Remote Sensing Technologies for Detecting Bridge Deterioration and Condition Assessment

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Michigan Technological University

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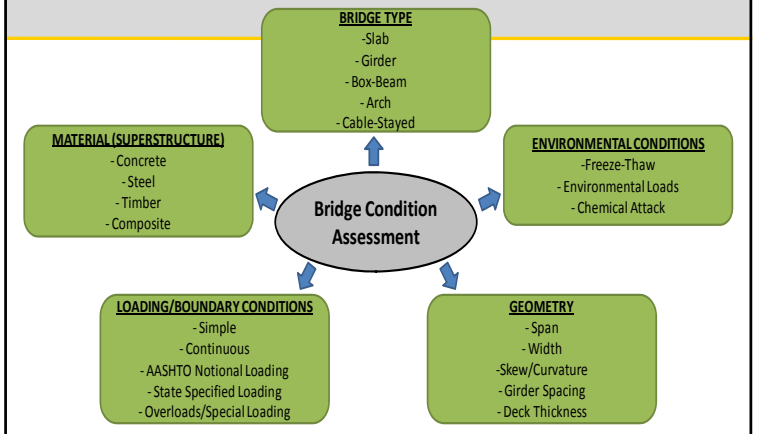
Michigan Tech | CAR | Department of MDOT Transportation

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



MECHANICAL (Global Structural Integrity)

Deflection
-Displacement Transducers
-- Tiltmeters (rotation)
- Seismic (accelerometers)
- Laser

Strain
-Electrical Resistance Gages
-Fiber-Optic Gages
- Vibrating Wire Gages

Thickness
- Caliper
- Ground Penetrating Radar

Stiffness
- Seismic (accelerometers)
- Displacement Transducers

DURABILITY (Local Material Integrity)

Cracking
- Visual Inspection
-Acoustic Emission
- Ultrasonic Pulse Velocity
- Thermography

Corrosion
- Half-cell Potential
- Acoustic Emission

Delamination
- Chain Drag
- Imact Echo

Thickness (Cover)
- Ground Penetrating Radar
- Impact Echo

Structural Health Monitoring

- Traditional Inspection Techniques
  - Visual, chain drag, half-cell potential, accelerometers
- Advanced Monitoring Techniques
  - GPR, impact echo, fiber optics, thermal IR, ultrasonic
  - Wireless remote monitoring
- **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.*"

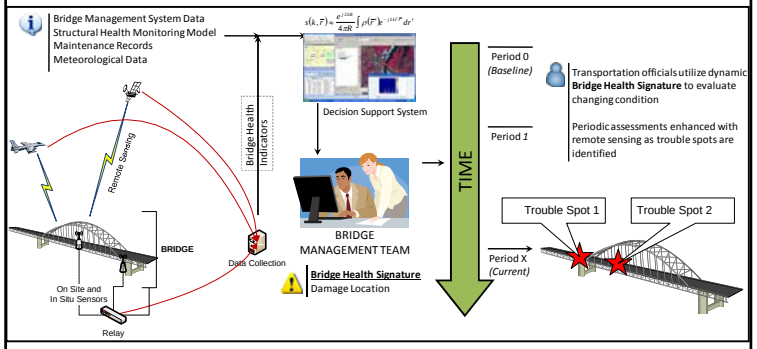
Top 10 Priorities / Challenges

- ***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 shortens over time - a location item and length change concern.

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

USDOT Project Concept



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Remote Sensing
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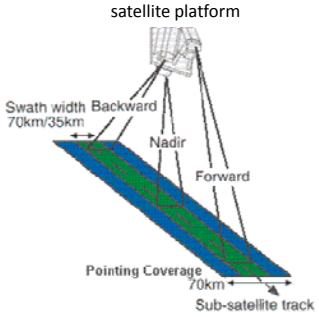
Electro-Optical Imagery

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)



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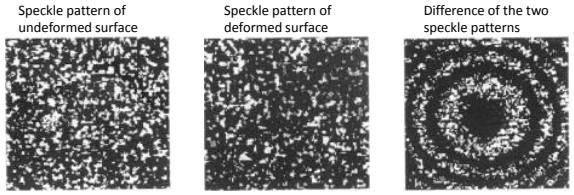
Speckle Photography and Speckle Pattern Interferometry

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.



