

A Summary of the 10th Quarterly Report
for the Technical Advisory Council

Bridge Condition Assessment Using Remote Sensors

Michigan Technological University

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EXECUTIVE SUMMARY

This quarterly report documents progress for “*Bridge Condition Assessment Using Remote Sensors*” during the tenth quarter for the period of April 1 – June 30, 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 10 activities bounded by dashed lines; note that a no-cost time extension was granted, extending the project to Sept. 30, 2012:

ID	Task Name	2010												2011												2012											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep			
1	Administration	[Gantt bar spanning all months]																																			
2	Bridge Condition Characterization	[Gantt bar spanning all months]																																			
3	Commercial Sensor Evaluation	[Gantt bar from Jun 2010 to Sep 2010]																																			
4	Decision Support System	[Gantt bar from Oct 2010 to Sep 2011]																																			
5	Field Demonstration	[Gantt bar from Apr 2011 to Sep 2011]																																			
6	Assessment	[Gantt bar from Apr 2012 to Sep 2012]																																			

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

The following deliverables are provided for Quarter 10 (as listed in Tech Memo 23, dated Jan 13, 2012 and included in Quarterly Report 8).

- ✓ Draft final report to project manager for review and comments. To be submitted July 2012.

TECHNICAL STATUS

Progress of each of the six tasks is documented below.

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:

Brooks, C. N., Dobson, R., Roussi, C., Shuchman, R. A., Ahlborn, T. M., "Development and Application of a 3-D Optical Bridge Deck Evaluation System", *NDE/NDT for Highways & Bridges: Structural Materials Technology (SMT) Conference 2012, New York NY, August 21-24, 2012*,. (American Society of Nondestructive Testing, New York, NY), CD-ROM. (peer-reviewed/refereed). (Accepted)

Vaghefi, K., Ahlborn, T. M., Harris, D. K., "Implementation of Thermal Infrared Imagery for Highway Concrete Bridge Decks", *NDE/NDT for Highways & Bridges: Structural Materials Technology (SMT) Conference 2012, New York NY, August 21-24, 2012*,. (American Society of Nondestructive Testing, New York, NY), CD-ROM. (peer-reviewed/refereed). (Accepted).

Hoensheid, R. C., Dean, D., Brooks, C. N., Harris, D. K., Ahlborn, T. M., Dobson, R., "The Evaluation of Surface Defect Detection using LiDAR for Bridge Structural Health Monitoring", *NDE/NDT for Highways & Bridges: Structural Materials Technology (SMT) Conference 2012, New York NY, August 21-24, 2012*,. (American Society of Nondestructive Testing, New York, NY), CD-ROM. (peer-reviewed/refereed). (Accepted)

Endsley, K. A., Brooks, C. N., Ahlborn, T. M., Harris, D. K., Vaghefi, K., "Utilization of Remote Sensing Data for Bridge Condition in Operational Decision Support", *NDE/NDT for Highways & Bridges: Structural Materials Technology (SMT) Conference 2012, New York NY, August 21-24, 2012*,. (American Society of Nondestructive Testing, New York, NY), CD-ROM. (peer-reviewed/refereed). (Accepted).

Endsley, K. A., Brooks, C. N., Harris, D. K., Ahlborn, T. M., Vaghefi, K., "*Decision support system for integrating remote sensing in bridge condition assessment and preservation*", *SPIE Smart Structures/NDE 2012: Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems*,. (International Society for Optics and Photonics, March 2012), (peer-reviewed/refereed). (Published).

The following presentation was documented for this quarter:

“Using Remote Sensing to Measure Bridge Condition-An Example of Collecting, Analyzing & Visualizing Thermal, Radar, 3-D Optical & LiDAR Data for the Same Michigan Bridges” presented by Colin Brooks to the Eastern Great Lakes Region & Western Great Lakes Region of the American Society for Photogrammetry and Remote Sensing (ASPRS) in Ann Arbor, MI, June 26, 2012.

Final Report Progress:

A final report has been drafted and is undergoing internal review. The draft document will be submitted in July 2012.

