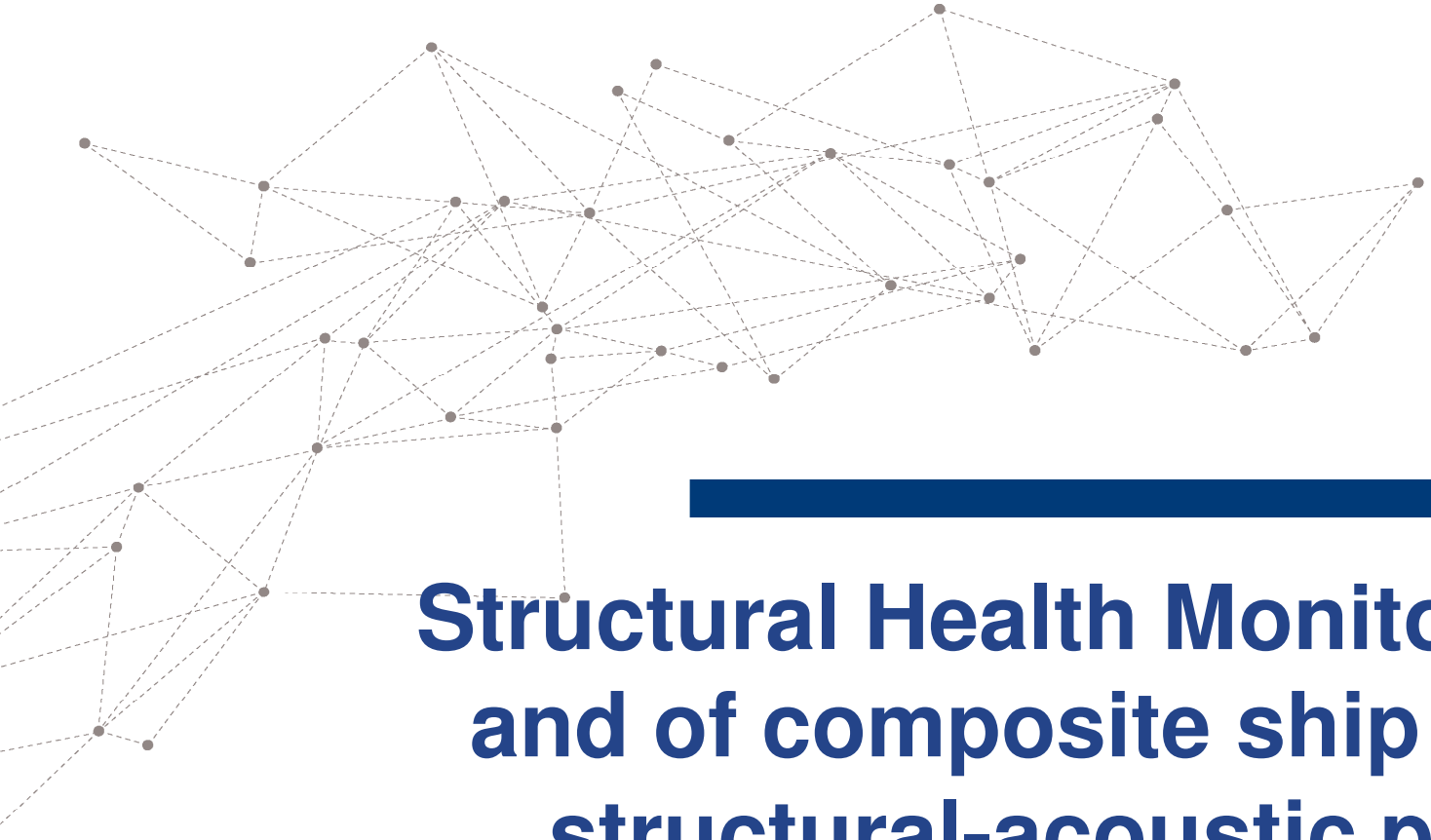


Structural Health Monitoring of ships and of composite ship domes with structural-acoustic purposes

Bremen, 29/01/2020

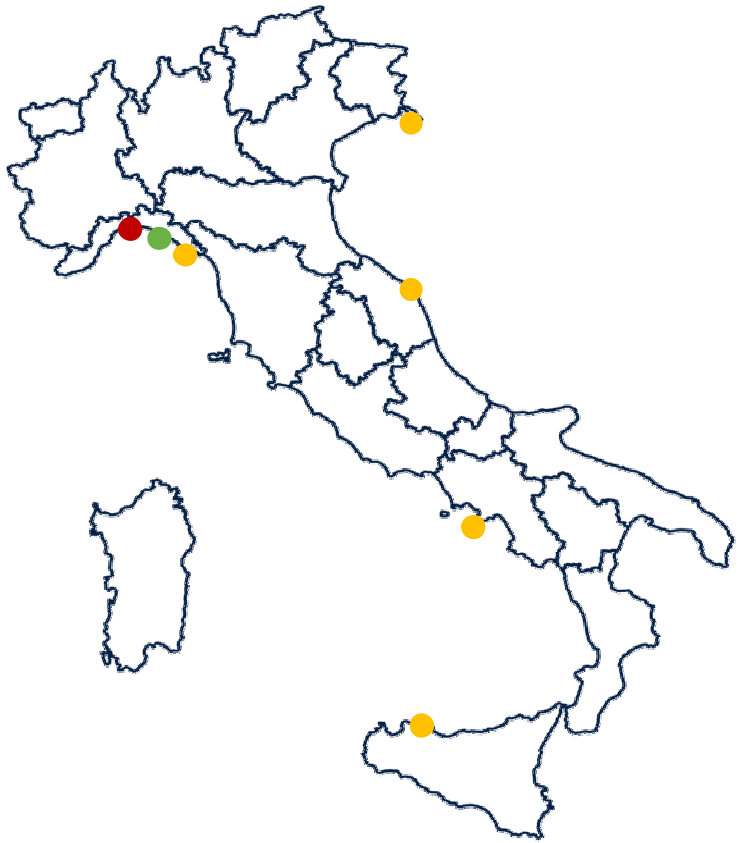
CETENA SpA

Established in 1962.

Part of FINCANTIERI Group.

Supports customers and develops research projects, combining competences and skills together to find tailored solutions.

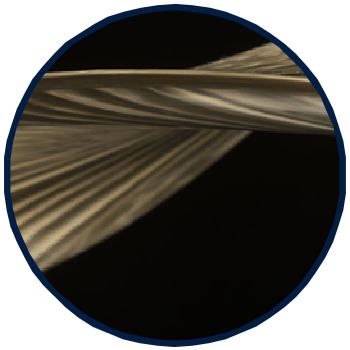
CETENA also cooperates with National and European research centers.



Main Office
- Genova

Workshop
- Riva Trigoso

Office
- Muggiano
- Trieste
- Ancona
- Castellammare
- Palermo



RESEARCH PROJECTS

ENGINEERING CONSULTANCY

EXPERIMENTAL ACTIVITIES

TRANSFER OF TECHNOLOGY

PRODUCTS

a FINCANTIERI COMPANY

Naval and merchant ships often undergo to heavy weather conditions.

Assessing and taking ship structural behaviour under control during operations in rough seas can be based on observations and on manual reporting by on-board personnel, but this approach…

…is unreliable, inefficient and affected by single person attitude and perception of the surrounding reality

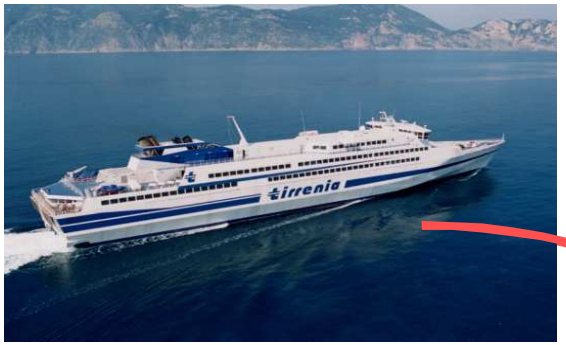
…is subjected to loss of records when crew is particularly busy, i.e. in critical conditions, when data are of maximum interest.

