 4:25  | 20300  |
| PORT 1    | tue 05 jan | 20:10 | PORT 3  | wed 06 jan | 08:30 | 12:20 | 19950  |
| PORT 3    | thu 07 jan | 14:23 | PORT 2  | fri 08 jan | 18:54 | 28:31 | 20150  |
| PORT 2    | mon 11 jan | 04:43 | PORT 1  | mon 11 jan | 09:20 | 4:38  | 20000  |
| PORT 1    | tue 12 jan | 20:14 | PORT 3  | wed 13 jan | 07:36 | 11:23 | 20250  |
| PORT 3    | wed 13 jan | 14:12 | PORT 2  | wed 13 jan | 19:34 | 5:23  | 20200  |
| PORT 2    | thu 14 jan | 00:57 | PORT 4  | fri 15 jan | 18:40 | 41:43 | 20320  |
| PORT 4    | sat 16 jan | 18:11 | PORT 2  | mon 18 jan | 01:29 | 31:18 | 20280  |

Ref. displacement value: 20200 [t] New displacement value: 0 [t]

DATA ANALYSIS FILTERS

NW angle: 37°15.7' N 23°33.1' E SE angle: 35°26.5' N 25°09.2' E

Sea area:  Sea speed:  Total power:  Wind speed:  Sea state:  Engines no.: =2 Fins status: IN C.O.G. [deg]: >=45.0 <=90.0 Cursor Interval A-B:

RESULTS CALCULATION

Selected signals:

Report file name:

Save filters settings  Save intermediate files

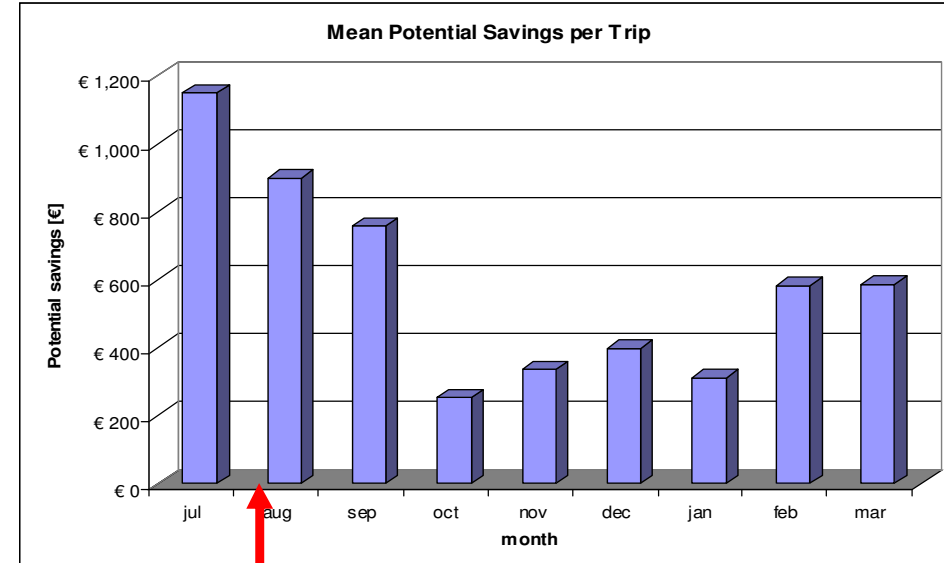
TIME HISTORY STATISTICS 20120

Signal 1: S.O.G. [kn] Signal 2: Total power [kW]

Cursor A: X= Y=0 Cursor B: X= Y=0

SHIP GPS TRACK

# Off-line deep Analysis of monitored data



Optimum Trim activation

**DATA ANALYSIS FILTERS**

NW angle: 37°15.7' N, 23°33.1' E  
 SE angle: 35°26.5' N, 25°09.2' E

Ship speed: >=10.0 <=12.0 [kn]  
 Total power: >=10000 <=15000 [kW]  
 Wind speed: <=20.0 [kn]  
 Sea state: <=5 [Douglas]  
 Engines no.: =2  
 Fins status: IN  
 C.O.G. [deg]: >=45.0 <=90.0

**RESULTS CALCULATION**

Selected signals: [List]  
 Report file name: [Text]  
 Save filters settings  
 Save intermediate files

**SHIP GPS TRACK**

120 nm

Retrofit assessment  
 Ship management assessment

**PRE-REFITTING** | **POST-REFITTING** | **SHIP NAME**

REFERENCE DISPLACEMENT: 19550  
 MINIMUM SPEED: 16  
 MAXIMUM SPEED: 23

E I [%] | Cleaned E I [%]  
 19.111 | 18.657

| Cleaned Date pre refitting | Cleaned S.O.G. pre refitting [kn] | Cleaned Norm. power pre refitting [kW] | Cleaned Date post refitting | Cleaned S.O.G. post refitting [kn] | Cleaned Norm. power post refitting [kW] |
|----------------------------|-----------------------------------|--|-----------------------------|------------------------------------|---|
| 1 Fri 12 sep               | 17.02                             | 13015.32                               | 1 Fri 24 oct                | 17.09                              | 10151.01                                |
| 2 Fri 12 sep               | 17.30                             | 13955.81                               | 2 Sun 26 oct                | 17.41                              | 10095.65                                |
| 3 Fri 12 sep               | 20.00                             | 17928.25                               | 3 Sun 26 oct                | 18.05                              | 11192.47                                |
| 4 Sat 13 sep               | 19.72                             | 17695.83                               | 4 Tue 28 oct                | 18.30                              | 11672.52                                |
| 5 Mon 15 sep               | 19.77                             | 17578.11                               | 5 Tue 28 oct                | 18.41                              | 11767.90                                |
| 6 Mon 15 sep               | 20.04                             | 17949.27                               | 6 Tue 28 oct                | 19.04                              | 12607.48                                |
| 7 Tue 16 sep               | 18.88                             | 17152.52                               | 7 Wed 29 oct                | 18.56                              | 12958.84                                |
| 8 Tue 16 sep               | 20.23                             | 18386.75                               | 8 Fri 31 oct                | 17.46                              | 11510.89                                |
| 9 Sat 20 sep               | 20.02                             | 19219.06                               | 9 Sat 01 nov                | 18.50                              | 12756.95                                |
| 10 Sat 20 sep              | 20.47                             | 19611.44                               | 10 Sun 02 nov               | 17.81                              | 10927.14                                |
| 11 Mon 22 sep              | 19.81                             | 17549.16                               | 11 Sun 02 nov               | 18.02                              | 11550.90                                |
| 12 Tue 23 sep              | 19.36                             | 16937.93                               | 12 Thu 06 nov               | 17.85                              | 11328.33                                |
| 13 Tue 23 sep              | 19.93                             | 18035.80                               | 13 Thu 06 nov               | 19.85                              | 15412.23                                |
| 14 Wed 24 sep              | 19.12                             | 16296.50                               | 14 Thu 06 nov               | 20.10                              | 15193.69                                |
| 15 Sat 27 sep              | 20.19                             | 19101.70                               | 15 Sat 08 nov               | 20.29                              | 15027.59                                |
| 16 Tue 30 sep              | 20.01                             | 16793.68                               | 16 Sat 08 nov               | 21.55                              | 19841.09                                |
| 17 Sat 04 oct              | 17.36                             | 14544.93                               | 17 Sat 08 nov               | 21.83                              | 18489.08                                |
| 18 Sat 04 oct              | 17.83                             | 14908.08                               | 18 Sat 08 nov               | 21.35                              | 16920.24                                |
| 19 Sun 05 oct              | 16.88                             | 14035.64                               | 19 Tue 11 nov               | 18.97                              | 13820.37                                |
| 20 Sun 05 oct              | 17.56                             | 15586.85                               | 20 Thu 13 nov               | 17.88                              | 10114.75                                |
|                            |                                   |  | 21 Thu 13 nov               | 17.17                              | 9815.59                                 |
|                            |                                   |  | 22 Fri 14 nov               | 18.21                              | 11334.38                                |
|                            |                                   |  | 23 Fri 14 nov               | 18.41                              | 12181.25                                |

