This is an Accepted Manuscript of an article published by Taylor & Francis Group in Enviromental Claims Journal 25/04/2017 29:2, 159-170, available online:
http://www.tandfonline.com/eprint/jDfdIzvdcng8KXNrxH6A/full

Current Status of the Use of Small Unmanned Aerial Systems for Environmental Monitoring

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Abstract

Unmanned Aerial Systems (UAS [aka, "drones"]) are becoming an effective method for both environmental assessment and monitoring. Newly enacted rules by the Federal Aviation Administration (FAA), recognize and promote the role of commercial UAS use and provide guidance on issues related to privacy concerns. Currently, the most common use of UAS is for aerial photography or video imagery. UAS craft can carry new light weight sensors specific to environmental monitoring. Regulatory agencies are currently varied in their acceptance of the use of UAS in environmental assessment. Routine UAS will become more common by environmental professionals as UAS-specific workflows are developed and verified.

Introduction

Other than the advent of self-driving cars, it is difficult to recollect in recent history a technology that has received more hyperbole as drone technology. This may stem from the military application of drones in warfare, promises of doorstep latte delivery, privacy concerns, or reports of an emerging multi-billion dollar commercial market. Unfortunately, many of the proposed uses of drones may not be economically viable, and appear to be "hammer looking for a nail" applications. When the technology is stripped down to its core function, a drone is a mainstream consumer-accessible helicopter. Yet, that is not insignificant. For safety-critical industries such as power utilities, oil & gas, mining and environmental, the ability to develop new aerial sensor workflows that remove people from hazardous environments is highly desirable. The opportunity to not have people hanging off ropes inspecting wind blade turbines, flying helicopters low and slow along high-voltage electric transmission lines (aka, "Dead

Man's Curve"[1]), or performing inspections on 150 foot high decaying brick emission stacks, will motivate these industries into mainstream adoption of drone technology. This paper examines the slower, more methodical adoption of drone technology into environmental data collection[2].

From an environmental study perspective, drones fill an interesting part of the National Airspace System (NAS). Previously, remote environmental data would be obtained from either satellite, fixed-wing aircraft, or helicopters. This type of service required obtaining assistance from firms with expertise in accessing satellite imagery files, or expensive contracting from an aerial flight service provider. Further, the data obtained from satellites or airplanes was not at a resolution suitable for environmental sites that may be from a few acres to a few square miles. The type of information that is required for the majority of environmental investigations needs to be: (1) at a scale that is appropriate for the site; (2) quantifiable; (3) repeatable; and (4) verifiable. That data can now be obtained from drones.

UAS, sUAS, RPAS and Drones

First, the term "drone" is inappropriate for this technology[3]. The accepted term used by the FAA is Unmanned Aerial Systems (UAS) and is defined as "An unmanned aircraft means an aircraft operated without the possibility of direct human intervention from within or on the aircraft"[4]. A small UAS (sUAS) is a UAS that weighs less than 55 pounds at takeoff. A UAS weighing greater than 55 pounds falls into a different class under FAA regulations and requires air worthiness certification[5]. The term Remotely Piloted Aircraft System (RPAS) is commonly used outside of the US, but is not used within FAA regulatory definitions or documentation.

The sUAS class is what is most commonly discussed because of the new rules enacted for the Operation and Certification of Small Unmanned Aircraft, 14 CFR Parts 21,43, 61, et. al. (FAA Part 107 Rule)[6] on August 29th, 2016. These rules give clear direction to entities on the use of sUAS for commercial purposes. The Presidential fact sheet that accompanied the FAA Part 107 Rule stated

"*To further grow our economy and encourage innovation, today, the Obama Administration is announcing ground rules to govern commercial, scientific, public safety, and other non-recreational uses of unmanned aircraft systems (UAS) —commonly known as 'drones'—in the National Airspace System. These ground rules will enable the safe expansion of a new generation of aviation technologies that will create jobs, enhance public safety, and advance scientific inquiry*."[7]

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[1] For a description of the helicopter flight performance curve known as "Dead Man's Curve", readers are directed to http://www.copters.com/pilot/hvcurve.html for a detailed explanation.

