RECLAMATION
Managing Water in the West

Scoping Project

Potential Reclamation Applications of the T-Hawk – A gasoline Micro Air Vehicle:

A Guide for Potential Reclamation UAS Users

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Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Emergency Management and GIS Group, 86-68260

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3/1/13
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Acronyms

AGL	Above Ground Level
AHRS	Attitude Heading Reference System
AMD	Aviation Management Division (now the OAS)
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
DOD	Department of Defense
DHS	Department of Homeland Security
DOI	Department of Interior
EO	Electro-Optical
EOS	Earth Observing System
FAA	Federal Aviation Administration
FWS	Fish and Wildlife Service
GDT	Ground Data Terminal
gMAV	Gasoline Micro Air Vehicle
GPS	Global Positioning System
LOL	Loss of Link
LOS	Line of Sight
LIDAR	Light Detection and Ranging
MAV	Micro Air Vehicle
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OAS	Office of Aircraft Services
OCU	Operator Control Unit (ground station)
SATCOM	Satellite Communications
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicle
USGS	United States Geological Survey

Executive Summary

Project Summary

There are potential gaps in acquiring remotely sensed data for use by Reclamation, particularly in the isolated, scarcely populated and occasionally hazardous environments. Unmanned Aircraft Systems (UAS) may provide the opportunity to fill some of those gaps, reduce the risk to personnel and, in some cases, offer a more cost effective alternative to obtaining certain information. UAS may also provide access to remote sensing data not previously available to Reclamation.

Initially the scope of this project focused on investigating Reclamation's current remote sensing needs, potential Reclamation applications of the T-Hawk and cost-benefits associated with the use of the T-Hawk (refer Section 1 for more information). As the project progressed, it became apparent that although identifying potential Reclamation applications of the T-Hawk was important, the needs of potential Reclamation UAS users included a more in depth understanding of the policies and procedures relating to the use of UAS by Reclamation. As a result, this document does not just focus on the T-Hawk, but includes information to guide potential Reclamation UAS users on their responsibilities when it comes to planning UAS missions for Reclamation.

T-Hawk Capabilities

The T-Hawk has a number of capabilities that stand out in comparison to fixed-wing UAS – it has the ability to loiter around a point (i.e. hover and stare), and has a gimbal for camera/image stabilization. The standard optical and infrared cameras available on the T-Hawk are generally insufficient for Reclamation needs, however, high definition optical cameras with 12MP or better capability have recently become available (Section 2 discusses T-Hawk technical specifications). Air density will affect flight and an increase in density altitude will affect the amount of fuel the T-Hawk can carry during flight and therefore decrease maximum flight time. The T-Hawk is likely to experience high altitude flight performance degradation at least 19 Reclamation dams, with the T-Hawk unable to fly at Platoro Dam due to operational performance issues at that altitude. Some flight degradation may be possible for any dam above 2000 feet (refer to Section 5 for more information on high altitude operational constraints).

Regulatory Constraints

In the US, a UAS pilot/operator, including small UAS, cannot go out and fly their UAS in an ad hoc fashion. They must abide by federal regulations with regards to operating a UAS in the US National Airspace System. In addition, the Department of Interior (DOI) has its own set of regulations and guidance for operation of UAS by DOI agencies, bureaus and offices. These regulations must be followed by Reclamation UAS users (refer to Section 3 for more information on UAS regulatory information). Any Reclamation personnel planning to utilize a UAS should familiarize themselves with the DOI and Office of Aviation Services (OAS) policies and guidance associated with UAS. **To ensure Reclamation remains in compliance with current UAS policies and regulations, the Reclamation Property Management Policy Group should be keep informed on all planned usage of UAS services.**

Recommendations from this Study

UAS like the T-Hawk provide an alternative to putting Reclamation personnel at risk during manned flights and have the potential to support Reclamation's many requirements for aerial imagery. A UAS with hover and stare capabilities; and a gimbal mounted high definition camera would be extremely beneficial to Reclamation, particularly when observing specific sections or over small (limited) areas. A fixed-wing UAS may be more appropriate for missions that will follow a linear trajectory over long distances. However, the T-Hawk has some payload restrictions and noise characteristics that must be considered. Additionally, many potential Reclamation UAS operators are unaware of the federal and DOI regulatory limitations associated with the use of UAS. *All Reclamation UAS missions* must go through both the Certificate of Authorization process (through the Federal Aviation Authority) that –for Reclamation UAS Users– includes submitting mission projects plans to the Regional Aviation Manager and Reclamation Aviation Manager. UAS ***cannot*** be flown for Reclamation purposes unless appropriate authorization is given by both DOI and the FAA.

Privacy issues will need to be considered when planning any Reclamation UAS mission. To avoid privacy issues a mission should be planned entirely over public lands and images of private property should not be taken unless written permission is given by private land owners.

Recommendation: Ensure appropriate UAS mission scoping is conducted. Expected flight altitude, photogrammetric specifications, privacy concerns and regulatory restrictions should all be addressed during mission planning.

Recommendation: To avoid unauthorized Reclamation use of UAS, Reclamation employees should be informed of their responsibilities and regulatory limitations when it comes to flying/operating UAS and appropriate UAS mission approval must be obtained (e.g. official memo).

With current payload considerations/restrictions, the T-Hawk may be most suitable for emergency response and media services purposes. For emergency response, rapid deployment of a T-Hawk, such as rapid response after an incident (e.g. after an earthquake), may be most beneficial. Use of the T-Hawk is likely to be most appropriate for special or cursory examinations, such as immediately after an earthquake or a near overtopping dam, when it may be difficult or unsafe for climb teams to access the dam. In terms of media services, the T-Hawk could be very useful for photos of dams, especially for photos requiring entry into a gorge or canyon. Currently, helicopters may not be provided sufficient access or space in these areas, and the T-Hawk could be used to capture both still images and video safely.

Recommendation: Conduct T-Hawk photogrammetric proof of concept missions for use in dam safety, operations and maintenance, media services, sedimentation and river hydraulics, environmental studies, water operations, etc. Consider mission requirements and determine payload requirements (e.g., high definition camera with at least an 11MP capability; methods to reduce camera vibration).

Although the T-Hawk has hover and stare capabilities that are potentially useful to Reclamation applications –such as dam safety applications– the noise generated by the gasoline engine of the T-Hawk make it less useful for security, law enforcement and environmental activities. Additionally, current imaging payload capabilities on the T-Hawk are not sufficient for some potential Reclamation users, especially those needing to track very small changes in dam faces. A quieter, smaller UAS (e.g. powered with an electric motor) may be more appropriate for security and law enforcement response, and environmental study needs. Electric motor sUAS with hover and stare capabilities, with high definition camera and imaging video capabilities are likely to be much more beneficial to Reclamation.

Recommendation: Investigate the usefulness of other UAS for security, law enforcement, environmental and dam safety purposes.

There was some consensus with those surveyed as to whether the current UAS available to DOI entities are sufficient or the best option for Reclamation needs. There are multiple current and emerging micro UAS technologies that provide the hover capability with high definition camera may be more appropriate for dam safety missions (e.g. Draganflyer; Rotomotion SR20). Many potential Reclamation UAS users would like the UAS to have LiDAR capabilities or LiDAR quality images that can assist with 3D terrain modeling. Access to a UAS with LiDAR capability would have the most cost-benefit to Reclamation. With technology changing so rapidly, it is unlikely that DOI policy will be able to keep up with user needs unless they pursue the option of contracting of UAS services.

Recommendation: Remain informed on any additional access to other UAS other than the Raven and T-Hawk. Maintain collaboration with USGS UAS Project Office, OAS and DOI.

Recommendation: Investigate whether the AgiSoft PhotoScan 3D Modeling Software is sufficient for Reclamation remote sensing post-processing needs.

Recommendation: Investigate whether Structure from Motion techniques can provide 3D imagery of high enough quality to supplement or replace the need for LiDAR data used for Reclamation applications. Investigate accuracy and limitations of these techniques.

There will be initial upfront costs associated with the training of pilots and the establishment of a UAS program. It is also likely that the ongoing maintenance of UAS will be less than that of manned aircraft, and per hour costs during a mission should also be less in comparison to manned flights. Additionally, the cost of certifying UAS pilots will likely be significantly less expensive than obtaining a manned aircraft pilots license. Although the failure rate of UAS is likely to much greater than a manned aircraft, the added benefit is that UAS may provide a safer option for Reclamation employees. Access to a UAS with LiDAR capability would have the most cost-benefit to Reclamation. A UAS with modular payload capabilities would be most beneficial if different types of sensors can be utilized on the one UAS.

Section 1. Background

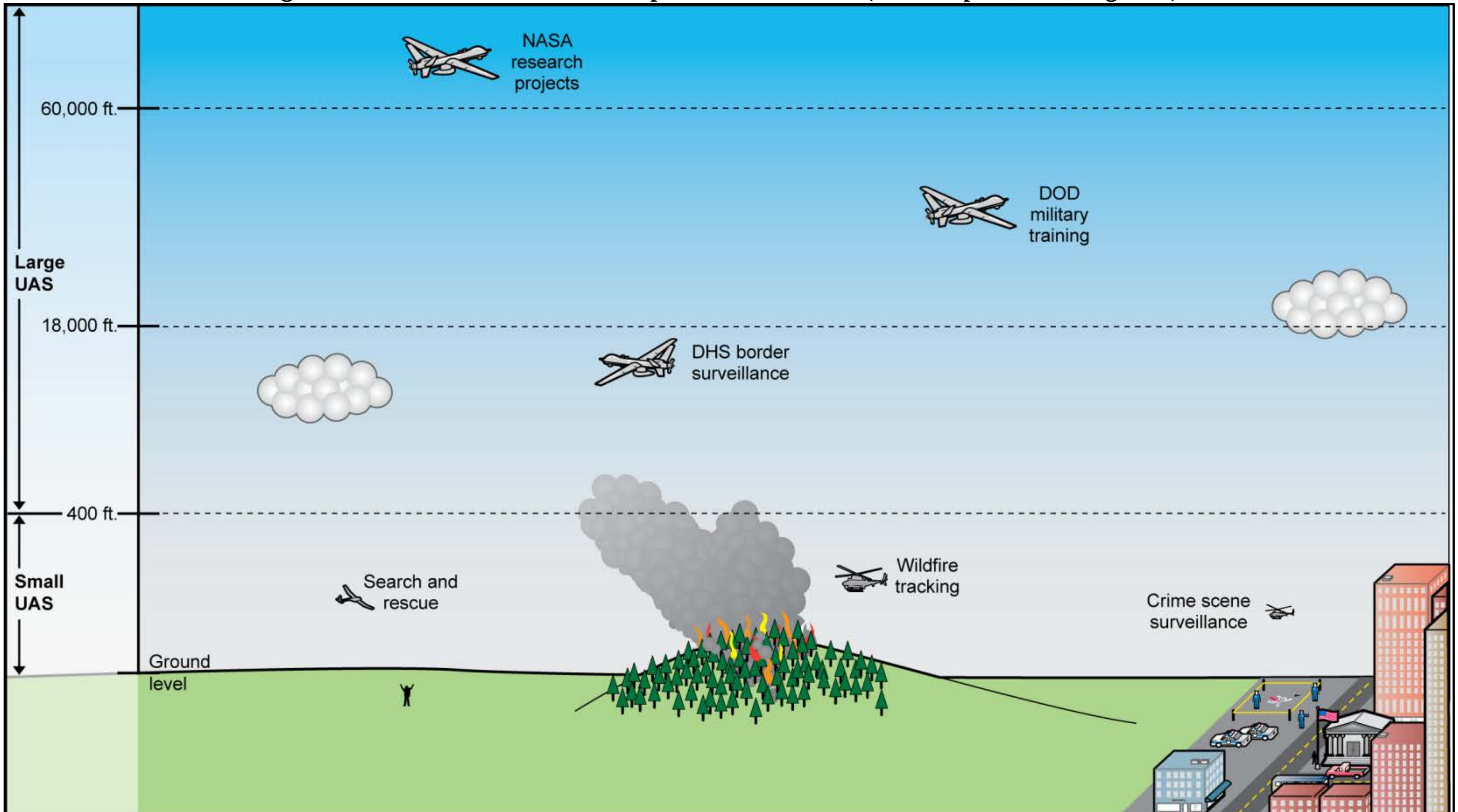
Introduction

Unmanned Aircraft Systems (UAS) were originally developed by the military and first effectively used around WWII (Nyquist, 1997). During the 1980s and early 1990s, a number of factors combined to initiate the development of UAS's for civilian applications (e.g. atmospheric research) (Soddell, 2003). UAS have been significantly developed in recent years with varying size, endurance and payload capabilities (e.g. Micro Air Vehicles such as the T-Hawk to the large-scale military UAS such as the Global Hawk). UAS costs can range from thousands of dollars to millions, excluding maintenance and operating costs. Typically, the smaller the UAS the greater the payload limitations (e.g. payload may be 10-25 percent of the gross weight of the UAS). By the mid 1990s, it was clear UAS with long duration flight capabilities, low operating speeds, and reduced size and cost would be extremely beneficial in filling the gap in atmospheric observations over remote areas. UAS can provide flexibility and observations for remote, sparsely populated, and sometimes dangerous locations. However, one of the greatest difficulties is identifying a UAS and suitable payload combination that meets mission requirements. Smaller UAS can provide a less expensive option, but may not perform the task required (e.g. camera resolution may be too low). It is valuable to perform a mission requirements analysis to identify payload and UAS system requirements.

Figure 1.1 (below) is from GAO Report to Congressional Requesters (2012) and provides an excellent visual summary of examples of current UAS uses and operational altitudes (see next page). There are potential gaps in acquiring remotely sensed data for use by Reclamation, particularly in the isolated, scarcely populated and occasionally hazardous environments. Data collection using satellite and manned aircraft can be problematic and may not provide cost effective and useful information. UAS's may provide the opportunity to fill some of those gaps and, in some cases, may offer a more cost effective alternative to obtaining certain information. UAS <u>may</u> provide options which are more cost effective and reduce the risk to personnel.

The United State Geological Survey (USGS) Unmanned Aircraft Systems Project Office was established in May of 2008 and is located at the Rocky Mountain Geographic Center in Denver Colorado. Their mission is to "[l]ead and coordinate USGS efforts to promote and develop UAS technology for civil and domestic applications that will directly benefit the DOI and USGS missions" (http://rmgsc.cr.usgs.gov/UAS/aboutUs.shtml). Their goal is to help support informed decision-making knowledge obtained from UAS technology. The UAS currently utilized by the USGS UAS Project Office includes the Raven RQ-11A, RQ-16A T-Hawk and MQ-9 Predator B. As part of their mission, the USGS UAS Project Office has obtained a fleet of Raven RQ-11's aircraft and gasoline Micro Air Vehicles, otherwise known as Honeywell Q-16A Tarantula Hawks (T-Hawks). The USGS produced an Unmanned Aircraft Systems (UAS) Roadmap 2010-2025 to specifically "document a strategic framework by which UAS will contribute to the mission of the USGS and the Department of the Interior" (USGS, 2011).

Figure 1.1: Current UAS Uses and Operational Altitudes (GAO Report, 2012; Figure 2).



Source: GAO.

Outline of this Project

Initially the scope of this project focused on investigating Reclamation's current remote sensing needs, potential Reclamation applications of the T-Hawk and cost-benefits associated with the use of the T-Hawk. As the project progressed, it became apparent that although identifying potential Reclamation applications of the T-Hawk was important, the needs of potential Reclamation Unmanned Aerial System (UAS) users included a more in depth understanding of the policies and procedures relating to the use of UAS by Reclamation. As a result, this document does not just focus on the T-Hawk, but includes information to guide potential Reclamation Unmanned Aerial System users on their responsibilities when it comes to planning UAS missions for Reclamation.

The T-Hawk is a small gasoline Micro Air Vehicle (gMAV) with short-range flight capabilities. Originally developed for the military and has frequently been used for combat missions (e.g. reconnaissance, surveillance and damage assessment). The T-Hawk was designed to be suitable for backpack deployment and single person operation. To-date most of the data provided by T-Hawk flights have been collected during military missions.

Research and specialized application needs frequently require the collection of data from dangerous/hazardous, remote and/or sparsely populated locations and may require repetitive monitoring missions. As only a small payload is likely needed for Reclamation purposes, a smaller UAS such as the gasoline T-Hawk may be an economical and beneficial addition to Reclamation's current remote sensing capabilities. This project will identify current T-Hawk payload capabilities (e.g. imaging systems) and help to determine how these payload capabilities can assist in data collection for Reclamation activities. Applications that may help to reduce risk to personnel (e.g. preliminary examinations before the use of climb teams) will be investigated. Use of the T-Hawk is likely to be most appropriate for special or cursory examinations, such as immediately after an earthquake or a near overtopping dam, when it may be difficult or unsafe for climb teams to access the dam. The T-Hawks unique vertical launch and land capabilities, and ability to hover and persistent stare <u>may</u> provide unique and innovative solutions to Reclamation needs, particularly when it comes to small area photogrammetric projects, preliminary damage assessments and dam examinations.

This project may lay the groundwork for the use of the T-Hawk for specific Reclamation applications, which ultimately should be of benefit to Reclamation water and power facility managers and stakeholders. The project should also help potential users understand their regulatory responsibilities when it comes to the use of a UAS by Reclamation. In addition, this project should help inform Reclamation as to whether we should request DOI assign any T-Hawk's to Reclamation and become be responsible for flying our own T-Hawk(s), or whether it is more cost effective to use USGS to work with the USGS conduct specific missions. Currently, the USGS Project Office is funded to conduct proof of concept (research and development) missions. Once a concept has been proven then a mission will be considered operational and a DOI entity can choose to (1) fly their own missions; (2) reimburse the USGS UAS Project Office or other DOI bureau of office for flying any missions; and –to be available in the near future– (3) taking advantage of the UAS data services contract USGS is putting together with the Office of Aviation Services (OAS) (*Pers. Comm. – email*, Hutt, M., Feb 21, 2013). The potential implications of UAS Federal Aviation Authority (FAA) and DOI regulations and flight restrictions (e.g. the Certifications of Authorization application and review process) are also discussed in this document.

Using the T-Hawk may help to better fulfill the Reclamation mission to manage, develop, and protect water and related resources in an environmentally, and economically, sound manner is in the interest of the American public. Improving safety for Reclamation employees may be another benefit. The T-Hawk may be a safe alternative to risking human life (e.g. initial assessment in dam inspections and assessments avoiding the need to have employees scaling potentially unstable dam walls).

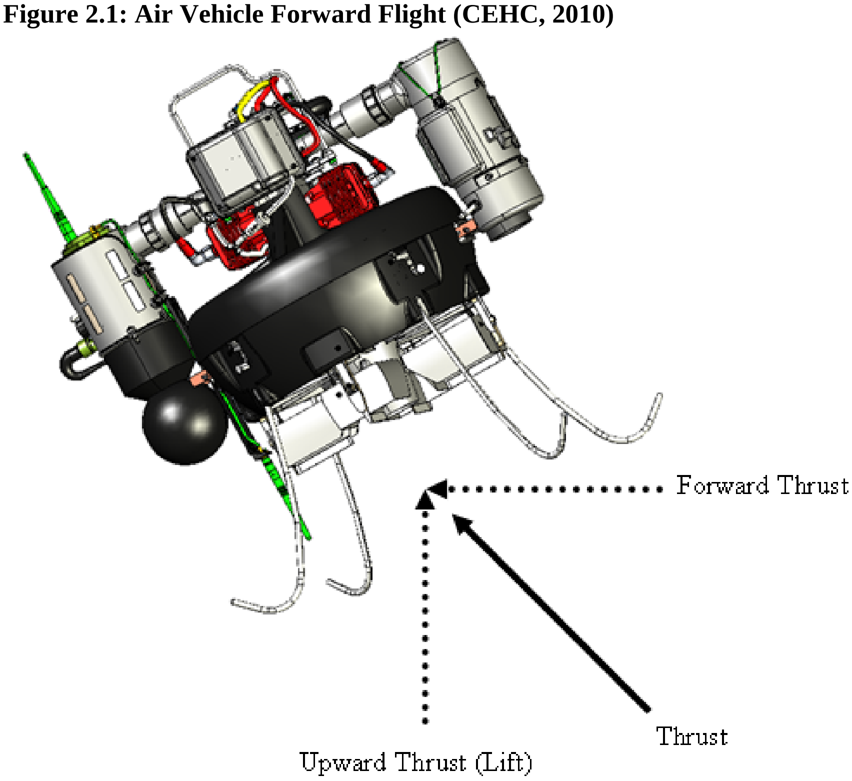
This is a scoping project that will document findings and make recommendations on how, or whether, to proceed with the use of the T-Hawk. One of the purposes of this scoping project is to ensure those who would like to use the T-Hawk are well informed on its specific capabilities and limitations. The ultimate aim of this proposal is to help understand and guide Reclamation in the use of UAS for Reclamation purposes.

Section 2. The T-Hawk Gasoline Micro Air Vehicle

Flight and System Characteristics of the T-Hawk

The T-Hawk is a gasoline engine Micro Air Vehicle with vertical take-off and landing capabilities and 40 minutes maximum endurance. The T-Hawk can be deployed in 10 minutes. The entire system fits into a portable carrier (the T-Hawk can be carried in a large backpack). It uses unleaded aviation fuel and a lithium battery for power and flies by means of vectored thrust using a Lift-Augmented Ducted Fan (LADF). "The ducted fan pushes air downward to produce thrust and uses the four control vanes below the duct to redirect airflow. A portion of the thrust is used to generate lift to keep the [Air Vehicle] airborne while the remaining thrust can be employed to propel the AV in a specified direction" (CEHC, 2010).

Figure 2.1: Air Vehicle Forward Flight (CEHC, 2010)



The T-Hawk is capable of manual, semi-autonomous and autonomous flight, with automatic launch and recovery (CEHC, 2010, p9). With the manual mode of flight the pilot directly operates the aircraft using a handheld manual piloting control box/unit, with no intervention from a computer. In the semi-autonomous flight mode, the pilot controls autopilot loop commands such as altitude, speed, direction and the autopilot maintains the control values. A semi-autonomous mission may also be a combination of both autonomous and manual flight (e.g. sections of the flight may be completely controlled by the computer while other sections of flight are manually controlled by the pilot). In the autonomous flight mode, a pre-designed flight plan is controlled by a computer but can be monitored and modified by an operator during flight. It is also possible for an operator to reprogram and re-task the T-Hawk during flight (CEHC, 2010, p5). Should GPS communications be lost the T-Hawk can automatically return to a predetermined location (e.g.

rally point, recovery point, last known link) or simply ascends until link it re-established (CEHC, 2010).

Manual flights are most useful when a detailed search is required. The T-Hawk can also perform a loiter maneuver permitting it to hover in the same position. The T-Hawk capability to hover and stare at vulnerable locations capability (e.g. targetable areas of interest) may be one of most use to Reclamation.

When T-Hawk take-off is at 8000ft, the maximum flight altitude of the T-Hawk is 500ft above ground level (AGL). Default low altitude for autonomous flight is 100ft (Honeywell, 2010, pN6-2). T-Hawk flight altitudes of less than 100ft AGL are typically flown in manual mode. Currently the T-Hawk can operate to a limit of about 5 feet above the surface (operational altitude) during manual flight (CEHC, 2010).

The T-Hawk uses a Global Positioning System for Guidance (GPS) and has a portable line-of-sight (LOS) Reconnaissance and Surveillance System (CEHC, 2010). To obtain near-real-time images the T-Hawk must stay within LOS of the Operator Control Unit (CEHC, 2010). The T-Hawk cannot be controlled manually once it is no longer within Line-of-Sight (LOS). Additionally, regulations require that a UAS be in LOS at all times during a mission (refer to Section 3 for more information). LOS is not needed for the autonomous flight mode. Before programming a flight path to the OCU, a T-Hawk operator should perform a detailed map reconnaissance (i.e. review the area the flight will occur) of the area the T-Hawk will be operated in (CEHC, 2010, p11). This is to ensure the pilot understands the terrain and potential problem areas. It should be noted this will not replace the need for LOS with the UAS during flight.

The Operator Manual, including pre-flight checklists, should be followed while operating the T-Hawk to ensure safety. This will reduce the risk to UAS users and any potential risk to the general public. Some of the safety concerns when using the T-Hawk are related to the use of unleaded aviation gasoline and lithium batteries for power. Proper hazardous materials precautions should be taken when handling gasoline. The use of gasoline may be a problem should the UAS crash, as there is a greater potential for ignition of the fuel. In addition, lithium batteries also have a small potential for fire upon any deficit in/destruction of the lithium battery casing.

Launch and Landing

An ideal launch and landing site would include no overhead obstructions (such as powerlines). A100ft by 100ft clearing is preferable for launching the T-Hawk. This will provide a large enough area so that any wind drift during take-off and landing (CEHC, 2010, p14).

System Weight

The total system weight of the T-Hawk is approximately 110lbs. This includes:

- Two Air Vehicles
- Ground Control Station (also known as an Operator Control Unit);
- Ground Data Terminal; and
- Support Equipment, including both an EO and IR camera (Honeywell, 2010, p3-2; CEHC, 2010, p5).

One T-Hawk consists of a center body, avionics pod, and two payload pods – an Electro-Optical (EO) Gimbal and an Infrared (IR) Gimbal (Honeywell, 2010). For more detailed information on the total T-Hawk system, including the Air Vehicle, Ground Control Station and Support equipment refer to the Operator's Manual for Flight Operations (Honeywell, 2010, Section 3).

Weather and Environmental Conditions Affecting Operation

The T-Hawk will continue to operate effectively in up to 0.5 inches of rain per hour, and in blowing sand and salt fog (CEHC, 2010, p6). High winds, "heavy precipitation, and heavy obscurants will seriously degrade system performance" (CEHC, 2010, p7).

The T-Hawk can fly in winds of up to 20 knots and takeoff in winds of less than 15 knots (CEHC, 2010, p5; Honeywell, 2010, pN6-1). However, if flight wind conditions include gusts less than 20 knots but are greater than 15 knots, then landing the T-Hawk should be considered (Honeywell, 2010). When wind gusts are greater than 15 knots the "hover look-around waypoint should not be used" (Honeywell, 2010, p2-10). The Operator's Manual recommends the use of the Kestrel Weather Tracker before, during and after flight. This is specifically to provide for real time weather monitoring. The two measurements essential to T-Hawk operations are: density altitude and wind speed. Density altitude is important as with an increase in density altitude there will be a corresponding decrease in the amount of thrust produced by the T-Hawk. High wind conditions can adversely affect the ability of the T-Hawk to fly (Honeywell, 2010, pN6-5). "In hot and humid conditions, the density altitude at a particular location may be significantly higher than the true altitude" (CEHC, 2010, p25). "The density altitude can affect both the efficiency of the propeller and the power output of the engine" (CEHC, 2010, p25).

System Limitations

The higher the density altitude the less thrust is produced by the T-Hawk. An increase in the density altitude will limit the amount (load) of fuel/weight the T-Hawk can carry during a flight. This will also have a negative impact on the flight time. The T-Hawk Operator's Manual Table 5-7: E-Fueler Fuel Load Calculation (Honeywell, 2010, pN5-17) provides a breakdown of Fuel Load, Density Altitude and flight time.

Table 2.1: Fuel Load Calculation (Honeywell, 2010, pN5-17).

DENSITY ALTITUDE	FUEL LOAD	TIME (MINS)
<7700ft (2286 m)	100%	40
>7700 and 8300ft (2500 m)	80%	32
>8300 and <8900ft (2713 m)	60%	24
>8900 and 9600ft (2926 m)	40%	16

Although specifics on the attrition (loss) rate of the T-Hawk were unavailable, UAS platforms have notoriously high attrition rates in comparison to manned aircraft. The engines and motors of UAS platforms are not required to go through the same rigorous testing process that manned aircraft do. The attrition and engine failure rates of UAS platforms, and subsequent risk to public safety was one of the causes for FAA concern and one reason commercial UAS flight was restricted in the US in 2005.

Communications Limitations

There are typically two ways for a UAS to communicate with the operator: Radio and Satellite. Both of these have their own advantages and disadvantages. UAS radio communication does present some problems with the initiation of radio frequency bandwidth constraints. Satellite communications allow for over-the-horizon operations (not currently permitted in US airspace at this time).

Payload Capabilities

Interchangeable surveillance payload pods (sensors) on the T-Hawk include a gimbaled Electro-Optical (EO) and Infrared (night) cameras. Typically a gimbal provides a pivoted support that allows pan and tilt, but not usually roll, of the camera during flight. Some of the earlier T-Hawk gimbals only had tilt and the operator would have to provide for pan. When the gimbal is stabilized this helps the camera to remain steady and reduces platform motion, providing a more stable image.

The T-Hawk can be configured with either the EO Camera or the IR Camera (see Figure 2.2), but not both at the same time (CEHC, 2010, p7). The EO camera has optical zoom capabilities to 10x, with a field of view (FOV) ranging from 5º to 46º and resolution of approximately 0.379 Mega Pixels. At zoom 5x and above, the EO camera's performance will degrade (CEHC, 2010). The IR Camera has 4x digital zoom capabilities. The FOV is 18º and the resolution is approximately 0.77 Mega Pixels. The EO Camera can also transmit live color video images. The "operator can take a snap shot, capture video, transfer and store it and /or download MAV video to a storage device" (CEHC, 2010, p22). Analysis of the ground resolution capability of the standard EO and IR can be found in Figures 2.3 and 2.4 (next page).

Figure 2.2: The T-Hawk (T-Hawk) and Camera Payloads (from USGS, 2011A).

