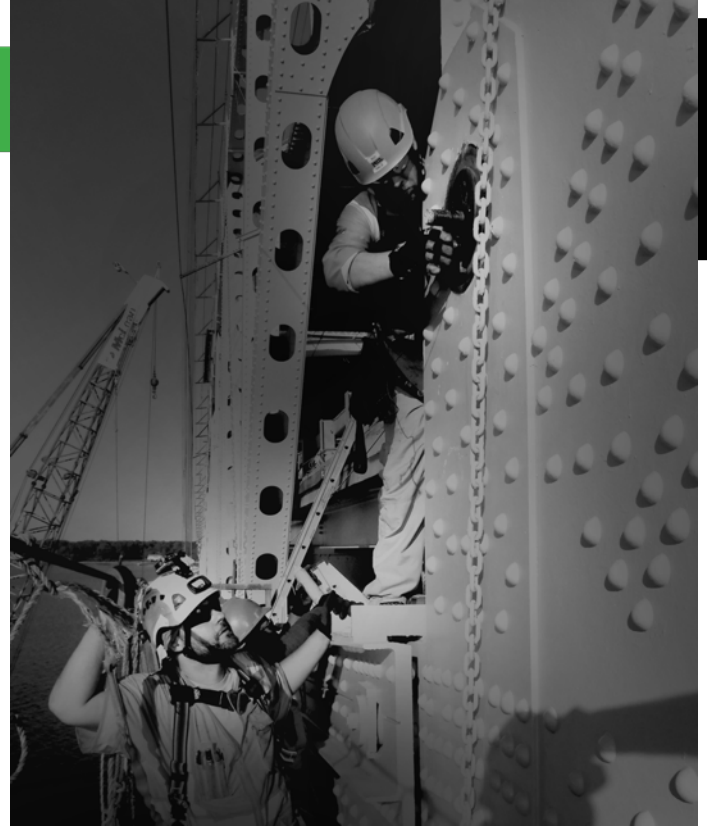
NONDESTRUCTIVE EVALUATION FOR BRIDGE DECKS AND PRESTRESSED CONCRETE STRUCTURES

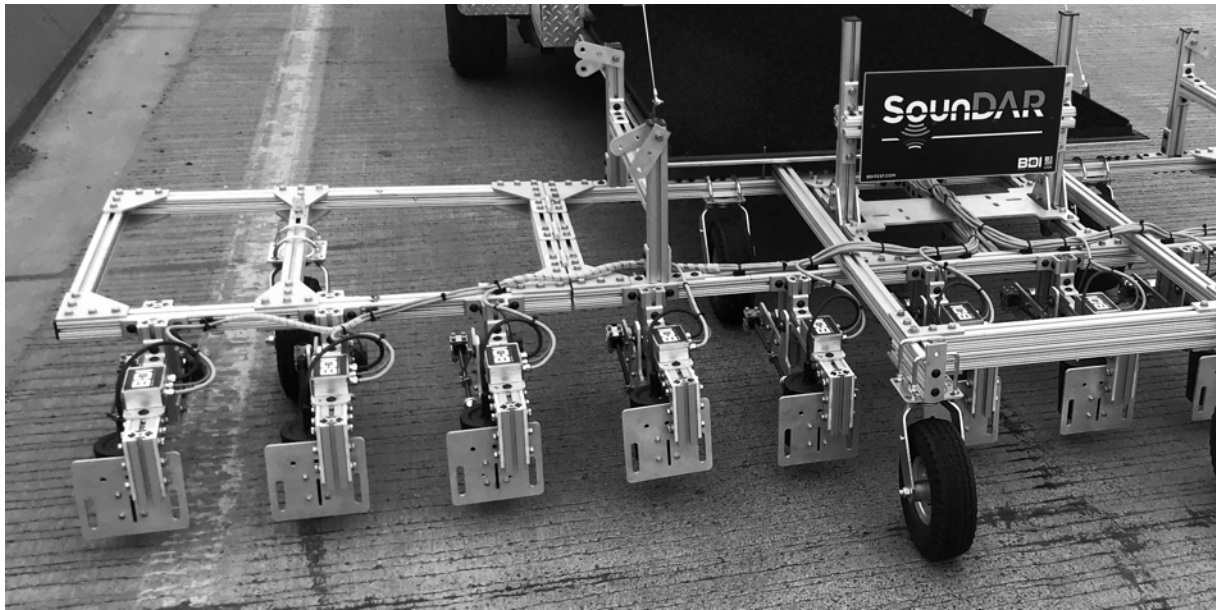
Shane D. Boone, Ph.D. – Vice President - NDE

RAW DATA. REFINED RESULTS.

AGENDA

- BDI
- INTRODUCTION TO NDE
- BRIDGE DECK EVALUATION
- TESTING OF PRESTRESSED CONCRETE



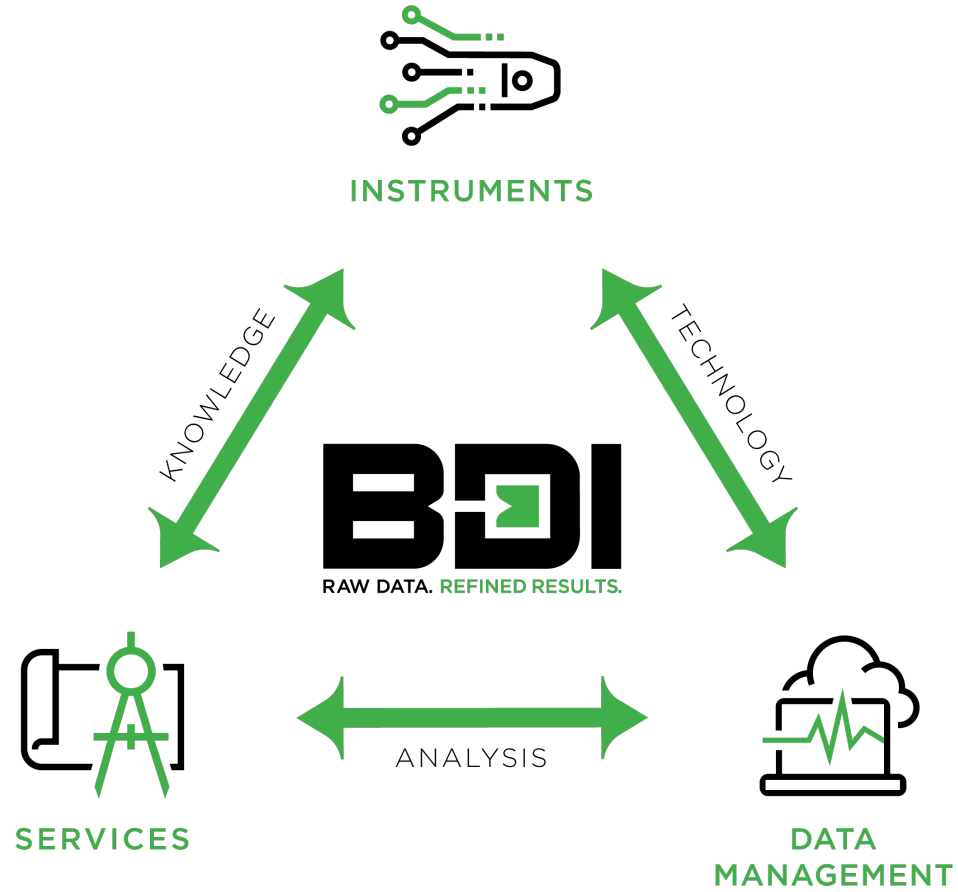


WHO IS BDI?

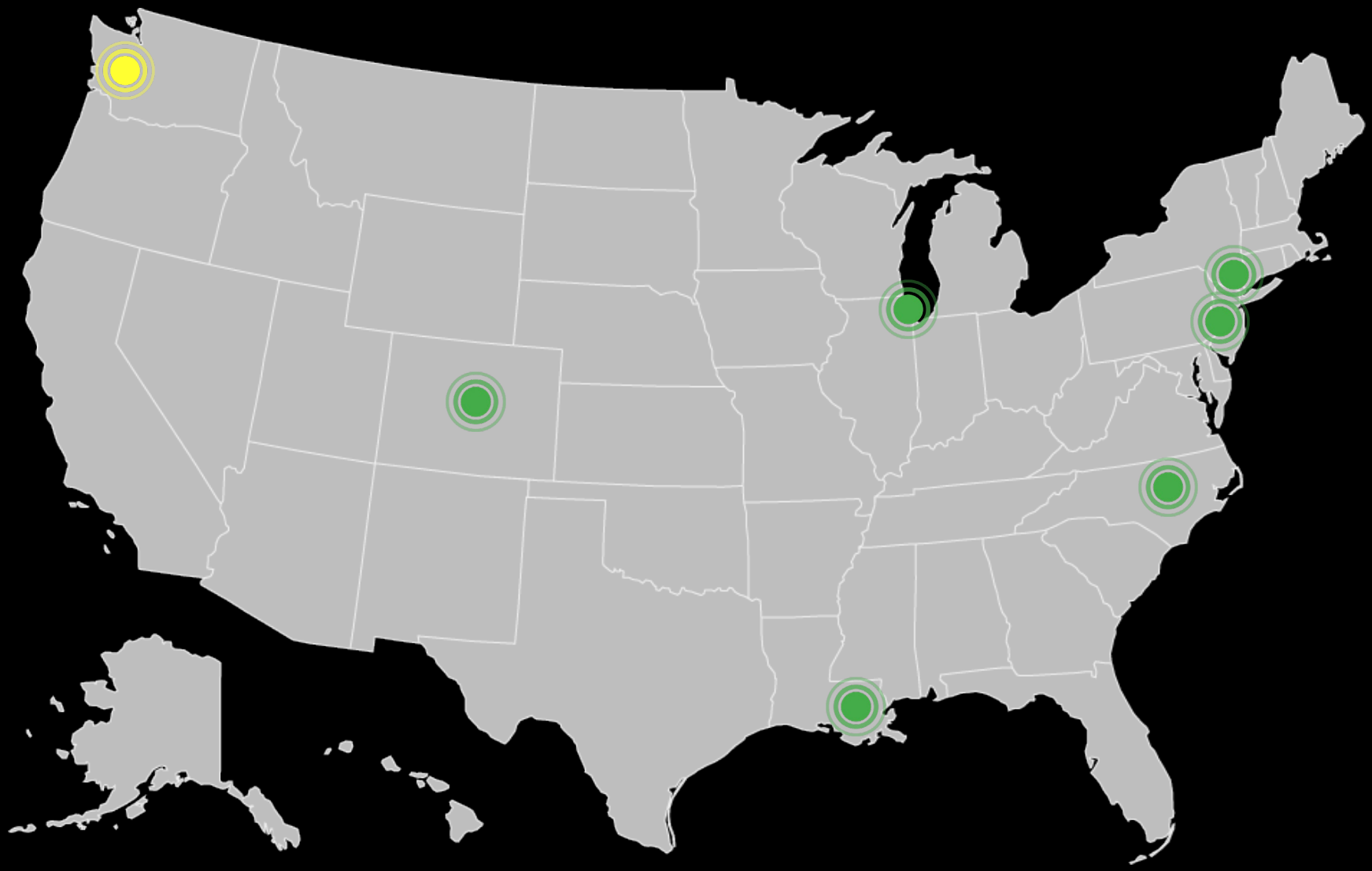
"Home" for 2 Years: 1989-1990

BDI International Headquarters 2020

30+ YEARS IN THE TESTING/MONITORING/NDE BUSINESS



LOCATIONS



BDI RAW DATA. REFINED RESULTS.

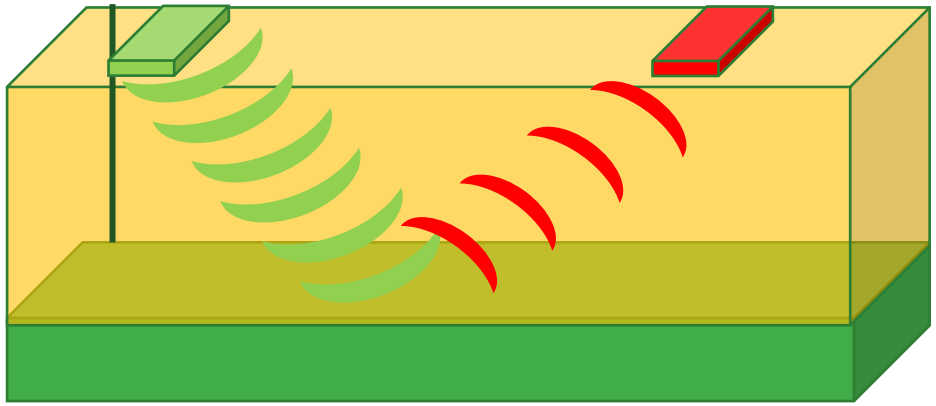
NDE SERVICES

- **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

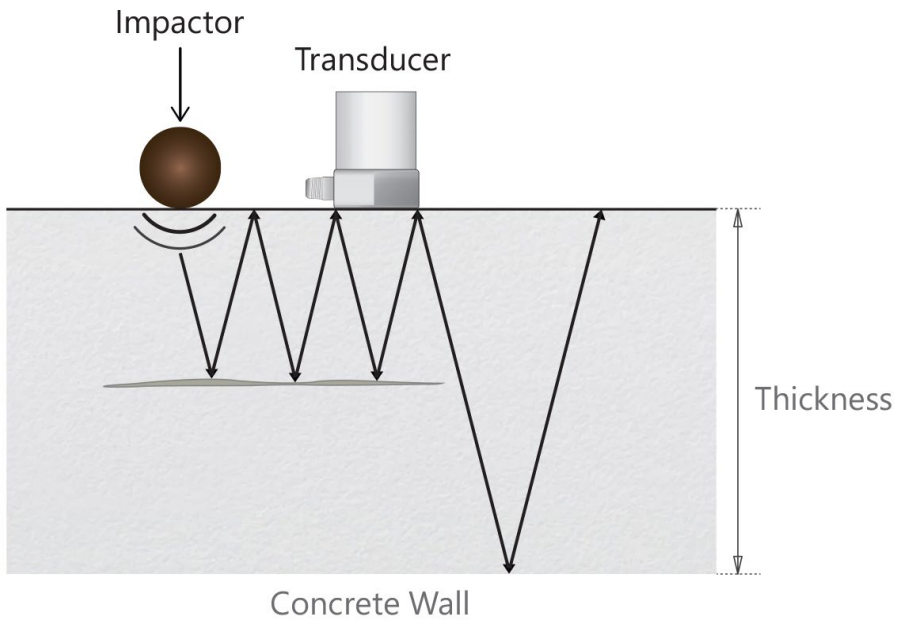
NONDESTRUCTIVE EVALUATION

- Nondestructive evaluation (NDE) or testing (NDT) is defined as a method to measure the physical properties of a material or system while causing little to no lasting effect on it.

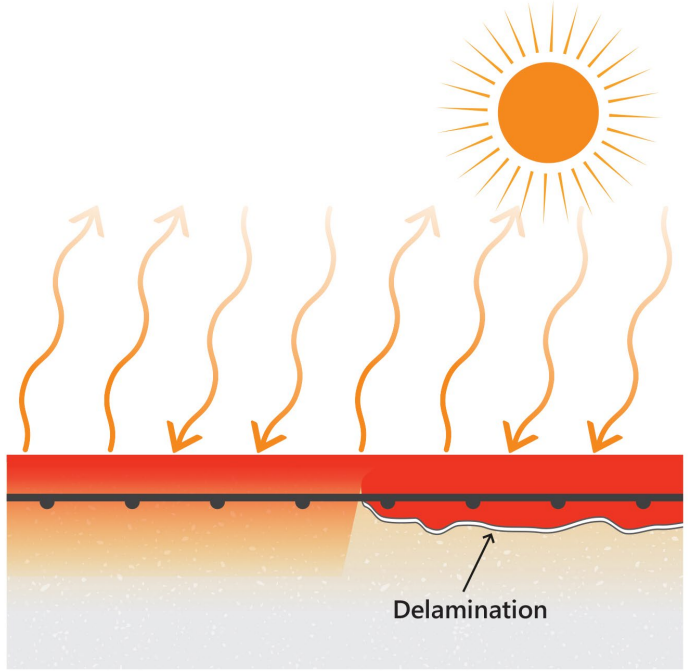
- Stud finding to hang a picture.

