

# SHRP2 R06G Implementation Phase

Liberty & Armstrong Tunnels- Pittsburgh, PA

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U.S. Department of Transportation  
Federal Highway Administration

AMERICAN ASSOCIATION  
OF STATE HIGHWAY AND  
TRANSPORTATION OFFICIALS

**AASHIO**

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

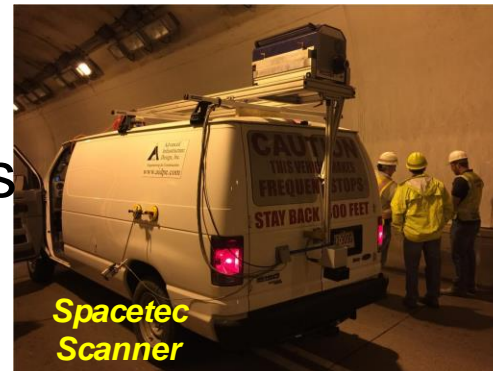
- AID Background
- Spacetec Technology
  - Equipment (Spacetec Scanner)
  - Capabilities
  - Software
- Testing of Pittsburgh Tunnels
- Post-processing/Analysis (Mapping & Database)
- Cost & other factors
- Limitations
- Conclusions

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## AID Background (staff of 30 in NJ and PA)

- NDT/E Assessment & Forensic Investigation
  - Tunnels
  - Bridge Decks
  - Bridge Substructures
  - Pavements

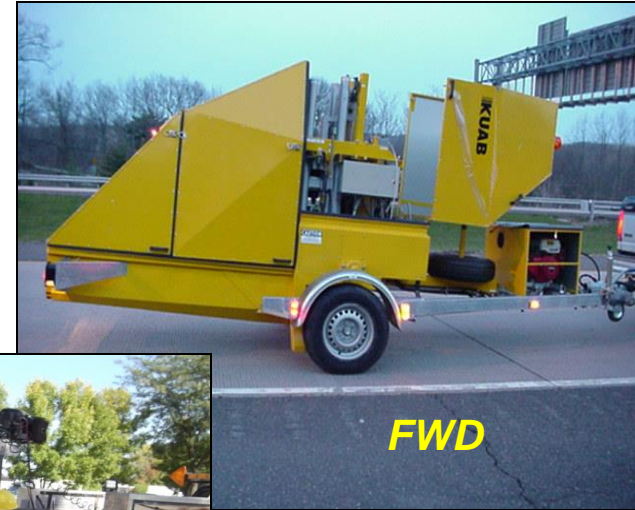


# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## AID Background

- Pavement Engineering
  - Testing
  - Design
  - LCCA
  - LCA



**FWD**



**DCP**



**Coring**

12.02

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## AID Background

- Asset Management
  - PMS Data Collection
  - LCMS
  - High Resolution Digital Video Collection
  - Pavement Treatment Recommendations



**AID Integrated Testing Vehicle (ITV)**

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## AID Background

- Utility Mapping  
(Multi-Channel GPR. Pin-point accuracy. Export to CAD. Export to Google Earth)



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

**This report (R06G) evaluated many available technologies and found Spacetec a mature and useful tool for tunnels.**



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The University of Texas at Austin

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Tunnels Scanned

Agency	Tunnel	# of Bores
MTA-NYCT	East River	2
MTA-NYCT	Newton Creek	2
Amtrak	East River	2
Amtrak	Hudson River	2
	<b>TOTAL</b>	<b>8</b>

**Railway/Subway  
Tunnels**

Agency	Tunnel	# of Bores
CBBT	Chesapeake Bay Bridge	1
MDTA	Baltimore Harbor	2
MDTA	Fort McHenry	4
SJTA	Brigantine	2
NJDOT	Rt. 29	2
NJ Transit	Roseville	1
PennDOT	Armstrong & Liberty	2
	<b>TOTAL</b>	<b>14</b>

**Vehicular  
Tunnels**



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Spacetec Technology

- Scanner
  - 300 Hz Mirror Speed
  - 360 ° View Angle
  - Highest Resolution:
    - 1.25 mph
    - 10,000 points/rotation
    - 0.3 mm Crack Size
    - 16 Ft. Optimal Distance



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Spacetec Technology

- Capabilities

- Visual Image

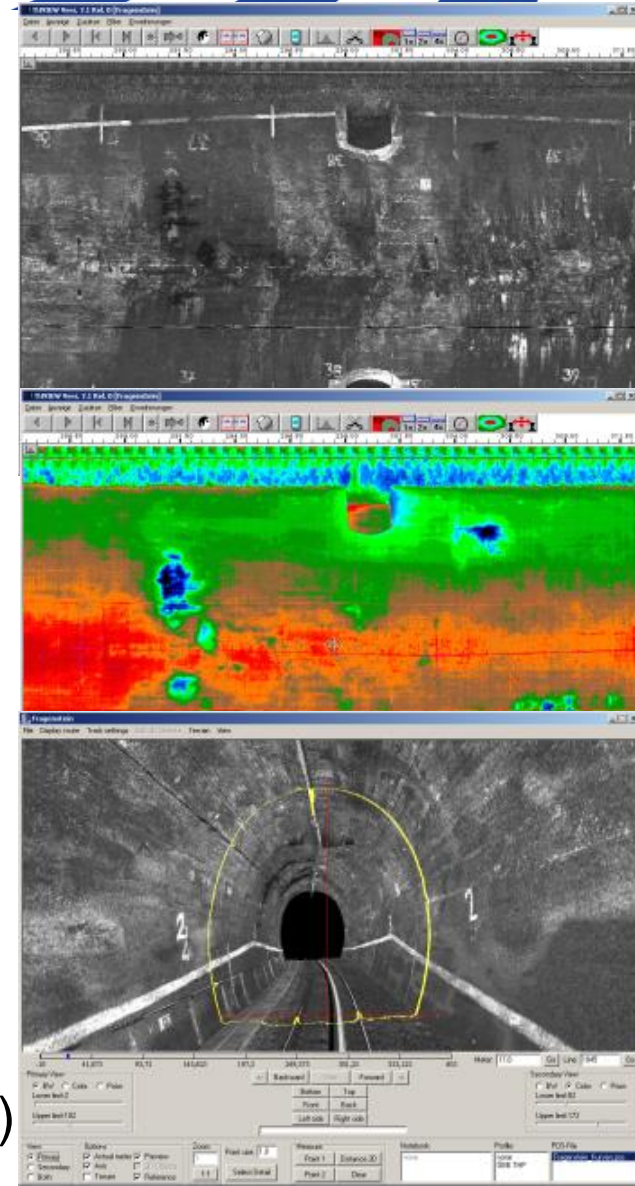
- ID all distresses (tied to Station)
    - Features (asset management)

- Thermal Image

- All moisture intrusions (tied to station)
    - Debonding (possible)

- Profile

- Profile (xyz)
    - Clearance
    - Close inspection of damage (zoom, 3D)



# SHRP2 R06G Pittsburgh Tunnels

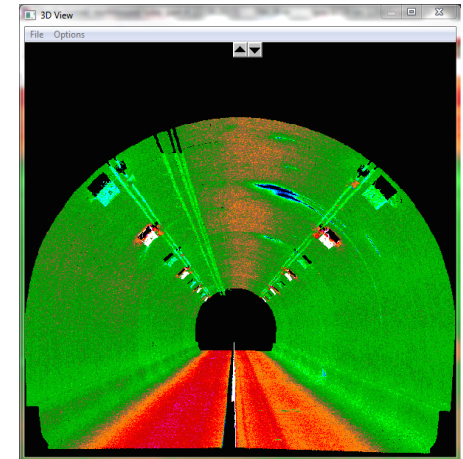
*Advanced Infrastructure Design (AID)*

## Spacetec Technology

- **Software** (options to purchase license. But not necessary)
  - TuView
    - View/print mapped data
    - Export to CAD
  - TuDrive
    - Virtual drive thru
    - View and measure analyzed data
  - Tunnel-Inspector
    - Comprehensive
    - Mapping/statistical/printing



Visual Channel



Thermal Channel

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Testing of Pittsburgh Tunnels

### Liberty Tunnels



### Armstrong Tunnels



#### **Liberty Tunnels: only NB**

Two tubes, horseshoe profiles, two-12 ft lanes. Only NB tube tested

Appx. length: 5,900 ft.

28.6 ft wide, max. height of 20.75 ft

Concrete lining, 24 in. thick

#### **Armstrong Tunnels: only NB**

Two tubes, horseshoe profiles, two 12 ft lanes. Only NB tube tested

Appx. length: 1,300 ft.