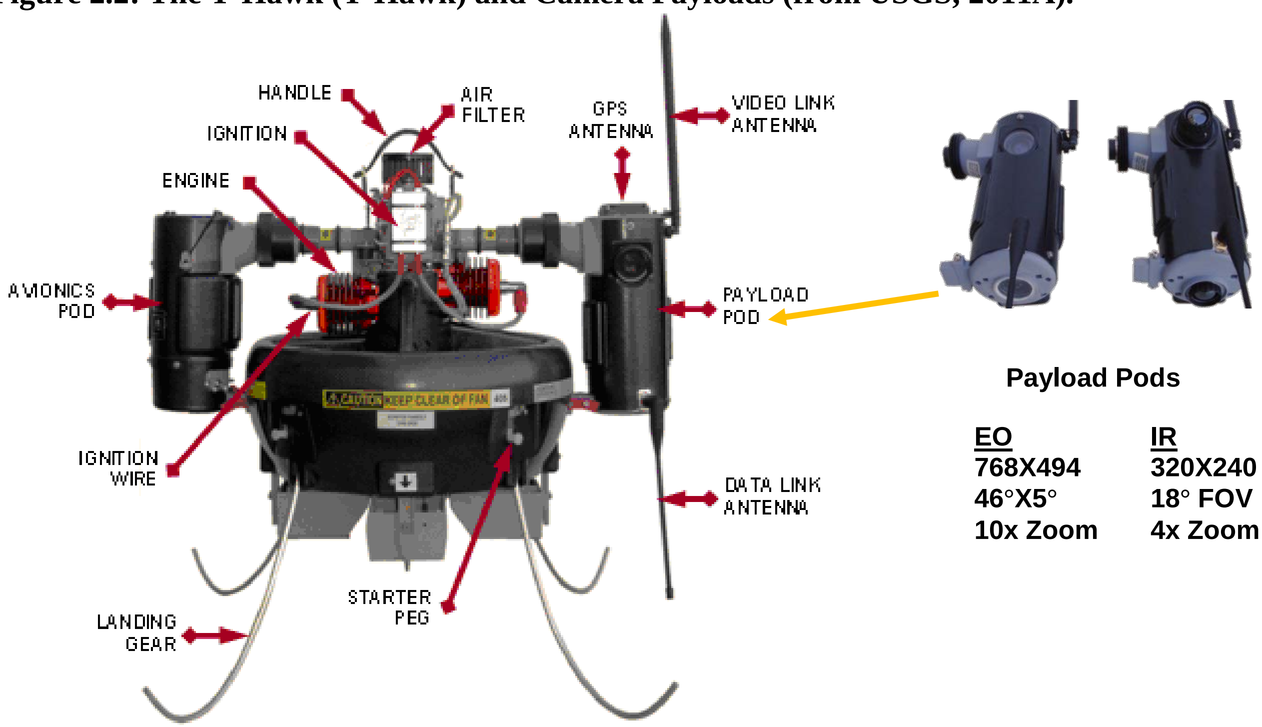


Figure 2.3: Ground Resolution Capability of T-Hawk Electo-Optical Camera for Different Fields of Vision (FOV)

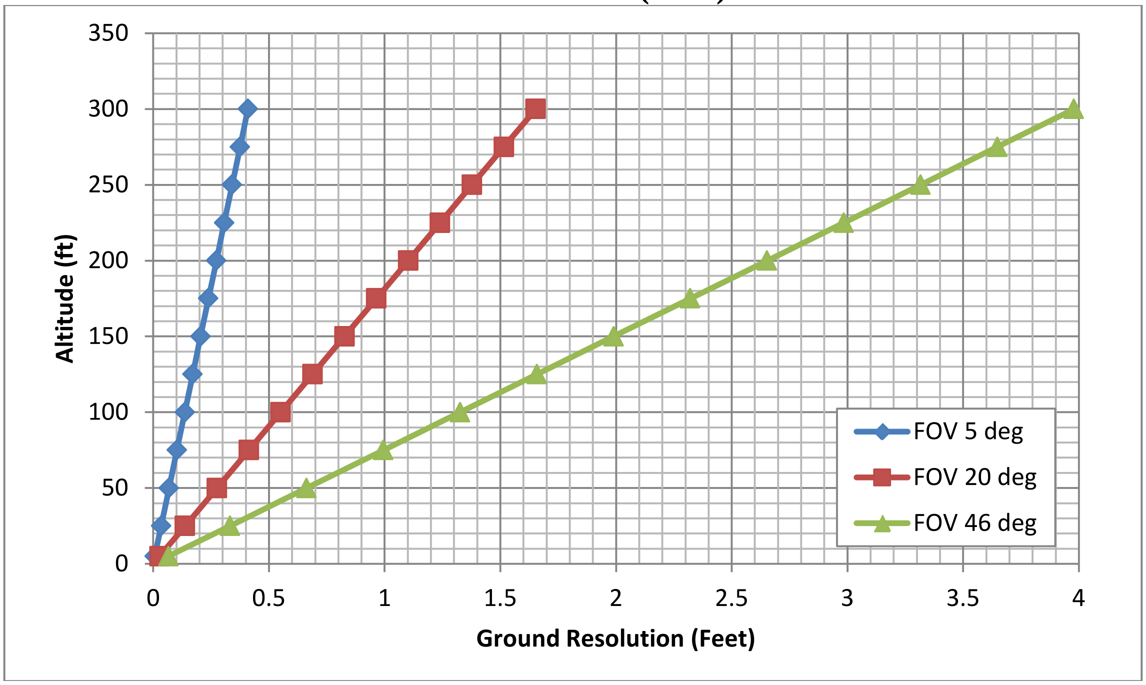
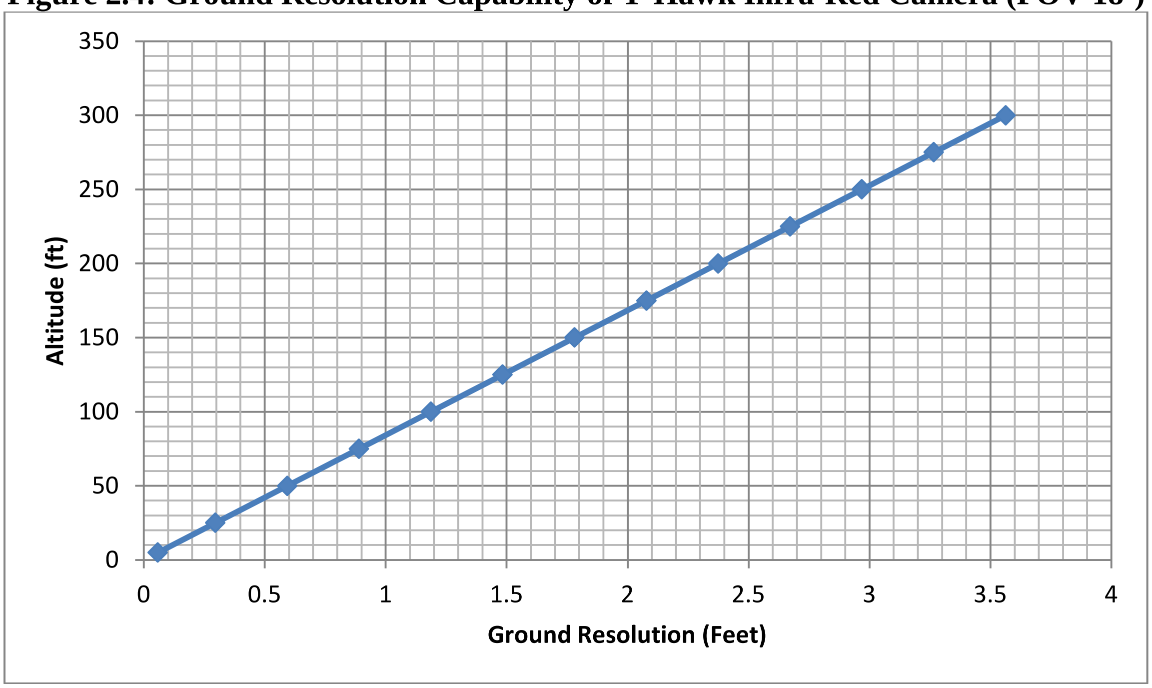


Figure 2.4: Ground Resolution Capability of T-Hawk Infra-Red Camera (FOV 18º)



Near Future T-Hawk Payload Capabilities

A radio telemetry sensor has been developed for the Raven but has not been flown on the Raven to-date. There is also the potential of chemical and gas detector payloads for use on the Raven and T-Hawk. At this stage, COAs have not been requested for flight with the chemical and gas detector equipment.

The most recent Elwha River Raven UAS flight (September 2012) utilized the GoPro Hero 2 camera with 11MegaPixel imagery. This resolution provided excellent detail. The expectation is that this GoPro Camera will be utilized on future T-Hawk flights.

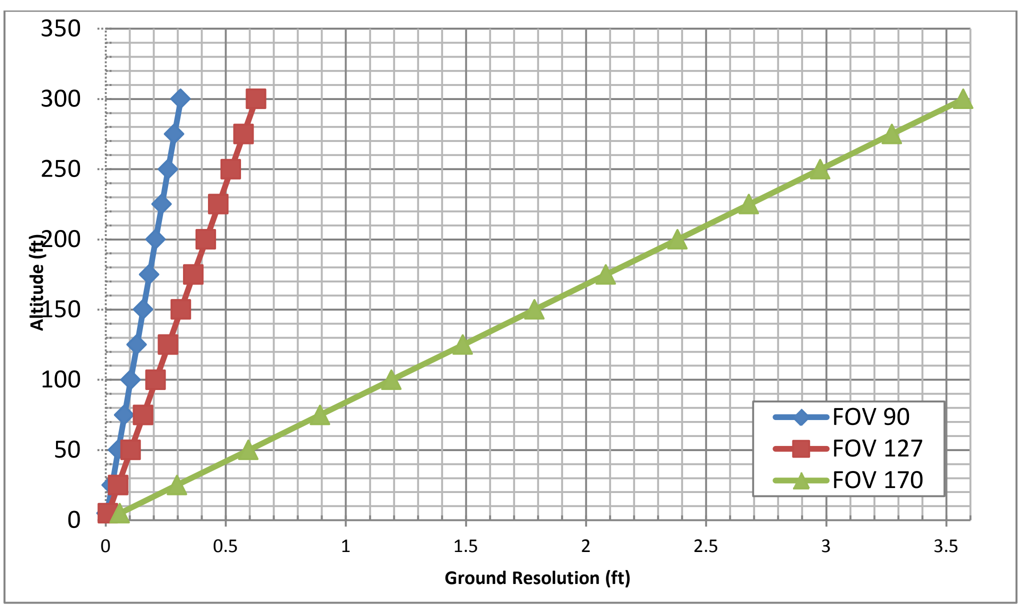
Go Pro Hero 2 and 3 Technical Specifications

The Go Pro Hero 3 camera (most recent Go Pro camera currently available as of January 2013). Information provided from the GoPro website http://gopro.com/product-comparison-hero3-cameras). The Go Pro Hero 3 has better specifications again, in comparison to earlier versions of the GoPro. Photo resolution is 5-12 MegaPixels depending on the version of GoPro Hero 3 you choose.

The GoPro Hero 2 was previously used by USGS and has field of view (FOV) capabilities ranging from 90º (narrow), 127 º (medium) with resolution of up to 11 Mega Pixels (1080p), and 170º (ultra wide) at a resolution of 720p or 960p. At a maximum (for lower resolutions) this can be at 30 frames per second and a 15 Mbit per second data rate. The 1080p video resolution for 1080p has 1920×1080 pixels (16:9) (refer to Figure 2.5 for analysis of the GoPro2 ground resolution capabilities). One of the disadvantages of the Go Pro 2 is that when the camera is placed on the T-Hawk it has the potential to limit the range of motion of the gimbal. However, the Go Pro Hero 3 has been released and is considerably smaller and lighter so this is likely to no longer be a problem.

The GoPro Hero 2HD does not have GPS but positional information can be incorporated onto the image during post-processing. In addition, a fisheye affected may occur when using the wide field lens (Hutt and Sloan, 2012). There are other cameras that have this GPS capability (e.g. Canon PowerShot DS 100 or FX 230) (*Pers. Comm.*, L. Brady, March 1, 2013).

Figure 2.5: Ground Resolution Capability of the GoPro Hero 2 Optical Camera



It should be noted that BLM has flown the GoPro camera on the T-Hawk and found the vibration from the T-Hawk is difficult to obtain good photogrammetric level images (e.g. orthoimages for DEM) (*Pers. Comm*., L. Brady, March 1, 2013). This may be a problem for all UAS that have the hover capability, although the gasoline engine of the T-Hawk may intensify the problem in comparison to an electric motor UAS (Pers. Comm., L. Brady, March 1, 2013). Camera rolling shutter sensor can cause these problems. There are solutions to help minimize the impacts of this vibration (e.g. sophisticated camera mounts).

Technical Specifications of the T-Hawk

The T-Hawk's characteristics are summarized in Table 2.2 (below – adapted from CEHC, 2010, p6 and Honeywell, 2010). There is a more recent upgraded version of the T-Hawk but is currently not available for use by the USGS.

Table 2.2: Technical Specifications of the T-Hawk

PARAMETER	CHARACTERISTIC
Diameter	23.5 in w/ pods (14.5 in w/o) (the T-Hawk has 4 payload pods)
Height	23 in w/ landing gear (18 in w/o)
Total System Weight (2 AVs, 1 OCU, 1 GDT, Support equipment	110+ lbs
Weight (dry)	17.2 lbs (w/ EO camera) / 17.5 lbs (w/ IR camera)
Fuel Capacity	2.2 lbs
Flight Duration	~40 minutes, less with reduced fuel for higher altitudes (16 mins at 9600ft).
Operating Ceiling	7700 ft density altitude (full fuel load) 9600 ft density altitude (reduced fuel load)
Flight Altitude (min)	50 ft (autonomous), 5 ft (manual)
Air Speed (max)	45 mph (72 kph) (manual flights limited to 6 mph) Max. forward speed is 70 knots but software restricts operational max. airspeed to 50 knots.
Descent Rate (max)	5 ft/s (1.5 m/s)
Climb Rate (max)	10 ft/s (3.0 m/s)
Range (max)	1.2 miles (2 km) line of sight (LOS)
Winds (max)	15 knots (takeoff/landing), 20 knots (aloft)
Battery	55 minutes (rechargeable)
Navigation	GPS, IMU, pressure altimeter, magnetometer
Communication	Data link radio and video link radio
Communication Channels	8 selectable channels
EO Camera Resolution	768 x 494 pixels (0.379 Mega Pixel)
IR Camera Resolution	320 x 240 pixels (0.077 Mega Pixel)
EO Camera FOV	46^{o} to 5^{o} (10x optical zoom)
IR Camera FOV	36^{o} (2x digital zoom)
Operating Temp	20^{o}F to 120^{o}F (-6^{o}C to 49^{o}C)
Storage Temp	0^{o}F to 160^{o}F (-18^{o}C to 71^{o}C)
T-Hawk Video and telemetry data onboard storge	10 minutes (stored imagery can be transmitted to the ground station)
GDT video and telemetry data storge	Up to 60 minutes

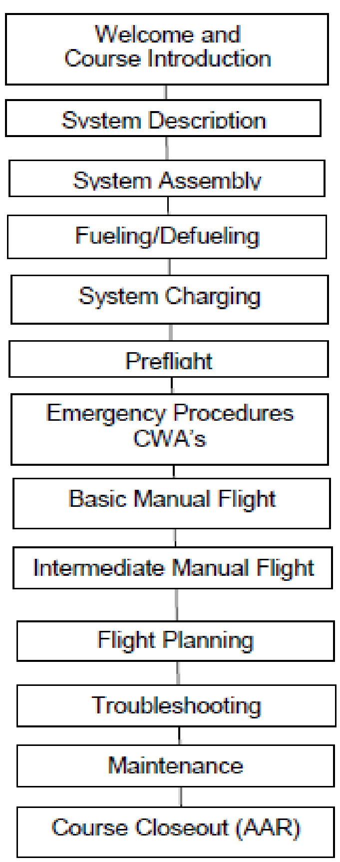
DOI UAS Training

Advanced training would be essential in ensuring successful complex missions and to fully understand the T-Hawk’s capabilities. For Reclamation and other DOI agencies this training is provided by the Aviation Management Division (AMD), now known as the Office of Aviation Services (OAS). The OAS is part of the DOI National Business Center and provides Interagency Aviation Training related to aircraft operations (https://www.iat.gov/). In addition to information on on-site and online training courses, this website provides other information including policy and training requirements, and a resource library with Handbooks, Guides and booklets.

As UAS comes under the responsibility of OAS, potential DOI UAS pilots must complete the required UAS training before they will be permitted to fly a UAS over DOI lands (DOI can self-certify personnel). Interagency Aviation Training (IAT) includes specific UAS operator training for the RQ-11A Raven and T-Hawk. This UAS includes basic, advanced and refresher courses. At this time four UAS courses are offered by the IAT: Small Unmanned Aircraft System (sUAS) Basic Operators Course (A-450); Raven sUAS Refresher Training (A-452R); T-Hawk Small UAS Operator Add-On Course (A-454); and Overview of small Unmanned Aircraft Operations (A-455). Participants sign up for the UAS Training Courses on the Interagency Aviation Training website. The Course list can be found at https://www.iat.gov/Training/course_list.asp.

A-454 T-Hawk Add-On

Course Map



Small Unmanned Aircraft System Basic Operator Course (A-450): This course includes training similar to that used by the US Army to train their Raven small UAS Operators. By the end of this course participants are qualified to perform the duties of a RQ-11A Raven UAS pilot, mission controller and observer. This is a two week course and must be conducted prior to T-Hawk small UAS training. A current Class II FAA medical is required before you can qualify as a DOI UAS pilot. Bureau approval is required before participants will be permitted to attend the training.

Raven sUAS Refresher Training (A452R): This course if for previously trained and qualified RQ-11A Raven operators. It is designed to refresh Raven pilot skills and re-qualify to operate the Raven UAS.

T-Hawk Small UAS Operator Add-On Course (A-454): The Small Unmanned Aircraft System Basic Operator Course (A-450) is a prerequisite for the T-Hawk Small UAS Operator Add-On Course. The A-450 course must be completed prior to enrolling in this course. This course is limited to only those who have an immediate mission need. The Bureau Aviation Manager (for Reclamation this is (S.) Jim Keiffer, Section Manager Property Management Policy Group) must provide approval before participants will be permitted to take the course.

Overview of small Unmanned Aircraft Operations (A-455): This course is aimed at managers and those who want a better understanding of the history and application of UAS. It details the operational capabilities and limitations of the current DOI sUAS fleet, and the requirements needed for operating sUAS in national airspace. It is NOT an operator's course and will only provide an overview of UAS. The course map on the previous page is from the participant workbook from the A-454 Honeywell T-Hawk SUAS Add On Course.

Topics included in both the Raven and T-Hawk Training: System description, assembly, charging and fueling; manual and autonomous flight; flight skills, emergency procedures; airspace management; aviation safety; crew coordination; and flight planning. The second day of T-Hawk training includes simulator practice and three days of field experience (see Appendix C for the T-Hawk training schedule).

UAS Pilot Training, Certification and Currency

Recertification is needed to continue the professional development of UAS operators. According to OPM 11-1, all potential DOI UAS pilots or mission operators must complete the DOI OAS UAS training (OPM 11-11 p4). This training was modeled on the military small UAS training. To become certified to fly the T-Hawk you must complete both the Raven UAS and T-Hawk UAS training course provided by USGS in Boise. There may also be the option of on-site training if there is enough of a demand at or near a specific location. A Class II FAA Medical Examination is also required before flying a UAS. This is a FAA requirement for commercial aircraft operations. Additional approvals must also be granted before permission to fly a DOI UAS will be granted (see Section 3 on Regulatory Limitations for more information). Refer to OPM 11-11 Section 6 for UAS pilot requirements.

The DOI requirements for pilot currency are based on current FAA standards and regulations for pilot currency of 3 takeoffs and landings in Category, Class and Type aircraft within 90 days (Raven and T-Hawk). See attached DOI Operational Procedure (OPM) policy Memorandum No. 11-11 for DOI Use of Unmanned Aircraft Systems (UAS) (Section 6. F) (*Pers. Comm.*, Swoboda, K., Sept 26, 2012). The lack of opportunities to fly UAS is one of the reasons for the DOI recertification requirement to stay current as a UAS pilot. Recertification can be completed on a simulator.

UAS Operational Safety Considerations

The FAA is still to define an acceptable loss (failure) rate for UAS. "High mishap rates are frequently cited as a deterrent to more widespread adoption of UA[S]" (DOD, 2004). Aircraft reliability and cost are closely coupled (DOD, 2004; DOD, 2005). A great deal of investment has been made in improving manned aircraft reliability so as to reduce equipment failures and the implication is that more investment in improving UAS equipment reliability can help to reduce failures and mishaps (DOD, 2004). McCauley (2004) stated that "accurate data on UAV reliability are difficult to obtain". However, there is sufficient information to easily determine the manned aircraft loss rate is several times smaller than that for UAS (McCauley, 2004). However, gasoline engines are typically prone to more problems than electric propulsion motors. Provided electric motors are operated within the specifications –batteries are sensitive to low temperatures– there is not as much that can go wrong as with an engine. There are many things that can go wrong with an engine (e.g. problems with carburetors, fuel to air ratio particularly at higher temperatures and altitudes, carbon build-up in engine).

Human error and equipment failure are two of the primary reasons for UAS aircraft loss rates. The lack of UAS operator experience can contribute heavily to loss rates. Human errors usually occur during UAS take-off and landing. According to the DOD (2004) the autonomous take-off and landing features of some UAS may prove more reliable than manual stake-off and landing. Another contributing factor to unreliability is maintenance experience (or inexperience). The DOD (2004) report states more system reliability is needed, particularly with the larger more costly UAS. These larger UAS have the potential to cause more destruction and fatalities upon failure.

The DOD (2004) report provides statistics on UAS mishaps versus aircraft mishaps (DOD 2004, Table 3.1). These statistics were for mishaps that cost more than $1 million or more in damages and/or involved destroyed aircraft and/or fatality(ies) and/or permanent total disability. Therefore, these were mishaps that involved larger UAS (i.e. Predator, Pioneer and Hunter) and military and regional commuter aircraft, and general aviation. Table 2.3 (below) is from the DOD (2004, Table 3.1) report. According to the USGS UAS Project Office, it is difficult to find documentation on the safety of sUAS or property damage resulting from sUAS failures (*Pers. Comm. – email*, M. Hutt, Feb 27, 2013). Unless someone dies, suffers from a serious injury or property damage occurs as a result of an accident involving a sUAS the National Transportation Safety Board does not track UAS accidents for UAS under 300 pounds (http://www.ntsb.gov/doclib/legal/ntsb_830_revision_aug2010.pdf, p **51954**).

Table 2.3: UAS and Aircraft Mishaps (per 100,000 flight hours)

UAV Mishaps	Aircraft Mishaps
Predator – 32*	F-16 – 3
Pioneer – 334*	General Aviation – 1
Hunter – 55*	Regional Commuter – 0.1
* much less than 100,000 flight hours	Large airliners – 0.01

According to McCauley (2004), a 2002 DOD study found that the Mean Time Between Failures (MTBF) for the Predator , Pioneer and Hunter were 44, 14 and 11 hours , respectively. The reliability of the Predator was determined to be 92%; the reliability of the Pioneer was determined to be 86%; and the reliability of the Hunter was determine to be 82%. There is no data available on smaller UAS. However, the MTBF results from actual observations collected during Naval Postgraduate UAS experiments appear to compare to the DOD 2002 results (McCauley, 2004). McCauley (2004) found that mishaps may typically occur once every 16-24 hours. Furthermore, McCauley (2004) documented a discussion with experienced small UAS operators and in their opinion the average airframe life is approximately 20 hours. Additionally, Mouloua, Gilson, and Hancock (2003) reported that "NATO lost 20 to 30 UA[S] during the 78-day Kosovo air operation. Although the percentage of these that were shot down was not reported, this rate of loss equates of once every 2.6-3.9 days. This loss may be substantially less when used for civilian purposes. It is reasonable to assume that mishaps do occur quite frequently and these mishaps and expected airframe life duration could be a problem for Reclamation should we pursue a request for UAS to be allocated to Reclamation.

The DOD (2004, p19) reported that the causes of UAS mishaps were mainly the result of: Power and Propulsion (37%); Flight Controls (25%); Human Error (17%); Communications (11%). The additional 10% of causes fell under miscellaneous. According to Thompson and Tvaryanas (2005), another DOD UAS Reliability study by the Office of the Secretary of Defense issued in 2003, reported that the "the proportions of human error-induced mishaps are nearly reversed between UASs and the aggregate of manned aircraft, i.e., human error is the primary cause of roughly 85% of manned mishaps, but only 17% of unmanned ones" and that it was the three areas of power/propulsion, flight control, and operator training that, in the past, have accounted for approximately 80% of reliability failures.

Two critical hazards associated with UAS operation were identified by Weibel and Hansman (2004). These hazards are:

- UAV impact
- Midair Collisions

Weibel and Hansman, 2004 assessed safety considerations associated with UAS operation. One of these considerations was analysis of the potential threat to human life associated with an uncontrolled UAS ground impact. The model analyzes whether a person will be located where the UAS makes ground impact and whether debris resulting from the ground impact makes it through into the shelter where the person is located. The levels of harm to the public were identified as: none; possible injury or fatality. UAS failures from system failure and human error were considered. Given ground impact of a UAS, preliminary probabilities of debris penetration into the shelter where a person is located were estimated. The probability of debris penetration was found to increase with increased size of the UAS. For example, a mini UAS such as the Wasp was found to only have a debris penetration probability of 5%. However, a large high altitude UAS such as the Global Hawk had an estimated probability of debris penetration of 90% (Weibel and Hansman, 2004, p4). This indicates the larger the UAS the greater the risk to people on the ground should ground impact occur. This does not consider the likelihood of UAS failure that results in a ground impact.

The equation provided in the Weibel and Hansman (2004) study demonstrates "the expected level of safety of a UAS system with respect to ground impact found fatalities is a function of the mean time between failures of the vehicle system". According to Weibel and Hansman (2004) the large UAV's capable of higher speeds (i.e. high-mass, high-velocity UASs) operation of the UAS in the National Airspace System (NAS) would need to be designed to that the time between failures needs to be greater than 10,000 hours to reduce the risk posed to the public. Smaller UASs pose less of a threat to the public so 100 hours between failures was considered acceptable (Weibel and Hansman, 2004).

Weibel and Hansman (2004) also assess the likelihood of mid-air collisions involving UASs. The FAA has a set a target level of 10^{-9} collisions/hr^3 for manned aircraft. The midair collision risk posed by unmanned aircraft will likely depend on the "region" of NAS where the UAS is being flown (e.g. near an airport, jet routes, victor airways). Weibel and Hansman (2004) were able to develop a preliminary estimate of the risk of UAS midair collision. They found that the "majority of collision risk is concentrated over metropolitan areas with major airports" and a collision risk over well-traveled routes. The overall collision risks did not meet the target level of safety expected of manned aircraft in these NAS regions. Victor airways (i.e., pre-determined routes flown by pilots using instrument flight rules) were also analyzed by Weibel and Hansman (2004) and they found that these also did not meet the target level of safety expected of manned vehicles. Weibel and Hansman (2004) did state that this was a preliminary hazard analysis but they did find it "may be possible to operate small [e.g. micro or mini] UAVs [UAS] in the NAS" provided they were operated away from densely populated areas.

Another safety concern with UAS is the potential a UAS crash has to start a fire. Although this is particularly a concern with the T-Hawk's gasoline engine, it still may be of concern with an electric UAS. If the lithium battery is breached as a result of a severe crash, it may have a potential to ignite when exposed to air. T-Hawk missions may not be able to be conducted over National Park Service lands due to the risk of fire from crash. This may limit missions and flight paths.

Section 3. Regulatory Limitations

In the US, a UAS pilot/operator, including small UAS, cannot simply go out and fly their UAS. They must abide by federal regulations with regards to operating a UAS in the US National Airspace System (NAS). In addition, the Department of Interior has its own set of regulations and guidance for operation of UAS by DOI agencies, bureaus and offices. These regulations are discussed below. Any Reclamation personnel planning to utilize a UAS should familiarize themselves with the DOI and Office of Aviation Services (OAS) policies and guidance associated with UAS. **To ensure Reclamation remains in compliance with current UAS policies and regulations, the Reclamation Property Management Policy Group should be keep informed on all planned usage of UAS services.** The current point of contact is the Section Manager, (S.) Jim Keiffer on 303-445-2044.

FAA Regulations

Concerned with the possible impact to public safety the FAA wanted to ensure that the use of UAS platforms will not in any way endanger the users of the NAS, or the safety of people or property on the ground, the FAA banned the commercial use of UAS in 2005. This ban was put into place to give the FAA time to figure out how to regulate UAS platforms. Until this ban, UAS operators claimed they could operate UAS under the same regulations of model (hobby) aircrafts used for recreation (Advisory Circular 91-57, Model Aircraft Operating Standards) (Elston *et al.*, 2011). The FAA was concerned that UAS may not operate safely among other aircraft, particularly general aviation or “non-cooperative aircraft” (i.e. aircraft that do not broadcast their position) and, therefore, are not being tracked by Air Traffic Control or via a transponder (FAA, 2005). Aircraft confliction occurs when two or more aircraft are sharing the same airspace and are operating too closely to be safe. This is a problem that is difficult to solve with unmanned aircraft, and has the FAA most concerned about safe operation of UAS in national airspace. Even model aircraft operators must ensure deconfliction with other aircraft (manned and unmanned) in their operation area.

In September 2005, the FAA established AFS-400 UAS Policy 05-01. This guidance was used to determine whether a UAS “may be allowed to conduct flight operations in the NAS”. FAA personnel were expected to use this policy guidance when evaluating a Certificate of Authorization (COA). Under this policy, it is considered the COA “applicant’s responsibility to demonstrate that injury to persons or property along the flight path is extremely improbable” (FAA, 2005). The AFS-400 05-01 Policy specifically states that “COA applications for civil UA operations will not be accepted”. The policy requires that civil UA operations should follow the airworthiness certification process in order to operate a UAS platform in NAS.

It was in 2005 the FAA’s Production and Airworthiness Division (AIR-200) started processing Special Airworthiness Certificates for experimental UAS platforms (FAA, 2006). The process was long and tedious, and very few applicants have been granted approval to fly. The FAA Unmanned Aircraft Program Office (AIR-160) was established in February 2006. The FAA was particularly concerned that certification of the UASs "must not degrade the current level of safety within the NAS" (FAA, 2006).

Regulations and Policies for Unmanned Aerial Systems

Current Rules for UAS Operation

The FAA considers UAS "aircraft" and only aircraft certified as air-worthy can operate in national airspace (AUVSI, 2012). There are currently no FAA standards to certify UAS and therefore are considered not able to operate safely in the NAS. Model aircraft are exempted from current FAA UAS restrictions. There is some FAA UAS guidance, including FAA Interim Operational Approval Guidance 08-01 (2008) which provides information on two methods of approval for UAS flight in NAS: certificate(s) of waiver or authorization (COA), and special airworthiness certificates. Currently, this guidance document applies to both civil and public operations of UAS. Public UAS users should use the COA application process and civil UAS users should use the airworthiness certificate. The COA application process is relevant to UAS operation by government departments, including the Department of the Interior. The COA application process is discussed later in this Section.