[2] A legal review of UAS regulations and laws can found in the recently published book – Nilsson, Sarah, *Drones Across America, Unmanned Aerial Systems (UAS) Regulations and State Law*, Chicago: American Bar Association, 2017.

[3] According to Merriam Webster Dictionary (https://www.merriam-webster.com/dictionary/drone), a drone can a: (1) stingless male bee (as of the honeybee) that has the role of mating with the queen and does not gather nectar or pollen; (2) one that lives on the labors of others; or (3) an unmanned aircraft or ship guided by remote control or onboard computers. All of which are inappropriate for this paper.

[4] 14 CFR §§107.1 and 107.3 AC 107-2

[5] FAA Special Airworthiness Certification: Certification for Civil Operated Unmanned Aircraft Systems (UAS) and Optionally Piloted Aircraft (OPA) https://www.faa.gov/aircraft/air_cert/airworthiness_certification/sp_awcert/experiment/sac/

[6] Published in Federal Register, Vol 81, No. 124, June 28, 2016. https://www.gpo.gov/fdsys/pkg/FR-2016-06-28/pdf/2016-15079.pdf

[7] The White House FACTSHEET: Enabling A New Generation of Aviation Technology, June 21, 2016. https://www.whitehouse.gov/the-press-office/2016/06/21/fact-sheet-enabling-new-generation-aviation-technology

The rules established a testing and certification for sUAS airmen to legally provide commercial sUAS services and set the parameters for how sUAS can be flown within the NAS.[8]

sUAS Operational Limitations

An abbreviated version of key operational limitations in the FAA Part 107 Rule are listed below[9]. The limitations generally relate to the certification of the pilot, incorporation of the operation of sUAS into the NAS, sUAS craft weight and maintaining visual line of sight (VLOS) when operating a sUAS, and other general rules for safe operation. The certification exam is related to understanding sUAS rules, pilot responsibilities, air space classification, and safe operation. The certificate exam does not require any actual time operating or demonstration of operation ability of a sUAS.

- A person operating a sUAS for commercial (non-recreational) operation must either hold a remote pilot airman certificate with a sUAS rating, or be under the direct supervision of a person who does hold a remote pilot certificate (remote pilot in charge).
- sUAS must weigh less than 55 pounds on takeoff, including everything on board or otherwise attached to the aircraft.
- sUAS may operate in Class B, C, D and E airspace[10] with the required Air Traffic Control (ATC) permission.
- sUAS may fly in Class G Airspace without ATC permission.
- sUAS are limited to a maximum groundspeed of 100 miles per hour and maximum altitude of 400 feet above ground level (AGL), or if higher than 400 ft AGL, remain within 400 ft radius of a structure; fly no higher than 400 feet above structure's uppermost limit.
- sUAS must remain within VLOS of the remote pilot in command (PIC) and the person manipulating the flight controls of the sUAS. Alternatively, the sUAS must remain within the VLOS of the visual observer (VO).
- sUAS may not operate over any persons not directly participating in the operation, not under a covered structure, or not inside a stationary vehicle.
- sUAS operations are limited to daylight-only operations, or civil twilight[11].
- External load operations are allowed if the object being carried by the sUAS is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft.

sUAS do not have any standard configuration or design. They may look like a scaled-down helicopter or airplane, or they may have "spider" type shape with multiple arms extending from a central body with either four (4) rotors (quadcopter), six (6) rotors (hexcoptor), or eight (8) rotors (octocopter). Whatever the physical shape of the sUAS, the two fundamental parameters for establishing the suitability for a particular flight mission are payload and endurance. Payload is the amount of weight the sUAS safely carry and remain under the 55-pound weight restriction. This includes the weight of the sUAS, power supply (batteries) and the payload (sensor or package). The endurance is the amount of time that the sUAS can remain airborne. Payload and endurance are interrelated because the payload affects the