Tile lining on the walls, concrete on the ceiling

# SHRP2 R06G Pittsburgh Tunnels

Advanced Infrastructure Design (AID)

## Liberty NB Tube



Spacetec Scanner



PSPA

### Spacetec Scanner:

Full coverage.

Only NB tube tested.

Testing Speed: 1.25 mph (full coverage)

Visual, 3D and Thermal images

Test date: 09/21/15

### Portable Seismic Property Analyzer (PSPA):

Limited coverage. Point by point testing.

Area of 200 ft. by 14 ft. tested (NB Tube).

Testing Speed: 1 min/point. 200 points tested

Dynamic modulus and resonant frequency (IE)

Test date: 11/05/15

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Armstrong NB Tube



### **Spacetec Scanner:**

Full coverage.

Only NB tube tested.

Testing Speed: 1.2 mph (full coverage)

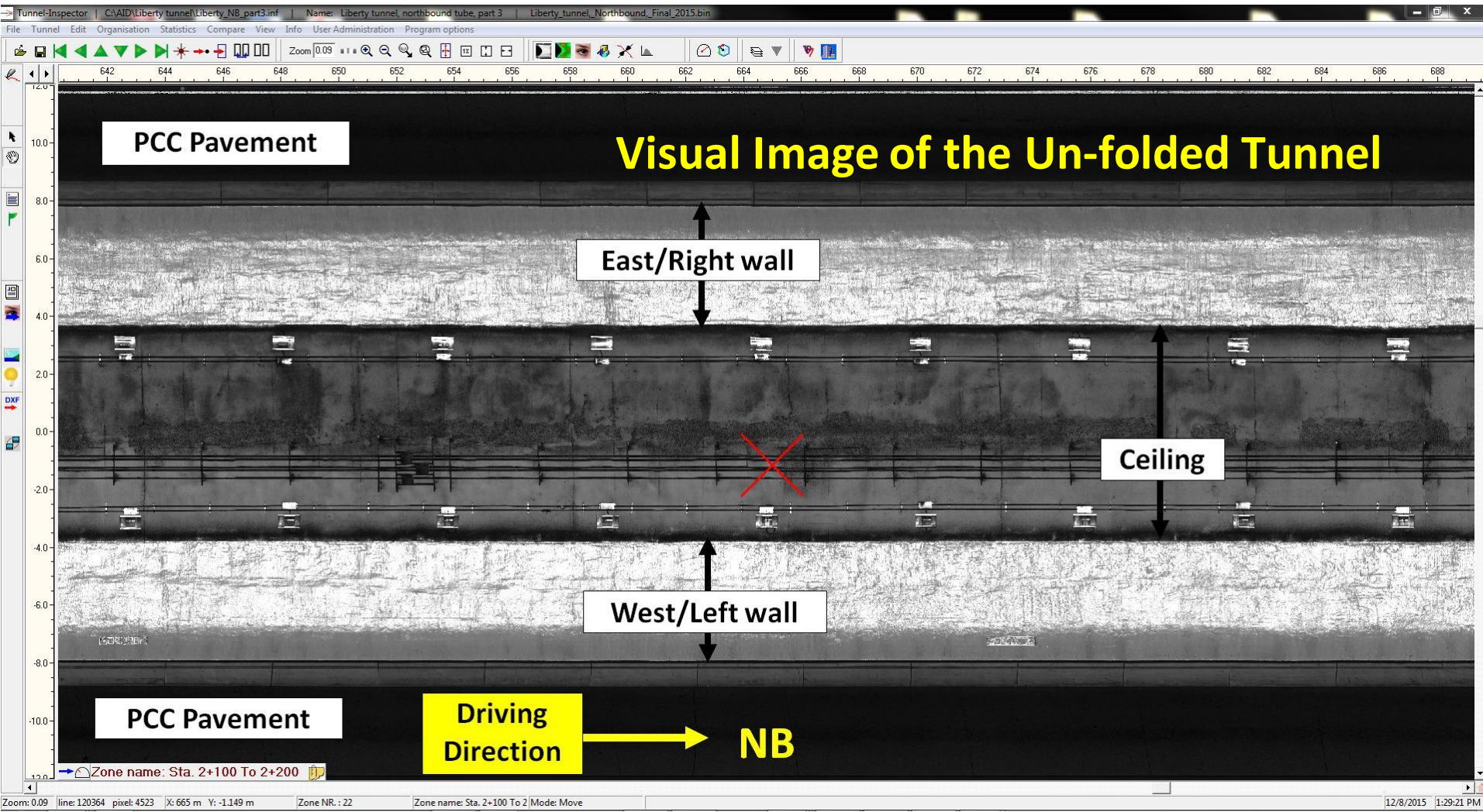
Visual, 3D and Thermal images

Test date: 09/21/15

# SHRP2 R06G Pittsburgh Tunnels

Advanced Infrastructure Design (AID)

## Post-processing/Analysis (Spacetec)



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Tunnel Features to be “Mapped”

### Visual Features

- Cracks < 1/8 in.
- Cracks > 1/8 in.
- Spalls
- Missing tiles
- Damage to ceiling/tiles
- Moisture
- Efflorescence
- Stalactites
- Visual Condition
- Other features/Elements

### Thermal Features

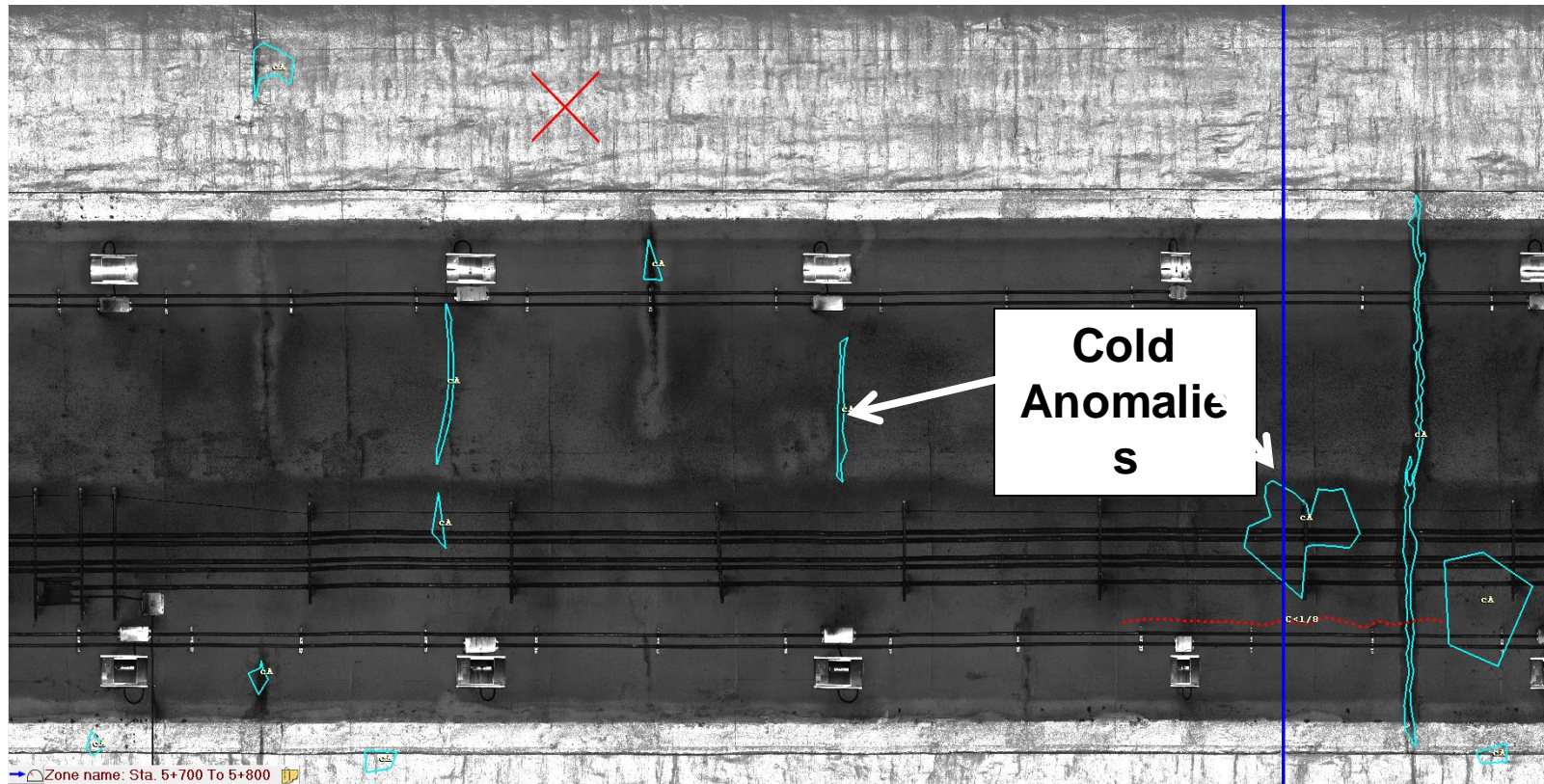
- Moisture (Cold Anomaly)
- Water intrusion (Cold Anomaly)
- Delamination & Debonding (Cold/Warm Anomaly)