The FAA does understand that UAS standards for certification are needed and that one-size does not fit all UAS (e.g. a micro UAS does not pose the same risk as a 23,000lb UAS such as the Global Hawk) (AUVSI, 2012). As a result, the agency is trying to provide updated regulations that will not affect safety and put lives at risk. Recently an FAA Bill was passed on February 14, 2012. This bill is known as the FAA Modernization and Reform Act of 2012 (Subtitle B – discusses Unmanned Aircraft Systems: H321/S, H322/S320, 607(a)(b)(d)(e)(f), H323-325/S, H326/S607(c)). It took five years and 23 extensions to get this bill passed (AUVSI, 2012). This bill included language that required the FAA "to safely integrate UAS into national airspace system". This integration is expected to occur by 30 September 2015 (AUVSI, 2012). Included in the bill are deadlines for the FAA. Some of these deadlines are specifically related to insure that provisions are made for: a UAS Roadmap; first responder access to UAS; UAS flight in the Arctic; six UAS test sites; and rules allowing integration of small UAS into the NAS. Current controversy regarding UAS and privacy concerns has already negatively affected some of these deadlines (e.g. selection of UAS test sites).

The AUVSI 2012 webinar presentation states that as part of the FAA Modernization and Reform Act deadlines were identified. These deadlines can also be found in the FAA Modernization and Reform Act of 2012 in Subtitle B (http://www.gpo.gov/fdsys/pkg/CRPT-112hrpt381/pdf/CRPT-112hrpt381.pdf). These deadlines include:

1. Expedited Certificate of Authorization (COA) for Public Use. This specifies COAs for UAS weighing under 25lbs where flight will be under 400ft AGL with Line-Of-Sight (LOS) requirements.

2. Establish six UAS test sites by August 12, 2012 (this deadline was missed in part due to a recent GAO report that discusses privacy concerns associated with UAS surveillance)
3. Develop a plan an initiate a process for designating areas in the Arctic where UAS less than 55lbs can operate 24/7. This would include operation beyond LOS; over water; and to at least 2,000ft AGL. This deadline was by August 12, 2012.
4. FAA developed comprehensive integration plan to safely accelerate the integration of civil UAS into the NAS November 10, 2012.
5. FAA develops 5 year Roadmap by February 14, 2013.
6. Final Rule on Small UAS (i.e. UAS 55lbs or less) by August 14, 2014.
7. Safe Integration of UAS into NAS by September 15, 2015 (AUVSI, 2012).

The documents below can be found on the FAA website. These do not include the most recent FAA Modernization and Reform Act of 2012. More information on FAA UAS regulations and policies can be found at http://www.faa.gov/about/initiatives/uas/reg/.

Title 14 Code of Federal Regulations

- Part 1, Definitions, Civil Aircraft, section 1.1
- Part 21, Certification Procedures for Products and Parts
- Part 21, Subpart H, Airworthiness Certificates, Experimental Certificates, sections 21.191 and 21.193

Advisory Circulars

- AC 21-12, Application for U.S. Airworthiness Certificate, FAA Form 8130-6
- AC 45-2, Identification and Registration Marking
- AC 91-57, Model Aircraft Operating Standards

Forms

- FAA Form 8130-6 (PDF), Application for U.S. Airworthiness Certificate

Orders

- Order 1110.150, Small Unmanned Aircraft System Aviation Rulemaking Committee (ARC)
- Order 8130.2, Airworthiness Certification of Aircraft and Related Products
- Order 8130.20, Registration Requirements for the Airworthiness Certification of U.S. Civil Aircraft
- Order 8130.34 (PDF), Airworthiness Certification of Unmanned Aircraft Systems

Policies

- Federal Register Notice - Clarification of FAA Policy (PDF), UAS Operations in the U.S. National Airspace System
- Interim Operational Approval Guidance 08-01 (PDF), Unmanned Aircraft Systems Operations in the U.S. National Airspace System
- UAS Certification Status, November 15, 2006 (PDF), includes FAA focal points for UAS certification project coordination

- UAS Certification Status, Optionally Piloted Aircraft and Accidents Involving UAS, August 18, 2008 (PDF), Revision to AVS Policy

Guidance

- Interim Operational Approval Guidance 08-01, Unmanned Aircraft Systems Operations in the US National Airspace System (NAS) (http://uas.usgs.gov/pdf/uas_guidance08-01.pdf). This is current guidance.

It is the FAA policies that have guided DOI Office of Aircraft Services –formerly the Aviation Management Division (AMD) – policies on the use of UAS by DOI agencies, bureaus and offices.

Department of Interior (DOI)

Office of Aircraft Services (formerly the Aviation Management Directorate)

The Office of Aviation Services (OAS), formerly known as the National Business Center (NBC), Aviation Management Directorate (AMD), was established in 1973. OAS is responsible for functions related to aircraft services and facilities across DOI. Aviation safety is their primary consideration. Some of OAS's responsibilities include:

- Aviation Safety and Program Evaluation;
- Aircraft Fleet Program Management;
- Aviation Training;
- Aviation Commercial Flight Services Support; and
- Aviation Policy Development, Implementation and Oversight

As Unmanned Aircraft Systems are considered aircraft, UAS and UAS services fall under the control of AMD (now OAS – DM 353, Chapter 1, Aircraft Contracting). Therefore, OAS maintain ownership of all DOI aircraft, including UAS. The policies contained DOI OPM 11-11, specifically Paragraph 4, state "….the overall responsibility of management with the Department of Interior rests with the Aviation Management Directorate (AMD)." Further, "Ownership of all aircraft, including UAS, is a function and responsibility of AMD." Finally, section 5 of OPM 11-11outlines specific procedures and guidelines including the use of approved sources (Paragraph C, Number 4). This means UAS are a function and responsibility of AMD (now OAS) including all UAS program oversight. A DOI agency, bureau or office is not authorized to acquire a UAS, and AMD (now OAS) must allocate a UAS to the DOI agency, bureau or office. AMD (now OAS) are also responsible for coordination with other federal agencies on the use of UAS. *DOI bureaus and offices **must** follow AMD (now OAS) policy and guidance when operating a UAS regardless of whether or not they are DOI-owned.* AMD (now OAS) policy and guidance clearly state that the Federal Aviation Authority (FAA) retains the authority to approve all UAS operations within the National Airspace System for Class A, B, C, D, E and G airspace (see OPM 11-11 Section 3A). When operating in any one of these six classes of airspace, a DOI UAS **must** be operated with an approved FAA Certificate of Waiver or Authorization, otherwise known as a COA (see OPM 11-11

Section 3B). Information on the National Airspace System operating classes (A, B, C, D and E) can be found online at http://dspace.mit.edu/bitstream/handle/1721.1/34955/Acr2113645.pdf?sequence=1. The procedures in OPM 11-11 outline the steps in preparing and submitting a COA. Access to the COA online system is required. More information on the COA application process is provided later in this Section.

DOI UAS Authorities

- Departmental Manual 112 DM 10: DM Chapter 1: General Administration
- Secretarial Order 3250 dated September 30, 2003, and
- NBC Director's Memorandum dated October 5, 2011.

DOI UAS Guidance

- OPM 11-11: DOI Operational Procedures (OPM) Memorandum No. 11-11 Dated 12/19/2011 (see Appendix I). This memo provides guidance on UAS operations and management. This memo supersedes OPM 09/11 from 08/24/2010.

USGS National Unmanned Aircraft Systems (UAS) Project Office

Established on May 8, 2008 and located in the Rocky Mountain Geographic Science Center in the Denver Federal Center, Colorado. The mission of the USGS UAS Project Office is to help promote and develop the UAS technology in a way that will benefit DOI and USGS missions. The USGS UAS Project Office has completed a number of missions since its inception. Some of the completed USGS missions are identified in Section 4. Many of these missions were in support of environmental, wildlife and wildlife monitoring in remote and difficult-to-access areas. The USGS UAS Project Office partners with a number of federal departments and agencies, including: AMD (now OAS), DOI agencies and bureaus, FAA, NASA, NOAA, DHS, and DOD. The UAS Project Office is responsible for providing a roadmap for the development of the UAS capability within the DOI. The USGS currently has a fleet of UAS that includes the Raven RQ-11(A) and T-Hawk gasoline Micro Air Vehicle. In coordination with AMD (now OAS), this office was also responsible for development of the Raven and T-Hawk operator training for DOI employees wishing to become pilots of DOI owned UAS. More information on this training is provided in Section 2. Currently, the USGS has provided the most efficient procedures for applying for and establishing COAs. More information on COAs is provided in this Section "Certificate of Authorization Process" (following page).

Reclamation

There are currently no Reclamation developed authorities and guidance that affect Reclamation UAS operation. However, Reclamation ***must*** comply with the DOI Policy and Guidance. To ensure compliance with FAA and DOI guidance, any employee planning a UAS mission over DOI lands or use of UAS services ***must*** inform the Reclamation Property Management Policy Group. The current point of contact is the Section Manager, (S.) Jim Keiffer on 303-445-2044. If Reclamation is not in operational control, UAS services are supporting another agency (e.g. local first responders), and/or the UAS is not flying over DOI lands, then liability may be transferred to the operating agency and it *may* be that prior approvals are not be required (*Pers. Comm. – email*, S. Jim Keiffer, March 29, 2012). However, the Reclamation Aviation Manager MUST be informed of ALL potential UAS missions. Note that before UAS flight, private entities should apply for a special airworthiness certificate (very difficult to obtain) and public entities should apply for a COA. The 2012 FAA reauthorization Act streamlines the COA process and expedites approvals for public agencies (FAA News).

As part of the COA mission planning process, spectrum frequency approval must be granted from Army Department of Defense to use specific frequencies during the mission. Additionally, a Range Certification is needed: this is a letter of permission from the owner of a property/facility that provides permission for the UAS fly over a specific area (*Pers. Comm.*, L. Brady, March 1, 2013).

The entire mission planning and preparedness process (i.e. spectrum frequency; range certification and COA application) can take 6 months before permission is granted to fly a mission (*Pers. Comm.*, L. Brady, March 1, 2013).

Certificate of Authorization Process

Background Information

Requests for public (civil) use of UAS are increasing. According to Willis and Williams (2010), there are currently four possible ways to fly a UAS in the National Airspace System. These include when the UAS:

1. Is completely contained within active Restricted and Warning Area airspace approved for aviation activities. In this case there is no need for FAA approval and range rules apply (e.g. for military use).
2. Is used for private recreational use and provided this use follows Advisory Circular 91-57 (**<u>for recreational use only</u>**).
3. Has been issued a Special Airworthiness Certificate - Experimental Category (For Private Institutions).
4. Has been issued a Certificate of Authorization (For Public Institutions).

Not all the ways listed above are available to all UAS operators. Both Public Agencies/ Institutions and Private Entities have different avenues for requesting permission to fly UAS. Public Agencies are any agency that operates UAS, and other public aircraft, not being used for a commercial purpose (FAR 14 CFR Part 1.1), and who receive federal government funding at some level (Hutt and Sloan, 2012). Public agencies (only Federal/State/Local government agencies and universities) can apply for Certificates of Authorization (COAs) for permission to fly a UAS for civilian purposes. Recently attempts to streamline this process have been made. These attempts include legislation (i.e. FAA Modernization and Reform Act of 2012). Private industry is restricted to applying for a Special Airworthiness Certificate, Experimental Category instead of applying for COAs. This section focuses only on the COA application process as DOI is a public agency. More information on the Special Airworthiness Certificate can be found at http://www.faa.gov/aircraft/air_cert/airworthiness_certification/sp_awcert/experiment/.

What is a COA?

A COA (Certificate of Authorization) essentially authorizes a UAS operator to use a specific area of operation (i.e. predefined airspace) for a specified amount of time (e.g. a single mission, a month, a year). "The FAA requires that the UA position be known with enough accuracy that air traffic controllers can inform nearby aircraft" (Elston *et al.*, 2011). According to Elston *et al.* (2011), this requirement can typically be satisfied through two avenues (1) Restrict the size of the COA area; or (2) specify a flight plan 72 hours in advance of a mission/flight. It should be noted that FAA regulations do require two people for the operation of a UAS: one pilot (operator) and one observer (medically certified with a Class II medical). Additionally, COAs typically require the UAS to operate in visual range of an observer (i.e. visual Line-of-Sight). Line-of-Sight requires an observer "spaced no more than one nautical mile horizontally and 3000-ft vertically from the aircraft at all times" (Elston *et al.*, 2011). The first UAS to be granted an "overarching" COA was the Global Hawk. The Global Hawk has proven its reliability and the FAA felt this UAS was safe to fly in National Airspace. This means there is a much reduced time required between contacting the FAA and being granted permission to fly a mission (Civil UAV Assessment Team, 2006).

How long does the COA Process Take for Approval?

The FAA has recommended guidelines for applying for a COA. For UAS, the FAA indicate this process should take around 60 days (although it has taken months for earlier UAS COA applications).

The FAA recently updated their COA application process. Figure 3.1 walks you through the COA requirement flowchart. This chart can help a potential UAS user identify whether or not they need to apply for a COA or a Special Airworthiness Certificate. Willis and Williams (2010) provided a graph of the number of COA applications submitted in 2008, 2009 and for part of 2010 (see Figure 3.2 on the following page). Each COA application needs to be individually reviewed and safety concerns addressed before a successful outcome (i.e. COA approval) will take place. The breakdowns of agency types applying for COAs are shown in in Figure 3.3 (Willis and Williams, 2010). According to Figure 3.3, in 2008, a greater number of COAs for the Department of Defense were issued than any other group. However, by 2009 academia has approximately the same number of COAs issued as the Department of Defense Willis and Williams (2010). In recent years, Law Enforcement has become more interested in using UAS for tactical operations (e.g. http://sheriff.mesacounty.us/template.aspx?id=10164). The Department of Homeland Security is supportive of the use of small UAS by law enforcement and other public safety agencies.

Agencies with limited COA application experience may receive more rejections of COA applications simple because they were unaware of some of the best practices seen in successful applications. Elston *et al.*, 2011 provides an overview of the COA application process and best practices for obtaining a COA. Those new to the COA application process may find information in the Elston *et al.* (2011) paper very useful to the process. They found that providing details on "area selection, airworthiness requirements, lost communications and [associated] emergency procedures, and ground crew proficiency requirements" and correct procedures for reporting any incidents and accidents, are vital to a successful application. “The overarching goal of the COA application is to demonstrate that the operations of the UAS have an equivalent safety of manned operations” (Elston *et al.*, 2011). Proving this level of safety/reliability can be difficult to accomplish with UAS (see UAS Operational Safety Considerations in Section 2).

Figure 3.1: Certificate of Waiver or Authorization Process
(FAA, 2012 - http://www.suasnews.com/2013/02/21163/new-faa-coa-guidelines-document/)

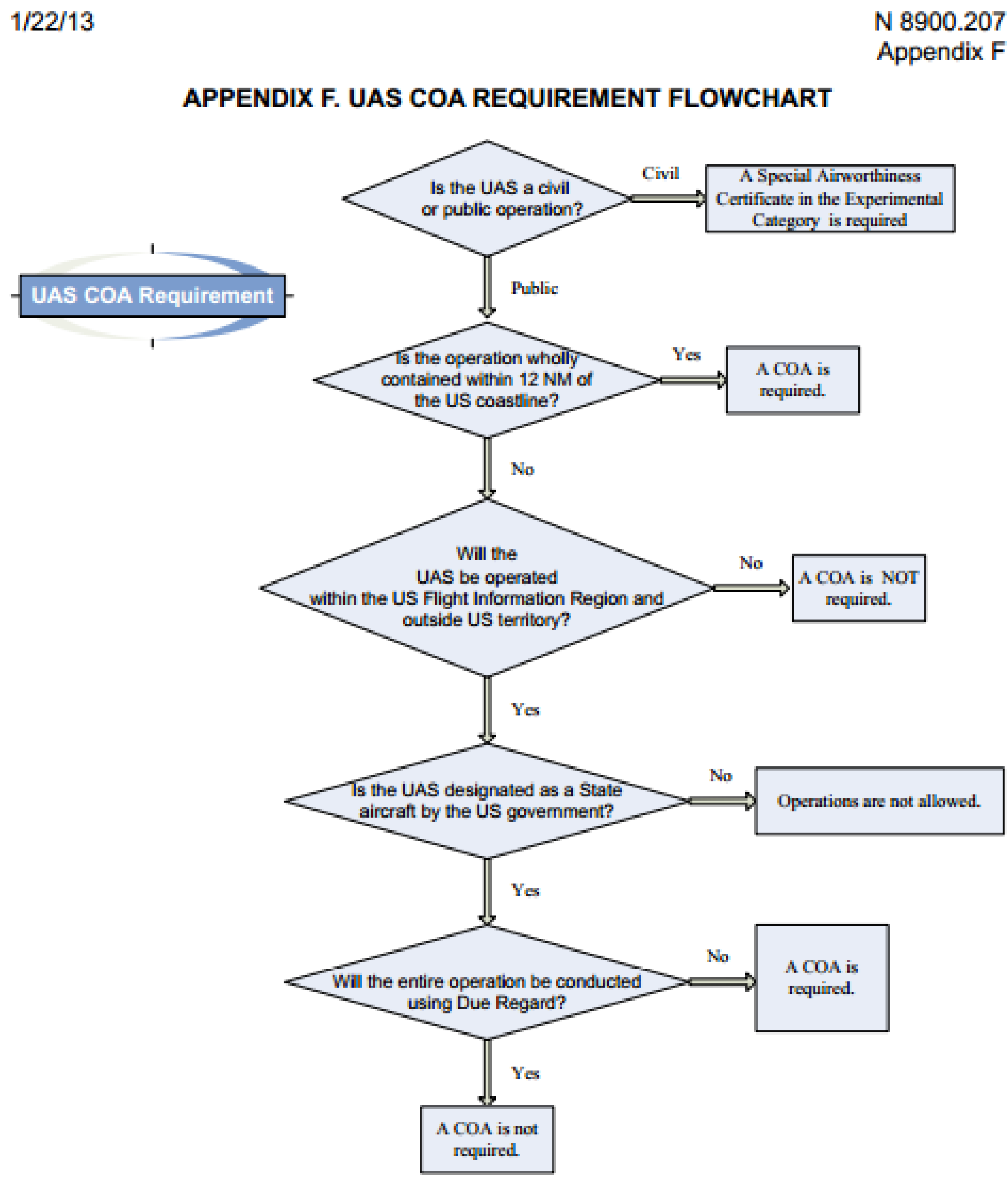


Figure 3.2: Number of COA Applications Submitted (by Calendar Year 2008-2010).

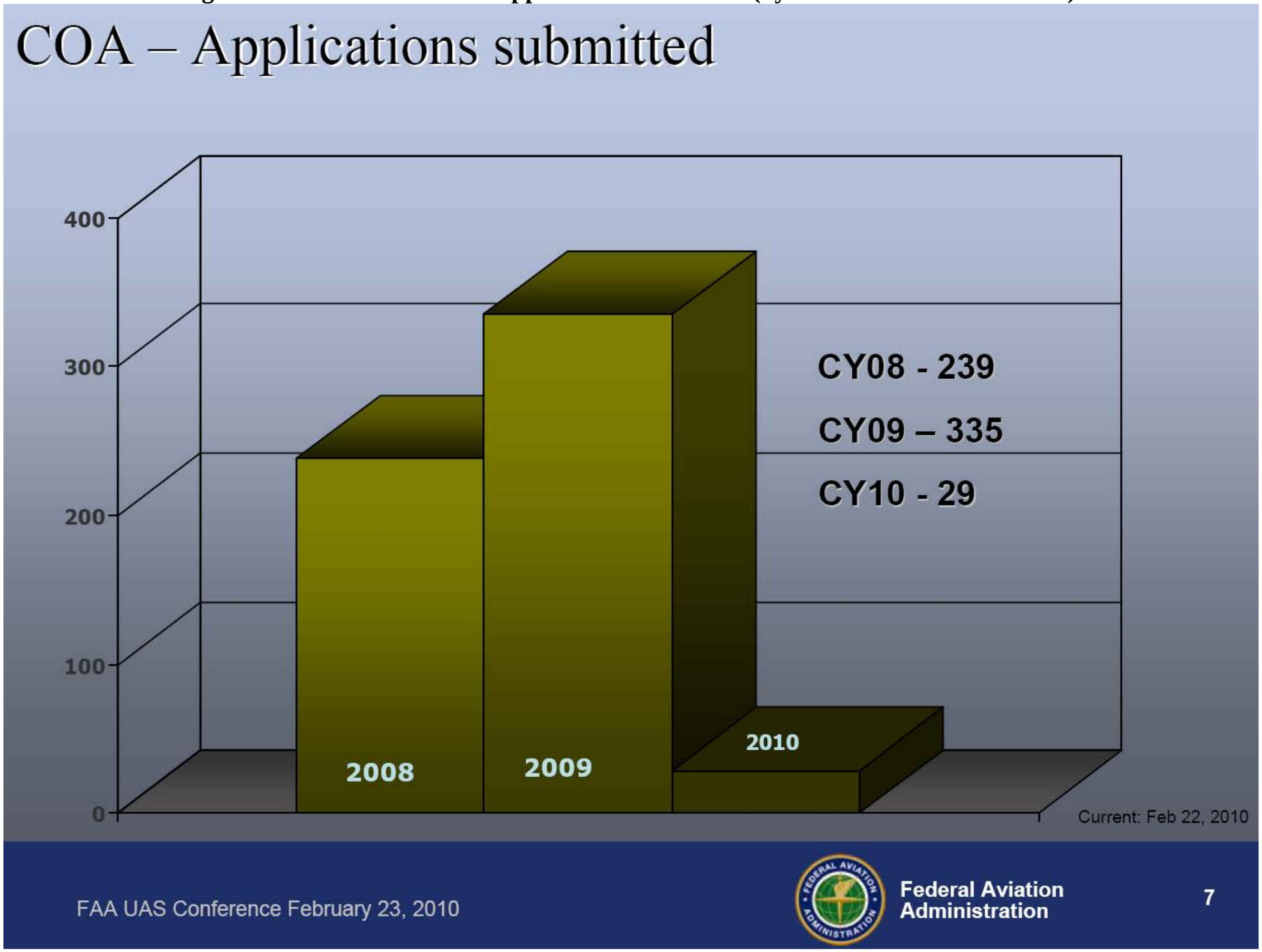
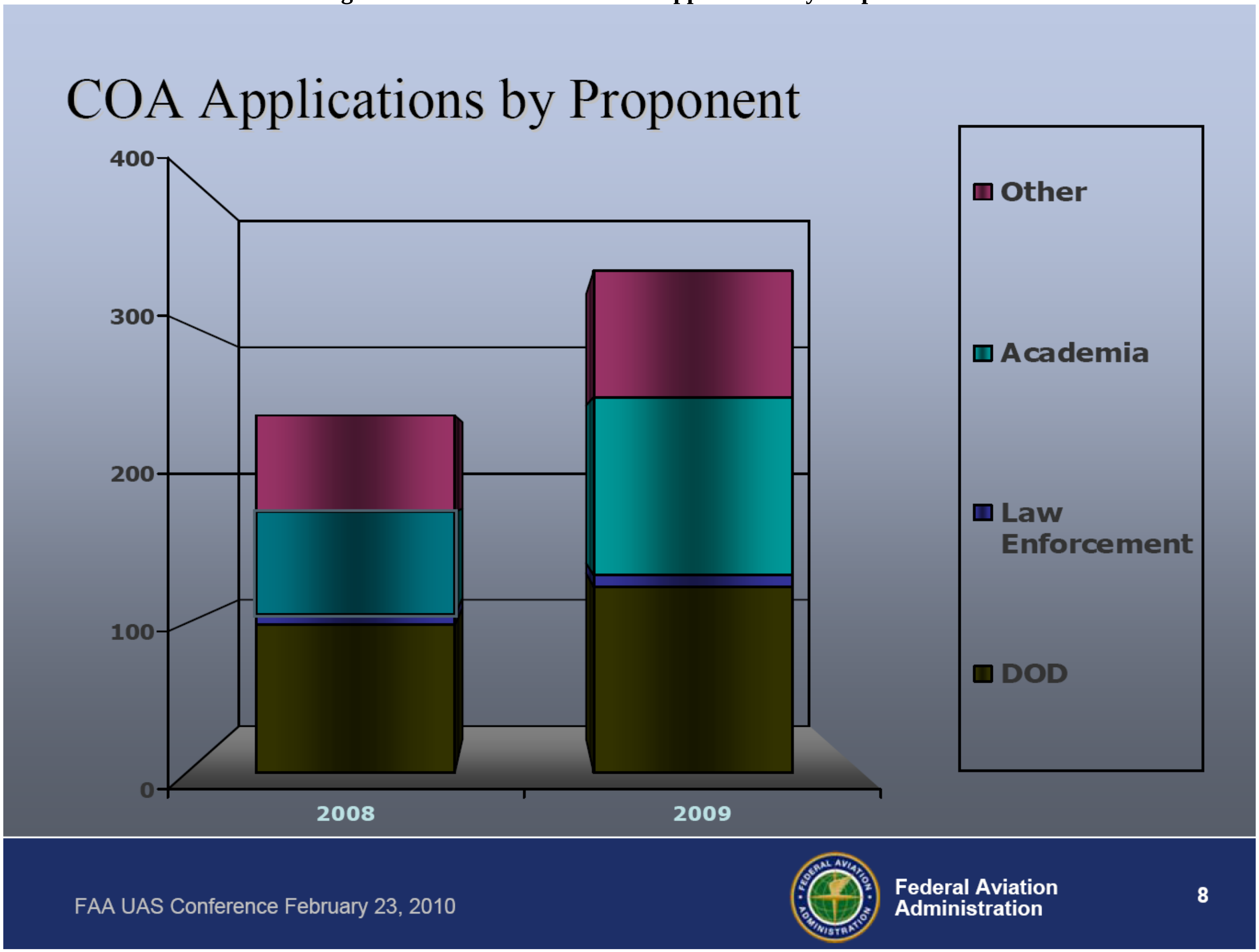


Figure 3.3: Breakdown of COA Applications by Proponent.



One of the pieces of required information for a COA application is an UAS Airworthiness Statement. Elston *et al.* (2011, p4-6) provide detailed information on what should go into the COA Airworthiness statement, including information on: Systems Engineering; Structures; Flight Technology; Propulsion; Air Vehicle Subsystems; Diagnostic Systems; Avionics; Electrical System; Electromagnetic Environmental Effects; System Safety; Computer Resources; Maintenance; and Other Considerations.

Table 3.1 from Elston *et al.* (2011, Table 3) provides a summary of typical FAA requirements for UAS operations.

Weather Minimums
Visibility of 3 statute miles.
UA must maintain 500-ft below and 2000-ft lateral separation from clouds.
Daytime operations only: 1 hour before sunrise until 1 hour after sunset.
Required Documentation
Vehicle Airworthiness document.
Class 2 medicals for both the PIC and observer.
PIC knowledge of FAR Part 91 (class G airspace).
Current private pilot certificate for the PIC (class E airspace).
Hard copy of COA document.
Operational Requirements
PIC must have 3 qualified events in last the 90 days.
Single UA operation only.
No dropping anything from the UA.
No loitering in Victor airways.
No operation in GPS test area or degraded RAIM.
PIC and observer must be in constant two-way communication.
UA cannot exceed 1000-ft vertical and 1/2 or 1-mile horizontal from observer.
NOTAM must be issued 72-48 hours prior to flight operations.
Incidents, Accidents, and COA boundary deviations must be reported 24 hours prior to any additional flights.
Monthly reports of operations must be submitted to the FAA.

UAS Project and COA Applications

The USGS has completed a number of COA applications for UAS operations. They have developed a checklist for COA applications that can be used for DOI agencies (refer to Hutt and Sloan, 2012). The COA application process includes a Scientist or Resource Manager Initiation a Project by contacting the UAS Project Office or Bureau Point of Contact. This will initiate the COA application process and project planning will begin. There is a long laundry list of information required for the COA, and additional information and special permits and approvals (e.g. radio frequency approval) are needed. Once the COA is ready it is then reviewed by the USGS National Aviation Safety Officer and DOI OAS. The COA is then submitted to the FAA (online for non-sensitive applications). The FAA review and approval process now takes about

60-90 days. Public agencies have an account administrator established (e.g. OAS POC is Harry Kieling) that manages their agencies access to the online COA application tool.

DOI Operational Procedures (OPM) Memorandum No. 11-11

The procedures in DOI OPM 11-11 outline the steps in preparing and submitting a COA. Access to the COA online system is required. The COA Online system is at https://ioeaaa.faa.gov/oeaaaA/Welcome.isp. The figure (3.4) on the following page provides information on the steps for the DOI COA Application Process.

