BDI

RAW DATA. REFINED RESULTS.

30 YEARS OF EXPERIENCE IN TESTING, MONITORING, AND EVALUATING STRUCTURES

BEST PRACTICES AND WHAT'S COMING NEXT

NATHANIEL DUBBS, PHD, PE, P.ENG.

AGENDA

- Introduction / history of BDI
- Asset management and performance data
- Data collection types
  - Overview of LLT, SM, NDE, and UF
- Relating these data collection types to asset management
- Challenges

WHO IS BDI?

"Home" for 2 Years: 1989-1990

BDI International Headquarters 2018

- 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 FE analysis 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, buildings, lock gates, and even rockets!
- We're an engineering services provider and product manufacturer – a **combination that keeps us sharp**!

30th YEAR IN THE TESTING/MONITORING/NDE BUSINESS

LOCAL OFFICE IN FORT WASHINGTON, PA

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

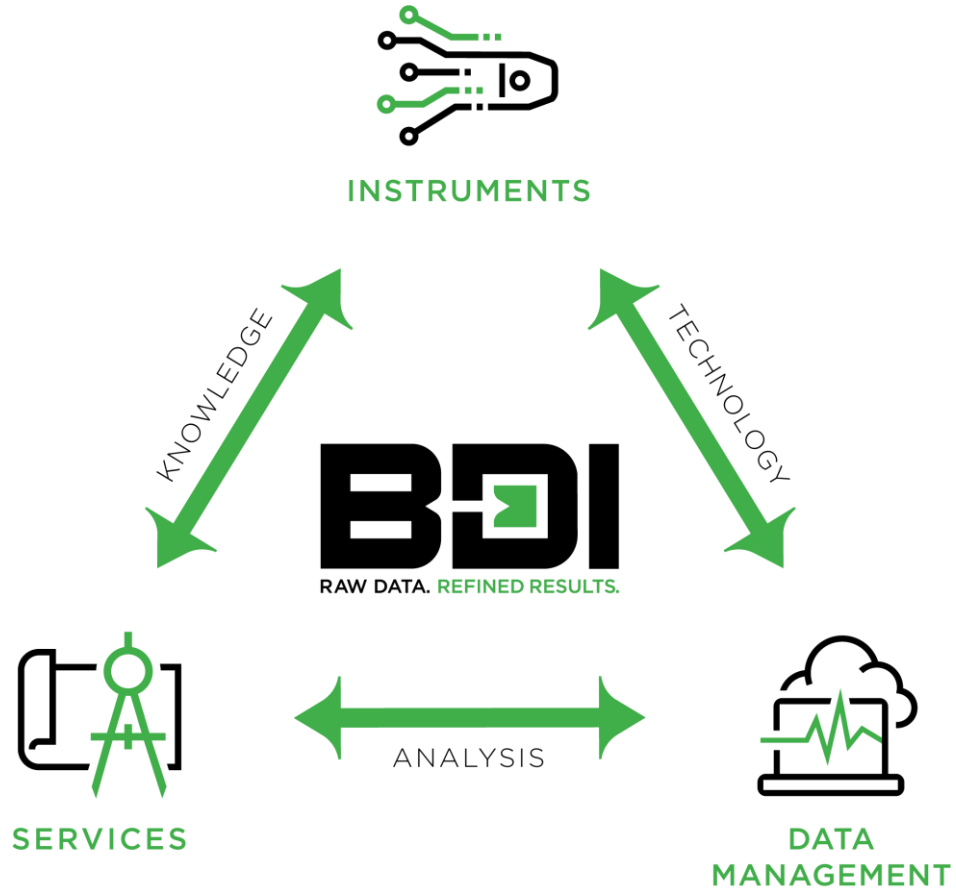
BDI OFTEN DEVELOPS CUSTOM SOLUTIONS FOR OUR CLIENTS

MISSION

We deliver the most reliable results that enable advanced infrastructure evaluation. Our trusted approach revolves around custom-built instruments, skilled engineering and field crews, and intelligent data analysis and presentation.

VISION

To be the definitive answer whenever and wherever civil infrastructure performance is questioned.



ASSET MANAGEMENT AND PERFORMANCE DATA

What are some of the issues plaguing agencies?

+ **Unknown condition**s or properties of current assets resulting in overly conservative assumptions (no as-builts, unknown foundations, unknown materials)
+ **Change in regulations** that require re-analysis and re-prioritization of assets (FHWA's memo on revised load models for highway bridges – SHV & EV)
+ How to **evaluate efficacy / life-cycle cost of innovative and/or novel approaches** to maintain current inventory of assets compared to full replacement or major rehabilitation?

While technology-based approaches can't solve all problems, they :

- Serve as a compelling alternative when traditional assessment fails to provide a path forward
- Are additional measures of condition and performance
- Can help streamline and optimize asset management plans by helping managers allocate resources where they are truly needed.

INTRODUCTION TO DATA COLLECTION TYPES

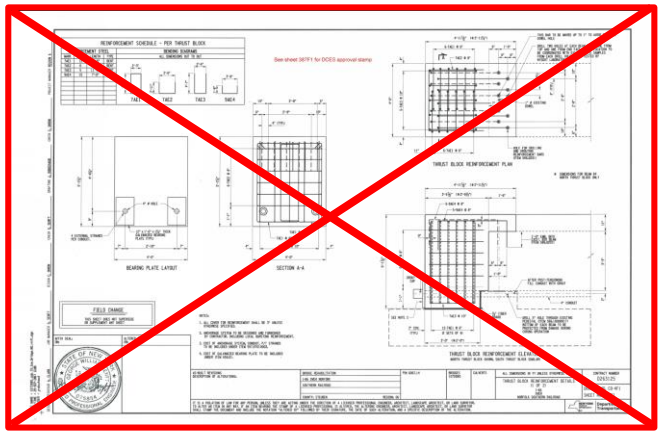
DIAGNOSTIC TESTING (LIVE LOAD TESTING)
STRUCTURAL MONITORING
NON-DESTRUCTIVE EVALUATION (NDE)
UNKNOWN FOUNDATION TESTING

