BDI

RAW DATA. REFINED RESULTS.

DIAGNOSTIC LOAD TESTING AND SHM FOR ALL TYPES OF BRIDGES

Jesse Grimson, Vice President

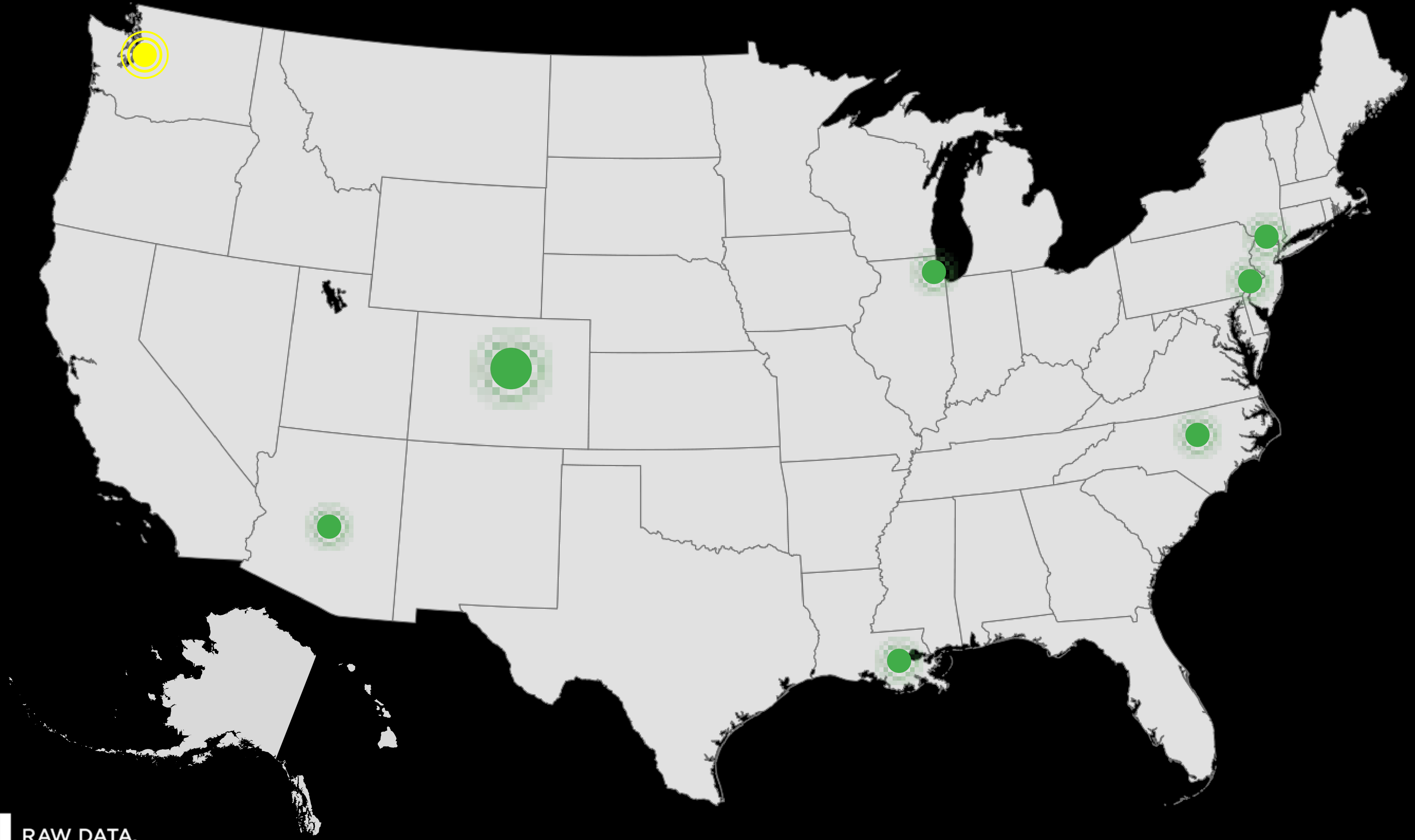
AGENDA

- WHO IS BDI?
- INSTRUMENTS
- DIAGNOSTIC LOAD TESTING
  - CASE STUDY
- STRUCTURAL HEALTH MONITORING
- DATA MANAGEMENT

WHO WE ARE

- Began research in **1987** at the University of Colorado sponsored by PennDOT and FHWA where basic techniques were developed for using live-load test data to better analyze bridge behavior.
- BDI formed in 1989 and began development of Structural Testing System and FEA software. In 1991, began adapting both hardware and software for use in field projects, and both are **still under constant development today**.
- To date, BDI personnel have tested and **evaluated thousands of structures** around the world including bridges, lock gates, and even rockets!
- We're an engineering services provider and product manufacturer – a **combination that keeps us sharp**!

USA LOCATIONS



RAW DATA.
REFINED RESULTS.

LOCATIONS

TESTINDO

Your Partner of Testing & Measuring Innovation Technology

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OVERVIEW

INSTRUMENTATION SERVICES

Diagnostic Testing

Short term sensor and data acquisition installation for issues such as force imbalances, misalignments, or failing members

Structural Monitoring

Permanent installation of sensor and DAQ for monitoring a variety of potential issues within a structure.

ANALYSIS SERVICES

Structure Evaluation

Complete structural analysis using FEA and model correlation through the test results

Data Evaluation

Simplified analysis through evaluating the collected data and providing feed back on the results

INSTRUMENTS

Sensors

Strain Transducers

Accelerometers

Tiltmeters

Foil Strain Gages

Displacement

Data Acquisition

STS4-4: 4-Ch rugged, modular field oriented DAQ

STS4-16: Multi-use data acquisition system

DATA ANALYSIS & MANAGEMENT

Data Collection

Remote Data collection

Web Hosting

Data analytics

NDT

Full Service NDE Shop

Concrete NDE

Steel NDT (Welds, Pin and Hangers, ASNT L3 Technicians)

High Speed Bridge Deck Evaluation

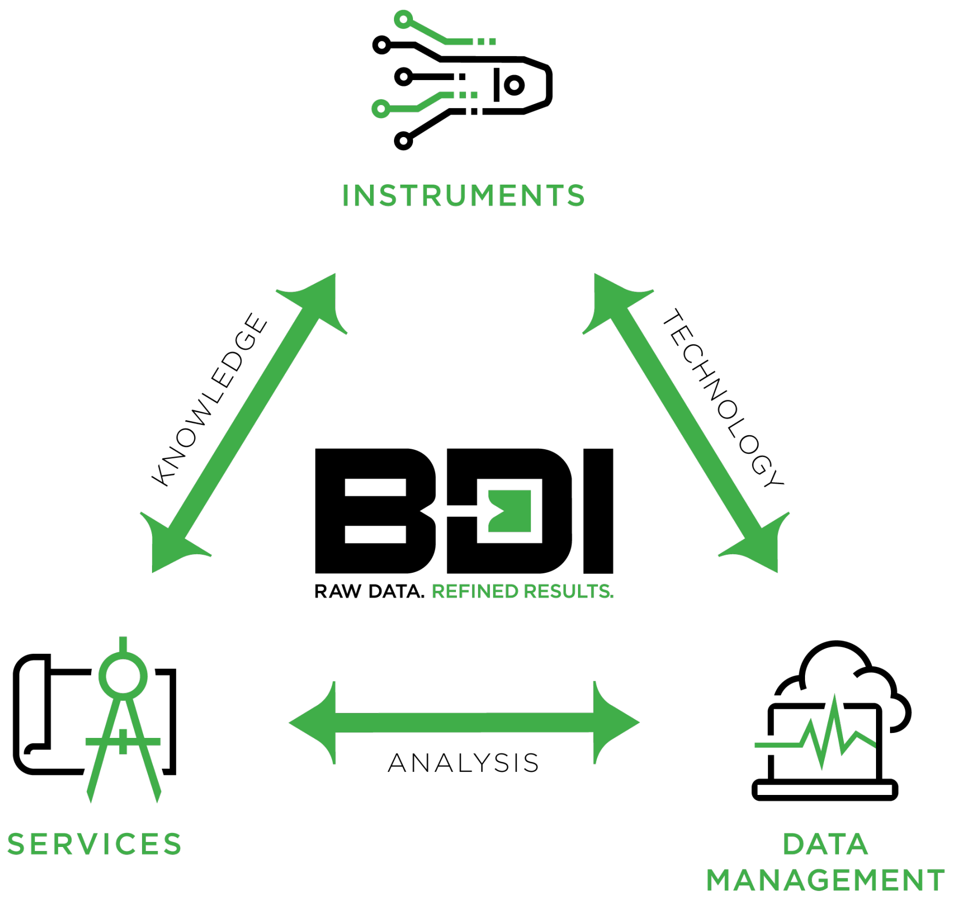
Material Testing

Unknown Foundations

BDI OFTEN DEVELOPS CUSTOM SOLUTIONS FOR OUR CLIENTS

WHAT MAKES BDI UNIQUE

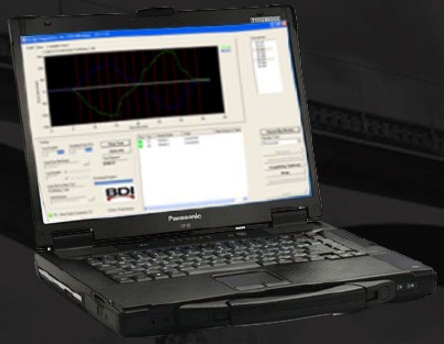
+ We are an engineering firm that provides instrumentation services.
+ We manufacture our own instruments based on our field experience.
+ We support our instruments through simple-to-use applications.
+ This rare combination makes BDI one of the most unique firms in the industry.



INSTRUMENTS

BDI INSTRUMENTS

During our extensive field-testing experience, we have determined the weaknesses of most existing data acquisition systems and sensors, usually the hard way: while in the cold wind and bouncing in a man lift!



Custom Software

STS4-4: 4-Channel Node

Custom sensors developed for harsh field environments

STS4-16: 16-Channel Node

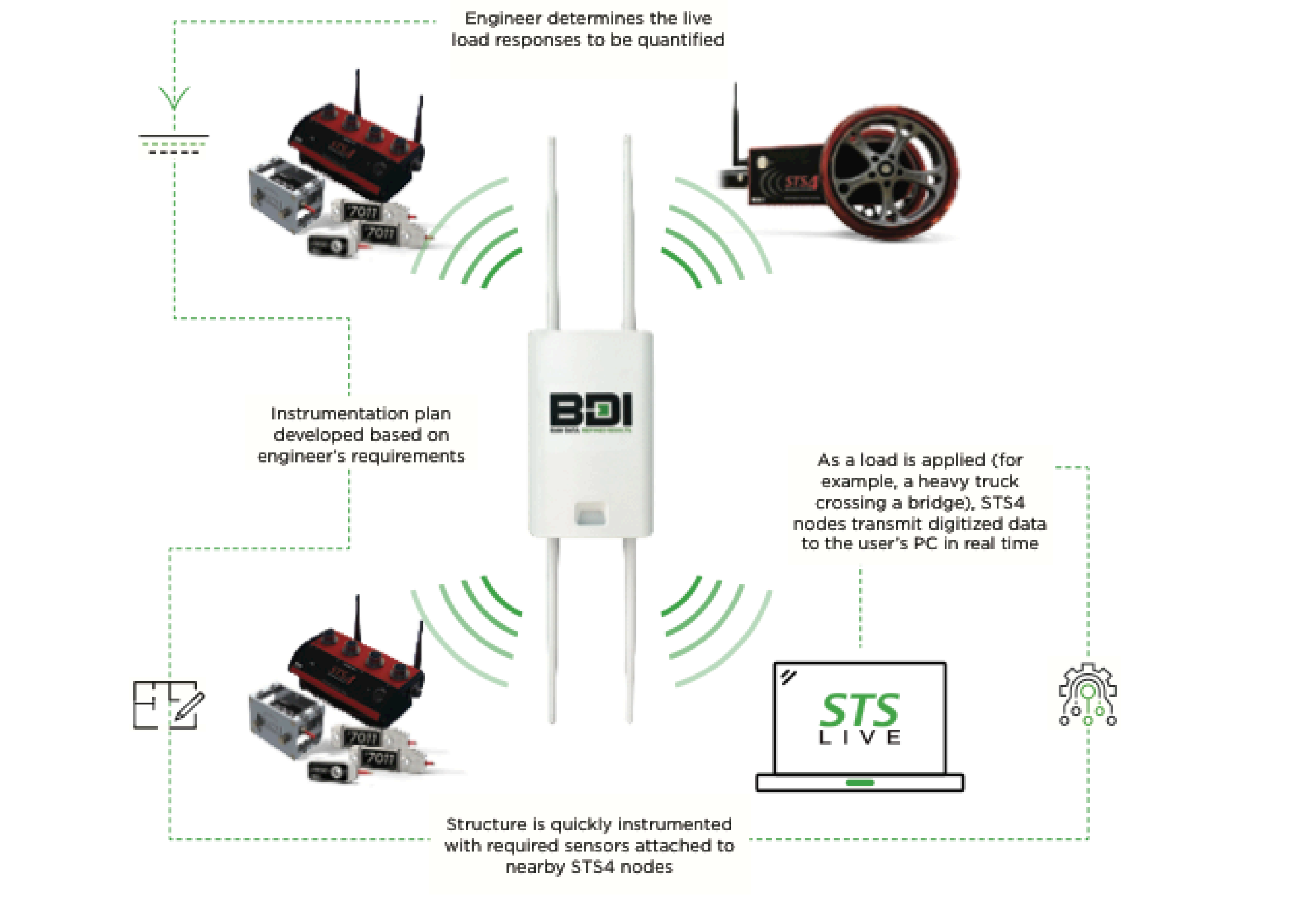
INSTRUMENTS

STRUCTURAL TESTING SYSTEM (STS)

The STS4 from BDI is the world's only data acquisition system designed by civil engineers expressly for diagnostic testing. The field time saved using the STS4, compared to standard data acquisition systems, will pay for itself after just a few uses.

The STS4 is rugged, highly efficient, and extremely easy to deploy.

HOW IT WORKS



- **STS DIAGRAM**

STRUCTURAL TESTING SYSTEM (STS)

INTELLIDUCER

Every BDI sensor is supplied with a customized “Intelligent” connector that stores relevant information such as its name and calibration factor. The result of this feature is that rather than attempting to track channel numbers during the instrumentation process, the only information that the field crew needs to record in the notes is the sensor name and its location on the structure. This feature dramatically reduces the potential for making mistakes in the field under hectic conditions.

STS4-4-IW3 NODE

Battery-powered and water-resistant with 40 hours of data collection time make these rugged nodes ideal for all diagnostic testing applications. Intelliducer connectors simplify the installation by automatically applying all sensor settings and can be used with the full range of BDI sensors, in addition to most analog sensor types.

WIRELESS BASE STATION

The Wireless Base Station is the device that generates the wireless network for the STS4 nodes and the user’s computer. Battery-powered and outdoor rated, with secondary 5GHz radio to link multiple WBS to create large wireless networks.

