Indian River Inlet Bridge
Structural Health Monitoring System

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The Monitoring System

- Full fiber-optic based system
- Over 120 sensors distributed throughout the structure
- Will operate 24/7 to gather
  - "Monitor data"….slowly varying data
  - "Event data"….dynamic data due to high winds, heavy vehicles
- Secure web-based interface with automatic alert notifications

Structural Health Monitoring System

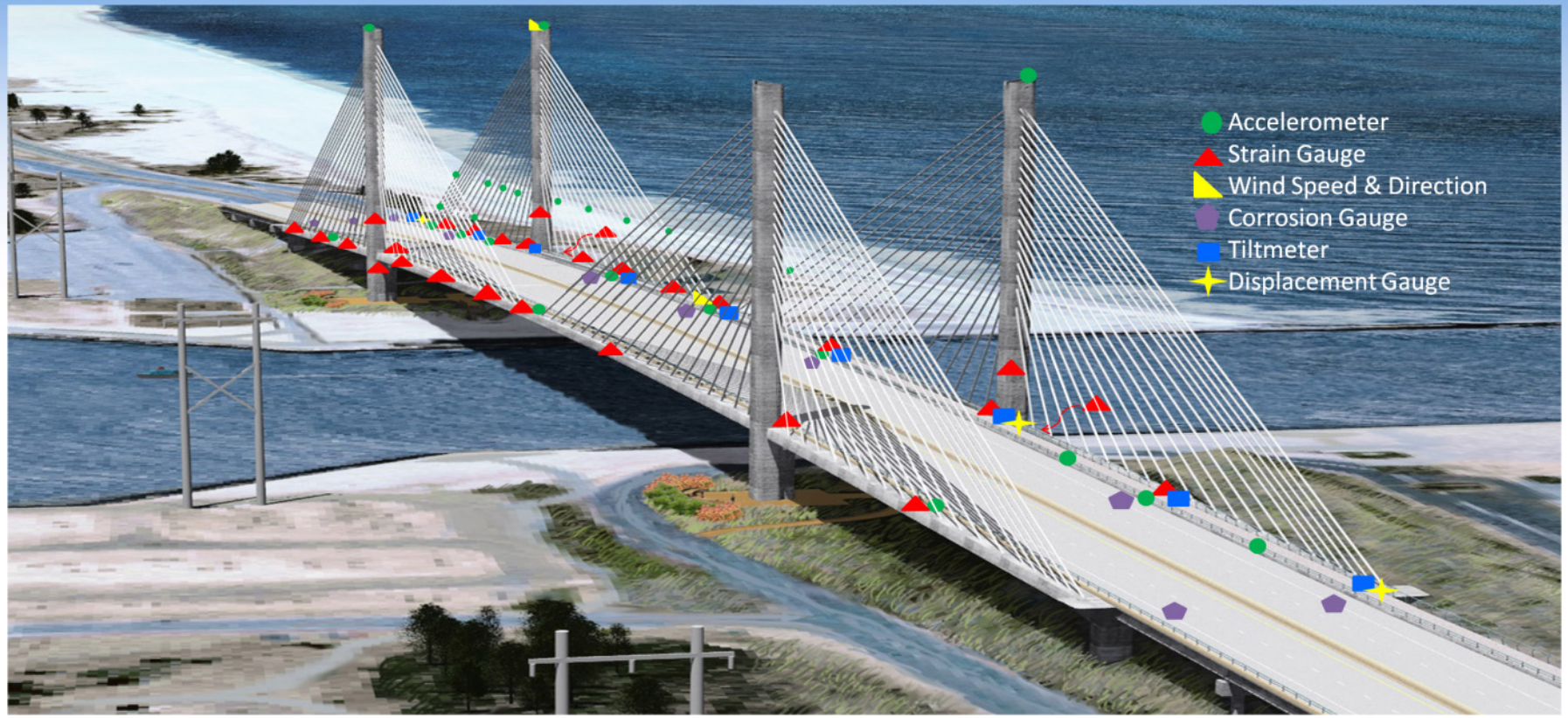
How the system will be utilized:

