THE STRUCTURAL HEALTH MONITORING SYSTEM OF THE RION ANTIRION BRIDGE "CHARILAOS TRIKOUPIS"

Akis Panagis

Monitoring engineer Gefyra S.A.

GEFYRA
RIO - ANTIRIO
CHARILAOS TRIKOUPIS

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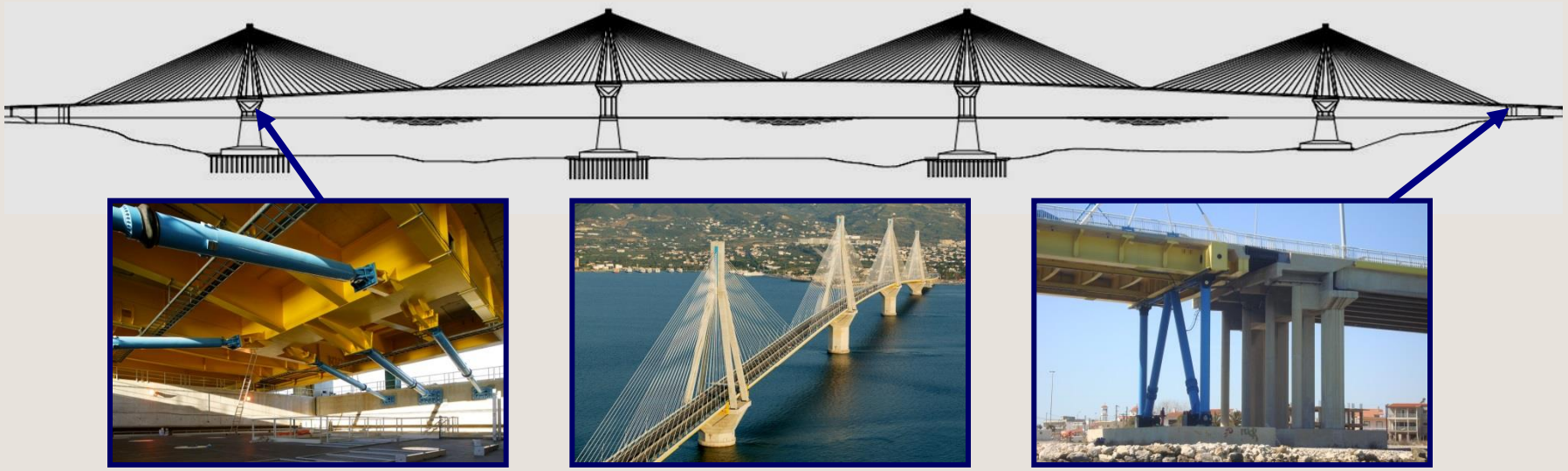
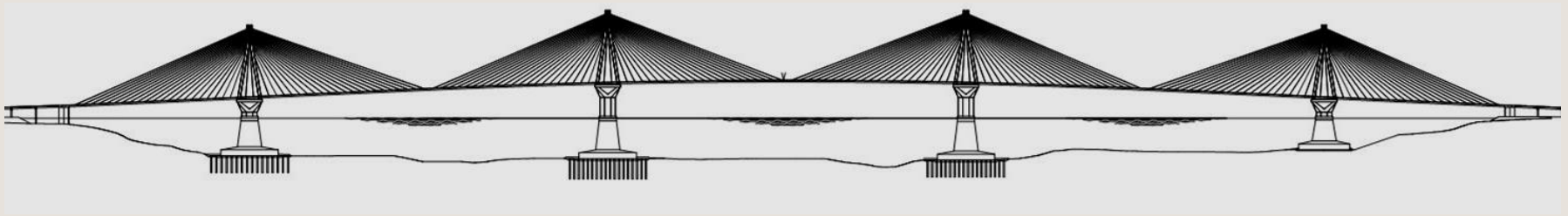
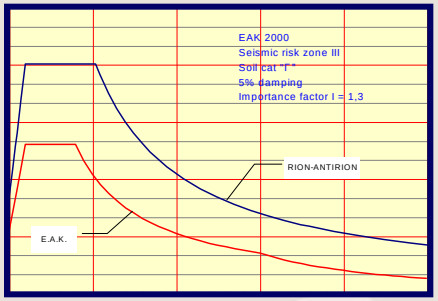
STRUCTURE DESCRIPTION