The only objective, reliable and undisputable method to detect and record ship behaviour and status in service is by means of an automated, unattended monitoring system: depending on its capabilities, it assumes the role of a *Decision Support System*.

- CETENA provides hull monitoring systems and DSS since '90s
- Nowadays CETENA systems are standardized and RINA Type Approved

Hull Monitoring Systems by CETENA: 20 years evolution

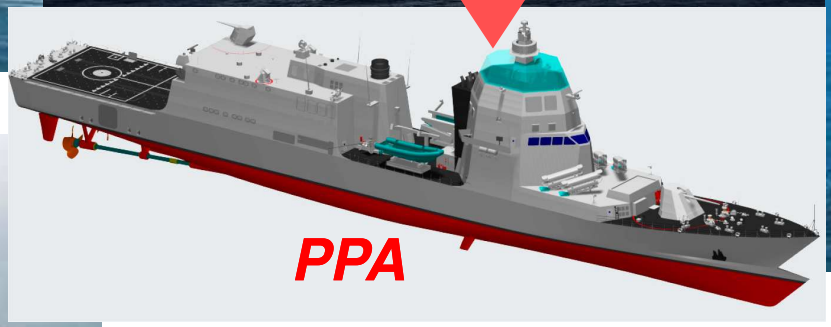
Aries



Scirocco

Cavour

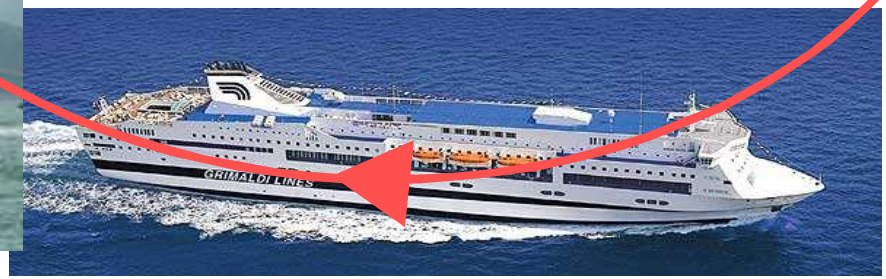
Fremm



PPA

Caribbean Princess

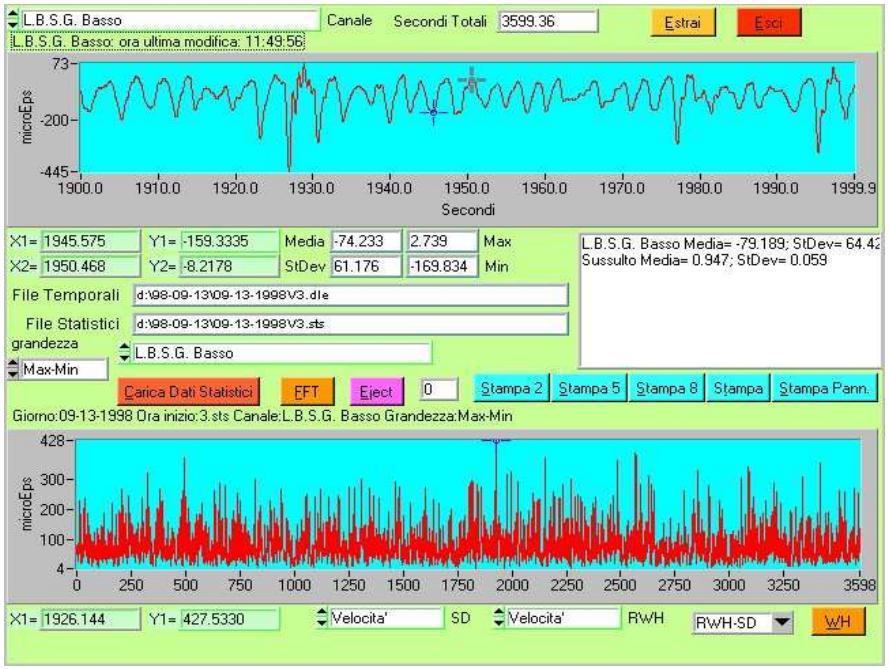
Bettica



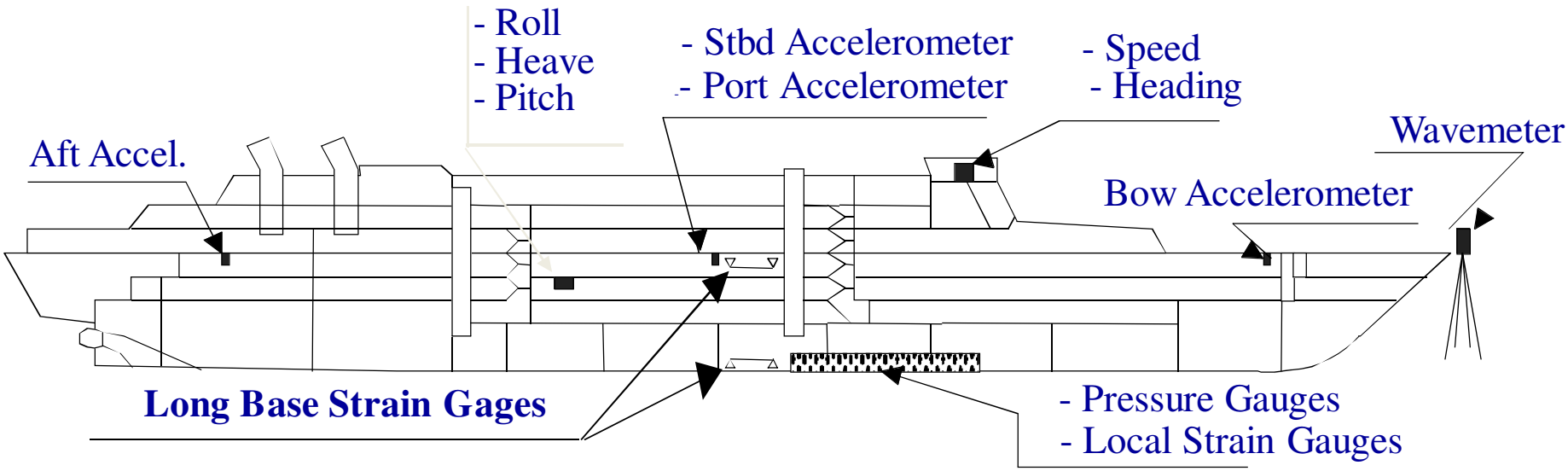
Fantastic

a FINCANTIERI COMPANY

Fast ferry MDV-3000 "Aries"



