# Development of Unmanned Aircraft System (UAS) for Agricultural Applications

## Quarterly Progress Report

Reporting Period: October – December 2016

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## Project Purpose

The Desert Research Institute (DRI), in collaboration with AboveNV, are deploying AboveNV's Unmanned Aircraft Systems (UAS) in support of agricultural and water management of critical crop fields owned and managed by Winnemucca Farms, Inc. We are testing the applicability of UAS data to address large-scale, multi-crop agricultural needs, particularly water-related crop stress and irrigation efficiencies. Winnemucca Farms, Inc. is one of the largest Nevada farms and they have expressed interest in assessing UAS data products to improve farm management. UAS activities are being conducted using AboveNV's Section 333 COA and we are working with the Nevada Institute for Autonomous Systems (NIAS) to become a NIAS Node that would allow us to use the NIAS blanket COA from the FAA. DRI and AboveNV propose a near-term and long-term approach to utilizing UAS collected imagery to monitor irrigation management and crop health.

The project is focusing on:

- UAS data acquisition to identify and map agricultural crop stress that will lead to improved water use while maintaining and/or improving crop yields (Project location is a portion of Winnemucca Farms' properties)

The primary outcomes of the potential efforts described herein will be:

- Formation of a partnership between the private sector and DRI to help grow a UAS business already located in Nevada (i.e., AboveNV).
- Enhancement of DRI's and AboveNV's UAS expertise leading to national recognition.
- Testing and refinement of platforms and sensors for commercial and governmental environmental applications, specifically agricultural applications.

## Section I: Progress

The focus during this quarter was on further refinement of image processing methods and to acquire UAS imagery of several newly tilled fields (bare soil conditions), which will allow us to assess the quality of elevation mapping results from standard image processing techniques.

**Major Accomplishment 1:**

A primary objective during this quarter was the development of digital elevation models (DEM) from the UAS images acquired. Developing a high spatial resolution 3-dimensional representation of elevation within each field will help provide a better understanding of the causes of decreases in crop cover. Several methods were tested to remove image frames and UAS data that cause errors in the development of a DEM. AgiSoft PhotoScan has been the primary software used on this project to process UAS images. This software was specifically developed to process the large number of UAS images acquired during a single acquisition

flight. We have found that this software encounters errors when calculating the camera orientations from the images acquired during flight. These orientation errors produce anomalous data, i.e., sparse and dense clouds that incorrectly position images above or below the ground surface. The sparse and dense clouds can be edited to some extent in AgiSoft, but alternative point cloud editing is likely to yield better results. An example of a simple re-alignment of images within AgiSoft that did provide a reasonable orientation correction is depicted in Figure 1. However, if the simple re-alignment process does not work, the resulting mosaic of images will include high and low spots in a DEM product generated from the images (Figure 2). To correct these errors other software are being explored, i.e., ENVI and ArcGIS.

