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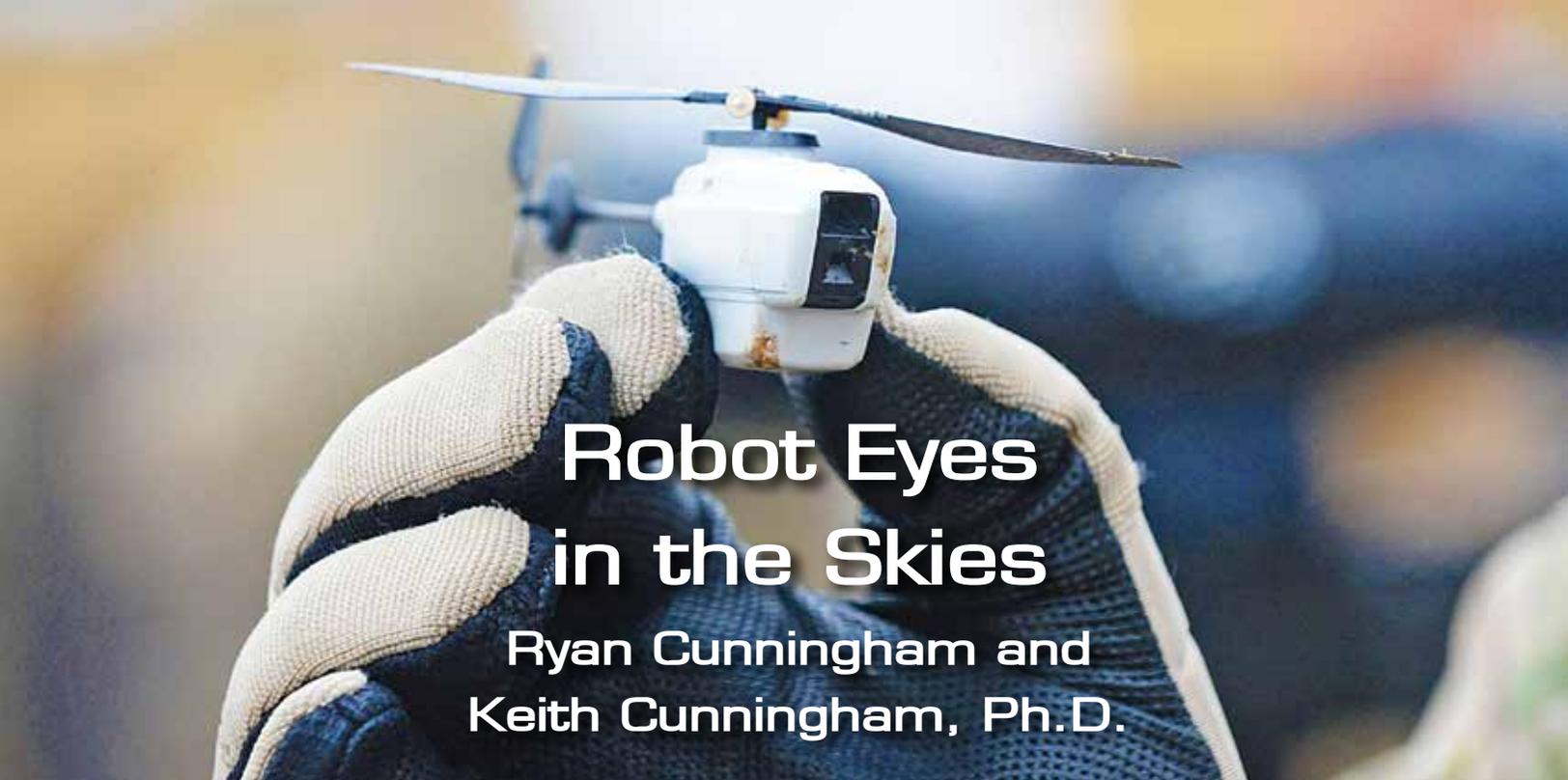
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Robot Eyes in the Skies

Ryan Cunningham and
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Unmanned aircraft are a huge presence in the popular imagination. Remotely piloted aircraft are constantly in the news: the military uses them for battlefield reconnaissance and for delivering supplies; they are the linchpin of counter-terrorism operations; and plans by police forces to use them for tactical surveillance have sparked public controversy. In an amusing turn, businesses have considered using drones to deliver tacos, hot pizza, and cold beer. And in 2010 even President Obama joked about using a Predator strike to protect his daughters from the Jonas Brothers' affections.