# SHRP2 R06G Pittsburgh Tunnels

Advanced Infrastructure Design (AID)

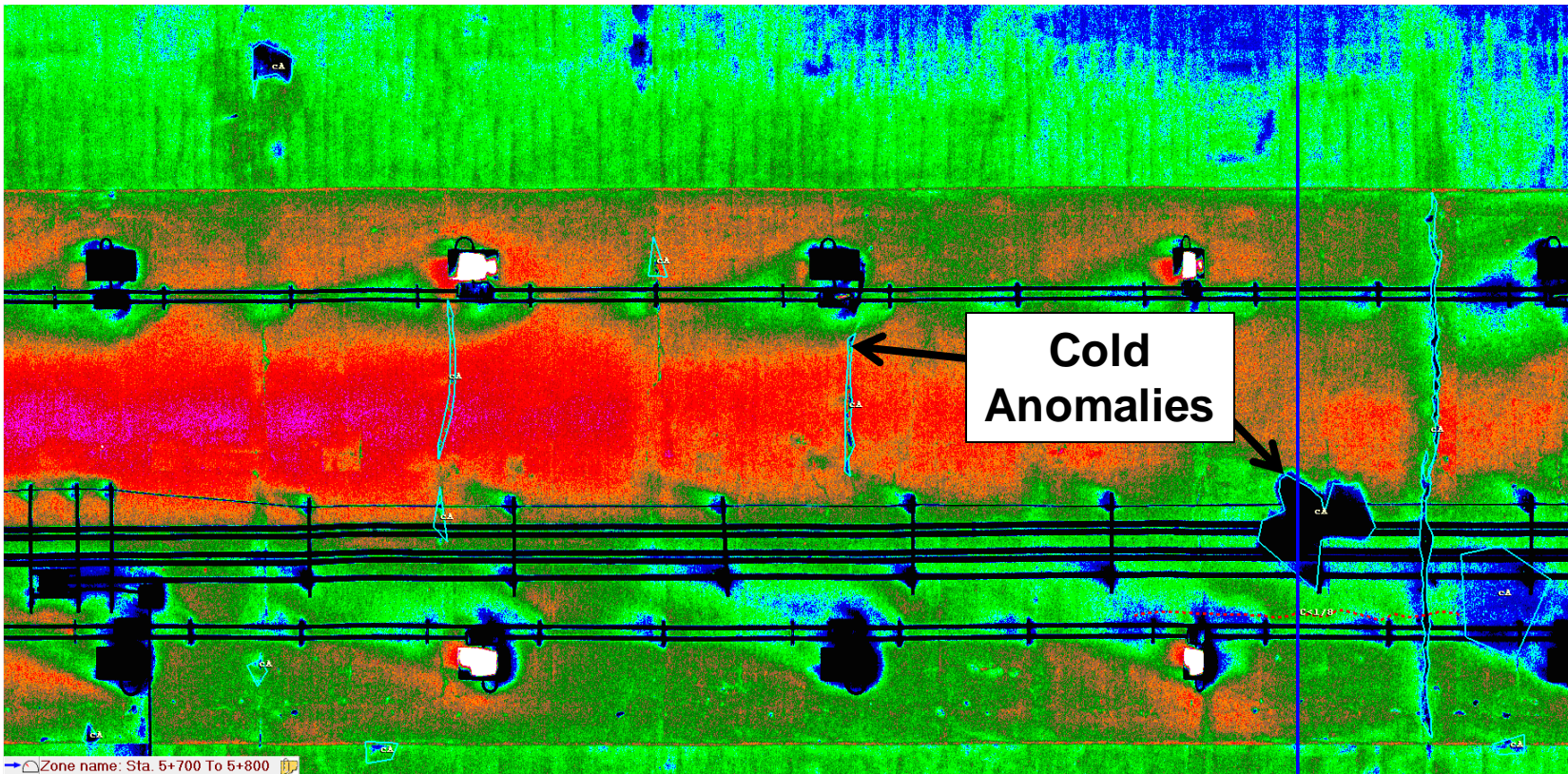
## Visual Profile (Spacetec)



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

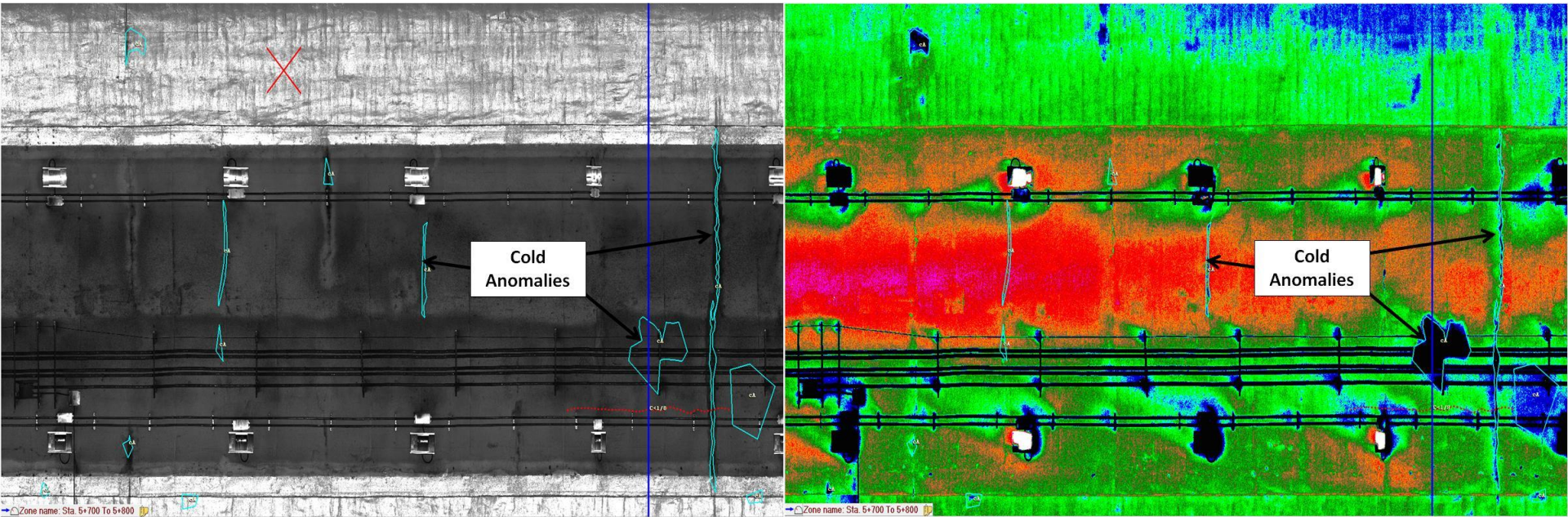
## Thermal Profile (Spacetec)



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Post-processing/Analysis (Spacetec)