AUTOMATIC LOAD POSITION TRACKER

Designed specifically for load testing bridges, this device wirelessly tracks the longitudinal position of the loading vehicle during the test so that data can be viewed as a function of load position rather than time.

INSTRUMENTS

STRUCTURAL MONITORING SYSTEM (SMS)

The SMS from BDI is an industrial and flexible system that is designed to measure a wide range of structural response through an expansive set of sensors.

The SMS has been designed so that field deployment is simple and quick, making this system on of the most economical choices on the market

HOW IT WORKS

PLATFORM INTERACTIVE DATA HOSTING

Service provided by BDI to host and present the data through our Microsoft Azure cloud hosted portal:
+ Custom post processing
+ Simple data visualization
+ 24/7 sta ed service center

DATA TRANSFER

+ **STS-SYNC:** Windows application to collected data on a defined schedule.
+ **Client Servers:** The SMS Data logger can be configured to either push data to client designated servers or setup to have data pulled by the servers.

SETUP/CONFIGURATION

+ STS-MONITOR application is used for setting up the monitoring system. System can be configured remotely or through direct connection on-site.
+ Systems can be preconfigured by BDI or by the Client.

POWER

Power is always one of the primary design consideration when deploying a SMS. We provide complete solutions for either AC or solar powered systems with integrated battery backup systems.
+ Wide range of solar panel options
+ Gel Cell Battery backup system
+ Remotely monitor the power system with email/SMS alerts directly from the Data Logger in the event of a power failure.

EXTERNAL COMMS

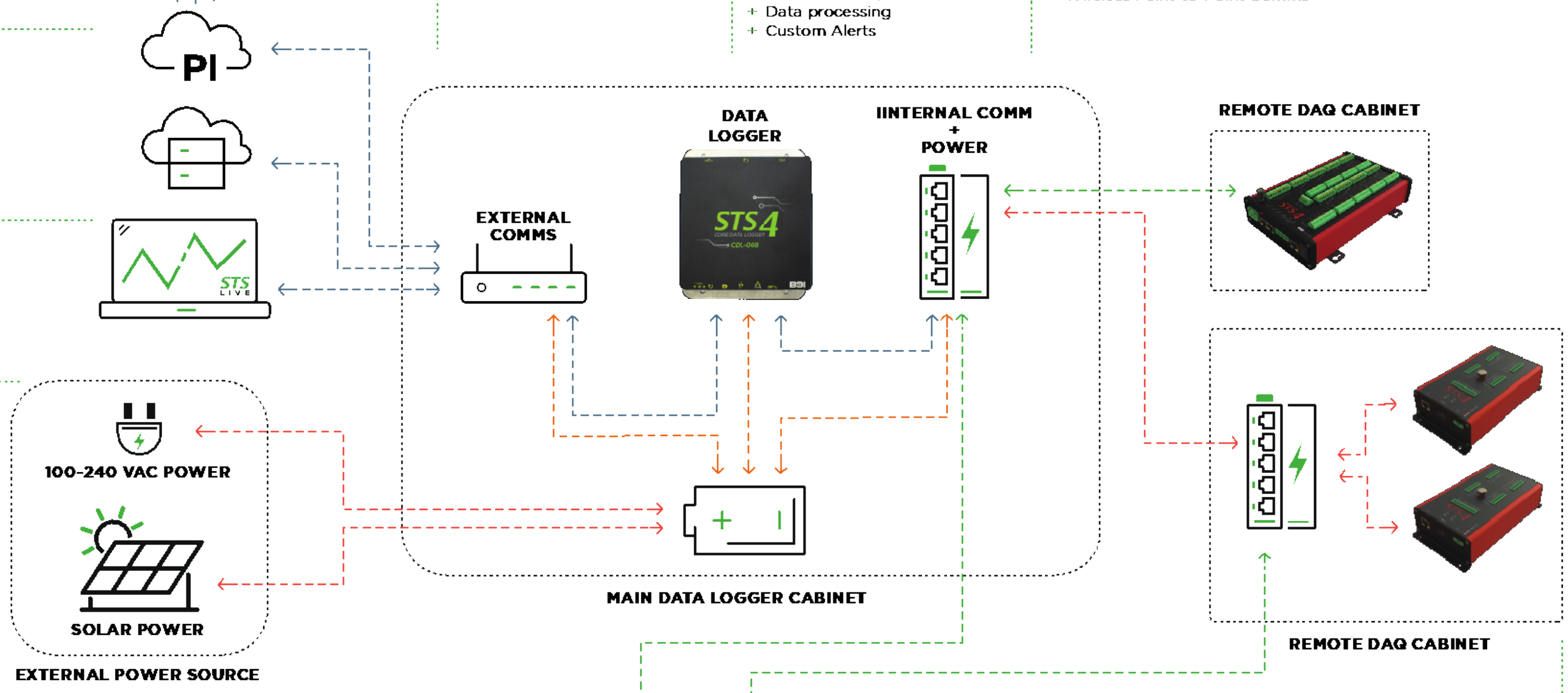
Getting the data from the data logger to an o -site location is another critical component in the SMS design.
+ Hard line communication link
+ Cellular Modem
+ Satellite modem

CORE DATA LOGGER

Our industrial rated core data logger is the essential component that collects, processes, stores, and transfers the data from the distributed DAQ nodes.
+ 128GB solid state hard drive
+ Dual Network ports
+ Data processing
+ Custom Alerts

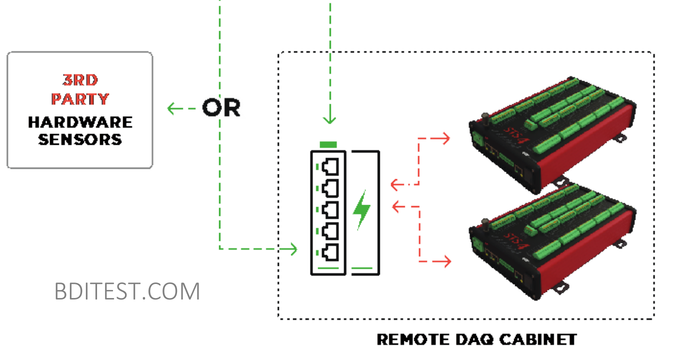
INTERNAL COMMS & POWER

The communication backbone is standard TCP/IP and the power distribution is 24/48 Vdc. To support this design, we supply the following components:
+ Industrial Ethernet Switches
  - Passive Power-over-Ethernet Injection
+ Industrial Ethernet cable
+ Custom armored Ethernet +Power cable
+ Wireless Point-to-Point Comms



THIRD PARTY HARDWARE/SENSORS

We recognized the need to integrate key components that are manufactured by third party vendors so that we can supply a complete system and continue to expand this capability.
+ Vibrating Wire Sensor Interface
+ Environmental sensors
+ Range of Digital Cameras
+ Generic digital sensors
+ Ask us to integrate your custom sensors!



DISTRIBUTED NODAL DAQ NETWORK

The architecture of our SMS is to easily distribute remote data acquisition cabinets throughout a structure where individual sensors are connected. We can supply the DAQ nodes or supply a turn-key solution
+ 4- or 16-Channel Terminal Nodes
+ Ethernet and Power distribution
+ Nema 4X Enclosures
+ Easy to expand
+ Up to 1kHz sample rate
+ Local disaster recovery data storage

SHM COMPONENTS

4/16-CHANNEL TERMINAL NODES

The economical terminal input nodes have been designed for both laboratory and long-term monitoring applications. Either 4 or 16 analog sensor inputs alongside an equal number of thermistor inputs make these nodes ideal for collecting high-speed data and correcting for temperature at the same time.

CORE DATA LOGGER

This rugged customized industrial computer is designed to collect and process data from our nodes in the harshest of environments. Proven to provide continuous reliable data collection, the CDL can process and store over 100 GB of data and transmit the data to the cloud or an office server/computer.

POWER & COMMUNICATION

From full system design to an extensive array of options, we have you covered.

+ Solar/AC battery backed power
+ Systems
+ Enclosures
+ Power/Communication cables
+ Wireless communication
+ Third party sensors/systems integration
+ Cellular/Satellite/Hard Line communications
+ Many more, please inquire

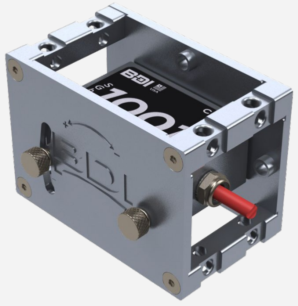
SENSORS

- **STRAIN TRANSDUCER**

The ST350 Strain Transducer has been designed for structural testing in tough field conditions. These accurate, rugged, and fully weatherproofed units can be installed very quickly for all types of measurement applications.

- **ACCELEROMETER**

The A1521 & A2521 Accelerometers have been designed for dynamic structural testing in tough field conditions. These accurate, rugged, and fully-weatherproofed units can be installed very quickly and are available in ranges between 2g and 100g.



- **TILTMETER**

The T500 electrolytic tilt sensor is a high precision sensor with integrated mechanical offset adjustment, designed for short-term testing applications. The T600 MEMS tilt sensors are ideal for longer term installations due to their temperature stability.

- **STRAIN GAGE COMPLETION MODULES**

Available in both 120Ω and 350Ω configurations, as well as standard or amplified outputs, these rugged and re-usable Strain Gage Completion Modules significantly reduces field installation time since only the lead wires from either a ¼-arm or ½-bridge foil gages are connected with a waterproof connector.

- **DISPLACEMENT SENSORS**

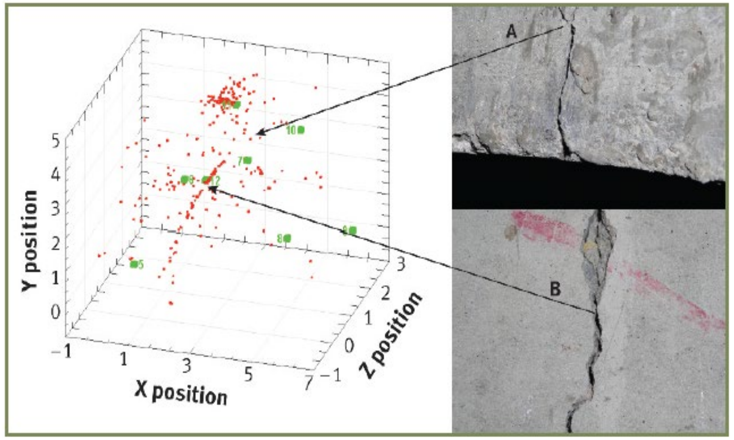
LVDTs are spring-loaded units that provide the "gold standard" for structural deflections when scaffolding or another reliable reference is available. In addition to LVDTs, we offer cable potentiometers, resistive displacement transducers, and ultrasonic displacement sensors.

ACOUSTIC EMISSION

AE has the advantages of real-time detection and monitoring for crack initiation and/or propagation in steel & concrete structures, detection and monitoring for potential wire breaks in post-tensioned and cabled structures

CONCRETE

- Crack identification
- Concrete crack growth
- PT breaks



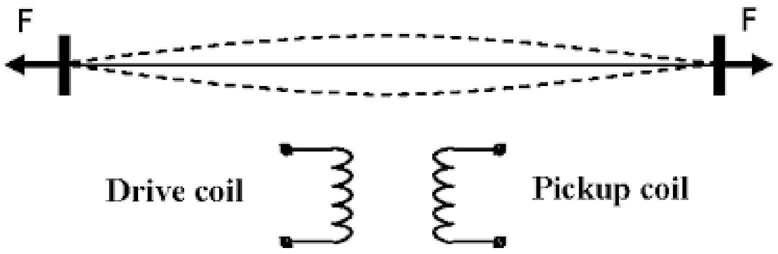
CABLES AND FRACTURE CRITICAL STRUCTURES

- Wire breaks
- Crack identification
- Crack propagation

DaisAE

- Detect wire breaks in main cables
- Fatigue cracking in steel
- Crack propagation in concrete
- 1 or 2 AE Channels
- 18 bit resolution
- 32 Gb local storage
- +24 Vdc Power over Ethernet

OTHER DISCRETE SENSORS



Vibrating Wire

Load Cells

Wind Speed

Weather

Pressure

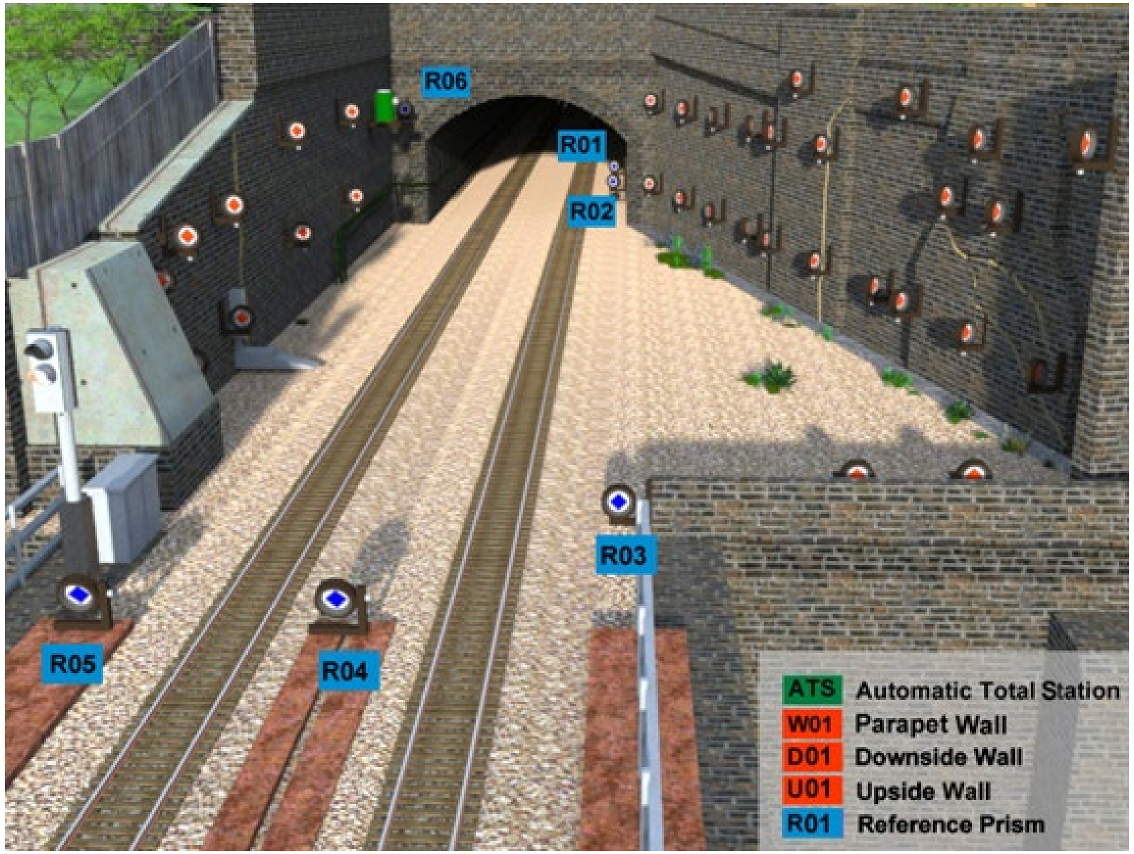
Weigh in Motion (WIM)

STS4 is a general purpose DAQ and can handle most analog sensors

GPS AND AMTS INSTRUMENTATION

GPS; 12-24 hour filtered

AMTS; seconds per prism



GEOTECHNICAL INSTRUMENTATION

Settlement

Soil Interaction

WIRELESS!

