Quarterly Progress 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: 7/1/21 – 9/30/21
Submission Date: September 30, 2021

Overview:

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

1. Evaluation and development of acoustic sensing techniques for concrete quality assessment – A set of concrete slabs with embedded defects were fabricated and assessed. These defects included styrofoam, bubble-wrap foam, water-dissolved rice paper and rock salt layer, and a mechanically separated delamination. The intent for these slabs is to serve as phantoms for evaluating acoustic test instruments. The styrofoam and water-dissolved rice paper and rock salt layer both performed quite well with audible and measurable frequency shifts occurring over the mock delaminations.

2. Assembly of an acoustic sensor arm for use on a UAV – A prototype lightweight arm with integrated tapper mechanism and microphone sensor has been assembled as a proof of concept. Figure 1 shows the use of acoustic sensor arm being used on concrete slab phantom with embedded defects.

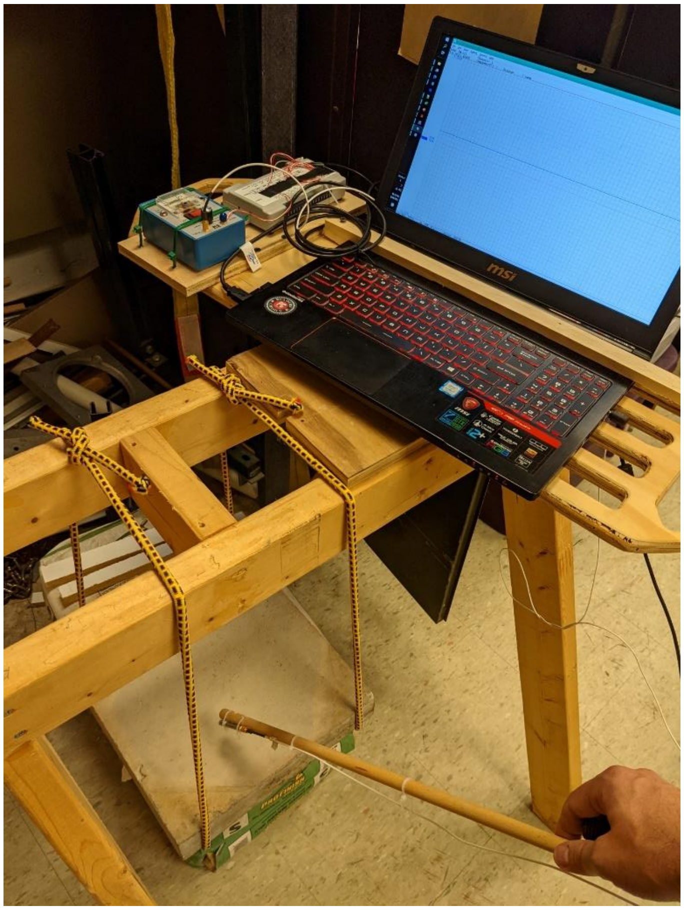


Figure 1. Testing of concrete delamination phantom with acoustic sensor arm and portable data acquisition system.

3. Examination of microwave transceiver for use on UAV – –shows the portable microwave transceiver.

In the past quarter, we investigated the effect of platform motion on SAR images. We used a portable SAR imaging sensor to inspect two laboratory concrete panels inside an anechoic chamber at UML. A wireless accelerometer was installed on the portable SAR imaging sensor to determine the relative displacement (by double integrals) between the radar and concrete panels. Figure 2 shows the two concrete panels used in this SAR imaging experiment. Figure 3 shows the displacement histories of the portable SAR imaging sensor.

