A Summary of the 9th Quarterly Report
for the Technical Advisory Council

Bridge Condition Assessment Using Remote Sensors

Michigan Technological University

Cooperative Agreement No. DTOS59-10-H-00001

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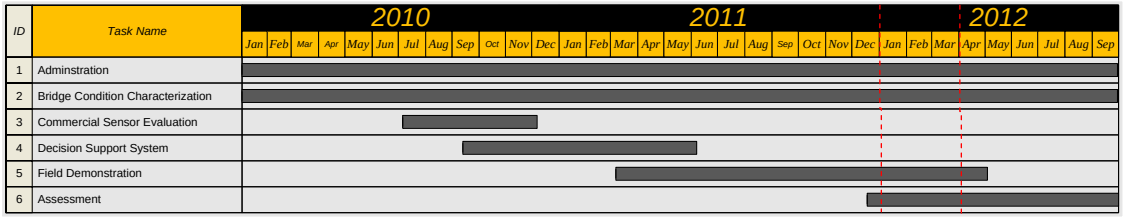
EXECUTIVE SUMMARY

This quarterly report documents progress for *"Bridge Condition Assessment Using Remote Sensors"* during the ninth quarter for the period of January 1 – March 31, 2012. 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 is exploring correlations between commonly used inspection techniques and remote sensing systems, and developing 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.

The project schedule is shown below with Quarter 9 activities bounded by dashed lines; note that a no-cost time extension was granted, extending the project to Sept. 30, 2012:



Accomplishments for this quarter are discussed below and include progress on all tasks.

The following deliverables are provided for Quarter 9 (as listed in Tech Memo 23, dated Jan 13, 2012 and included in Quarterly Report 8). All technical memos are located at the end of this document and are discussed in the relevant tasks below.

- ✓ Technical Memorandum No. 26 describing final papers developed for each technology and the economic evaluation.

- ✓ Technical Memorandum No. 27 explaining the DSS beta version evaluation by our Michigan Department of Transportation focus group through a secure web-portal, summarizing the capabilities of the DSS for integrated bridge assessment as well as the DSS.

TECHNICAL STATUS

Progress of each of the six tasks is documented below with references to the Technical Memos, which are located at the end of this document.

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 are downloadable from our website under the "Tasks & Deliverables" link.

The following publications were documented for this quarter:

- Endsley, K.A., Colin Brooks, Devin K. Harris, Tess Ahlborn, Khatereh Vaghefi, *"Decision support system for integrating remote sensing in bridge condition assessment and preservation,"* in **SPIE Smart Structures and Nondestructive Evaluation and Health Monitoring**, SPIE, Editor. March 11-15, 2012, SPIE: San Diego, CA, U.S.A. (Also presented March 13, 2012 by K.A. Endsley.)

The following were presented at the Transportation Research Board (TRB) 91st Annual Meeting in Washington, DC – January 22-26, 2012:

- *"Deploying Remote-Sensing Technologies for Bridge Condition Assessment"* presented by Dr. Devin Harris on behalf of Dr. Tess Ahlborn at the Sensing Technologies for Transportation Applications workshop. Jan 22, 2012.

- Presented by PhD student Ms. Khatereh Vaghefi for the team of Dr. Tess Ahlborn, Dr. Devin Harris, Vaghefi and Colin Brooks, *"Measuring and Communicating Bridge Performance with Remote-Sensing Technologies"* at the Bridge Performance Measures and Communicating Metrics to the Public session. Jan 26, 2012.

- *"Implementation of the Digital Image Correlation Method as a Bridge Condition Assessment & Bridge Performance Measurement Tool"* at the AFH30 committee meeting on Application of Emerging Technologies to Design and Construction Committee was presented by Ph.D. student Ms. Renee Oats. Jan 24, 2012.

Final Report Progress:
Preparation of the final report continues to follow the outline provided in Tech Memo 23 (Quarter 8) and listed below. **Technical Memorandum 26** reports progress for Chapter 5 (Technology Performance and Evaluation) and Chapter 7 (Economic Evaluation).

FINAL REPORT OUTLINE
Project Documentation Page
Executive Summary
Acknowledgments
Disclaimer
Table of Contents
List of Figures
List of Tables
List of Appendices
Chapter 1 – Introduction, Project Overview
Chapter 2 – Selected RS literature review, cite Appendix A (CSE report)
Chapter 3 – State of the Practice, cite Appendix B (SOA report)
Chapter 4 – Methodology: Lab work, field demonstration (general)
Chapter 5 – Technology Performance and Evaluation
Chapter 6 – Decision Support System
Chapter 7 – Economic Evaluation
Chapter 8 – Implementation and Field Readiness
Chapter 9 – Conclusions and the Path Forward

Decision Support System (DSS) and Economic Evaluation Focus Group meeting was held in Lansing, MI with external guests; Becky Curtis (MDOT), Rich Kathrens (MDOT), Jason DeRuyver (MDOT) and Amy Trahey (Great Lakes Engineering). (See **Technical Memorandum 27**.)