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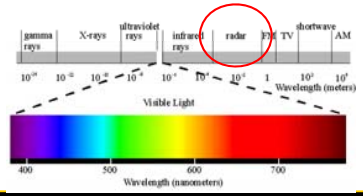
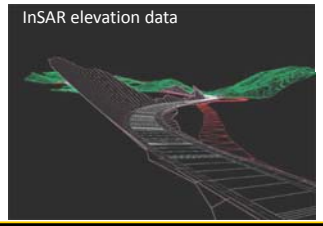
Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR)

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





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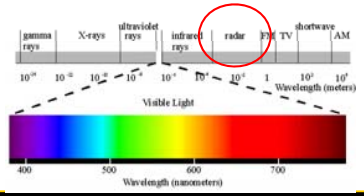

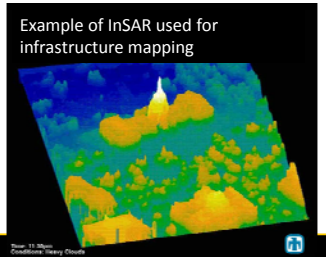

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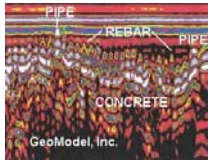
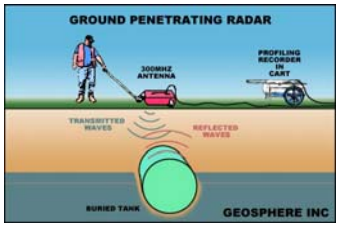
Ground-Penetrating Radar (GPR)

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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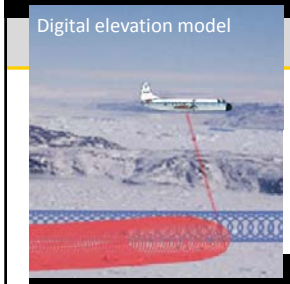
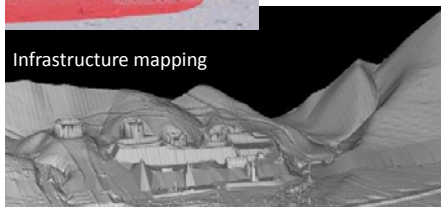
LiDAR / Laser Scanning



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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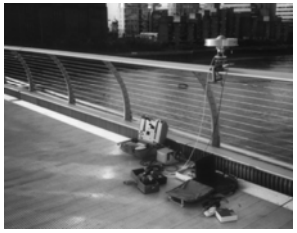
GPS/Geodetic Measurement

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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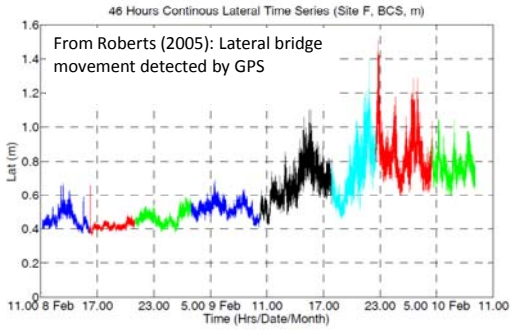
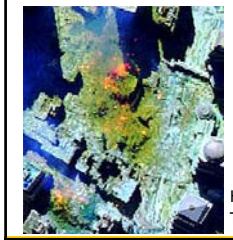


Infrared Thermography and Spectroscopy

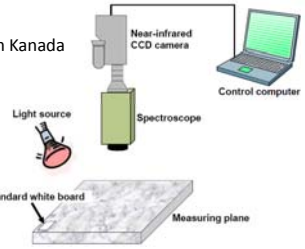
Definition: Images collected in thermal infrared spectrum from which features are identified by their size/shape (thermography) or their spectral content (spectroscopy)

