Chicago-Kent College of Law
Scholarly Commons @ IIT Chicago-Kent College of Law

All Faculty Scholarship

Faculty Scholarship

April 2014

Drones

Henry H. Perritt Jr.
IIT Chicago-Kent College of Law, hperritt@kentlaw.iit.edu

Eliot O. Sprague
Modovolate Aviation, eosprague@gmail.com

Follow this and additional works at: http://scholarship.kentlaw.iit.edu/fac_schol

Part of the Administrative Law Commons, Air and Space Law Commons, Communications Law Commons, Computer Law Commons, Energy and Utilities Law Commons, Internet Law Commons, Law and Society Commons, Law Enforcement and Corrections Commons, Science and Technology Law Commons, and the Transportation Law Commons

Drones

Henry H. Perritt, Jr.[1]

and

Eliot O. Sprague[2]

Contents

---

[1] Professor of Law and former Dean, Chicago-Kent College of Law, the law school of Illinois Institute of Technology, which he served as Vice President and Chief Academic Officer for the Downtown Campus from 1997 to 2002. Executive Manager and Pilot, Modovolate Aviation, LLC. Mr. Perritt is a private helicopter and airplane pilot, and received his bachelor of science degree in aeronautics and astronautics from MIT. He worked as an application engineer and senior sales planner for Lockheed Aircraft Corporation from 1968 to 1971. He has written twenty books and nearly a hundred articles, many of them on law and technology. He served as the principal investigator of a review of the FBI's Carnivore system commissioned by the Attorney General of the United States, and was a member of the Computer Science and Telecommunications Board of the National Research Council. He is a member of the bar of Virginia (inactive), Pennsylvania (inactive), the District of Columbia, Maryland, Illinois, and the Supreme Court of the United States.

[2] Professional ENG helicopter pilot with U.S. Helicopters, Inc.; Director of Market Development and Commercial Pilot, AM Air Service; helicopter flight instructor, Midwestern Helicopter. Director of Operations and Chief Pilot, Modovolate Aviation, LLC. Mr. Sprague is a graduate of Hillsboro Aviation flight school and holds helicopter CFII, CFI, and commercial pilot ratings, and a commercial airplane rating. Mr. Sprague taught Mr. Perritt how to fly helicopters.

I. Introduction

"You're not risking human life to get a great shot. In an era where TV news is losing its audience to bloggers and other Internet sources drones can cheaply and easily obtain video images that only incredibly expensive helicopters could previously cover. . . . Drones for Electronic News Gathering or ENG will become routine.[3]

A small UAS costing between $30,000 and $50,000 is more likely to be purchased by state and local law enforcement entities because the cost is nearly equivalent to that of a patrol car."[4]

Science fiction, or is the beast already upon us?

---

[3] TV Stations to start using military drones, http://rt.com/usa/military-drone-law-news-444/ (Sept. 5, 2012) (quoting Snaproll's Preston Ryon). Snaproll Media equips drones with state-of-the-art digital movie cameras http://snaprollmedia.com/

[4] http://cnsnews.com/news/article/faa-has-authorized-106-government-entities-fly-domestic-drones (reporting on Congressional testimony by Governmental Accountability Office).

Drones are well beyond science fiction, as hundreds of dead leaders of al Queda in Afghanistan, Pakistan, and the Middle East could testify—if they were still alive.[5] What the armed forces and intelligence agencies do halfway around the world, however, does not mean that the same thing is inevitable on U.S. soil. It reveals something about technological capabilities, but it does not reflect the factors that will shape business and political decisionmaking in the U.S.

What is clear is that that drone technology is evolving rapidly and that microdrones—what the FAA calls "sUAS"—already have the capability to supplement manned helicopters[6] in support of public safety operations, news reporting, and powerline and pipeline patrol. Microdrones weighing five pounds or less and priced at the $1,000 level are on the market now.[7] They can provide crucial support in circumstances where manned helicopter support is infeasible, untimely, or unsafe. They could fly short range missions at heights and in proximity to targets that would be too dangerous for manned helicopters. Indeed, they are flying such missions now in Europe and other parts of the world. But their deployment, even for testing and demonstration, is not practicable in the United States because of the FAA's sluggish implementation of its Congressionally mandated plan to integrate drones in the national airspace.

Larger drones–"machodrones"–are not yet available outside battlefield and counterterrorism spaces. Approximating the size of manned helicopters, but without

---

[5] The FY 2012 inventory ranges from the Navy's 44,600-pound aerial combat X-47B and the Air Force/Navy 14,900 pound Global Hawk to the Army's 4.2-pound, hand-launched Raven. DOD, Report to Congress on Future Unmanned Aircraft Systems Training, Operations, and Sustainability (April 2012), (RefID:7-3C47E5F) at p.2. In 2010 the Air Force had 192 drones, the Army 364, the Navy 15, and the Marine Corps 28, in addition to some 6,200 small unmanned aircraft, which require less support. Government Accountability Office, Unmanned Aircraft Systems Table 1 at p.6 (March 2010), http://www.fas.org/irp/gao/uas2010.pdf.

[6] Rotary wing drones have the distinct advantage over fixed-wing drones that they do not need a specially prepared place to operate from. In addition, depending on their basic design, they may have much simplified control systems. See § XXX Accordingly, the article focuses on rotary wing drones instead of fixed wing drones.

[7] Assessing the impact of drones requires differentiating between two kinds: "microdrones"—what the FAA calls "sUAS," and machodrones, larger unmanned aircraft intended to be integrated into the flow of manned aircraft. Microdrones, hard to distinguish from model helicopters, are already widely available; only FAA restrictions on "commercial use" (See § XXX) have slowed their productive deployment. The University of Missouri's Drone Journalism program suffered a setback when the FAA told it to stop flying its drones on news gathering missions until it obtained a Certificate of Authorization. http://www.missouridronejournalism.com/Is this science fiction or aviation's future?.

pilots, or with human pilots being optional, their design is still in its infancy as designers await greater clarity in the regulatory requirements that will drive airworthiness certification.

This article evaluates drone technology and design and considers how well existing and likely drone capabilities satisfy mission requirements. It draws upon the authors' collective experience in flying news helicopters, giving helicopter flight instruction, practicing and teaching law, flying drug surveillance mission, evaluating best practices for helicopter support for public safety activities, and in aeronautical engineering.

It concentrates on electronic news gathering,[8] law-enforcement support,[9]. and pipeline and powerline patrol because these activities are most likely to benefit from drone operations.

Its analysis and conclusions with respect to microdrones are supported by empirical results obtained from a series of flight tests of currently available microdrones. Its assessment of machodrone deployment necessarily is more speculative. There, it explains the engineering design process and identifies the strengths and weaknesses of existing technologies, compared with likely regulatory requirements.

It concludes that the ready availability of microdrones will tempt users to deploy them even before their operational use is legal. If the FAA wants to achieve its goal of managing the introduction of these new flight technologies into the national airspace system safely, it must accelerate the regulatory process and do a better job of matching regulatory requirements with mission reality and likely aircraft characteristics. Integration of machodrones will take longer, and the FAA has more time to work with stakeholders to evolve a framework to test the limits of remote control technologies as

---

[8] See generally David Goldberg et al, Remotely Piloted Aircraft Systems and Journalism: Opportunities and Challenges of Drones in News Gathering, https://reutersinstitute.politics.ox.ac.uk/fileadmin/documents/Publications/Working_Papers/Remotely_Piloted_Aircraft_and_Journalism.pdf (June 2013) [hereinafter "Reuters Report"]

[9] These two uses are similar in many respects: the nature of the flight profiles--relatively low and relatively stationary—the equipment required--high-definition cameras with, for law-enforcement, infrared imaging capability--and the use of a pilot and a sensor monitor--usually called a Tactical Flght Officer ("TFO") in law-enforcement, and a photojournalist, usually abbreviated to "photog," in newsgathering. The capability to supplement or supplant these manned helicopter uses are similar for both industry sectors

substitutes for pilots in the cockpit.[10] The main question here is not whether the FAA will be able to channel technology, but whether the ultimate cost and capabilities of machodrones will make them attractive to purchasers and operators and whether actual vehicles will be able to compete with manned helicopters.

The article begins with an exploration of drone technology and what it suggests about drone design. It describes law-enforcement and newsgathering missions that could be performed with existing designs—if FAA regulations permitted it—and then probes particular technology developments that would enhance such missions.

It then moves to consider legal restrictions, focusing particularly on the FAA's Congressionally mandated effort to adapt its regulations to permit drones to be integrated into the National Airspace System, concluding with a projection of when different kinds of operations will be permitted. These regulatory initiatives necessarily are intertwined with further technology development, and this relationship is considered in some detail.

It concludes with projections about the likely future of drones, considering supply chain factors, labor markets, and politics.

II.   Possibilities

Aircraft design, like politics, is the art of the possible. But even more than politics, aircraft design is the art of making trade-offs. Howard Hughes build the impressive "Spruce Goose"—an eight-engine wooden aircraft intended to serve World War II transatlantic logistics needs, but it was unable to fly out of ground effect—higher than 70 feet.[11]

Trade-offs, like what is possible, are a function of the technologies available when the design decisions are made. Technologies change. The question in the background for any aircraft design is how many past design decisions should be revisited. Usually, the answer is, "not many." Empirical results and customer acceptance are well-established for existing designs, and airworthiness certification is far less demanding when a

---

[10] Now, drones are flown with an operator—what the article refers to as a "DROP." In the future, drones will be flown on their own. See § ___.

[11] http://en.wikipedia.org/wiki/Hughes_H-4_Hercules

proponent approaches the FAA with a modification of an existing design rather than something completely new.

Sometimes new mission concepts lead to completely new designs, as the need for high-altitude reconnaissance led to the U-2, the need for intercontinental ballistic missiles to deliver multiple independently retargetable warheads led to inertial guidance systems, and the goal putting a man on the moon led to the multistage Saturn rocket with a small orbiter payload.

Other times, the practicability of new technologies causes people to dream up new missions. The helicopter, which first became practicable after World War II, is an example. It caused people to think, "what could we do if we didn't need runways and could remain stationary in the air?"