FINAL REPORT OUTLINE

- Documentation
- Executive Summary
- Acknowledgments
- Disclaimer

- Table of Contents
 - List of Figures
 - List of Tables
 - List of Equations
 - List of Appendices

Acronyms

01. Introduction
02. Background
03. Methodology
04. Designing and Deploying the 3D Optical Bridge-Evaluation System
05. Deployment of the Bridge Viewer Remote Camera
06. Image Data Collection Gigapan System
07. Surface Defect Detection Using LiDAR
08. Implementation of Thermal Infrared Imagery
09. Evaluation of Digital Image Correlation Method
10. Ground Penetrating RADAR
11. Synthetic Aperture RADAR
12. Assessing the Overall Condition Using Commercial Multispectral Satellite Imagery
13. Demonstration Decision Support System
14. Economic Evaluation of Promising Commercial Remote Sensors and Systems
15. Project Findings

Project Wrap-up Meeting:

A final project wrap-up meeting was held in Houghton, MI on June 19, 2012. Program Manager Caesar Singh attended, along with numerous team members. Team members that were off-campus participated through a conference call and an Internet meeting session. The project team presented the findings from the project, and summarized the technical assessment and economic evaluation. Project goals were reviewed and are

listed below for completeness. These three individual goals combine to meet the higher-level primary goals on page one. The project performance/outcome for each individual goal is also listed. The full project wrap-up presentation is included as Appendix A.

Goal 1. Assess the potential for commercial remote sensors to be used to assess bridge condition and performance.

Performance/Outcome:

Remote sensing has the capability to improve current bridge inspection and evaluation processes. Currently, some technologies (e.g. ground-penetrating radar and infrared thermography) are being deployed by transportation agencies, but not on a widespread basis. The distinct advantage of using remote sensing technologies is the ability to conduct non-contact assessment without interrupting traffic. While these remote sensing technologies do not provide a complete solution for condition assessment, they are effective in quantifying a number of characteristics (e.g. % spall, % delamination) used for condition ratings along with a visual reference and others characteristics which may be useful in future evaluations e.g. roughness, patch extent).

Goal 2. Deploy commercial sensors on in-service bridges to assess condition.

Performance/Outcome:

The project team successfully deployed several remote sensing technologies on three bridges with varying condition states in Michigan. The scope of the deployments were limited to concrete bridges with concrete decks, but aligned well with the technologies evaluated. The field deployment provided confidence to the laboratory studies on the various technologies, but also highlighted those (3DOBS, Thermal IR, LiDAR, Gigapan, BVRCS) that appear better suited for bridge assessment and those requiring additional study (Radar, Digital Image Correlation). The field deployment also highlighted the critical next steps for the investigation, which includes progressing the key technologies to near-highway speeds.

Goal 3. Develop decision support system (DSS) for integrating remote sensing into current bridge assessment practices.

Performance/Outcome:

Currently within the transportation community, there is no decision support system available for bridges. A number of tools exist that have characteristics of a DSS, but none dedicated to aiding the decision making process and definitely none capable of integrating GIS referenced remote sensing data for condition assessment. A flexible beta DSS was developed and tested with project stakeholders with great success. The system demonstrated how remote sensing results could be collected, synthesized, and used effectively for bridge decision-making scenarios, but also how the technologies could be integrated with current assessment methods and strategies.

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. 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 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 as a result of the DSS Focus Group on March 1, 2012 and our TAC webinar series on April 26 and 27, 2012. Many features were exhibited during the webinar 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 DSS development and features are documented in the final report.

Task 5: Field Demonstration

No field demonstrations were deployed in Quarter 10. A bridge underside 3-D optical assessment is still being considered to provide a more detailed evaluation of the capabilities of 3DOBS to provide a more complete assessment of bridge surface health. However, limited project time means that the final decision on this field deployment is still being made.

Task 6: Assessment

The assessment-related activities concluded this quarter. A final cost benefit analysis was conducted for the commercially available remote sensing technologies investigated in this study. A technology performance review was also conducted and was presented at the Project Wrap-up Meeting. Both technical and economic assessments will be included in the final report.

PROBLEMS ENCOUNTERED

No technical problems were encountered during this quarter.

FUTURE PLANS

The primary focus of the activities in Quarter 11 will follow the revised project plan included in Quarter 8 Technical Memorandum No. 23, and will focus on the completion and submission of the final project report.

ADVISORY/STEERING COMMITTEE

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

All but one TAC member was able to participate in one of the two DSS webinars provided on April 26 and 27, 2012. Each session gave participants an overview of the project and allowed individual access to use the beta test version of the DSS. The TAC members provided valuable input for future DSS developments.

Members will be provided with a summary of Quarter 10 activities.