

**A Summary of the 3rd Quarterly Report
for the Technical Activities Council**

**Bridge Condition Assessment
Using Remote Sensors**

Michigan Technological University
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EXECUTIVE SUMMARY

This quarterly report summarizes progress for “*Bridge Condition Assessment Using Remote Sensors*” during the third quarter for the period of July 1, 2010 – September 30, 2010. Our Michigan Tech research team is investigating the use of remote sensing technologies to assess the structural health of bridges and provide additional inputs to bridge asset management systems. The project will explore correlations between commonly used inspection techniques and remote sensing systems, and develop a decision support system to combine various inputs to create a unique bridge signature that can be tracked over time.

The primary goals of this project are to:

1. Establish remotely sensed bridge health indicators.
2. Develop a baseline bridge performance metric, the “signature,” for benchmarking overall bridge condition.
3. Provide a system that enhances the ability of state and local bridge engineers to prioritize critical repair and maintenance needs for the nation’s bridges.

Accomplishments for this quarter are discussed below and include the completion of the commercial sensor evaluation report, and progress on Tasks 1, 2, 3 and 4. Also, according to the Revised Cost Proposal submitted June 26, 2009, and included as Attachment 2 of that cost proposal, the following deliverables were cited for Quarter 3. All technical memos are located at on the website and are discussed in the relevant tasks below. http://www.mtri.org/bridgecondition/Tasks_and_Deliverables.html.

- ✓ Technical Memorandum No. 7 that defines the feasibility testing progress (Task 2.2).
- ✓ Technical Memorandum No. 8 that outlines the structural modeling development (Task 2.3).
- ✓ Technical Memorandum No. 9 documents the findings of the commercial sensor evaluation (Task 3.0) including describing which sensors can perform most effectively on measuring high priority bridge conditions characteristics.
- ✓ Technical Memorandum No. 10 discussing the progress toward developing the decision support system (DSS), (Task 4.0).

TECHNICAL STATUS

Progress of each of the six tasks is documented below and references Technical Memos which are located on the website.

Task 1: Administration

Several sub-tasks within the administration have been initiated and completed.

The project website continues to be updated: www.mtti.mtu.edu/bridgecondition . This website includes an overview of the project, information related to the project schedule, tasks and deliverables, the decision support system, project team partners, and key links for the project. All presentations, papers and reports, including the State-of-the-Practice Synthesis completed during the previous quarter, are downloadable from our website under the “Tasks & Deliverables” link.

The following dissemination was documented for this quarter:

- A poster was presented by Dr. Devin Harris at the International Conference on Short & Medium Span Bridges in Niagara Fall, ON. August 3-6, 2010: Harris, D.K., Ahlborn, T.M., Brooks, C.M., Vaghefi, K., Evans, D.C., Oats, R.C., and Endsley, K.A., (2010). *“Commercial Remote Sensing Technology Evaluation for Bridge Condition Assessment.”*
- A technical conference paper (*“Evaluation of Remote Sensing Technologies for Detecting Bridge Deterioration and Condition Assessment”*) was presented by Dr. Tess Ahlborn at the NDE/NDT for Highways and Bridges: Structural Materials Technology (SMT) 2010 Conference, held in New York City, NY, August 16-20, 2010.
- Dr. Ahlborn was invited to present a brief overview of the project to bridge engineers and FHWA officials at the AASHTO T-10 (Concrete Bridges) Committee meeting during the PCI Committee Days event in Chicago, IL, September 23, 2010. *“Remote Sensing Technologies for Detecting Bridge Deterioration and Condition Assessment.”*
- The Michigan Tech Research Institute partners participated in and presented at the MTRI Annual Poster Session on Michigan Tech’s Houghton campus, October 1, 2010.
- Deliverable 3-A, the commercial sensor evaluation report, titled *An Evaluation of Commercially Available Remote Sensors for Assessing Highway Bridge Condition*, is described below under Task 3 activities. The final report is also posted on the project website.

An internal project wiki site has been established for correspondence across the entire Michigan Tech, MTRI, and CAR team related to the project and includes the state-of-practice report, project presentations, literature, and other working documents that are shared within the research team. All team members have access to this project website for updating information and keeping members informed of progress. Below is a screen-shot of the wiki site showing an example of how we post documents and comments to help with effective and timely delivery of documentation and reports.

