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Unmanned Aerial System (UAS) for Reclamation Bridge, Canal, and Infrastructure Inspections

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Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

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.

Disclaimer

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Bureau of Reclamation
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Acronyms and Abbreviations

3D	three-dimensional
AI	artificial intelligence
AMS	Aviation Management Specialist
AS PMB	Assistant Secretary, Policy of Management and Budget
COA	Certificates of Authorization
COTS	commercial-off-the-shelf
DEM	digital elevation model
DoD	Department of Defense
DOI	Department of the Interior
DIU	Defense Innovation Unit
EMAO	Emergency Management and Aviation Office
FAA	Federal Aviation Administration
fps	frames per second
GE	Government Edition
GNSS	global navigation satellite system
GPR	ground penetrating radar
GPS	global positioning system
GSA	General Services Administration
HDR	high dynamic range
IDIQ	indefinite-delivery and indefinite-quantity
IR	infrared
km	kilometer
lb	pound
LiDAR	light detection and ranging
m	meter
MAS	Multiple Award Schedules
MOA	Memorandum of Agreement
Mbps	megabits per second
MP	megapixel
NAM	National Aviation Manager
NAMP	National Aviation Management Plan
NDAA	National Defense Authorization act
OAS	Office of Aviation Services
OPM	Operational Procedures Memorandum
Reclamation	Bureau of Reclamation
SRR	Short Range Reconnaissance
sUAS	small unmanned aircraft system
TSC	Technical Service Center
UAS	unmanned aircraft system
USC	United States Code
USGS	United States Geological Survey

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Executive Summary

The Bureau of Reclamation's (Reclamation) facilities are often in remote and hard-to-access locations with inaccessible components. Photos of our infrastructure, videos of our operations, and data for our infrastructure and the impacted environment are crucial to identifying potential issues, developing more effective operations, and providing a data framework for designs and other analyses. Using personnel inspections may entail safety and other risks. This investigation was to identify unmanned aircraft systems (UAS) that would be most useful to Reclamation for infrastructure inspection, surveying, and photogrammetric mapping projects, and to provide information on the process needed to procure identified UAS.

UAS platforms can carry sophisticated sensors that can identify potential infrastructure issues, collect imagery and videos for a range of analyses, identify plant cover, and provide other vital functions. The UAS deployment within Reclamation comes under a hierarchy of control, starting at the Department level. The Department of the Interior (DOI) has an Office of Aviation Services (OAS) that oversees UAS operations across all its agencies and serves to provide direction in flight safety, efficiencies, and operations (Reclamation 2020).

Reclamation's involvement with UAS applications began in 2012 and has grown considerably. Most of these missions involved photogrammetric data collection. Other missions included thermal imaging, sink hole mapping, and canal seepage detection (Klein et al. 2019). Proposed projects for UAS broaden the range of UAS capabilities and include: aerial imagery, topographic surveys, geomorphic or structural change detection, infrastructure inspection, biological surveys, river hydraulic measurements, water quality testing, surveillance and security monitoring, surface and shallow sub-surface surveys, and emergency response. Each UAS mission will require different capabilities to obtain the data appropriate for the intended use.

Broadly speaking, there are three main mission categories that require slightly different platform functionality: general photogrammetric mapping missions (which may or may not include thermal image acquisition), inspections that generate orthoimagery and crack maps as well as provide spatial reference and deterioration pattern recognition (e.g., dams, cliff faces, transmission towers, bridges etc., that may or may not require photogrammetric camera specifications), and UASs that can carry heavier payloads for specialized and research applications (e.g., light detection and ranging [LiDAR], aeromagnetometers, or other heavy payloads).

Recently, all DOI UAS activities were grounded by a Secretarial Order 3379, "Temporary Cessation of Non-Emergency Unmanned Aircraft Systems Fleet Operations." (DOI 2020 Order). Under this order, only drone use for emergency operations such as fighting wildfires, search and rescue, and dealing with natural disasters that may threaten life or property is allowed. Additional congressional action also prohibits the acquisition or use of "UAS that are manufactured or assembled by certain entities, including entities subject to influence or control by China, with exceptions." (American Security Drone Act of 2021). Currently, we understand that the order is under review and may be altered, rescinded, or replaced by new legislation. A 2020 update from Secretary Bernhardt provides clarification on the definition of "Designated UAS" and support for the Department of Defense's

(DoD) Defense Innovation Unit (DIU) small Unmanned Aircraft Systems (sUAS) Blue UAS initiative (DOI 2020 Update). We understand that the Blue UAS program is under review by OAS. The current DOI UAS fleet grounding remains in effect with the exception of operations for emergency use.