DIAGNOSTIC FIELD TESTING - BRIDGES

Undesirable ratings or load changes

Permit / special loads

Retrofit / construction evaluation

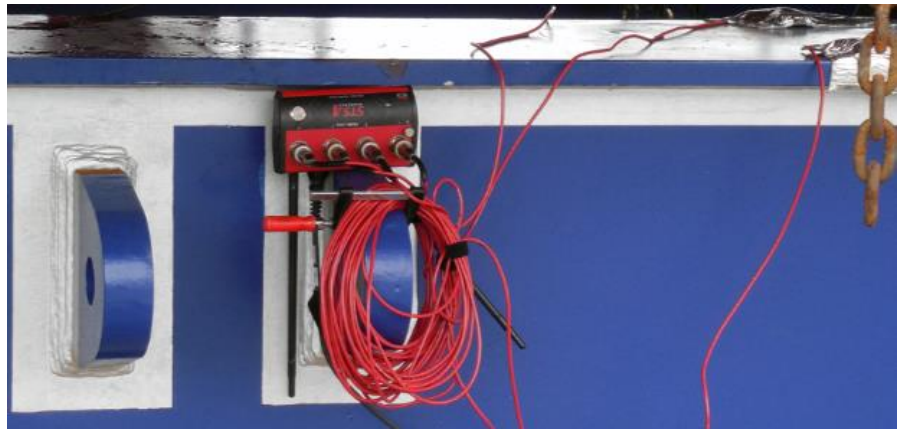


Missing / incomplete plans

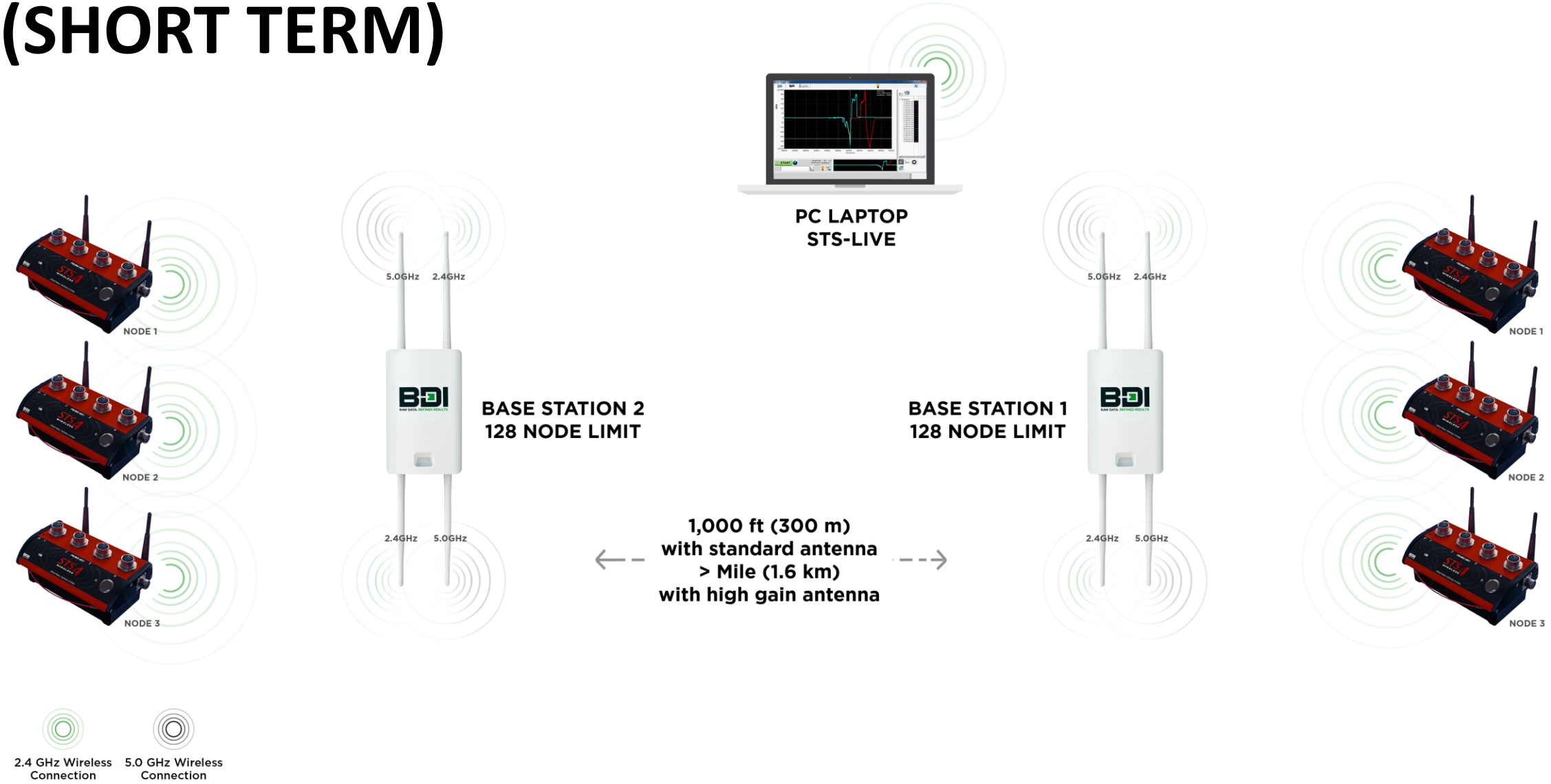
- **BDI'S integrated approach**
  - Confirmation / Reconstruction of as-builts using NDE and inspection
  - Rapid field testing using wireless hardware and in-house sensors
  - Streamlined FE analysis and model calibration procedures
  - Reporting and QC by licensed professionals

LOAD TEST PROCESS

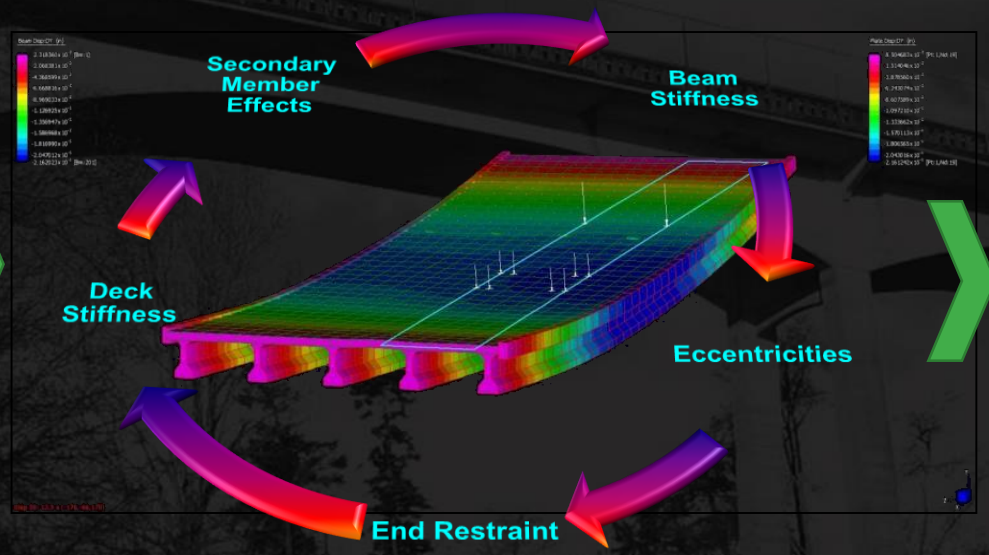
- Work with client to develop objectives
- Design instrumentation plan
  - Max pos/neg moment
  - Max displacement
  - Max rotation
  - End restraint
  - Composite action
- Specify load
- Install the sensors and execute test
  - Typically 1-2 days install depending on access with 1 day for testing / teardown
  - BDI has ropes access staff to cut down on install logistics costs!

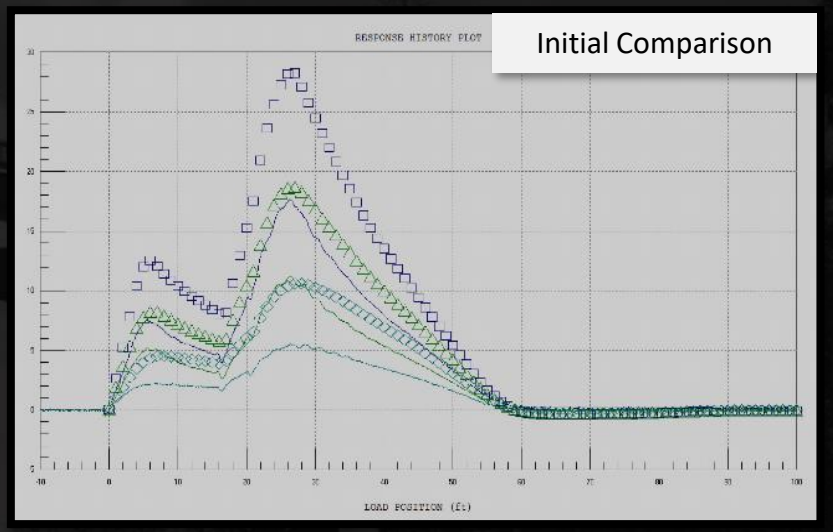


HOW IT WORKS: LIVE LOAD TESTING SYSTEMS (SHORT TERM)

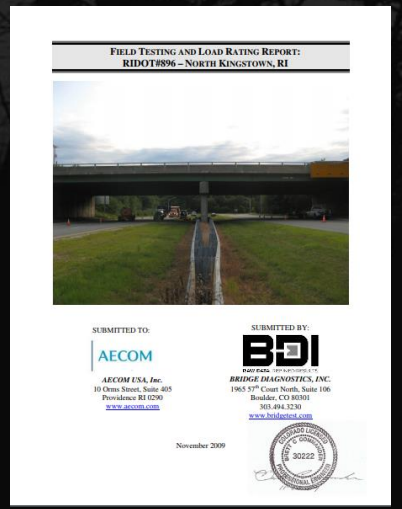


REFINED BRIDGE LOAD RATING PROCESS





Initial Comparison



FIELD TESTING AND LOAD RATING REPORT:
RIDOT#896 – NORTH KINGSTOWN, RI

SUBMITTED TO:
AECOM
AECOM USA, Inc.
10 Orms Street, Suite 405
Providence RI 0290
www.aecom.com

SUBMITTED BY:
BDI
BRIDGE DIAGNOSTICS, INC.
1965 57th Court North, Suite 106
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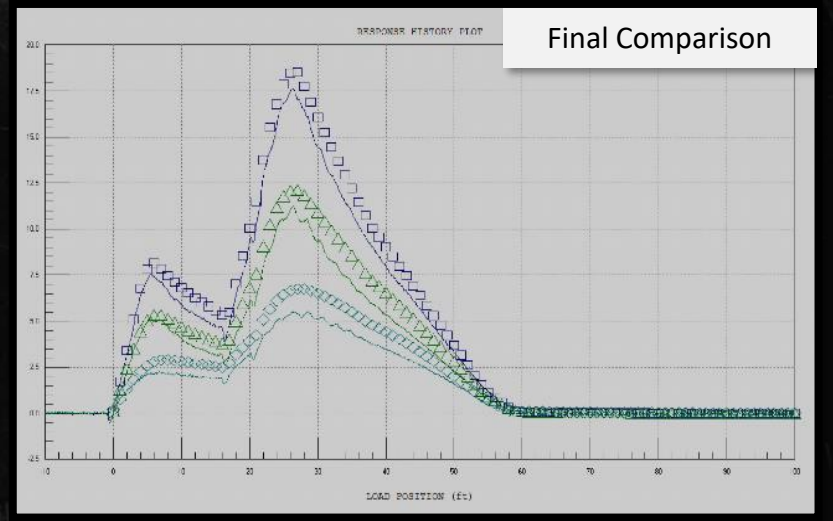
November 2009

Can we rely on updated parameters for rating?

