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THE STATE UNIVERSITY OF NEW JERSEY

Center for Advanced Infrastructure and Transportation (CAIT)

# The Role of Accelerated Testing in Bridge Performance Research

*Presented by*
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Professor
Rutgers University

Funding provided by the USDOT, FHWA, NIST, NSF, NJDOT

Motivation:

# Some Critical, Open (and billion dollar) Questions

- What are the primary factors that lead to poor bridge durability and how do they interact with one another?
  - Construction techniques, quality? Structural characteristics, design details? Environmental inputs? Live load? De-icing agents? Others?
- What are the best practice design and maintenance actions to ensure good long-term bridge performance?
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# Structuring Bridge Performance

**Key goal of bridge performance research**

- Live load
- Environmental inputs
- Maintenance
- Preservation

…

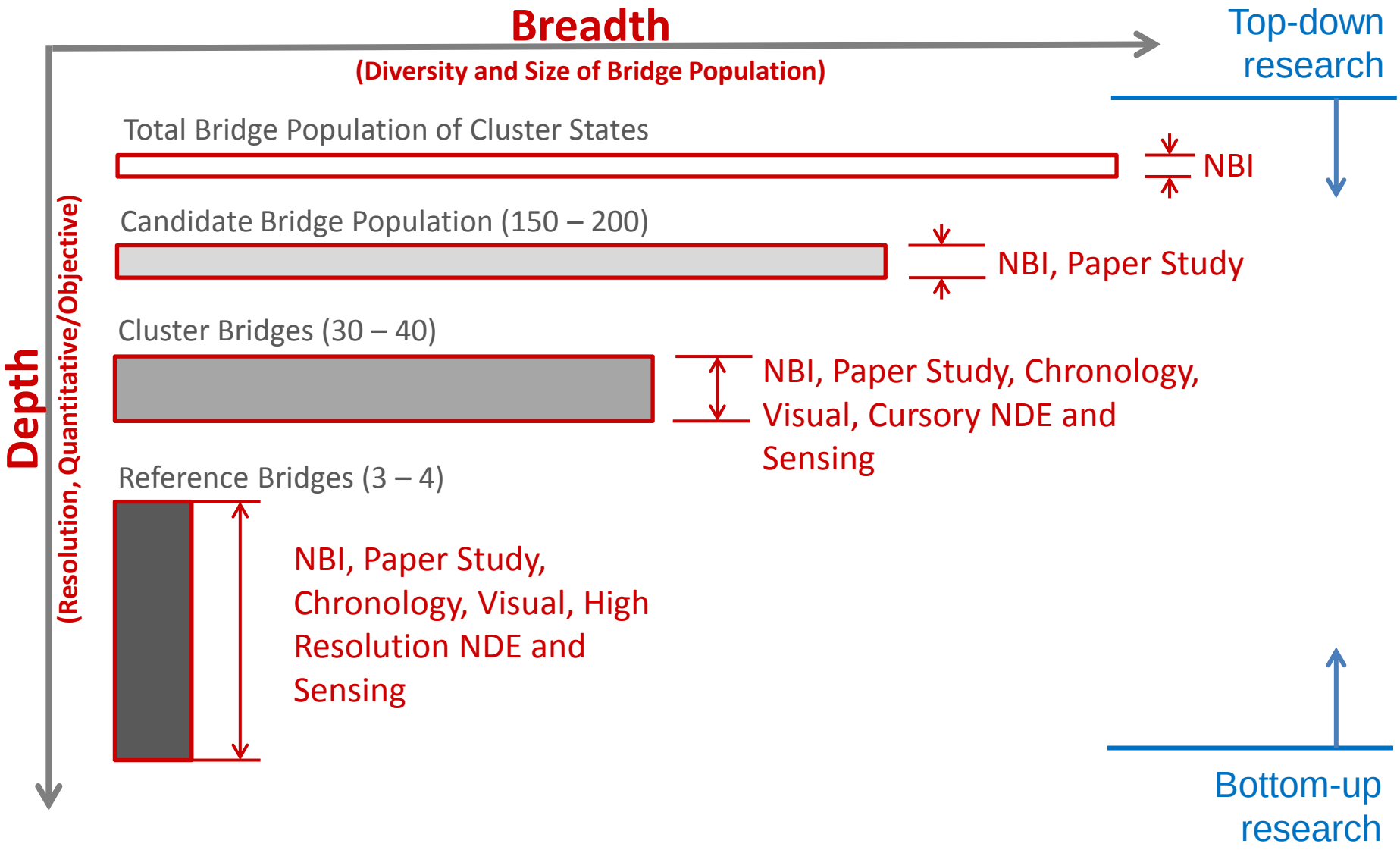
$f$(Attributes, Inputs) = **Bridge Performance**

- Age
- Design details
- Materials
- Structural Characteristics
- Construction Quality