Hull monitoring
June 1998 – December 1999



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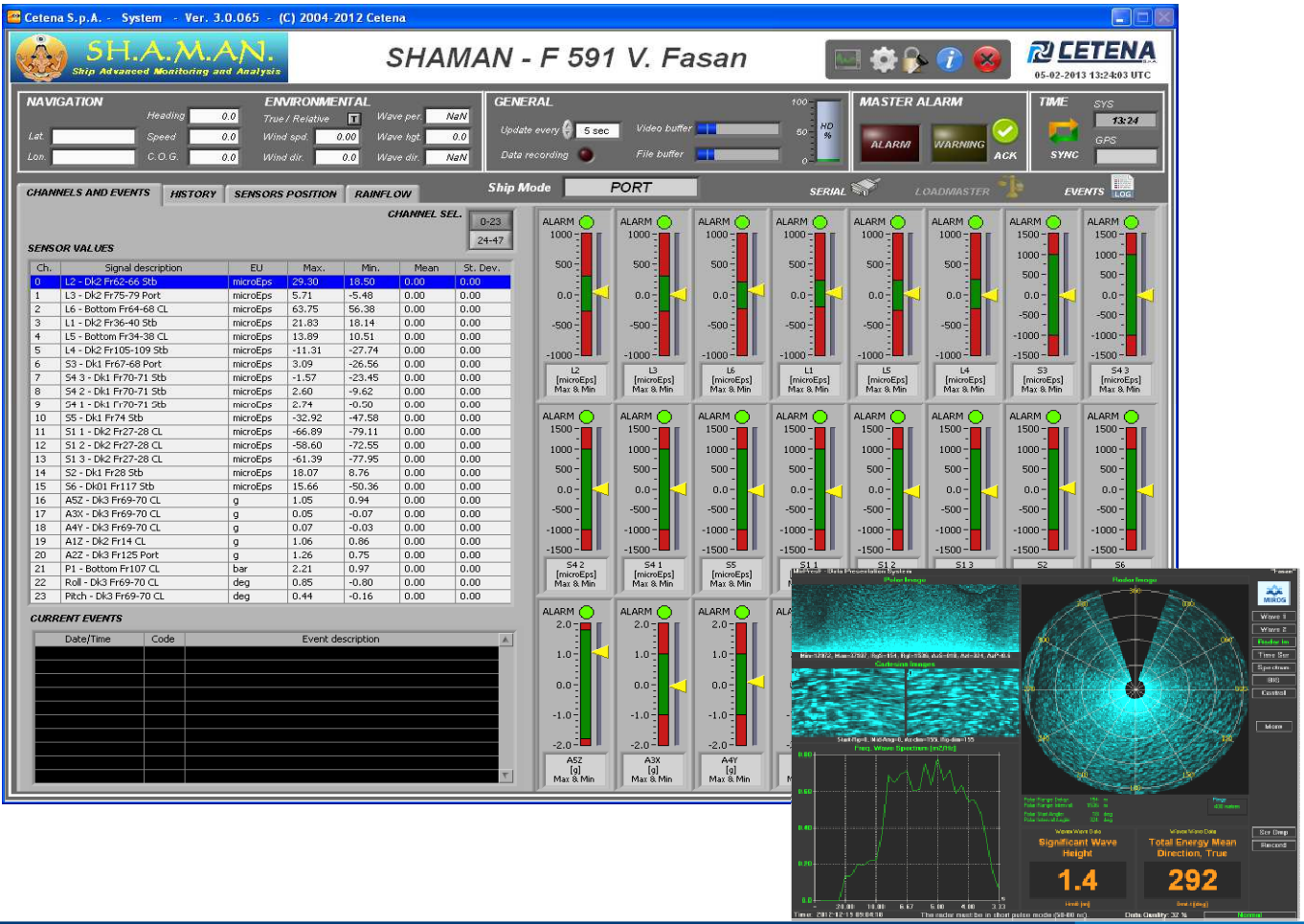
HMS Sh.A.M.An. on board FREMM frigates

- ✓ First installation in 2012 on F590 "Bergamini"
- ✓ Delivered on 9 ships
- ✓ Under delivery on 1 ship



Main features of HMS Sh.A.M.An.

- ✓ Real time acquisition and analysis
- ✓ Hardware COTS
- ✓ Modular architecture
- ✓ Interconnection with ship systems
- ✓ Direct measurement of sea state
- ✓ Fatigue cycles counting
- ✓ Compliant with RINA Registry
- ✓ Compliant with IMO Alarm Code
- ✓ RINA MON-HULL+S Class

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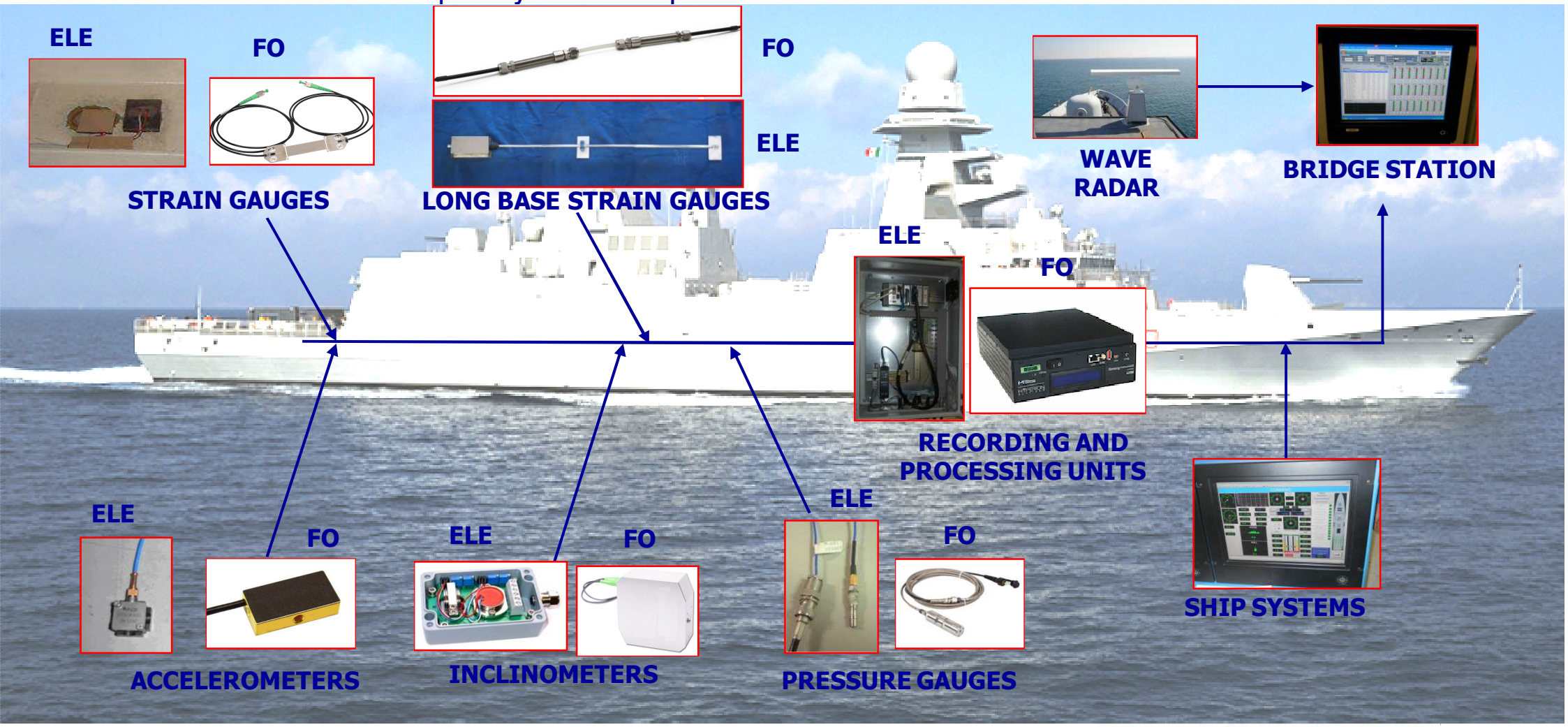
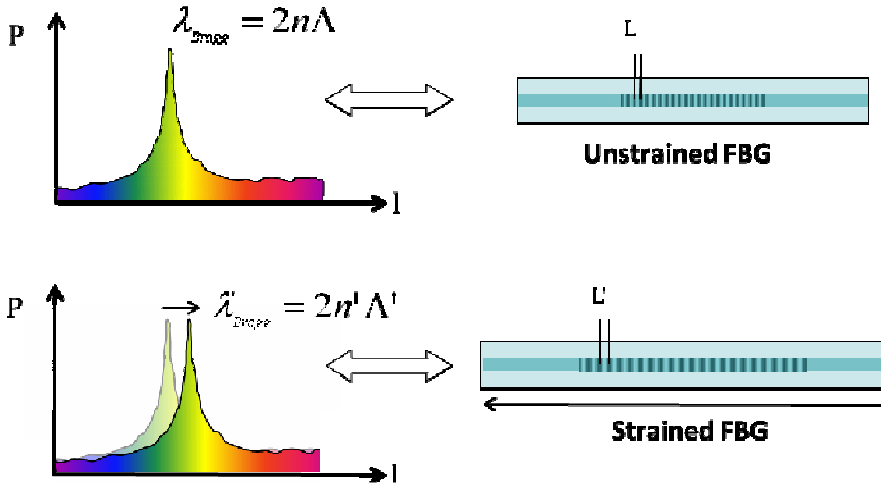
HMS - Hull Monitoring System (*with traditional and/or fiber optic technology)*