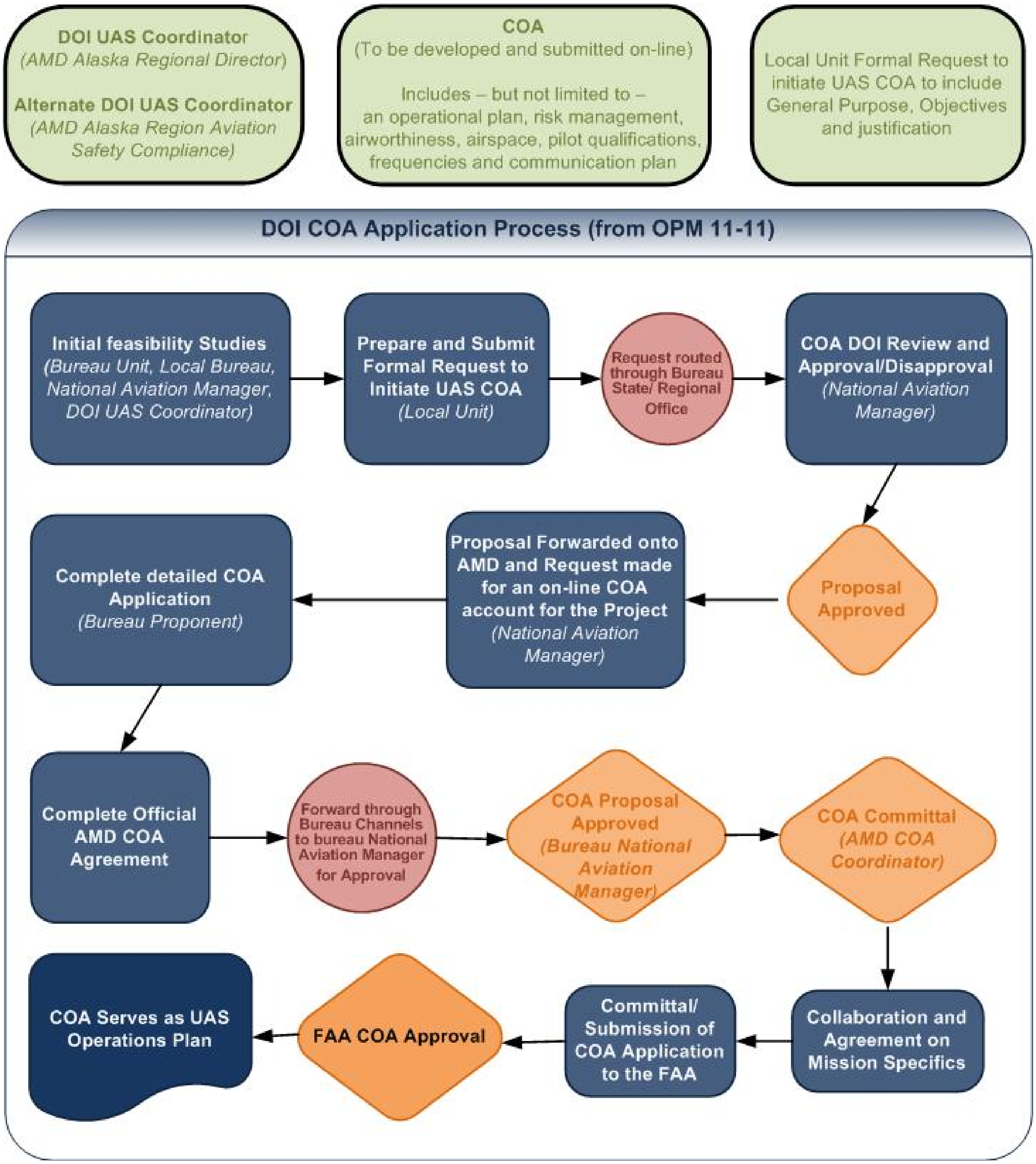
Overall, the OPM 11-11(from 5C) minimum requirements that must be met before operating a UAS include:

1. Obtain approval from bureau National Aviation Office
2. Obtain (1) a valid and current COA issued by the FAA or (2) MOU with the controlling agency for operations wholly within Restricted/Prohibited and Warning Areas.
3. Exercise operating limitations in accordance with the COA/MOU Range provisions/COA and OPM 11-11.
4. Meet DOI UAS Pilot/Mission Operator/Observer Training and Certification Requirements. Personnel must possess training certificates from AMD (now OAS) or AMD (now OAS)-approved sources prior to receiving AMD (now OAS) certification.
5. Possess a DOI UAS Operator Letter of Authorization. This letter must specify the UAS that they are authorized to operate.
6. Visual Flight Rules cloud clearances and visibilities for Class E airspace will be used regardless of the type of airspace the UAS is operating in. The only exception is when operating the UAS in Class Airspace where 14 CFR Part 91.155 applies.

Operations outside restricted areas, warning areas, prohibited areas, and/or Class A airspace may only be conducted during daylight hours, unless authorized in the Special Provisions Section of the COA. Some DOI operations may require both an FAA Pilot Certificate and COA, while others may only require a COA. Refer to OPM 11-11 to obtain details on what operations may require both (6C) or just the COA (6D).

For future reference, although DOI UAS missions currently must go through the full COA process, OAS has started putting together an agreement between DOI and the FAA that will mean DOI UAS missions will not have to go through the *full* COA process under certain conditions.

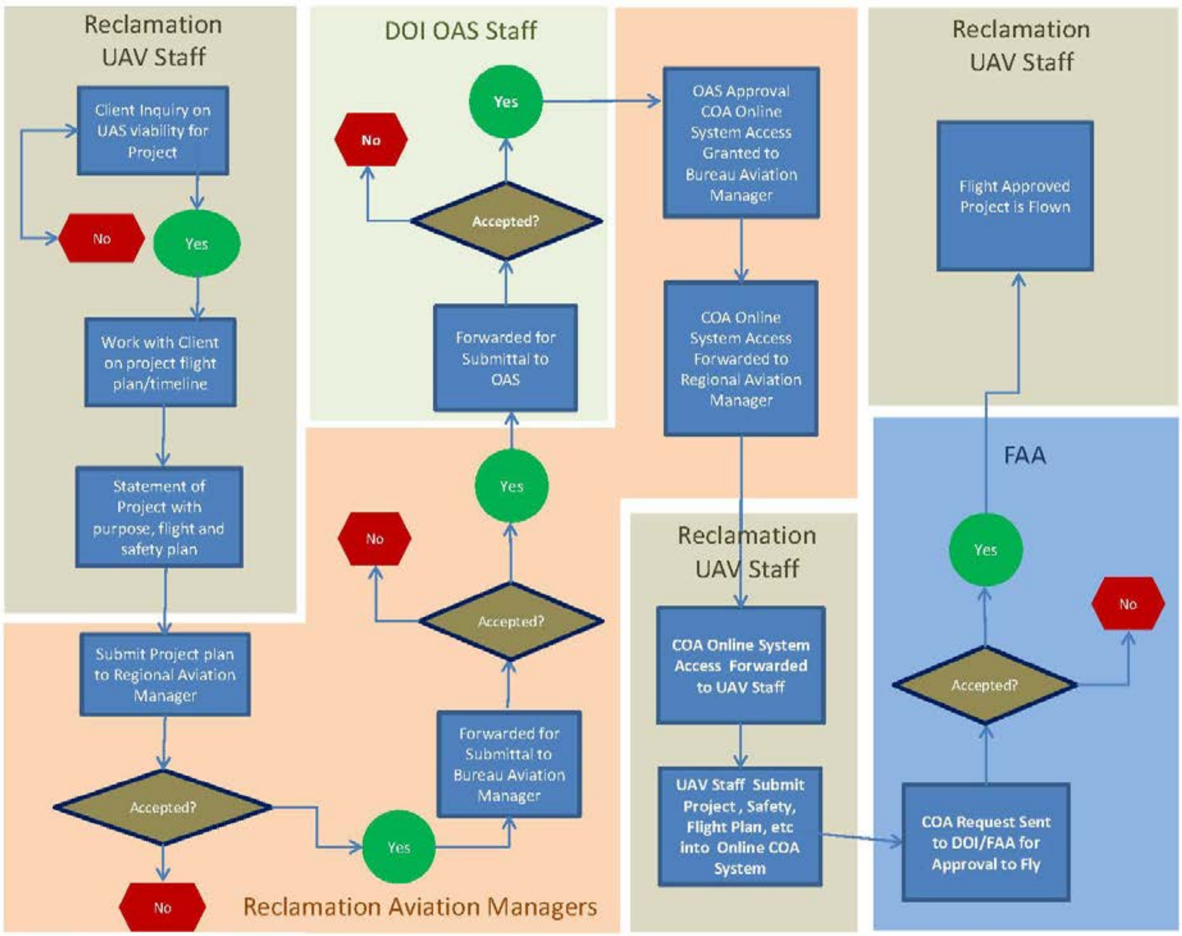
Figure 3.4: DOI OPM 11-11 COA Application Process



Reclamation UAS COA Application Process

The Reclamation COA Application Process will look something like the flowchart below. UAS users cannot simply go out and fly a UAS without preapproval. Even small UAS typically used for private recreational use will need a COA if used to collect any sort of data (including images). **All** potential Reclamation UAS missions **must** follow this process before proceeding with any UAS missions. Liability issues arise when these procedures are not followed. The Reclamation Pacific Northwest Region currently has two DOI certified UAS pilots who developed the Reclamation COA Application Process shown in Figure 3.5.

Figure 3.5: Reclamation COA Application Process
(From Reclamation Pacific Northwest Region UAS, 2012)



DOI Regulations Impact on Potential Reclamation UAS Missions

As a DOI entity, Reclamation is under the jurisdiction of the Office of Aviation Services (formerly the Aviation Management Division). OAS maintain ownership of ALL aircraft including UAS. OAS has a fleet UAS that they have approved for use by DOI entities, and can allocate these preapproved UAS to DOI bureaus and offices. OAS will not approve missions over DOI land if the UAS is not already in the DOI fleet. Currently the Raven and T-Hawk are the only UAS approved by OAS. OAS will only look at procuring and approving other UAS platforms no earlier than 2014 (most likely the 2014 field season), so as to give them time to review new FAA policies and to reduce the potential liability related to UAS failures. New technology is rapidly developing and newer UAS may provide capabilities more in line with

Reclamation's mission. However, this newer technology will not be available for Reclamation use in the near future.

UAS Privacy Concerns

One of the biggest concerns with using UAS is the problem with violating individual's right to privacy and protection from unreasonable search. Senator Rand Paul introduced a Bill "S.3287 (112^{th}): Preserving Freedom from Unwarranted Surveillance Act of 2012" on Jun 12, 2012. This will was written to protect individual privacy against unwarranted governmental intrusion through the use of the unmanned aerial vehicles (i.e. UAS) commonly called drones, and for other purposes (http://www.govtrack.us/congress/bills/112/s3287). Senator Rand Paul has expressed concern that surveillance from UAS may violate the Fourth Amendment of the US Constitution. This Amendment guards against unreasonable search and seizure (June 15, 2012, CNN article, http://www.cnn.com/2012/06/14/opinion/rand-paul-drones/index.html). Additionally, due to privacy concerns the city of Charlottesville in Virginia recently became the first to pass a resolution restricting the use of UAS (US News Article, February 2013, http://usnews.nbcnews.com/_news/2013/02/05/16857529-virginia-city-becomes-first-to-pass-anti-drone-resolution?lite). Other State Senates have introduced Bills that would criminalize UAS flight in that State (e.g. Oregon Senate Bill 71). There appears to be a lot of concern over privacy issues relating to the use of UAS with camera/imaging capabilities, the same level of concern regarding the use of helicopters with camera and video capabilities (e.g., news helicopters) does not appear to have the same level of interest. Although, a recent news report stated that a legislator from New Hampshire has introduced a State bill (HB619) that will ban all civilian aerial photography (http://www.suasnews.com/2013/02/21309/new-hampshire-bill-seeks-total-ban-on-civilian-aerial-photography/).

Section 4. Current UAS Mission Types

This section should help potential UAS users to better understand what UAS have been used for a provide a better understanding of the current UAS capabilities available to Reclamation.

T-Hawk Missions Completed by the US Military and Emergency Response Agencies

Most of the T-Hawk missions completed to date were military-based. Many of the missions provided intelligence capabilities and provided effective situational awareness. T-Hawks are able to follow and zoom on a target or subject. The T-Hawk differs from other fixed wind UAS which lose the visual ground reference around a point as they circle. According to CEHC (2010a, p9), typical mission sets of the T-Hawk have included:

- Area/Zone Reconnaissance
- Route Reconnaissance and Clearance
- Remote Tactical Reconnaissance and Surveillance
- Improvised Explosive Device (IED) Hunting Missions
- Assists in remote investigation of suspicious vehicles or packages
- Battle Damage Assessment
- Post Blast Investigation
- Route Reconnaissance
- Convoy Operations
- Cordon and Search
- Force Protections
- Culvert Denial Systems Monitoring (Culvert Denials block unauthorized access to culverts and channel water)

The T-Hawk was also used in 2011 to aid emergency workers at the Fukushima Daiichi nuclear facility during the Tsunami recovery. The T-Hawk was used to obtain close up video and photographs from within the plant while emergency personnel were working on limiting further radiation releases (Honeywell, 2011).

Current Completed UAS Missions (USGS)

As of September 2012, the first COA/FAA approval for USGS to fly the T-Hawk was recently been processed. This is for a mission to fly over the West Virginia Coal Mines in November 2012. USGS plans to submit COAs for approval so they can use both the Raven and T-Hawk platforms for most of the future other project missions. It is unlikely USGS will apply for COAs to use the T-Hawk for wildlife studies because of the noise produced by the T-Hawk during flight. The USGS National UAS Project Office is continually conducting more and more UAS missions to assist in many different program areas. This Project Office is under the Land

Remote Sensing Branch of the USGS in the Geoscience and Environmental Change Science Center.

Currently not many T-Hawk missions have been conducted by the USGS. However, mission already completed by the USGS include those by the Raven and may be also appropriate for the T-Hawk. These missions cover four major areas: Environmental, Public Safety, Resource Management and Scientific Research. See below for a list of missions in these four areas. This information was provided in a USGS PowerPoint briefing presented to Reclamation on August 10, 2012. In addition, USGS has recently had approval from the FAA to fly the T-Hawk over West Virginia coal mines in November 2012 (*Pers. Comm. – email*, Jeff Sloan, Sep 24, 2012).

<u>Public Safety missions include:</u>

- Abandoned Mine Lands Survey, CO
- Flood Mapping- Missouri/Mississippi Rivers
- Wildfire Incident Support & Prescribed Burns, AZ, FL
- Monitor Volcanic Activity, HI
- Survey Surface Mines, WV
- Levy Inspections- Mississippi River
- Coal Seam Fire Detection and Mine Monitoring , CO, WV, MT
- Geological Hazards - Landslides

<u>Scientific Research missions:</u>

- Fire Science Research, FL
- Hydrographic Survey, MT
- Mapping Dinosaur Tracks, CO
- Monitor Forest Health, CO
- Missouri River Bank Erosion Study, SD
- Glacier Temperature Study, WA, MT
- Assess Impacts of Elwha Dam Removal, WA (Reclamation)

<u>Resource Management missions:</u>

- Fence Inspection, Invasive Surveys, HI
- Archeological Survey of Mohave Nat. Preserve, CA
- Environmental Survey of Palmyra Atoll, Northern Pacific Ocean

<u>The Environmental Study missions include:</u>

- Sandhill Crane Population Survey, CO
- Pygmy Rabbit Landscape Habitat Study, ID
- Riparian Survey John Day River, OR
- Grizzly Bear Monitoring, MT
- Elk Population Survey, MT
- Vegetation Inventory and Water Survey, MT
- Sage Grouse Inventory, CO
- EPA Superfund Site, DE
- Forest Health Inventory- Pine Beetle Infestation, CO

Electro-Optical and Thermal IR Images from Completed USGS Missions

The USGS has completed some missions that compare both color and infrared images. The section below provides some insight to current USGS UAS capabilities that can be made available to Reclamation (refer to images collected by Hutt and Sloan, 2012). Two of these include Electro-Optical (Color) and Thermal Infra-Red (IR) Images of Water Discharge at Red Rock Lakes in Montana (see Figures 4.1, 4.2 and 4.3 on following pages). Other images from a 2011 Mississippi River Case Study were also provided by Hutt and Sloan (2012). Refer to figures 4.4 and 4.5.

Figure 4.1: Electro-Optical Image of Water Discharge from Montana (above)

Figure 4.2: Infra-Red Image of Water Discharge from Montana (below)

Figure 4.3: Infra-Red Mosaic of Water Discharge using Raven IR Video Capture

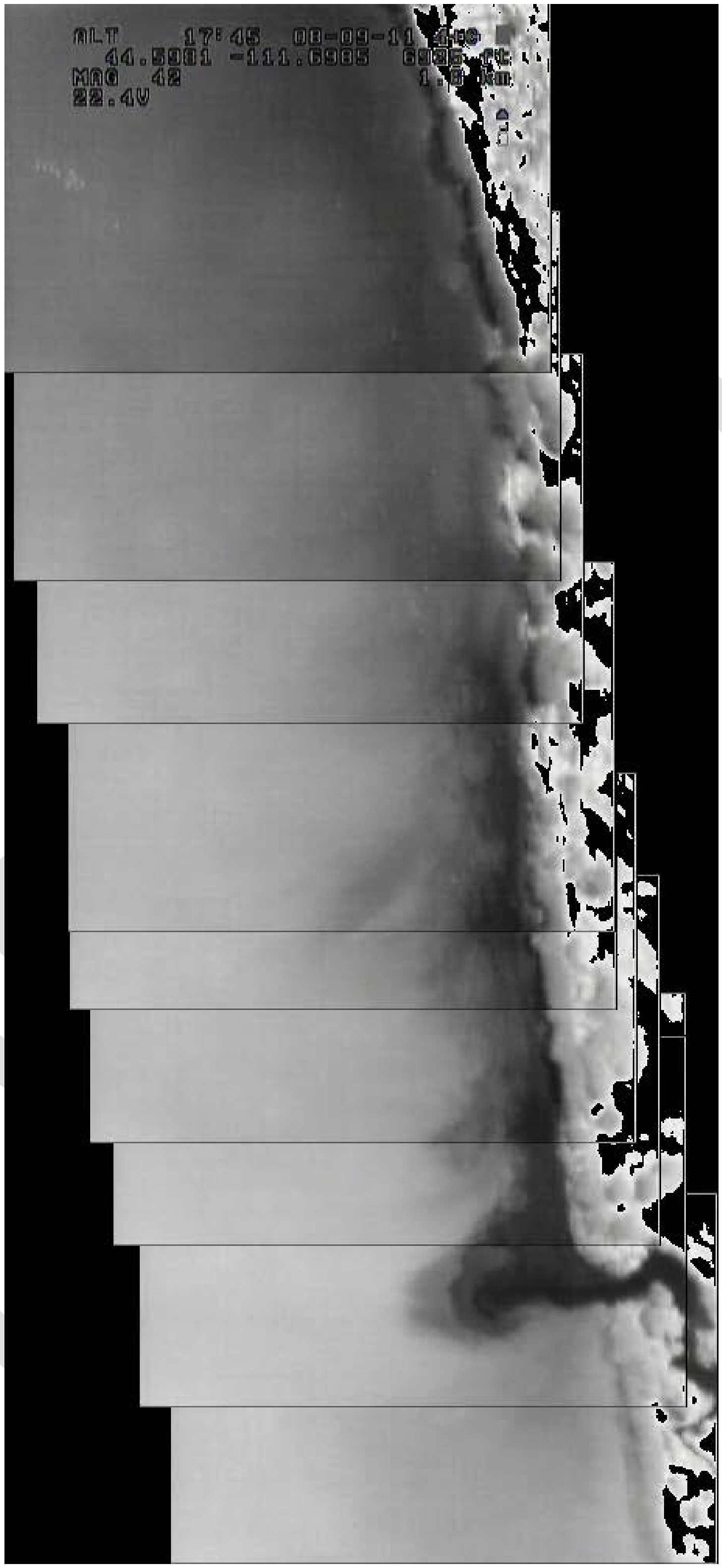


Figure 4.4: 2011 Mississippi River UAS Case Study

The Predator UAS

The DOI certified UAS – the Raven and the T-Hawk – are currently both available to Reclamation. However, another UAS may also be made available – upon request – to obtain imagery for Reclamation. The OAM Predator B, Customs and Border Patrol UAS may be utilized by Reclamation under certain conditions. The Department of Homeland Security, Customs and Border Patrol (DHS-CBP) is will to support emergency operations; law enforcement incidents and search and rescue operations by collecting data on a non-interference basis, especially if a dam was displaying potential failure conditions and there was a potential risk to the public (*Pers. Comm*. – *email*, Hutt, M., Feb 21, 2013). There is also a possibility that they may be able to collect data if the dam is within standard COA area a mission as the mission may be categorized as a training mission for them). Some Reclamation Dams may be within 50 miles of the Predator normal flight routes. It may be possible to request collection of image data using the Predator. Although all imagery data would be beneficial, the Predator's infrared data may be most useful; especially during an emergency as information on potential new areas of seepage may be identified. This data would be provided at no cost. Post-processing of the data by Reclamation personnel may be labor intensive. As of yet, there is no information on how long this post-processing might take. It has been recommend that DOI put together an agreement with the DHS-CBP to document the process for requesting Predator support (*Pers. Comm*. – *email*, Hutt, M., Feb 21, 2013).

Section 5. Potential Reclamation Missions

The following information provides some considerations for T-Hawk operation and discusses Reclamation's current remote sensing capabilities and future UAS preferences/needs.

Considerations for High Altitude UAS Operation

Density Altitude

A major consideration when scoping a UAS mission is the altitude (height above sea level) and density altitude you may expect to encounter during a mission. Understanding the effect of air density on UAS performance is critical to a successful mission. Atmospheric conditions play a large role in aircraft operations (e.g. engine power, rate of climb, etc) (FAR AIM 2003, p7-5-3). High density altitude can significantly decrease aircraft performance. Factors affecting air density are: barometric pressure, altitude, temperature and humidity (i.e. dewpoint temperature). Air density decreases with altitude and this will decrease the engine power performance of the UAS. High temperatures and high humidity can compound the problem even more. Any elevation 2,000ft above sea level has the potential to significantly affect the air density. Mountain waves can also cause changes in air density that impact aircraft performance. UAS pilots can run into trouble when operating UAS in hot weather and at high altitudes. Aircraft performance can be substantially reduced in mountainous areas and high altitudes.

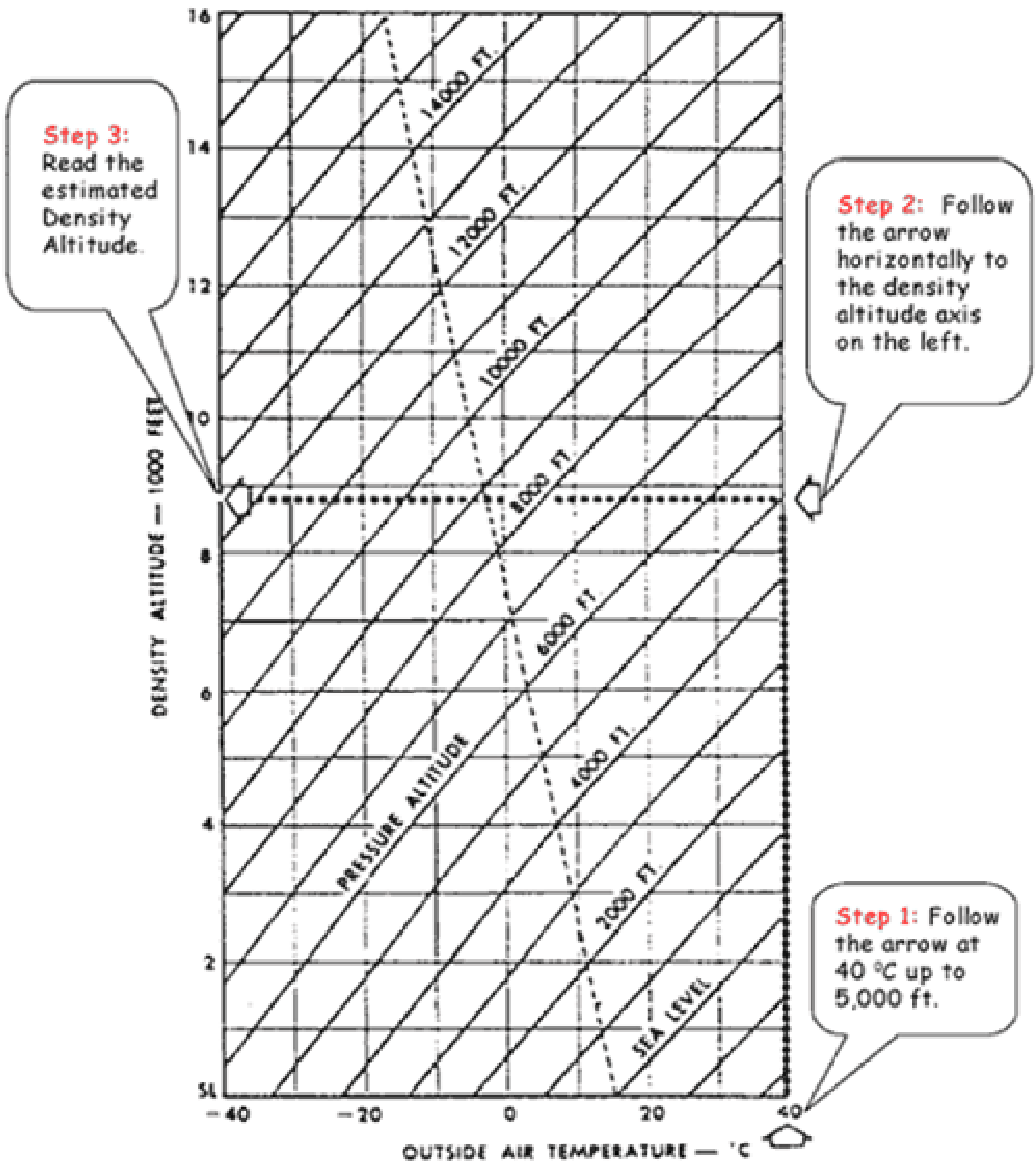
Understanding the effect of density altitude on the operational performance of the T-Hawk is crucial to a mission. There is a significant adverse impact to the performance characteristics of the T-Hawk when the density altitude is greater than 7700ft (see Table 2.1). Density altitude is affected by atmospheric temperatures and humidities. The higher the temperature and/or the higher the relative humidity can increase the effect the density altitude, so that actual altitude (or height above mean sea level) is lower than the density altitude. This means the actual altitude (height above sea level) a T-Hawk is being flown, may differ substantially from the density altitude and could negatively impact on the performance of the T-Hawk. For instance, if the crest elevation of the dam is 7,481 feet (e.g. Olympus Dam) the density altitude may be significantly higher if atmospheric temperatures and humidities are high, and the T-Hawk will experience degradation in operational performance. For example, when the temperature is very hot (e.g. 100°F) and the relative humidity is very low (e.g., at 15%), a UAS may suffer from a reduction in flight performance even at a dam with an elevation of 4100 feet (i.e., ~7680ft density altitude). If the temperatures are very hot (e.g., 100°F) and the relative humidity is very high (e.g., 90%) then density altitude increases even more (i.e., ~8263ft density altitude). Even with a temperature at 76°F and relative humidity of 50% an altitude of 5000ft has a density altitude of ~7419ft. Tools to assist in calculating density altitude include the Density Altitude Calculator at http://www.pilotoutlook.com/calculators/density-altitude-calculator and a Density Altitude Chart (frequently used as a quick guide by pilots). The Density Altitude Chart (shown on the following page) can be downloaded at
http://quest.arc.nasa.gov/aero/virtual/demo/weather/youDecide/DensityAltitudeChart.html

To ensure no –or limited– degradation of flight performance, the time of day and atmospheric conditions should be considered during mission planning. The optimum time of day and weather should be considered when planning flights at altitudes above 2000ft. For areas that frequently experience high temperatures, early morning missions –just after sunrise– should be considered.

Figure 5.1: Density Altitude Chart – downloaded at http://quest.arc.nasa.gov/aero/virtual/demo/weather/youDecide/DensityAltitudeChart.html

Density Altitude Chart Tutorial

Use this chart to compute density altitude given temperature and pressure altitude.



Reclamation Dams

Approximately 15 Reclamation Dams have a crest elevation of more than 7700ft. Platoro Dam has a maximum crest elevation of 10,048ft. The T-Hawk would be unable to fly at Platoro Dam even at very low temperatures and humidities, and will most likely experience a degradation in flight performance for any dam over 7700ft. Even with high humidity and low temperatures at Platoro Dam, the density altitude may be lower than 10,048ft but it is still unlikely that the T-Hawk would perform well at this elevation. UAS flight at dams with altitudes of more than 4000-5000ft may experience some degradation in flight performance and operational limitations if temperatures are high. This should be considered during all mission planning. Density altitudes should be checked for any missions expecting to include flight greater than 2000ft. The Performance characteristics provided in the below are just estimations and should not be considered final. They are just intended to be used as a guide.

Table 5.1: Reclamation Dams and Associated Crest Elevation (Dam Statistics from DSIS Schema).