…

**Structural Safety**
**Serviceability and Durability**
**Functionality and Utility**
**Cost**
**…**

# Approaches to Studying Bridge Performance



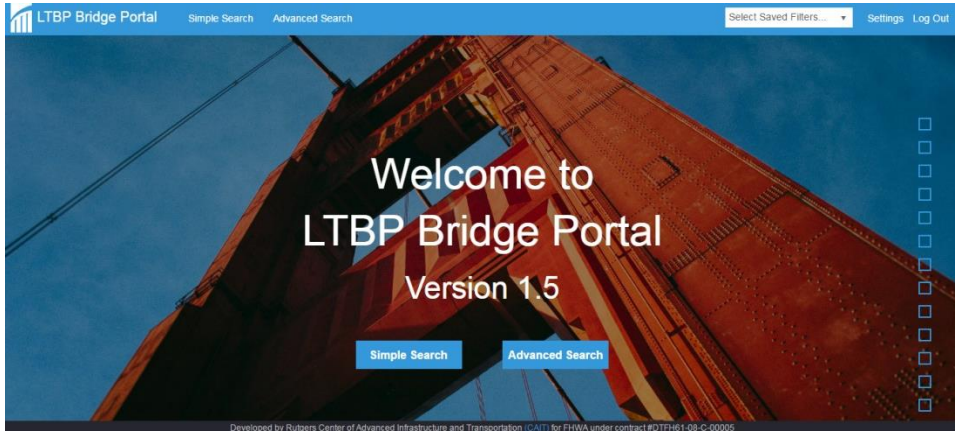
# Top-down Research Efforts

***LTBP Portal, Deterioration modeling, Machine learning, etc.***

# LTBP Portal Data Sources and Functionality

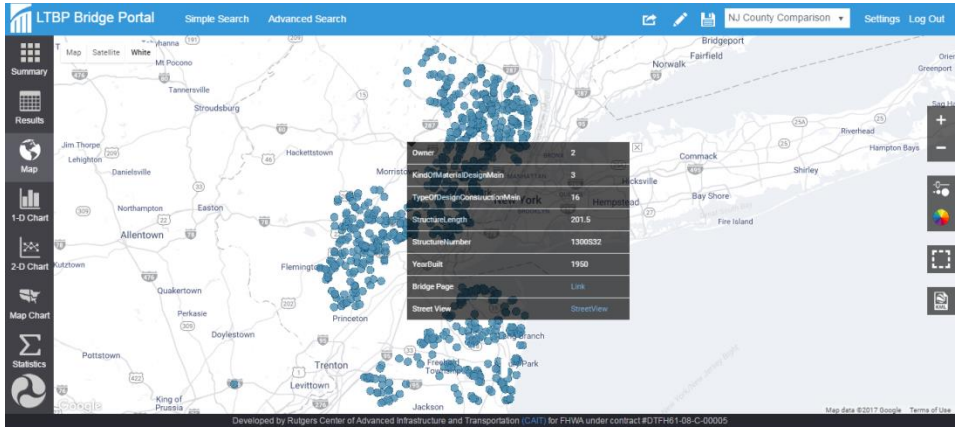
## Current Data Sources

- National Bridge Inventory (NBI) (1992 – 2016)
  - Historical Condition Data
  - Historical Traffic Data
- Element Level Inspection from a Few States (1997 – 2014)
- Environmental Data (1992 – 2016)
  - No. of snowfalls
  - No. of freeze-thaw cycles
- LTBP Data
  - Field Testing (80 bridges)
  - Legacy Data Mining