In a market economy, neither the new-mission-invites-new-design nor new-technologies-inspire-new-missions process is unidirectional. Engineers and entrepreneurs come up with new design ideas all the time. Operators go shopping for systems that can perform new missions. When their ideas resonate with each other, something new happens, and the market either accepts or rejects it.

Sometimes the mission-driven process prevails; at other times the technology-driven process prevails.

In the worlds of law-enforcement and ENG, mission will drive design for machodrones, and technology will inspire new missions for microdrones.

Mission profiles for law-enforcement support and for ENG are well-established and well-accepted by the decision-makers of both communities. Neither police departments nor TV stations are fired up about redefining their air-support missions. Accordingly, one part of growing revolution will be shaped by interest in having drones to do pretty much what police and ENG helicopters do now. ENG machodrones would look similar to current ENG helicopters. Microdrones lack the capability to support that kind of ENG.[12] The news industry has certain expectations of news gathering helicopters, like speed and capability. ENG drone performance would need to be similar to existing ENG helicopters. Likewise, the law-enforcement community is comfortable with its existing helicopter designs, which look very much like ENG helicopters.

---

[12] Camera equipment weights would disqualify microdrones from the ENG world. Current ENG helicopters are deployed with 200-400 pounds of ENG equipment.

At the other end of the spectrum, however, for both law-enforcement and ENG, the new microdrone technologies will stimulate the development of new kinds of missions.

The following sections survey the technologies most relevant to law-enforcement support and ENG, identifying developments that can enable new design tradeoffs. Then they consider the interplay between mission and design with respect to machodrones and microdrones. A final section discusses purely autonomous drones.

A.   Technologies

Designing an air vehicle that excludes people opens up design constraints that historically have driven size, weight and power requirements. Now, the long-standing debate over the relative merits of man versus unmanned spaceflight is moving to aviation more generally. It raises the question: how can aircraft be flown safety from the ground, with no one actually aboard? To do that requires sensory input for the DROP (DRone Operator) roughly similar to what a pilot in the cockpit has and some robust link between the DROP and the aircraft.

One engineer says to a colleague, "We got a helicopter that weighs 2200 pounds. What happens if we don't need to have the pilot and the photog onboard? They'll stay on the ground."

"That gives us another 400 pounds of payload."

"Wait a minute? Why was it this big in the first place?"

"To carry the people and to carry the fuel

"But if we don't have the people, we don't need as much fuel. What could it do if we scale it way down, as much as by a factor of a hundred or a thousand?"

And so the design chase is on.

The following subsections consider the technologies central to this reconfiguration: electric propulsion of lighter vehicles, design of DROP ground stations, and the wireless links between vehicle and DROP.

1.   Electric powerplants

Manned helicopters must be big enough and have enough power to carry a human pilot. Unmanned helicopters can be much smaller. At smaller sizes, electric propulsion systems become practicable. Multiple rotors can be driven by small electric motors.

Their thrust can be varied by changing RPM[13] rather than changing the pitch of the blades, thus eliminating the complexity of pitch-change mechanisms.

Electrical propulsion systems are desirable because they simplify drive-train and control-system requirements and features[14] Electrical propulsion systems do not require mechanical gearboxes or mechanical shafts, all of which are sources of energy loss in piston engine or turbine powered aircraft. Instead, appropriately sized wires transfer electrical power from battery or generator to electric motors powering the rotors. In addition, because electrical motors have more favorable torque output over a wide range of RPM, rotor thrust can be varied efficiently by changing RPM, obviating the need for blade-pitch variation, as explained more fully in § XXX.

For these reasons, electrical propulsion systems predominate in microdrones. The main reason electrical component propulsion systems are not in wider use in manned aircraft and in larger drones is battery weight.

2. Control systems

Well-trained human beings are extremely good at integrating very fine and rapidly changing sensory inputs and responding appropriately, as anyone knows who can fly a helicopter—or play tennis, golf, or the piano. Robots have been around for a long time but it is only recently that robotics have gained the capability to replicate very fine human coordination.[15]

Designing systems for controlling aircraft from the ground requires attention to three cooperating subsystems: the ground control station, the subsystems aboard the aircraft for collecting data that otherwise would be sensed directly by the pilot and for applying his control inputs to hardware on the aircraft, and connecting the two. Each influences the others. For example a high resolution video display for the DROP does not assist him in flying unless cameras aboard the aircraft feed the displays with the requisite

---

[13] The torque available from piston and turbine engines peaks at a particular RPM and falls off sharply at higher and lower RPMs. See http://www.epi-eng.com/piston_engine_technology/power_and_torque.htm (explaining why torque falls off at lower and higher RPMs in piston engines, and providing graphs). The torque available from an electric motor is greatest at zero RPM and falls off gradually as RPM increases, over a much wider RPM range than for piston and turbine engines. See http://www.fastelectrics.com/elecmotorbasics.htm.

[14] See § XXX for a fuller explanation of control system simplification.

[15] CITE athleticism video

high-definition imagery. Even if the DROP is highly skilled in responding to sensory inputs, his fine control movements have to get back to the aircraft quickly and change its flight orientation.

The following subsections consider the ground station, the onboard data collection subsystem and the link. Little attention is paid to translating pilot control inputs to the hardware because that is already done in most aircraft to some extent, and the same system would be used in drones. Any aircraft has a means for translating the control inputs received from the human operator into mechanical forces applied control surfaces--to the pitch rods for the main and tail rotors in helicopters. The same means used in simple systems to reduce pilot effort or in more sophisticated autopilots for manned helicopters are a straightforward way to do this. Servo mechanisms are installed on each control.[16]

a) "Cockpit" design

If the analysis in this article is correct, that DROPs will need visual information comparable, insofar as practicable, to what they would have if they were in the cockpit. One can envision a ground station layout with a multiplicity of high definition video screens that provide real-time imagery captured from multiple cameras on the drone. The images on the screens would replicate a field of view roughly 270° laterally and 90° up and down

The biggest concern is whether, even with high-definition cameras on the drone and wraparound video displays at the console, the DROP will be able to see as much as he

---

[16]   "[A] servo system involves the control of power by some means or other involving a comparison of the output of the controlled power and the actuating device. This comparison is sometimes referred to as feedback." I. A. Getting, Servo Systems, http://www.jlab.org/ir/MITSeries/V25.PDF (basic explanation of different types of servo systems).

In a typical remotely controlled model helicopter, for example, a small electric motor rotates or otherwise moves a shaft to a position set by the user and holds it there until the user commands a different position. How to Choose the Right Servos for your RC Helicopters, http://www.rchelicopter.com/category/rc-helicopter-servos/. The source of power--the actuator--can be hydraulic as well as electrical, and typically is on larger, manned helicopters.

The Piccolo II is a 7.7 ounce avionics package that offers a full-featured automatic pilot and datalink channels for drones. https://www.cloudcaptech.com/Sales%20and%20Marketing%20Documents/Piccolo%20II%20Data%20Sheet.pdf

could if he were in the cockpit. Ensuring adequate field of view is possible with the multiplicity of cameras and video screens. Zoom lenses theoretically would give him greater visual acuity, but it takes longer to zoom a lens, even with the best human-factors design, than it does to swivel your head and focus on a particular object.

Providing depth perception, however, is a challenge without an obvious solution. Depth perception is important in spotting other traffic. For example, the FAA's standards for pilot medical certificates requires depth perception, even in pilots with serious visual deficiencies in one eye.[17] Depth perception is not possible with even the best two-dimensional image produced by the best monocular camera. 3-D movie and medical technology might address the depth perception problem.[18]

The complexity of two cameras, however, shooting each angle with just the right aiming points and fields of view would complicate the sensors on the drone and would be collateral to mission equipment. They would be necessary only for control and traffic separation. So this would represent weight and power consumption unnecessary on a manned helicopter. Likewise, the DROP might find it cumbersome to wear 3-D goggles to look at his display.

In addition, the human perceptual apparatus has the capacity instantly to focus and concentrate on a particular object within the field of view. Cameras, of course, can pan and zoom, but they cannot do it as quickly as a human can focus his visual concentration.[19] The latency in image shift is a function of the DROP having to move a mechanical controller of some kind, plus the time required for servomotors in the

---

[17] See generally
https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aam/ame/guide/app_process/exam_tech/et/31-34/mv/

[18] Research on laproscopic surgery using two-dimensional flat-panel displays compared with three-dimensional simulation with da Vinci cameras and polarizing glasses showed significant improvements in performance times and surgeon satisfaction with the 3-D simulation. It also showed, however, that experienced surgeons use monocular cues to compensate for lack of depth perception, including motion parallax by shifting the camera, relative position and size of instruments and anatomical structures, and shading of light and dark. Kazushi Tanaka, et al., Evaluation of a 3D system based on a high-quality flat screen and polarized glasses for use by surgical assistants during robotic surgery, 30(1) Indian J. Urol. 13 (2014), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3897045/.

[19] If the video display available to the DROP exactly replicates what he could see from the cockpit, he can use this perceptual flexibility just as he could in the cockpit.

camera to respond, plus latency in the connection. Even in hardwired systems, such as those installed in ENG helicopters, the latency is appreciable. It will be even greater when the video camera control inputs must traverse the uplink, depending on the bandwidth of the uplink and computer processing time on both ends.

Empirical work should precede any commitment to 3-D photography or any conclusion that there is a serious inherent problem with providing good visual information to the DROP.

b) *Cameras*

Law-enforcement support and ENG depend on good imagery. Accordingly, drones must be equipped with stabilized video camera similar to those installed on Electronic News Gathering ("ENG") helicopters.[20] These camera systems have gimbaled mounts to neutralize helicopter vibration, and servo motors that permit quick changes in azimuth and elevation relative to the helicopter's heading, and quick zooming.

The FAA plans for drone integration into the NAS reinforce this need. As § XXX explains, traffic separation in the National Airspace System depends on a see-and-avoid philosophy. This is not likely to change until well after 2020. That means that DROPs must have real-time video imagery captured from the drone—and it must be good imagery.