- Unintended composite action
- Barrier participation
- End restraint

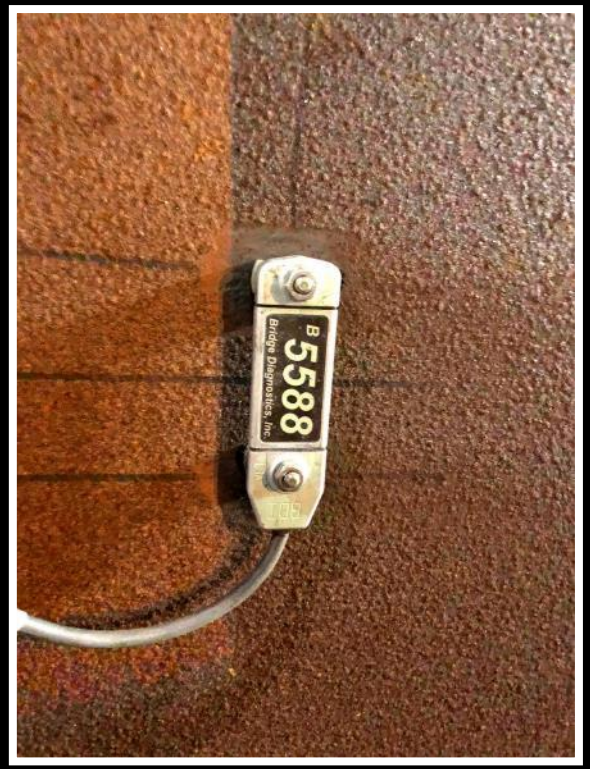


Final Comparison

BDI RAW DATA. REFINED RESULTS.

EXAMPLE - LOAD TEST FOR PERCEIVED LARGE DEFLECTIONS

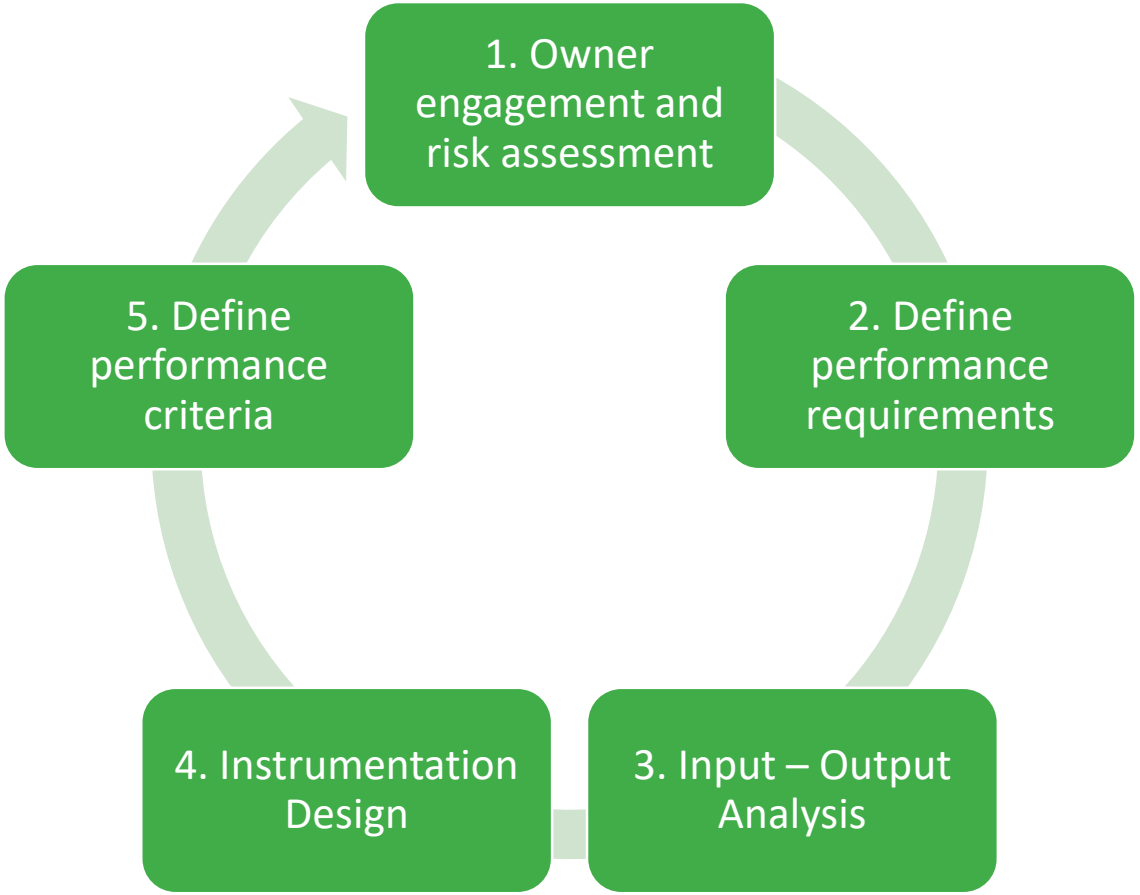
Load testing and refined load rating using BDI instrumentation (strain gage shown).



BDI provided load testing services to calibrate an FE model of a newly constructed multi-girder structure. There were perceived large deflections in the multi-girder system and suspected poor construction (designed composite but level of composite action was questioned).

STRUCTURAL HEALTH MONITORING (SHM) - WHY?

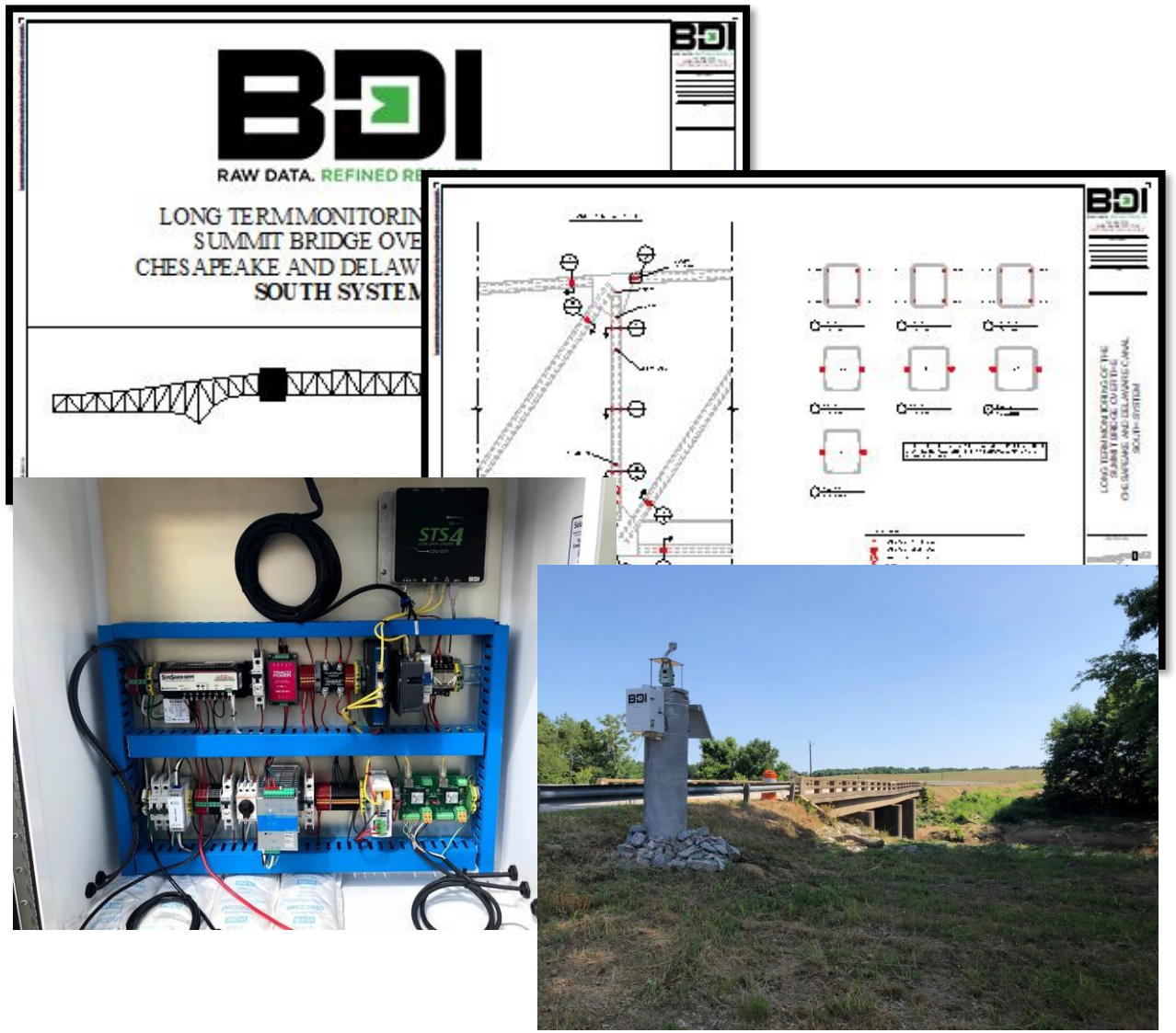
+ **Structural Performance**
  - Settlement
  - Temperature induced stresses
  - Construction monitoring
  - Verify new design techniques
+ **Inspection Support**
  - Bearing and joint performance
  - Linkage performance
  - Repair / retrofit evaluation
  - Damage tracking / propagation
+ **Operations and Maintenance**
  - Keep a remote eye on potential problems
  - Road surface condition
  - Weather