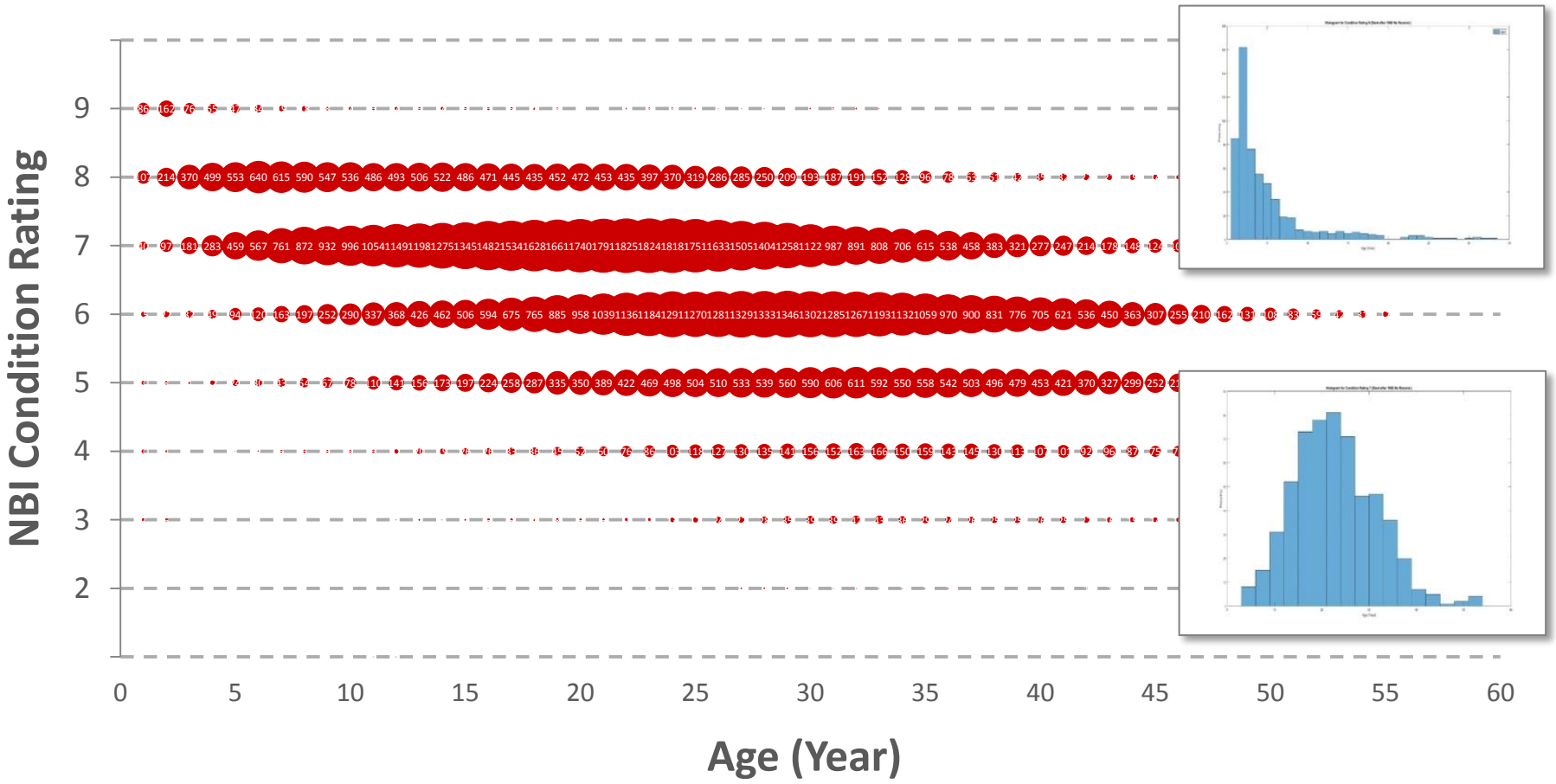

## Current Functionality

- Search Mechanism
- Advanced GIS
- Analytics Tools
- Reporting
- Bridge Historical Data
- Deterioration Modeling