Task 2: Bridge Condition Characterization

This task consisted of several sub-tasks including feasibility studies with limited laboratory and small scale field investigation and demonstration. As highlighted in the previous quarterly reports, the focus of the study shifted away from a structural integrity focus primarily to an assessment focus, the highlights of which have been included in previous reports. No new updates have been added to the bridge condition characterization (Task 2) and this task is considered complete from an activities perspective. A summary of the findings of this task will be included in the final report.

Task 3: Commercial Sensor Evaluation

The commercial sensor evaluation was completed during Quarter 3 and is documented in the report *An Evaluation of Commercially Available Remote Sensors for Assessing Highway Bridge Condition*. The report can be downloaded from www.mtti.mtu.edu/bridgecondition by clicking on "Tasks and Deliverables" and

"Deliverable 3-A". It continues to inform our study, has served a steady reference during project work and will be integrated into the final report.

Task 4: Decision Support System

Progress on the Bridge Condition Decision Support System (DSS) has continued to create a user-friendly, stable, and robust framework for integrating remote sensing results while providing access to existing bridge condition data. In particular, several improvements were made to the Bridge DSS in advance of the DSS Focus Group on March 1, 2012. Many new features were exhibited during the DSS Focus Group meeting including BridgeViewer RCS photo points, GigaPan photo points, remote sensing overlays, and a "Bridge Deck Health Signature" utility that presented a user-configurable score based on remote sensing metrics of bridge deck condition. The participants gave excellent feedback and identified needed improvements and desired features including the removal of 'N' rating counts from NBI rating distributions, the ability to plot rating distributions for a subset of filtered data, plotting of bridge deterioration curves, and visualizing more bridges than the current page limit (30) allows at one time on the map. Many of these improvements will be made in advance of the TAC group demos on April 26 and 27. Details of the MDOT Focus Group meeting and progress related to the DSS developments are presented in **Technical Memorandum No. 27**.

Task 5: Field Demonstration

No field demonstrations were deployed in Quarter 9. An April 2012 field data collection is being planned to extend and more fully test the capabilities of 3-D optical technology to characterize bridge surfaces. The 3-D Optical Bridge-evaluation System (3DOBS), which uses close-range photogrammetric remote sensing methods, was developed by the project team to assess the condition of bridge decks through creating a very high-resolution digital elevation model of the deck surface. The same technology and system should be capable of evaluating other structural components, such as the underside of decks, which can have significant spalling problems of interest to bridge managers. If 3DOBS could be successfully deployed to evaluate the underside of a bridge, then a more complete comparison of the capabilities of 3-D optics vs. more expensive LiDAR technology could be made as part of this project. The April 2012 field data collection is planned to assess the underside of the Freer Road test bridge (which goes over Interstate 94 near Chelsea, MI). A moving window of 2-hour single lane closures is anticipated to be able to collect the complete underside of the Freer Road bridge. Cooperation for this closure is being sought from the Michigan Department of Transportation, who has helped with the previous needed lane closures.

Task 6: Assessment

The assessment-related activities made progress in two major areas this quarter: (1) finalized cost estimates and (2) conducted a second round interview with bridge inspection and management experts. The cost estimates supplement field cost data collection and help develop a concept of operations (CONOPS) for sustainable adoption of remote sensing technologies within a bridge operations and maintenance program.

Cost data (both equipment and service) were collected through a series of interviews with vendors at the 2012 TRB Exhibit and with representatives of companies selected by the research team for phone interviews. The second round interviews with MDOT stakeholders served to (1) assess the benefits of new bridge inspection technologies, as well as incentives and barriers to their implementation; and (2) to assess the benefits of the decision support system (DSS) to MDOT's bridge management program. Their valuable input will help the research team to develop deployment scenarios and conduct a final cost benefit analysis. The focus of Task 6 for the upcoming quarter is to complete a draft evaluation chapter titled "Economic Evaluation of Commercial Remote Sensing and Decision Support System for Bridge Health Monitoring." The evaluation outline for Chapter 7 is presented in **Technical Memorandum No. 26**.

PROBLEMS ENCOUNTERED

No technical problems were encountered during this quarter.

FUTURE PLANS

The primary focus of the activities in Quarter 10 will follow the revised project plan included in Quarter 8 Technical Memorandum No. 23, and will focus on preparation of the final report, including finalizing the technology performance, beta testing of the DSS and economic evaluation.

ADVISORY/STEERING COMMITTEE MEETING

Members of the Technical Advisory Committee include:

Steve Cook – Michigan Department of Transportation
C. Douglas Couto – Transportation Research Board
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
Carin Roberts-Wollmann – Virginia Tech
Amy Trahey – Great Lakes Engineering Group

Members will be provided with a summary of Quarter 9 activities. Technical memorandums are posted to the website.

To beta test and provide feedback on the current decision support system (DSS) version, web-based TAC meetings are scheduled for April 26 and 27, 2012, 1-5pm EDT. TAC members are asked to attend one of the two meeting times.