**Speed Over Ground - Mean Propulsive Power**

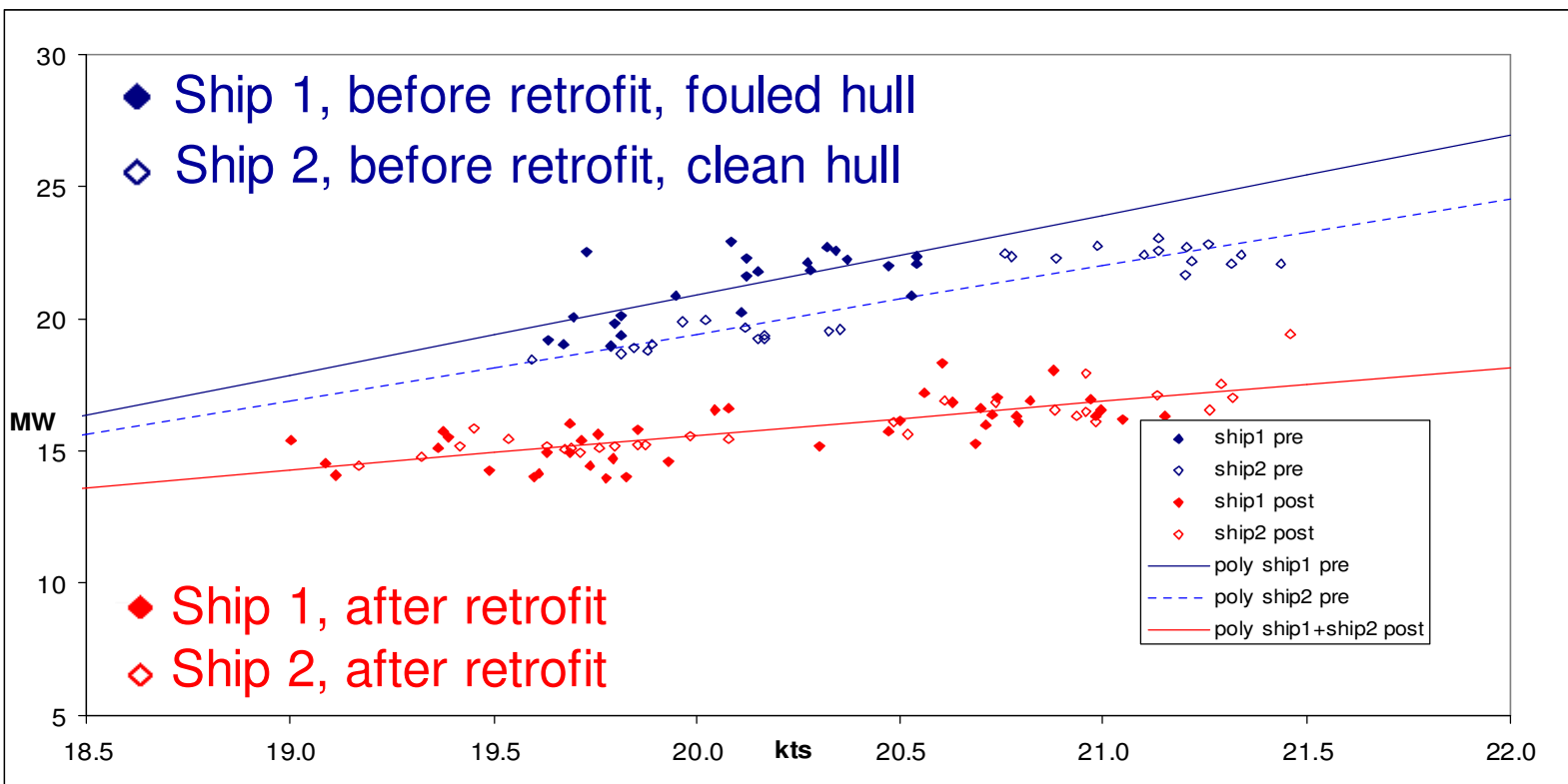
Graph showing Speed Over Ground [Kn] vs Mean Propulsive Power [kW]. Legend: Pre-refitting (blue dots), Post-refitting (green dots). Labels: P pre, P post, V cruise.