Piezos

Ground Anchors

VIBRATION INSTRUMENTATION

Remote Monitoring

Structural Vibrations

Ground Vibrations

WEIGH IN MOTION (WIM)

STRUCTURAL LOADING IS AN INVALUABLE PARAMETER FOR ENGINEERING ANALYSIS.

Why?

- ADT
- Fatigue cycle comparison
- Real-time load testing
- Validation of actual service loads

In-road Piezo Strips

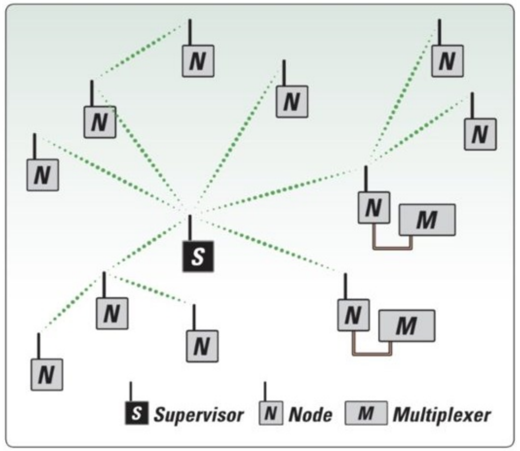
- Economical
- Approx. 80% accuracy
- Ideal for truck classification & load estimation

In-road Scales

- Better than 95% accurate
- Ideal for refined analysis and real-time load testing

WIRELESS TECHNOLOGY

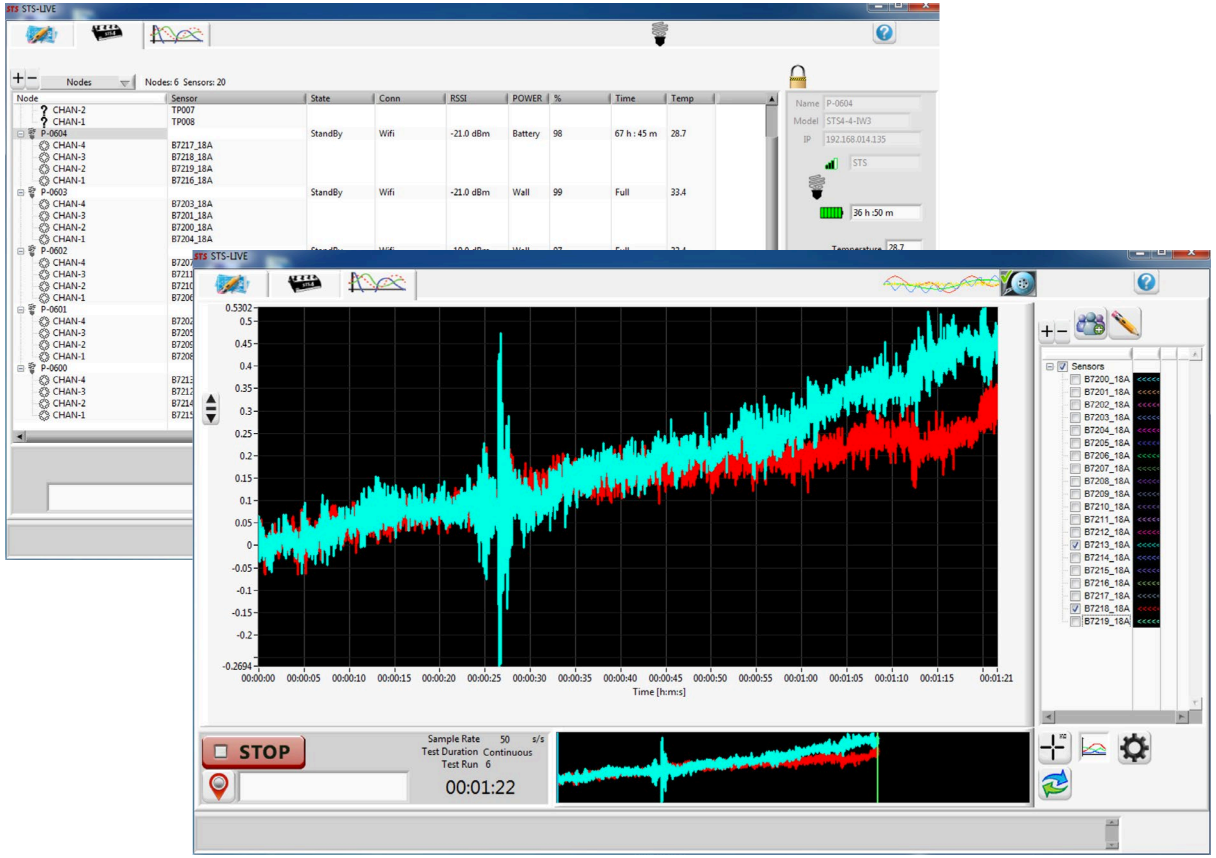
Wireless technology is a very simple way to control costs on highly dispersed instrument locations.
Ideal for slow measurements but cannot be used for dynamic data collection or data that requires heavy filtering.



DATA COLLECTION SOFTWARE

STS-LIVE: DATA ACQUISITION SOFTWARE HAS BEEN DESIGNED WITH ALL THE FEATURES REQUIRED TO EVALUATE THE QUALITY OF THE DATA COLLECTED QUICKLY AND UNDER THE PRESSURE OF ON-SITE FIELD PROJECTS!

- Automatic recognition of all hardware!
  - All calibration data is automatically applied.
- Real-time data display
  - Group sensors within data display
  - Range of filtering options
  - Convert data to frequency domain
- Virtual Sensors
  - Create virtual sensors using mathematical functions
- Monitoring Configuration
  - Capture event based data blocks
  - Rainflow histogram data (fatigue analysis)
  - Historic trend data
- Custom LabView programming
  - Open STS-CORE software for clients to develop custom programs
  - BDI can develop custom applications for our clients

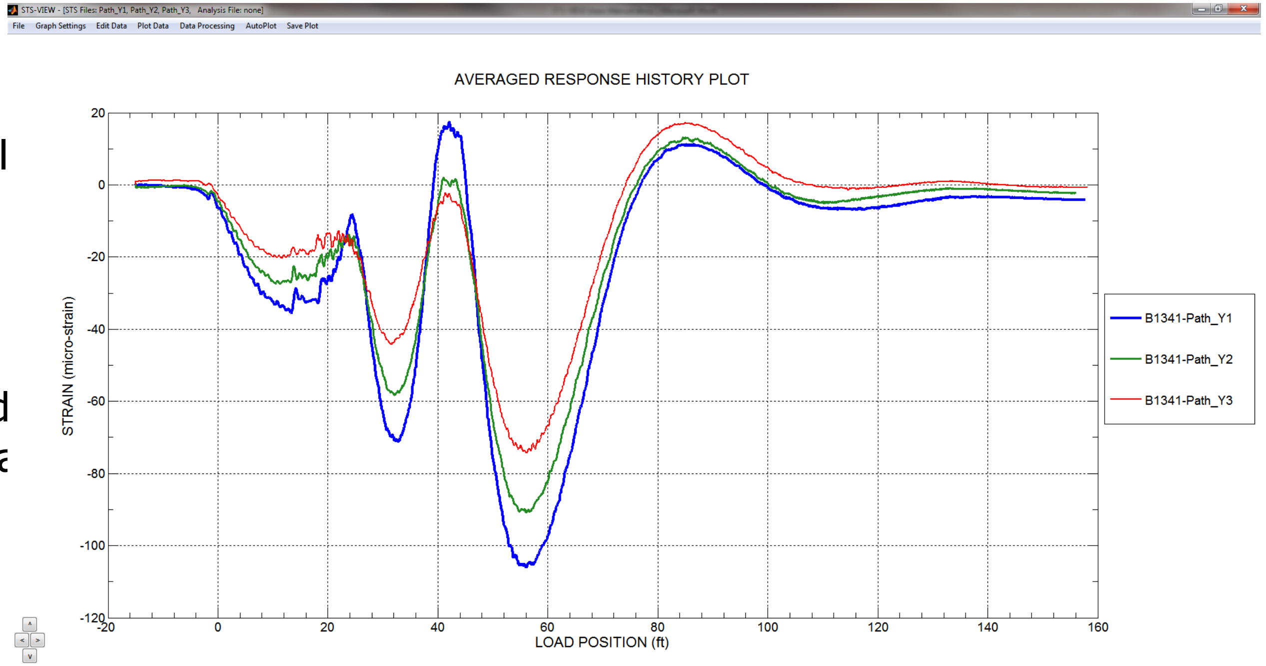


DATA PROCESSING SOFTWARE

STS-VIEW: DATA ACQUISITION SOFTWARE HAS BEEN DESIGNED WITH ALL THE FEATURES REQUIRED TO EVALUATE THE QUALITY OF THE DATA COLLECTED QUICKLY AND UNDER THE PRESSURE OF ON-SITE FIELD PROJECTS!

- Compatible data files
  - Works with BDI *.tdms & *.dat data file structure
  - Compatible with Campbell Scientific data files
- Data display options
  - Response, curvature, neutral axis plots
  - Group sensors for averaged range calcul
  - Range of filtering & decimation options
  - Convert data to frequency domain
- Input Options
  - Load finite element analysis results for d
  - Graphical comparison with collected data
- Extract Data
  - Excel spreadsheet
  - Text file
  - Max/Min value extraction

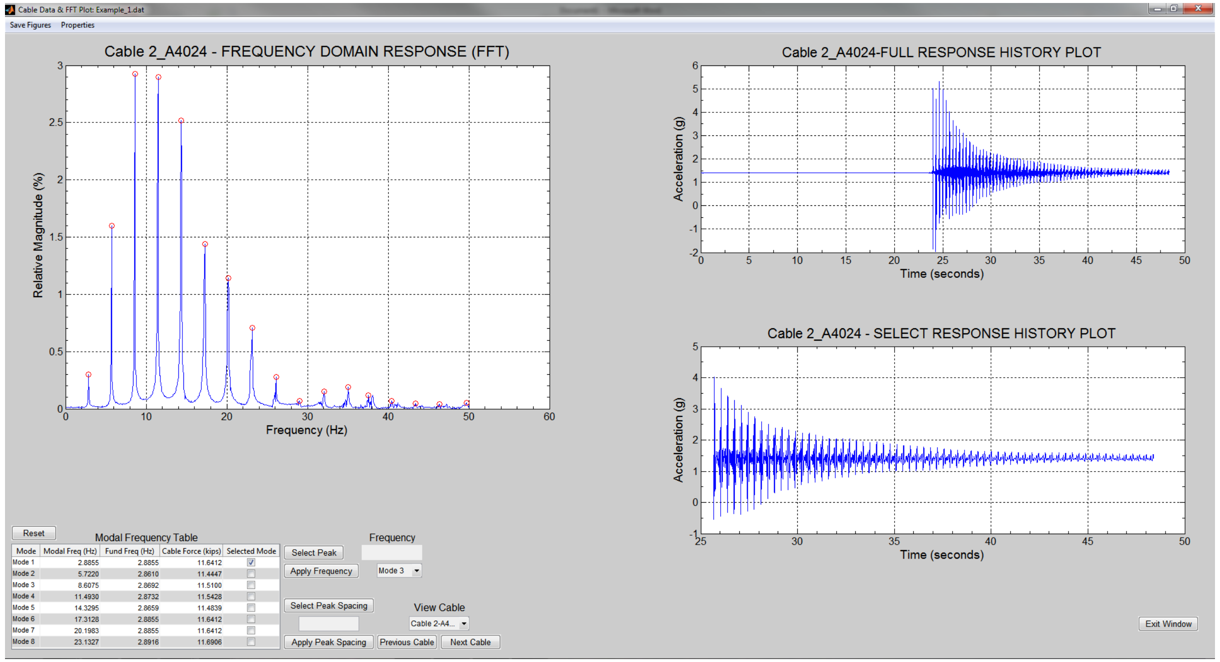
- Auto Plot Graphs
  - Generate graphs for reports



DATA PROCESSING SOFTWARE

STS-CFA: DATA PROCESSING SOFTWARE HAS BEEN DESIGNED TO CALCULATE AND DISPLAY TENSION FORCES IN CABLES USING THE VIBRATION METHOD.

+ Compatible data files
  - Works with BDI *.tdms & *.dat data file structure
+ Data display options
  - Plots acceleration response history
  - Automatic frequency plot (FFT)
  - Convert time domain data to frequency domain
+ Input Cable properties
  - Cable Length
  - Cable unit weight
+ Peak Finding
  - Automatic FFT peak finding
  - Manually select peak locations
  - Manually adjust peak spacing
  - Historic trend data
+ Generate Cable Force Report
  - Output cable force data to MS Excel or text file
  - Compare differences between cables (balancing
  - multiple cable forces)

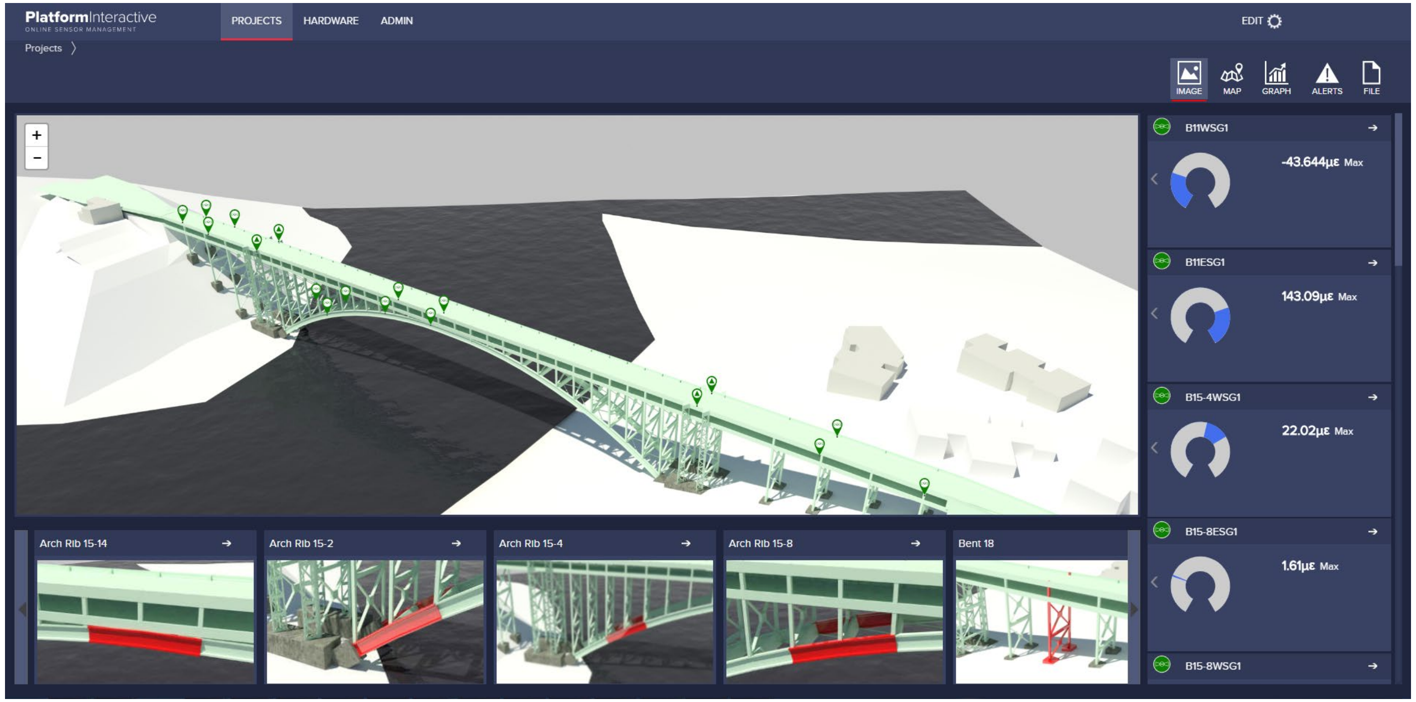


DATA MANAGEMENT

PlatformInteractive

ONLINE SENSOR MANAGEMENT

+ Monitor an unlimited number of sensors
+ Several alert types such as emails and texts
+ Real time data presentation using advanced graphing engine
+ Assemble and organize data from multiple data sources
+ Easily input manually collected data
+ Custom reporting tools
+ Based on industry-leading computing platform-Microsoft® Azure cloud
+ Utilize and configure for your existing data acquisition systems
+ BDI data hosting service is backed with a 24/7 quality monitoring guarantee