But one camera is not going to be enough. A human pilot has a nearly 180-degree horizontal field of view--95% away from the nose on each side--and 60-degrees upward. With eyeball rotation (but no head inclination or rotation), the horizontal field increases to almost 270 degrees.[21] He can shift his field of view in an instant by rotating and inclining his eyes and turning his head.

Replicating this visual perspective for the DROP is challenging. It will require multiple cameras, as many as five, one pointing forward, one pointing left, one pointing right,

---

[20] For example the FLIR Ultramedia HD system contains a Sony HDC-1500 camera, a 3-chip, 2/3-inch CCD device. It has 2.2 effective megapixels and 14-bit bit depth. The greater bit depth, compared with HDR-AS10 consumer camera, permits greater precision in representing the brightness of each color. A competing product from Cineflex, uses the Sony HDC-2400 camera. See http://www.cineflex.com/Our-Products/Cineflex-Media

[21] http://en.wikipedia.org/wiki/Human_eye#Field_of_view

one pointing up, and one pointing down, and a multiplicity of display screens arranged so that the DROP can see what he would see from the cockpit.

Infrared imagery, in addition to color imagery, is desirable for law-enforcement applications but not for ENG applications. Infrared imaging equipment is not presently available for microdrones. For full-sized manned helicopters, infrared equipment weighs on the order of 100 pounds and consumes about 350 watts of electrical power.[22]

Night vision equipment may be more necessary for a DROP to fly a drone at night than for a pilot in a helicopter cockpit. Even the best cameras have limitations on low-light image capture, compared with the human eye. If the camera cannot capture an image, the DROP cannot see it on his screens. Night vision equipment may be desirable for law-enforcement applications, but it is not relevant to ENG operations, unless news organizations develop a demand, not yet evident, for night-vision photography.

Any useful drone must have transceivers and antenna systems to downlink video imagery. The weight of such systems currently on the market for manned helicopters is about five pounds[23] and falling.

The technology for video imaging is changing rapidly, fueled in large part by consumer demand for lighter, higher-resolution cameras, that are sparing of battery power. It is certain that the weight, cost, and power consumption of camera for law-enforcement and ENG will fall dramatically over the next several years.

c)   *High-bandwidth wireless data links*

Because drones do not have a human pilot onboard, they must have a data link capable of transferring information about the drone's position and flight profile down to the DROP and of transferring control inputs up to the drone.

Remote control of flight vehicles is not a new undertaking. Space probes fly to Mars and collect samples on the ground;[24] deep-space probes penetrate the outer reaches of the galaxy, sending photography back to Earth.[25] None of these activities can be successful

---

[22] http://gs.flir.com/uploads/file/products/brochures/star_safire_380-hd_a_ltr.pdf

[23] http://www.trollsystems.com/images/Troll_DataSheetsPDF/SkyLinkMINI_2_DataSheet.pdf

[24] National Geographic, Mars Exploration, http://science.nationalgeographic.com/science/space/space-exploration/mars-exploration-article/ (describing Mars exploration by unmanned vehicles).

[25] See NASA, Voyager: the Interstellar Mission, http://voyager.jpl.nasa.gov/

without robust control links and other data links.[26] In comparison to the demands of space-vehicle-control technology, the requirements for terrestrial drones is modest—well within the capabilities of existing technology.[27]

Such data links comprise radio transceivers on the ground and in the drone operating on the same frequency, using compatible modulation [28] schemes and exchanging compatible data structures.

Data-link design involves determining frequencies, transmitter power, receiver sensitivity, and standardizing data structures[29] so that the transmitting and receiving units can understand each other. Depending on the distance from the DROP to the drone, relay stations may be necessary.

Each end of the link listens continuously to the other.[30] The sending side sends the pertinent data structures over and over again, with changed values if the operator has moved one of the controls, or the drone has changed position.

A variety of things can happen to corrupt or interrupt the data link. A burst of static from a lightning strike can cause a bit to be missed or a bit to be inserted. Another radio

---

[26] See NASA, Basics of Space Flight, Section II, chap. 10, http://www2.jpl.nasa.gov/basics/bsf10-1.php (describing frequencies, signal strength, coding, modulation, and ground and airborne equipoement); NASA, Basics of Space Flight, Section II, chap. 11, http://www2.jpl.nasa.gov/basics/bsf11-2.php (describing typical onboard systems). See also Space Today Online, NASA's Deep Space Network, http://www.spacetoday.org/SolSys/DeepSpaceNetwork/DeepSpaceNetwork.html (generally describing network for communicating with space systems); Nature, Laser telemetry from space (26 July 2002), http://www.nature.com/news/2002/020726/full/news020722-8.html (describing how the demands of high-quality video from space probes threaten to overwhelm available radio bandwidth).

[27] Obstructions to line of sight are not a problem, however, for space communications. Unmanned space vehicles also can tolerate much lower data rates in the control link, because they, unlike terrestrial drones, do not need to maneuver quickly. That means that the bandwidth required of drone datalinks is higher than that required for space communications.

[28] Modulation is the combination of information with a basic radio signal, known as a *carrier*.

[29] D*ata structure* is the term used by computer scientists to refer to standard ways of exchanging information between computers or between different parts of the same computer system. The data structure for positional information transmitted to the DROP by a drone might have altitude in the first field, latitude in the second field, longitude in the third field, and so on. Each field must be defined in terms of its length, and in terms of how the information is coded. The data structure for commands transmitted by the DROP to the drone could have collective position in the first field, cyclic longitudinal position in the second field, cyclic lateral position in the third field, and yaw position in the fourth.

[30] It does this by programming the computer algorithm on each end to run in the loop. It looks for new information, then processes it, and then asks for new information again.

signal on or near the data-link frequency for the drone can overpower the drone control signal.

When this happens, both ends of the data link must have a strategy for reestablishing communication if possible. They might step back for a short time interval and restart, looking for the beginning of a packet, in an attempt to resynchronize. Or, if it seems hopeless to reestablish the link, the drone should go into an autonomous state and perform some maneuver that ensures safety, such as climbing to improve line-of-sight signal reception, or autonomously returning to "home."

Datalinks can be encrypted for security, using well understood and widely available encryption algorithms.

As drone use becomes widespread, and as the demand for higher quality video increases, the limitations on available radio spectrum will become a constraint. Wireless spectrum is already crowded with voice and data communications related to manned aircraft operation. Widespread drone use will crowd spectrum further, although the FAA Roadmap assumes, "8. Communications spectrum is available to support UAS operations."

Most microdrones presently assign both their controlling and video downlink frequencies to the unlicensed Wi-Fi bands. The availability of spectrum is not likely to be a problem as long as only one drone as flying within the range of the Wi-Fi transceivers on the drone in the DROP station.

But it will not be long before multiple drones are flying in the vicinity of a public safety incident or newsworthy event, which in turn may be located in an area where multiple residents and businesses are using Wi-Fi in their ordinary activities. In such a situation, frequency congestion will occur, degrading performance for everyone and possibly interfering with effective drone control.

The wider use of drones will stress spectrum availability only if it stimulates more demand for aviation support of law enforcement and newsgathering. If the total amount of video downlink--the biggest user of spectrum--remains about the same as collected by manned helicopters now, supplemented by drone-collected video, – video

downlink spectrum requirements will not increase. The spectrum requirements for control links and ADS-B Out[31] are relatively modest.

3. Autonomous drone flight

In the near to medium term, drones will be piloted, in the sense that they will be controlled by a DROP at a ground facility who has essentially the same sensory inputs that he would have if he were aboard, and who has controls and makes control inputs similar to those he would have if he were aboard.

Technology permits drones to be autonomous: to fly some or all of their missions without a DROP.[32] The boundary between autonomous and piloted is not dichotomous: current microdrones, for example, have autopilots that are capable of hovering without operator input, and many of them have a return-to-home feature that permits them to navigate back to the launching point if the control link is lost. At the other end of the autonomy spectrum, even if a drone is authorized to fly most of its mission autonomously, a DROP might make the takeoff and landing or might fly certain parts of mission.

Already on the market are microdrones such as the ARDrone2.0 elite, costing well under $1000,[33] which have the capability to fly from waypoint to waypoint, programmed by the DROP on a movable map, using familiar GPS mapping capability. With software currently available, the DROP can assign altitudes for each waypoint, direct the drone to hover or orbit at particular waypoints, and then to return to the launching point.

An autonomous drone assigned to a law-enforcement formation, for example, could be programmed to fly a grid or more complicated patterns of particular streets in particular parts of the city, sending imagery back to a DROP and DROTFO. A drone assigned to a search-and-rescue mission could be automatically programmed to fly a standard search grid. In either case, the DROP and DROSOP could concentrate their energies on looking for anomalous situations that might indicate the target of a search effort or criminal activity rather than flying the aircraft.

---

[31] See § XXX.

[32] The FAA Roadmap says, "7. Autonomous operations are not permitted." It defines autonomous operations as any system design that precludes any person from affecting the normal operations of the aircraft." Roadmap at 33-34.

[33] See § ___ for an analysis of microdrones now on the market.

Possible roles for of autonomous drones in newsgathering is less clear. ENG helicopters, unlike police helicopters, do not engage in routine patrol according to predictable patterns; they fly ad-hoc to cover newsworthy events. It is conceivable, however, that autonomous drones could be programmed to fly traffic surveillance.

The implications of greater autonomy on performance, safety, and acceptance are hard to predict with any confidence. Labor costs would not necessarily be reduced, because it is quite unlikely safety considerations would permit an autonomous drone to operate without close human monitoring and control by personnel having the same skills required for non-autonomous operations. Autonomous drones will engender more opposition because of the perception that a human pilot can deal with an unanticipated problems better than an autopilot. Indeed, only an anticipated problem and be programmed into autopilot software. And, the greater capabilities of the software and the electronics necessary to perform autonomous missions safely undoubtedly will increase weight, cost, and power consumption.

B.   Matching mission and design

Conventional mission concepts for law enforcement and ENG will drive design for machodrones, while new technologies will inspire new missions for microdrones.