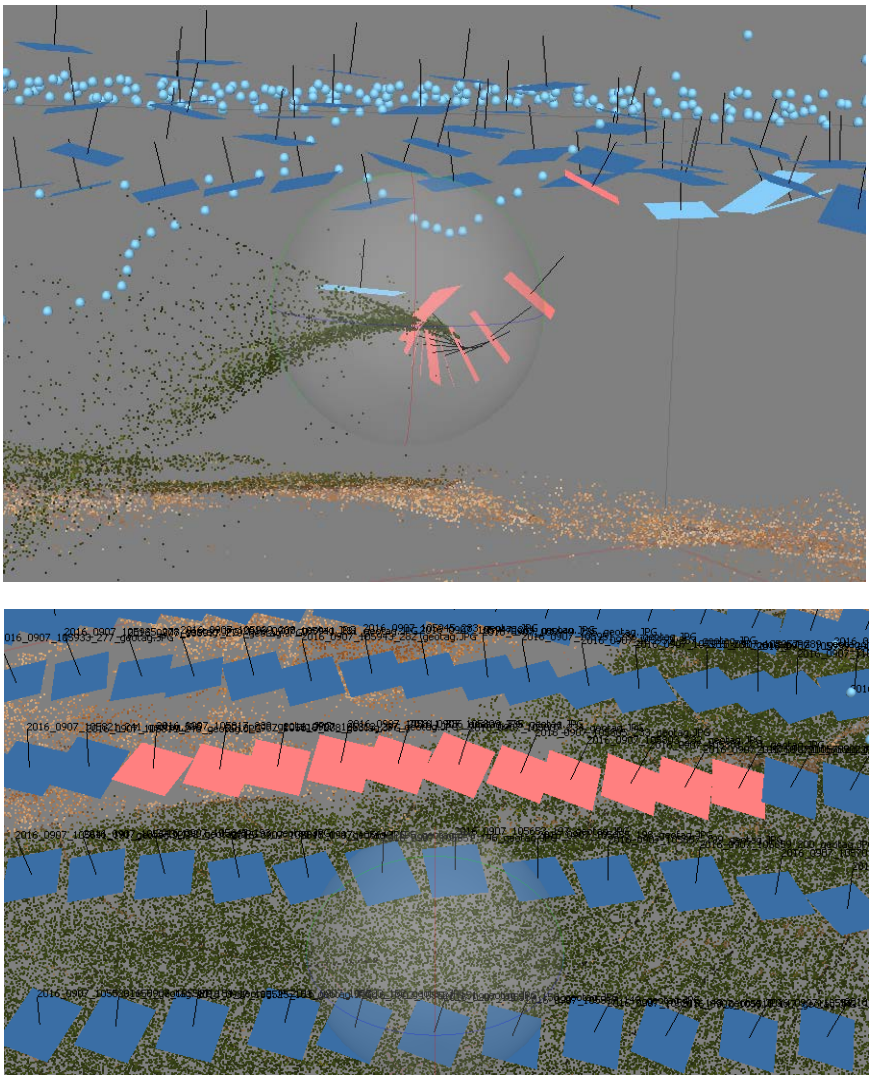

Figure 1. The top figure depicts a representation of UAS image frames (blue and pink squares) for which AgiSoft generated erroneous image orientations (orientation is represented by the black lines extending from the image frame) where the erroneous oriented frames are represented by pink squares. The bottom figure depicts the same erroneous image frames (pink squares) after they have been manually corrected.

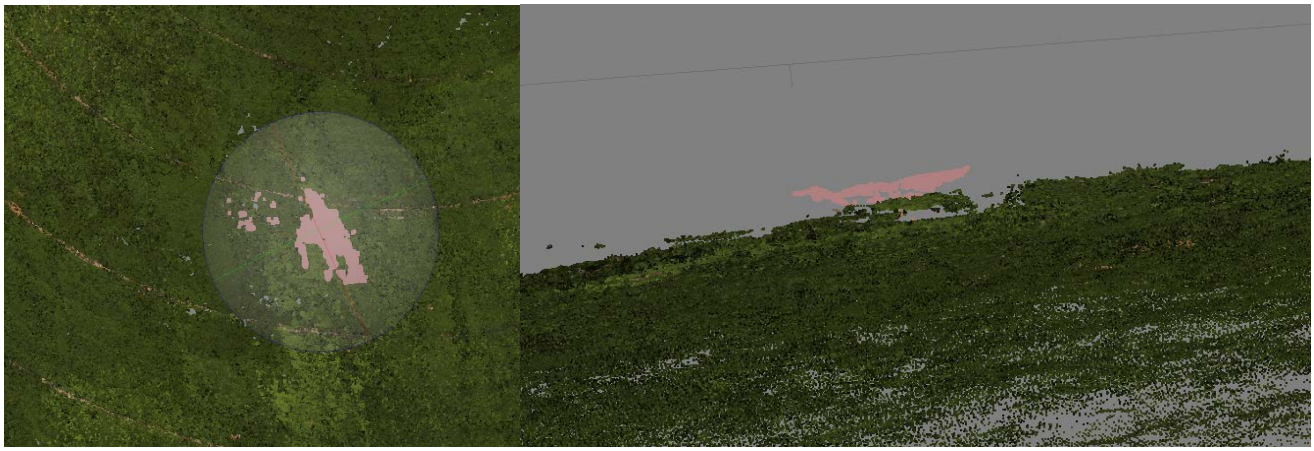

Figure 2. The image on the left depicts the location of erroneous image frames (pink) within a small portion of a center pivot field. The image on the right depicts how these erroneous frames are elevated above the surface of the other image frames for this field.

AgiSoft allows export of image mosaic files in a LAS format, a public file format for 3-dimensional point cloud data such as LiDAR data or in this case 3-dimensional UAS data. Both ENVI image processing and ArcGIS software provides algorithms for editing LiDAR data (LAS formatted files) that appear to work well with the UAS data. The ArcGIS LAS editing algorithms are limited for point cloud manipulations. ENVI software has provided better editing results to date. We also plan to test Pix4D, which is another very popular software for processing UAS imagery.

**Major Accomplishment 2:**

Final 2016 UAS Flights – Several UAS flights were conducted on November 8 by the project's business partner, AboveNV. Both fixed wing and rotor platforms were deployed to acquire RGB and near infrared imagery of newly plowed and planted fields of winter wheat that will enable comparison between bare soil and pre-harvest DEM images. Although we anticipate that without significant geometric control, it will be very difficult to accurately estimate crop height by comparing DEM derived from bare soil images with DEM derived from images acquired during peak crop height. It would likely require the establishment of 50 or more target points in each field for which altitude as well as latitude and longitude would have to precisely be measurement (within few cm accuracy) using survey-grade GPS coupled with a GPS base station at a known geodetic point.