This report describes actions that Reclamation may pursue if UAS are approved for DOI and Reclamation mission flights. It includes details on the specifications that are recommended for the three Reclamation use categories mentioned above as well as provides details on how to work with OAS to procure airframes that would meet the requirements for Reclamation uses.

Introduction and Background

Problem the Study Addresses

Reclamation's facilities are often in remote and hard-to-access locations. Photos of our infrastructure, videos of our operations, and data for our infrastructure and the impacted environment are crucial to identifying potential issues, developing more effective operations, and providing a data framework for designs and other analyses. Using personnel inspections may entail safety and other risks. Closing bridges or shutting down facilities for inspections can put operations on hold.

Monitoring continuous operations such as water flows or time lapsed data such as sedimentation rates can require regular trips to job sites that may not be feasible and expensive. UAS can provide the data needed at much less expense as these systems are able to access spaces, periodically return to preprogramed locations, or stay in one location for a short period of time.

Moreover, UAS platforms can carry sophisticated sensors that can identify potential infrastructure issues, collect imagery and videos for a range of analyses, identify plant cover, and provide other vital functions.

Study Objectives and Approach

This investigation objective was to identify UAS and sensors that would be most useful to Reclamation for infrastructure inspection, surveying, and photogrammetric mapping projects, and to provide information on the process needed to procure identified UASs. The report is limited to the current UAS inventory and that available through the current Blue UAS initiative. Sensors described are those either already acquired or those typically used, tested, and vetted by either OAS or the U.S. Geological Survey (USGS).

Background

Reclamation Aviation Management – UAS

UAS deployment within Reclamation comes under a hierarchy of control, starting at the Department level. DOI's OAS oversees all aviation including UAS operations across all its bureaus and serves to provide direction in flight safety, efficiencies, and operations. Groups and committees include the: Executive Aviation Board, Executive Aviation Committee, Executive Aviation Subcommittee, and Interagency Aviation Training Subcommittee (Reclamation 2020).

Reclamation's Aviation Management is a program within the Programs and Policy Directorate, Emergency Management and Aviation Office (EMAO). Ultimately, all Reclamation UAS operation decisions reside with the Commissioner. Beneath the Commissioner is the Director of Programs and

Policy, followed by the Chief of EMAO, the National Aviation Manager (NAM), and Regional Directors. At the Technical Service Center (TSC), this would be the TSC Director. Working under the direction of the NAM is an Aviation Management Specialist (AMS) who works and coordinates all aviation needs within Reclamation—not just UAS activities. Within each region/directorate with an aviation program, a liaison is assigned to coordinate with the all aviation related activities with the AMS and provide a conduit of communication from aviation management to aviation managers, supervisors, and users.

The NAM, AMS, and liaisons form the Reclamation Aviation Council where much of the requirements and procedures for Reclamation's UAS activities are discussed and incorporated into Reclamation's National Aviation Management Plan (NAMP). Line Managers (Directors) and immediate supervisors are also involved in aviation management and training to review aviation documents and ensure employee safety. The aviation users (both manned and unmanned) have training and compliance requirements in order to operate safely, reliably, and efficiently.

Previous Work

Reclamation's UAS History and Status

Reclamation's involvement with UAS applications began in 2012 (DOI 2020). Initial steps included using excessed military grade UAS that provided initial experience with the technology. The industry advanced rapidly and commercial-off-the-shelf (COTS) platforms became available that included necessary features such as integrated cameras with video downlinks for real-time viewing on a screen, battery monitoring and management to ensure adequate flights, and automated navigation functions relying mostly on global navigation satellite systems (GNSS), and more recently, optical and acoustic sensors to help with collision avoidance and emergency situations.

In 2016, the UAS technology and usefulness matured to the extent that the Federal Aviation Administration (FAA) legalized the use of commercial UAS and provided a procedure to certify UAS remote pilots with the adoption of Part 107 (FAA 2016). OAS included the FAA's Part 107 requirements into its current UAS regulatory and certification system that included several existing UAS Memorandum of Agreements (MOA) and Certificates of Authorization (COA) (DOI 2021). The first certified remote pilots in Reclamation completed their training soon afterwards. Reclamation currently has 27 remote pilots who perform UAS operations as collateral duty to collect UAS data for a wide range of analyses including structural and hydraulic engineering, biology, economics, geospatial sciences, and geomorphology. These pilots have a diverse range of expertise.

