# Small Unmanned Aircraft and the U.S. Forest Service

## Benefits, Costs, and Recommendations for Using Small Unmanned Aircraft in Forest Service Operations

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**14. ABSTRACT**

This paper provides information to Forest Service leadership about how the agency could use unmanned aircraft across different programs, especially in program areas where aircraft use is currently limited. It draws from published uses of unmanned aircraft as well as conversations with peer federal agencies that have established unmanned aircraft programs, including the Department of the Interior (DOI) headquarters and two of its bureaus: the National Park Service (NPS) and the Bureau of Land Management (BLM).

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## Introduction and Purpose

Use of unmanned aircraft, commonly known as "drones," has the potential to reduce cost, increase efficiency, and enhance safety of a range of existing Forest Service program activities, including those where manned aircraft are not currently used. Unmanned aircraft could also provide a low-cost way to expand the type of images and data the Forest Service collects, thus enhancing the Forest Service's capacity to monitor its land and systems.

The goal of this paper by the U.S. Department of Transportation's Volpe Center (Volpe) is to provide information to Forest Service leadership, especially in program areas where aircraft use is currently limited, about how the agency could use unmanned aircraft across different programs. It draws from published uses of unmanned aircraft as well as conversations with peer federal agencies that have established unmanned aircraft programs, including the Department of the Interior (DOI) headquarters and two of its bureaus: the National Park Service (NPS) and the Bureau of Land Management (BLM).

This white paper describes:

- An overview of unmanned aircraft technology and its benefits and drawbacks.
- How other public, private, and academic organizations currently use drones.
- Potential ways the Forest Service can use these aircraft.
- An overview of the regulatory and logistical constraints to unmanned aircraft.
- Options for next steps in creating an unmanned aircraft program.

Unmanned aircraft are often associated with military use, but public sector agencies are increasingly finding that these aircraft have a variety of uses even beyond those where manned aircraft have historically been used. These uses include traffic management, infrastructure inspections, emergency management efforts, wildlife tracking, agriculture, shipping, and internet connectivity. Current Forest Service policy, as discussed in the March 2015 letter from the Chief of the Forest Service (Appendix B), states that unmanned aircraft are subject to the same agency policies as manned aircraft. Please refer to the UAV Agency Policy discussion at the conclusion of this paper for information regarding acquisition and operations.

Benefits of unmanned aircraft include reduced costs, increased safety for operators, and expanded data collection. By 2035 civilian federal agencies are expected to operate approximately 10,000 unmanned aircraft.[1] State government inventories are also expected to grow to 10,000 by the same year. However, incorporating unmanned aircraft into public agency operations also comes with risks and costs, such as privacy, noise, and safety when interacting with other aircraft. Increased use of unmanned aircraft by visitors and the general public poses similar risks, but risks from authorized agency use are easier to predict and minimize. Navigating the risks while developing a program that reaps the benefits of unmanned aircraft is vital to successfully integrating unmanned aircraft into government operations.

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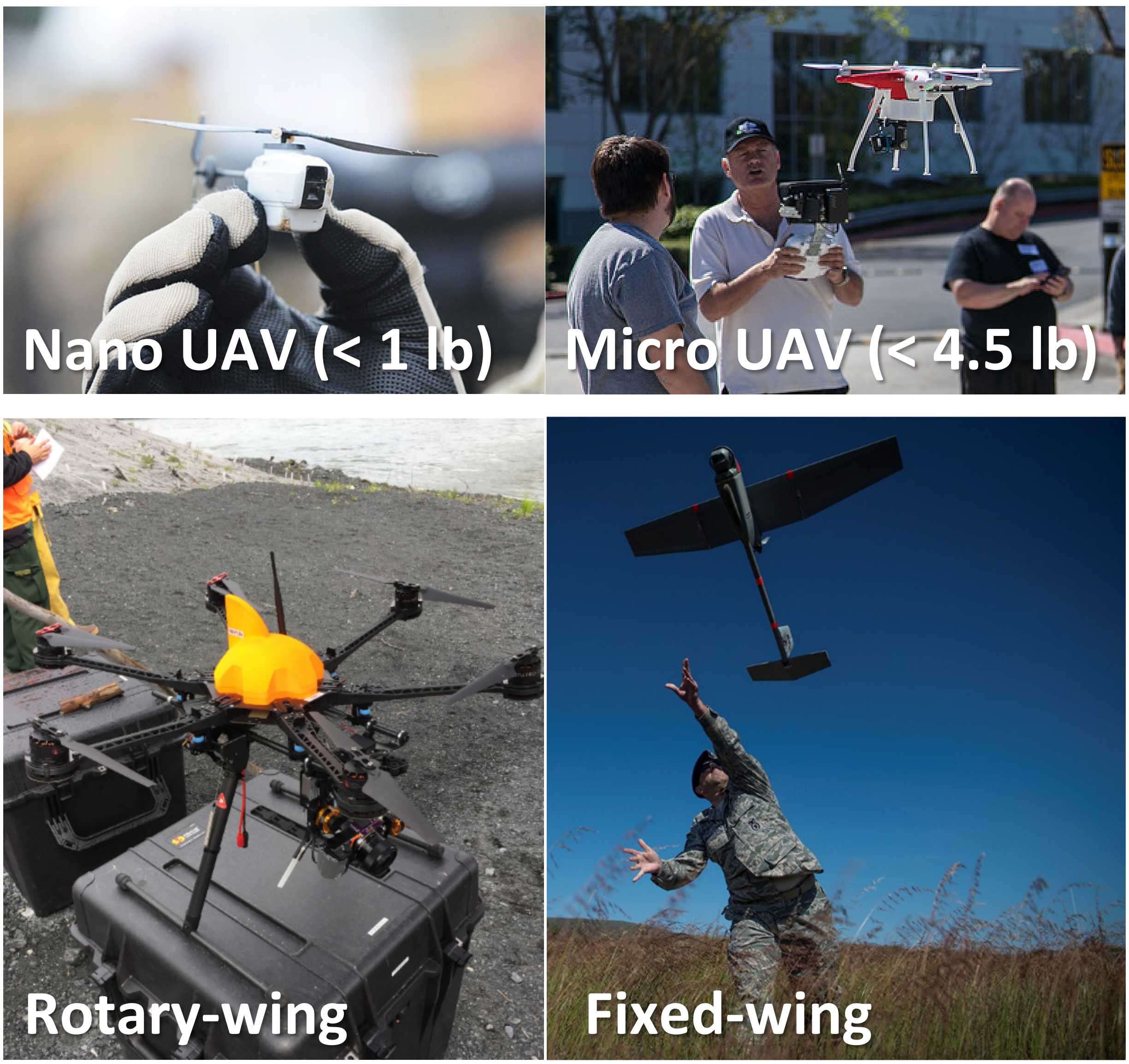
[1] Volpe National Transportation Systems Center, Unmanned Aircraft System (UAS) Service Demand 2015 – 2035: Literature Review & Projections of Future Usage, Version 1.0 (U.S. Department of Transportation, 2014).

## What is a Small Unmanned Aerial Vehicle?

The term “unmanned aircraft” refers to variety of types of vehicles and supporting equipment. When referencing the vehicle, the Federal Aviation Administration (FAA) calls unmanned aircraft Unmanned Aerial Vehicles (UAV). The FAA uses term “Unmanned Aircraft System (UAS),” on the other hand, to reference the entire system required to support the vehicle, which includes the launching platform and support staff. Operators can pilot UAVs remotely or pre-program a flight in the system’s computer. This paper will use the terms UAV to describe a number of aircraft categories based on size and type of aircraft.

The FAA classifies UAVs by their size and operating method. The “Aircraft Type and Equipment” section below discusses different sizes and types of UAVs for potential Forest Service use in more depth, but the photos on this page provide a general illustration.

**Figure 1: Clockwise from top-left, a nano UAV (<1 lb), micro UAV (<4.5 lb), rotary-wing UAV, and fixed-wing UAV.**



# Potential Forest Service uses for Unmanned Aircraft

The following sections provide examples of public agencies, private companies, and academic researchers using unmanned aircraft and discuss how the Forest Service could use unmanned aircraft in similar activities. These examples draw from documentation and discussion about the use of unmanned aircraft published in the last five to ten years. However, technology regarding unmanned aircraft is rapidly advancing. Therefore, all of the costs and capabilities cited in these examples might not reflect current costs and capabilities. In many cases, the costs have since decreased and capabilities have improved and expanded. [2]

## Infrastructure Inspection and Planning

Small UAVs with advanced cameras can obtain detailed, close-up views of bridges, communications towers, or buildings that would be impossible or unsafe for a human. Using UAV technology in place of or in addition to conventional methods to inspect and assess transportation infrastructure has the potential to reduce costs by reducing the man hours needed to complete these operations, increase safety, and produce additional data the agency previously has not collected.