Microsoft Azure Compliancy & Certifications:

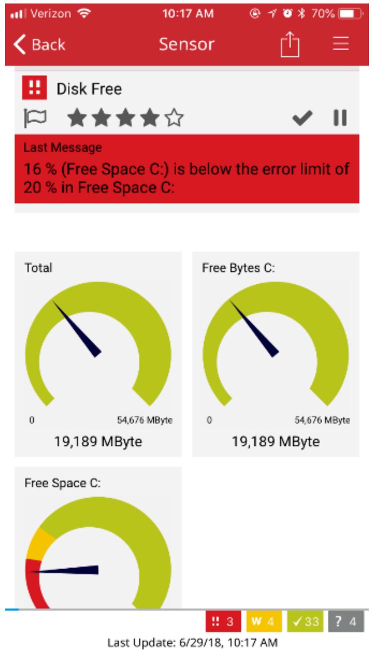
ISO 27001
SOC 1
SOC 2
FedRAMP
UK G-Cloud
PCI DSS
HIPAA

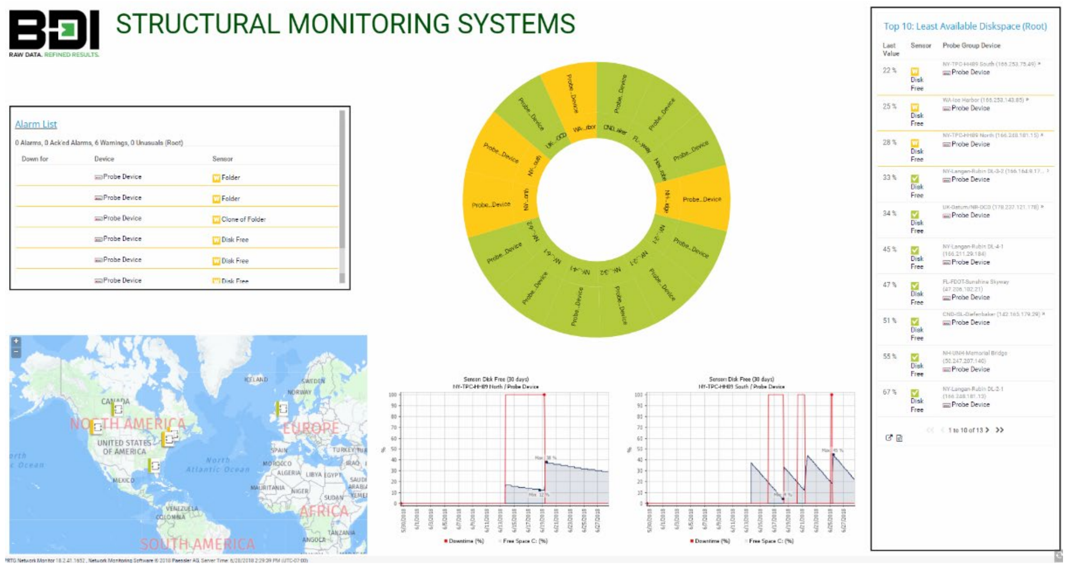
Microsoft Azure

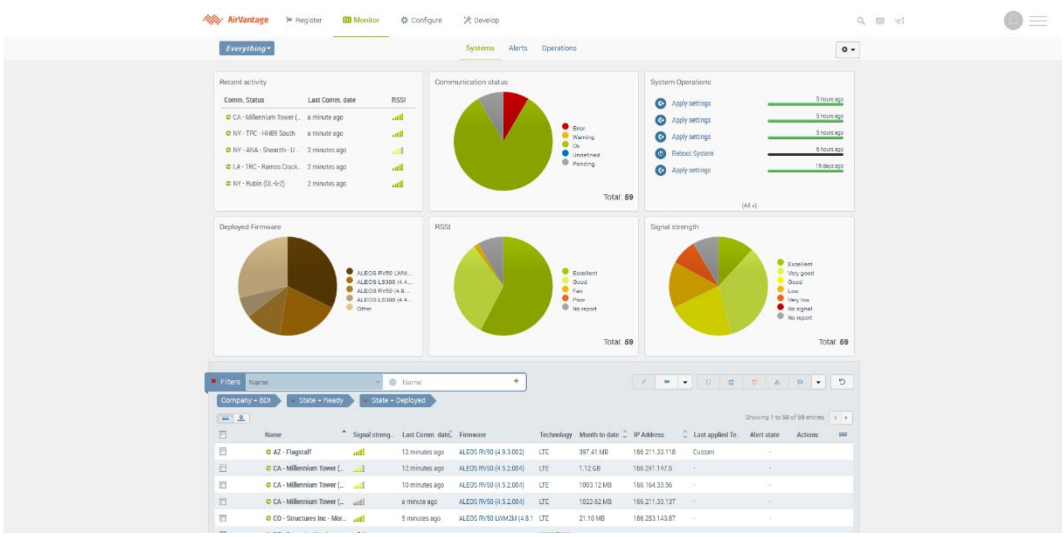
QUALITY CONTROL

System Monitoring:

- Data age
- Modem connectivity
- Disk space
- Data traffic







Off-site backup technical support :

- BDI technical staff can support help desk at any time using mobile based and RDP applications

BDI RAW DATA. REFINED RESULTS.

DIAGNOSTIC LOAD TESTING

Diagnostic Load Testing

1. Identify whether a load test can meet desired objectives
2. Select the type of load test to meet the test objectives
3. Understand the outcome of a load test, learn how to use this outcome to meet the test objectives, as well as to evaluate bridge structural behavior
4. Determine the structural safety of a bridge, quantified by the probability of failure, updated with the information from the load test

Introduction

- Measure the actual response of the structure against known loads so that realistic analytical models can be established.
- Often used to reduce uncertainties with respect to as-built condition that cannot be analyzed through traditional methods.
    - Boundary conditions, transverse distribution, secondary non-structural elements, etc.
- Typically use maximum service load for load test and can be performed in a very short time frame with low impact on traffic.
- Data is used to refine and validate analytical approach.
- Final result is typically an updated load rating for the bridge with critical load rating locations.

Typical load test being conducted on a short span structure that has been posted with a load limit.

Diagnostic Load Testing

- **PROCESS**

DEFINE OBJECTIVES & DELIVERABLES

Diagnostic Load Testing

- **KEY CONSIDERATIONS**

- Must clearly define the objectives of the load test, so that they are understood by all parties involved.

Some typical reasons to conduct a load test:

- field verification of design assumptions;
- distribution of live load effects;
- measurement of stress response in certain members;
- determining actual performance of bridge appurtenances that affect structural boundary conditions (i.e., expansion joints or pinned connections);
- measuring the maximum unexpected stresses in members connected to a "frozen" pin or other malfunctioning appurtenance; and
- development of load ratings for particular vehicle configurations.

Cost Benefit Analysis

- Before undertaking a load test, it is important to evaluate the cost benefit

Typical Load Rating:

- $1,500 - $5,500

Typical Diagnostic Load Test and Load Rating:

- $25,000 - $35,000
- MPT and access not included

Alternative:

- Replacement
- Strengthening/Repairs
- Load Posting

Must be able to calculate the alternative!

More to come on cost benefit analysis

Case study – Key Considerations

About the Structure:

- Four span, cast-in-place reinforced concrete slab single lane bridge
- Current load rating below acceptable limit for the service loads
- Condition of the bridge was good, no signs of degradation

Objective:

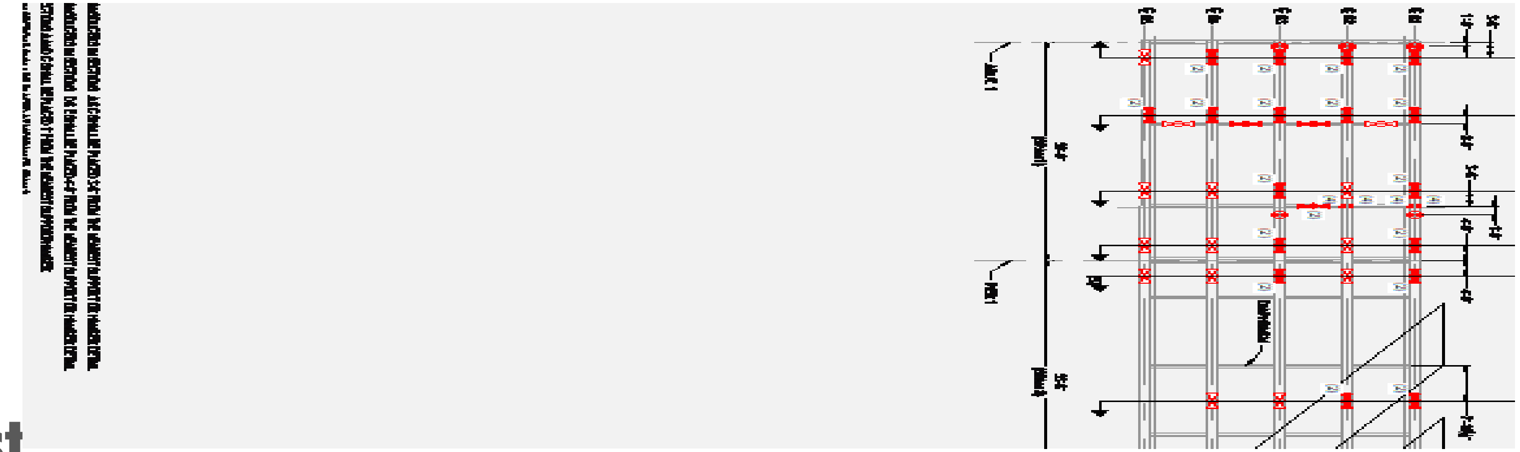
- Provide a more accurate load rating through a diagnostic load test

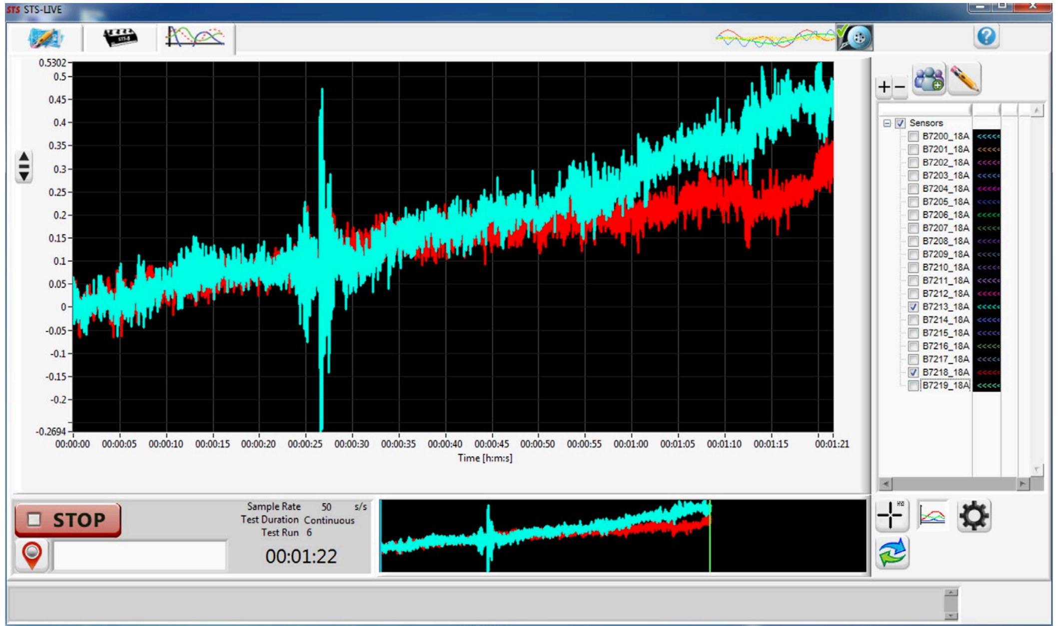
Cost-Benefit Analysis:

- Simplified approach, comparing the cost of strengthening to load testing
- Estimated strengthening cost ~ $250,000
- Diagnostic Load Test ~ $30,000

Planning & Execution

1. **Develop instrumentation plans**
2. **Project site planning**
   a. Bridge access, traffic control plan, and loading vehicle
3. **Execute diagnostic load test**
4. **Validate data on-site**