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[8] The new regulations do not apply to "model aircraft operations" that meet the all of the criteria specified in Section 336 of Public Law 112-95 (which is now codified in part 101), including the stipulation that they only be operated for hobby or recreational purposes.
[9] FAA News, "Summary of Small Unmanned Aircraft Rule (Part 107)" June 21, 2016. https://www.faa.gov/uas/media/Part_107_Summary.pdf
[10] FAA airspace classes are described at the following address: http://aspmhelp.faa.gov/index.php/Airspace_Classification
[11] 30 min before official sunrise to 30 min after official sunset with appropriate anti-collision lighting.

endurance. For example, a sUAS may list an endurance of 30 minutes without a payload, but when the craft is carrying the maximum payload, the endurance maybe reduced to less than 10 minutes. The majority of sUAS use rechargeable lithium-ion polymer batteries. New designs have recently been released that use a gasoline powered engine (gassers). The endurance of sUAS crafts using gasser engines can be upwards of six (6) hours.

Low to middle-end sUAS use manual flight controls that are typically integrated with a smart phone or tablet. The upper-end sUAS systems have sophisticated flight control systems that use survey-grade global positioning system (GPS) sensors that allow autonomous flight along pre-selected flight plans[12]. This is a critical feature for flights collecting environmental data as they are documented, quantifiable and repeatable. The flight plan becomes a permanent record of the location, altitude and path that the sUAS flew for that particular data collection effort.

sUAS Sensors

Other than the ability to fly, the sUAS craft does nothing more than carry sensors. These sensors may be as simple as a camera, or sophisticated as a Light Detection and Ranging (LiDAR) sensor. With the popularity and commercial potential for the sUAS market, sensor manufactures are rapidly developing ever sophisticated sensors for the sUAS market. Cameras and sensors, that only a few years ago weighed in the 10 to 50 pound range have been reduced in size and weight to well below 1 to 10 pounds to meet the payload capacities of sUAS. In most basic terms, if it has a shape, smells, changes temperature, reflects light, or emits energy; there is likely a sUAS sensor that can detect it. If that sensor is not currently available, might already be in commercial development. Listed below is a list of sUAS sensors that are available from manufacturers and have commercial environmental measurement applications. See Table 1 (each sensor type includes a footnote with an example of a commercially available sensors that can be referenced for futher details).

Table 1. Commercially Available sUAS Environmental Measurement Sensors

sUAS Sensor Type	Commercial Environmental Measurement Application
LiDAR[13]	Terrain mapping, power line vegetation management, change detection
Imagery[14]	Photogrammetric mapping, asset inspection, volume calculation, corridor inspection, habitat assessment, emergency response
Video[15]	High resolution video, corridor evaluation, asset management
Multispectral/Hyperspectral[16]	Plant identification, vegetative health, noxious weed invasion, habitat, wetlands, hydrocarbon spills, emergency response, exploration
Thermal/Infrared[17]	Heat loss, solar panel assessment, wind turbine blade inspection, insulators, qualitative methane leaks detection

[12] An example of sophisticated flight control software is the Pulse Aerospace HeliSyth™ software (www.pulseaero.com)
[13] Riegl UAS LiDAR VUX-1 Sensor: http://www.riegl.com/products/unmanned-scanning/riegl-vux-1uav/
[14] Phase I Camera: https://www.phaseone.com/en/Products/Camera-Systems/XF100MP
[15] Sony 4K Video UAS Camera: https://pro.sony.com/bbsc/ssr/cat-broadcastcameras/cat-pov/product-UMCS3C%2FP/
[16] Headwall UAS Hyperspectral Camera: http://www.headwallphotonics.com/spectral-imaging/hyperspectral/nano-hyperspec
[17] Flir UAS Thermal Camera: http://www.flir.com/suas/vuepror/

sUAS Sensor Type	Commercial Environmental Measurement Application
Magnetometer[18]	Unexploded Ordnance (UXO), geological studies, resource evaluation, exploration
Gamma[19]	Abandoned uranium mine characterization, UXO (depleted uranium), radiological leaks, frac flow back water (radionuclides in formation)
Corona[20]	Power transmission line loss, power line asset management
Laser Methane Detection[21]	Quantitative assessment of methane leaks, landfill gas assessment

