The Role of Broadband in Bridge Monitoring in Minnesota

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Presentation Outline

- A brief history of bridge testing
- Current needs for information transfer
- A vision to the future

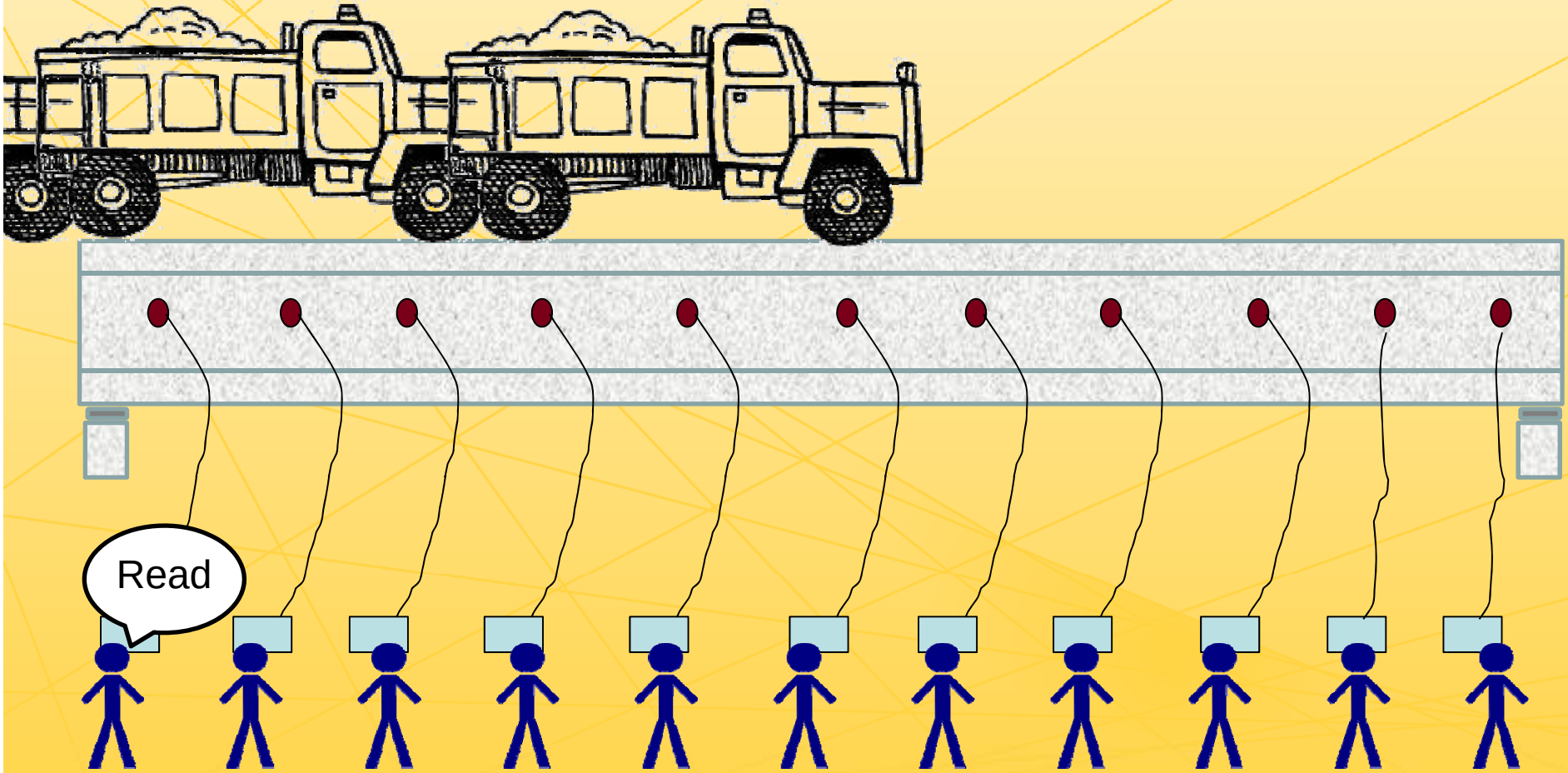
Problem/Background

- Bridges are large complicated structures that generally deteriorate locally

- Challenges
  - Difficult access
  - Ever changing environmental loading
  - Methods don’t exist for early detection of problems using sparsely distributed sensors