DESIGN WITH A PURPOSE AND REALISTIC BUDGET

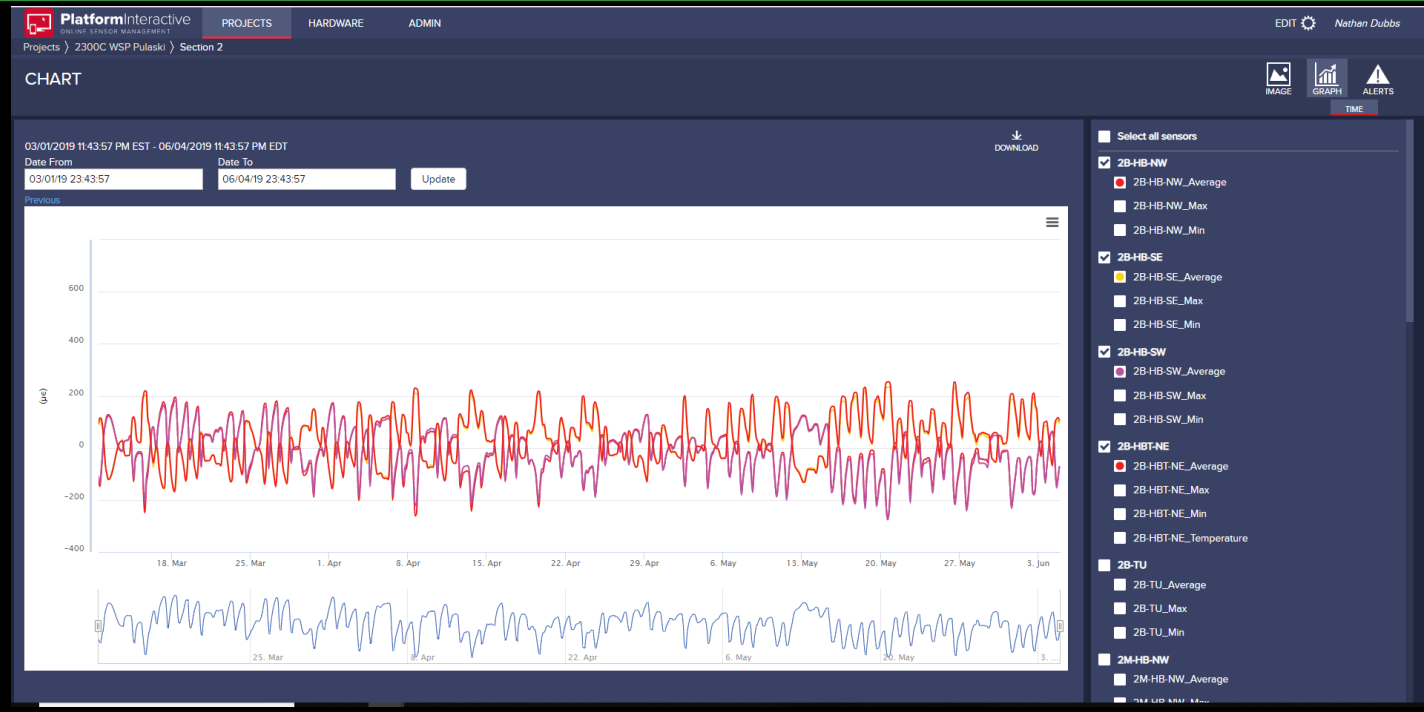
MONITORING SERVICES

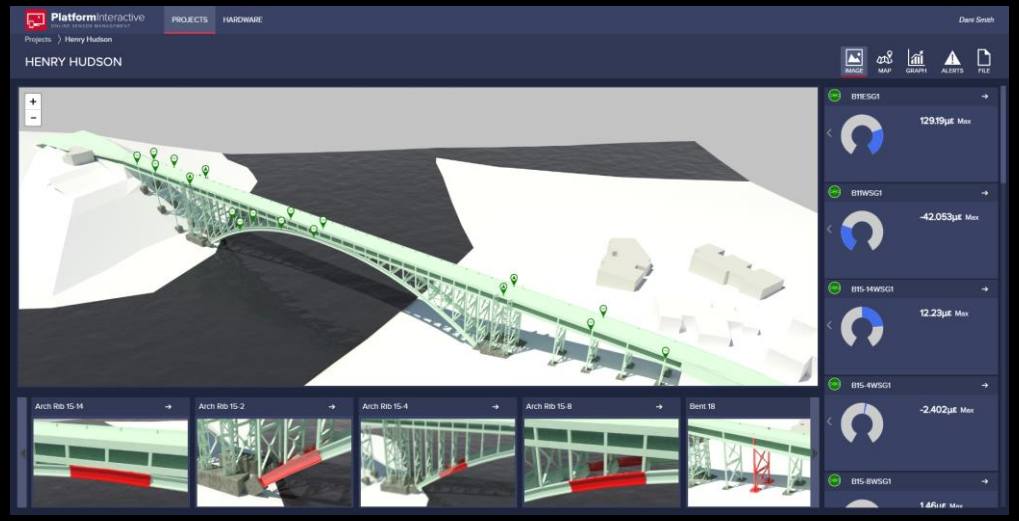
- **How?**
  - Help define the tender specifications
  - Complete SHM system design and configuration
  - Develop custom instrumentation plans for the project, including all installation procedures
  - Project management
  - System installation, testing and commissioning
  - Data management
  - Reporting
- **We control our own fate on monitoring projects with in-house …**
  - R&D department to help design new and innovative technologies
  - Electrical engineers to design properly functioning power systems
  - Engineers to develop instrumentation drawings
  - Production to manufacture equipment
  - Trained field technicians for installation
  - Engineers for interpretation / analysis / data management & reporting



DATA MANAGEMENT – THE SYSTEM ISN'T COMPLETE WHEN IT'S INSTALLED!!

- Client monitoring system portal
- Microsoft AZURE cloud-based hosting service
- 24/7/365 Helpdesk support
- Features:
  - Scalable architecture
  - Drag-and-drop setup and configuration to minimize site development time
  - Sensor agnostic
  - Microsoft IoT ready
  - Automated alerts
  - Secure / reliable / safe





BDI RAW DATA. REFINED RESULTS.

STRUCTURAL PERFORMANCE MONITORING EXAMPLES

BDI RAW DATA. REFINED RESULTS.

HOW IT WORKS: STRUCTURAL HEALTH MONITORING

PLATFORM INTERACTIVE DATA HOSTING

Data hosting through Microsoft® Azure that allows:

+ Simple and secure data measurement
+ 24/7 staffed service center
+ Custom alerts and notifications
+ Advanced graphing options

DATA TRANSFER

+ **STS-SYNC:** Microsoft® Windows® application to collect data on a defined schedule.
+ **Client Servers:** The Core Data Logger can be configured to push data to a client designated server.

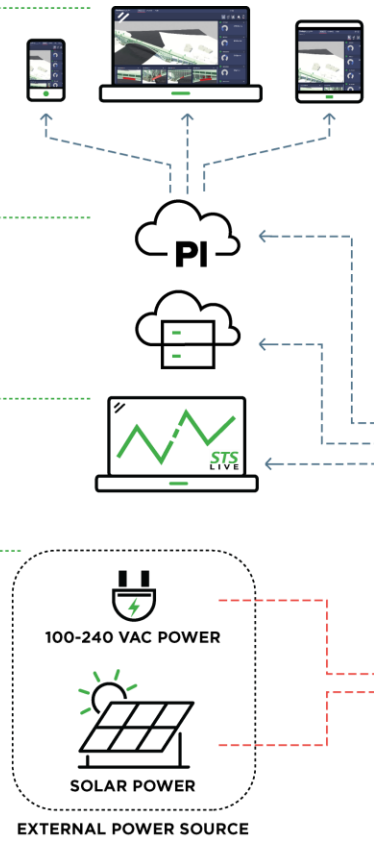
SETUP/CONFIGURATION

+ STS-MONITOR is used for configuring the system, either remotely or through direct on-site connection.
+ Systems can be preconfigured by BDI or by the Client.