sUAS Application to Environmental Risk Study

Multispectral/Hyperspectral Imagery

Multispectral/hyperspectral imagery is an example of an emerging sUAS sensor technology that has broad environmental applications. The scientific theory behind these sensors is well beyond the scope of this article, however, in a broad sense a multispectral or hyperspectral sensor is a camera that is designed to finely quantify portions of the reflected light spectrum that are both visible and invisible to the human eye including infrared. Whereas the human eye will breakdown a color into red-green-blue bands, the multispectral camera will breakdown the light into 4 or 5 bands (red, green, blue, near infrared, infrared). The near infrared is important to environmental work and agriculture because healthy plants reflect light in the near infrared spectrum of light. Therefore, when a plant is healthy a multispectral or hyperspectral sensor will see a large amount of light in the near infrared. When the plant is stressed or dying, the plant stops reflecting in the near infrared portion of the spectrum but still appears healthy and green to the human eye.

The hyperspectral sensor takes this same concept a level further by dividing and quantifying the light into 100 bands (including visible and near infrared). An analogy of the differences between the multispectral and hyperspectral sensors is while the human eye would see a "book", the multispectral sensor would see a "book and be able to divide the book by chapters". The hyperspectral sensor would see the "book, chapters and individual pages". As applied to vegetation, the human eye would see a field of grass, the multispectral camera would see a field of grass and areas where the grass was stressed due to the watering being inefficient. The hyperspectral would see the grass, areas of stress and variations in grass species in the field. The overall dataset from a hyperspectral camera is often referred to as "data cube", meaning that there is the two-dimensional image and the third dimension of the cube refers to all of the additional information known about the reflectance values of specific spectral ranges The hyperspectral data can also be shown as a graph of reflectance intensity per each spectral band. The result is a "spectral signature" that would be unique to that type of plant or groundcover.

Multispectral and hyperspectral images collected from fixed-wing aircraft or satellite imagery is well accepted[22], and using the same multispectral/hyperspectral technology with higher resolution and ease

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[18] GemSys UAS Magnetometer: http://www.gemsys.ca/uavs-pathway-to-the-future/
[19] Imitec UAS Gamma Sensor: http://imitec.co.uk/autonomous-airborne-radiation-monitoring-system/
[20] Ofil Systems UAS Corona Sensor: http://www.ofilsystems.com/products/rompact.html
[21] Pergam UAS Laser Methane Sensor: http://pergamusa.com/gascopter/
[22] Shippert, P, "Why Use Hyperspectral Imagery", *Photogrammetric Engineering and Remote Sensing*, April 2004. pp. 377:380

of collection via a sUAS, will broaden the use of this technogy. Multispectral imagery could be used to understand the impact on vegetative health in wetlands after a chemical spill or assessing the impact of nuisance herbicide overspray on adjacent properties. The hyperspectral technology is currently being used and tested for noxious weed invasion quantification in western range lands. Non-vegetative hyperspectral assessments may include evaluation of mine tailing spills into a riverine environment, or hydrocarbon spills.

LiDAR Change Detection

LiDAR uses light emission and return of light pulses to map objects or terrain. Airborne LiDAR has been commercially available since the mid-1990s and has been used extensively in large scale mapping projects such as US Federal Emergency Management Agency for digital flood risk mapping. LiDAR can be measured from a ground-based unit on a tripod (terrestrial LiDAR), on a moving vehicle (mobile LiDAR), from a helicopter/fixed-wing (aerial LiDAR) and now, mounted on a sUAS (UAS LiDAR). Mapping of ground terrain was the first well-accepted technology for LiDAR because of the ability for the LiDAR pulse to penetrate light to moderate vegetation. This was an advantage over the primary limitation of photogrammetry[23] where the groundsurface was not able to be mapped under vegetative cover. The accuracy was relatively crude (2 to 3 measurements [points] per square meter [ppsm]) and it was difficult to process the data. Modern terrestrial and mobile LiDAR are now able to capture 2 to 6 thousand ppsm. This allows very accurate measurement (down to millimeters)[24]. New UAS LiDAR sensors collecting data below 400 feet altitude are able to collect over 1,000 ppsm with low centimeter accuracy. The ability to quickly and efficiently collect terrain data has direct application to remedial efforts where volumes can be rapidly assessed for mine tailings and/or coal ash residual ponds even when vegetation is present.