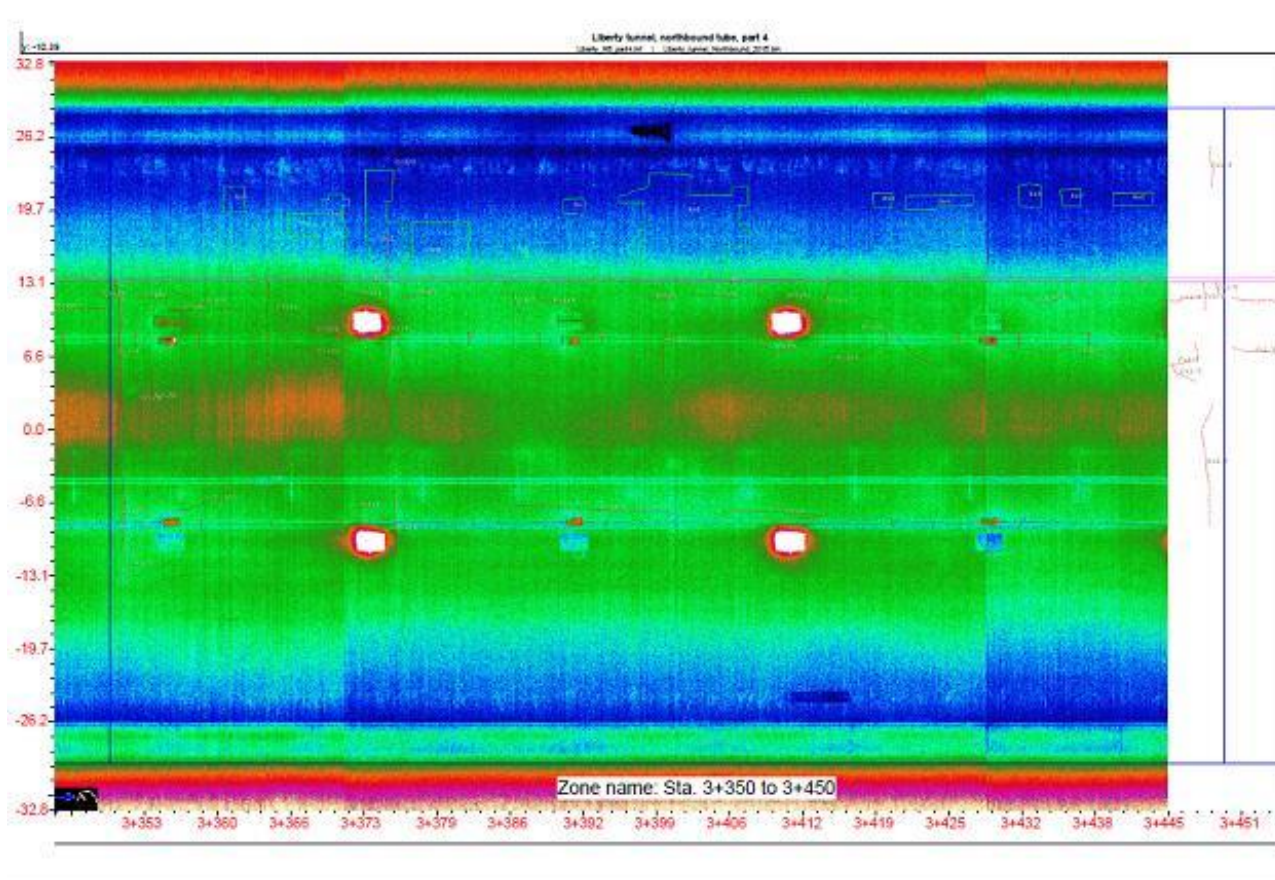


**Visual/Thermal (Side-by-Side View)**

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Post-processing/Analysis (Spacetec)

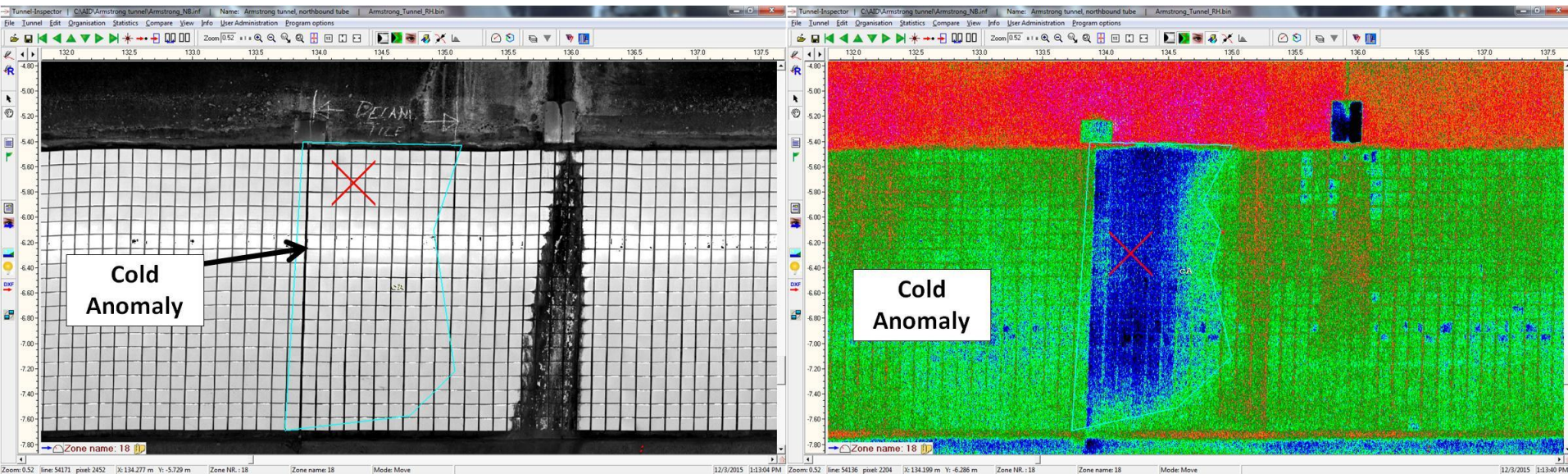


**Liberty Tube:** Debonding Results Not Conclusive  
(not enough thermal gradient)

# SHRP2 R06G Pittsburgh Tunnels

Advanced Infrastructure Design (AID)

## Post-processing/Analysis (Spacetec)



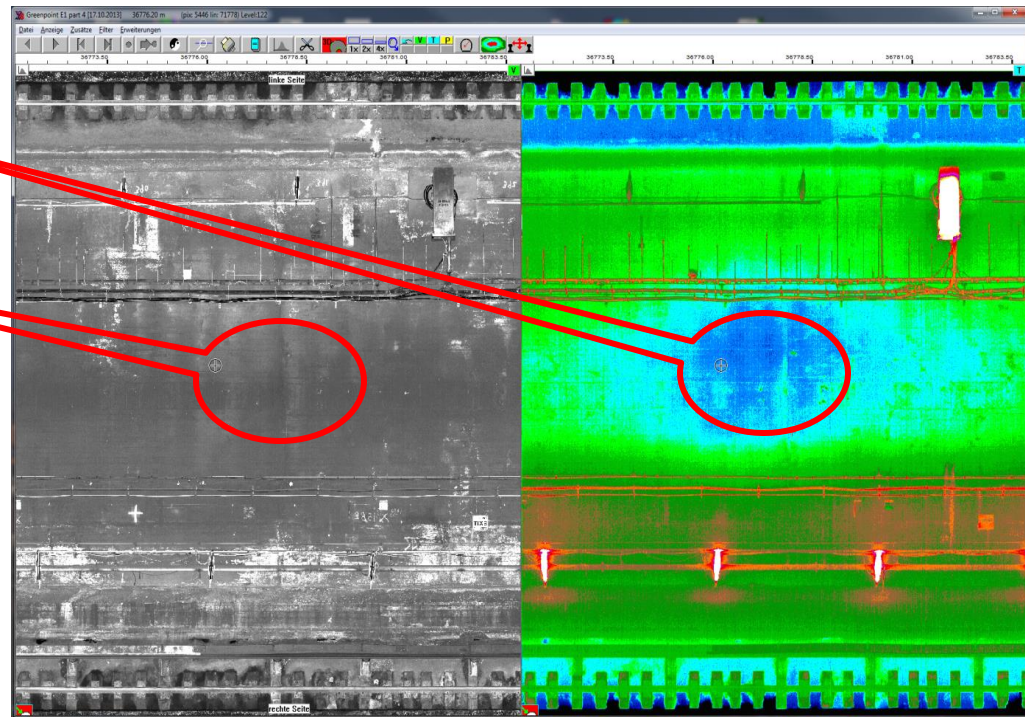
**Armstrong Tube: Debonding Results Successful.**  
(confirmed with sounding)

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Sample Results (Spacetec)

Thermal data indicates presence of moisture in the ceiling while no such indication is observed in the Visual data