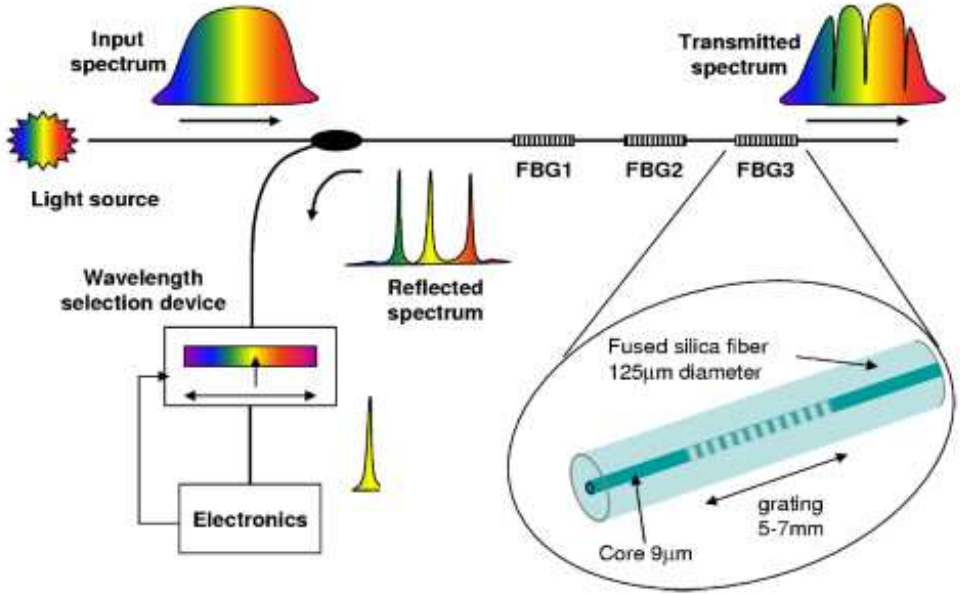
- developed for merchant and naval ships, including ATEX environment (for fiber optic system)
- continuously improved to an unified product with COTS components and dedicated SW
- RINA Type Approval certified, suitable for MON-HULL additional Class notation
- Sensor costs for fiber optic system comparable with traditional ones



Fiber optic technology main benefits

- ✓ BUS configuration: less cables
- ✓ Total noise immunity
- ✓ Up to 3 Km between sensors and processing unit
- ✓ IP 67, ATEX
- ✓ Suitable for extreme solicitations (> 10000 µm/m)
- ✓ Only one main processing unit even for big structures
- ✓ High resolution
- ✓ Thermal compensated
- ✓ No maintenance





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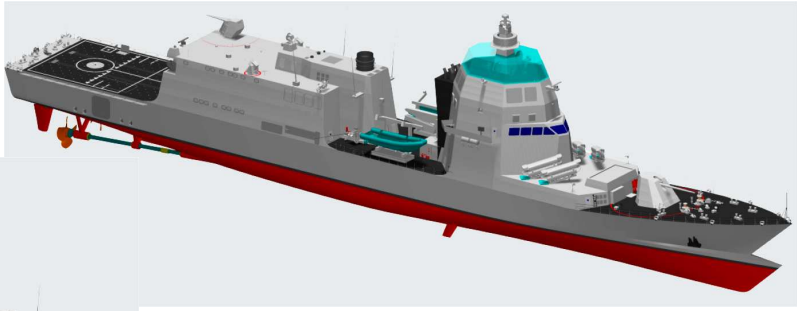
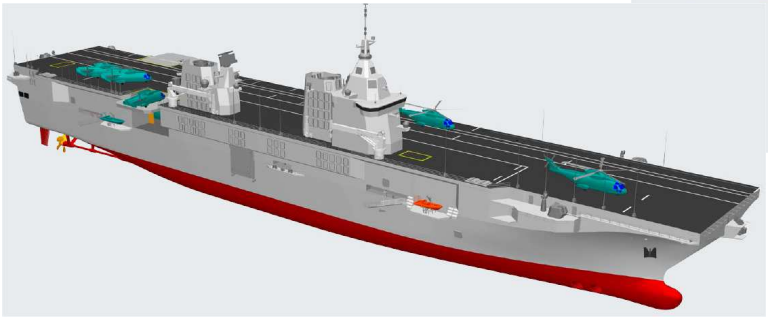
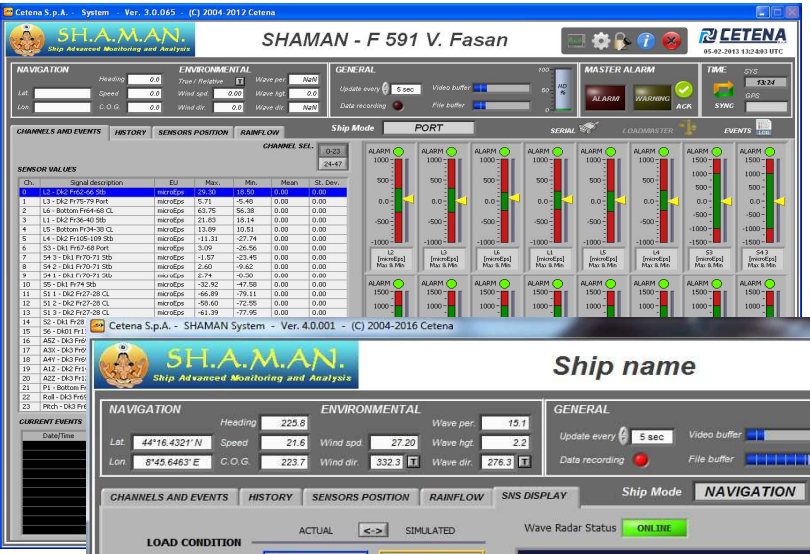
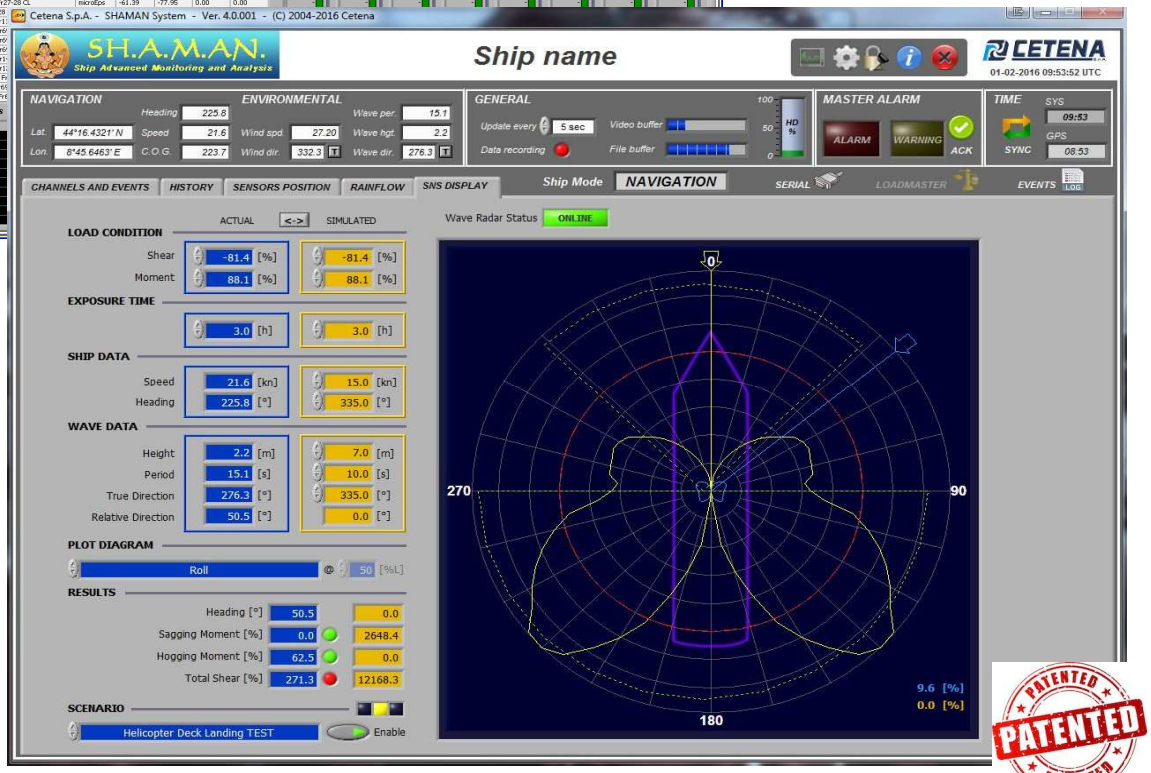
HMS Sh.A.M.An. "ESNS" on board PPA & LHD