Photos: David Gonzalez Mn/DOT

The early days of bridge testing



Bridge Testing in the 90s-00s

- Portable data acquisition ~50-100 sensors
- Attempt at communication via modem and later cell (usually unsuccessful)
- Powered by battery or solar or direct line
- Typically have to visit site every 2 weeks to change out data storage modules
- No onsite processing power
- Ok if you knew exactly where to instrument and what you were looking for
  - i.e. monitoring known defect

Bridge Testing Today

- Fixed and portable data acquisition systems
- Number of wired sensors only limited by budget
- Powered by battery charged by solar cell (or if lucky direct line)
- Data from multiple systems can be fed to a local on-site server
- Usually have onsite processing power
- Wired internet connection for data download, messaging, and access to data acquisition system

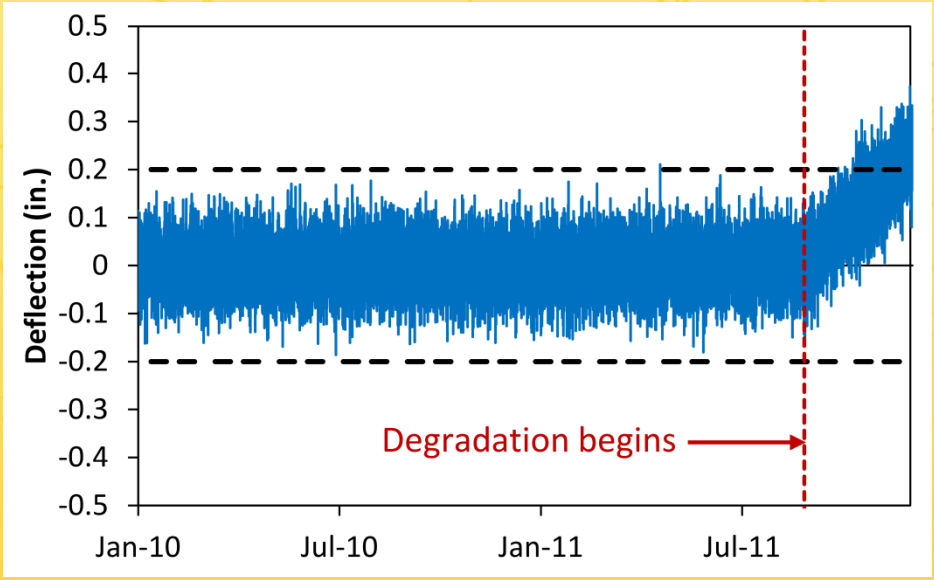
Goals of Bridge Monitoring

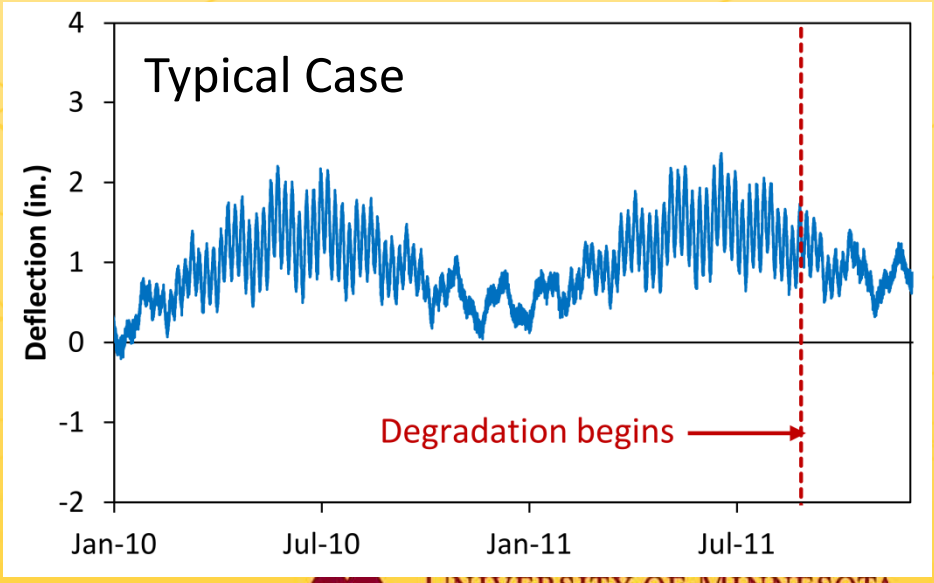
- Extending long-term serviceability of transportation structures critical for economic, long-lasting infrastructure.
- Structural monitoring should be able to assess the behavior of bridge and inform owners of potential deterioration.
- Therefore, the goal is to integrate monitoring data into maintenance and inspection strategies to extend bridge life.

