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# Impact of flight regulations on effective use of unmanned aircraft systems for natural resources applications

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**Abstract.** Unmanned Aircraft Systems (UAS) have great potential for rangeland assessment, monitoring, and numerous other applications in natural resources management. In order for UAS to become a dependable tool for public land management agencies in carrying out their government-mandated responsibilities, it is necessary to integrate UAS into the National Airspace System (NAS), which includes all aircraft, manned or unmanned. To achieve this, Federal Aviation Administration (FAA) regulations have to be followed to assure public safety. UAS operators need to know that FAA safety regulations, which incorporate line-of-sight restrictions, will only allow slow progress towards an operational system, and they must plan accordingly for the extra time necessary to prepare and complete flight missions. By following approved safety procedures, UAS operators can develop a UAS flight team that is capable of accomplishing missions anywhere in the United States while contributing to a totally integrated NAS comprised of all aircraft systems that can be used jointly for natural resources management. At the same time, it is hoped that FAA regulations will change in the future based on the capabilities and experience of the UAS flight team and on the locale in which operations take place, especially over large, remote, and sparsely populated areas.

**Keywords:** Small unmanned aircraft systems, FAA regulations, National Airspace System, civilian applications, aerial photography, rangeland management.

## 1 INTRODUCTION

There are many military applications of UAS (sometimes called unmanned aerial vehicles) including the location of enemies, launch of missiles against enemy positions, and general monitoring of enemy resources and changes over time. Some very direct spinoffs from these military uses are patrol of national borders, monitoring of traffic flow on highways, and inspection of remote facilities. Although not as numerous as military uses and related spinoffs, civilian natural resources applications are a rapidly growing area for UAS development. The UAS generally possess the capability to obtain very high resolution (hyperspatial) imagery that can be repeated numerous times making such approaches applicable to assessing land cover change and monitoring of infrastructure, such as dams and irrigation canals. Because rangeland is the primary global land surface cover and usually remote, the use of UAS for rangeland assessment, monitoring, and management is an ideal natural resources application [1, 2]. UAS are also used in precision agriculture because of the need for both high resolution and repetitive imagery [3, 4]. The Washington State Department of Transportation has also tested UAS for utility in snow avalanche control as well as for traffic surveillance in snowy regions and found considerable promise for both

applications. They concluded that the main UAS limitation was the institutional regulations of FAA which has caused other UAS operators to terminate their UAS projects [5]. Another way to look at this is that certain UAS or their operators do not meet today's regulatory standards.

UAS are better suited to certain tasks than manned aircraft. Because of the low flight altitudes that UAS are capable of, imagery can generally be acquired at much higher resolution. Imagery can be acquired with small and relatively less expensive UAS airplanes, and the lack of a pilot and the use of consumer-grade cameras result in greatly decreased flight costs. The unmanned approach also results in a safer mission from the pilot's standpoint. The low altitude missions are more compatible with FAA regulations which prefer light/mini (5-50 kg) UAS [1] that fly near the ground rather than at higher altitudes where potential conflicts with piloted aircraft are more common.

This does not imply that UAS systems are currently designed to acquire natural resources data without some modification. It is necessary to examine the sensors available on specific UAS platforms. Almost all UAS have a default sensor, usually a video camera which is a remnant of military applications. For natural resources applications, we have limited use for the video camera aside from possibly using it for real time guidance purposes. Video cameras have too poor resolution to be of use for natural resource mapping applications. Basic UAS sensors are a digital camera and a multispectral sensor, thus making pan-sharpening a definite possibility. Alternative UAS remote sensing packages, depending on available payload capability, could include a hyperspectral radiometer, a thermal infrared radiometer, LIDAR, and SAR for specific purposes. Elimination of the video camera could provide room for one or more of the above sensors in some UAS.

