The Role of Technology in Managing Aging Highway Bridges

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The Role of Technology

- Objective
  - To make the case that quantitative data is essential for adequate management of the multi-trillion dollars worth of assets we refer to as the highway infrastructure.

The Role of Technology

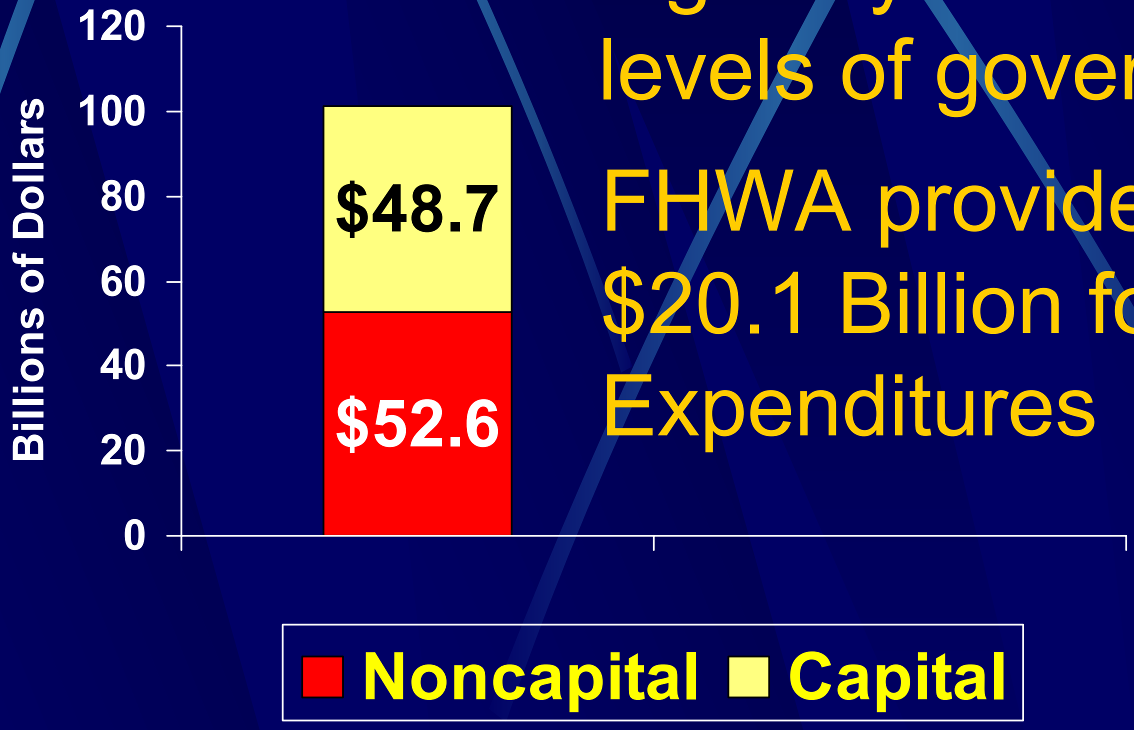
Overview

- Present background on infrastructure management in the United States
- Present a few examples of how technology has been used in infrastructure management
- Discuss future directions and research needs for infrastructure management and the role of technology

Some National Highway Statistics

- 3.95 million miles of public roads
- 8.3 million lane miles
- 2.5 trillion vehicles miles in 1997
- 593,000 highway bridges
- 3.2 billion square feet of bridge deck
- 3 billion bridge crossing per day

Total Highway Expenditures



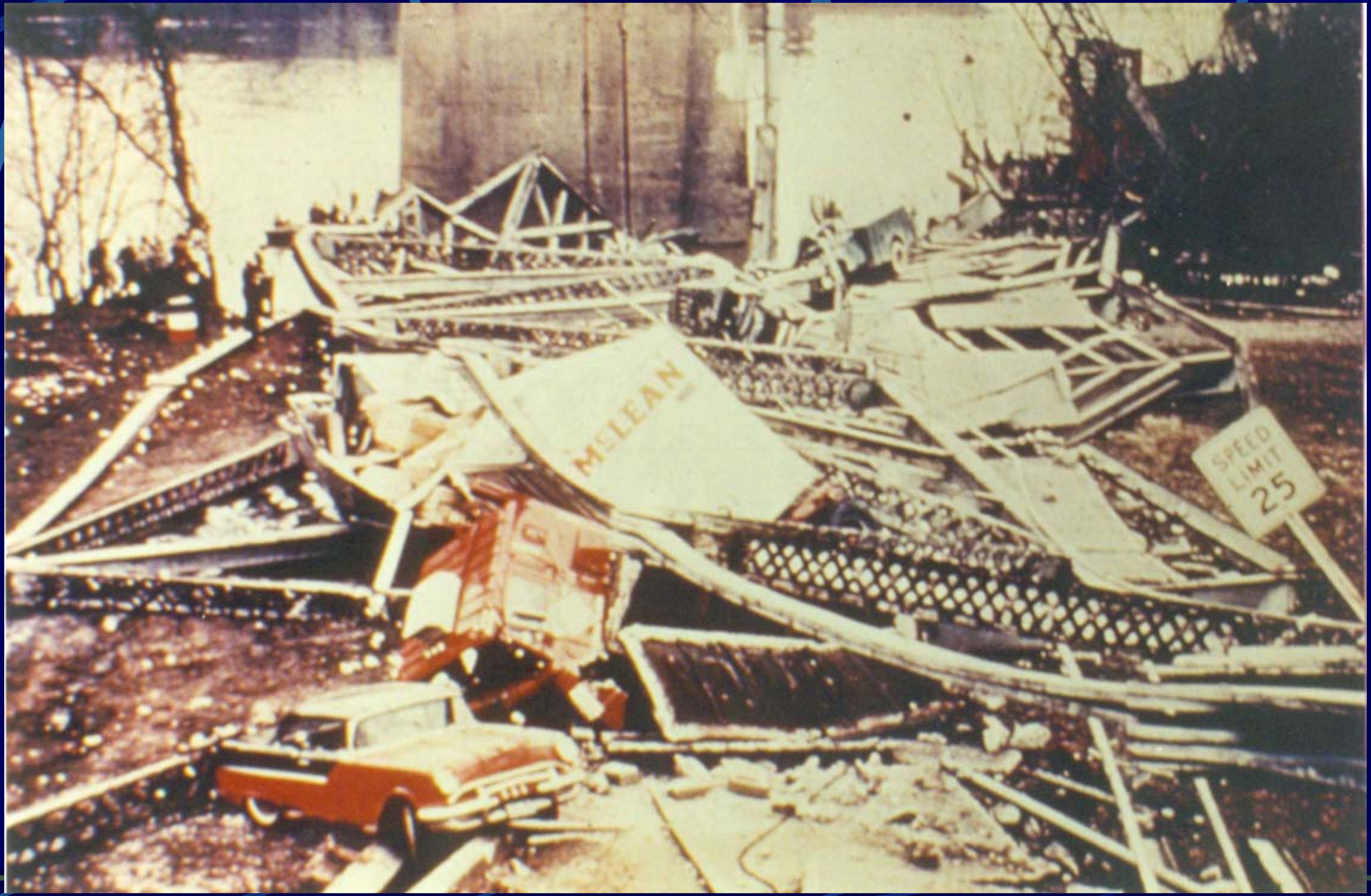
$101.3 Billion expended on highways in 1997 by all levels of government

FHWA provided $20.1 Billion for Capital Expenditures

The Role of Technology

- Bridge management as example
  - History of national bridge program
  - Current bridge management practice
  - Limitations of BMS
  - Summary of recent R&D to address limitations
  - The technology in the management of bridges

Silver Bridge Collapse December,1967 46 Fatalities



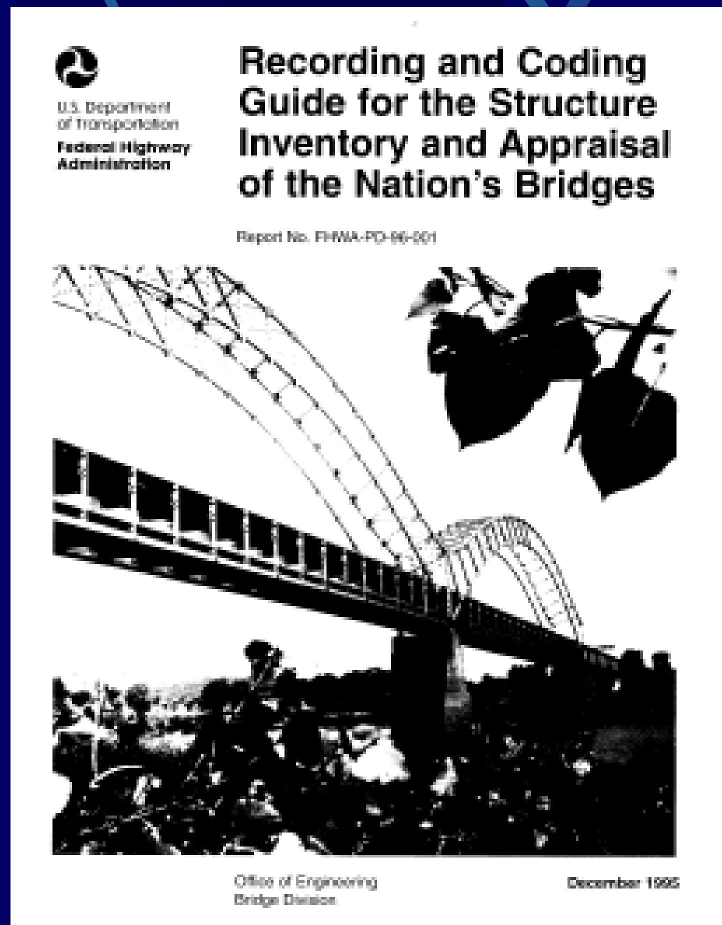
FHWA Bridge Program

- NBI Program began in 1971
- Establishment of National Bridge Inspection Program and National Bridge Inventory
- Focused on Elimination of Deficient Bridges

National Bridge Inspection Program

- National Bridge Inspection Program
  - Bi-annual Inspections
  - 593,000 bridges
  - 116 fields of data collected
  - Inspectors provide condition and appraisal ratings
- Eligibility for HBRRP determined by deficiency

NBI Coding Guide



NBI Ratings
(Numeric Code 0 to 9)

- Condition Ratings
  - Superstructure
  - Substructure
  - Deck
  - Culverts
- Appraisal Ratings
  - Waterway Adequacy (Frequency of overtopping)
  - Structural Evaluation (Load rating)
  - Approach Alignment
  - Deck Geometry (Roadway Width)
  - Underclearances (Vertical and Lateral)

