Final Report:
Project Number and Title: C3. Condition Assessment of Corroded Prestressed Concrete Bridge Girders
Research Area: Thrust #1: Transportation Infrastructure Monitoring and Assessment for Enhanced Life
PI: Tzuyang Yu (UMass Lowell)
Co-PI(s): Susan Faraji (UMass Lowell), Chang Hoon Lee and Moochul Shin (Western New England University or WNEU)
Reporting Period: 01/01/2019 ~ 09/30/2025
Submission Date: 09/30/2025

******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.

Summary of the project:

The problem we are trying to solve is the condition assessment of corroded prestressed concrete (PC) bridge girders in New England. The problem is important because that PC bridge girders are a critical component of highway bridges. Concrete spalling and prestressing strand corrosion not only cause losses in prestress but also lead to premature failures of PC bridges. We propose to 1) conduct multiplysical field inspection (using 3D photogrammetry, radar, impact-echo, and ultrasound) and to 2) develop an integrated assessment framework for predicting the level of structural damage and prestress losses for PC bridge girders. From this collaborative project between UML and WNEU, our achievements are summarized in the following.

- We have collected more SAR images of intact and corroded RC cylinders for pattern analysis.
- For the SAR image of **intact** RC cylinder, an angularly-uniform scattering pattern is found. For the SAR image of **corroded** RC cylinder, a non-angularly-uniform scattering pattern is found.
- In terms of SAR amplitude, intact RC cylinder shows greater amplitudes than the one of corroded RC cylinder in their SAR images.
- The revision of specimens was conducted, exploring the multiple failure modes under pull-out test depending on the mixtures.
- The results reveal that the responses are dependent on the mixture proportions and the dosage of (basalt) fibers. Nonetheless, the designated variations of the experimental variables produced the post peak behavior (i.e., decay profile).

Overview:

- Development of 3D models of steel rebars for describing steel rebar corrosion

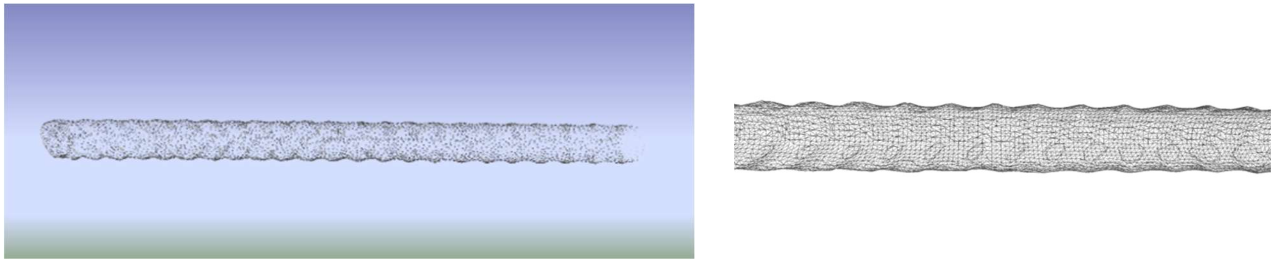
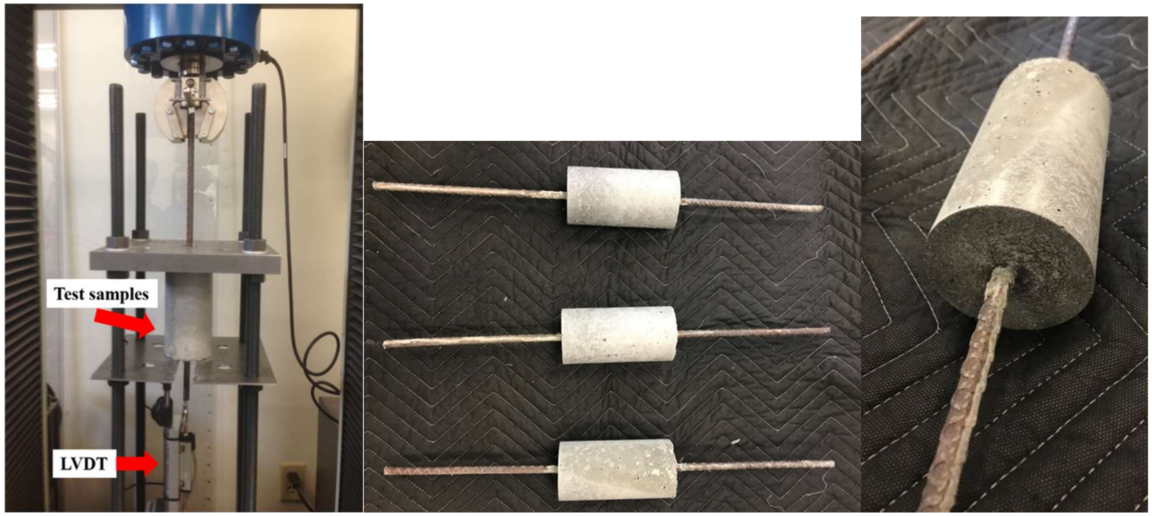


Figure 1. 3D point cloud models of a #3 steel rebar.

- Development of an apparatus for pull-out testing of reinforced concrete specimens.

(a) (b)



(c) (d) (e)

Figure 2. (a) Apparatus of pull-out test and (b) the specimens for compressive strength test.