The central thesis of this article is that microdrones will be deployed in support of newsgathering, law-enforcement, and pipeline/powerline patrol activities long before machodrones will be available or cost effective. Machodrones face a much more arduous regulatory regime, considered in more detail in Part XXX, and the result of meeting regulatory requirements will drive up their price and limit their operational flexibility. Machodrones intended for civilian use have not been designed or built yet.

Microdrones capable of performing useful missions, on the other hand, are already available. While current regulatory requirements for their commercial use presently are cumbersome and, in some respects, irrational, the FAA projects near-term relaxation of the requirements.

The next two sections analyze designs and mission capabilities for the two basic categories of drones. Because machodrones are not yet available, the section on them

probes the design process more deeply than the section on microdrones, utilizing basic aerodynamic principles and rules of thumb, and speculating about cost.[34]

1.   Microdrone

Microdrones provide an example of new technologies driving new mission concepts. The point is not the microtones can do the same job that manned helicopters can. They cannot. But they can supplement helicopters.

Microdrones capable of useful missions already exist. The authors have flown two of them for educational purposes. The first, the Phantom 2 Vision,[35] is a quadcopter[36] with battery life of about a half hour that flies as high as 500 feet at 30-35 knots. Priced at $1,200, it weighs about 2.5 pounds, and has a built-in high-definition video camera that is controllable in elevation by the operator, using an iPhone. The operator can see camera imagery while he flies, and download the video recording while in-flight or after the vehicle lands.[37] The aircraft also has an autopilot that keeps it stable in a hover when the operator makes no control inputs. If the control link is lost, the aircraft automatically flies back to its point of departure on that flight and lands.[38] The second is the Parrot AR.Drone2.0.[39] It weighs less than a pound and has endurance of 15-25 minutes.

---

[34] One rule of thumb, for example, says that one horsepower is required for each 10 to 25 pounds of weight, and that the figure of merit is 60 to 80%. The figure of merit is a parameter used in helicopter design to represent the percentage of engine shaft power reflected in rotor torque. Sometimes the figure of merit includes gearbox losses; sometimes it excludes them.

These figures are validated by the descriptive facts for the Robinson R22 Beta II, which has a maximum gross weight of 1370 pounds, and a maximum continuous power rating of 124 HP. For a FOM of 60%, the weight per unit of power is 18.4; for a ROM of 80%, the weight per unit of power is 13.8, both well within the range of 10-25 pounds per unit of horsepower.

[35] http://www.dji.com/product/phantom-2-vision/

[36] A quadcopter is a rotorcraft with four main rotors, obviating the need for a tail rotor.

[37] A significant advantage of the AR over the Phantom is that the AR offers the option for streaming its high-definition video to the iPad control station, where it is automatically recorded. To obtain the video captured by the Phantom camera, one must download it from the chip after the Phantom lands.

[38] The co-authors have flown the Phantom 2 Vision for some 10 to 15 hours and confirmed its advertised capabilities. The camera does not have azimuth control, nor does it have a zooming lens, but there's no reason to believe that these features will not be added in future models or offered in competing products.

[39] http://ardrone2.parrot.com/

Based on their experience with the Phantom and the AR and an analysis of what is available to the international market,[40] the authors commissioned, through their drone R&D firm,[41] the design and construction of XXX, a microdrone they they will use for recreational and educational purposes until FAA approval is obtained for more formal commercial flight testing.

The basic design has a lightweight carbon fibre body sized to accommodate upgrades. The flight control system has a magnetometer and GPS tracking. The basic design has four pods and a quadcopter design, intended eventually to become an octocopter, with four additional motors and motors installed on the same pods that have the initial four. It has range capabilities greater than the Phantom or AR, GPS, FPV, and Bluetooth for Ipad support. It also has a built in IOC (Intelligent Orientation Control) to avoid control reversal as the orientation of the drone changes. It is designed eventually to achieve close to an hour's endurance, speeds in the 40-50 knot range and service ceilings up to 1,000 feet.

---

[40] The Aerialtronics Altura , www.aerialtronics.nl/en/products/altura, is a larger entry, with a gross weight approaching 10 pounds, endurance of up to 50 minutes, with a correspondingly larger payload. It is configured as a hybrid between a quadcopter and an octocopter, with two rotors on each hub. Dutch in origin, it is being marketed in Europe, but not yet in the United States. Some European vendors quote a price of €8,000 (about $11,000). The IRIS Custom "Spec Ops" Package, http://shop.aeroworksproductions.com/IRIS-Custom-Spec-Ops-Package-ISpecOps.htm. priced at $1,669, offers longer endurance, approaching an hour, and flexibility to configure according to user requirements, for example, by installing different cameras in the gimbal system. The 3DR Y6 Copter ARF (Special Order) http://shop.aeroworksproductions.com/3DR-Y6-Copter-ARF-Special-Order-3DRY6.htm. priced at $1,100 offers lower endurance, but flexibility in GPS waypoint autonomy. The Turbo Ace X830-D RTF (one of several options http://www.wowhobbies.com/turboacex830-dquadcopterrtfwdevo10rx1002gps4x35aescandbrushlessmotorsmgpower5300mah3s35cbatterytxbatterycx-b601strap.aspx, priced at $1,297, offers flight times of up to 30 minutes and payloads approximating two pounds. The IRIS Custom "Spec Ops" Package, http://shop.aeroworksproductions.com/IRIS-Custom-Spec-Ops-Package-ISpecOps.htm. priced at $1,669, offers longer endurance, approaching an hour, and flexibility to configure according to user requirements, for example, by installing different cameras in the gimbal system. The 3DR Y6 Copter ARF (Special Order) http://shop.aeroworksproductions.com/3DR-Y6-Copter-ARF-Special-Order-3DRY6.htm. priced at $1,100 offers lower endurance, but flexibility in GPS waypoint autonomy. The Turbo Ace X830-D RTF (one of several options http://www.wowhobbies.com/turboacex830-dquadcopterrtfwdevo10rx1002gps4x35aescandbrushlessmotorsmgpower5300mah3s35cbatterytxbatterycx-b601strap.aspx, priced at $1,297, offers flight times of up to 30 minutes and payloads approximating two pounds.

[41] www.movoaviation.com.

It has a fixed FPV camera mounting point, and a built-in 12V regulator to power FPV equipment and a gimbal. It also offers room for additional mission equipment such as higher quality video camera, FPV gear, OSD, sonar sensors, telemetry radios, and infrared cameras. and other devices. Bolt-on mounting points make it straightforward to mount sensors, cameras, and other devices.

It has GPS navigation and an autopilot to deliver autonomous hover, autonomous takeoff and landing, autonomous GPS-defined waypoint tracking, including waypoint navigation, loiter, circle, and return to launch and return to home. Mission-planning software enables unlimited waypoints for reliable, repeatable missions, and flight data analysis. Geofencing and robust failsafes ensure safe operation

Its propulsion system uses four (in the initial version) or eight (in an enhanced version) 880 Kv brushless motors

Its electrical system has a 12-volt regulator to run FPV and gimbals and a I2C splitter for extra sensor and device connections. It is compatible with large batteries (up to 12,000 mAh 4cell LiPo)

It has a dedicated controller and permits viewing real-time flight data and imagery using an iPad, an Android tablet, or a computer. A Tarot 2D brushless gimbal uses two-axis stabilization technology to ensure stable video in any flight condition.

The imagery system streams live video with superimposed live telemetry data, fed by a variety of cameras. It has its own 5.8 Ghz video transmitter and receiver pair, two 900 mAh LiPo batteries.

Additional 4S 6000 mAh batteries can be accommodated to increase endurance and payload.

It accommodates FPV DROP control with goggles.

All of these have built-in high-definition cameras, capable of streaming real-time imagery back to the ground. They all have some level of automated hover and return-to-home capability, and vary in their ability to accept different equipment. Several of these microdrones can fly a pre-programmed flight plan comprised of GPS waypoints at specific altitudes. They can hover near or orbit waypoints. All of them have the capability of operating at or near the anticipated ceiling for sUAS operation under

anticipated regulations.[42] All of them can fly at 25-35 knots, adequate for ENG, law-enforcement support, SAR, and pipeline/powerline patrol. Even the most expensive cost much less than a patrol car or ENG van.

The authors' flight tests revealed several shortcomings that suggested enhancements to mission capabilities in the XXX. First, and most significantly, the DROP's controls are reversed when the Phantom's orientation is not aligned with the DROP's line of sight. As the aircraft gets further away, it is difficult for the DROP to see which way it is aligned. In the flight test that resulted in loss of the aircraft, the authors were doing speed tests at a height of about 150 feet above the ground. As the Phantom reached the outer boundary of the test range, the DROP was unable to determine its orientation unambiguously and also was unable to determine whether the Phantom was flying away or back toward the test team as he manipulated the controls. The Phantom flew out of sight before control could be regained. Shortly thereafter, the control link and the video link were lost as well.

For reasons yet undetermined, the Phantom's return-to-home feature did not work, although it had worked on three occasions previously. The authors hypothesize that the 10 to 12 knot wind pushed the Phantom further away whiles its return-to-home feature was calculating the course it needed to fly.[43]

Any practicable microdrone must be indifferent to the orientation of the aircraft with respect to the DROP—like the AR--or, at a minimum, must provide the DROP with information about the aircraft's heading and direction of flight.

The video imagery available from the Phantom's forward-looking camera, displayed on an iPhone mounted on the control console, is insufficient to permit the DROP to fly the

---

[42] See § ___.

[43] In the 1 February 2014 flight test, control was lost when the Phantom was at 600 feet above the ground and about 600 feet slant range away from the drop. The onboard video shows that it took approximately three minutes for the Phantom to return to its launching point, and that much of this time was spent in a very gradual descent and relatively low forward speed, probably not exceeding ten knots over the ground.

Assuming that is what the Phantom did on last test flight, the wind well may have overwhelmed its slow forward speed on his return flight and kept it in the air until its batteries were exhausted.

What happened after that is unknown. A ground search, including one attempting to regain the Phantom's Wi-Fi signal, was unsuccessful.

