"Drones" and the Future of Domestic Aviation

By JOHN VILLASENOR
University of California Los Angeles (UCLA), Los Angeles, CA, USA
Brookings Institution, Washington, DC, USA

Say the word "aircraft," and most people will envision an airplane or a helicopter with an onboard human pilot. But we are rapidly moving toward a future in which a majority of aircraft will be unmanned. "Drones," or more formally, unmanned aircraft systems (UAS), are poised to revolutionize the domestic[1] aviation landscape, raising complex questions regarding privacy, property rights, and airspace safety.

UAS have been around for a very long time. In fact, the earliest work on unmanned aircraft predates the Wright Brothers' 1903 demonstration of sustained, powered, heavier-than-air flight. In the mid-1800s, for instance, there were several successful flights of steam-powered unmanned helicopters. In the decades following the Wright Brothers' first flight, both manned and unmanned aircraft grew increasingly sophisticated. In the years preceding and during World War II, military airplanes were sometimes refitted to allow them to be flown remotely for use in target practice during training. In the second half of the 20th century, countries including the United States, the Soviet Union and then Russia, France, and Japan developed unmanned aircraft for use in military reconnaissance applications. Unmanned aviation, in short, has always been a part of the aviation story.

However, over approximately the last decade a confluence of multiple rapidly maturing technologies has spurred a dramatic increase in the pace of innovation in unmanned aircraft design and use. Imaging systems developed to meet the enormous global demand for digital cameras, smartphones, and tablet computers are also well suited for use on unmanned aircraft. Integrated circuit advances have made it possible to build small, lower power chips allowing sophisticated onboard processing of high-resolution, high-frame-rate video. Advances in wireless communication and networking are making it easier than ever before to deliver real-time information from an unmanned aircraft located 50 m—or 5000 km—away from its operator. Improved airframe design and flight control methods have enabled the construction of smaller, more capable unmanned aircraft, some of which can perform highly complex maneuvers.

Today's unmanned aircraft are amazingly diverse. There are jet-powered UAS that are the size of small business jets and have a range of thousands of kilometers. Video-capable hobbyist "quadcopters" costing only a few hundred dollars and weighing under a kilogram are now widely available in the consumer market. Under funding from the Defense Advanced Research Projects

[1]As used here, "domestic" unmanned aircraft refers to all nonmilitary unmanned aircraft, including those operated by companies, private individuals, and nonmilitary government entities such as law enforcement agencies

Digital Object Identifier: 10.1109/JPROC.2014.2302875

Agency (DARPA), California-based AeroVironment built the video-capable Nano Hummingbird, which weighs less than 20 g [1]. In 2013, a team of researchers at Harvard University reported the successful flight demonstration of the RoboBee, a robotic insect weighing 80 mg (less than one three-hundredth of an ounce), and powered by electricity delivered through a thin wire attached to an external power source [2]. In the future, advances in ultralight batteries will allow insect-like UAS to fly without needing to be tethered to a power supply.

The domestic applications for UAS are as diverse as the platforms themselves. UAS can be used for search and rescue, news reporting, crop spraying, air quality monitoring, after-the-fact crime scene investigation, surveying, disaster response, wildlife tracking, research into the dynamics of violent storms, spotting wildfires, filmmaking, and traffic monitoring. The UAS industry is large, global, and rapidly growing, with significant research and development now ongoing in dozens of countries including Australia, Brazil, Canada, China, France, Germany, India, Iran, Israel, Japan, Pakistan, Russia, Turkey, the United Kingdom, and the United States.

Aviation regulations around the world are also being updated to prepare for the era in which skies are increasingly shared by both manned and unmanned aircraft. In the United States, under the Federal Aviation Administration (FAA) Modernization and Reform Act of 2012 (FMRA), national, state, and local government agencies have had access since 2012 to expedited licenses for certain smaller (no more than 25 lb) UAS, which must be operated less than 400 ft above the ground, within the line of sight of the operator, and during daylight [3]. More comprehensive regulations for government-operated UAS are due by the end of 2015. In addition, while commercial UAS use is currently prohibited in the United States, in late 2013, the FAA released a five-year roadmap [4] addressing the integration of "civil" UAS into the national airspace system. Other countries are also working to update their aviation regulations to address unmanned aircraft, and in some cases are already permitting commercial UAS use. In Japan, agricultural spraying is commonly performed using unmanned helicopters. In Australia, some types of commercial UAS operations have been allowed for over a decade.

I. PRIVACY

Unmanned aircraft make it possible for anyone to easily and inexpensively acquire overhead imagery, including images of spaces that most people would consider private, such as the interior of a fenced-in yard not visible from the street. This has given rise to legitimate privacy concerns. Legal privacy frameworks are, of course, jurisdiction specific, so the privacy protections relevant to UAS will vary strongly across (and sometimes within) different countries.