LiDAR has become the standard for vegetation management along power transmission lines[25]. LiDAR data of the power transmission line and corridor vegetation can be used to calculate the risk of vegetation grow-in and/or fall risk to the high-voltage power lines. The majority of the LiDAR measurements are performed by either fixed-wing aircraft or helicopter. Primarily related to safety concerns, sUAS is starting to be tested at increased transmission lengths and testing for FAA waivers to allow sUAS power transmission line surveys beyond the visual line of sight (BVLOS). In addition to the vegetation issue, the power transmission surveys are being performed for asset inspection (visual, thermal, corona discharge) and construction management to understand if transmission lines were installed to specifications.

From an environmental claims perspective, one of the more interesting applications of LiDAR data is the ability to do change detection. The LiDAR data is an assemblage of many point measurements, or "point cloud" that represent the three dimensional image. Because the all of the points are geographically referenced to a coordinate system, the point clouds can be combined, divided, or subtracted. The point clouds can also be classified, or grouped as similar objects. Vegetation can be "classified" and removed

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[23] "*Photogrammetry is the science of making measurements from photographs. The output of photogrammetry is typically a map, drawing, measurement, or a 3D model of some real-world object or scene. In Aerial Photogrammetry the camera is mounted in an aircraft and is usually pointed vertically towards the ground. Multiple overlapping photos of the ground are taken as the aircraft flies along a flight path. These photos are processed in a stereo-plotter (an instrument that lets an operator see two photos at once in a stereo view). These photos are also used in automated processing for Digital Elevation Model (DEM) creation*." Electronically sourced at www.photogrammetry.com

[24] King, Valerie. "The Latest on LiDAR", *POB Point of Beginning*, Volume 42, Number 5, February 2017, Pages 12:14

[25] Hooper, B and Baily, T, "Aerial Survey to Calculate Vegetation Growth, *"Transmission and Distribution World"*, October 2004.

from a surface to show only the data recorded from the groundsurface. Much like a word processing program such as Microsoft WORD™, that can compare documents and provide a file that indicates the differences or changes between the two documents, one LiDAR file can be subtracted from a previous LiDAR file of the same spatial area to determine what has changed.

For example, terrestrial LiDAR and UAS LiDAR data can be integrated to understand changes to a petroleum refinery before and after an accident that resulted in structural damage. If baseline LiDAR imagery of the refinery was performed using a terrestrial LiDAR scanner before the accident, a supplemental LiDAR scan could be performed by a sUAS LiDAR platform without ever entering the property to perform a post-accident scan. The baseline and post-accident LiDAR files could be compared to provide a detailed image of the structural damage or structural movement as a result of the accident.

A second example would be evaluation of a levee breach during a flooding event. Assuming a baseline LiDAR scan was performed, LiDAR change detection would be able to fully characterize the size of the breach, volume of material discharged below the breach, erosional features caused by the breach, and impact on structures and vegetation affected by the levee breach inundation. This same concept could be applied equally well to landslides or storm damage.

Application Success of sUAS Environmental Measurement Depends on Workflows

Data collection for environmental studies is filled with workflows. US Environmental Protection Agency (USEPA) performs Remedial Investigations (RI) for Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as Superfund sites, to define the nature and extent of the contamination while following a defined workflow from project planning, data quality objectives (DQOs), sampling under Standard Operating Procedure (SOPs), laboratory analysis, and quality control through final reporting. This workflow is repeated over and over and is neither contaminant, nor location-specific. The acceptance and persistence of sUAS sensors for environmental measurements will be the integration of sUAS into these types of existing workflows.