- Development of bond-slip models for the prediction of pull-out strength

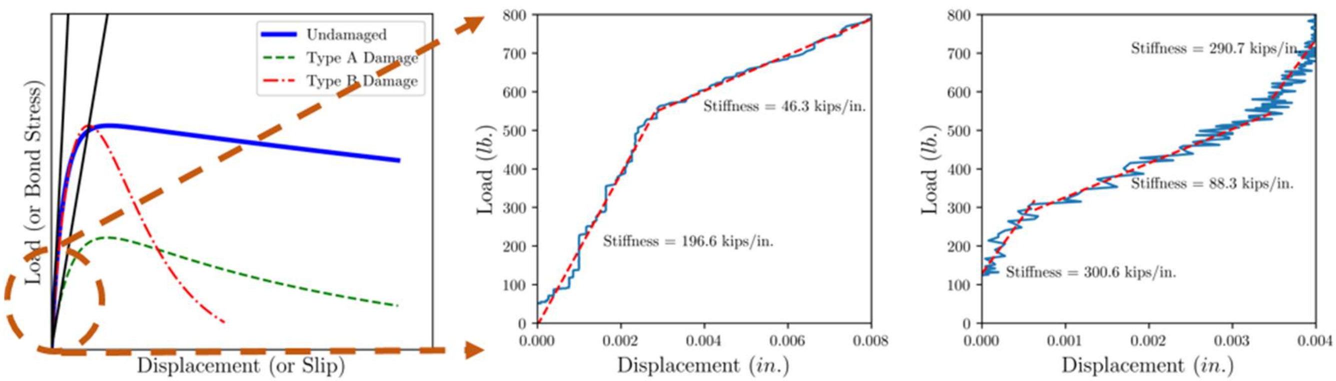
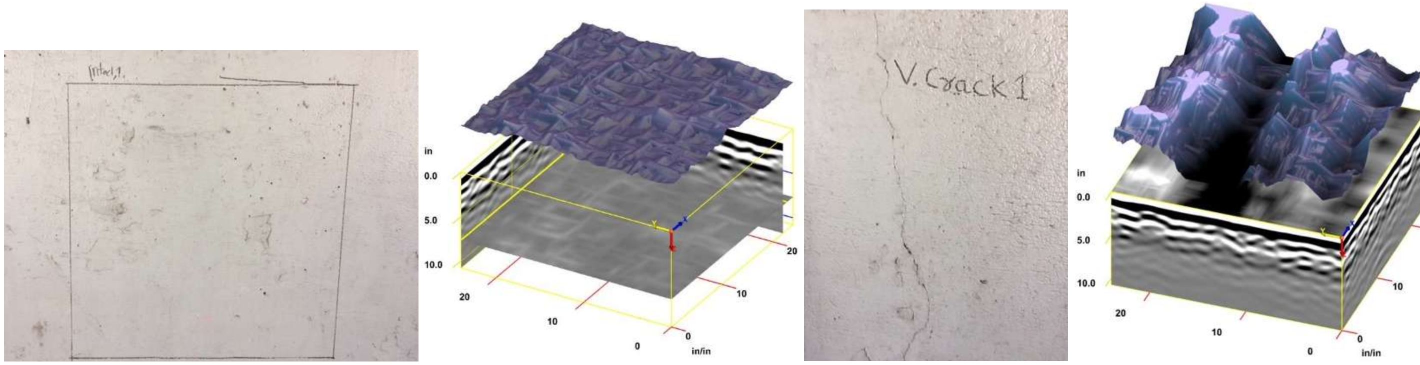


Figure 3. (a) Bond-Slip Model, (b) Calibration result (Trial 1), and (c) Calibration result (Trial 2)

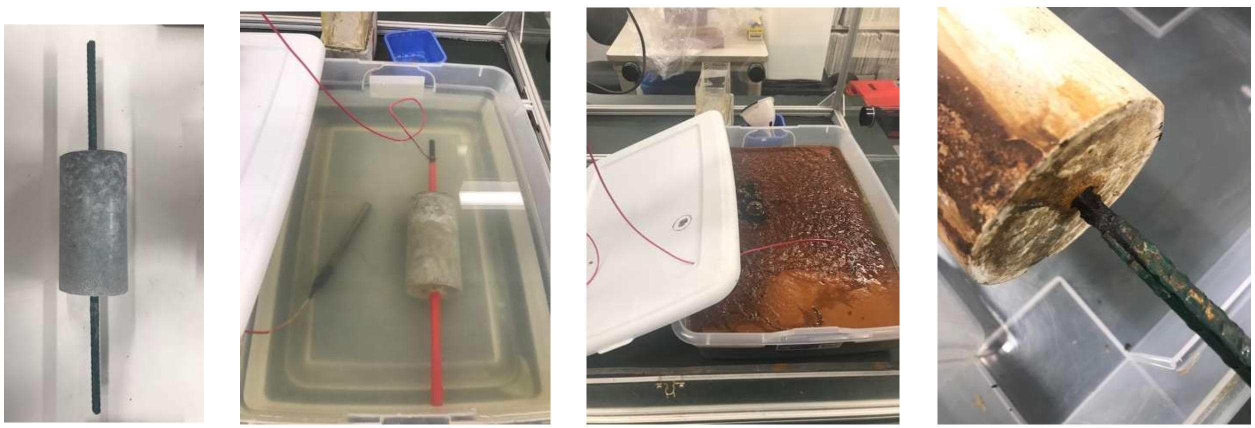
- Modeling of corrosion-induced cracking in reinforced concrete bridges



(a) Intact surface and its radar image (b) Damaged surface and its radar image

Figure 4. Photos and radar images of intact and damaged surfaces on a highway bridge in Lowell, MA.

