Rapid Exploitation of Commercial Remotely Sensed Imagery for Disaster Response & Recovery

Principal Investigator: Jarlath O'Neil-Dunne
Program Manager: Caesar Singh

COOPERATIVE AGREEMENT
No. RITARS-12-H-UVM

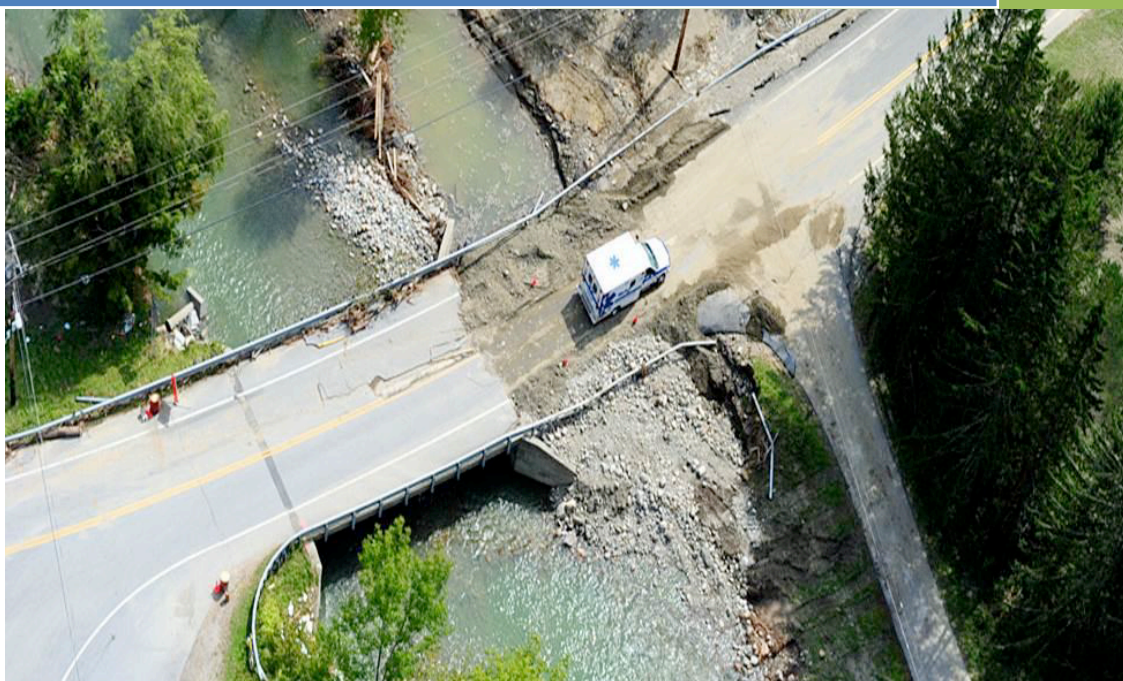# Quarterly Progress Report #3

July 1, 2013 through September 30, 2013

TRC UNIVERSITY OF VERMONT
TRANSPORTATION RESEARCH CENTER

University of Vermont
Spatial Analysis Lab

United States
Department of Transportation

Table of Contents

Glossary

3D	Three Dimensional
AASHTO	American Association of State Highway Transportation Officials
CAD	Computer-Aided Design
CNL	Cognition Network Language
COA	Certificate of Authorization
CRS	Commercial Remote Sensing
DOT	Department of Transportation
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
GIS	Geographic Information Systems
HDDS	Hazard Data Distribution System
ICS	Incident Command System
LiDAR	Light Detection and Ranging
NAIP	National Agricultural Imagery Program
NIMS	National Incident Management System
NOAA	National Oceanic and Atmospheric Administration
OBIA	Object-Based Image Analysis
OGC	Open Geospatial Consortium
PI	Principal Investigator
PM	Program Manager
RiP	Research in Progress database
RITA	Research and Innovative Technology Administration
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SAL	Spatial Analysis Laboratory (University of Vermont)
SI	Spatial Information
TAC	Technical Advisory Committee
TRC	Transportation Research Center
UAV	Unmanned Aerial Vehicles
USDOT	United States Department of Transportation
USGS	United States Geological Survey
UVM	University of Vermont
VAOT	Vermont Agency of Transportation (also known as Vtrans)
VTrans	Vermont Agency of Transportation (also known as VAOT)
XML	eXtensible Markup Language