An example of a sUAS-specific workflow developed by the author integrates sUAS data collection for abandoned uranium mines using a multitude of environmental sensors[26]. The sUAS workflow was developed specifically for the abandoned uranium mine (AUM) cleanup process around collection of high-quality data. Use of LiDAR, imagery, and gamma is to expeditiously understand the nature and extent of contaminants of concern (COC) related to technically enhanced naturally occurring radioactive material (TNORM) and develop a sound remedial approach to mitigate site risks by meeting the remedial action objectives (RAOs). An outline of the sUAS specific workflow is described below:

- The transect gamma survey will be conducted using a commercial vertical takeoff and landing (VTOL) sUAS that will be equipped with gamma, LiDAR, and static digital photographic imagery sensors.

[26] U.S. Provisional Patent, James M. Oliver, Jason R. Kack, Robert Mark Pitchford, “Collection of Data Using An Unmanned Aerial Vehicle to Assess Uranium Contamination” Serial No. 62/339,515

- The sUAS will be equipped with a survey grade inertial measurement unit (IMU) that will be used to correct sensor measurements taken from the sUAS that may be influenced by in-flight movement of the sUAS, producing consistently stable geographic location data.
- LiDAR light pulse measurements will be collected at a rate of 500,000 measurements per second to establish a point cloud of the ground surface topography to an accuracy of +/- one centimeter.
- LiDAR point cloud data will also be processed to isolate vegetation point clouds and remove vegetation from the final ground surface topography digital elevation model (DEM).
- Vertical aerial photography will be collected using a 36-megapixel still imagery and processed using orthophotographic processing software to create a 3-dimensional orthographically-corrected imagery of the survey area.
- Gamma measurements will be collected using a sUAS gamma sensor equipped with both a unidirectional and multi-directional multi-spectral Cadmium Zinc Telluride (CZT) detectors. The gamma sensor will be deployed on the sUAS at a constant elevation above ground terrain based on the LiDAR DEM, collecting gamma data at a minimum of 1 measurement per second[27].
- The gamma sensor flights will follow a rigorous Quality Assurance/Quality Control (QA/QC) SOP for calibration and repeatability. A flight path will be pre-programmed to ensure minimum overlapping readings that will be rectified using LiDAR collected DEM data as spatial control.
- The site boundaries and sUAS sensor measurements will be referenced to site benchmark established by Real Time Kinematics (RTK). Use of survey grade RTK will allow establishment of a site benchmark that has an accuracy of +/- 2 centimeters.
- Visible aerial ground targets will be surveyed to allow for positioning and correction of aerial photography (orthographic projection).
- All sUAS flights will use pre-determined autonomous transect flight paths with specific “no-fly” boundaries. The “no-fly” boundaries will restrict the autonomous flight operations to only occur within the investigation boundaries, eliminating potential for unintended and unauthorized fly-over of other land parcels.
- Flights will be performed within VLOS with visual observers and areas cleared of non-participants prior to flight operations to address Personally Identifiable Information (PII) concerns in compliance with the National Telecommunication and Information Administration (NTIA) UAS privacy best practices document[28].
- Specific flight operations will be designed to assess complete mine operations (pits, waste piles, waste rock, haul roads, etc.) and background conditions. Gamma data will be processed during field operations and assessed if additional coverage is needed complete survey of mine operations or background areas.

The current standard workflow is to have field crews spending weeks walking with gamma meters or driving the site with all-terrain vehicles equipped with gamma detectors. This example of sUAS workflow not only reduces worker exposure to radiological contaminants, it obtains data necessary related to mine site operations and topography needed to develop an Engineering Evaluation/Cost Analysis (EE/CA). The workflow does not eliminate the need for field crews to access the AUM sites, but it does limit the exposure to soil sample collection activities. The AUM workflow is provided as an

[27] Sampling times are based on UAS flight velocity and desired sample point density.