Power/fuel saving

## Retrofit assessment (re-blading, appendages, silicon painting, ...)

- Acquisition and recording of propulsive performances in the short-medium term before and after the retrofit.
- Assessment and measurement of retrofit effectiveness

### Re-blading and hull cleaning on two sister ships

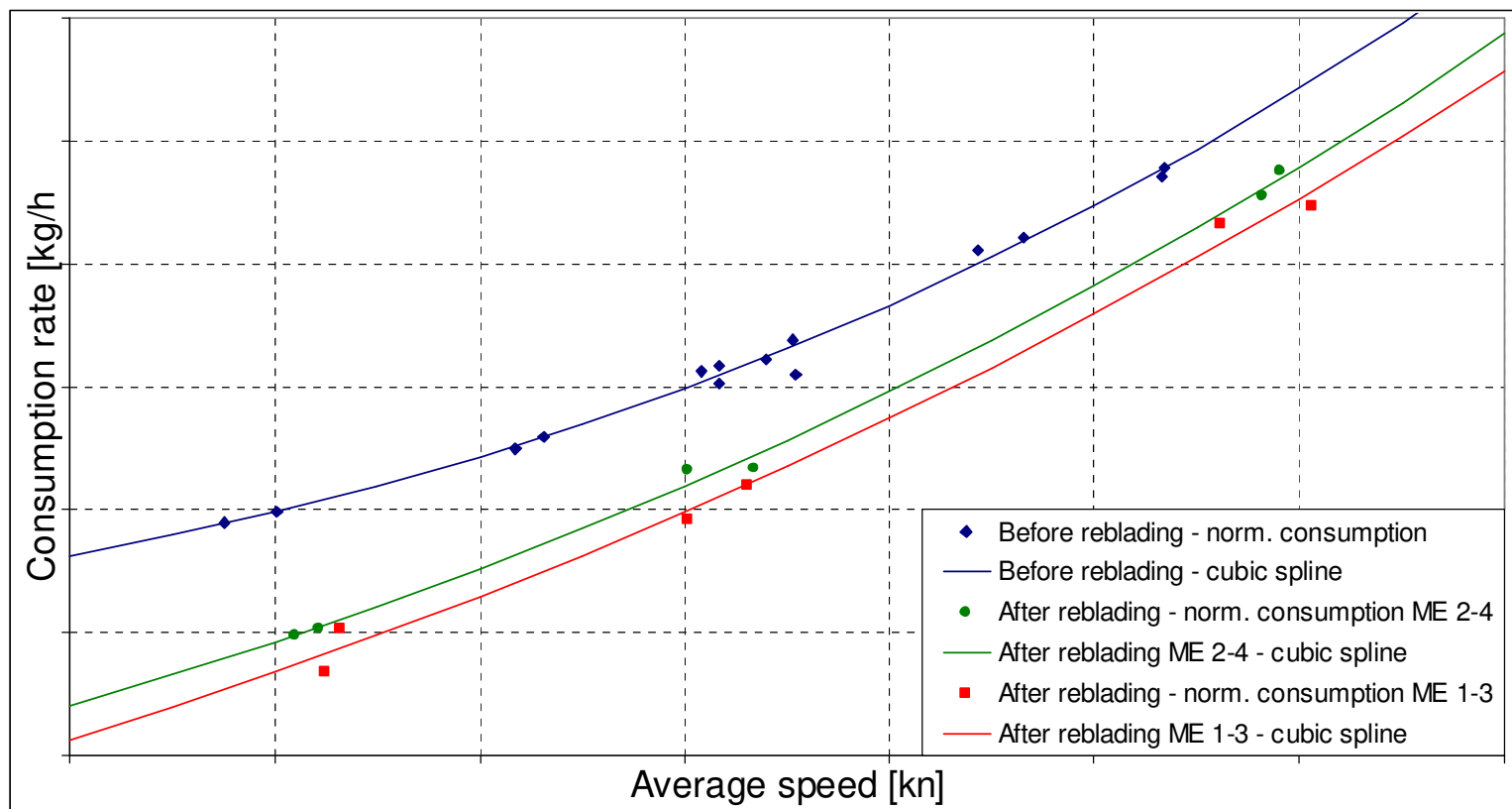


| SHIP 1       |            |       |              |
|--------------|------------|-------|--------------|
| Speed<br>kts | Power [kW] |       | R<br>%       |
|              | before     | after |              |
| 19.5         | 19410      | 14921 | 23.13        |
| 20           | 20918      | 15573 | 25.55        |
| 20.5         | 22427      | 16226 | 27.65        |
| 21           | 23935      | 16878 | 29.48        |
| <b>EI</b>    |            |       | <b>26.5%</b> |

| SHIP 2       |       |       |              |
|--------------|-------|-------|--------------|
| Speed<br>kts | PB    | PA    | R<br>%       |
|              | kW    | kW    |              |
| 19.5         | 18177 | 14921 | 17.92        |
| 20           | 19453 | 15573 | 19.95        |
| 20.5         | 20729 | 16226 | 21.72        |
| 21           | 22005 | 16878 | 23.30        |
| <b>EI</b>    |       |       | <b>20.8%</b> |



## Assessment of re-blading and engine overhauling effect on fuel consumption



- Dedicated sea trials before reblading (4 ME running) and after (2 ME running)
- after reblading ME 2-4 (none overhauled): 11,5%
- after reblading ME 1-3 (one overhauled): 14%

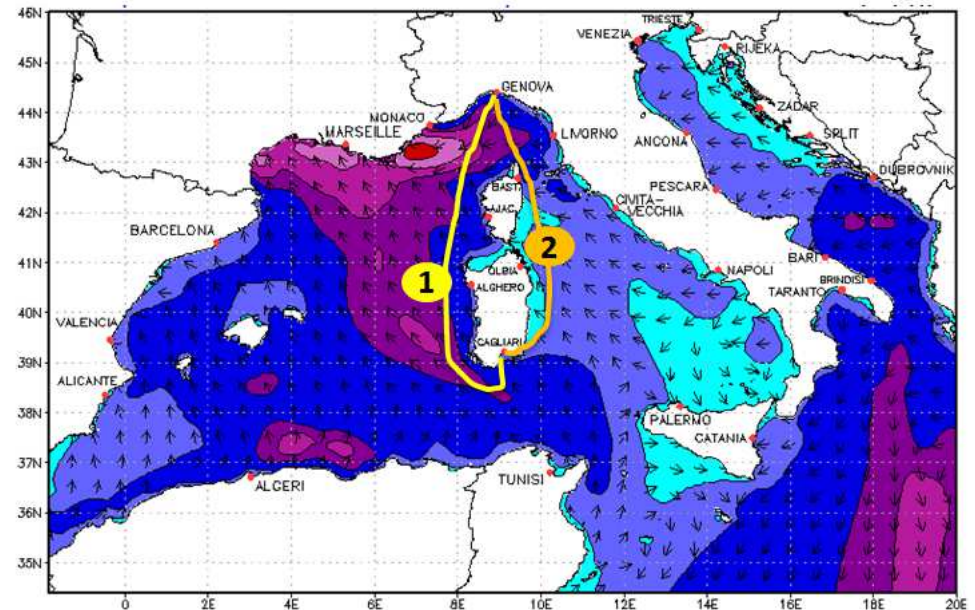


An automated module can help Master to save fuel:

- best route depending on weather condition
- best engine configuration for each sub-trip along the route

Stating the main voyage data:

- ATD: actual time at departure
- ETA: estimated time at arrival
- Ship power generation configurations
- Max allowed speed with sea state
- Voyage waypoints



The sailing assistant provides information on minimal consumption route and on power (engine) configuration to be set for each trip in order to optimize the overall fuel consumption and fulfilling the ETA required.