Executive Summary

Natural disasters can severely impact transportation networks. In the hours and days following a major flooding event, knowing the location and extent of the damage is crucial for incident managers for a number of reasons: it allows for emergency vehicle access to affected areas; it facilitates the efficient rerouting of traffic; it raises the quality and reduces the cost of repairs; and it allows repairs to be completed faster, in turn reducing the duration of costly detours. Commercial Remote Sensing (CRS) imagery is increasingly being used in disaster response and recovery, but the ability to acquire CRS data far surpasses the ability to extract actionable information from it. An automated approach to damage assessment is needed, but traditional automated image analysis techniques are inadequate for identifying or characterizing transportation infrastructure damage from high-resolution CRS imagery. Furthermore, new CRS technologies, such as Unmanned Aerial Vehicles (UAV) provide a novel approach to gathering imagery during a crisis in which traditional satellite and aerial systems are either cost prohibitive, ineffective, or unresponsive. We propose a project with two objectives: 1) to develop, calibrate and deploy a decision support system capable of identifying road and bridge damage from high-resolution commercial satellite images and; b) to estimate the amount and type of fill material required for repairs using digital surface models derived from lightweight Unmanned Aerial Vehicles (UAV) programmed to fly over damage road segments. This approach would employ state-of-the-art, object-based image analysis techniques, cost-based image matching, and other advanced computing techniques. We also propose to collaborate with state departments of transportation to develop a web-based interface to share information derived from CRS Imagery.

Technical Status

Task 1 - Creation of a Technical Advisory Committee
We will recruit a committee of relevant professional (e.g. state DOT representatives, academics) near the outset of the project to advise on project activities. A full description of the project tasks can be found in Section 2 of the Cooperative Agreement.

Output/Deliverables: The Advisory Board comprised of 6 to 8 members will provide guidance in specific technical and policy recommendations that the team would take into consideration for implementation. Notes will be taken at each meeting and provided to members as a brief summary report.

Accomplishments:
Provide a clear and complete account of work performed on each task and its relationship to task objectives and milestones.

- There were no Advisory Committee Meetings during this quarter. However, we did hold internal project team meetings to discuss progress and reporting efforts.

Problems Encountered:
Describe any problems encountered or anticipated that will affect the completion of the agreement within the time and fiscal constraints as set forth in the agreement, together with recommended solutions to such problems, or a statement that no problems were encountered.

- None

Future Plans:
Discuss work planned for the next period and its relationship to the present period. Provide an outline of the work to be accomplished during the next report.

- The TAC will meet in person or by video conference twice per year or on an as needed basis. Notes will be taken at each meeting and provided to members as a brief summary report.
- We plan to convene a TAC meeting after the project team has been trained on how to use the UAV, in preparation for testing and calibration flights. This meeting will also serve as a system design review.
- Internal project team meetings to occur on a regular basis.

Schedule:
Highlight any changes to the schedule as previously reported.

- The System Design Review with the TAC was supposed to occur in the third quarter, but will actually occur soon after the October 16-17, 2013 field training for the UAV. The field training was slightly delayed due to airfield availability, causing a delay in the System Design Review, but we do not anticipate this causing an overall delay of the project.

Effort Expended:
Effort expended by task for all staff categories must be reported.

Employee Name/Labor Category	Budgeted Hours	Year 1 (hours)				Cummulative (hours)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy	200	56.5	13.34	24		93.84
Jarlath O'Neil Dunne	50	30				30
Ernest Buford	0					0
Amanda Hanaway	180	16	25	20		61
Sean MacFadden	0					0
James Sullivan	24	6	4	2		12
Technician	0					0

Task 2 - Creation of a project website
We will create a project website which will stay in operation throughout the duration of the project and will help to organize, centralize, and disseminate information from the project.

Output/Deliverables: A project web site will be created on the University of Vermont domain (www.uvm.edu) containing a password protected section for internal documents and data products that have access/use restrictions associated with them (e.g. commercial satellite imagery) as well as access to up-to-date documents deemed suitable for the public domain.

Accomplishments:
Provide a clear and complete account of work performed on each task and its relationship to task objectives and milestones.

- Website:
    - This Quarterly Report has been added to the website.

Problems Encountered:
Describe any problems encountered or anticipated that will affect the completion of the agreement within the time and fiscal constraints as set forth in the agreement, together with recommended solutions to such problems, or a statement that no problems were encountered.

- Website – No problems were encountered.
- Data acquisition
    - We have obtained the majority of the satellite imagery needed from DigitalGlobe, but are awaiting addition scenes that need to be pulled from the archive.
- Software and Equipment Acquisition:
    - Computer hardware – Computer hardware is on hand and functioning as expected.
    - UAV – UAV is on hand and functioning as expected.

