

RANGELAND RESOURCE ASSESSMENT, MONITORING, AND MANAGEMENT USING UNMANNED AERIAL VEHICLE-BASED REMOTE SENSING

Albert Rango¹, Andrea Laliberte², Kris Havstad¹, Craig Winters¹, Caiti Steele², and Dawn Browning¹

¹USDA-ARS Jornada Experimental Range, 2995 Knox St., Las Cruces, NM 88003

²New Mexico State University, Jornada Experimental Range, 2995 Knox St., Las Cruces, NM 88003

Abstract - Civilian applications of Unmanned Aerial Vehicles (UAV) have rapidly been expanding recently. Thanks to military development many civil UAVs come via the defense sector. Although numerous UAVs can perform civilian tasks, the regulations imposed by FAA in the national airspace system and military equivalent agencies in restricted airspace need to be closely considered and followed in order to make progress in civilian applications. Personnel at the Jornada Experimental Range have developed approaches to abide by FAA and military regulations. Because of this, the enormous potential of UAVs for rangeland assessment, monitoring, and management is starting to be realized.

Keywords: unmanned aerial vehicle regulations; robotic sensing systems; rangeland applications; photography; cameras

I. INTRODUCTION

Civilian applications of Unmanned Aerial Vehicles (UAV), sometimes referred to as Unmanned Aircraft Systems (UAS), have been increasing in recent years. Most UAVs employed in civilian applications result from prior military development. As recently as 2004, civil UAVs were outnumbered by about 50 to 1 by military UAVs [1]. However, growth in the civil UAV sector is exploding and so-called Light UAVs (<150 kg) are expected to dominate natural resources applications. Unmanned Vehicle Systems (UVS) International [2], a European-based organization, has started a project focused on surveying Light UAV use around the world because of their belief that this category of UAV will likely be the one used the most for non-military, civil applications. Their early conclusions are that: 1) numerous countries are already flying missions according to existing regulations in their countries; 2) current flight operations are taking place not according to existing regulations or with no existing rules and regulations in some countries; and 3) numerous applications for Light UAVs have been identified and manufacturers, flight service suppliers, and current and potential users want to see the regulatory situation evolve rapidly.

II. APPLICATIONS

The non-military or civil use of UAVs has resulted in applications ranging from weather research and marine resource monitoring to a variety of land-based studies including archeology site assessment [3] and agricultural monitoring of crops [4], [5]. Because the largest global land cover type is rangeland, numerous investigators have published UAV results on rangeland assessments [6], [7], [8], [9]. High resolution aerial photographs have important rangeland applications [10], but for certain determinations even these conventional aerial photos do not possess the necessary resolution, and we must turn to hyperspatial data that can be obtained from Light UAVs.

The advantages of UAVs are numerous for rangeland and other civilian land applications. UAVs can fly low and autonomously to produce the high resolution photography required (~6 cm) over the particular area of interest. Additionally, flights can be done when required if the user of the data also owns the UAV, and resulting costs are much more reasonable than those involved with piloted aircraft. Other advantages with the UAV over piloted aircraft include flexibility in takeoff and landing locations, improved scheduling of flights, and greater safety for the flight crew.

There are also disadvantages to using the UAV approach. The UAV platform is less stable than a larger piloted plane which makes registration and mosaicing of individual, small images challenging. Operating a UAV requires virtually the same preparations needed for a piloted mission, but the Federal Aviation Administration (FAA) regulations are more restrictive for a UAV mission than a piloted flight. The FAA regulations for UAVs present a major challenge to accomplishing the mission unless you know exactly how to operate in this system, which is difficult because the regulations are under constant development and, therefore, changing. The overall conclusion about operating in the FAA National Airspace System (NAS) is that you can acquire the needed data, but certain tradeoffs are necessary; e.g. increases in time to accomplish the mission because the pilot must always be within visual range of the UAV and much additional training for the entire UAV flight crew.