Drones were originally developed by the military for aerial gunnery practice. But the military and the Federal Government no longer have a monopoly on unmanned aircraft systems. In the coming years unmanned aircraft will begin to replace conventional aircraft in a range of civilian and commercial applications.

Unmanned aircraft systems excel in performing flights not well suited for manned aircraft. They are often employed in tasks that fall under the rubric of what the industry calls the 4-Ds—tasks that are dull, difficult, dirty, or dangerous. The military drone pilot can sit comfortably in an air-conditioned room thousands of miles away, and the aircraft's pilot crew can operate in shifts. As a result, the aircraft can stay operational during long missions. Remote piloting further allows the aircraft to be deployed in areas and perform tasks that would expose a conventional aircraft's pilot to physical harm. These advantages can be realized equally by military and civilian operators.



Marilyn Monroe assembling a WWII target drone (<http://www.uasvision.com/2013/07/30/marilyn-monroe-assembled-world-war-ii-target-drones/>)

Unmanned aircraft systems have a number of other advantages over manned aircraft. They can operate under low clouds that would prevent manned aircraft operations. Small unmanned aircraft systems do not require the complicated and expensive aerospace infrastructure needed by larger aircraft. They can easily be operated from austere locations far from commercial airstrips. Some systems can be launched from and recovered by ships at sea or dropped from a balloon. Small unmanned aircraft systems can even be carried by hand in a briefcase. Some drones are literally the size of insects.

However, regulations governing unmanned aircraft system operations in the United States are strict and vigorously



Black Hornet drone used for surveillance by United Kingdom troops in Afghanistan (<http://www.defenceimagery.mod.uk>) (photo by Richard Watt/MOD)

enforced by the Federal Aviation Administration (FAA) because of aviation safety issues. Currently, all commercial operations in the United States are prohibited from using unmanned aircraft systems without special waivers from the FAA. The rules currently enforced date to 1981 and were created for model aircraft operations (FAA 1981). In 2012 Congress responded to the stringency of these controls by passing the FAA Modernization and Reform Act, which directed the FAA to implement standards for the safe operation of unmanned aircraft systems in the national airspace. An explosion of new commercial unmanned aircraft system activity is expected in the United States when the agency releases the new standards in 2015. The Association for Unmanned Vehicle Systems International estimates that as many as 10,000 unmanned aircraft could be flying in the national airspace within 5 years, creating 100,000 jobs and \$13.7 billion for the U.S. economy (Space Daily 2013).

However, drones are already in use in other countries with more liberal flight safety regulations and in countries without regulations. Property mapping and surveying figure prominently in unmanned aircraft system applications in many of these countries.

Drone technology could revolutionize property mapping, measurements, and assessment practices. Unmanned aircraft systems equipped with high-resolution cameras can perform the same tasks as manned aircraft more frequently and at a lower cost. Unmanned aircraft systems can easily collect on-demand appraisal imagery, and oblique imagery taken from a low altitude would give assessors a more detailed look at properties. Even more exciting is a new imaging technology evolving along with unmanned aircraft system platforms that can create three-dimensional computer renderings from oblique aerial imagery. Unmanned aircraft systems are ideally suited for these types of missions.

In a few years it is conceivable that a property appraiser could unpack from a briefcase a small helicopter drone, program it to fly over a new subdivision, and use the resulting high-resolution imagery for property valuations. Unmanned aircraft systems have the potential to be a disruptive technology for assessing officers worldwide.

More than an Aircraft

A number of terms are used for drones, but *unmanned aircraft system* is preferred for civilian use. What exactly is the *system* to which this refers? And in what way is an unmanned aircraft

system different from a target drone or hobbyist's model aircraft?

Fundamentally, an unmanned aircraft system is an aircraft that can be programmed to fly itself robotically. An unmanned aircraft system is typically equipped with a global positioning system and an autopilot navigation system that can be programmed to follow a specific flight plan.

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The term *unmanned aircraft system* encompasses much more than simply the aircraft and navigation computer. The supporting system of the complete unmanned aircraft system constitutes the payload, such as a camera, as well as any equipment necessary for its launch, recovery, and other operations. This support may include the airfield, radar, and air traffic control infrastructure necessary for a larger unmanned aircraft to take off and operate safely.

Definitions of Terms

Drone. Historic term for aircraft used in target practice.

Model Aircraft. A hobbyist's recreational toy.

Remotely Piloted Aircraft (RPA). An aircraft operated from afar by a pilot using a telemetry link.