PM&OTE - Sailing assistant, CONFIGURATION CONSOLE.vi

### SAILING ASSISTANT CONFIGURATION CONSOLE

VOYAGES CONFIGURATION

#### AVAILABLE VOYAGES

| # | Voyage                      | trips | distance [nm] | time [h:m] |
|---|-----------------------------|-------|---------------|------------|
| 1 | VADO LIGURE - CIVITAVECCHIA | 8     | 209.9         | 00:00      |
| 2 | TARRAGONA - VADO LIGURE     | 8     | 377.7         | 00:00      |

#### VOYAGE TRIPS' DETAILS

| # | Latitude         | Longitude        | name              | start time       | speed [kn] | time [h:m] | dis |
|---|------------------|------------------|-------------------|------------------|------------|------------|-----|
| 1 | 44° 16' 0.12" N  | 8° 28' 0.12" E   | PORTO VADO LIGURE | 17/09/2018 10:01 | 2.00       | 01:40      |     |
| 2 | 44° 13' 48.00" N | 8° 31' 30.00" E  |                   | 17/09/2018 11:41 | 9.38       | 08:43      | 8   |
| 3 | 43° 4' 59.98" N  | 9° 33' 0.00" E   |                   | 17/09/2018 20:35 | 9.38       | 04:07      | 3   |
| 4 | 42° 31' 0.12" N  | 9° 58' 0.12" E   |                   | 18/09/2018 00:32 | 9.38       | 01:42      | 1   |
| 5 | 42° 27' 0.00" N  | 10° 19' 0.12" E  |                   | 18/09/2018 02:14 | 9.38       | 04:16      | 4   |
| 6 | 42° 7' 0.12" N   | 11° 5' 60.00" E  |                   | 18/09/2018 06:31 | 9.38       | 02:49      | 2   |
| 7 | 42° 3' 42.12" N  | 11° 41' 30.12" E | TSS IN            | 18/09/2018 09:30 | 5.00       | 00:40      |     |
| 8 | 42° 6' 27.00" N  | 11° 44' 6.00" E  | TSS INBOUND       | 18/09/2018 10:01 | END        | VOYAGE P   |     |

#### SCHEDULING

**VADO LIGURE - CIVITAVECCHIA**

Actual Time at Departure  
 ATD 17/09/2018 @ 10:01

Expected Time at Arrival  
 ETA 18/09/2018 @ 10:01  
 18/09/2018 @ 12:21

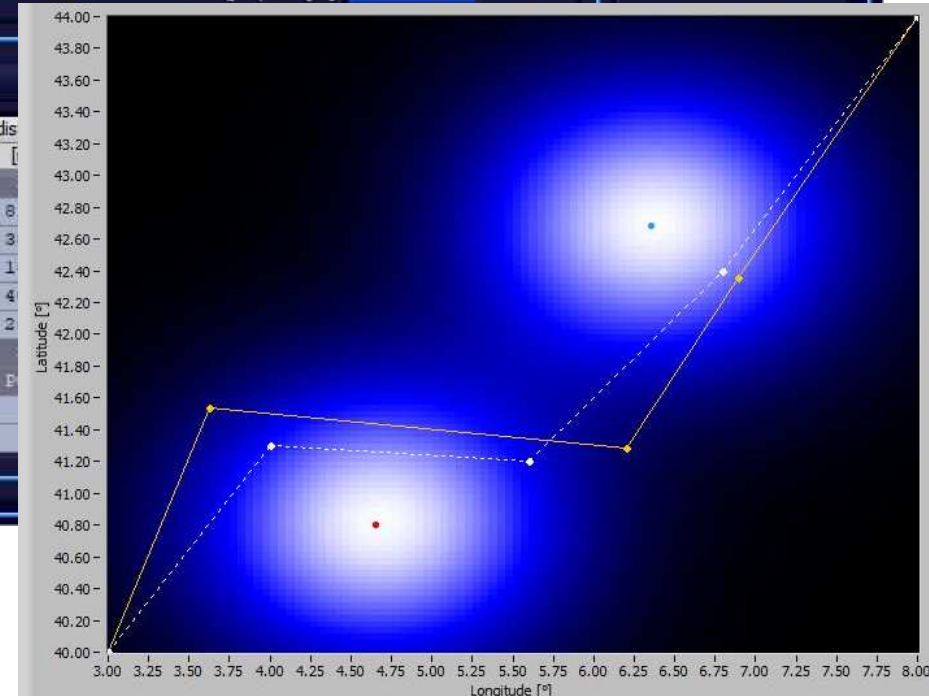
Sailing time [h] 24:00

Voyage extension [nm] 209.92

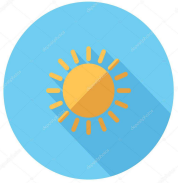
Average speed [kn] 8.75

ETA advance: 02:20

Sailing assistant allows to get a fuel-optimized route starting from the initial route chosen by crew

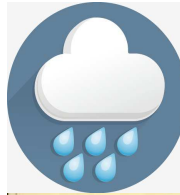






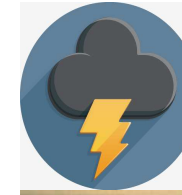
**BEAUFORT FORCE 3**  
WIND SPEED: 7-10 KNOTS

SEA: WAVE HEIGHT 6-1M (2-3FT), LARGE WAVELETS, CRESTS BEGIN TO BREAK. ANY FOAM HAS GLASSY APPEARANCE, SCATTERED WHITECAPS



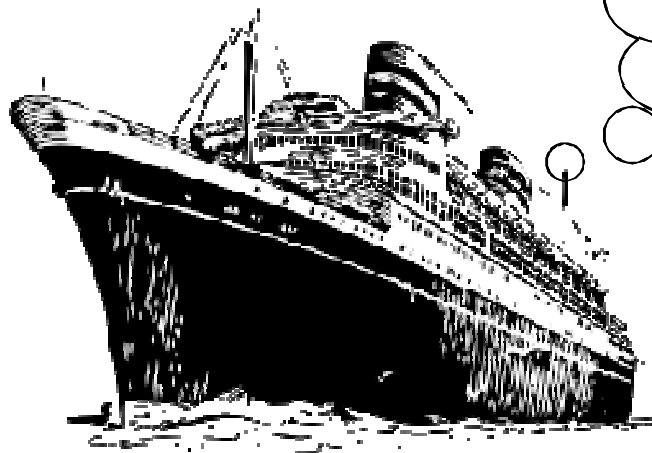
**BEAUFORT FORCE 7**  
WIND SPEED: 28-33 KNOTS