- Load Rating
  - Response to know loads
  - Response to site-specific traffic
- Monitoring and Evaluation
  - During and after extreme events
    - Hurricanes, earthquakes, vehicle accidents, fires on or under
  - Email and text notifications
- Maintenance and Operation
  - Monitoring for changes in performance due to damage or degradation

Sensors

- 70 Strain (temperature)
- 27 Acceleration
- 3 Displacement
- 9 Inclination (tilt)
- 16 Chloride
- 2 Wind speed and direction

Sensors


Accelerometer
Strain Gauge
Wind Speed & Direction
Corrosion Gauge
Tiltmeter
Displacement Gauge

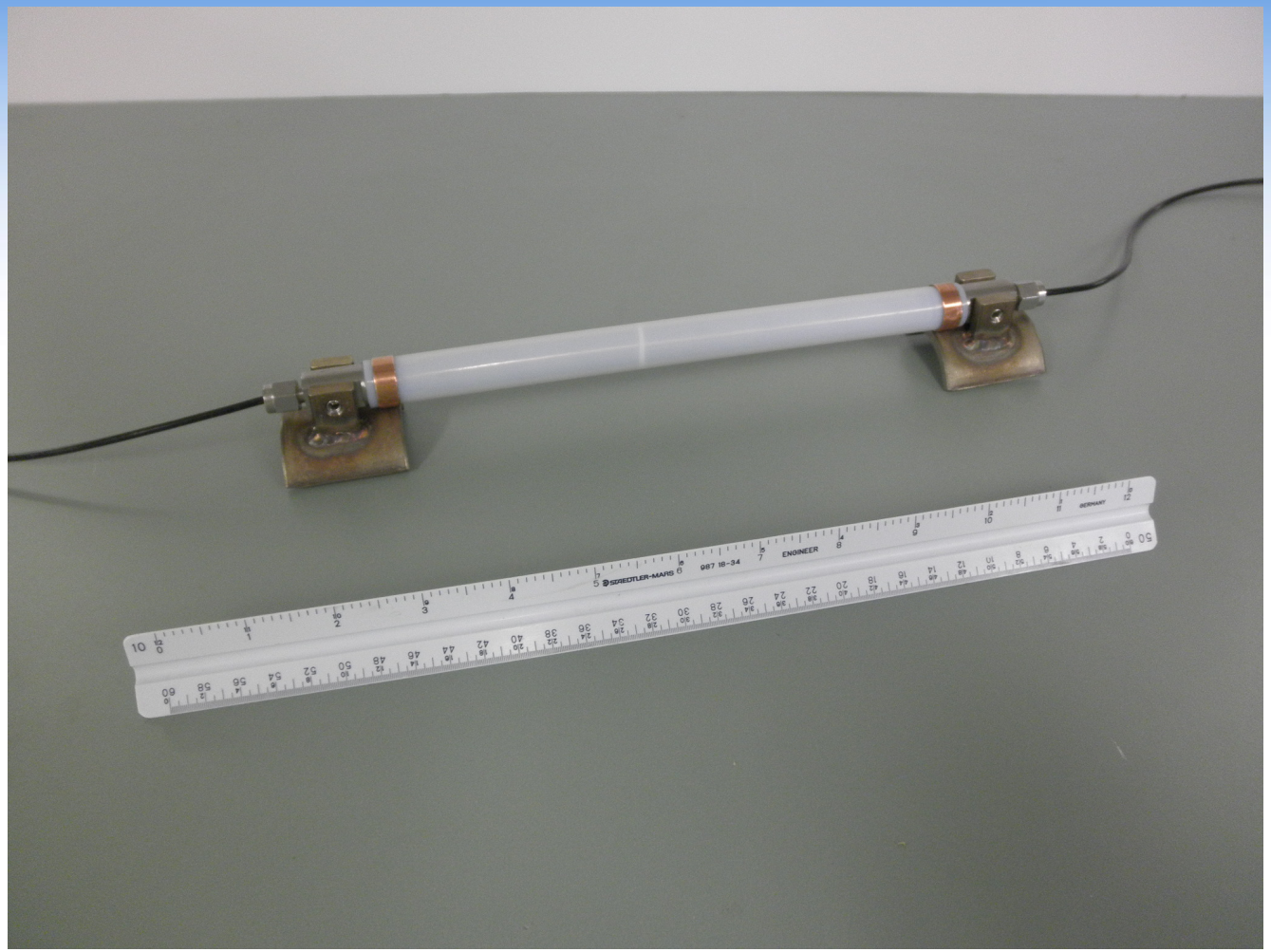
Strain & Temperature Sensors

Purpose

Identification of axial & bending stresses

- Measure thermal effects
- Measure loss of post-tensioning
- Stay-cable stress loss
- Quantify loading effects under static loads & extreme events

Micron Optics OS3600 Strain Sensor



Strain measurement using FBG

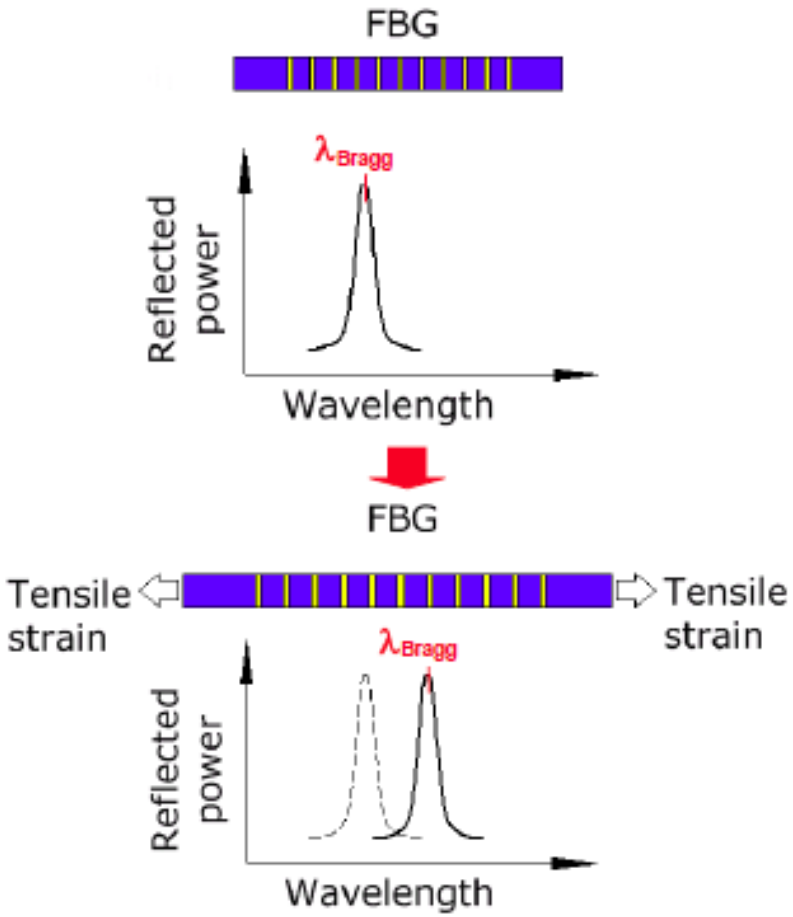
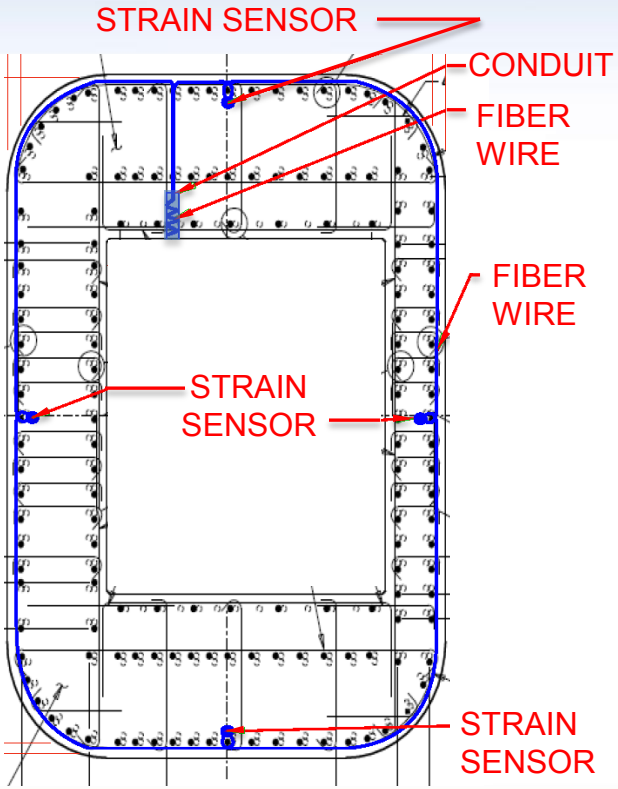