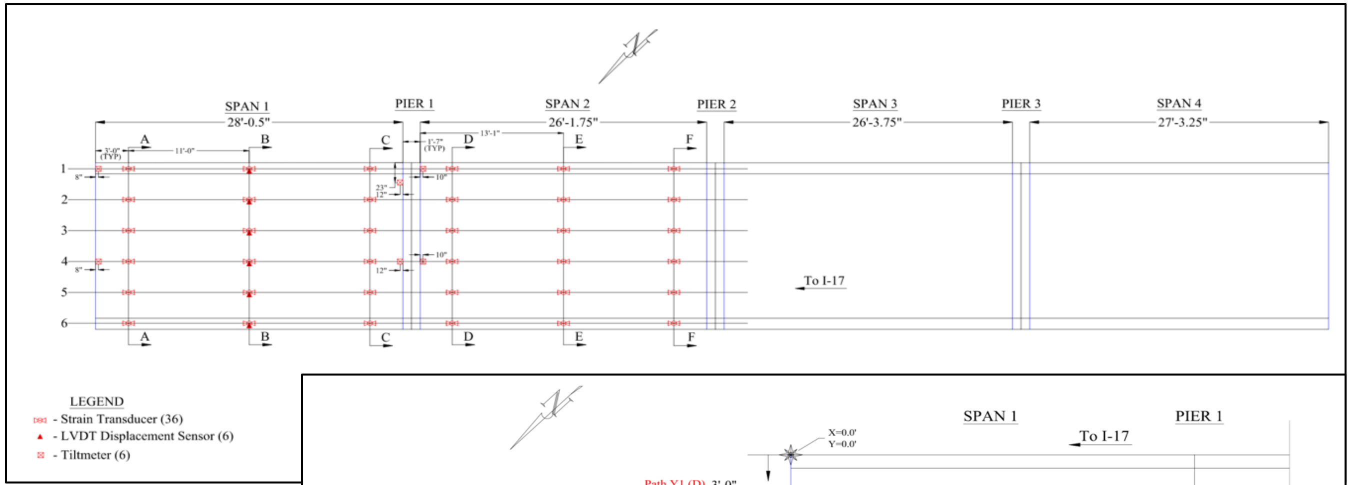


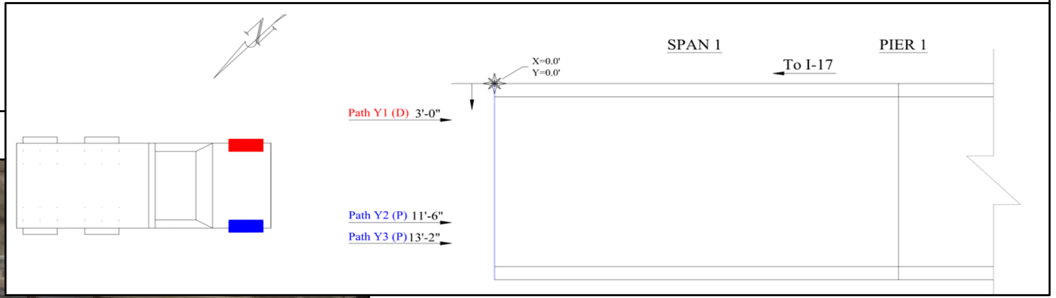


Case study – Planning & Execution

Instrumentation Plans:

- Focus on 2 of 4 spans with 6 cross sections on sensors
- Strain, displacement, and rotation as primary measurements
- 3 lateral load paths defined



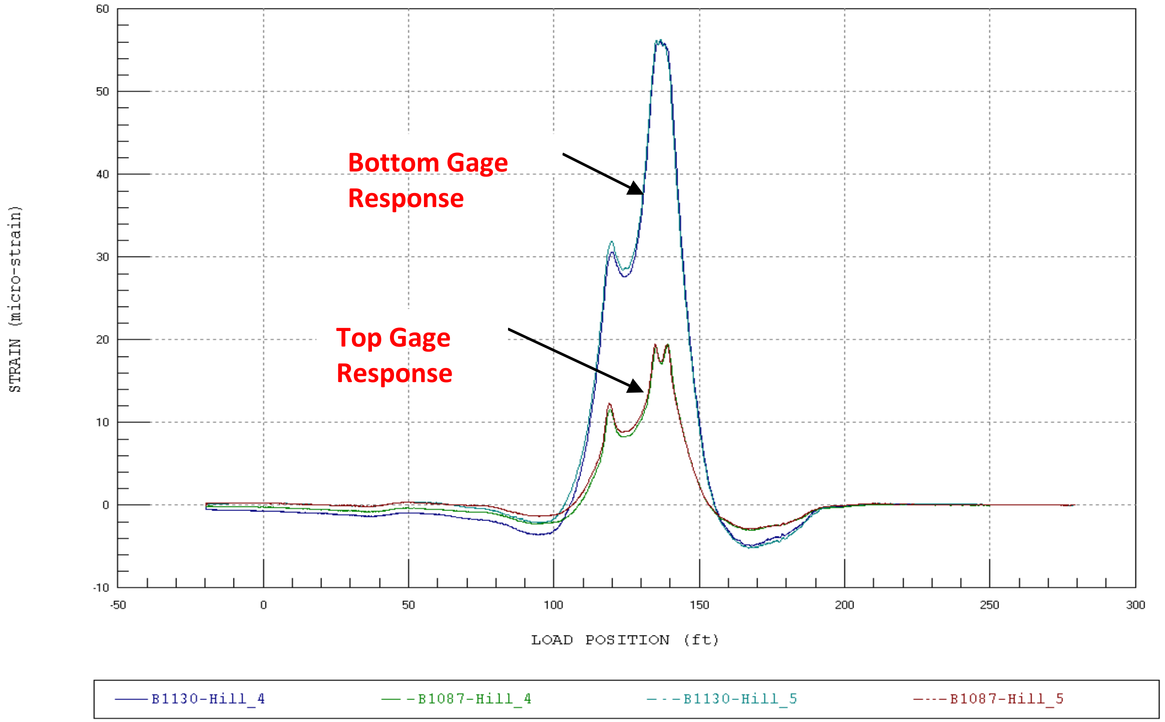


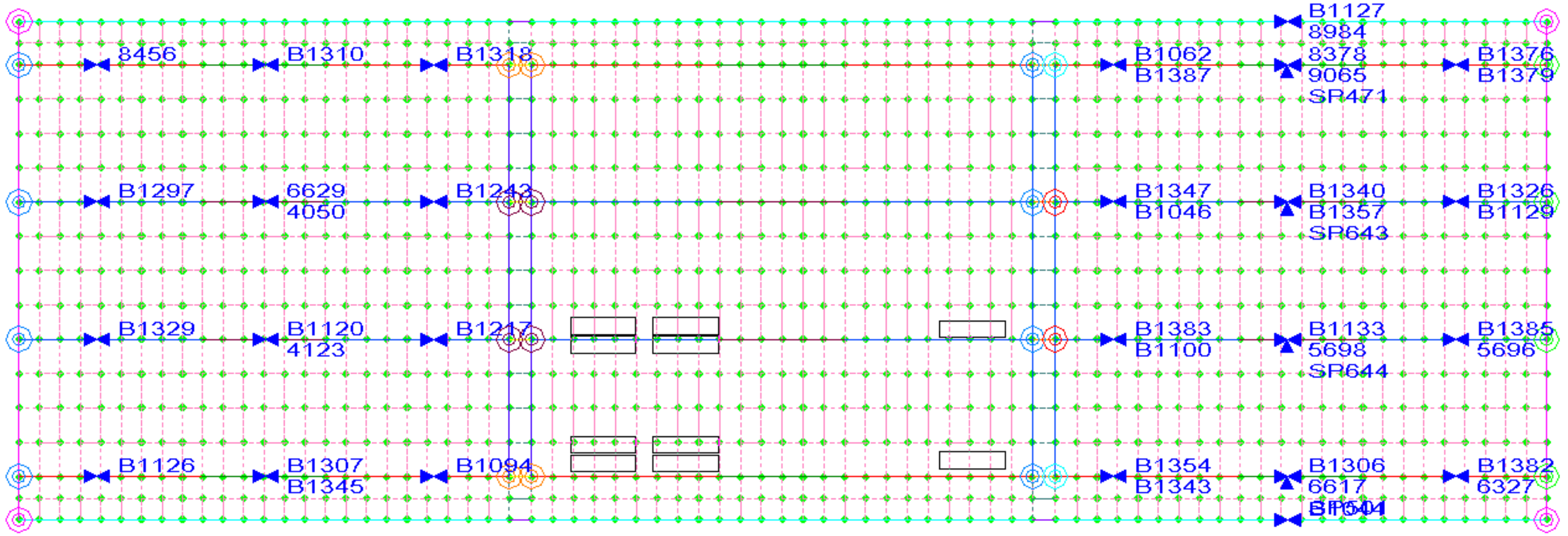
Site Planning:

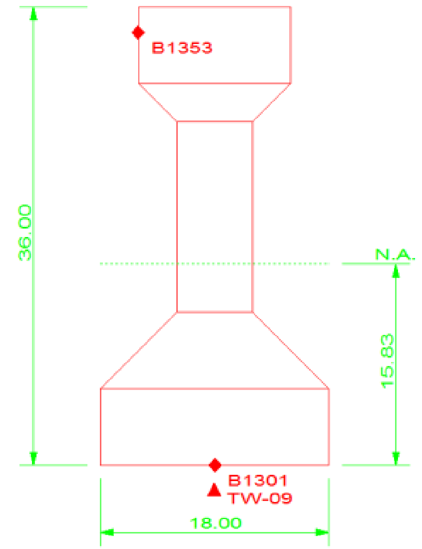
- Access via scaffolding and step ladders
- Traffic control was performed by load testing crew (low volume road)
- Tandem dump truck loaded to the legal limit used as test vehicle

Data Interpretation

1. **Qualitative data review**
2. **Develop analytical model**
   a. Identify and assign initial model parameters
3. **Validate and refine analytical model**
   a. Adjust model parameters to match field responses
4. **Final field-verified model**



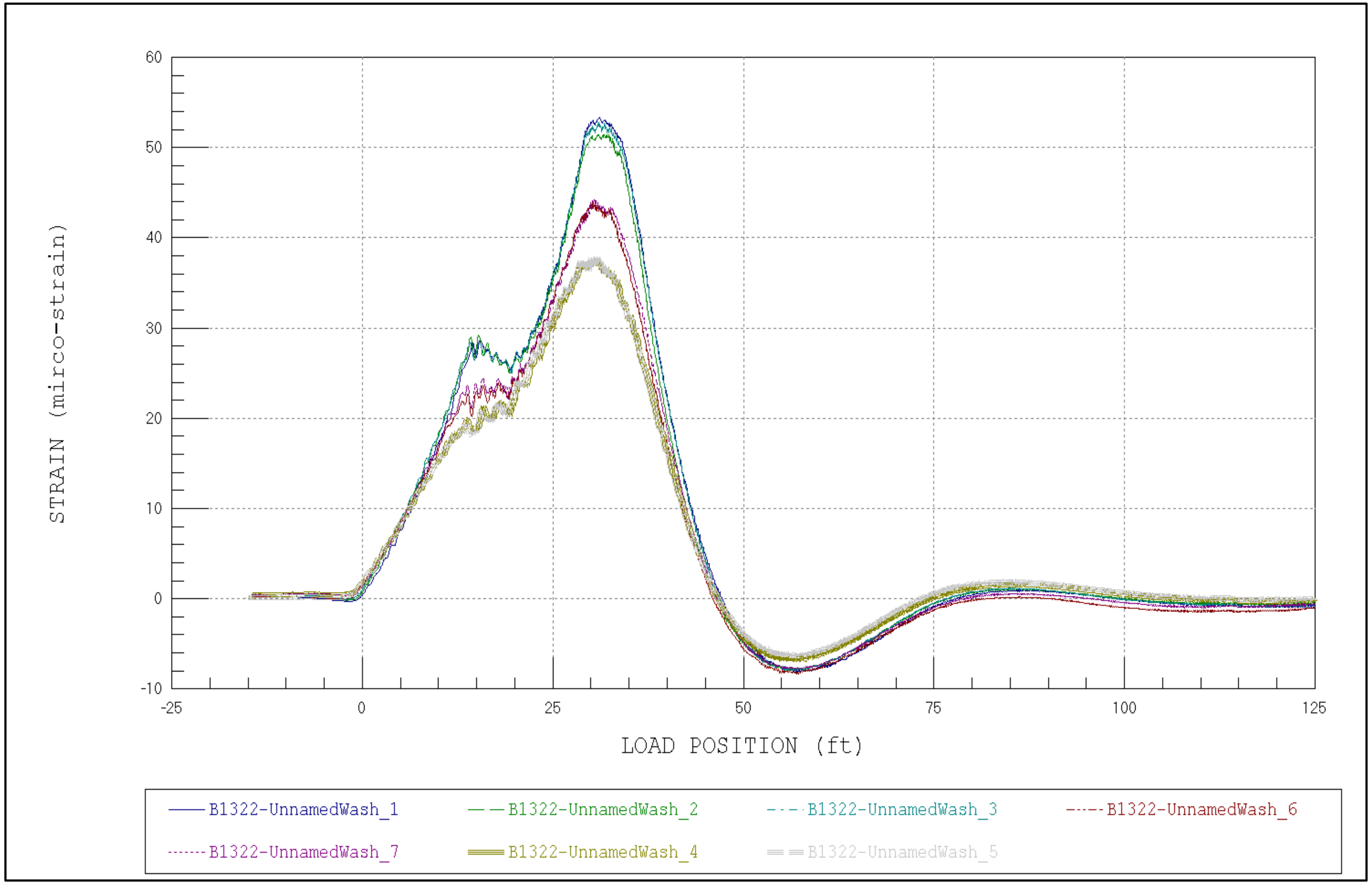




Case study – Data Quality Review

Key Points:

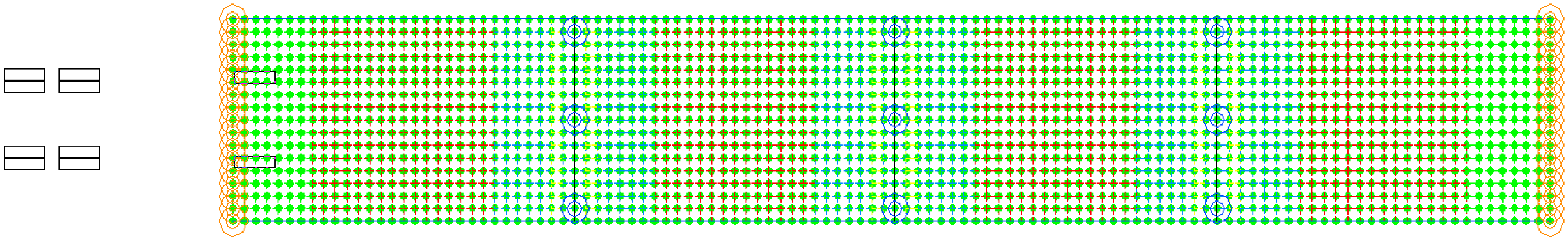
- **Reproducibility and linearity of responses**
- **Thermal drift not an issue**



Modeling Parameter Refinement

Element Type and Mesh Size	Strain or stress output, depending on the element type and mesh size at sensor locations, must be comparable to the gage length and orientation of strain sensors used in load test.
Secondary Members	Secondary members such as barriers, sidewalks, diaphragms, etc., need to be properly included for their geometrical, material, and stiffness properties.
Bearing Support Conditions	Typical bridge bearings, of fixed or expansion, provide a rectangular patch support to the superstructure. Expansion bearings usually have frictional resistance. Use of idealized fixed or roller point or line supports in the analytical model may cause discrepancies with load test measurements due to simplifications.
Elastic Modulus of Concrete (E_c)	E_c is usually estimated from the specified concrete compressive strength (f_c') using an empirical formula. In reality, most concrete mixes are placed at a higher strength than design requirements, and concrete continues to gain strength over time. When modelling the sectional stiffness, both the effect of the concrete strength and the provided reinforcement are considered. If test data is available, using the actual material properties instead of nominal values will improve the fidelity of results from the model.
Link Members for Eccentricities	Use of line or planar elements in a FEM requires the use of link members to address the eccentricities between intersecting or connecting bridge members. Proper definitions of the stiffness properties of the link members are important to simulate the overall behavior of the structural system, including intended or unintended composite actions between adjacent members.
Member End Connection Stiffness	For steel members of I-shaped or other types that do not have a full moment connection at the end in the framing system, e.g., the commonly used partial web height double-angle bolted connection, the actual rotational stiffness of the connection falls between those of a fixed and a pinned connection. Depending on the type of elements used in the model, adjustments can be made to the rotational stiffness for better agreement with field measurements. For example, a rotational stiffness constant can be defined at the connection when beam members are used in the model.