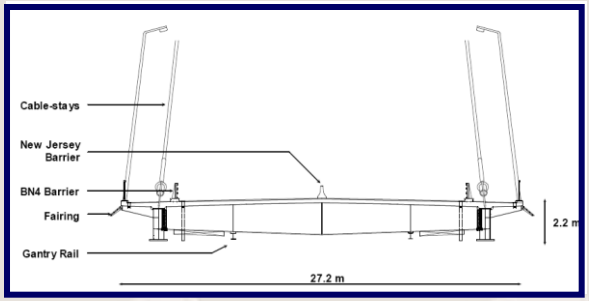


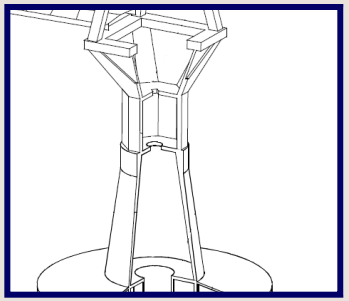
- 5 span cable stayed bridge (286 m + 560 m + 560 m + 560 m + 286 m)
- 4 main pylons with height 189 m up to 227 m
- Continuous composite deck (2252 m) fully suspended from pylons
- 386 cable stays with total length 79 m up to 295 m
- Special steel rotating frames (RF) at each deck extremity
- Transversally fusing restrainers at pylons and rotation frames location (±10500 kN and ±3400 kN respectively)

DESIGN MAIN LOADS









- Return period 2000 years
- PGA 0.48 g
- Max Sa 1.20 g
  (0.2 up to 1.0 sec)
- Tectonic movements up to 2m (in particular span)

- Design Wind speed 32 m/sec
  (hour mean at 10 m)

- Ship collision
- 86000 dwt bulk carrier (full laden) at 16 knots
- 180000 dwt tanker (on ballast) at
  16 knots

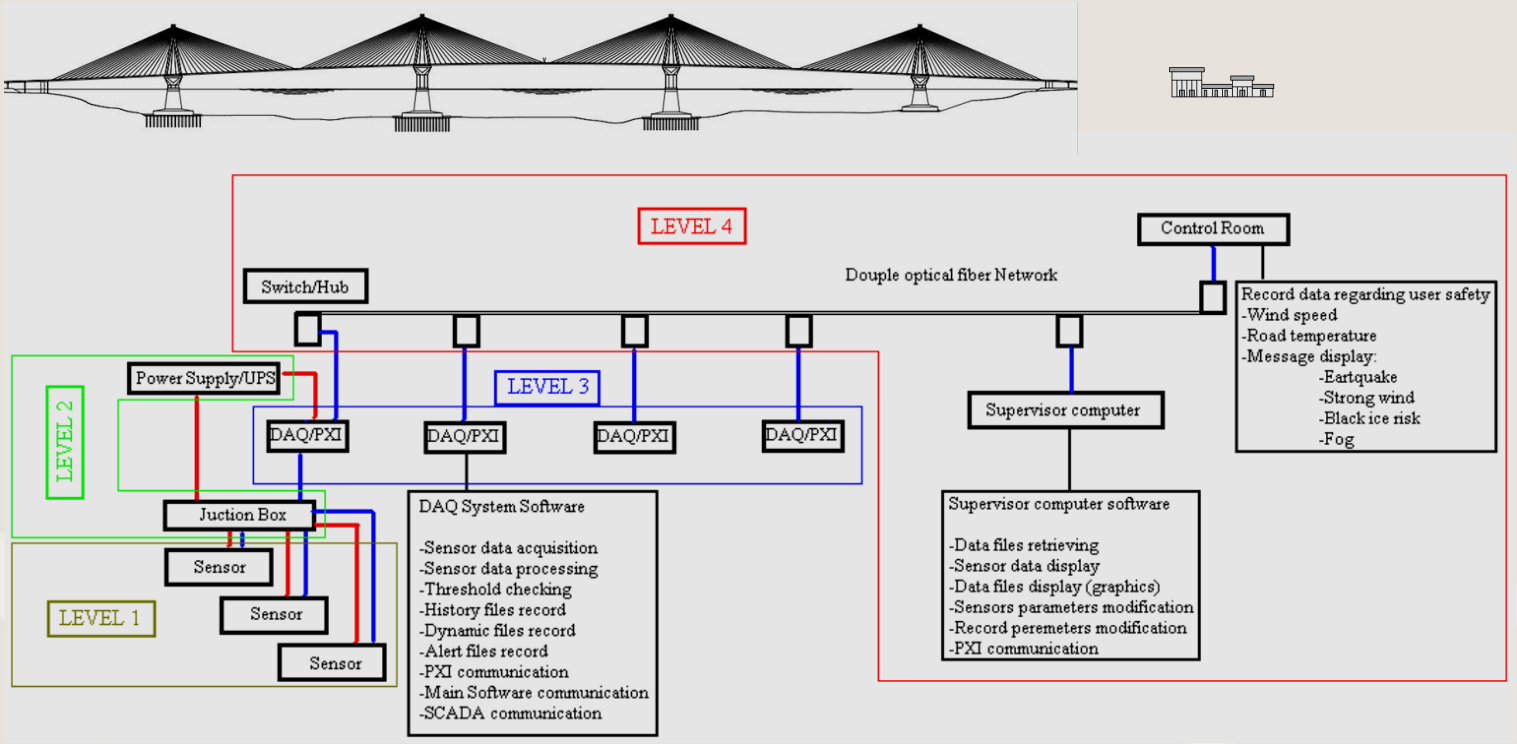
MONITORING SYSTEM DESCRIPTION (cont'd)