POWER

Many solutions are available depending on site requirements:

+ 90-220 VAC line input
+ Wide range of solar power options
+ UPS battery backup system
+ Remotely monitor the power system with email/SMS alerts directly from the Core Data Logger in the event of a power failure.



EXTERNAL COMMS

Data transfer from the Core Data Logger to an off-site location can be accomplished by:

+ Hard line communication link
+ Cellular modem
+ Satellite modem

CORE DATA LOGGER

Our industrial-rated Core Data Logger is the essential component that collects, processes, and stores the data from the distributed DAQ nodes.

+ 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
+ Armored Ethernet & power cable
+ Wireless point-to-point comms

THIRD PARTY HARDWARE/SENSORS

BDI 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 our capability.

+ Vibrating wire sensor interface
+ Environmental sensors
+ Digital cameras
+ Digital sensors
+ Ask us to integrate your sensors!

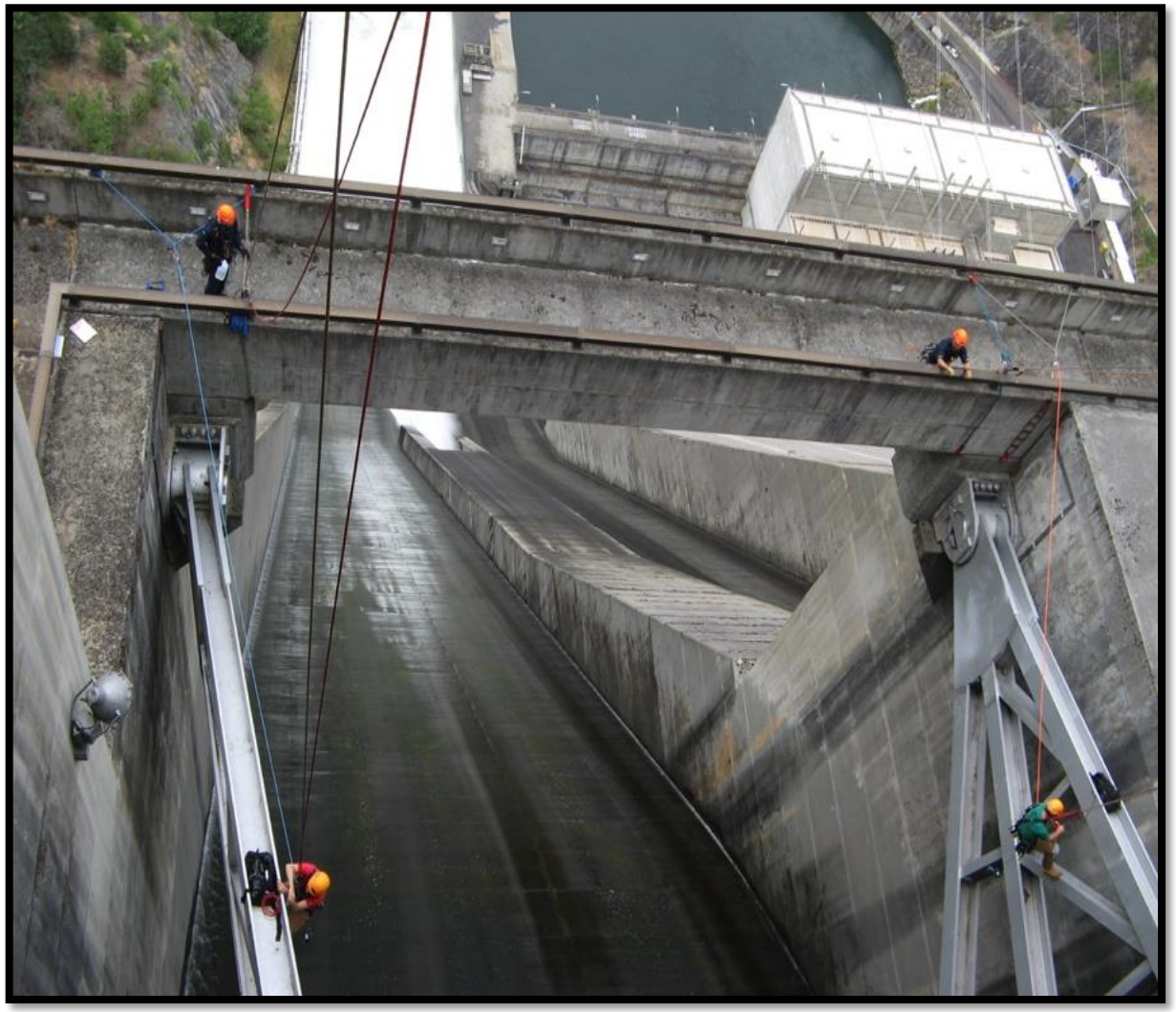
DISTRIBUTED NODAL DAQ NETWORK

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 a turn-key solution.

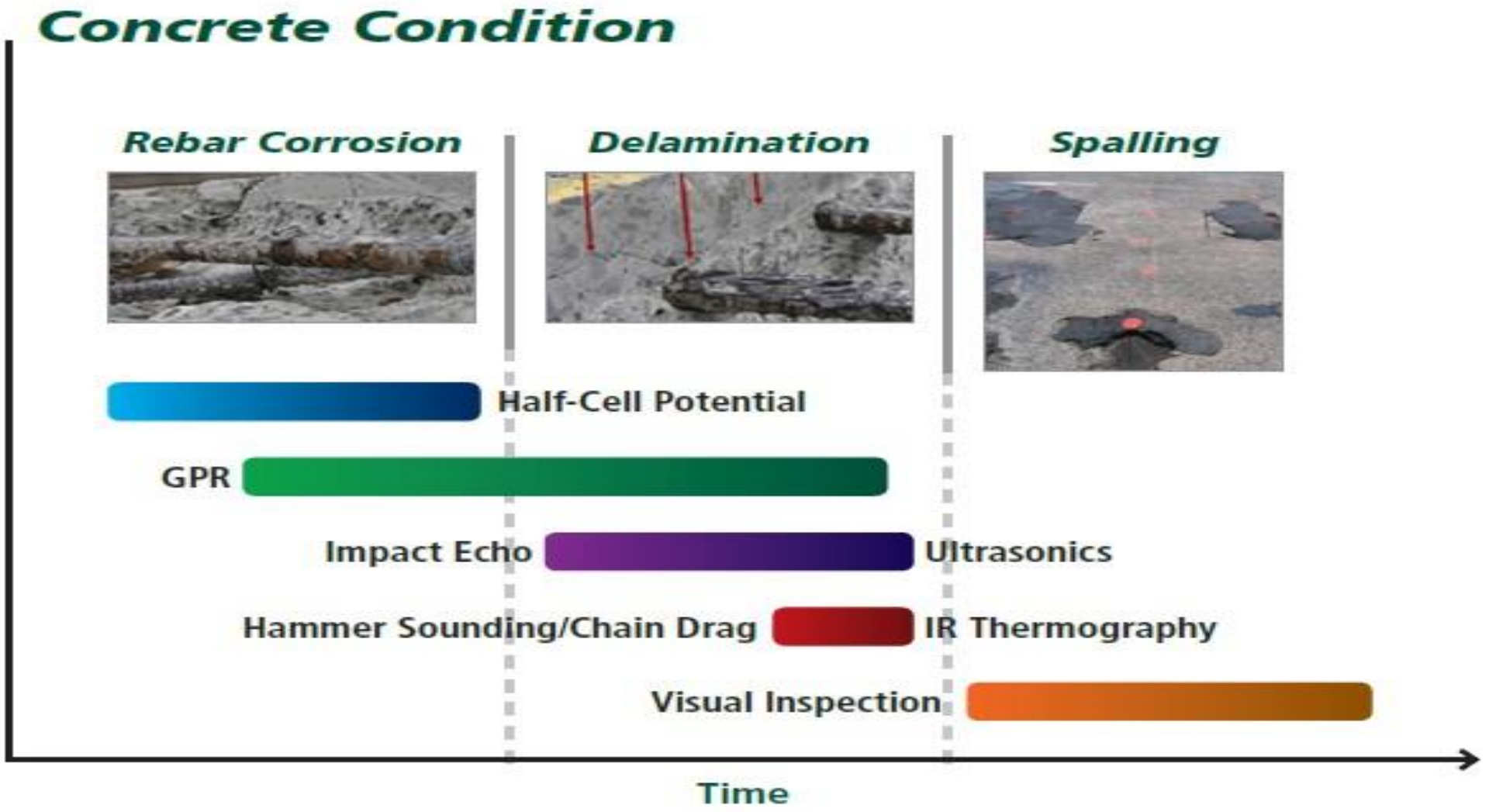
+ 4- or 16-Channel Terminal Input Nodes
+ Ethernet and power distribution
+ Nema 4X enclosures
+ Easy to expand
+ Up to 1kHz sample rate
+ Local disaster recovery data storage