- Conducted accelerated corrosion testing of reinforced concrete cylinders



(a) RC cylinder (b) Beginning of ACT (c) End of ACT (d) Corroded RC cylinder

Figure 5. Photos and radar images of intact and damaged surfaces on a highway bridge in Lowell, MA.

Figure 6. Pull-Out UHPC specimens with un-corroded bar.

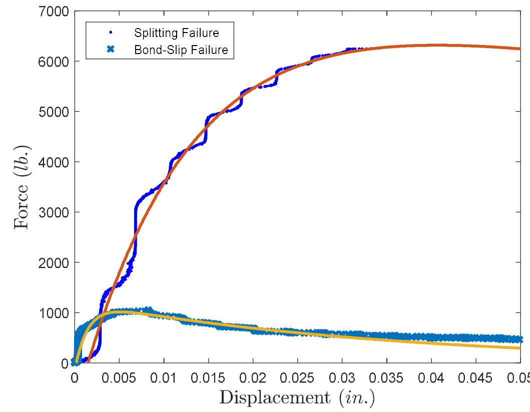


Figure 7: Pull-out force and displacement response

- Conducted radar imaging of corroded reinforced concrete cylinders.

Figure 8. Close-up of damaged RC cylinder.

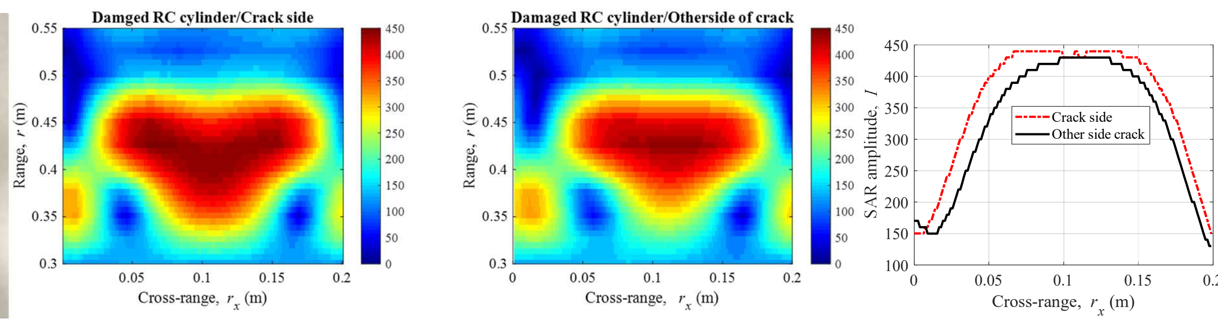
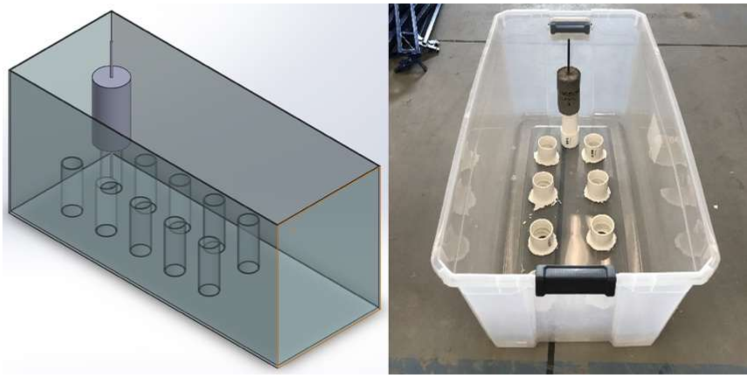


Figure 9. Radar images from two sides of damaged RC cylinder

- Design and manufacturing of a corrosion chamber at WNEU



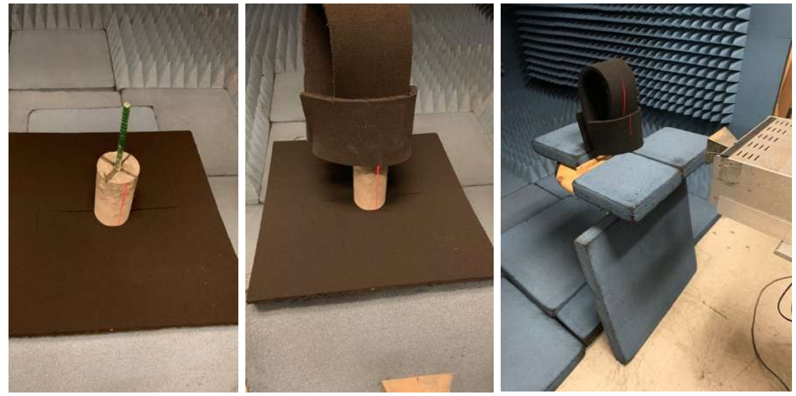


Figure 10. Design and photo of a corrosion chamber at WNEU. **Figure 11.** Improvised SAR imaging shielding at UML

- Laboratory radar imaging of corroded reinforced concrete cylinders
- Petrographic analysis of corroded reinforced concrete cylinders

