MONTANA UNIVERSITY SYSTEM RESEARCH INITIATIVE

Autonomous Aerial Systems for Wildfire Management in Montana

Second Quarterly Report - July 22, 2016

Submitted by:

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http://www.umt.edu/aaso/DroneFire/

Executive Summary

This document describes activities, accomplishments, and progress in the second quarter of DroneFire. Activities are organized by objectives and milestones, as reported in the Project OTOs. Expenditures and photos are included at the end of the document. Quarter One activities focused primarily on development of organizational structure, science teams, regulatory procedures, and private sector partnerships. Quarter Two activities have focused on aircraft operations, data acquisition and workflow, prototyping instrumentation and data collection for science missions.

A blanket Certificate of Authorization (COA) from the FAA has allowed us to begin testing airframes and sensors. Fifteen data acquisition missions were completed using three combinations of airframes and sensors. These missions are being used to develop sound aircraft operations, data acquisition techniques, and processing workflows as well as to prototype science applications. Missions have been conducted to support scientific investigations into fuel dynamics in the Fire-Fire Surrogate Study at Lubrecht Experimental Forest (LEF), stream course evolution in the Ninemile Placer Restoration Project, tree regeneration success at LEF, and weather forecasting at the SUATS flight facility in Kalispell, among others.

Our public-private partnerships are developing quickly, with primary links to Skyfish (Missoula), SUATS (Kalispell), and Commander Navigation (Hamilton). We are working with Skyfish to test their M4 rotor wing platform, gimbal system, and software. SUATS is integrating and testing thermal infrared and meteorological sensor configurations on several platforms. Commander Navigation is prototyping multispectral and longwave thermal IR sensors on a larger, long-dwell-time fixed wing platform. We will host field trials at LEF with Skyfish and Commander Navigation later in the summer. We have set up contracts with eight Montana companies to streamline collaborative efforts. These contracts provide access to 21 different platforms, 22 sensors (Electro-Optical and Thermal IR), and 12 processing streams.

The project remains on schedule and we are currently resolving several challenges related to flying in complex terrain and gaining access to higher flight ceilings and non-line-of-site locations. New regulations from the FAA have created a need for development of common interpretation of COAs regarding training, mission procedures, and documentation. Looking forward, we are: a) developing capacity to fly active fires in the southeastern United States this winter to document fire behavior and effects with drones, b) working with agency partners to perform metric and radiometric calibration of our imaging systems, and c) negotiating with industry partners to build and to contract platforms and sensors that greatly expand DroneFire's capacity.

Highlights:

- *Acquired blanket Certificate of Authorization from the FAA to fly in Class G airspace (nationally) below 400 feet. Procedures have been tested in ten deployments.*
- *Sited Droneport at Lubrecht Experimental Forest. Six missions have been flown from Droneport in Quarter. Four electro-optical camera systems have been tested.*
- *Established contracts with eight Montana companies. Contracts provide access to 21 platforms, 22 sensors (EO and Thermal IR), and 12 processing streams.*
- *Certified second pilot and trained six students to conduct safe flight operations, to pre-plan acquisitions and post-process drone imagery, and document missions and general maintenance.*
- *Trained 22 students in UAS flight operations and data collection in classes at MT Tech and UM.*
- *Developed photogrammetric workflows for three aircraft/camera systems.*
- *Signed MOU with the TESLA Foundation (http://teslafoundationgroup.org/) to partner in developing training curriculum for drone operators.*
- *Conducted site visits to five UAS companies.*
- *Tested longwave thermal IR and TAMDAR-like meteorological sensors at SUATS flight facility in Kalispell.*
- *Collected and processed preliminary data for six science team members.*

Photogrammetric point cloud of the Payne Native American Center on the UM Campus derived from drone imagery. The image is a 3-dimensional model from which precise measurements of length, height, volume, and shape can be derived.

<u>Objective #1</u>. Develop project management organization and workplan, prepare communications plans encompassing economic impacts, progress, and deliverables; develop strategy for end-of-grant transition to UM AASO

Milestone 1) Develop project oversight organizational structure to manage functional areas: a) Administration, Compliance, Training; b) Technology and Operations; c) Research and Applications (end of year 2015)

- *Organizational structure and management is in place. The project continues to grow, necessitating increased focus on intra-project communication to ensure that investments remain aligned with project goals.*

Milestone 2) Develop Workplan, Milestones, and Timelines (end of January 2016)

- *Project workplan with objectives, timelines, and deliverables are complete.*

Milestone 3) Develop communications plan; economic impact plan; summary of deliverables; and progress to date (preliminary accomplishments Jan 2017 - final documents June 2017). 4) Develop strategy for hand-off through UM AASO.

