

MONTANA UNIVERSITY SYSTEM RESEARCH INITIATIVE
Autonomous Aerial Systems for Wildfire Management in Montana
Third Quarterly Report – October 31, 2016



Submitted by:

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

Executive Summary

This document describes activities, accomplishments, and progress in the *third* 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. In Quarter Three, the majority of effort has focused on data collection, with emphasis on measurements in the fire environment. The project remains on schedule and within budget.

The most significant effort in the Quarter was deployment of unmanned aircraft on active wildfire. Although the use of drones in operational fire has so far been limited nationally due to safety concerns associated with UAS in airspace shared with piloted aircraft, we accomplished four missions on the Roaring Lion Fire in partnership with the Bitterroot National Forest. Two small rotor-wing platforms were deployed on a portion of the fire to test instruments and techniques for providing fireline intelligence. We achieved four primary goals: 1) developed and tested agreements and protocols for operating UAS in the fire environment on a USFS administered active wildfire; 2) demonstrated UAS capabilities and flight procedures to USFS fire personnel; 3) Tested performance of small rotor-wing platforms for gathering real-world fireline intelligence in the form of video inspection and mapping of fireline; and 4) Acquired thermal infrared imagery to identify presence/absence of heat. These missions represent an important precedent in fire management that are expected to lead to additional R&D in the fire environment.

We applied for a new Certificate of Authorization (COA) from the FAA to operate drones up to 18,000 feet AGL at our Lubrecht flight facility without pilot line-of-sight (LOS). Documents outlining high-elevation mission procedures, lost link and lost communications procedures, and procedures for maintaining LOS from manned-aircraft were developed and are currently under review by the FAA. The application is halfway through the approval process. Acquiring this COA would be an unparalleled accomplishment for a university research enterprise, would facilitate extraordinary opportunities for drone development and testing, and would attract partners and funding.

Our public-private partnerships continue to grow. We acquired a locally-built, high performance M4 quad-copter from the Missoula company Skyefish and conducted training flights at the Lubrecht Drone Port to aid in advancements in flight planning software suitable for mountainous terrain. Contracts and project specifications were finalized with Commander Navigation of Hamilton to acquire multispectral and thermal data for fire reference sites at Lubrecht Forest from a long-dwell time fixed wing platform. Data collection is scheduled for late November 2016. We have acquired and processed reference data for two of three Fire-Fire Surrogate experimental blocks to support the efforts with Commander Navigation and Skyefish with additional acquisitions ongoing.

Looking forward, two of our graduate students have advanced to the final round of the Barrett Business Challenge with a proposal to develop a drone-based wildfire defensible space technology company and we have committed modest support to a student start-up to assist with development of aircraft and sensors focused on measurements of snow and water. Mission planning for our winter prescribed fire campaign has been completed and permissions secured. A new UM course (*Introduction to Unmanned Aircraft systems and GIS*) has been developed will be offered in Spring 2017.

Objective #1. 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)

- *Project oversight in place and functional- described in first Quarter Report*

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.

- *Presented tour of project on UM campus to Montana faculty, academic administration, and legislature, and attended presentations of all other MREDI projects. Developed a fact sheet outlining project progress and accomplishments to date (Sept 27-28, 2016).*

Objective #2. 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)

- *Complete*

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)

- *Five companies placed under contract (>\$100K) for data services, platform development, sensor integration, and system evaluation and testing*
- *Completed and signed contract with Commander Navigation for Lubrecht fly-in and testing of MicaSense and Trillium HD25; mission scheduled for late November, 2016.*

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

- *Formalized relationship with Missoula tower. Demonstrated capacity to tower manager in field flights and received clearance to fly within MSO five-mile flight radius with identified exceptions.*
- *Refined protocols to interact with our local Flight Standards District Office including filing of NOTAMs. Procedures were tested in 12 new deployments.*

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.