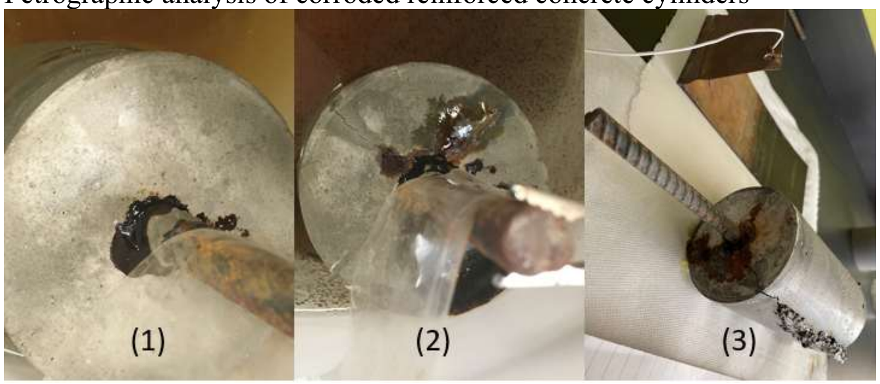
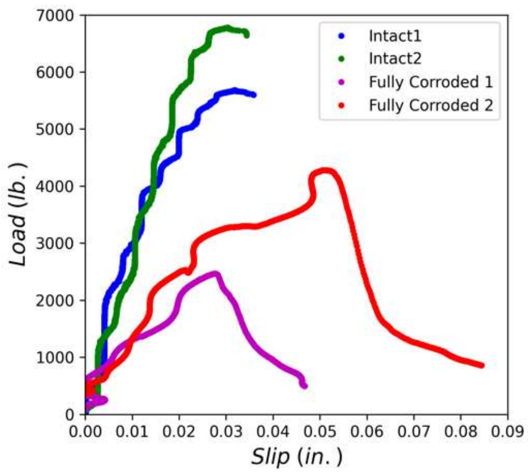
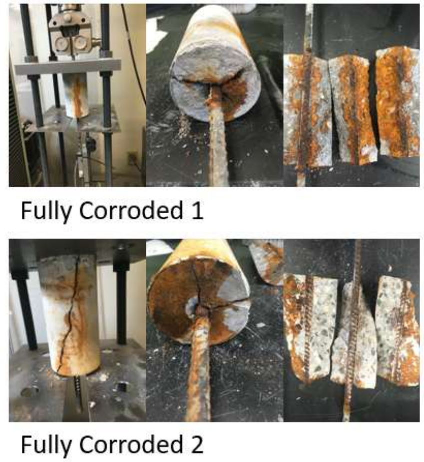


Figure 12. Observation of corrosion progress; (1) $Fe(OH)_2$ is leaked from the top surface. No visible crack (about 0.5mm to 1mm) is detected, (2) Hair line cracks were initiated around the rebar. However, they are not propagated to the side surface. (3) A primary visible crack (i.e., 1-2mm) is propagated to the surface. (Note that all observations were detected at the latest time of each phenomena, possibly being occurred before the observations.)

- Pull-out tests of corroded reinforced concrete cylinders at different corrosion levels





(a) (b)

Figure 13. (a) Comparison of bond-slip response between intact and “fully” corroded specimens (State (3)). (Note that the term, “fully,” is used for the convenience, and the quantification is in-progress.) (b) Failure modes of the specimens; Other than the existing crack due to corrosion, two additional structural cracks were formed during the pull-out test. The difference in the response between Fully corroded 1 and 2 would be induced by different time span between State (1) and (3).

- Revised corrosion chamber at WNEU

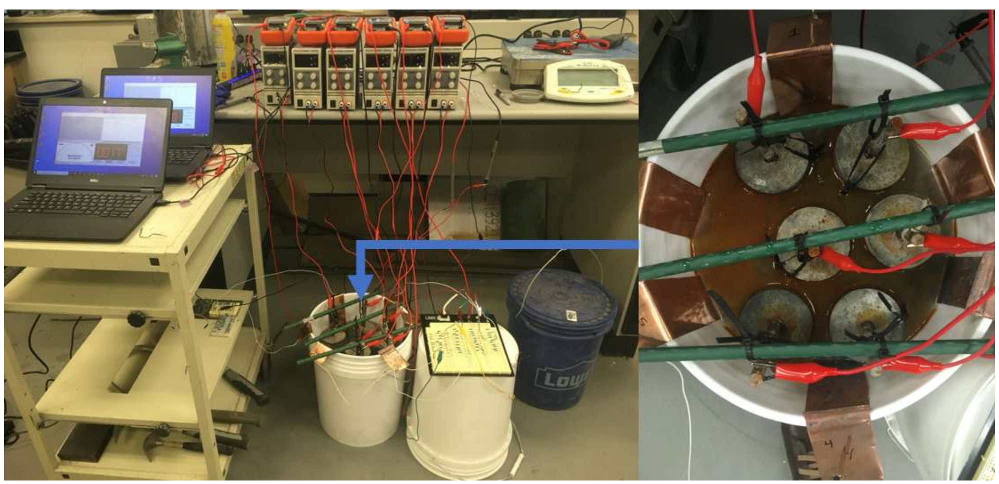


Figure 14. Revised accelerated corrosion chamber for testing multiple specimens.

- Laboratory SAR imaging of corroded reinforced concrete cylinders

Figure 15. Laboratory SAR imaging configuration at UML.

