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

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COOPERATIVE AGREEMENT
No. RITARS-12-H-UVM

Quarterly Progress Report #8

October 1, 2014 through December 31, 2014

TRC TRANSPORTATION RESEARCH CENTER

University of Vermont Spatial Analysis Lab

United States Department of Transportation

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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.

- On November 5th, 2014, the project team met to discuss the final deliverables for the project.
- The project team has been working with the Technical Committee to identify areas that we can fly the UAV to collect data. This partnership allows us to accomplish the data collection associated with Task 3, as well as get a head start on the outreach and communication associated with Task 6. The data is collected, while at the same time providing a demonstration to the Technical Committee members. We provide a full list of these partnerships later in this report.

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.

- A final Technical Advisory Committee will be planned before the close of the project to demonstrate the findings and final deliverables.
- Internal project team meetings to occur on a regular basis.

- The Annual Project Progress Meeting with the US DOT Project Manager, Caesar Singh, is scheduled for 11 am on January 12, 2015 at US DOT HQ – East Building (Navy Yard)

Schedule:

Highlight any changes to the schedule as previously reported.

- The project end date has been revised to May 30, 2015. TAC meetings and internal project team meetings will be planned as necessary.

Effort Expended:

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

Employee Name/ Labor Category	Budgeted Hours	Revised Budgeted Hours*	Revised Budgeted Hours**	Year 1 (hours)				Year 2 (hours)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(hours)
Austin Troy	200	93.84	93.84	56.5	13.34	24								93.84
Jarlath O'Neil Dunne	50	129.52	129.52	30		15	14.38	15	15		40.14			129.52
Ernest Buford	0	0.00	0.00											0
Amanda Hanaway	180	263.96	150.13	16	25	20	23.13	20	20	8	18			150.13
Sean MacFadden	0	0.00	0.00											0
James Sullivan	24	24.00	20.00	6	4	2	6	2						20
Zachary Borst	0	TBD	120.00					30	30	30	30			120
Technician	0	0.00	0.00											0

*Note: Austin Troy has left the University of Vermont, and Jarlath O'Neil-Dunne has taken over as PI. Austin's remaining hours for this task (106.16 hours) have been divided up equally between Jarlath and Amanda Hanaway (106.16 hours/2 = 53.08 hours). In an effort to keep the cost of the project the same, the number of hours were factored by the difference in salaries (53.08 hours of Austin's time = 79.52 hours of Jarlath's time = 83.96 hours of Amanda's time = $6,194.44).

**Note: As we approach the conclusion of the project, there have been some shifts in effort. The project team met to discuss what effort was needed to complete the project. For Task 1, 3, 4, 5, and 6, surplus hours that were budgeted for Jarlath, Amanda, and James's time, were transferred to Sean, Zachary, and the Technician. After transferring the hours, there was still approximately $6,000 left in the budget for salaries, and that amount has been re-budgeted as approximately $2,000 for an undergraduate student to work on the project, and approximately $4,000 in additional flight equipment. That being said, as we approach the end of the project, these estimates will shift as necessary to complete the work on time.

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.

- This Quarterly Report has been added to the website.
- One new blog post has been linked to from the project 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.

- 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 four blog post about various aspects on the project. We will provide a link from the project website to the remaining "Letter from the SAL" blog posts once they are complete.
- Update the website by uploading and linking TAC meeting minutes and Quarterly Reports, as well as any other necessary upgrades and updates.

Schedule:

Highlight any changes to the schedule as previously reported.

- The project end date has been revised to May 30, 2015. The final deliverables, including blog posts, video tutorials, and white papers will be added to the website as they become available. .

Effort Expended:

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

Employee Name/ Labor Category	Budgeted Hours	Revised Budgeted Hours*	Revised Budgeted Hours**	Year 1 (hours)				Year 2 (hours)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(hours)
Austin Troy	42	38.88	38.88	15	13.75	10.13								38.88
Jarlath O'Neil Dunne	16	18.34	18.34	9	0						9.34			18.34
Ernest Buford	6	6.00	6.00		6									6
Amanda Hanaway	76	78.47	78.47	32.75	12.75	4	5	5	5	7	7			78.5
Sean MacFadden	0	0.00	0.00											0
James Sullivan	36	36.00	36.00	18.38	10.38	2	5.24							36
Zachary Borst	0	0.00	0.00											0
Technician	0	0.00	0.00											0

*Note: Austin Troy has left the University of Vermont, and Jarlath O'Neil-Dunne has taken over as PI. Austin's remaining hours for this task (3.12 hours) have been divided up equally between Jarlath and Amanda Hanaway (3.12 hours/2 = 1.56 hours). In an effort to keep the cost of the project the same, the number of hours were factored by the difference in salaries (1.56 hours of Austin's time = 2.34 hours of Jarlath's time = 2.47 hours of Amanda's time = $182.05).

