Memo

To: USDOT/RITA research team members

From: C.N. Brooks

CC: P. Hannon

Date: October 15, 2010

Number: 10

Re: Decision Support System update

The initial software development for the decision support system (DSS), including how we will be creating code for integrating sensor data and normalcy models for sensor response, is described below.

For beginning the development of the DSS, our work on the Commercial Sensor Evaluation (Deliverable 3-A), has provided important guidance to our DSS design. This will continue as we assess technologies as part of our lab work plans and eventual field testing. The framework we designed and applied to rating remote sensing technologies (repeated in the figure below) will be important to the DSS as well. Remote sensing technologies that already appear to be promising to evaluate particular bridge condition indicators, or could do so with focused additional investigation as part of this study, will be important to integrate into a DSS, as allowed by study funding. As recommended by the TAC, making sure any DSS demonstration ties into existing bridge management tools and methods is also critical.

				Rating Based, in Part, on Theoretical Sensitivity for Measurement Technologies											
Location	Challenges	Indicator	Desired Measurement Sensitivity	GPR	Spectra	3D Photo-grammetry	EO Airborne/ Satellite Imagery	Optical Inter-ferometry	LiDAR	Thermal IR	Acoustics	DIC	Radar (Backscatter/ Speckle)	InSAR	Streetview-Style Photography
Deck Surface	Expansion Joint	**Torn/Missing Seal**		0	8	14	12	11	13	11	0	0	9	0	13
		Armored Plated Damage		0	0	14	12	11	13	11	0	0	0	0	13
		Cracks within 2 Feet	0.8 mm to 4.8 mm (1/32" to 3/16") width	0	8	14	0	12	12	11	0	0	9	0	13
		Spalls within 2 Feet	6.0 mm to 25.0 mm (1/4" to 1") depth	0	8	14	12	12	12	11	0	0	9	0	13
		Chemical Leaching on Bottom		0	11	0	0	0	0	0	0	0	0	0	0
	Map Cracking	Surface Cracks	0.8 mm to 4.8 mm (1/32" to 3/16") width	0	8	14	12	12	12	11	8	0	9	0	13
	Scaling	Depression in Surface	6.0 mm to 25.0 mm (1/4" to 1") depth	0	8	14	12	12	12	11	0	0	9	0	13
	Spalling	Depression with Parallel Fracture	6.0 mm to 25.0 mm (1/4" to 1") depth	0	8	14	12	12	12	11	0	0	9	0	13
	Delamination	**Surface Cracks**	0.8 mm to 4.8 mm (1/32" to 3/16") width	0	8	14	0	12	12	11	8	0	0	0	13
Deck Subsurface	**Expansion Joint**	**Material in Joint**		0	0	0	0	11	0	0	0	0	0	0	0
	Delamination	**Moisture in Cracks**	Change in moisture content	11	0	0	0	0	0	11	0	0	0	0	0
		Internal Horizontal Crack	Approximately 0.1 mm (0.004") level	0	0	0	0	0	0	11	8	0	0	0	0
		Hollow Sound		0	0	0	0	0	0	0	8	0	0	0	0
		Fracture Planes / Open Spaces	Change in signal from integrated volume	12	0	0	0	0	0	0	8	0	12	0	0
	Scaling	Depression in Surface	6.0 mm to 25.0 mm (1/4" to 1") depth	12	0	0	0	0	0	11	0	0	0	0	0
	Spalling	Depression with Parallel Fracture	6.0 mm to 25.0 mm (1/4" to 1") depth	12	0	0	0	0	0	11	0	0	0	0	0
	Corrosion	Corrosion Rate (Resistivity)	5 to 20 kΩ-cm	0	0	0	0	0	0	0	0	0	0	0	0
		Change in Cross-Sectional Area	Amplitude of signal from rebar	13	0	0	0	0	0	0	8	0	13	0	0
	Choride Ingress	Choride Content through the Depth	0.4 to 1.0 % chloride by mass of cement	12	0	0	0	0	0	0	0	0	12	0	0
Girder Surface	**Steel Structural Cracking**	Surface Cracks	< 0.1 mm (.004"), hairline	0	8	11	0	12	0	11	0	0	0	0	0
	Concr. Structural Cracking	Surface Cracks	.1 mm (.004")	0	8	11	0	12	0	11	8	0	0	0	0
	Steel Section Loss	Change in Cross-Sectional Area	Percent thickness of web or flange	0	0	11	12	0	13	11	0	0	11	0	0
	Paint	**Paint Condition**	Amount of missing paint (X %)	0	9	0	0	0	0	11	0	0	0	0	0
	Concrete Section Loss	Change in Cross-Sectional Area	Percent volume per foot	0	0	11	12	0	13	11	7	0	11	0	0
Girder Subsurface	**Concr. Structural Cracking**	Internal Cracks (e.g. Box Beam)	Approx 0.8 mm (1/32")	0	0	0	0	0	0	11	8	0	0	0	0
	Concrete Section Loss	Change in Cross-Sectional Area	Percent volume per foot	0	0	0	0	0	0	0	7	0	11	0	0
	Prestress Strand Breakage	Change in Cross-Sectional Area	Wire 2 mm or strand 9.5 mm diameter	9	0	0	0	0	0	0	8	0	9	0	0
	Corrosion	Corrosion Rate (Resistivity)	5 to 20 kΩ-cm	0	0	0	0	0	0	0	0	0	0	0	0
		Change in Cross-Sectional Area	Amplitude of signal from rebar	8	0	0	0	0	0	0	8	0	13	0	0
	Choride Ingress	Choride Content through the Depth	0.4 to 1.0 % Chloride by mass of cement	10	0	0	0	0	0	0	0	0	11	0	0
Global Metrics	Bridge Length	**Change in Bridge Length**	Accuracy to 30 mm (0.1ft) (smaller)	0	0	15	13	0	0	0	0	9	0	12	0
	Bridge Settlement	Vertical Movement of Bridge	Approximately 6 mm to 12 mm	0	0	12	0	0	12	0	0	9	0	12	0
	Bridge Movement	**Transverse Directions**	Approximately 6 mm to 12 mm	0	0	12	0	0	12	0	0	9	0	12	0
	Surface Roughness	Surface Roughness	Change over time	0	9	14	13	12	12	0	0	0	11	13	13
	Vibration	Vibration	.5 -20 Hz, amplitude?	0	0	0	0	12	0	0	0	10	12	12	0