In the United States, UAS privacy has two very different subcategories. With respect to government-operated UAS, the constitutional protection is found in the Fourth Amendment, which provides the "right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures." The U.S. Supreme Court has never specifically addressed the question of what forms of warrantless UAS surveillance would violate the Fourth Amendment. However, twice in the 1980s, in *California v. Ciraolo* and *Florida v. Riley*, the Court considered overhead observations of property adjacent to a home from manned aircraft. Both times, the Court found no Fourth Amendment violation. However, this does not mean that *all* UAS observations of a home or its surroundings will be deemed constitutional. The Court's decision in *Ciraolo*, for example, was limited to naked-eye observations from an aircraft flown in "public navigable airspace." With UAS, by contrast, there are not any naked-eye observations, and the question of what constitutes public navigable airspace is more complex than for manned aircraft.

In addition, in *Kyllo v. United States*, a 2001 ruling in a case unrelated to UAS but nonetheless involving technology-facilitated observation of a home, the Court wrote that when "the Government uses a device that is not in general public use, to explore details of the home that would previously have been unknowable without physical intrusion, the surveillance is a 'search' and is presumptively unreasonable without a warrant" [5]. In discussions about UAS privacy, the protective power of *Kyllo* is sometimes questioned on the grounds that it is only a matter of time before UAS are in general public use, and therefore potentially outside the scope of the Court's *Kyllo* holding. Yet, that is an overly pessimistic interpretation, as a careful reading of the *Kyllo* decision makes it clear that the Court did not go so far as to *endorse* the constitutionality of using a widely available technology to observe a home. The above rulings in combination with Supreme Court's broader Fourth Amendment jurisprudence suggest that the Fourth Amendment will offer more protection from government UAS observations than is commonly assumed.

For UAS operated by nongovernment entities (including both companies and private citizens) in the United States, the privacy framework involves the tension between the First Amendment on the one hand, and common law and statutory invasion of privacy protections on the other hand. The First Amendment, which provides that "Congress shall make no law. . . abridging the freedom of speech, or of the press. . .," provides strong freedom to gather information. In a 2011 ruling upholding the right of a citizen to record (using a mobile phone, not a UAS) the actions of police in a public space, the First Circuit wrote that it "is firmly established that the First Amendment's aegis extends further

than the text's proscription on laws 'abridging the freedom of speech or of the press,' and encompasses a range of conduct related to the gathering and dissemination of information" [6]. That does not mean, however, that those freedoms are unbounded. A person who, without permission, flies a UAS up to the third floor window of a residence, hovers a few inches outside, and obtains images of the interior is clearly violating privacy. Such behavior can be addressed using common law invasion of privacy torts including intrusion upon seclusion. In addition, many states have statutory invasion of privacy protections that would be implicated.

Much of the current UAS privacy debate centers on the issue of whether new UAS-focused privacy laws are needed to augment the frameworks described above, and if so, how those laws should be written. Congress has considered multiple bills that would specifically address privacy from UAS observations, though none have yet been enacted. Legislative initiatives relating to UAS privacy have also been proposed in dozens of states; in several, including Texas, Tennessee, and Virginia, new laws have been enacted.

It is easy to write laws that provide UAS privacy protection. It is much harder to do so in a manner that ensures that those laws are constitutional and that avoids creating collateral damage by prohibiting or severely limiting UAS uses that almost everyone would agree are beneficial. Many proposed (and some enacted) UAS laws, for instance, would prohibit the use of UAS imagery in criminal proceedings, unless the images were obtained pursuant to a warrant. But what happens if a UAS engaged in traffic monitoring happens to obtain video of a violent crime occurring on a nearby sidewalk? And suppose that video is the only evidence definitively identifying the suspect? Would society really be better served by laws prohibiting its use as evidence?

Laws that would prohibit private UAS operators from using unmanned aircraft to photograph people or private property without permission can also raise multiple concerns, including the prospect that they could conflict with the First Amendment. In addition, there is the practical reality that, at all but the lowest altitudes, the geometries of flight can sometimes make it hard to take *any* sort of image from aloft without incidentally including some private property within the image frame.

Despite these concerns, there are certainly some respects in which new laws are appropriate. Anti-stalking statutes, which are now on the books in all 50 U.S. states, should be updated to prohibit stalking using UAS. State invasion of privacy statues can also be modified to add UAS to the list of technologies that cannot lawfully be misused to violate privacy.

More broadly, it is also important to keep in mind that UAS, like mobile phones, the Internet, and many other technologies, offer benefits while also raising legitimate and important privacy concerns. Under some circumstances, it does indeed make sense to consider technology-specific privacy laws. But in doing so, it is also important to keep in mind the protective power of broader, non-technology-specific protections such as the Fourth Amendment.