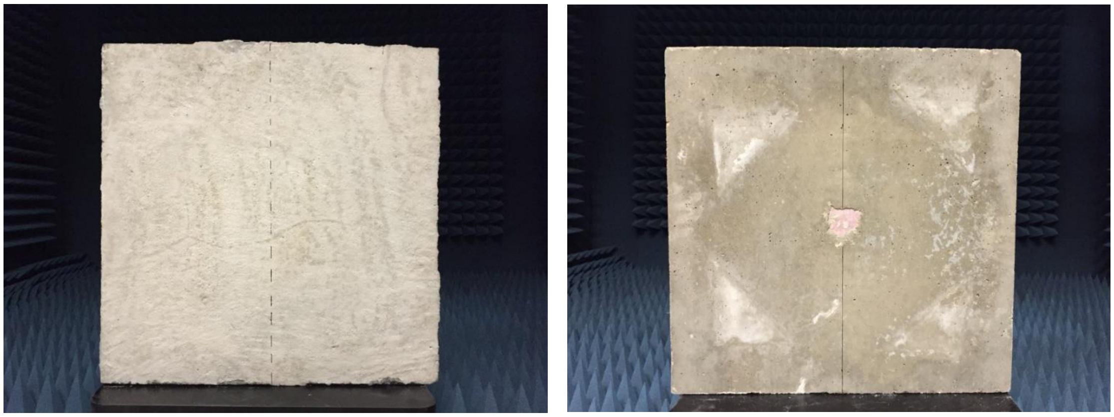
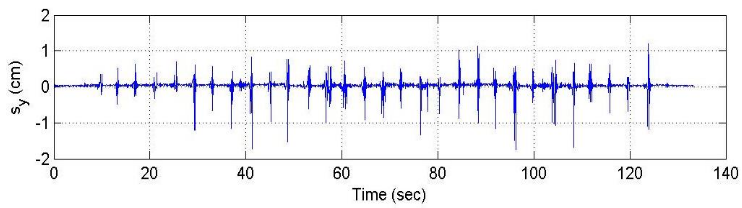
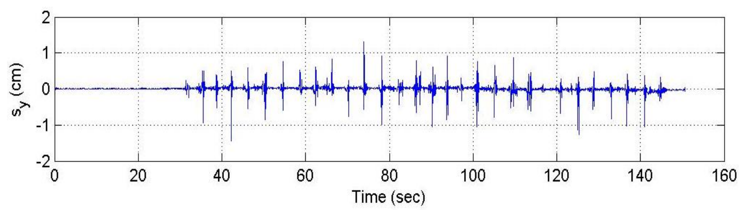


Figure 2 (a) Intact concrete panel (50 cm-by-50 cm-by-10 cm) (b) Damaged concrete panels



(a)



(b)

Figure 3 (a) Hand displacement history in Intact-HP (b) Hand displacement history in Damaged-HP

Next, we collected SAR images by using a stationary positioner (automatic) and by using two hands (manual) are shown in Figure 4. In Figure 4, the effect of platform motion on SAR images is clearly observed. Both phase shift and amplitude change are found in the manually collected SAR images.

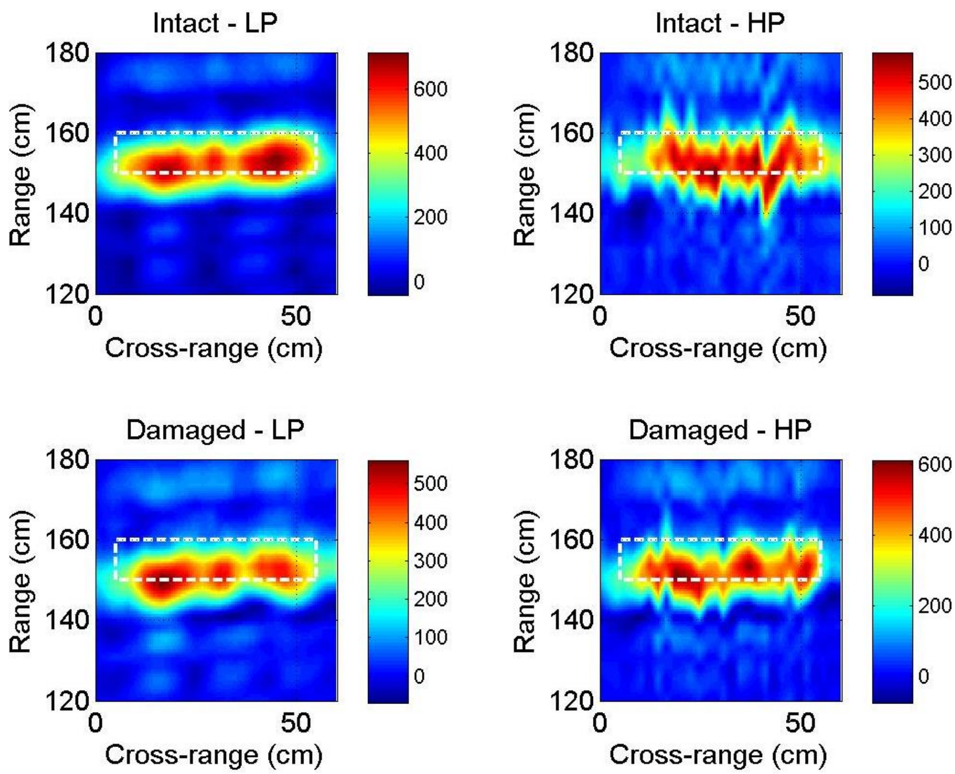


Figure 4. (left) SAR images collected by using a positioner / (right) SAR images collected by using two hands

Meeting the Overarching Goals of the Project:

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 is 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 custom UAV fabrication, acoustic sensing and microwave sensing customized for use as concrete damage detectors deployed on a UAV.