	DAM NAME	CREST ELEVATION (FT)
Unable to Fly	PLATORO	10,048
Flight degradation Expected. May be Unable to Fly at High Temperatures.	SUGAR LOAF	9,879
	BONHAM	9,801
	TAYLOR PARK	9,344
	TWIN LAKES BOR	9,210
	SILVER JACK	8,938
	MEEKS CABIN	8,706
	SHADOW MOUNTAIN	8,375
	GRANBY	8,290
	LEMON	8,167
	MOON LAKE	8,145
	WILLOW CREEK BOR CO	8,140
	VEGA	7,997
	GREEN MOUNTAIN	7,960
	RUEDI	7,788
	CURRANT CREEK	7,678
	VALLECITO	7,673
	SCOFIELD	7,636
	SOLDIER CREEK	7,612
Flight degradation possible. Especially at very high temperatures. The higher the altitude the greater the likelihood of performance degradation.	BLUE MESA DAM	7,528
	OLYMPUS	7,481
	GRASSY LAKE DAM	7,218
	HERON	7,199
	JOES VALLEY	7,004
	EL VADO	6,915
	NAMBE FALLS	6,840
	JACKSON LAKE DAM	6,780
	BIG SANDY	6,769
	RATTLESNAKE	6,595
	CRAWFORD	6,578
	FONTENELLE	6,519
	PAONIA	6,460
	ANCHOR	6,453
	SEMINOE	6,361
	ISLAND PARK DAM	6,309

	DAM NAME	CREST ELEVATION (FT)
Flight degradation possible. Especially at very high temperatures. The higher the altitude the greater the likelihood of performance degradation.	KORTES	6,169
	STUBBLEFIELD	6,137
	NAVAJO	6,108
	FLAMING GORGE DAM	6,047
	LOST CREEK	6,022
	RIFLE GAP	5,978
	STAMPEDE	5,970
	DEERFIELD	5,920
	PATHFINDER	5,858
	HUNTINGTON NORTH	5,845
	BULL LAKE	5,813
	PROSSER CREEK	5,761
	FOURMILE LAKE DAM	5,749
	STARVATION	5,725
	EAST CANYON	5,715
	CAUSEY	5,704
	PALISADES DAM	5,630
	BOCA	5,612
	CLARK CANYON	5,578
	ECHO	5,570
	STEINAKER	5,527
	ALCOVA	5,510
	FRUITGROWERS	5,493
	FLATIRON	5,486
	PILOT BUTTE	5,467
	DEER CREEK	5,425
	BUFFALO BILL	5,395
	DEADWOOD DAM	5,340
	LITTLE WOOD RIVER DAM	5,249
	HYATT DAM	5,025
	PUEBLO	4,925
	PINEVIEW	4,908
	CRESCENT LAKE	4,860
	GERBER	4,842
	CASCADE DAM	4,840
	LAKE SHERBURNE	4,815
	NEWTON	4,781

	DAM NAME	CREST ELEVATION (FT)
Flight degradation possible. Especially at very high temperatures. The higher the altitude the greater the likelihood of performance degradation.	BOYSEN	4,758
	GIBSON	4,726
	HYRUM	4,680
	PACTOLA	4,655
	FISH LAKE DAM	4,649
	CLEAR LAKE	4,544
	HOWARD PRAIRIE DAM	4,539
	SOLDIERS MEADOW DAM	4,523
	CRANE PRAIRIE DAM	4,455
	GUERNSEY	4,430
	ELEPHANT BUTTE	4,414
	KEENE CREEK DAM	4,413
	AMERICAN FALLS DAM	4,367
	WICKIUP DAM	4,347
	SUMNER	4,301
	COMO DAM	4,255
	MINIDOKA DAM	4,250
	ANDERSON RANCH DAM	4,206
	CABALLO	4,190
	LAHONTAN	4,174
	RYE PATCH	4,144
	WILLOW CREEK - MT	4,144
	MINATARE	4,140
	KEYHOLE	4,134
	MASON DAM	4,082
	BOX BUTTE	4,024
	UNITY DAM	3,827
	CANYON FERRY	3,809
	BONNY	3,742
	GLEN CANYON DAM	3,715
	YELLOWTAIL	3,660
	HUNGRY HORSE DAM	3,565
	WASCO DAM	3,526
	SLY PARK	3,482
	BUMPING LAKE DAM	3,435
	WARM SPRINGS DAM	3,409
	AGENCY VALLEY DAM	3,348
	ARTHUR R. BOWMAN	3,264
	ARROWROCK DAM	3,216
	ANGOSTURA	3,199
	AVALON	3,194
	YELLOWTAIL AFTERBAY	3,180
	OCHOCO DAM	3,154
	THIEF VALLEY DAM	3,143
	ENDERS	3,138
	TIBER	3,026
	CLEAR CREEK DAM	3,015
	ANITA	3,010
	BELLE FOURCHE	2,990
	MERRITT	2,956
	TIETON DAM	2,935
	MANN CREEK DAM	2,903
	BOISE RIVER DIVERSION DAM	2,830

	DAM NAME	CREST ELEVATION (FT)
Flight degradation possible. Especially at very high temperatures. The higher the altitude the greater the likelihood of performance degradation.	TRENTON	2,793
	OWYHEE DAM	2,675
	RED WILLOW	2,634
	FRESNO	2,596
	BULLY CREEK DAM	2,529
	KEECHELUS DAM	2,525
	BLACK CANYON DIVERSION DAM	2,500
	DICKINSON	2,437
	MEDICINE CREEK	2,415
	TRINITY	2,395
	SALMON LAKE DAM	2,330
	SHADEHILL	2,318
	CONCONULLY DAM	2,301
	KACHESS DAM	2,268
	EMIGRANT DAM	2,254
	CLE ELUM DAM	2,250
	THEODORE ROOSEVELT	2,218
	RESERVOIR A DAM	2,200
	CEDAR BLUFF	2,198
	SHERMAN	2,178
	HEART BUTTE	2,124
	HORSESHOE	2,044
No degradation in operational performance expected.	TWIN BUTTES	1,991
	WEBSTER	1,944
	HORSE MESA	1,915
	LEWISTON	1,910
	BARTLETT	1,821
	KIRWIN	1,779
	FOSS	1,697
	MORMON FLAT	1,666
	LOVEWELL	1,616
	ALTUS	1,564
	STEWART MOUNTAIN	1,530
	AGATE DAM	1,520
	GLEN ELDER	1,500
	JAMESTOWN	1,471
	CHENEY	1,454
	MOUNTAIN PARK	1,424
	FORT COBB	1,380
	PINTO DAM	1,351
	MCKAY DAM	1,330
	HOOVER	1,232
	WHISKEYTOWN	1,228
	EAST PARK	1,199
	SHASTA	1,078
	NORMAN	1,071
	O'SULLIVAN DAM	1,061
	ARBUCKLE	920
	STONY GORGE	847
	SPRING CREEK DEBRIS	816
	BRADBURY	766
	TWITCHELL	692

	DAM NAME	CREST ELEVATION (FT)
No degradation in operational performance expected.	LITTLE PANOCHE DETENTION	676
	DAVIS BOR	655
	COLD SPRINGS DAM	630
	KESWICK	596
	CASITAS	585
	FRIANT	581
	LAURO	567
	B. F. SISK (SAN LUIS)	554
	FOLSOM	481
	MONTICELLO	456
	PARKER	455

	DAM NAME	CREST ELEVATION (FT)
No degradation in operational performance expected.	GLEN ANNE	402
	LOS BANOS DETENTION	384
	SCOGGINS DAM	313
	SENATOR WASH	265
	O'NEILL FOREBAY	233
	NIMBUS	132
	MARTINEZ	72
	ARTHUR V. WATKINS	0
	CONTRA LOMA	0
	NORTON	0
	PALMETTO BEND	0
	SANFORD	0

Current Observations Performed by DOI Bureaus

Many DOI bureaus and offices are already taking remote sensing observations. The USGS provided a summary of the types of observations currently performed by DOI Bureaus – including Reclamation – in the USGS UAS Roadmap (USGS, 2010, Table 1, p68).

Table 5.2: Types of Observations currently performed by DOI Bureaus.

	Bureau							
Observations	**BIA**	**BLM**	**BOEMRE**	**BOR**	**NPS**	**OSM**	**FWS**	**USGS**
Archaeological and historic inventory	•	•		•	•	•	•	•
Dam inspection	•	•		•	•	•	•	
Geophysical surveys		•	•	•		•		•
Global change	•	•	•	•	•	•	•	•
Hydrology	•	•	•	•	•	•	•	•
Disturbed surface monitoring	•	•		•	•	•	•	•
Law enforcement	•	•			•		•	•
Mine inspection	•	•			•	•		
Resources	•	•	•	•	•	•	•	
Road inspection	•	•		•	•		•	
Vegetation, habitat and invasive species inventory	•	•	•	•	•	•	•	
Volcano hazards					•			•
Wildfire	•			•	•		•	•
Wildlife inventory, management and health	•	•	•	•	•	•	•	•

Reclamation observations listed were specifically: Archaeological and historic inventory; Dam Inspection; geophysical surveys; Global Change; Hydrology; Disturbed Surface Monitoring; Resources; Road Inspection; Vegetation, habitat and invasive species inventory; Wildfire; and

Wildlife Inventory, Management and Health. UAS missions already flown by USGS for Reclamation and other DOI agencies include: Search and Rescue; Damage Assessment; Wildlife Monitoring; Flood Monitoring; Aerial Photography; Storm Research and Asset Monitoring. The section below is intended to discuss these observations in more detail.

Current Reclamation Remote Sensing Observations

Although potential applications for UAS are discussed in this section, discussion tends to be more focused on current remote sensing needs, and potential T-Hawk applications under "Current Reclamation Needs" (heading below below). Much of the information provided in this section was derived from data collected from survey participants. The purpose of the survey was to assist in identification of potential Reclamation Applications for the T-Hawk. The data from this survey may be used to guide future research using the T-Hawk. Two requests for participation in the written survey were sent out via email to approximately 50 selected potential UAS users designated as potential members for a UAS Community of Interest, including representatives of the Technical Resources (TR) and Security, Safety, and Law Enforcement (SSLE) Directorates, Regions and Area Offices. The second request went out to the potential UAS Community of Interest and contained a more simplified version of the earlier more comprehensive survey. The simplified version contained more yes or no answers so as to reduce the time participants needed to complete the survey. Some participants preferred to be interviewed in-person or over-the-phone. Although, written survey responses were typically received from an individual, in many cases this represented a collaborative effort between 2 or more people. Approximately 10 survey responses were received, about half were representing groups of people rather than individuals. It should be noted that not all Reclamation programmatic areas responded to the survey. Therefore, the responses below should be considered a guide, as it may be possible other Reclamation applications of the T-Hawk and other UAS will be identified in the future.

Some of the survey participants, particularly those from some of the Regions, noted that they either have limited or negligible remote sensor capability. There was dependence on lengthy acquisition process to acquire imagery to satisfy their needs. Frequently there are missed opportunities because of the time and expense involved in acquiring these data. Area offices tend to rely primarily on their stakeholders to supplement data requirement needs. The US Department of Agriculture Aerial Photography Field Office provides NAIP data (typically with a 1-meter resolution) at a frequency of every 3-4 years out to a decade (e.g. decadal collection over the Middle Rio Grande). This data have a compressed distribution format with radiometric balancing that decreases the quality of or destroys the data for some of the applications used by Area Offices. Survey participants suggested that to improve the quality of these data, or to obtain data currently unavailable, more time and money is most likely needed to contract locally for collections. Data are not always available from stakeholders, and when they are available they are at an undesirable spatial, temporal and/or spectral resolution. A taskable high resolution sensor should be able to help fill some of the current gaps in data.

Current Reclamation Remote Sensing Activities

There may be additional remote sensing activities used by various groups in Reclamation that have not been identified here. The information provided below focuses on information provided by survey participants on their current remote sensing activities and capabilities. The utility of the T-Hawk will be discussed in another section below.

Dam Safety Remote Sensing

Reclamation has specific photogrammetric needs related to dam safety. Current forms of data collection revolve around posted cameras or satellite imagery. High resolution cameras are needed to obtain detailed digital terrain models for measurements. The ground resolution needed is 0.01 to 0.1 feet.

Current collection platforms include:

- Tripod;
- Mast system (can get up to about 40 ft. above ground);
- Range pole (up to about 16 ft. off the ground);
- Helium balloon; and
- Boat.

Frequently, a large zoom factor lens is used to obtain photos from 1000+ft. High resolution images of 10-12 megapixels are needed to create detailed digital terrain models and develop 3D images that are used to make measurements on rock surfaces, concrete and embankment dams and appurtenances.

Typically, photogrammetry could be used for identifying dam safety concerns such as: exposed rock in abutments and spillway channels; excavated foundation surfaces at construction sites for geologic mapping and as-excavated surface (topography); rock slopes for stability analysis and mitigation; monitoring and measuring cracks, offsets, deterioration or other defects in concrete structures; monitoring and measuring sinkhole enlargement, soil erosion. Photogrammetry can also be helpful identifying planar features in rock masses; digital terrain models; volumes; change in surfaces over time; enlargement of cracks over time; volume quantities at borrow areas: difference between two surfaces; structural deflection of concrete dams; embankment deformations.

Time Period Needed for Observations or Measurements

The time period needed for observations is variable and dependent on the type of data needed. For dam safety, observations may need to be taken over a period of hours or days for each field trip. In terms of resampling for the monitoring of movement or cracks on structures: monthly, twice yearly, yearly, etc. is determined by the project team may be needed. A one-time only field trip may be needed after a flow event. Spillway channels where there may be ongoing erosion, may need multiple/reoccurring field trips.

For dam safety, the frequency of the observation needed may be in minutes rather than seconds or milliseconds as there is a need to analyze movement over time. Currently, no simultaneous observations are needed at more than one location.

Observation Constraints

Wind affects the ability to fly balloons and launch boats (as with the T-Hawk). Obstructions such as vegetation can inhibit a camera from obtaining two images with similar points, thereby causing a mismatch and can make seamless mapping difficult.

Canal Assessment and Monitoring

In addition to dam safety applications, there have been some Reclamation remote sensing activities relating to inspection of canals. Ground resolution of 6-12 inches is typically needed. Monitoring, inspection and assessment of canals may require remote sensing data over long linear distances. Reclamation is currently looking for cost-effective solutions for monitoring and assessment of current canal conditions.

Information and Imagery Management

The Lower Colorado (LC) Region's Information Management and Imagery Group currently utilizes a helicopter to conduct high definition aerial photography and collection of video footage. Varying levels of accuracy and definition are needed. At least one project requires the collection of high definition images (24 megapixels) from approximately 1500-2000ft. A D3X Nikon 24 megapixel (~6000x4000 pixels) camera is used to collect these images. The camera uses a 35mm lens and can provide a wide swatch when the flight altitude is around 2000 feet. With this camera resolution and flight altitude, the ground resolution may be around 7 inches, but could get down to 4-6 inches. Images are collected every 3 seconds. Meta-data with latitude and longitude is collected so that georeferenced data can be mosaicked together. The use of a helicopter –and not a UAS– permits flight beyond just line-of-sight. Beyond line-of-sight is frequently needed for images collected from large sections of river (e.g. may acquire up to 220 miles of data from the San Juan River in a single flight). Typically, the helicopter video footage and images of lower resolution are most used for media relations purposes (e.g. Reclamation promotional video has been placed on YouTube at http://www.youtube.com/watch?v=GmdriQZI5uk&list=PL97E2B161CFD30D5B&index=11). There is also currently a plan to purchase a FLIR high definition camera system and infrared camera for use with a helicopter. This system is expected to enhance LCs current capabilities.

Technical Services Remote Sensing

Currently there are multiple remote sensing data, including photogrammetric uses, utilized for technical services. Some of these uses have been broken out into sections below based on survey responses.

Sedimentation and River Hydraulics

There are several types of observations currently used in Sedimentation and River Hydraulics Group. These observation types include:

- LIDAR Data – mostly land-based but some are bathymetric
- Helium Balloon for use with photogrammetry
- Fixed Wing Aircraft for use with photogrammetry

Time Period Needed for Observations or Measurements

Observations are from an instant in time (e.g. photographs or LiDAR pulse time). Simultaneous or instantaneous data collection –or consecutive with minimal delay– is needed. At least two photographs are needed for a single point. Three may be needed depending on overlap.

Observation Constraints

Currently, a balloon can be used to make LiDAR measurements at as many different areas as the client can pay for. Although the balloon is a useful platform that can be used to make LiDAR measurement, the operator still must be able to access the entire site he/she is are trying to survey (i.e. walk the entire site). Typically, remote sensing in support of sedimentation studies produces very dense point clouds on the order of inches. The disadvantage of the balloon is that it is very weather dependent. It does not perform well in wind or in rain. However, there is a similar problem with the T-Hawk and other micro or small UAS. When using the balloon, site conditions can cause difficulties, especially in the presence of heavy vegetation and steep inclines (It is essential to walk the area to be imaged). A UAS like the T-Hawk may provide a better a*nd safer alternative in areas of dense/heavy vegetation and difficult inclines.*

Environment

With respect to wildlife biological studies, for at least some of the area offices, current observation techniques include people on the ground with cameras and notebooks. This is highly labor intensive and can require considerable time and effort to collect sufficient information. Other remote sensing observations may be needed to help monitor conditions for fish species are also be vital for Reclamation (e.g. water quality and availability for fish, such as the silvery minnow in the Pecos River and The Rio Grande).

Currently, Reclamation is conducting in-stream habitat studies for the Fish and Wildlife Service. High definition images using a 24 megapixel camera, fitted to a helicopter, is being used to collect images that are later mosaicked together. The altitude used for collection of these images is typically 1500-2000ft. This flight altitude ensures a wide enough swath is obtained so as to see the entire width of the river. Ground resolution needed is typically 4-6 inches up to 1 foot. High definition video is also used during flight. This video can be used as a back-up for missing still frames even though it is at a lower resolution than the 24MP images – this ensures there is no missing river information. Currently, non georeferenced images are being utilized. Mapping scale measurements of 1:10,000 is sufficient for these studies.

Idaho Power has in the past used UAS to survey Chinook salmon nests in the Snake River (http://www.suasnews.com/2013/02/20921/idaho-power-uses-drones-to-find-salmon-in-the-snake-river/). It has also used UAS in the past to assist in this surveying (the FAA has since ground the UAS because Idaho Power had not gone through the COA certification process). One of the main motivations for Idaho Power using the UAS was considerations for safety. In recent years there has been a crash involving Idaho Fish and Game personnel on a mission and another crash resulting in the loss of the life of an Idaho Fish and Game wildlife biologist in 2000 - http://www.klewtv.com/news/local/81041442.html. The use of UAS for surveying missions will likely decrease the risk to Reclamation personnel.

Water Operations, Supply and Demand

Aerial photographs are frequently used to assist in water operations, and supply and demand forecast decision-making. These images help provide information on river flow, discharge rates and runoff. These measurements may be taken year round, or from just after post-runoff season to approximately the end of irrigation season.

In addition to aerial photographs, daily observations are made in person or using gauges. These types of observations, although useful, do not offer the benefit of seeing a feature of change through time from an aerial perspective. Access can be limited at certain locations (e.g. access to the river at drying locations). Other types of observations may be collected as needed and when funding is available. The costs associated with different observations depends on the complexity and level of detail needed.

The largest remote sensing data acquisition for the Albuquerque Area Office is for the Middle Rio Grande Decadal data collection. This is to monitor how the river changes over 10 years. A taskable system like a UAS may be very beneficial and could be used to supplement collection of data.

Security, Law Enforcement and Emergency Response

Currently the LC Region is utilizing the Reclamation helicopter as a platform to provide support for security, law enforcement and emergency response activities. The time needed to conduct observation is incident-specific, but frequently can be over a period of hours. Images gathered using a helicopter platform is frequently used for improved situational awareness: geographical data for approach information, assessment, and planning (e.g. during heightened security alert levels, other incidents, or to better understand any changes over time). This remote sensing information is used by first responders, for law enforcement applications and security personnel.

The typical area to be covered is approximately 3 square miles and the time needed to collect the data may be frequently over 1-2 hours. The observations are most likely only needed during an emergency or annually. Although the frequency of image capture needed is incident-specific, images may be needed as infrequently as once every minute. The ability to loiter around a point on the ground, and perform vertical and horizontal profiling is required. Some of the constraints associated with utilizing the helicopter are: the costs involved with operation and maintenance, pilot safety, and inclement weather conditions.

Another capability available to the LC Region is the ability to deploy a Long Ranger Bell 204 helicopter (currently leased from the Office of Aviation Services) to assist in emergency response (see image on following page). This helicopter can be rapidly deployed all of the southwest to assist in response to an incident at a dam.

Long Ranger Bell 204 - Photo: Andy Pernick – Lower Colorado Region

Summary of Reclamation Remote Sensing Observation Requirements and Guidance for Potential Reclamation Users

The section below summarizes the information above and provides some guidance to potential Reclamation UAS users. This should help potential UAS users and operators determine whether the T-Hawk or other UAS can provide them with sufficient data collection capabilities for their needs.

Minimum Reclamation Photogrammetry Requirements

Camera Resolution	EO camera images of at least 11 megapixels, with 12 or more megapixels preferred. *[24 megapixels required in one case (e.g., habitat monitoring). LiDAR remote sensing technology is essential to some applications.]*
Accuracy	Many of the applications need sufficient UAS positional and altitude knowledge when photos are taken.
Spatial Resolution	Dam safety spatial resolution of 0.01-0.1 feet needed. Some program areas (e.g. sedimentation and river hydraulics) need an accuracy of 6 inches. Others only need measurements down to a 1 foot or even out to a yard.
Real-Time versus On-Board Data Storage	There is a need for both real time data (e.g. for dam safety applications) or on-board storage for processing data later (e.g. for sedimentation studies).

Measurement Requirements

Ground Resolution Needs

Camera Resolution

Based on survey data, most dam safety photogrammetric needs require EO camera images of at least 10 megapixels, with 11 or 12 megapixels preferred. In one case, a camera resolution of 24 megapixels was needed. Highly accurate data was needed in many cases. At the onset of this project, this camera resolution was not available on the T-Hawk. The standard camera fitted on the T-Hawk does not have a resolution sufficient to capture changes in topography. However, the GoPro Hero2 and GoPro Hero3 are now available and a COA has been provided for the T-Hawk fitted with a GoPro Hero2. The Hero2 and Hero3 both have camera resolution capabilities of at least up to 11 megapixels. This should be sufficient for *most* Reclamation needs.

Cameras

Any camera utilized on the T-Hawk would preferably have the same specifications as the current cameras in use by Reclamation. Two of the cameras currently being utilized to collect images include the Nikon D300 (~12.3 megapixels) and the Nikon D3X (~24 megapixels). However, T-Hawk is currently not capable to flying with a payload of this weight.

Field of View (FOV)

The current FOV of the GoPro cameras should be sufficient for most Reclamation needs. Some of the survey participants noted the need for a FOV suitable for riverine environments where a swath would need to include the entire width of the river. Depending on the ground resolution needed, the T-Hawk may need to be flown at a higher altitude.

Accuracy

Dam safety requires an accuracy of 0.01-0.1 feet, other program areas such as sedimentation and river hydraulics, need an accuracy of 6 inches, while others only need measurements down to a foot or even a yard.

Mapping Scale

Survey participants stated the need for mapping scales between 1:200 and 1:24,000. The mapping scale typically used for some dam safety applications is 1:200 to 1:3000.

Spatial Resolution

Spatial resolutions requested by survey participants ranged from six inches, one foot to one yard. If LiDAR data is needed, the spatial resolution may need to be down to centimeters.

Temporal Resolution

The temporal resolution needed for images is standard. The frame-rate of the GoPro cameras should be sufficient. One participant stated the need to have images taken at a rate sufficient to create 3D mosaics.

Positional and Altitude of UAS

Most applications will need accurate positional information. Altitude knowledge will also be advantageous, and when it comes to 3D images – essential.

Operational Requirements – T-Hawk Flight Parameter Expectations

Survey participants provided information on what they expected their operational needs were when it came to UAS missions. This information helps to better understand whether the T-Hawk would be appropriate for use for their applications. This information can help guide potential T-

Hawk users during any mission scoping and planning (e.g. arrange missions in early morning to avoid afternoon winds and higher temperatures).

Maximum Altitude

Most of the survey participants indicated that they had variable needs when it came to maximum flight altitude. Some stated that it was dependent on the type of data they were collecting and maximum altitude could range from 500 up to 5000 feet. Others stated that up to 400 feet was sufficient. Others stated that they needed to be able to view the width of the river (a little over 0.5 miles) and would need the T-Hawk to be able to provide this field of view. Two participants indicated that they needed to fly 1500-2000 feet to obtain a swath wide enough to view the width of the river. For many dam safety applications it is likely that images that provide high spatial ground resolution (e.g. 6 inches down to cm) would require the T-Hawk to be positioned fairly close to the target area. For most the potential applications the desired ground resolution and field of view (or footprint) will drive the maximum flight altitude. Maximum altitudes below 400ft are preferable when applying for Certificates of Authorization (see Regulatory Limitations section for more information).

Weather Conditions

Temperature and Humidity Range

Reclamation needs robust remote sensing equipment that is able to operate in variable operating conditions. This equipment needs to be able to successfully operate under both low and high temperatures (e.g. 15-105 degrees Fahrenheit) and variable humidity (i.e. low humidity of less than 15% and highs of 100%). Potential T-Hawk users should review the earlier section on how temperature and humidity can negatively impact on T-Hawk performance at higher altitudes (e.g. refer to figure 5.1).

Winds

Reclamation remote sensing equipment needs to be able to successfully operate in areas that frequently experience high winds (i.e. greater than 15 miles per hour). The T-Hawk is capable of flying in winds up to 20 knots and can take-off and land in winds of up to 15 knots. However, there are some Reclamation regions that may require data be collected when winds are greater than 15-20 knots. *To address this, it may be possible to schedule missions to in the morning, near to sunrise, to avoid flying in high afternoon winds.*

Estimated Range and Length of Flight

Most of those surveyed indicated that the estimated range needed for flight was dependent on the type of information needed. Most survey participants did not see the need for persistent surveillance but need a UAS to obtain images for mosaicking. One group participating in the survey indicated the data collection area covered two reaches (approximately 20-30 miles) on a single flight line. Another indicated up to 220 miles on a linear path following a river is needed. Others wanted to cover at least 1 square mile. Repeated observations of the same site may or may not be needed, but some indicated annual observations would be necessary. Another indicated that daily observations at certain sites would be useful but were concerned about what cost that might entail.

In optimum conditions, the T-Hawk can only stay aloft for 40 minutes. The T-Hawk would be in need of refueling before completing the mission. The T-Hawk may be most suited to close range, small square mileage areas, and hover type missions. A winged UAS (e.g., Raven) may be more appropriate for missions that will need to cover larger areas. However, all UAS missions will be limited by the FAA Line-of-Sight (LOS) restrictions. To ensure LOS, the T-Hawk may need to land and re-launch many times or would require a chase plane or chase vehicle to ensure LOS with the T-Hawk is maintained. Both these options add inconvenience. Using a chase plane will increase cost and defeat the purpose of using the UAS instead of a manned aircraft. In terms of canals or small sections of a river, a chase vehicle may be possible if the vehicle has access to a road that runs parallel to the canal or river. This vehicle would need to maintain LOS with the T-Hawk or other UAS at all times.

Proximity to Cities and Airports

Due to FAA flight restrictions a UAS will not be permitted to operate within proximity of densely populated areas – such as cities – nor within close proximity to airports. The FAA will not approve flight of a UAS if the flight path is expected to occur within 5 miles of the airport. This is to reduce the risk of a UAS interfering with a manned aircraft. In addition, the high probability of UAS failure or mis-operation may put densely populated areas at risk should the UAS be flying overhead at the time of failure.

Some of the survey participants indicated they may need to operate the UAS within proximity to a city or populations and/or within 5 miles of an airport. Any Reclamation missions close to dense populations and/or airports pose an increased risk to the public and are unlikely to be approved by the FAA. This proximity to cities and airports should be considered during the early stages of mission scoping. A UAS would not be appropriate for use within proximity to any populations-at-risk or within 5 miles of an airport.

Flight Characteristics

Reclamation has variable needs when it comes to the type of maneuvering needed or wanted for data collection. Most Reclamation needs evolve around collection of imaging data. Flight plans that support the collection of images to create photomosaics would be most beneficial. In many cases, a constant height with the camera facing downward may be sufficient. Programmable flight plans with a stabilized camera (i.e. camera mounted on a gimbal) would be preferable. Missions requiring observation of a dam face should utilize a gimbal to ensure image stabilization and directed data collection. One advantage of the T-Hawk is that it has a gimbal available to mount the camera.

Current Reclamation Needs

Most of those who participated in the survey were relatively new to UAS and their current knowledge of the applications of UAS was fairly limited. However, one participant has processed imagery from UAS in the past. The information below was largely provided by survey participants and may not identify all possible Reclamation Applications of the T-Hawk.

Gaps in Reclamation Remote Sensing

According to some of the survey participants, in some cases there is currently insufficient access to imagery data and/or limited or non-existent on-site and near real-time sensing capability. Many participants are hopeful that the T-Hawk or other UAS would be useful in helping to fill some of those gaps, as well as provide an alternative that may prove to be both safer and cost effective.

Future Potential Reclamation Missions

Those participating in the survey had some suggestions for potential Reclamation missions. It is unclear as to whether the T-Hawk would be able to acquire this information. Experimental/trial missions may be the best indicator as to how well the T-Hawk performs this data collection successfully. Cost of the use of the UAS in comparison to current remote sensing techniques used currently will also need to be considered, and potential applications of a UAS will be somewhat dependent on cost versus benefit. In general, Reclamation programs, groups, initiatives and activities that may benefit from the use of a UAS include, but are not limited to:

- Dam Safety (e.g., before and after assessment of dam after repairs to infrastructure; initial inspection before climb teams; monitoring for seepage)
- Operations and Maintenance (e.g., water operations; canal monitoring)
- Facilities and Lands (e.g., monitoring of restoration projects)
- Fisheries and Wildlife Resources (e.g., habitat monitoring)
- Geotechnical Engineering and Geology (e.g. monitoring and measuring of cracks; deterioration in concrete)
- Instrumentation (e.g., assist in routine monitoring of dam performance
- Materials Engineering and Research Lab (e.g., assist in the development of as-built drawings; monitoring of cracks)
- Sedimentation and River Hydraulics (e.g., sediment transfer; river morphology)
- Any individual or group that relies on geospatial data for operations or decisions support.

Reclamation is in the early stages of evaluation to determine whether UAS will be suitable and a cost-effective alternative for use with these applications. A fixed-wing UAS, rather than a UAS with vertical take-off and landing and hover and stare capabilities, may be more appropriate for use for some of these applications. Specific potential UAS applications relevant to Reclamation needs include:

- Aerial Photography/Imagery Management/Media Relations
- Archeological Site Mapping and Monitoring
- Canal monitoring
- Crop identification and yield forecasting
- Dam and levee inspections
- Emergency management response
- Estimating algae density in sewage lagoons
- ET estimation
- Flood hazard analysis
- Flood risk assessment
- Flow to habitat relations

- Habitat mapping
- Identification of canal encroachments
- Identification of flood plain encroachments
- Imaging to make ortho-rectified maps
- Integrating remote sensing and point data info
- Law enforcement
- Moisture content in snow
- Monitoring dam faces and canals for seepage
- Post construction monitoring
- Riparian surveillance
- River corridor change detection
- River restoration monitoring/change detection
- Root zone soil moisture estimation
- Sediment transfer
- Snow depth
- Urban/canal interface mapping
- Volume estimation
- Water spreading
- Water turbidity
- Wetlands classification

Survey participants provided some more in-depth information on potential Reclamation applications of the T-Hawk and other UAS in general. Some of the survey responses are discussed in more detail below.

Dam Safety, Operations and Maintenance, Facilities and Lands

The T-Hawk may provide an alternative for assessment of a dam before and after repairs to infrastructure (e.g., dams, spillways, appurtenances, and other operational equipment), assessment during tests, and monitoring of movement and seepage at embankment dams. Temporal information associated with dams, infrastructure and erosion sites can be important. Additionally, the T-Hawk –or other UAS– may provide high resolution aerial inventory of facilities provided the data is appropriately georeferenced, georegistered and orthorectified to suit needs. Orthophotos would be needed in support of most programmatic functions. In many cases, mosaics of images will be sufficient, and video would not be required, although considered beneficial.

A UAS fitted with a high definition camera may also be useful for riverine work. However, a fixed wing aircraft may be more appropriate for this type of data collection. UAS monitoring of restoration projects, to track incremental changes, may also be a potential use. UAS like the T-Hawk may be beneficial to embankment dam monitoring provided camera distortions are eliminated. Software is currently available to assist with the elimination of distortions. In addition to high definition optical cameras, the use of infrared cameras could to help identify and monitor potential areas of seepage in embankment dams and/or canals.

Photogrammetry and photo documentation of various dam features may be an appropriate use for the T-Hawk. There is a question as to whether a UAS could assist climb teams. A UAS that can hover and that has image stabilization capabilities may be useful to climb teams in certain situations, especially if potential problematic areas can be identified. However, all UAS require some form of communication to operate. This can be done in two ways: (1) via radio communications; or (2) via satellite communications. This means the UAS antenna must be in line-of-sight of the radio or satellite to be operated (and the FAA requires an observer with a visual line-of-sight). Not all UAS have satellite communications and it is highly unlikely that there would be sufficient satellite communications within even a very large Morning Glory Spillway, especially when considering GPS resolution error. Additionally, without strategically placed repeater, radio communications may be difficult. Such potential communications limitations make it unlikely that a T-Hawk or other UAS could be operated in a Morning Glory or Tunnel Spillway or other enclosed spaces such as diversion tunnels. However, the T-Hawk or other UAS with hover and image stabilization capabilities may be very useful for photogrammetry of hard to reach abutments, and mapping of cracks in the buttresses of a slab and buttress dam, or photos/mapping of cracks on the downstream face of Reclamations arch dams. One respondent suggested the development and use of image processing software to flag cracks, offsets, etc. to help identify areas of potential concern.