Grounding of DOI UAS Fleet

In January 2020, the Secretary of the Interior ordered the temporary cessation of non-emergency unmanned aircraft systems fleet operations (DOI, 2020). Concerns were raised about the cybersecurity, technology, and domestic production of UASs—and the temporary cessation was implemented. Under this order, only drone use for emergency operations such as fighting wildfires, search and rescue and dealing with natural disasters that may threaten life or property is allowed.

During this time, the Department of Defense (DoD) initiated the Blue UAS procurement project. "This project developed trusted sUAS for the broader Department of Defense (DoD) and Federal Government partners" (DoD 2021). The Blue sUAS purpose is to provide the National Defense Authorization Act (NDAA) Section 848 compliant sUAS options for the DoD and Federal Government for purposes of reconnaissance and surveillance. The Blue UAS project currently has 5 available platforms designed for military use and their use for professional grade mapping and inspection is extremely limited.

Reclamation UAS Applications

In the spring 2019, the TSC, with sponsorship from Reclamation's Research and Development Office, polled Reclamation to identify UAS research needs and identify the most desired UAS applications (Klein et al. 2019). One of the questions asked respondents which UAS applications were useful to them or their office. The top five categories indicated that Reclamation felt that aerial photography/videography, photogrammetric three-dimensional (3D) modeling, geographic information systems (GIS) mapping, infrastructure inspection, topographic mapping, and LiDAR (light ranging and detecting) scanning would be the most useful UAS applications. This echoes a similar poll that was conducted in 2014, where mapping and surveys were some of the top UAS applications (Clark 2014).

Reclamation TSC Strategic Plan

During the 2020 grounding of the DOI UAS fleet, the TSC UAS team created a strategic plan to inform and guide through the future of UAS operations within the TSC (Wille et al. 2021). As part of this effort, the TSC UAS team identified areas where the TSC team could provide services that are not readily available from the regional UAS programs. One of these areas was the inspection of infrastructure and high hazard areas (e.g., cliff faces), using sensors outside of the visible range in addition to the commonly used optical cameras. These operations also include complex planning and operation techniques for operating the UAS in tight, confined, or otherwise difficult flying environments.

Reclamation UAS Needs

Project Types

Reclamation's UAS teams have completed 522 missions between October 2017 and October 2020. These missions covered a wide range of applications including digital orthophotos, 3D models, contour generation, digital elevation model (DEM) production, thermal and infrared (IR) mapping, live video feeds, video and still image production, training, and aircraft testing (OAS 2021).

Proposed projects for UAS broaden the range of UAS capabilities and include:

- Aerial imagery
- Topographic surveys
- Geomorphic or structural change detection
- Infrastructure
- Biological surveys
- River hydraulics
- Water quality
- Surveillance and security monitoring
- Surface and shallow sub-surface surveys
- Emergency response

UAS Data Collection General Specifications

Each UAS mission will require different capabilities to obtain the data appropriate for the intended use. Multiple platforms and sensors will be required. For example, an ideal UAS for inspecting, surveying, and mapping of Reclamation infrastructure would include several capabilities:

- Professional (non-hobbyist level) high-resolution cameras/sensors capable of acquiring and delivering detailed imagery data to be used to produce high quality orthophotography and 3D reconstruction applications for infrastructure inspection, surveying, and photogrammetric mapping activities.

- Fully integrated (non-hobbyist level), UAS platform specific flight planning, flight management, and imagery data acquisition software and hardware. Ability to perform 3D inspections in complicated environments such as towers, bridges, indoor flying, other infrastructure.

- Fully integrated, 360-degree collision detection and obstacle avoidance capability.

- Greater than 15-minute flight times. A one-hour, or longer operational flight time, at full payload capability, would be optimal for the near future.

- Sensor ability to capture images on the underside of infrastructure components (under bridges, dam faces, etc..) with either a top-mounted camera/sensor or using a gimbal camera/sensor mount with a +/- 90-degree tilt from horizontal range, without capturing the UAS propeller blades, antennas, or other parts of the airframe.