[28] NTIA best practices:
http://www.ntia.doc.gov/files/ntia/publications/voluntary_best_practices_for_uas_privacy_transparency_and_accountability_0.pdf The best practices were developed as a response to the February 15, 2015 Presidential Memorandum (see footnote 2).

illustration of how workflows can be modified and improved using sUAS sensor technology. Other workflows may include use of sUAS in the identification and mitigation of noxious weeds in Sage Grouse habitat, methane emission assessment at landfills, UXO detection, or rapid evaluation of frac flowback water spills. Further, given the cost and efficiency of sUAS operations and ability of some sUAS to carry multiple sensors, workflows are not limited to the use of one sensor. Environmental assessment can be performed based on multiple data layers to support and confirm the environmental action.

Increases Environmental Worker Safety

Increased safety of operations that include worker risk was specifically called out in the Executive Summary of the recently adopted FAA Part 107 regulations. The following text in the Executive Summary stated,

"*Technological advances in small UAS have led to a potential commercial market for their uses by providing a safe operating environment for them and for other aircraft in the NAS. In addition to enabling this industry to develop, the FAA anticipates that this final rule will provide an opportunity to substitute small UAS operations for some risky manned flights, such as inspection of houses, towers, bridges, or parks, thereby averting potential fatalities and injuries."*

Applying this to the sUAS AUM workflow, the two most important factors in radiation hazard reduction related to the regulatory requirement of **A**s **L**ow **A**s **R**easonably **A**chievable (ALARA)[29] radiation safety principle are, decreasing time of exposure and increasing the distance from the source of radiation. The use of sUAS creates a new state of technology for ALARA AUM investigation. The sUAS survey technology keeps workers at safe distances and minimizes the time near radiation sources. The use of sUAS technogy workflow reduces the weeks that field crews are currently exposed to radiation during walk around gamma and volume surveys and minimizes exposure time to the confirmation sampling effort.

Beyond the radiation hazards during field activities, the potential for trip/fall and venomous snake and spider bites remain during field work. These type of hazards become even more significant and life threatening in the remote AUM locations where communication is limited and access and response time to medical services could be hours away. The use of sUAS site surveys lessen the physical hazards by decreasing the field crew size and distances that crews would have to navigate the AUM sites in addition to reducing the overall number of days mobilized in the field to collect this data.

Federal Department and Agencies sUAS Policies

The acceptance of sUAS operations and sensor data by federal environmental natural resource departmens and agencies is a critical part of sUAS adoption. The process of federal agency and department integration of sUAS technology is listed, in a February, 15th 2015 Presidential

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[29] As defined in Title 10, Section 20.1003, of the *Code of Federal Regulations* (10 CFR 20.1003), ALARA is an acronym for "as low as (is) reasonably achievable," which means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Memorandum,[30] describing the President's directive to the executive departments and agencies on use of sUAS technology. The memorandum establishmed the adoption of a sUAS policy, and agencies were specifically directed to have a publically policy available within one year of the data of the Presidential Memorandum (timeline ending February 15, 2016). As described in the memorandum, the primary motivation in development of a sUAS policy was around the theme of public privacy consideration.

In response to the memorandum, many federal departments and agencies have established UAS policies including the Department of Agriculture for the US Forest Service[31], Department of Justice (DOJ)[32] and Department of Defense (DOD)[33] National Oceanic and Atmospheric Administration (NOAA)[34]. The most relevant to many environmental investigations would be the policy adopted by the Department of Interior (DOI)[35] and the following nine technical bureaus that fall under its jurisdiction:

1. Bureau of Indian Affairs
2. Bureau of Land Management
3. Bureau of Ocean Energy Management
4. Bureau of Reclamation
5. Bureau of Safety and Environmental Enforcement
6. National Park Service
7. Office of Surface Mining and Reclamation and Enforcement
8. US Fish and Wildlife Service
9. US Geological Survey

