Quarterly Progress and Performance Indicators Report:
Project Number and Title: C20.2020: Advanced Sensing Technologies for Practical UAV-Based Condition Assessment
Research Area: Transportation Infrastructure Monitoring and Assessment for Enhanced Life
PI: Dryver Huston, University of Vermont
Co-PI(s): Tian Xia, University of Vermont; Eric Landis, University of Maine; Tzuyang Yu, University of Massachusetts Lowell
Reporting Period: 7/1/22 –9/30/22
Submission Date: October 3, 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 rows 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:

This is a collaborative research project with the University of Vermont, University of Maine, and University of Massachusetts Lowell. This quarter was the fifth quarter of activity on the project. Some of the highlights are:

- Redesign of acoustic sensor arm for use on a UAV – This is an upgrade of the previously developed rack and pinion mechanism with the goal being to reduce the weight and make it more compatible with a UAV. This includes using a smaller weight motor and a digitizing microphone that eliminates the need for a standalone data acquisition system, Figure 1.
- Began to develop algorithms to capture the digital microphone signals and use on a Raspberry PI microcomputer.

Meeting the Overarching Goals of the Project:

How did the previous items help you achieve the project goals and objects? Please give one bullet point for each bullet point listed above.
The overarching goals of this project center on the synergistic application of unmanned aerial vehicles (UAVs) with active acoustic sensing (AAS) and synthetic aperture radar (SAR) for the underside inspection of bridge decks. Employing such UAV-AAS-SAR systems may i) reduce inspection cost by more than 50%, ii) improve inspectors' safety, and iii) mitigate traffic interference with little or no traffic control measures needed. The plan has five main Goals 1) develop an acoustic sensor capable of actively interrogating concrete delamination of bridge decks from underneath, 2) develop a compact radar sensor capable of remotely scanning concrete surface for delamination detection, 3) develop a UAV platform capable of housing the acoustic and the radar sensors for bridge inspection, 4) develop image processing and interpretation algorithms for condition assessment, and 5) work with partners in the bridge inspection industry to guide design decisions to produce a practical and useful system.

Progress in this past quarter advanced the goals of the project with efforts at evaluating two different acoustic sensing techniques, and microwave sensing and signal processing for the specialized case of detecting damage on the underside of bridge decks.

- Redesign of an acoustic sensor arm for use on a UAV – Aligned with Goal 1) develop an acoustic sensor capable of actively interrogating concrete delamination of bridge decks from underneath
- Develop algorithms for processing signals from digital microphone – Aligned with Goal 1) develop an acoustic sensor capable of actively interrogating concrete delamination of bridge decks from underneath

- Continued with UAV development. This included the acquisition of most of the parts for a kit to assemble a low-cost UAV for testing concepts and as a platform for the next steps of sensor development and verification. – Aligns with Goals 1), 2) and 3).
- Plan for a field test at a bridge in Maine, preferably in October or November of 2022 – Aligns with Goals 1), 2), 3), and 5).

Accomplishments:

List any accomplishments achieved under the project goals in bullet point form…

- Assembled lightweight acoustic tapper mechanism and digital acoustic microphone for improved UAV mounting.

- Tested and down selected algorithms for processing signals from tapper used data collected from small concrete slabs in the laboratory.

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- Acquired most of the parts for a kit needed to build a UAV for sensor prototyping purposes. Began assembly.

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: Title	Start Date	End Date	% Complete
Task 1.1 (Phase 1.A): Survey of Commercial UAVs	4/1/21	6/30/21	100
Task 2.1 (Phase 1.A): Design and build acoustic sensor arm (ASA)	4/1/21	6/30/22	100
Task 2.2 (Phase 1.A): Select and configure acoustic sensors	4/1/21	6/30/22	100
Task 3.1 (Phase 1.A): Calibration of baseline interference on radar signals	4/1/21	6/30/22	100
Task 3.2 (Phase 1.A): Development of radar signal and image conditioning algorithms through laboratory tests	4/1/21	6/30/22	100
Task 7.1 (Phase 1.A): Documentation	4/1/21	6/30/22	85
Phase 1.A Overall	4/1/21	6/30/22	97.5%
Task 2.3 (Phase 1.B) Select and configure acoustic signal processing system	7/1/22	3/31/23	25%
Task 2.4 (Phase 1.B) Assemble ASA system and test performance in laboratory	7/1/22	6/30/23	50%
Task 4 (Phase 1.B) Laboratory validation and correlation of AAS and radar sensors	7/1/22	6/30/23	0%
Task 5 (Phase 1.B) Laboratory integration of UAV, AAS, and radar sensors	7/1/22	6/30/23	20%
Task 6.1 (Phase 1.B) Field modification of UAV-AAS-radar system, data collection, and data analysis	3/1/23	6/30/23	0%