III. UAV OPERATIONS IN NEW MEXICO'S CHIHUAHUA DESERT

The USDA-ARS Jornada Experimental Range has purchased a complete UAV system from MLB Co. in Mountain View, CA. The system is comprised of the MLB Bat-3 UAV (see characteristics in Table 1), a ground control station, and a catapult launcher which operates from the top of a support vehicle. A Certificate of Authorization (COA) to operate a UAV in the U.S. must be acquired from the Federal Aviation Administration (FAA). Once the COA is obtained, automated, overlapping photography can be acquired and stored on board. At the end of the flight, manual or autonomous control is used to land the Bat-3 on a short runway. Acquired data are downloaded and processed and then mosaiced for larger area coverage.

Operational requirements include a minimum crew size of 5-6 people, of which one crew member, usually either the external or internal pilot, functions as the Pilot-in-Command and possesses a private pilot license. Proficiency needs to be maintained with at least three flights during a three month period. The Jornada Bat-3 acquires aerial photos at about 700 ft (215 m) resulting in a resolution of about 6 cm with forward and side overlap required for orthorectification and mosaicing. The flight duration is usually 1-2 hours.

If a UAV is operating in FAA airspace, close coordination with FAA is required for permission to fly, even after the COA has been obtained. In restricted or military airspace, similar coordination with the agency in control of the airspace is required. Our flight personnel have overlapping responsibilities and can fill-in for numerous positions except for the Pilot-in-Command. Training is conducted for manual and autonomous flight control, observers, data processing, and image analysis. Once permission to fly is obtained, notification to other occupants of the airspace is required. In our case, we have received excellent continuing support from the Bat-3 manufacturer which is valuable when problems are encountered while in the field and will be even more valuable when we change sensors in the future and need re-integration of the entire system.

Costs are an important consideration for future operational use. We have purchased an entire system that we control ourselves. We have two identical Bat UAVs, one ground control system, and one launcher that total \$73,000 (\$48,000 if only one airplane is purchased). Replacement parts, additional training for the crew, and travel to sites away from Jornada have not been costly. We rate the cost effectiveness and flexibility of operation we have developed as very high.

Figure 1 shows a typical flight plan used when we have to move the external pilot in steps to fly a location greater than 0.8 – 1.1 km away from the launch site

meaning that the target area is outside visible range of the external pilot.

Although this does not take into account the full capabilities of most UAVs, including the Bat-3, we feel this approach is workable. We hope that by operating this way, we can provide data to our users and at the same time provide data to FAA that will be useful in the development of the optimum UAV regulations governing flight.

Table 1. Specifications for MLB Bat-3 UAVs

Power	Gas
Wingspan	1.8 m
Length	1.4 m
Gross Weight	10 kg
Payload Weight	1.1 kg
Max Speed	30.9 m/s
Operational Speed	18.0 m/s
Max Altitude	3,048 m
Endurance	5 hrs
System Cost	\$48,000
Sensors	Video, Digital camera
Manufacturer	MLB Co.
Launch	Catapult
Landing	On Wheels

IV. DATA PROCESSING, ANALYSIS AND POTENTIAL FOR OPERATIONAL USE

We rely almost totally on simple, digital high resolution photography in our data collection and subsequent rangeland analysis. There are challenges involved in using imagery from Light UAVs due to the low flight altitudes which result in a small image size as well as data sometimes being collected under conditions of moderate turbulence. A small aircraft platform usually has GPS and altitude information with relatively low accuracy. Because of the small image size, operational application dictates that we mosaic the images together to cover operational study areas. These factors make it more difficult to apply commercially available orthorectification software, therefore, we have developed our own necessary software. There are two data volume issues with a Light UAV program, first, there is the volume of data involved during the work flow to go from raw images to the final product. Second, there is the volume of permanent storage required to archive the results and critical metadata from the processing operation. This all totals about 1-2 Gb per typical 300 image mosaic of a rangeland study area. Some of our projects require imaging of multiple sites and at multiple times so that processing loads tend to come in bursts of a dozen mosaics at a time which can require about 25 Gb of storage capacity.