Future Plans:
Discuss work planned for the next period and its relationship to the present period. Provide an outline of the work to be accomplished during the next report.

- Website:
    - The contract requires a blog post about various aspects on the project after the first six months. We will provide a link from the project website

to the "Letter from the SAL" blog post once we have conducted our initial UAV flight operations.
- o Update the website by uploading and linking TAC meeting minutes and Quarterly Reports, as well as any other necessary upgrades and updates.
- Software and Equipment Acquisition:
  - o None

Schedule:
Highlight any changes to the schedule as previously reported.

- The first blog post is three months behind schedule because we are waiting to do the blog post after the UAV field training, scheduled for October 16-17, 2013. The delay in the blog post does not cause a delay in any other aspect of the project.

Effort Expended:
Effort expended by task for all staff categories must be reported.

Employee Name/Labor Category	Budgeted Hours	Year 1 (hours)				Cummulative (hours)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy	42	15	13.75	10.13		38.88
Jarlath O'Neil Dunne	16	9	0			9
Ernest Buford	6		6			6
Amanda Hanaway	76	32.75	12.75	4		49.5
Sean MacFadden	0					0
James Sullivan	36	18.38	10.37	2		30.75
Technician	0					0

Task 3 - Damage detection system methods development
Design, develop, deploy, and validate a decision support system that automates the detection of post-event damage to roads from CRS satellite imagery and provides actionable information to incident commanders.

Output/Deliverables: We will develop, validate, and accurately assess a methodology for automating the identification of large road damage. This methodology will result in the development of a "knowledge base" of expert classification rules that remote sensing technicians can then reuse in other location. This knowledge base will be made available on our website along with documentation and tutorials on using it (see Task 6). We will also create and post an ESRI geoprocessing utility or standalone utility that extracts the geographic coordinates of the center of each damage polygon and then sends that coordinate to a web server (see Task 5).

Accomplishments:
Provide a clear and complete account of work performed on each task and its relationship to task objectives and milestones.

- Image Registration Routines complete
- Import Routines complete
- Ruleset Set Development in progress
    - Improved the image registration routines.
    - Added flexibility to the import/data loading operation.
    - Continued testing under a variety of image conditions.

Problems Encountered:
Describe any problems encountered or anticipated that will affect the completion of the agreement within the time and fiscal constraints as set forth in the agreement, together with recommended solutions to such problems, or a statement that no problems were encountered.

- No problems were encountered.

Future Plans:
Discuss work planned for the next period and its relationship to the present period. Provide an outline of the work to be accomplished during the next report.

- The contract requires the following deliverable at 12 months: A knowledge base of feature extraction and classification rules for identifying road damage from highresolution imagery, for re-use in commercially available object-based image analysis software.
- Damage Detection Routine Testing to be completed
- Ruleset Set Development to continue

Schedule:

Highlight any changes to the schedule as previously reported.

- We do not anticipate any schedule changes.

Effort Expended:

Effort expended by task for all staff categories must be reported.

Employee Name/Labor Category	Budgeted Hours	Year 1 (hours)				Cummulative (hours)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy	42		8.66	20		28.66
Jarlath O'Neil Dunne	30		13			13
Ernest Buford	0					0
Amanda Hanaway	170		11	12.75		23.75
Sean MacFadden	1191	325	406.25			731.25
James Sullivan	30		10	5		15
Technician	0					0

Note: The labor hours for Sean MacFadden were listed incorrectly in the contract. To correct this error, we moved his hours from Task 4 to Task 3, Task 5 to Task 4, and Task 6 to Task 5. All the tables in this report reflect this correction.

Task 4 - Fill calculation system methods development
Design, develop, deploy, and validate a decision support system that uses CRS Unmanned Aerial Vehicles (UAV) to estimating the amount and type of fill material needed to fill damaged areas.

Output/Deliverables: We will develop, validate, accurately assess and document a methodology for automating the calculation of the quantity of fill by type for road damage voids caused by flooding. We will produce a technical document and tutorial that outlines this methodology (see Task 6). We will also produce and make available an ESRI geoprocessing tool capable of performing the fill calculations.

Accomplishments:
Provide a clear and complete account of work performed on each task and its relationship to task objectives and milestones.

- Developed fill estimation decision support design detailed specifications
- Conducted UAV Software Training
- Organized flight training and testing
- Fill Calculations Prototyping in progress

Problems Encountered:
Describe any problems encountered or anticipated that will affect the completion of the agreement within the time and fiscal constraints as set forth in the agreement, together with recommended solutions to such problems, or a statement that no problems were encountered.