- Capable of operation and data acquisition in environments where GNSS are unavailable.

UAS Sensors

Determining Reclamation's data requirements is critical to determining the type of sensor and platform needed. The type of sensor needed will also guide the desired platform capabilities for carrying that sensor. Table 1 below is taken from the TSC UAS FY21 Strategic Plan and summarizes the sensors and/or payloads by mission type as well as gives several examples of that mission (Wille et al. 2021).

Table 1. Summary of UAS Applications from TSC UAS FY21 Strategic Plan (Wille et al. 2021)

Mission Type[1]	Sensors or Payload	Example Applications
Aerial Imagery	Optical, Multispectral	Aerial photography, videography, and orthoimagery.
Topographic Surveys	Optical, LiDAR, Ground Penetrating Radar	Topographic and bathymetric surface development. Water surface elevation measurements. Volume and capacity measurements for construction estimates.
Geomorphic or Structural Change Detection	Optical, LiDAR, Thermal, Ground Penetrating Radar	Spillway, rock face, landslide, or sinkhole monitoring. Sedimentation monitoring. Restoration site evolution monitoring.
Infrastructure	Optical, LiDAR, Multispectral, Thermal, Magnetometer	Mapping concrete surface deterioration (cracks, spalls, etc.). Seepage detection (canals or levees). Inspecting buildings, bridges, roads, dams, and other infrastructure. Inspecting indoor Reclamation infrastructure such as penstocks, tunnels, powerhouses, and draft tubes. Detecting weak spots in steel structures. Geometric 3D modeling using photogrammetry.
Biological Surveys	Optical, LiDAR, Multispectral, Radar, Radio Telemetry	Vegetation mapping. Habitat monitoring. Animal and fish tracking. Invasive species monitoring.
River Hydraulics	Optical, LiDAR, Thermal	Discharge measurements.
Water Quality	Optical, Multispectral, Sample Acquisition Apparatus	Monitoring algae blooms. Estimating turbidity. Acquiring samples for water chemistry tests.
Surveillance and Security Monitoring	Optical, Thermal, Chemical	Construction site security monitoring. Remote location monitoring. Hazardous materials and locations sampling and monitoring.

Mission Type[1]	Sensors or Payload	Example Applications
Surface and Shallow Sub-Surface Surveys	Optical, LiDAR, Multispectral, Ground Penetrating Radar	Cultural resource documentation and monitoring. Geologic and geotechnical mapping.
Emergency Response	Optical, Thermal, Multispectral, Chemical, Cargo Sling	Fire or other disaster response. Hazardous materials sampling. Search and rescue operations. Delivery of small tools or small amounts of food, water, or first aid supplies.

[1] Organized by descending order in popularity.

The most common sensor requested is the optical sensor, which are useful in almost all applications and can often collect data in conjunction with other sensor types. High on the list of sensors are the multispectral, LiDAR, ground penetrating radar (GPR) and thermal payloads. Other less requested sensor or payload include radio telemetry (animal surveys) and sample acquisitions (i.e. water sampling).

Reclamation currently has optical, multispectral, and thermal sensor capabilities—but does not have aerial LiDAR, GPR, or magnetometers. Aerial LiDAR is one of the most requested sensor. LiDAR capabilities are application for projects such as topographic mapping in areas with a high vegetation cover, canal seepage detection, utility line inspections, geologic and geotechnical surveys, low light, and others. Aerial GPR is useful for locating and documenting targets beneath or behind surfaces. These surfaces might be the ground, concrete structures, roads, bridges, or buried objects. GPR has many other applications, including locating buried utilities, conducting a structural assessment, and identifying buried artifacts. Airborne magnetometers are useful for seepage detection, surveying wetlands, heavily vegetated areas, extreme terrain, or protected lands. This sensor can also be used for identifying abandoned wells, pipes, and storage tanks. An airborne magnetometer can be used to survey archaeological sites without disturbed it. When used for geological surveys, variations in the magnetic field are easily detected. This capability is currently being evaluating though UAS trials are postponed until the grounding is lifted (Rittgers, 2020).

UAS Platforms

As described earlier, per Secretarial Order 3379, all current UAS platforms are grounded except for emergency operations. The current platforms in our inventory are not authorized to fly unless in an emergency situation or for proficiency/currency flights for emergency readiness. The Blue UAS platforms authorized by the Secretary (DOI 2020 Update) have limited functionality for Reclamation use as these are focused on the military requirements of reconnaissance, surveillance, and target acquisition.

