Quarterly Progress and Performance Indicators Report:
Project Number and Title: Thrust #1 Distributed Fiber Optic Sensing System for Bridge Monitoring
Research Area: Thrust #1
PI: Xingwei Wang, Electrical and Computer Engineering Department, University of Massachusetts Lowell
Co-PI(s): TzuYang Yu, Civil Engineering Department, University of Massachusetts Lowell.
Reporting Period: *4/1/2022-6/30/2022*
Submission Date: *6/30/2022*

****IMPORTANT: Please fill out each section fully and reply with N/A for questions/sections with nothing to report. For ease of reporting to the USDOT, please do not remove, or change the order of, any sections/text. You may remove/add each row in tables as needed. Thank you! ****
The report is due on the last day of the reporting period in .doc format to tidc@maine.edu.

Overview:

- We performed new temperature calibration tests based on the same layer structure with the testing sensing textile and a temperature chamber.
- We are working on BOTDA data analysis based on the simulation model of a simple bridge.
- The launching fiber of the sensing textile was broken under the bridge, and we were trying to find a way to splice the broken point.
- We have reviewed three bridge candidates and will choose one for testing: M-17-017I-93 Methuen bridge, C-08-026 Chelmsford Bridge and L-15-076 Lowell Bridge.

Meeting the Overarching Goals of the Project:

How did the previous items help you achieve the project goals and objectives? Please give one bullet point for each bullet point listed above.

- The same layer design of testing sample gives us a more precise linear sensing section and temperature coefficient.
- The simulation model of bridge model can verify the BOTDA data of the theoretical strain distribution.
- New bridge structure can have a better understanding and also further study of stain distribution using sensing textile.

Accomplishments:

- We tested different linear sensing sections for different temperatures using the same sample structure of testing sensing textile.
- We studied new temperature coefficient using a new simulation bridge model.
- We have carefully chosen a suitable new bridge for testing smart sensing textile system.
- We have made new plans for installation using both interrogation systems of OFDR and DTS.

Task, Milestone, and Budget Progress:

Complete the following tables to document the work toward each task and budget

Table 1: Task Progress			
Task Number: Title	**Start Date**	**End Date**	**% Complete**
Task 1-1: Sensor development	1/1/2019	6/30/2019	Complete
Task 1-2: Signal processing and sensor characterization on sensors before installation	1/1/2019	12/30/2019	Complete
Task 1-3: Preliminary field tests on bridge	10/1/2019	9/30/2021	Complete
Task 2-1: Algorithm optimization for temperature compensation	9/30/2021	12/2022	80%
Task 2-2: Algorithm development for color coded temperature and strain reconstruction	9/30/2021	12/2022	70%
Task 2-3: Sensor signal response to different weather conditions throughout a year of study.	1/1/2020	12/2022	80%
Task 2-4: Implementation of FBG sensors for newly constructed bridges assessment	1/2022	12/2022	40%
Task 3-1: Signal Processing for sensors on different bridges	01/01/2023	06/30/2023	0%
Task 3-2: Explore OFDR interrogation system	07/01/2021	12/31/2023	40%
Task 3-3: Long-term monitoring for more than 1 year of study	01/01/2021	06/30/2023	40%
Phase 1 Overall	1/1/2019	9/30/2021	100%
Phase 2 Overall	9/30/2021	12/2022	75%
Phase 3 Overall	1/2023	12/31/2023	15%

Table 2: Milestone Progress			
Milestone #: Description	**Corresponding Deliverable**	**Start Date**	**End Date**
Milestone 1: Signal processing	• Understand the effects of Brillouin peaks on the signal. • Study the effects of spatial resolution on the Signal to Noise Ratio. • Develop a complex matrix on how different parameters affect the signal.	01/01/2021	06/30/2021
Milestone 2: Strain gauge comparison	• Comparison between distributed optical sensors and strain gauge data	07/01/2021	ongoing
Milestone 3: Temperature compensation scheme	• A prototype of a smart textile with tubing embedded for temperature compensation.	07/01/2021	ongoing
Milestone 4: Explore OFDR interrogation system.	• Analysis of the dynamic responses of the OFRD measurement on bridges.	01/01/2022	ongoing