**Note: As we approach the conclusion of the project, there have been some shifts in effort. The project team met to discuss what effort was needed to complete the project. For Task 1, 3, 4, 5, and 6, surplus hours that were budgeted for Jarlath, Amanda, and James's time, were transferred to Sean, Zachary, and the Technician. After transferring the hours, there was still approximately $6,000 left in the budget for salaries, and that amount has been re-budgeted as approximately $2,000 for an undergraduate student to work on the project, and approximately $4,000 in additional flight equipment. That being said, as we approach the end of the project, these estimates will shift as necessary to complete the work on time.

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.

- Development of interface for damage detection

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.

- Continue to develop user interface for damage detection

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

- The project end date has been revised to May 30, 2015. However, this task is essentially complete, so we don't expect any changes to Task 3.

Effort Expended:

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

Employee Name/ Labor Category	Budgeted Hours	Revised Budgeted Hours*	Revised Budgeted Hours**	Year 1 (hours)				Year 2 (hours)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(hours)
Austin Troy	42	28.66	28.66		8.66	20								28.66
Jarlath O'Neil Dunne	30	49.98	49.98		13	6	6	15	5		4.98			49.98
Ernest Buford	0	0.00	0.00											0
Amanda Hanaway	170	170.00	123.13		11	37.13	35	10	10	10	10			123.13
Sean MacFadden	1191	1191.00	1191.00	325	406.25		172.25	172.25		115.25				1191
James Sullivan	30	30.00	30.00		10	5	15							30
Zachary Borst	0	0.00	0.00											0
Technician	0	0.00	0.00											0

*Note: Austin Troy has left the University of Vermont, and Jarlath O'Neil-Dunne has taken over as PI. Austin's remaining hours for this task (13.34 hours) have been shifted to Jarlath. In an effort to keep the cost of the project the same, the number of hours were factored by the difference in salaries (13.34 hours of Austin's time = 19.98 hours of Jarlath's time = $1,556.78).

**Note: As we approach the conclusion of the project, there have been some shifts in effort. The project team met to discuss what effort was needed to complete the project. For Task 1, 3, 4, 5, and 6, surplus hours that were budgeted for Jarlath, Amanda, and James's time, were transferred to Sean, Zachary, and the Technician. After transferring the hours, there was still approximately $6,000 left in the budget for salaries, and that amount has been re-budgeted as approximately $2,000 for an undergraduate student to work on the project, and approximately $4,000 in additional flight equipment. That being said, as we approach the end of the project, these estimates will shift as necessary to complete the work on time.

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.

- UAV data collection is complete for this project. All future data collection will be in conjunction with the new project UAS for Transportation Decision Support.
- The fill estimations from the field have been validated
- 3D models have been developed and shared with collaborators

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.

- None

Schedule:

Highlight any changes to the schedule as previously reported.

- The project end date has been revised to May 30, 2015. However, data collection and the fill estimation system are essentially complete, so we don't expect any changes to Task 4.

Effort Expended:

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

Employee Name/ Labor Category	Budgeted Hours	Revised Budgeted Hours*	Revised Budgeted Hours**	Year 1 (hours)				Year 2 (hours)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(hours)
Austin Troy	20	10.00	10.00			10								10
Jarlath O'Neil Dunne	295	309.98	255.02		71.38	68.38	4	61.88	39.38		10.00			255.02
Ernest Buford	226	226.00	226.00		34.63	167.21				24.16				226
Amanda Hanaway	49	49.00	10.00							10				10
Sean MacFadden	366.9	366.90	366.90				166.9	166.9		33.1				366.9
James Sullivan	40	40.00	26.76			10	12.76	4						26.76
Zachary Borst	0	TBD	0.00											0
Technician	50	50.00	50.00				20	8	8		0			36

*Note: Austin Troy has left the University of Vermont, and Jarlath O'Neil-Dunne has taken over as PI. Austin's remaining hours for this task (10 hours) have been shifted to Jarlath. In an effort to keep the cost of the project the same, the number of hours were factored by the difference in salaries (10 hours of Austin's time = 14.98 hours of Jarlath's time = $1,167).