SEA: WAVE HEIGHT 4-5.5M (13.5-19 FT), SEA HEAPS UP. WHITE FOAM FROM BREAKING WAVES BEGINS TO BE BLOWN IN STREAKS ALONG THE WIND DIRECTION



**BEAUFORT FORCE 8**  
WIND SPEED: 34-40 KNOTS

SEA: WAVE HEIGHT 5.5-7.5M (18-25FT), MODERATELY HIGH WAVES OF GREATER LENGTH, EDGES OF CREST BEGIN TO BREAK INTO THE SPINDRIFT, FOAM BLOWN IN WELL MARKED STREAKS ALONG WIND DIRECTION.



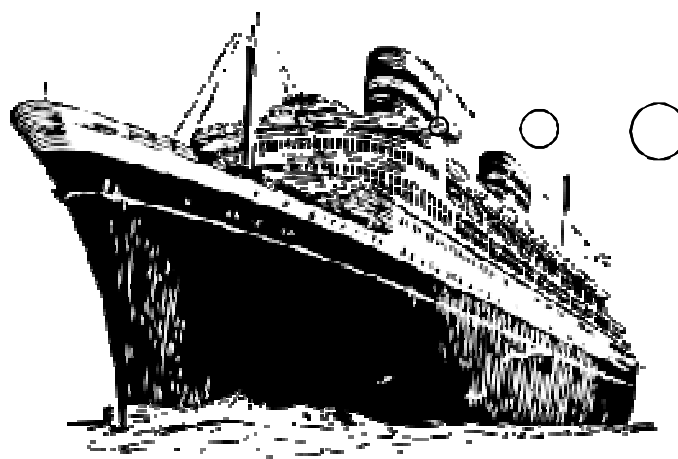
Which weather can be expected during navigation?

- **Wave radar**
  - High accuracy
  - Reduced range prediction
  - High installation costs
- **Weather forecast service**
  - Good accuracy
  - High range prediction
  - Reduced costs

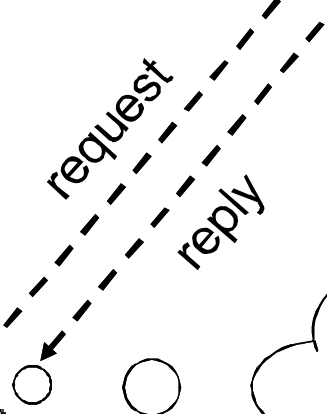
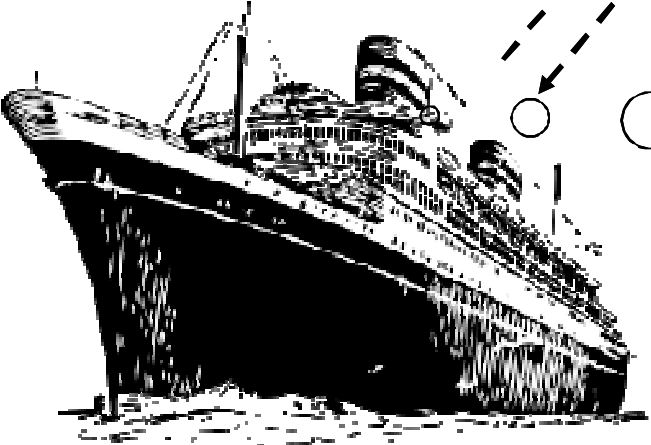
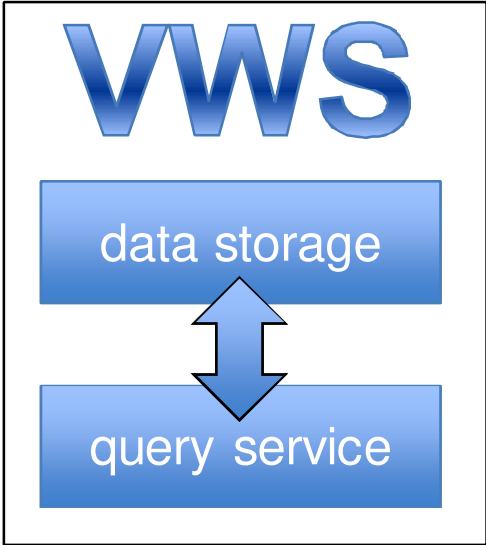
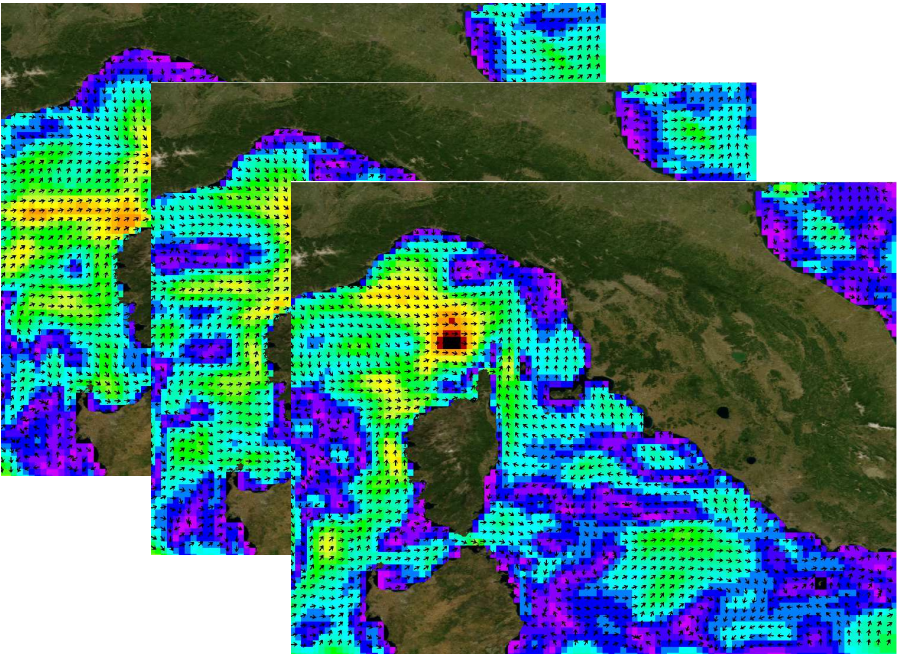
CETENA is currently developing a Virtual Weather Station aimed to:

- **Collect weather condition data**, characterized by
  - 1 hour averaging
  - Reduced spatial resolution
  - Different kind of data, such as current, wave, temperature, wind
- **Provide a query service for different kind of applications:**
  - Sailing assistance (performance and safety)
  - Voyage prediction
  - Post-process analysis

*The accuracy of this kind of data has already been checked during international cooperative research project*



Which weather  
can be expected  
during  
navigation?