Milestone 5: Hardware smart textile improvement	• Provide a system to connect fiber to the sensing textile.	07/01/2022	
Milestone 6: Software	• Software capable of integrating the data from the BOTDA to a 3D model.	01/01/2023	
Milestone 7: Long term monitoring	• Study of the effect of weather conditions on the BOTDA data. • Procedure to characterize the sensors for temperature and strain.	01/01/2023	

Table 3: Budget

Project Budget	Spend – Project to Date	% Project to Date*
Phase 1: $102.1k	$102.1k	100% - 9/30/2021
Phase 2: $103K	$57.5k	60% - 6/15/2022
Phase 3: $104k	$0	0%
Complete Project: $ 309,838.00	$ 159,614	51.5%

Include the date the budget is current to.

Match part expenditure:

Table 3: Budget Progress			
Cost Share budget	**Xingwei Wang course release**	**RA tuition and fees**	**%Percentage to Date**
$310k	$82k	$130,763	69%

Is your Research Project Applied or Advanced?

☒ **Applied** (*The systematic study to gain knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.)*

☐ **Advanced** *(An intermediate research effort between basic research and applied research. This study bridges basic (study to understand fundamental aspects of phenomena without specific applications in mind) and applied research and includes transformative change rather than incremental advances. The investigation into the use of basic research results to an area of application without a specific problem to resolve.)*

Education and Workforce Development:

Answer the following questions (N/A if there is nothing to report):

1. Did you provide any workforce development or training opportunities to transportation professionals (already in the field)? If so, what was the training? When was it offered? How many people attended? (i.e. The research team provided an in the field training for the

SAR technology for 3 maintenance crew members of the , on 3/31/2021. The members learned how to use the technology and interrupt the data.)
N/A

I.

2. Did you hold meetings with any transportation industry organizations or DOTs? If so, what was the meeting's purpose? When was it offered? How many people attended? (i.e. The research team held a meeting with MaineDOT to update them on the progress of the research findings and how the findings can be implemented on 3/31/2021. 15 DOT maintenance members were present at the meeting.)
N/A

3. Did you host/participant in any K-12 education outreach activities? If so, what was the activity? What was the target age/grade level of the participants? How many students/teachers attended? When was the activity held? (i.e. 25 8th graders and 2 teachers visited the concrete lab and created small concrete trinkets like Legos on 3/31/2021. They learned about the different types of fibers that can be used in the concrete.)

N/A

Technology Transfer:
Complete all of the tables below and provide additional information where requested. Please provide ALL requested information as this is one of the most important sections for reporting to the USDOT. ***ONLY provide information relevant to this reporting period.***

Use the table below to complete information about conference sessions, workshops, webinars, seminars, or other events you led/attended where you shared findings as a result of the work you conducted on this project:

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events

Type	Title	Citation	Event & Intended Audience	Location	Date(s)
i.e. Conference, Symposium, DOT/AOT presentation, Seminar, etc.	Presentation Title	Full Citation	Name of event (i.e. TIDC 1st Annual Conference) or who was the presentation given to?		
Seminar	Installation of the Fiber Optics Sensing Textile for Bridge Monitoring		Infrastructure Research Seminar	Online	3/24/2022
Seminar	Composite Bridge Monitoring Using Smart Fiber Optics Sensing Textile		Infrastructure Research Seminar	Online	3/3/2022

Seminar	Distributed Fiber Optic Sensing System for Bridge Monitoring		Infrastructure Research Seminar	Online	2/24/2022

Use the table below to report any publications, technical reports, peer-reviewed articles, newspaper articles referencing your work, graduate papers, dissertations, etc. written as a result of the work you conducted on this project. Please list only completed items and exclude work in progress.