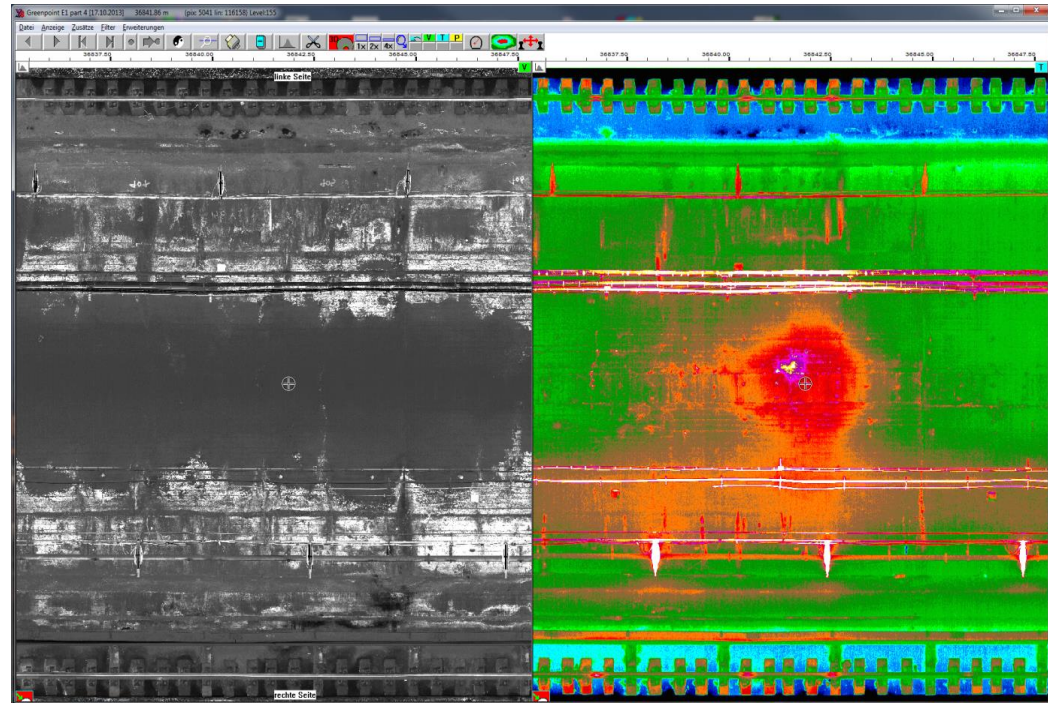


# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Sample Results (Spacetec)

Thermal data indicates a heat source behind the ceiling while no such indication is observed in the Visual data

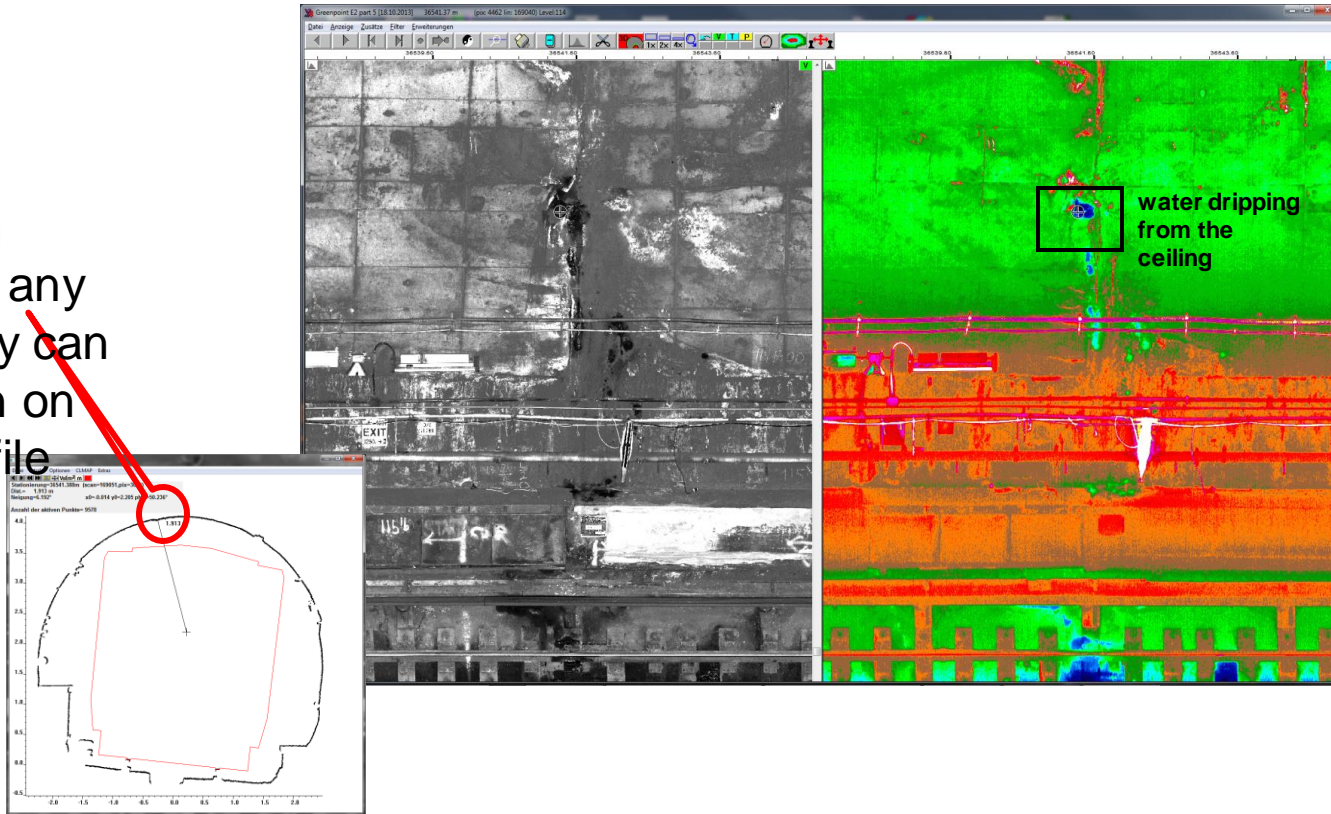


# SHRP2 R06G Pittsburgh Tunnels

Advanced Infrastructure Design (AID)