NDE – IN-HOUSE CAPABILITIES

- **Acoustic**
  - Concrete:
    - Impact/Pulse Echo
    - Ultrasonic Surface Wave (USW)
    - Spectral Analysis of Surface Waves (SASW)
  - Steel:
    - ASNT Level II/III UT, PT, MT, ET, RT
    - Phased Array Ultrasonic Testing (PAUT)
  - Guided Wave for Defects and Tension in Trunnion Anchor Rods
- **Electromagnetic**
  - Ground Penetrating Radar (GPR)
  - Infrared Thermography
  - Radiography
  - Magnetic Methods (Eddy Current, Magnetic Flux Leakage, Magnetic Particle, Ferroscanning)
- **Electrochemical**
  - Half Cell Potential
  - Electrical Resistivity
- **Unknown Foundations**
  - Parallel Seismic, Downhole and Crosshole testing
  - Ultraseismic and Sonic Echo/Impulse Response
- **Physical Methods**
  - Coring
  - Petrography
  - Chloride Sampling and Testing
  - Rebound Hammer



CONCRETE DEGRADATION DETECTION WITH NDE

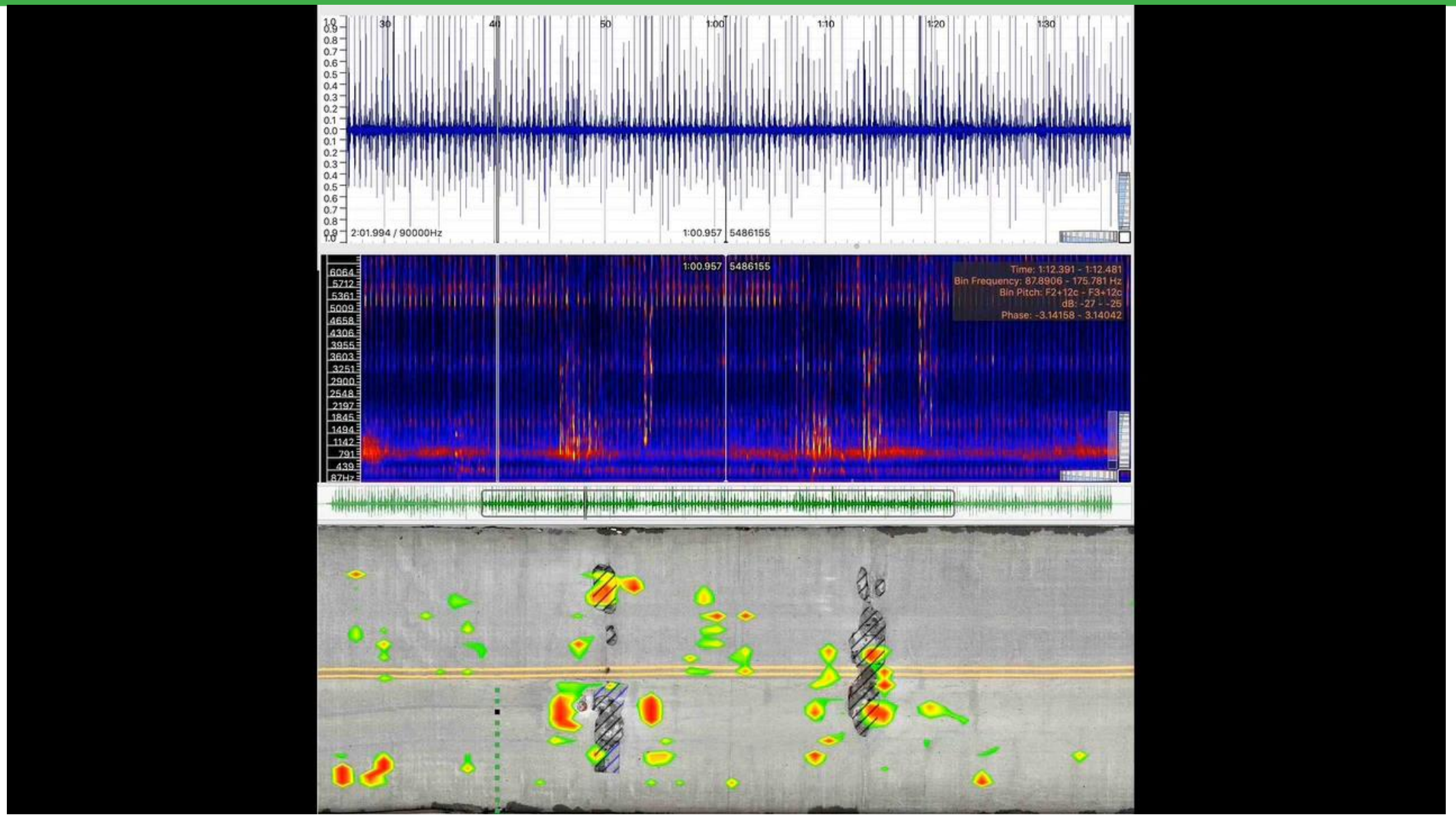


SOUNDAR

RAW DATA.
REFINED RESULTS.