Much data can be collected with UAS in a very short period of time. Because of low flight altitudes, UAS can obtain images with high spatial resolution (about 6 cm when flying at 213 m altitude with a low-cost consumer camera), but the image areas are small (approximately 160 x 213 m). As a result, you need to acquire numerous images to cover small to medium size study areas which can generate large data volumes [1]. Storing and archiving of both raw and processed imagery requires sufficient data storage capacity, such as large hard drives or servers. The fact that UAS are a less stable platform than piloted aircraft means that orthorectification and subsequent mosaicing of the small footprint images are difficult. Because instability caused by turbulence strongly affects small UAS, existing photogrammetric software is not commonly suited for the entire workflow. This has led us to develop our own algorithms for orthorectification of the UAS imagery [6]. At present, we are working on developing a near real-time image processing capability.

The hyperspatial capabilities of the UAS of approximately 6 cm resolution can also be obtained by a limited number of other platforms including manned aircraft equipped with large- or medium-format digital aerial mapping cameras [7] or ultralight aircraft [8] equipped with digital cameras. The differences compared to UAS are cost and the format and character of the data. Digital mapping cameras provide multispectral, high radiometric resolution data, whereas low-flying ultralights can provide millimeter resolution data with digital cameras. Image acquisition costs are lowest with UAS, and most costly with manned aircraft with digital aerial mapping cameras. The selection of the best platform to use must be based on the specifics of the application, cost of acquisition, and ease of operation, and it must be made by the individual operator.

All these technical issues are of extreme importance [1], namely, choice of specific UAS, choice of sensors employed, and timely data processing. However, it is just as important to address the challenges of non-technical, regulatory issues associated with flying the UAS in order to make UAS useful for natural resources applications. At present, the regulations are cumbersome and have resulted in fewer UAS applications than expected. The purpose of this paper is to assist UAS users in navigating through the bureaucratic process in order to make effective legal use of UAS and to produce meaningful remote sensing data. Without

guidance, it is feared that many UAS operators will find the regulations too restrictive or difficult to interpret and will either abandon development of UAS methods or may fly their UAS without the necessary approvals which could result in reduced levels of safety.

## 2 USING UAS LEGALLY AND SAFELY

Even though a UAS can be acquired, it cannot immediately be flown when and where a user wants. There are two types of airspace in the United States. The NAS is controlled by the FAA. The second type of airspace is referred to as Restricted, Prohibited, or Warning Area Airspace and is controlled by the military agency or institution in charge [9]. It is important to note that approval from the controlling agency of the relevant airspace is required. Countries other than the United States will have somewhat differing airspace designations and considerably different UAS regulations. Because most natural resource UAS applications in the United States will take place in the NAS, FAA regulations and their effects on utilization of UAS will be discussed in this paper. Much confusion exists in the minds of UAS operators, including law enforcement agencies, who have thought they were operating properly, only to be prevented from operations by FAA [5]. Hopefully, reference to some of the documents cited in this paper will help clear up the confusion.

Model airplanes have been regulated by the FAA since 1981 [10]. These regulations state that model aircraft are limited to 122 m above the ground, can operate no closer than 4.8 km to an airport, cannot fly autonomously, and cannot be used for commercial purposes such as acquiring aerial photography for a customer. It is logical that confusion may result because many of the early UAS natural resources applications were first developed using modified model airplanes [11-14]. As modifications proceeded, it was only natural that new functions for model airplanes were tested and the distinction between model airplanes and UAS began to blur. However, it is relatively easy to determine if model airplane regulations apply by closely examining AC 91-57 [10]. Many, if not all, of the modifications made by researchers have converted the model airplane to a UAS, eliminating use of model airplane regulations from consideration for UAS flights.