A Current Example - 35W Bridge

Challenges of Long-Term Monitoring

- Behavior of in-service bridges depend on many complex natural phenomena.
- Damage is not necessarily sudden and can be masked by normal, safe variations in behavior.





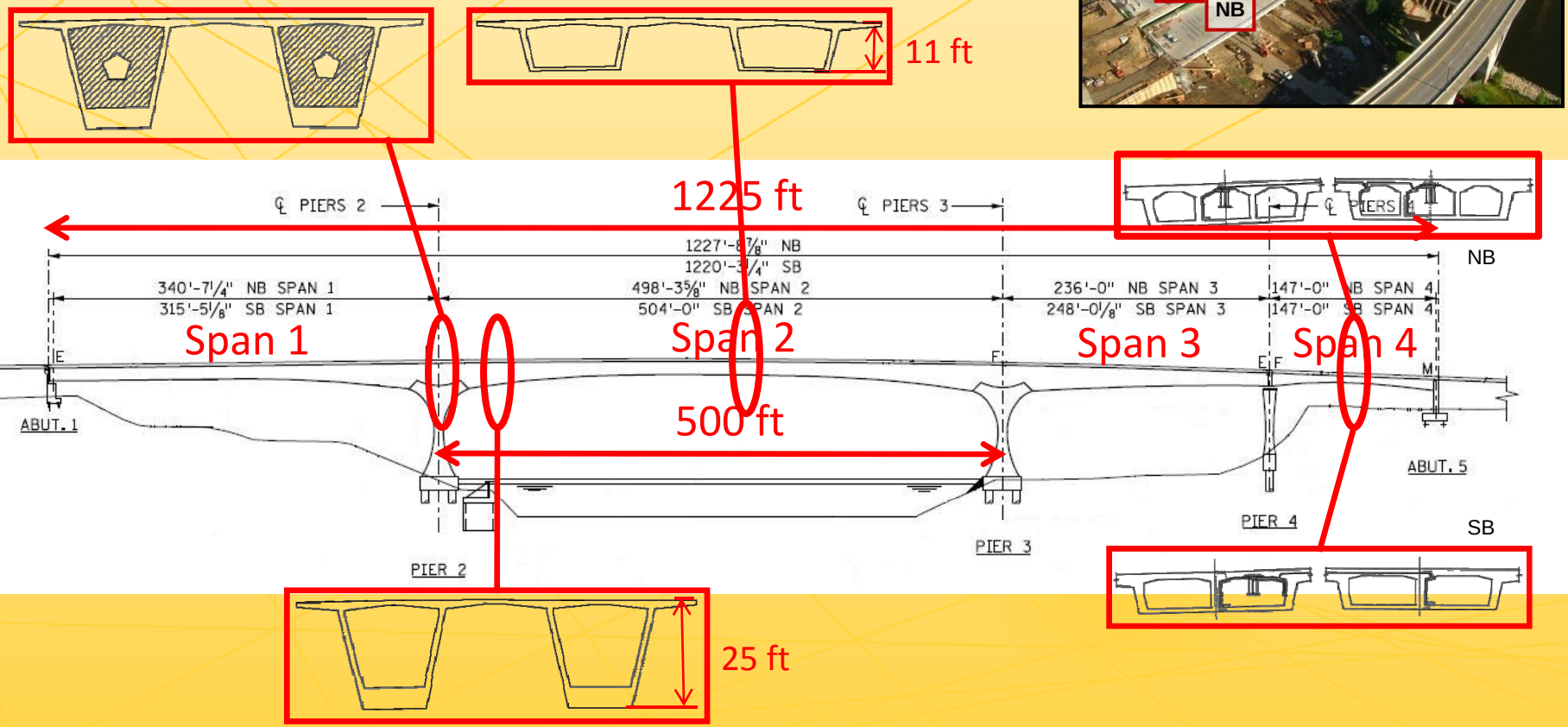
35W Bridge

Investigative Approach

- Examine sensor data from the I-35W St. Anthony Falls Bridge as a test case to better understand the behavior.
- Analyze finite element models to estimate long-term behavior of the bridge.
- Develop data normalization and anomaly detection techniques for extracting unexpected changes in the structural behavior
  - Update analytical predictions with measured data to predict future “normal” behavior