- Development of failure modes of corroded reinforced concrete cylinders in pull-out testing

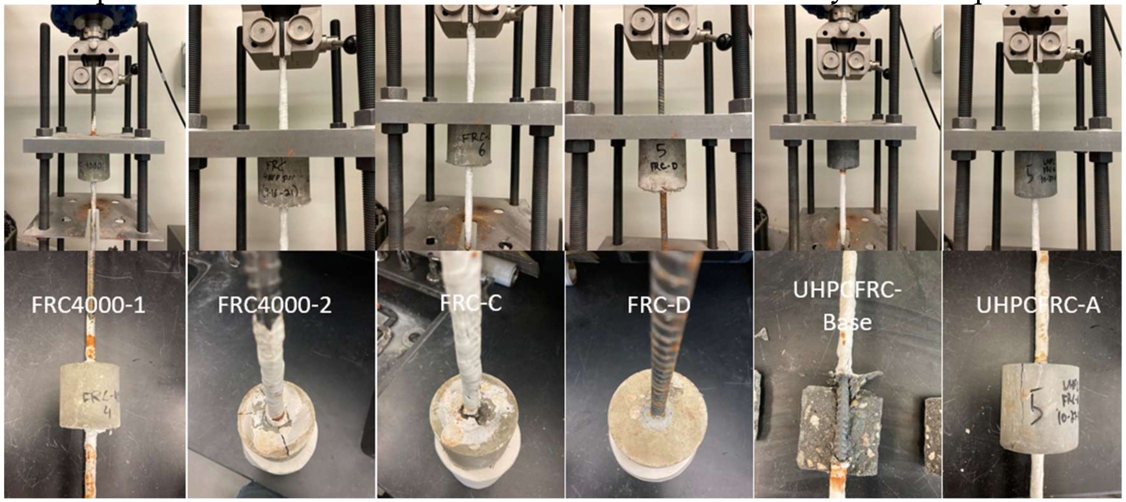


Figure 16. Experimental setup (upper panels) and failure mode (lower panels).

<u>Meeting the Overarching Goals of the Project:</u>

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 corrosion model is incorporated with the damage model, herein, the bond-slip failure. To correlate to the degree of corrosion, the calibration data representing various failure modes must be obtained. While the mode depends on the size of reinforcement, concrete mixture and its strength, cover depths, and the capacity of available testing machines, it is critical to find the sweet spot in terms of those experimental conditions. During this reporting term, the research team successfully identified as testing the wide variations of the specimens.

- Calibrated developed corrosion-damage model based on the experimental data of corroded FRC and UHPC specimens.
- The first-order kinetics model is a special case of a general-kinetic based model. However, it has been reported that the general-order kinetics model would be more suitable for the concrete property development/damage (i.e., stiffening behavior of cement-based materials).
- The developing framework must be applicable the concrete with various mixture proportion. While it is reported that the strength of the concrete generally used for the prestressed concrete bridges is over 5,500 psi, it is required to evaluate the developing framework (i.e., experimental calibration) is still applicable to such a case. The outcome from this period confirmed the possibility.

Accomplishments:

- We have distinguished the difference in the scattering pattern and amplitude of SAR images of intact and corroded RC cylinders.
- We found that the using sealant only will provide good protection for the penetration of solution and unexpected corrosion.
- Numerical framework to apply the damage model has been established.
- The development of the corrosion damage model at WNEU is performed at two phases: (a) determination of corrosion degree in the context of structural behavior, and (b) integration of the corrosion degree model with the mechanistic behavior model, herein, bond-slip response. When merging the specimen into the electrolyte (i.e., salt solution), observations of the detail process are challenging because the solution is contaminated by corrosion products. Thus, a new testing platform was built, enabling one to observe at least the top surface of the cylindrical specimen in the progress of corrosion.

Task, Milestone, and Budget Progress:

Complete the following tables to document the work toward each task and budget (add rows/remove rows as needed, make sure you complete the Overall Project progress row and include all tasks even if they have ended or have not been started)…

Table 1: Task Progress

Task Number	Start Date	End Date	Percent Complete
Task 1: (Component- and System-Level) Field Inspection/Measurements	3/1/19	9/31/19	100%
Task 2: (Meso-to-Macro Level) Development of Macro-Scale Mechanical Damage Model due to corrosion	9/1/19	2/28/20	80% (stalled)
Task 3. (System Level) Development of capacity reduction model for PC bridges due to corrosion	10/1/19	3/31/20	50% (stalled)

Table 2: Milestone Progress

Milestone #: Description	Corresponding Deliverable	Start Date	End Date
Milestone 1: Design of laboratory reinforced concrete (RC) specimens at various corrosion levels	Experimentation design matrix; manufactured RC specimens (100%); Quarterly reports on 3/31/19, 6/30/19, and 9/30/19.	3/1/19	9/30/19
Milestone 2: Manufacturing of laboratory RC specimens at various corrosion levels / Laboratory SAR imaging of	Manufactured RC specimens (100%); SAR images of RC specimens (95%); Quarterly reports on 9/30/19, 12/31/19,	9/1/19	12/31/22

corroded RC specimens and development of a robust baseline SAR image of concrete	3/31/20, 6/30/20, 9/30/20, 12/31/20, 3/31/21, 6/30/21, 9/30/21, and 12/31/21.		
Milestone 3: Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Field inspection of corroded RC structures	SAR images of RC specimens and structures (80%); Quarterly report on 12/31/20, 3/31/21, 6/30/21, 9/30/21, and 12/31/21.	12/1/20	03/31/22
Milestone 4: Development of capacity reduction model for PC bridges due to corrosion	Capacity reduction models (85%); Quarterly reports on 12/31/19, 3/31/20, 6/30/20, 9/30/20, 12/31/20, 3/31/21, 6/30/21, 9/30/21, and 12/31/21.	10/1/19	12/31/22
Milestone 5: Documentation and dissemination of our research outcomes	Quarterly reports on 3/31/19, 6/30/19, 9/30/19, 12/31/19, 3/31/20, 6/30/20, 9/30/20, 12/31/20, 3/31/21, 6/30/21, 9/30/21, and 12/31/21.	3/1/19	12/31/22