Phantom by looking at the video screen. [44] The larger screen of an iPad used to control the AR provides better guidance, but sunglare and the limited angle of view are still problems. The DROP easily gets disoriented and has to require visual contact with the drone to re-establish navigation.

The loss of the Phantom on the 22 February flight test and the coauthors' inability to recover it were also due, in part, to the lack of positional information when control was lost. Any operational microdrone must provide latitude and longitude information at the point that the control link is lost. That would facilitate recovery.

For a microdrone to be useful for law-enforcement, ENG, or powerline/pipeline patrol, it must have better features. A police officer or photojournalist attempting to obtain video imagery from the back yard of a residence, an alley, or a photojournalist attempting to obtain a side or rear view of a fire would certainly lose sight of the microdrone's orientation, and well might lose the control link as well. For the return-to-home feature to work only in zero- or light-wind conditions would exclude conditions likely to exist in most real-world incidents, when the stress on both the aircraft and the DROP would be significantly higher than in the relatively relaxed atmosphere of the authors' flight test activities.

Practicable application requires longer endurance, better control, and more robust return-to-home features. It should not be difficult to evolve existing products to offers these enhancements. Longer endurance is simply is available simply from increasing battery capacity. As a general matter, basic airframe weight, exclusive of battery, motors, and control systems scale linearly. As power requirements increase, motor weight increases linearly. Likewise, as battery capacity increases, battery weight increases linearly.

Extending the range of the control link is lost is mainly a matter of increasing transmitter power and receiver sensitivity. Some gain also might be achieved by putting

---

[44] On one part of the 22 February 2014 flight test, the DROP was attempting to fly the Phantom with reference only to the video image, while the other member of the team kept the Phantom in sight and provided oral cues about its position, orientation, and flight path. The intended flight path took the Phantom some 15 or 20 feet over some electric power lines towards the roof of a school. The DROP was able see the rooftop on the video display but not the power lines. The video display also was inadequate to enable him to determine the orientation and direction of flight except at the grossest level. He would have lost control of it without the oral cues provided by the other member of the team.

a directional antenna on the control unit. Because the microdrone is designed to be operated always within the DROP's line of sight, it is reasonable to assume that he will always keep the control console pointed at the drone. Transmitter power can be increased mainly by redesigning circuits, perhaps adding an amplifier stage, resulting in greater power consumption. It is not likely to increase weight much.

Microdrones similar in basic design to those already on the market, but with the improvements outlined in the preceding paragraphs, would enable the following kinds of new missions, for both law-enforcement support and ENG.

Law-enforcement microdrones would be deployed and controlled by ground personnel to augment their tactical situational awareness. For example, a unit searching for a suspect might launch a microdrone to search rooftops and back yards in a residential area, or to search sidestreets and alleys in a commercial district. In many situations, one or more microdrones might be launched to enforce a perimeter. In the case of foot- or vehicle-pursuits, microdrones might be launched to keep the suspect or his vehicle in sight, and reduce the risk of surprise threats to personnel pursing on foot or of vehicle collisions.

Newsgathering microdrones would be standard equipment on ENG ground trucks, enabling the journalists to launch them to obtain different perspectives of a newsworthy scene. As more ordinary citizens have them, their use would accelerate the trend toward TV station use of amateur-captured imagery, as is already common with iPhone video. Intermediaries are beginning to emerge that link mainstream broadcasters with ordinary citizens who post news, including videos, to social media.[45]

Still, many law-enforcement and ENG decisionmakers will resist widespread use of microdrones. They will object to any ine-of-sight restriction: the DROP must be in the same general vicinity as the drone. Moreover, microdrone assets will have to be widely distributed, one in each patrol district, for example, for law-enforcement, and one in each ENG truck for newsgathering[46] Widely distributing them still does not fulfill the

---

[45] Leslie Kaufman, Teaming With Data-Mining Security Firms to Get a Lead on the News, N. Y. Times, Feb. 24, 2014 at B3 (reporting on deal between MSNBC and Vocativ, a startup that mines social media for patterns identifying news leads, and identifies video footage not available on larger sites like YouTube that are scrubbed by Google and other search engines).

[46] But see Sec. XXX, considering the possibility for launching and controlling microdrones from a manned helicopter.

requirements for effective news gathering. ENG trucks cannot make it through traffic delays to get to a scene faster than a helicopter. ENG trucks cannot cover hundreds of miles worth of roads in a single news broadcast. One of the advantages of helicopters is that they can be dispatched from a central location and be on the scene in a matter of minutes.

For pipeline and powerline patrols in rural areas, inspection personnel would carry a microdrone in their truck. They would launch it and it would patrol 20 miles or so of pipeline or powerline.[47] The DROP and his console would be in the truck. The truck would follow and retrieve it when its battery is battery is exhausted. Then the crew would plug in a fully charged battery and repeat the process. The drone would capture video, downlink it to the crew, and record it.

This scenario presents a number of problems however. The body of the truck would weaken the control datalink signal, and limit the DROP's view of the microdrone. In remote areas, the full right of way often is not accessible by ground vehicle; that's one reasons helicopters perform the patrol function. If the control and video downlink signals are carried by WiFi the drone would quickly fly out of range; the truck is not going to able to maintain 40 miles/hour over unimproved roadways under powerlines or beside pipelines.

Analysis raises significant doubts about whether this microdrone scenario would provide any benefits over manned-helicopter patrols. The helicopter can do 90 miles or so per mission, with no need for a ground crew to follow it. It can rely on visual observation by the flight crew rather than video to be reviewed after the fact. Indeed, a microdrone-centered operation might cost more than a helicopter-centered operation and be less effective.

Microdrones can play only a limited role in search operations, essentially supporting ground personnel when manned helicopters are unavailable.

2.   Machodrone

Machodrones will be late arrivals in the civilian world, preceded by microdrones. But microdrones will be suitable only for a relatively small part of the missions now flown

---

[47] Assuming endurance of a half hour and speed of 40 miles per hour.

by manned helicopters, mainly supplementing manned helicopters by flying at lower heights and closer in to the target.

The novelty of microdrone applications and their limitations compared with familiar manned helicopters, will cause many potential purchasers to focus their interest on machodrones, with altitude, speed, endurance and imagery capabilities now required of ENG and law-enforcement patrol helicopters.

Two alternative approaches exist for machodrone design to meet these requirements: adaptation of an existing type, or bottoms-up conceptualization of something new. The second approach is far more ambitious and riskier, but more likely to produce an aircraft that matches technology to mission.

The first, more cautious, approach would take an existing light helicopter model and make modifications so that it can be flown remotely to meet mission requirements for ENG or law-enforcement support and to satisfy FAA regulations for NAS integration.[48] The central advantage of this approach is that much of the design and fabrication of the base aircraft could remain intact, saving much engineering effort. There would be no need to change the fuselage, the engine, or the drivetrain, including the gearbox. Main- and tail-rotors and their hubs would remain the same. The seats for pilot and passenger and the instrument panel would be removed and mission equipment installed in their place. Cameras and an antenna assembly would be installed on the outside of the fuselage.

A system--basically the backend of an autopilot[49]—would move the control rods and the throttle linkage according to DROP inputs received over the control link.[50] Existing

---

[48] This has already occurred in the defense context. Boeing developed an unmanned version of the Robinson R22 in 1999, which became the Renegade. The effort evolved into the A160T Hummingbird, a turbine-engine adaptation of the R22,[48] and the Unmanned Little Bird, a modified MD 530F. http://www.boeing.com/boeing/rotorcraft/military/ulb/index.page?.

[49] The baseline autopilot would have more capability that the typical two-axis commercial system for light helicopters. See R. Randall Padfield, Cobham HeliSAS Brings Viable Autopilot to Light Helicopters (HAI Convention News 2013), http://www.ainonline.com/aviation-news/haiconvention-news/2013-03-06/cobham-helisas-brings-viable-autopilot-light-helicopters (reviewing performance of autopilot marketed for Bell 406, Bell 407 and Eurocopter AS350). The machodrone's on-board system would need to be capable of flying the helicopter in coupled mode. See generally See generally Frank Lomardi, Automatic Flight Control Systems, Rotor & Wing, June 1, 2013, http://www.aviationtoday.com/rw/commercial/technology/Automatic-Flight-Control-

technology would couple flight-director features to the autopilot. The flight director, in turn would be controlled remotely by the DROP, almost certainly modified to allow fine adjustments by the DROP around or along any axis, as well as the typical gross controls of heading, altitude and speed found on manned autopilot interfaces. Systems for remote control of lights, electrical systems, and engine start also would have to be installed.

The second, more ambitious, approach would not depend on any existing type of helicopter; it would aim at creating an entirely original design.[51]

Such an original design would likely result in an electrically powered quadcopter the side and capability of a manned light helicopter. Such an aircraft would avoid the 30% purely parasitic power consumption of the tail rotor by the counter rotating multiple rotors. It would avoid the weight and complexity of mechanical linkages to control blade pitch by relying on electric propulsion.[52]

The cost side of the design equation is not zero, however. Every basic system—structures, airfoils, rotors, electric motors and their control systems, batteries, flight control systems, and sensors—would be designed from basic principles. Theory would produce drawings and models; wind tunnel aerodynamic and static and destructive structures testing would provide iterative adjustments to basic design concepts; materials alternatives would be identified and choices made, flight control algorithms conceived and debugged. Then full-scale prototypes would be fabricated, and flight testing would result in further design changes. At every step of the process, performance would be traded-off against weight; performance and weight would be

---

Systems_79368.html#.Uvkw4PldU40 (explaining differences among stability-augmentation systems, stability-and-control-augmentation systems, and true, fully coupled autopilots).

[50] Electrical, hydraulic, or electro-hydraulic servos would move the cyclic forward and aft, left and right, to move the tail-rotor pitch control left and right, and to position the collective up or down. A combination of mechanical correlator and electrical governor, already installed on many helicopters, would manage the throttle setting in accordance with collective position.