Which weather can be expected during navigation?



## Ship monitoring effects on ship management

1. Monitoring of current sailing condition in real time
2. Analysis of ship performances depending on: crew, season, route, operating condition
3. Real time evaluation of maintenance effects on ship performances, stating the KPI prescribed by international standards
4. Improvement of the usual maintenance planning stating the monitored performances
5. Fuel consumption reduction through route optimization
6. Optimisation of structural maintenance and reduction of insurance costs



**Green ship means...**



**...spend money?**

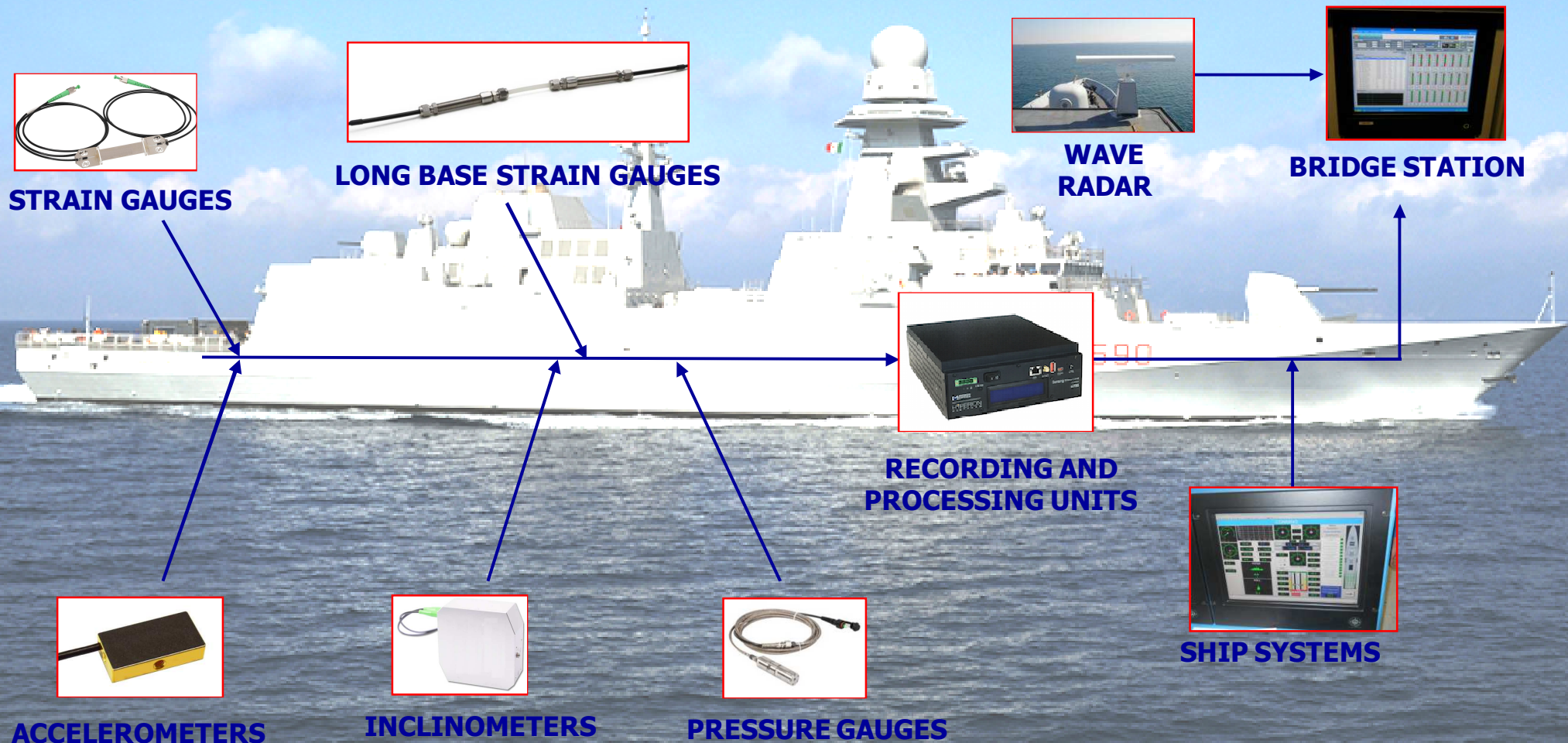


**Not always!**

a **FINCANTIERI** COMPANY

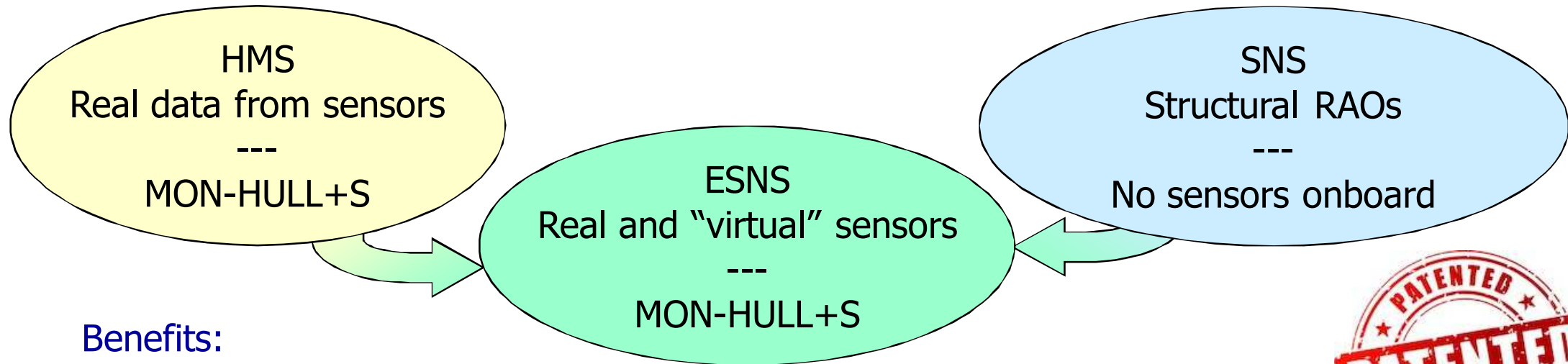
## HMS - Hull Monitoring System based on Fiber Optic Technology