**Note: As we approach the conclusion of the project, there have been some shifts in effort. The project team met to discuss what effort was needed to complete the project. For Task 1, 3, 4, 5, and 6, surplus hours that were budgeted for Jarlath, Amanda, and James's time, were transferred to Sean, Zachary, and the Technician. After transferring the hours, there was still approximately $6,000 left in the budget for salaries, and that amount has been re-budgeted as approximately $2,000 for an undergraduate student to work on the project, and approximately $4,000 in additional flight equipment. That being said, as we approach the end of the project, these estimates will shift as necessary to complete the work on time.

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.

- Web-site Front End/Back End Work is ongoing
- Manuals for users and website administrators are being created

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.

- Web-site Front End/Back End Work to continue.
- Work on manuals for users and website administrators to continue.

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

- The project end date has been revised to May 30, 2015. The work involved with Task 5 will continue on through the new project end date. Essentially, we need to complete the web portal and create the necessary manuals.

Effort Expended:

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

Employee Name/ Labor Category	Budgeted Hours	Revised Budgeted Hours*	Revised Budgeted Hours**	Year 1 (hours)				Year 2 (hours)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(hours)
Austin Troy	24.5	0.00	0.00											0
Jarlath O'Neil Dunne	157	193.70	10.00								10			10
Ernest Buford	158.02	158.02	158.65							39.22	126.75			165.97
Amanda Hanaway	40	40.00	0.00											0
Sean MacFadden	197.08	197.08	798.35				148.35	148.35		197.06	325			818.76
James Sullivan	16	16.00	0.00											0
Zachary Borst	0	TBD	0.00											0
Technician	880	880.00	880.00				79.5	37.5	49.5					166.5

*Note: Austin Troy has left the University of Vermont, and Jarlath O'Neil-Dunne has taken over as PI. Austin's remaining hours for this task (24.5 hours) have been shifted to Jarlath. In an effort to keep the cost of the project the same, the number of hours were factored by the difference in salaries (24.5 hours of Austin's time = 36.70 hours of Jarlath's time = $2,859.15).

**Note: As we approach the conclusion of the project, there have been some shifts in effort. The project team met to discuss what effort was needed to complete the project. For Task 1, 3, 4, 5, and 6, surplus hours that were budgeted for Jarlath, Amanda, and James's time, were transferred to Sean, Zachary, and the Technician. After transferring the hours, there was still approximately $6,000 left in the budget for salaries, and that amount has been re-budgeted as approximately $2,000 for an undergraduate student to work on the project, and approximately $4,000 in additional flight equipment. That being said, as we approach the end of the project, these estimates will shift as necessary to complete the work on time.

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
- Worked on technical documentation and manuals
- Worked on publications. Abstracts submitted to the American Society for Photogrammetry and Remote Sensing (ASPRS) Conference. Final papers due in April.
- Worked on presentations
- Finalized the “best practices” technical document
- Made the following presentation:
    - UAV Use for Planning Purposes. Tuesday December 16, 2014, meeting with the UVM Facilities group to discuss UAV use for planning purposes and as an overview of current rules and regulations and how we work with partners in order to fly our aircraft. They are interested in using the aircraft in pedestrian and traffic management for the massive construction project scheduled to start summer of 2015 due to the significant traffic interruptions and rerouting.

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.

- Stakeholder/partner meetings to review decision support systems
- The next Quarterly Progress Report.
- Presentations:
    - Unmanned Aerial Systems for Transportation Decision Support. Sunday, January 11, 2015 9:00AM - 12:00PM at the Transportation Research Board (TRB) Annual Meeting in Washington, DC.
    - Unmanned Aerial Systems for Mapping. Thursday, January 15, 2015, via webinar on behalf of the Vermont Center for Geographic Information (VCGI).
- Provide a link to the "best practices" technical document from our website.
- Write technical documentation and manuals
- Write publications
- Write presentations
  Draft final report

Schedule:

Highlight any changes to the schedule as previously reported.