- *Nine missions were flown from Droneport in Quarter using rotor-wing platforms.*
- *Initiated discussions/negotiations with Lubrecht Forest to construct a physical facility at the Jones Pond Flight Area including shelter, power, internet, airstrip, landing pad, windsock, weather station, and fencing. Identified priorities and obstacles.*

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

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

- *Compiled field and remote sensing data of Lubrecht Resource Inventory Plots (RIP), Larson Stem Map Plots, and Fire-Fire-Surrogate Plots.*

Objective #4. 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 Wildlife Biology to use UAS for thermal measurements of tree canopies to study microclimate impacts on insect lifecycles.*
- *Finished data collection with UAS radiosonde prototype at SUATS flight facility in Kalispell. Goal was acquisition of atmospheric data from recoverable instruments at fine scales to improve weather modeling and forecasting. Data are being processed and used to inform drone-radiosonde standard operating procedures.*
- *Compiled instance of Weather Research and Forecasting Model (WRF) on DroneFire computer to ingest drone-radiosonde data. Partnered with UM physics department to code WRF processing threads. These efforts support the SUATS radiosonde testing described above.*

- *Modified thermal infrared camera to produce radiometric temperature data and began bench-calibration of instrument. Tested camera performance on field-instrumented burning slash piles at Lubrecht Forest*
- *Developed mission plan and agreement with Bitterroot National Forest for data acquisition of a stream reach in Lost Horse Canyon to support NSF-funded Geosciences proposal. Acquisition is scheduled for Nov 7, 2016.*
- *Partnered with Missoula Parks and Recreation and flew Moon-Randolph Historical Site for Archaeological Survey. Hosted UM Archaeology class to demonstrate utility of drones for archaeological applications.*

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 comprehensive drone imagery for 2 of 3 Fire-Fire Surrogate Plots at Lubrecht Forest. Each acquisition contains 500-600 photos. Ground control was established for each flight and orthomosaics and pointclouds have been produced. We have implemented an individual tree segmentation algorithm and are comparing stem detection on lidar and drone-based imagery.*
- *Tested open-source flight planning software, Mission Planner, a windows-based flight planning suite*
- *Conducted four drone missions on the Roaring Lion Fire, in partnership with the Bitterroot National Forest. We used multiple small rotor-wing platforms and sensors to complete linear surveys of the fire edge with a thermal infrared camera, performed inspections of known areas of heat, tested procedures for automated flying of waypoints, and mapped burned areas. These deployments represent a significant milestone in fire management in terms of developing the agreements, procedures, and protocols for operating drones on active wildfires.*
 - *The deployments provide foundation for answering the following questions: 1) What is the effective area of operation along a fireline? 2) What constraints do FAA line-of-site and elevation requirements impose on a typical fireline acquisition? 3) What is the relative value of real-time videography versus orthometric mapping products for inspecting fireline 4) How does a firefighter maintain drone positional awareness in the fire environment? 5) Can orthometric imagery be used to characterize the pattern of burn in terms of burned/unburned and severity; 6) What are the characteristics of heat that a UAS Thermal IR camera detects?*

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

- *Built 28-core processing workstation to handle photogrammetric workflow. New hardware and workflow reduces processing time by a factor of six in initial testing (from 48 hours to 8 hours for each Fire-Fire-Surrogate dataset).*

- *1TB of raw and processed imagery collected and archived to date on Open Stack repositior.*

Objective #5. 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.

- *Acquired locally-built, high performance M4 quad-copter from Missoula company Skyefish. Conducted training flights at Lubrecht Drone Port with gimballed Sony A6000 camera. We are actively collaborating with Skyefish to improve flight planning software in the following areas:*
 - *Create flight plans for mapping, e.g., take the camera characteristics and a mapping areas and generate a flight plan to acquire images with user-specified sidelap/endlap. Additionally, provide tool for matching appropriate flight speed with shutter speed and ISO.*
 - *Develop a method of importing sample points that the M4 system will fly to and image efficiently. For example, suppose we need a stratified random sample of a burned area with the strata being severity classes. We want the drone to acquire images at each of the sample points at specified AGL and with specified camera settings, requiring the ability to ingest shapefiles, text, or another file format from geospatial software such as ArcGIS*
 - *Terrain follow and allow a user to upload a local DEM or Canopy Height Model*
 - *Overcome current acquisition constraints related to elevation above ground and elevation above launch point*
 - *Ensure that we can interrupt a mission for battery change or other cause and pick up the mission where we left off*
- *Completed construction of low-cost vertical-take-off fixed wing aircraft with wide camera bay. The Firefly 6 transitions to fixed wing flight for efficient image acquisition and is capable of carrying MicaSense, SonyA1600, and gimballed GoPro.*
- *Acquired second DJI Inspire Quadcopter with X5 camera as training platform for students and staff.*

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 Certificate of Authorization from FAA to operate drones to 18,000 feet AGL at Lubrecht flight facility without pilot line-of-sight (LOS). LOS would be maintained by observers in communication with pilot. Developed high-elevation mission procedures, lost link and lost communications procedures, and procedures for maintaining LOS from manned-aircraft. Documents are currently under review by the FAA and the application is about halfway through the approval process. Acquiring this COA would be an unprecedented accomplishment for a university*

research enterprise, would facilitate extraordinary opportunities for testing, and would attract partners and funding.

