MONTANA UNIVERSITY SYSTEM RESEARCH INITIATIVE

Autonomous Aerial Systems for Wildfire Management in Montana

Fifth Quarterly Report – May 30, 2017

Submitted by:

Carl Seielstad, Project Lead and Principle Investigator

FireCenter – The University of Montana – Missoula

May, 31, 2017

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

Executive Summary

This document describes activities, accomplishments, and progress in the *fifth* quarter of DroneFire. Activities are organized by objectives, as reported in the Project OTOs. Accomplishments are mapped to project objectives in this report (as in Quarter 4) rather than to milestones within objectives to eliminate redundancies from previous reports. Expenditures and photos are included at the end of the document. The project remains on schedule and within budget.

The majority of effort in the Quarter occurred under Objective #4, *Develop a science cadre to test applications and conduct research; build infrastructure for data management; produce and test field-usable data products.* In partnership with researchers from many agencies, organizations, and universities, Dronefire flew operational infrared missions with the Prescribed Fire Science Consortium, tested radiosondes, characterized snow melt, monitored trumpeter swans, prairie dogs, and sage grouse, mapped lichens, developed 3-D models of fuel beds, and measured fire energy. The breadth of effort reflects expansion of Dronefire technical capacity as well as growth in interest from the research and land management communities. The sheer amount of activity has precipitated development of a sales and service structure and pricing for MUS-wide use of UAS platforms and sensors in a post-Dronefire environment.

We have largely completed scheduled fly-ins with contractors, specifically Commander Navigation of Hamilton and SUATS of Kalispell, among others. The former fly-in allowed us to test UM's novel Certificate of Authorization. We used FAA-specified leasing procedures to fly aircraft under the guidance of UM pilots beyond pilot line-of-sight (using aerial observers). The COA in combination with Dronefire's skilled staff and pilots has proven to be a valuable commodity for testing UM and private sector systems.

The Dronefire team also designed, built, and tested two low-cost fixed wing systems suited for mountain flying in forested terrain. The UM Quadranger is a vertical takeoff system (quadcopter) which transitions to horizontal flight. The UM Talon is a conventional fixed wing suitable for mapping large areas. Both systems address shortcomings in existing drone technology for natural resource applications discovered by the Dronefire team. These efforts have developed high-level, end-to-end capacity to integrate flight systems, electronics, software, and sensors.

We continue to teach and train students, researchers, and managers in use of UAS. The first official UM class specific to drones was completed last week. Finally, the project team has applied for $1.8 million in grants and contracts to continue UAS-related research and application beyond the end of the project.

<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

- *Developed sales and service structure and pricing for MUS-wide use of UAS platforms and sensors post-Dronefire.*

<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.

- *Completed Fly-in with Commander Navigation of Hamilton at Lubrecht Droneport. Used FAA-specified leasing procedures to fly aircraft under UM Certificate of Authorization beyond pilot line-of-sight to 2000 ft AGL. Tested procedures for using remote observers to maintain line of sight with aircraft.*
- *Completed testing of radiosonde system in series of five missions with SUATS of Kalispell*
- *Sagetech transponder software integration is 50 percent complete. Flight testing scheduled for mid-June.*

<u>Objective #3</u>. 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.

- *Nineteen missions were flown from Droneport in Quarter using rotor-wing platforms; 14 fixed-wing missions flown.*
- *Expanded flight area to UM's Bandy Ranch in the Ovando area to access large, flat open areas to test experimental fixed-wing aircraft.*
- *Began fencing Lubrecht Droneport to exclude cattle.*
- *Procured weather station with cellular telemetry for droneport.*

<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.