Canal Assessment and Monitoring

In addition to dam safety specific applications, Reclamation is currently in need additional remote sensing technology to help monitor its canals. A UAS may provide a cost effective alternative to assist in gathering of remote sensing imagery that can help identify areas of concern. In addition to color images, thermal or infrared imagery could help to identify potential areas of seepage. The current T-Hawk standard infrared camera has insufficient resolution for this application. Canal remote sensing will require lengthy linear flight paths and will require need a chase vehicle with an observer that can maintain visual contact (line-of-sight) with a UAS.

Technical Services

River Sedimentation and Hydraulics

Current river observations capabilities for river sedimentation and hydraulics projects include the use of a helium balloon and fixed wing aircraft. The T-Hawk may be able to provide temporally relevant imagery and assist photogrammetric modeling of highly dynamic river reaches. UAS missions may be able to provide information on changing in river channel structure and morphology; vegetation and soil mapping. Some other proposed T-Hawk uses include: identification, assessment and monitoring of sediment plugs and low flow areas.

Environment

The T-Hawk fitted with a high resolution camera (e.g. GoPro Hero2 or Hero3) may be able to help with annual habitat data revisions and updates so as the data needed can be automatically extracted and classified. This may not only provide imagery but also streamline the revision and update process provided the data has sufficient pixel depth to facilitate an automated process. Depending on the ground resolution needed, the T-Hawk may be used for monitoring of restoration projects. This may be especially true should the use of a UAS like the T-Hawk prove to be inexpensive enough to repeat flights annually so as to track changes and process photos.

UAS may be a good alternative for the collection of data to support of wildlife studies. However, the gasoline engine on the T-Hawk is very noisy and there are additional risks associated with the potential for fire should the T-Hawk crash. A UAS with electric propulsion capability (i.e. electric motor) may be more appropriate for any studies that require a lot of flight over protected National Park Service areas or collection of data over areas where wildlife my might affected by noise.

Understanding environmental conditions for fish species is important for Reclamation. The T-Hawk –or other UAS– may also be able to provide information as to how wet the river is during summer months. This would be important for assessing whether there is sufficient water and water quality for various fish species. A UAS may also be useful for pre- and post-construction imagery of wetlands. UAS to assist with the Reclamation RiverEyes Program may also be another potential use. The RiverEyes program helps to provide current information on river flows and river drying and allows prompt reaction to changing river conditions on the Rio Grande, Isleta and San Acacia Reaches. This situational awareness will help to facilitate to prevent and prepare for impact to silvery minnow populations. Monitoring for drying within reaches of a river is just one example of the types of remote sensing observations needed. This type of mission, a single UAS may provide sufficient coverage to monitor multiple locations of a reach during a single flight. Early morning flights just after sunrise would be preferred. However, a UAS with loiter and stare capabilities may not be necessary for this type of mission and a fixed wing UAS may be sufficient.

Some potential UAS users have indicated that access to UAS with both LiDAR quality image data and RADAR capabilities, would be very beneficial, as they would likely be able to provide a service previously too expensive for their clients. If metadata of sufficient quality cannot be provided by the UAS avionics, the addition of an external GPS-INS system (GPS and Inertial Navigation System would also be advantageous. A GPS-INS system would provide the aircraft, and therefore camera image, position and attitude. This is particularly important for LiDAR data which require aircraft metadata for processing. Access to a UAS with LiDAR and/or RADAR capabilities would be a preference to many Reclamation potential UAS users.

Archeology

There is a need for high resolution environmental imagery to distinguish features at archeology sites. Archeology information has been collected by Reclamation to help address issues related to the protection and conservation of these sites. The T-Hawk fitted with a high resolution camera (e.g. GoPro Hero2 or Hero3) may be able to provide sufficient ground resolution at archeology sites to provide more detailed information at these locations.

Reclamation Materials and Engineering Research Laboratory (MERL)

Other uses for a UAS that can loiter and perform both vertical and horizontal profiling (like the T-Hawk) are: close range photogrammetry to assist in the creation of as-built drawings of dams and spillways, and monitoring of concrete for cracks and deformation after construction. However, ground resolution with current payloads may not be sufficient to help detect cracks of less than 0.05mm. The Materials and Engineering Research Laboratory (MERL) would also like to have the opportunity to obtain data using thermal infrared sensors. However, although infrared sensors are currently available on the T-Hawk, the resolution is very low and the infrared sensors cannot be flown at the same time as the optical sensors. This means image data need to be collected in two separate flights so as to capture both visible and infrared image data.

Water Operations, Supply and Demand

Generally UAS – the T-Hawk in particular – may be appropriate for use when procuring images of Reclamation reservoirs at various stages and low capacities to get accurate water polygons for volume calculations and assist digital elevation modeling. UAS may be used to help with situational awareness associated with rivers that typically flood and affect Reclamation facilities. A pre-stationed UAS at an area office during potential flooding activity may assist with flood extent investigations. Monitoring of river and Reclamation facilities during irrigation season may also help operators better prepare for stakeholder demand.

Security, Law Enforcement and Emergency Operations

The Reclamation domains most likely to find immediate benefit from the use of UAS are security, law enforcement, and emergency operations. This is because current uses of UAS include situational awareness, intelligence, and surveillance. The T-Hawk was designed to be used specifically for situational awareness. The T-Hawk's capability to loiter or hover may be extremely beneficial. The addition of UAS to Reclamation capabilities would be a major enhancement to supplement our current capabilities and coordination application with adjacent agencies and support personnel. Additionally, once small UAS platforms can carry LiDAR equipment, then there may be a demand for rapid response LiDAR data.

The T-Hawk may be useful to both the Area Offices and Regions when a rapid/emergency response is needed. Potential monitoring activities the T-Hawk or other small UAS *may* be useful include: situational awareness; physical security assessments of dams, canals, and related water structures; real-time law enforcement and security applications during incidents (e.g. dam security utilized by the command and control center/on-site security); flood/inundation extent surveillance; and observation for potential structural damage and damage along canals (e.g. damage assessment after potential infrastructure damage from an earthquake). The use of UAS, such as the T-Hawk, may also help federal law enforcement and promote better information sharing with local law enforcement. Thermal imagery may be extremely useful in emergency response and detecting areas of seepage in canals and on dams.

However, one limitation of T-Hawk for law enforcement and security activities is noise and its size may make it an easy target. There are likely to be smaller, electric based UAS with loiter/hover capabilities that may be of more use than the T-Hawk. Unfortunately, at-this-time OAS policy will not allow DOI agencies to pursue other technology.

USGS – Current and Potential Remote Sensing Observations

In addition to Reclamation participation in the survey, the USGS National UAS Project Office was given the same opportunity to participate in the same survey completed by potential Reclamation UAS users. Most of the information provided below is from the completion of this survey. This information can help us to better understand how the USGS is utilizing UAS data, and may provide information also relevant to Reclamation remote sensing needs.

Current Observations

The USGS currently uses remotely sensed data for short-term and long-term monitoring, emergency response, vegetation health, volumetric measurements, wildlife population counts, climate change, wildfire applications, amongst other uses.

USGS currently continually collects aerial and satellite imagery for use in mapping and monitoring. They use many different mapping scale measurements (e.g. 1:10,000; 1:50,000; 1:1,000,000). Satellite, visible, infrared and thermal imagery is collected. Microwave sensing such as radar is also used. Currently, environmental air, water and soil sampling is not conducted. Time periods observed by USGS range from seconds to days depending on the needs.

The costs associated with aerial and satellite imagery can be a major constraint. The frequency of satellite orbit and target opportunities can also be a problem with aerial and, particularly, satellite imagery. The use of a UAS may or has, in some cases, been beneficial in reducing costs and can provide opportunities to better target specific areas of analysis.

Current Photogrammetric Needs

Real-time monitoring is needed, but on-board storage of data to be processed later is sufficient in many cases. A ground resolution down to one foot can be needed but more coarse/higher altitude data are also used. Data for Digital Elevation Models, orthrectified maps, contours and video are needed. USGS uses various types of photogrammetric software so as to perform their own rectification and refinement of any images collected.

The stability of the UAS during flight or camera system (e.g. using a gimbal) can aid in imagery accuracy and rectification. Additionally, they have found the use of an GPS-INS can greatly speed up the rectification process.

T-Hawk Flight Parameter Expectations

The USGS typically needs a UAS to stay in the air for up to 1 hour, with an estimated flight range of greater than 6 miles and area to be covered can be 1-4 square miles. The maximum flight altitude may be up to 1200 feet. Site visits to observe the same area again may need to occur quarterly or annually. An image capture rate may be once every 1 to 3 seconds. The UAS platform will need to be able to perform both horizontal and vertical profiling, as well as loitering around a point on the ground.

Future Uses of UAS

Noise from the T-Hawk may make some missions, such as wildlife monitoring or use in urban areas, difficult. However, the T-Hawk may be useful for many other applications, such as search and rescue and emergency response. Over the next 5-10 years, especially once imaging systems become more capable (e.g. of high definition photogrammetry), UAS should become very useful for applications related to dam monitoring and restoration. In addition to potential Reclamation UAS applications, other DOI agencies, the DOD, DHS and Department of Agriculture are likely to begin using UAS more and more.

Post Processing of Images

Imagery data from UAS will be an essential component of UAS missions (e.g. BLM have conducted UAS flights where 6 days of missions provided 26,000 images). Procedures for the post-processing of these data are extremely important. The section below provides some information on current USGS and Reclamation procedures utilized or available to process imagery data. Some Reclamation applications require advanced 3D modeling, requiring extensive post-processing of remote sensing data.

USGS Procedures

Post-processing of images has the potential to be quite labor intensive depending on the needs of the client/user.

GOM Media Player

To undertake batch capture capturing of still frames images from video, USGS currently uses software including the GOM Media Player, MS Office 2010 Picture Manager and Windows Live Photo Gallery (Raven Image Mosaic Procedures, USGS 2012). The USGS procedures for mosaicking images can be found in Appendix G.

It is currently unclear as to what Reclamation applications the GOM Media Player Mosaicked images would be suitable for as many of the Reclamation needs require a georegistration or georeferencing.

Agisoft PhotoScan

USGS now has access to advanced image based 3D modeling software called Agisoft PhotoScan (http://www.agisoft.ru/products/photoscan/). This software can automatically create (reconstruct) high quality 3D content from still images. *It is still uncertain as to whether the AgiSoft Photoscan software is sufficient for Reclamation applications but this software is more advanced that the GOM Media Player processing and can provide 3D models.* A potential area for Reclamation research would be to determine how well suited this software is for Reclamation (e.g. a comparison of remote sensing and post processing techniques). The professional version of this software is less than $3500 and may provide a suitable and cost effective alternative to the current software used by Reclamation (i.e., AdamTech software).

Reclamation Procedures

Adam Technology: 3DM Analyst Mine Mapping Suite

Adam Technology (AdamTech) has 3D measurement, camera calibration and block adjustment software that is a lot less ridged and restrictive than other 3D measurement programs. The AdamTech software does not require a straight flight path and can be used to process images collected by the balloon equipment. This software is used for photogrammetric purposes (Photogrammetry is the process of determining 3D locations of objects from 2D images).

Details on this software can be found in the AdamTech Mapping Suite User Manual (AdamTech, 2010). This software does provide the capability of absolute orientations that permit data to be registered against real-world coordinate systems (i.e. georeferenced). One capability of this software is able to extract 3D data from digital images. When a series of photos are taken and coordinated with known locations of the area imaged the software is capable of automatically generating 3D surface models, contours and cross-sections. This can be done to an accuracy of 1:10,000 of the size of the area covered by a single image. This is best suited for terrestrial applications (AdamTech, 2010, p16).

The AdamTech User Manual (AdamTech, 2010) highlights six key factors when planning to take images to be used for photogrammetric purposes (i.e., to compute absolute orientation):

1. Avoiding Image Movement (e.g. use of a gimbal to mount camera to help provide a stable platform with the capability of focusing on a point and therefore reduce movement)
2. Site Considerations (e.g. understand terrain hazards; occlusion; surface texture; regular image features; lightning conditions)
3. Target signs and Placement (e.g. place and survey targets for georeferencing)
4. Digital Camera and Lens Settings (e.g. Zoom; Focal Length; Field of View; Aperture; ISO Speed; Auto Rotate)
5. Types of Photography Projects; and
6. Additional/Optional Equipment (e.g. Laser range finder; GSP Transceiver).

At $50,000 this software is expensive and the length of time it takes to process the images is dependent on the quality of the images. High quality images with good stereo pair positioning may only take minutes to process. Poor quality images with poor or bad stereo pair positioning may take days to weeks to process. The benefit of this software is that it does not need images to be taken in a straight flight path. Currently, there is no way to tell whether the AgiSoft PhotoScan software will provide an equivalent or near-equivalent alternative to the AdamTech Software. See Appendix H for steps on how to process photogrammetry images using the AdamTech Software. This process was written by Connie Svoboda, Hydraulic Investigations & Laboratory Services (86-68460) in March 2010.

UAS and LiDAR

There are currently UAS that have the capability of producing LiDAR quality terrain data. Additionally, the USGS UAS Project Office has been "very impressed with the potential of Structure from Motion to supplement, if not replace, LiDAR for many applications" (*Pers. Comm. – email*., M. Hutt, Feb 27, 2013). Structure from Motion techniques/algorithms allow recovery or reconstruction of a complete 3D model from calibrated (and in some cases non-calibrated) images (e.g. Dellaert *et. al*.).

The University of Alaska has conducted numerous UAS studies in support of research in survey technology; marine wildlife and coastal habitats. They have been experimenting with the collection on 3D data to produce LiDAR quality terrain data. In addition to the University of Alaska research, some NASA UAS missions have focused on high resolution topographic mapping and change-detection using UAS LiDAR measurements. Data are collected over a "series of offset, parallel, overlapping flight tracks to build up a corridor of data covering the region of interest" (Civil UAV Assessment Team, 2006). NASA determined that UAS may be useful in determining river discharge, where data would be collected on the "volume of water flowing in a river at multiple points" (Civil UAV Assessment Team, 2006). These data could then be used for water balance studies.

Conclusions

Research must be conducted to test the ability of the T-Hawk to meet Reclamation’s remote sensing needs. Missions that are localized and do not require linear trajectories over long distances would be more appropriate for use with the T-Hawk. T-Hawk and other UAS missions that are expected to be flown at higher altitudes (height above sea level) may experience flight performance degradation, especially at high temperatures and/or high relative humidities. This should be considered during any UAS mission planning. The standard camera currently available on the T-Hawk is insufficient for Reclamation needs, but the GoPro Hero 2 or Hero 3 cameras may provide sufficient image resolution for most of Reclamations remote sensing needs. However, vibration issues may limit the T-Hawk applicability for photogrammetric purposes unless this can be addressed. Should LiDAR, RADAR or hyperspectral capabilities become available on the T-Hawk or other UAS, this would be of considerable interest to Reclamation. A UAS with modular payload capabilities would be most beneficial. One significant benefit of the T-Hawk over the Raven is the gimbal available on the T-Hawk that assists in image stabilization and focusing on a specific point. UAS, in general, may be a safer option; reduce the cost of data; and improve data continuity for Reclamation.

Section 6. Future UAS for DOI and Reclamation?

Although OAS is exploring other possibilities for the use of UAS (e.g. contracting out services) at this point in time, the Raven and the T-Hawk are the only UAS platforms are available to the USGS and other DOI entities (as per DOI OAS policy – refer to Section 3 for more information). However, there are other UAS that are currently considered more capable than these two UAS. One of the Reclamation personnel who participated in the survey suggested Reclamation may need a Reclamation UAS that is more than a micro air vehicle (Tier I) – something that has more Short or Medium Range Tactical capabilities (e.g. a Tier II or III). Another Reclamation employee has identified four currently commercially available UAS that should meet Reclamations needs for mapping-orthoimagery-digital elevation model production (see information in "UAS of Potential Interest to Reclamation" section below). In addition, UAS technology improves rapidly. The capabilities UAS have available for use in the near future may provide use with as LiDAR, RADAR and hyperspectral sensing capabilities that would be extremely beneficial to Reclamation. Unfortunately, OAS will not be looking at procuring or approving other UAS platforms until the 2014 field season. DOI are also currently working on a data service contract to help supplement the DOI fleet of UAS. The earliest this is likely to happen is the 2014 field season (*Pers. Comm.–email*, M. Hutt, Feb 27, 2013) Some information on current UAS either recommended for use by USGS or is of interest to Reclamation is provided below.

UAS Recommended by USGS

The USGS currently recommends for future use include the Puma, Gatewing and Draganflyer. Small UAS with hover and image stabilization capabilities may be most appropriate for dam safety needs. However, flight endurance should also be considered.

Puma AE

The Puma AE (All Environment) is a small UAS by AeroVironment. It is a winged UAS that is fully waterproof and capable of landing on water (including saltwater), and has a gimbaled camera payload that allows for


Image from USGS UAS Briefing Presentation to Reclamation August 10, 2012

image stabilization and 360 degrees continuous pan. The electro optical, infrared camera and infrared illuminator are all part of the payload. The two hour endurance of the UAS is much greater than the T-Hawk. It weighs approximately 13lbs (see Puma AE datasheet at http://www.avinc.com/downloads/PumaAE_0910.pdf). The Puma AE also uses a Ground Control Unit that is compatible with the Raven Platform.

Gatewing

The Gatewing, by Trimble, has 10 megapixel camera capability designed specifically for digital mapping and orthogonal photography. According to the July 15, 2012 news release Gatewing has produced LIDAR quality orthophotos (see Marshall, 2012). This LiDAR capability would be of particular interest to Reclamation. For more information on Gatewing refer to their website at http://www.gatewing.com/. See section “UAS of Interest to Reclamation” for image.

Draganflyer

The Draganflyer is another UAS that USGS would like to recommend for OAS future use by DOI agencies and bureaus. The Draganflyer is a small UAS helicopter that has been tested by the Mesa County Sheriff’s Office in Colorado (see http://www.draganfly.com/news/2012/03/02/mesa-county-sheriffs-office-demonstrates-the-draganflyer-x6-police-uas-helicopters-search-capability/). Mesa County, CO Sheriff's Department has been impressed by its ability to provide complete situational awareness. The Draganflyer X8 is electric powered, weighs only about 1.7lbs and is able to carry a 1080p video camera provided the payload weighs less than 800g. The Draganflyer has hover and stare capabilities. Without a payload the Draganflyer has a maximum flight time (endurance) of only 20 minutes and maximum altitude above sea level is ~8000ft (see Technical Specifications at http://www.draganfly.com/uav-helicopter/draganflyer-x8/specifications/).

UAS of Interest to Reclamation

Alan Bell, a Physical Scientist with the Emergency Management and GIS Group has researched a number of UAS and identified four that should meet most of Reclamation's mapping needs. He provided the information on these for UAS (discussed in more detail below).

Falcon

Image captured by Jon Becker, July 2012

The Falcon UAS Company is based in Colorado and is another UAS utilized by the Mesa County (CO) Sheriff's Department. The Falcon UAS is hand or bungee launched, weighs less than 10lbs and has a1 hour flight endurance. Typical flight altitude is 300-1500 feet above ground level. The payload includes a Sony Block Camera and a Thermal Infrared Camera. Base unit cost is approximately $25,000-$30,000 (see the technical specifications of the Falcon UAS at http://www.falcon-uav.com/falcon-uav-info/).

Gatewing x100

Image from Gatewing product website at http://www.gatewing.com/X100

The Gatewing X100 is a UAS identified to meet Reclamation's mapping needs, especially with its highly accurate mapping capability, and is also one of the UAS recommended by USGS. The Gatewing x100 base price is approximately $80,000-$100,000.

More information on the Gatewing X100 can be found at http://www.gatewing.com/X100.

eBee

The eBee is a very small UAS. It has a wingspan of less than 3 feet, weighs just 630g and has a flight time of approximately 45 minutes. It has a 16 mega pixel camera for high definition images and is able to produce precise orthomosaics and 3D models. Another selling point is that it is carry-on luggage size. It's base price is approximately $25,000-$35,000. More information on the eBee can be found at http://www.sensefly.com/products/ebee
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Image from Sensefly eBee product website at http://www.sensefly.com/products/ebee

Image from Rotomotion product website at
http://www.rotomotion.com/r_product_2_sr20.html

Rotomotion SR20

The Rotomotion SR20 is an electric propulsion helicopter with a payload capacity of 12.5lbs not including battery sets. This payload capacity is reduced with the inclusion of the battery sets. With one battery set it has 25 minutes of hover time and 35 with forward flight. When two battery sets are used this increases hover time to 50 minutes and forward flight to 65 minutes. As a helicopter it is hover and stare capable. It is possible that full-sized digital camera (e.g. the Nikon D3X with 24 MP capability or D800 with 36 MP capability) could be mounted to this system. The entire turnkey system with ground station is approximately $35,000-$45,000). More information on the Rotomotion UAS can be found at http://www.rotomotion.com/r_product_2_sr20.html.

AirCover/Lockheed Martin Skunkworks – QuadRotors (QR420e; Lifesaver 425)

The Reclamation Pacific Northwest Region is currently working with a local Sheriff's Department who will be sponsoring the UAS company AirCover to support the Shasta County Bomb Squad and SWAT operations during an exercise at a Reclamation facility. AirCover has been recently focusing on dams, levees, and river inspections and assessments, as well as law-enforcement, fire and rescue and other emergency response activities. The benefit of this type of UAS is that it can be flown very close to a surface (e.g. inches) and has high definition and infrared camera capabilities. In terms of future dam safety applications, small electric motor UAS such as these, with sufficient imaging payloads, may be suitable for Reclamation needs.

Image from AirCover Product Information Pamphlet, Dec 2011

Conclusion

Other quad- or multi- rotor copters with hover and star capabilities may also suit many of Reclamation's needs. Many potential Reclamation UAS users have indicated they are extremely interested in higher definition thermal, LiDAR, RADAR and hyperspectral sensors. Sensor technology is very dynamic and once technology allows for miniaturization of these sensors with LiDAR, RADAR then any UAS with these sensors would be advantageous to Reclamation.

Section 7. Reclamation Cost-Benefit of the T-Hawk

One of the largest constraints when it comes to remote sensing data can be the cost of data acquisition. High resolution data, especially over large areas, can be costly to obtain. This section provides data on some of the costs associated with aircraft data collection and attempts to document some of the costs involved with UAS operations. Until Reclamation conducts sufficient Reclamation UAS missions it is difficult to compare the costs of manned aircraft missions versus unmanned missions. The cost-per-byte of other types of remote sensing data has not been documented in this report. However, many of the survey participants indicated the expense associated with a lot of the remote sensing data they used or would like to use, especially LiDAR data, was quite high and less expensive alternatives would be highly desirable.

Expenses Associated with Manned Aircraft

The USGS UAS Roadmap (2010-2025) provides a summary of analysis of aircraft costs per hour, conducted by the US Customs and Border Protection Office. The table below provides a cost per hour summary of aircraft costs, including the Predator B UAS. Costs range from $1,141 - $7,034 per hour. These costs will be compared with UAS later.

Table 7.1: Aircraft Costs per Hour from Customs and Border Protection Office (Table E1- USGS, 2011b)

Platform	Type	Costs per Hour ($)	Platform	Type	Costs per Hour ($)
P3	Aircraft	7,034	Pilatus PC-12	Aircraft	2,781
King Air C12	Aircraft	5,245	Dash 8	Aircraft	2,568
Blackhawk	Helicopter	5,233	Aerospatiale Astar	Helicopter	1,932
King Air	Aircraft	3,994	MD-600N	Helicopter	1,841
Agusta Westland AW139	Helicopter	3,744	Cessna 210	Aircraft	1,727
UH1H (Huey)	Helicopter	3,476	American Eurocopter EC-120	Helicopter	1,617
Cessna Citation	Aircraft	3,395	Hughes OH6	Helicopter	1,441
UAS (Predator B)	UAS	3,234*	Piper PA-18	Aircraft	1,141

* Cost to Reclamation $0 but will not always be available and only available for some select all dams.

A similar analysis of Reclamations aircraft costs per hour was conducted as part of this research. The information below was provided by the DOI OAS. Aircraft per hour costs incurred by Reclamation to collect imagery and other data range from $160-$4301 per hour, not including labor costs of personnel involved in data collection. This information is meant to help potential Reclamation UAS users better understand the per hour costs of utilizing manned aircraft to assist with aerial remote sensing. These costs per hour are only for manned aircraft services provided to Reclamation. Costs associated with Reclamation owned aircraft operations and maintenance and pilot training and certification are not included in this document.

Table 7.2: Reclamation Aircraft Costs per Hour for 2010 (Data provided by the DOI Aviation Management Division)

Platform	Costs per Hour ($)	Platform	Costs per Hour ($)
Kaman K1200	4301	Beech A90	1119
McDonnell-Douglas 369E	3750	Beech King Air 200	1054
Bell 205	3695	Bell 206B III	1026
Bell 206L-I	2044	Beech B200	947
Aerospatiale AS350B3	1850	Bell 206 L III	942
McDonnell-Douglas MD 600N	1790	Piper PA31	911
Eurocopter Astar 350B-2	1515	Bell 206L-3	872
Bell 206 L IV	1512	Bell 206L-4	654
Aerospatiale AS350B2	1506	Bell 206B III	585
Beech B90	1449	Cessna 206 Stationair-6	465
Piper Cheyenne III	1432	Cessna 172	398
Beech 200	1340	Cessna Skyway 185	303
Cessna 208 Caravan	1242	Cessna 182	295
Piper Cheyenne II	1142	Cessna 205	250
Cessna 208	1140	Cessna 206G	160
Beech King Air 90	1127		

Table 7.3: Reclamation Aircraft Costs per Hour for 2011 (Data provided by the DOI Aviation Management Division)

Model	Cost per Hour ($)	Model	Cost per Hour ($)
Aerospatiale AS350B2	1547	Bell 206 L-3	735
McDonnell Douglas 369FF	1542	Bell 206B III	689
Pilatus PC12	1241	Robinson R44II	500
Cessna 2108	1113	Cessna T210	430
Beech A90	1103	Cessna 206	395
Aerospatiale AS350B3	1069	Cessna 182	315
Piper PA31	1052	Cessna 172	174
Beech B200	1044		

Potential Reclamation Costs Associated with UAS

Costs associated with UAS Training

The DOI OAS UAS Aviation Training is provided at no cost to the participants. The Reclamation costs associated with this training are related to labor and travel. To complete both the Raven (required prerequisite) and the T-Hawk training it will be 17-20 days of labor, and travel expenses to the training facility in Boise Idaho. The costs associated with labor are dependent on whether costs associated with personnel will be at a fully burdened rate or are whether personnel are from the Technical Service Center (TSC). TSC personnel have a higher daily rate than other Reclamation employees. The costs below are provided for the higher TSC rate to provide upper limits for costs associated with UAS; however actual training costs are not expected to be this high when non-TSC personnel complete the UAS training.

The total labor only costs for T-Hawk Training based on TSC FY13 rates is provided in the table below. It should be noted that daily fully burdened rates associated with non-TSC personnel (i.e. personnel from the regions and areas offices) would be considerably less than that used in the estimates below (see Table 7.4). Since, at a minimum, both an operator and an observer are needed to fly a T-Hawk the total labor costs associated with training will be doubled. This means that total labor costs, including both training days and days for travel (15 training days plus an additional 5 labor days during travel), will be somewhere between $19,500 to almost $35,000. The combined total training costs including both labor and non-labor costs associated with certifying a TSC pilot to fly the T-Hawk will be, at minimum, $32,500 to approximately $48,000 per team. This does not include the cost of obtaining a Class II Medical Examination, nor recertification costs (DOI requires UAS operators and observers recertify every 3 months). The medical examination could be estimated to be approximately $150 for examination but does not include associated labor costs (which as likely to be minimal). If UAS operators and observers recertify annually and operators demonstrate continuing capability on the simulator every 2 months, then approximately another 5 days of labor will be needed annually (~$1440-$4360 TSC labor rates for skill level 1-3 – see Table 7.4). Even using TSC rates, these UAS training costs are much less than the costs associated with obtaining a pilot's license. It should be noted that these training costs will essentially be recovered during missions; the more UAS missions completed the more training costs will be spread out over these missions; making these missions much more cost effective.

Table 7.4: Total TSC Personnel Training FY13 Labor Costs (for 20 days)

Total Training Labor Costs (for 20 days)			
Skill Level	***Grades***	***Daily Rate***	***Training Expense per Person (Labor)***
1	1-10	$488	$9,760
2	11/12	$696	$13,920
3	13 - 15	$872	$17,440

Although, arguably, the costs associated with training are possibly the largest costs associated with Reclamation T-Hawk operation, DOI agencies are fortunate that DOI is providing training at no cost. For non DOI agencies, Honeywell worked out some training costs for the T-Hawk. A single training course for 1-6 students is estimated to cost $89,500. T-Hawk instructor training costs are even higher (sUAS news article "Honeywell set out training costs for T-Hawk MAV" at http://www.suasnews.com/2010/08/628/honeywell-set-out-training-costs-for-t-hawk-mav/).

Other Costs associated with T-Hawk Operation

Other costs associated with T-Hawk operations include: Repair and ongoing maintenance costs (minimal); COA development and coordination (~10-14 days typically needed); and T-Hawk deployment (variable but typically around 3-4 days). Although the T-Hawk commercial replacement costs (depending on the model of the T-Hawk) are likely to be $200,000-$700,000, these costs should not be considered in this analysis. Cost estimates based on website and news reports (e.g Emery, 2009; Military Equipment Price List, 2011; Jain Bharti, 2010; International Online Defense Magazine, 2009). Over 21 T-Hawk systems were donated by military to the DOI USGS National UAS Project Office (see website for more information – http://rmgsc.cr.usgs.gov/UAS/gMav.shtml). These T-Hawks would be utilized until none are left available for use. The DOI T-Hawks can be used for spare parts so that if these T-Hawks are damaged during operation, repairs would be completed on any system that was repairable (*Pers. Comm.*, M. Hutt, Feb 21, 2013). Given the expense of these systems, it is unlikely that DOI would support the purchase of additional T-Hawks should they be damaged beyond repair, especially while there are other T-Hawks available to use as a replacement.

Once no more T-Hawks are available to DOI, it would be most prudent and beneficial to review whether other less expensive UAS may be a more appropriate replacement. One of the UAS USGS would like OAS to approve is the Draganflyer. The 2010 cost of a single the Draganflyer was ~$41,000 (Musgrave, 2010). As new UAS technologies become available, more UAS with technical specifications that are more advanced may be available at lower cost. OAS has indicated no additional UAS will be approved for use by DOI until 2014.