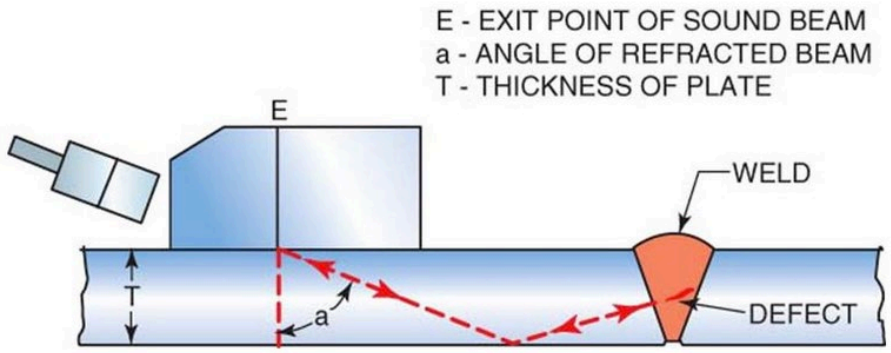


NONDESTRUCTIVE EVALUATION

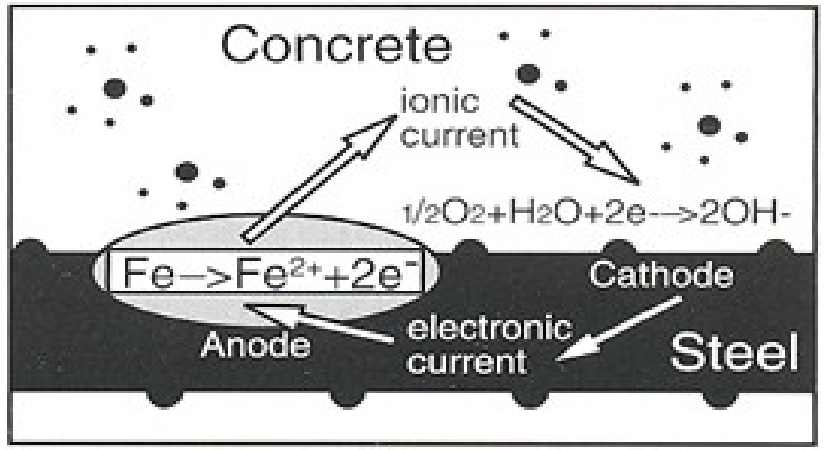


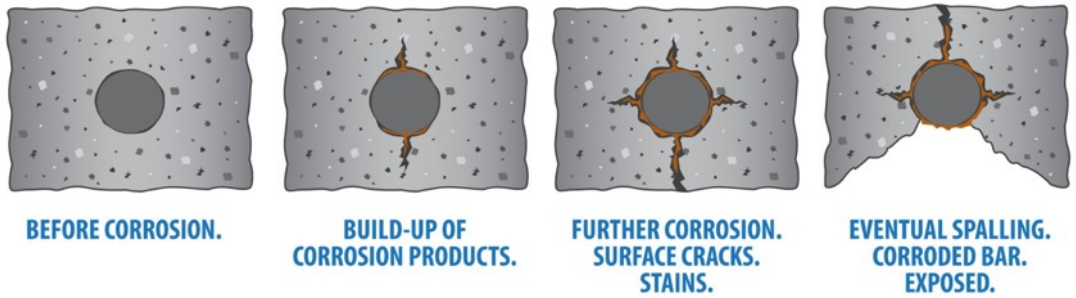
(a) Measurement Principle



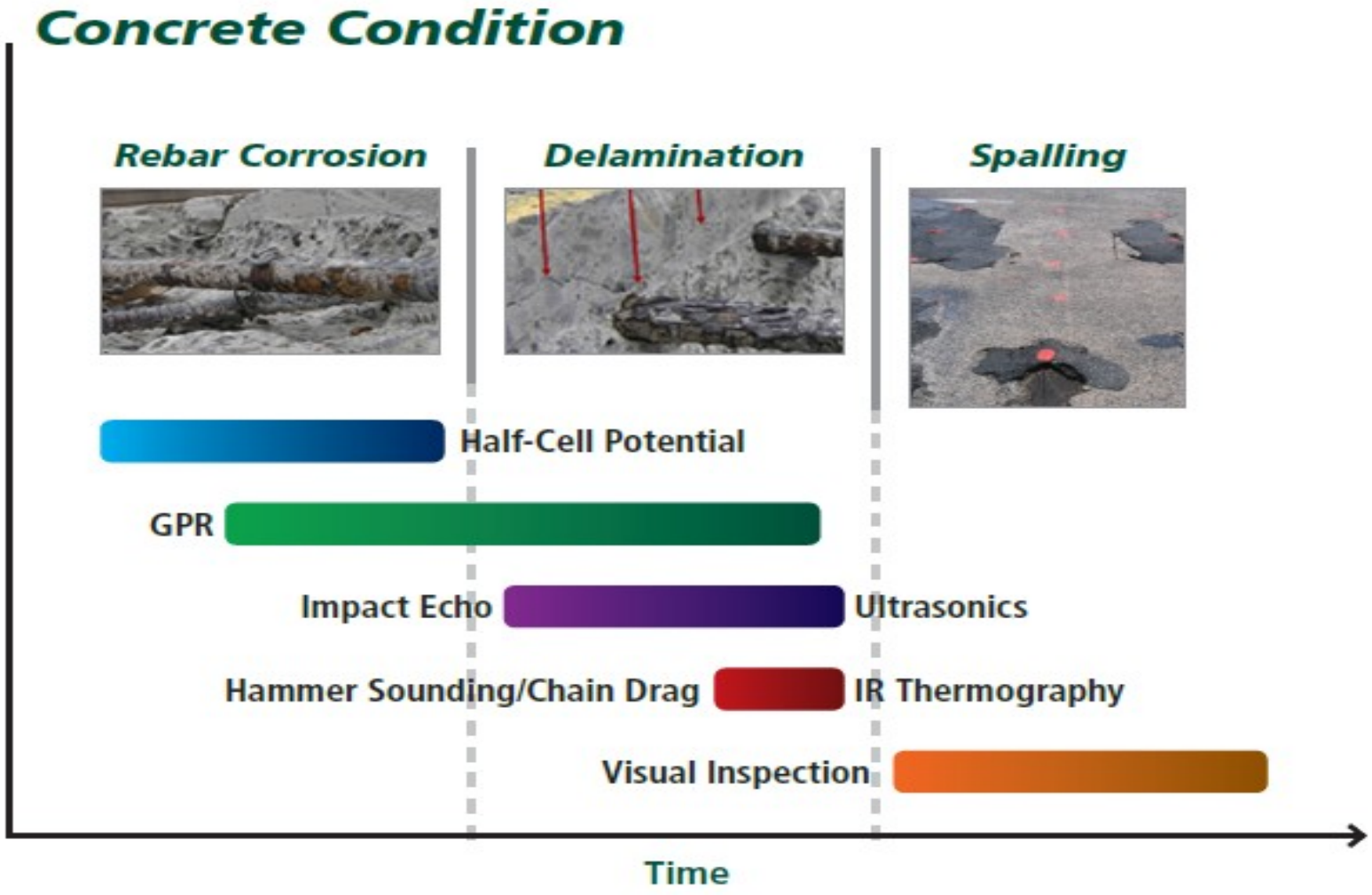


DEGRADATION VIA CORROSION





CONCRETE DEGRADATION DETECTION WITH NDE



PHASED APPROACH FOR BRIDGE DECKS

- **PHASE 0 – High level screening to determine which decks need inspection (high level down):**
  - Typical NBIS data review
  - Aerial based HRV/IR surveys (corridors or entire states within days)

- **Phase I - Highway speed testing with GPR, IR, and HRV**
  - Network level inspection provides data on large quantities in a short period of time without the need for traffic control

- **PHASE II – Deck acoustics and material sampling**
  - Programmatic testing, provides additional data for analysis and modeling

- **Phase III – Preservation**
  - All data is combined to identify best approach for preservation – maintenance and/or monitoring

BRIDGE DECK INSPECTION

Phase 0

Phase I

Phase II

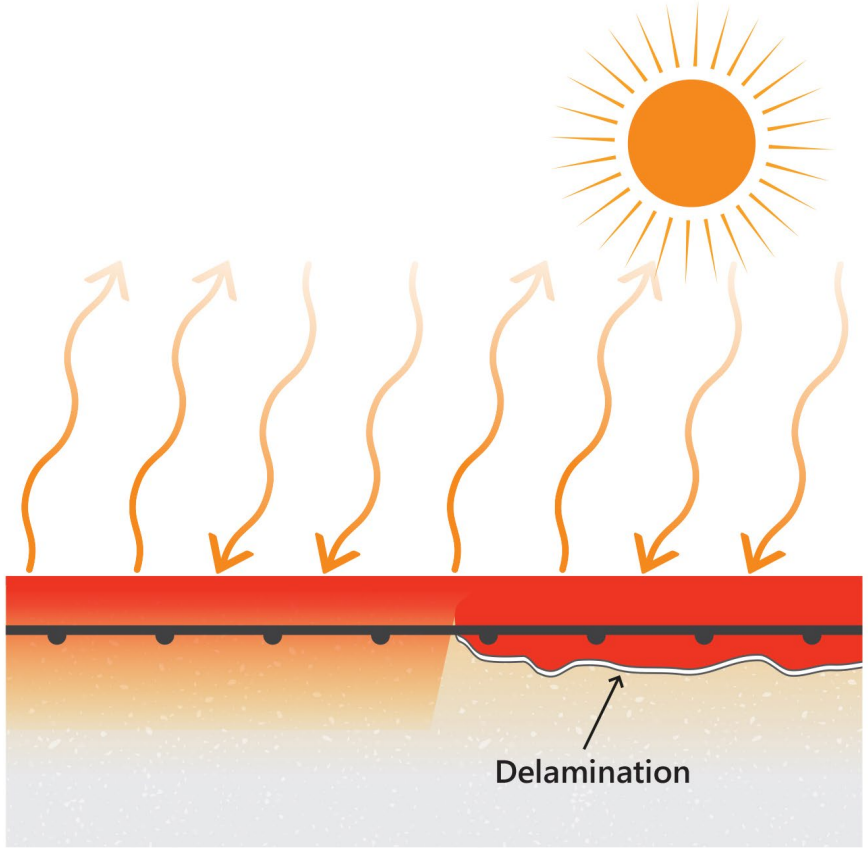
BDI RAW DATA. REFINED RESULTS.

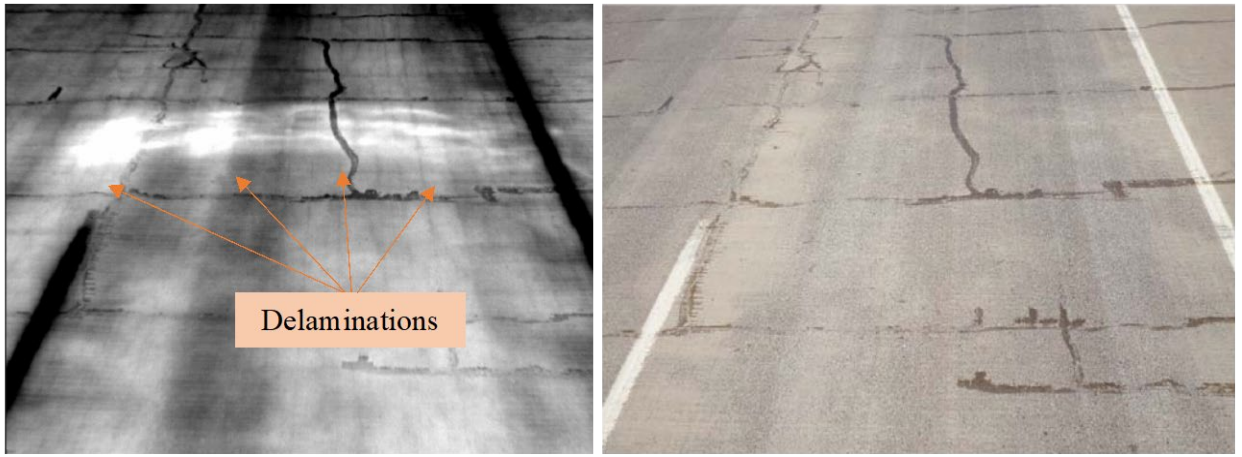
INFRASENSE

PHASE 0 - AERIAL INFRARED THERMOGRAPHY

- Aerial IR used for high level screening of large bridge corridors.
  - High resolution IR camera with telephoto lens.
  - Altitude of approximately 1,000 feet.
  - Bridges located via GPS.
- Can also be performed via drone.