State Departments of Transportation (DOTs) and other organizations are increasingly testing and using unmanned aircraft to inspect assets such as bridges and roads. State DOTs have used rotary-wing and fixed-wing aircraft for these operations, depending on the type of data collection needed. In general, peer federal lands agencies have not extensively used unmanned aircraft for infrastructure responsibilities.

### *Bridge Inspection*

The Forest Service is responsible for around 6,000 road bridges and 7,000 trail bridges. The Forest Service inspects road bridges beyond a certain size under the National Bridge Inspection Standards (NBIS) and reports data to the Federal Highway Administration (FHWA). These bridges are inspected on a 24-month recurring basis, and bridges that have been compromised due to damage from an event such as a vehicular accident or flood receive a timely added inspection. Under current NBIS standards, inspectors must personally inspect certain critical elements using a “hands-on” approach, but DOTs are beginning to use small unmanned aircraft for other bridge inspection components.

#### Forest Service - Placer River Trail Bridge Inspection

In September 2015, the Forest Service tested UAV technology for inspection of a bridge. The Forest Service collaborated with University of Alaska – Fairbanks and George Mason University to collect and analyze data on the Placer River Trail Bridge in Alaska. During the test, the UAV provided high-resolution images of the structure from angles only possible with a UAV, but it was unable to capture images from sections of the interior of the bridge because it could not safely access them. The study noted that the low-wind speeds and remote location meant that camera stability and privacy were not major issues. Overall, using UAV for the inspection saved time and increased safety for the inspectors. However, due to the type of images captured, the study found that processing the images into 3D models was a highly

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[2] For example, some of the cases in this paper discuss pilots operating an unmanned aircraft manually during flight. In recent years, capabilities for flight control and autonomous or pre-programmed flights have improved. Pilots have the option to take control, but can also program the aircraft to operate autonomously according to a flight plan programmed ahead of time.

time intensive process. The study anticipated that these costs could be reduced in the future, depending on the methods used.

### Florida DOT and Minnesota DOT- Bridge Inspection Pilots

Between 2013 and 2015, Florida DOT (FDOT) conducted a study that also provides an example of how the Forest Service could use UAV technology for bridge inspections. FDOT's recommendation in inspecting five bridges was that using UAVs for routine bridge inspection could reduce costs and provide comparable results to traditional methods. They also found that rotary-wing UAV work better than fixed-wing aircraft because rotary-wing aircraft can capture images of all portions of a bridge with far less effort. The FDOT study outlines clear methodology for testing UAV use for different components of bridge inspections.

In July 2015, Minnesota DOT (MnDOT) published the results of their own pilot of UAVs use during four bridge inspections across that state. The study found that UAVs are a useful tool for bridge inspection teams, and recommended that the agency make small unmanned aircraft available to team leaders as a way to reduce disruptions from inspection, reduce the need for inspectors to place themselves in potentially unsafe situations, and obtain photos and inspection details that would otherwise not be possible for a routine inspection.

### Summary of Bridge Inspections

**Small unmanned aircraft can obtain data on bridges that would not otherwise be available and reduce the need for inspectors to perform hazardous activities.** However, UAVs are currently a supplement to human inspection, not a replacement. In addition to NBIS requirements, enabling inspectors to directly see and touch certain bridge elements may always be important, especially for bridges in critical condition. The ability of UAVs to detect cracks and deficiency is always improving. FDOT found that UAVs could detect cracks up to 0.02 inches in bridges.

**Weather and wind speed are factors in the ability of UAVs to obtain useful images and data.** The FDOT study provides the following information regarding wind speed:[3]

**Table 1. Performance of unmanned aircraft at different wind speeds.**

| Average Wind Speed | Gust Wind Speed | Safe Distance from Target |
|---|---|---|
| **7 mph** | 10 mph | 1 ft |
| **15 mph** | 20 mph | 3 ft |

Conventional methods for inspecting bridges can also face limitations due to weather and conditions. E.g. rope access inspections can become dangerous for the inspectors in high wind speeds.

**Although bridge inspectors using small unmanned aircraft require additional training, using this technology can reduce the staff time and cost required to perform each inspection.** The FDOT study analyzed personnel training costs and personnel-hours of work during operation in order to compare to conventional methods. Operators completed training in an average of 2.75 hours. The study measured training time for people with varying levels of education, of different ages, and with different levels of experience using UAVs. They found that people with a younger age, which correlated to prior

[3] Otero, Luis Daniel, Proof of Concept for Using Unmanned Aerial Vehicles for High Mast Pole and Bridge Inspections (Florida Institute of Technology, June 2015), 67.

experience using video games, and higher levels of education moved through training in a shorter amount of time than the other groups.[4] After training, FDOT followed FAA recommendations for obtaining a private pilot's license to operate a manned aircraft, which entails 40 hours of flying time, including 20 hours under the supervision of a certified flight instructor and 20 hours unsupervised with at least 10 take-offs and landings. FAA currently only recommends that operators of unmanned aircraft take a knowledge test.

FDOT calculated the difference in person-hours of labor to conduct an inspection on an 820-foot long bridge with eight sections.

**Table 2. Comparison of person-hours required for conventional and UAV bridge inspections.**

| | Conventional Inspection | UAV Inspection |
|---|---|---|
| Number of Workers Required | 7 | 3 |
| Average Hours Required | 3.5 | 5.43 |
| **Person-Hours of Labor** | **24.5** | **17.3** |

However, it is important to note that these hours do not include the time required to process the images taken by the UAV camera if the images are not processed by the system in real time. With the technology FDOT used, the real time camera could only register cracks up to 0.16 cm, while the inspections required reports of cracks up to 0.10 cm. Analyzing the images after the inspection doubles the data collection time and induces additional software costs. However, it is important to note that a different camera could provide higher-resolution real-time images, and that camera technology is continually improving and becoming more affordable.

**Specialized small unmanned aircraft for bridge inspections may be expensive, but costs are decreasing and less expensive units may be able to achieve much of the benefits**. The FDOT study assessed the equipment and maintenance costs of operating UAVs, finding that purchasing the UAV, platform, sensors, and battery totaled around $25,000. MnDOT identified a model with key features such as a 360-degree camera that can view images above the vehicle, and is expected to sell for $45,000. However, the Forest Service might be able to conduct similar activities with less costly UAVs, such as a DJI Phantom or comparable system, which cost less than $2,000.

[4] *Ibid.*, 110.

### *Road and Trail Inspection*

The Forest Service could also use UAV technology to survey location and conditions on its roads and trails. Using UAVs to inspect linear routes such as roads and trails requires more post-processing and is still a relatively new concept compared to inspection of bridges or other fixed assets.

Currently, the Forest Service collects information on overall roads deferred maintenance by conducting in-person inspections of an annual random sample of roads. The agency is also discussing methods to collect additional condition data on its limited Federal Lands Transportation Program network of roads with the FHWA.

The Forest Service has also made collection of spatial locations for its 157,000 miles of trails a priority, and UAVs could be a useful tool in collecting this data.

#### Utah DOT - Alternative to Satellite Data for Surveying Road Project Sites

When Utah DOT (UDOT) tested using UAVs to survey the development of a highway construction project, it found that the high-resolution images captured by cameras on the UAVs would allow for more frequent updates to its GIS database than satellite images currently provide. UDOT flew an AggieAir, a fixed-wing UAV, to take images of the site before and after the reconstruction of a highway corridor. The AggieAir was relatively low cost, easy to use, and could fly for up to one hour with two cameras (one visual and one infrared), which an onboard computer directed.[5] Though largely successful, the study faced the following challenges: wind affected the quality of the images and the AggieAir could only fly in winds up to 25 mph, and the flat landscape made it difficult to automatically stitch together the still images collected. In addition, the study noted that UDOT would need to consider safety issues when flying UAVs and weather, such as rain or snow, posed limitations on flying. However, these issues, aside from weather, could be addressed during the set up for the operation.

#### Michigan Tech - Collection of Unpaved Road Condition Information

Michigan Technological University has a U.S. DOT grant to use UAVs to assess and inventory the condition of unpaved roads. They developed the Aerial Unpaved Road Assessment (AURA) system, which uses a 36-megapixel digital camera that has 3D processing software, distress detection analysis capacity, and GIS outputs.[6] Agencies could use the resulting images to identify potholes, drainage conditions, and other issues. The project has used two UAVs, a Bergon hexacopter (11 pounds, about $5,000) and a DJI Phantom quadcopter (2 pounds, about $700) to collect images from 100 feet above ground.[7] The project team plans to expand the program to make the system commercially available to transportation agencies.