Objective #6. 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)

- *Policies and procedures for UAS operations are available on the AASO website. The site is updated when new regulations and practices come online.*

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

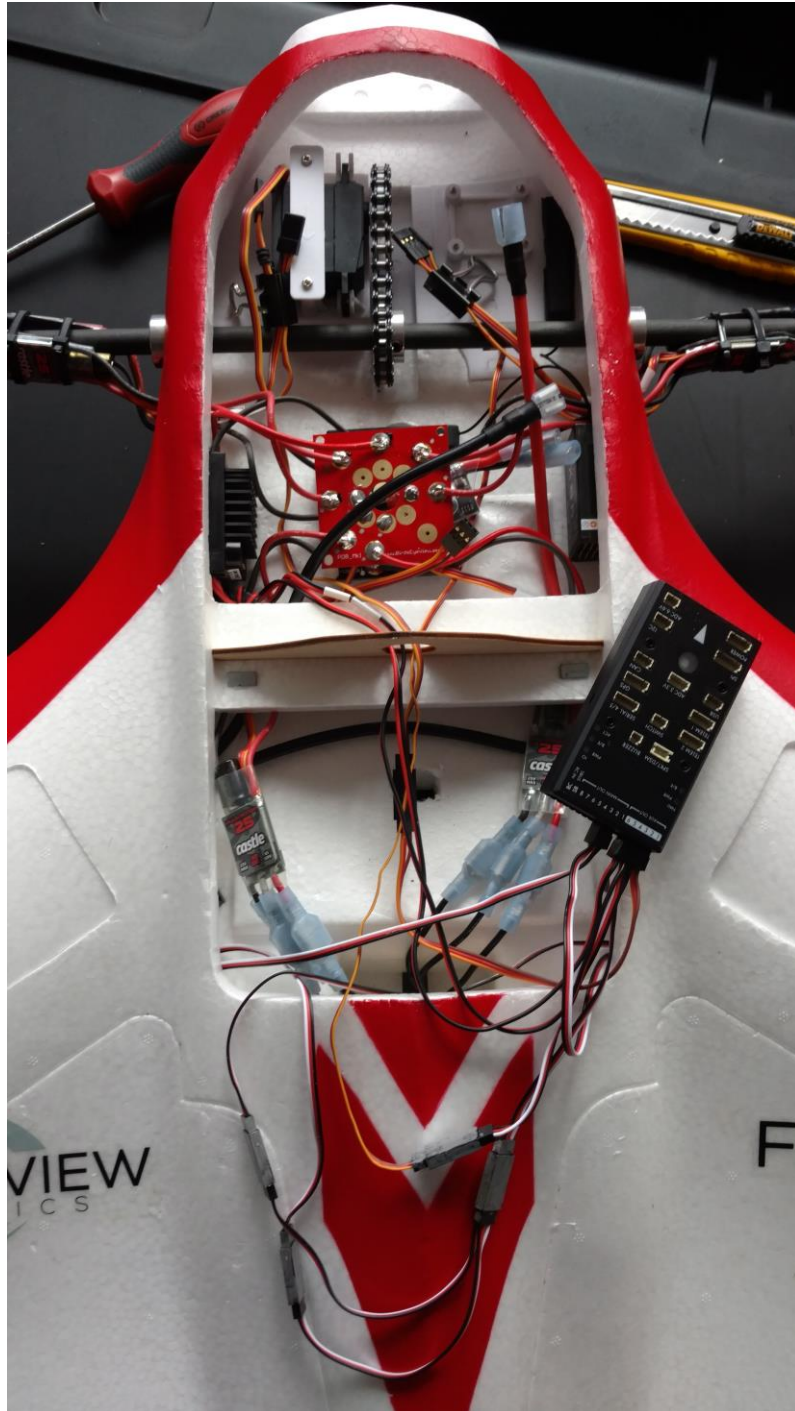
- *Trained project pilots and observers for dual-operator missions in which one person operates the aircraft and the other operates the sensor.*
- *Project graduate student is completing an internship with Missoula company Skyefish.*
- *Two of our graduate students have advanced to the final round of the Barrett Business Challenge with a proposal to develop a drone-based wildfire defensible space technology company.*
- *Committed modest support to student start-up to assist with development of aircraft and sensors focused on measurements of snow and water.*