If UAS of any type are employed for any purpose in the NAS, formal approval must be requested from FAA, through application for a Certificate of Authorization (COA) for government applicants or a Special Airworthiness Certificate (SAC) in the experimental category for civil applicants. A COA application usually takes two to three months, although at times six months is a possibility. FAA is currently operating under interim guidelines for UAS [9]. Applications for a COA are increasing, and they are only accepted from public entities such as U.S., State and local government agencies as well as some public state universities. The COA form and associated guidance can be found on the internet at [http://www.faa.gov/about/office\\_org/headquarters\\_offices/ato/service\\_units/systemops/aaim/organizations/uas/coa/](http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/coa/). Establishment of regional flight test centers such as the one at New Mexico State University, Physical Science Laboratory in Las Cruces, New Mexico may be able to reduce the number of COA applications going directly to FAA, and thus, reduce the wait time for COA awards [15].

For manufacturers who are not eligible to apply for the COA, but are trying to develop commercial and civil uses, it is possible to apply for a SAC [16]. Not as many SACs have been issued as have COAs, so the length of time for approval is uncertain.

Because the time of approval for both the COA and SAC can be lengthy and somewhat uncertain, it is necessary to build a variable time line or cushion into any project requiring UAS image coverage. In order to avoid delays that would hinder UAS research progress or the meeting of operational deadlines, it is best to apply early and allow for at least six months for the application to be considered.

Some confusion can arise during the application process because the regulations are correctly labeled as interim. These regulations are under development and will change as they are adapted to the UAS program from the manned aviation program regulations. It is estimated from a review of the current applicability of the manned aviation regulations to UAS flight operations that 30% apply directly, 54% may apply or require modification, and 16% do not apply. In certain situations, new rules and regulations are needed for UAS, especially for light/mini UAS [17]. As the final UAS regulations are being developed, the information requested for COAs and the basis for decisions may change from earlier COA applications. Additional changes in the regulations may occur as the FAA gathers more information and data related to UAS performance and characteristics. While this process proceeds, the UAS operators need to be flexible. For example, the FAA recently released a set of recommendations from the Small Unmanned Aircraft System Aviation Rulemaking Committee pertinent to regulating use of small Unmanned Aircraft Systems (sUAS) in the NAS [18]. It is important to follow the progress of this set of recommendations as they are transformed into actual regulations because light/mini UAS will most likely be used for a majority of natural resources applications and manned aviation regulations have the least pertinence to this class of UAS [17]. The FAA maintains a website with the latest UAS regulations and policies at <http://www.faa.gov/about/initiatives/uas/reg/>.

Safety is the overriding concern guiding FAA decisions. They are attempting to regulate the process sufficiently in order to avoid collisions with piloted aircraft or another UAS, crashes of UAS into populated areas, and even incidents that might endanger the UAS flight crew. The result is that even if you acquire a UAS, you cannot immediately utilize the technology (even with the proper flight training), despite the fact that you might be in a very remote and unpopulated area in the NAS. Manufacturers should supply purchasers of UAS with up-to-date information on what is required to fly their newly-acquired UAS in the NAS. This information and general awareness is currently lacking and should be required information associated with the purchase or lease of a UAS.

Sensing and avoiding other aircraft is a big safety issue that must be addressed by small UAS operators. Currently this issue is being resolved by the utilization of ground observers communicating with the UAS pilot and the pilot communicating with Air Traffic Control (ATC). UAS pilots, because they are removed from the cockpit, rely on these communications as well as on monitoring data sent back from the UAS and generation of information by the computer ground control station about the UAS status [17]. In order to have safe UAS flights, UAS operators must be extra vigilant in monitoring all information that is available to them, especially because they are not in a cockpit.

### **3 OPERATIONS UNDER A COA**

Once a COA has been awarded, the UAS operator is obliged to fly according to the terms of the COA. Although the time period the COA is in force is variable, they usually are awarded for a one year period and can be renewed. The situation covered by the COA is stated in the award. An example of an award statement is: "the MLB Bat-3 operated in Class G airspace at or below 1,000 ft (305m) above the ground (AGL) in the Murphy Airport, Idaho area under the jurisdiction of the Salt Lake Air Route Traffic Control Center (ARTCC)." The COA specifies the safety provisions that the COA applicant must make in order to fly in the UAS flight area to ensure a level of safety equivalent to the level that would exist if a pilot were on board the UAS.