- *Continue to document activities, impacts, and accomplishments with emphasis on intra-protect communication and coordination.*

<u>Objective #2.</u> Establish contracts and coordinate flight operations with Montana's UAS companies and FAA for fly-in/field campaign at Lubrecht Experimental Forest. Overall Purpose: Leverage and grow UM's research enterprise through private sector partnering.

Milestone 1) Design and implement UM's Autonomous Aerial Systems Office (AASO) website to facilitate contracting and flight planning operations including a listing of current UAS platforms and payload technologies for existing 333 exemption holders in Montana. (January 29, 2016)

- *As noted in Quarter One, a DroneFire website has been developed (http://www.umt.edu/aaso/DroneFire/) under the aegis of the AASO. By structuring the project within AASO, we are working toward continuity at project end. A list of current UAS platforms and technologies for existing 333 exemption holders who have agreed to collaborate with the project is included under the project partners tab of the website.*

Milestone 2) Contract template for Statement of Work needed from contractors as part of UM's procurement process, non-disclosure agreement template for contractors, and memorandums of understanding for field lab and training operations areas. (March 1, 2016)

- *Completed bid process in UM GRIZMART to (streamline) contracting with Montana UAS companies. We have established contracts with eight companies: Advanced Aviation Solutions, Big*

Sky UAV, Bridger Aerospace, Commander Navigation, One Binding Systems, Sands Unmanned Aircraft Training (SUATS), RDO Holdings, Birds Eye of Big Sky.

- *Contracts provide access to 21 platforms, 22 sensors (EO and Thermal IR), and 12 processing streams.*
- *Contracting procedures are intended to simplify the MUS bureaucracy in terms of sole source contracting- necessary due to short duration of the project and its Montana-centric focus.*
- *Site visits were conducted with the following Companies:*
  - *MicaSense, Seattle, WA*
  - *Skyyfish, Missoula, MT*
  - *Trillium Engineering, Hood River, OR*
  - *Commander Navigation, Hamilton, MT*
  - *SUATS, Kalispell, MT*

Milestone 3) FAA coordination for Lubrecht field campaign. (June 1, 2016); 4) Plan for potential second fly-in Spring 2017.

- *We acquired a Certificate of Authorization from the FAA to fly in Class G airspace below 400 ft AGL and have established protocols to interact with our local Flight Standards District Office including filing of NOTAMs. Procedures have been tested in ten deployments.*
- *Evolving regulatory environment is requiring on-going effort to maintain currency and ensure that we are operating within the strictures of UM, FAA, and the State of Montana.*

Objective #3. Establish field laboratory for UAS research and development, where UAS can be deployed consistently to measure and monitor forest fuels. Overall Purpose: Grow emerging UAS field in MT by providing permanent R&D facility and demonstrating new instruments and technology.

Milestone 1) Establish UAS launch site/airport adjacent to test areas at LEF; Identify forest stands across range of forest conditions; Complete MOUs, FAA documentation, and flight protocols; Coordinate/inform adjacent landowners as necessary.

- *Droneport is located in meadow adjacent to Jones Pond at Lubrecht Experimental Forest (46°53'41"N 113°26'18"W) to provide a large take off and landing zone and long lines of site. Droneport is adjacent to highly instrumented and heavily measured Fire-Fire Surrogate (FSS) Plots which contain recently measured forest and fuels attributes relevant to this project.*
- *Six missions have been flown from Droneport in Quarter with rotor-wing platforms.*
- *Four electro-optical camera systems have been tested from Droneport in the FFS study area and adjacent lands.*

Milestone 2) Collect & integrate field and remote sensing validation data; Establish ground control - identify proximate GPS stations

- *Established pilot and operator checklists and platform-specific flight operations manuals for data acquisition, aerial observer briefing and data collection forms, procedures for establishing and documenting GPS based ground control.*
- *Acquired aerial survey targets to geolocate imagery.*
- *Existing field data will largely support the project. Additional ground control may be necessary.*

Milestone 3) Produce maps of test areas; Document activities, advertise, and post on website

- *Compiled geospatial data (e.g., forest inventory, digital terrain models) of Lubrecht test areas.*
- *Completed state-of-science review of applications of UAS in forest inventory and presented at the Inland Northwest Growth and Yield Cooperative meetings in Spokane, WA on April 19.*

<u>Objective #4.</u> Develop a science cadre to test applications and conduct research; build infrastructure for data management; produce and test field-usable data products. Overall Purpose: Leverage MUS research enterprise targeted at private sector; build future customer base.