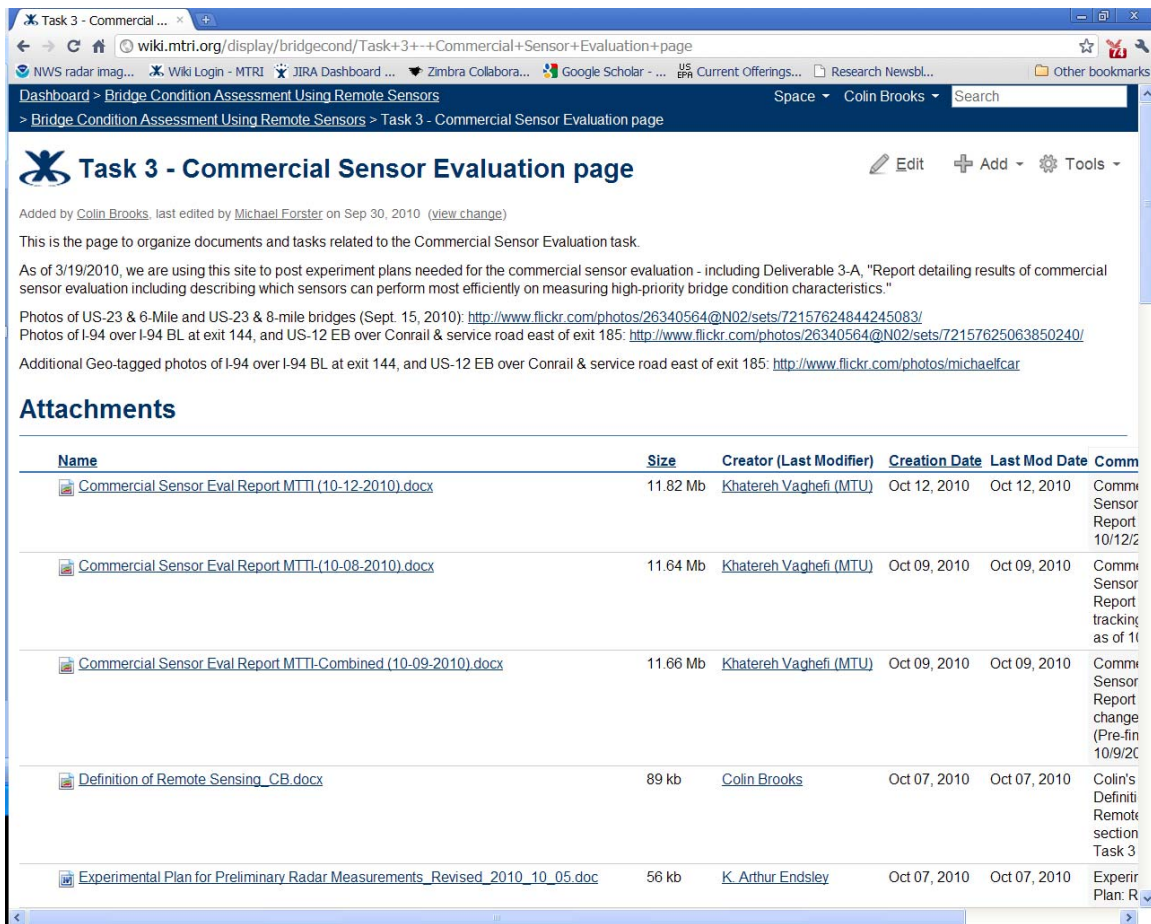


Figure A: An example of the internal project collaborative wiki site used for all team members to share documents, comments, and links across team members at Michigan Tech’s main campus, MTRI, and CAR.

Task 2: Bridge Condition Characterization

This task consists of several sub-tasks: the State-of-the-Practice Synthesis, feasibility studies (through laboratory and small scale field investigation and demonstration), and structural modeling. These sub-tasks are being accomplished through several activities.

A significant activity of this task is to assess performance of commercially available sensors and their potential application to bridge health monitoring. With interactions from TAC members, and with the completion of the commercial sensor evaluation report, realistic work plans to demonstrate the feasibility of implementing several remote sensing techniques for bridge condition assessment have been identified. Originally, these work plans had been referred to as “laboratory testing plans”. It is more appropriate to refer to these work plans as “feasibility studies” that will focus on proof-of-concepts, as many of the identified promising technologies are

not in need of isolated or detailed laboratory studies. We intend to continue performing focused testing of promising remote sensing technologies that meet the priorities of the transportation community, based on our TAC and MDOT input.