INFRARED THERMOGRAPHY





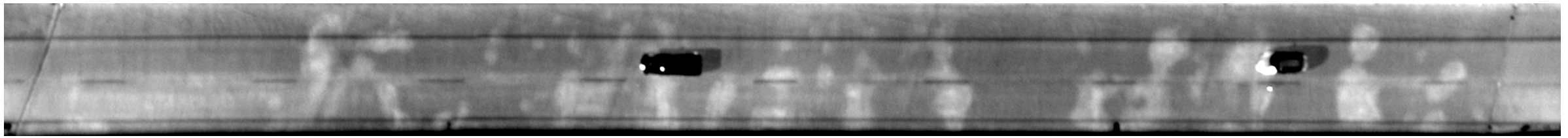
PHASE I – IR AND HRV

PHASE I – IR AND HRV

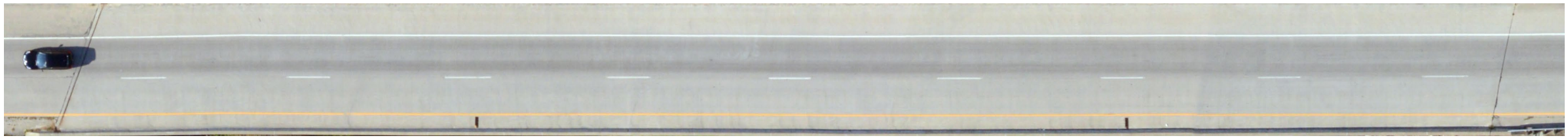
Vehicle-Based IR

Aerial IR

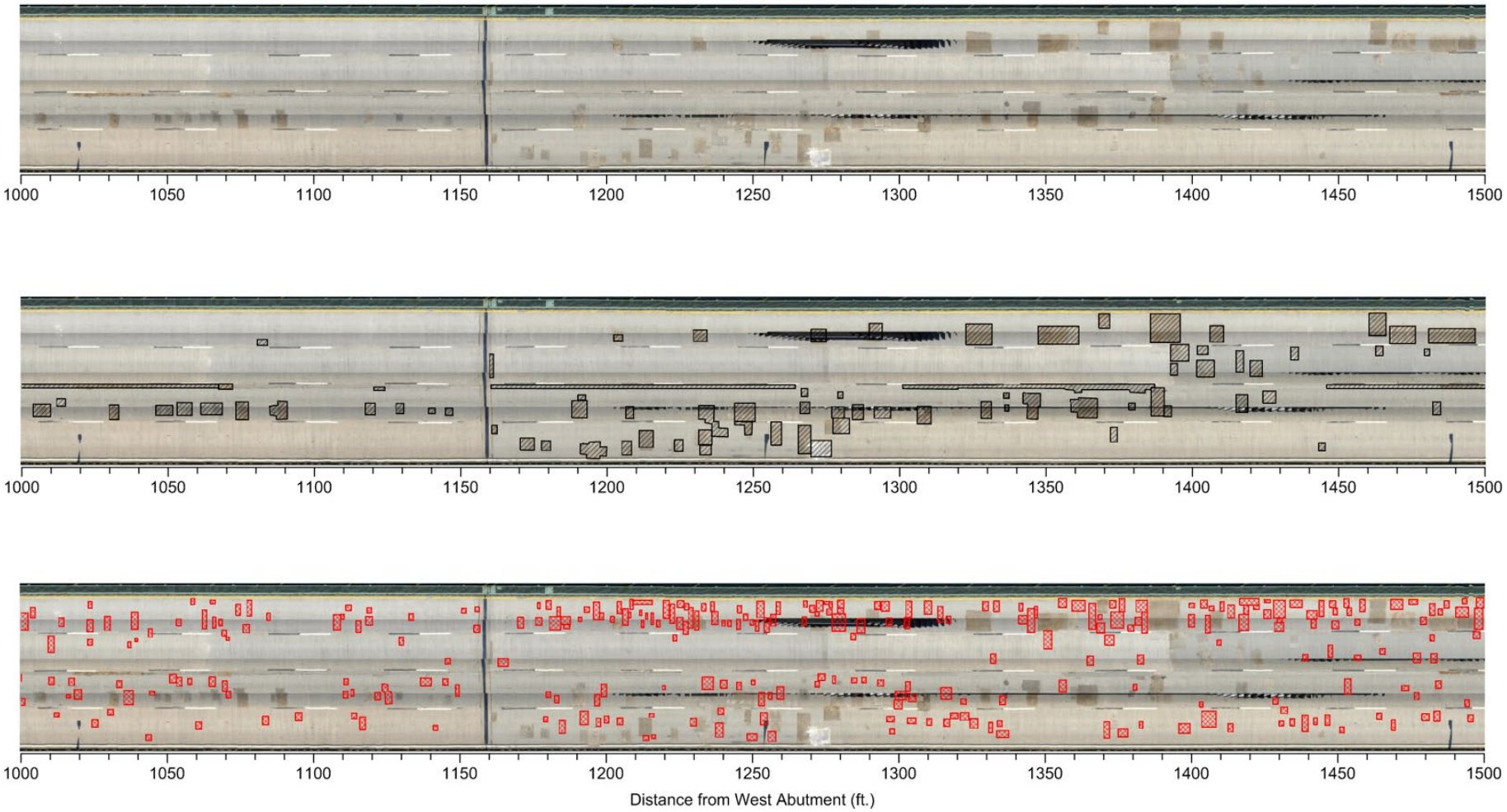
Confirmed with hammer sounding



Aerial Visual



IR and HRV MAPPED RESULTS

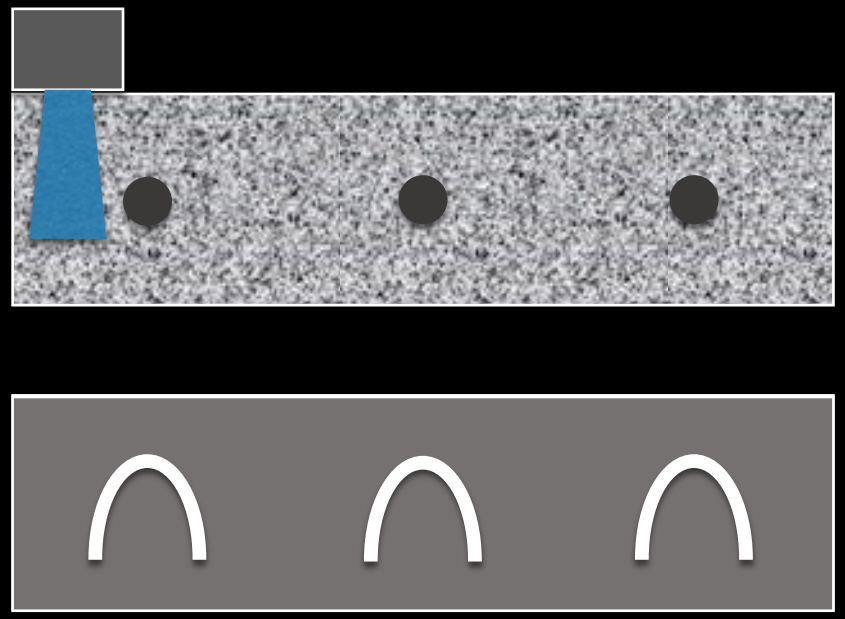


PHASE I – HIGH SPEED GPR

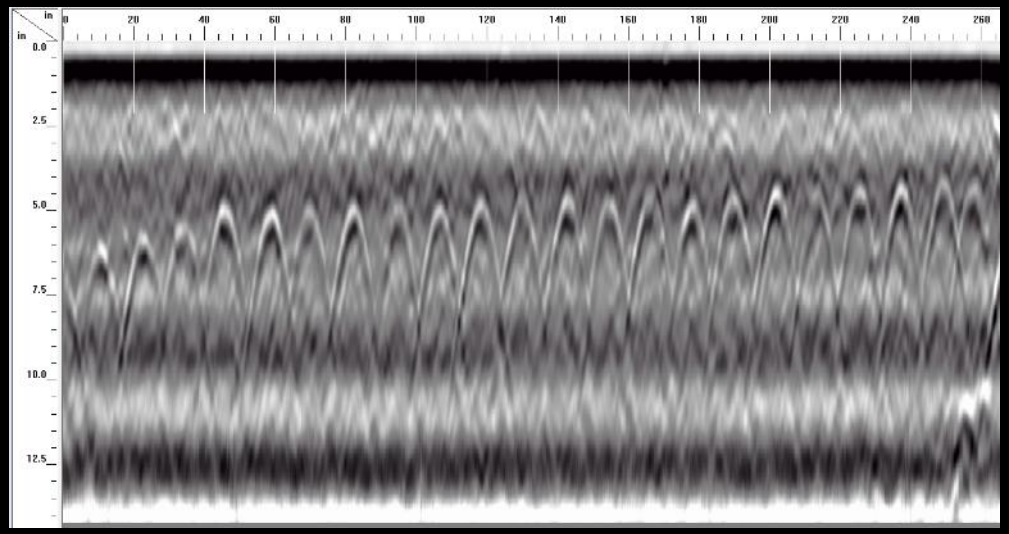
Ground Penetrating RADAR (GPR)

- Theory of Operation
  - Uses electromagnetic waves to evaluate the condition of the concrete and spillway subsurface by measuring the reflections from the various features below the GPR antenna

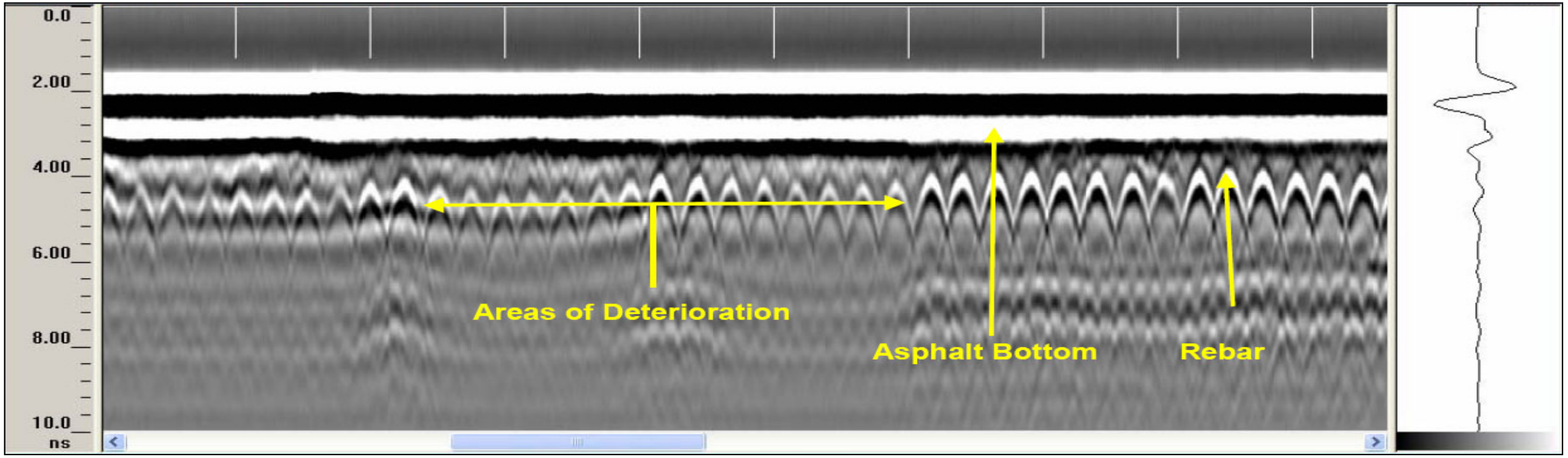
Theoretical



Actual

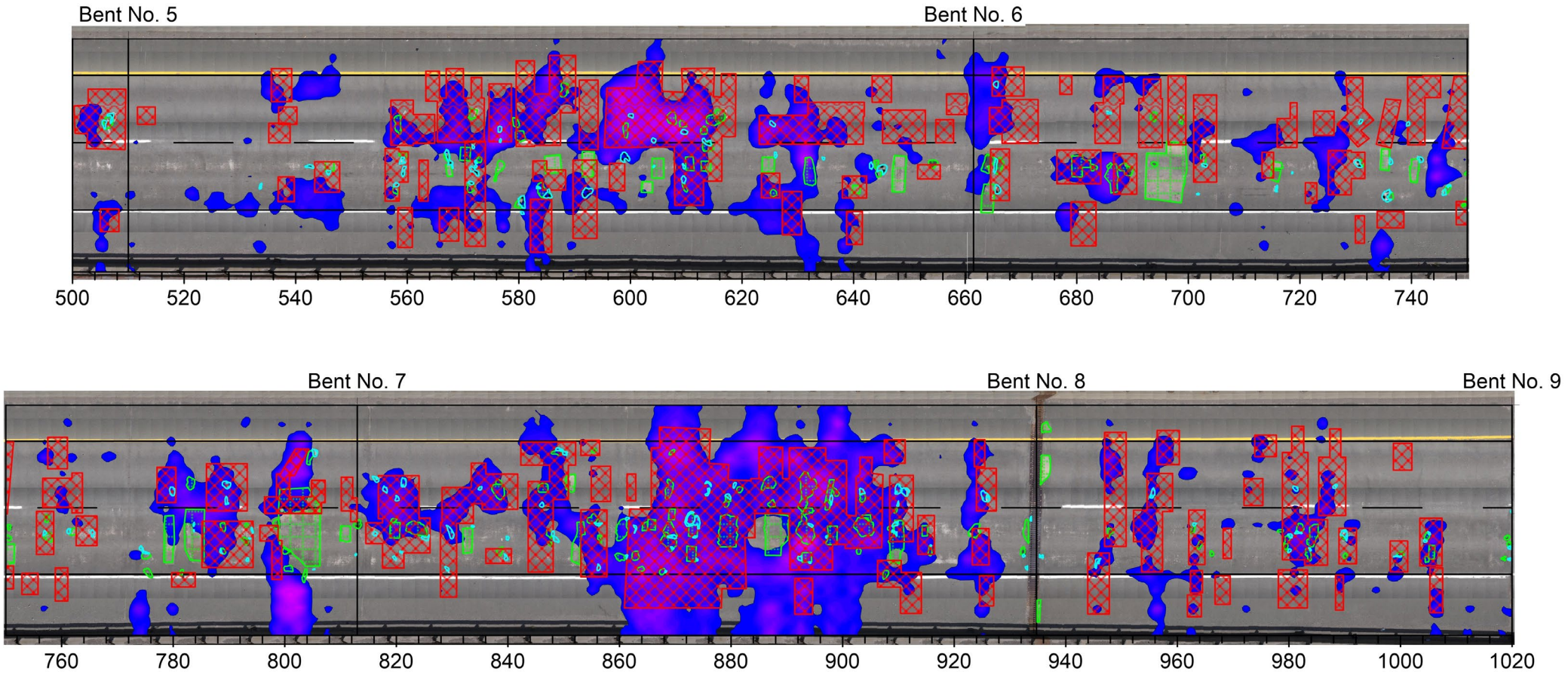


GPR FOR BRIDGE DECKS



- Electromagnetic waves penetrate elastic materials and reflections are based on the materials dielectric permittivity (ability to absorb light).
- Locates Rebar, Degradation due to corrosion, Moisture, Voids

PHASE I RESULTS

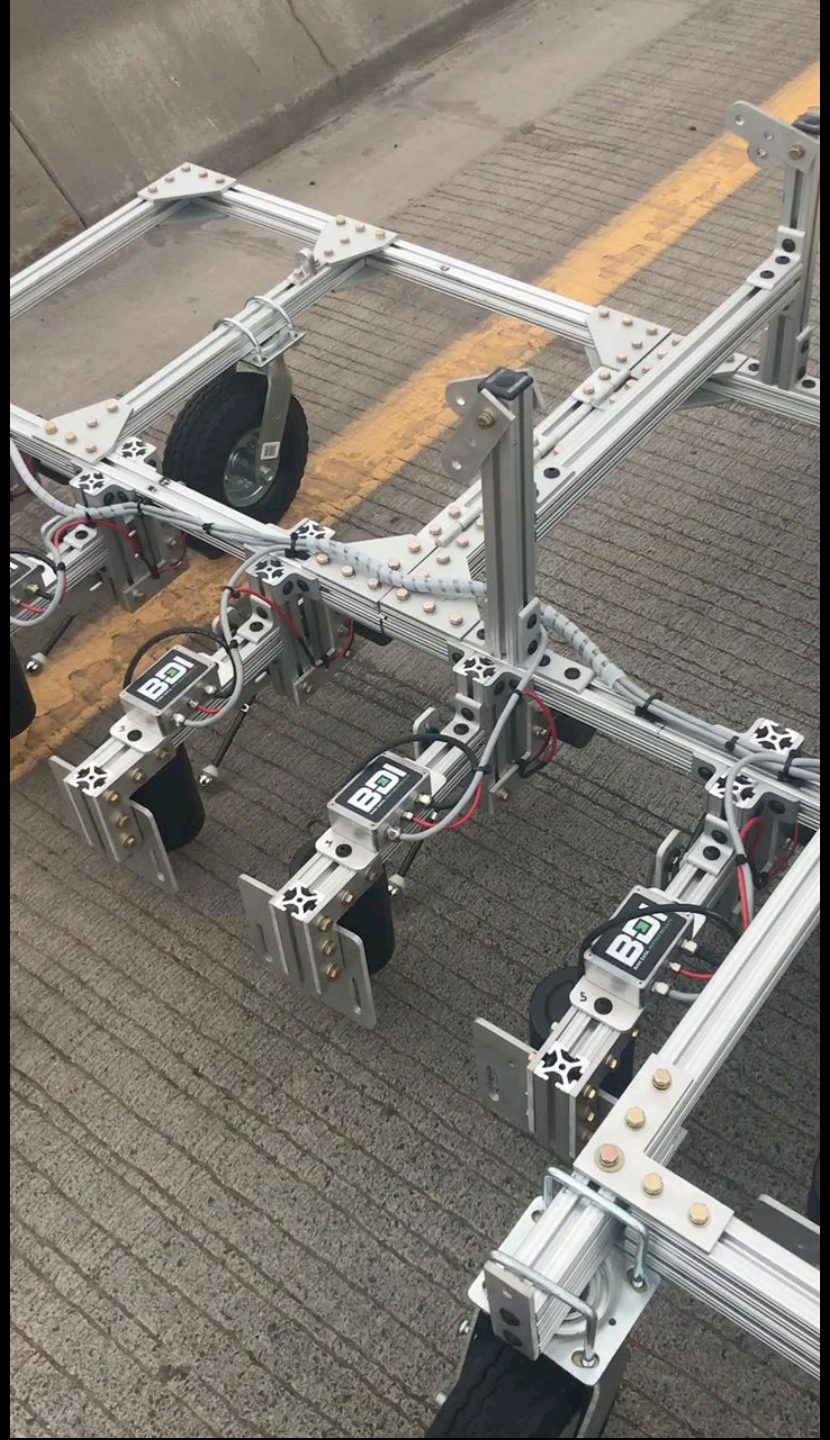


PHASE II - SounDAR

BDI RAW DATA. REFINED RESULTS.

AIR COUPLED IMPACT ECHO

- Modular impactors – spheres can be adjusted from 6mm to 25mm
  - Smaller spheres result in shorter impact times and higher frequency dynamic induction.
- Impacts are ~40ms apart to avoid acoustic crosstalk
- Microphones are designed to focus the acoustic energy and isolate external noise (primarily traffic noise).