As a federal department, DOI has taken an active response to the USEPA cited February 15, 2015 Presidential Memorandum and developed both a policy and five-year integration strategy[36]. The August 9, 2016 policy (DOI Operational Procedures Memorandum [OPM] – 11) produced by the US DOI Office of Aviation Services indicates that is in accordance with February 15, 2105 Presidential Memorandum (DOI Policy can be found at: (https://www.doi.gov/aviation/pressreleases/updated-opm-11-doi-use-unmanned-aircraft-systems-uas)[37]. The introduction of the March 2, 2015 DOI UAS Integration Strategy states "Development of the UAS program within DOI will support in the accomplishment of our mission through better ***Science***, greater ***Safety*** and increased ***Savings***." The USGS has taken the UAS operations even further by creating a National Unmanned Aircraft Systems Project office in Denver, Colorado. The US Environmental Protection Agency (USEPA) has yet to develop a sUAS policy and make the policy publically available. Until the release of the EPA's UAS policy, the agency does not allow use of UAS on USEPA sites.

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[30] Presidential Memorandum: Promoting Economic Competitiveness While Safeguarding Privacy: https://www.whitehouse.gov/the-press-office/2015/02/15/presidential-memorandum-promoting-economic-competitiveness-while-safegua

[31] USFS UAS Policy: http://www.fs.fed.us/science-technology/fire/unmanned-aircraft-systems

[32] DOJ UAS Policy: https://www.justice.gov/opa/pr/department-justice-establishes-policy-guidance-domestic-use-unmanned-aircraft-systems

[33] Department of Defense UAS Home: http://www.defense.gov/UAS

[34] NOAA UAS Home: http://uas.noaa.gov/

[35] DOI UAS Policy

[36] DOI UAS Integration Strategy (2015-2020): https://www.doi.gov/sites/doi.gov/files/uploads/DOI_UAS_Integration_Strategy_2015-2020.pdf

[37] DOI Office of Aviation Services, *Operational Procedures Memorandum (OPM) -11, DOI Use of Unmanned Aiercraft Systems (UAS),* January 1, 2017. Boise, Idaho.

Conclusion

Where we go from here?

sUAS are neither expected to be filling our skies like robotic gnats, nor are they a passing technological whim that will disappear in the next couple of years. As acceptance of the presence of the sUAS craft in the NAS becomes more widely accepted and sensor technology continues to develop, commercial sUAS operations will be incorporated in an ever expanding list of environmental data collection workflows. The use of sensors in environmental assessment ranging from laboratory analytical methodology to field screening is well accepted technology for quantifying environmental impairment or impact. The attachment of these same sensors, or sensor technologies, to sUAS should not change the applicability of these sensors for environmental investigations. Application of specialized sensors will continue to be refined and match information that can be obtained from field crews. In some circumstances, sUAS data will provide a higher level of accuracy, precision and repeatability than could be achived by ground-based field crews. Technical professionals, the legal profession, and regulators will all need to understand what this technology is and how it can be used in understanding environmental conditions. It is also expected that US natural resource agencies will continue to develop their own sUAS programs and internal workflows using sUAS in compliance and monitoring.

Future Trends

More case studies and investigations will be published showing comparison of sUAS derived data to traditional field methods. These studies will help move the technology from early adopters "across the chasm[38]" to the mainstream environmental community. Sensors will get smaller and lighter and bring over proven technology being utilized by ground based sensors. Research is already underway on new sensors for methane and greenhouse gas detection. It is also expected that physical sampling (air, water) will also be able to be performed by sUAS in the near future. The most significant changes may come from the FAA in lessening restrictions related to BVLOS restrictions and nighttime operations. As the FAA compiles more data on sUAS operations it is expected that selected sUAS operators will be given permission to fly BVLOS based on their positive flight experiences.

About the Author

Mr. Oliver is a professional geologist who has been performing environmental and technology consulting for over 30 years. He is currently the Manager of UAS Technogy at Maser Consulting P.A.

[38] Moore, Geoffrey, *Crossing The Chasm, Marketing and Selling Disruptive Products to Mainstream Customers*, New York: Harper Collins, 1991.