Technical Memorandum No. 7 summarizes the work plans for the feasibility studies of each identified technology. Refined work plans are stored on the wiki project website for internal use.

For all remote sensing technologies being evaluated in the work plans, we are focusing on understanding the measurement requirements for indicators of bridge condition important to DOTs. This enables us to select the remote sensing technologies that can meet those requirements, if they exist, and can be reasonably implemented. This requirements definition process will continue to be a high priority for our team.

Technical Memorandum No. 8 addresses the status of the structural modeling activities. The modeling will be coordinated with the sensor evaluation process underway in the feasibility study work plans related to global metrics and responses.

Additional Task 2 activities – Bridge Inspections:

The project team has worked with MDOT to shadow two state bridge inspectors during the inspection of four bridges. Information on each bridge inspection visits is described below. The purpose of these visits was to gain a better understanding of what some bridge inspectors deal with when inspecting various bridge types in several environments, and to obtain firsthand knowledge of what changes to the inspection process (techniques, equipment, training, etc) would be most valuable and immediately implementable. Approximately three hours was spent at each bridge site over a two-day period. In addition to the two state bridge inspectors, four to six team members participated in each of the inspections.

September 15, 2010:

1st Bridge (Ann Arbor, MI US-23 – 6 Mile Road – Lat 42° 23' 40.9", Long – 83° 45' 48.50")

- A steel stringer bridge with a concrete deck built 1962 and rehabilitated in 1989 (reconstruction, but no details). Currently the bridge is on a 12 month inspection cycle.
- Overall, the bridge scored in the poor category for the deck (4) and fair for the superstructure (5) ratings on the previous inspection (10/27/2009).
- The low deck rating was primarily attributed to heavy leaching and map cracking on the underside with locations of delamination and spalling. The top surface also exhibited transverse and map cracking with multiple large patches applied.
- The superstructure rated fair due to some minor section loss and corrosion.
- Visual inspection only, no additional techniques employed.

2nd Bridge (Ann Arbor, MI US-23 – 8 Mile Road – Lat 42° 25' 43.11", Long – 83° 46' 0.81")

- A steel stringer bridge with a concrete deck built 1962 and reconstructed in 2006 (deck overlay). Currently the bridge is on a 12 month inspection cycle.
- Overall, the bridge scored in the poor category for both the deck (4) and superstructure (4) ratings on the previous inspection (10/27/2009).
- The low deck rating was primarily attributed to issues on the underside of the deck which exhibited significant map cracking, delaminations, and spalls. The top surface rated well, likely due to the recent overlay application.
- The superstructure rated poorly primarily due to an extremely warped girder, resulting from a high load hit. The elevation of the girder is below current design standards and has a previous history of high-load hits, preventing heat straightening (replacement required).
- Visual inspection only, no additional techniques employed.

September 21, 2010:

1st Bridge (Jackson, MI I-94BL SB – Lat 42° 16' 38.56", Long – 84° 19' 16.50")

- A steel stringer bridge with a concrete deck built 1949, scheduled for complete replacement in 2012, currently on a 6-month inspection cycle.
- Overall, scored low in most categories during previous inspection (4/21/2010), including joints (2 critical), deck bottom surface and general (3 serious), girders (4 poor), and section loss (1 imminent failure).
- Section loss at most beam ends (lower flanges and webs), serious corrosion at piers, between plates, abutment bearings and on all beams, heaviest near joints.
- Minimum maintenance on bridge for the past few years as reconstruction is anticipated.
- A bridge deck overlay was applied as a repair technique in 2009 to stabilize the deck, improving the deck top surface rating from poor (4) to very good (8).
- Visual inspection only, no additional techniques employed.

2nd Bridge (Ypsilanti, MI US-12 EB – Lat 42° 14' 46.22", Long – 83° 33' 34.69")

- A prestressed concrete adjacent box-beam bridge reconstructed 1995 (original steel bridge built in 1944) and uses original abutments.
- Overall, the bridge scored in the satisfactory category for both the deck (6) and fair for the superstructure (5) ratings on the previous inspection (10/27/2009).
- A thin epoxy overlay was added prior to 2006.
- The box beams showed longitudinal cracking on the underside of the majority of girders with rust staining indicating corrosion of the prestressing strands. Visible shear cracking was noted near the support in the exterior fascia beam. Although no crack width measurements were taken, previous inspections indicated only tight shrinkage cracks existed.
- Visual inspection only, no additional techniques employed.