Objectives

- Ensure continuously the user safety against ambient conditions. (Wind/Black ice/fog etc)
- Characterize the loads applied to the structure (Earthquake/Wind/Traffic)
- Verify the theoretical models
- Determine alterations of the structure behavior through time evolution of proper indices for optimization of Heavy Maintenance
- Evaluate the Bridge response and status after a severe event (Earthquake/Wind etc)

MONITORING SYSTEM DESCRIPTION (cont'd)

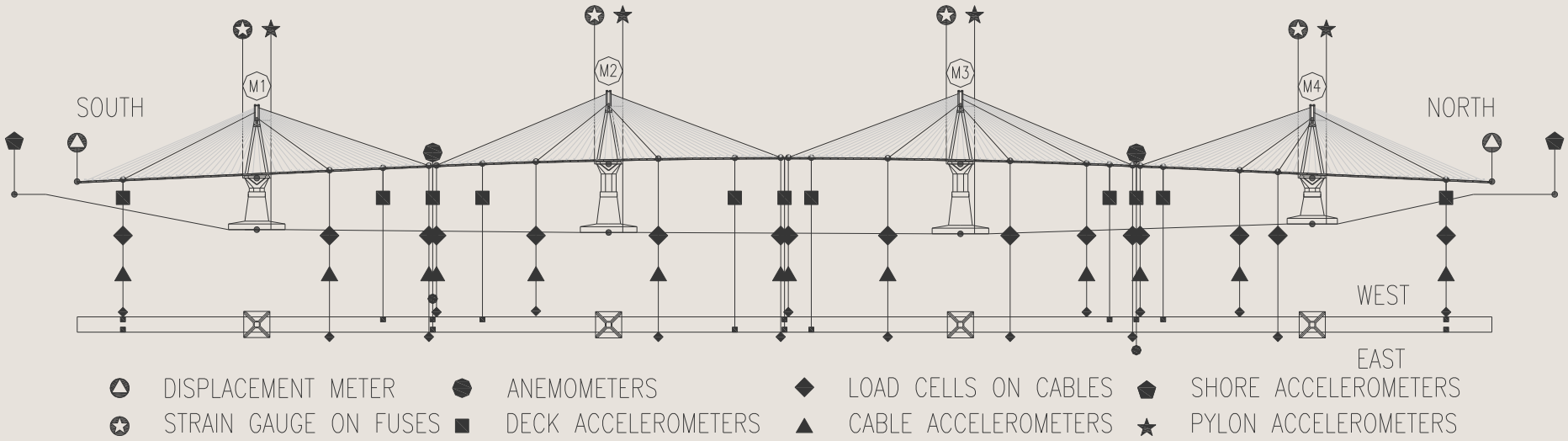
Overview



- LEVEL 1: Sensors
- LEVEL 2: Power supply & signal transfer
- LEVEL 3: Digitalization, acquisition & signal processing
- LEVEL 4: Communication network, data management

MONITORING SYSTEM DESCRIPTION (cont'd)