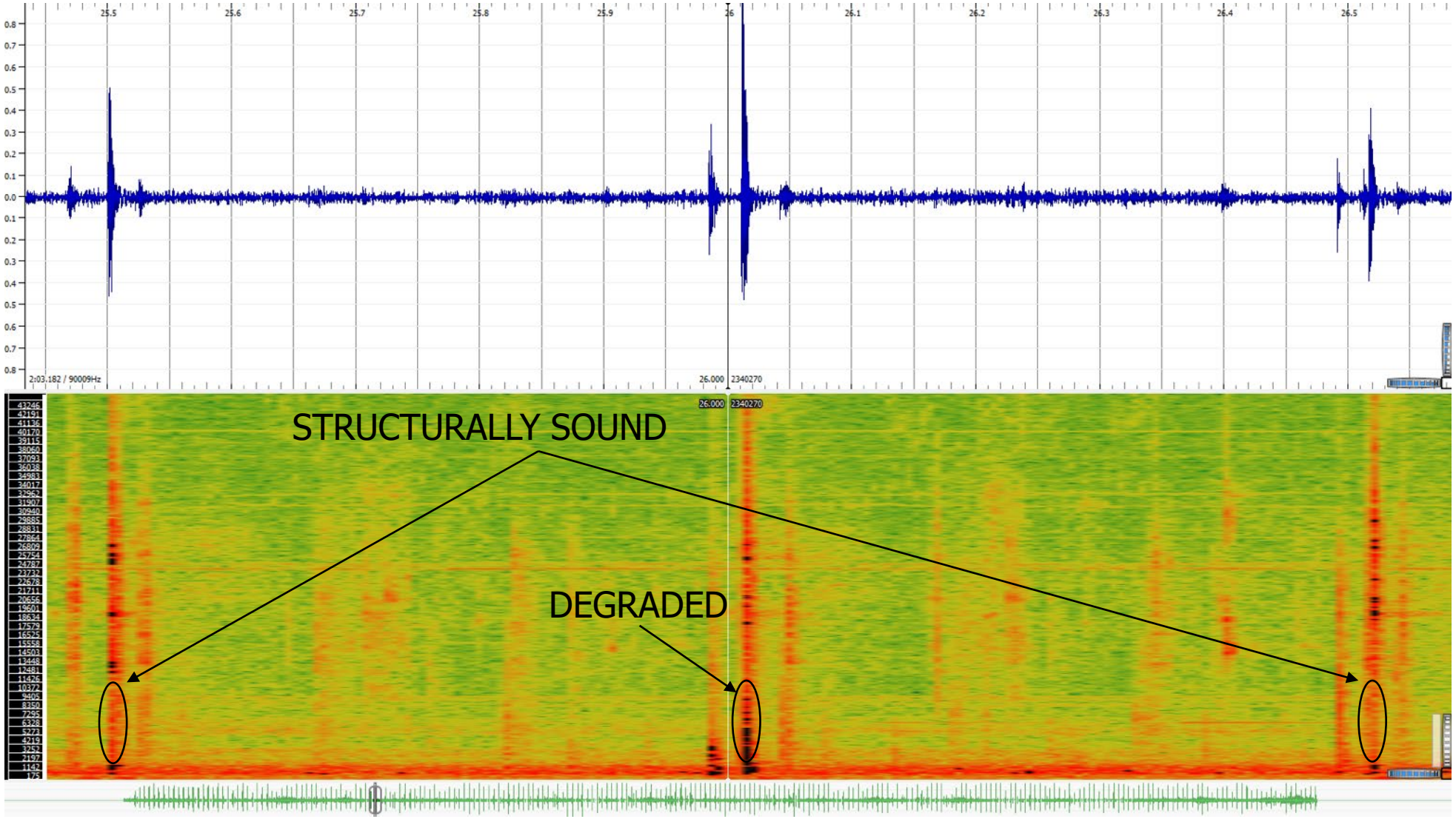


SounDAR

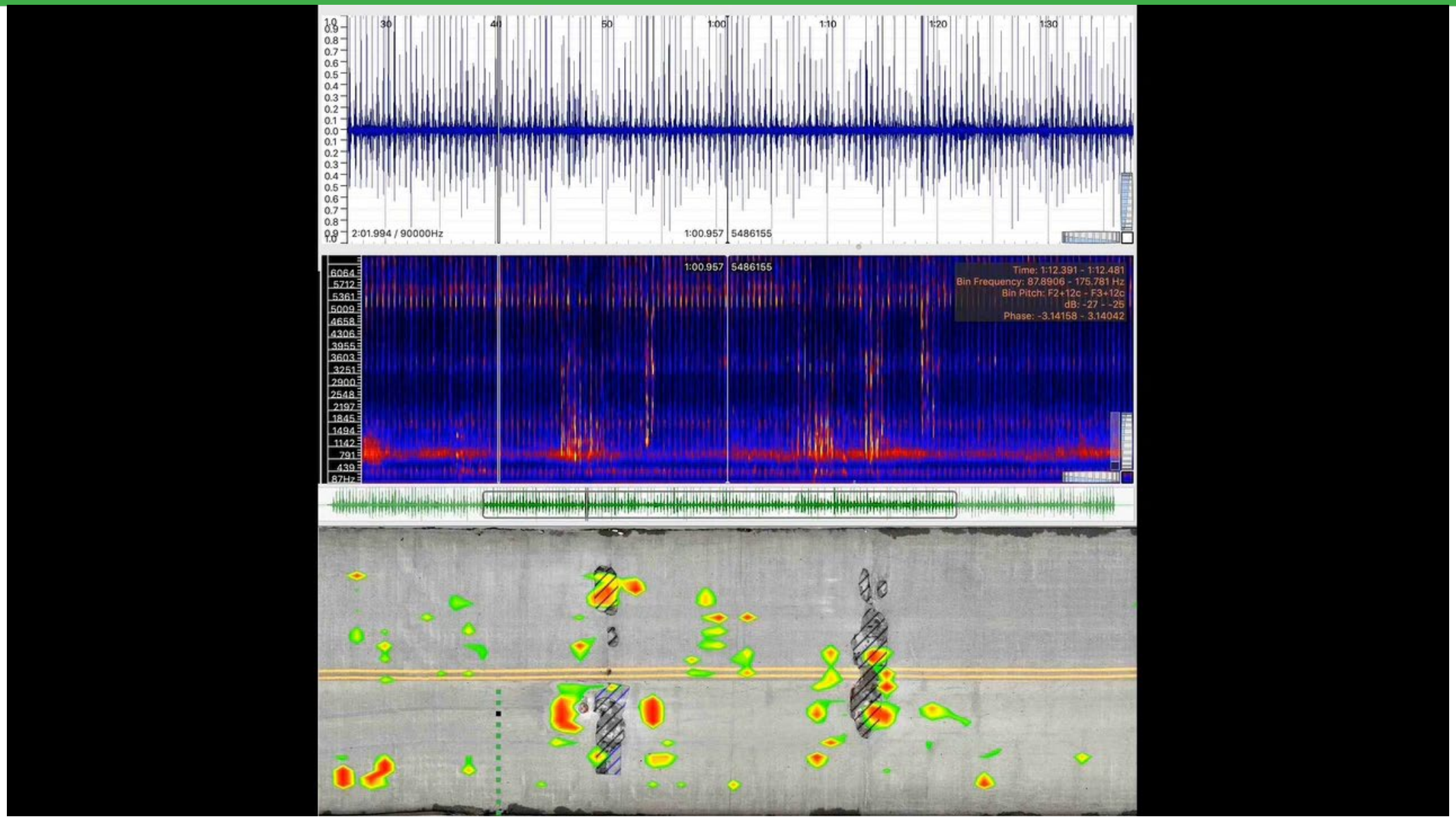
DECK ACOUSTIC RESPONSE (DAR)

- Deck Acoustic Response (DAR) vs. Impact Echo.
- Concepts are similar, but DAR is identifying changes of frequency response across an entire structure that correspond to flaws.
  - Like the human ear and sounding.
- Data can then be analyzed for specific depths if needed.

SPECTROGRAM OF FILTERED DATA

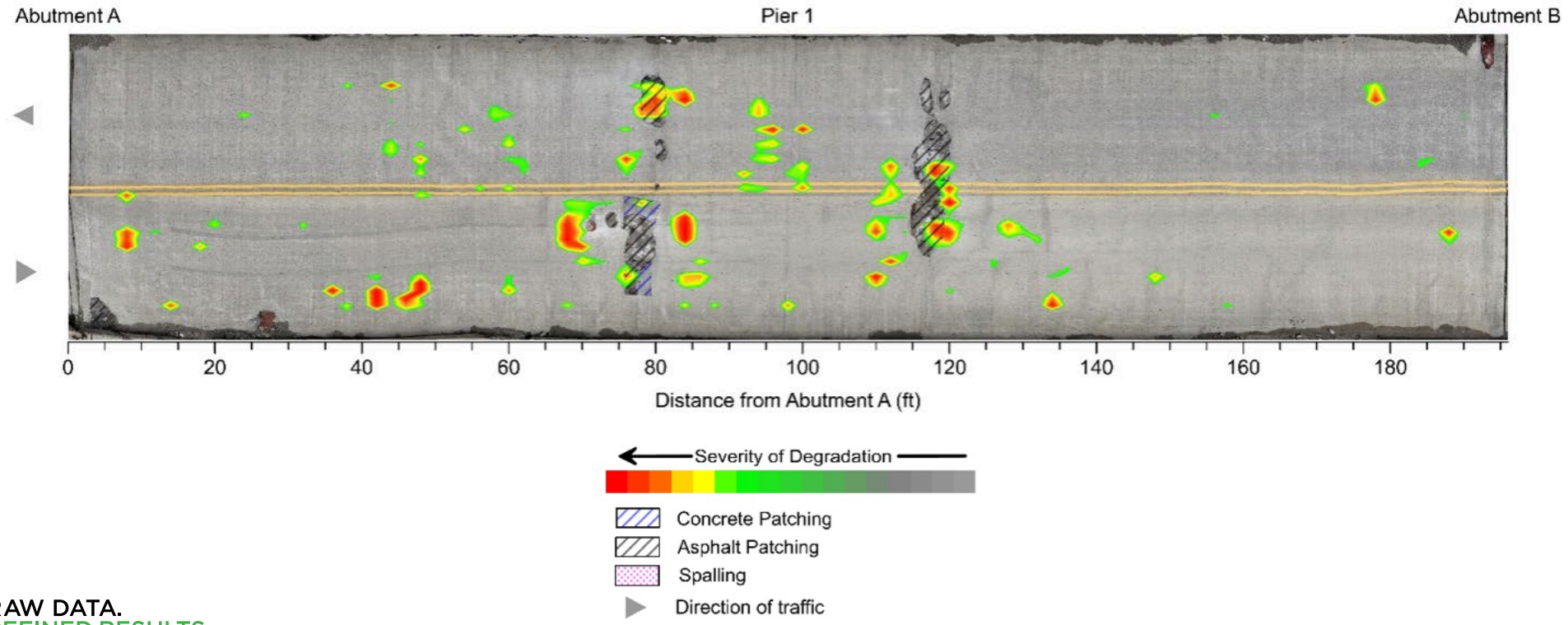


SounDAR ANALYSIS AUTOMATION



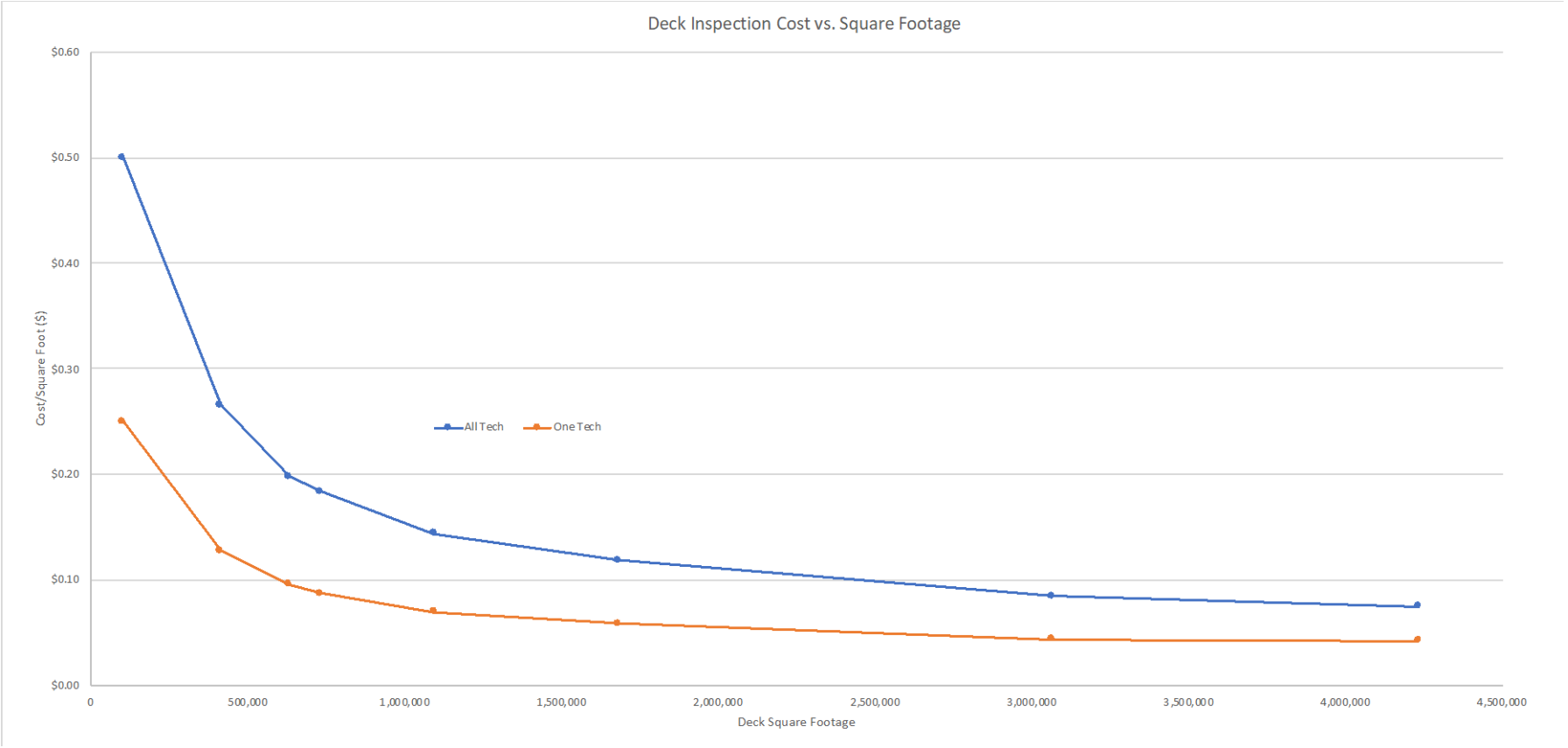
SounDAR RESULTS

- 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).

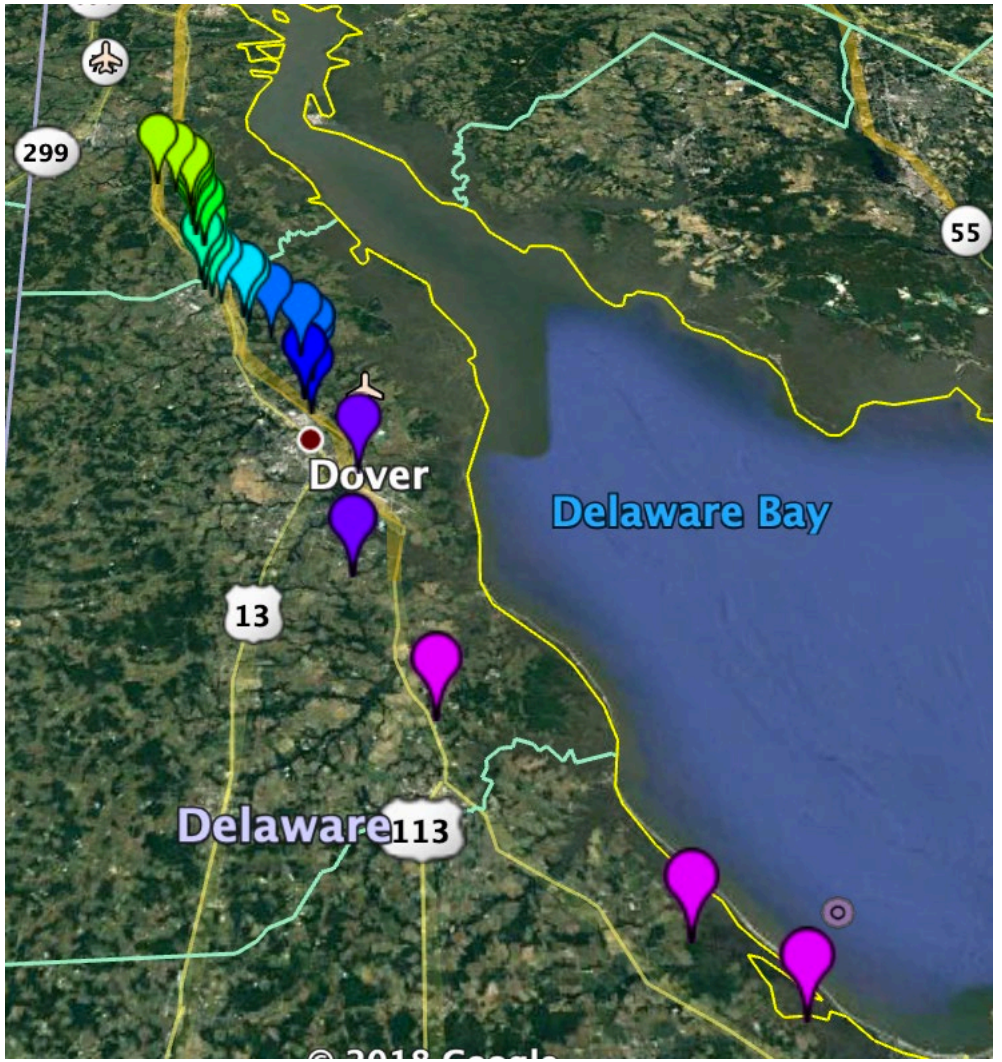


ASSOCIATED COSTS AND TURNAROUND

- Economy of Scale
- Turnaround based on size and complexity of structure, but not typically more than 3-4 weeks.