The discussion of the platforms below is limited to the UAS in Reclamation's inventory and those potentially available under the Blue UAS program.

Current Reclamation Airframes

The current platforms are described in a report detailing UAS data collection at Reclamation sites, however, a brief summary is provided here (Klein et al. 2019).

3DR Solo: The 3D Robotics Solo has been the backbone of DOI UAS operations since active missions began. It is a light weight, reliable platform that allows for interchanging several different sensors. Its drawbacks include an aging fleet with a manufacturer no longer producing this model. In addition, the flight times per battery are relatively short, on the order of 10 to 15 minutes, depending on flight variables.

Parrot Anafi: This was a recent acquisition prior to the fleet grounding. The unit is highly portable and comes with a high-quality camera. It is also extremely light and weighs less than 0.7 lbs with battery. The entire unit with controller weighs less than 2.2 lbs. The camera is affixed to a pivoting gimble, allowing for overhead and underfoot imaging. The camera comes with 4K 100 megabits per second (Mbps) bitrate and with a built-in high dynamic range (HDR) video option. The Parrot comes with a dolly zoom capability, a hyperlapse mode that can increase footage speed to 240x, and a slow-motion mode that can capture footage at 120 frames per second (fps). Flight time is advertised at 25 minutes. However, a major drawback for mapping and photogrammetric missions is the lack of a global shutter on the camera and the small sensor size. In addition, this UAS does not come with any sense and avoid capabilities.

DJI Mavic Pro Government Edition (GE): The Mavic Pro GE is also a recent acquisition and has not been used widely. This is a highly capable UAS that combines automated flight modes and obstacle avoidance in a very small package. The UAS has exceptional distance control allowing flights up to 7 kilometers (km) away and streams video at 1080p. Because this is an integrated system, camera settings can be adjusted on the controller. The system is also very light weight at 1.6 lbs. The flight time is considerable with an advertised flight time of 27 minutes. There is only a forward and down-looking sense and avoid system. As with the Anafi Parrot, the mapping suitability is limited by both a rolling shutter rather than a global shutter on the camera and the small sensor size. The camera is equipped with a 12 megapixel (mp) sensor.

OAS Fleet

The airframes designated as available by DOI include the current airframes described above (3DR Solo, DJI Mavic Pro, and the Parrot Anafi) in addition to the following:

DJI Matrice 600 Pro Government Edition (GE): The Matrice 600 (M600) Pro GE is a heavy lift capable UAS. This UAS is capable of lifting up to 13.2 pounds (lb). The M600 has the automated flight controls of the Mavic Pro GE—but no sense and avoid capabilities. The flight time varies depending upon the weight of the payload. With a full payload the flight time is between 16 and 18 minutes. The M600 Pro GE works well for professional aerial photography and industrial applications. The M600 Pro GE can also carry custom payloads including LiDAR, GPR, and magnetometers.

BirdsEyeView Aerobotics FireFLY6 PRO The FireFLY6 PRO is the only fixed wing UAS in the OAS inventory. The wingspan is 5 feet and has a flight time of between 20 – 40 minutes. The take off and land is vertically and can land within 10 square feet. The FireFLY6 PRO can also fly and loiter for closer imagery. This airframe can be launched from land or from a boat. The total payload capacity is 1.5 lbs. The payloads that can be used with the FireFLY6 PRO include the Sony a6000, Sony RX1R II, Slant Range 4P, Slant Range 4P Plus, MicaSense RedEdge-MX, Parrot Sequoia, Gimbaled GoPro HERO4, Gimbaled FLIR Vue Pro, Gimbaled FLIR Vue Pro R, and NicaDrone OpenGrab EPM.

Autel EVO: This is another small and light weight airframe weighing in at just under 2 lbs. The EVO comes with forward looking obstacle avoidance, rear obstacle detection and bottom sensors. Flight times up to 30 minutes with a range of 4.3 miles. The camera is as limited as the Mavic Pro GE and Parrot Anafi with a 12 mp sensor. The camera does include a 3-axis stabilize gimbal that records video at 4k resolution up to 60 frames per second and a recording speed up to 100 mbps.

Blue sUAS

Each of the five UAS options have airworthiness approvals to fly in DoD and national airspace and meet the criteria required for U.S. Government procurement.