To have this equivalent level of safety, visual observers, either ground-based or airborne, must be used to assist the UAS pilots in ensuring that there is safe operating distance between all manned and unmanned aircraft at all times. In addition to collision avoidance with all

aircraft, safety precautions must be taken to preserve the safety of persons or property on the ground.

The UAS pilots must have the necessary training for flying the UAS by radio control as well as through autonomous flight. In order to operate safely in NAS, the UAS pilots must have the capability to communicate with ATC and understand FAA regulations pertinent to the airspace in which they operate the UAS. Pilots must pass the knowledge test for a private pilots license (FAA Ground School) and keep their aeronautical knowledge up-to-date. Observers must have observer training and be able to communicate to the pilot evasive action directions required to stay clear of conflicting traffic. Both pilots and observers need to possess a second class or higher airman's medical certificate.

In order to operate an UAS flight mission, the UAS must have a Pilot-in-Command (PIC) who is directly responsible for the overall operation of the UAS. The PIC must have passed FAA Ground School or have the military equivalent. Depending on the particular COA, the PIC may or may not be required to have a Pilot's license for a manned aircraft. This decision is based on many factors including the remote nature of the flight area, experience of the flight crew, population in the vicinity, air traffic in the region, and proximity to an airport. Whether a private pilot's certificate is required or not, the PIC must be deemed to be proficient by having three qualified proficiency events with the current UAS system in the 90 days preceding an UAS mission. The PIC is responsible for the preflight inspection of the UAS to ensure airworthiness and the safety of the UAS ground crew and persons and property along the UAS flight lines. This may require the closing of certain roads under the flight lines during the mission. The PIC will control the UAS aircraft to the same standards as the pilot of manned aircraft, and to do that, the PIC must have two-way communications with the ATC and have the ability to maneuver the UAS according to ATC instructions while taking into account any warning information from the ground observers.

Other positions on the UAS flight team include the internal (or computer controlled flight) pilot and the external (or radio controlled flight) pilot. Both of these pilots are required to have passed FAA Ground School and obtained second-class medical certificates. Either the internal or external pilot on an UAS mission can also serve as the PIC. In some cases, especially when either the internal or external pilot is also serving as the PIC, another position called mission commander can be utilized to take responsibility for the overall UAS mission operations to leave the more pilot-related functions to the PIC.

Some additional or related provisions of the COA include that usually UAS missions are conducted under Visual Flight Rules and only during daylight hours, except as noted in the COA. Visual observers are spaced at intervals that allow at least one observer to be in visual range of the UAS. With most light/mini UAS, this distance is commonly 0.8 – 1.1 km apart. The UAS pilot must also be within this distance from the airplane. A Notice to Airmen (NOTAM) shall be issued 48 hours before an UAS mission by the PIC or mission commander specifying the location and altitude of the operating area, time of operations, and nature of the activity. The proponent of the COA must not only abide by the COA regulations, but it is also their responsibility to report all incidents or accidents in the NAS to FAA. Table 1 summarizes the steps necessary for flying an UAS safely in FAA-NAS.

#### **4 CURRENT VERSUS DESIRED FUTURE UAS OPERATIONS**

It is deemed useful to compare our current UAS rangeland monitoring under FAA regulations with what we can envision for the future. In a future preferred mode of operation, we would send out a NOTAM before the UAS flight to inform piloted aircraft of our activities as well as conduct frequency scans in our area to assure there will be no interference with our control of the UAS. Following crew briefs and preflight checks, we would prefer to catapult launch our UAS from the top of a support vehicle at a takeoff point near the center of the Jornada Experimental Range (JER), have the UAS orbit near the launch location while we upload a

detailed preplanned flight pattern, fly to the rangeland area of interest (out as far as 16 km from the launch site) and proceed to fly overlapping transects, return to a central landing strip autonomously, make a landing, and download the high resolution photographs acquired. The four closest airports to the JER central launch location are 35-45 km away, and the closest airport with a control tower is 108 km away.