- *Developed MOU with Quantum Weather System of St Louis University to ingest UAS weather data stream for site-specific power utility forecasting.*
- *Signed MOU with Montana Technology and Development Center to compare UAS weather data stream with USFS weather platform.*
- *Submitted Montana Board of Research and Commercialization Technology proposal with SUAT to commercialize UAV-radiosonde weather system ($130K)*
- *Submitted Murdock Commercialization Grant with SUAT ($171K) for UAV-radiosonde weather system.*

- *Submitted proposal to ESTCP. 'Demonstrating How UAV Systems Enhance Fire Management' ($1.5 million).*
- *Continued weather analysis with data from UAS, comparing Large Eddy Simulation (LES) wind fields with non-large eddy simulations. The choice of LES gives us a different forecast at high resolution model runs (<200m) and has a significant impact on computational time. We are currently comparing model runs with our collected data and honing fluid dynamics package choices for regular forecasting runs.*
- *Purchased hyperspectral camera system from Resonon (Bozeman). SUAT integrating on fixed-wing UAS (Agbird) for precision agriculture demonstration.*
- *Tested use of thermal infrared remote sensing for monitoring prairie dogs and sage grouse at the Matador Ranch in eastern Montana (Malta), in partnership with The Nature Conservancy. Developed an MOU and completed three-day mission.*
- *Completed UAS missions to monitor trumpeter swans in the Blackfoot River corridor, in partnership with The Blackfoot Challenge and US Fish and Wildlife Service*
- *Flew eight infrared missions with the Prescribed Fire Science Consortium at Tall Timbers Research Station in Tallahassee, Florida. Measured radiative energy from fire, coincident with other measurements and observations. We worked with researchers and land managers from many other universities, the federal government and NGO's.*
- *Provided the platform for InterMet XQ weather sensor missions. Performed test flights and collected temperature, relative humidity, air pressure and GPS data during prescribed fires in Florida. The sensor was provided by the National Oceanic and Atmospheric Administration for their Joint UAS/Sensor Evaluation for Wildfire Mapping and Environmental Intelligence program.*
- *Conducted site-visit with Infrared Cameras Incorporated in Beaumont, TX. Toured the facility, learned about their infrared sensors and tested the ICI HALO UAS.*
- *Completed eight snow-mapping missions at Lubrecht Experimental Forest to support study of snow ablation during snowmelt. The missions occurred weekly from snow-max to snow-free conditions. Developed protocols for flying in cold weather.*
- *Installed and tested a Neutral Density filter (0.5) for the FLIR Zenmuse XT IR camera, doubling the temperature range. We can now measure temperatures up to 1100C. Calibrated the FLIR Zenmuse XT with the ND filter using a high temperature blackbody at the Missoula Fire Science Lab in Missoula, Montana.*
- *Developed 3-D models of surface fuel beds at Lubrecht Experimental Forest from below-tree drone flights, conducted a prescribed fire, and characterized fire behavior using a drone-mounted thermal IR sensor. The data are being integrated and analyzed to understand how fuels variability controls fire behavior.*
- *Established techniques for acquiring and processing survey-grade data at very close ranges beneath tree canopies. Low cost platforms such as DJI Phantom 4 Pro provide lowest risk option for data collection and obstacle avoidance allows safer manual flight in close confines*

Objective #5. Procure and test research UAS complementary to private sector systems.

- *Completed field testing of QuadRanger fixed wing platform with vertical takeoff configuration (for use in forested mountainous terrain). Consists of two redundant airframes utilizing open source hardware and firmware. Both frames are flight worthy with one set of backup components each.*
- *QuadRanger flight tests continued, resulting in successful transition from rotary-wing to fixed-wing flight. Calibration and flight tuning has been completed with a payload of 600 grams. Autonomous flight duration is 45 minutes, falling short of goal of 60 minutes. We have upgraded motors and reduced weight by 500 grams to improve flight-times. Additional flight-time testing is ongoing.*
- *Completed build of Talon fixed-wing mapping platform. Flight testing is ongoing.*
- *Upgrading flight controllers to Pixhawk 2.1*
- *Integrated multiple sensors, including Sony A6000, Sony A7RII, Micasense Red Edge.*
- *Developed onboard computing capabilities.*
- *Acquired Matrice-100 and Matrice-600. The former is a duplicate of a current system that is reliable, easy to use, rugged. The latter is a heavy-lift capable hexacopter for use with multi-camera systems.*
- *UGCS ground control station software implemented to include DJI, Pixhawk, and other flight controllers.*
- *Agisoft Photoscan image processing software (X4) configured and tested for multi-thread/multi-processor computing across several computers. Reduces processing time significantly.*