A primary outcome of these inspections was understanding the reality that bridge inspectors confront daily with traffic conditions, limited inspection tools (a hammer, camera and clipboard), and the limited ability to monitor quantifiable measures such as the rate of crack width growth. The inspections confirmed the need for remote sensing technologies to be applied (and new technologies to be developed and refined) to enhance the nation’s bridge inspection program. The inspectors indicated that any technologies that could be immediately implemented would be welcomed.

Task 3: Commercial Sensor Evaluation

The commercial sensor evaluation has been completed this quarter and is documented in the report *An Evaluation of Commercially Available Remote Sensors for Assessing Highway Bridge Condition*. **Technical Memorandum No. 9** documents the completion of the CSE Report and information on accessing the report through the project website and internal wiki site. The report can be downloaded from www.mtti.mtu.edu/bridgecondition by clicking on “Tasks and Deliverables” and “Deliverable 3-A”.

As of the previous quarterly report, we had indicated concern that this task might be challenging to complete by the September 30th deadline. Due to timely and focused input using the expertise of our team, we have written what we submit is a high-quality and timely commercial sensor evaluation. We will monitor lessons learned about commercial sensor capabilities during the next six months of the study, and stand ready to write a supplement if we and the Program Manager recommend one needs to be issued. We have been concentrating on evaluating remote sensing technologies that have the capability to be implemented on a practical basis and those that most effectively measure high priority bridge conditions characteristics.

For completeness, the **Executive Summary** is included here:

The nation’s bridge program faces some daunting challenges as our transportation infrastructure continues to age. Current bridge inspection techniques consist largely of labor-intensive subjective measures for quantifying deterioration of various bridge elements. Some advanced non-destructive testing techniques such as ground penetrating radar are being implemented, however little attention has been given to remote sensing technologies.

Remote sensing technologies can be used to assess and monitor the condition of bridge infrastructure and improve the efficiency of inspection, repair, and rehabilitation efforts. Most important, monitoring the condition of a bridge using remote sensors can eliminate the need for traffic disruption or total lane closure as remote sensors do not come in direct contact with the structure.

The challenges of understanding deterioration common to bridges throughout our nation have been grouped into five broad areas: deck surface, deck subsurface, girder surface, girder subsurface, and global response. Each area has specific indicators that identify condition or deterioration (e.g. map cracking, delamination,

and excessive vibration). A number of remote sensing technologies have been reviewed to evaluate potential applicability for monitoring bridge condition and structural health.

This report focuses on evaluating twelve forms of remote sensing that are potentially valuable to assessing bridge condition. The techniques are: ground penetrating radar (GPR), spectra, 3-D optics (including photogrammetry), electro-optical satellite and airborne imagery, optical interferometry, LiDAR, thermal infrared, remote acoustics, digital image correlation (DIC), radar (including backscatter and speckle), interferometric synthetic aperture radar (InSAR), and high-resolution "Streetview-style" digital photography.

Using a rating methodology developed specifically for assessing the applicability of these remote sensing technologies, each technique was rated for accuracy, commercial availability, cost of measurement, pre-collection preparation, complexity of analysis and interpretation, ease of data collection, stand-off distance, and traffic disruption. Key findings from the evaluation are that 3-D optics and "Streetview-style" photography appear to have the greatest potential for assessing surface condition of the deck and structural elements, while radar technologies including GPR and higher frequency radar, as well as thermal/infrared imaging demonstrate promise for subsurface challenges. Global behavior can be best monitored through electro-optical satellite and airborne imagery, optical interferometry, and LiDAR.

Monitoring how damage or deterioration changes over time will provide state and local engineers with additional information used to prioritize critical maintenance and repair of our nation's bridges. The ability to acquire this information remotely from many bridges without the expense of a dense sensor network will provide more accurate and near real-time assessments of bridge condition. Improved assessments allow for limited resources to be better allocated in repair and maintenance efforts, thereby extending the service life and safety of bridge assets, and minimizing costs of service-life extension.