## Sample Results (Spacetec)

Exact location (xyz) of any anomaly can be seen on the profile data

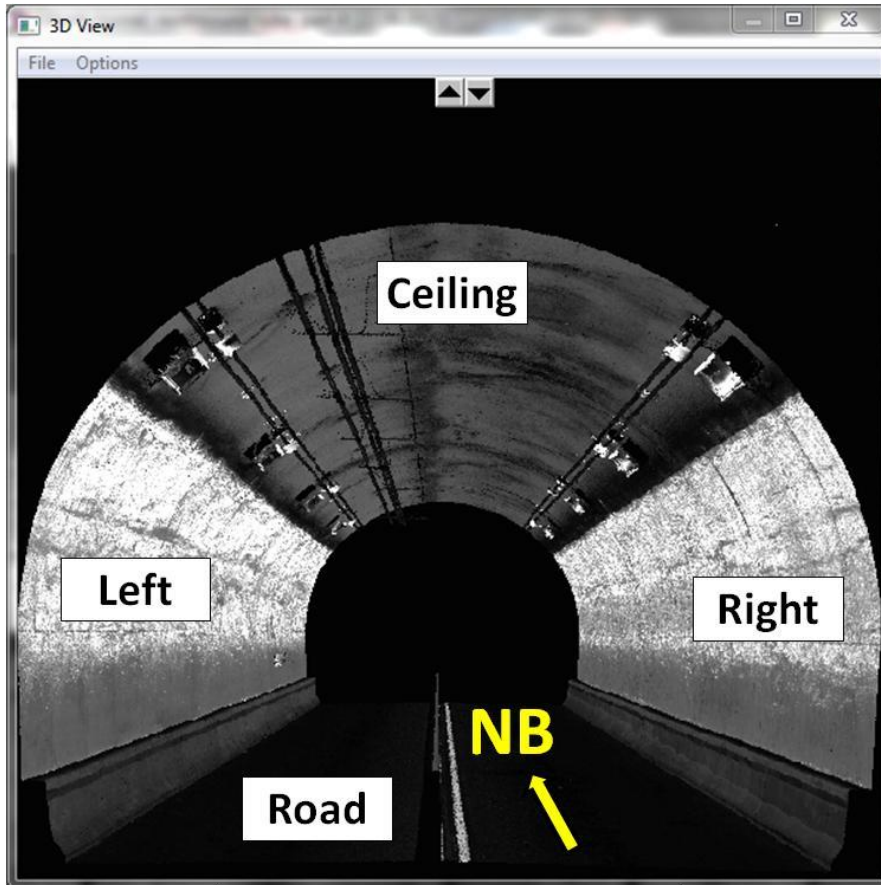




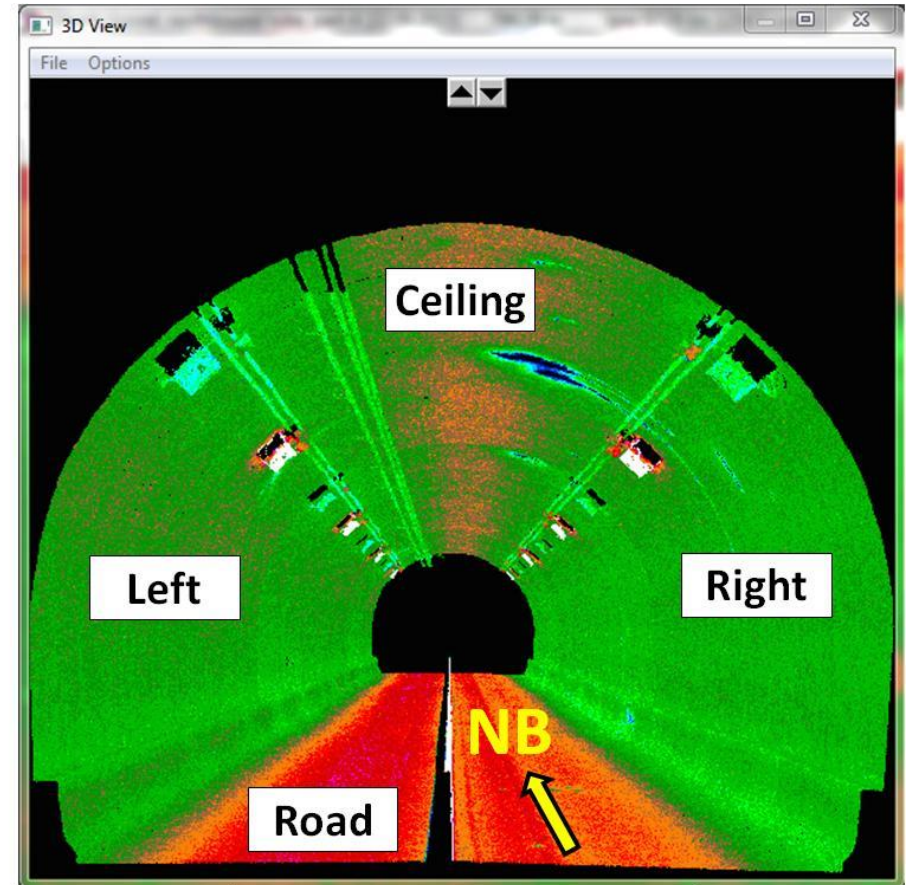
# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Post-processing/Analysis (Spacetec)



Visual Channel

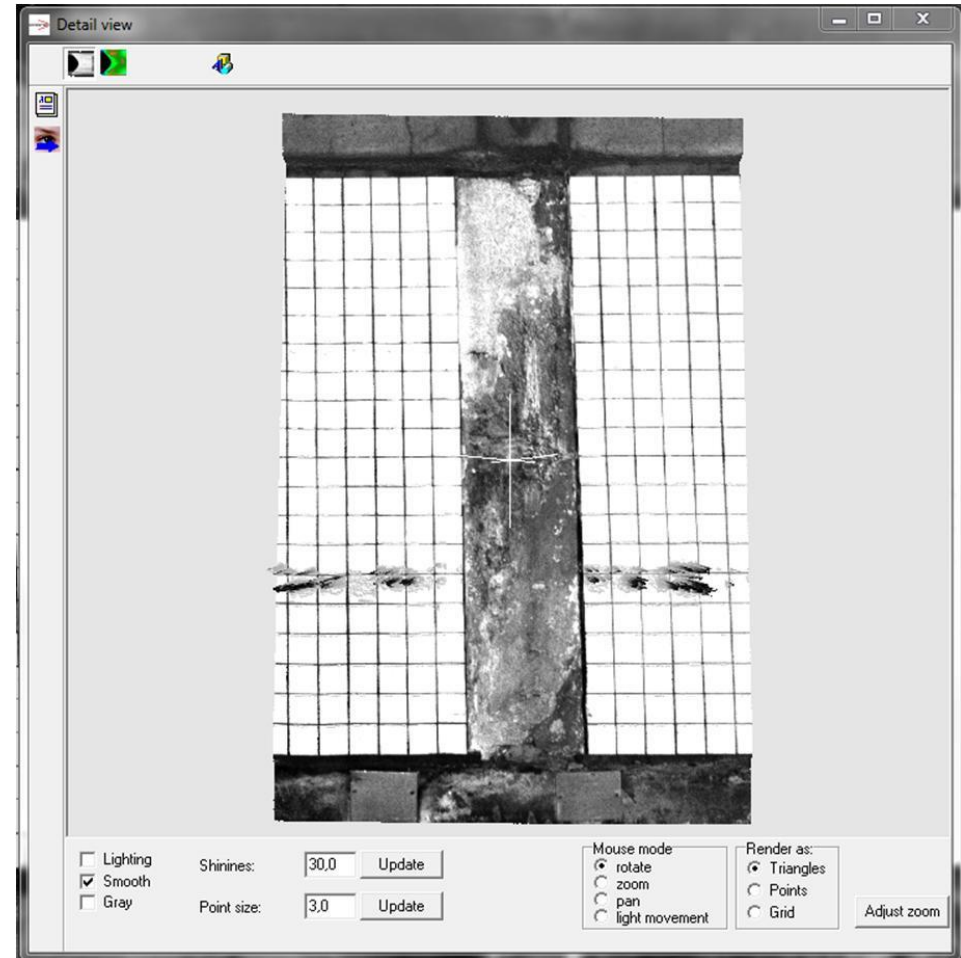
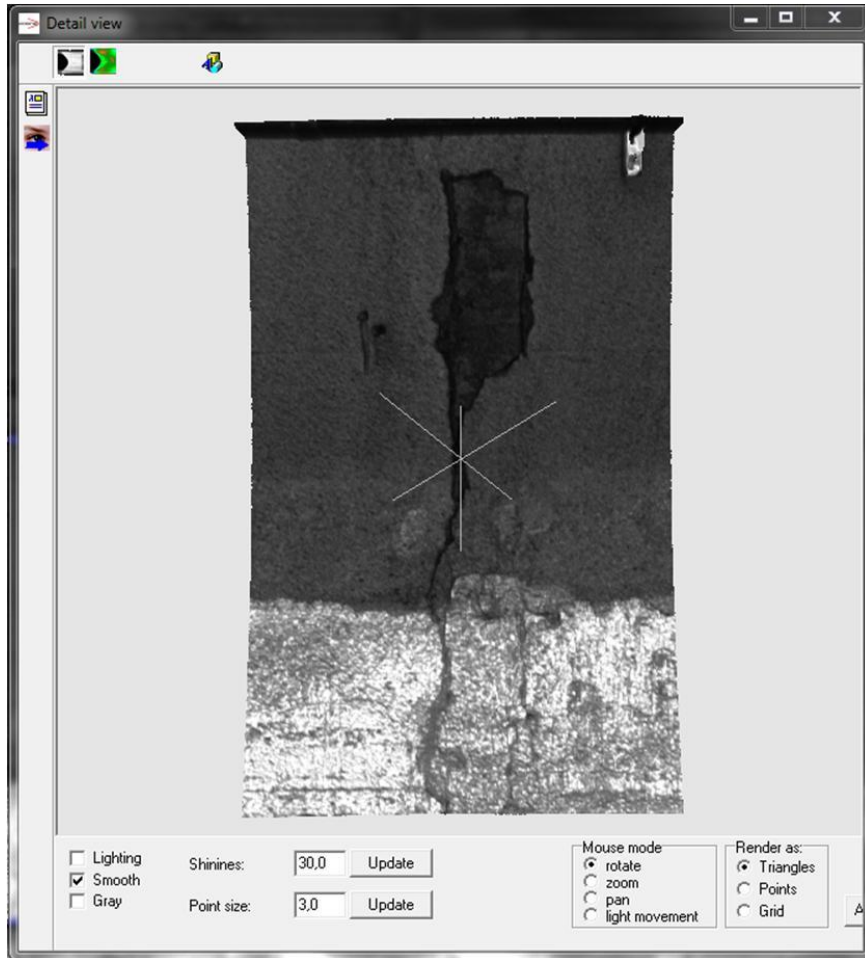


Thermal Channel

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Post-processing/Analysis (Spacetec)