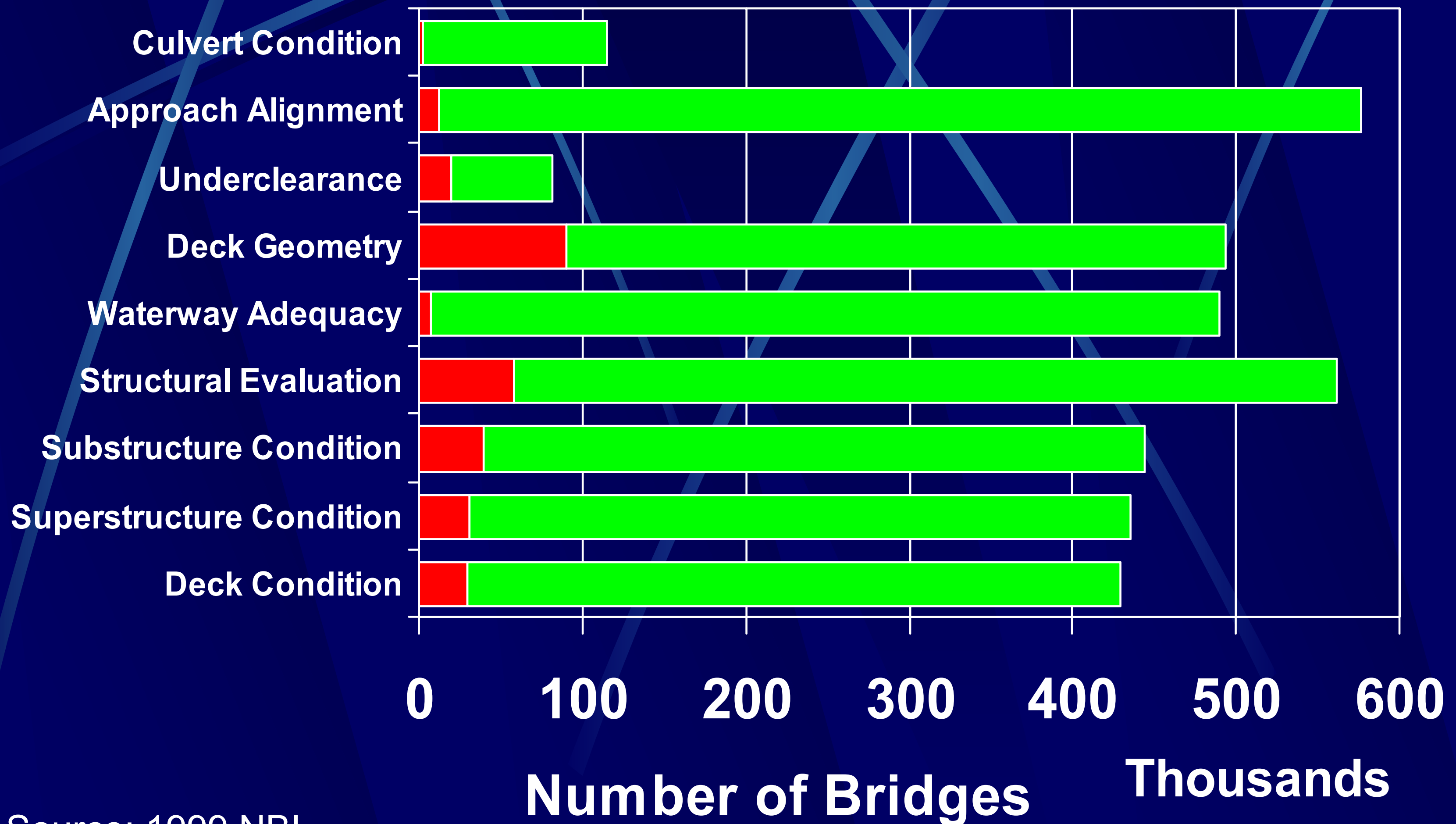
NBI Condition Ratings

- 9 - EXCELLENT CONDITION
- 8 - VERY GOOD CONDITION
- 7 - GOOD CONDITION
- 6 - SATISFACTORY CONDITION
- 5 - FAIR CONDITION
- 4 - POOR CONDITION
- 3 - SERIOUS CONDITION
- 2 - CRITICAL CONDITION
- 1 - "IMMINENT" FAILURE CONDITION
- 0 - FAILED CONDITION.

NBI Appraisal Ratings

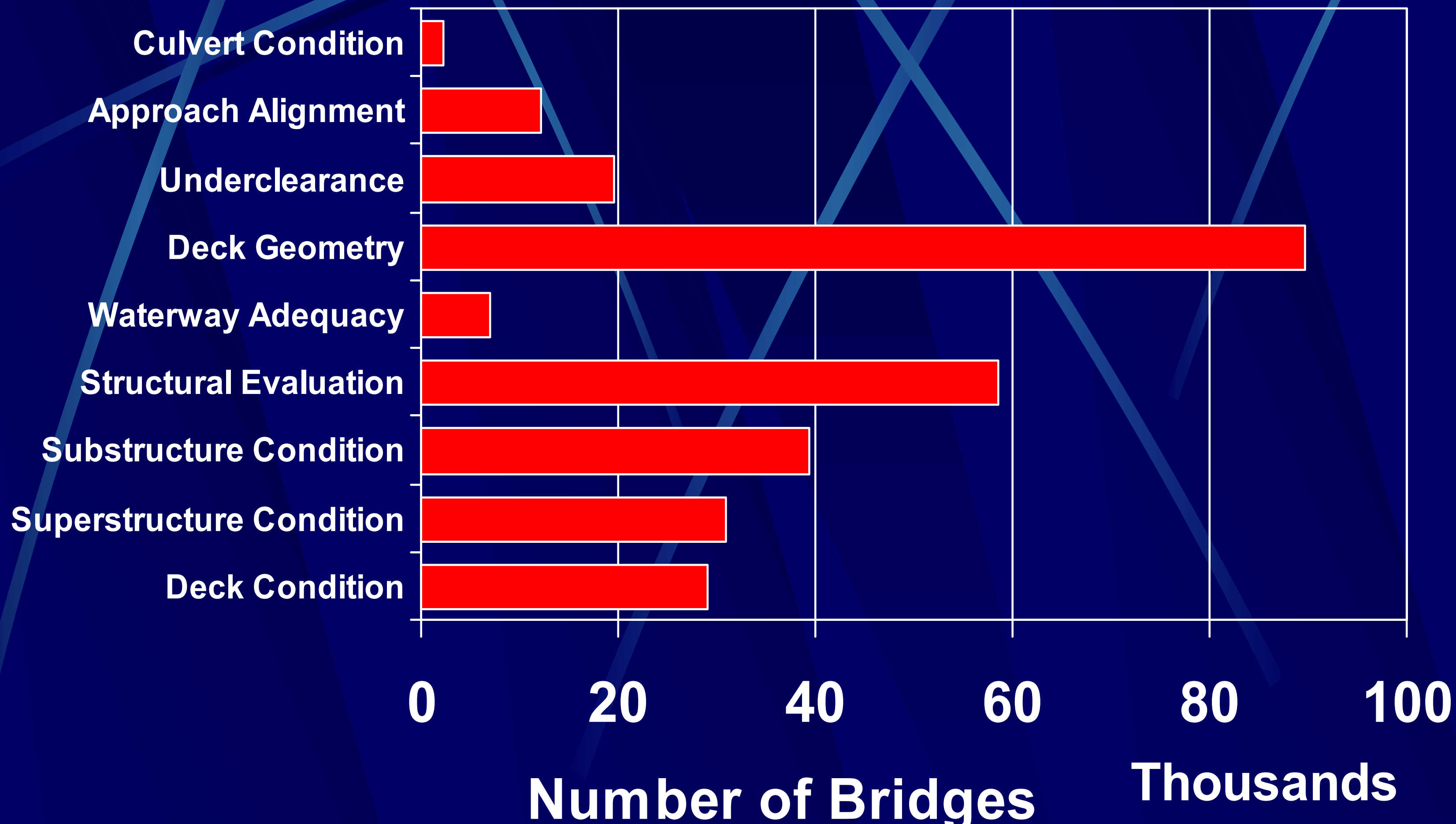
- 9 - Superior to present desirable criteria
- 8 - Equal to present desirable criteria
- 7 - Better than present minimum criteria
- 6 - Equal to present minimum criteria
- 5 - Somewhat better than minimum adequacy to tolerate being left in place as is
- 4 - Meets minimum tolerable limits to be left in place as is
- 3 - Basically intolerable requiring high priority of corrective action
- 2 - Basically intolerable requiring high priority of replacement
- 1 - not used
- 0 - Bridge closed