Skydio's X2D: The X2D has an impressive list of capabilities that suit an inspection program well. The system incorporates advanced computer vision and artificial intelligence (AI) which allow for a reliable 360-degree obstacle avoidance and flight planning even in GPS-denied environments (Skydio, 2021). The optical camera comes with a 16 x digital zoom capability which will be an asset for inspections. The combined FLIR Boson® thermal camera greatly adds to its capabilities however the resolution is lower. The rolling shutter and small sensor size makes is not ideal for mapping purposes.

Parrot Anafi USA: This system carries three cameras: two optical cameras with different fixed focal lengths and a FLIR Boson™ infrared camera. The flying range is about 2.5 miles with an advertised flight time of 32 minutes. The unit is light at 1.1 lbs. The cameras are stabilized on a gimbal and provides a moderate look-up capability. While this unit does not have sense-and-avoid capabilities, it does have flight planning capabilities. Although a capable UAS for other uses, there are limitations for both mapping and inspections.

FLIR Ion M440: This system is a tactical quadcopter designed for military, firefighter, police, and special operations applications. It has a long flight time, advertised at 35 minutes and an almost 2-mile range. It does have forward sense and avoid capabilities and four sensors. These sensors include a wide and narrow electro-optical lens, a FLIR BOSON, and a zoom sensor. The camera is attached to a gimbal system with a -90-to-90-degree gimbal range. The unit can operate in a global positioning system (GPS)-denied environment. There is no advertised information about the type of shutter, but it is probably a rolling shutter. No information is provided about flight planning capabilities.

Teal Drones Golden Eagle: The Golden Eagle has an advertised flight time of about 50 minutes and a range of 2 miles. Like other UAS in this program, it comes with both an optical and thermal camera (FLIR Hadron) and incorporates forward looking sense and avoid. While the cameras do operate on a gimbal however, the upwards direction control is limited to 45 degrees. While no information is provided on the shutter type, it is assumed to be rolling and of limited use for mapping and photogrammetry. No information is provided about flight planning capabilities.

Vantage Robotics' Vesper: The Vesper advertises the longest flight time of this group at 50 minutes. As with the other units, this system carries both optical and thermal IR cameras operating on a gimbal. The video streaming is limited to 5 miles with a directional antenna. Sense and avoid is not currently available although it is expected as a future upgrade. No information is provided about flight planning capabilities.

Current DOI Procurement Processes

Background

The only airframes permitted for use by all DOI agencies are those listed by the OAS (DOI 2021). The DoD's Defense Innovation Unit's (DIU) Blue sUAS Program is not yet available (DoD 2021).

OAS

"The DOI's platform acquisition strategy treats sUAS as an aircraft based on the FAA's classification and therefore applies the same procedures to sUAS procurement and management as they do manned aircraft. According to DOI Operational Procedures Memorandum (OPM) OPM-11 DOI Use of UAS, only the OAS may purchase sUAS, and the purchased platform is classified as fleet aircraft and remains under OAS's ownership. To acquire platforms OAS works in collaboration with DOI bureaus to develop contract solicitations and establishes indefinite-delivery and indefinite-quantity (IDIQ) contracts for specific sUAS platforms.

To acquire a DOI UAS Fleet platform once an IDIQ contract has been put in place DOI Bureau's must:

Complete OAS-13U DOI Small Unmanned Aircraft Systems Acquisition Request Form, which identifies the specific number and type of sUAS to be purchased. And then submit the completed form to the appropriate Bureau National Aviation Manager

AND

Complete OAS-93U Fleet Information Document, which provides the required funding information and approvals." (USGS 2021)

The process for evaluation and approval of equipment not currently in OAS's inventory needs clarification.

Blue sUAS

The Blue UAS program provides secure, trusted, small drone capability to the U.S. government and provides market opportunity for American-made small drones. "The Blue sUAS project developed trusted sUAS for the broader Department of Defense (DoD) and Federal Government partners. This effort builds upon the U.S. Army's sUAS program of record, Short Range Reconnaissance (SRR), for an inexpensive, rucksack portable, vertical take-off and landing sUAS. Blue sUAS systems share the SRR air vehicles' capabilities but integrate a vendor provided ground control system**."** (DoD 2021)

"Prior to Secretarial Order 3379 that grounded the DOI UAS fleet, procurement of UAS was under the General Services Administration's (GSA) Multiple Award Schedules (MAS) program. GSA has recently determined that, due to the significant risk associated with offering drones under this program, it removed all drones as defined by 49 United States Code (USC) Chapter 448 from MAS contracts, except those drones approved by DIU through its Blue sUAS Program" (GSA 2021). Although general UAS procurement can be done through the MAS program, UAS within DOI must be procured through the OAS. The most current Assistant Secretary, Policy of Management and Budget (AS PMB) memo (Cameron, 2021) rescinds a prior AS PMB order (Combs, 2019) that disallowed any UAS purchases, including Blue UAS.