- The project end date has been revised to May 30, 2015. The work involved with Task 6 will continue on through the new project end date. Essentially, we need to complete some of the manuals, publications, and the final report.

Effort Expended:

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

Employee Name/ Labor Category	Budgeted Hours	Revised Budgeted Hours*	Revised Budgeted Hours**	Year 1 (hours)				Year 2 (hours)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(hours)
Austin Troy	100.5	10.62	10.62			10.62								10.62
Jarlath O'Neil Dunne	78.18	123.12	71.79		5			30	30		6.79			71.79
Ernest Buford	0	0.00	0.00											0
Amanda Hanaway	69.99	114.93	77.00			12	10	13.75	13.75	13.75	13.75			77
Sean MacFadden	0	0.00	0.00											0
James Sullivan	165.98	165.98	23.76			5.38		18.38						23.76
Zachary Borst	0	TBD	270.02					43.13	43.13	43.13	43.13			172.52
Technician	70	70.00	22.50								0			0

*Note: Austin Troy has left the University of Vermont, and Jarlath O'Neil-Dunne has taken over as PI. Austin's remaining hours for this task (89.88 hours) have been divided up equally between Jarlath and Amanda Hanaway (89.88 hours/2 = 44.94 hours). In an effort to keep the cost of the project the same, the number of hours were factored by the difference in salaries (44.94 hours of Austin's time = 67.32 hours of Jarlath's time = 71.08 hours of Amanda's time = $5,244.50).

**Note: As we approach the conclusion of the project, there have been some shifts in effort. The project team met to discuss what effort was needed to complete the project. For Task 1, 3, 4, 5, and 6, surplus hours that were budgeted for Jarlath, Amanda, and James's time, were transferred to Sean, Zachary, and the Technician. After transferring the hours, there was still approximately $6,000 left in the budget for salaries, and that amount has been re-budgeted as approximately $2,000 for an undergraduate student to work on the project, and approximately $4,000 in additional flight equipment. That being said, as we approach the end of the project, these estimates will shift as necessary to complete the work on time.

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	Revised Total Budgeted Hours*	Revised Total Budgeted Hours**	Year 1 (hours)				Year 2 (hours)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(hours)
Austin Troy	429.00	182.00	182.00	71.5	35.75	74.75	0	0	0	0	0			182
Jarlath O'Neil Dunne	626.18	824.64	534.65	39	89.38	89.38	24.38	121.88	89.38	0	81.25			534.65
Ernest Buford	390.02	390.02	390.65	0	40.63	167.21	0	0	0	63.38	126.75			397.97
Amanda Hanaway	584.99	716.36	438.73	48.75	48.75	73.13	73.13	48.75	48.75	48.75	48.75			438.76
Sean MacFadden	1,754.98	1,754.98	2,356.25	325	406.25	0	487.5	487.5	0	345.41	325			2376.66
James Sullivan	311.98	311.98	136.52	24.38	24.38	24.38	39	24.38	0	0	0			136.52
Zachary Borst	0.00	TBD	390.02	0	0	0	0	73.13	73.13	73.13	73.13			292.52
Technician	1,000.00	1,000.00	952.50	0	0	0	99.5	45.5	57.5	0	0			202.5

Funds Expended for the Program

Provide a chart showing current and cumulative expenditures versus planned expenditures