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[5] Barfuss, Steven L., Austin Jensen, and Shannon Clemens, Evaluation and Development of Unmanned Aircraft (UAS) for UDOT Needs (Utah Department of Transportation Research Division).

[6] "Characterization of Unpaved Road Conditions through the Use of Remote Sensing," http://www.mtri.org/unpaved/ .

[7] "Michigan Tech Researches Feasibility of Drone Use in Transportation," last modified February 5, 2014, http://www.mtu.edu/news/stories/2014/january/michigan-tech-researches-feasibility-drone-use-transportation.html .

## Summary of Road and Trail Inspections

**As the Forest Service begins to collect condition data for its Federal Lands Transportation Program roads and develop related business processes, this could be an opportunity to see if use of small unmanned aircraft could reduce costs.** While there are few immediate precedents for road data collection using UAVs, the Forest Service might consider how it can account for future developments in UAV data collection on roads. For example, as it designs the process for data input, would it be possible to account for data generated from video obtained from an unmanned aircraft? Would the FHWA be interested in providing funds for the Forest Service to pilot UAV road data collection on a particular forest or set of forests?

**Remote imagery from unmanned aircraft could supplement the collection of geospatial trails data.** Using UAVs to collect images of Forest Service trails could reduce the need to purchase costly satellite images or fly expensive manned aircraft. However, the Forest Service would have to determine how to overcome challenges such as collecting data in inclement weather.

**Figure 2. Michigan Tech sets up a small UAV for operation (Source: Michigan Tech).**

### *Inspection of Communications Towers, Dams, and Other Fixed Assets*

The Forest Service can also use UAVs to inspect other types of infrastructure, such as communications towers, dams, and buildings. Communications towers enable critical communication among Forest Service staff as well as partners. Like bridges, these fixed assets are often large and inspecting them can present hazards to staff and be time-consuming. However, examples from private companies and other public agencies suggest that the Forest Service could use UAVs to potentially lower costs and reduce the safety risks of inspections.

#### National Park Service - Boundary Fences

In 2012, the Department of the Interior, the United States Geological Survey (USGS), and the National Parks Service (NPS) used UAVs to inspect the boundary fences bordering the Haleakala National Park in Hawaii. Park staff face difficulties inspecting the fence, which prevents animals that threaten park wildlife species from entering, given extreme elevation changes in the terrain. The team used a Raven A UAV, a fixed wing aircraft that weighs only 4.45 pounds, to take images from 150-200 feet above ground. Benefits included increased safety for staff conducting these activities, as well as reducing damage to vegetation around the fence. [8]

**Figure 3. Unmanned aircraft inspecting power lines (Source: CSIRO).**

[8] Post-mission poster developed by the USGS in 2012 http://rmgsc.cr.usgs.gov/UAS/pdf/HI_HaleakalaNP/HaleakalaNPHI_18x24.pdf

### Insurance and Energy Companies - Inspection of Buildings and Power Infrastructure

Allstate, a major insurance company, has begun to use UAVs to inspect homes, and their roofs in particular, before insuring them.[9] In Michigan, Consumer's Energy is one of four energy companies in the country to receive FAA approval to operate UAVs.[10] The company uses unmanned aircraft to inspect power lines, wind turbines, and other equipment. Consumer's Energy is investigating whether or not UAVs can replace helicopter operations to inspect high voltage lines and restore service after storms. Using UAVs to conduct this work would increase the safety of these activities because the aircraft do not have passengers and do not use flammable fuel.

### Summary of Fixed Asset Inspections

**Similar to bridge inspections, small unmanned aircraft appear to be a safe and fast way to view important parts of infrastructure that can be hazardous to approach in person.** In addition to supplementing formal, required inspection, UAVs may also be a tool for other staff to investigate buildings, towers, or other infrastructure on a more ad-hoc basis to see if the asset is damaged or if further inspection is needed.

**Small unmanned aircraft may be less disruptive to the infrastructure or surrounding environment than conventional inspection or use of manned aircraft.** Because of their small size, a UAVs can navigate around obstacles and infrastructure that are challenging or disruptive for humans or manned aircraft. In addition to safety benefits, this limits the risk of damaging the infrastructure or surrounding resources.

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[9] Robert Galbraith, "Home insurer Allstate's drone project takes flight," *Reuters*, December 17, 2015, http://www.reuters.com/article/us-allstate-drones-idUSKBN0U035P20151217.

[10] Zlati Meyer, "Consumers Energy to use drones for power line check," *Detroit Free Press,* June 23, 2015, http://www.freep.com/story/money/business/michigan/2015/06/23/consumers-energy-drones/29151059/ .

## Emergency Response to Natural Disasters

Employing UAVs in responses to natural disasters, such as wildfires, avalanches, and search and rescue missions is a widely discussed topic in the field of disaster relief and among public lands agencies that face these issues. Fire management is a key program area for manned aircraft and future opportunity area for unmanned aircraft of all sizes. Similarly, after an avalanche, seismic event, or landslide, the Forest Service must assess conditions and take action to protect assets and the public. In addition, the Forest Service conducts search and rescue missions when visitors are lost or injured. While the focus of this paper is understanding where small unmanned aircraft could benefit program areas that do not currently use aviation extensively, below is a brief discussion of potential uses for UAVs in fire management operations.

Currently, the Forest Service itself, the NPS, and many local agencies are experimenting with using UAVs in these situations, illustrating their effectiveness and identifying the costs and benefits of their use. Small UAVs provide the benefit of increasing the safety of operations, as pilots would not enter into dangerous situations, and reducing costs.

### Forest Service and National Park Service - Paradise Fire

The Forest Service and other Federal Lands agencies such as NPS have tested UAV technology to monitor wildfires. For example, in 2015 NPS and the Forest Service used a ScanEagle, a 50 pound UAV, to gather infrared imagery on the Paradise fire in Olympic National Park so that firefighters could pinpoint the fire perimeter and identify areas with intense heat. Surveying an area with a thick tree canopy required them to use infrared imagery. NPS found UAVs have several advantages over manned aircraft, noting, "UAS are quieter than manned aircraft, use less fuel, and present a much lower risk to employees."[11] However, NPS contacts noted that the need for internal agency and FAA authorizations currently limits their ability to use UAVs in the initial stages of fire response.

**Figure 4: NPS employs unmanned aircraft to observe a wildfire in Olympic National Park (Source: NPS).**

### Department of the Interior - Tepee Springs Fire

In September 2015, the Department of the Interior used a 75-pound (not small UAV), 10- ft unmanned aircraft to collect imagery of the Tepee Spring Fire in Idaho for up to 18 hours at a time over the course of five days.[12] Unlike smaller UAVs, this aircraft was able to fly for an extended period of time, flying up to a distance of 60 miles from the launch site. The images and infrared data provided fire fighters with up-to-date information about the movement and intensity of the fire.

[11] "Small Unmanned Aircraft Systems and the National Park Service," https://www.nps.gov/fire/aviation/safety/unmanned-aerial-systems.cfm

[12] Zatkulak, Karen, "Drones could help protect firefighters in Idaho" KTVB.com, September 23, 2015, http://legacy.ktvb.com/story/news/2015/09/23/drones-could-help-protect-firefighters-idaho/72709626/

### USGS/BLM/Mesa County - Debeque Canyon Landslide

In October 2013, the USGS, BLM, and Mesa County Sheriff's office collaborated to use a UAVs to take 650 images of the Debeque Canyon Landslide using a 12 megapixel point and shoot camera.[13] They stitched together the images to create a comprehensive aerial view of the landslide. Interstate-70 crosses through the area and was damaged in past landslides. The study found that damages or impacts of future movement can be assessed using UAV images.

### Washington State DOT - Post-Avalanche Road Conditions

Washington State DOT found that using UAVs to assess road conditions after avalanches was effective and cost efficient. In 2006, Washington DOT gathered video with both a 25-pound fixed-wing UAV and a 150-pound rotary wing UAV.[14] Cameras on both aircraft provided video and images that the DOT used to assess conditions on roads after avalanches. The DOT found that the fixed-wing aircraft was more difficult to use because launching it required a 100-ft long stretch of flat roadway and the operator had to ground the aircraft due to strong turbulence. The rotary-wing aircraft had a more stable flight, successfully flying along the road's centerline to survey road conditions. The rotary-wing aircraft was also able to hover and provide the camera with a stable platform for capturing images. Washington DOT also used the rotary-wing aircraft to search for people in a wooded area. It found that the video camera could not sufficiently identify a person because of the terrain, but that an infrared camera would likely identify people more effectively, particularly because snowy terrain provides a greater temperature contrast.