II. AIRSPACE SAFETY

Privacy is not the only important issue raised by domestic unmanned aircraft, though it is the topic that has received most of the attention in the press. There are also important safety considerations that must be addressed to enable manned and unmanned aircraft to safely share the airspace. In particular, the operator of a UAS must have the capability to sense and avoid other aircraft. This is a very complex task. With manned aircraft, there is a mature set of standards and procedures that have been developed over many decades for ensuring that aircraft remain safely separated. However, since the information available to a UAS pilot can be very different from that available to the pilot of a manned aircraft, many of these methods cannot be directly applied to UAS operation. The task becomes even more complicated if the UAS is autonomous, i.e., flying without a human at the controls. For this reason, at least for the foreseeable future, it is unlikely that the FAA will permit autonomous UAS operation in places where there is also manned aircraft traffic.

Another complication involves the interactions of pilots with the air traffic control system, which developed under an assumption that aircraft generally had onboard pilots who could hear and immediately respond to instructions from controllers. With UAS, the pilot and aircraft are no longer at the same location, so there are more communication links involved. In addition, UAS integration raises important questions regarding the information flow among the controller, pilot, and aircraft and the procedures governing communication and control.

Some measure of safety can be obtained through license categories requiring unmanned aircraft to remain at altitudes that are lower than those most commonly used by manned aircraft. This is why the class of unmanned aircraft licenses for government operators made available as of 2012 under the FMRA requires operation less than 400 ft above the ground. However, manned helicopters sometimes fly at sub-400-ft altitudes. Fixed-wing aircraft also transition through low altitudes during takeoff and landing, and for some uses (e.g., crop dusting) stay at low altitudes for extended periods of time. And, some unmanned aircraft need to operate at very high altitudes. Thus, restrictions on UAS to low-altitude operation can be a component of a safety solution but not the whole solution, as both unmanned and manned aircraft will often need to operate at overlapping altitudes.

The small size of some UAS also complicates the task facing pilots of manned aircraft, who, meteorological conditions permitting, are supposed to

see and avoid other traffic. It is already difficult enough for a pilot to spot an approaching full-sized manned aircraft, especially when closure rates can be many hundreds of knots. Many unmanned aircraft are well under a meter in length, and could be essentially impossible for the pilot of a manned aircraft to see against ground clutter.

There are also other unmanned aircraft safety issues that will need to be addressed differently than for manned aircraft. What should the standards be for certifying that an unmanned aircraft is airworthy? What criteria should be used to determine when airworthiness certification is even needed? How should certification of unmanned aircraft pilots be handled?

Unsurprisingly, the airspace safety aspect of UAS integration is complex, and there is a wide range of techniques that can be called into play. For collision avoidance, for example, the solution is easier when the aircraft involved are flying along known trajectories and, even better, when they can collaboratively identify steps needed to maintain sufficient separation. But there will be situations in which there will be imperfect knowledge regarding all of the aircraft in the vicinity. While there is a significant amount of ongoing research and regulatory activity aimed at addressing the integration of UAS into the airspace, there is much work that still remains to be done, and regulators will undoubtedly proceed extremely cautiously.

III. RECOGNIZING THE BENEFITS OF CIVILIAN UNMANNED AVIATION

It is important to acknowledge and address the legitimate challenges that will accompany the growth of domestic unmanned aviation, including privacy and airspace safety. But it is also important not to let those challenges mask the many benefits that unmanned aviation will provide. In the coming years, unmanned aircraft will help save lives after natural disasters. They will help search-and-rescue teams find lost hikers and allow police forces that cannot afford manned helicopters to obtain vital, potentially lifesaving overhead imagery during hostage standoffs. When used safely and in a manner respecting privacy, domestic UAS can become important tools for private citizens, firefighters, scientists, news reporters, filmmakers, and others to more effectively observe the world around them.

More broadly, the 21st century will, in many ways, be the century of robotics, and unmanned aircraft will be an important part of that story. A strong robotics industry—and thus a strong unmanned aircraft industry—will be an essential ingredient to economic competitiveness. ■

REFERENCES

[1] AeroVironment Inc., "AeroVironment develops world's first fully operational life-size hummingbird-like unmanned aircraft for DARPA," Press Release, Feb. 17, 2011. [Online]. Available: http://www.avinc.com/resources/press_release/aerovironment_develops_worlds_first_fully_operational_life-size_hummingbird

[2] Wyss Institute for Biologically Inspired Engineering at Harvard University, "Robotic insects make first controlled flight," Press Release, May 2, 2013. [Online]. Available: http://wyss.harvard.edu/viewpressrelease/110/

[3] Federal Aviation Administration (FAA), "FAA Modernization and Reform Act of 2012 (FMRA)," Pub. L. No. 112-95, § 331, 126 Stat. 11, 72 (2012), §334(c)(2)(C).

[4] Federal Aviation Administration (FAA), "Integration of civil unmanned aircraft systems (UAS) in the National Airspace System (NAS) Roadmap," 2013, 1st ed. [Online]. Available: http://www.faa.gov/about/initiatives/uas/media/UAS_Roadmap_2013.pdf

[5] *Kyllo v. United States*, 2011, 533 U.S. 27, 40.

[6] *Glik v. Cunniffe*, 2011, 655 F.3d 78, 82.