NBI Bridge Deficiencies



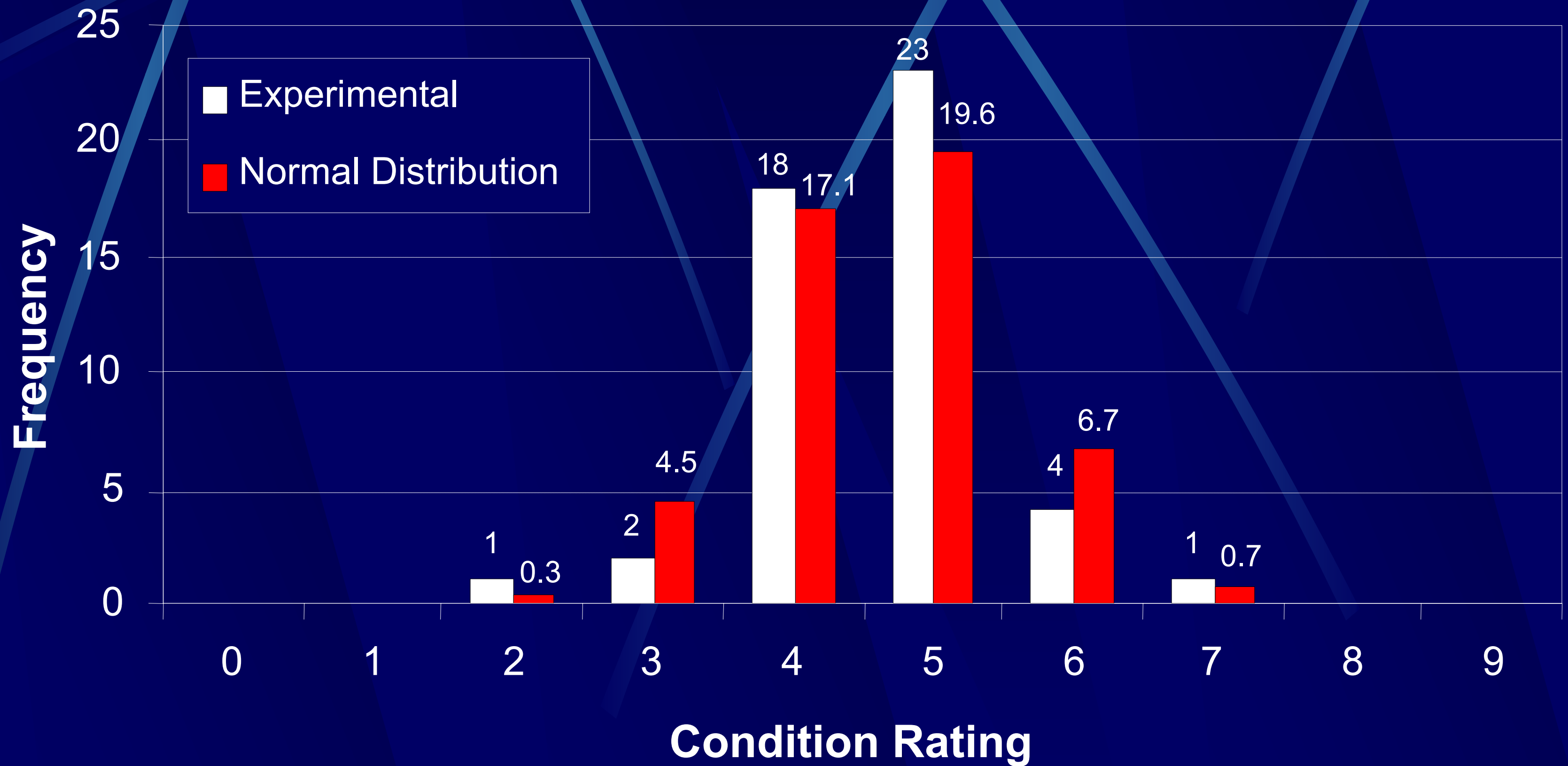
Source: 1999 NBI

NBI Deficiencies



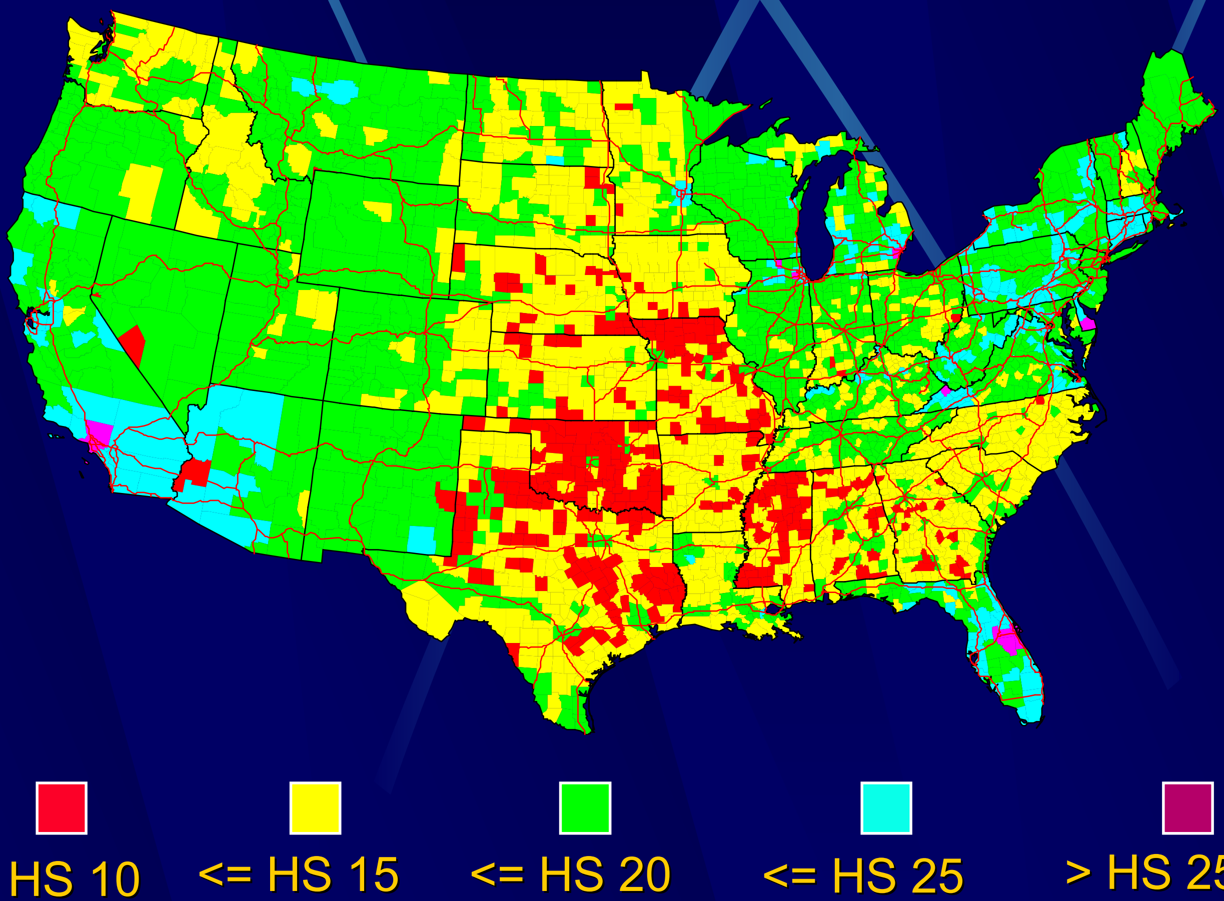
Source: 1999 NBI

Reliability of Condition Rating?



NBI Data

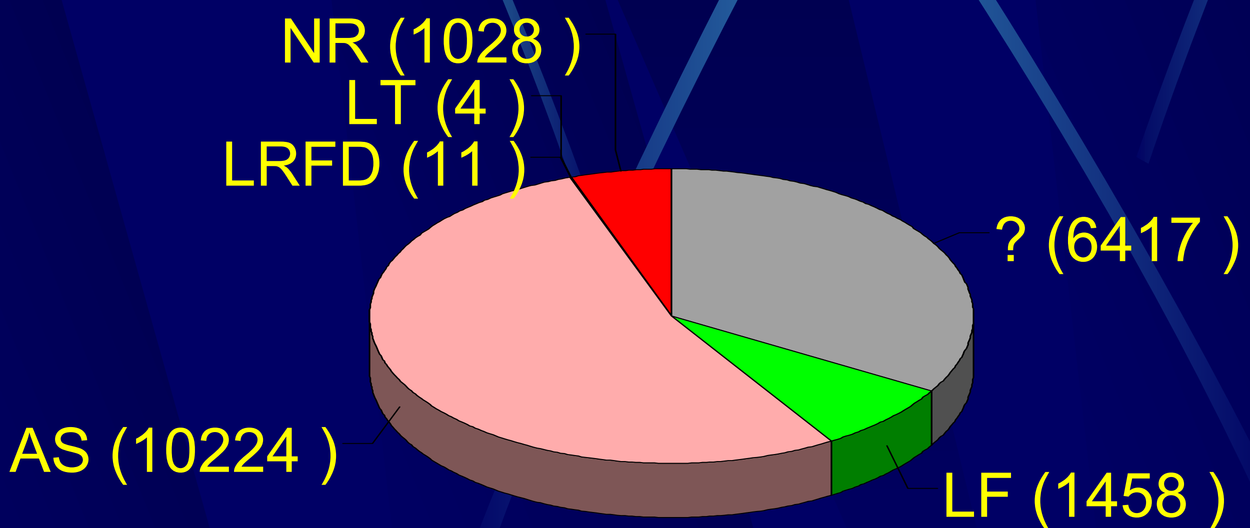
Average HS Inventory Rating



Reliability of Load Ratings?

1999 SD Bridges (SA Only)

Method used to Determine IR



Shortcomings of NBIP

- NBIP adequate for administration of national HBRRP program
- Inadequate for bridge performance measurement
- Most states augment NBI data
- Condition Ratings based on subjective visual inspection
- Not adequate for owner level bridge management

Element Level Inspection

- PONTIS
  - Element level inspections
  - More discretized condition state data
  - More quantitative condition state data
  - Provides network (population) level decision support
- Significant advance

Typical Condition State Definition Open Steel Stringer (Painted)

- Condition State 1
  - Sound paint, no corrosion, no section loss
- Condition State 2
  - Early distress of paint, little or no corrosion, no section loss
- Condition State 3
  - Paint not effective, surface rust, no section loss
- Condition State 4
  - Paint failed, surface pitting, section loss incidental
- Condition State 5
  - Paint failed, advanced corrosion, section loss sufficient to warrant analysis
- Quantity in each state recorded

Limitations of Element Inspections

- Condition states still based solely upon visual inspection
- Invisible deterioration, damage or distress not detected or measured
- Operational performance not measured
- Vulnerability and reliability not adequately considered

Detection and measurement needs

- Damage
  - Impact
  - Overload
  - Scour
  - Seismic
  - Fracture
  - Settlement
  - Loss of section
  - Inoperative bearings
  - Movement
  - Lack of movement
  - Cracking
- Deterioration
  - Corrosion
  - Fatigue
  - Water absorption
  - Loss of prestress
  - Unintended structural behavior

Detection and measurement needs

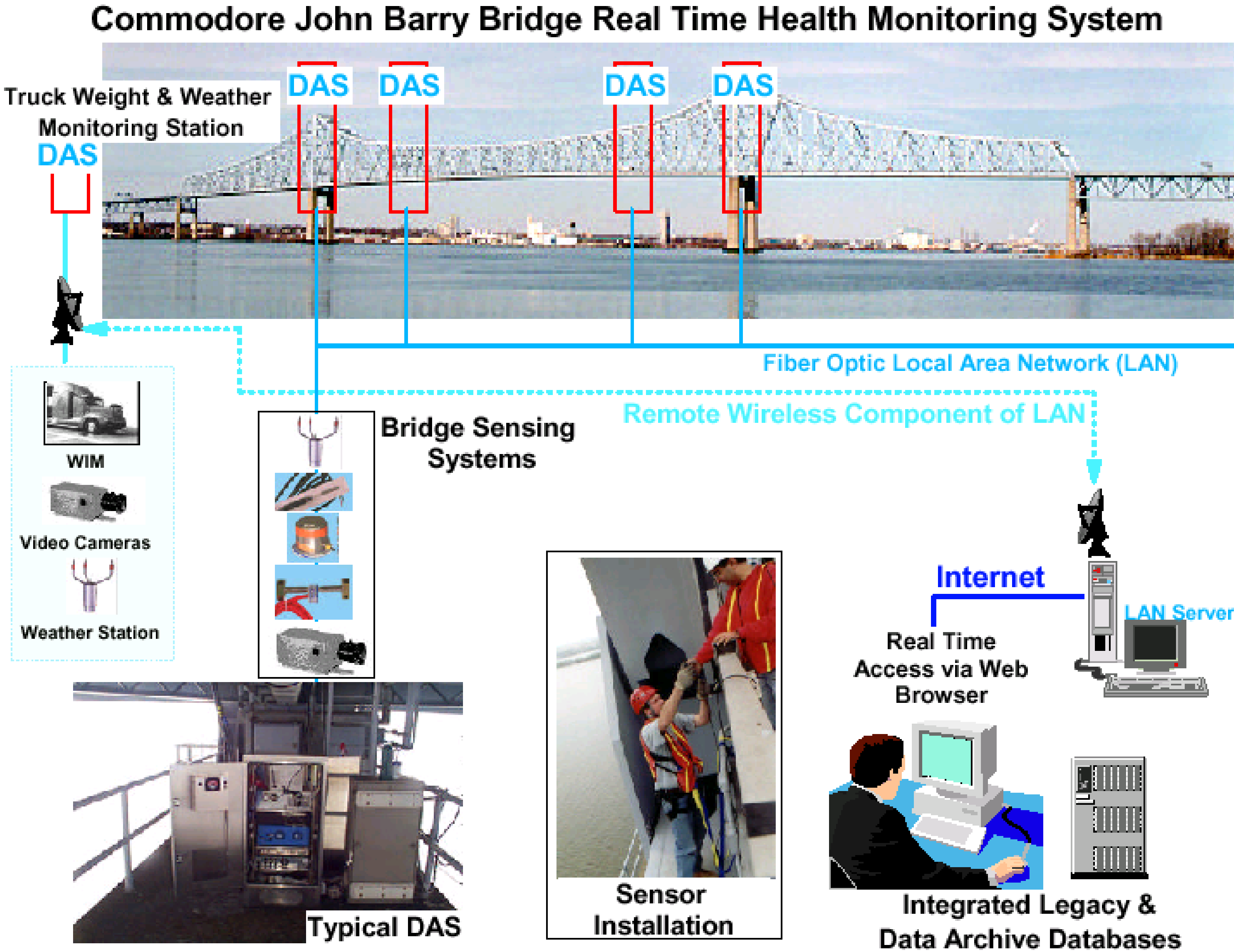
- Operation
  - ADT
  - WIM
  - Stress
  - Strain
  - Deflection
  - Displacement
- Service
  - Congestion
  - Accidents
  - Side friction
  - Performance measures