Washington DOT found that UAVs have become increasingly affordable compared to alternatives. The models it assessed started at $50,000 and it estimated operator training costs at $15,000. Renting a helicopter to conduct similar operations costs Washington DOT at least $800 per hour, which sums to $2,900 per day. Considering these tests occurred almost 10 years ago, operating an unmanned aircraft likely costs much less than when Washington DOT published the report. Furthermore, operating a helicopter might be more expensive, given increased fuel, labor, and insurance costs. However, Washington DOT also noted concerns with the difficulty of obtaining FAA approval, reliability and costs of replacement given their use in extreme conditions. Despite these concerns, Washington DOT concluded that UAVs have potential to serve various important operations.

### Disaster Relief Abroad

International agencies and reporters have also used UAVs to conduct inspections of buildings and infrastructure after natural disasters. For example, CNN and a number of international agencies used UAVs to assess damage after the earthquake in Nepal in spring of 2015.[15] CNN found that the UAVs provided higher resolution images than satellite images would provide. Emergency responders could use the UAV imagery to identify where survivors remained and assess the damage to buildings and transportation infrastructure. Furthermore, CNN spoke with an expert in the field who discussed how in the future, responders could use UAVs to deliver aid packages. He also stressed the ability of UAVs to

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[13] Post-mission poster developed by USGS in 2013, http://rmgsc.cr.usgs.gov/UAS/pdf/CO_DebequeLandslide/poster_map_oct_2013_58x42_300dpi.pdf

[14] McCormack, Edward D., The Use of Small Unmanned Aircraft by the Washington State Department of Transportation (Washington State Department of Transportation, 2008).

[15] "Using Drones in Disaster Response," last modified May 5, 2015, CNN New Story, http://www.cnn.com/videos/tv/2015/05/05/exp-ns-nepal-meier-humanitarian-UAS.cnn/video/playlists/nepal-earthquake/

provide images from unique angles as compared to satellite imagery.[16] In some cases, even when emergency responders can enter a building, using a UAV can increase safety for responders.

### Emergency Relief for Federally Owned Roads

The Forest Service, along with other federal lands agencies like NPS and BLM, receives post-disaster funding for the repair of roads and trails damaged in disaster from the Emergency Relief for Federally Owned Roads Program (ERFO). To qualify for funding, the Forest Service must submit a Notice of Intent describing the proposed repairs no greater than 45 days after a disaster occurs. However, damage to the road and trail system can make it difficult to quickly and safely assess damage to those same assets, even very generally.

UAVs can help view damage in circumstances where it is difficult or dangerous for staff to attempt to assess damage directly. In November 2015, Forest Service Region 6 obtained UAV video footage of a road washout on the Okanogan-Wenatchee while the region was submitting the notification for ERFO funds. This highlighted to the region the potential benefit of using UAVs to assess damage from future disasters.

### Summary of Natural Disaster Emergency Response

**While responding to natural disasters is a complex operation, small unmanned aircraft can complement manned aircraft in a safe and cost efficient manner.** In the case of wildfires, the Forest Service can employ UAVs to provide infrared imagery to help determine the location of hot spots and assess conditions. For all natural disasters, UAVs can help rapidly understand damage from an incident and develop up-close views or aerial imagery that can be compared to prior conditions. This is particularly useful for making timely requests for ERFO funding given potentially limited access conditions to disaster-struck areas.

Although current rules make ad-hoc use challenging, in the future, emergency responders could potentially carry UAV equipment in a backpack and use the unmanned aircraft to firespot or survey areas that they plan to enter. Future field tests and upcoming FAA rules will help to identify the exact ways in which the Forest Service can operate UAVs to assist in combatting wildfires and conducting emergency response operations in the case of natural disasters.

**The need for prior FAA authorization may be an impediment, especially to search and rescue.** As discussed below, FAA must issue a Certificate of Waiver or Authorization (COA) before a public agency uses small unmanned aircraft. The authorization itself can cover large areas and multiple years, but must be put in place in advance. However, the FAA also has an emergency COA process that provides a shorter turnaround (as quickly as 12 hours from request to authorization) for agencies that hold an existing COA, in order to ensure that UAVs could benefit disaster relief operations.

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[16] Ibid.

## Environmental Monitoring

Unmanned aircraft could also be used for helping the Forest Service monitor and manage natural resources, for example to assess timber coverage and wildlife populations. A number of public lands agencies and academic researchers have employed UAVs in these or similar capacities. Their findings demonstrate the benefits of using UAVs for these tasks, particularly in instances where a small amount of land needs to be covered. In cases where the Forest Service needs aerial imagery of a large amount of land, manned aircraft are more efficient since UAVs have comparatively short flying times.

### *Land and Natural Resources*

#### Forest Management

Images taken using small unmanned aircraft can provide insight regarding tree crowns and gaps, forest stand mapping, tree volume, pests, and harvesting. A 2014 study in tropical forests in Mexico tested using UAVs for community-based forest monitoring.[17] Small unmanned aircraft offered remote, impoverished communities the opportunity to assess resources in a low-cost, easy-to-operate manner. The study identified the advantages of using UAVs, including the ability to take high-resolution images at between 50 and 300 meter elevation, insensitivity to cloud cover due to low flying altitude, the relatively quick training period, low cost as compared to satellite images and ground surveys, and the ability to access remote areas with difficult terrain. Furthermore, the study noted that UAVs are much less invasive than ground surveys because operators do not disturb wildlife.

The study also catalogued the following disadvantages that would be relevant to Forest Service work: the small size of the aircraft requires using a smaller camera that may produce lower quality images, issues and distortions with geo-referencing the images, the time consuming, labor-intensive method for processing images, sensitivity to weather (which would also affect manned aircraft), short flight endurance (about one hour), and the potential for collisions. However, many of these risks are also present or greater when using manned aircraft for assessing forest health or other forestry activities. Using unmanned aircraft as a substitute or supplement to manned aircraft where aviation resources are already used could limit the risks to human health from crashes.

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[17] Paneque-Gálvez, Michael K. McCall 1, Brian M. Napoletano, Serge A. Wich, and Lian Pin Koh, "Small Drones for Community-Based Forest Monitoring: An Assessment of Their Feasibility and Potential in Tropical Areas," Forests (5) (2014), 1481-1507: doi:10.3390/f5061481

## Other Natural Resources

Federal and State agencies have also used UAVs to conduct various activities surveying environmental conditions. The table below describes the variety of activities and types of UAVs used in some of these activities:

**Table 3. Federal and State agency use of UAVs to survey natural resources.**

| Agency | Activity | Type of UAV | Operators | Location | Year |
|---|---|---|---|---|---|
| **UDOT**[18] | Classify wetland plant species | AggieAir, bungee-launched fixed-wing aircraft, photo and infrared camera | 2 | Utah | 2011 |
| **USGS, Lower Brule Sioux Tribe**[19] | Surveying soil erosion | Raven RQ-11A: Hand-launched fixed- wing aircraft, photo/video camera | 2 | Lower Brule Reservation, South Dakota | 2011 |
| **USGS, Bureau of Reclamation, NPS**[20] | River impacts of dam removals | Raven RQ-11A: Hand-launched fixed- wing aircraft, photo/video camera | 2 | Olympic National Park | 2011 |
| **USGS**, **FAA**[21] | Fluvial mapping, sediment monitoring, estimating river velocity | T-Hawk with Canon camera | 2 | Platte River, Nebraska | 2013 |
| **USGS, NPS, FAA**[22] | Identifying abandoned objects | Raven RQ-11A: Hand-launched fixed- wing aircraft, photo/video camera | 2 | Mojave National Preserve | 2013 |
| **USGS, NPS**[23] | Seashore mapping | Raptor Maps, fixed-wing | - | Cape Cod Seashore | 2016 |
| **USGS**[24] | Mine inspections/ surveys | Fixed-wing, others | - | West Virginia; Pitkin County, CO | 2012 |