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports

Type	Title	Citation	Date	Status
i.e. Peer-reviewed journal, conference paper, book, policy paper, magazine/newspaper article	Publication title	Full citation		**i.e. Submitted, accepted, under review (by org. submitted to)**
Journal	Pipeline monitoring using fiber optic textile for Structural Health Monitoring	Biondi, A. M., Zhou, J., Guo, X., Wu, R., Tang, Q., Gandhi, H., Yu, T., Gopalan, B., Hanna, T., Ivey, J., & Wang, X. (2022). Pipeline structural health monitoring using distributed fiber optic sensing textile. *Optical Fiber Technology*, *70*, 102876. https://doi.org/10.1016/j.yofte.2022.102876	03/26/2022	**Published**
Journal	Structural Health Monitoring of a bridge using optic sensing textile			Under review from other coauthors

Answer the following questions (N/A if there is nothing to report):

1. Did you deploy any technology during the reporting period through pilot or demonstration studies as a result of this work? If so, what was the technology? When was it deployed?
   N/A

2. Was any technology adopted by industry or transportation agencies as a result of this work? If so, what was the technology? When was is adopted? Who adopted the technology?
   N/A

3. Did findings from this research project result in changing industry or transportation agency practices, decision making, or policies? If so, what was the change? When was the change implemented? Who adopted the change?
   N/A

4. Were any licenses granted to industry as a result of findings from this work? If so, when? To whom was the license granted?
   N/A

5. Were any patent applications submitted as a result of findings from this research? If so, please provide a copy of the patent application with your report.
   N/A

6. Did industry organizations or DOTs provide cost-share (cash or in-kind) to your research during the reporting period? Who was the organization? Please provide an in-kind support invoice from the organization with your report (this is kept confidential and used for record keeping purposes only).
   N/A

Please add figures/images that can be included on the website and/or in marketing/social media materials to further clarify your research to the general public. This is very important to our Technology Transfer initiatives.

Insert figures here

Figure 1 The fiber broke due to the aging of plastic coating.

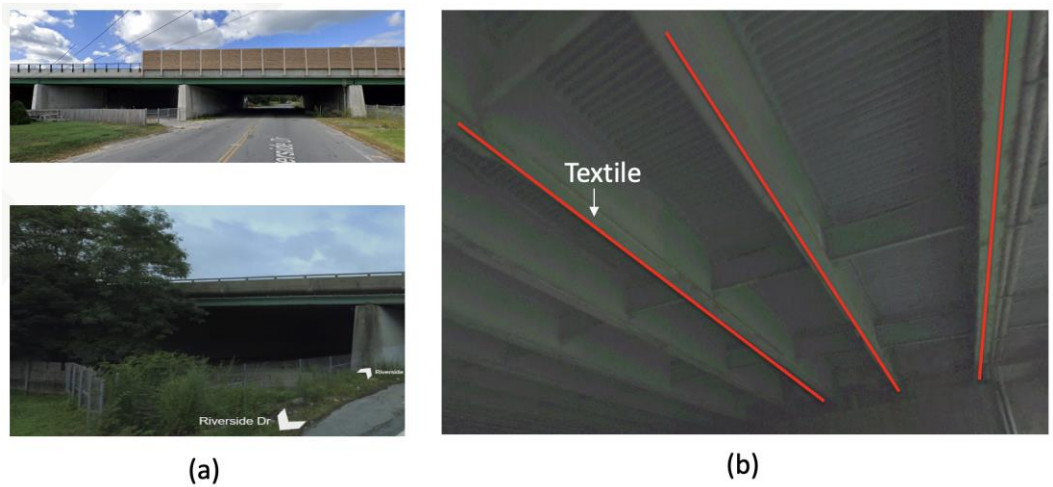

Figure 2 (a) Side view of the bridge (b) Bottom view of the bridge M-17-017I-93 Methuen bridge.

Figure 3 (a) Side view of the bridge (b) Bottom view of C-08-026 Chelmsford Bridge.