Image courtesy of Chandler Monitoring Systems

Strain & Temperature Sensors

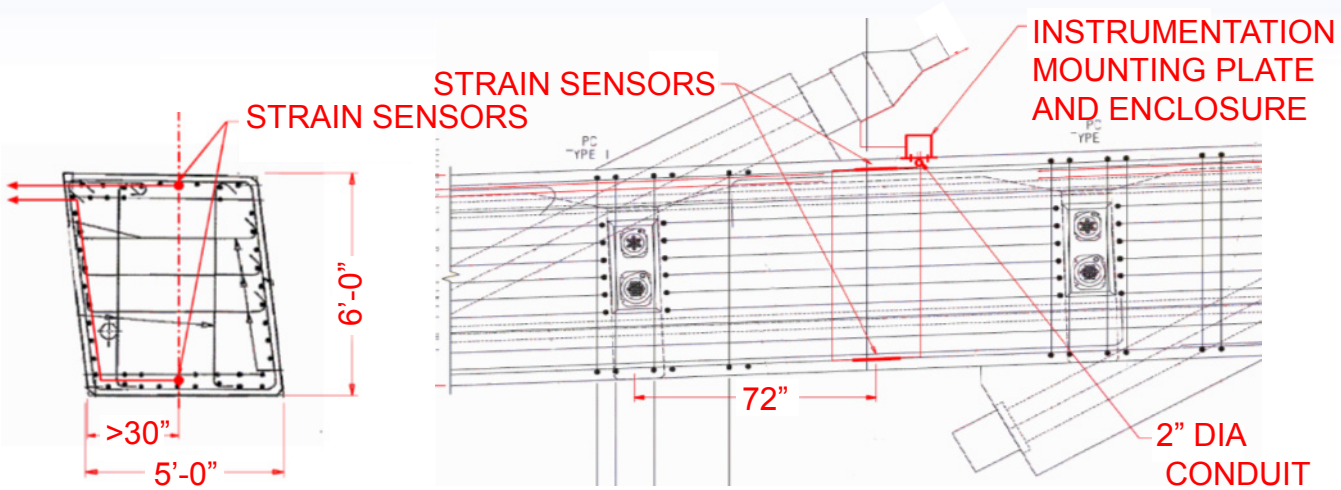
- Pylons- 3 of 4 pylons
  - 2 elevations per pylon
  - 4 sensors per cross-section
- Deck- 17 cross-sections
  - Top, bottom, East and West

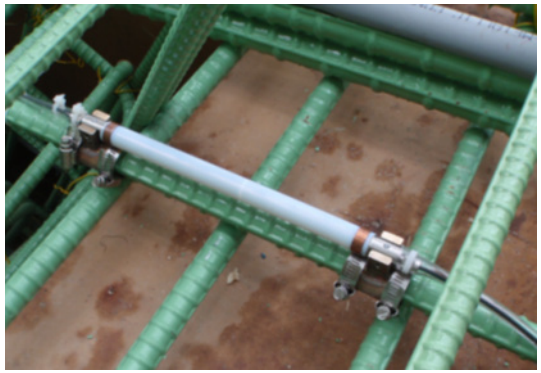


Close-up of Sensor Installed

Strain & Temperature Sensors

- Deck gauges





Accelerometers

- Pylons- 3 of 4 pylon tops
- Deck- ¼ points of each span
- Stay-cables- 11 stays