Task 7.1 (Phase 1.B) Documentation, dissemination, and reporting	7/1/22	6/30/23	25%
Phase 1.B Overall	7/1/22	6/30/23	20%
Task 2.5 (Phase 2) Integrate ASA system into UAV	7/1/23	6/30/24	0%
Task 2.6 (Phase 2) Laboratory and field testing of UAV with integrated ASA:	7/1/23	6/30/24	0%
Task 2.7 (Phase 2) Data analysis, reporting and dissemination	7/1/23	6/30/24	0%
Task 3.3 (Phase 2) Modification of onboard SAR imaging sensor through field tests	7/1/23	6/30/24	0%
Task 6.2 (Phase 2) Field modification of UAV-AAS-radar system, data collection, and data analysis	7/1/23	6/30/24	0%
Task 7.3 (Phase 2) Documentation, dissemination, and reporting	7/1/23	6/30/24	0%
Phase 2 Overall	7/1/23	6/30/24	0%

Table 2: Milestone Progress

Milestone #: Description	Corresponding Deliverable	Start Date	End Date
Milestone 1: Survey of Commercial UAVs	Report summarizing results of survey	4/1/21	12/31/20 - Delivered
Milestone 2: Design and build Acoustic Sensor Arm (ASA)	Report describing design and fabrication of ASA	4/1/21	3/31/22 – Pending, expected delivery 8/31/22
Milestone 3: Select and configure Acoustic Sensors	Report describing selection and operation of acoustic sensors	4/1/21	3/31/22 – Pending, expected delivery 8/31/22
Milestone 4: Calibration of baseline interference on radar signals	Report describing calibration of baseline interference on radar signals	4/1/21	3/31/22 – Pending, expected delivery 8/31/22
Milestone 5: Development of radar signal and image conditioning algorithms through laboratory tests	Report describing development of radar signal and image conditioning algorithms	5/1/21	3/31/22 – Pending, expected delivery 8/31/22
Milestone 6: Documentation	Quarterly reports for Phase 1-A	4/1/21	3/31/22 – Pending, expected delivery 8/31/22

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Milestone #: Description	**Corresponding Deliverable**	**Start Date**	**End Date**
Milestone 1: Survey of Commercial UAVs	Report summarizing results of survey	4/1/21	12/31/20 - Delivered
Milestone 2: Design and build Acoustic Sensor Arm (ASA)	Report describing design and fabrication of ASA	4/1/21	3/31/22 – Pending, expected delivery 7/31/22
Milestone 3: Select and configure Acoustic Sensors	Report describing selection and operation of acoustic sensors	4/1/21	3/31/22 – Pending, expected delivery 7/31/22
Milestone 4: Calibration of baseline interference on radar signals	Report describing calibration of baseline interference on radar signals	4/1/21	3/31/22 – Pending, expected delivery 7/31/22
Milestone 5: Development of radar signal and image conditioning algorithms through laboratory tests	Report describing development of radar signal and image conditioning algorithms	5/1/21	3/31/22 – Pending, expected delivery 7/31/22
Milestone 6: Documentation	Quarterly reports for Phase 1-A	4/1/21	3/31/22 – Pending, expected delivery 7/31/22
Milestone 7: Select and configure acoustic signal processing system	Report describing acoustic signal processing system	7/1/22	3/31/23
Milestone 8: Assemble ASA system and test performance in laboratory	Report describing ASA performance in laboratory	7/1/22	6/30/23
Milestone 9: Laboratory validation and correlation of AAS and radar sensors	Report describing laboratory validation and correlation of AAS and radar sensors	7/1/22	6/30/23
Milestone 10: Laboratory integration of UAV, AAS, and radar sensors	Report describing laboratory integration of UAV, AAS, and radar sensors	7/1/22	6/30/23
Milestone 11: Field modification of UAV-AAS-radar system, data collection, and data analysis	Report describing field modification of UAV-AAS-radar system, data	3/1/23	6/30/23

	collection, and data analysis		
Milestone 12: Documentation, dissemination, and reporting	Quarterly reports for Phase 1-B	7/1/22	6/30/23
Milestone 13: Integrate ASA system into UAV	Report describing	7/1/22	6/30/23
Milestone 14: Laboratory and field testing of UAV with integrated ASA	Report describing	7/1/23	6/30/24
Milestone 15: Data analysis, reporting and dissemination	Report describing	7/1/23	6/30/24
Milestone 16: Modification of onboard SAR imaging sensor through field tests	Report describing	7/1/23	6/30/24
Milestone 17: Field modification of UAV-AAS-radar system, data collection, and data analysis	Report describing	7/1/23	6/30/24
Milestone 18: Documentation, dissemination, and reporting	Quarterly and final project report	7/1/23	6/30/24

Table 3: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date (6/30/2022)
Phase 1.A Full Budget $144,000	Phase 1.A $175,851.20 (Federal + Cost Share)	Phase 1.A 122.11% Spent
Phase 1.B Full Budget $120,000	Phase 1.B $0 (Federal + Cost Share)	0%
Phase 2 Full Budget $120,000	Phase 2 $0 (Federal + Cost Share)	0%

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 MassDOT on 3/31/2021. The members learned how to use the technology and interrupt the data.) NA

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.)
Eric Landis of the University of Maine held planning meetings for possible field test with Maine DOT.