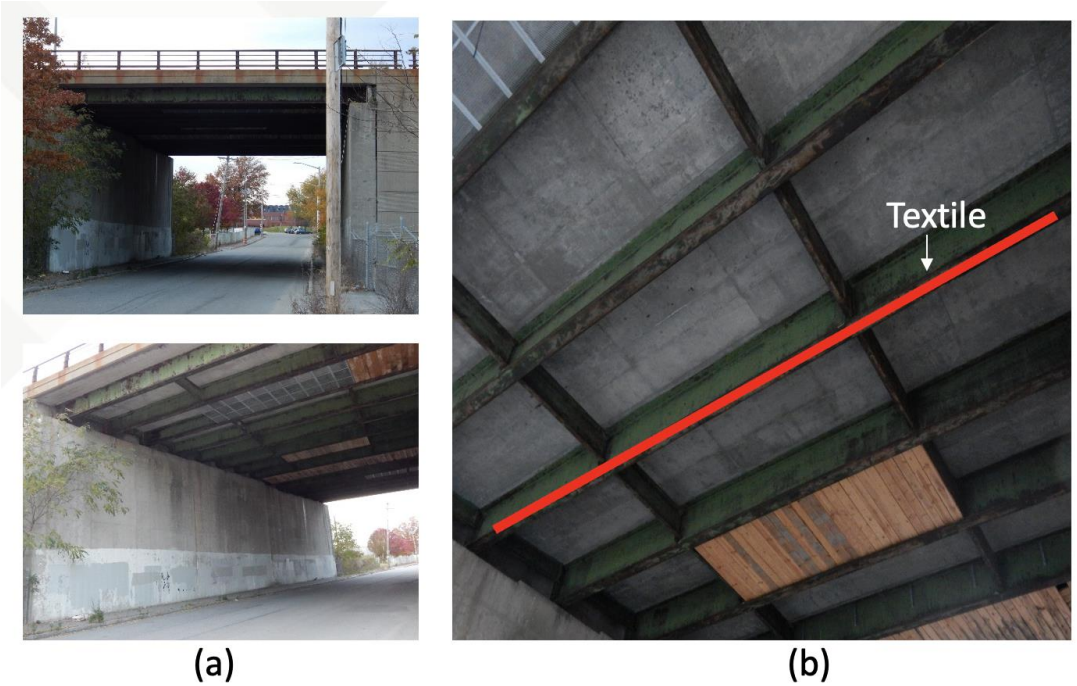

Figure 4 (a) Side view of the bridge (b) Bottom view of L-15-076 Lowell Bridge.

Describe any additional activities involving the dissemination of research results not listed above under the following headings:

Outputs:

Definition: Any new or improved process, practice, technology, software, training aid, or other tangible product resulting from research and development activities. They are used to improve the efficiency, effectiveness, and safety of transportation systems. List any outputs accomplished during this reporting period:

- Examples: New sensing technology was developed. This technology will… A UAV was created to hold new monitoring technology. This will allow maintenance crews to… A new college course was created based on the research findings. This will train future transportation professionals to…

New sensing textile has been developed. This technology could be used not only on bridges, but also in many other large infrastructure monitoring applications.

Outcomes:

Definition: The application of outputs; any changes made to the transportation system, or its regulatory, legislative, or policy framework resulting from research and development activities. List any outcomes accomplished during this reporting period:

- Example: The developed sensing technology was installed in Bridge A in town, state on 1/1/2021. This installation will… The UAV was successfully used by ___ Organization to inspect ___ Bridge in in town, state on 1/1/2021… The newly created college course was taken/completed by __ students in the 2021 fall semester.

The developed sensing textile was installed on Salmon River Bridge in NH and has been under monitored since winter 2019. The students were trained in signal processing skills. Now the ECE students are working together with Civil Engineering students to understand how to interpret the data in bridge health conditions.

Impacts:

Definition: The effects of the outcomes on the transportation system such as reduced fatalities, decreased capital or operating costs, community impacts, or environmental benefits. The reported impacts from UTCs are used for the assessment of each UTC and to make a case for Federal funding of research and education by demonstrating the impacts that UTC funding has had on technology and education. NOTE: The U.S. DOT uses this information to assess how the research and education programs (a) improve the operation and safety of the transportation system; (b) increase the body of knowledge and technologies; (c) enlarge the pool of people trained to develop knowledge and utilize technologies; and (d) improves the physical, institutional, and information resources that enable people to have access to training and new technologies. List any outcomes accomplished during this reporting period:

- Example: The developed sensing technology's successful deployment resulted in the adoption of the technology by the State DOT. The technology will be installed in all new bridge installments of this type. This adoption will… The new UAV monitoring technology was adopted by __ organization to be used for __ bridges inspections. This will allow inspectors to… The college course has been adopted by another member university…

The long-term monitoring data of the sensing textile on this railway bridge has demonstrated that the novel sensing system is robust for more than two years and can provide stable signals. With improved packaging, the fiber cables can be more robust. It could provide more information to estimate the safety of the bridges. In addition, it increased the body of knowledge or sensing textile. The students were trained in how to conduct field tests and solved unexpected problems on site.