- developed for Navy ships and merchant ships, including ATEX environment
- RINA Type Approval certified, suitable for MON-HULL additional Class notation
- Sensor costs comparable with traditional ones



## Enhanced Safe Navigation System

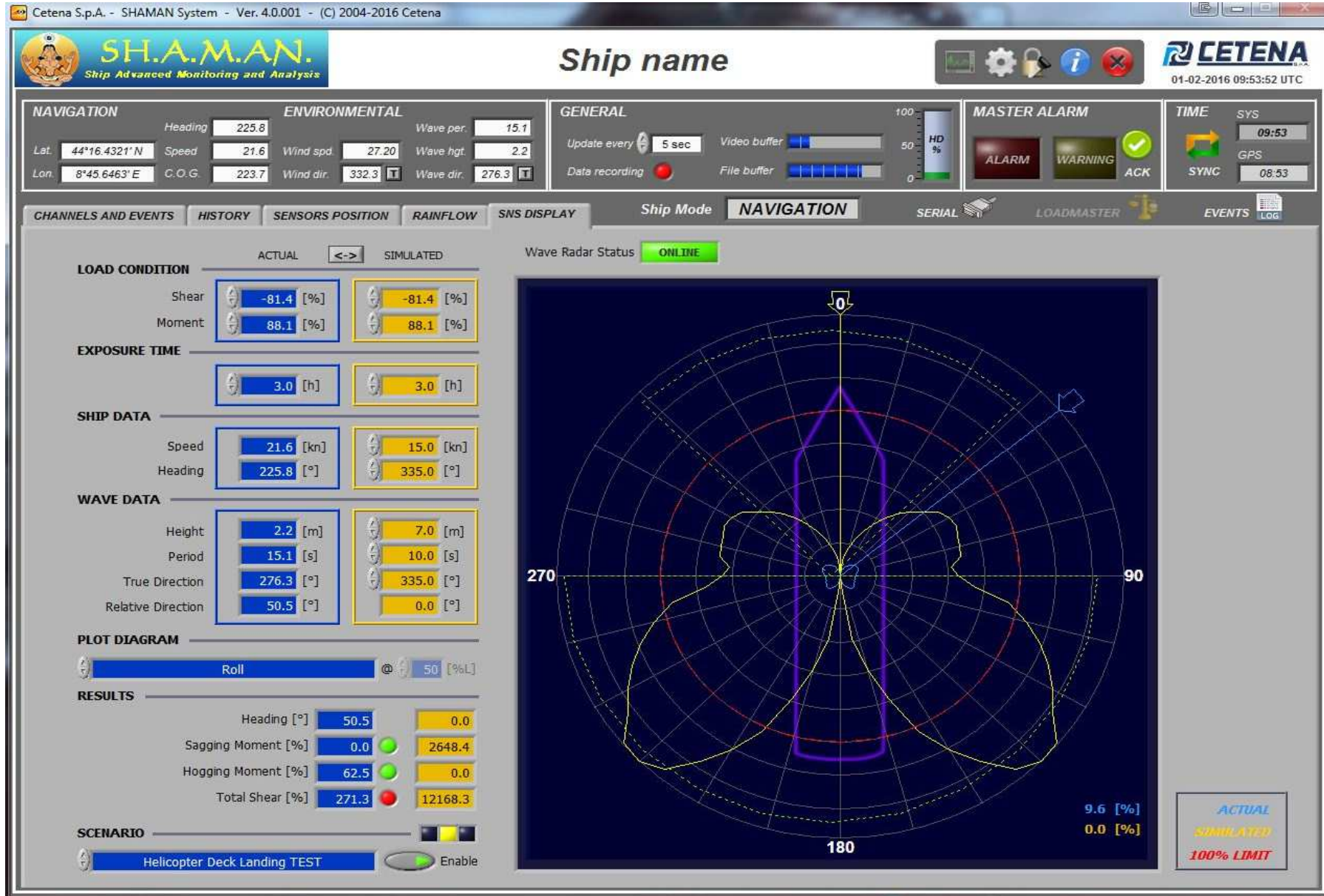
- Hybrid systems using few sensors and FEM/CFD model results for higher accuracy and enhanced decision support system;



### Benefits:

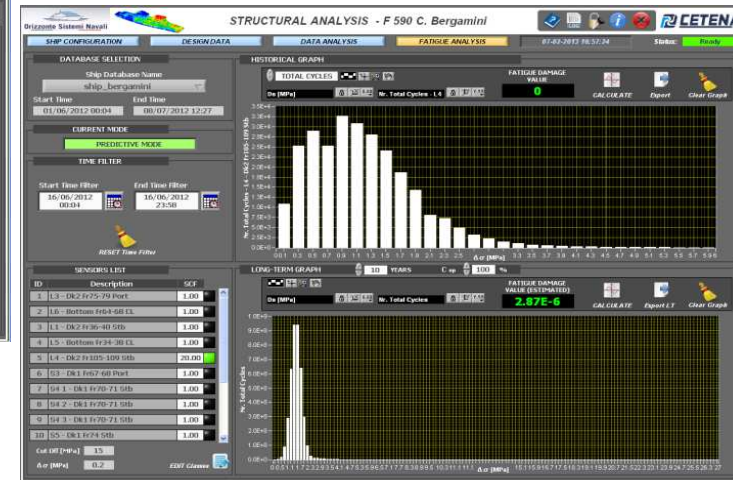
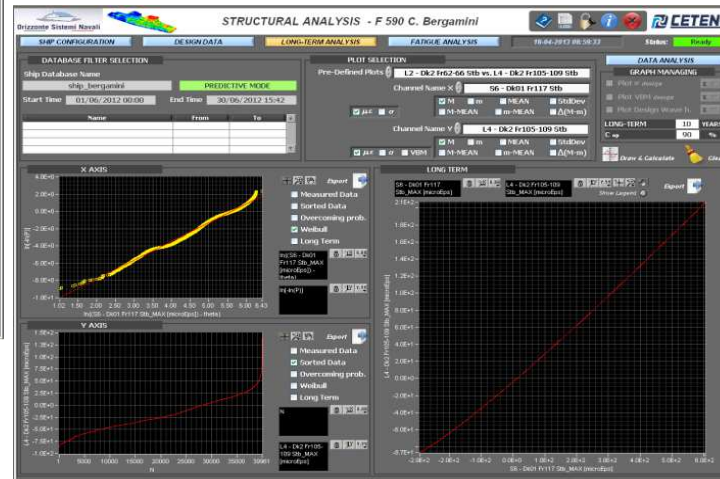
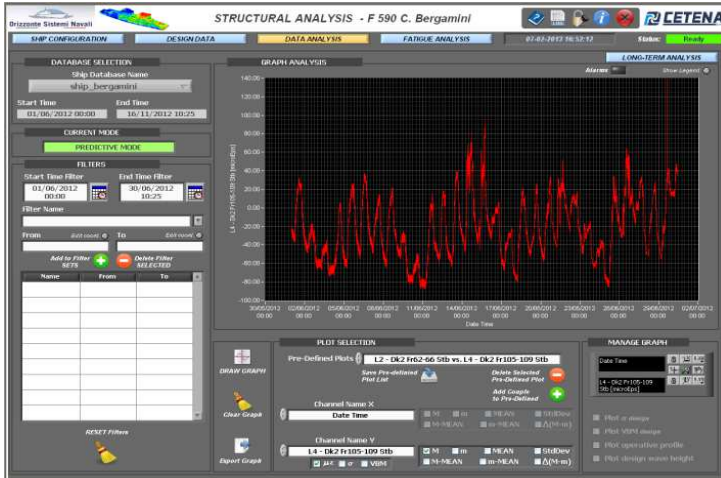
- Joins benefits from HMS (real data) and from SNS (provisional tool)
- Virtual sensors (no cables);
- Ship motions and loads forecast tuned by using sensors data: higher accuracy (local and global effects);
- Ship operating windows widened;
- Operating Envelope Diagrams aid in ship operations (landing / take off, operations at sea, ...): more support to Master decision.