Employee Name/ Labor Category	Total Invoiced for Salary	Revised Total Invoiced for Salary*	Revised Total Invoiced for Salary**	Year 1 (Invoiced Salary)				Year 2 (Invoiced Salary)				Year 3 (hours)		Cummulative
				Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Quarter 9	Quarter 10	(Invoiced Salary)
Austin Troy - Regular	$50,816.24	$21,558.40	$21,558.40			$8,723.04		$0.00	$0.00	$0.00	$0.00			$8,723.04
Austin Troy - Cost Share				$8,343.78	$4,171.89									
Jarlath O'Neil Dunne - Reg	$48,779.45	$64,239.71	$41,649.19	$3,038.10	$6,962.71	$6,962.71	$1,899.20	$9,494.45	$6,962.70	$0.00	$6,329.38			$41,649.26
Jarlath O'Neil Dunne - CS														
Ernest Buford	$22,137.54	$22,137.54	$22,173.44	$0.00	$2,306.16	$9,490.84	$0.00	$0.00	$0.00	$3,597.45	$7,194.33			$22,588.78
Amanda Hanaway	$43,160.56	$52,852.72	$32,369.31	$3,596.78	$3,596.78	$5,395.53	$5,395.53	$3,596.78	$3,596.78	$3,596.78	$3,596.78			$32,371.71
Sean MacFadden	$107,413.55	$107,413.55	$144,214.28	$19,891.95	$24,864.94	$0.00	$29,839.88	$29,839.88	$0.00	$21,142.55	$19,893.25			$145,472.43
James Sullivan	$23,559.89	$23,559.89	$10,309.62	$1,813.91	$1,813.91	$1,813.91	$2,988.70	$1,868.32	$0.00	$0.00	$0.00			$10,298.73
Zachary Borst	$0.00	TBD	$18,381.64	-	-	-	-	$3,446.62	$3,446.62	$3,446.62	$3,446.62			$13,786.47
Technician	$19,891.05	$19,891.05	$18,946.23	$0.00	$0.00	$0.00	$1,979.26	$905.09	$1,143.80	$0.00	$0.00			$4,028.15
Non-Salary Expenditures	$30,530.67	$30,530.67	$30,530.67		$25,987.91	$3,603.04	$939.72	$1,333.84	$322.00	$4,063.82	$798.20			$37,048.53
Non-Salary Cost Share										$300,000.00				$300,000.00
Total	**$315,758.28**	$311,652.86	$309,602.12	**$36,684.51**	**$69,704.29**	**$35,989.07**	**$43,042.29**	**$50,484.97**	**$15,471.89**	**$35,847.21**	**$40,460.35**	**$0.00**	**$0.00**	$327,684.57

Cost Share:	$382,630.00	$382,630.00	$382,630.00	$8,343.78	$4,171.89	$0.00	$0.00	$0.00	$0.00	$300,000.00	$0.00			$312,515.67
Invoiced:	$371,750.00	$371,750.00	$371,750.00	$28,340.74	$65,532.40	$35,989.07	$43,042.29	$50,484.97	$15,471.89	$35,847.21	$41,258.55			$315,967.10
Total:	**$754,380.00**	$754,380.00	$754,380.00	**$36,684.51**	**$69,704.29**	**$35,989.07**	**$43,042.29**	**$50,484.97**	**$15,471.89**	**$335,847.21**	**$41,258.55**	**$0.00**	**$0.00**	**$628,482.77**

*Note: Austin Troy has left the University of Vermont, and Jarlath O'Neil-Dunne has taken over as PI. Austin's remaining hours were divided up between Jarlath and Amanda.

**Note: As we approach the conclusion of the project, there have been some shifts in effort. The project team met to discuss what effort was needed to complete the project. For Task 1, 3, 4, 5, and 6, surplus hours that were budgeted for Jarlath, Amanda, and James's time, were transferred to Sean, Zachary, and the Technician. After transferring the hours, there was still approximately $6,000 left in the budget for salaries, and that amount has been re-budgeted as approximately $2,000 for an undergraduate student to work on the project, and approximately $4,000 in additional

flight equipment. That being said, as we approach the end of the project, these estimates will shift as necessary to complete the work on time.

Notes on Cost Share

1) The $300,000 match from Trimble was recorded in quarter 3 of 2014.
2) GeoEye, who agreed to the original match, was acquired by DigitialGlobe after the project began. In addition, the program manager who made the agreement with us left the company after the acquisition. Fortunately, DigitalGlobe agreed to honor the imagery donation. We are working with the new program manager to get the financial certification documents.

Budget for Non-Salary Expenditures

Airfare Domestic	$234.80
Computing Supplies	$163.48
Conference Regstr Fee Domestic	$375.00
Consult/Prof Svcs Org Fees	$1,820.00
Express Mail & Delivery Svcs	$90.22
IC - Micro Comp Srvcs/Accsr	$72.00
Laboratory & Research Supplies	$338.62
Mileage Domestic	$220.92
Non-Cap Cmptr Hardware <$5000	$3,047.72
Non-Cap Moveable Equip >$5000	$24,167.91
Grand Total	$30,530.67

Meetings

List of Advisory Committee Meetings to Date:

- 3/19/2013 Meeting. Meeting minutes and webinar recording are provided on the project website.
- 12/6/13 Meeting. Meeting minutes and webinar recording are provided on the project website.