Based on our evaluation so far, several remote sensing technologies appear very promising to significantly help with bridge condition assessment and the generation of bridge condition. These include 3-dimensional optics (including photogrammetry), LiDAR (notably researched by our colleagues at UNC-Charlotte), StreetView-style high-resolution digital photography; other high-rated technologies useful for several bridge condition indicators include some applications of GPR, electro-optical airborne and satellite remote sensing, optical inteferometry, and InSAR (Interferometric Synthetic Aperture Radar). Several of these techniques will undergo further testing (Task 2) before we recommend these as practical, valuable technologies for remote sensing of bridge condition.

Task 4: Decision Support System

This task officially began during Quarter 3 and we have begun to develop the foundation for the decision support system. In developing the commercial sensor evaluation

report, we looked for specific indicators and their potential to be measured with remote sensing methods. Where needed measurement sensitivities could be determined, based on the literature and expert judgment, these will feed rules that the Decision Support System (DSS) will need to turn remote sensing data into useful information. **Technical Memorandum No. 10** describes our start in this area. Key to a successful DSS will be remembering the advice of our Technical Advisory Committee, which clearly described how any remote sensing-based technology assessments made available through our DSS and its algorithms should be compatible with existing tools, assessment methods, and data sources, such as the standards and data used to inform the National Bridge Inventory (NBI) rating system, in use by state DOTs and local transportation agencies.

Task 5: Field Demonstration

No progress was planned for this task in Quarter 3.

Task 6: Assessment

No progress was planned for this task in Quarter 3. However, members of the assessment team participated in both the bridge inspection visits and the sensor evaluation activities to become better acquainted with the inspection process and more knowledgeable about the candidate technologies. These efforts generated information that will be useful in establishing different categories of costs and benefits that will be needed for an effective economic evaluation of the developed monitoring system.

FUTURE PLANS

Quarter 4 activities will continue to follow the general schedule outlined within the technical project proposal. Task 1 administrative activities are progressing well. From a technical perspective, the primary focus of the activities in Quarter 4 will continue on the bridge condition characterization (Task 2) progressing through the proof-of-concept testing and further evaluation of commercial sensor technologies. In addition, activities related to the decision support system described in Task 4 will commence.

Anticipated Activities and Deliverables for Quarter 4 include:

- Progress on work plans to demonstrate the feasibility of implementing several remote sensing techniques for bridge condition assessment (Task 2.2).
- Further development of structural modeling for component indicators, and finite element calibration with laboratory testing (Task 2.3).
- Outreach to stakeholders and meeting with TAC discussing useful metrics in the DSS for bridge management teams (Task 4.1).

- Development of the method for implementing and testing algorithms of the DDS for bridge health (Task 4.4).
- A group meeting of the Technical Advisory Council is planned during Quarter 4 to update the TAC on our activities and obtain feedback on our future planned activities (Task 1.0).
- Preparation of a journal article for submission to introduce the results from the commercial sensor evaluation report to the bridge engineering community (Task 1.0).
- Preparation for the TRB workshop on remote sensing sponsored by Joint Committee ABJ50-ABJ60 scheduled for Sunday, January 23, 2011 (Task 1.0).

ADVISORY/STEERING COMMITTEE MEETING

Members of the Technical Advisory Committee include:

Steve Cook – Michigan Department of Transportation
 C. Douglas Couto – Transportation Research Board
 Charles Ishee – Florida Department of Transportation
 Michael Johnson – CALTRANS
 Dan Johnston – Independent Materials Consultant
 Dennis Kolar – The Road Commission for Oakland County
 Duane Otter – Transportation Technology Center, Inc.
 Keith Ramsey – Texas Department of Transportation
 Roger Surdahl – Federal Highway Administration
 Peter Sweatman – University of Michigan Transportation Research Institute
 Krishna Verma – Federal Highway Administration
 Carin Roberts-Wollmann – Virginia Tech
 Amy Trahey – Great Lakes Engineering Group

TAC members will be provided with a summary of Quarter 3 activities. The Technical Advisory Council is scheduled to meet during Quarter 4 for an update on our activities and to obtain feedback on our future planned activities. During the past quarter, TAC member Amy Trahey has been a source of advice on linking bridge inspections to measurable bridge indicator needs. We anticipate that TAC members will continue to fulfill an occasional advice role to this project between formal TAC meetings.