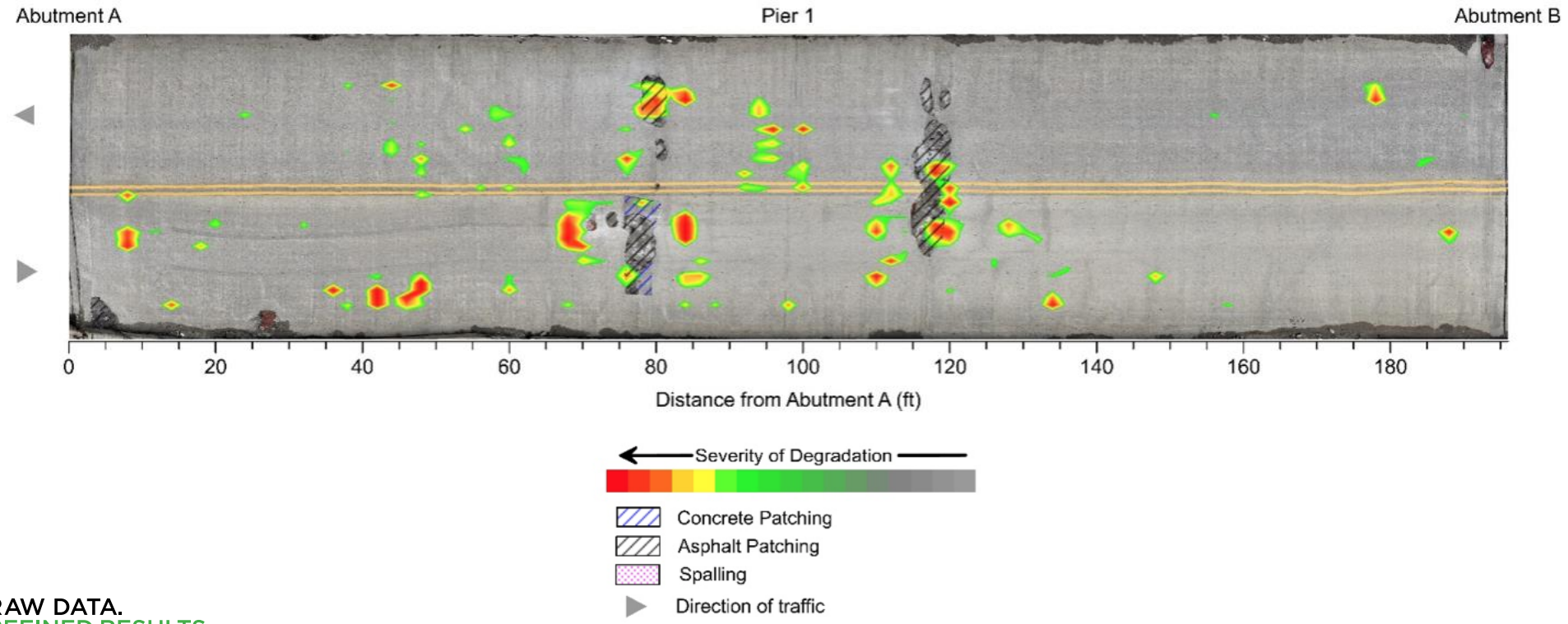
SounDAR

SOUNDAR ANALYSIS AUTOMATION



SOUNDAR RESULTS

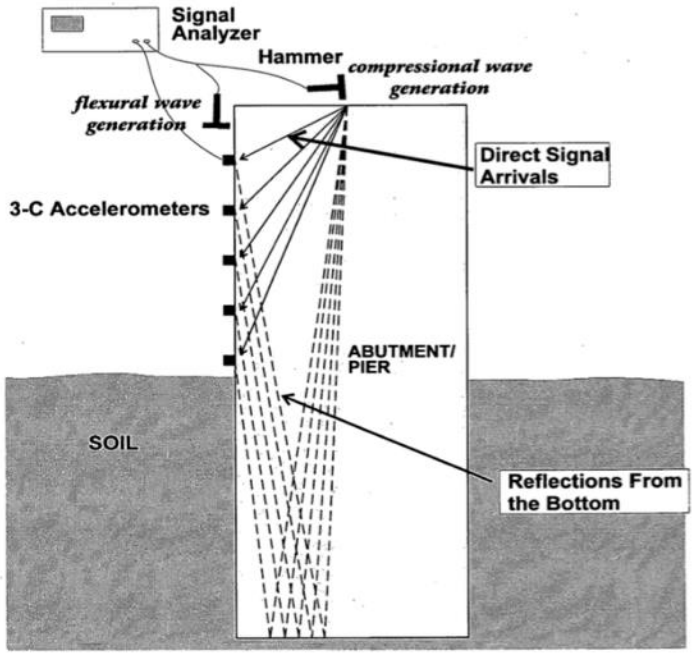
- Thousands of impacts are analyzed through automated algorithm to identify flaws.
- Data mapped to identify areas of intact and poor concrete.
- Results mirror those identified with traditional sounding and are geospatial.
- Paired with High Resolution Video for improved mapping and NBE classification (CS1 – CS4).



UNKNOWN FOUNDATION TESTING

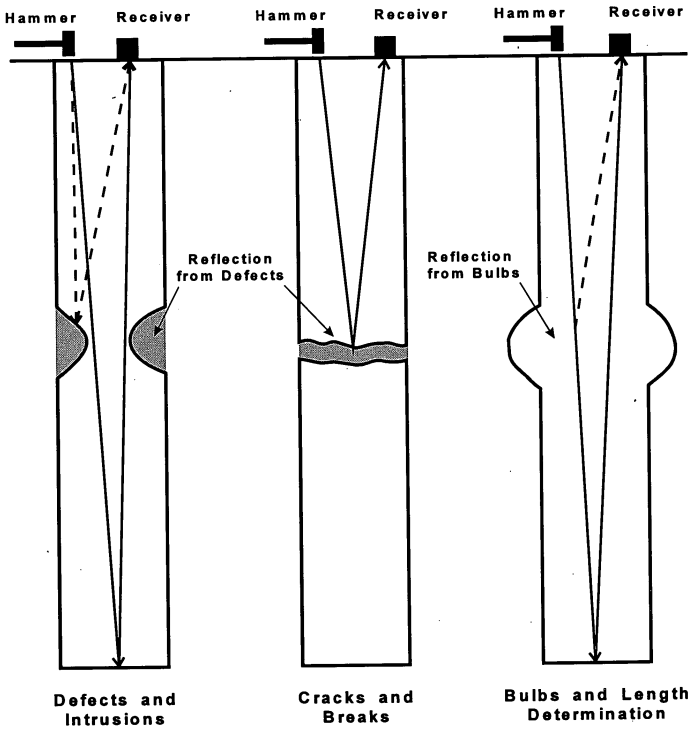
BDI RAW DATA. REFINED RESULTS.