List of Meetings with the USDOT Project Management Team:

- 1/15/14 Meeting. A technical and financial update was provided to Caesar Singh and Vasanth Ganesan. The meeting minutes will not be posted to the website due to the detailed level of information exchanged in the meeting.
- 8/8/14 Meeting. The USDOT Project Manager, Caesar Singh, visited the University of Vermont. The visit included a demonstration of the UAV flight and post-processing procedures. It also included a discussion of a Modification to the original proposal. The modification would act as a Phase II and would focus on more flights that demonstrate the versatility of the UAV, as well as establishing a process whereby it can be incorporated into State Agency operations.

Presentations

- Emerging Remote-Sensing Technologies for Studying the Vermont Landscape. Thursday, December 12, 2013, University of Vermont, Aiken Center.
- Sensing Technologies for Transportation Applications. Sunday, January 12, 2014, 9:00 am to 12:00 pm (noon), Hilton, Columbia Hall 11, Washington D.C.
- Rapid Assessment of Storm-related Damage Using Commercial Remote-sensing Imagery. Thursday, May 8, 2014, Geospatial Information Systems for Transportation Symposium in Burlington, Vermont.
- Rapid Exploitation of Commercial Remotely Sensed Imagery for Disaster Response & Recovery. Friday, June 6, 2014. University of Vermont Transportation Research Center, Brown Bag Lecture Series.
- Unmanned Aerial Systems for Disaster Response and Recovery.
    - Tuesday, May 6, 2014, Geospatial Information Systems for Transportation Symposium in Burlington, Vermont.
    - Wednesday, July 16, 2014, broadcast live via web cast from U.S. DOT Headquarters. Office of the Assistant Secretary for Research and Technology (OST-R) Transportation Innovation Series.
- UAV Use for Planning Purposes. Tuesday December 16, 2014, meeting with the UVM Facilities group.

Partnerships

The Project Team has been collaborating not only with the project's Technical Committee, but the following organizations as well:

- Vermont Agency of Natural Resources. The project team has been working with ANR on their stream monitoring program. The discussions have been focused around using Unmanned Arial Vehicles to monitor sections of rivers and streams that are difficult to access on the ground. After Tropical Storm Irene, it was determined that debris which had accumulated upstream was forced downstream and caused severe blockages.
- Vermont Agency of Transportation. The project team has been working with the Maintenance and Operations Department at VAOT on their culvert maintenance program. The discussions have been focused on what is happening upstream which may be causing culverts downstream to become blocked. The Vermont Research Advisory Council (RAC) Program recently chose the following project for funding: "Using Remote Data Collection to Identify Bridges and Culverts Susceptible to Blockage During Flooding Events.
- Department of Emergency Management and Homeland Security. The project team has been working with DEMHS on their critical infrastructure program. The discussions have been focused on how UAVs and GIS data can be used to determine what should be considered critical infrastructure, and how to maintain and protect it better in the future. The project team also conducted a demonstration of the UAV flight operations to DEMHS.
- Green Mountain Power. The project team has been working with Green Mountain Power to determine ways that a UAV could be incorporated into their processes and procedures.
- Vermont Department of Environmental Conservation. The project team has been working with Todd Menees, P.E., P.H., a River Management Engineer in the Watershed Management Division of the Rivers Program at VT DEC, flying sites eligible for Hazard Mitigation Grant Program (HMGP) Buyout money through FEMA. The homes demolished by Irene are removed and the flood zone needed survey data to determine how to re-stabilize the banks.
- Town of Readsboro. The project team assisted the town by acquiring UAV data of an area damaged by flooding. The data is being used by the town for transportation and disaster response planning.
- Town of Wardsboro. The project team assisted the town by acquiring UAV data of an area damaged by flooding. The data is being used by the town for transportation and disaster response planning.
- Windham Regional Planning Commission. The project team assisted the commission by acquiring UAV data of an area damaged by flooding. The data is being used for transportation and disaster response planning.
- UVM, Dr. Jeff Frolik, The project team was able to borrow a Terrestrial LIDAR scanner from Dr. Frolik for use in the fill estimation validation task. The Terrestrial LiDAR scanner was obtained through a previous National Science Foundation Grant.

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