Description of Bridge

Two bridges (NB, SB) each with two boxes



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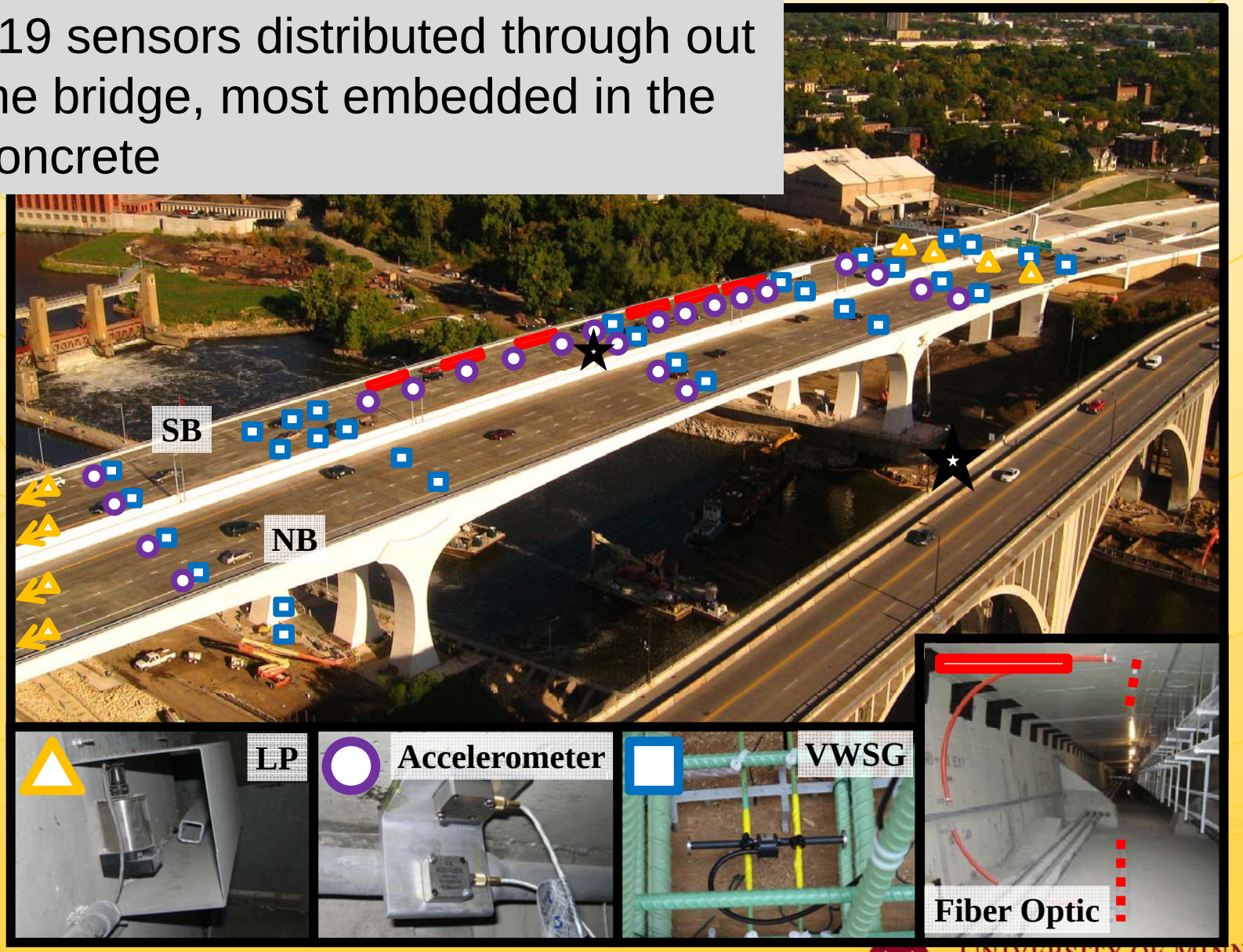
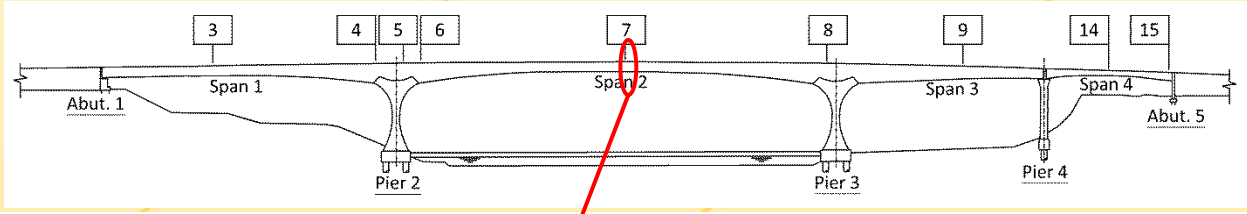
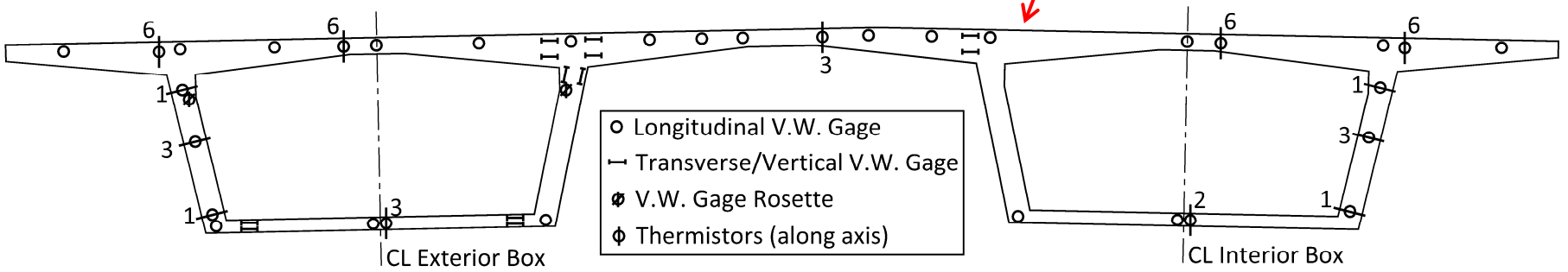
Bridge Instrumentation