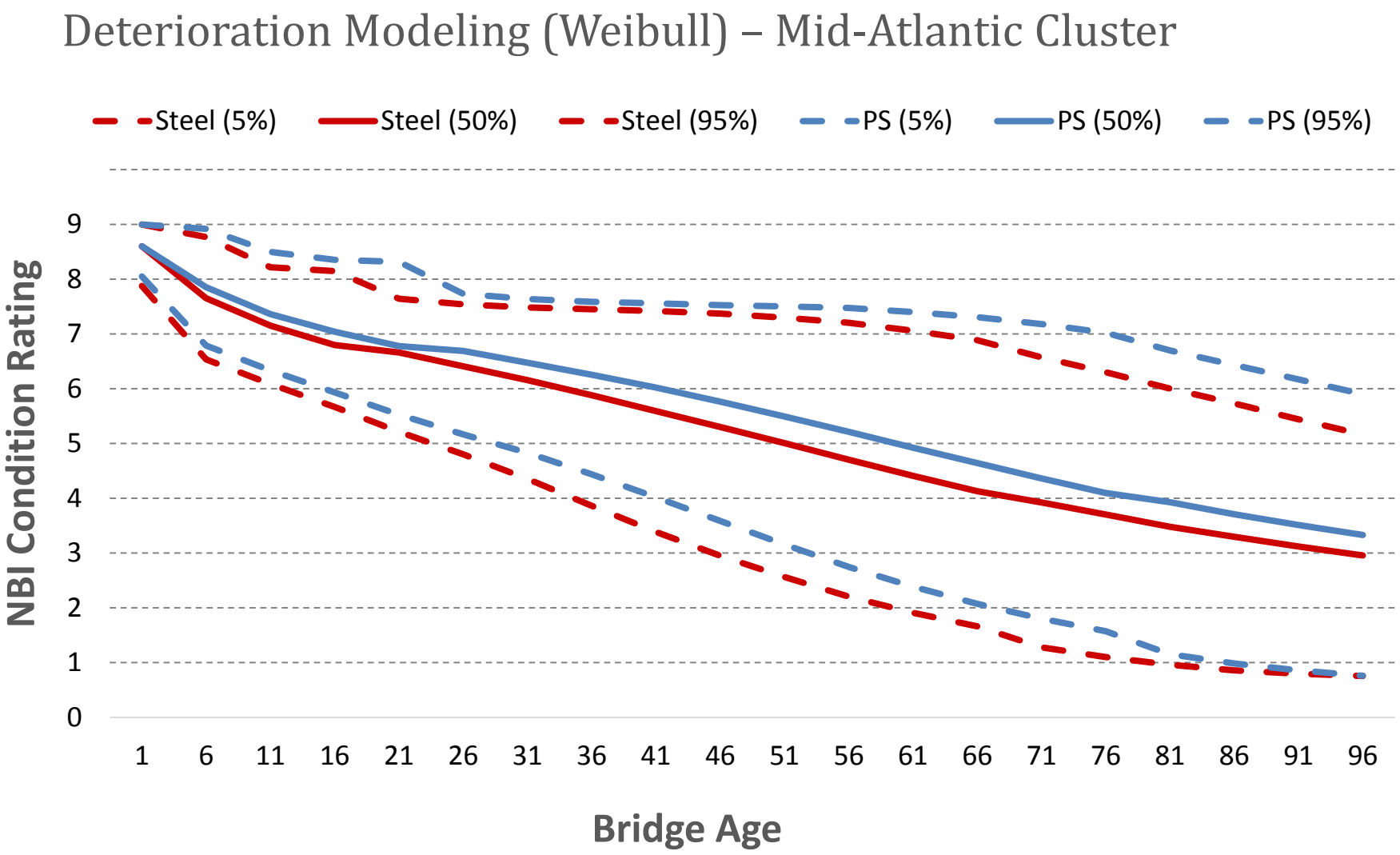


# Current Basis for Deterioration Models

## Raw NBI Data – Mid-Atlantic Cluster (Steel, Multi-Girder >1960)

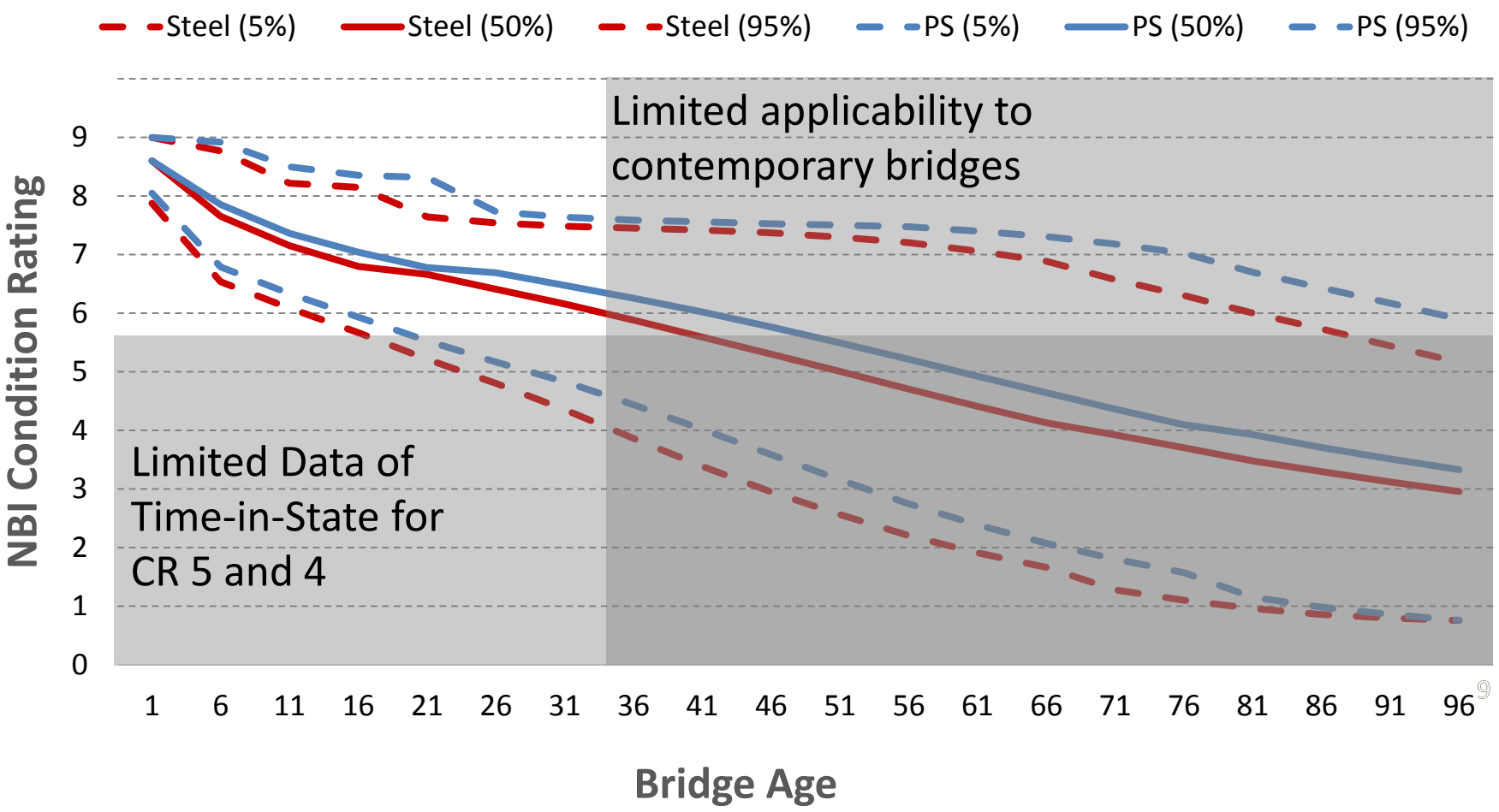


# Variability of Resulting Deterioration Models



# Fundamental Limitations of Top-down Studies

## Deterioration Modeling (Weibull) – Mid-Atlantic Cluster



# Path Forward for Top Down Research

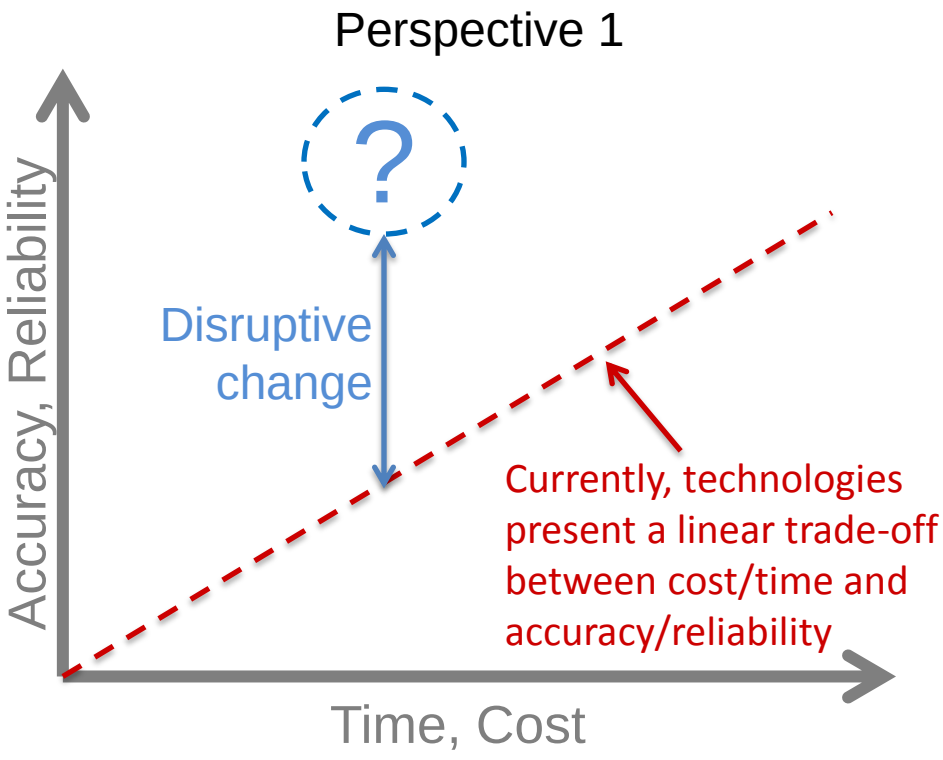
- Improving the data sets – increased reliability and resolution through…
  - Element-level data sets
  - Legacy data collection (LTBP)
- Improving the tools used to model the data
  - Machine learning…
    - Is fundamentally data driven – generates models directly from input-output data
    - Does not rely on explicit, static programming
    - Offers the ability to examine and model large, disparate data sets
    - Can identify complex correlations and patterns that may be indicative of causal relationships