LARGE SQUARE FOOTAGE



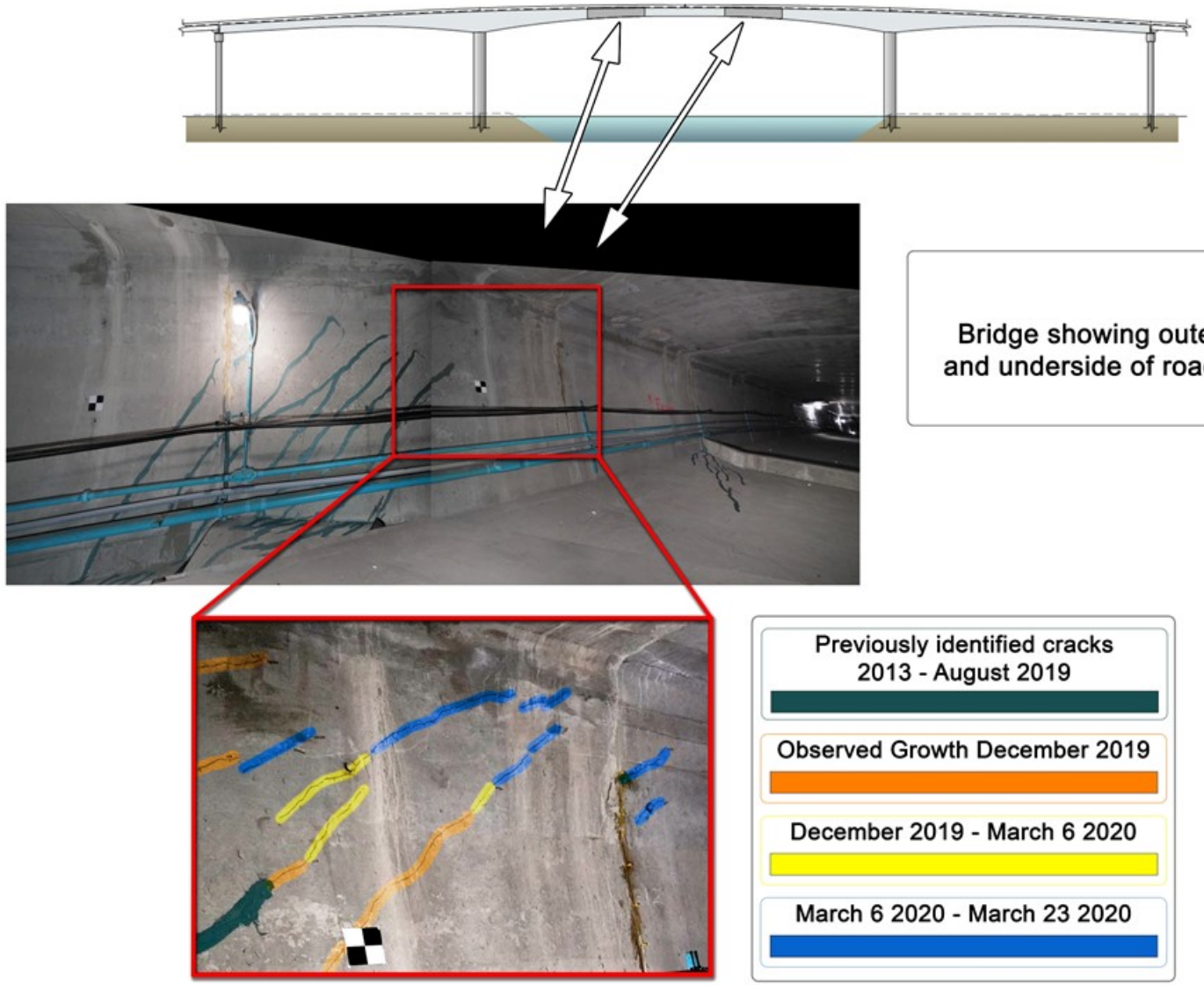
PHASED APPROACH FOR DECK NDE

- Phased approach allows for program and network level inspections:
  - Phase 0 – High level screening
  - Phase I – Highspeed NDE
  - Phase II – High resolution automated sounding
  - Phase III – Data driven preservation and maintenance

PRESTRESSED CONCRETE EVALUATION

- Prestressed concrete bridges pose difficult inspection scenario.
- Cracks in members are difficult to identify and measure.
- Voided PT ducts can potentially lead to corrosion of tendons and failure of the structure
- Multi-technology approach allows for nondestructive solution.

CRACKS IN SEGMENTAL SECTIONS



Bridge showing outer wall and underside of road deck.

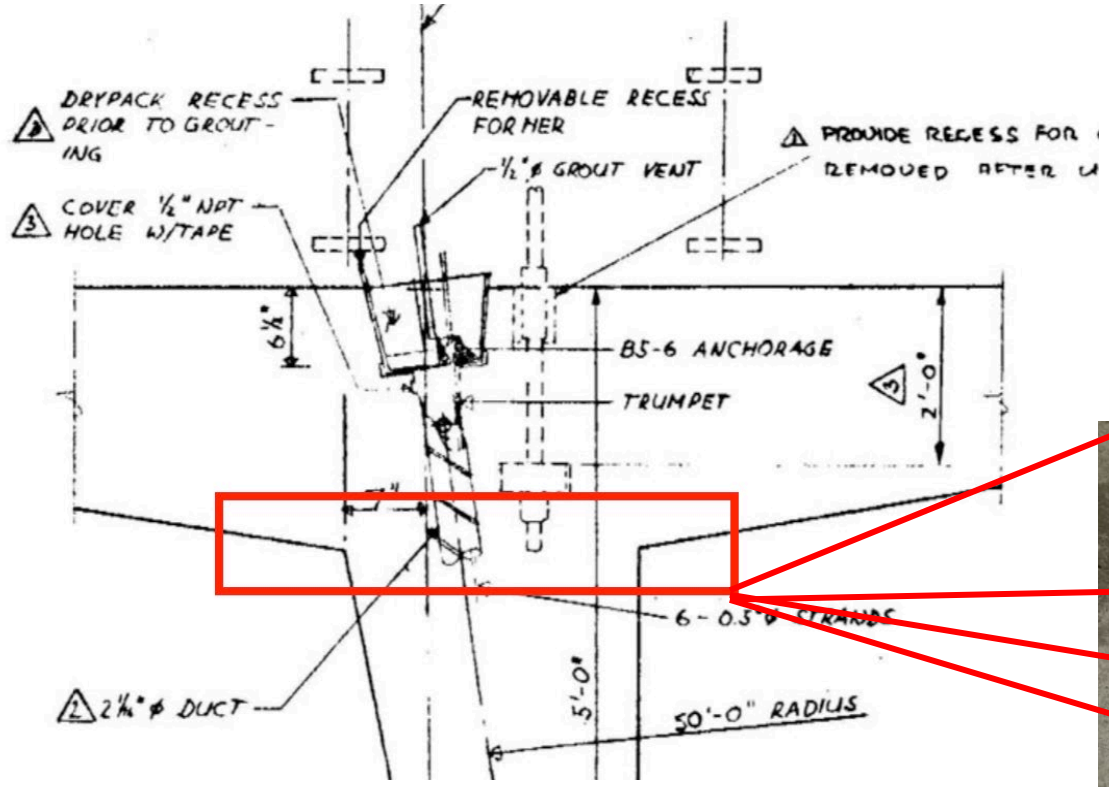
Previously identified cracks 2013 - August 2019

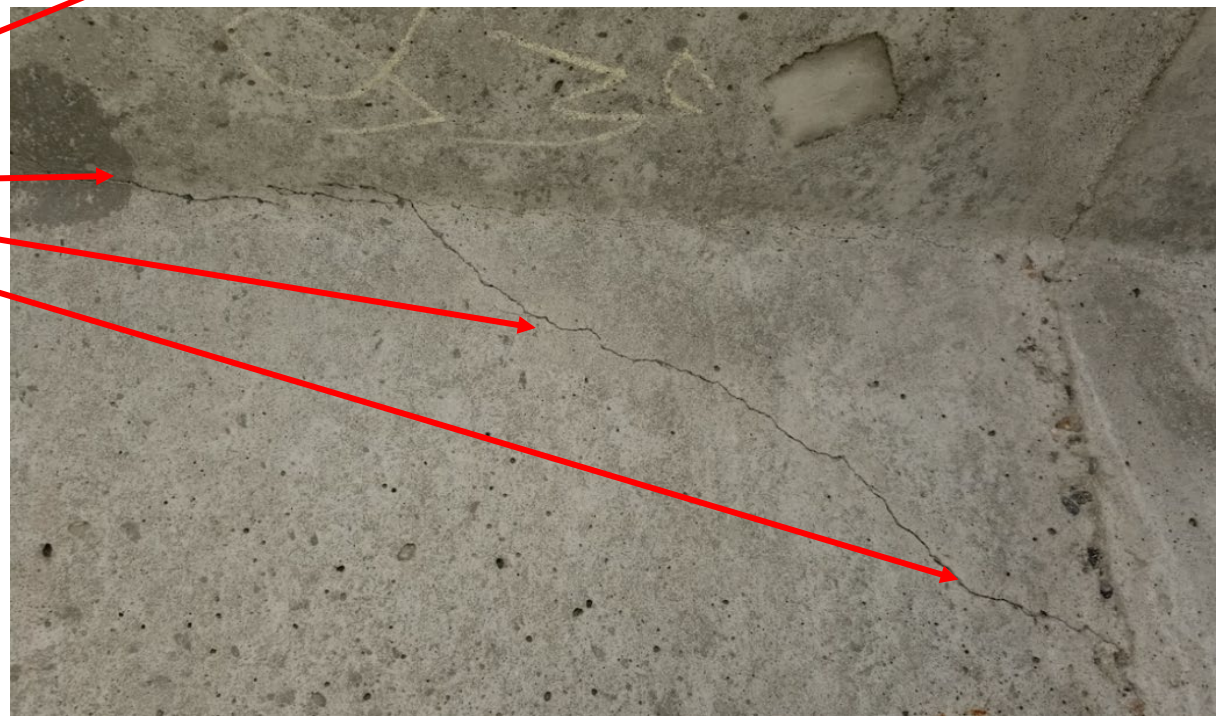
Observed Growth December 2019

December 2019 - March 6 2020

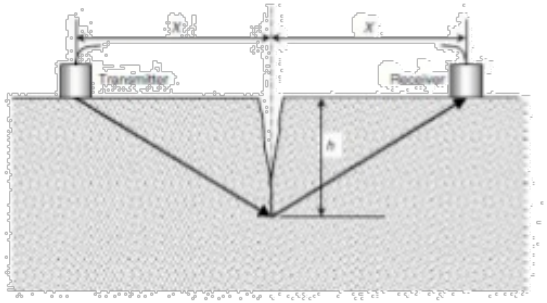
March 6 2020 - March 23 2020

CRACKS IN SEGMENTAL SECTIONS



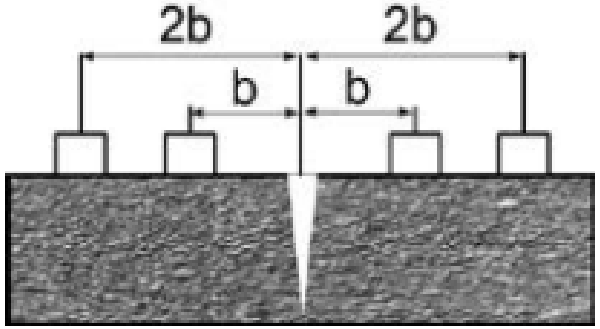


ULTRASONIC PULSE VELOCITY (UPV)

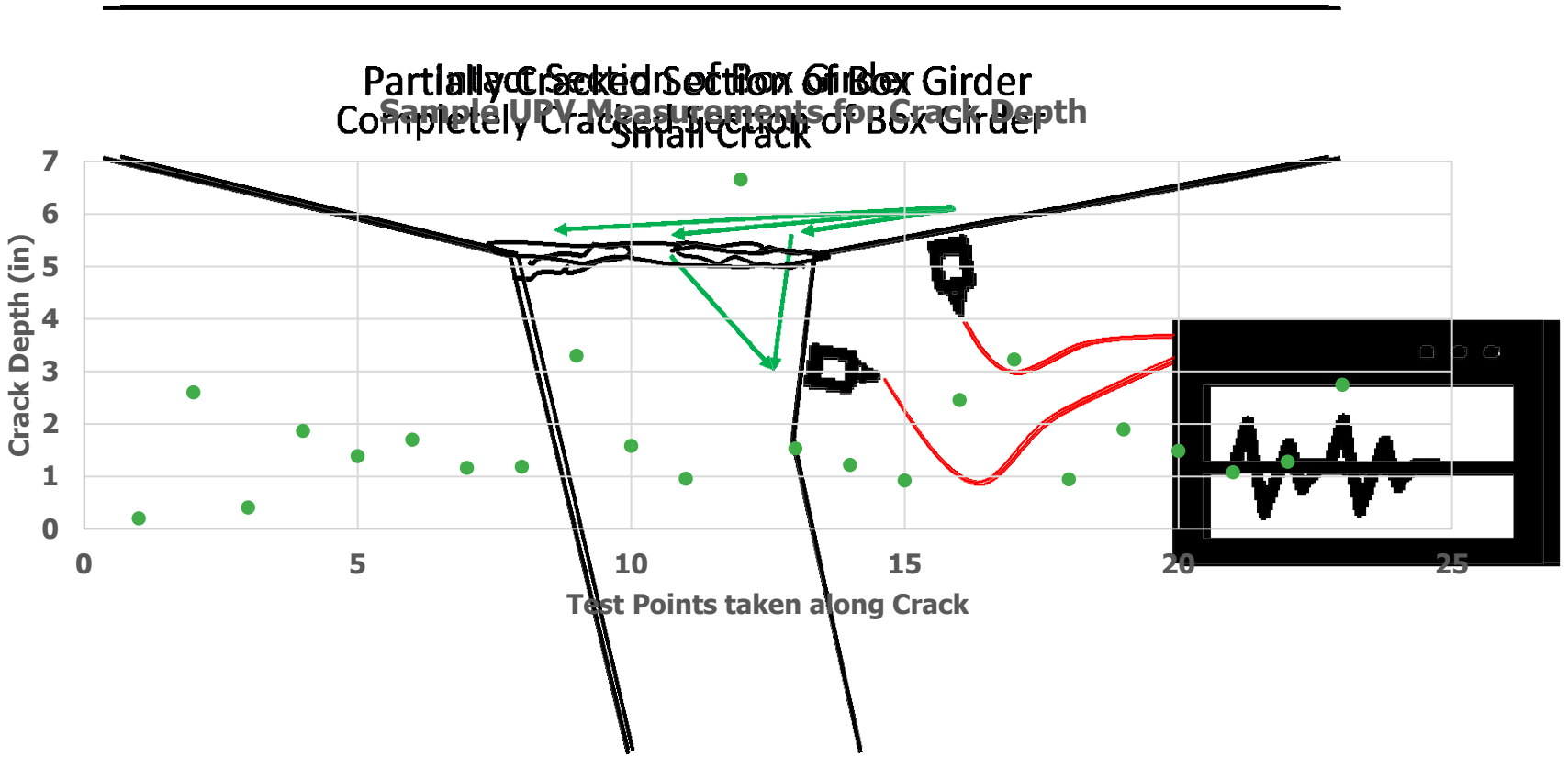


$$\text{crack depth, } h = x\sqrt{\left(\frac{T_c^2}{T_s^2} - 1\right)}.$$

x = distance of transducer from the crack
Tc = transmit time around the crack
Ts = transmit time along the surface of the same type of concrete without any crack