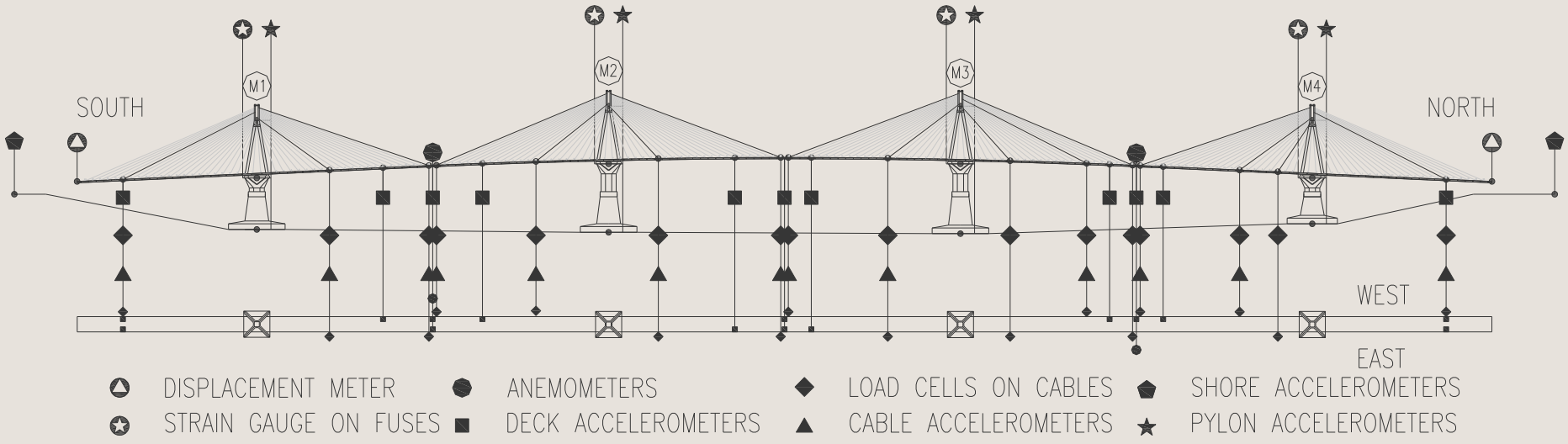
LEVEL 1: Sensors

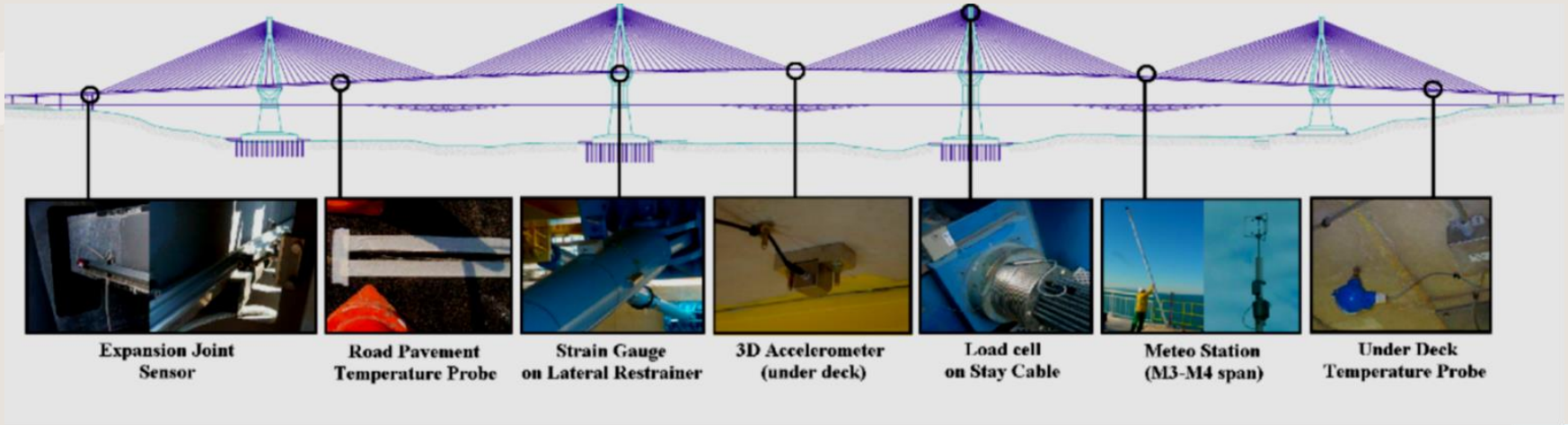


Sensor	Quantity	Expected range	Sensor range	Monitored phenomenon
3D anemometers	2	0-50 m/sec	0-60 m/sec	Wind intensity
Temperature and Humidity sensor	2	50º C/0-100%RH	-50ºC, up to 50ºC/ 0- 100% RH	Thermal loading
3D Pylon accelerometers	12	±1.9g (top) ±1.0g(base)	±20g(top) ±3g(base)	Pylon vibration (Earthquake/wind)
1D/3D Deck accelerometers	3/12	±2.7g	±3g	Deck vibration (Earthquake/wind)
3D Ground accelerometers	2	±0.48g	±3g	Earthquake
3D Cable accelerometers	13	-	±3g	Cable vibration Wind
Monostrand load of cables	16	0 up to 75% F_{GUTS} (199 kN)	0-320 kN	Cable load variation (Wind/Earthquake/Balance)
Magnetic distance meter	2	+1260/-1150 mm	3 m	Expansion joint opening (Earthquake/Balance/Thermal)
Strain gauges (full bridge)	4	±10500 kN	±1500$\mu\varepsilon$ ±17000 kN	Wind induced lateral load
Road temperature sensors	4	-	-50ºC, up to 50ºC	User safety (black ice risk)
Deck temperature sensors	5	-	-10ºC, up to 80ºC	Thermal loading

MONITORING SYSTEM DESCRIPTION (cont'd)

LEVEL 1: Sensors





MONITORING SYSTEM DESCRIPTION

LEVEL 2: Power supply & signal transfer

- Sensors more than 400 m away from DAQ unit
- AC/DC convertors (~230 V to 24 VDC)
- Signal conditioning (Amplifiers)

LEVEL 3: Digitalization, acquisition & signal processing

- 4 acquisition points (one per pylon)
- Low pass filtering at 10 kHz
- Digitalization at 500 Hz
- Signal conversion to engineering unit
- Alert checking and file creation & Real time data transmission
- Synchronization (SNTP)