Remotely Piloted Aircraft System (RPAS). A term used by the International Civil Aviation Organization.

Unmanned Aerial Vehicle (UAV). A term describing the aircraft as a platform for carrying sensors.

Unmanned Aircraft System (UAS). A standard term that includes the aircraft, sensors, pilot, and variety of supporting components

The complete system also includes the aircraft's human operators and any other personnel involved in carrying out the mission—pilots, engineers, scientists, and the specialists who operate the aircraft's sensor payload and later process the data collected.

Thus the term *system* implies that there is considerable support involved in the operation of an unmanned aircraft system. And because safety is one of the most important aspects of the system, there are a variety of rules and regulations that must be followed when operating an unmanned aircraft system.

What Are the Rules?

FAA regulations currently prohibit all commercial operations of unmanned

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aircraft systems in the United States. In 2015, the FAA is expected to release rules governing how unmanned aircraft systems can be safely integrated into the national airspace for commercial purposes. Until then, only nonprofit, public agencies conducting research for the public good can apply for a special FAA waiver called a Certificate of Authorization (CoA). For this reason, public universities are at the vanguard of unmanned aircraft system operational research.

The CoA application process emphasizes flight safety, above all else. The FAA requires that unmanned aircraft systems, like manned aircraft, possess an airworthiness certificate. The FAA also considers the aircraft's pilot essential to safe operations. Although an unmanned aircraft is a programmable robot, a trained pilot who can observe see-and-avoid visual flight rules is integral for flight safety.

The pilot monitors the aircraft's flight at all times and conducts safety procedures designed to prevent mid-air collisions with other aircraft. Accordingly, the pilot is required to always remain within the line of sight of the aircraft.

Depending on the aircraft and mission, the FAA may require additional



Puma ready for launch from a ship in the Aleutians. Note the oblong device (back right) with a blue panel and yellow trim—this is a radar unit from the University of Alaska Fairbanks to watch for other aircraft in the vicinity. (photo by Keith Cunningham)

aircraft spotters, called observers, to assist the pilot in monitoring the airspace. The FAA can also require that the pilot have a commercial pilot's license.

To augment the role of the pilot, engineers are developing a new navigation technology that allows an unmanned aircraft to autonomously perform collision avoidance procedures to prevent possible mid-air collisions. This sense-and-avoid technology is expected to be operational in the next decade at a cost of more than \$1 billion (Warwick 2013). Sense-and-avoid technology will be required for longer commercial missions that extend beyond the pilot's visual line of sight.

The CoA may require special airspace management and communications procedures, which must be followed in the event that the communications link between the pilot and the aircraft is lost. Depending on the system and the CoA, the aircraft can be programmed to automatically land at its current location, return to a pre-determined rally point, or fly the remainder of its programmed mission and then land. These automated landing rules depend on the type of aircraft, that is, fixed-wing or helicopter, and whether the unmanned aircraft is operating over land or water, among other details.

The FAA is evaluating new safety procedures. The new regulations are also likely to streamline the long and complicated procedure of applying for a CoA. To assist in this process, the agency is creating several flight test ranges in collaboration with research partners. The FAA has received 37 proposals from 51 applicants vying for the six research sites. A special Arctic test site created by the Modernization and Reform Act is now operational.

In addition, the FAA has issued its first commercial restricted category-type certificates to ConocoPhillips.



Puma splashdown for ocean recovery. Note that the Puma floats and is not affected by salt water. (photo by Keith Cunningham)

The certificates are for two types of unmanned aircraft systems: the 55-pound Boeing ScanEagle and the smaller, 13-pound AeroVironment-manufactured Puma. The catapult-launched ScanEagle has a long, 20-hour operational endurance and will be used to monitor sea ice that could interfere with oil exploration. The hand-launched Puma is designed to splash down in the water when

its mission is completed and will be equipped with an infrared camera to scout for whales.

A Transformative Technology

The remote sensing capabilities of unmanned aircraft systems will allow surveyors, mappers, and assessors to collect high-quality imagery with greater frequency and flexibility. This is not a far-off pipe dream—the sophistication



The catapult-launched ScanEagle is a larger model of an unmanned aircraft system. (photo by Keith Cunningham)

of unmanned aircraft systems sensing technology has already been demonstrated in projects like search and rescue and wildlife population studies.

The University of Alaska Fairbanks has been a leader in the use of unmanned aircraft system technologies for a wide variety of applications, in part because it is the only university operating a rocket range. As a result, it has decades of experience in managing its airspace during rocket launches. Examples of the university's activities include working with oil companies to monitor infrastructure and oil spill response, working with biologists to count seals and sea lions, surveying archaeological sites, conducting search-

and-rescue missions, monitoring wildfires, and assisting Alaska native villages with property surveys.