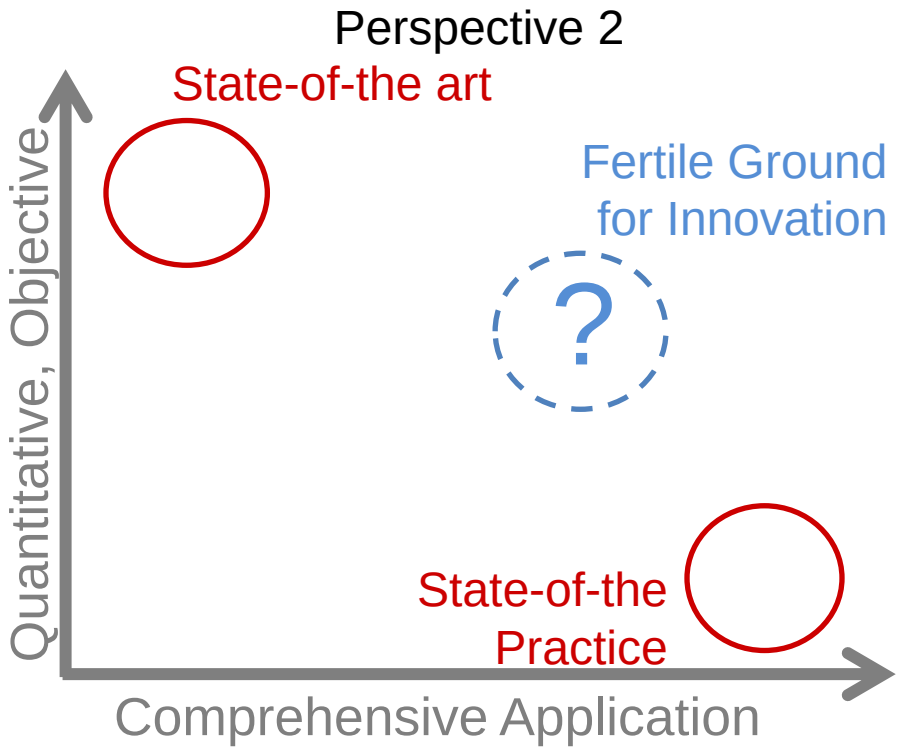
# Bottom-up Research Efforts

***Target Hits for Modal Parameter Estimation and Rating (THMPER), Robotic Assisted Bridge Inspection Tool (RABIT), Mobile LiDAR***

Cost, Time, Accuracy – Pick Two

# Innovation Space



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# THMPER™ System for Rapid Capacity Evaluation

## Targeted Hit for Modal Parameter Estimation and Rating

**Step 1**
Rapid modal impact testing using a self-contained mobile device

**Step 2**
Semi-Automated pre- and post-processing to obtain global frequencies and mode shapes

**Step 3**
Automated FE modeling using NBI data and on-site assessment

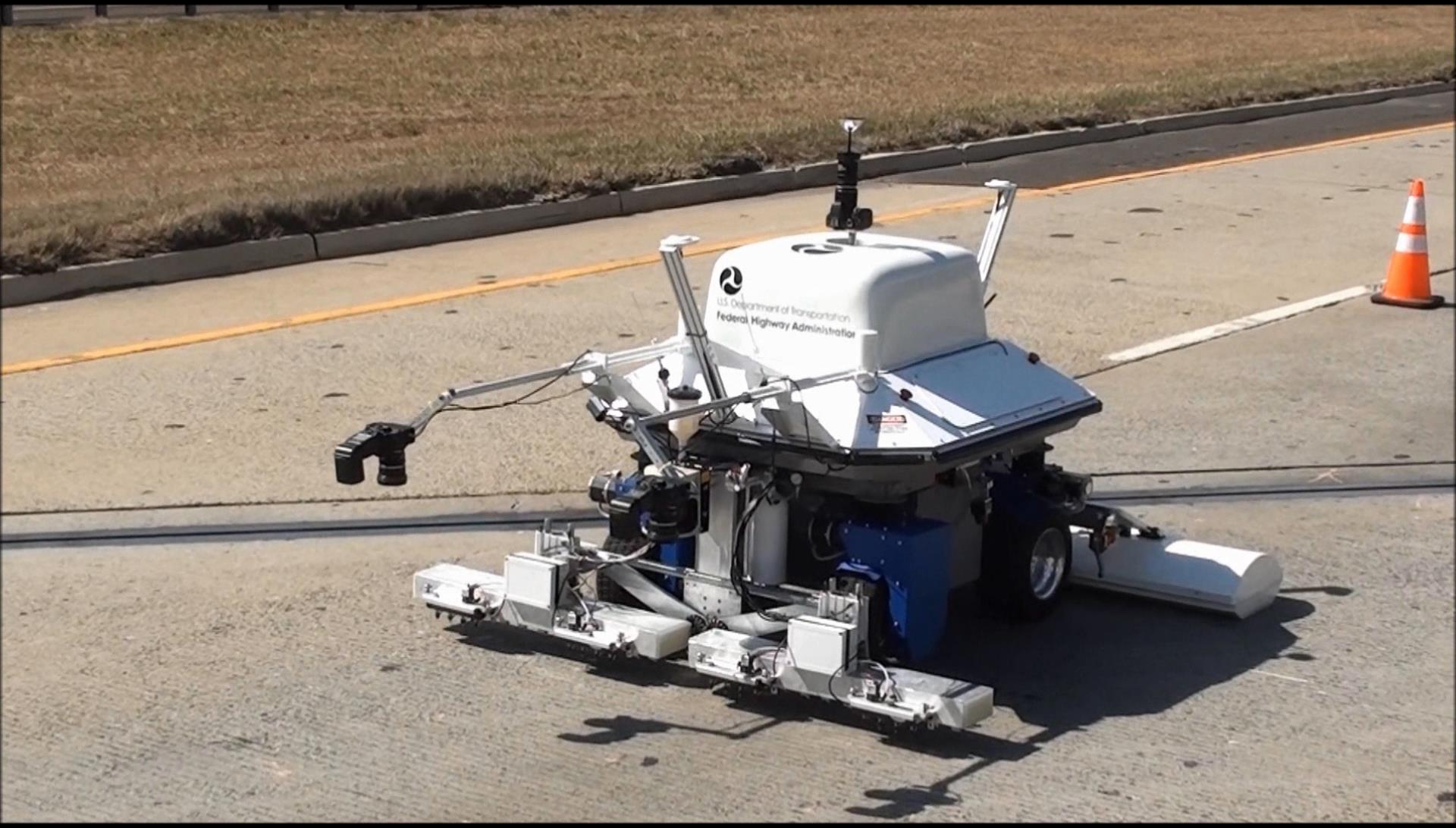
**Step 4**
Automated FE model calibration and load rating