[18] Barfuss, Steven L., Austin Jensen, and Shannon Clemens, Evaluation and Development of Unmanned Aircraft (UAS) for UDOT Needs (Utah Department of Transportation Research Division).
[19] Post-mission poster developed by the USGS in 2011, http://rmgsc.cr.usgs.gov/UAS/pdf/SD_MissouriRiverBankErosion/Missouri%20River%20Poster.pdf
[20] Post-mission poster developed by DOI and USGS in 2011, http://rmgsc.cr.usgs.gov/UAS/pdf/WA_BORRiverSedimentMonitoring/BoRElwhaDamRemoval_18x24.pdf
[21] Post-mission poster developed by DOI and USGS in 2013, http://rmgsc.cr.usgs.gov/UAS/pdf/NE_EmergentSandbarHabitats/South%20Platte%20NE%20USGS.pdf
[22] Post-mission poster developed by DOI and USGS in 2013, http://rmgsc.cr.usgs.gov/UAS/pdf/CA_MojaveNP/NPS%20Mojave%20Poster_v2.pdf
[23] Mary Ann Bragg, "USGS plans to use unmanned drone to map Cape Cod National Seashore," *Cape Cod Times,* February 29, 2016, http://www.capecodtimes.com/news/20160229/usgs-plans-to-use-unmanned-drone-to-map-cape-cod-national-seashore
[24] http://rmgsc.cr.usgs.gov/uas/pdf/usgs_uas_presentations/Oct%202014%20USGS%20UAS%20Presentation.pdf, Page 17, 18

## Summary of Natural Resource Uses

**As compared to using manned aircraft, using unmanned aircraft can drastically increase the safety of operations to asses forest health and natural resources.** Such operations on manned aircraft pose safety risks for pilots and personnel. Replacing manned operations with unmanned operations removes much of the risk to agency staff. Small unmanned aircraft can also collect aerial data that would not be practical for collection using satellite images or manned aircraft. For example, UAVs could collect images from below the tree canopy, which would be impossible with manned aircraft, and collect images of tree cover more frequently.

**Because resource monitoring activities can be planned well in advance, other agencies have found these to be relatively natural opportunities to pilot UAVs use and become familiar with FAA approvals.** Once approval is obtained for a given area and activity, a UAV can be deployed much more quickly than a typical manned aircraft.

### *Wildlife Tracking*

Small unmanned aircraft provide a non-invasive, cost-effective method to track and survey wildlife. The Department of the Interior, partnering with its USGS and U.S. Fish and Wildlife Service bureaus, has used UAVs to track and survey wildlife in the following ways:

**Table 4. Federal agency use of UAVs to survey wildlife.**

| Activity | Type of UAV | Operators | Location | Year |
|---|---|---|---|---|
| **Survey of Sage grouse, Sandhill cranes, waterfowl**[25] | Unclear | 2 | Denver, Colorado | 2013 |
| **Population survey of Refuge Pelican** | Raven RQ-11A: Hand-launched fixed- wing aircraft, live stream video | 2 | Chase Lake, North Dakota | 2014 |
| **Population estimates of Sandhill cranes**[26] | Raven RQ-11A: Hand-launched fixed- wing aircraft, thermal infrared camera | 2 | Monte Vista, Colorado | 2011 |
| **Survey in white pelicans**[27] | | 2 | Pyramid Lake Paiute Reservation, Nevada | 2015 |
| **Study landscape habitat of Pygmy Rabbits**[28] | Raven RQ-11A: Hand-launched fixed- wing aircraft, thermal infrared camera | 2 | Idaho | 2011 |
| **Monitoring breeding of Greater Sage-Grouse**[29] | Raven RQ-11A: Hand-launched fixed- wing aircraft, thermal infrared camera | 2 | Grand County, Colorado | 2013 |

The Raven RQ-11A, the UAV the DOI used, weighs only 4.2 lbs and requires only two people for operation. This model is no longer in production, but similar Raven system costs around $250,000, with

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[25] Post-mission poster developed by DOI and USGS in 2013, http://rmgsc.cr.usgs.gov/UAS/pdf/UAS_Bird_Survey_Poster.pdf

[26] Post-mission poster developed by DOI and USGS in 2011, http://rmgsc.cr.usgs.gov/UAS/pdf/CO_SandhillCranesMonteVistaNWR/MVNWR%20Raven%20Poster%202011_18x24.pdf

[27] Post-mission poster developed by DOI and USGS in 2015, http://rmgsc.cr.usgs.gov/UAS/pdf/NV_AnahoIslandNWRPelicans/Anaho%20Raven%20Poster%202015_18x24.pdf

[28] Post-mission poster developed by DOI and USGS in 2011, http://rmgsc.cr.usgs.gov/UAS/pdf/ID_PygmyRabbitsLandscape/pygmyRabbitsPoster2011.pdf

[29] Post-mission poster developed by DOI and USGS in 2013, http://rmgsc.cr.usgs.gov/UAS/pdf/CO_GrandCountySageGrouseLeks/GreaterSageGrouse%20Raven%20Poster%202013_18x24.pdf

the vehicle costing $35,000 and the rest of the system costing more than $200,000.[30] Depending on the needs of the study, a more affordable system may be appropriate.

### Summary of Wildlife Tracking Uses

**Because UAVs are smaller than manned aircraft and many are electric-powered rather than using internal combustion engines, they are less noisy and may disturb wildlife less.** However, unmanned aircraft can still cause environmental disruption. Such operations must take into account harassment and other restrictions related to wildlife tracking. NPS and the Volpe Center are also conducting research on noise impacts of UAVs, which may help agencies including the Forest Service understand what types of UAVs are appropriate for different kind of wildlife monitoring operations.

**Wildlife monitoring is a relatively well-established use of unmanned aircraft with demonstrated time and cost advantages.** For example, three Canadian researchers at different Universities conducted a study using unmanned aircraft to survey the population of a colony of large common terns.[31] The study found that the UAVs accounted for more than 90% of the terns counted in the ground survey, but required less time and staff. The Table below compares the time and man-hour costs of the two methods:

**Table 5. Comparison of Person-hours of labor of a ground survey and UAV survey.**

| | Ground Survey | UAV Survey |
|---|---|---|
| Persons Required | 12 | 2 |
| Time Required (hours) | 4 | 1.5 |
| **Person-hours of Labor** | **26** | **3** |

## Other Uses for Unmanned Aircraft

Public and private sector users also employ unmanned aircraft to conduct a number of other activities that are likely less relevant to Forest Service operations. For example, surveillance is the most known and discussed function of unmanned aircraft, due to the military's use of drones. Surveillance activities include border patrol, anti-terrorism, and police investigations. In the agricultural industry, farmers use UAVs to survey and spray crops. In the technology sector, companies like Facebook have used UAVs to provide internet service in remote areas and companies in shipping hope to use UAVs to delivery packages.

## Overall Benefits and Drawbacks

Employing unmanned aircraft to provide aerial images and video has a number of important benefits that illustrate how this technology can effectively supplement current manned aircraft or ground operations. Those advantages include:

- **Safety:** UAVs provide a safer alternative than traditional methods of inspecting infrastructure or conducting operations in manned aircraft.
- **Low cost:** Operating UAVs to obtain aerial images can be significantly less expensive than obtaining satellite images, conducting a ground survey, or operating a manned aircraft.

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30 http://www.suasnews.com/aerovironment-rq-11-raven/

31 Dominique Chabot, Shawn R. Craik, and David M. Bird, "Population Census of a Large Common Tern Colony with a Small Unmanned Aircraft," PLoS ONE 10(4) (2015): e0122588. doi:10.1371/journal.pone.0122588.

- **No cloud interference:** UAVs fly at a low altitude, meaning that cloud cover will not affect the images in the same way they affect imagery acquired from satellites.
- **Access to remote and inaccessible areas:** UAVs can access areas that are inaccessible on foot or in manned aircraft, as they can fly at a low altitude and enter into inaccessible areas such as buildings or caves.
- **Less disturbance to wildlife:** UAVs can be quieter than manned aircraft and likely less disruptive than ground surveys to an area's wildlife.
- **Easy to use:** UAVs are easier to operate than manned aircraft, and therefore require less training.
- **Increased image coverage:** UAVs can provide aerial imagery at oblique angles, capturing views that are not otherwise possible.