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As with all technology, unmanned aircraft systems are experiencing rapid improvements in capabilities. An excellent example is a count of Steller sea lions in the Aleutian Islands last winter.

A small quad-copter was tested in rain and snow, as well as in high winds. The unmanned aircraft system performed well in the extreme weather and was able to collect high-resolution images that were easily mosaicked. These mosaics permitted biologists to count and classify the sea lions by age and sex. The detail of these images is such that biologists studying sea lions in the Aleutian Islands were able to identify the sex of individual animals. In fact, the images were good enough to read the brands marking the animals that allow biologists to track the animals' Pacific migrations. The quad-rotor is capable of vertical takeoff and landing, making it a very flexible system for op-



Aeryon Scout quad-rotor assembled from travel case with ground control station on nautical chart. (photo courtesy of Vladimir Burkanov)

erating from a ship at sea, even in high waves and strong winds.

The figure shows 37 images collected with the quad-rotor and the resulting mosaic. The blue squares represent the location at which each image was collected by the quad-copter. The overlap in the images can generate a three-dimensional model of the ground and sea lions. The three-dimensional model is then draped with the original images to render a single three-dimensional mosaic.

Small unmanned aircraft systems are equipped with high-resolution electro-optical cameras that allow its operators to capture streaming video, thermal-infrared, and very-high-quality still images. With this technology

assessors would be able to examine individual properties in far greater detail than provided by conventional aerial imagery. Realtors in Los Angeles have even used imagery from drones to show properties to potential buyers, although these flights were illegal and the operation was shut down by the FAA (sUAS News 2013).

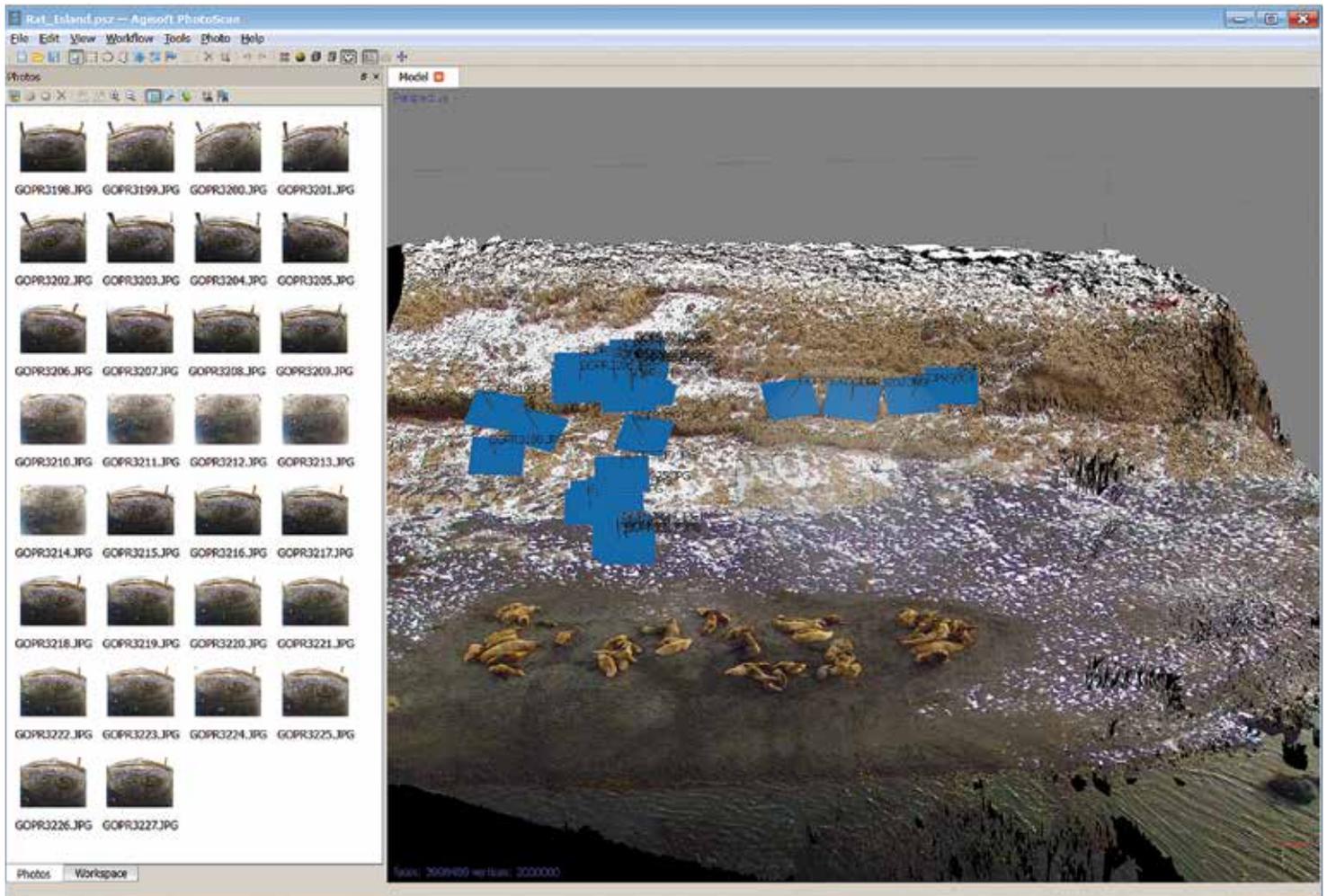
More importantly, unmanned aircraft systems would be able to gather high-quality images far more quickly and efficiently than ground systems such as street-view imaging. Unmanned aircraft are not merely a supplement to current property assessment practices—they will likely change the ways property imaging is collected in the future.