Accelerometers

Purpose

Estimate vertical, torsional, and transverse modes

Estimate damping ratios

Estimate stay-cable forces

Estimate displacements via double integration (+ tilt & expansion joint data)

Tilt & Linear Displacement Sensors

- Tiltmeters- ¼ points & bearing supports
- Linear displacement sensors at 3 expansion bearings

Tilt & Linear Displacement Sensors

Purpose

Estimation of static deck profile (+ accel & temp data)

- Daily & seasonal thermal displacements estimated
- Bearing & expansion joint DI
- Estimation of baseline stiffness properties
- Damage identification

Chloride Sensors

- Chloride sensors
  - 10 locations w/ conventional galvanic ladder system
  - 5 similar locations w/ fiber-optic

Chloride Sensors

Purpose

Estimate chloride ion ingress

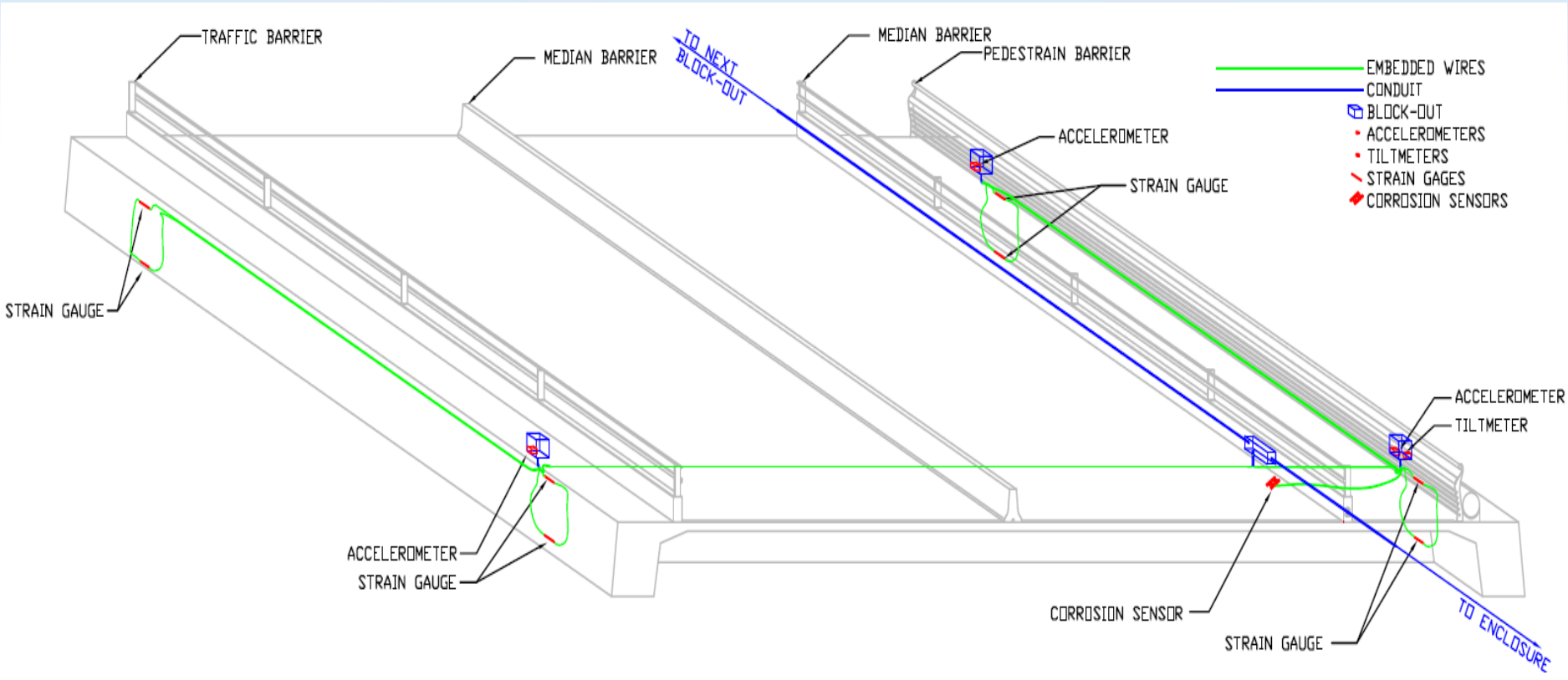
- Indication of potential corrosion at monitored locations
- Generate typical chloride ingress profile
- Calibrate fiber-optic chloride sensor