- ✓ Order for installation on 8 ships









Additional ESNS features on PPA-LHD

- ✓ Fiber optic technology
- ✓ ESNS module
- ✓ Ship motions and loads forecast
- ✓ Forecast data tuned with sensors data
- ✓ Virtual sensors (no cables)
- ✓ Operating Envelope Diagrams for DSS in ship operations (landing / take off, operations at sea, …)
- ✓ Slamming detection module

PATENTED

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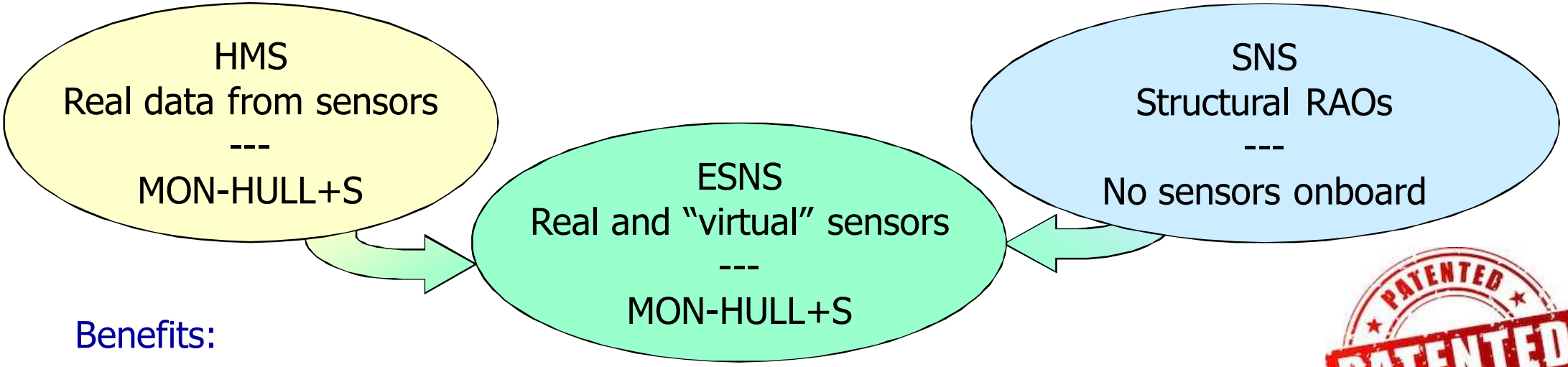
Enhanced Safe Navigation System

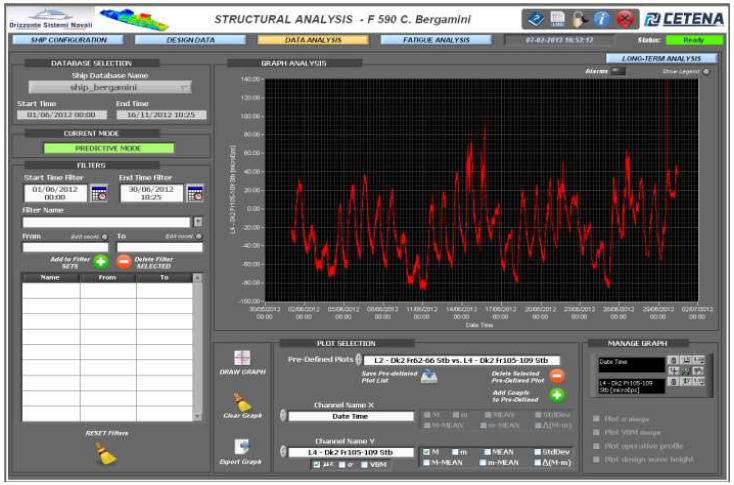
- Integrates data from sensors and FEM/CFD model response for higher accuracy and enhanced decision support system;



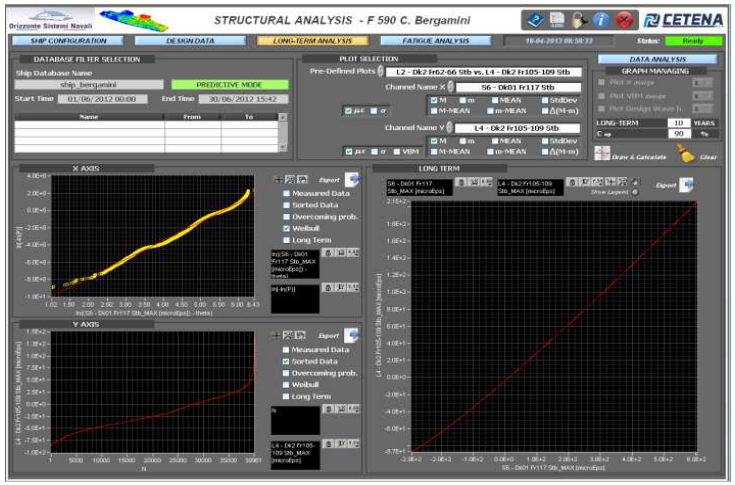
Benefits:

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

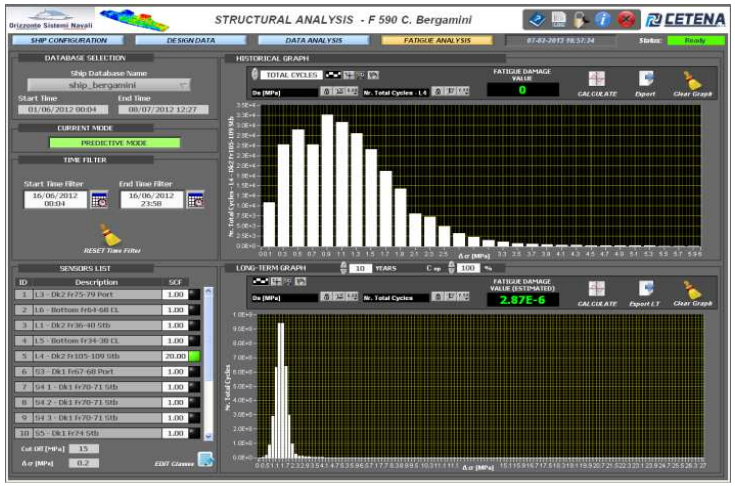
Post-processing of data recorded by Sh.A.M.An. Hull Monitoring System