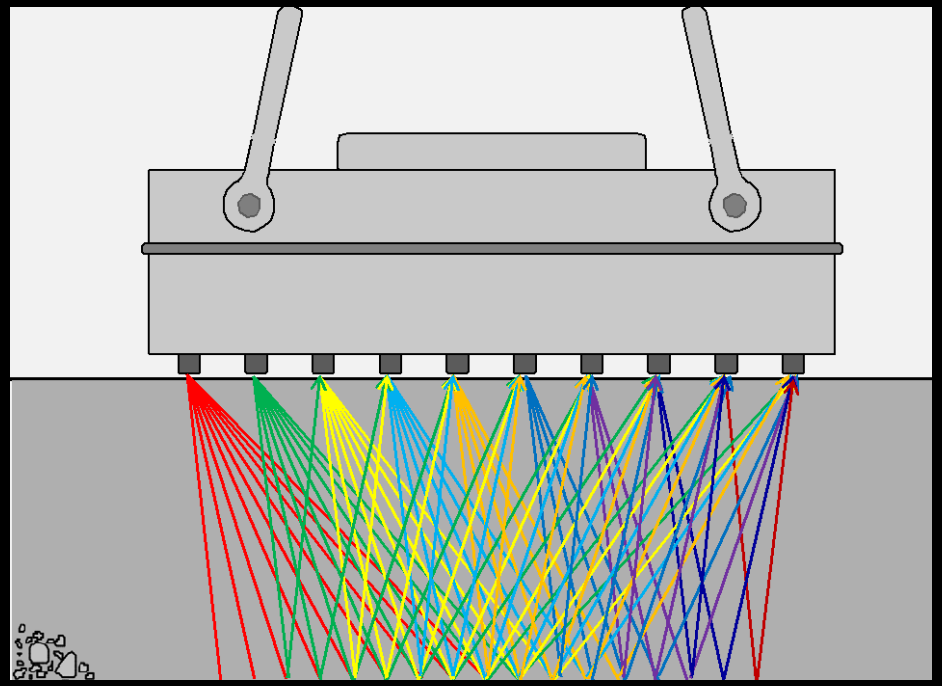


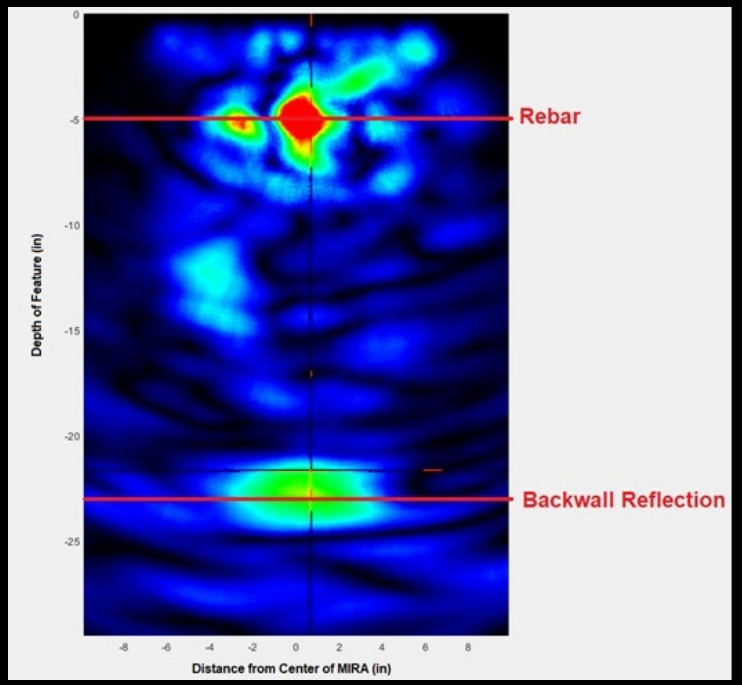
ULTRASONIC PULSE VELOCITY (UPV)



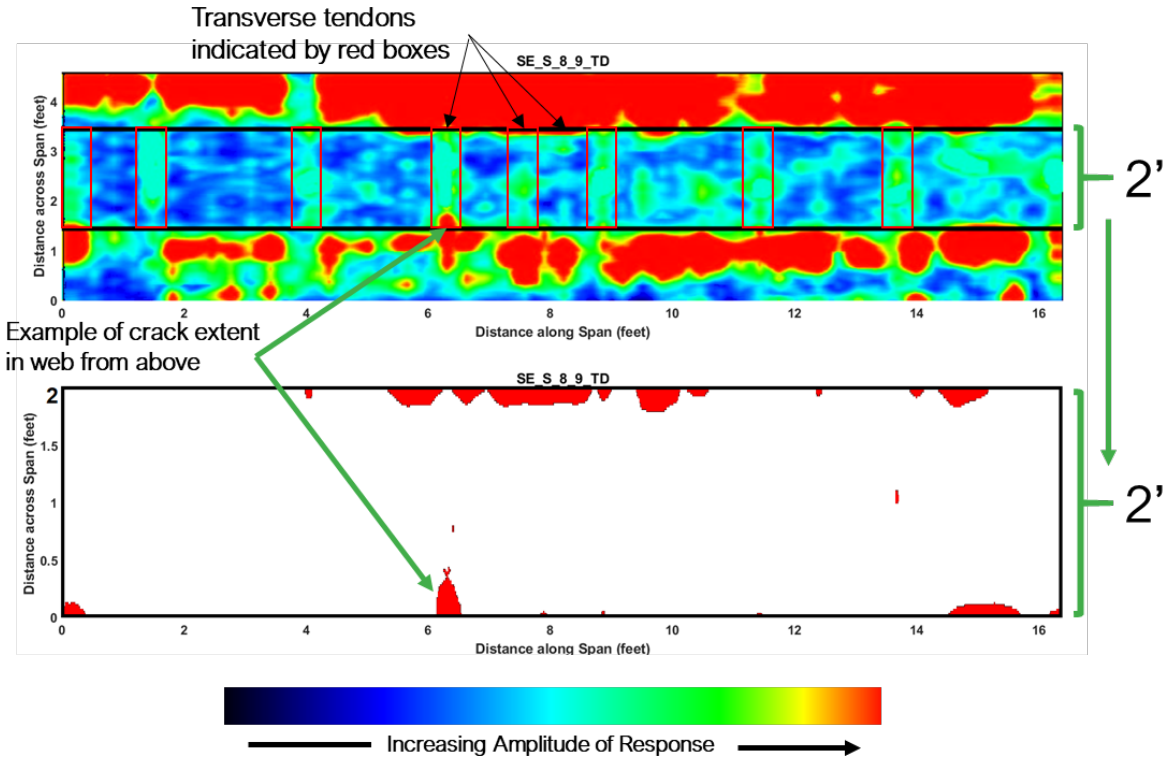
ULTRASONIC TOMOGRAPHY (MIRA)

- Ultrasonic Tomography
- 40 point dry coupled accelerometers
- Synthetic Aperture Focusing Technique (SAFT)

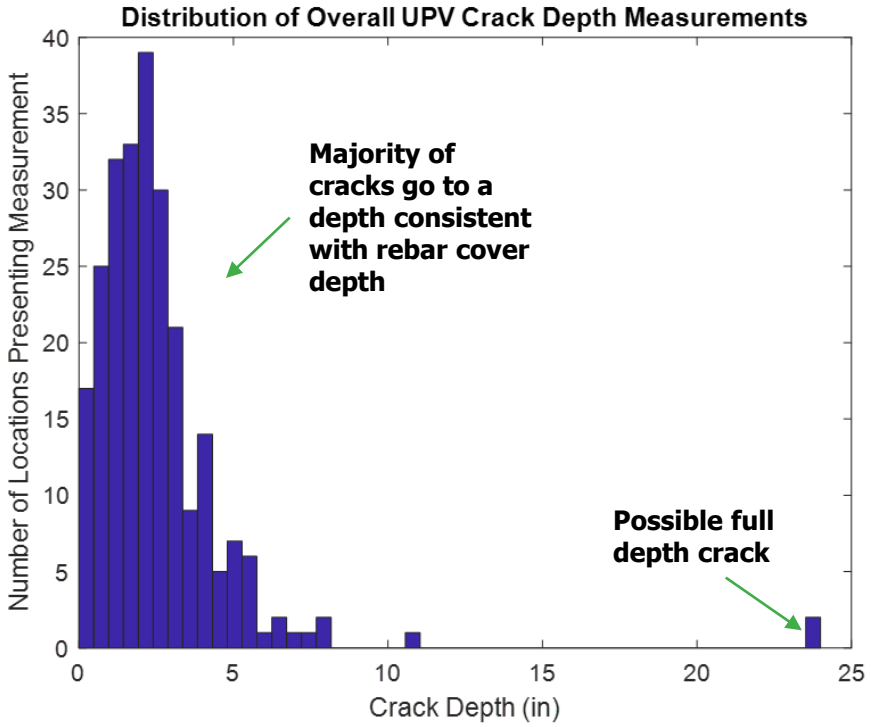


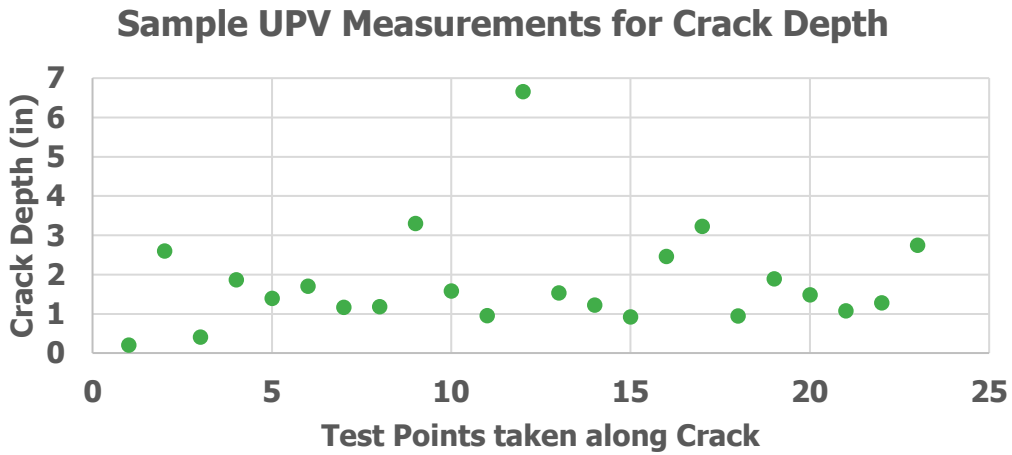


TOPSIDE MIRA CRACK MEASUREMENT



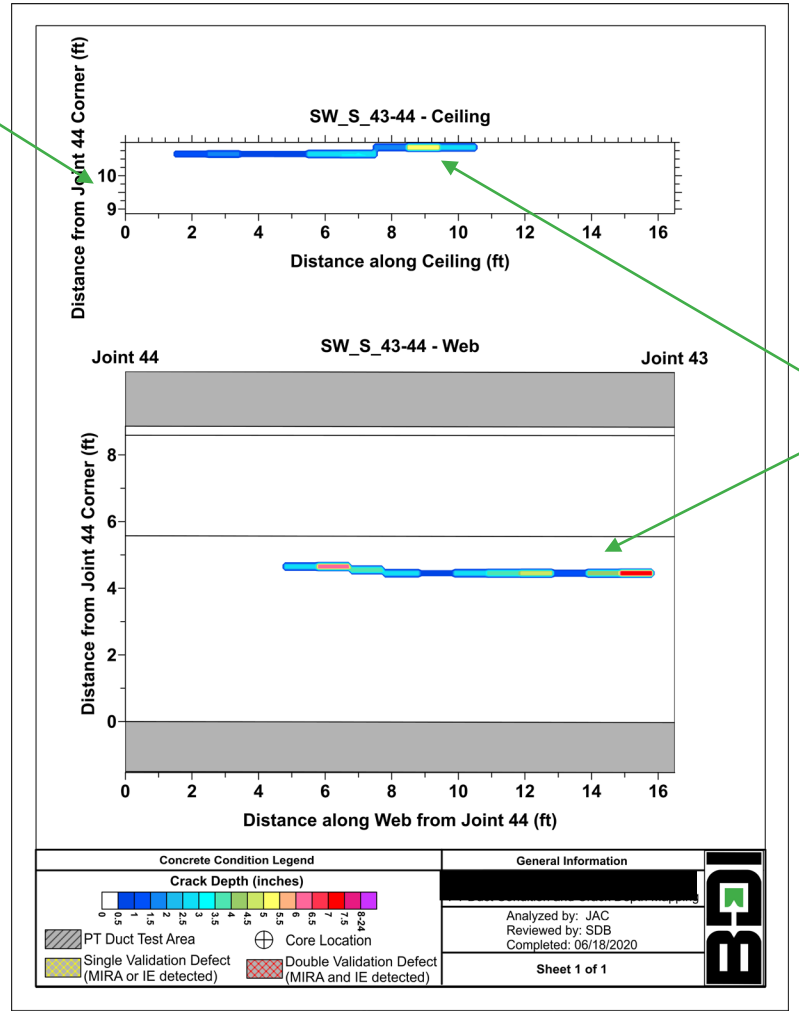
COMBINED UPV AND MIRA CRACK MEASUREMENT DATA