The procurement of UAS is a two-step process and includes submitting OAS-13U DOI Small Unmanned Aircraft Systems Acquisition Request Form and OAS-93U Fleet Information Document, which provides the required funding information and approvals. These documents are then submitted to the National Aviation Manager (NAM). The NAM will then either approve or disapprove and the purchase can then proceed.

Conclusion

Current Grounding Status

It is understood that the Secretarial Order 3379 is currently under review and that the grounding may either be upheld, amended, or rescinded. The Blue UAS is being reviewed by OAS to determine if they meet DOI operational needs and budgetary considerations in which case, flights may resume. A recent Blue UAS initiative (Blue UAS 2.0) is apparently expanding the U.S. market such that manufactures not currently on the Blue UAS list that can presently meet or approximate the DIU requirements. This is a developing situation (DUI 2021).

UAS Specifications Most Needed by Reclamation

Reclamation has been using UAS in some capacity since 2012. Since that time, the number of flights and the types of missions has grown, not only in number, but in mission complexity. Originally, the missions were mostly reconnaissance in nature, soon transitioning to topographic mapping, using of different sensors, and starting infrastructure inspections. As these missions gained complexity, so did all other aspects of mission planning, execution, and post flight data processing in addition to constant training and maintenance of pilot capabilities. The UAS airframe being used is a critical component and determines the effectiveness of all flight plans.

As missions increased in complexity, so did the demands on the airframes. Experience has shown that not all airframes are suitable for all missions. Initially, the 3DR Solo served all purposes from mapping, to public affairs imagery/video, and inspections. Although an admiral airframe, the ability to do all missions also meant it could not do them all well. This is becoming more critical as Reclamation moves more into infrastructure inspections which will require much more advanced airframe capabilities. The current airframes on the market today usually incorporate at least some object detection and avoidance. The airframes are also becoming smaller, quieter, and with much longer flight times, sensor integration, and GPS-denied stability and operation.

Sensors are increasingly integrated with flight control and now starting to use artificial intelligence (AI) and machine learning to detect, inspect, and analyze its surroundings accurately in 3D space. Through sensor integration, many airframes now feature combined airframes and sensor(s). Many of the Blue UAS airframes come with both an optical sensor and a thermal sensor. This would be of tremendous utility if the sensors themselves were adequate for Reclamation purposes. Many of the Blue UAS sensors (both optical and thermal) are not useful for high-resolution mapping purposes.

For other types of data collection, the ability to either carry more than one sensor or easily swap sensors on an airframe will be important. Often, missions will require a multispectral sensor solution. Canal inspections, for example, will benefit from the standard optical sensing but imagery collected in the infrared and thermal spectrum will also provide valuable insights into canal integrity. The ability to conduct multispectral imaging of a canal and then follow-up on the same mission with the same airframe but with an aerial magnetometer would provide a complete solution to a canal inspection. Other sensors that can be swapped on the same airframe might include LiDAR and Ground Penetrating Radar. The flexibility, especially on a heavy lift airframe, would be an important consideration.

Until recently, airframe costs were reasonable. However, if DOI adopts the Blue UAS ,costs will increase significantly. More than one airframe is usually carried to a missions to provide backup if one fails. However, the requirements to purchase from a limited pool of airframes may make this luxury prohibitive.

Ideally, Reclamation will have a suite of airframes and sensors to draw upon and fit the selection to the mission. These would include mapping specific airframes capable of extended flying times, high quality cameras, with more than one sensor. Inspection airframes would be able to scan the target, create a 3D model internally, develop a flight plan, and obtain high-resolution imagery of the entire target while flying in a GPS-denied environment. Finally, a heavy lift platform capable of handling and swapping out a series of large sensors would be useful for those missions requiring unique requirements.

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