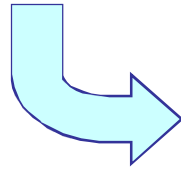




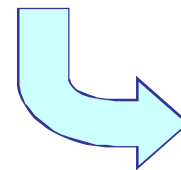
# Post-processing of data recorded by Sh.A.M.An. Hull Monitoring System



- ✓ Data-Base archive
- ✓ time histories plot
- ✓ data filtering
- ✓ operative profile assessment

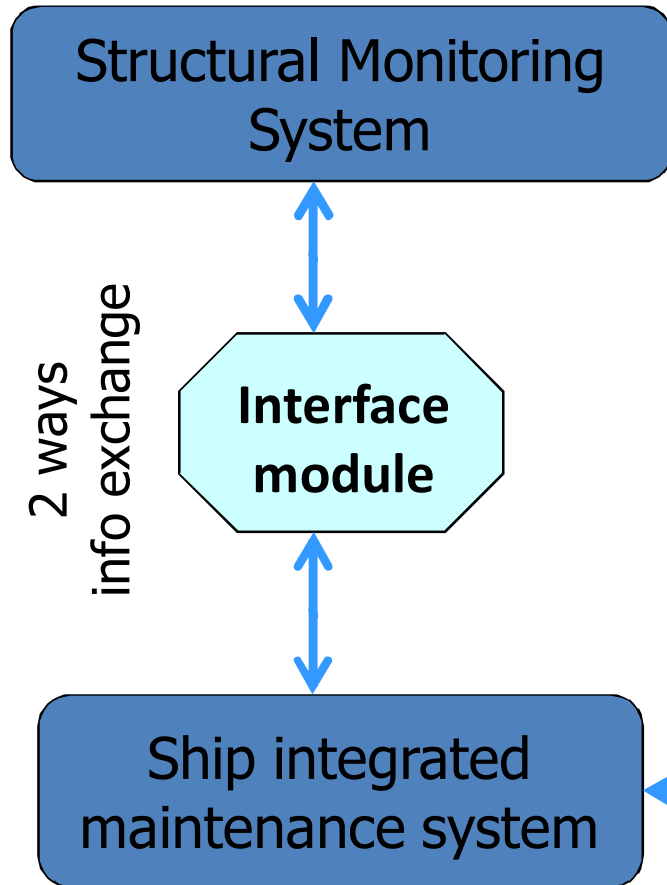


- ✓ long term statistical extrapolation
- ✓ highest expectable loads estimation

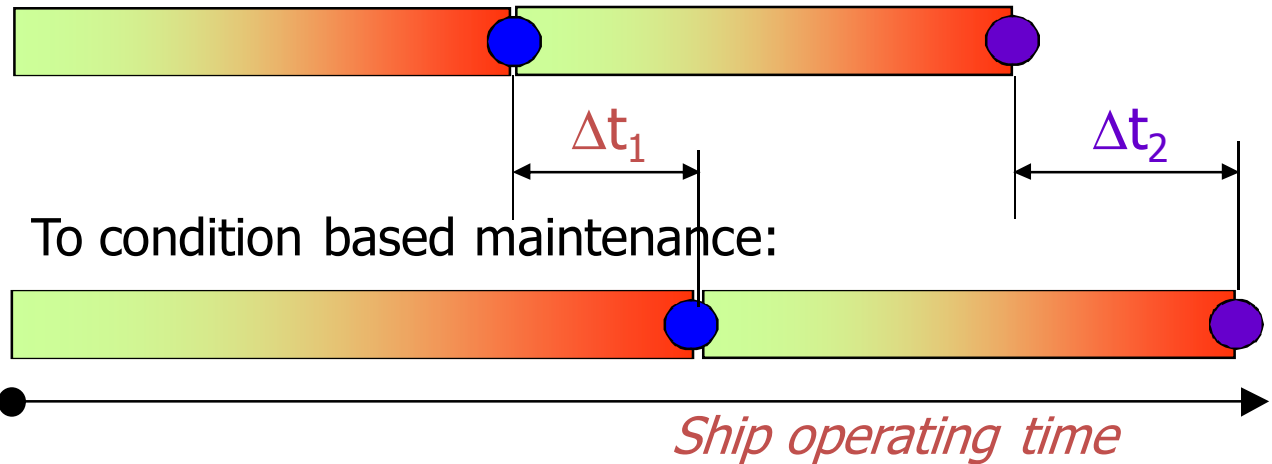


- ✓ elapsed and long term forecasted fatigue life
- ✓ estimate effects on fatigue life by vessel use, detail geometry/surface

If integrated with the on-board maintenance suite, the Sh.A.M.An. System can allow to extend the CBM concept to ship structures.



From traditionally scheduled maintenance:



Maintenance tasks

- local / global inspections
- structure repair
- cargo inspection
- system maintenance



**Thanks for your kind attention.**



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