Summary of Costs Associated with the T-Hawk

The table below summarizes the expected Reclamation costs associated with the T-Hawk. Until multiple T-Hawk missions are conducted by Reclamation it is difficult to estimate all costs associated with the use of the T-Hawk.

Table 7.5: Summary of Costs Associated with the T-Hawk

Activity	Estimated Cost ($)
DOI UAS Training Courses (includes FAA training course)	$0
Labor and Travel Costs associated with T-Hawk Training (Team of 2)	$32,500-$48,000 (TSC personnel – one time training)
Class II Medical Examination	$150 + labor (minimal cost)
Each Re-certification (Team of 2) (2 days of training required annually)	Variable (est. $2,000 annually)
Each OAS certified UAS Operator is required to complete UAS operations or simulator time (i.e., 3 take-off and landings) every 3 months	Variable (est. $1,000 every 3 months for TSC operator)
Maintenance of T-Hawk (ongoing)	Minimal
COA Development and Coordination (Variable but at typically could be a 10-14 day effort)	8,720-$12,208 (TSC personnel Skill Level 3) per application
Field Work/T-Hawk Deployment Labor Costs per Hour [Lower amount: based on minimum 2x Skill level 1 TSC team of 2; Upper amount: Skill level 3 TSC team of 2)]	$48-$220 per hour
Field Work/T-Hawk Deployment Travel Costs (dependent on locality of travel and length of deployment) – should include labor used for travel to and from deployment site and per diem as well as hotel, car rental, airfare, etc.	Variable – A typical mission would last 3-4 days and require hotel and car rental and per diem; Generator rental is $150 per week; Shipping costs are ~$300-400 each way.

Table 7.5 (above) indicates a substantial up-front cost associated with training a 2 person T-Hawk deployment team. The hourly cost associated with T-Hawk deployment is typically much lower than aircraft rental. However, these costs do not consider additional expenses associated with COA development; pilot recertification; travel costs associated with deployment; and ongoing maintenance and repair. It is anticipated travel costs associated with deployment may be comparable to balloon deployment and aircraft image collection. There may be additional costs associated with T-Hawk maintenance and repair should the choice be to request a/multiple T-Hawks to be allocated to Reclamation. UAS reliability may be a concern, and hard takeoff and landings or crashes are highly likely, even with experienced pilots (*Pers. Comm.,* S. Keep, 2001). UAS have not yet proved their reliability in comparison to manned aircraft (e.g. Tvaryanas *et al*., 2005, p5-2). The costs associated with both repair and ongoing maintenance may noticeably, increase the hourly rate associated with of UAS, particularly if the payload (e.g. camera) is damaged. The USGS currently has additional (spare) T-Hawks that can be utilized

for spare parts so that their maintenance and repair costs associated with the T-Hawk is minimal (*Pers. Comm.,* M. Hutt, Feb 21, 2013), provided a specialized payload is not damaged.

Does Reclamation have the budget and/or the time to sustain a UAS Program?

Typically, private industry offers two options when it comes to UAS operation. Some companies offer outright ownership of their UAS (i.e. sale to customer), while others offer a Fee-for-Service UAS Operations Plan (e.g. Aerosonde). The Fee-for-Service Plan provides clients with the option of hiring the company to fly the UAS on specific missions. The potential for loss, destruction and replacement costs are typically included in this fee. This Fee-for-Service Option is considered a less expensive option, without the cost and liability involved with the ownership of a UAS fleet (e.g. no maintenance and repair costs). Some companies offer both options (e.g. Insitu).

Although OAS is investigating the option of contracting UAS services, currently, DOI does not permit contracting with private industry nor can an individual DOI agency, bureau or office "own" their own UAS. There are *currently* two options available to Reclamation: Request DOI allocate a Raven(s) and/or T-Hawks to Reclamation for operation by our own pilots, or have the USGS conduct Reclamation missions. Some of the factors that can be useful in deciding whether Reclamation should request allocation of a UAS or fleet of UAS include: the time and budget commitment to ongoing systems maintenance and repair, operator training and recertification, deployment costs, and the current payload limitations. It is recommended that these somewhat unknown costs be considered before a decision is made as to whether Reclamation should pursue UAS to be allocated to Reclamation or whether utilizing other DOI agency UAS is a possibility. There are both advantages and disadvantages for operating our own UAS allocated to Reclamation. Reclamation's Pacific Northwest Region will test UAS for both cost effectiveness and mission utility in the short term. Once these analyses have been performed, Reclamation will know whether contracting with outside vendors is desirable. Contracting also comes with its own costs. For instance, both aircraft and pilot must be certified by OAS.

Section 8. Recommendations and Conclusions

UAS like the T-Hawk provide an alternative to putting Reclamation personnel at risk during manned flights and assist Reclamation's many requirements for aerial imagery. A UAS with hover and stare capabilities; and a high definition camera and a gimbal for camera stabilization would be extremely beneficial to Reclamation. These capabilities would be of benefit to many of Reclamation's aerial imagery needs, particularly those that may require observation of specific sections or over small areas. A fixed-wing UAS may be more appropriate for missions that will follow a linear trajectory over long distances. The T-Hawk has the capabilities important to many of Reclamation's aerial imagery needs; however, the T-Hawk has some payload restrictions and noise considerations that must be taken into account. At a minimum, a 11MP camera must be used before it can meet Reclamation's minimum photogrammetric requirements. The noise of the T-Hawk's gasoline engine also makes it unsuitable for any law enforcement and security applications. In addition to these considerations, the T-Hawk is likely to experience flight degradation at least 19 Reclamation dams. For instance, the T-Hawk would unable to fly at Platoro Dam due to altitude. Some flight degradation may occur for any dam above 2000 feet.

Many potential Reclamation UAS operators are unaware of the federal and DOI regulatory limitations associated with the use of UAS. Model aircraft cannot be flown under "hobbyist" or "model aircraft" regulations because the UAS is not being used for recreational purposes, and Reclamation employees are paid to collect data. Currently only the Raven and T-Hawk are DOI approved aircraft. All UAS missions must go through the Certificate of Authorization process which includes submitting mission projects plans to the Regional Aviation Manager and Reclamation Aviation Manager. UAS *cannot* be flown unless appropriate authorization is given by both DOI and the FAA.

Privacy is a big outstanding issue with all UAS operations. Bills are currently being introduced into the US Senate to insure public privacy. Some States are also considering introducing strict legislation which, in some cases, will prohibit the use of UAS. The main concern is non-compliance with the fourth amendment which protects against unreasonable searches and seizures. These restrictions will need to be considered when planning any Reclamation mission involving a UAS. USGS routinely conduct missions over federal lands or with written permission from private land owners (*Pers. Comm.–email*, M. Hutt, Feb 27, 2013). If a mission is planned entirely over public lands, provided images of private property are not also acquired, the mission should comply with the fourth amendment. Missions that require flight over private property can be conducted, provided written permission is given by the private land owners.

Recommendation:* *Ensure appropriate UAS mission scoping is conducted. The altitude of the dam, photogrammetric needs, privacy concerns and regulatory restrictions should all be addressed during mission planning.

Recommendation:* *To avoid unauthorized Reclamation use of UAS, Reclamation employees should be informed of their responsibilities and regulatory limitations

when it comes to flying/operating UAS and appropriate UAS mission approval must be obtained (e.g. official memo).

With current payload considerations/restrictions, the T-Hawk may be suitable for emergency response and media relations (e.g. aerial photography and video display of Reclamation facilities and lands) purposes. For emergency response after an incident such as an earthquake, rapid deployment of a T-Hawk may be very useful. However, the question remains whether this will be sufficient for rapid emergency response. The 40 minute maximum flight time and FAA line of sight requirements may also limit the T-Hawk usability during emergency response. In terms of media services, the T-Hawk may be very useful for photos of dams especially those requiring entry into a gorge or canyon. Currently, helicopters may not provide sufficient access to these areas and the T-Hawk could be used to capture both still images and video safely.

Recommendation: Conduct T-Hawk photogrammetric proof of concept missions for use in dam safety, operations and maintenance, media services, sedimentation and river hydraulics, environmental studies, water operations, etc. Consider mission requirements and determine payload requirements (e.g., high definition camera with at least an 11MP capability; methods to reduce camera vibration).

Although the T-Hawk is currently used for military support and has hover and stare capabilities, the noise generated by the gasoline engine of the T-Hawk make it less useful for security, law enforcement and environmental activities. The US Army chose not to use the T-Hawk because of the noise. However, the Navy, Air-Force, Special Operations and DARPA currently use T-Hawks for a variety of missions (e.g. Improvised Explosive Device detection; radiation and chemical detection) (*Pers. Comm.– email*, Hutt, M., Feb 21, 2013). Generally, smaller UAVs/MAVs are typically less expensive. Unfortunately, this also usually translates to a reduced payload and limited instrumentation. Current imaging payload capabilities on the T-Hawk are not sufficient for some potential Reclamation users, especially those needing to track very small changes relating to a dam. Electric motor sUAS with hover and stare capabilities, and real-time video capabilities may be more suitable for Reclamation requirements.

Recommendation: Investigate the usefulness of other UAS for security, law enforcement, environmental and dam safety purposes.

There was some consensus with those surveyed as to whether the current UAS available to DOI bureaus are sufficient or the best options for Reclamation needs. Many potential Reclamation UAS users would like the UAS to have LiDAR capabilities or LiDAR quality images that can assist with 3D terrain modeling. With UAS technology changing so rapidly, it is worth considering whether DOI policy, training, and UAS inventory will be able to keep up with user requirements, unless, for instance, contracting UAS services are allowed.

Recommendation: Remain informed as to UAS technologies other than the Raven and T-Hawk. Maintain collaboration with USGS UAS Project Office, OAS and DOI.

Recommendation: Investigate whether the AgiSoft PhotoScan 3D Modeling Software is sufficient for Reclamation remote sensing post-processing needs.

Recommendation: Investigate whether Structure from Motion techniques can provide 3D imagery of high enough quality to supplement or replace the need for LiDAR data used for Reclamation applications. Investigate accuracy and limitations of these techniques.

There will be initial upfront costs associated with the training of pilots and the establishment of a UAS program. It is also likely that the ongoing maintenance of UAS will be less than that of manned aircraft and per hour mission costs should also be less in comparison to manned flights. Reclamation's Pacific Northwest Region will test UAS for both cost effectiveness and mission utility in the short term. Once these analyses have been performed, Reclamation will know whether contracting with outside vendors is desirable.

Although the failure rate of UAS is likely to greater than a manned aircraft, UAS may be a safer option for Reclamation employees. Access to a UAS with LiDAR capability would have the most cost-benefit to Reclamation. A UAS with modular payload capabilities would be most beneficial if different types of sensors can be utilized on the one UAS.

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Appendix A. Survey of Reclamation T-Hawk (gMAV) Application Data Needs

Below are the two surveys sent out to potential Reclamation UAS/T-Hawk users. The first one is the full survey; the second one is a simplified version of the survey.

Full Survey

The DOI Office of Aviation Services OAS –formerly the Aviation Management Directorate or AMD– provides oversight, training, and safety policy in support of aviation functions within DOI. AMD has taken possession of, and is currently, providing training in the use of an Unmanned Aerial System called the T-Hawk. This is a small gasoline Micro Air Vehicle (gMAV). The T-Hawk has been used in combat and emergency situations. Other possible potential capabilities may include photogrammetry and dam face analyses.

The following are video links that describe and illustrate current uses of this vehicle. The first link will take you to a set of demonstration videos provided by the manufacturer, Honeywell (http://thawkmav.com/demos.php). The additional links are video taken by the T-Hawk at the Fukushima Daiichi Nuclear Power Plant (http://www.youtube.com/watch?v=_UyNBoKvhQ4; http://news.cnet.com/8301-17938_105-20051499-1.html; http://www.youtube.com/watch?v=fRTlJYeU_wo)

Demonstrated Capabilities:

- Field level asset
- Single person portable
- Operates in complex terrain
- Manual or automated flight
- Ability to hover
- Vertical take-off and recovery
- Electrical-optical and Infrared Cameras
- Situational awareness, surveillance, reconnaissance

Potential Applications:

- Observing wildfire behavior
- Verification- Validation of test sites
- Archeological Site (cliff art) Mapping
- Small area photogrammetric projects
- Damage assessments
- Dam Inspections
- Monitoring Volcanic Activity
- Law enforcement
- Emergency management

PARAMETER	CHARACTERISTIC
Weight (dry)	17.2 lbs (w/ EO camera) / 17.5 lbs (w/ IR camera)
Fuel Capacity	2.2 lbs
Total System Weight	51 lbs (1AV, 1 OCU, 1 GDT, Support equipment)
Flight Duration	~40 minutes, less with reduced fuel for higher altitudes (16 mins at 9600ft).
Operating Ceiling	7700ft density altitude (full fuel load) 9600ft density altitude (reduced fuel load)
Flight Altitude (min)	50 ft (autonomous), 5 ft (manual)
Air Speed (max)	45 mph (72 kph) (Manual flights limited to 60 mph)
Range (max)	1.2 miles (2 km) line of sight (LOS)
Winds (max)	15 knots (takeoff/landing), 20 knots (aloft)
EO Camera Resolution	768 x 494 pixels (0.379 MPixel)
IR Camera Resolution	320 x 240 pixels (0.077 MPixel)
High Definition Resolution	1920x1080 pixels (2.1MPixel – video mode); (Up to 11 MPixel – Photo mode) (Should be available in very near future)
Flight Characteristics	Hover and Stare Capable; Vertical Take-off and Recovery

Questions for Potential T-Hawk User

The purpose of this survey is to identify potential Reclamation Applications for the T-Hawk. The data from this survey *may* be used to guide future research using the T-Hawk. ***Note:*** Some of these questions are modified versions of what is contained in the USGS UAS Roadmap 2010-2025.

Please fill in the survey below as best you can. If you have any questions please contact Jade Soddell at jsoddell@usbr.gov or 303-445-2538.

Name:

Contact Information:

Title:

Programmatic Area (e.g. Dam Safety, Security, etc):

YOUR CURRENT INSTRUMENTS' CAPABILITIES TO MAKE OBSERVATIONS OR MEASUREMENTS
What remote sensing data are you gathering? What landscape elements or infrastructure measurements are you taking? What are you observing? **Please provide any information on your current instruments' capabilities to make observations or measurements.**

Over what time period do you measure or observe? (seconds, minutes, hours, days)
What is the frequency of observation or measurement during a mission? (milliseconds, seconds, minutes, etc)
Do you make simultaneous observations at more than one location? Please describe.
Do you make the same measurement or observation at different geographical areas? If yes, how many? Where?
With what mapping scale are measurements made (e.g. 1:10,000, 1:50,000, 1:1,000,0000)
What constraints exist for performing measurements or observations? Please describe.

YOUR CURRENT INSTRUMENTATION	
What type of instrumentation (scientific or operational) are you currently using to take these measurements or observations [Choose all that apply]	
Image-based surveillance (e.g. satellite, posted cameras) (Y/N)	
Environmental air sampling (e.g. air, water, soil) (Y/N)	
Do you have real-time Communications (e.g. upload images in real-time) (Y/N)	
Optical Sensing (Y/N)	
Optical sensing – LIDAR (Y/N)	
Microwave sensing – radiometer (Y/N)	
Microwave sensing – radar (Y/N)	
Other (provide description):	
Comment:	

If optical sensing is required, what wavelength ranges are desired?	
How much does your current equipment weigh (pounds or kilograms)?	
Is there a need for Stabilization of the Equipment? (e.g. focus on a point with gimbal) (Y/N) Gimbal definition: A gimbal is a pivoted support that allows the rotation of an object about a single axis. A set of three gimbals, one mounted on the other with pivot axes orthogonal, may be used to allow an object mounted on the innermost gimbal to remain independent of the rotation of its support (cf. vertical in the first animation). For example: on a ship, the gyroscopes, shipboard compasses, stoves, and even drink holders, typically use gimbals to keep them upright with respect to the horizon despite the ship's pitching and rolling.	
Will real-time monitoring of your subject be required or will onboard storage of your data, to be processed later, be sufficient?	*Real-Time Y/N* *Post-Flight Y/N*
CURRENT RECLAMATION NEEDS	
The T-Hawk has an Electro-Optical (visible) Camera Capability. The resolution of the camera is 768x494 (0.39 MPixel). The Field of View ranges from 46º to 5º (10x Optical Zoom).	
Please list any projects/applications this visible camera capability may be suitable for. Explain.	
What visible camera resolution would be suitable for your needs? Explain.	
The T-Hawk (gMAV) has an Infrared Camera Capability. The resolution of the Infrared Camera is 320x240 (0.077 MPixel). The Field of View is 18º.	
Please list any projects/applications this infrared capability may be suitable for. Explain.	

What infrared camera resolution would be suitable for your needs? Explain.
A higher definition camera called the GoPro Hero 2 may be available to be installed on the T-Hawk in the very near future. The resolution of the GoPro Camera is 1080p (1920x1080) and 90-170 º Field of View for Video. Photo 5-11 MPixel photos with a Field of View 127-170 º.
Please list any projects/applications this high definition camera resolution may be suitable for. Explain.
What high definition camera resolution would be suitable for your needs? Explain.
CURRENT RECLAMATION PHOTOGRAMMETRIC NEEDS

Would any of these below be useful?	
Still Imagery	

How much ground resolution do you need (e.g. foot, inch, cm, mm)?	
Will you need any of the following:	
Individual Photos with no georeferencing[++] *(Y/N)*	
Photos with Georeferencing /Image Mosaicing	
Georeferencing with Aircraft GPS Location Only (Y/N)	
Rough georeferencing to 100ft level (rough photo georegistration) (Y/N)	
Photomosaic – smoothed mosaic images not geomatically correct (Y/N)	
Combination of GPS and camera attitude method to get to output georegistration (Y/N)	
What accuracy do you need georegistration[+]*?*	
Absolute position on ground use differential GPS (Real Time Kinematic) (Y/N)	
3D terrain reconstruction/dam shape reconstruction (Y/N)	
Laser Scanner (i.e. controlled steering of laser beams followed by a distance measurement at every pointing direction for 3D scanning) (Y/N)	
Video	
Standard Definition Video (e.g. 720 pixels × 480 lines or 640 pixels × 480 lines (Y/N)	
High Definition Video (e.g. 1,920×1,080 pixels (1080i/1080p)) (Y/N)	
T-HAWK FLIGHT PARAMETER EXPECTATIONS	
What is the estimated maximum flight altitude (feet above ground level or take-off altitude)?	
What is the estimated range of flight (miles)?	
How long will you need the UAS to stay aloft? (Hours)?	
What is the area to be covered (square miles)?	
How often will you need to make the observations or revisit the site(e.g. one-time, annually, quarterly, monthly, emergency)?	
What is the Spatial Resolution needed (ground sample distance in feet or meters)?	
What is the Temporal Resolution (frames or samples per second)?	
Climate – What is the expected estimated max and min temperature?	
Will the T-Hawk be in an area that frequently experiences high winds (e.g. greater than 15miles per hour)?	
Will the relative humidity more likely be low or high?	
What is the typical proximity to population (miles)?	
What is the typical proximity to an airport? Or do you expect to need to fly within 5 miles of an airport?	
What type of maneuvering will you want from the platform in order to collect your measurements or observations, for example: loiter, vertical profiling (moves up or down), or other?	
Will you require accurate positional and altitude knowledge of the UAS (i.e. its instrumentation)? *If yes, what accuracy would you require for this knowledge (feet)?*	
How often should the positional and altitude measurements be sampled to satisfactorily acquire the data you need (milliseconds)?	
THE FUTURE OF UAS FOR RECLAMATION	
What is your opinion about the use of the T-Hawk to accomplish your mission requirements?	

What Reclamation missions do you foresee for the T-Hawk or other UASs over the next 5-10years?

How would you characterize your current knowledge of the applications of Unmanned Aerial Systems, such as the T-Hawk? (None/Novice, Beginner, Competent, Proficient, Expert)	
List any individuals or groups who may benefit from the use of the T-Hawk or other UASs.	
Is there any additional information you would like us to know?	

+Georegistration Definition: An image that has been geographically referenced or rectified to an Earth model, usually to a map projection. Sometimes referred to as geocoded or geometric registration.
++Georeferencing definition: Aligning geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data. Georeferencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting, or orthorectifying the data.
+++Orthorectification definition: Is the process of removing the effects of image perspective (tilt) and relief (terrain) effects for the purpose of creating a planimetrically correct image. The resultant orthorectified image has a constant scale wherein features are represented in their 'true' positions. This allows for the accurate direct measurement of distances, angles, and areas (i.e. mensuration). Orthorectified images are commonly used as in visualization tools such as Google Earth, OSSIM Planet, ArcMap, WMS, etc.

Simplified Survey

The purpose of this survey is to identify potential Reclamation Applications for the T-Hawk. One outcome of this survey will be to identify potential programmatic applications of the T-Hawk. The data from this survey *may* be used to guide future research using the T-Hawk. ***Note:*** Some of these questions are modified versions of what is contained in the USGS UAS Roadmap 2010-2025 and an earlier more comprehensive version of the Potential Reclamation T-Hawk User Survey.

This is a simplified version of the earlier survey. Many of the questions contained in the survey require yes/no answers. Some of the questions may require some more elaboration. ***For those who already filled out the earlier survey there is no need to complete this survey again and I would like to thank-you again for your participation.***

Please fill in the survey below as best you can. If you choose to fill this survey out as a group, can you please list how many participants were involved in answering the questions? If you have any questions please contact Jade Soddell at jsoddell@usbr.gov or 303-445-2538. If you would prefer to schedule 15 minute conference call or in-person meeting so I can ask you these survey questions directly, please feel free to contact me to discuss a time that will be convenient for you. I would like to thank-you in advance. You support in completing this survey is very much appreciated.

Name:

Contact Information:

Title:

Programmatic Area (e.g. Dam Safety, Security, Operations and Maintenance, Emergency Management/Response, Security, Water Operations, etc):

Number of Participants filling out this survey:

YOUR CURRENT REMOTE SENSING INSTRUMENTS' CAPABILITIES TO MAKE OBSERVATIONS OR MEASUREMENTS
Are you currently collecting any aerial or satellite imagery, or conducting close range photogrammetry? Please explain. Please note what programmatic area this may be (e.g. dam safety, operations and maintenance, emergency management/response, security, water operations, etc).
Over what time period do you measure or observe? (seconds, minutes, hours, days)
What constraints exist for performing measurements or observations? Please describe.

For what purpose do you gather remotely sensed data? Explain.

YOUR CURRENT INSTRUMENTATION		
	Yes	**No**
Are mapping scale measurements made at 1:10,000?		
Are mapping scale measurements made at 1:50,000?		
Are mapping scale measurements made at 1:1,000,000?		
Other mapping scale measurements are made at what ratio? Please specify.		
Are you using infrared or thermal imagery?		
Would infrared or thermal imagery be useful?		
Do you use satellite data?		
Do you use posted cameras?		
Do you conduct any environmental air sampling (e.g. air, water, soil) (Y/N)		
Do you conduct any environmental water sampling?		
Do you conduct any environmental soil sampling?		
Do you use microwave sensing such as radar?		
Will real-time monitoring be required?		
Will onboard storage of your data, to be processed later, be sufficient?		
Is there a need for an IMU (Inertial Measurement Unit)?		
Is there a need for a gimbal? (e.g. focus on a point with gimbal) Gimbal definition: A gimbal is a pivoted support that allows the rotation of an object about a single axis. A set of three gimbals, one mounted on the other with pivot axes orthogonal, may be used to allow an object mounted on the innermost gimbal to remain independent of the rotation of its support (cf. vertical in the first animation). For example: on a ship, the gyroscopes, shipboard compasses, stoves, and even drink holders, typically use gimbals to keep them upright with respect to the horizon despite the ship's pitching and rolling.		

CURRENT RECLAMATION PHOTOGRAMMETRIC NEEDS		
	Yes	**No**
Do you need a ground resolution of 1 foot?		
Do you need a ground resolution of 1inch?		
Do you need a ground resolution of 1cm?		
Do you need another ground resolution? Please specify.		
Do you need digital elevation models?		

Do you need orthorectified maps?		
Do you need contours?		
Do you need video?		
T-HAWK FLIGHT PARAMETER EXPECTATIONS		
What is the estimated maximum flight altitude (feet above ground level or take-off altitude)?		
What is the estimated range of flight (miles)?		
How long will you need the UAS to stay aloft? (hours)?		
What is the area to be covered (square miles)?		
How often will you need to make the observations or revisit the site(e.g. one-time, annually, quarterly, monthly, emergency)?		
What is the Spatial Resolution needed (ground sample distance in feet or meters)?		
How often/frequently do you need to capture images (e.g. once every <1 second, once every minute, once an hour, etc)		
	Yes	**No**
Do you need the platform to loiter (center around a point on the ground)?		
Do you need the platform to perform vertical profiling (move up and down in altitude)?		
Do you need the platform to perform horizontal profiling (move horizontally over a preset area)?		
THE FUTURE OF UAS FOR RECLAMATION		
What is your opinion about the use of the T-Hawk to accomplish your current and future mission requirements?		
What Reclamation missions do you foresee for the T-Hawk or other UASs over the next 5-10years?		
List any individuals or groups who may benefit from the use of the T-Hawk or other UASs.		

Is there any additional information you would like us to know with respect to possible T-Hawk deployment?

Appendix B. Glossary Definitions

Many of the definitions below are from the UAS Interim Operational Approval Guidance 08-01 (Aviation Safety Unmanned Aircraft Program Office, 2008). The following definitions apply to terms used in this document.

Airworthiness: For the UAS to be considered airworthy, both the aircraft and all of the other associated support equipment of the UAS must be in a condition for safe operation. If any element of the systems is not in condition for safe operation, then the UA would not be considered airworthy.

Availability is the number of times a given aircraft type is able to perform its missions compared to the number of times it is tasked to do so, expressed as a percentage (describes the performance of a system while on standby) (McCauley, 2004).

Chase aircraft: A manned aircraft flying in close proximity to an unmanned aircraft that carries, in addition to the pilot in command (PIC) of the aircraft, a qualified visual observer.

COA: A COA or Certificate of Authorization provides a UAS operator with permission to fly in a certain airspace for a certain period of time. For more information on COAs refer to http://www.faa.gov/about/initiatives/uas/cert/. The COA application form (Form 7711-2) can be found at http://www.faa.gov/documentlibrary/media/form/faa7711-2.pdf

Cooperative aircraft: Aircraft that have an electronic means of identification (i.e., a transponder) aboard and operating.

Georeferencing: Aligning geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data. Georeferencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting, or orthorectifying the data.

Georegistration: An image that has been geographically referenced or rectified to an Earth model, usually to a map projection. Sometimes referred to as geocoded or geometric registration.

Gimbal: A gimbal is a pivoted support that allows the rotation of an object about a single axis. A set of three gimbals, one mounted on the other with pivot axes orthogonal, may be used to allow an object mounted on the innermost gimbal to remain independent of the rotation of its support (cf. vertical in the first animation). For example: on a ship, the gyroscopes, shipboard compasses, stoves, and even drink holders, typically use gimbals to keep them upright with respect to the horizon despite the ship's pitching and rolling.

Inspection: The routine performance of inspection tasks at prescribed intervals. The inspection must ensure the airworthiness of an aircraft up to and including its overhaul or life limits.

Mishap Rate is the number of accidents occurring per 100,000 flight hours (McCauley, 2004).

Mean Time Between Failure (MTBF) is the ratio of hours flown to the number of maintenance-related cancellations encountered (expressed in hours) (McCauley, 2004).

Non-Cooperative aircraft: Aircraft that do not have an electronic means of identification (i.e., a transponder) aboard or not operating such equipment due to malfunction or deliberate action.

Off-Airport: Any location used to launch or recover an unmanned aircraft that is not considered an airport (i.e., an open field).

Orthorectification: Is the process of removing the effects of image perspective (tilt) and relief (terrain) effects for the purpose of creating a planimetrically correct image. The resultant orthorectified image has a constant scale wherein features are represented in their 'true' positions. This allows for the accurate direct measurement of distances, angles, and areas (i.e. mensuration). Orthorectified images are commonly used as in visualization tools such as Google Earth, OSSIM Planet, ArcMap, WMS, etc.

Pilot in Command (PIC): The person who has final authority and responsibility for the operation and safety of flight, has been designated as pilot in command before or during the flight, and holds the appropriate category, class, and type rating, if appropriate, for the conduct of the flight. The responsibility and authority of the pilot in command as described by 14 CFR 91.3, *Responsibility and Authority of the Pilot in Command*, apply to the unmanned aircraft PIC. The pilot in command position may rotate duties as necessary with equally qualified pilots. The individual designated as PIC may change during flight.

Public aircraft: An aircraft operated by a public user which is intrinsically governmental in nature (i.e. federal, state, and local agencies). Examples of public entities are Department of Defense (DoD) and its military branches; other local, state, and federal government agencies; and state universities. Refer to 14 CFR 1.1, *General Definitions*, for a complete definition of a public aircraft.

Reliability is 100 minus the percentage of times a launched mission is either canceled before takeoff or aborted during flight due to maintenance issues, expressed as a percentage (describes the performance of a system while in operation) McCauley, 2004).

Scheduled Maintenance (Routine): The performance of maintenance tasks at prescribed intervals.

Supplemental Pilot: Supplemental pilots are those pilots assigned unmanned aircraft flight duties to augment the pilot in command. It is common for applicants to have both an “internal” and an “external” unmanned aircraft pilot. The supplemental pilot can assume either of these positions. The supplemental pilot may also assume duties of the pilot in command if they meet the qualifications.

Unmanned Aircraft: A device used or intended to be used for flight in the air that has no onboard pilot. This includes all classes of airplanes, helicopters, airships, and translational lift aircraft that have no onboard pilot. Unmanned aircraft are understood to include only those aircraft controllable in three axes and therefore, exclude traditional balloons

Unscheduled Maintenance (Non-Routine): The performance of maintenance tasks when mechanical irregularities occur. These irregularities are categorized as to whether or not they occur during flight time.

Visual Line-of-Sight: A method of control and collision avoidance that refers to the pilot or observer directly viewing the unmanned aircraft with human eyesight. Corrective lenses (spectacles or contact lenses) may be used by the pilot or visual observer. Aids to vision, such as binoculars, field glasses, or telephoto television may be employed as long as their field of view does not adversely affect the surveillance task.

Visual Observer: A trained person who assists the unmanned aircraft pilot in the duties associated with collision avoidance.