Performance ratings of commercial remote sensing technologies, from *An Evaluation of Commercially Available Remote Sensors for Evaluating Highway Bridge Condition* (Deliverable 3-A). Note: Higher scores equal higher ratings for a particular combination of technologies, needed measurements, and bridge condition indicators. For a detailed description of how these ratings were arrived at, please see the Deliverable 3-A at [*www.mtti.mtu.edu/bridgecondition/Tasks_and_Deliverables.html*](www.mtti.mtu.edu/bridgecondition/Tasks_and_Deliverables.html)

Our visits to four bridges on two days with Michigan DOT bridge inspectors were also informing for our DSS design. We learned that any DSS that reaches the field needs to be mobile and rugged to survive environments where sometimes uneven and steep surfaces must be traversed. The idea of an application available in a ruggedized iPad type computer was discussed by the inspectors and the project team (rugged cases are now becoming available – see the “iPad defender” for an example at http://www.otterbox.com/ipad-cases/ipad-defender-series-case/). A rugged, lightweight, and easy-to-use computer such as the iPad would form the hardware base for a tool that the inspectors would use out in the field. The tool would provide bridge locations and bridge inspection data in an easy-to-use graphical mapping interface such as Google Earth. As most bridges do not have typical resolvable street addresses, the DSS application would direct inspectors to the bridge location based on the latitude and longitude of the bridge. With almost 1,000 bridges in MDOT’s University Region (which our inspectors operate out of), this was described a significant need that we had not expected. The DSS interface would then bring up historical inspection reports about a bridge, and provide the ability to enter new bridge inspection data, which would get automatically integrated with MDOT's Bridge Management System. In addition to this sketch of useful DSS provided by our MDOT bridge inspectors, we recommend including the results of any remote sensing analyses performed prior to visiting a bridge, such as an InSAR satellite imagery analysis that could have indicated bridge settlement since the last inspection. The DSS would also then be capable of integrating remote sensing results incorporated as part of inspections, where such tools to become part of standard or enhanced inspections and little further processing was needed. For example, high-resolution digital Streetview-style photography could be linked into the DSS on the iPad-like device so that any noteworthy indicators of interest (such as significant spalling) would always have a photograph attached to notes about the indicator, and the locations where those photos were taken. The idea of a DSS being useful before field work (for mission planning) and in the field also integrates well with the TAC recommendation that a DSS be able to highlight locations with “red light / green light” indicators of bridge problems based on traditional bridge inspection and remote sensing data.

Over the next quarter, we will be turning these ideas into a demonstration set of code that will be able to display sensor data tied to bridge condition indicators, using desired measurement sensitivities tied to NBI Condition Ratings where possible. This should prove the more quantitative way of tying remote sensing measurements into actual indicators of bridge condition. Because we expect to learn a great deal from both lab testing and field demonstrations, we are now anticipating that the Decision Support System period may have to end coincidentally with Task 5, the Field Demonstration. This would provide an additional six months to create a practical and useful DSS demonstration as part of this project. We will produce a status report at the current deadline (April 2011), but would like to have the flexibility to produce an enhanced DSS nearer the end of the study once more information is available.