LEVEL 4: Communication network, data management

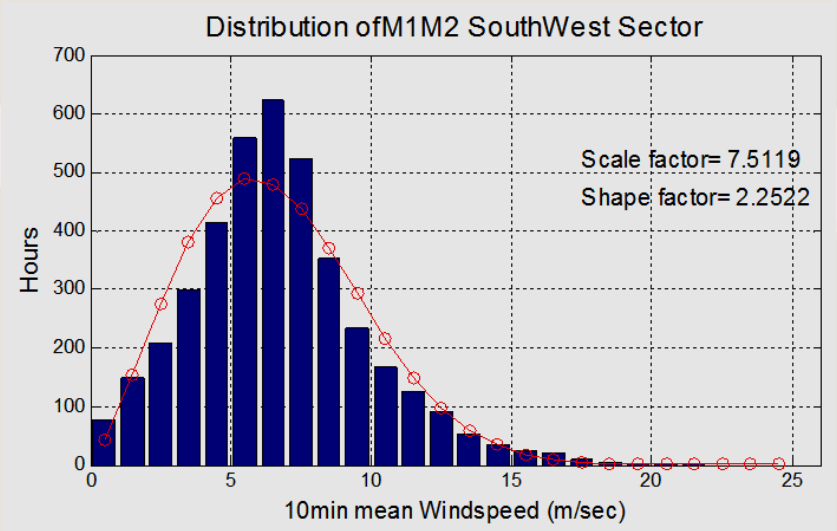
- Optic fiber network in ring configuration for redundancy
- Communication with Supervisor Server (SE) for permanent file storage/visualization/parameter management

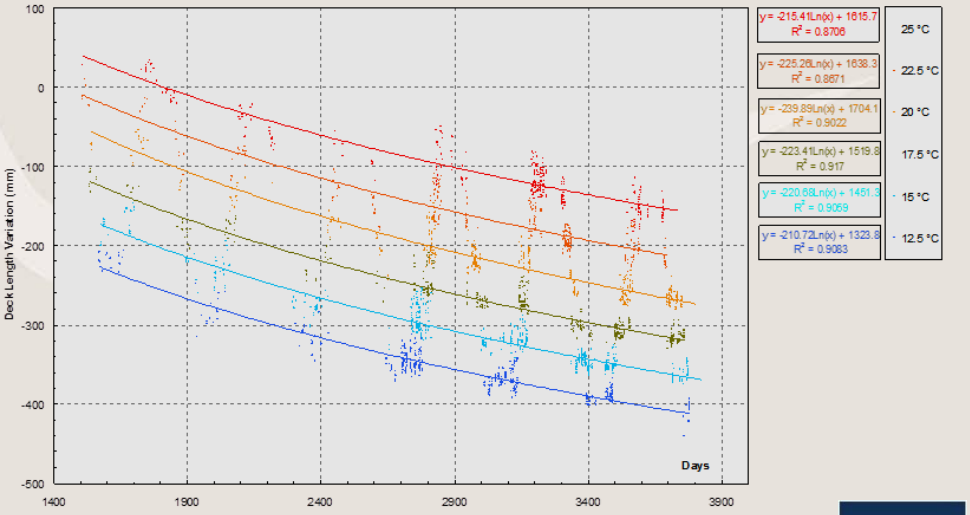
DATA RECORDS AND APPLICATIONS (cont'd)

Data files categories

- History files (0.5 sec averaged values recorded every 30 sec)
- Dynamic files (High sampling frequency >100 Hz)
  - Automatic (recorded every 2 hours)
  - Alert (Recorded due to threshold overpass)
  - Request (on end user demand)

History files





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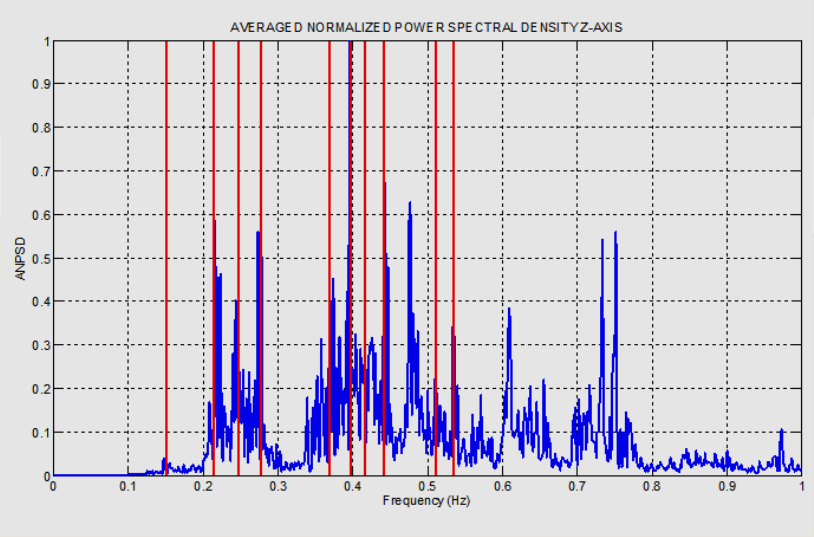
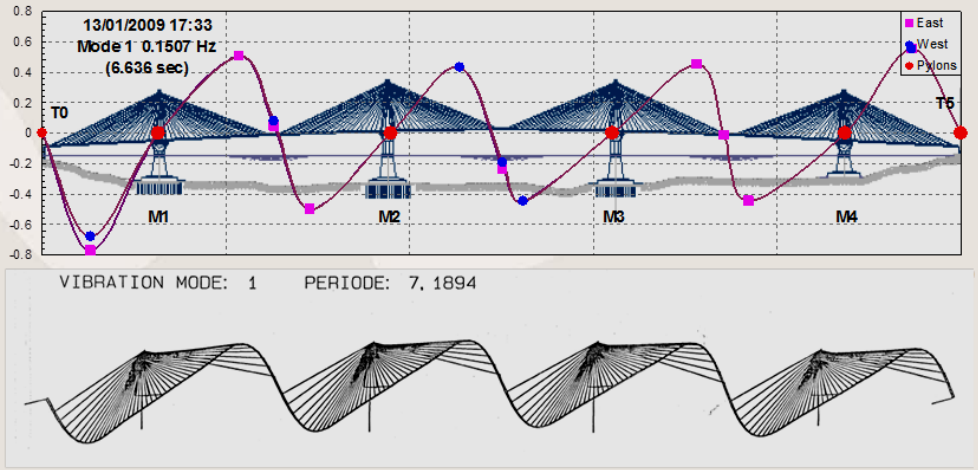
Automatic files