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

- *Developed Training Protocols for UM drone pilots. Currently field testing protocols with UM Grad Student (Wildlife Biology) in study of bighorn sheep.*
- *Trained UM Grad Student (Wildlife Biology) and provided UAS to map lichens in Alaska in support of study of caribou food sources.*
- *Completed first UAS - GIS course at UM (Introduction to UAS) through Physics Department (7 students).*
- *Contracted with Birds Eye of the Big Sky to map waste water management area for Missoula with students. Will provide students training on survey-grade data acquisition and data processing (using Agisoft Photoscan and DroneDeploy).*
- *Presented two posters ('Unmanned Aerial Systems in Fire Management' and 'Drones to Data') at the Montana Society of American Foresters State meeting in Missoula, Montana.*
- *Visited the 4th grade at Paxson Elementary School in Missoula, Montana and gave a presentation on the use of UAS and infrared cameras in fire science.*
- *Presented 'Drone Applications in Fire Management' at Region 1 Incident Fire Management Team Meetings.*

- *Purchased Ebee fixed wing platform and partnered with Missoula's RDO Equipment Company to train researchers in data collection and processing from Flathead Lake Biological Station*
- *Conducted site visit to ALASKA CENTER FOR UNMANNED AIRCRAFT SYSTEMS INTEGRATION (ACUASI) in Fairbanks, AK. ACUASI is the most advanced university-based center in the US. The visit allowed Dronefire to examine organizational structure, funding models, applications, and public relations.*
- *Attended AUVSI's Xponential unmanned systems expo in Dallas Texas to contrast UM drone capacity with state-of-science and to gain insights into latest technology, applications, and business opportunities.*

Expenditures/Budget Summary to Date

A rebudget was performed during the reporting period at the request of UM Office of Research and Sponsored Programs. A final rebudget will be completed at the end of June.