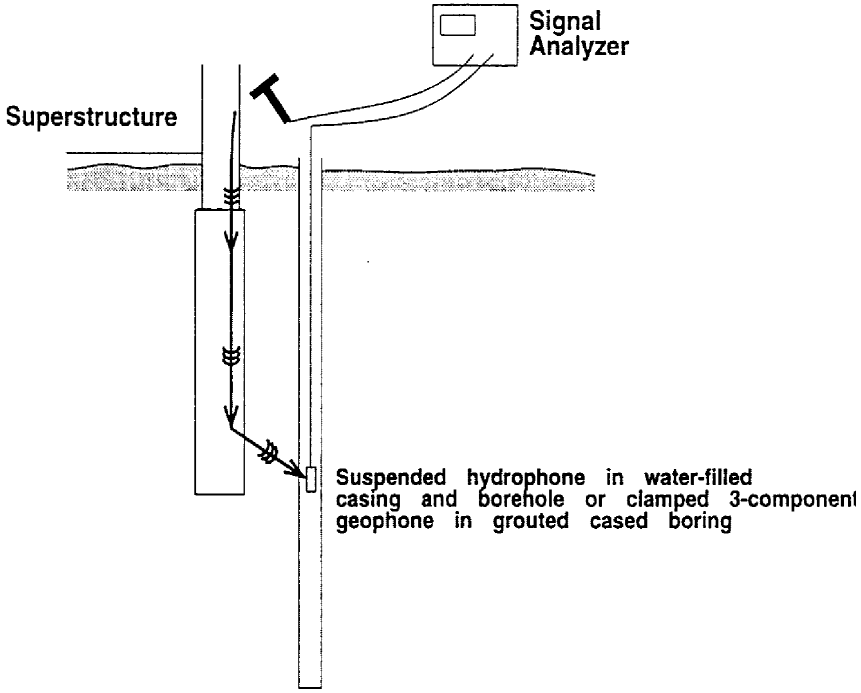
STRESS WAVE PROPAGATION METHODS



Ultraseismic Testing

Sonic Echo / Impulse Response

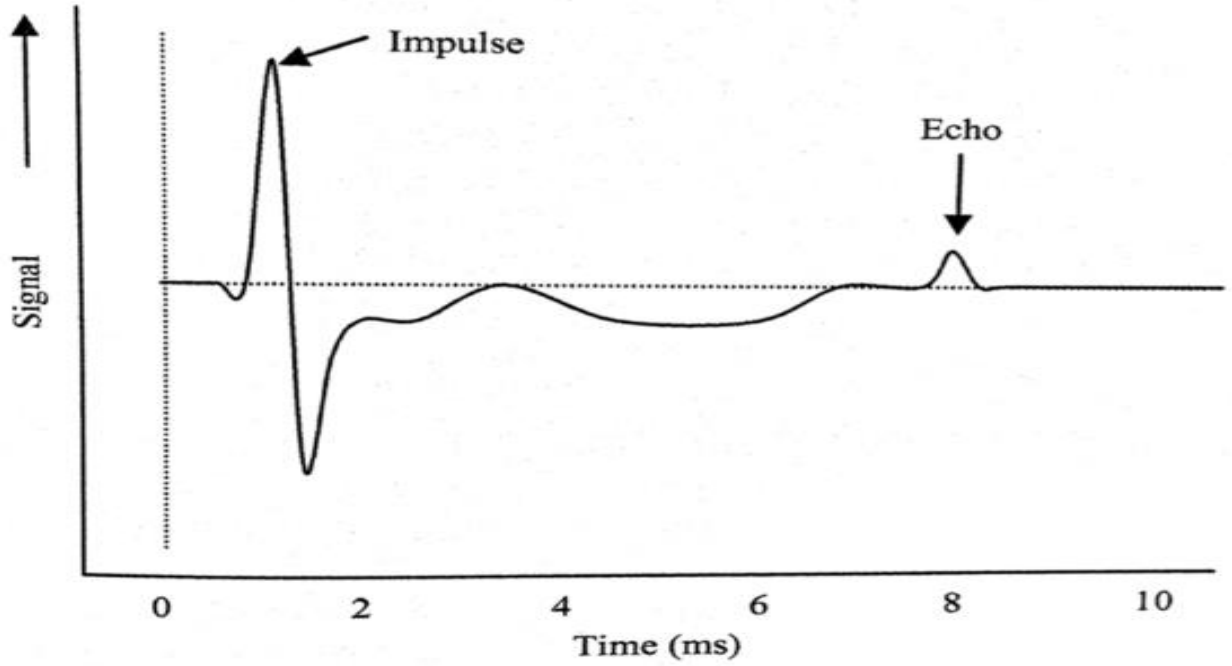




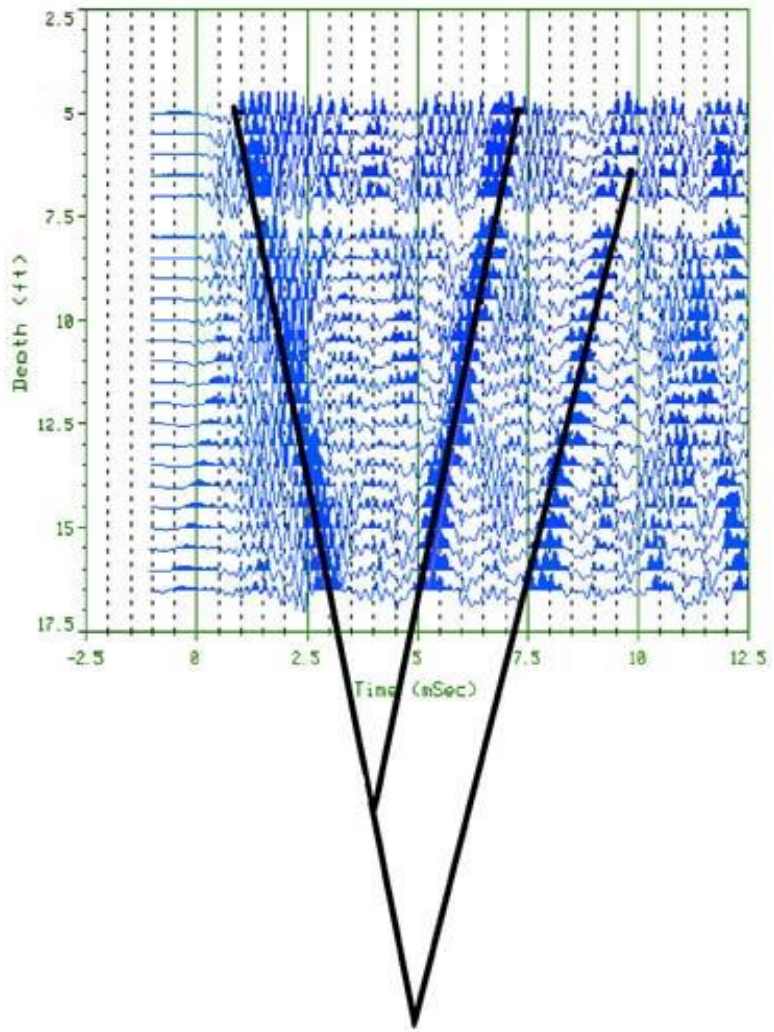
Parallel Seismic Testing

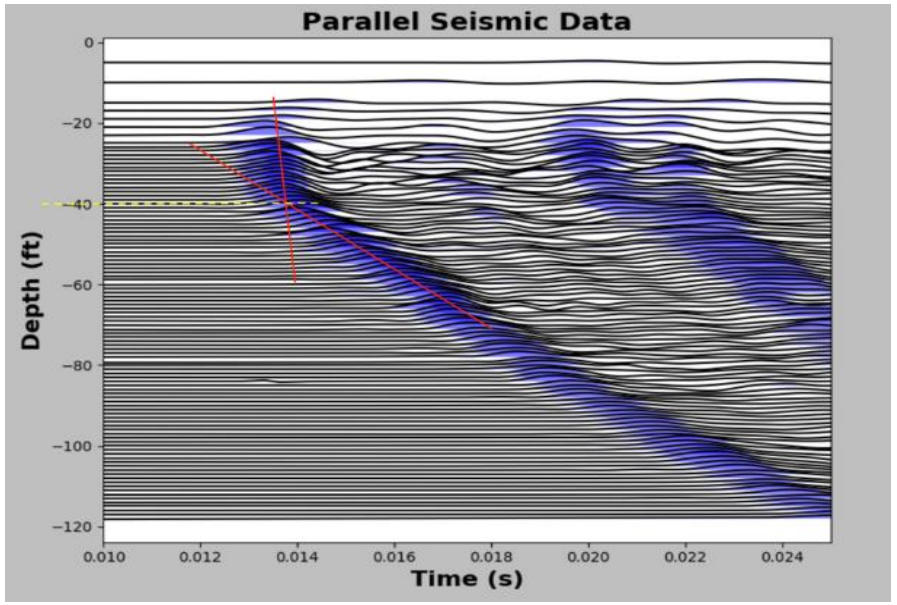
CRUDE UNKNOWN FOUNDATION ANALYSIS

- Data is analyzed in the time domain to identify the impulse and echo of the wave generated.
- With wave speeds measured in the field, the depth is calculated.



UNKNOWN ANALYSES





CIRCLING BACK…

How do we use these data collection tools to support asset management:

- Re-creation of as-builts (NDE & inspection)
  - Eliminate overly conservative assumptions
- Minimize uncertainty in actual structural performance and demands (LLT)
  - More accurate ratings, more efficient assessment of bridges requiring postings/replacement
- Deck condition deterioration forecasting (NDE)
  - Manage the assets and program in maintenance / replacements
- Life cycle cost assessment of novel maintenance approaches (SM)
  - Use instrumentation to evaluate pilot projects or novel approaches where life cycle cost savings may be significant
- Inspection support (SM)
  - Fill in the two year gaps of information with low cost consistent measurements
- Supporting P3 project funding – quantifying condition and performance
  - Put all positions in a better party for asset turnover at end of concession period with documentation of structural condition in a quantifiable manner

CHALLENGES

The largest challenge
- SHM is not a cons
data supported, e
- Bigger isn't better
- There is no silver b
requires a breadth
- Contracting mech

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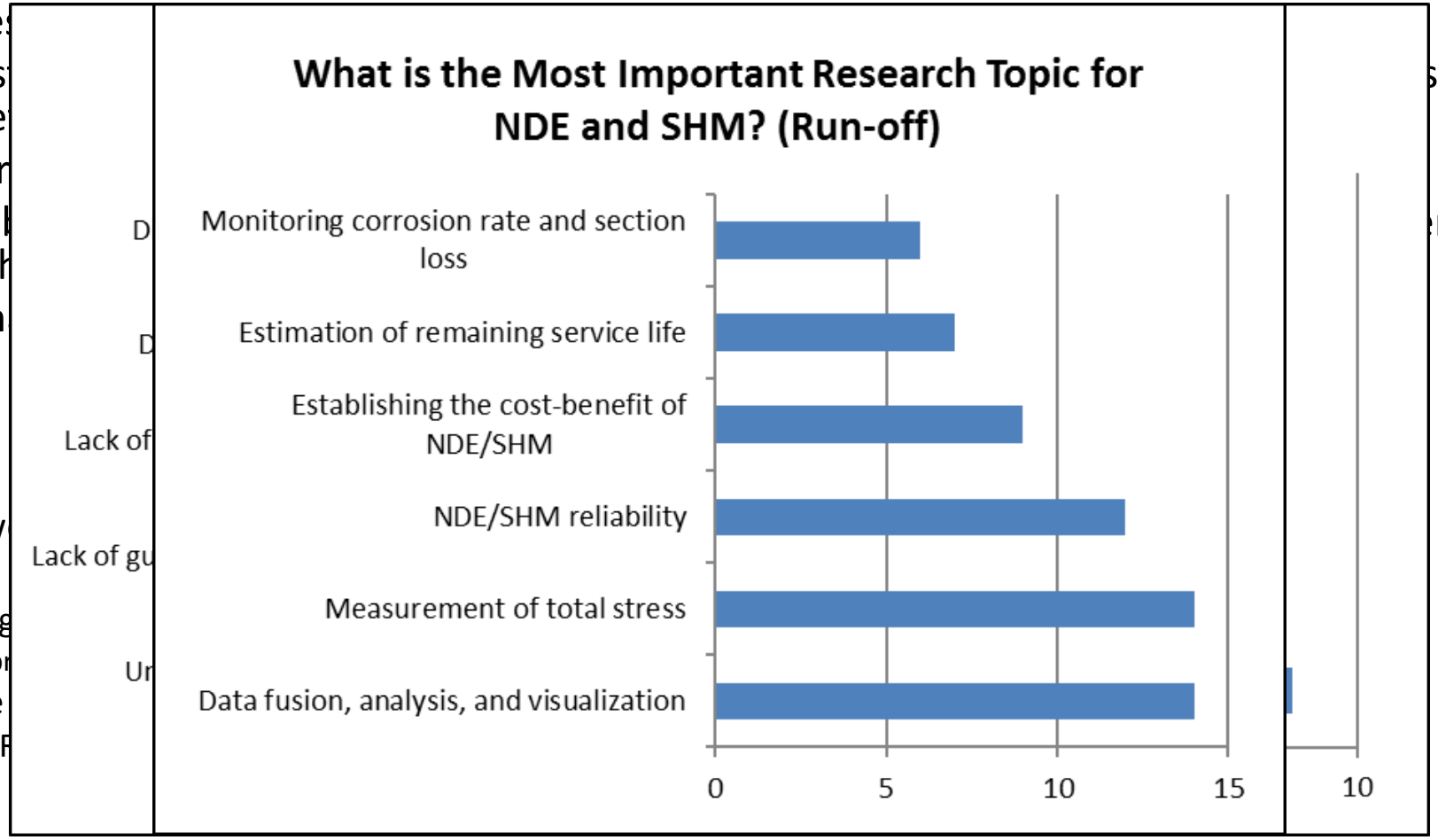
nging and

Owners Perspective:
+ FHWA held a w
+ Key outcomes:
Foster on-going
+ No repr
SHM Guidance
NDE Research F



THANK YOU!

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