However, using unmanned aircraft also presents certain drawbacks or disadvantages that the Forest Service would have to overcome through its program design, including:

- **Cost/Image quality balance:** UAVs have the capacity to produce high-resolution images and some can perform desired post-processing as they collect data. However, the higher the image quality, the more costly the system. An agency must determine how to balance data needs and costs.
- **Post-processing images:** If a UAV does not analyze data as it is collected, or if the analysis is too complex for that kind of automation, the agency must often use staff time and other computational resources to process the data.
- **Data management:** UAVs collect large quantities of data that sometimes contain personally identifiable information. An agency must have adequate, secure, and transparent storage for this data.
- **Sensitivity to weather:** UAVs, like manned aircraft and ground surveys, are sensitive to inclement weather to varying degrees. Small UAVs can be more sensitive to wind or rain than larger aircraft.
- **Short flight endurance:** UAVs generally have a shorter flight endurance than manned aircraft, which limits their area of collection.
- **Noise concerns:** Although UAVs make less noise than manned aircraft, they create noise impacts that have potentially negative environmental effects.
- **Potential for collisions:** Although sense and avoid technology has improved, UAVs still pose a potential for collisions with objects including other aircraft.

Unmanned aircraft can provide important safety and cost reduction benefits to Forest Service operations, as well as increase the amount of data the agency can use to analyze its land. Specific opportunities for agency use of unmanned aircraft are described in the following section.

# Aircraft Type and Equipment

## Unmanned Aircraft Size

FAA classifies unmanned aircraft in three categories: Small UAS/UAVs (sUAS), which weigh between 4.5 and 55 pounds and can typically fly between 1 and 4 hours at a time; micro UAVs, which weigh between 1 and 4.5 pounds and can fly up to one hour at a time; and nano UAVs, which weigh less than a pound and can fly for less than an hour at a time. Currently, FAA uses classifications for manned aircraft to describe unmanned aircraft that weigh more than 55 pounds. Appendix B provides additional information about theses classifications. This paper focuses largely on small, micro, and nano UAVs, as the majority of public agencies use these smaller aircraft for operations and new regulations (14 CFR part 107, or “Part 107”) apply only to UAS/UAVs under 55 pounds.


**Figure 5. (from left) a “Black Hornet” Nano UAV used by U.S. and European militaries (Source: Richard Watt). DJI Phantom, a common micro UAV among hobbyists and small commercial users (Source: Kevin Baird).**

## Types of Unmanned Aircraft

Small unmanned aircraft are typically constructed either as rotary-wing aircraft (like a helicopter) or fixed-wing aircraft (like an airplane). Each category of unmanned aircraft has advantages and disadvantages that make them better and less suited for use in the Forest Service. Rotary-wing aircraft, such as quad-copters, are useful on occasions when a land strip is not available, but are not well suited for long flights. Given the varied terrain of national forests, rotary-wing aircraft would likely prove useful. Fixed-wing aircraft have more flight endurance than rotary-wing aircraft, but are less maneuverable in tight spaces.


**Figure 6. Rotary-wing unmanned aircraft on the left (Source: Forest Service pilot UAV trail bridge inspection in Alaska) and a hand-launched, fixed-wing unmanned aircraft on the right (Source: U.S. Air Force)**

## Unmanned Aircraft Operation

Unmanned aircraft can operate in two main ways: pilots can manually operate the aircraft from the ground during flight or pilots can program the aircraft ahead of time to fly autonomously. In the past, pilots have more frequently operated the aircraft manually. However, technological advancements in recent years and increased the capacity of autonomous operations. Programming flight paths ahead of time potentially helps ensure data from the needed geographic areas are collected and enables staff to maximize time in the field.

## Camera and Data Collection Equipment

Unmanned aircraft can be equipped with different types of cameras and sensors that collect data and images for analysis. Remote sensing pictures and video in various forms are the primary benefits that small UAVs could deliver to the Forest Service. For example, UAVs can carry infrared cameras, video cameras, or still cameras that take images with varying degrees of resolution. In some instances, the images require post-processing, which is an added cost of staff time and equipment that is important to consider. However, other cameras allow for real-time analysis, or provide raw images that are themselves useful. These types of cameras are particularly important to use during emergency relief and time sensitive operations.

## Overall UAV Types and Potential Uses on the National Forest System

Based primarily on the characteristics above, there are roughly three "types" of UAVs:

- Low cost UAVs with built-in cameras ($5,000 or less): A number of commercial micro and nano UAV, such as DJI's Phantom series (pictured above), are inexpensive, quiet, and provide users with still images or video. This type of UAV could potentially be used for a number of operations that inspect infrastructure and the environment, including ad-hoc visual inspection.
- Unmanned aircraft with separate sensor system ($5,000 – $25,000): A number of larger UAVs, such as the rotary-wing aircraft pictured above, are more complex systems that can fly at a higher altitude for longer time spans than some of the lower cost options. These UAVs can use a number of different cameras, depending on the needs of the operation, including cameras for aerial mapping, infrared photography and video, and high-resolution images. The Forest Service could use these aircraft for operations that cover larger swaths of land or require infrared images.
- Large unmanned aircraft (more than $25,000): Some Forest Service operations could require the use of UAVs that are larger than 55 pounds. These aircraft are significantly more expensive than small unmanned aircraft, and their operating requirements are more similar to conventional manned aircraft. On such occasions, other public lands agencies have contracted with commercial operators. These are not the focus of this paper.

# Regulations and Operating Constraints

## Part 107 Rule

The FAA regulates private use of UAVs under Section 333 of the FAA Modernization and Reform Act of 2012 and the CFR 14 part 107 rule (effective August 29, 2016).[32] Public agencies such as the Forest Service can fly under part 107 or obtain a Certificate of Waiver or Authorization from the FAA (COA) "that permits public agencies and organizations to operate a particular aircraft, for a particular purpose, in a particular area. The COA allows an operator to use a defined block of airspace and includes special safety provisions unique to the proposed operation. COAs usually are issued for a specific period – up to two years in many cases."[33] In order to obtain a COA, an agency must demonstrate that the UAV is airworthy and would not be a threat to the public or to other aircraft. The COAs enable an agency to fly UAVs in a certain area, rather than by flight. Therefore, once an agency obtains a COA, it can operate a UAV multiple times within a certain geographic area. The FAA works with agencies to develop specific conditions to ensure the safety of operations, such as limiting use to low population areas. The FAA also has the following guidelines regarding operation:

- The aircraft must be in the line of sight of an operator or observer. In some cases, the FAA has permitted a public agency to fly a UAV beyond the line of sight of the operator, such as in the case of combatting wildfires, if a temporary flight restriction for all other aircraft is in place.
- The aircraft cannot fly within 5 miles of an airport to ensure safety.
- The aircraft cannot fly at night.
- Public agencies cannot use the aircraft for commercial operations

Constructing a program that is parallel to current manned aircraft operations better ensures that the operations will be safe, well tested, and approved by FAA.

### *Operations at Night and Beyond Visual Line of Sight*

Currently, FAA must grant special exemptions for night operations and beyond visual line of sight operations (BLOV). More flexibility is also afforded to operators during emergency airspace restrictions, for example during a wildfire. Currently, there is legislation pending before congress directing FAA to streamline approvals for night and beyond visual line of sight operations. The ability to operate beyond the visual line of sight may be especially valuable to the Forest Service, which has many dispersed assets that are time-consuming for staff to access.

## Concerns with Small Unmanned Aircraft

While UAVs can provide benefits to a range of Forest Service activities, it is important to address concerns regarding safety, privacy, and effectiveness when integrating UAVs into operations. These concerns are more significant for public use of UAVs, but still worth considering for agency operations by a trained professional.

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[32] FAA summary of part 107 available here:
https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20516

[33] FAA describes the Certificate of Authorization process on its website:
https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/coa/

### *Safety*

Recreational UAVs have nearly collided with commercial airliners on multiple occasions, posing a serious risk to public safety.[34] It is unlikely that this would be an issue for the Forest Service, as operators would complete comprehensive training. Furthermore, UAV operators have experienced lost command and control link, causing the aircraft to drift off their pre-programmed course, which means they could fly into unsafe spaces or interfere with manned aircraft operations. The Forest Service could mitigate risk by only using aircraft with a history of safe, reliable operations. Furthermore, a comprehensive training program that complies with the Part 107 rules would guard against operator error.

### *Privacy*

Privacy is a widespread concern about unmanned aircraft given that they fly closer to the ground than manned aircraft and generally record images or video. However, the bulk of the privacy concern has to do with surveillance over private, rather than publicly owned, land and is therefore less relevant to the Forest Service. Regardless, the privacy of Forest Service neighbors and visitors is important to keep in mind when planning flights and communicating with the public.

### *Noise*

In general the noise from small UAVs is low, however they can be tonal and cause annoyance and disruption to humans and wildlife, especially in low ambient settings. This may be a particular concern given that small UAVs can operate in much closer proximity to terrestrial wildlife than manned aircraft. Given the wide variety of UAV configurations and sizes, there is less documentation on noise effects than exists for manned aircraft. For situations where a significant number of operations are planned, the Forest Service or partners could use existing noise models to estimate potential effects on visitors and wildlife.