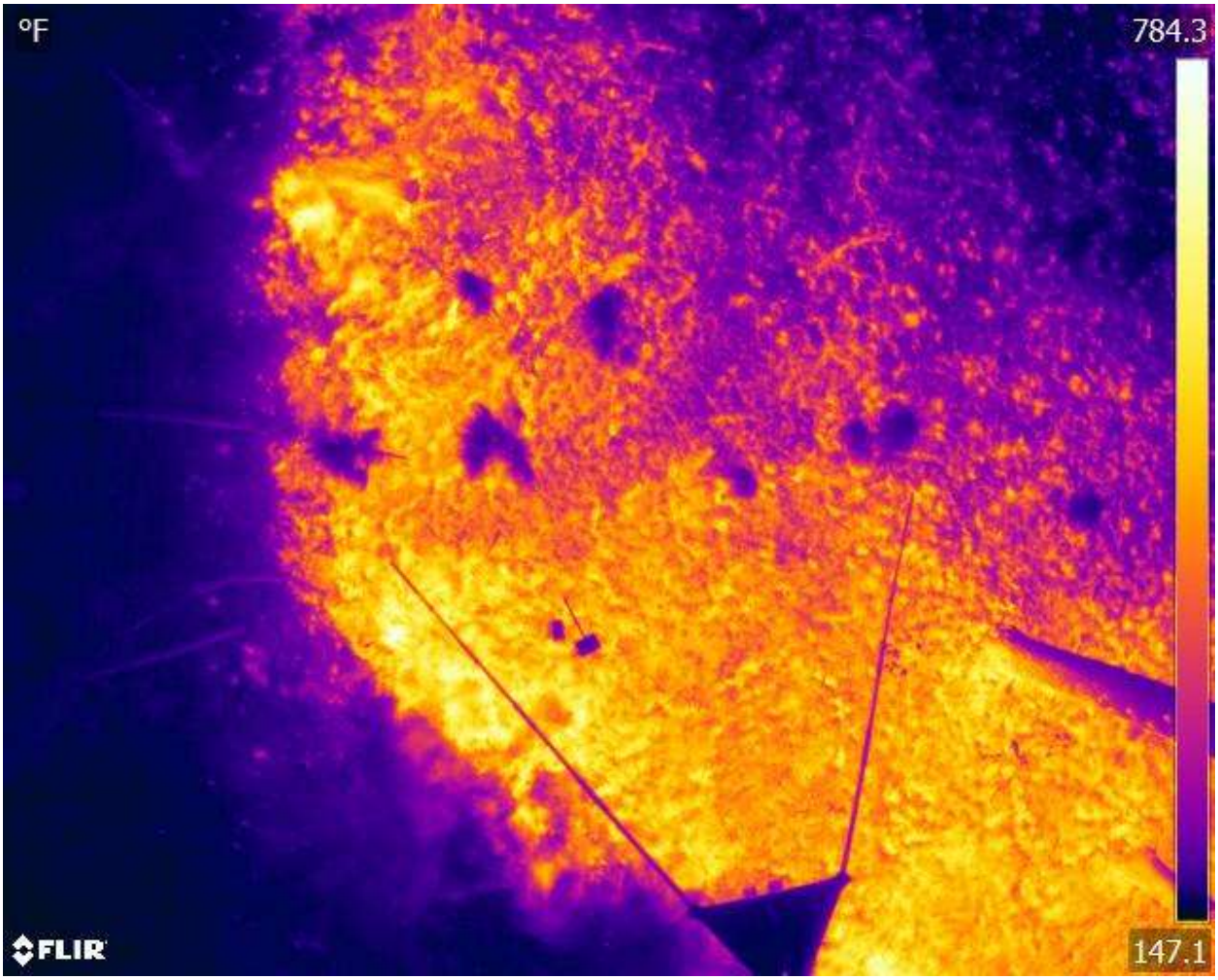
MFRR13					
		Initial Budget	Expense to Date	Encumbrances	Amount remaining
Contracted Services		$ 225,000.00	$ 31,529.80	$ 49,980.00	$ 143,490.20
Supplies		$ 45,000.00	$ 156,754.35		$ (111,754.35)
Communications		$ 1,000.00	$ 1,320.84		$ (320.84)
Travel		$ 60,000.00	$ 39,624.63		$ 20,375.37
Salary		$ 334,930.00	$ 194,028.28	$ 57,019.00	$ 83,882.72
Benefits		$ 112,474.00	$ 75,085.20	$ 13,050.46	$ 24,338.34
Tuition		$ 32,596.00	$ 25,391.53		$ 7,204.47
Equipment		$ 80,000.00	$ 79,984.98	$ 91,802.50	$ (91,787.48)
Other Services		$ 10,000.00	$ 5,409.04		$ 4,590.96
TOTAL Expenses		$ 901,000.00	$ 609,128.65	$ 211,851.96	$ 80,019.39

A UM drone flying with a University of Florida drone on a prescribed fire in Florida.