Match part expenditure:

Table 3: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**
$89,403 (UML)	$89,403 (UML)	100%
$85,000 (WNEU)	$85,000 (WNEU)	100%

***Include the date the budget is current to.*

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):

- 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

- 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.)

  Yes. The WNE research team (PI Lee) held a meeting with technical staffs from LeHigh Cement and Mapei (i.e., manufacturer of fibers and chemical admixtures) that visited the WNE campus for discussing about the progress of research (11/2/2022).

- 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.)
  - Yes. On three different dates (11/12/24, 11/16/24, and 11/19/24) for the visits of Chelmsford High School students at the senior year at UML. There were nine students and one teacher on 11/12, twenty-six students and three teachers on 11/16, and eight students and one teacher on 11/19. In total, there were 43 students and 5 teachers in these visits. These visits were held in the NDT/SHM Lab in Southwick Hall Room 130.
  - The WNE research team gave a presentation about the corrosion of reinforcements and the project overview in "Academic Student Day" on 4/3/2022, where high-school juniors/seniors and their parents (i.e., about 25) attended.
  - The WNE research team gave a presentation about the corrosion of reinforcements and the project overview in "Open House" (2/20/2023) where high-school juniors/seniors and their parents (i.e., about 15 x 2 sessions) attended.
  - The WNE research team (PI Lee) gave a presentation about the corrosion of reinforcements and the project overview in "Open House" (11/13/2022) where high-school juniors/seniors and their parents (i.e., about 15 x 2 sessions) attended, as shown in Figure 1.

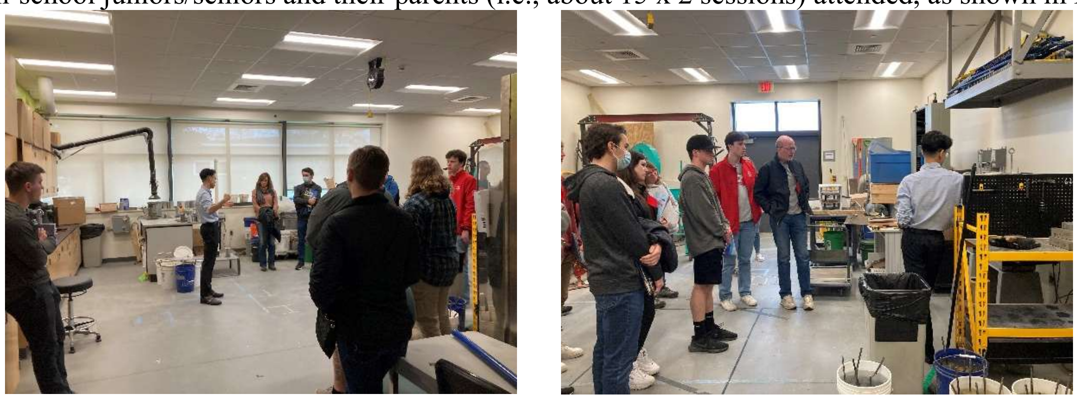


Figure 17. PI Lee hosting high-school juniors/seniors and their parents in the lab on 11/13/2022

<u>Technology Transfer:</u>

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?		
2025 TIDC Annual Conference	Long-term Structural Health Monitoring on Grist Mill Bridge	Full Citation	Guoqiang Cui	UMaine Wells Conference Center	August 6-7, 2025
Seminar talk	Noncontact Quantification of Chloride Ion Content in Concrete Specimens using Radar Images	Department of Mechanical and Materials Engineering, Worcester Polytechnic Institute (WPI)	Research seminar & WPI faculty and graduate students	Worcester, MA	March 30, 2023
Conference Presentation	Aggregate Morphology in Cement-Based Materials	Chang Hoon Lee, Aggregate Morphology in Cement-Based Materials, ACI Fall Convention 2023, Boston, MA	American Concrete Institute Fall Convention 2023	Boston, MA	10/29/2023 – 11/02/2023
Conference	Bond-Slip Damage due to Corrosion of Reinforcement	Shtefan, W., Laframboise, S., Lee, C. H., Shin, M., “Bond-Slip Damage due to Corrosion of Reinforcement,” 2024 TIDC Annual Conference, University of Maine, August, 2024.	2024 TIDC Annual Conference	University of Maine	August 2024