**Step 5**
Reporting

* Patent pending

NIST

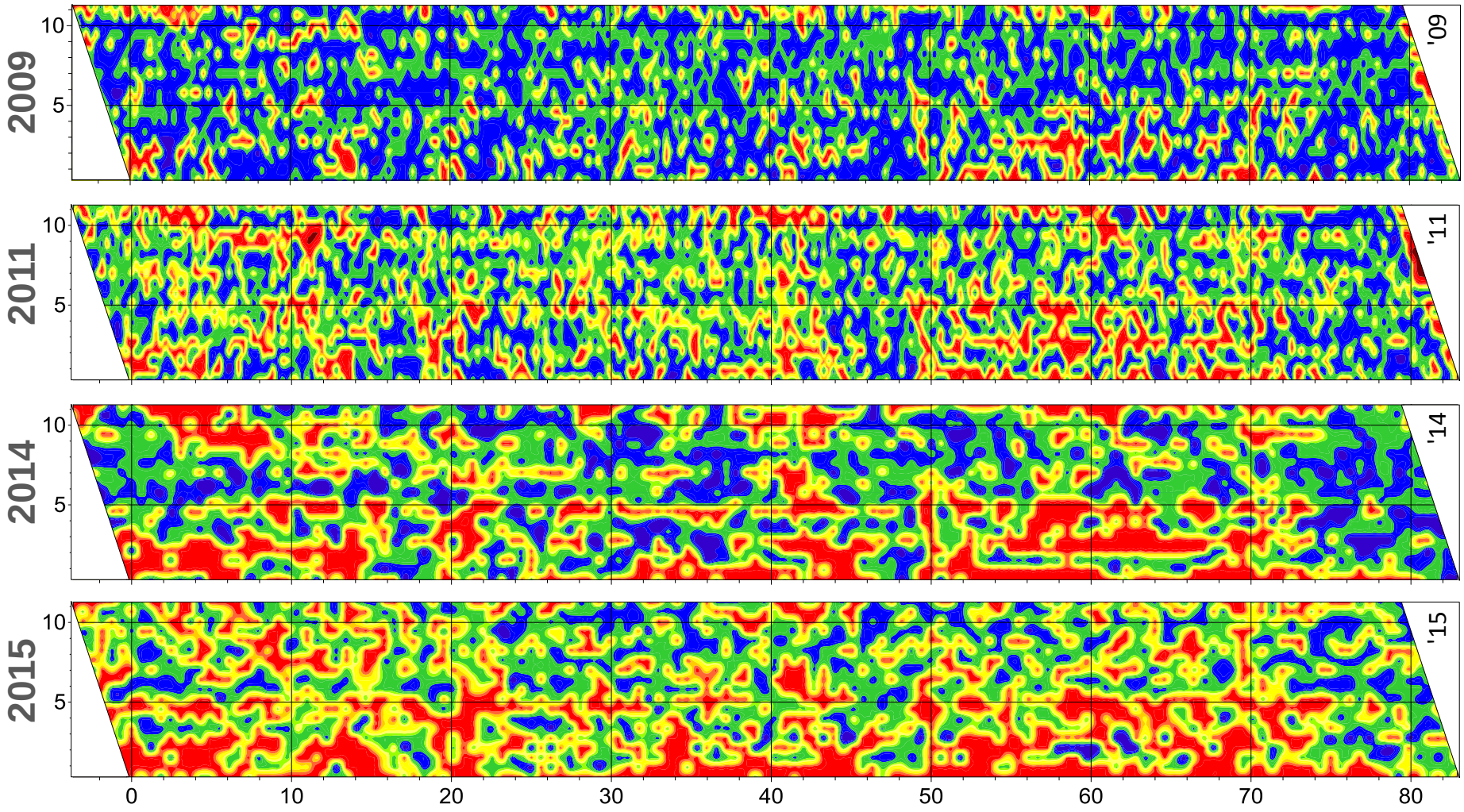
# THMPER System – Rapid Data Collection




Courtesy of  Dr. Nenad Gucunski

# Quantitative Tracking of Deterioration

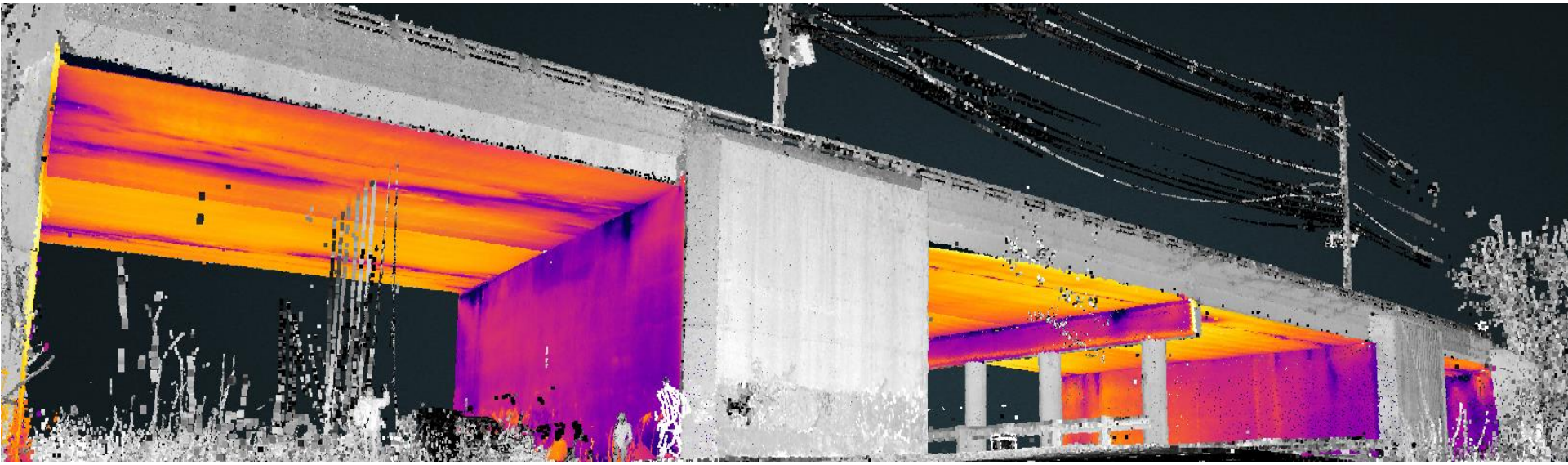
## Delamination Maps (IE) for the Haymarket, VA Bridge



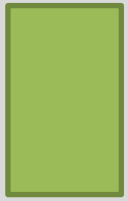
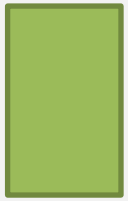
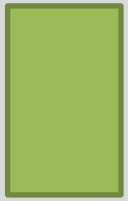
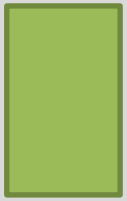

Developed by Dr. Nenad Gucunski

# Mobile, Remote Geometry Capture

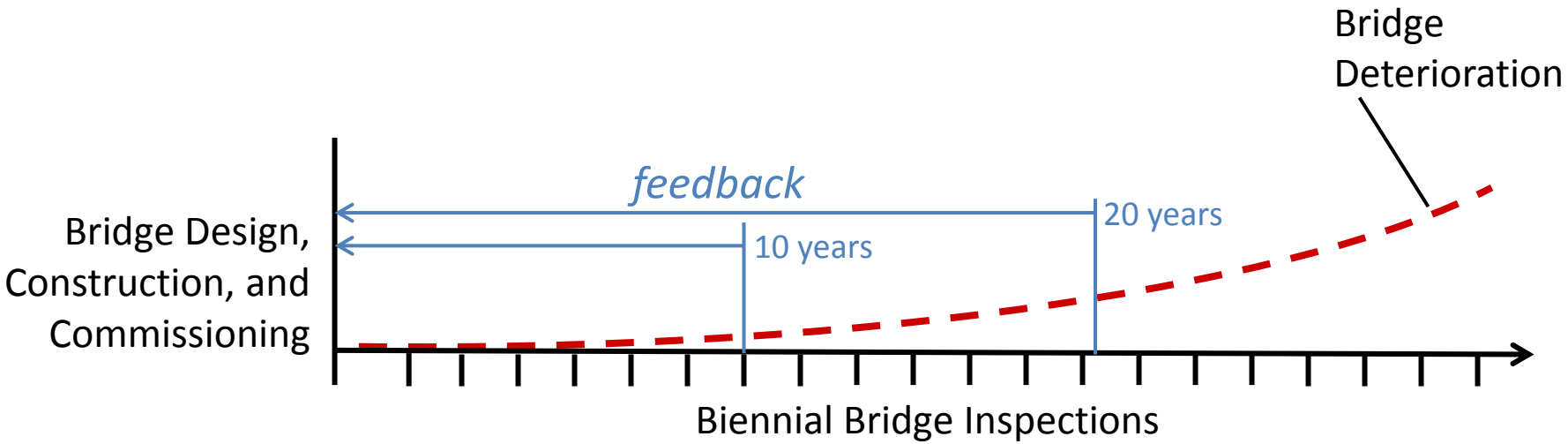
# Context, Augmented Reality



# Synergies Between Research Strategies

| | Quantitative, objective data | …in a timely manner… | …across large populations of bridges. |
|---|---|---|---|
| Top-down Approaches |  |  |  |
| Bottom-up Approaches |  |  |  |
| Controlled, Accelerated Testing |  |  |  |