[51] A similar approach has been followed by Agusta/Westland in its Project Zero, aimed at designing a feasible electrically powered in-wing tiltrotor technology demonstrator. See http://www.agustawestland.com/node/6902

[52] See § ___ for an explanation of why electric propulsion systems for rotorcraft obviate the need for blade pitch change.

traded off against raw materials costs and manufacturing costs; and everything would be tested against marketability.[53]

The development effort would be enormous, but the result would be a machodrone optimized to perform machodrone missions, rather than a prisoner of design decisions made in the past to optimize a vehicle to carry people.

Either type of machodrone would be designed to perform missions similar to those performed today by manned law-enforcement and ENG helicopters.

Missions begin either with the aircraft already in the air on routine patrol, or with the aircraft sitting on the ramp. Preflight inspection is done as soon as the crew's watch begins. Before the mission begins, the DROP and DROSOP are at their console in the ground control facility. DROPs and DROTOGs are stationed at the drone deployment site. Presumably the operators would be located at an airport or heliport, requiring a control room with the equipment necessary to fly the drone and systems for the DROTOG to work the camera and feed video to the news station. Having the two operators allow good teamwork and smooth operations.

The crew gets a call requiring deployment of the drone to provide support for ground units involved in a particular incident, or to provide coverage of newsworthy occurrences . The initial call out will be ambiguous as to certain aspects of location. The drone is airborne within 60 seconds and headed toward the incident, complying with ATC instructions and maneuvering to avoid other traffic in the vicinity. Enroute, the crew maintains voice communications with appropriate ground units, commanders or newsdesks over regular VHF or UHF voice frequencies

The drone sends real-time video imagery captured by its cameras, with quality equivalent to that that captured by state-of-the-art ENG cameras. The video imagery field-of-view would include 270° lateral coverage,[54] and -10 to +90° vertical coverage.

When the drone reaches the incident scene, it hovers or flies a low-altitude orbit, 300-500 feet above ground level, at no more than 30 knots ground speed. In this flight

---

[53] An accessible but excellent summary of the design process for a much simpler vehicle is available from the University of Maryland team that designed the runner up in the Sikorsky human-powered aircraft competition. See http://www.agrc.umd.edu/gamera/docs/pubs/gamera2-design.pdf

[54] The peripheral cameras need not have the same resolution as the forward-looking camera. Their purpose is to support traffic avoidance by the DROP, not to capture mission imagery.

configuration, the DROSOP must be able to pan the camera in elevation and azimuth and zoom the lens optically to achieve 100-times magnification when it is zoomed out. The imagery downlink to the ground station would provide quality equivalent to 1920 x 768 HD mpeg-4. Either the DROP or the DROSOP would be able to toggle the forward-looking camera between infrared and full-color modes and see the results on the console displays. The system would have video recording equipment that can capture up to three hours of video in the same quality available over the downlink. The recording equipment would be on board both the drone and the ground station to allow for interruption of the downlink.

For law-enforcement applications the DROSOP would be able to control the high-intensity searchlight on the drone in elevation and azimuth and to link its orientation to that of the forward looking camera.

The use of machodrones for powerline and pipeline patrol is even easier to contemplate. These operations occur in remote areas and require less ad-hoc, scene specific, maneuvering than law-enforcement and ENG applications. A machodrone could be programmed to fly the line of a pipeline or powerline and send its imagery back to the DROP and a utility specialist, who could take control when he sees something that requires a closer look. It also is desirable for a remote DROP flying powerline or pipeline patrol missions to be able to hand off control to the ground crew on the scene, especially if a machodrone actually is involved in delivering components for installation.[55]

Machodrones can support search and rescue missions flying like manned helicopters conducting a search. They would fly a standard search grid with no more than 50 feet deviation from any leg and delivering to the DROSOP real-time full-motion, high-definition, video and infrared imagery equivalent to that obtained by the a manned helicopter They could record the full-motion video and infrared imagery on board the drone or at the ground station, at the option of the DROSOP. They could illuminate the ground with the high-intensity searchlight at all of the specified altitudes, be able to broadcast an oral message originating with the DROSOP in real time to a person on the

---

[55] The idea is similar to that of a remotely control locomotive in a rail freight classification yard. If the crew on the ground directly controls the vehicle, they avoid delays and potential errors involved in communicating commands to the operator – the engineer of the locomotive, analagous to a DROP in a remote location.

ground at an audio level of at least 95 DB on the ground, and be capable flying at speeds from a hover to 60 knots at the option of the DROP

They could fly for six hours at heights above the ground from 200 feet to 3,000 feet at the option of the DROP or DROSOP

Eventually machodrones could accomplish rescues or providing logistical support in disaster areas. They would have all of the capabilities specified for a search and rescue drone, and, in addition, be capable of landing within a person or object on the ground within a radius of 25 feet, under the control of the DROP, where they would release a pallet or similar container with up to 100 pounds of relief supplies such as blankets, water, food rations, and a handheld radio

The DROP would have system function/malfunction indications equivalent to those available on manned helicopters.

The drone would have the capability to fly autonomously and land successfully at the launching point if the control link is lost for more than two seconds, or if the remaining battery charge is insufficient to fly back to the launching point, plus 15 minutes. If other specific system malfunctions occur, the drone would remain under the control of the DROP, so that he can make decisions about the safest course of action.

Either of the machodrone design approaches would result in an aircraft that could perform the same basic functions as a manned helicopter in law-enforcement support, newsgathering, and pipeline/powerline patrol activities. Merely because it can be done, however, does not answer the crucial questions that will decide whether it *will* be done:

First, why is a machodrone necessary, as compared with a microdrone or a manned helicopter designed to perform the same functions?

Second, will the cost and capabilities of a machodrone make it attractive to customers?

The first question is easier to answer than the second. Machodrones, compared with microdrones, will be able to carry more payload, at higher altitudes, beyond the line of sight of the DROP.[56] Relaxing these limitations of microdrones is essential to achieve

---

[56] The microdrone limitations are not the result of technology; range of the control link, payload, and ceiling can be scaled up. The limitations are the result of microdrone mission concepts being driven by what is already on the market.

mainstream mission performance. Law-enforcement agencies, TV stations, and utilities use manned helicopters now because they can quickly get from one place to another in an operating radius of a couple hundred miles. They can carry 500- to 1,000 pounds of high definition color video and infrared cameras, automatic tracking downlink microwave antennas, and searchlights. They hover, orbit, and quickly change position as developments on the ground indicate. They can safely fly anywhere from 300 feet above the ground to several thousand feet. Microdrones can do none of these things, although as § XXX explains, they can do useful things at the margins of current mission requirements. Why machodrones, as compared with manned helicopters, are necessary depends on their capabilities and cost.

This leads to the second, harder, question: whether machodrones can be built that will be attractive to customers who have a wide variety of manned helicopters available for purchase lease or contract to perform the same missions. In every instance in which a vendor might offer a machodrone, the customer can decide between it and a manned helicopter. The customer is not going to choose a machodrone unless it provides some concrete, quantifiable advantages, such as one or more of the following:

It can fly missions that would jeopardize the lives of a helicopter flight crew. This is the predominant reason why machodrones are attractive to the armed forces, intelligence agencies, and special operations units. They can fly into situations where the aircraft flight crew might be lost. Their ability to do this expands this set of missions likely to be approved. It also reduces the cost of supporting systems such as those to retrieve pilots who have been shot down, thus reducing overall system cost. This is a major reason why drones are attractive to military and intelligence commanders. It is far less likely to be an important consideration in law-enforcement support, newsgathering, or pipeline and powerline patrol, except, perhaps, for close in inspection or delivery of components for installation on powerlines.

They will have lower direct operating costs. The most significant components of direct operating costs are fuel and labor costs for the flight crew and mechanics. The skill levels – thought maybe not the temperament – required for DROPS will be similar to that required of helicopter pilots. There is a reason to believe that compensation levels for DROPS will be lower. Nor is there any reason to believe that labor hours per flight hour will be any different. Likewise, mechanic labor input and skill levels are likely to be equivalent to that for helicopters, so therefore the compensation will be the same.

Fuel costs are likely to be similar to helicopters for machodrones powered by piston or turboshaft engines. For machodrone designs employing electric power, comparing helicopter fuel costs with the equivalent for the machodrone will require a more complicated calculation, one that takes into account the trade-offs among engine weight, fuel weight, electricity to recharge the batteries, and so on.[57] But basic energy calculations suggest that the propulsion costs will be comparable, absent radical changes in oil prices.

Utilization may be higher for machodrones.[58] There is no reason to believe this would be the case, unless maintenance costs are lower, which is unlikely.

Acquisition costs for machodrones may be lower than for helicopters. This might be the case because machodrones can be a bit smaller and still have the same payload capabilities, because there are no people aboard. It might be the case because physical features, such as energy-absorbing seats, intended to protect the flight crew from harm, are not necessary. It might be the case because onboard displays and instrumentation for the flight crew is not necessary. The first two of these might reduce acquisition costs, but the third is illusory. Whatever is necessary to be displayed in the cockpit for regular helicopter pilot will have to be displayed on the ground to the DROP.

Several factors may cause machodrones to cost *more* than manned helicopters, even before development costs are amortized over a production run. Sophisticated, reliable control systems are necessary for machodrones and unnecessary for manned helicopters. Special cameras and displays will be necessary for DROPs to obtain a replica of the visual site picture naturally available if they were the cockpit. The degree of automation for flight controls will be higher for machodrones than for manned helicopters. It is easier to fly manned helicopters with stabilization systems or autopilots then to fly them without such systems, but a human pilot easily can fly safely with less sophisticated flight controls.

---

[57] The authors acknowledge good research contributions on battery technology from Patrick Grimaldi, Chicago-Kent College of Law, Class of 2016.

[58] Utilization is a common measure of efficiency for aircraft operations. Typically, efficiency is represented by the average number of revenue hours per day divided by 24 hours. It can be influenced by crew available ability, schedule constraints, or aircraft downtime for maintenance.

Then there is the question of recovering development costs. New aircraft are introduced in the marketplace only when a sufficient number of customers are willing to pay a price necessary to recover the direct cost of manufacturing, and to permit the developer to recover its development costs over the total number of sales. Aircraft manufacturers and their investors simply will not go forward with a program unless they believe that they will sell enough to recover development costs and earn a reasonable return on investment as well. Development costs of any machodrone program will be enormous, particularly one that is zero-based.[59]

Some rough numbers might be helpful in understanding the issue.