Proposed Application: Locating delaminations and other subsurface defects



Hot Spots at World Trade Center

From Kanada



Commercial Sensor Evaluation

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

Location	Challenges	Indicator	Desired Measurement Sensitivity / Rating	Spectra	3-D photogrammetry	EO airborne & satellite imagery	inteferometry	LiDAR	thermal IR	acoustic	digital image correlation
Girder Surface	Steel structural cracking	Surface Cracks	*< 0.1 mm (.004"), hairline*	x	x	x	x	x	x	0	x
	Concrete structural cracking	Surface Cracks	*.1 mm (.004")*	x	x	x	x	x	x	0	x
	steel section loss	loss/change in x-sect area	*% thickness of web or flange*	0	x	x	0	x	x	0	0
	Paint	paint condition	*amount of missing paint (X %)*	x	0	0	0	0	x	0	0
	concrete section loss	loss/change in x-sect area	*%volume per foot*	0	x	x	0	x	x	x	0
Girder Subsurface	concrete structural cracking	internal cracks (e.g. box beam)	*approx 0.8 mm (1/32")*	0	0	0	0	0	x	0	0
	concrete section loss	loss/change in x-sect area	*%volume per foot*	0	0	0	0	0	x	x	0
	prestress strand breakage	loss/change in x-sect area	wire that 2 mm (0.08") in diameter or strand 9.5 mm (3/8") diameter	0	0	0	0	0	x	0	0
	Corrosion	Corrosion rate (resistivity)	5 to 20 kΩ-cm	0	0	0	0	0	x	0	0
	choride Ingress	Choride content through the depth	0.4 to 1.0 % Chloride by mass of cement	0	0	0	0	0	x	0	0
Global Metrics	Bridge Length	Change in bridge length	*Accuracy to 30 mm (0.1ft) (smaller)*	0	x	x	0	x	0	0	x
	Bridge Settlement	Vertical movement of bridge	*approximately 6 mm to 12 mm (1/4" to 1/2")*	0	x	x	0	x	0	0	x
	Bridge Movement	Transverse directions	*approximately 6 mm to 12 mm (1/4" to 1/2")*	0	x	x	0	x	0	0	x
	Surface roughness	Surface roughness	*Change over time*	x	x	x	x	x	0	0	0
	Vibration	Vibration	5 -20 Hz, *amplitutde?*	0	0	0	x	0	0	0	x

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

Commercial Sensor Evaluation

- 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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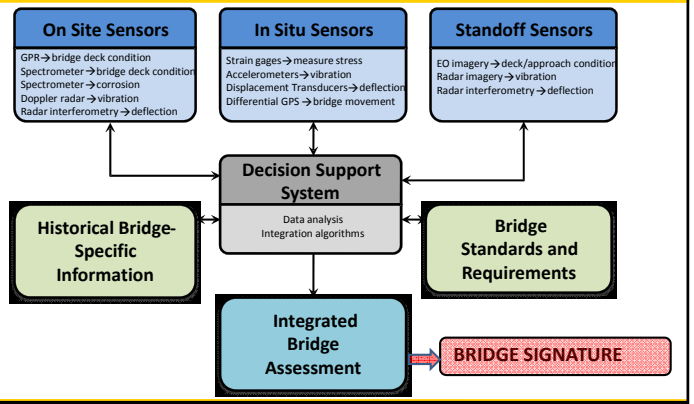
Commercial Sensor Evaluation
Decision Support System
Field Demo

Decision Support System Integration



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Commercial Sensor Evaluation
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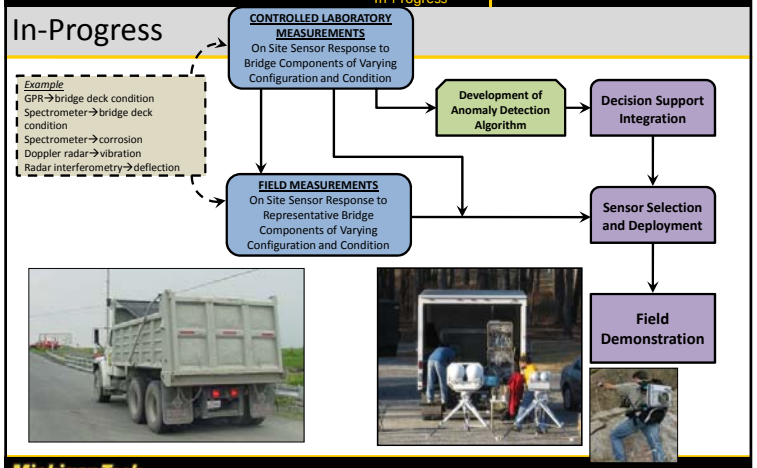

Acknowledgements

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- Technical Advisory Council

Thank You

www.mtti.mtu.edu/bridgecondition/

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