- UAV shipment took longer than expected due to international customs issues thereby delaying training and initial flight operations.

Future Plans:
Discuss work planned for the next period and its relationship to the present period. Provide an outline of the work to be accomplished during the next report.

- UAV flight training to be completed
- Initial UAV flight operations to be completed
- Fill calculation prototyping to continue
- Cost-Based Image Matching to be started
- Fill Calculations Geoprocessing Tool Development to be started

Schedule:

Highlight any changes to the schedule as previously reported.

- Delays in obtaining the UAV may impact our planned flight operations for the summer, but we are working to get back on track.

Effort Expended:

Effort expended by task for all staff categories must be reported.

Employee Name/Labor Category	Budgeted Hours	Year 1 (hours)				Cummulative (hours)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy	20			10		10
Jarlath O'Neil Dunne	295		71.38			71.38
Ernest Buford	226		34.63			34.63
Amanda Hanaway	49					0
Sean MacFadden	366.9					0
James Sullivan	40			10		10
Technician	50					0

Task 5 - Development of web portal decision support tool
Develop web-based decision support tools and GIS data layers, and disseminates information on road damage via social media.

Output/Deliverables: Outputs will include development of a front-end website prototype on our own servers which will pull data from Google Fusion Tables, which is a cloud-based platform. We will then work with our VTrans partners to make these data sets and web resources available to them so that they can freely integrate them into their online information systems. We will document the process of developing the portal and will write up manuals for both users and for website administrators.

Accomplishments:
Provide a clear and complete account of work performed on each task and its relationship to task objectives and milestones.

- No progress slated for this quarter.

Problems Encountered:
Describe any problems encountered or anticipated that will affect the completion of the agreement within the time and fiscal constraints as set forth in the agreement, together with recommended solutions to such problems, or a statement that no problems were encountered.

Future Plans:
Discuss work planned for the next period and its relationship to the present period. Provide an outline of the work to be accomplished during the next report.

- Web-site Front End/Back End Work to be started
- Post Damage Geoprocessing Tools to be started

Schedule:
Highlight any changes to the schedule as previously reported.

Effort Expended:
Effort expended by task for all staff categories must be reported.

Employee Name/Labor Category	Budgeted Hours	Year 1 (hours)				Cummulative (hours)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy	24.5					0
Jarlath O'Neil Dunne	157					0
Ernest Buford	158.02					0
Amanda Hanaway	40					0
Sean MacFadden	197.08					0
James Sullivan	16					0
Technician	880					0

Task 6 - Project outreach and communication
Make the methods and technologies developed in this project to be easily transferable to other state DOTs.

Output/Deliverables: We will complete, make available and disseminate all outreach materials. For the damage-detection methodology, this will include our knowledge base of classification/detection rules, which can then be ported and reused in object-based image-classification software using different imagery, as well as a detailed methodological document and video tutorial that will assist technicians in replicating this system. For the fill calculation task, it will include the ArcGIS geoprocessing tool files and user manual, a methodological document, and a set of video tutorials. For the decision support portal development, we will include a methodological document about setting up the interface and serving the data from Google Fusion Tables, as well as guides for users and administrators. We will hold a focus group meeting with select partners to get feedback on our outputs and determine what additional information or clarification may be needed for subsequent adopters to make use of the project's methods. We will also follow up with VTrans and, if applicable, other New England DOTs, to determine if and how the methods we developed were actually employed and what improvements could potentially be made. Finally, we will write a final report (draft and revised versions), give presentations on the project at professional meetings and prepare manuscripts on the project for publication.

Accomplishments:
Provide a clear and complete account of work performed on each task and its relationship to task objectives and milestones.

- Submitted a Quarterly Progress Report
- No other progress slated for this quarter

Problems Encountered:
Describe any problems encountered or anticipated that will affect the completion of the agreement within the time and fiscal constraints as set forth in the agreement, together with recommended solutions to such problems, or a statement that no problems were encountered.

- None.

Future Plans:
Discuss work planned for the next period and its relationship to the present period. Provide an outline of the work to be accomplished during the next report.

- The contract requires a minimum of two presentations on the project or aspects of the project at regional or national transportation/geospatial conferences, the first to occur within the 12 months.

- The next Quarterly Progress Report.
- HDDS Tutorial Video to be completed

Schedule:
Highlight any changes to the schedule as previously reported.

- **None**

Effort Expended:
Effort expended by task for all staff categories must be reported.