Development costs for new commercial airliners is approaching $20 billion per offering.[60] Development costs for the Global Hawk were estimated as $2.5 billion by the GAO, in 2006,[61] compared with $178 million for the Predator.[62] The order-of-magnitude difference resulted, among other things, from "immature" technologies employed in the Global Hawk, compared to "mostly mature" technologies in the Predator.[63]

With a length of 27 feet, a wingspan of 49 feet, and a maximum gross weight of 2250 pounds, the Predator is roughly the size of a machodrone with capabilities equivalent to

---

[59] In the past, new civilian aircraft designs have been introduced only because much of the development has been paid for by the Defense Department for military versions. The 747 was drawn from Boeing's entry into the C-5 heavy logistics system competition. Most early civilian helicopters were only minor variations of designs that has been paid for by the armed forces. That is not likely to be the case for civilian machodrones, because their mission requirements are so different from those for armed forces or intelligence applications, which emphasize combat environments and delivering fires. It should be no surprise that impressive machines exist in the national security context that have no civilian application. F-18s, F-35's, and nuclear submarines are obvious examples.

[60] http://www.booz.com/global/home/what-we-think/industry-perspectives/display/2013-aerospace-industry-perspective?pg=all (identifying price tag for large commercial wide-bodyes as more than $19 billion).

[61] GAO, Unmanned Aircraft Systems: New DOD Programs Can Learn from Past Efforts to Craft Better and Less Risky Acquisition Strategies (March 2006), http://www.gao.gov/assets/250/249317.pdf at page 9.

[62] Id. at page 10.

[63] Id. at 11. "New signals intelligence and multiplatform radar systems were still in technology development, not expected to be mature and be tested in an operational environment until sometime between 2009 and 2011. . . [T]here is risk that the aircraft, already being produced, will not have sufficient space, power, or cooling or that the sensor systems will weigh more than planned, reducing aircraft performance and ability to meet overall mission requirements—altitude, speed, and endurance." Id. at page 16.

that of a light manned helicopter. A civilian machdrone of similar size would not need the armament or targeting systems in the Predator, but it would need everything else. Even if the simpler civilian design cut the development cost by 90%, development would still cost on the order of $20 million.[64]

An AS350B2 news helicopter is priced at about $2.2 million. If that price reflects manufacturing costs only, because AS350 development costs have been fully recovered, it is reasonable to assume that manufacturing costs for a comparable machodrone would be similar. So a machodrone would have to sell 40 copies at a price $500,000 higher than an AS350B2 to recover its development costs.

There are 757 AS-350 helicopters presently registered in the United States.[65] That means that a machodrone manufacturer would have to displace 5% of Airbus Helicopters' market share to achieve a profitable program.

3. Hybrid helicopter/drone operations

The principal limitations of microdrone capability relate to the logistics of getting them where they are needed and then retrieving them after they exhaust their limited range. An attractive way to deal with the first of these limitations is to use a hybrid approach: a combination of a manned helicopter and one or more microdrones. This is more interesting in the context of ENG and pipeline/powerline patrol, because in law-enforcement applications ground units are usually on the scene already and can deploy microdrones themselves, even if manned helicopters also are involved. Once machodrones become commercially available, one can envision law-enforcement or ENG missions in which a manned helicopter controls drones that are deployed on an ad-hoc basis to capture imagery that could not safely be captured by the manned helicopter--for example close-up shots of a fire or a vehicle involved in an accident, or of a suspect taken from an angle that is unavailable to the manned aircraft without compromising safety. It is not clear, however, how much closer a drone could get than the effect of a manned helicopter with a zoom lens.

---

[64] Separating airworthiness certification cost from other development costs is essentially arbitrary, because the certification process and design development process are iterative. A particular subsystem design is submitted to the FAA and tested and found deficient in one way or another, so it is redesigned. The same kind of proof of design testing would be necessary, even without FAA airworthiness certification requirements.

[65] FAA aircraft registration database (search results for name and model).

In the hybrid application, a manned helicopter would be equipped with one or more microdrones to be deployed from the helicopter in-flight. The DROP would be aboard the helicopter, in addition to the customary crew of pilot and photog.

The helicopter would be deployed to the scene of a newsworthy event in the same way that it is presently. Once it gets to the scene, helicopter crew and the station personnel would make a decision as to whether deployment of microdrones would aid in coverage. If they decide it would, the pilot would maneuver the helicopter so the drone could be launched safely without the risk of its impacting the main or tail rotor, or being overpowered by the downwash.[66]

The microdrone could then fly flight profiles desirable for photographic coverage while the helicopter collects its own imagery from a flight profile that is safe for it. Microdrones, for example, could hover with the tailwind or come closer to a fire or situation involving gunfire, either of which would endanger the personnel in the helicopter.

Similarly, for pipeline/powerline patrol, one or more microdrones would be launched from a manned helicopter and the microdrones would be flown closer to the hardware than the helicopter safely could do. For pipeline/powerline patrol, a greater degree of autonomous flight[67] by the microdrone would be desirable, relieving the DROP of the monotony of having to fly up along a regular and completely predictable path followed by the pipeline or powerline.

How the microdrones would be retrieved after their battery power is exhausted is a matter that requires further consideration. It is unlikely to be cost-effective to equip the helicopter to retrieve them in flight. So they would land somewhere. Then, in a rural setting, the helicopter might land the pick them up, or they could be retrieved by ground personnel later.

---

[66] One way to reduce the risk would be to launch the drone from the right side of the helicopter, while the helicopter is in a slight sideslip to the left. This would ensure that the rotor wash blows the micro drone away from rather than into the tail rotor.
Even if a safe altitude for the helicopter exceeded the ceiling of the microdrone, the microdrone would just descend under control to its operating altitude, where its available thrust would balance would balance gravitational forces.

[67] See § XXX.

This mission definition takes advantage of comparative advantages of both types of vehicles: the superior imagery available from the helicopter and its flexibility of higher altitude and flexible deployment, and the microdrone's abilities to operate in closer quarters in regimes that would be hazardous to the helicopter.

A number of caveats are necessary, however. Safety becomes a concern with multi-purpose-role ENG platforms. Drones flying near helicopters are a potential collision hazard. Drones impact obstacles frequently due to DROP uncontrollability. Drones become a hazard to bystanders on the ground.

ENG teams will not have the ability to manage multiple tasks. The first concern is the pilots' situational awareness becoming over saturated. The Photog has a duty to provide the station with two pictures while shooting the scene. DROPS are challenged with flying a small drone under the limits of line of sight.

III.   Regulatory constraints

The FAA's regulatory approach, which has considerable buy-in--at least at the philosophical level--from major industry groups and other interested parties, is to establish separate regulatory regimes for microdrones and machodrones. Microdrones will be regulated under an adaptation of the non-mandatory FAA protocols for model aircraft flight. Machodrones will be regulated under an adaptation of the basic rules for manned aircraft, requiring certification of aircraft and personnel, and detailed flight rules.

The FAA's plans for integrating drones into the NAS roughly classifies them into two size categories: microdrones (sUAS) and machodrones (all other UAS).[68] Microdrones will fly only at low heights within sight of the DROP, but will be subject to only a few equipment requirements aimed at traffic separation. Machodrones will be able to fly in any unrestricted airspace, subject to aircraft certification, pilot certification, and

---

[68] The distinction originates with section 313 of the 2012 Act, which obligates the FAA to determine if certain drones possessing the characteristics of microdrones can be operated safely before the overall plan is implemented.

demanding equipment requirements to ensure traffic separation.[69] In effect, microdrones are segregated, while machodrones will be integrated.

This approach makes sense. As drones become larger and more advanced, flying higher, faster and out of line of sight, model aircraft rules are insufficient. Regulatory requirements must reflect a tradeoff between weight and capability, on the one hand, and equipment and operating-rule flight restrictions, on the other. If a drone weighs more than, say, ten pounds, drones be equipped with ADS-B Out, so that low flying aircraft have a chance to "see" and avoid it. The DROP needs training and certification on how to operate the drone safely as not to cause interference with other aircraft. The bigger and better performing the drone, the more regulatory oversight it and the DROP need to fly safely. The smaller and lesser performing drones need less certification and under a certain weight class ADS-B should not be mandatory.

The FAA's definition of the boundary between microdrones and machodrones is critical to their safe integration onto the NAS and to their utility in the marketplace. The philosophy for microdrone regulation is to keep them mostly out of airspace used by manned aircraft and to keep them within the line of sight of the operator so as to reduce the need for him to rely on sophisticated video subsystems to maintain control, navigate, and avoid other traffic. A weight restriction for the microdrone category conceptually limits the damage resulting from collision with another aircraft or with an object or person on the ground.

The very light microdrones now on the market for hobbyists, such as the ARDrone2.0 and the Phantom 2 Vision, are not likely to represent much of a hazard, unless one of them happens to hit the tail rotor of a helicopter.

---

[69] The basic outline for regulation of drones is reasonably clear, based on the 2012 Act and the FAA's Comprehensive Plan and the FAA Roadmap. FAA, Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap (2013), http://www.faa.gov/about/initiatives/uas/media/UAS_Roadmap_2013.pdf [hereinafter "Roadmap"]. The Roadmap addresses aircraft certification, operating rules, and airman qualification, generally following the recommendations of an industry advisory group. Roadmap sec. 1.4.3 at p. 11 (summarizing RTIC principles). The RTCA has not been free from difficulties. See Bill Carey, New RTCA Committee Seeks to Expedite UAS Standards, AINonline, http://www.ainonline.com/aviation-news/2013-04-05/new-rtca-committee-seeks-expedite-uas-standards (Apr. 5, 2013) (reporting on slow progress of 2004 committee and its replacement by new committee with mandate to expedite drone-integration standards development).

The core of the evolving regulatory environment is the identification of technologies that will allow drones and manned aircraft to co-exist.