Challenges

The integration of unmanned aircraft into U.S. commercial airspace. However, a number of legal and privacy concerns have arisen. These objections will not derail the introduction of unmanned aircraft systems into civilian airspace, but it is important that they be addressed. The public should understand exactly what drone technology means for them, and the legal issues surrounding these systems should be explored so that individual privacy is respected.

Some of these privacy concerns arose from public safety applications. Police forces across the nation have begun employing small unmanned aircraft systems for tactical and surveil-

Figure. Multiple images collected with the Aeryon Scout mosaicked and draped over a three-dimensional terrain model. Note the resting sea lions and the snow on the beach.



lance purposes. Unmanned aircraft could be a boon to police: for example, a police team could use a camera-equipped rotary-winged drone to find a concealed gunman, locate hostages, or follow a fleeing suspect. The public has expressed alarm, however, that law enforcement could be watching an individual at home, where there is a legal expectation of privacy, especially when the monitoring is conducted without a warrant.

Another privacy concern is airborne spying by neighbors with recreational unmanned aircraft. Hobbyists could hover outside a window and peer inside like a Peeping Tom. Although there are existing laws protecting citizens from peepers on the ground, these laws appear vague on certain questions. For example, is surveillance legal if the unmanned aircraft remains over the property of the pilot? And how low can unmanned aircraft legally fly?

In fact, trespass laws were originally defined such that landowners had rights to their airspace extending “to the heavens.” However, airspace rights are now defined as that airspace above their land that landowners could reasonably expect to use. Thus unmanned aircraft and their pilots now have to be careful and not operate the aircraft too close to private property, though what that exactly means is not legally clear—it could be anywhere up to 500 feet. This is the major entanglement of unmanned aircraft systems with issues of property rights and privacy.

Lawmakers have been sensitive to these concerns. Many states have passed laws that would require police to obtain a warrant before deploying unmanned aircraft systems, even for a search-and-rescue mission. A highly restrictive bill proposed in the New Hampshire House of Representatives would prohibit anyone from using an unmanned aircraft to take photos of an individual’s property. The State of Virginia went even

further by banning drones in the state’s civilian airspace outright.

Citizens’ privacy concerns about the operation of unmanned aircraft systems are real, and there should be laws protecting individuals from unwanted snooping. However, heavy-handed measures threaten to quash the many positive and unobtrusive applications for unmanned aircraft. Assessors should be alert to the legal status of data collected by unmanned aircraft systems and should work toward implementing laws that would allow aerial imaging for legal purposes.

The Future of Property Assessment

Property assessment by unmanned aircraft systems is on the cusp of reality. Drones will allow assessors to do their jobs more frequently, efficiently, and effectively. Nevertheless, a variety of operational and legal issues remain to be resolved so that unmanned aircraft can be safely integrated with manned aircraft in the national airspace. As is the case with all revolutionary technologies, laws and regulations are struggling to keep up with the technology’s potential and its possibilities for misuse. But the very potential of unmanned aircraft systems technology lies in its challenge to the status quo. Unmanned aircraft have already changed the way we think about aerial data collection. The future for unmanned aircraft systems, in fact, is now.

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