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

Peer-reviewed journal	Interrelation of Morphological Indices and 2-D Generalized Regularity for Coarse Aggregate in Cement-Based Materials	C. H. Lee, S. J. Lee, M. Shin, and S. Bhattacharya, "Interrelation of Morphological Indices and 2-D Generalized Regularity for Coarse Aggregate in Cement-Based Materials," Construction and Building Materials, 2020, 118984	08/10/2020	Published
Short-term Mechanical Strength Prediction of Ultra-High Performance Concrete using Noncontact Synthetic Aperture Radar Imaging	2021 SPIE Smart Structures/NDE Conference	Conference presentation	Virtual meeting	March 22, 2021
Conference paper	Detection of steel rebar corrosion in bridge piers using 1.6GHz ground penetrating radar	Raisi, K., R. Batchu, **T. Yu**, Detection of steel rebar corrosion in bridge piers using 1.6GHz ground penetrating radar, In: *Proc SPIE Smart Structures/NDE*, vol. 12487, March 15, doi: 10.1117/12.2657731.	May 2, 2023	Published
Conference paper abstract	Corrosion detection of steel-reinforced concrete specimens using synthetic aperture radar	Koosha Raisi, Maryam Abazarsa, Tzuyang Yu, SPIE Smart Structures/NDE Symposium	December 11, 2023	Published
Journal paper	Multiphysical Characterization for Predicting Compressive Strength of Portland Cement Concrete using Synthetic Aperture Radar, Ultrasonic Testing, and Rebound Hammer	Maryam Abazarsa, Tzuyang Yu, *Scientific Reports*	November 7, 2024	Published
Journal paper	On the simulation of artificial cracks using Julia set fractals	Tzuyang Yu, Albert Paradis, *Multiscale Science and Engineering (MSAE)*, doi: 10.1007/s42493-024-00120-y	November 5, 2024	Published

Conference paper abstract	Assessing the Effect of Inspection Angle on Corrosion and Crack Detection in Reinforced Concrete Structures by using 1.6 GHz GPR	Maryam Abazarsa, Tzuyang Yu, 2025 SPIE SS/NDE Symposium	September 30, 2024	Published

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

- 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

- 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

- 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

- 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

- 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

- 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.

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:

- We developed a procedure of laboratory accelerated corrosion test for reinforced concrete cylinders. This procedure can generate corroded concrete specimens with known corrosion levels, as a basis to inversely estimate the corrosion level of real concrete bridges to improve the safety of transportation infrastructure by better condition assessment.
- The developed model calibration has been conducted on the basis of pull-out test results for concretes with various mixtures including fiber-reinforced and high-performance concretes.

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 UML-WNEU team identified interferential effects during accelerated corrosion tests involving multiple specimens in a single corrosion chamber. Despite multiple revisions to the experimental apparatus, the issues depicted in Figure 1 (a) and (c) occasionally persisted. The potential problem is attributed to the penetration of saltwater at the boundary between the concrete and rebars, leading to corrosion of the steel rebar at the intersection.

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:

- **Improved Transportation Safety and Monitoring**
  Our research on the phenomenon of steel rebar corrosion in concrete structures has demonstrated the quantitative effect of reduced pull-out strength. This knowledge allows the state DOTs to better assess the severity of steel rebar corrosion in concrete highway bridges, leading to an more accurate bridge inspection approach to ensure transportation safety and monitoring.

- **Contribution to Knowledge and Technology Development**
  Our research on various topics in this project has made progress in filling the knowledge gaps in this area. The revised pull-out test apparatus developed by WNEU allows researchers to conduct similar tests in a systematic manner. Our developed laboratory radar imaging configuration at UML provides a standardized approach to compare different radar images for corrosion assessment. These findings were published in various journal and conference papers, as well as in many conference presentations.

- **Education and Workforce Development**
  We hosted many K-12 students at both UML and WNEU in lab visits and open houses. In terms of workforce development at the college level, we trained many college students from this project, especially at WNEU (see Table 7). The students worked on the project have gained a solid understanding and hands-on experience on assessing the mechanical effect of steel rebar corrosion in concrete structures.

- **Enhanced Research Infrastructure**
  We collaborated with four partners and one project champion to transition laboratory R&D findings to practice by working with industry experts with design and construction experience. The collaboration between UML and WNEU also allows the undergraduate and faculty researchers to access the research facility at an R1 institution to form an inter-school research infrastructure.

<u>Participants and Collaborators:</u>

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	**Email Address**	**Department**	**Role in Research**
Tzuyang Yu	Tzuyang_Yu @UML.EDU	Civil and Environmental Engineering	Project principle investigator and Institutional Lead at UML; overseeing all projects and working on radar imaging and interpretation
Susan Faraji	Susan_Faraji @UML.EDU	Civil and Environmental Engineering	Structural analysis and design of bridge girders
Chang Hoon Lee	Changhoon.Lee @WNE.EDU	Civil and Environmental Engineering	Development of degradation model and design concrete for pull out test specimen (Task 2)
Moochul Shin	Moochul.Shin @WNE.EDU	Civil and Environmental Engineering	Data analysis of the pull-out test results (Task 2)

*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	**Email Address**	**Class**	**Major**	**Role in research**