Table 1. Steps in order to fly in the National Airspace System Under FAA Regulations.	
<b>1. Qualifications, Exams, Training</b>	<ul style="list-style-type: none"> <li>• FAA Ground School (for external and internal pilots)</li> <li>• Special observer training</li> <li>• Second class or higher FAA airman's medical certificate</li> <li>• FAA Private Pilot's License (Pilot-in-Command)</li> <li>• Radio control training and experience (External Pilots)</li> </ul>
<b>2. Application for Certificate of Authorization (COA)</b>	<ul style="list-style-type: none"> <li>• Ownership of UAS by public government entity</li> <li>• Manufacturer training on UAS operations and maintenance</li> <li>• Submit COA application with a 3-6 month waiting period (<a href="http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/system_ops/aaim/organizations/uas/coa/">http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/system_ops/aaim/organizations/uas/coa/</a>)</li> </ul>
<b>3. Flying the UAS</b>	<ul style="list-style-type: none"> <li>• Receive COA and fly according to all specifications in COA</li> <li>• Pre-flight planning to               <ul style="list-style-type: none"> <li>- establish home location coordinates for use after launch and in case of loss of link to UAS</li> <li>- establish flight pattern for travel to and from test site and for photography over test site with desired forward and sidelap</li> <li>- establish landing flight pattern</li> <li>- locate observer positions and road blacks during flight pattern</li> <li>- establish evasive maneuver protocol if air traffic approaches flight area</li> </ul> </li> <li>• <b>Flight Mission</b> <ul style="list-style-type: none"> <li>- issue Notice to Airman (NOTAM) 48 hours before flight</li> <li>- contact local designated FAA office to provide flight details</li> <li>- check for any frequency conflicts in area of the flight</li> <li>- provide radio broadcasts on day of flight to inform manned aircraft of UAS flight</li> <li>- conduct flight crew briefing before flight and de-briefing after flight</li> <li>- conduct airplane and control center checklists</li> <li>- launch UAS, upload flight plans, acquire photography, and land UAS</li> </ul> </li> </ul>
<b>4. Documentation</b>	<ul style="list-style-type: none"> <li>• File incident reports, if any, with FAA</li> <li>• Update log books and keep complete records</li> </ul>

In contrast to this preferred future mode of operation, we currently operate under a FAA-COA in the following manner. We first issue a NOTAM, perform the frequency checks and conduct crew briefs and preflight checks. Because we cannot send our UAS out-of-sight from the pilot, we have developed the following ways to cover areas that will be greater than 1.1 km from the external pilot. Since we can catapult launch from almost any location, we have constructed several small landing strips around the JER so that distance between takeoff, photo acquisition, and landing can be minimized. We have also developed a method of orbiting the JER Bat-3 UAS while the external pilot moves from 1.1 km on one side of the Bat-3 to the same distance on the other side of the UAS. The Bat-3 is moved in this manner across the JER landscape until the desired study areas are reached and automated

photography can begin. Then the same procedure is used to get the pilot and UAS to one of the landing sites. Properly trained ground observers are positioned around the areas that the UAS will traverse, and they can be moved in a manner similar to the pilot, if necessary. They are in contact with the pilot to relay information regarding any observed manned aircraft traffic which the pilot needs to know about in order to take evasive action. An example of how we operate is illustrated in Fig. 1 where we must move the UAS and external pilot to three different areas for photo acquisition.