Accomplishments:

Built a prototype acoustic sensor arm and tested on concrete slab phantoms.

Tested the effects of motion similar to that of a UAV on microwave SAR sensing of damage.

Task Progress and Budget:

Table 1: Task Progress			
Task Number	**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	3/31/22	45
Task 2.2 (Phase 1.A): Select and configure acoustic sensors	4/1/21	3/31/22	25
Task 3.1 (Phase 1.A): Calibration of baseline interference on radar signals	4/1/21	3/31/22	20
Task 3.2 (Phase 1.A): Development of radar signal and image conditioning algorithms through laboratory tests	4/1/21	3/31/22	20
Task 7.1 (Phase 1.A): Documentation	4/1/21	3/31/22	50
Task 2.3 (Phase 1.B): Select and configure acoustic signal processing system	4/1/22	9/30/22	0
Task 2.4 (Phase 1.B): Assemble ASA system and test performance in laboratory	4/1/22	3/31/23	0
Task 4 (Phase 1.B): Laboratory validation and correlation of AAS and radar sensors	4/1/22	3/31/23	0
Task 5 (Phase 1.B): Laboratory integration of UAV, AAS, and radar sensors	4/1/22	3/31/23	0
Task 6.1 (Phase 1.B): Field modification of UAV-AAS-radar system,	7/1/22	3/31/23	0

data collection, and data analysis			
Task 7.2 (Phase 1.B): Documentation, dissemination, and reporting	4/1/22	3/31/23	0
Task 2.5 (Phase 2): Integrate ASA system into UAV	4/1/23	9/30/23	0
Task 2.6 (Phase 2): Laboratory and field testing of UAV with integrated ASA	4/1/23	9/30/23	0
Task 2.7 (Phase 2): Data analysis, reporting and dissemination	4/1/23	9/30/23	0
Task 3.3 (Phase 2): Modification of onboard SAR imaging sensor through field tests	4/1/23	9/30/23	0
Task 6.2 (Phase 2): Field modification of UAV-AAS-radar system, data collection, and data analysis	4/1/23	9/30/23	0
Task 7.3 (Phase 2): Documentation, dissemination, and reporting	4/1/23	9/30/23	0
Phase 1.A Overall	4/1/21	3/31/22	43.3%
Phase 1.B Overall	4/1/22	3/31/23	0
Phase 2 Overall	4/1/23	9/30/23	0

Table 2: Budget Progress University of Vermont		
Project Budget	**Spend – Project to Date 6/30/21**	**% Project to Date 6/30/21**
Phase 1.A $144,000	$ $ 37,341.95	25.93%
Phase 1.B Full Budget	0	0
Phase 2 Full Budget	0	0

Professional Development/Training Opportunities:
NA

Technology Transfer:

Continued to communicate with Technical Champion industry partner Robert Blunt of VHB about possible field testing later this year.

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
Advanced Sensing Technologies for Practical UAV-Based Condition Assessment of Underside Bridge Decks	VT STIC Stakeholders Meeting and the 2021 AOT Research and Innovation Symposium	Poster and online presentation	Online	9/8-9/2021

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
NA				

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**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

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Damien Garland		MS	Mech Eng	Research on UAV sensing, self-funded
Yi Liu		MS	Mech Eng	Research on UAV sensing

Joshua Allen		Junior	Mech Eng	Research on UAV sensing
Zahra Ameli		PhD	Civil Eng	Research on UAV sensing

Table 7: Students who Graduated During the Reporting Period			
Student Name	**Degree**	**Graduation Date**	**Employment or continued degree**
NA			

Table 8: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
NA						

Table 9: Other Collaborators			
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Contribution to Research**
NA			

Who is/are the Technical Champion(s) for this project? List all.
Name: Robert Blunt
Title: Senior Project Manager
Organization: VHB
Location: South Portland, ME
Email Address: rblunt@vhb.com

Changes:

Due to delays in finalizing the contracts and budgets, the project did not on the proposed date of October 1, 2020, and instead started on April 1, 2021. The task schedule listed in this report has been adjusted accordingly. No other significant changes to the project plan and scope to date.

Planned Activities:

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

1. Acoustic sensing – Continue with laboratory testing on more realistic delaminated concrete samples. Develop customized signal processing methods.

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 – Attempt to conduct field tests in autumn before winter.