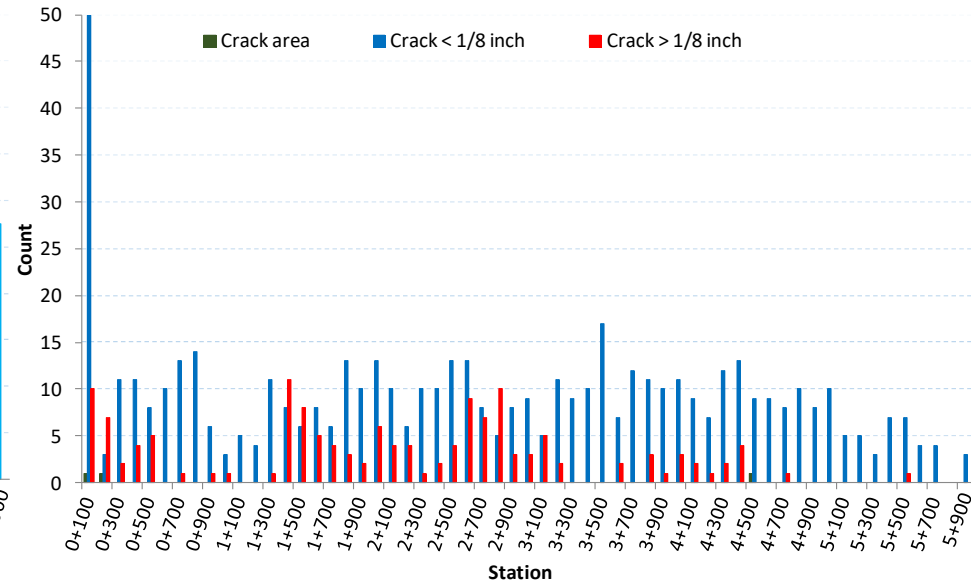
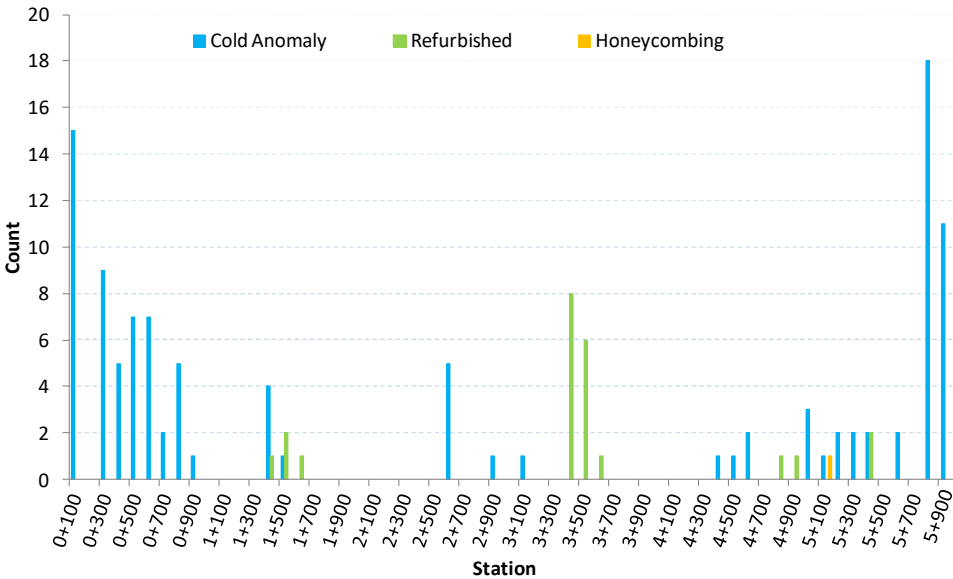


**Zoom & 3D-View Capability**

# SHRP2 R06G Pittsburgh Tunnels

Advanced Infrastructure Design (AID)

## Reporting (Spacetec)

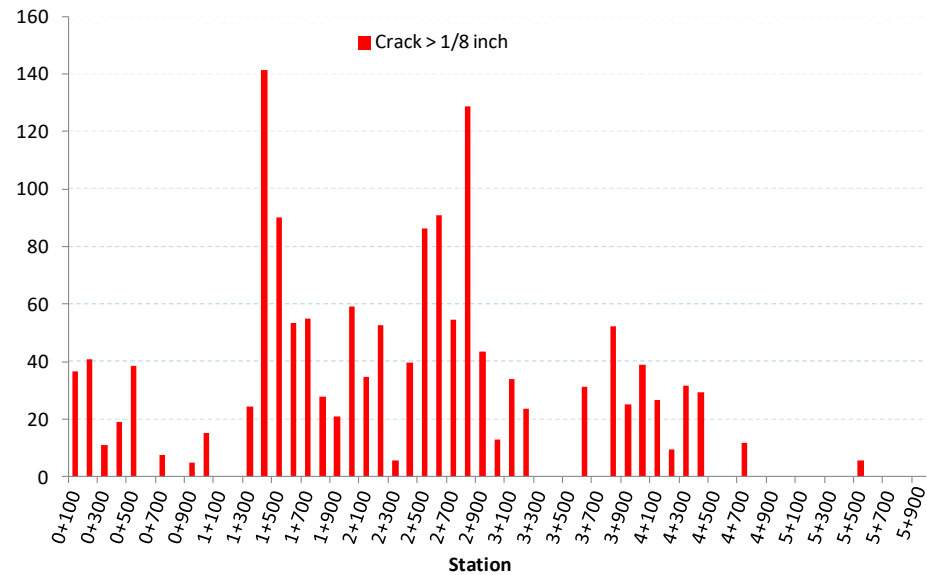
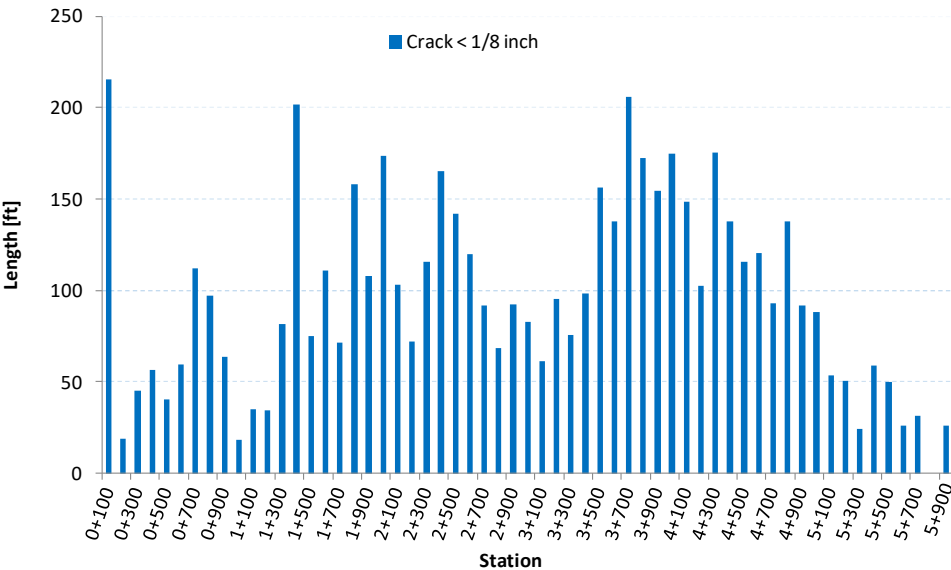


Summary Results in Graphical & Tabular Formats

# SHRP2 R06G Pittsburgh Tunnels

Advanced Infrastructure Design (AID)

## Reporting (Spacetec)



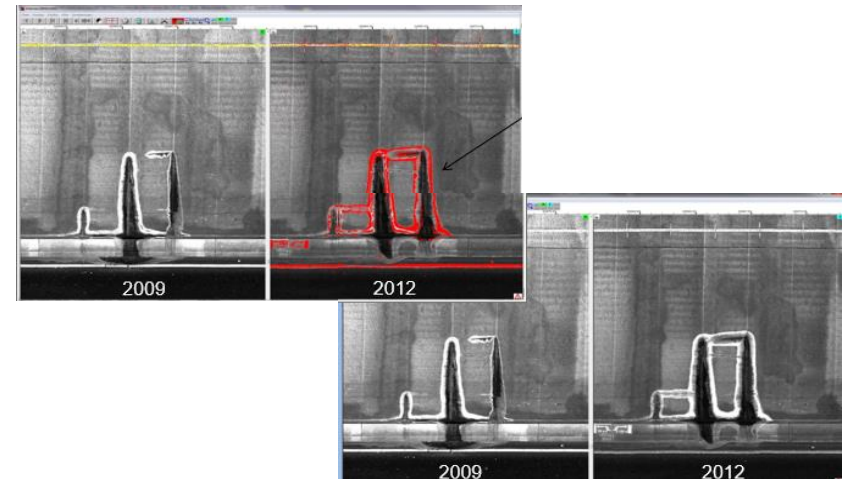
Summary Results in Graphical & Tabular Formats

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Asset Management Application (Spacetec)