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)

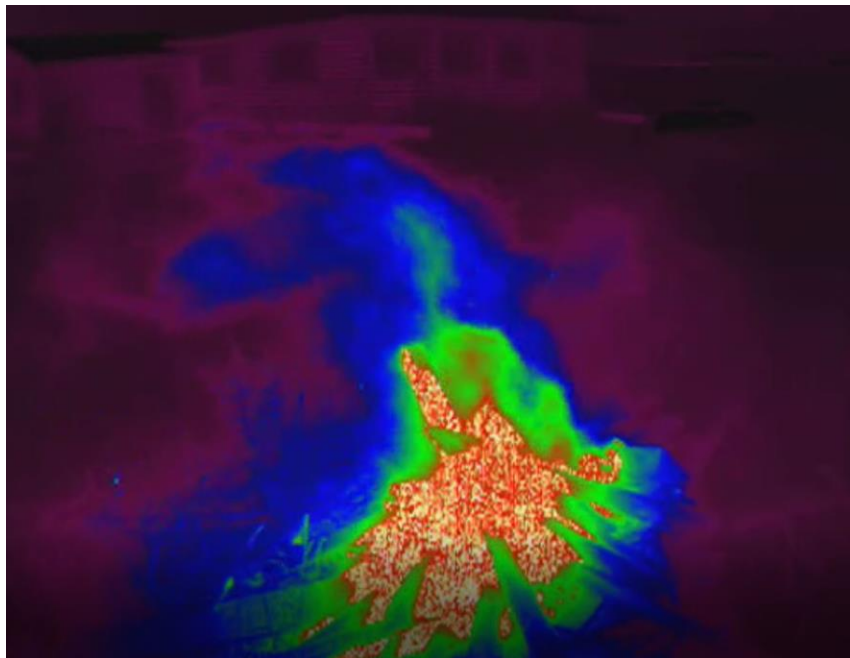
- *In partnership with TESLA Foundation, we have developed a new undergraduate course to be offered in Spring 2017, GPHY291 Introduction to Unmanned Aircraft systems and GIS*

Expenditures/Budget Summary to Date

	Initial Budget	Expenses to Date	Encumbrances	Amount Remaining
Contracted Services	\$225,000.00	\$ 67,677.80		\$ 157,322.20
Supplies	\$ 45,000.00	\$ 66,355.96		\$ (21,355.96)
Communications	\$ -	\$ 132.36		\$ (132.36)
Travel	\$ 60,000.00	\$ 7,390.24		\$ 52,609.76
Salary	\$334,930.00	\$ 135,847.84	\$ 38,246.97	\$ 160,835.19
Benefits	\$112,474.00	\$ 27,771.45	\$ 14,459.28	\$ 70,243.27
Tuition	\$ 32,596.00	\$ 17,398.19		\$ 15,197.81
Equipment	\$ 80,000.00	\$ 42,695.98		\$ 37,304.02
Other Services	\$ 10,000.00	\$ 4,852.30		\$ 5,147.70
TOTAL Expenses	\$900,000.00	\$ 370,122.12	\$ 52,706.25	\$ 477,171.63



Construction of a vertol drone that takes off and lands as a rotor-wing and flies as a fixed-wing. Dronefire is testing the platform to exploit the advantages of a rotor-wing for take-off and landing in small forest openings and the advantages of a fixed-wing for covering large areas more efficiently.



Characterizing thermal energy produced in pile combustion at the Lubrecht Forest flight area using ground-based sensors (top) and from drone (bottom). The bottom image is from a drone-mounted thermal infrared camera sensing at 8-14 micron wavelengths.



Overview of launch site on Roaring Lion Fire, Bitterroot National Forest.



Dronefire researcher and private partner (Commander Navigation) interact at DroneFire project tour.