Case study – Parameter refinement



Finite Element Model Stats:

- 2D composed of shell elements, frame elements, and springs
- 2-D footprint of test truck consisting of 10 vertical point loads
- Loading increments every 2ft. (204 load cases)
- 9,792 measurement comparisons (36 strain, 6 disp., 6 rotation)

Finite Element Model Adjustments:

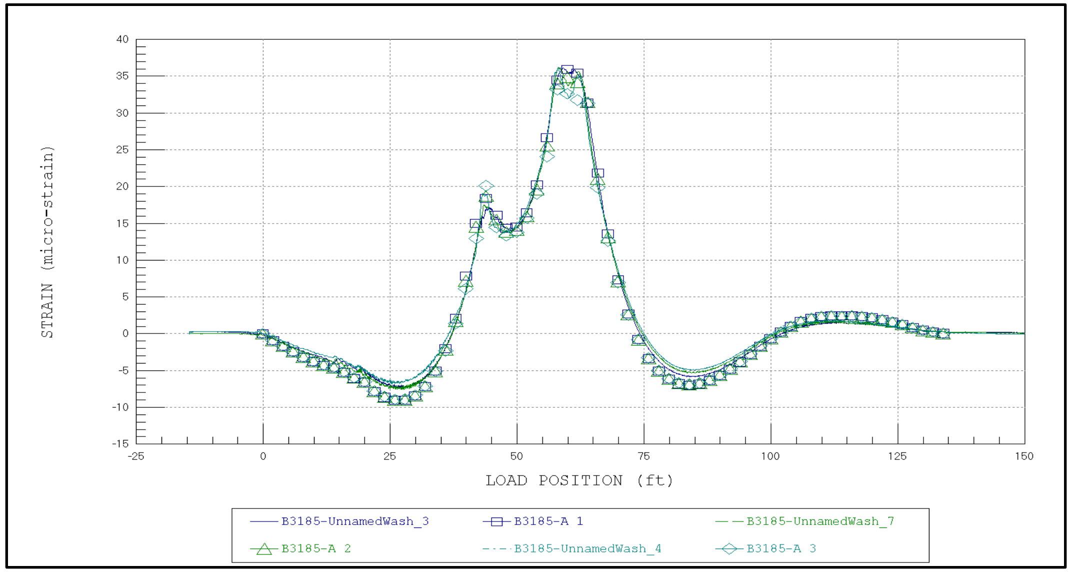
- Friction-Based Rotational Resistance: Bottom of the slab at piers (Fx)
- Slab Stiffness: Midspan Slab (E)
- Slab Stiffness: Slab near abutments (E)
- Slab Stiffness: Slab near piers (E)
- Slab Stiffness: Slab adjacent to piers (E)

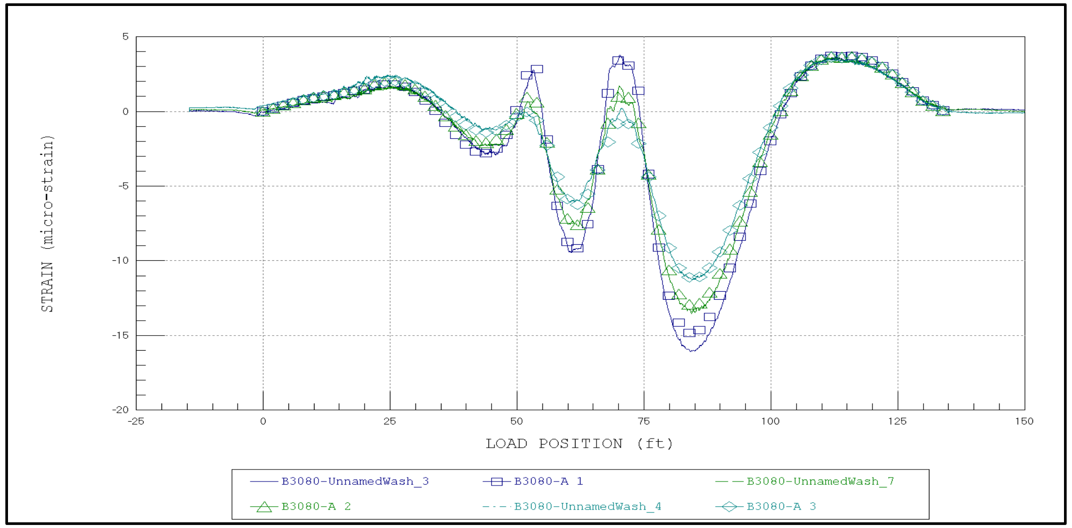
Case study – Parameter refinement

Final Model:

- **Excellent correlation with measured response**

Modeling Parameter	**Initial Model Value**	**Final Model Value**
Slab Stiffness		
- Slab at midspan (E)	3,200 ksi (22.06 GPa)	2,600 ksi (17.93 GPa)
- Slab near abutments (E)	3,200 ksi (22.06 GPa)	3,300 ksi (22.75 GPa)
- Slab near pier (E)	3,200 ksi (22.06 GPa)	3,300 ksi (22.75 GPa)
- Slab directly adjacent to piers (E)	3,200 ksi (22.06 GPa)	2,150 ksi (14.82 GPa)
- Spring Resistance at Piers (F_x)	0	400 kip/in (70.1 kN/mm)
Model Correlation	Initial Model Value	Final Model Value
Correlation Coefficient	0.9782	**0.9856**





Load Rating

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

1. Model adjustments for load rating

a. Remove/reduce parameters that may not be counted on reliably.

2. Calculate member capacities

a. Member capacities are calculated using the applicable code [MBE].

3. Apply dead and live load

a. Dead load may have to be applied separately (non-composite)
b. Apply design live loads according to applicable code [MBE].

4. Extracting results

a. Typically rating factors should be produced for all elements where capacities were assigned.

Reporting

- **FOCUSED REPORT OUTLINING THE RESULTS AND RECOMMENDATIONS. NOT A RESEARCH REPORT!**

1. **Executive summary with load rating results**
2. **Summary of load test procedure and instrumentation plans**
3. **Analysis approach**
   a. Data quality, notable observed behavior
   b. Modeling approach (2D/3D) and comparison between analytical model and field measurements
   c. Summary of parameters refinement results and justification
4. **Final load rating and recommendations/advice**
   a. Summary of final modeling parameters used for load rating
   b. Load rating parameters: load factors and capacities used for load rating along with assumptions made
   c. Detailed load ratings for requested vehicle configurations
   d. Recommendations, if any

STRUCTURAL HEALTH MONITORING

STRUCTURAL HEALTH MONITORING (SHM) - why?

- **Structural Performance**
  - Settlement
  - Temperature induced stresses
  - Construction monitoring
  - Verify new design techniques

- **Inspection Support**
  - Bearing and joint performance
  - Linkage performance
  - Repair / retrofit evaluation
  - Damage tracking / propagation

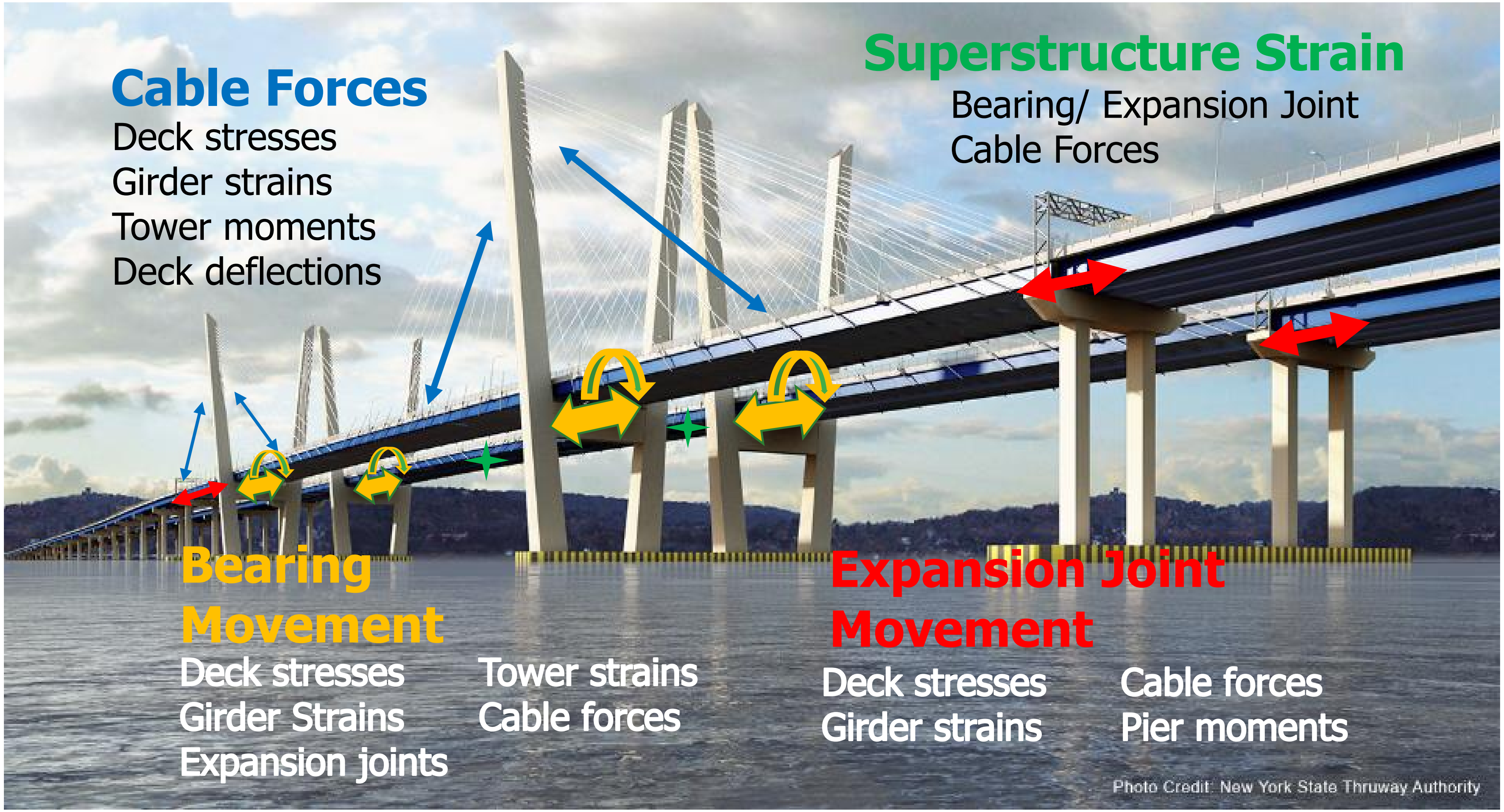
- **Operations and Maintenance**
  - Keep a remote eye on potential problems
  - Road surface condition
  - Weather

- **Digital Twin Calibration**
  - Upload data to validate and adjust a digital twin model
  - Identify changes in performance
  - Target maintenance funding

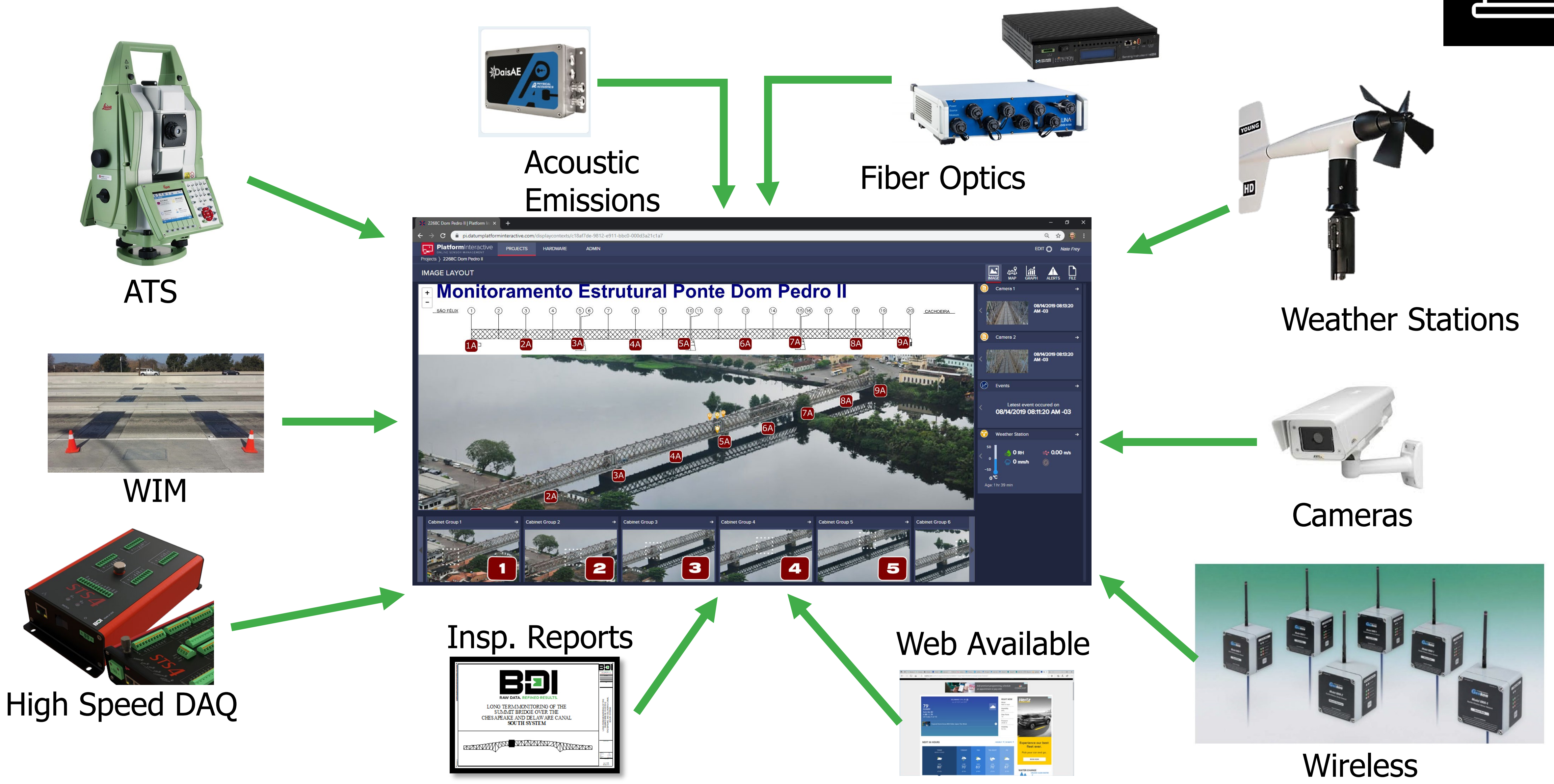
DESIGN WITH A PURPOSE AND REALISTIC BUDGET

SHM - COMPONENT PERFORMANCE INTERACTION

(Replaceable components over life of structure)



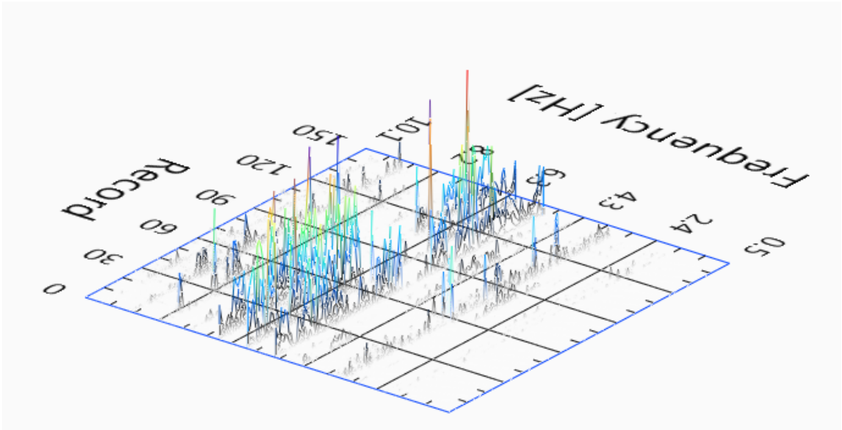
WHAT KIND OF DATA?