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.) NA

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)
NA					

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
NA				

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? NA

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? NA

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? NA

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

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. NA

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). NA

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.

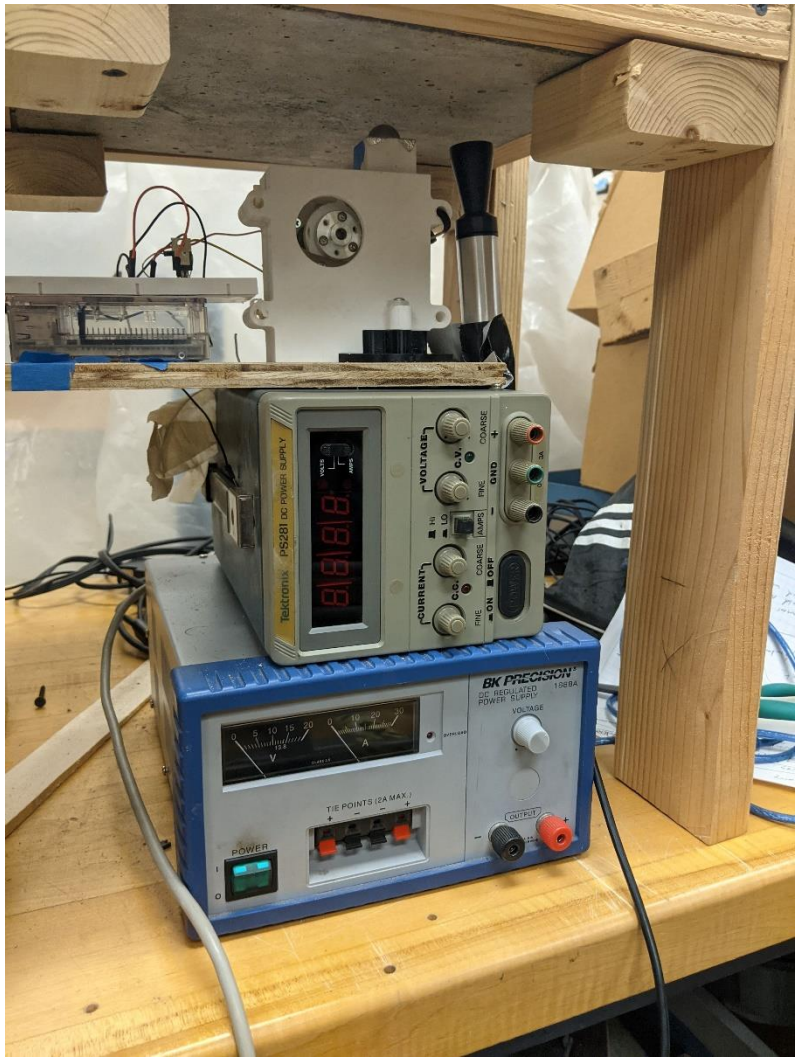

Figure 1. Acoustic sensor arm with digital microphone in laboratory slab test setup

Figure 2. Close up of acoustic sensor arm with digital microphone in laboratory slab test setup

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:

- Evaluated use of different signal processing algorithms applied directly to signals captured by digital microphone.

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:

- NA

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:

- NA

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
Dryver Huston	dryver.huston@uvm.edu	UVM	Mech Eng	PI
Tian Xia	txia@uvm.edu	UVM	Elec Eng	Co-PI
Eric Landis	landis@maine.edu	UM	Civil Eng	Co-PI
Tzuyang Yu	tzuyang_yu@uml.edu	UML	Civil Eng	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
Richard Laverty	6/1/2022	pending	D. Huston		BS	Mech Eng	TIDC	Research on UAV sensing
Damien Garland	10/1/2021	3/31/2022	D. Huston		MS	Mech Eng	Self-funded	Research on UAV sensing, self-funded

Yi Liu	10/1/2021	12/31/2021	D. Huston		MS	Mech Eng	TIDC	Research on UAV sensing
Zahra Ameli	10/1/2021	3/31/2022	E. Landis		PhD	Civil Eng	TIDC	Research on UAV sensing

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			

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**
NA		List the amount	List the amount	Mark with an "x" where appropriate		

*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.*

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
Robert Blunt		VHB	10/1/2021 – 12/31/2021	Technical Champion

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**
NA		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:

The project is delayed a couple of months in completion of Phase 1.A. A no-cost extension request will be submitted, probably for 3 months.

Planned Activities:

List the activities planned during the next quarter.

The planned activities for the next quarter generally follow those laid out in the original proposal. These include:

1. Acoustic sensing – Redesign the acoustic sensor arm to reduce weight and improve integration with UAV. This includes using a smaller motor and a digital microphone that eliminates the need for a separate data acquisition system. Continue with laboratory testing.

2. Microwave sensing – Configure the microwave sensor to fit on UAV and evaluate background noise. Develop customized signal processing methods.

3. UAV system – Continue with custom UAV system development.

4. Field testing – Plan for field testing of components and integrated system at bridges in Maine, Massachusetts, and Vermont.