**Business Partnering**

The business partner for this project, AboveNV, is a Nevada-based (Reno) start-up company. One of the goals of this project is to help foster the successful growth of this company and to help them develop a product for Nevada's agricultural community.

**Intellectual Property**

NA

**Programmatic & Project Changes**

During this past quarter, DRI made modifications on the data transfer and visualization approach. The original intent had been to provide results to both AboveNV and Winnemucca Farms, Inc. as a Geographic Information System (GIS) database; specifically QGIS, a free, open-source software package was being considered as a likely tool. After discussions with the Winnemucca Farms, Inc. manager (Tim Topliff), it was determined that a GIS database would not be suitable. They did not want to spend time training a current staff member or hire a new staff member to interface with the data. The manager thought jpeg or tiff image files of the analysis results would be sufficient. However, because individual image files do not provide an overall spatial assessment of the collective imagery, we have decided to pursue a secure web-based interface that the farm manager and his staff will be able to use from a computer or any mobile device. We believe this will be an innovative approach that will benefit AboveNV's business model and marketing.

**Looking Forward**

UAS flights at Winnemucca Farms are discontinued for the winter months and the remainder of flights will occur during the 2017 growing season. The focus for the next quarter will be on further refinement of data analysis methods, data visualization and transfer of knowledge gained and lessons learned to AboveNV. Specifically, we will look at: coupling GNSS (Global Navigation Satellite System) height and GPS with GNSS IMU (Inertial Measurement Unit) i.e., roll, pitch and yaw but this requires accounting for a time drift between GPS measurement and image acquisition; testing Pix4D; and recommending that the number of images acquired for each center pivot field is maximized. Figure 3 provides an example of how a larger number of images acquired per field can produce a more precise DEM product.

Figure 3. The image on the left is a mosaic from a larger number of images acquired for Field 37 in July versus a smaller number of images acquired for the same field in August (image on the right). The horizontal striping in the top half of the left image are the tractor tracks for the rows of potatoes that are a residual from planting. Another observable feature are the circular irrigation tracks from wheels preventing crop growth. The speckles present in the image on the right are the impact of minor image orientation errors on DEM generation.

## Section II: Knowledge Fund Performance Metrics

The legislation enacting the Knowledge Fund program listed several metrics by which the success of Knowledge Fund projects might be assessed. The common factor of these metrics is the growth of Nevada's economy. For this project the primary performance metrics include: number of jobs created; number of newly funded projects; and the number of UAS platforms sold by AboveNV.

Jobs Created: No new jobs were created during this quarter at DRI, but DRI has engaged an additional faculty member to participate in the data visualization portion of the project. To date, two new jobs have been created; one at AboveNV and one at DRI.

Internships: Only one UNR intern (funded under UNR's Nevada Advanced Autonomous Systems Innovation Center (NAASIC)) is continuing to gain experience and training by participating in development projects that directly relate to this project.

Grants Received: No new grants were received during this quarter, but DRI did submit a new agriculture and water related proposal to WaterStart that has been selected for funding. Both DRI and AboveNV have been using the work completed to date to help market expertise in UAS applications for agricultural assessment.

AboveNV Equipment Sale: DRI has placed an order with AboveNV for a UAS that will be used to meet project data collection requirements on a new effort with the Army Corps of Engineers.

Students Placed with Companies: AboveNV personnel help educate students at Truckee Meadows Community College (TMCC) about UAS. AboveNV anticipates hiring TMCC students to assist with UAS maintenance and operations.

## Section III: Budget

The following table summarizes expenditures for this quarter through the end of December 2016. Expenditures included salary coverage for AboveNV UAS operations, one UAS data acquisition trip and continuing data analysis of all images acquired to date. Travel included airfare and other costs for L. Fenstermaker and J. Medema to fly from Las Vegas to Reno, ground transportation, and lodging and per diem in Winnemucca. Expenditures are appropriate and meet the anticipated expenditures at this point in the project, i.e., 58% of the total project amount has been expended.

**DRI UAS Agriculture Application**

For Reporting Period

July-September, 2016

| | Quarter Actuals | Total Budget (at start of project) | Remaining Budget |
|---|---|---|---|
| **Total Salary & Benefits** | 8,717.47 | 72,562.00 | 40,155.96 |
| **Travel** | 1,371.76 | 14,176.00 | 9,645.57 |
| **AboveNV Subcontract** | 6,250.00 | 62,500.00 | 18,750.00 |
| **Other Direct Costs** | 61.45 | 3,000.00 | 867.56 |
| **Total** | **$ 16,400.77** | **$ 152,238.00** | **$ 64,419.09** |