519 sensors distributed through out the bridge, most embedded in the concrete



Most Heavily Instrumented Cross Section on SB





NOTE: Cross-section view facing north. Number by thermistor symbol equal to number of sensors along symbol axis.

SB Structure, Location 7

37 strain gages
6 fiber optic gages
79 thermisters
2 accelerometers
124 gages at one cross section

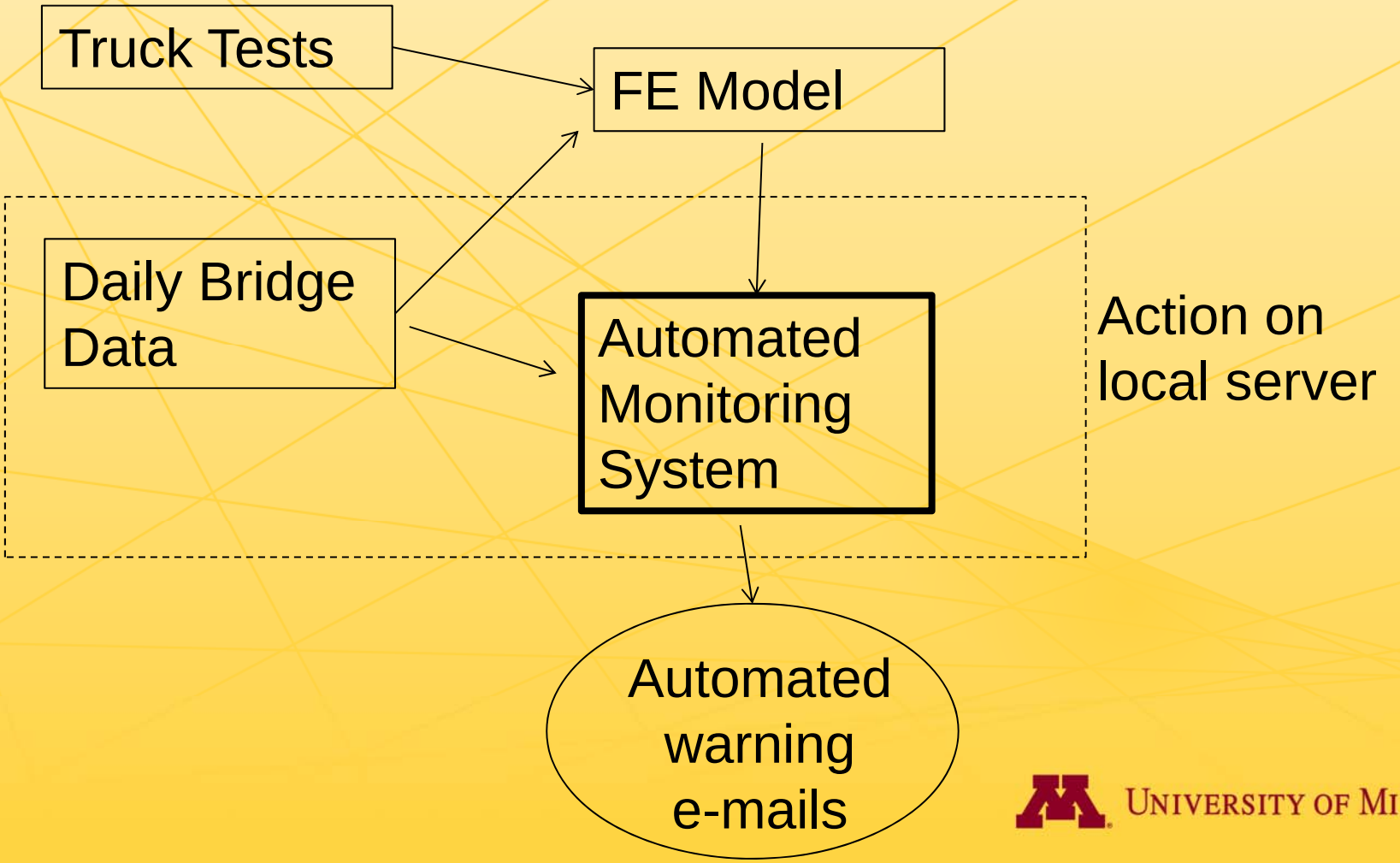
Data Rate and Quantity

- Accelerometers
  - 26 sensors, 100Hz 24/7
- String Pots and Resistive Strain Gages
  - 36 sensors, 4Hz 24/7
- Vibrating Wire Strain Gages & Thermisters
  - 442 sensors, 5 samples hourly
- Fiber Optic Strain Gages
  - 12 sensors, 3 samples hourly

→ ~10 million samples per hour or 240 million samples per day or 85 billion samples per year

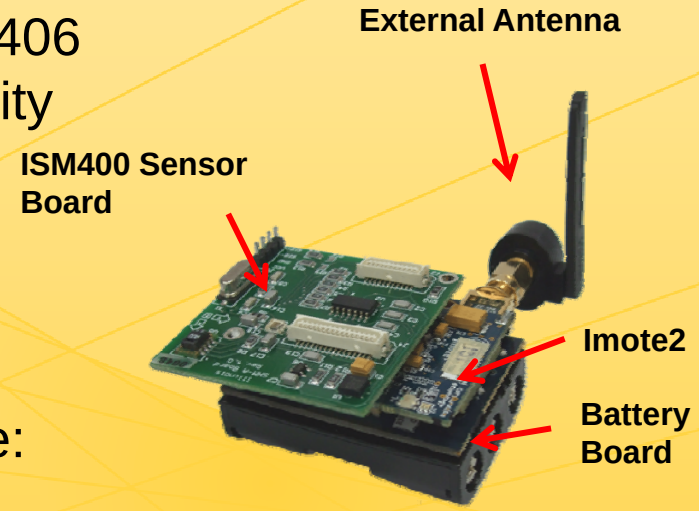
What Happens to the Data?

- Currently automated monitoring only happens for longitudinal bridge motion



The Future – Wireless Sensors

- **Imote2** Smart Sensor Platform
  - Variable-speed processor from 13 to 406 MHz for enhanced computational ability
  - Flexible sensor interface



- ISHMP Toolsuite
  - Modular service-oriented architecture:
    - Foundation services
    - Application Services
    - Tools and Utilities

First Large-Scale Deployment

- Jindo Bridge (South Korea)
- US (University of Illinois) – Korea Collaboration
- Deployed August 2010
- 680 channels on 113 nodes
- All nodes powered by solar panels

The Future 2 - Campaign Monitoring

- Transportable wireless systems
- Campaigned for short time periods (1 to 6 months)
- Real-time monitoring via internet

- No real need to monitor bridges 24/7 over their lifetime
- Still need
  - Better models for predicted behavior in complex environments
  - Methods to optimize sensor locations
  - Inexpensive sensors
  - Methods to automate data analysis

Summary

- Bridge monitoring has been transforming over the last 30 years as technology changes
- Cost is still prohibitive
- Wifi and broadband will be part of the solution

Instrumentation cabling for 400 wired strain sensors