Milestone 1) Identify science cadre members and outreach to MUS partners (Jan-June 2016)

- *Completed letter of support for NSF proposal in Geosciences to use UAS for stream channel measurements.*
- *Tested FLIR View Pro (longwave thermal IR) camera on SUATS rotor-wing aircraft in Kalispell with the purpose of identifying microclimates within tree canopies (thermal entymology). Data collections are supporting pending NSF Proposal to examine micro-meteorological effects on insect lifecycles.*
- *Began testing TAMDAR-like (Tropospheric Airborne Meteorological Data Reporting) meteorological sensors on SUATS Sandstorm in Kalispell in conjunction with traditional radiosonde measurements. Goal is acquisition of atmospheric data from recoverable instruments at finer scales to improve weather modeling and forecasting. To date, project has tested pressure and virtual temperature measurements through 700 feet of altitude.*
- *Acquired and processed imagery of Upper Ninemile Placer Restoration Project (Mineral County, MT) to test ability of drones to collect highly resolved digital terrain surfaces and vegetation heights. Generated and assessed 3-D point clouds, ortho-imagery, and digital terrain models with and without ground control. Goal: to characterize microtopography, coarse wood, and vegetation in restored streamside and forested systems.*
- *Collected imagery from sub-canopy drone flights for two long-term monitoring plots in the Fire-Fire Surrogate study area to assess capacity of drones for fine-grained fire monitoring and fuels characterization. Tested acquisition parameters (using nadir, oblique, and multi-elevation data).*
- *Tested drones as sampling tools for conducting tree regeneration assessments following harvest and planting. Initially, we established sampling plots in the treatment unit and conducted a census of regeneration in those plots. We acquired drone images systematically across a range of*

elevations for each plot to assess optimality. Preliminary results identify a need for more highly resolved imagery at closer ranges, and perhaps oblique perspectives. Tree regeneration inspection is promising application for Drones.

Milestone 2) Acquire data for test areas at LEF (June - Oct 2016; March - May 2017); Develop data processing streams including geometric corrections and calibrations (Aug 2016 - Feb 2017); Compare UAS-derived results to field metrics and data from other remote sensing data sources (June 2016 - end of project)

- *Acquired six datasets for test areas at LEF and five datasets from campus from three platform/camera combinations including pre- and post-data for a prescribed fire.*
- *Developed mission preplanning with ground control; flight planning to ensure full coverage of project area and terrain avoidance; battery/power planning to optimize operational efficiency; hazard avoidance protocols; acquisition and flight operations; maintenance schedules.*
- *Integrated flightlogs and data in Open Stack computing cluster; conducted initial processing to determine image location tie points; re-optimized using surveyed ground control points (GCPs); generated sparse point clouds, dense point clouds and orthomosaics.*
- *Developed and tested workflows to filter 3-D point clouds to classify vegetation and ground. Tested interpolation methods for generating digital terrain surfaces/models.*
- *Tested flight planning software: Ground Station (DJI); Pix4D Capture; DroneDeploy; MapPilot; Selected MapPilot due to multiplatform capacity, ease of use, control of image format and overlap.*
- *Compared camera outputs and demonstrated need for RAW format imagery rather than jpg (compressed) format for mapping applications.*
- *Assessed acquisition parameters by varying flying height, aircraft speed, image overlap, image type and size.*
- *Tested and adopted Drone Logbook to upload mission data for to tracking location, duration, personnel, maintenance, and instruments. Drone Logbook is available to project team via WWW.*

Milestone 3) Develop a data management, archiving, and sharing system (continuous, beginning January 2016 with functional system by July 2016); Expand customer base.

- *Developed photogrammetric workflows for three aircraft/camera systems.*
- *Completed data repository on Open Stack, arranged to accommodate photogrammetric workflow.*
- *500GB of raw and processed imagery collected and archived to date.*

<u>Objective #5</u>. Procure and test two research UAS complementary to private sector systems. Overall Purpose: leverage overall enterprise in both public and private sectors.

Milestone 1) Market research for COTS mapping system (Jan-March 2016). Identify Montana UAS manufacturers and available specifications on UAS. (March 1, 2016) Purchase will be made based on complementing private sector UAS platform options. Repeat for second UAS August 26, 2016.