NPS currently monitors noise impacts from sources including aviation, and especially air tours. Working with the Volpe Center, the agency identified measures operators can take to minimize noise effects on wildlife and visitors.[35] As agencies including the Forest Service begin using UAVs in a pilot program, this may be an opportunity to research and understand noise effects so that they can be minimized or avoided in the future.

### *Role with Manned Aircraft and Current Practices*

Unmanned aircraft are primarily a way to supplement, not replaced, manned aircraft use and manual inspections. UAVs with cost effective sensors and camera equipment cannot yet produce the same quality of images or conduct the same quality of inspection as when using the conventional, manned method. Thoroughly testing vehicle and sensor effectiveness before deciding to switch from a conventional method is vital to the successful integration of UAVs into Forest Service operations. In some cases, manned aircraft or no aircraft use will continue to be the best choice for an activity. The Forest Service may also determine that a combination of using unmanned aircraft and conventional operations methods is the most efficient course. For example, the agency might use UAVs for an initial inspection of infrastructure to determine if it needs to conduct a follow up manned inspection.

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[34] Craig Whitlock, "Near-collisions between drones, airliners surge, new FAA reports show," *The Washington Post,* November 26, 2016.

[35] See Volpe Center website on this project: https://www.volpe.dot.gov/policy-planning-environment/environmental-science-and-engineering/mitigating-air-tour-impacts

## Logistical Constraints to Using Unmanned Aircraft

Integrating UAV technology into Forest Service operations also presents a number of logistical constraints illustrated in the examples discussed above.

### *Training*

Operating UAVs requires an extensive training program to produce qualified, experienced pilots. FDOT estimated that the training would require 3.5 hours.[36] Although first-time training is a one-time cost, it is a major investment and could reduce the cost-effectiveness of using UAVs. In addition, operators would likely need recurrent training to maintain proficiency. Establishing a proper training program requires that the Forest Service dedicate staff and resources to setting up the program and making it available to staff in dispersed locations. As discussed below, other agencies have fully or partially used contractor operators to avoid upfront training and procurement costs, although there are trade-offs in flexibility.

### *Cost*

Purchasing a UAV can cost as little as a few thousand dollars, but more sophisticated systems can cost tens or hundreds of thousands of dollars. Cheaper UAVs equipment may have cameras and sensor systems that do not provide high enough quality of data. The Forest Service would therefore need to determine which models are cost-effective and provide satisfactory data for different purposes. The Forest Service would also need to factor in the cost of processing and analyzing the data. The cameras on different UAVs will require different amount of data processing, which in some cases can require more time than conducting the flight. BLM estimates that 80% of the workload related to UAV data is post-processing.[37]

However, the Forest Service can use UAVs to conduct activities that have differing data requirements. For example, it is imperative that operations assessing wildfires provide a feed of real-time data so that firefighters can have access to the most up to date information. These activities require sensor and camera packages that can provide real-time data. Conversely, other activities, such as conducting wildlife surveys and assessing timber, are not as time sensitive as emergency management and therefore do not require real-time data feeds. Cheap UAVs may also be appropriate for more ad-hoc inspections where a staff member just needs to look at a piece of infrastructure from a particular angle to see if there is a problem that needs to be investigated. A follow-up, more formal inspection could use a more expensive UAVs.

### *Risk/Liability*

Risks are inherent to use of any type of aircraft, manned or unmanned. UAVs can potentially crash or otherwise be destroyed, particularly during operations in inclement weather. Although human safety risks are lower than those with manned aircraft, as pilots are not involved and the aircrafts typically do not use combustible fuel, they are still costs and potential liabilities that the Forest Service should consider.

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[36] FDOT also required 40 hours of flying time for their study, but the agency based this on FAA requirements for private manned aircraft. For unmanned aircraft, the FAA recommends that operators pass a knowledge test and exhibit familiarity with the aircraft.

[37] Guilbert Dustin, telephone interview with author, March 25, 2016

## Next Steps

The Forest Service can take a number of actions to begin using UAV and gather more information about its appropriateness for agency use.

### *Trial Unmanned Aircraft in Different Applications*

First, the Forest Service can continue to test using UAVs in different regions and for different operations. According to current Forest Service policy as outlined in the directive in Appendix A, staff must obtain approval from the appropriate Regional Aviation Officer to operate unmanned aircraft and must go through the Aviation AQM Branch to acquire an unmanned aircraft. Please note that purchasing and using unmanned aircraft on one's own is not permitted.

Following a similar procedure to the Placer River trail bridge inspection in Alaska, program areas (Recreation, Engineering, etc.) within the agency can identify potential ways to use UAVs to enhance their work. The lead program areas would work with Fire and Aviation, FAA, and relevant partners (such as FHWA for bridge inspections) to pilot UAV use and potentially make these tools more available to staff depending on the results. For each test in a different geographic area or for a particular purpose, the agency will need to obtain a COA from FAA.

**Figure 7. Unmanned aircraft above California (Photo Source: Ken Kistler)**

### *Potential for a Unmanned Aircraft Program*

To facilitate these pilots, the Forest Service might consider creating an unmanned aircraft program. For example, the Department of the Interior has a UAV program with a dedicated staff member, a model reflected in a number of DOI bureaus such as NPS, USGS, and BLM. A dedicated program could help set a common approach for UAV on national forests. However, it would need to coordinate closely with relevant program areas across the agency.

#### Contracting vs. Agency Fleet

For example, the agency can determine if it will buy or lease the systems or contract the work conducted with UAVs. Many other public lands agencies use a combined approach, owning a number of typically smaller unmanned aircraft and contracting private companies to conduct other work. NPS uses "end product contracts" that specify the images that they would like to obtain, but does not specify how a contractor would obtain these images (e.g. they can use manned or unmanned aircraft, but UAVs are typically cheaper and hence used). NPS estimates that the ratio of agency-owned to contractor UAV use mirrors its manned aircraft operations: about 10 – 15% of NPS manned aircraft operations use an NPS-owned aircraft and the remaining use contracted aircraft. By using this combined approach, the agency avoids the full cost of maintaining a large fleet, but have enough aircraft on hand to be able to quickly conduct certain operations without a contract.

#### Agency UAV Policy

In March 2015, following the February 2015 White House and FAA policy on unmanned aircraft, the Forest Service Chief released a letter (Appendix A) outlining the agency's current policy and discussing next steps. The policy requires that Forest Service staff must obtain approval and coordinate with the appropriate Regional Aviation Officer prior to using unmanned aircraft and that all acquisitions be processed through the Aviation AQM Branch. Regional Aviation Officers can also provide further guidance and support for unmanned aircraft operations.

The Forest Service established an Executive Steering Committee tasked with coordinating efforts with state and federal partners and developing Forest Service policy on the operation of unmanned aircraft for both recreational and staff use on Forest Service land. The committee includes representatives from Regional executive leadership and Deputy Area Directorates with interests in unmanned aircraft mission, policy, or acquisition.

Beyond obtaining the FAA authorizations, other public lands agencies have also developed their own internal policies on UAV operation. For example, NPS bans public use of UAVs in national parks and requires an NPS associate director to approve every agency operation. Unlike the FAA COA, the authorization does not permit multiple flights within the same geographic area over a long period of time. The process is time consuming, which limits the agency's ability to use UAVs in time-sensitive or emergency response activities.

The Forest Service can use information gathered during its tests and from the experience of partner agencies to ensure its own policy reflects the agency's own goals and mission. There may also be opportunities to partner with DOI or other partners to understand and account for potential noise effects on wildlife. (See above section on Noise, including NPS and Volpe Center research).

## Conclusion

The Forest Service has the opportunity to increase safety, reduce costs, and expand the type of data collected during key operations by employing unmanned aircraft. Unmanned aircraft can supplement operations that currently use manned aircraft, such as combatting wildfires, land surveys, and disaster response. They can also supplement operations that have not traditionally used aircraft at all, such as infrastructure inspections and timber condition and wildlife population surveys. Moving forward, the Forest Service can develop a program and set of policies that ensures the safe, responsible, and practical employment of UAV technology that will enhance the agency's operations and better serve its mission.

# Appendix A

Letter from the Chief of the Forest Service and revision with relevant guidance from Fire and Aviation Management.