Appendix C. T-Hawk Training Course Schedule

<table>
<tr><th colspan="6">A-454 T-Hawk SUAS Add-On Course</th></tr>
<tr><th rowspan="2">Time</th><th rowspan="2">Monday</th><th rowspan="2">Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><th colspan="3">Hours may vary due to weather and/or class need.</th></tr>
<tr><td rowspan="3">8:00-8:50</td><td>Welcome/Introductions</td><td rowspan="3">Troubleshooting/
Maintenance</td><td rowspan="12">Flight Day #1

Setup
Preflight
Fueling
Starting
Ground Run Procedures
Manual Launch
Manual Flight
Landing
Cleanup
Storage

Flight Time Reporting</td><td rowspan="12">Flight Day #2

Basic Flight Plans
Go To
Snapshots
Intermediate Flight
Planning
Autonomous Flight</td><td rowspan="10">Flight Day #3

Practice Skills
Execute Scenarios

Checkride</td></tr>
<tr><td>DOI UAS Policy</td></tr>
<tr><td>System Description</td></tr>
<tr><td>9:00-9:50</td><td>System Assembly</td><td rowspan="4">Simulator Practice</td></tr>
<tr><td rowspan="2">10:00-10:50</td><td>System Charging</td></tr>
<tr><td>System Fueling</td></tr>
<tr><td>11:00-11:50</td><td>Preflight</td></tr>
<tr><td>12:00-1:00</td><td>Lunch</td><td>Lunch</td></tr>
<tr><td>1:00-1:50</td><td>Emergency Procedures</td><td>Assembly Practice
(Hangar)</td></tr>
<tr><td>2:00-2:50</td><td>Manual Flight</td><td>Fueling Practice
(Hangar)</td></tr>
<tr><td>3:00-3:50</td><td rowspan="2">Flight Planning</td><td>Preflight Practice
(Hangar)</td><td rowspan="2">Travel Back to Boise

Course Closeout</td></tr>
<tr><td>4:00-4:50</td><td>Pack-up Equipment
Load Truck for Range</td></tr>
</table>

Appendix D. Current Reclamation Instrumentation

Instrumentation/ Imaging Type (Y/N)	Dam Safety Geology/Geo Tech	Facilities and Lands (AAO)	Sedimentation & River Hydraulics – Balloon	Geography and Wildlife Biology (AAO)	Materials Engineering and Research Lab (MERL) – Simplified Survey	LC Region Security/Law Enforcement (Simplified Survey)	LC Region Media Services/ Info. & Imagery Mgmt (Phone Discussion)
Image-based surveillance (e.g. satellite, posted cameras) (Y/N)	Y	Y	N	N	N	Y (helicopter, posted cameras)	Y (helicopter)
Environmental air sampling (e.g. air, water, soil) (Y/N)	N	Y	N	N	N	N	N
Do you have real-time Communications (e.g. upload images in real-time) (Y/N)	N	Some	N	N	N	Y	N
Optical Sensing (Y/N)	Y	Y	Y	Y (Pictures from Observer)	N	Y	Y
Optical sensing – LIDAR (Y/N)	N	Y	Y	N (But could be helpful eventually if non-cost probative)			
Microwave sensing – radiometer (Y/N)	N	Y	N	N	N		
Microwave sensing – radar (Y/N)	N	N (but has unutilized application)	N	N	N	Y	
How much does your current equipment weigh (pounds or kilograms)?	Up to 6lbs		~20lbs	None	N/A	N/A	N/A
Are you using infrared or thermal imagery? (Y/N)					N/A	Y	

Appendix E. Desired Reclamation Instrumentation Needs

Instrumentation/ Imaging Type (Y/N)	Dam Safety Geology/Geo Tech	Facilities and Lands (AAO)	Sedimentation and River Hydraulics	Geography and Wildlife Biology (AAO)	Materials Engineering and Research Lab (MERL) – Simplified Survey	LC Region Security/Law Enforcement (Simplified Survey)	LC Region Media Services/ Info. & Imagery Mgmt (Phone Discussion)
If optical sensing is required, what wavelength ranges are desired?		Similar to NAIP NIR and color spectrums		If LIDAR feasible at some point, then red and green (although water likely contains way too much sediment for adequate green laser penetration)			
Real-time onboard monitoring of subject (Y/N)	Y	Not required, but potentially beneficial	N	Y (within an hour)	N	Y	N
Onboard storage of your data, to be processed later (Y/N)	N	Y	Y	Y	Y	Y	Y
Is there a need for Stabilization of the Equipment? (e.g. focus on a point with gimbal) (Y/N)	N	Y	Y (one of the issues with the balloon is that it is difficult to control)	Primary need is for latitude/longitude of visual so vertical (down) with gyro, heading, and GPS	Y	Y	Y
Is there a need for an Inertial Measurement Unit (IMU)? (Y/N)					Y	N	

Appendix F. Current Reclamation Photogrammetric Needs

Instrumentation/ Imaging Type (Y/N)	Dam Safety Geology/ Geo Tech	Facilities and Lands (AAO)	Sedimentation and River Hydraulics	Geography and Wildlife Biology (AAO)	Materials Engineering and Research Lab (MERL) – Simplified Survey	LC Region Security/Law Enforcement (Simplified Survey)	LC Region Media Services/ Info. & Imagery Mgmt (Phone Discussion)
Still Imagery							
How much ground resolution do you need (e.g. foot, inch, cm, mm)?	.1 to .01 ft.	6"	6"	Foot/yard	Foot/yard/cm (Sufficient resolution to produce dam as-builts and detect ~0.5mm cracks)	1 Foot 1 Inch	
Do you need digital elevation models?					Y	Y	
Do you need orthorectified maps?					Y	N	
Do you need contours?					Y	Y	
Individual Photos with no georeferencing++ *(Y/N)*		Maybe	N	N			
Photos with Georeferencing /Image Mosaicing			Y				
Georeferencing with Aircraft GPS Location Only (Y/N)		N	Y	N (BUT DEPENDS ON GYRO AND COSTS)			
Rough georeferencing to 100ft level (rough photo georegistration) (Y/N)		N	N	Y (maybe)			
Photomosaic –		Y	N	?			

smoothed mosaic images not geomatically correct (Y/N)							
Combination of GPS and camera attitude method to get to output georegistration (Y/N)		Y	Y	Y			
What accuracy do you need georegistration+?							
Absolute position on ground use differential GPS (Real Time Kinematic) (Y/N)		Y	Y	~ (we don't need this level of accuracy daily, but may occasionally)			
3D terrain reconstruction/dam shape reconstruction (Y/N)		Y	Y	N			
Laser Scanner (i.e. controlled steering of laser beams followed by a distance measurement at every pointing direction for 3D scanning) (Y/N)		Y	Y	N			
Video							
Do you need video?					Y	Y	
Standard Definition Video (e.g. 720 pixels × 480 lines or 640 pixels × 480 lines (Y/N)		Y	Y	N			
High Definition Video (e.g. 1,920×1,080 pixels (1080i/1080p)) (Y/N)		Y	Y	N			

Appendix G. USGS GOM Media Player Procedures for Creating Image Mosaics

USGS Procedures for mosaicing images (all information from Raven Image Mosaic Procedures, USGS 2012) :

1. Capture the video (current usable formats: .avi, .mpg)
2. Open Video with the GOM Media Player
3. Run ‘Burst Capture’ Routine to automatically capture still frame images at set intervals
4. Open still frame images into Microsoft Office Picture Manager
5. Select all the images that need to be ‘cropped’
6. Select one image, crop out borders and/or labeling, and apply to all images
7. Rotate all the images to the direction of flight
8. Open the cropped and rotated images into Windows Live Photo Gallery
9. Select all the images and Create a Panorama (mosaic)
10. Adjust contrast, brightness, sharpen, etc.

Appendix H. Adamtech Photogrammetry Software

How to Process Photogrammetry Images in 3DM Software

March 2010, Written by Connie Svoboda, Hydraulic Investigations & Laboratory Services (86-68460)

General Notes

- Computer location:11th floor computer area
- Log-on: Joe, Password: Denver21
- Dongle is needed to use 3DM CalibCam and 3DM Analyst software
- ASCII file of control point locations is needed before starting. Create comma-delimited file with columns as “control point name, x, y, z”. Save file as .txt or .xyz file.
- Project files saved someplace like: C:3DM-Projs\HydroLab\ConnieLogjamModel

Process Image Pairs in 3DM CalibCam

Step 1: Import and Digitize Images

1.) On *Manager* tab, Choose D700_HLab_20mm_HLab_f5.6 from camera list (or other applicable camera file)
2.) Drag down to New Project on left menu
3.) Right click on D700_HLab_20mm_HLab_f5.6 and click Add Image
4.) Open all image files collected in the data run
5.) Rotate all photos in the same direction (90 or 180 degrees)
6.) Click *Digitizing Tools* on top menu – choose Generate Relative-Only Points – leave default setting at 1000 and All Images – click Start
7.) When finished, click on *Images* tab at the bottom left. Green points are recognized commonalities; red points show locations with no commonality.

Step 2: Import Control Point Data

8.) On *Manager* tab, click *Data Set* on left menu – Right click for Add Data Set – select feet in units – browse to find ASCII file of control point data – click OK

Step 3: Bundle Adjustment

9.) Click *Exterior* tab from top menu – choose Free Network – click Resection – click Adjust (sigma value should be around 1 or less). Click box for View HTML summary report (or click on *Reports* – choose Last Bundle Adjustment).
10.) In HTML summary report, look under Image Photo Points for RMS Error Summary – total RMS error should be less than 0.2. Also look at Posteriori Variance Factor at top – should be less than 1. If the residuals are too high, you can remove bad points later to bring down the residuals.
11.) Save file as .Cam file

12.) If bundle adjustment fails due to lack of commonality, you must:

   a. Click “Dual Cursor” icon (looks like two pluses in boxes)
   b. Move cursor to a common point on both images.
   c. Type “l” to lock the position and type “space bar” to digitize the points.

Step 4a: Remove points with poor residuals manually

13.) Click “Toggle between Image and residual report” button (it looks like a square with a diagonal line through it) – allows you to view points and residuals

14.) Click *View* – choose Residual Table and View data >1

15.) Click *Edit* – choose Point ID – click Relative Only Points with residuals from 1 pixel.

16.) Do another bundle adjustment after points are removed– click *Exterior* – choose Free Network – do not need to resection – click Adjust. Click box for View HTML summary report (or click on *Reports* – choose Last Bundle Adjustment)

17.) In HTML summary report, look under Image Photo Points for RMS Error Summary – total RMS error should be less than 0.2. Also look at Posteriori Variance Factor at top – should be less than 1

Step 4b: OR Remove points with poor residuals automatically

18.) Click on button that looks like a square with a diagonal line through it – allows you to view points and residuals

19.) Click Edit – choose Remove Bad Relative-Only Points and it will identify bad points and remove them for you

20.) Do another bundle adjustment after points are removed – click *Exterior* – choose Free Network – do not need to resection – click Adjust. Click box for View HTML summary report (or click on *Reports* – choose Last Bundle Adjustment)

21.) In HTML summary report, look under Image Photo Points for RMS Error Summary – total RMS error should be less than 0.2. Also look at Posteriori Variance Factor at top – should be less than 1

Step 5: Digitize the control points

22.) In *Manager* tab, click on icon near top menu bar called “Target Cursor” (blue bullseye)

23.) In box, write the control point # (e.g. 101). Always label control points between 0 and 1000 since the relative-only points increase from 1000. Click on the control point location in the image. Change the control point # in the box and click on the next control point location in the image. Identify all control points on the image. Hit ESC to exit the “Target Cursor”.

24.) If you make a mistake when labeling control points, you can:

   a. Click on the red X icon and delete specific control points.
   b. Or you can use the “Renumber Control points” icon. Type in the correct number in the menu bar, click the “Renumber” icon, and then click on the control point that needs to be corrected.

25.) In the *Manager* tab, click on the icon near the top menu bar called “Add Point or Natural Point Cursor” (it looks like a green target)

26.) Change the number in the box to the first control point that you want to digitize. For each control point, zoom in to the target (move the up/down/right/left arrows as needed to get to the center of the target), then click “centroid” to center all of the control points at the exact location.

27.) Complete centering targets for all control points. Hit ESC to exit when finished.

28.) Repeat the process of digitizing control points for all photos.

Step 6: Incorporate the control points into the photos

29.) Click *Exterior* tab – choose Control Network – click Resection – click Adjust – click box for View HTML summary report (or go into *Reports* – choose Last Bundle Adjustment)

Step 7: Choose photo pairs

30.) Click *Report* – choose Image Pair List

31.) Choose the photo pairs that you want to look at in 3DM Analyst. You will likely choose images that are next to each other. The images with the greatest commonality will have a higher ratio (e.g. 1:5) than images with little commonality (e.g. 1:1).

32.) Click Generate Names – click Create Projects – click Close

33.) Check in project folder and there should be .Vwr files for the photo pairs that you have selected

Analyze Photo Pairs in 3DM Analyst

Step 1: Produce DTMs and DEMs

1.) Open .Vwr file (image pair)

2.) Click Go button to create DTM (digital terrain model) points and triangles

3.) If you click the mouse and then press the Ctrl button, a new cursor will appear and the XYZ coordinates will appear for that location.

4.) Click DEM (digital elevation model) icon. Keeping the distance between points and model area the same for all image pairs will make it possible to directly compare points between photo sets.
   a. Choose distance between points (e.g. x=0.05 ft, y=0.05 ft)
   b. Choose model area to be digitized (lower left point and upper right point).

5.) If you want to delete specific points in the DTM or the DEM (points are out of your area of interest or points are skewing your DTM or DEM):
   a. Click on the red X icon and click on an individual point to delete
   b. Or click on the red X icon and hold down right mouse button to extend the box. Click on the left mouse button and wait to delete points from the area outlined by the box.

Step 2: Create Contours and Sections

6.) Click Contour icon to create contours at specified spacing (e.g. 0.05 ft)

7.) Click Sections icon to create sections at specified location

Step 3: Export Data

8.) To save a screen capture (e.g. for the photograph with contours on top, you can turn on the image and contours, turn off DTM, DEM, x/y/z reference, and camera locations on icon bar. Click Camera button to get a high quality .jpg or .tif screen capture.

9.) Click on File – Export to export DTM or DEM data as .dxf (AutoCAD) or .maf (text file). A DTM or DEM exported as a .dxf file can be bought into AutoCAD to determine the elevation difference between 2 images or ArcGIS to map topography.

How to Produce a Trim Template

1.) Open 3DM Analyst Trim program
2.) Load a .Vwr file from CalibCam and look at "3D View" (view photo & turn off triangles)
3.) Load .fdf file (in Hydrolab directory, e.g. friz.fdf)
4.) Select "ara" in drop down menu ("ara" means area inside will be retained, "hol" means area outside will be retained)
5.) Move mouse to first trim location
6.) Click Ctrl – click F – click Space
7.) Move mouse to next trim location and click mouse
8.) Click Ctrl – click Space
9.) Move mouse to next trim location and click mouse
10.) Click Ctrl – click Space, etc, unless you reach the beginning location
11.) Click "s" for Save on keyboard
12.) You should see the defined trim line on the screen
13.) Click on "Build" menu tab – click on "Reset DTM triangulation – and wait for image to be trimmed at the new trim line
14.) Save .Vwr file.
15.) Save as .pnl file by clicking File – Features – Save as .pnl file. This is the trim template for multiple images, so you will want to name the file something broader than the original .Vwr file name.

How to Trim an Image

16.) Open 3DM Analyst program and load any .Vwr file
17.) "File", "Features", "Load", and load .pnl file to trim the image.
18.) Click "Build", then "Reset DTM Triangles" to trim the DTM.
19.) Save trimmed .Vwr file.

How to Combine Multiple DEMs into a Single DEM

1.) Open "Pt Avg DEM Generator" software (icon on desktop).
2.) Click "Add" to add .Vwr files to merge.
3.) Under "DEM", choose grid spacing (e.g. 0.02 ft).
4.) Click "Check All" and "Generate DTMs".
5.) A .dxf file is created called "Data.dxf" in your folder; rename to a unique name. The .dxf file can be imported into AutoCAD or ArcGIS.
6.) If you want to view the combined DEM, open one of the .Vwr images in 3DM Analyst; load FDF file; click "edit FDF" and add 4 as "POINTS"; click on "point", change color to orange; then File – Import – .dxf file; orange DEM points should appear on the DTM image).

Appendix I. DOI Use of UAS (OPM 11-11)

United States Department of the Interior
National Business Center
Aviation Management
300 E. Mallard Dr., Ste 200
Boise, Idaho 83706-3991

DOI OPERATIONAL PROCEDURES (OPM) MEMORANDUM NO. 11-11

Subject:	DOI Use of Unmanned Aircraft Systems (UAS)
Effective Date:	December 19, 2011
Supersedes:	OPM 09-11 issued on August 24, 2010
Expiration:	December 31, 2012

1. **PURPOSE.** The purpose of this OPM is to provide guidance on the operations and management of Unmanned Aircraft Systems (UAS).

2. **AUTHORITY.** This policy is established by the Associate Director, Department of the Interior, Aviation Management (AM) in accordance with the provisions of Departmental Manual 112 DM 10: 350 DM 1; Secretarial Order 3250 dated September 30, 2003, and NBC Director's memorandum dated October 5, 2011.

3. **BACKGROUND.** Current FAA policy is provided in Interim Operational Approval Guidance 08-01, Unmanned Aircraft Systems Operations in the U.S. National Airspace System (NAS).

   A. FAA retains the authority to approve UAS operations within the NAS in Class A, B, C, D, E and G airspace.

   B. When operating in Class A, B, C, D, E and G airspace, DOI UAS's must be operated with a FAA Certificate of Waiver or Authorization (COA).

   C. COAs are not required in Restricted, Prohibited, or Warning airspace. However, UAS operations in these specific airspaces will be regulated and approved by the Controlling Authority (a.k.a. "Range Control").

4. **POLICY.** UAS by definition are considered aircraft. While their size, method of control, and airspace utilization procedures are different than manned aircraft, the overall responsibility for management within the Department of Interior (DOI) rests with the Aviation Management Directorate (AMD). Ownership of all aircraft, including UAS, is a function and responsibility of AMD. Additionally, AMD will coordinate with other federal agencies on use and cooperate with the FAA on existing and proposed rule making. Department of Interior bureaus shall employ the following procedures when using any UAS, either DOI-owned or DOI contract vendor-owned and operated.

5. **PROCEDURES AND GUIDELINES.**

   A. UAS Project and COA Application:

      1. The AMD Alaska Regional Director, Harry Kieling is the DOI UAS Coordinator for FAA COA applications, harry_kieling@nbc.gov, 907-271-5626, 907-271-6569 (Fax).

      2. The alternate UAS Coordinator is Alaska Region Aviation Safety Compliance Specialist, Rod Russell, rod_russell@nbc.gov. 907-271- 5004, 907-271-4788 (Fax).

      3. Only a U.S. (Federal/State/Local) government agency or university may apply for a COA.

4. The COA includes, but is not limited to the operational plan, risk management, airworthiness, airspace, pilot qualifications, frequencies and communication plan, and should be developed and submitted using the COA online system (https://ioeaaa.faa.gov/oeaaaA/Welcome.isp). This web site is password protected.

5. Initial feasibility discussions will be conducted between bureau unit, local bureau and National Aviation Manager and, if necessary, DOI UAS Coordinator.

6. The local unit will prepare and submit a formal request to initiate a UAS COA. This proposal shall include the general purpose, objectives and justification for utilizing UAS.

7. The request shall be routed through the bureau state/regional office to the bureau National Aviation Manager for review and approval/disapproval.

8. If approved, the proposal will be forwarded to AMD and a request will be made for an on line COA account for the project.

9. Following the establishment of the on line COA account, the bureau proponent will complete the detailed COA application. When the proponent feels the application is ready for review and submittal, it should be forwarded through bureau channels to the Bureau National Aviation Manager for approval and then to the AMD COA coordinator for **committal** to the FAA.

10. Collaboration and agreement will occur prior to official commitment of the application. Status of the COA can be followed on the On Line web site. The COA, once issued, shall serve as the UAS Operations Plan.

B. Restricted/ /Prohibited and Warning Area Utilization:

1. Operations conducted entirely within Restricted/Prohibited and Warning areas do not require a COA; however, an MOU for UAS use will be established between the using bureau/AMD and the controlling agency and the request process outlined above is still necessary, requiring Bureau National Office approval.

C. Minimum Operational Requirements: The following requirements must be met prior to any operational use of UAS:

1. Obtain approval from bureau National Aviation Office

2. Obtain (1) a valid and current COA issued by the FAA or (2) MOU with the controlling agency for operations wholly within Restricted/Prohibited and Warning areas.

3. Exercise operating limitations in accordance with the COA/MOU Range provisions/COA and this OPM.

4. Meet DOI UAS Pilot/Mission Operator/Observer Training and Certification Requirements. DOI operators of UAS vehicles must first receive bureau authorization and concurrence and then must receive training in the specific vehicle to be operated. The using bureau and AMD will identify appropriate training. Personnel must possess training certificates from AMD or AMD-approved sources prior to receiving AMD certification.

5. Possess a DOI UAS Operator Letter of Authorization. The LOA must specify the UAS vehicle(s) that are authorized to operate.

6. VFR cloud clearances and visibilities for Class E airspace will be used regardless of airspace the UAS is operating in, except when operating in Class Airspace where 14 CFR Part 91.155 will apply.

7. Operations outside of restricted areas, warning areas, prohibited areas, and /or Class A airspace may only be conducted during daylight hours, unless authorized in the Special Provisions Section of the COA.

6. UAS Pilot Qualifications and Certification

A. <u>General UAS Pilot Responsibilities</u>: The pilot in command, (PIC) of a UAS is directly responsible for, and is the final authority as to the operation of that aircraft.

1. One PIC must be designated for all flights.
2. Pilots are responsible to perform a thorough preflight inspection of the UAS.
3. Pilots, Mission Operators and observers will not have concurrent responsibilities during the mission. They may not perform more than one crew duty at a time (i.e. Pilot/Mission Operator/Observer).
4. Per 350 DM 1.8, Reporting Requirements, an AMD 2 or AMD 23 will be required for each flight.

B. <u>UAS Pilot Certification Factors:</u> Rating requirements for the UAS PIC depend on the type of operation conducted and fall into two categories. The requirement for the PIC to hold a pilot certificate is based on various factors including:

1. Location of the planned operations.
2. Mission profile.
3. Size of the UA.
4. Whether or not the operation is conducted within or beyond visual line of sight. Each application will be carefully reviewed to assess the feasibility of allowing that type of operation.

C. <u>Operations that require a FAA pilot certificate and Letter of Authorization:</u>

1. All operations approved for use in Class A, B, C, D, and E airspace.
2. All operations conducted under IFR (FAA instrument rating required).
3. All operations approved for nighttime operations. Night operations are authorized in Restricted/Warning/Prohibited areas without a FAA pilot certificate unless prohibited by the Controlling Authority. Also the night operations without a FAA pilot certificate are permitted if specifically allowed in the Special Provisions Section of the COA.
4. All operations conducted at joint use or public airfields.
5. All operations conducted beyond line of sight.
6. Operations above 400 feet AGL or with visual line of sight conducted greater than one NM from the UAS observer. A FAA pilot certificate may not be required for altitudes to 1000 ft in Restricted/Warning/Prohibited areas if not prohibited by the Controlling Authority. Also, the higher altitude is authorized without a FAA pilot certificate if specifically allowed in the Special Provisions Section of the COA.
7. At any time the FAA (as specified in the COA) has determined the need based on the UAS' characteristics, mission profile, or other operational parameters.

8. For those operations that require a certificated pilot, the PIC, in order to exercise the privileges of his certificate, shall have flight reviews and maintain currency in manned aircraft per 14 CFR 61.56, *Flight Review* and 61.57, *Recent Flight Experience: Pilot in Command.*

9. For operations approved for night or IFR, the PIC shall maintain currency per 14 CFR 61.57, *Recent Flight Experience: Pilot in Command*, as applicable.

D. **Operations requiring only a Letter of Authorization:** The PIC *may not* be required to hold an FAA pilot certificate for the following operations:

1. Approved and conducted solely within visual line of sight.

2. In Class G or Restricted/Prohibited or Warning airspace.

3. Conducted in a sparsely populated location.

4. With visual line of sight conducted no further than 1 NM laterally from the UAS observer and at an altitude of no more than 400 feet above ground level (AGL) at all times. Altitudes to 1000 ft are authorized in Restricted/Warning/Prohibited areas unless prohibited by the Controlling Authority. Also, the higher altitude is authorized if specifically allowed in the Special Provisions Section of the COA.

5. Conducted during daylight hours only. Night operations are authorized in Restricted/Warning/Prohibited areas unless prohibited by the Controlling Authority. Also the night operations are authorized if specifically allowed in the Special Provisions Section of the COA.

6. Conducted no closer than 5 NM from any airport or heliport.

7. If the pilot in command (PIC) is not required to hold a FAA pilot certificate for such operations and stated in the approved COA he/she must have in lieu of a pilot certificate one of the following:

    a. Successfully completed an FAA private pilot ground instruction, and have passed the written examination, or

    b. Completed a tailored aviation course approved by DOI-AM covering applicable sections of the FAR/AIM or other aviation publications that will enable the pilot to safely operate a specific UAS in the class of airspace desired. This training will include but not be limited to weather (as applicable to a UAS pilot), emergency procedures, aircraft mishap reporting, SAFECOM Program, lost link, Air Traffic Control (ATC communications) and NOTAM procedures, classes of airspace, system operating limitation all other applicable DMs and OPMs pertaining to aviation.

E. **UAS Specific Training and Certification for all UAS Pilots and Operators:**

1. All UAS pilots/mission operators will complete the manufacturer's UAS specific training or equivalent, be tested on their knowledge, and be certified to operate the UAS upon graduation. These courses will be monitored by AMD Tech Services/Alaska Regional Director.

2. DOI-AM or approved Bureau inspectors will provide a Letter of Authorization (LOA) under the direction of the DOI-AM Chief of Tech Services/Alaska Regional Director. The LOA will specify the UAS vehicle(s) that are authorized to operate.

F. Flight Currency:

1. PIC must demonstrate three takeoffs (launch) and landings (recovery) in the specific UAS in the previous 90 days. If currency is lost prior to a mission, operator must regain currency by flying three emergency scenarios in the UAS simulator or fly under the observation of a current UAS pilot.

G. Medical Qualification: The PIC shall maintain, and have in their possession, at a minimum, a valid FAA Class 2 medical certificate issued under 14 CFR Part 67. For operations that are covered in paragraph 5G above, alternate medical certification that is as rigorous as the Class II, may be considered and approved on a case by case basis by the bureau National Aviation Manager and AMD. After approval this alternate certification must be listed on the COA.

H. General UAS Observer Responsibilities:

1. Observer duties include but are not limited to the following:

   a. Have a clear view of the area of operation.

   b. Be in communications with the PIC either within speaking distance or with a portable radio/cell phone.

   c. Keep the pilot advised of any possible hazards such as power lines, birds, other aircraft, rocks, and hazardous weather conditions.

   d. The observer can also act as the launch person for a hand launched aircraft.

2. Observer Training: Observers must have completed sufficient training to communicate to the pilot any instructions required to remain clear of conflicting traffic. This training, at a minimum, shall include knowledge of the rules and responsibilities described in 14 CFR 91.111, *Operating Near Other Aircraft;* 14 CFR 91.113, *Right-of-Way Rules: Except Water Operations;* and 14 CFR 91.155, *Basic VFR Weather Minimums;* knowledge of air traffic and radio communications, including the use of approved ATC/pilot phraseology; and knowledge of appropriate sections of the *Aeronautical Information Manual.* This training will be reviewed and approved by the Chief of Tech Services/Alaska Regional Director.

3. Observer Medical Qualification: The provisions of Paragraph 5J above will apply to observers.

I. Maintenance:

1. Maintenance inspectors will require the same qualifications (DOI/AMD 6700.202) as current AMD inspectors plus knowledge of UAS procedures. Until AMD can develop specific UAS maintenance inspection procedures, Mil Handbook 516, or similar document will be used. Initially Rod Russell, Alaska Regional Office, AMD, should be contacted to evaluate any specific UAS airworthiness questions.

2. A conditional Inspection must be performed during preflight and must be logged in the aircraft flight log for the first flight of each day as part of a continuing airworthiness compliance program. This entry should read "I have inspected this aircraft in accordance with (site the publication and reference) and have found it to be in condition for safe operation, and be signed and dated.

3. Log and maintain progressive flight hours of the aircraft in the aircraft logbook to validate inspection intervals, component times, and time life items i.e.; batteries.

4. Record malfunctions (loss of link), damage (parts that require repair to be airworthy again), and serial numbered parts that require replacement (wings, tail booms, etc). Record serial number of the part coming off and serial number of the part going on.

5. Every twenty four months, a biennial airworthiness inspection and carding by qualified maintenance personnel will be performed. At this time a new AMD 36 Aircraft Data Card will be attached to each aircraft within the system kit.

6. A maintenance inspector training and evaluation program will be developed for each system specific and in compliance with the POH.

7. AMD inspectors will coordinate with the FAA to ensure airworthiness criterion has been approved if required. AMD inspectors will then issue an AMD 36A/36B for UAS aircraft.

J. **Radio Frequencies:** Radio frequencies to be used will be coordinated with the Bureau's Radio Office and the FAA and be included in the COA application.

K. **Cooperator Aircraft:** This could include work with universities, other governmental agencies such as the Department of Defense, or multiple agency collaborative projects. Bureau involvement in these projects does not necessarily mean that the bureau has operational control; therefore it is important for field units to communicate with the bureau National Aviation Manager on all UAS projects to determine the extent of bureau responsibilities. UAS projects must have a COA (except those covered in paragraph 3c) and shall be obtained by the agency having operational control. Even if the COA is not requested by DOI (i.e. another government agency), it must be coordinated with Bureau aviation personnel and AMD COA administrator.

1. Involvement in a UAS project but no operational control: DOI personnel collect data but do not own, operate, or participate directly in the UAS process. This will be handled similar to an end product contract, field units need only to advise the bureau aviation manager and DOI COA Administrator. However, because of the nature of the responsibilities associated with the COA application and approval process, the individual/organization with Operational Control must file the COA.

2. DOI has operational control but does not own or operate the UAS: Bureaus would follow the procedures to include the formulation of a Project Aviation Safety Plan (PASP) identifying all agencies involved in the project, outlining their responsibilities and level of involvement. Each project will be evaluated on its own merits of involvement, complexity, and standards of safety. Therefore, responsibilities will be determined on a case by case basis as determined by the bureau National Aviation Manager and DOI-AM.

7. **EXCEPTIONS, LIMITATIONS.** Per 350 DM 1.9., Deviations from this OPM must be approved by the Associate Director, Aviation Management.

Mark L. Bathrick

Associate Director

Appendix J. Acknowledgements

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