- ✓ 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

Extension of Condition Based Maintenance from ship plants to ship structures

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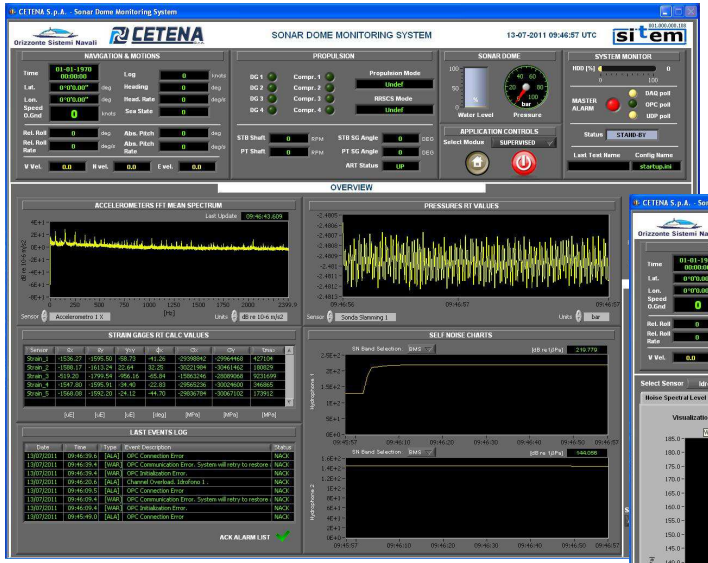
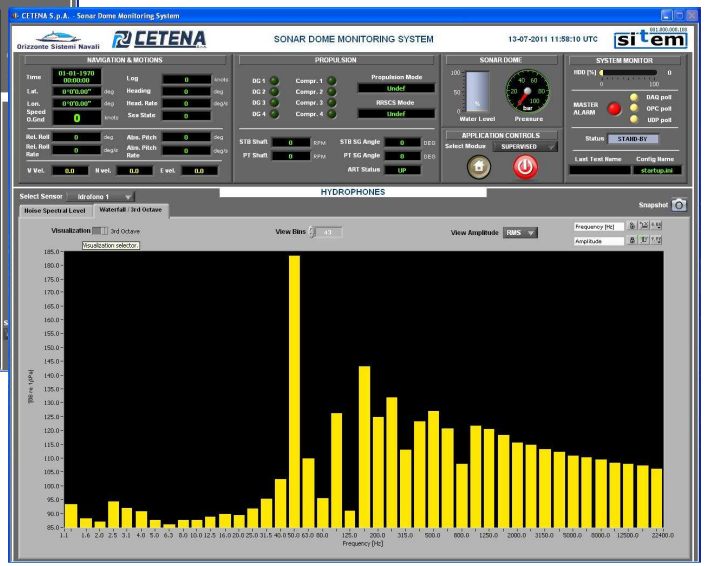
Development, design, on-board installation, commissioning, management and data analysis of structural&acoustic monitoring system for a composite-made Sonar Dome on frigate bow

- *accelerometers* on dome and on ship structure to detect and correlate vibrations
- *hydrophones* to detect self-noise
- *strain gauges* to monitor structural strains
- *pressure gauges* to acquire slamming pressures





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Sonar Dome

- Shape: hydrodynamic CFD
- Strenght: structural analysis FEM
- Acoustics: proper design

Strenght: thick structure

- Hydrodynamic pressures
- Shock and slamming impact loads

Acoustics: thin structure

- Acoustic transparency
- Density similar to water

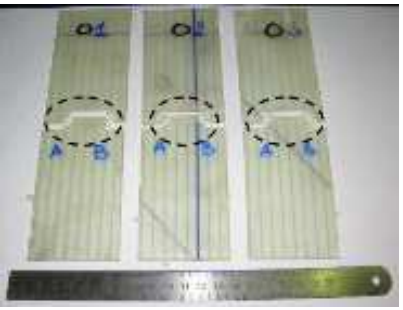
Design: wide tests on materials

- Mechanical characterization

compression

traction

In-plane shear



Flexural

Interlaminar shear

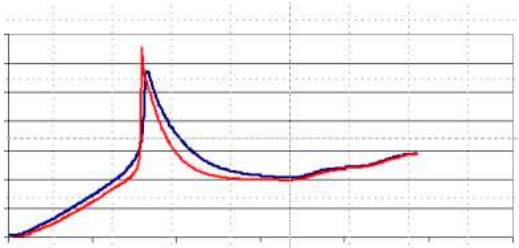
Interlaminar traction

G module

Transverse shear

- Acoustic characterization and acoustic/thickness relationship

- Resin cure thermal characterization



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Main target of the customized structural&acoustic monitoring system

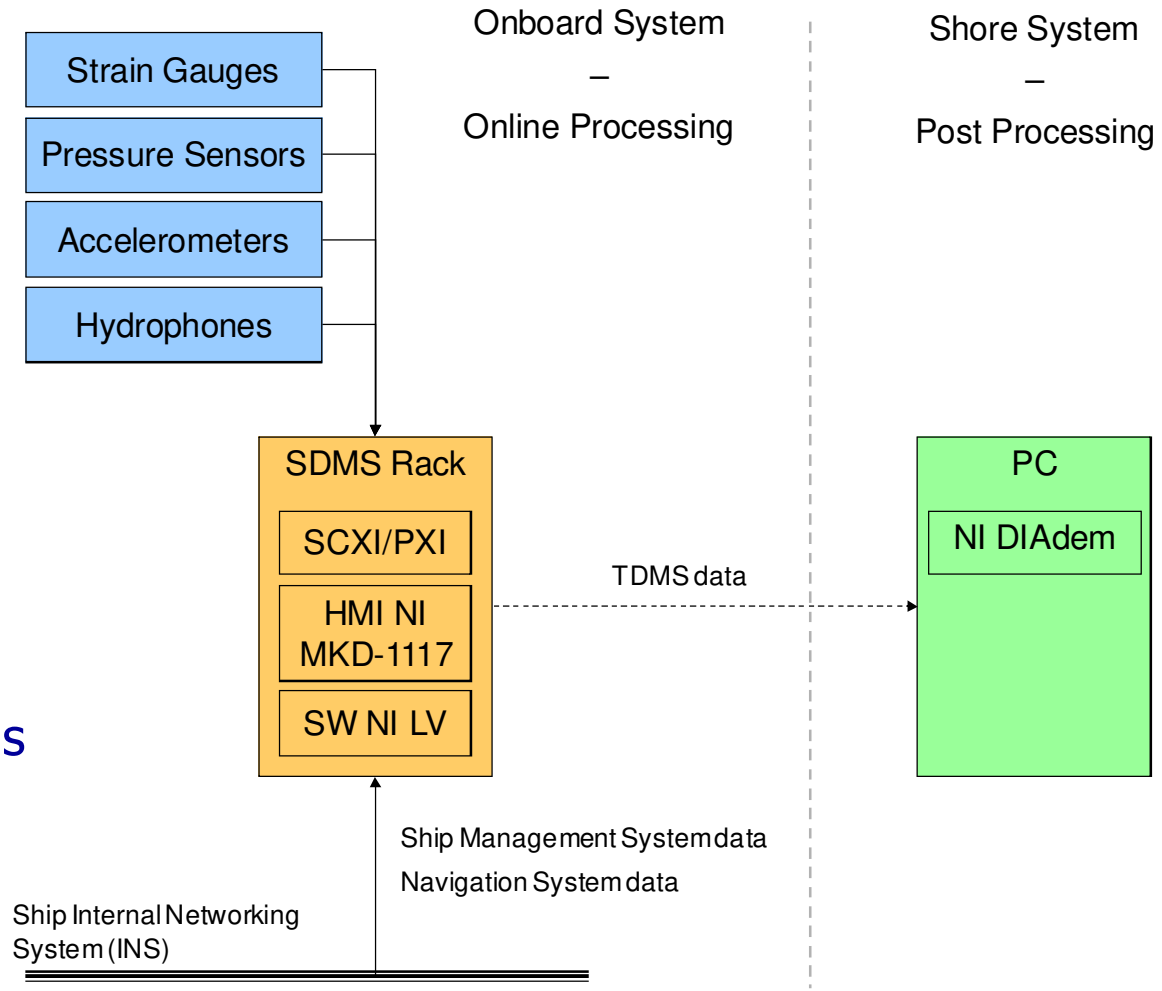
- ✓ *assessment* of structural and acoustic properties "as built"
- ✓ *feedback* on innovative solution
- ✓ *resolution* of disputes with other suppliers
- ✓ *data collection* to prevent eventual damages
- ✓ *data collection* to improve design for future ships