Additional Data Needs

- Data to support life cycle cost analysis
- Data to support performance based specifications
- Data to support performance measures

R&D to meet these needs

- Global health monitoring
- Rapid measurement of load capacity
- Vulnerability
  - Fatigue and fracture
  - Flood and seismic
  - Overloads
  - Impacts
- Critical component monitoring
- Integration with BMS



Commodore John Barry Bridge Real Time Health Monitoring System
Truck Weight & Weather Monitoring Station
DAS
DAS
DAS
DAS
DAS
Fiber Optic Local Area Network (LAN)
Remote Wireless Component of LAN
WIM
Video Cameras
Weather Station
Bridge Sensing Systems
Internet
LAN Server
Real Time Access via Web Browser
Typical DAS
Sensor Installation
Integrated Legacy & Data Archive Databases

Laser Radar Measurement System

Rapid non-contact measurement of structural deflections

Range 2 to 30 meters

Resolution ~0.1 mm

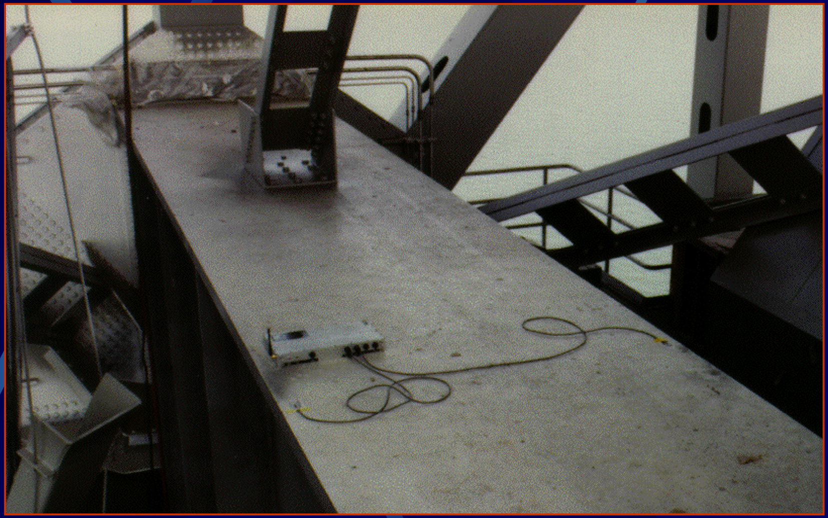
Rapid measurement capabilities (100's of points per minute)

Totally portable

Recent Brittle Fracture

Milwaukee, WI December 2000

Wireless Strain Measurement

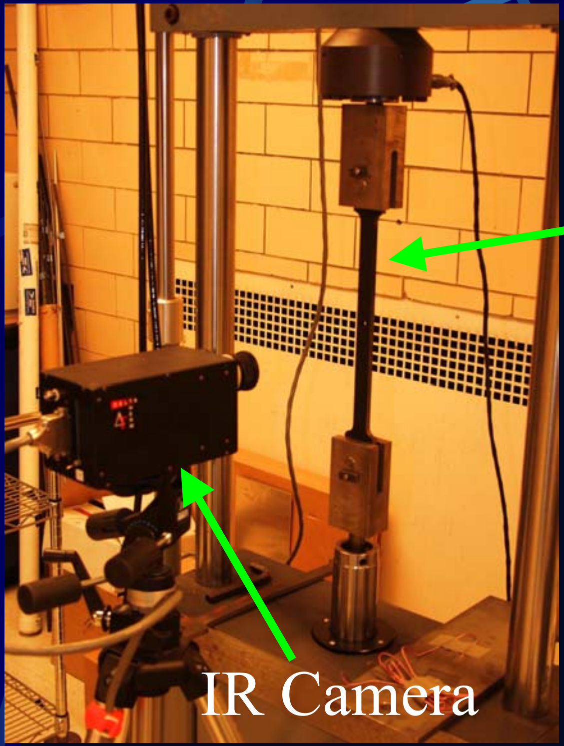


- Characterization of fatigue
- Measures random cyclic stress at several locations
- Battery powered

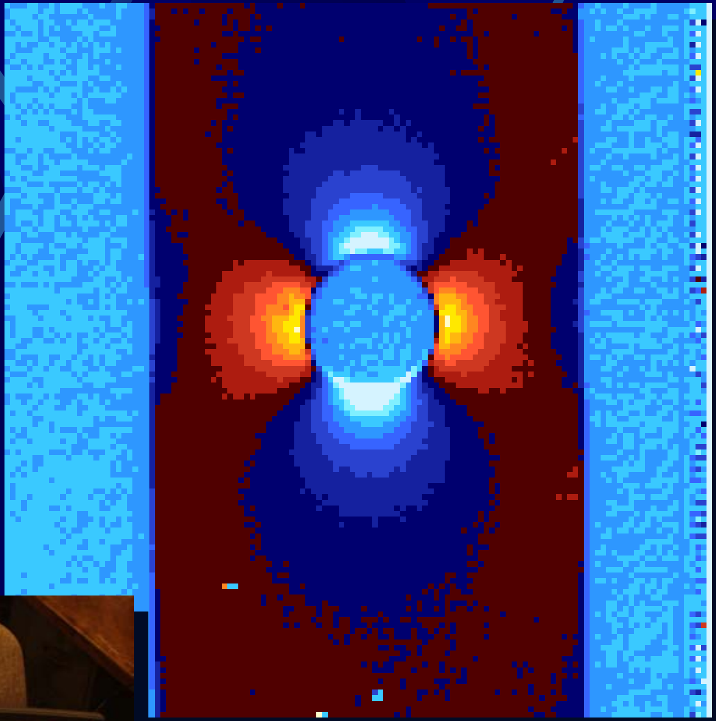
- Digital Spread Spectrum
- Adaptive wireless network
- Telemetry Range (~1.5 Km)
- Low Noise
- High Dynamic Range

Thermoelastic Measurement of Stress Concentrations

- Determine the stress concentrations at welded details in fatigue categories
- Correlate the apparent concentration with the fatigue category
- Might define fatigue categories more accurately – or differently - for un-catalogued details



Specimen w/ hole



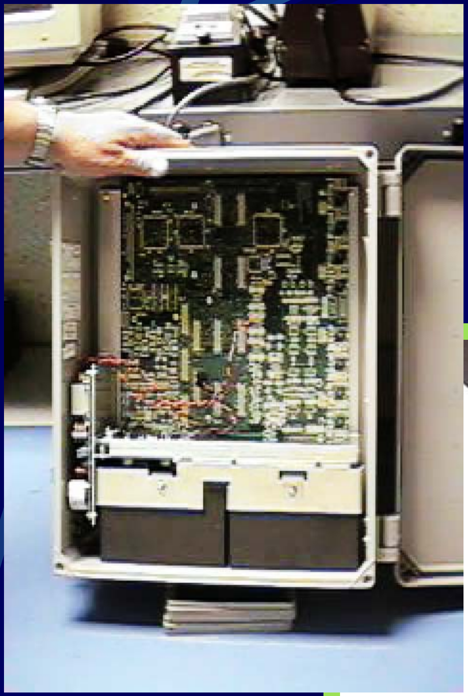
Laptop computer

Passive Fatigue Load Measurement

- Two aluminum coupons with manufactured fatigue cracks
- Fully characterized fatigue crack growth behavior
- Integrated continuous resistive crack length gage
- Placed on in-service bridged for extended time

New AE System for Bridges

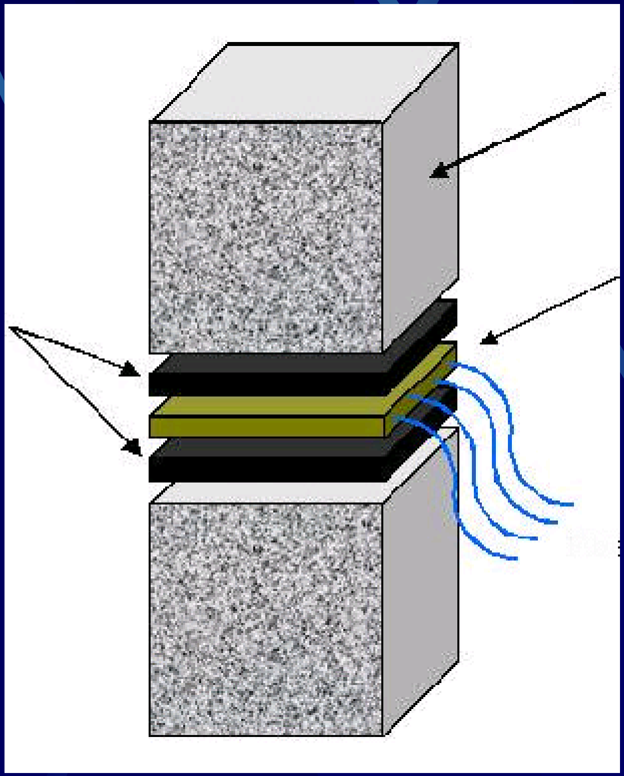
Battery powered
8 AE channels
11 Parametric channels
Totally Digital
Remote access and data download



Smart Bearings

Neoprene Pads

Prototype



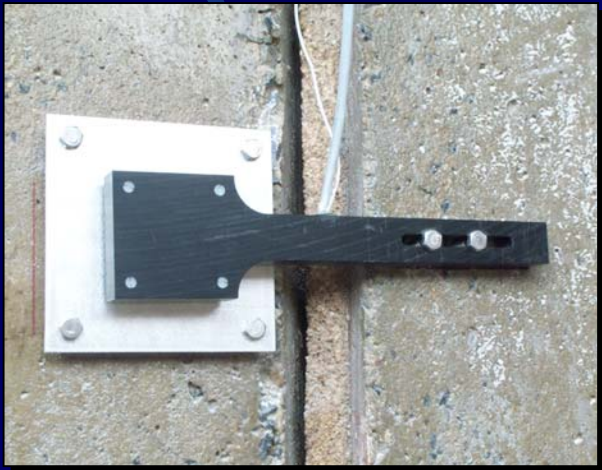
Bridge

Composite load cell using multi axis fiber optic strain sensors

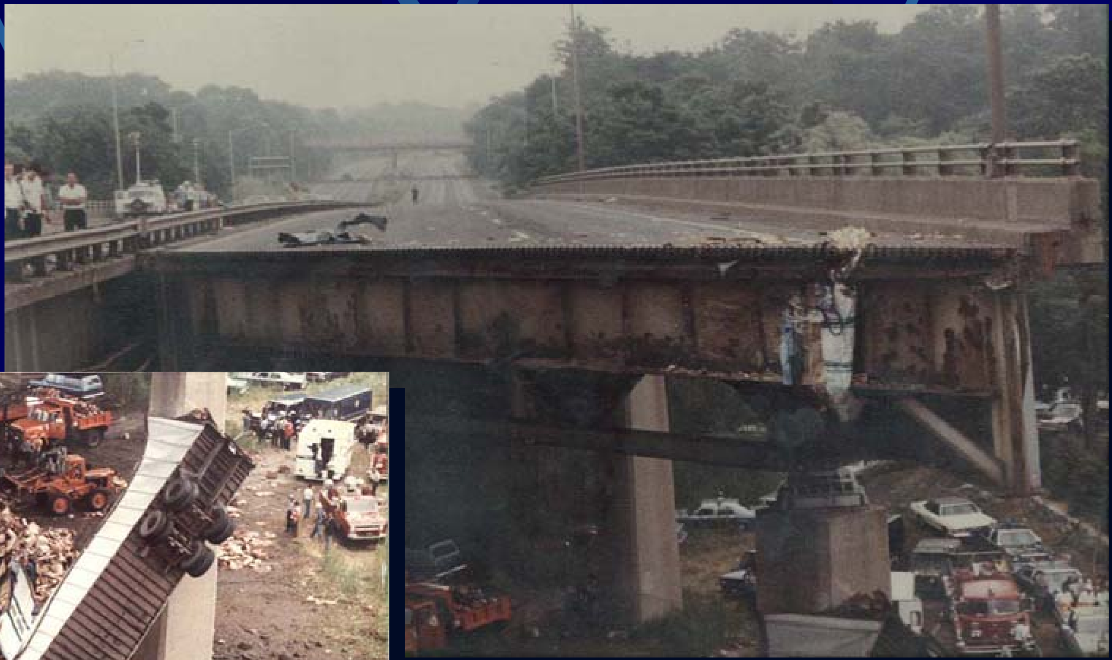
*Images obtained from Blue Road Research