These would be the same procedures we would follow if we were operating over populated areas, but the JER permanent population density is one person/ 783 km<sup>2</sup> which is indicative of a remote, low population density rangeland. The driving force for these current UAS regulations is overall safety precautions and not the capabilities of the UAS itself or because of a significant danger to population inside the boundaries of the JER. Dalamagkidis et al. [17] mention that in remote areas the safety requirement adapted from manned aviation regulations results in an over-conservative regulation for the UAS program.

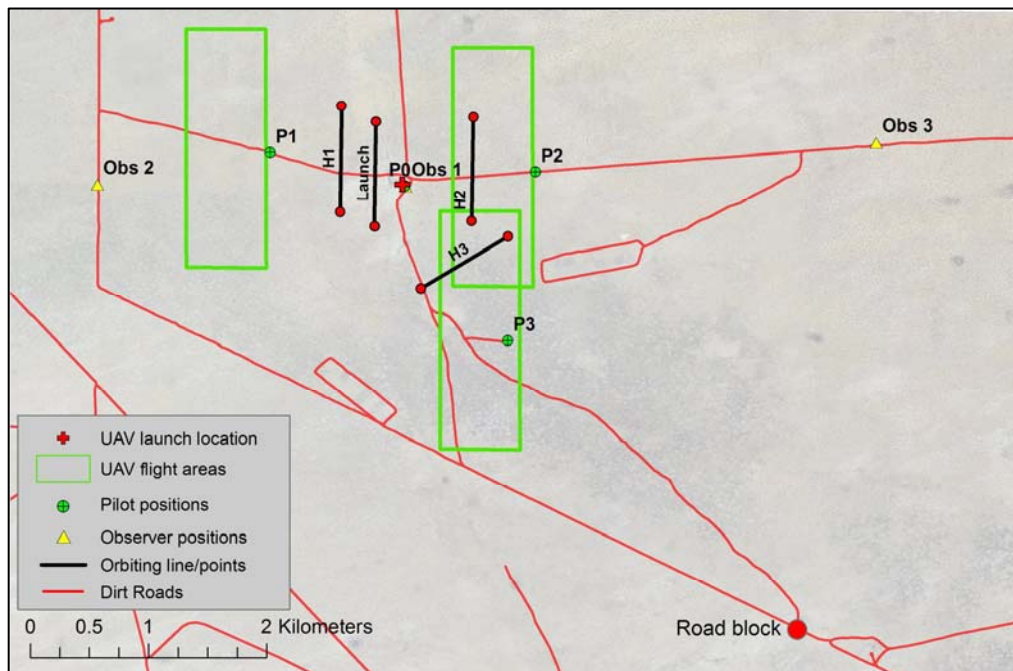


Fig. 1. Map of a UAS flight operation in the NAS at the JER. The initial external pilot (EP) position is at P0. The UAS is launched at the red cross position into the launch orbit, and is then moved to the H1 holding orbit. Once the EP has moved from P0 to P1, the UAS acquires imagery over the first flight area in the northwest near P1. After completion, the UAS is moved back to H1. The EP moves back to P0. The UAS is moved to the H2 holding orbit. The EP travels to P2. The UAS 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 UAS 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.

## 5 RAMIFICATIONS OF FLYING WITH COA

Many of the regulations associated with the COA are adapted from the manned aircraft program and, as such, may not be directly pertinent to UAS characteristics and capabilities.



At the moment, this has led to UAS operations much different than those originally intended by the UAS designer or what the operator would prefer. As a result, UAS are currently operated much closer to launch and landing points than originally anticipated, and the operator cannot take full advantage of a UAS's autonomous flight capability to range cross country collecting data across long and extensive transects. It appears that UAS operations will be limited to line-of-sight distances (unless a chase aircraft is employed) for a long time to comply with sense-and-avoid provisions. The limitations on altitude do result in high resolution images, but the capability of flying higher and further could provide variable resolutions across different land cover types. UAS were especially designed to fly over unpopulated and remote areas where little danger to people would be encountered. Current restrictions on UAS flight cause all operations to appear as if they were flying in populated regions rather than in desolate rural or near wilderness areas.