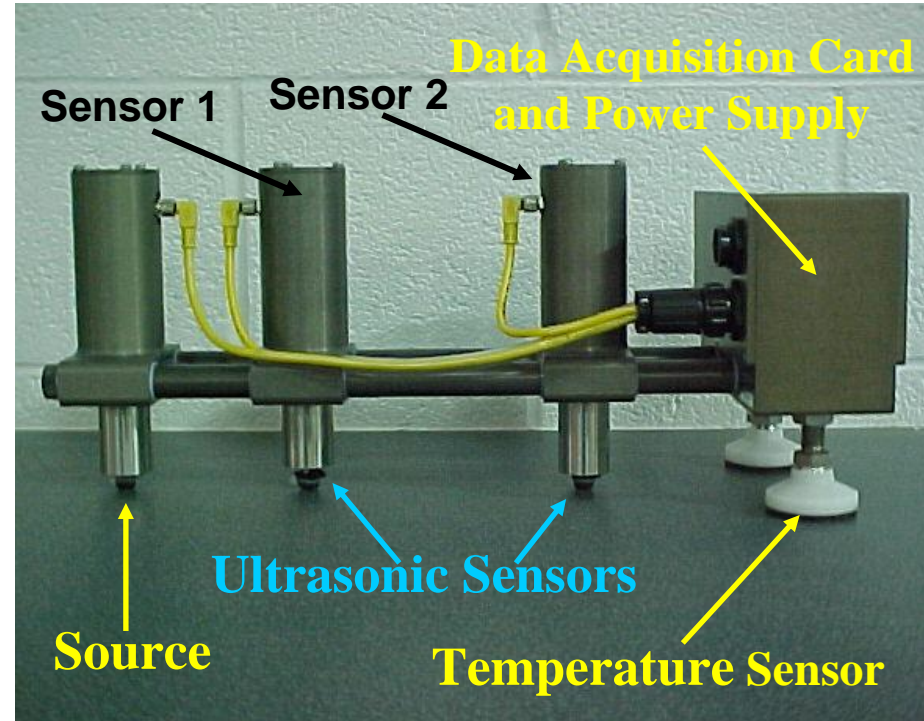
- See and Measure all features in the tunnel including Signs, Mechanical, Electrical and Lighting Systems
- See and measure changes of any particular feature in consecutive inspections of a tunnel (via an automatic algorithm that highlights the change)



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Post-processing/Analysis (PSPA)



### **PSPA conducts two Analyses:**

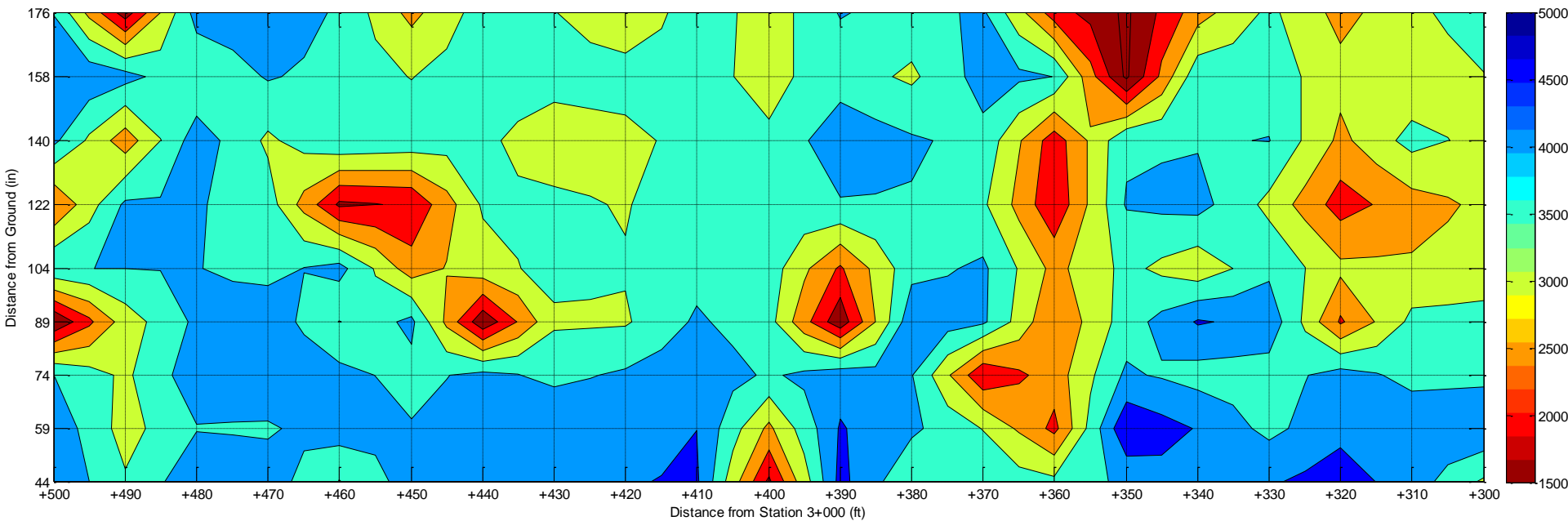
Modulus analysis: determines the variation in modulus with depth of the exposed layer in the field (USW Method, ASTM C1383, ASTM C215)

Impact Echo (IE) tests: To obtain the frequency spectrum (as per ASTM C1383)

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Post-processing/Analysis (PSPA)



### Modulus Results:

Dynamic/seismic modulus measured with PSPA can be approximately correlated with concrete strength.

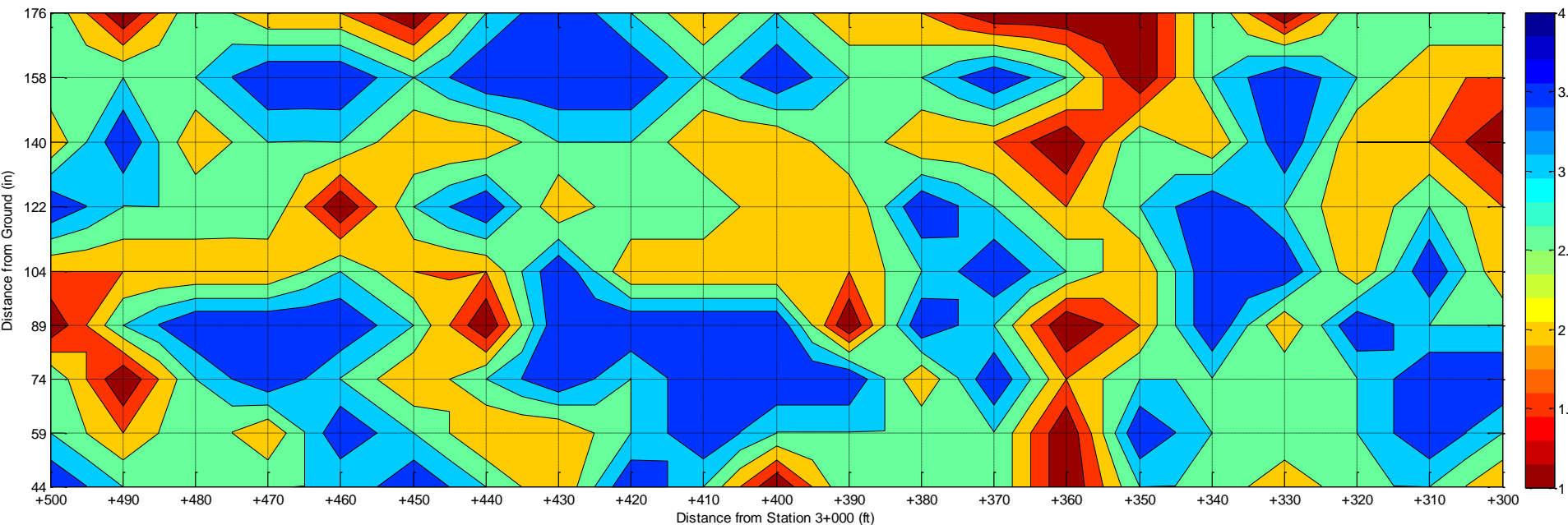
In general, larger modulus corresponds to larger strength.

A correlation can be obtained if compressive strength data available

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Post-processing/Analysis (PSPA)



### IE Results:

Frequency domain of the seismic waves is analyzed.

Larger variations from the dominant frequency indicate delamination/debonding

Intact vs. Debonded locations can be obtained.



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Cost

- AID is Spacetec's representative and service provider in North America.
- AID does not own the system yet!
- Scanners need to get shipped to US
- Cost depends on scan length (SL):
  - Most tubes need to be scanned only once (distance between scanner and any point <16')
  - 3.8 \$/SL to 12 \$/SL

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Limitations

- Debonding is not full-proof! It can be detected only if sufficient temperature gradient exists (between debonded areas and the adjacent areas) at the time of scanning.
- Probes can be inserted into tunnel walls to determine the most optimum time, however:
  - The ideal time for scanning may not correspond to Authority's desired time for closure
  - Requires additional closure (for probe installation)
  - Costs more!

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Conclusions

- A mature/mobile system (SHRP2 study)
- A complete survey of all distresses (walls and ceiling)
- A complete survey of all locations with moisture intrusion
- An excellent tool for asset management
- See growth of distresses over time
- Tie profile to survey base-line
- Debonding, if sufficient temperature gradient exists at time of scanning

# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Drive-Thru Simulation (Visual)



# SHRP2 R06G Pittsburgh Tunnels

*Advanced Infrastructure Design (AID)*

## Drive-Thru Simulation (Thermal)