Employee Name/Labor Category	Budgeted Hours	Year 1 (hours)				Cummulative (hours)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy	100.5			10.62		10.62
Jarlath O'Neil Dunne	78.18		5			5
Ernest Buford	0					0
Amanda Hanaway	69.99			12		12
Sean MacFadden	0					0
James Sullivan	165.98			5.38		5.38
Technician	70					0

Business Status

Labor-Hours Expended for the Program
Provide a tabulation of the planned, actual and cumulative labor-hours expended for the program.

Employee Name/Labor Category	Total Budgeted Hours	Year 1 (hours)				Cummulative (hours)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy	429.00	71.5	35.75	74.75	0	182
Jarlath O'Neil Dunne	626.18	39	89.38	0	0	128.38
Ernest Buford	390.02	0	40.63	0	0	40.63
Amanda Hanaway	584.99	48.75	48.75	48.75	0	146.25
Sean MacFadden	1,754.98	325	406.25	0	0	731.25
James Sullivan	311.98	24.38	24.37	24.38	0	73.13
Technician	1,000.00	0	0	0	0	0

Note: Dr. Austin Troy left the University of Vermont in August. The Project Manager has been notified, and the official request for change in key personnel has been submitted. The request included a breakdown on how Dr. Troy's labor hours will be redistributed. Once approved, we will include the revised budgeted hours in the remaining quarterly reports.

Funds Expended for the Program
Provide a chart showing current and cumulative expenditures versus planned expenditures

Employee Name/Labor Category	Total Invoiced for Salary	Year 1 (Invoiced Salary)				Cummulative (Invoiced Salary)
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Austin Troy - Regular	$50,816.24			$8,723.04		$8,723.04
Austin Troy - Cost Share		$8,343.78	$4,171.89			$12,515.67
Jarlath O'Neil Dunne - Regular	$50,013.61	$3,038.10	$6,962.71	$0.00		$10,000.81
Jarlath O'Neil Dunne - Cost Share		$3,038.10				$0.00
Ernest Buford	$22,470.35	$0.00	$2,306.16	$0.00		$2,306.16
Amanda Hanaway	$43,808.73	$3,596.78	$3,596.78	$3,596.78		$10,790.33
Sean MacFadden	$98,881.57	$19,891.95	$24,864.94	$0.00		$44,756.89
James Sullivan	$23,559.89	$1,813.91	$1,813.16	$1,813.91		$5,440.97
Technician	$19,891.05	$0.00	$0.00	$0.00		$0.00
Non-Salary Expenditures			$25,987.91			$25,987.91
Non-Salary Cost Share						$0.00
Total	**$309,441.45**	**$36,684.51**	**$69,703.54**	**$14,133.72**	**$0.00**	**$120,521.78**
Cost Share:	$382,630.00	$8,343.78	$4,171.89	$0.00	$0.00	$12,515.67
Invoiced:	$371,750.00	$28,340.74	$65,531.65	$14,133.72	$0.00	$108,006.11
Total:	**$754,380.00**	**$36,684.51**	**$69,703.54**	**$14,133.72**	**$0.00**	**$120,521.78**

Note: Due to an accounting error, Jarlath O'Neil Dunne's time was reported incorrectly as cost share for the first quarter. This has been revised in the table above, as well as in our accounting system. The expenditures shown in the table above are approximate, and are subject to variations from what is shown on the project invoices due to University Wide Salary and Cost of Living Adjustments. Also, hours reported for each task are estimated for the current quarterly report and then revised in the next quarterly report to reflect what is presented on invoices.

Advisory Committee Meetings

List of Advisory Committee Meetings to Date:
- 3/19/2013 Meeting. Meeting minutes are attached in Appendix A. Also, the meeting was recorded using GoToMeeting software. A link to the recording can be found on the project website: http://bit.ly/11ZzJmA

Quarterly Report Submission Timeline

If the submission due date is a holiday/weekend please ensure that the submission is made by the subsequent business day. Deliverables covering partial periods of performance up to one month will be rolled over into the subsequent quarterly progress report.

- Quarterly Report for Period covering January 01 to March 31 is due by April 15
- Quarterly Report for Period covering April 01 to June 30 is due by July 15
- Quarterly Report for Period covering July 01 to Sept. 30 is due by October 15
- Quarterly Report for Period covering October 01 to December 31 is due by January 15

Appendix

Appendix A – Purchasing and Flying UAVs in Vermont: Lessons Learned (so far)

Appendix A
Purchasing and Flying UAVs in Vermont:
Lessons Learned (so far)