Participants and Collaborators:

Use the table below to list individuals (compensated or not) who have worked on the project other than students.

Table 6: Active Principal Investigators, faculty, administrators, and Management Team Members

Individual Name & Title	Dates involved	Email Address	Department	Role in Research
Xingwei Wang		Xingwei_wang@uml.edu	Electrical and Computer Engineering	PI
TzuYang Yu		Tzuyang_yu@uml.edu	Civil Engineering	Co-PI

*Use the table below to list **all** students who have participated in the project during the reporting period. (This includes all paid, unpaid, intern, independent study, or any other student that participated in this project.) **ALL FIELDS ARE REQUIRED.***

Table 7: Student Participants during the reporting period								
Student Name	**Start Date**	**End Date**	**Advisor**	**Email Address**	**Level**	**Major**	**Funding Source**	**Role in research**
Andres Biondi	*1/1/2022*	*3/31/2022*	Xingwei Wang		Ph.D.	ECE	TIDC	Conducted field tests and analyzed signals
Rui Wu	*1/1/2022*	*3/31/2022*	Xingwei Wang		Ph.D.	ECE	TIDC	Conducted field tests and analyzed signals
Lidan Cao	*1/1/2022*	*3/31/2022*	Xingwei Wang		Ph.D.	ECE	TIDC	Conducted field tests and analyzed signals.
Sabrina Abedin	*1/1/2022*	*3/31/2022*	Xingwei Wang		Ph.D.	ECE	TIDC	Conducted field tests and analyzed signals.

Use the table below to list any students who worked on this project and graduated or received a certificate during this reporting period. Include information about the student's accepted employment during the reporting period (i.e. the student is now working at MaineDOT) or if they are continuing their students through an advanced degree (list the degree and where they are attending).

Table 8: Students who Graduated During the Reporting Period			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
NA			Please list the organization or degree

Use the table below to list any students that participated in Industrial Internships during the reporting period

Table 9: Industrial Internships			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
NA			Please list the organization or degree

*Use the table below to list **organizations** that have been involved as partners on this project and their contribution to the project during the reporting period.*

Table 10: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
		List the amount	List the amount	Mark with an "x" where appropriate		
Luna Innovation	Virginia. USA					
Omnisens	Switzerland					
Saint Gobain	MA. USA					

*Use the table below to list **individuals** that have been involved as partners on this project and their contribution to the project during the reporting period. (**List your technical champion(s) in this table.** This also includes collaborations within the lead or partner universities who are not already listed as PIs; especially interdepartmental or interdisciplinary collaborations.)*

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
NA	For internal use only			(i.e. technical champion, technical advisory board, test samples, on-site equipment, data, etc.)

Number of active industrial partners involved in this research project

- 1 Saint Gobain

Number of technologies deployed in transportation applications through pilot or demonstration studies because of this research project. We conduct weekly meetings to discuss the project progress. UML Ph.D. student, Andres Biondi, went to Saint Gobain from time to time to work with their engineers on the sensing textile testing.

- LUNA

LUNA Innovation has provided an extension module to be used with the OFDR controller.
LUNA software updated.

Number of active State DOT partners involved in the research project.

- MA DOT, we have met MA DOT, presented our work, and discussed more field test plans.

Number of technical Champions actively involved in this project:

Craig Stratton.
Director of Sensing Sales- Northeast USA and Canada.
Email: strattonC@lunainc.com.
Phone: 864-509-7635

Use the following table to list any transportation related course that were taught or led by researchers associated with this research project during the reporting period:

Table 12: Course List

Course Code	Course Title	Level	University	Professor	Semester	# of Students
i.e. CE 123		Grad or undergrad?	Where was the course taught?	Who taught the course?	Enter Spring, Fall, Summer, Winter and the year	How many students were enrolled in the class?

Changes:

List any actual or anticipated problems or delays and actions or plans to resolve them (list no-cost extension requests here)…

N/A

List any changes in approach and the reasons for the change…
N/A

Planned Activities:

List the activities planned during the next quarter.

- Conduct a field test in a MA bridge
- Compare signals from distributed optical sensors and strain gauges