Wingwall Monitor

Eddy Current
Displacement Sensor

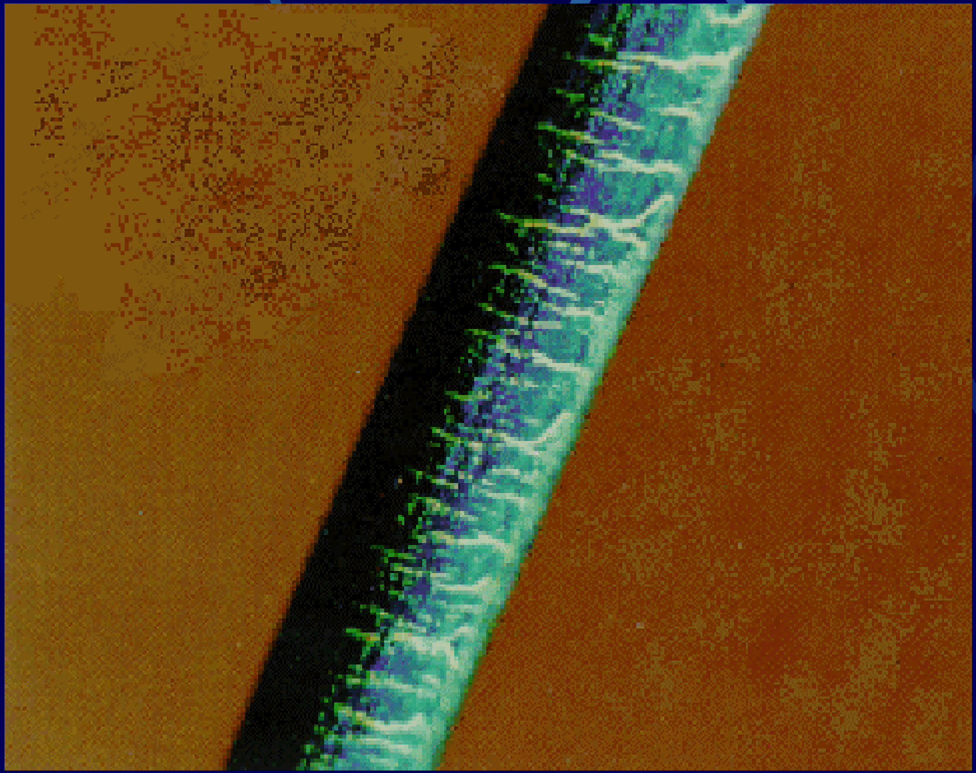


Mianus River Bridge 1983
Pin & Hanger Failure

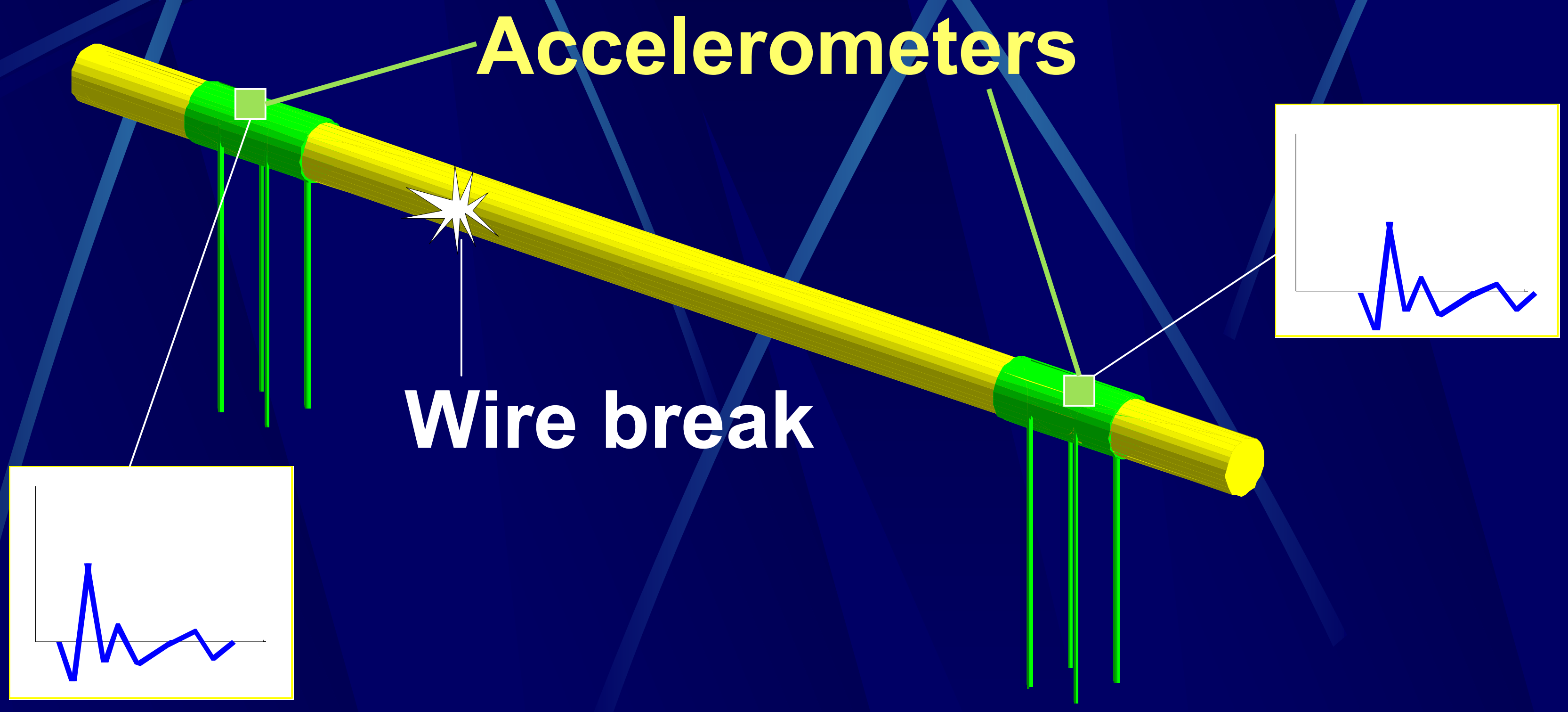


Monitoring Critical Bridge Components

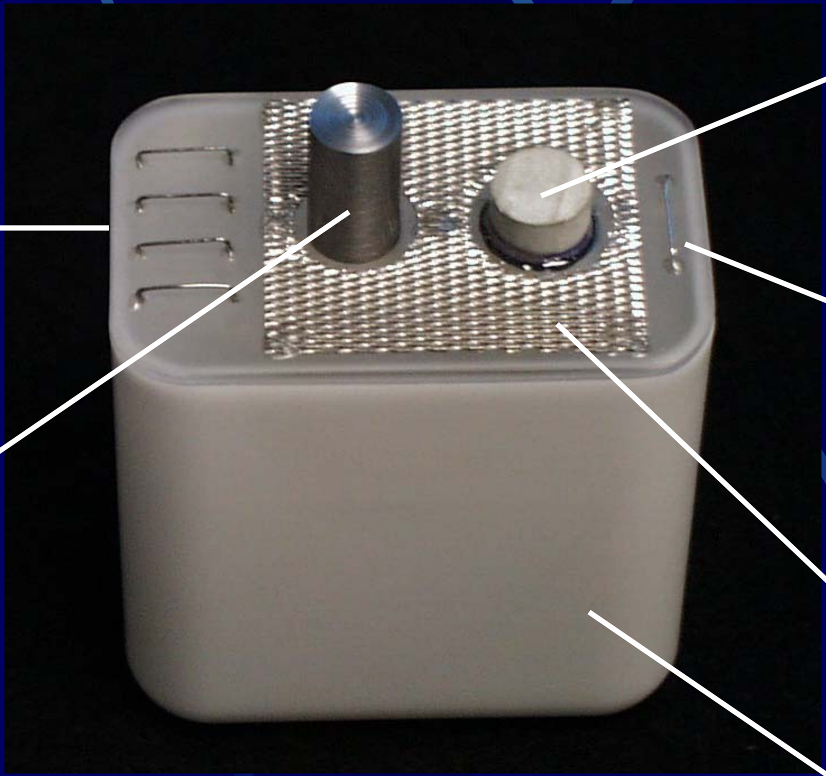
High strength steel wires are susceptible to stress corrosion cracking



Acoustic monitoring of wire breaks



Embeddable Corrosion Sensor



4-pin conductivity probe

Steel working electrode (Corrosion Sensor)