Main challenges to face with

- ➢ Sonar Dome filled with pressurized salt water: *all sensors to be waterproof / salt proof*
- ➢ Sound detection not influenced by ship vibrations: *hydrophones to be suspended*

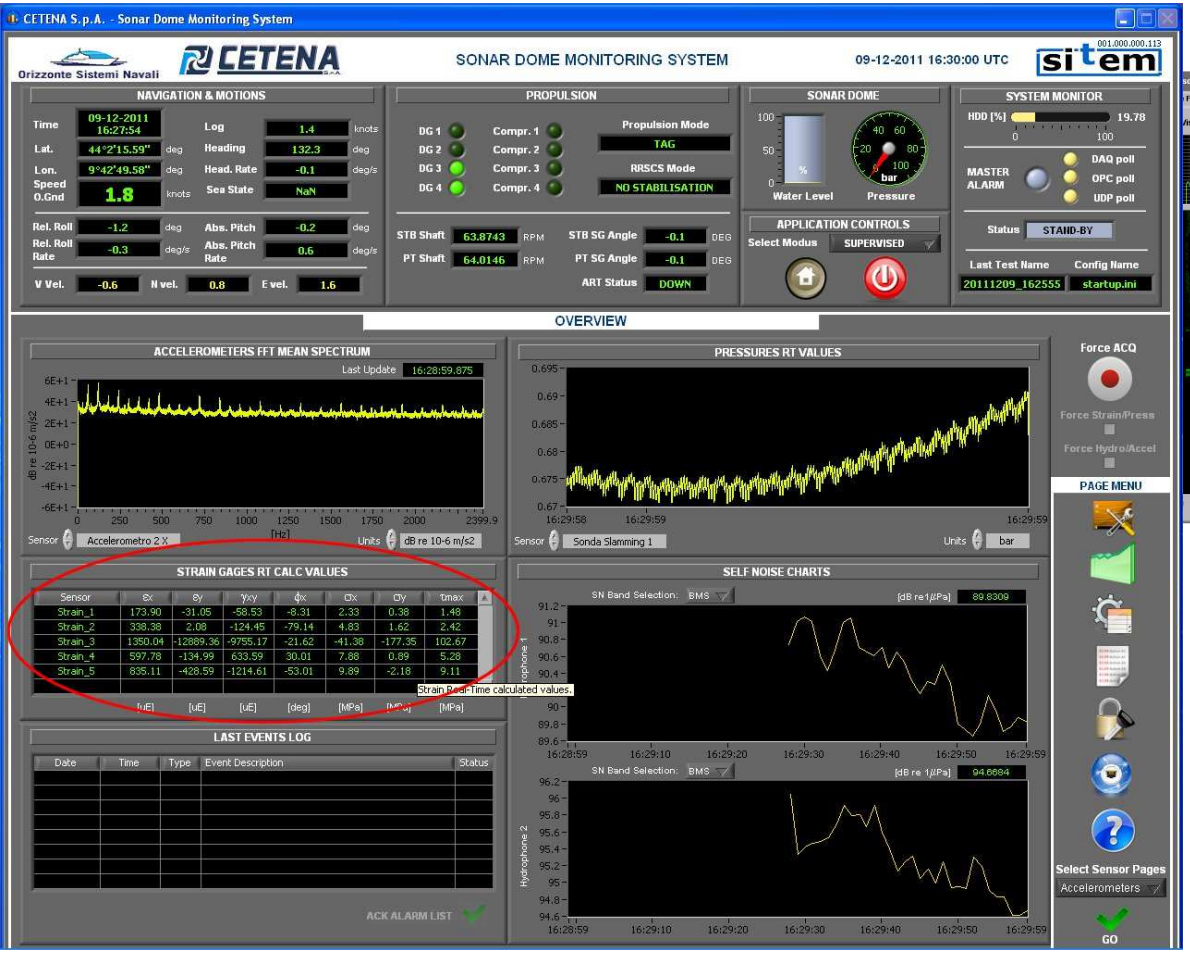
Dedicated high-performance HW/SW architecture

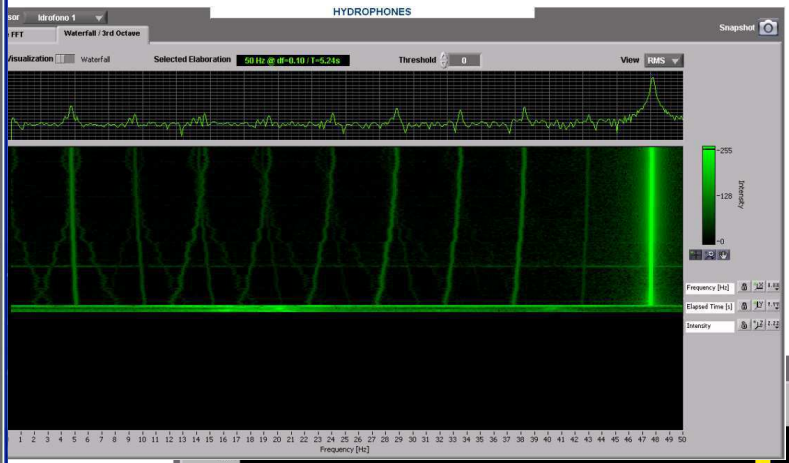
- Acquisition rates selected based on different sensors typologies
  - ✓Strain gages 200 Hz (slamming transient structural response)
  - ✓Pressure gauges 3 kHz (slamming peaks detection)
  - ✓Accelerometers 10 kHz (acoustic contribution from ship/dome structural vibrations)
  - ✓Hydrophones 200 kHz
- Acquisition of ship operational conditions to correlate sensors data with
- Online fast data processing
- Offline detailed data processing

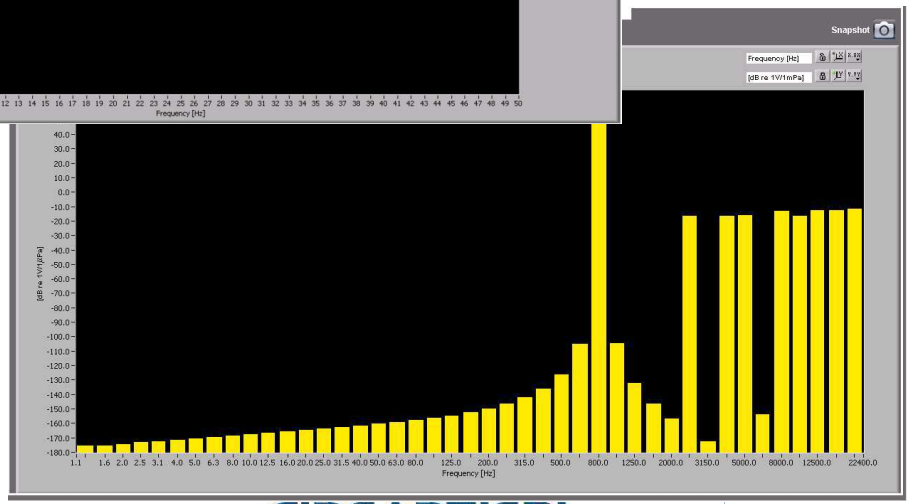


Online fast data processing

- Slamming events detection and energy calculation
- Narrow band structural response FFT
- Strain levels and fatigue cycles counting
- Hydrophones: Self-noise, narrow band waterfall diagrams, third octave FFT