# Principal Challenge – Slow Feedback Loop




***The long-durations of the current feedback loop are stifling innovation***


Best Cell Phone (2007)
"Offers everything you could want in a cell phone"
-PC World

AT&T Phone (1997)
Big Breakthrough…
- Internal antenna

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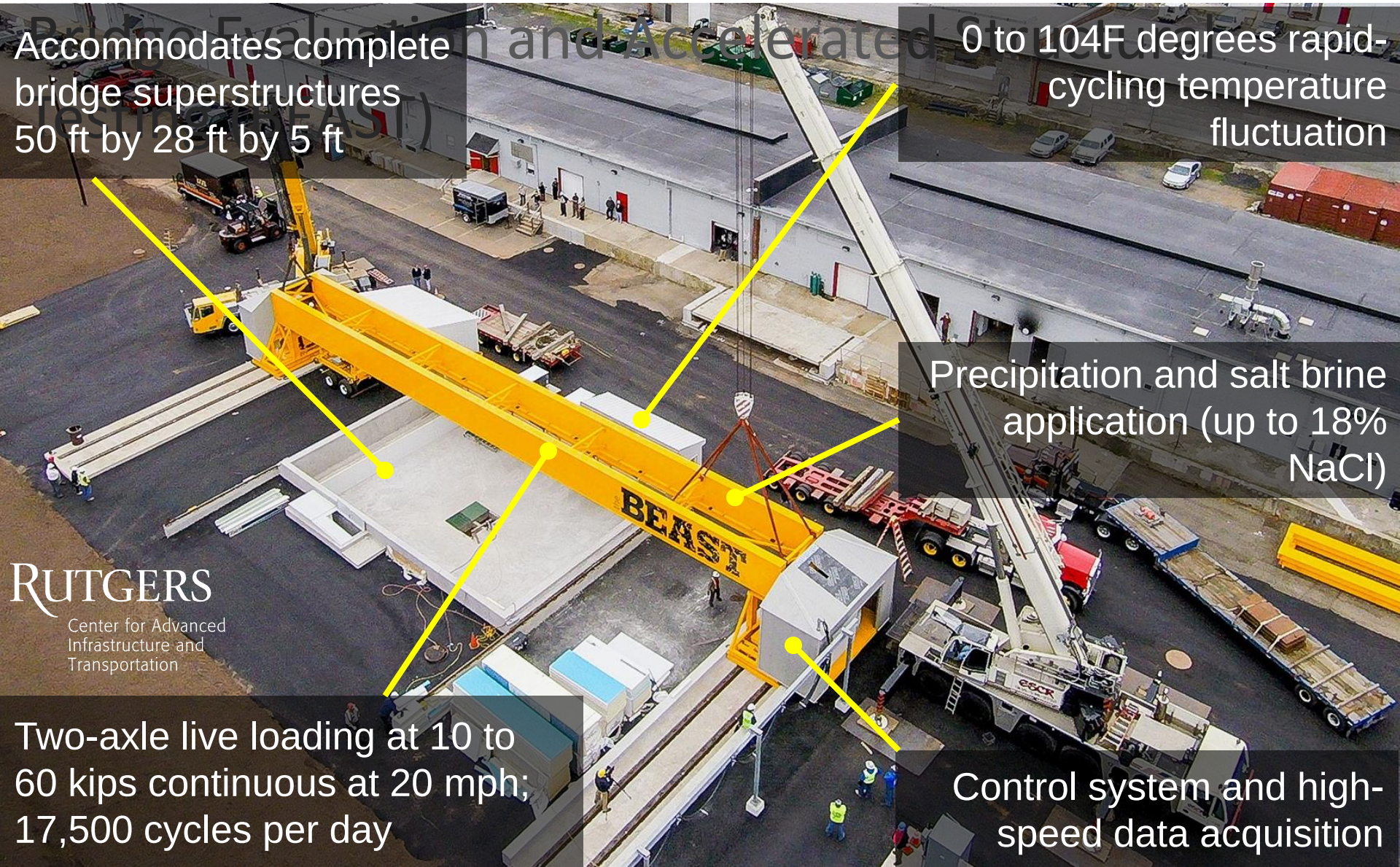
# The BEAST – Accelerated Aging of Bridges




BEAST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# Potential Focuses of Primary Objectives

## *Performance of Primary Components*

- Longitudinal – deterioration curves for nominal bridge decks, steel coatings, joints, bearings, etc.
- Comparative – examination of different rebar coatings, steel coatings, cover depth/variability, live load levels, etc.

## *Effectiveness and Performance of Repair Techniques*

- Longitudinal – deterioration curves for various overlays, repaired decks, etc.
- Comparative – examination of different overlays, different application times, different application approaches

## *Effectiveness of Maintenance and Preservation Activities*

- Comparative – examination of bridge washing, joint cleaning, various sealants, etc.

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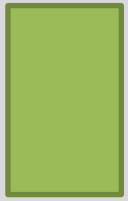
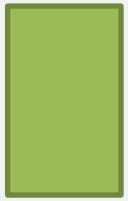
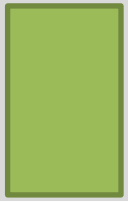
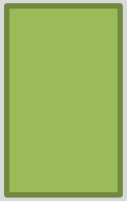
| Top-down Approaches |  |  |  |
| Bottom-up Approaches |  |  |  |
| Controlled, Accelerated Testing |  |  |  |

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# Same Old Story…

## 1 Opening a pathway

Porous materials
Cracking/damage
- Shrinkage
- Intrinsic Forces
- Temperature
- Live Loads
- Settlements

## 2 Entering

Water
Deicing chemicals
Intrinsic materials/chem

## 3 Expanding

Freeze-thaw
Corrosion
Chemical reactions (ASR)