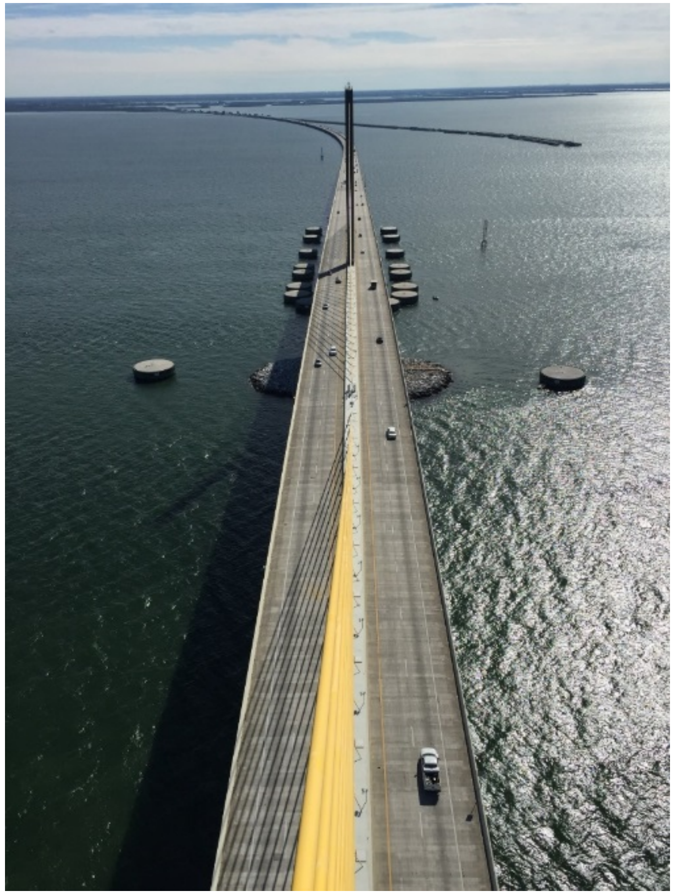


SUSPENDER ROPE BEHAVIOR

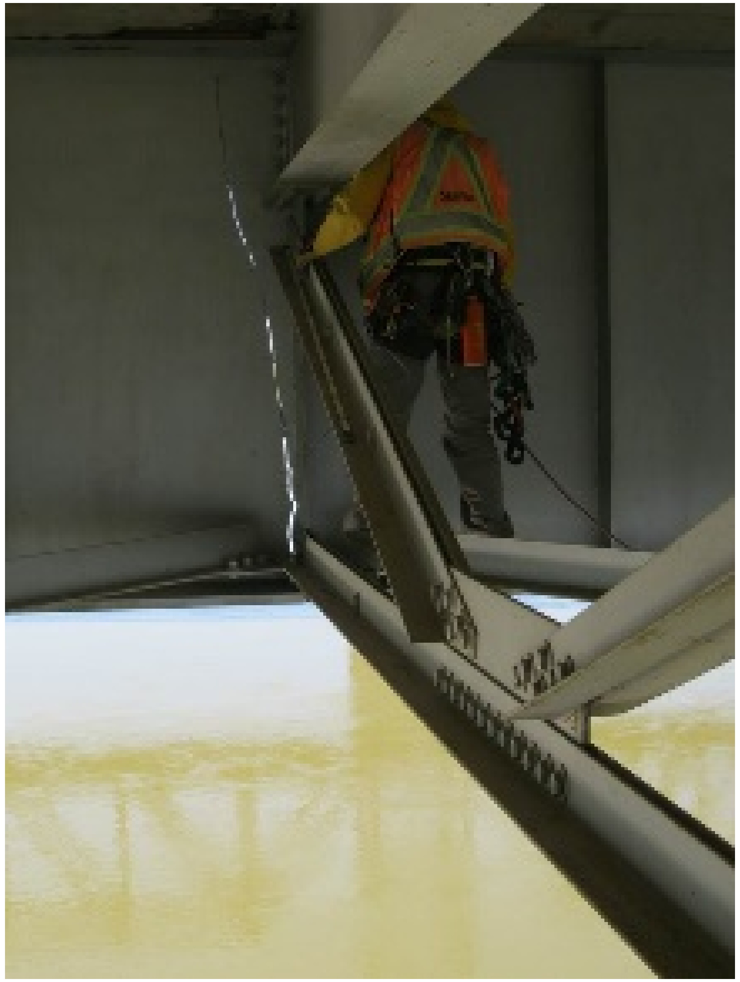
Inspection and maintenance of stay cables is covered in NCHRP Synthesis 353, and is bridge-specific

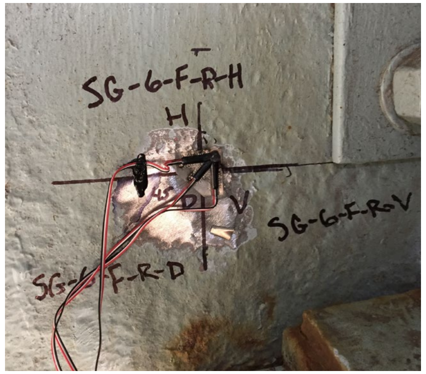
- Taut Cable Vibration Method
  - Cable forces within tolerance
- Acoustic Emission monitoring
  - Wire breaking due to corrosion
- Tower/Cable Survey
  - Geometry indicative of large, global issue

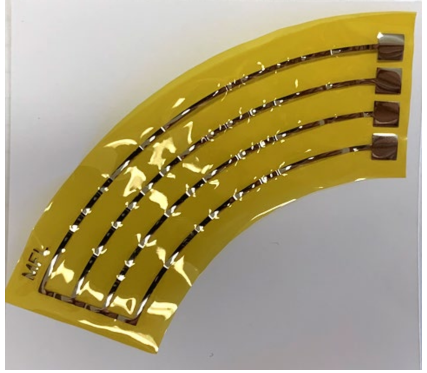




FRACTURE CRITICAL & FATIGUE MONITORING







Strain Gaging

- Mainly for further evaluation
- Cycle counting
- Stress levels
- Performance evaluation
- Model Calibration

Acoustic Emissions

- Best for ongoing monitoring
- Don't need to know exactly where crack is
- Locating Cracking
- Crack detection
- Crack propagation

Binary Crack Gage

- Low power and economical ongoing monitoring
- Need to know where crack is
- Crack detection
- Crack propagation

PIER/TOWER MOVEMENT AND SETTLEMENT

Several ways to measure pier rotation and settlement. Different means for different applications.

WIRELESS TILTMETERS

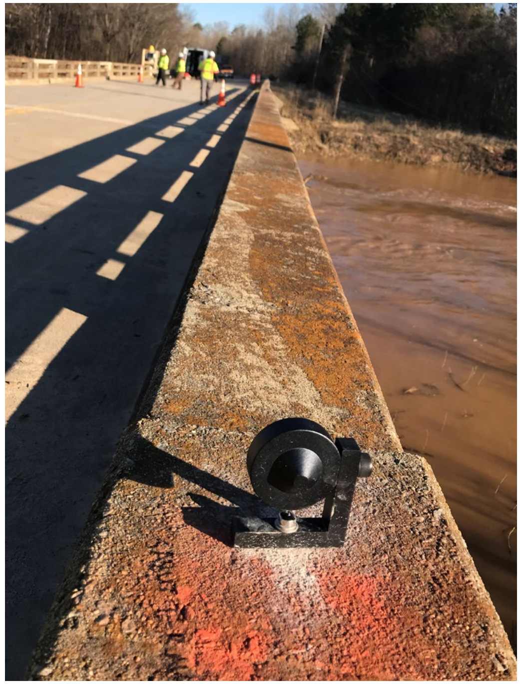
- Biaxial rotation
- Approx. movements
- Economical

GNSS (GPS)

- Absolute X, Y, Z
- Slow sample rate (2 per day)
- Single point

ROBOTIC TOTAL STATION

- Absolute X, Y, Z
- Measurement every 15-20sec
- Lots of points, requires clear sighting between ATS and prism



CONCRETE CRACKING

Several ways to measure cracking. Different means for different applications.

TELL-TALES

- There's nothing wrong with the old-fashioned way
- Requires visual readings
- Zero cost sensor, but not measuring!

SLOW-SPEED DISPLACEMENT

- Economical digital measurement
- Slow sample rate
- Wireless capable
- Not good in dynamic application

DYNAMIC DISPLACEMENT

- Requires high speed DAQ
- very high resolution available
- Req'd to measure under Live Load

VESSEL COLLISION

ALL COMPONENTS FOR VESSEL COLLISION ARE NORMAL SHM COMPONENTS—ACCELEROMETER, TILTMETER, AND CAMERAS/ JUST ADD TRIGGER LEVELS AND LOCATE COMPONENTS APPROPRIATELY.

- Accels trigger system and send alarms.
- Bi-axial rotations indicate damage.
- Other sensors also trigger and record for further evaluation.
- Pan/Tilt/Zoom cameras evaluate damage remotely.
- Add’l cameras capture vessel markings (IR always a good add-on)

ACOUSTIC EMISSIONS

CABLES

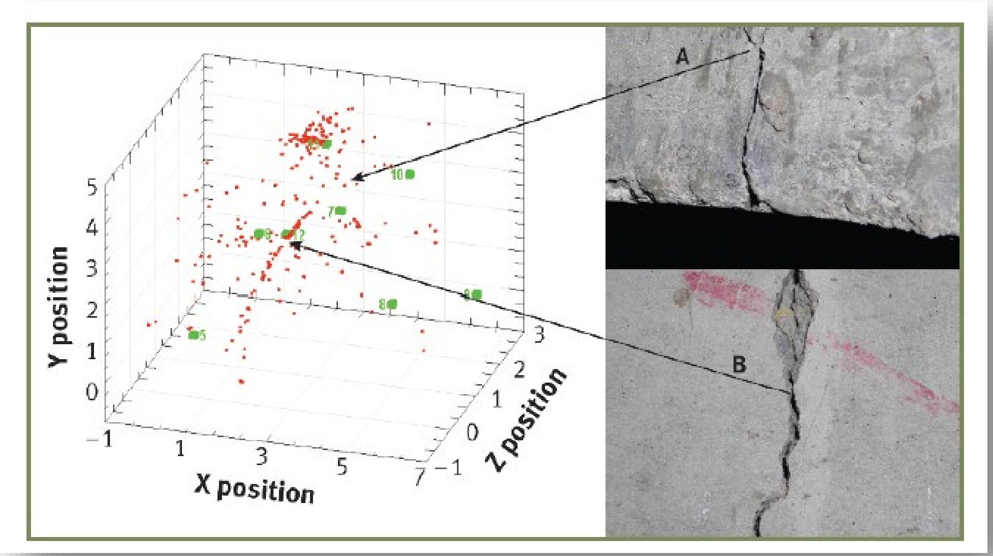
- Wire breaks
- Crack propagation
- Anchorage breaks

FRACTURE CRITICAL STRUCTURES

- Pin fractures
- Crack growth
- Crack identification

CONCRETE

- Concrete crack growth
- Tendon Wire breaks



WEIGH IN MOTION

STRUCTURAL LOADING IS AN INVALUABLE PARAMETER FOR ENGINEERING ANALYSIS.

Why?

- ADT
- Fatigue cycle comparison
- Real-time load testing
- Validation of actual service loads

In-road Piezo Strips

- Economical
- Approx. 80% accuracy
- Ideal for truck classification & load estimation

In-road Scales

- Better than 95% accurate
- Ideal for refined analysis and real-time load testing

INTEGRATING TRAFFIC CAMERAS

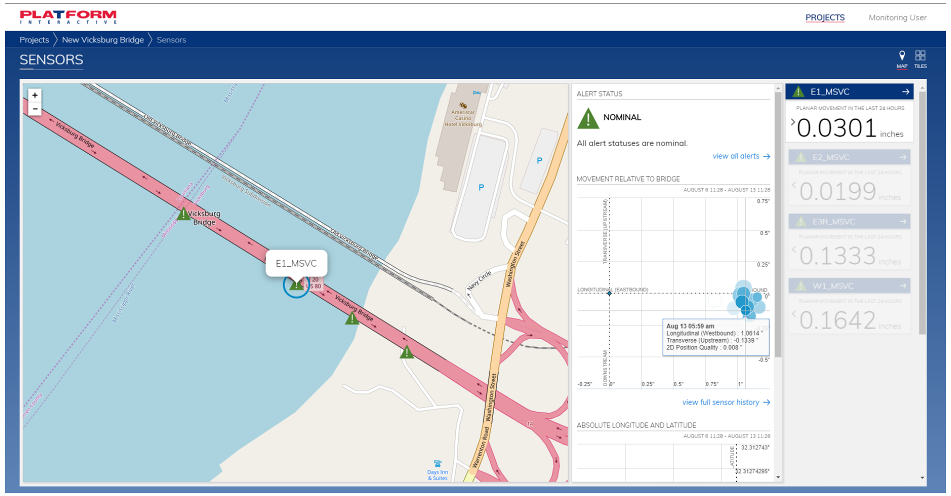
CAMERAS ARE A TRICKY DATA SOURCE BECAUSE A LOT OF MANUFACTURERS RUN PROPRIETARY PROTOCOLS. INTEGRATION IS POSSIBLE BUT WILL DEPEND ON BRAND AND MODEL.

- Analog or digital?
- Analog: much easier, add video encoder
- Digital: depends on brand and transparency of data.

Why do traffic cameras need integrating?

- Review change in response data: both data and video will be time stamped.
  - Cross-reference security footage at time of change (no cost).
- Event Capture: Have integrator add small amount of system compatible cameras.
  - Likely lower cost than integrating existing cameras.
  - E.g., vessel collision
- In many cases the cameras' software will have millions of dollars worth of development that has gone into it.
  - Why reinvent the wheel, just use that tool.