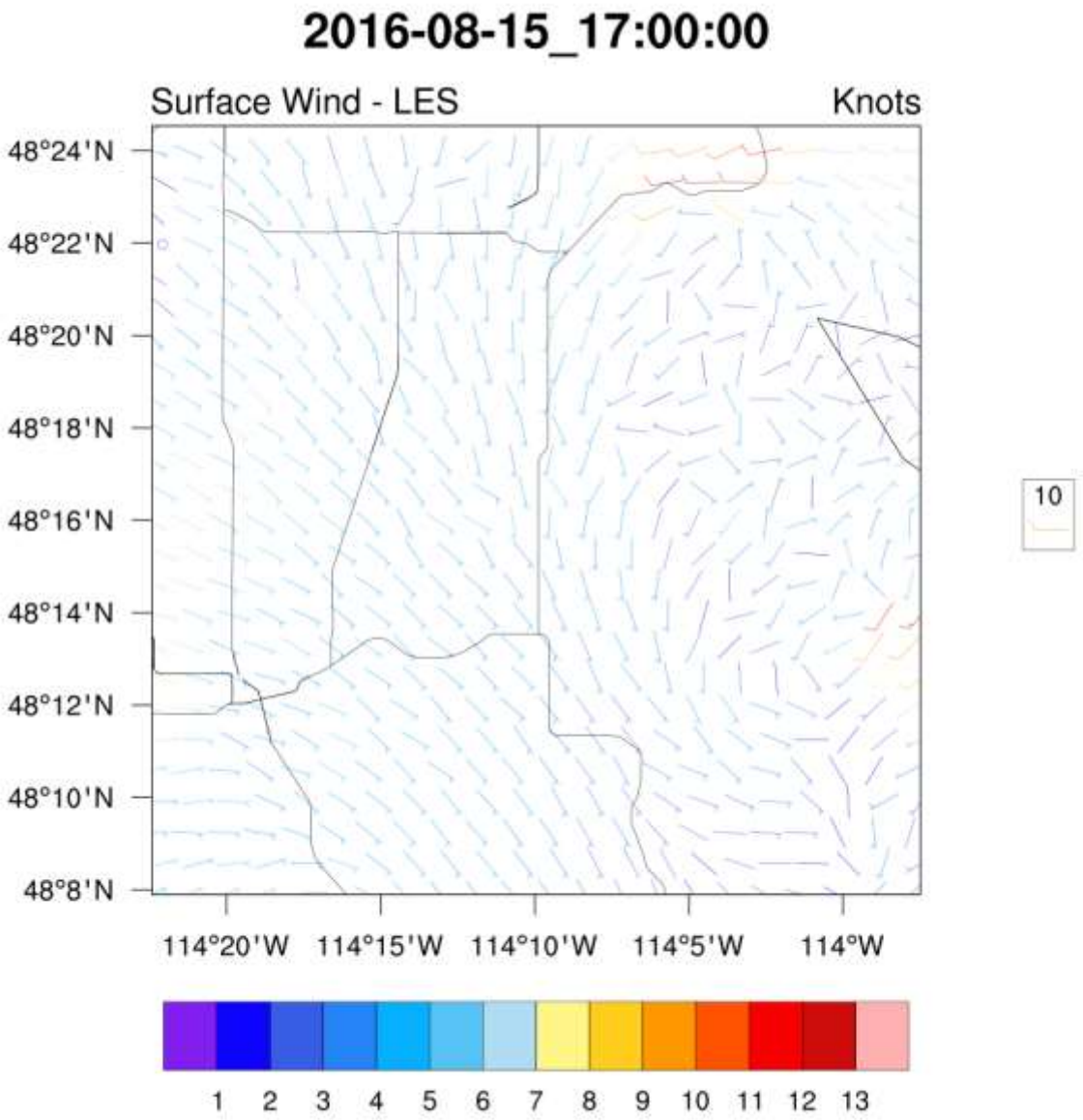
Dronefire and Nature Conservancy staff preparing to image prairie dog towns with thermal IR camera near Malta, MT.

Testing the vertol Quadranger transition from hover to forward flight at UM's Bandy Ranch near Ovando, MT

Dronefire pilot discussing mission with fire manager in Florida.



Thermal IR image of fire burning through a research plot. The rectangular and triangular features are *in situ* sensors measuring fire energy.



Modeled wind field from drone measurements.