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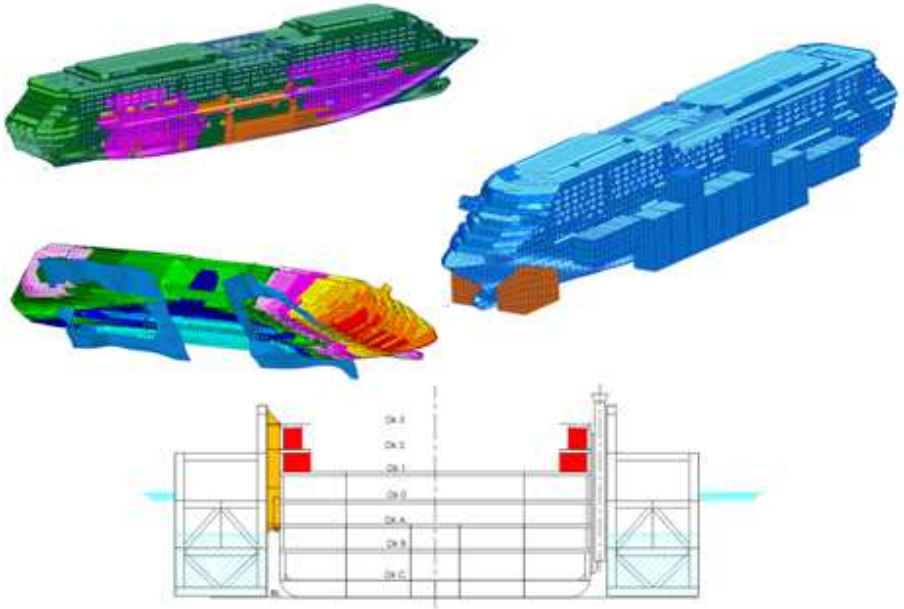
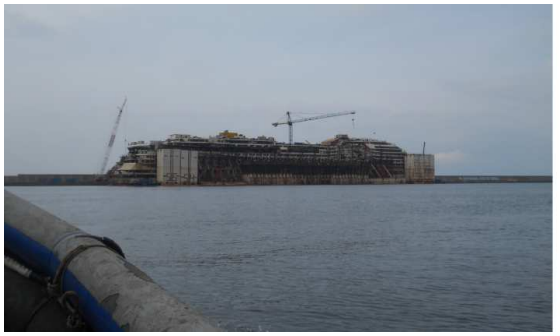
Special application: CETENA HMS on CONCORDIA wreck (dismounting surveillance)

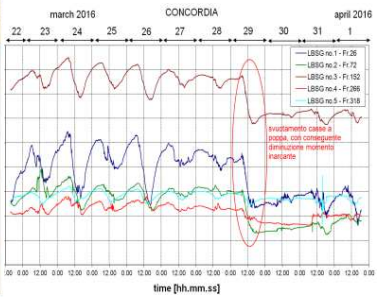
Ad-hoc designed and developed hull monitoring system on board Costa Concordia wreck, for:

- ✓ Monitoring structural stress on decks
- ✓ Prevent breaks during wreck transport and demolition
- ✓ Forecasting the consequences of decks removal
- ✓ Perform a safe wreck dismounting

FEM analyses to design and “guide” wreck removal, transport and dismounting







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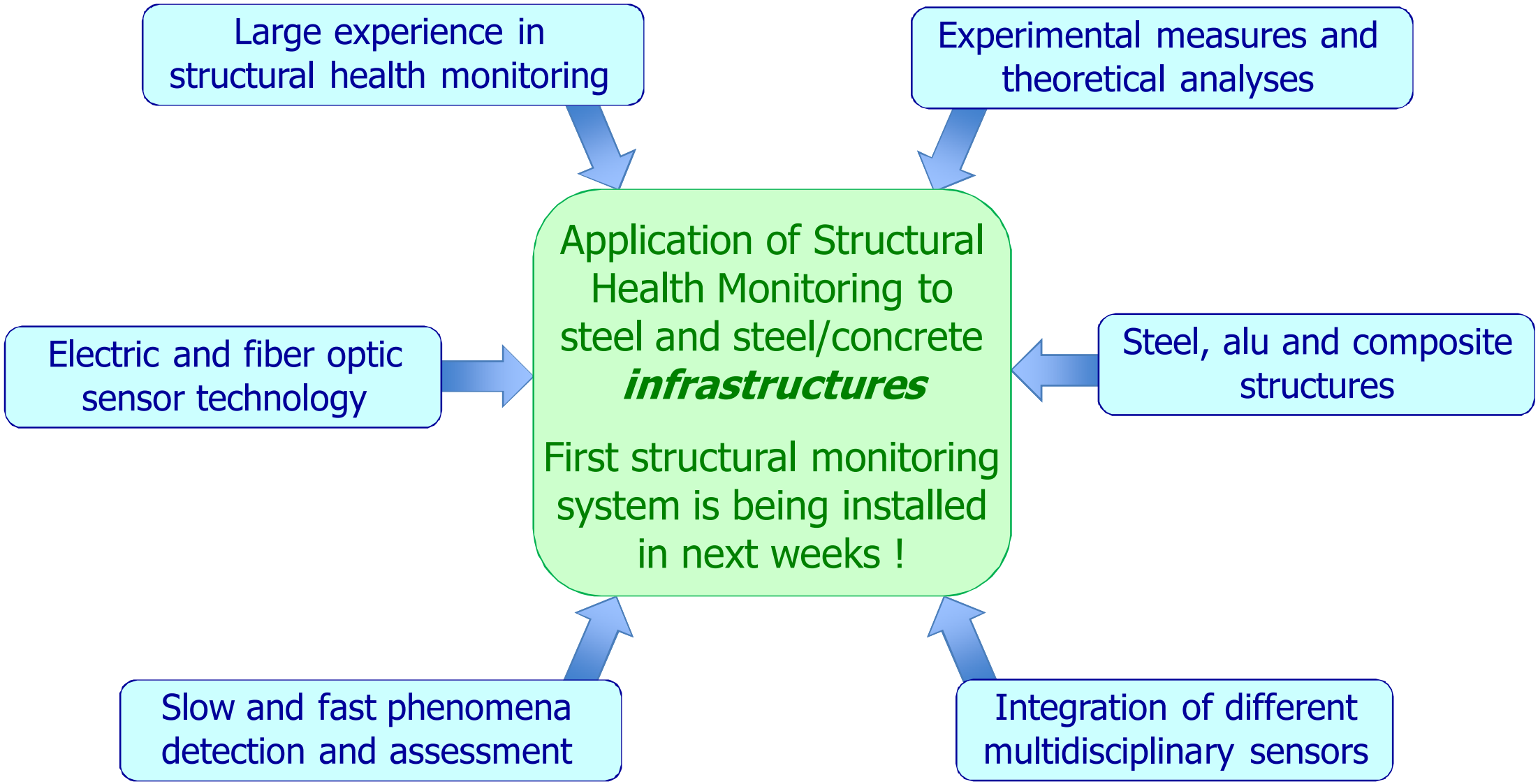

Thanks for your kind attention.

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