Once the UAV data were processed, we tested their usefulness by providing images of the Jornada Experimental Range in New Mexico to rangeland health experts for visual interpretation of randomly selected transects. Plant canopy

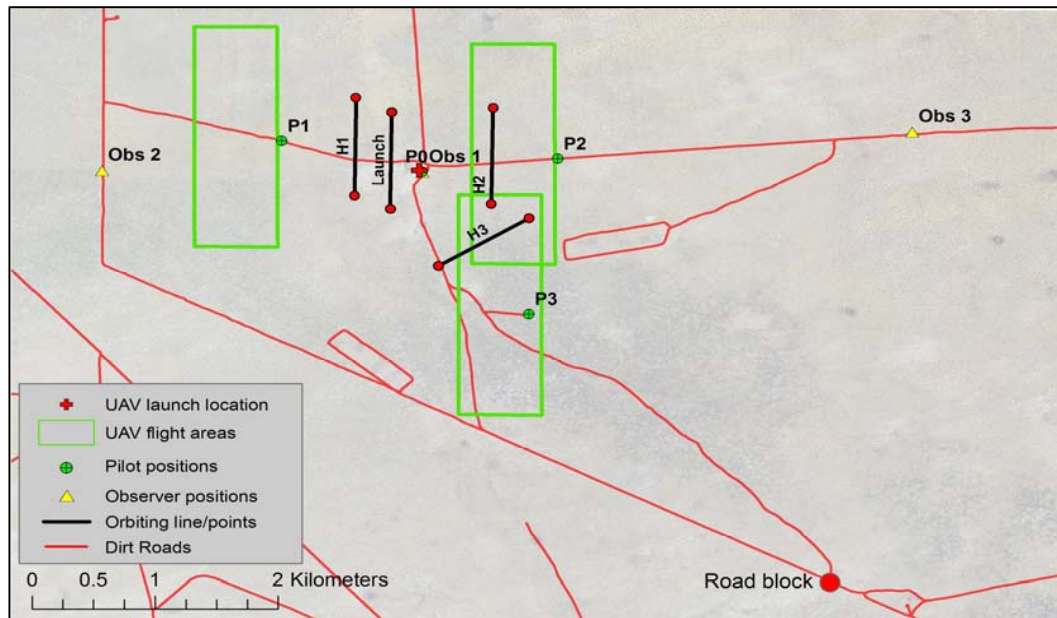


Figure 1. Map of a UAV flight operation in the NAS at the Jornada Experimental Range. The initial external pilot (EP) position is at P0. The UAV is launched at the red cross position into the launch orbit, and is then moved to the H1 holding orbit. Once the EP has moved from P0 to P1, the UAV acquires imagery over the first flight area in the northwest near P1. After completion, the UAV is moved back to H1. The EP moves back to P0. The UAV is moved to the H2 holding orbit. The EP travels to P2. The UAV then acquires imagery over the second flight area in the east near P2. The same procedure is repeated for the southern flight area near P3 and the return to the landing site. The objective is to keep the UAV within visual range and control of the EP. Three observers are used: one remains with the pilot throughout the mission, the other 2 are located at elevated positions to scan for conflicting air traffic. A roadblock is maintained throughout the flight.

cover, bare soil, and gap sizes between vegetation were recorded similar to how these scientists normally acquire ground-based line point intercept surveys. Additionally, we used the digital images and an object-oriented image analysis program to classify rangeland into four primary cover types: bare soil, shrubs, subshrubs, and herbaceous plants. In a similar study conducted on rangeland in Idaho, we found very good correlations between percent cover values from classified UAV images and detailed ground line point intercept measurements taken coincident with the UAV flights with R^2 values ranging from 0.86 – 0.98. Once the line point intercept plots exceeded eight, the UAV approach was more cost efficient [11].

Personnel of operational agencies charged with conducting rangeland surveys involving numerous ground measurements could save time, effort, and money by incorporating UAVs into their methodology. Work is underway to add UAV remote sensing capabilities to operational rangeland monitoring and measurement protocols. Additional developmental work is ongoing to provide georectified image mosaics in near real time so that data are readily available to rangeland scientists. We speculate that operational district offices could purchase and operate UAV systems that would be cost effective when compared to costs incurred from ground measurements in

today's climate of limited human and financial resources. The processing of the remote sensing data could be conducted in-house or by contractors trained in the remote sensing analysis techniques. Future work includes upgrading sensors on Jornada's Bat-3 to include a six-band multispectral digital camera and acquiring a larger UAV to carry LIDAR, SAR, and other instruments.