- *Completed comprehensive comparative evaluation of photogrammetric software: selected Pix4D.*
- *Acquired thermal imaging capability with designed optics and imaging array for multi-rotor aircraft.*
- *Acquired new MFT aerial camera and gimbal that is integrated onto rotor wing aircraft that supports dual-operator missions (simultaneous pilot and camera operators).*
- *Conducted review of thermal IR and multispectral instruments, including site visits to Trillium Engineering and MicaSense.*
- *Conducted coordination meeting with Commander Navigation and toured manufacturing facility.*

Milestone 2) Submit Certificate of Operation or 333 exemption application on new UAS (March 31st, 2016). Repeat for second UAS September 30, 2016.

- *Applied for and received blanket Certificate of Authorization from FAA to operate drones in all Class G airspace in U.S. below 400 ft elevation AGL. Certificate allows operation across all of Lubrecht Experimental Forest and is additionally valuable because private contractors can fly under the UM COA in research and development activities.*
- *The project is currently exploring options for gaining access to higher flight elevations and non-line of sight flying and examining whether integration of onboard transponders will alleviate safety concerns of these practices.*

<u>Objective #6</u>. UAS UM course development, training and certification. Overall Purpose: Develop more-capable workforce; grow emerging field of UAS applications.

Milestone 1) Policies and procedures for UAS operations with the University of Montana (March 1, 2016)

- *The FAA released Small Unmanned Aircraft (<55 lbs) Regulations in June under Part 107 of the Federal Aviation Regulations, as anticipated. These regulations have changed requirements for operating drones, making operation easier overall. Changes significant to this project include: (1) pilots must obtain a remote airman certificate with a small UAS rating by passing an FAA knowledge test; (2) line of site with aircraft can be maintained by a visual observer if the pilot is flying First Person View; (3) aircraft remain restricted to 400 ft AGL without a waiver; (4) drones must be available for FAA inspection; (5) Injuries and property damage must be reported.*
- *Dronefire is currently adapting training and operations practices to accommodate Part 107.*
- *Policies and procedures for UAS operations are available on the AASO website. The site is updated when new regulations and practices come online.*

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Milestone 2) Training and certification program for UM UAS operators (January 29th, 2016); Conduct mid-project review and evaluation (September 2017)

- *Pilot training: Second pilot certified through Choice Aviation (Hamilton, MT).*
- *Six students and staff trained to conduct safe flight operations.*

- *Four individuals trained to pre-plan acquisitions and post-process drone imagery.*
- *Two individuals trained on properly documenting missions and general maintenance.*

Milestone 3) UM Course for UAS operations and applications to serve as a template for best practices of UAS operations. This course will include information on private sector activities through lectures, course work, and guest speakers. (Fall 2017)

- *Developed and signed MOU with the TESLA Foundation (http://teslafoundationgroup.org/) to partner in training curriculum for drone operators.*
- *Completed site visit to Sinclair College's National UAS Training and Certification Center in Dayton, OH to help fast-track development of training and education. Sinclair focuses on precision agriculture and operates 100 UAS. Most students are hired by agriculture, insurance, and power companies. They have a full training curriculum from flight to maintenance to processing.*
- *Conducted introduction to UAV piloting and data collection on UM Oval for 12 students in UAV GIS class. Students received instruction in safety checks, airspace awareness, and airframe control. Students were paired with observers and flew aircraft and collected imagery of campus which they processed in the classroom.*
- *Flew data collection mission in Butte with Montana Tech students to image gravity and magnetic transects. Processed the data into georeferenced maps and digital elevation models of the study site. Trained 10 students in UAV piloting, similar to training offered at UM.*