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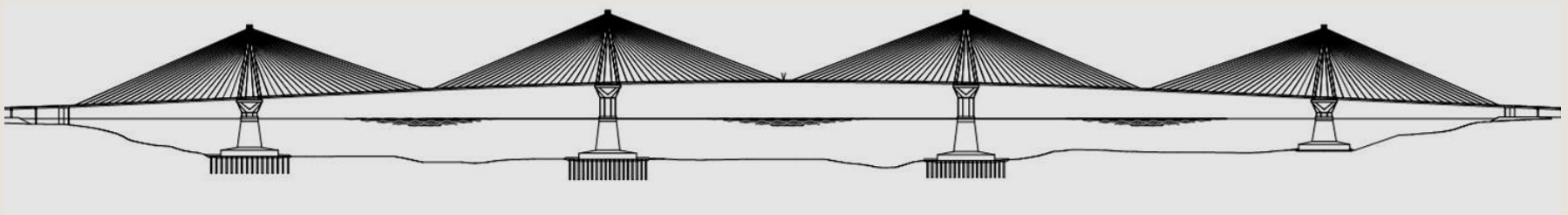
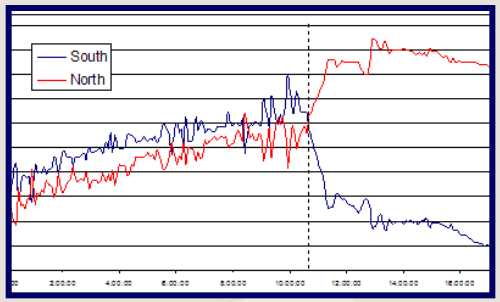
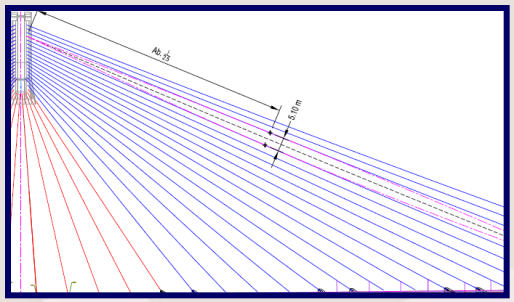
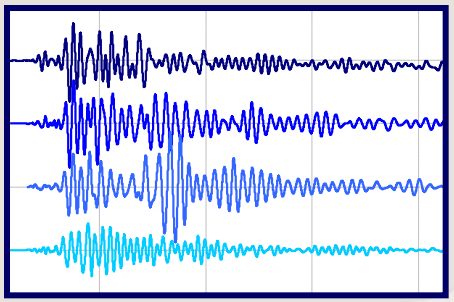