To fly over unpopulated rangeland and abide by COA guidelines, flight crews for a typical UAS mission are much larger than one would anticipate. Currently for UAS flights over public rangelands, the makeup of the flight crew for a light/mini UAS (from 5 - 50 kg like the MLB Bat-3) [1] over southern New Mexico rangeland consists of the external (or radio control) pilot, internal (or computer flight control) pilot, mission commander (not formally called for in FAA regulations), ground observers (at least two and up to as many as five), a launch team who supports the external pilot (usually two people), support team for internal pilot (one – two people), and a safety support crew of one – two people to block key roads while the UAS mission is underway. The minimum size of the crew when either the external or internal pilot can serve also as the PIC is six. Note that the size of this crew is much larger than crew sizes for small commercial airline flights. Because of our experience with time spent developing the flight plans for UAS missions that meet the goals of a research project and also satisfy FAA safety requirements, we know that the planning time is two - four times in excess of the time actually spent in flying the mission. Ancillary training time for pilots and ground observers, in accordance with FAA requirements, must also be factored into the preflight preparation.

Additional time is spent keeping records of flights in case FAA needs to review the records in the future. Beyond that, the records also illustrate that the FAA regulations do definitely slow down attainment of the main operational or research objectives because we spend at least four times longer than if we operated using the full capabilities of our UAS which are typical of the capabilities of most light/mini UAS on the market. The time savings would result from sending the UAS out to locations as distant as 16 km to acquire data without having to move the external pilot in 1.6 – 2.2 km increments after launch while having the UAS orbiting and waiting for the pilot to get into position to always keep the UAS in visual line-of-sight and then back again for landing. If we were able to send the UAS directly out to the target area to take data and not move the pilot, significant time would be saved (50 – 75% less time). We could still operate in a safe manner using a chain of observers along the flight path who would maintain contact via radio with the pilot, especially when we are operating in unpopulated rangeland in remote regions with little or no air traffic.

We do have one safety feature that we are prepared to take in remote rangeland areas that is not available to manned aviation. If oncoming air traffic is observed and reported heading toward our flight area, we first will descend quickly to 35 m altitude. If a collision still appears unavoidable, we are prepared to sacrifice the UAS as a last resort by attempting a crash landing so that a manned aircraft is not put in peril.

We would suggest to FAA that the remoteness of the area covered by UAS missions be more strongly factored into the COA regulations. In the recent recommendations issued by the Small Unmanned Aircraft System Aviation Rulemaking Committee [16], it appears that the remoteness and population of the operational area may eventually be considered in deciding on flight regulations. Remote rangelands should be handled differently than urban / suburban areas and areas near airports. The vicinity of the flights to populated areas needs to

be taken into consideration, and where the acceptable level of risk threshold is not exceeded, the regulations should be modified to take into account the extensive UAS capabilities, when feasible. The past record of the applicant flight crew and UAS being flown should be also considered along with the size of the UAS being employed.

## **6 FLYING IN RESTRICTED AIRSPACE**

Flying in non-FAA regulated areas such as Restricted, Prohibited, or Warning (Military) Airspace requires similar preparation. Permission to fly in these areas must be requested and obtained from the installation in charge of the restricted airspace in question. The regulations to be followed will likely be different from those of FAA in certain ways, but they will be similar enough that those experienced in flying in the NAS should have no problem adapting to flying in the non-NAS.

## **7 DISCUSSION**

We suggest that a prospective UAS operator selects a UAS manufacturer who has a product that meets the objectives of the operator's applications. An ideal situation would be to select a UAS that has been tested and shown to be reliable. Furthermore, the ideal manufacturer would offer training and continuing support. For future applications, it would also be best if the UAS chosen can fly different sensors in its payload interchangeably, and if either the operator or manufacturer (preferable) can integrate new sensors into the UAS after purchase. Associated with this, when purchasing a UAS, the purchaser should visit with UAS manufacturers and other operators to glean a better understanding of the different capabilities, safety features (such as a return-to-home capability), sensor availability, and operational procedures. The prospective purchaser should also gain experience with the UAS in question by attending demonstrations, conferences, exhibits, and open house opportunities.