Forest Service Washington Office 1400 Independence Avenue, SW
Washington, DC 20250

**File Code:** 5100/4000; 5100; 5450; 5700; 6100; 7100; 2320 **Date:** March 27, 2015
**Route To:**

**Subject:** Unmanned Aircraft Systems

**To:** Regional Foresters, Station Directors, Area Director, IITF Director, Deputy Chiefs and WO Directors

The Forest Service is committed to utilizing the best available science, technology, and information to accomplish our mission of "Caring for the land and serving people." We must introduce new tools into the management of National Forest System lands wisely, acting as good stewards of the land while maintaining fiscal integrity.

Unmanned Aircraft Systems (UAS) have the potential to augment the Agency's capacity to gather information to support several natural resource management programs. Examples include mapping, monitoring the condition of natural resources, and assessing the effectiveness of natural resource management projects.

Use of UAS in the Forest Service will be consistent with all laws, as well as policy implemented by the White House, the Department of Agriculture, the Forest Service, and the Federal Aviation Administration. On February 15, 2015, the White House and the Federal Aviation Administration (FAA) issued new policy and information regarding UAS. The Presidential Memorandum promotes economic competitiveness while safeguarding privacy, civil rights, and civil liberties in domestic use of UAS. The FAA released proposed regulations to allow routine use of certain small UAS in the National Airspace System.

The Forest Service will also operate UAS consistent with our interagency partners to the extent possible. Since UAS are "Aircraft Systems," the responsibility for UAS in the Forest Service is the Aviation division within Fire and Aviation Management in State and Private Forestry. Acquisition of any UAS will follow existing Forest Service policy. Operation of UAS within Regions will be coordinated with the appropriate Regional Aviation Officer.

To help govern this relatively new technology that is gaining widespread attention throughout the United States, I am establishing a Forest Service UAS Executive Steering Committee (ESC). The UAS ESC will include representation from Regional executive leadership, as well as each Deputy Area and Directorate with UAS mission, policy, or acquisition interests. The initial tasking of the committee will be to coordinate efforts with our State and Federal partners and to develop additional Forest Service Policy on the operation and use of UAS, to include recreational use or any other use on National Forest System lands. The previously established UAS Working Group will be used as needed for subject matter expertise.

Some specific UAS guidance will be necessary even as the steering committee is being formed. Celebrating the 50th anniversary of the Wilderness Act is an opportunity to describe the Forest Service position on support of new technologies while protecting wilderness values and ethics.

Forest Service Policy states that unmanned aircraft will be considered the same as manned aircraft and follow the same policy. Under current policy, UAS are considered "mechanized" equipment and consequently cannot take off from, or land in, congressionally designated Wilderness Areas. Enclosed you will find a briefing paper and other relevant material, including information on Wilderness prohibitions.

Safety of Agency employees and the public, personal privacy, and protection of wildlife are just a few of the many issues raised by UAS. Establishing clear policy and direction will ensure these advanced capabilities may be considered toward the overall benefit of our public lands.

*/s/ Thomas L. Tidwell*
THOMAS L. TIDWELL
Chief

Enclosures

Cc: Art Hinaman, Paul Linse, Drag Sharp, Engineering, Research and Development, Acquisition Management, Regional Fire Directors

Forest Service
Washington Office
1400 Independence Avenue, SW
Washington, DC 20250

**File Code:** 5100; 5700 **Date:** April 17, 2015
**Route To:**

**Subject:** Unmanned Aircraft Systems, Direction and Additional Guidance

**To:** Regional Foresters, Station Directors, Area Director, IITF Director, Deputy Chiefs and WO Directors

This letter will provide the field with direction and additional guidance in support of the recent correspondence (March 27, 2015) from the Chief's Unmanned Aircraft Systems (UAS) Letter.

A UAS is an "aircraft" as defined in the Federal Aviation Administration's (FAA) authorizing statutes and is therefore subject to regulation by the FAA. Forest Service policy states UAS must be considered the same as manned aircraft, in terms of acquisition, approval and carding of pilots and aircraft, inspections, maintenance, avionics, training, and operations. Where this manual or FSH 5709.16 states aircraft, this must include UAS. The acquisition or lease of UAS (of any size) will be approved by the Washington Office Director, Fire and Aviation Management.

The Agency plans to support a limited number of UAS missions on National Forest System Lands utilizing partners and cooperators.

**All UAS Missions**

- [ All UAS operations shall adhere to FAA UAS regulations.
- [ Federal Partners – Forest Service units may use UAS approved by Federal Partners for specific special missions without re-inspection.
- [ An approved agreement/MOU specific to UAS operations is required to utilize Federal Partner/ Cooperator aircraft on Forest Service system land and for Forest Service benefit.
- [ Cooperators – Use of cooperator operator/UAS shall be approved by official letter by the Regional Aviation Officer (RAO), FSM 5712.41.
- [ All UAS operations, activities, concerns, or requests shall be coordinated through the Regional Aviation Officer (RAO). This includes resource (non-incident) and incident operations and any clarification of hobby or recreational use of remote controlled aircraft on Forest Service lands.
- [ The RAO shall be notified prior to Federal Partner/Cooperator resource (non-incident) and incident UAS operations.
- [ In addition to FAA requirements, commercial UAS operations may require a special use authorization from the local Forest consistent with 36 CFR 251 and FSM and FSH direction.

- The FAA has advised the Forest Service that news media must meet requirements for civil operations (non-governmental) and may not fly under model aircraft operations guidelines.

- SAFECOMs shall be used to report any condition, observation, act, maintenance problem or circumstance with personnel or the aircraft (UAS) that has the potential to cause an aviation-related mishap.

- UAS use through end-product contracts have additional considerations and should not be used to circumvent the direction in this letter. End-product contracts shall be considered on a case-by-case basis by the Regional Aviation Officer.

**Resource missions (non-incident)**

- An approved Project Aviation Safety Plan (PASP) is required for all resource (non-incident) aviation missions.

**Incident (fire and fire management)**

- Incidents must be Unified Command (Forest Service and Federal Partner, state or local agency). The cooperator shall retain operational control.
  - In situations of Unified Command, if the Federal Partner/Cooperator agency orders the UAS they are considered to have "operational control" of the aircraft and may be utilized under their authority to accomplish the unified mission.

- Incident UAS use shall be coordinated through the incident commander.

All employees must be aware of the Federal regulations and Forest Service policy for the acquisition and use of UAS.

The UAS advisory group website provides extensive resources to for reference. http://www.fs.fed.us/science-technology/fire/unmanned-aircraft-systems. Additional Agency communication material can be found at: http://www.nifc.gov/PIO_bb/fs.html

The direction and guidance in this letter expires December 31, 2015, or when rescinded.

TOM HARBOUR
Director FAM

cc: Maria Knott, Art Hinaman, Paul Linse, Drag Sharp, Engineering, Research and Development, Acquisition Management, Regional Fire Directors, Aviation Branch Chiefs, Walker Craig, Tom Ricks, John Nelson, Gary Sterling, Rock Parrilla

# Appendix B

Table 6. FAA Aircraft Classification

| UAV Description | Weight (Pounds) | Overall Size (Feet) | Mission Altitude (Feet Above the Surface) | Mission Speed (Miles per Hour) | Mission Radius (Miles) | Mission Endurance (Hours) |
|---|---|---|---|---|---|---|
| **Nano** | < 1 | < 1 | < 400 | < 25 | < 1 | < 1 |
| **Micro** | 1 to 4.5 | < 3 | < 3,000 | 10 to 25 | 1 to 5 | 1 |
| **Small UAV/UAS (sUAS)** | 4.5 to 55 | < 10 | < 10,000 | 50 to 75 | 5 to 25 | 1 to 4 |
| *Ultralight Aircraft** | *55 to 255* | *< 30* | *< 15,000* | *75 to 150* | *25 to 75* | *4 to 6* |
| *Light Sport Aircraft** | *255 to 1320* | *<45* | *< 18,000* | *75 to 150* | *50 to 100* | *6 to 12* |
| *Small Aircraft** | *1,320 to 12,500* | *<60* | *< 25,000* | *100 to 200* | *100 to 200* | *24 to 36* |
| *Medium Aircraft** | *12,500 to 41,000* | *TBD* | *< 100,000* | *TBD* | *TBD* | *TBD* |
| *Large Aircraft*** | *41,000 to 300,000* | | | | | |

**These are classifications for manned aviation. FAA currently does not have corresponding classifications for unmanned aircraft.*

*** Other than the X-47B Pegasus (AV-1), there are no UAV in this weight range. However, it is expected a new class of DOD aircraft will emerge as optionally pilot aircraft. These aircraft, some of which will be flown unmanned depending on mission, will begin to replace current manned aircraft with the same of similar missions as bombers and transport aircraft.*