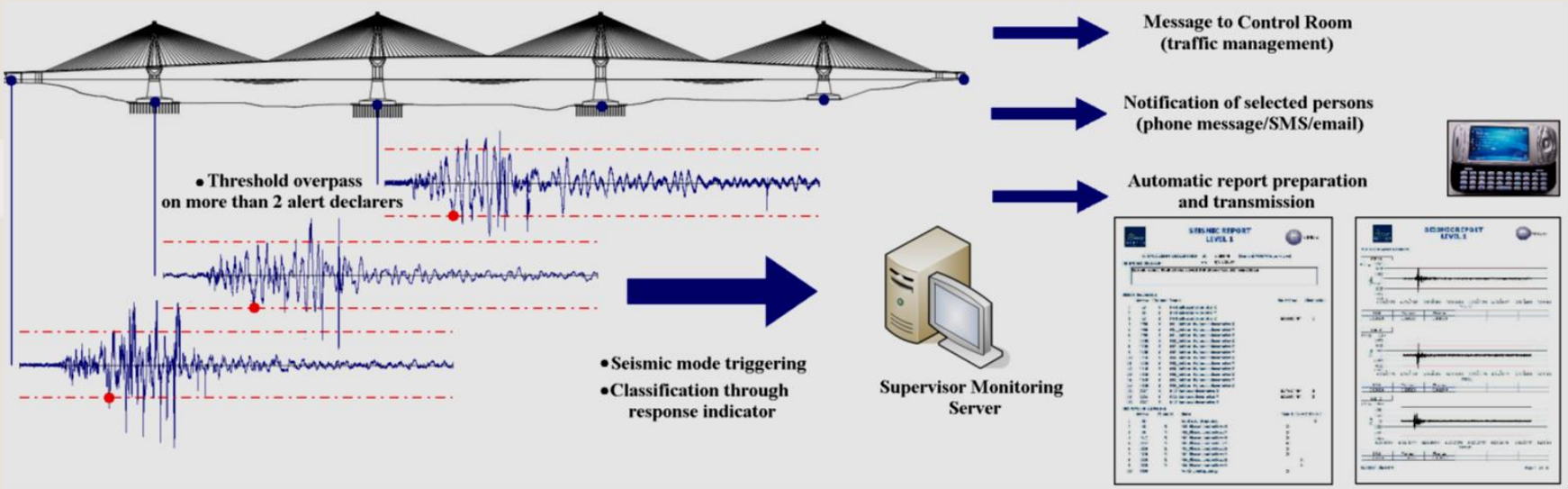
EVENTS RECORDED/ASSISTED BY THE MONITORING SYSTEM

- Lightning impact on C1S23W cable
- 2006 Intense cable vibration
- 2008 Achaia-Ilia Earthquake M=6.5
- Several small EQs and strong wind events

AUTOMATED PROCESS (SMART MONITORING) (cont'd)

Earthquake events

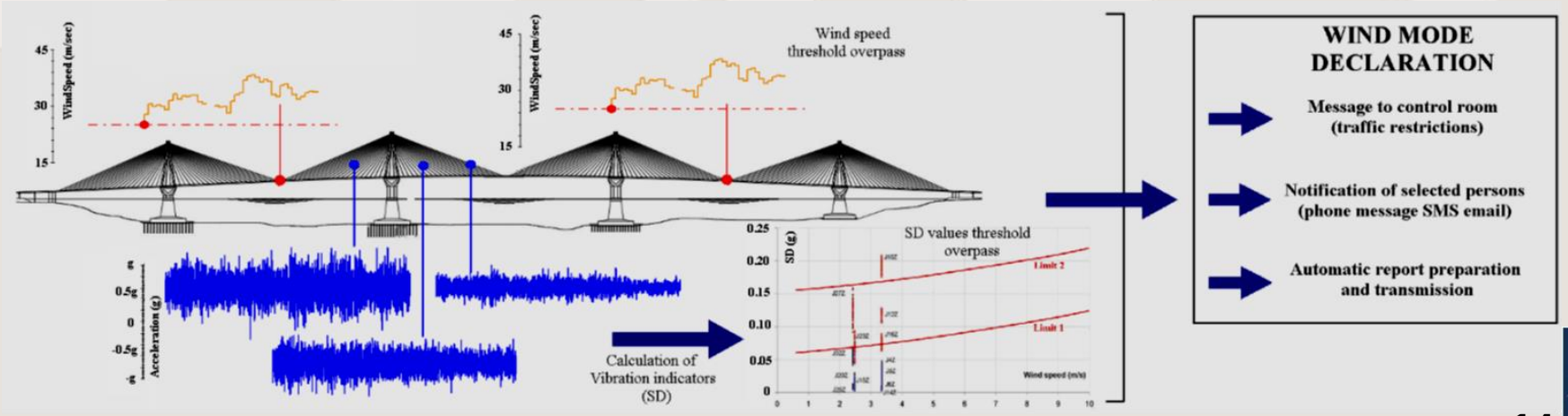
- Earthquake Identification/false alert prevention/ignore small events
- Real time evaluation of structural response (3 cases)
- Real time transmission of information-message to CR (traffic management)
- Notification of selected personnel (email/SMS/phone message)
- Automatic report creation within short time after the event and transmission to selected personnel



AUTOMATED PROCESS (SMART MONITORING)

Wind events

- Event Identification/false alert prevention
  - Event identification based on wind intensity
  - Event identification based on relevant structural response
- Modification of acquisition parameters
  - Lower acquisition frequency
  - Increased record duration
- Real time transmission of information-message to CR (traffic management)
- Notification of selected personnel (email/SMS/phone message)
- Automatic report creation within short time after the event and transmission to selected personnel