Once the purchase has been made (if not before), the new UAS operating team should start FAA Ground School and pass the Ground School test, obtain the required FAA medicals, and also obtain observer training. At a minimum, four to six members of the UAS team will require this training. For external pilots, radio control training should be emphasized right from the beginning. Additionally, for either external or internal pilots, private pilot training is a necessity. The alternative is to add existing private pilots to the UAS ground team to serve as PICs or external and internal pilots so that the pilots will be integrated from Day 1 into the complete UAS training. It is important that the flight crew is sufficiently large with redundancies built in so that there are backups for each position. Additionally, for natural resources research applications, a ground truth team should collect appropriate field data to compare to the UAS data. The size of this ground truth team will vary according to the specific objectives of the natural resources research or operations.

For documentary purposes, keep a log book of all missions from training to operational flights. This should include information on who serves in which functions, the hours of flight time, maintenance performed, replacement parts, fuel loads, and other UAS specific records. All this information will save time during the planning and evaluation of future missions, as well as provide data needed for COA applications.

The potential of UAS for applying remote sensing to natural resources management is so great [1, 2, 14] that the operator must do everything possible to assure that all regulations are known and followed. In order to do this, UAS operators need to be prepared to spend significant extra time in preparation to fly their missions as well as extra time to complete flight missions resulting from abiding by line-of-sight restrictions. In order to accomplish this, the UAS operator needs to become fully aware of regulations in the NAS and non-NAS areas to be flown and acquire formal approvals well ahead of when the necessary missions are

scheduled or needed. It is the responsibility of the UAS operator to seek out the pertinent regulations because they generally will not be provided by the UAS manufacturer and only by FAA, if requested or searched for on the internet.

The major drawback to flying UAS is that the time for preparation and the time for the completing the flights is much longer than expected due to the regulations that must be met. But, there are positive aspects as well. In spending the time necessary to fly safely, you are assembling a UAS flight team that knows how to fly in the NAS (and non-NAS) and can use that experience to accomplish missions anywhere in the United States. This capability becomes even more important as more and more operators of UAS want to gain access to the NAS in future years. Additionally, by taking the required steps now, you are also contributing to the building of a totally integrated NAS comprised of manned and unmanned aircraft systems that can be used jointly for natural resources monitoring, assessment, and management.

## **9 CONCLUSIONS**

One of the growing civil applications for UAS is in natural resources, particularly in rangeland management. Many promising results have been accomplished using a light/mini UAS equipped with a consumer-grade digital camera to acquire 6-cm resolution imagery. The approach has been developed to the point where it is nearly operational. Small UAS is a rapidly growing industry, and many more choices of UAS will be available for rangeland management in the future. As a result of our experience in this research, we have identified one major area that is restricting progress in UAS natural resources applications, namely, working through FAA regulations in order to fly the UAS in a safe and productive manner. Once the regulations are known, applications submitted, proper training received, COA issued, and flight crews assembled, a large amount of time has been expended not directly associated with acquiring the UAS data. Once all the necessary steps have been accomplished, however, it is possible to fly in the NAS (and most likely in Restricted, Prohibited, or Warning Area Airspace with separate approvals) and acquire meaningful data. Because the UAS data have such great potential value, it is certainly worth the preliminary planning time to get ready to fly and the extra time spent flying according to the FAA regulations. It is recommended that FAA take into account the remote, unpopulated characteristics of rangelands in future regulations as well as the inherent capabilities of the UAS team approved to fly under the specific COA. In the long term, such evolution of the regulations for UAS will allow for many more advances in natural resource applications and the safe integration of many more UAS in the NAS.

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