Anemometers

- 2 Ultrasonic Anemometers to measure wind speed and direction.
- 1 At the top of Pylon 6E
- 1 At the mid span deck
- Pylon top is 10’ above the top of the pylon.

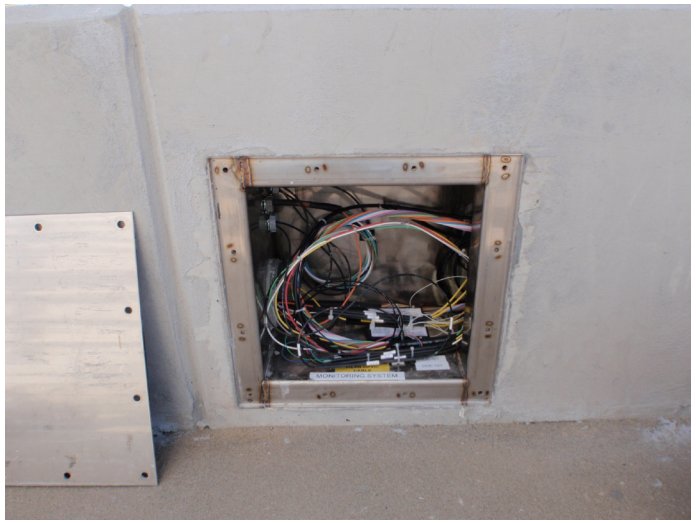
Cabling and Conduit

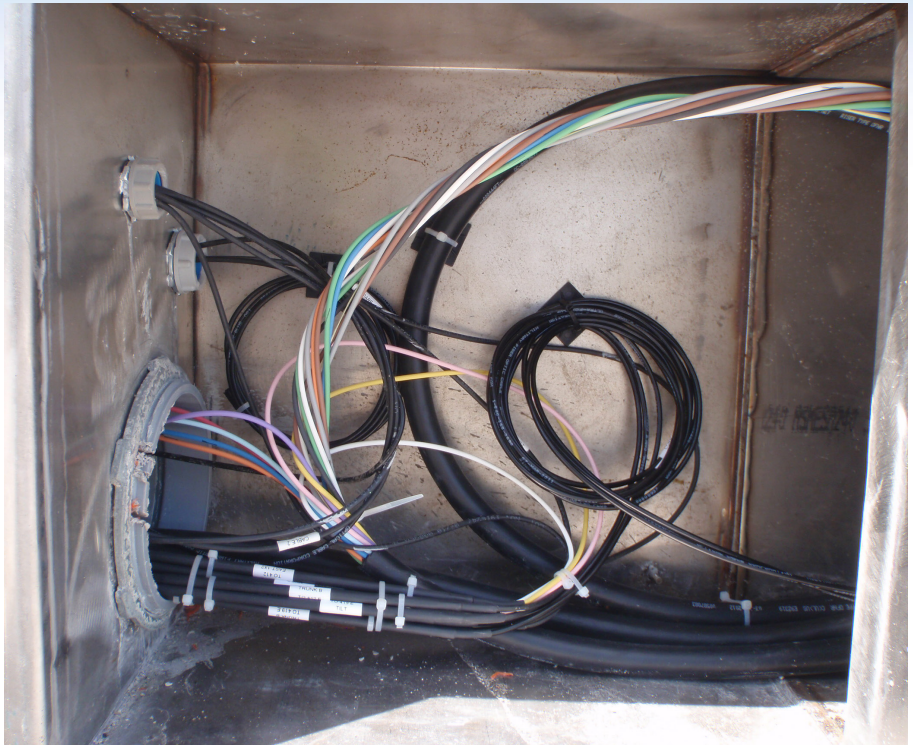
Typical Deck Layout



Traffic / Pedestrian Barrier Junction Boxes

- 8 Junction boxes
- Connects sensor arrays to the main trunk fiber



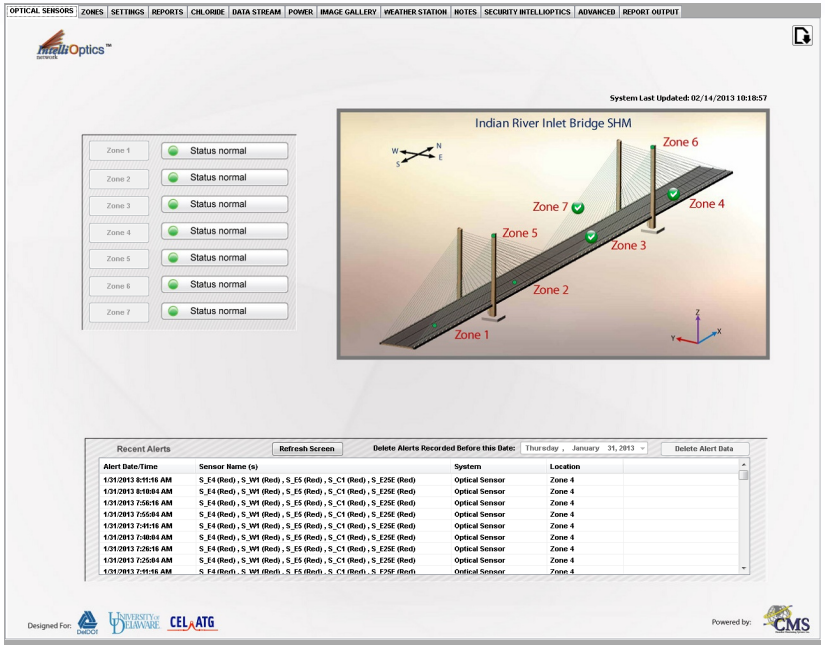


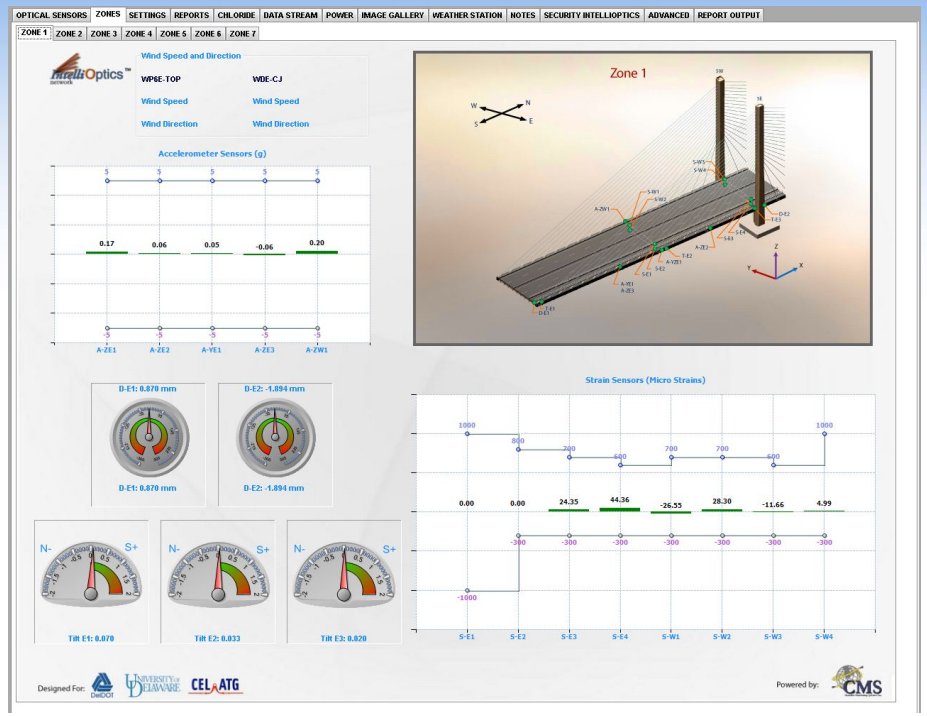
Interrogator/Computer Control

- 2 Micron Optics SM130 interrogators
  - "excite" & "acquire"
- 2 Optical Multiplexers allowing for 32 fiber optic inputs
- 2 Computers for redundancy
- RAID array hard drive storage
- Remote access

Command and Control of the Monitoring System

Setup and operation handled through full feature GUI software





Command and Control of the Monitoring System

- Real Time Monitoring
  - The monitoring system is connected to the state network allowing remote connection.
  - Allows access to key personnel at any time on any computer through a VPN.
  - Can view streaming system data, weather station data and traffic camera video simultaneously.

Command and Control of the Monitoring System