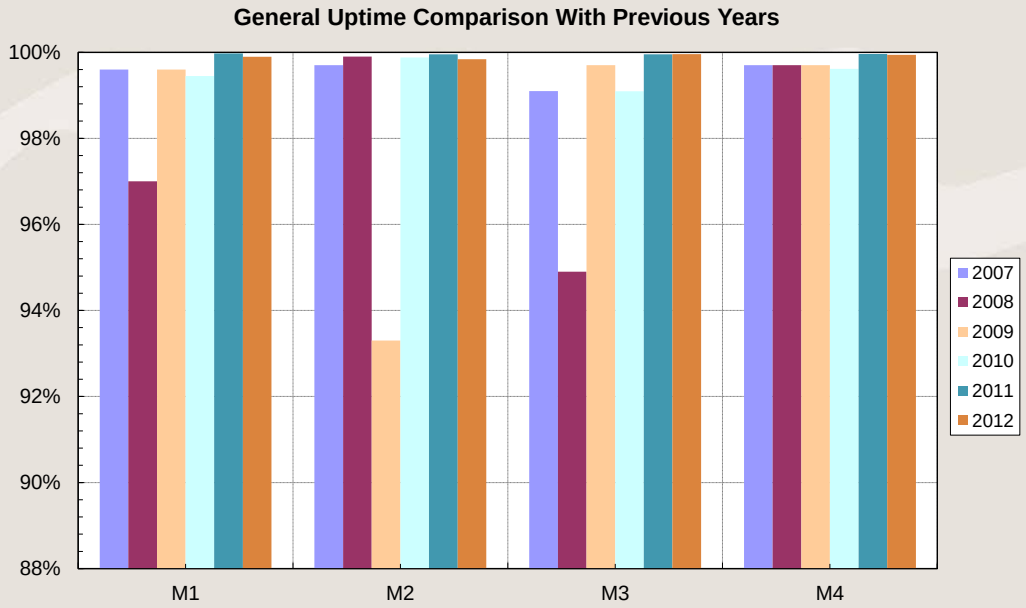


MAINTENANCE

Actions for successful system functionality

- Persistent follow up of acquired data
- Logging each possible malfunction & measurement quality degradation
- Constant availability of all required spare parts at site's storehouse
- Immediate notification of specialized personnel for troubleshooting and repair
- Computerized annual maintenance of monitoring system (levels 1 to 3) and specialized maintenance every 5 years (including sensors calibration)

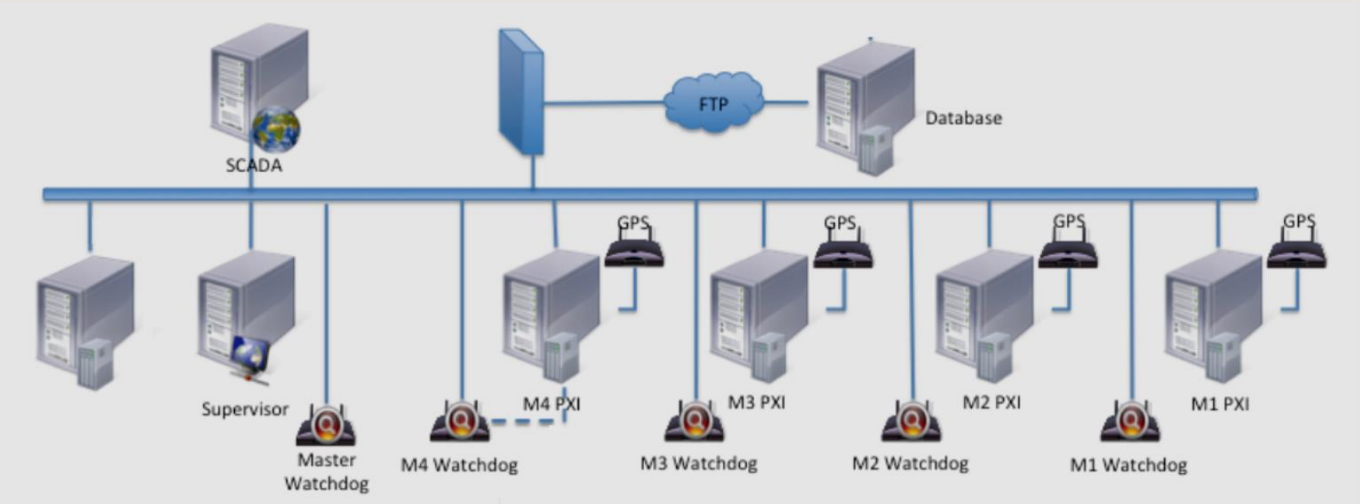
Uptime of monitoring system >99.9% in 2012



FUTURE ENHANCEMENTS (on-going)

New monitoring system architecture

- Improvement of DAQ synchronization accuracy through independent GPS antenna configuration (target Δt< 1 msec)
- Redistribution of computational tasks over different hardware
  - Minimize failure risk due to hardware insufficiency
  - Increase flexibility (additional sensors implementation)
  - Allows more elaborate automatic process
- Enhancement of anti-aliasing policy by configurable hardware low pass filters
  - Increase data quality (removing EM noise due to wiring)



CONCLUSIONS

- Management of important infrastructure such as Rion Antirion Bridge is assisted by a smart Structural Health Monitoring System

- During operation period (2004-present) a number of “Special” events occurred, which were successfully recorded and analyzed thanks to the monitoring system records
  - Strong wind events
  - Earthquake events

- Continuous maintenance and follow up of the system is required to ensure data quality and significant uptime

- Further improvements should be implemented to maintain system updated with regards to new requirements

THANK YOU

FOR YOUR ATTENTION