V. CONCLUSIONS

Civilian applications of UAVs have been expanding rapidly in recent years. One of the main focus areas has been rangeland resource assessment, monitoring, and management employing remote sensing using light UAVs because operations are suited for remote rangeland sites with low population density and little air traffic. Many potential civilian operators have been discouraged by airspace regulations which do not take UAV capabilities fully into account. We have found, however, that becoming closely familiar with both FAA and military regulations has allowed us to operate within regulations and still get valuable, high resolution image data. This kind of operation requires additional flight time to keep the external pilot always within visual line of sight of the UAV, and, it requires additional training for the UAV flight crew as well

as more time spent on designing efficient flight plans. We feel that this greater effort, however, is well worth it because of the quality of the data acquired and the increased capability for improving rangeland management.

REFERENCES

- [1] L. R. Newcome, *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles*, 171 pp., American Institute of Aeronautics and Astronautics, Inc., Reston, VA, 2004.
- [2] UVS International, unpublished data
- [3] J. W. Walker, "Low Altitude Large Scale Reconnaissance: A Method of Obtaining High Resolution Vertical Photographs for Small Areas," *Interagency Archeological Service*, 127 pp. National Park Service, Denver, CO, 1993.
- [4] S. R. Herwitz, L. Johnson, S. Dunagon, R. Higgins, D. Sullivan, J. Zheng, B. Lobitz, J. Leung, B. Gallmeyer, M. Aoyagi, R. Slye, J. Brass, and G. Witt, "Coffee Field Ripeness Detection Using High Resolution Imaging Systems on a Solar-Powered UAV," *Proc. 30th Symp. Rem. Sens. Environ.* Honolulu, HI, TS-12.3, 3 pp, 2003.
- [5] L. F. Johnson, S. Herwitz, S. Dunagan, B. Lobitz, D. Sullivan, and R. Slye, "Collection of Ultra High Spatial and Spectral Resolution Image Data over California Vineyards with a Small UAV," *Proc. 30th Symp. Rem. Sens. Environ.* Honolulu, HI, TS-12.4, 3 pp., 2003.
- [6] M. C. Quilter and V. J. Anderson, "A Proposed Method for Determining Shrub Utilization Using (LA/LS) Imagery," *J. Range Manage.* Vol. 54, pp. 378-381, 2001.
- [7] P. J. Hardin and M. W. Jackson, "An unmanned aerial vehicle for rangeland photography," *Range. Ecol. Manage.* Vol. 58, pp. 439-442, 2005 [DOI:10.2111/1551-5028(2005)058[0439:AUAVFR]2.0.CO;2]
- [8] A. Rango, A. Laliberte, C. Steele, J. E. Herrick, B. Bestelmeyer, T. Schmugge, A. Roanhorse, and V. Jenkins, "Using Unmanned Aerial Vehicles for Rangelands: Current Applications and Future Potentials," *Environ. Pract.* Vol. 8, pp. 159-168, 2006 [DOI:10.1017/S1466046606060224].
- [9] A. S. Laliberte and A. Rango, "Texture and Scale in Object-Based Analysis of Sub-Decimeter Resolution Unmanned Aerial Vehicle (UAV) Imagery," *IEEE Transactions of Geosc. Rem. Sens.* Vol. 47, pp. 761-770, 2009. [DOI:10.1109/TGRS.2008.2009355].
- [10] A. Rango, and K. Havstad, "The Utility of Historical Aerial Photographs for Detecting and Judging the Effectiveness of Rangeland Remediation Treatments," *Environ. Prac.* Vol. 5, pp. 107-118, 2003. [DOI:10.1017/S1466046603031065].
- [11] A. S. Laliberte, J.E. Herrick, A. Rango, and C. Winters, "Acquisition, Orthorectification, and Classification of Unmanned Aerial Vehicle (UAV) Imagery for Rangeland Monitoring," *Photogram. Engineer. Rem. Sens.*, Vol.76(6), pp. 661-672, 2010