- "Monitor" data
- Purpose: capture the slow, daily or seasonal response of structure over long periods of time
  - 5 to 10 seconds average
  - Once an hour, every hour (or few hours)
  - Minimal data storage
- Lifecycle changes
- Began collecting this data in May of 2012

Command and Control of the Monitoring System

- "Event" data
- Purpose: capture the rapid structure response over short periods of time
  - High frequency recording (250 - 1000 Hz)
  - Infrequent dynamic events
    - high winds
    - heavy loads
  - Triggered event

“Event Data”

- System was actively monitored during Hurricane Sandy and the following Nor’Easter.

Time	Temperature (F)	Pressure (in. Hg)	Rainfall (in)	Wind Gust (mph)	Wind Speed (mph)
10/29/2012 18:15	51.7	28.35	**0.03**	35.5	31.2
10/29/2012 18:10	51.5	28.34	**0.03**	37.2	31.2
10/29/2012 18:05	51.5	28.35	**0.02**	40.7	34.4
10/29/2012 18:00	51.6	28.34	**0.02**	38.6	33.3
10/29/2012 17:55	51.4	28.34	**0.03**	39.1	33.8
10/29/2012 17:50	51.2	28.35	**0.05**	39.4	33.6
10/29/2012 17:45	51.1	28.34	**0.05**	40.3	33.5
10/29/2012 17:40	51.2	28.34	**0.05**	40.4	35.3
10/29/2012 17:35	51.3	28.34	**0.03**	36.9	33
10/29/2012 17:30	51.2	28.33	**0.03**	38.1	34.5