Ahmed Alzeyadi	Ahmed_Alzeyadi @student.uml.edu	Ph.D.	Civil and Environmental Engineering	Design and manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing
Sanjana Vinayaka	Sanjana_Vinayaka @student.uml.edu	Ph.D.	Civil and Environmental Engineering	Manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing
Jade Man	KarHei_Man @student.uml.edu	Sophomore	Civil and Environmental Engineering	Manufacturing of laboratory specimens
Ronan Bates	Ronan_Bates @student.uml.edu	Junior	Civil and Environmental Engineering	Manufacturing of laboratory specimens, laboratory radar imaging
Caleb Tourtelotte	caleb.tourtelotte @wne.edu	Senior	Civil Engineering	Specimen manufacturing
Nicholas Pantorno	nicholas.pantorno @wne.edu	Junior	Civil Engineering	Specimen manufacturing
Cameron Cox	cameron.cox @wne.edu	Junior	Civil Engineering	Specimen manufacturing
Andrew Masullo	andrew.masullo @wne.edu	Junior	Civil Engineering	Specimen manufacturing
Jacob Eberli	jacob.eberli@wne.edu	Senior	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Tyler Yesu	tyler.yesu@wne.edu	Junior	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Daniel Doyle	daniel.doyle@wne.edu	Junior	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Christa Cicerone	christa-elizabeth.cicerone@wne.edu	Sophomore	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Archer Parker	archer.parker@wne.edu	Sophomore	Civil and Environmental Engineering	Construction of Corrosion Chamber.

Brian LeClair	brian.leclair@wne.edu	Sophomore	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Adam Garstka	adam.garstka@wne.edu	Freshman	Civil and Environmental Engineering	Construction of Corrosion Chamber
Aiyad Alshimaysawee	Aiyad_Alshimaysawee@student.uml.edu	Ph.D.	Civil and Environmental Engineering	Laboratory radar imaging and data processing
Charles Maloy	charles.maloy@wne.edu	Sophomore	Civil Engineering	Experimental set up
Thomas schreiber	thomas.schreiber@wne.edu	Freshman	Civil Engineering	Experimental set up
Conner McLeod	conner.mcloed@wne.edu	Sophomore	Civil Engineering	Experimental set up
Simon Banas	sb595734@wne.edu	Sophomore	Civil Engineering	Preparing concrete mix

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?
Ahmed Alzeyadi	Design and manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing	Ph.D. in CEE at UML	Yes. Infrasense, MA
Ronan Bates	Preparation of specimens	B.S. in CEE at UML	Yes. SGH, MA
Cameron Cox	Preparation of specimens	B.S. in CEE at WNEU	Yes
Andrew Masullo	Preparation of specimens	B.S. in CEE at WNEU	Yes
Jacob Eberli	Preparation of specimens	B.S. in CEE at WNEU	Yes
Evan Blake	BS in Civil Engineering	5/2023	Yes, Stonefield Engineering, NJ
Christa-Elizabeth Cicerone	BS in Civil Engineering	5/2023	Yes, Tighe & Bonds, RI

Brian LeClair	BS in Civil Engineering	5/2023	Fuss & O'Neill, NH
Archer James Parker	BS in Civil Engineering	5/2023	Watson Civil Construction, FL

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		
Massachusetts Department of Transportation (MassDOT)	Boston, Massachusetts				X	X
City of Lowell	Lowell, Massachusetts			X	X	X
LeHigh Cement Company	Glen Falls, NY		X			
Mapei	Deerfield Beach, FL		X			

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.)
Mark Jen	Mark.Jen@kiewit.com	Kiewit Corporation	07/21/24	Technical champion

Number of active industrial partners involved in this research project
Four

Number of technical Champions actively involved in this project:
One

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?
CIVE 5570	Structural Dynamics	Grad	UMass Lowell	Tzuyang Yu	Fall 2021	18
ENGN 2050	Statics	Undergrad	UMass Lowell	Tzuyang Yu	Fall 2021	41
CIVE 5110	Inspection and Monitoring of Civil Infrastructure	Graduate	UMass Lowell	Tzuyang Yu	Spring 2022	17
ENGN 2070	Dynamics	Undergrad	UMass Lowell	Tzuyang Yu	Spring 2022	37
CEE310	Civil Engineering Research	Undergraduate	WNEU	Chang Hoon Lee	Spring 2022	4
CEE410	Civil Engineering Research	Undergraduate	WNEU	Chang Hoon Lee	Spring 2022	1
CEE451	Construction Materials	Undergraduate	WNEU	Moochul Shin	Spring 2022	23
CEE310	Civil Engineering Research	Undergraduate	WNEU	Chang Hoon Lee	Fall 2022	5
CEE451/551	Construction Materials	Undergraduate/Graduate	WNEU	Chang Hoon Lee	Spring 2023	17

CEE310/410	Civil Engineering Research	Undergraduate	WNE	Chang Hoon Lee	Spring 2023	8
CIVE 5570	Structural Dynamics	Senior/Graduate	UML	Tzuyang Yu	Fall 2023	16
ENGN 2070	Dynamics	Sophomore	UML	Tzuyang Yu	Fall 2023	20
CEE310/410	Civil Engineering Research	Undergraduate	WNE	Chang Hoon Lee	Fall 2023	8
CIVE 5570	Structural Dynamics	Senior/Graduate	UML	Tzuyang Yu	Fall 2023	16
ENGN 2070	Dynamics	Sophomore	UML	Tzuyang Yu	Fall 2023	20
CEE310/410	Civil Engineering Research	Undergraduate	WNE	Chang Hoon Lee	Fall 2024	8
CIVE 5120	Structural Stability	Senior/Graduate	UML	Tzuyang Yu	Fall 2024	13
ENGN 2070	Dynamics	Sophomore	UML	Tzuyang Yu	Fall 2024	32

<u>Changes:</u>

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

<u>Planned Activities:</u>

List the activities planned during the next quarter.
N/A