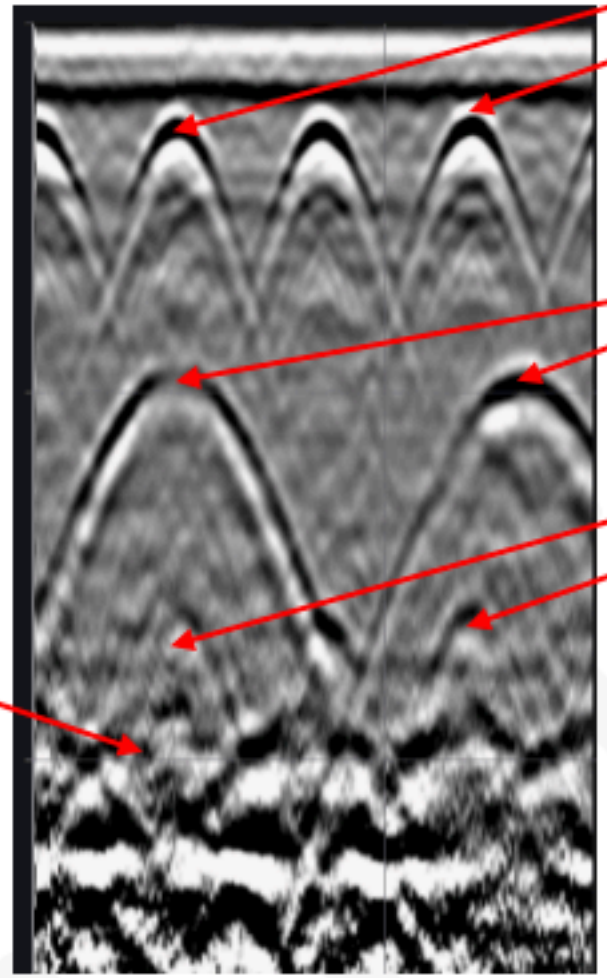
PRESENTATION OF CRACK RESULTS

Ceiling crack positions measured from bottom corner of web

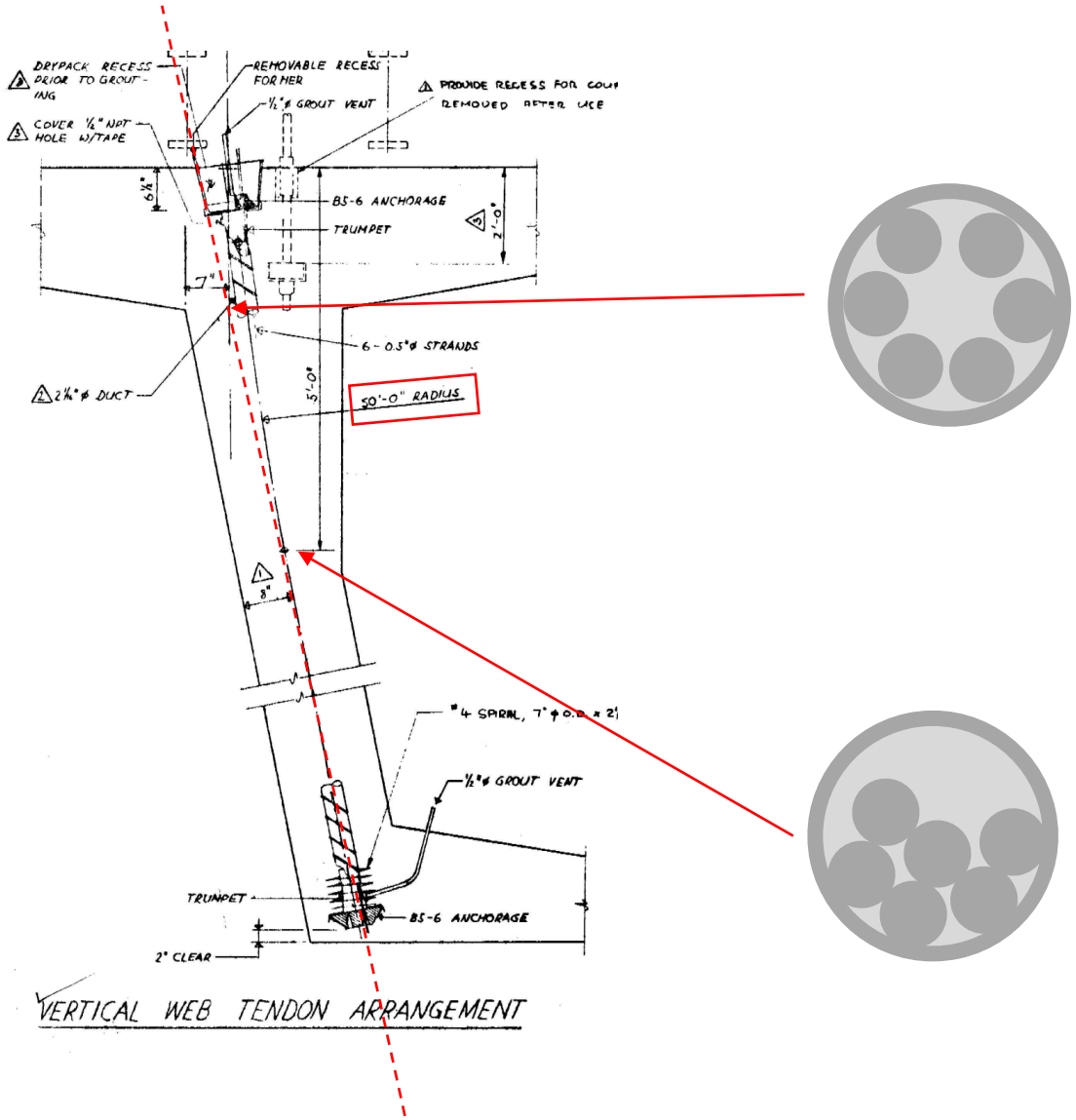


Cracks measured with UPV / MIRA

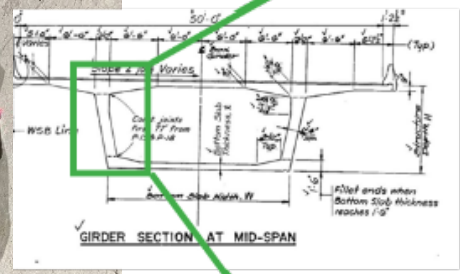
PT DUCT LOCATION

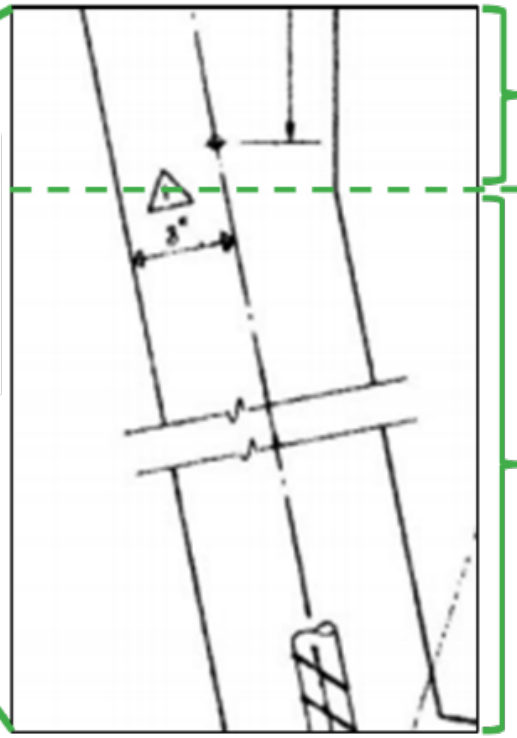


TENDON BUNCHING

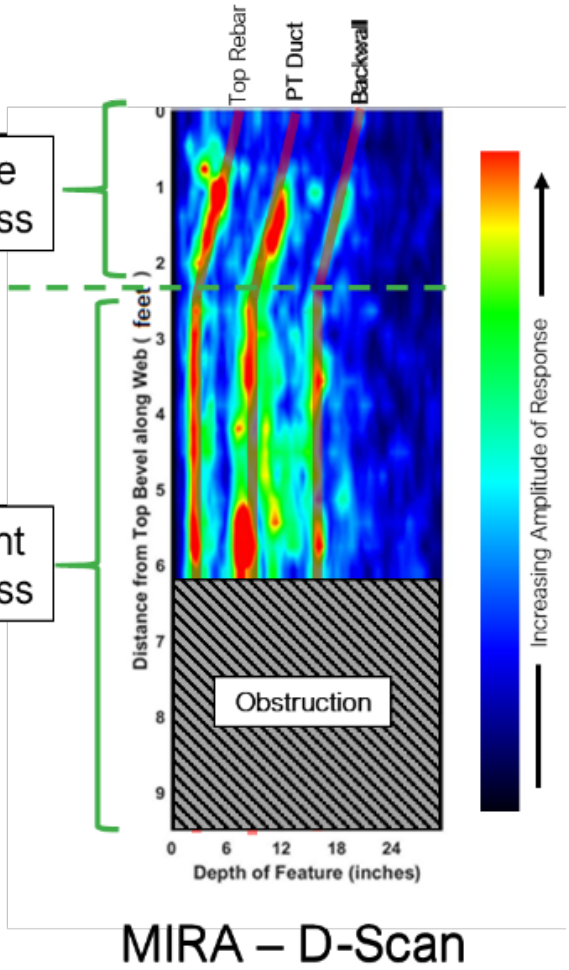


MIRA TESTING OF PT DUCTS



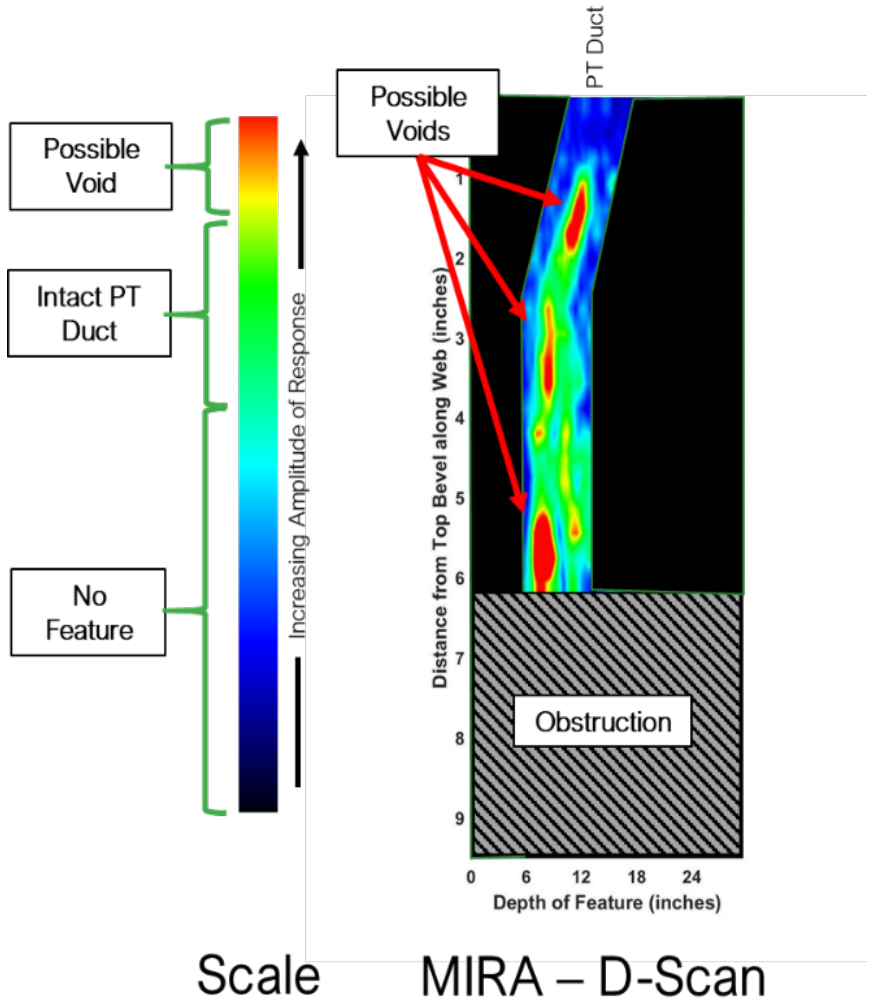


Drawing

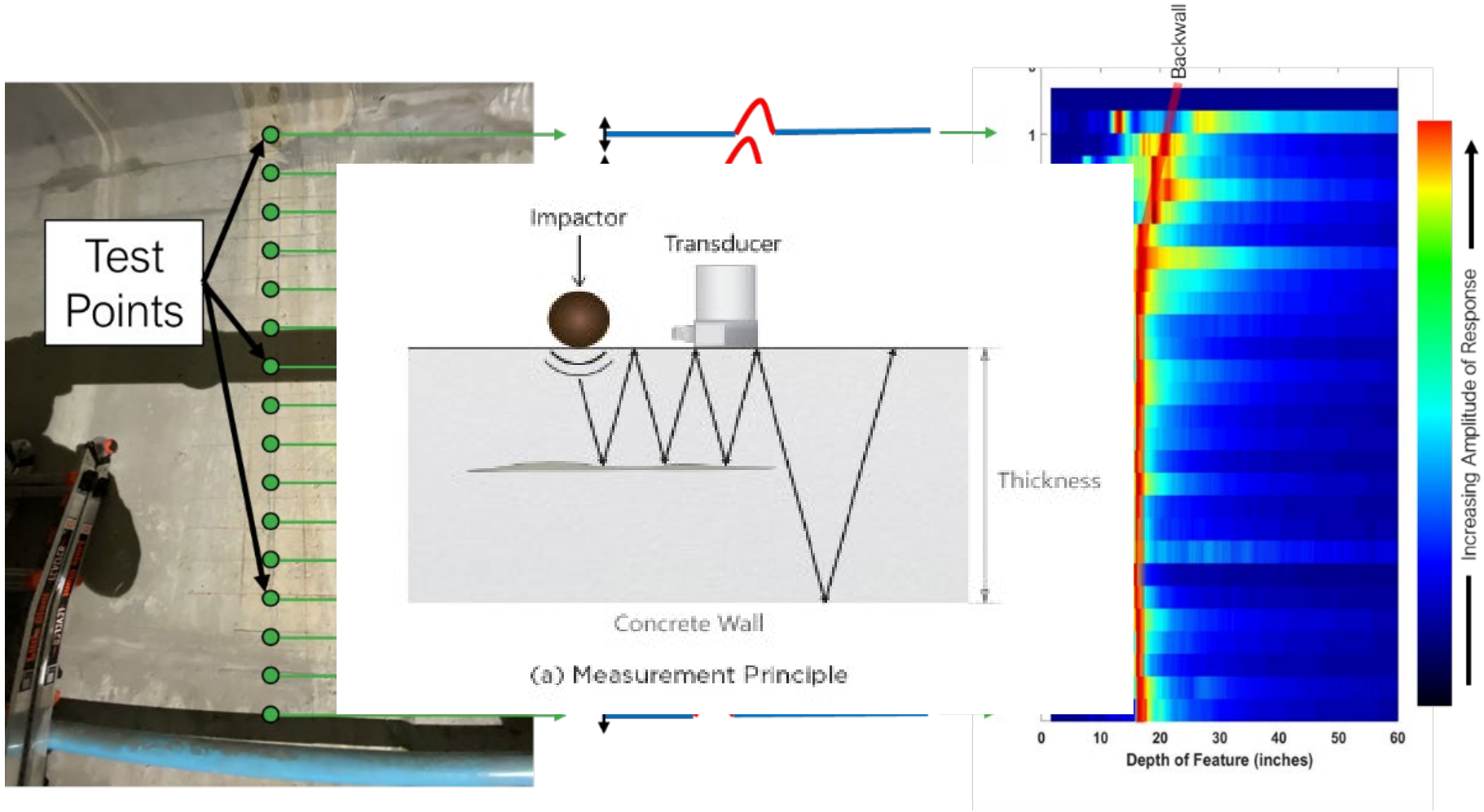


MIRA – D-Scan

VOID LOCATION WITH MIRA

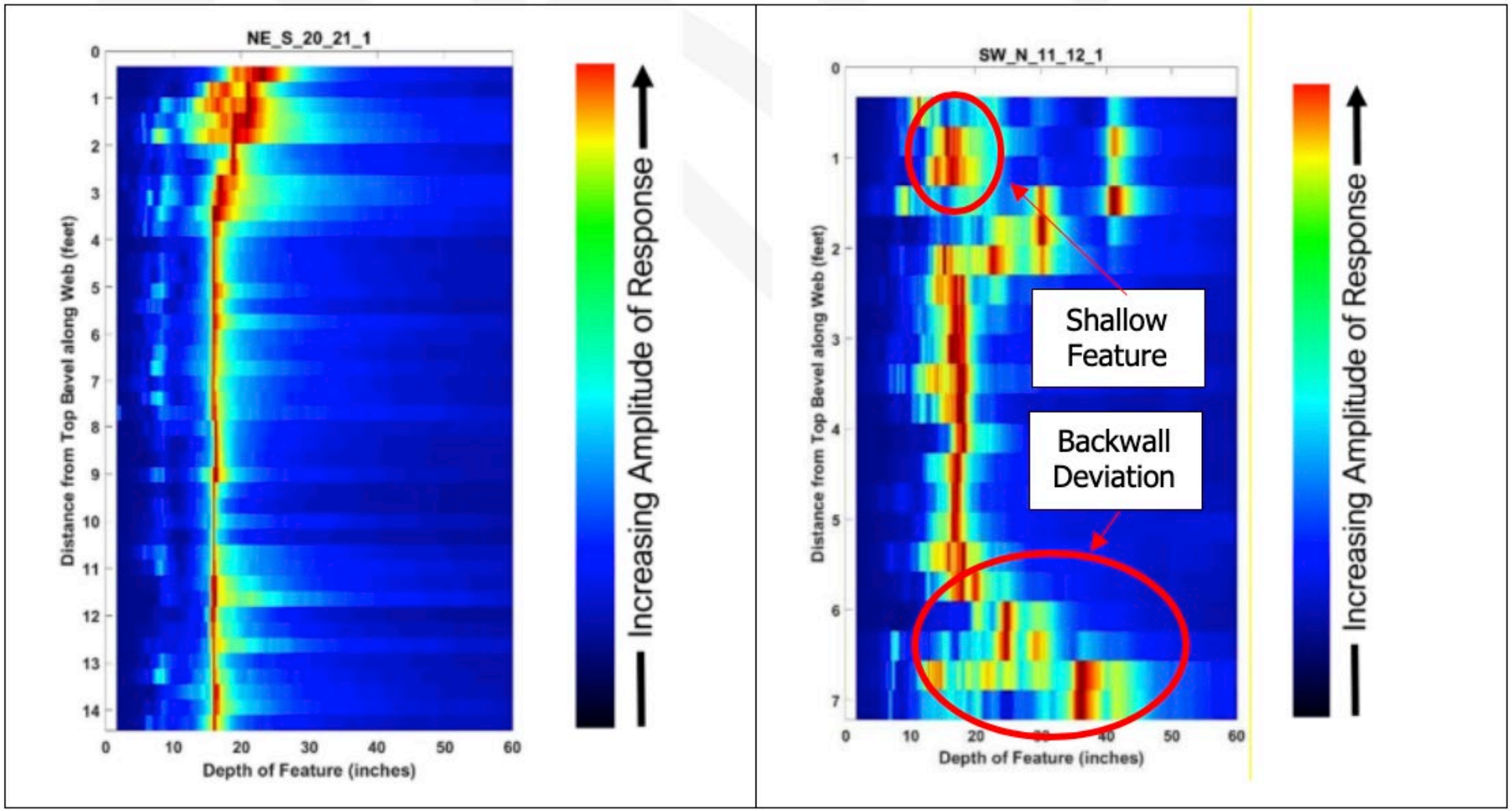


IMPACT ECHO TESTING OF PT DUCTS

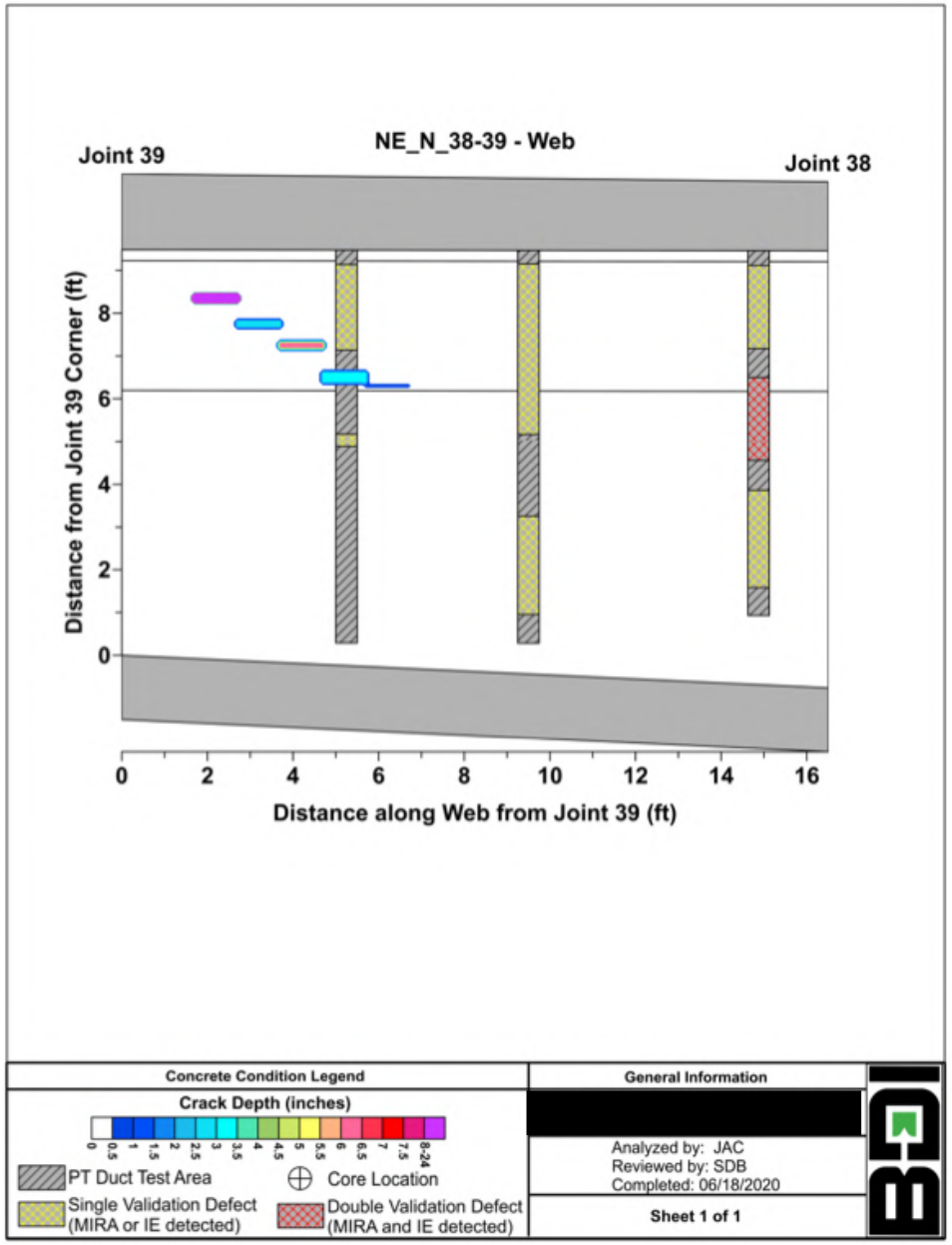


Test Grid On-Site IE – Individual Signals IE – B-Scan

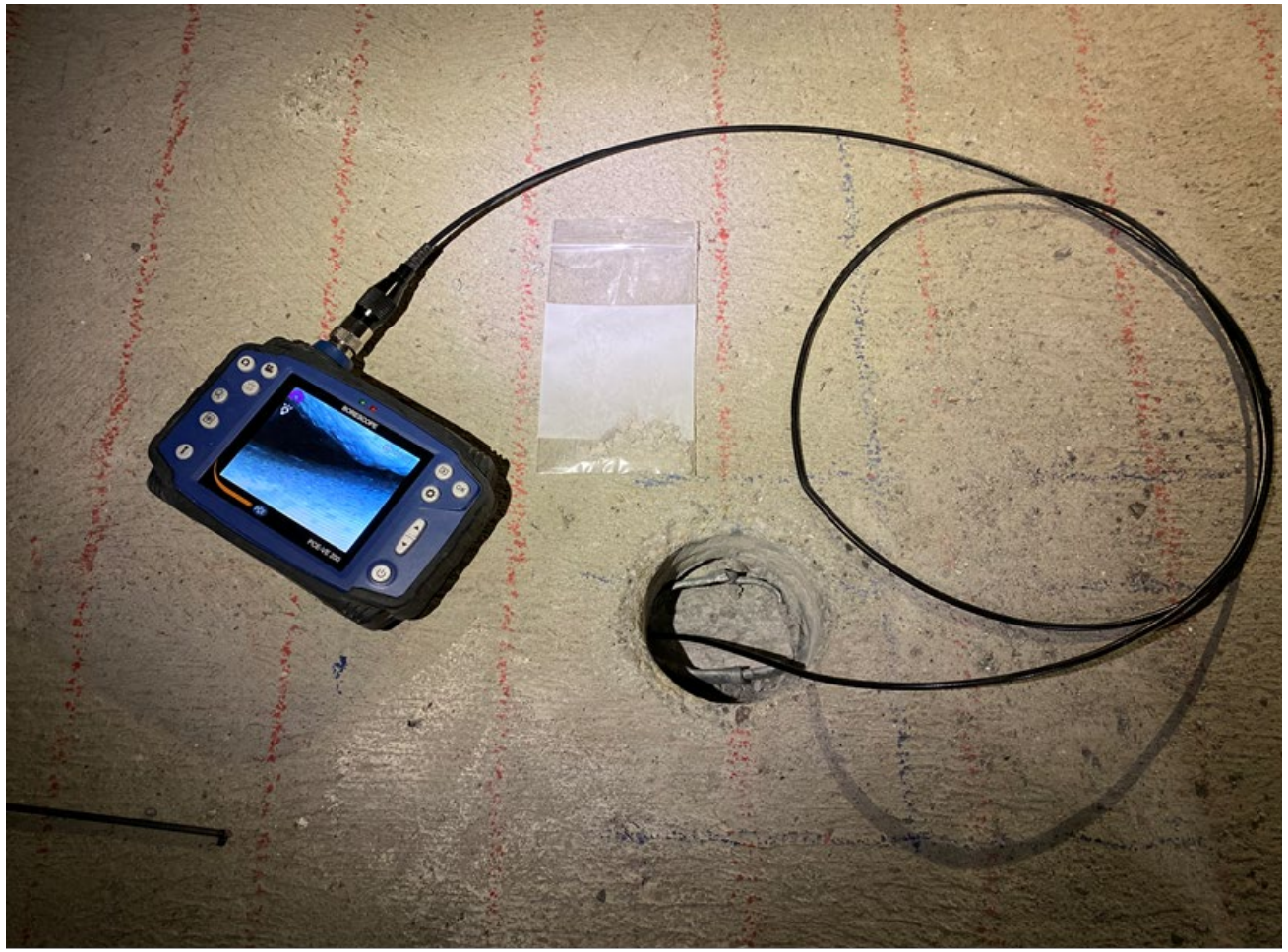
VOID LOCATION WITH IE