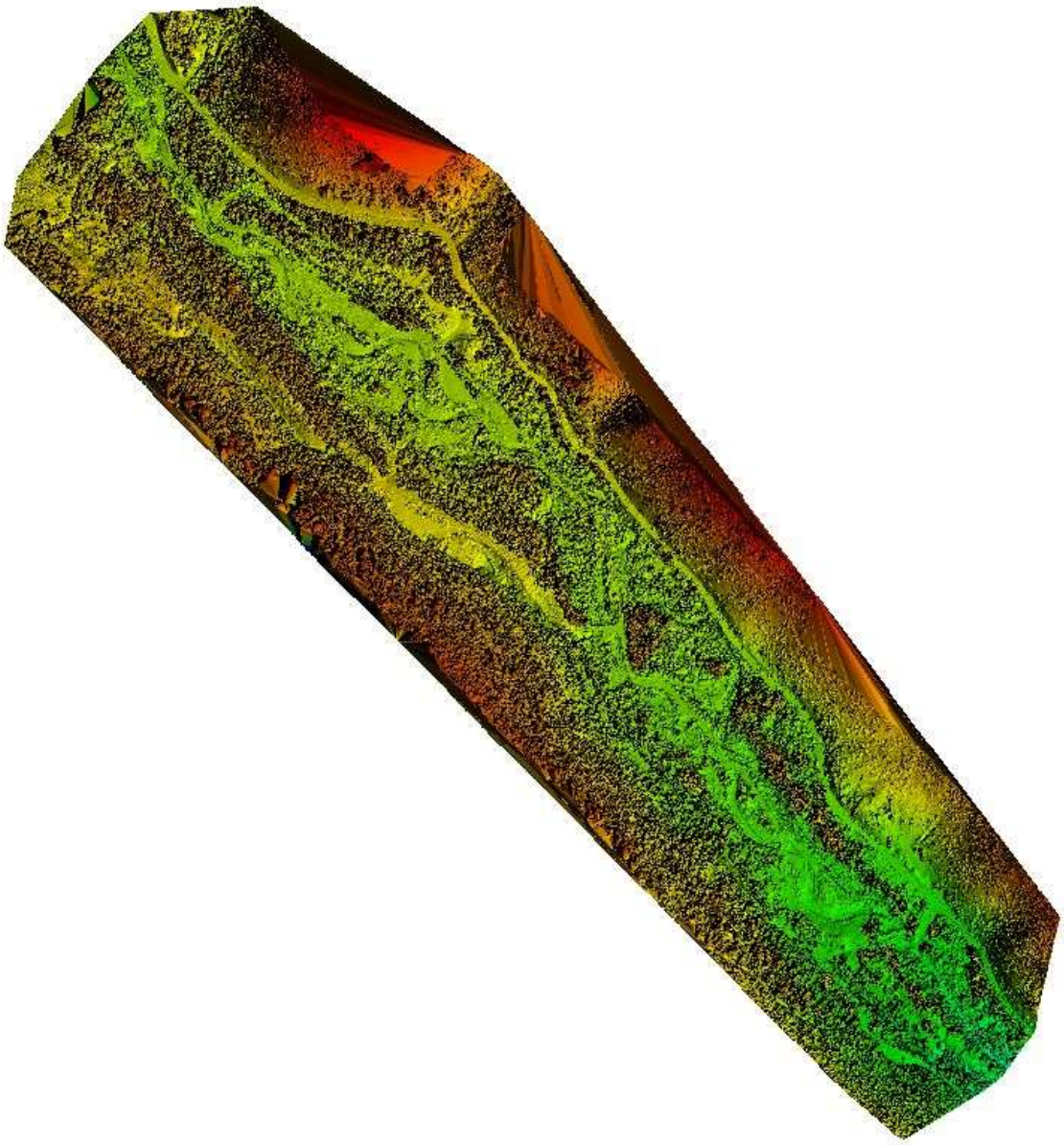
Expenditures/Budget Summary to Date

		Initial Budget	Expense to Date	Amount remaining
Contracted Services		$225,000.00	$997.80	$224,002.20
Supplies		$45,000.00	$27,094.13	$17,905.87
Communications		$0.00	$0.00	$0.00
Travel		$60,000.00	$991.87	$59,008.13
Salary		$334,930.00	$48,328.15	$286,601.85
Benefits		$112,474.00	$5,855.95	$106,618.05
Tuition		$32,596.00	$6,145.44	$26,450.56
Equipment		$80,000.00	$15,026.98	$64,973.02
Other Services		$10,000.00	$974.50	$9,025.50
TOTAL Expenses		$900,000.00	$105,414.82	$794,585.18

Students prepare for flight within forest canopy to image fuel plots in the Fire-Fire Surrogate Study at Lubrecht Experimental Forest.

UM researchers testing meteorological sensors on drones with SUATS enginners at the SUATS flight facility in Kalispell.

UM graduate student establishing ground control for drone data acquisition at the Ninemile Placer Restoration Project in the Ninemile Valley, MT.



Digital surface model of the Ninemile Placer Restoration area. Data values are within ±15 cm relative to GPS ground control. Colors show object heights resolved to 0.5 m. Measurements are being used to examine vegetation and topographic controls on water flow in restored stream channels.