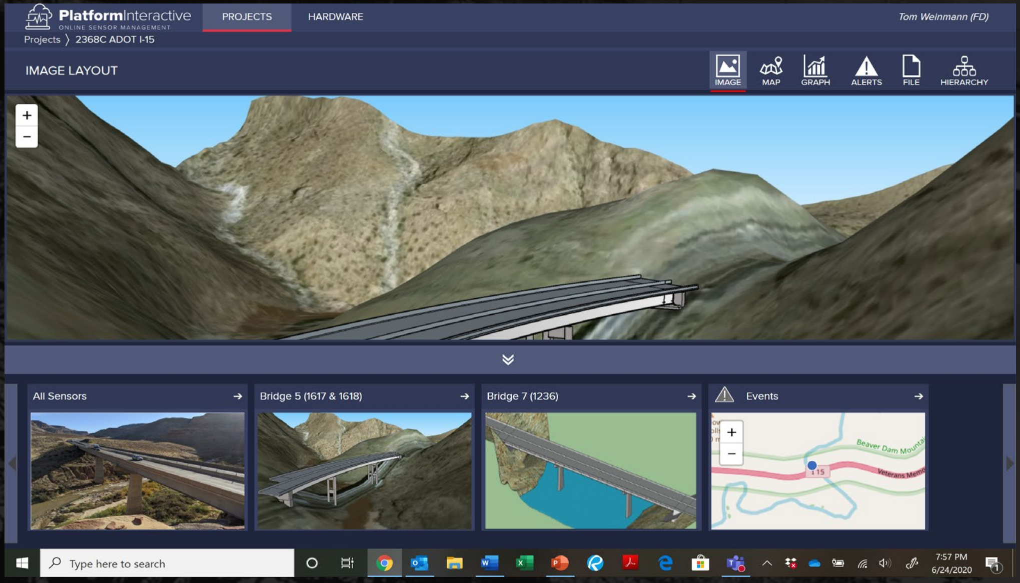
DATA MANAGEMENT AND VISUALIZATION

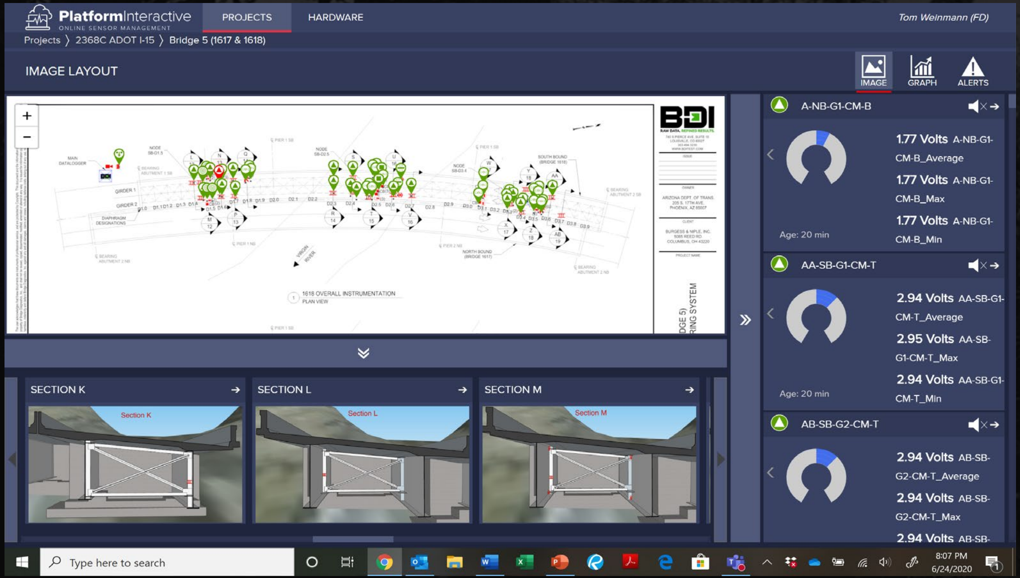


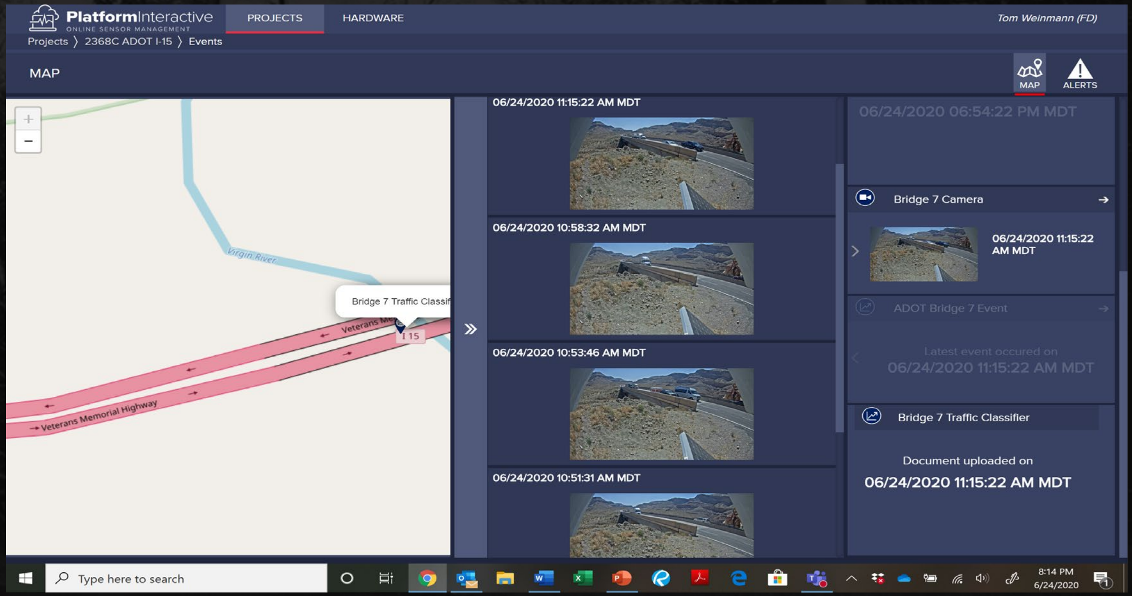
- Designed for Civil Infrastructure
- Client monitoring system portal
- Microsoft AZURE cloud-based hosting service
  - Enterprise level security
  - 99.99% uptime
  - Multiple layers of redundant backup
- 24/7/365 Helpdesk support

- Features:
  - Scalable architecture
  - Drag-and-drop setup and configuration to minimize site development time
  - Sensor agnostic
  - Fully customizable
  - Automated & manual data compatible
  - Microsoft IoT ready

SHM – ADOT I15 PAIR OF BRIDGES (critical conditions)







RAW DATA.
REFINED RESULTS.

MONITORING THE MONITORING SYSTEMS

System Monitoring:

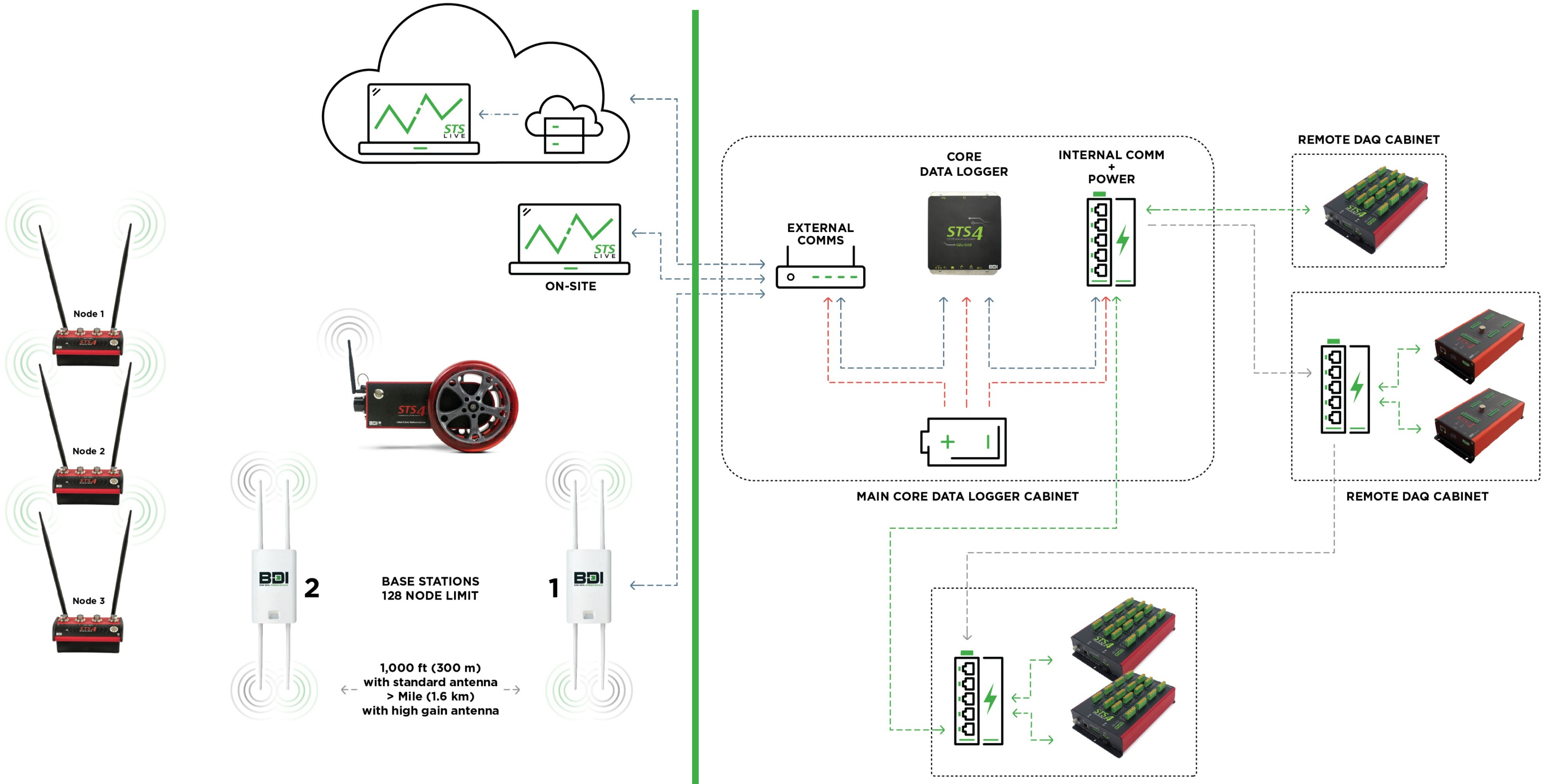
- Data age
- Modem connectivity
- Disk space
- Data traffic

Off-site backup technical support :

- BDI technical staff can support help desk at any time using mobile based and RDP applications
- Review data integrity

BDI RAW DATA. REFINED RESULTS.

MIXING LOAD TESTING WITH SHM



Add'l equipment for load testing

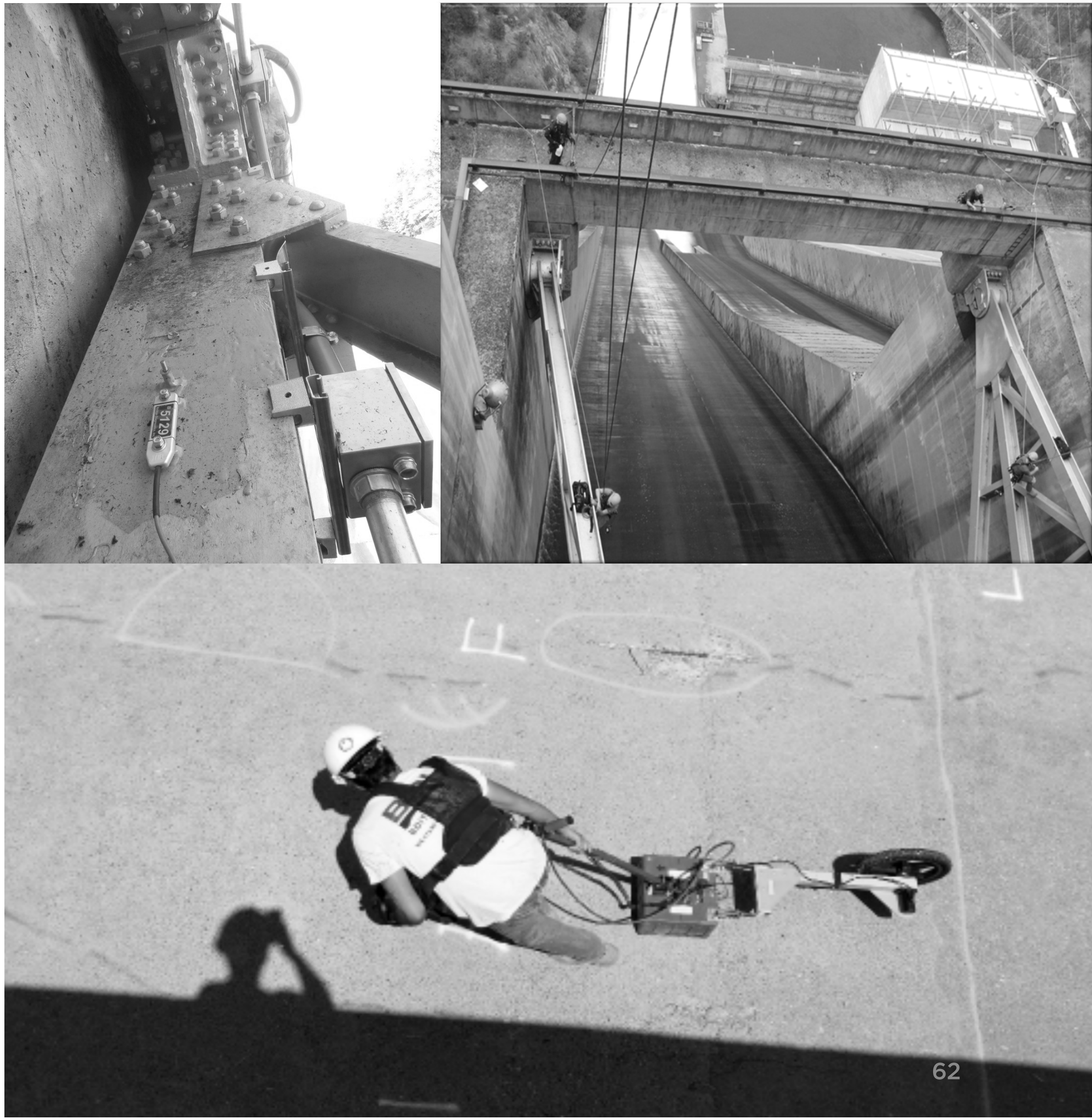
Permanent system

AGENDA

- Questions?

- Contact us at:
  - Jesse: jesseg@bditest.com
  - Zulfriki: za@testindo.com
  - Iwan: iwanzark@gmail.com

- Check out and **download the Handouts** shown in the handout section of this webinar



TESTINDO
Your Partner of Testing & Measuring Innovation Technology

BDI
RAW DATA. REFINED RESULTS.

DATA YOU CAN TRUST.
RESULTS YOU CAN BUILD ON.