CRACK AND PT DUCT RESULTS COMBINED



PT DUCT INSPECTION WITH BORESCOPE

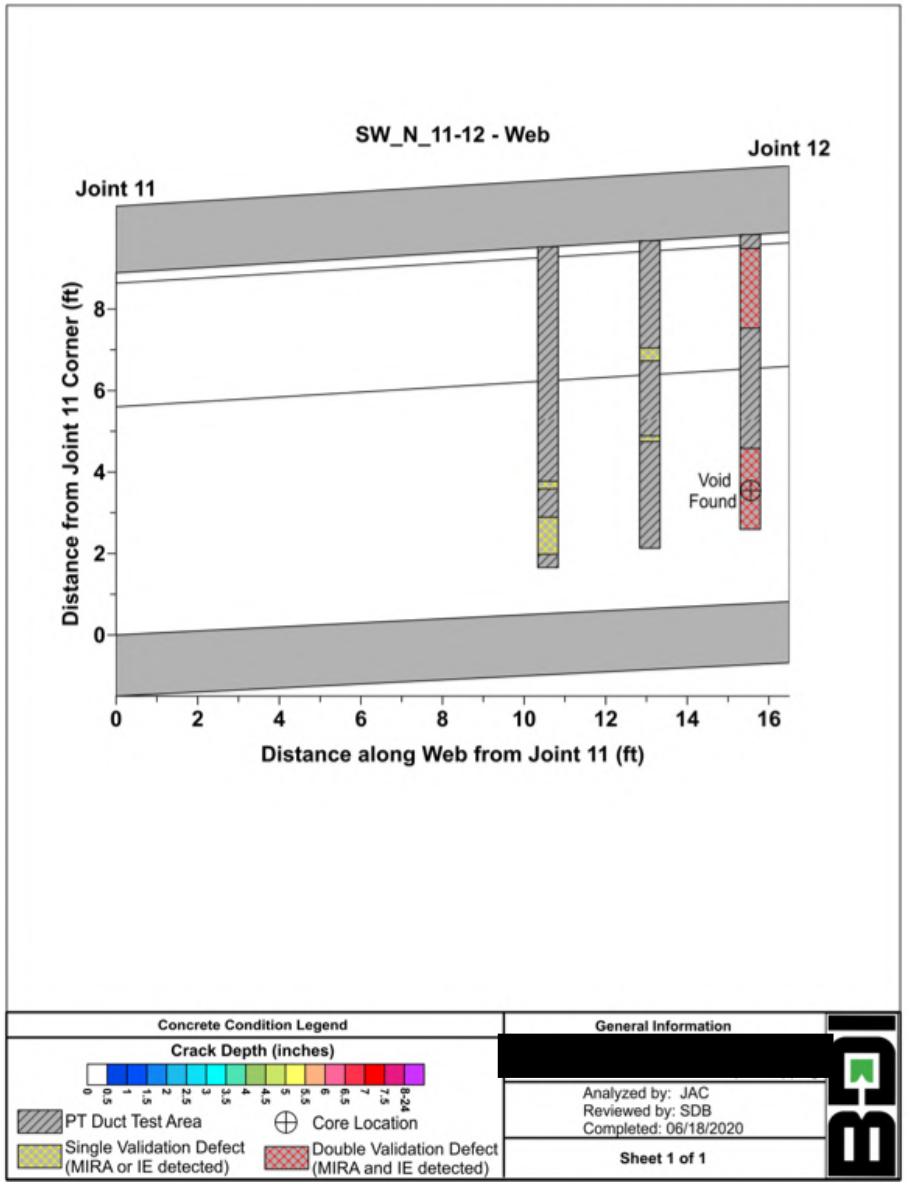


PT DUCT INSPECTION – TENDON BUNCHING

PT DUCT INSPECTION - VOIDS

PT DUCT INSPECTION - VOIDS

VOID VALIDATION



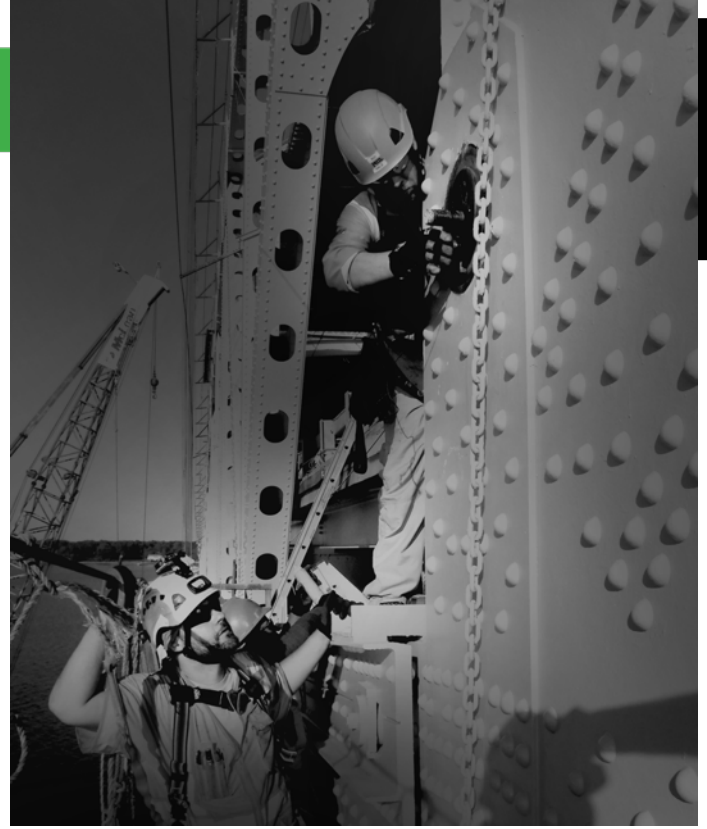
MATERIAL SAMPLING

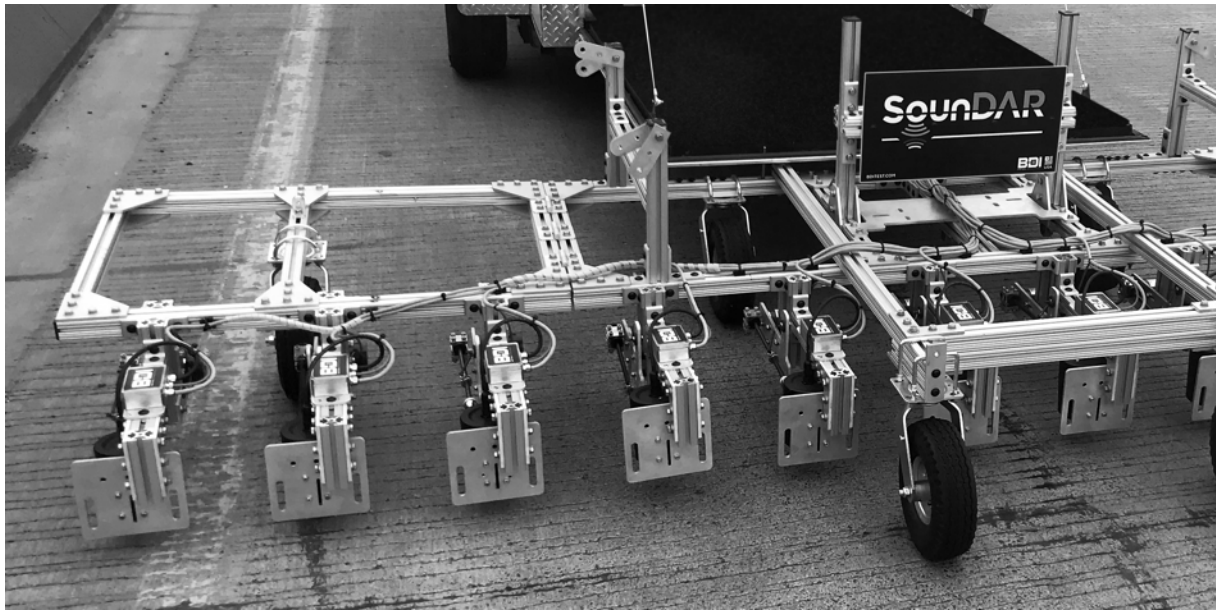
PRESTRESSED CONCRETE EVALUATION

- Multi-technology approach allows for nondestructive solution.
  - UPV and MIRA for crack depth detection
  - GPR for PT duct location and depth
  - MIRA and IE for PT void identification
  - Physical sampling and borescope evaluation for validation.

- THANK YOU FOR ATTENDING!!!
- Please remember to download the brochures attached to the webinar.
- Contact:

shaneb@bditest.com
919.907.8887





BDI RAW DATA. REFINED RESULTS.