Remote Sensing Technologies for Detecting Bridge Deterioration and Condition Assessment

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Structural Health Monitoring

- Ensuring structural integrity and safety
- Static/dynamic field testing
- Periodic and continuous monitoring
- Routine and special inspections
- Data management / interpretation
- Decision support
Structural Health Monitoring

- Traditional Inspection Techniques
  - Visual, chain drag, half-cell potential, accelerometers
- Advanced Monitoring Techniques
  - GPR, impact echo, fiber optics, thermal IR, ultrasonic
- Remote Sensing: Non-contact data collection
  - “the collection of data about an object, area, or phenomenon from a distance with a device that is not in contact with the object.”

Project Goals

- Establish remotely sensed bridge condition “signature”
  - Assess the potential for commercial remote sensors to be used to assess bridge condition and performance
  - No lane closures, no traffic disruption, no contact with bridge
- Provide bridge inspectors with data to enhance inspection processes
  - Provide condition monitoring between required inspections
- Create the framework for a decision support system to prioritize needs
  - Correlate on-site, in-situ, and stand-off sensors with conventional assessment methods, historic bridge information, and bridge standards and requirements

Top 10 Priorities / Challenges

- Scour/Settlement – The group agreed that scour is a project within itself and beyond the scope of this project. However, settlement is something that should be considered.
- Corrosion damage of prestressed concrete beams is a serious concern, especially with end deterioration, section loss, and strand damage.
- Steel beam section loss is also a serious concern, often most serious at the end of the beams and base of columns.
- Vibration can be an indication of other concerns with the bridge.
- Large cracking is an indication of structural damage.
- Decks - delamination/spalling, one of the largest influences on public perceptions of road condition.
- Decks – map cracking and other material related distresses.
- Expansion joint failure – expansion joint damage can be an indicator of water and other damage that can lead to further problems.
- Chloride ingress – if DOTs had a better way of estimating the chloride level, deck replacements would be scheduled differently.
- Length of bridge – the typical bridge shortages over time - a location item and length change concern.
Electro-Optical Imagery

**Definition:** Any digital photography in the optical, thermal infrared, and near infrared parts of the spectrum collected from an aerial, satellite, or other platform.

**Proposed Application:** Mapping bridge features; 3D models; characterizing deck surface (spalling, cracks).

Speckle Photography and Speckle Pattern Interferometry

**Definition:** Speckle patterns are high-contrast, fine-scale, granular patterns produced by light reflected from optically rough surfaces.

**Proposed Application:** Interferometry of speckle patterns produces fringes from which deformations or displacement gradients (strain) can be inferred.

Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR)

**Definition:** SAR collection uses multiple radar (electromagnetic [radio] wave reflections) returns from small(er) antennae to simulate one radar measurement from a single, large antenna; increases effective resolution.

**Proposed Application:** Bridge dynamics, vibration, and strain; bridge stiffness; bridge settlement.

Example of InSAR used for infrastructure mapping.
Ground-Penetrating Radar (GPR)

**Definition:** Depth sounding by radio waves emitted over a wide frequency band either continuously or in discrete pulses as an antenna sweeps the ground.

**Proposed Application:** Characterization of deck subsurface; detection of delaminations, voids, etc.

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LiDAR / Laser Scanning

**Definition:** 3D mapping (scanning) of surfaces or objects by timing the reflection of millions of laser pulses.

**Proposed Application:** 3D modeling; detecting bridge displacement; measuring size and shape of features

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GPS/Geodetic Measurement

**Definition:** Use of precision measurements of position to determine movement over time

**Proposed Application:** Absolute displacement measurements of structural elements; measuring bridge length

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From Roberts (2005): Lateral bridge movement detected by GPS
Infrared Thermography and Spectroscopy

**Definition:** Images collected in thermal infrared spectrum from which features are identified by their size/shape (thermography) or their spectral content (spectroscopy)

**Proposed Application:** Locating delaminations and other subsurface defects

![Hot Spots at World Trade Center](Image)

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### Commercial Sensor Evaluation

<table>
<thead>
<tr>
<th>Location</th>
<th>&quot;Top 10&quot; Priorities/Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Surface</td>
<td>Map cracking, Scaling, Spalling, Delaminations (thru surface cracks), Expansion Joint External Issues</td>
</tr>
<tr>
<td>Deck Subsurface</td>
<td>Scaling, Spalling, Delaminations, Expansion Joint Internal Issues, Corrosion, Chloride Ingress</td>
</tr>
<tr>
<td>Girder Surface</td>
<td>Structural Steel and Structural Concrete Cracking, Paint Condition, Steel or Concrete Section Loss</td>
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<tr>
<td>Girder Subsurface</td>
<td>Structural Concrete Cracking, Concrete Section Loss, Chloride Ingress, Prestress Strand Breakage</td>
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<tr>
<td>Global Metric</td>
<td>Bridge Length, Settlement, Transverse Movement, Vibration, Surface Roughness</td>
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</tbody>
</table>

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### Performance metrics for each technology

- Commercial availability
- Sensitivity of measurement
- Cost
- Ease of pre-collection prep
- Ease of data collection
- Complexity of analysis
- Stand-off distance rating

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**Table:**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Deck Surface</th>
<th>Deck Subsurface</th>
<th>Girder Surface</th>
<th>Girder Subsurface</th>
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**Notes:**

- **X** = potential for technology to meet measurement needs; **0** = little or no potential
Acknowledgements

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  – Commercial Remote Sensing and Spatial Information Program Manager: Caesar Singh
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  – Michigan Tech Research Institute
  – Center for Automotive Research

• Technical Advisory Council

Thank You

www.mtti.mtu.edu/bridgecondition/

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