10/29/2012 17:25	51.2	28.34	**0.04**	41.6	35.4
10/29/2012 17:20	51.1	28.33	**0.06**	41.2	36
10/29/2012 17:15	51.2	28.34	**0.08**	46.7	35.2
10/29/2012 17:10	51.2	28.36	**0.07**	41.8	33.9
10/29/2012 17:05	51.2	28.36	**0.09**	41	33.9
10/29/2012 17:00	51.4	28.36	**0.07**	37.5	31.8
10/29/2012 16:55	51.3	28.37	**0.06**	36.9	32.8
10/29/2012 16:50	51.2	28.38	**0.07**	40.1	33.9
10/29/2012 16:45	51.1	28.37	**0.07**	41.4	34.3

Scheduled “Event Data”

- Load testing of the bridge
  - Performed on a regular basis to calibrate the system and produce a model of the bridge.
  - Provide feedback from a known load at a known location on the structure.

Scheduled “Event Data”

- Cable stay vibration testing
  - Induce a vibration into the cable stay
  - Collect high speed accelerometer data
  - Used to provide characteristics of the cable stays and cable stay system

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Data Analysis and Reporting

- Data to be used by DelDOT Bridge Management group
- Continuously collected
- Reported intermittently
  - Monthly report
  - Yearly report
- Alert system
  - Text and email messages sent to appropriate people when thresholds on certain sensors are automatically exceeded


Thank you