Force ERE20 reference electrode

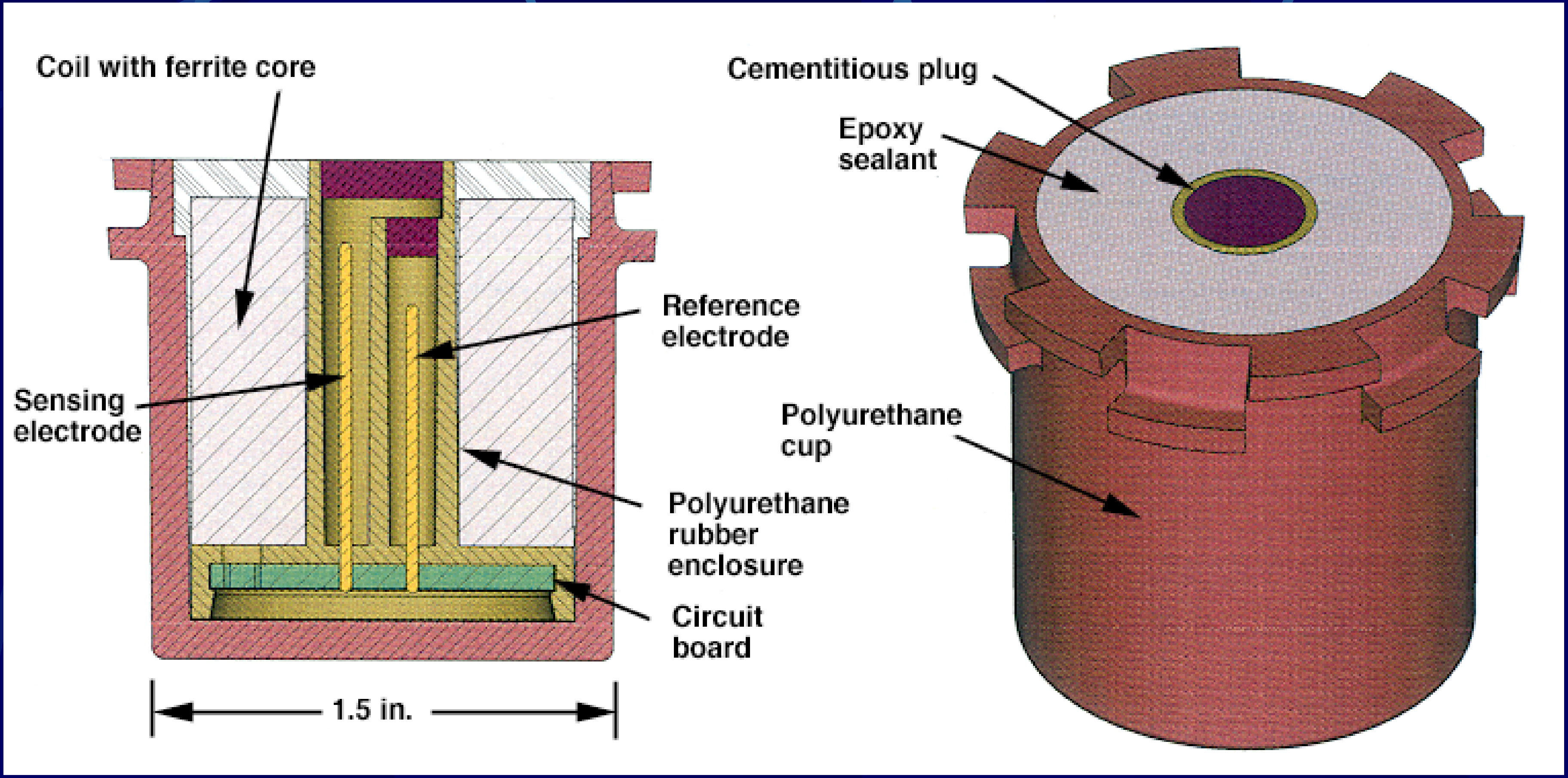
Ag/AgCl electrode (Cl-sensor)

Counter electrode

Casing for electronics

Wireless RF power & telemetry

Smart Pebble Construction

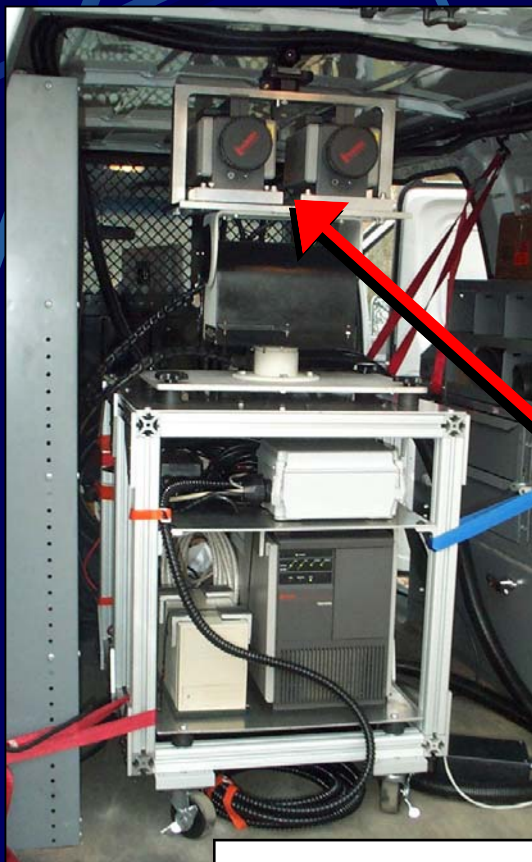


Smart Pebble™

Infrared Defect Detection

- Inspection of concrete and concrete/composite structures
- Passive methods use heat contained within the intact concrete vs. heat in thin layers (delaminations)

System Description



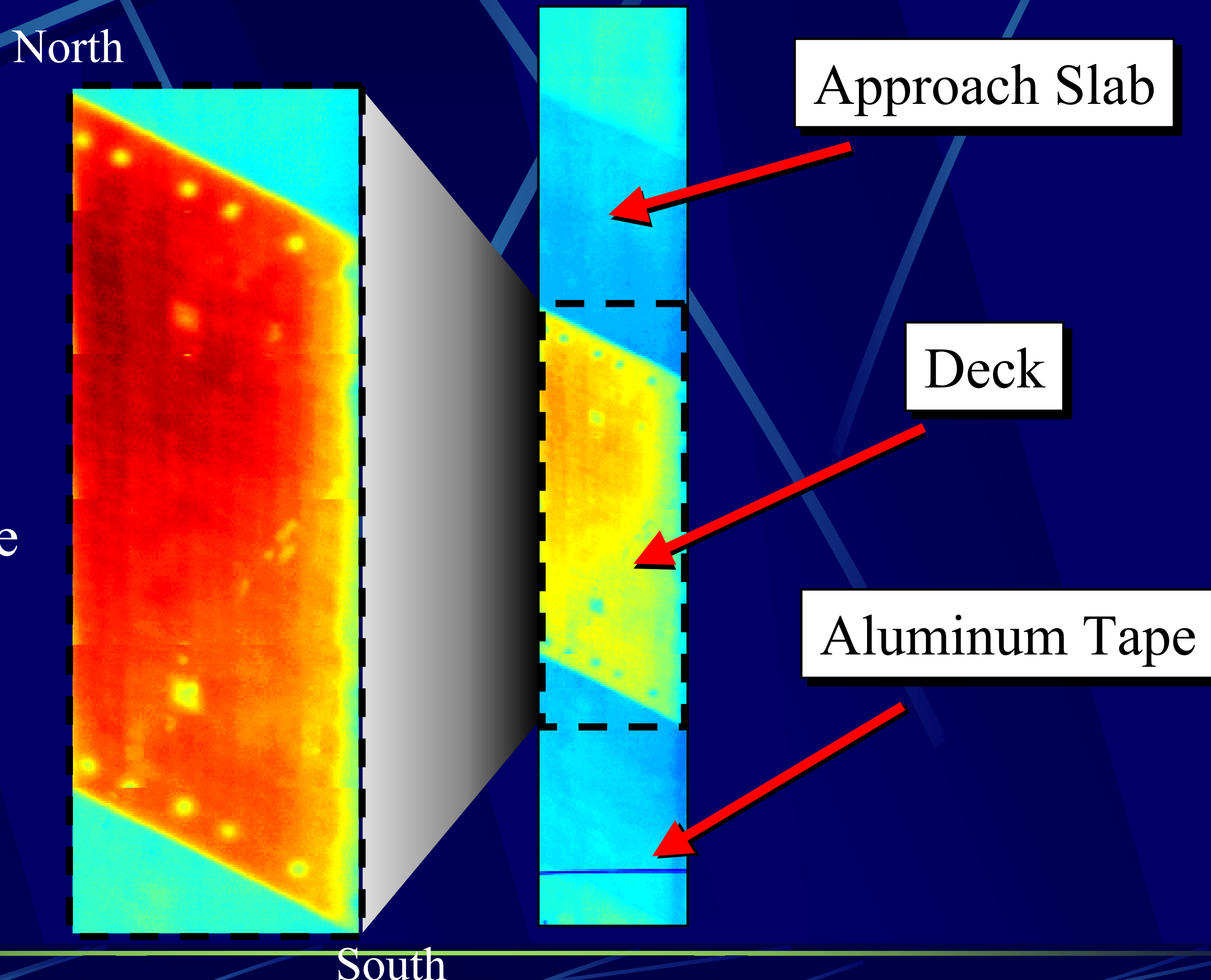
Infrared Cameras

Main System

Infrared Data

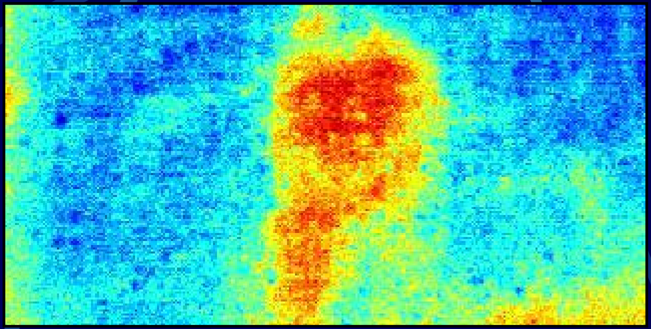
Rt. 248 South of Rexville, NY

Northbound Lane

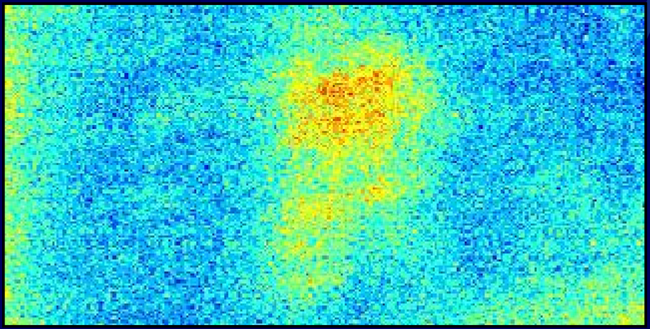


Infrared Data

NDEVC Test Bridge, Van Buren St



Long Wave

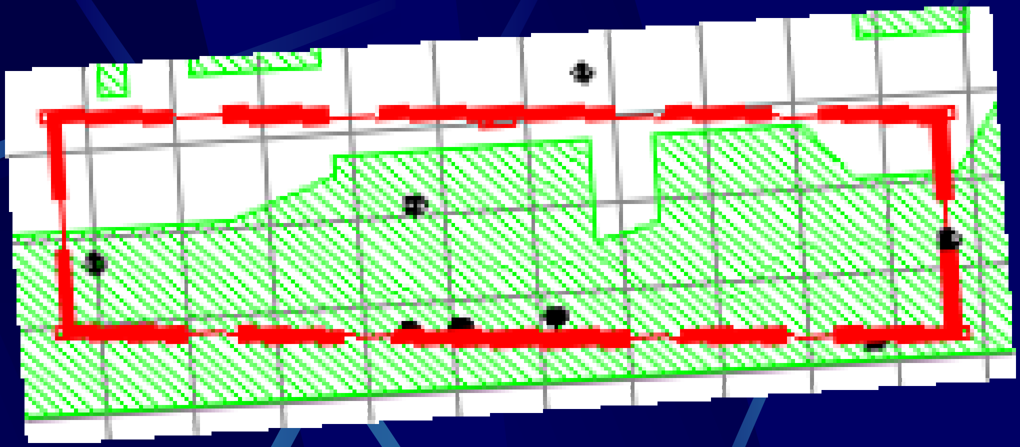


Short Wave

Video Image

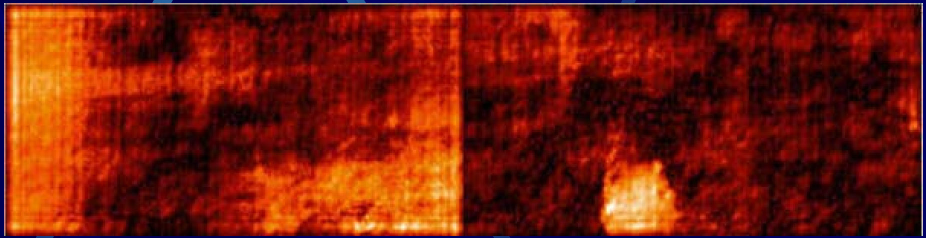
PERES II
Ground Penetrating Radar

Chain drag data:
Lake Anna Bridge deck
Green hatch=delaminated

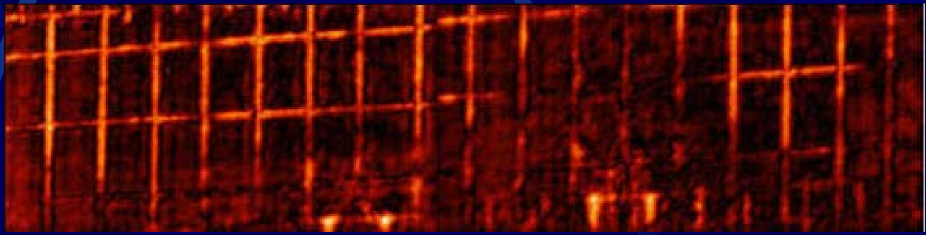


PERES II data:

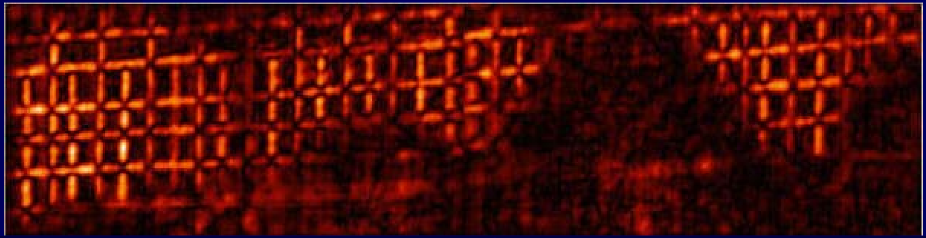
Surface reflection



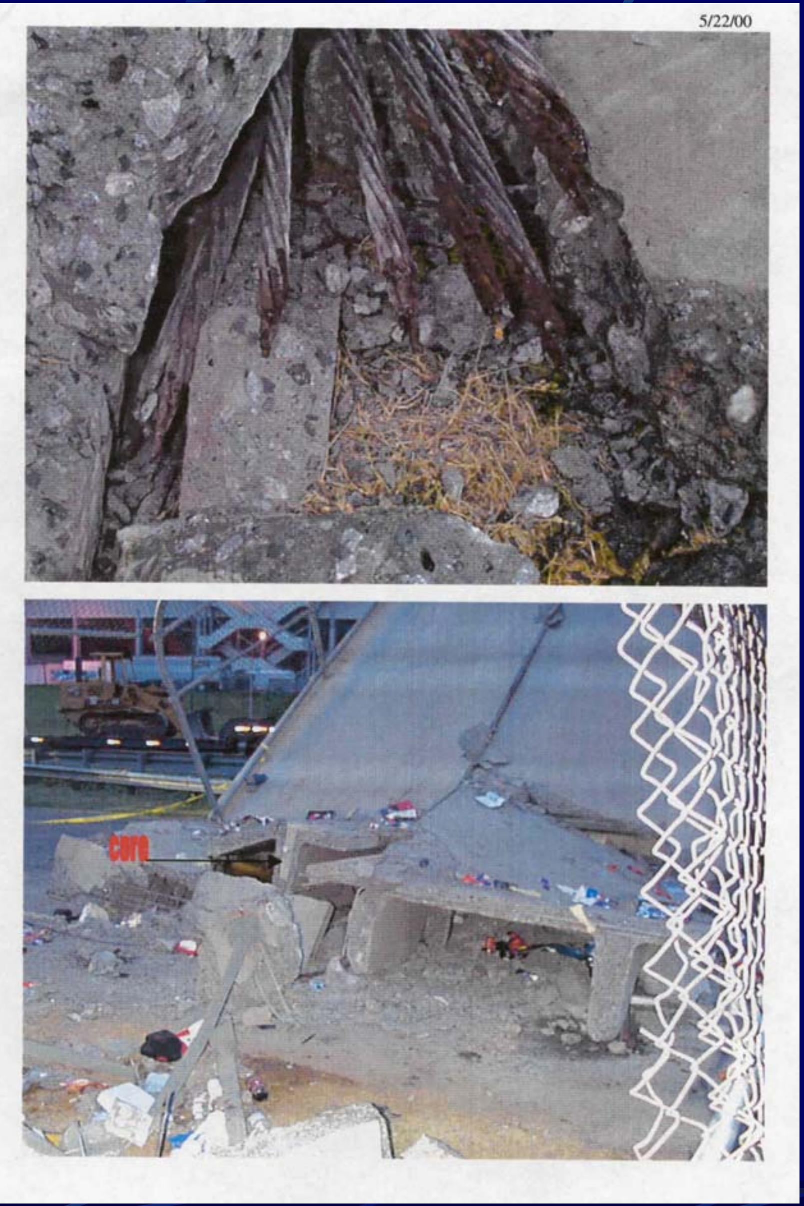
Top layer of
reinforcing steel



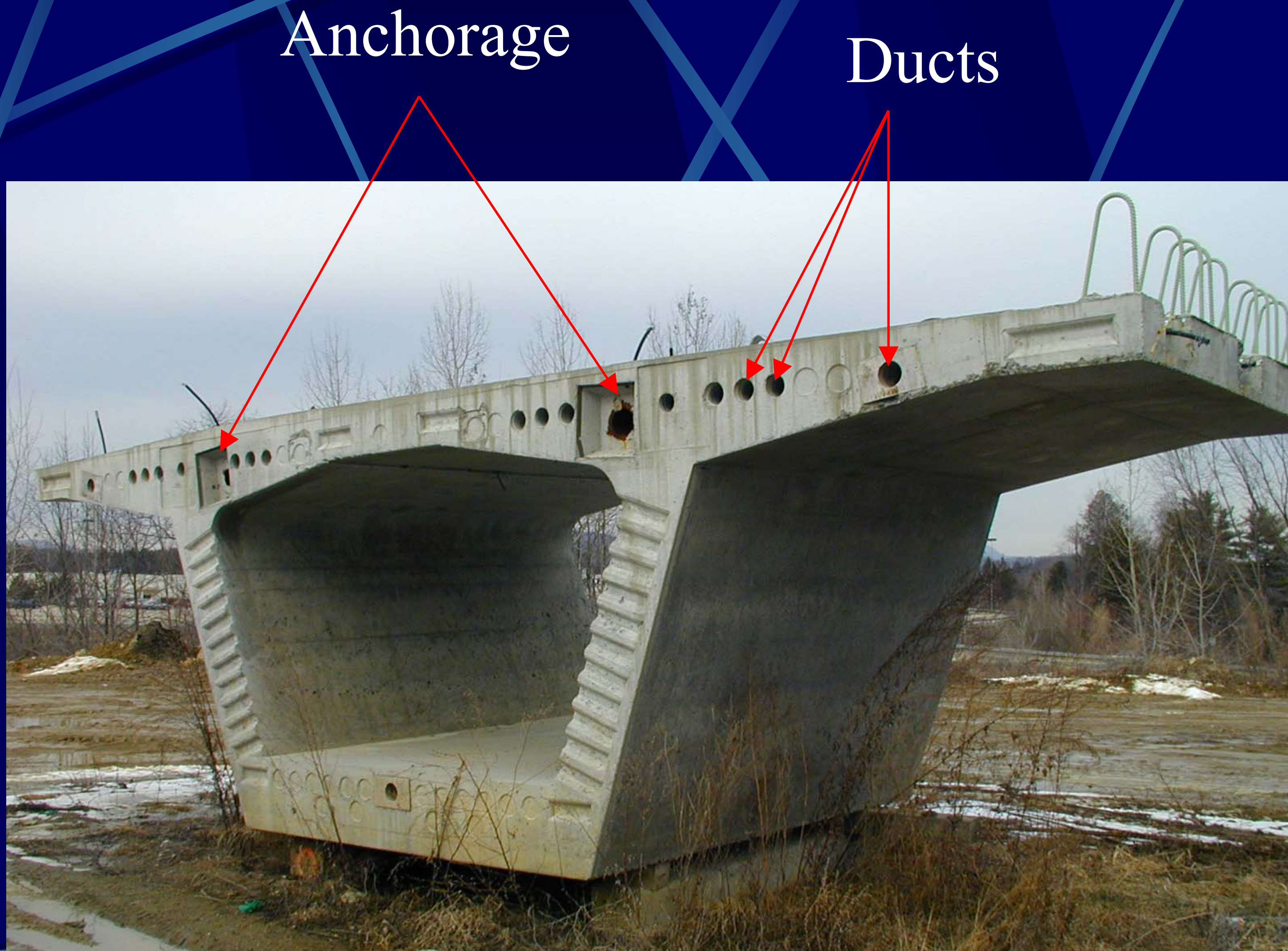
Bottom layer of
reinforcing steel



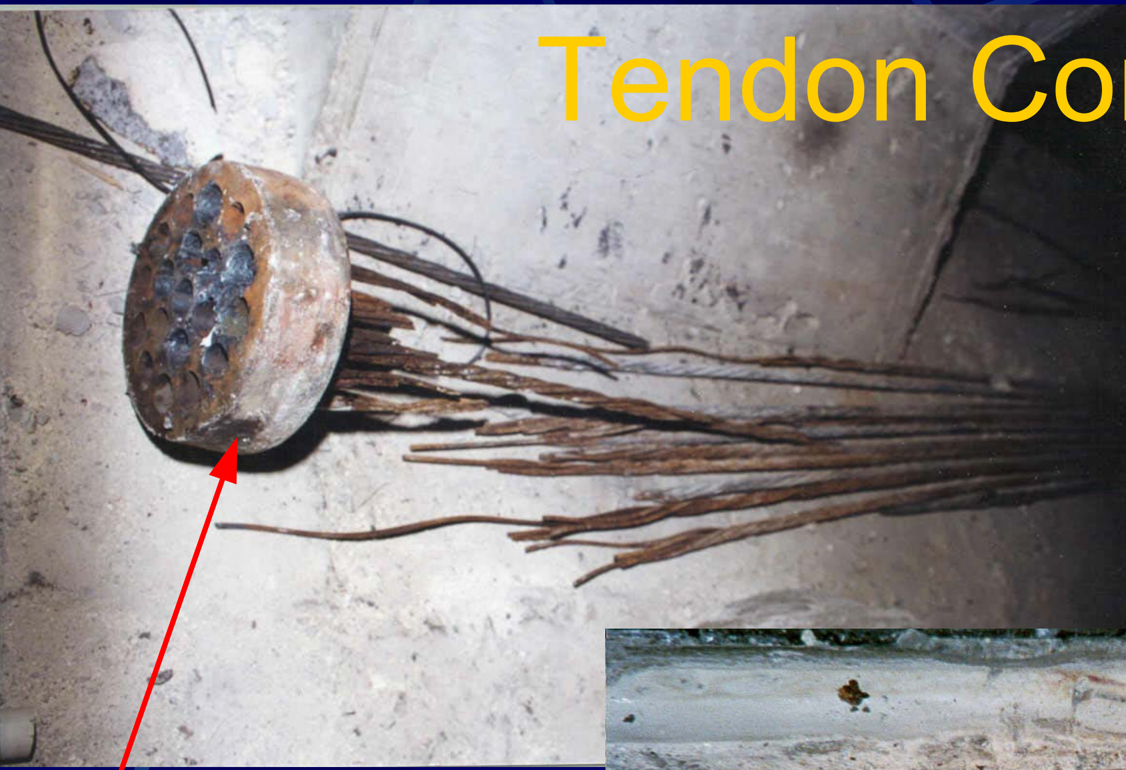
Lowe's Motor Speedway North Carolina



Segmental Construction



Tendon Corrosion



Anchor Block

Strand

Grout

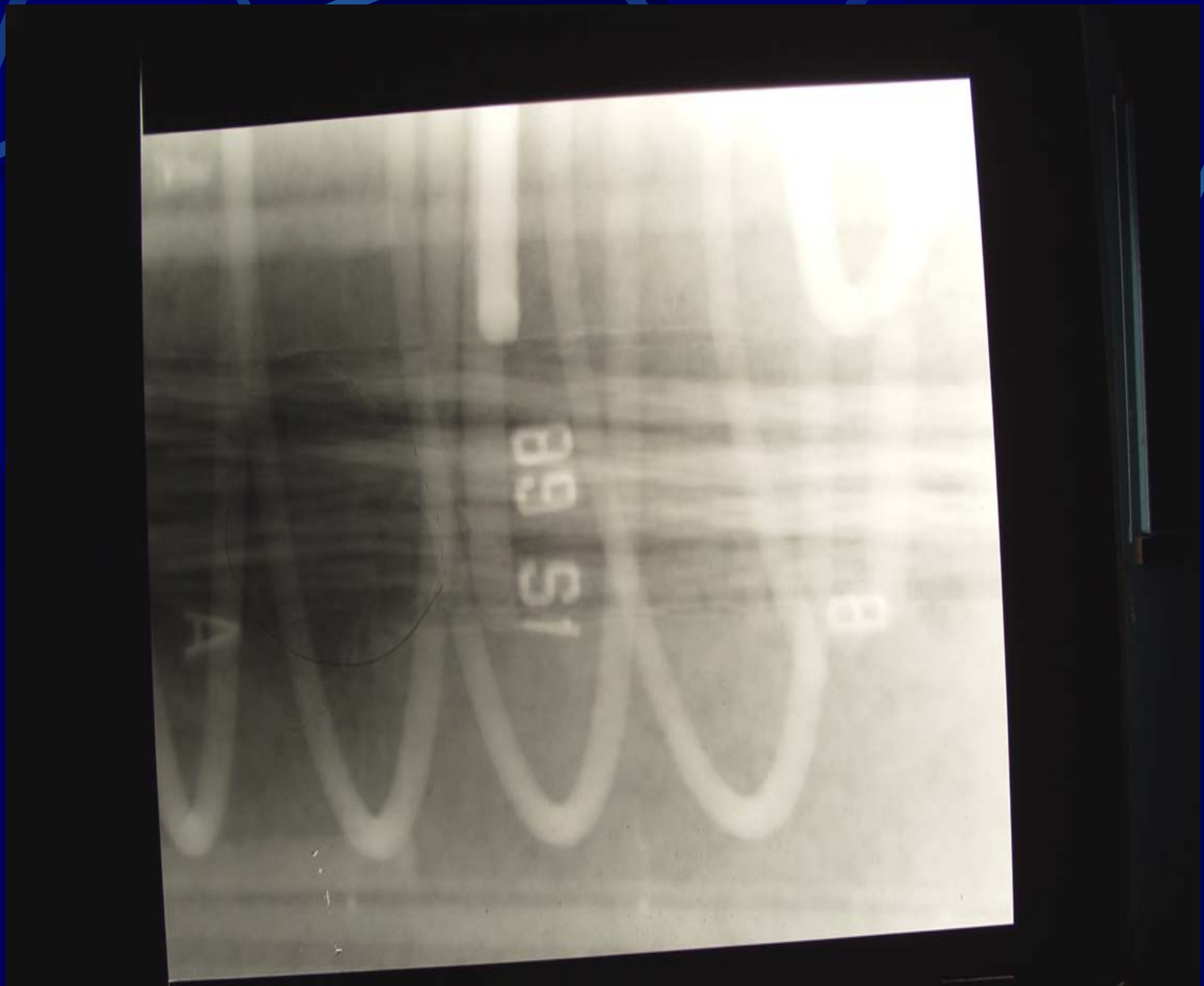
HDPE Duct

RADIOGRAPHY OF BRIDGES

X-ray source

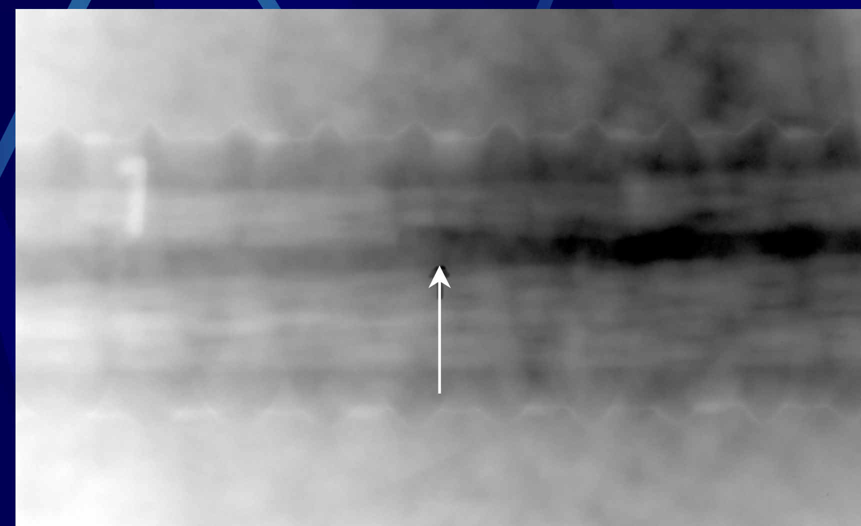
Film loading

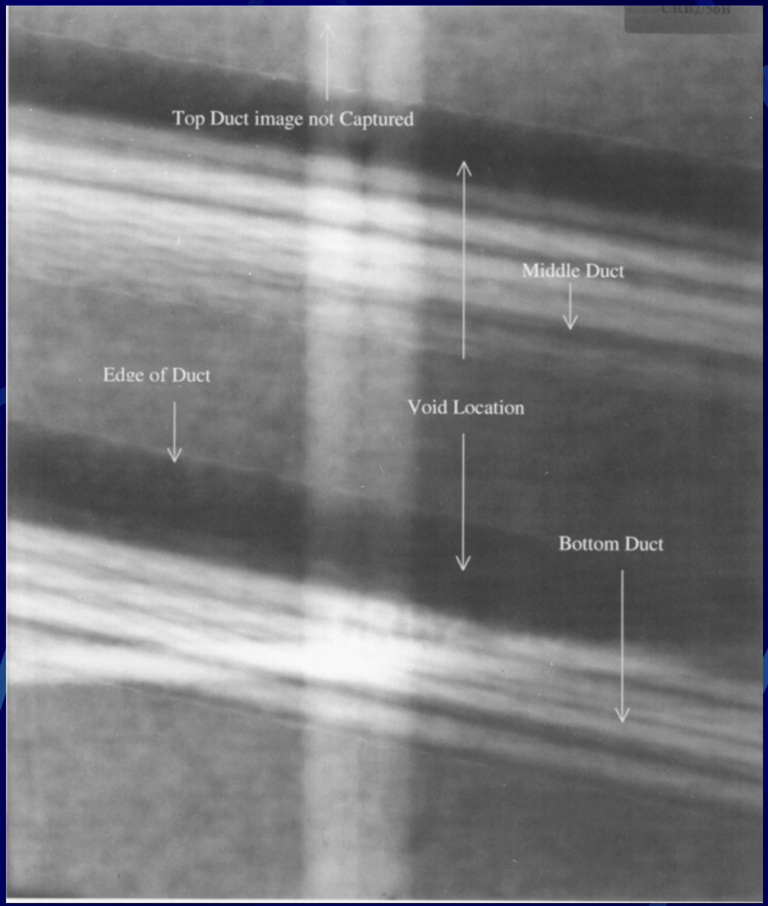
RESULTS

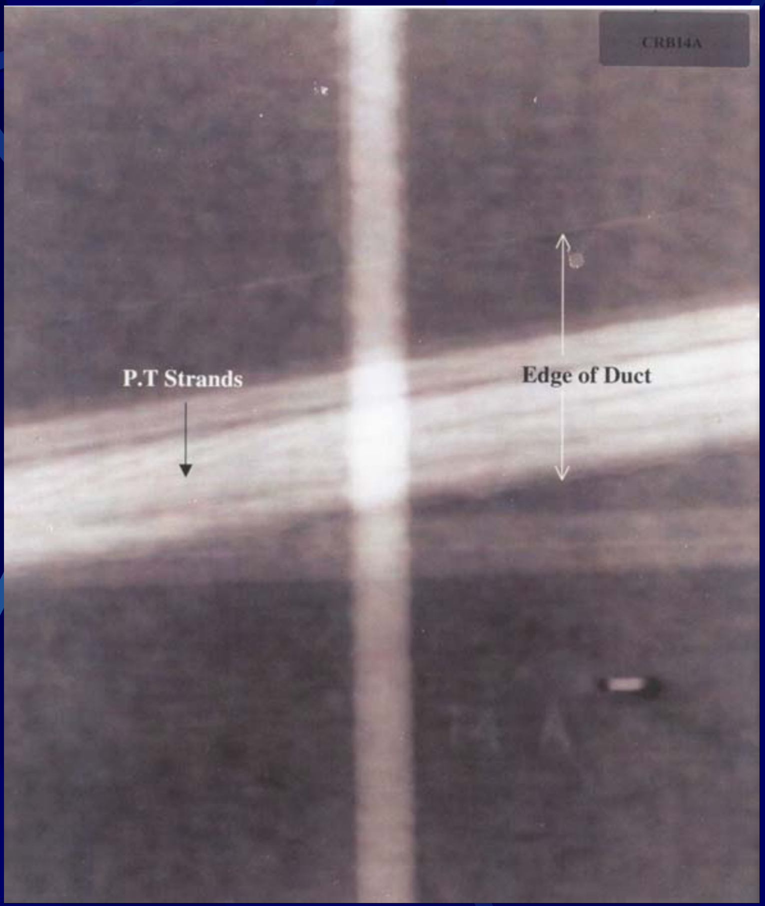


X-ray radiograph of duct

Detection of Broken Strands







Void

No Void

REF: Central Artery/Tunnel Project
Radiography: Jack Moore Associates, Inc.

The Washington Times FINAL
TUESDAY, FEBRUARY 20, 2001
25 cents

Thousands of 'intolerable' U.S. bridges pose risk for drivers

No warnings on many defective spans

Technology will provide the basic information necessary to effectively manage civil infrastructure throughout its life cycle

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Thank You!