A.   "Integration"

The 2012 legislation[70] requires the Secretary of Transportation, in consultation with interested parties, to "develop a comprehensive plan to safely accelerate the integration of civil unmanned aircraft systems into the national airspace system."[71] The FAA's Comprehensive Plan explicitly assumes that routine UAS operation should not require exceptions or unique authorizations.[72]

1.   Segregating microdrones

Paradoxically, microdrones will be "integrated" essentially by being segregated into parts of the airspace not generally used by manned aircraft. Like model aircraft, they must be flown only where they can be seen by the operator and not near airports or areas of dense population. Additionally, microdrones will be subject to a maximum weight restriction.

Thus restricted, micro drones need less scrutiny of control-link integrity, imaging sensors, display of imagery to the drop, and they do not need traffic avoidance systems.

Working out detailed requirements for microdrones is relatively straightforward: only about a half-dozen specific decisions must be made. Accordingly the regulatory regime for microdrones will be in place much sooner than that for machodrones.

The requirements for public-use microdrones have crystallized in a form that resembles rules for non-commercial model aircraft flight.[73] The requirements for civil microdrones are still in their infancy, but can be expected to resemble those for public-use.

The 2012 Act requires the FAA to decide if microdrones represent a separable category that can be regulated in a simpler regime than is necessary for machodrones.[74] The FAA

---

[70] FAA Modernization and Reform Act of 2012, Pub.L. 112-95, 126 Stat. 11 (Feb. 14, 2012).

[71] Id. sec. 332(a)(1). Section 332 of the 2012 Act obligates the FAA, in consultation with the aviation industry, to develop a plan to integrate drones into the National Airspace System. Sec. 332(a)(1), 126 Stat. 73.

[72] Comprehensive Plan at p.8.

[73] See § ___

appears to have concluded that the answer to the question is, "yes,"[75] but it has not followed through with early-stage procedures that permit available microdrones to be flown, even in test and demonstration environments, let alone to lay any real groundwork for their operational deployment. For example, microdrones, even tiny ones like the Hubsan,[76] may not be flown for commercial purposes at all unless they have a special airworthiness certificate. The current application for special airworthiness certificates[77] provides, among other things:

- Only manufacturers can obtain airworthiness certificates for production flight testing.[78]
- Flight is limited to geographic areas specified in the SAC.[79]
- Applicants must submit, "flight manuals" and checklists, evidence of a training program for crewmembers, who must be licensed pilots or have completed an FAA-approved training program,[80]
- FAA inspection of aircraft, control stations, and support equipment[81]
- The microdrone must be equipped with a transponder[82]
- Two-hour advance coordination with ATC[83]
- Annual inspection by a certified mechanic[84]

---

[74] Section 333, Pub.L. 112-95, 126 Stat. 11 (based on size, weight, speed, operational capability, proximity to airports and populated areas, and operation within visual line of sight).

[75] Roadmap at p.58 (section C.6, discussing goal of accelerated regulatory safe harbor for sUAS).

[76] [CITE and describe Hubsan]

[77] FAA Order 8130.34C, http://rgl.faa.gov/regulatory_and_guidance_library/rgOrders.nsf/0/10947cee0052205886257bbe0057bd76/$FILE/8130.34C.pdf

[78] Id., section 2, paragraph 4(a)(2), at page 2-4.

[79] chap. 3, sec. 1, para. 3, at page 3-1; Appendix A, para. 3.

[80] id. at page A-4 (requiring PIC with at least a private pilot certificate)

[81] Id. at pages 3-3 and 3-4;

[82] Id. at page A-7.

[83] Id. at page A-8.

[84] Id. at page A-9.

Existing microdrones, even the larger ones, cannot satisfy these requirements. One might try to defend the FAA's position by arguing that the requirements are necessary to ensure safety of other aircraft and persons or property on the ground. But this is not so.

There is no apparent reason why the FAA could not simply formalize its guidance for model aircraft, along the lines approved by the Congress in section 336 of the 2012 Act, and permit microdrone test and demonstration programs for commercial purposes under those rules.

The contents of the application for a special airworthiness certificate and especially Appendix A of the order, are manifestly unsuited for microdrones, given their size, payload, and flight profiles. The transponder requirement, the geographic limitations, and the reference to chase planes are entirely inconsistent with the features of microdrones. Unless the FAA provides for a separate pathway for microdrone testing, it is not acting consistent with its declared intention to accelerate integration of microdrones into the NAS.

Nor is it feasible to shift the burden of applying for certification to manufacturers of microdrones, allowing operators to fly certificated microphones within specified limitations. Part of the content of each certificate defines limited geographic areas within which microdrones can be operated, and presumably a new certificate would be required for each purchaser.

a) *Public use*

Federal, state, and local governmental entities may not fly drones in the national airspace unless they obtain a Certificate of Waiver of Authorization ("COA") from the FAA.[85] The 2012 Act requires the Secretary to expedite issuance of COAs for public UAS. [86]

Section 334 of the FAA Modernization and Reform Act of 2012[87] requires the FAA, within 90 days of enactment, to enter into agreements with government agencies to "simplify the process for issuing certificates of waiver or authorization" for small drones operated:

---

[85] FAA Makes Progress with UAS Integration, http://www.faa.gov/news/updates/?newsId=68004.

[86] Id. § 334.

[87] Pub. L. 112-95, 126 Stat. 11.

"(i) within the line of sight of the operator;

"(ii) less than 400 feet above the ground;

"(iii) during daylight conditions;

"(iv) within Class G airspace; and

"(v) outside of 5 statute miles from any airport, heliport, seaplane base, spaceport, or other location with aviation activities."[88]

The FAA reported that it "and the Department of Justice's National Institute of Justice have established an agreement that meets the congressional mandate. Initially, law enforcement organizations will receive a COA for training and performance evaluation. When the organization has shown proficiency in flying its UAS, it will receive an operational COA. The agreement also expands the allowable UAS weight up to 25 pounds."[89]

Pursuant to the Congressional mandate, the FAA simplified its process for considering governmental requests for COAs.[90] It expanded the default period of authorization to 24 months from 12, increased allowable weight to 25 pounds, and announced that it would issue COAs to law-enforcement agencies for training and performance evaluation, to be followed by operational authority once the applicant establishes proficiency.[91] It established a web-based application procedure, and provided for expedited procedures for one-time approvals of time-sensitive disaster relief missions.[92]

b) *Remote-controlled model aircraft*

The microdrone requirements resemble those for remotely controlled model airplanes, under a 1981 FAA Advisory Circular.[93] The Congress has essentially embraced these restrictions. Section 336 of the 2012 Act prohibits the FAA from promulgating rules for model aircraft, which it defines as "unmanned aircraft . . . (2) flown with visual line of

---

[88] Pub. L. 112-95 § 334(c)(2).

[89] http://www.faa.gov/news/updates/?newsId=68004 (May 14, 2012).

[90] http://www.faa.gov/news/updates/?newsId=68004.

[91] Id.

[92] Id.

[93] AC91-57 (June 8, 1981), http://www.modelaircraft.org/files/540-c.pdf.

sight of the person operating the aircraft; and (3) flown for hobby or recreational purposes.[94] The prohibition applies only if:

"(1) the aircraft is flown strictly for hobby or recreational use;

"(2) the aircraft is operated in accordance with a community-based set of safety guidelines and within the programming of a nationwide community-based organization;

"(3) the aircraft is limited to not more than 55 pounds unless otherwise certified through a design, construction, inspection, flight test, and operational safety program administered by a community-based organization;

"(4) the aircraft is operated in a manner that does not interfere with and gives way to any manned aircraft; and

"(5) when flown within 5 miles of an airport, the operator of the aircraft provides the airport operator and the airport air traffic control tower (when an air traffic facility is located at the airport) with prior notice of the operation (model aircraft operators flying from a permanent location within 5 miles of an airport should establish a mutually-agreed upon operating procedure with the airport operator and the airport air traffic control tower (when an air traffic facility is located at the airport))."[95]

c) *Height and weight restrictions*

Heavier drones have more potential than lighter drones to create damage to bystanders and personal property. If a Cessna 172 crashes, it will not have the same effect as a Boeing 777 crashing. Heavier drones also, because they have more mass, have more kinetic energy to destroy opposing aircraft. Lighter drones will have less demanding certification requirements than heavier drones and will not require specific operator certification.

(1) Height restriction

Limiting the maximum height above the ground for microdrone flights promote safety by reducing the likelihood of encountering conflicting traffic. Lower heights also mean

---

[94] Sec. 336(c)

[95] Sec. 336(a), 2012 Act. The 1981 Circular adds: "No flight higher than 400 feet above the surface.

less kinetic energy stored in a drone falling out of the sky, but a few calculations about terminal velocity will show this is not very important

The height restriction for micro-drones may not be as effective as it might seem, however. Seaplanes, for example, regularly fly enroute only 300 feet above the water. There are some areas of the country, such as the area north of Boeing Field in Seattle, and in the Anchorage Alaska area, where the effectiveness of the see-and-avoid rule is crucial at low altitudes.

In the vicinity of the Kenmore (W55) and Seattle (0W0) seaplane bases, near Seattle, for example, the floor of the Seattle-Tacoma (KSEA) Class B airspace is 1800 feet MSL and the class C airspace for Boeing Field begins just to the south. Aircraft flying instrument approaches into runway 13 fly under this airspace, talking to approach control rather than CTAF. To the southeast, the Rogers Post Memorial Seaport (W36) lies under the Class D airspace for Renton (KRNT). News helicopters, traffic into Boeing Field and seaplanes operating into Kenmore and Seattle intermingle a regular basis, communicating on the CTAF frequency. Seeing other traffic and taking appropriate of a selection is crucial in a space like this.

There are maybe a half-dozen parts of the country in which see-and-avoid is equally challenging. One way to deal with this is to prohibit either microdrone or machodrone flights in these areas.

<div align="center">(2)   The weight restriction</div>

Imposing a height restriction on microdrone operation is not enough; manned aircraft fly below 400 feet, and a microdrone mishap can endanger persons or property on the ground regardless of the height at which the drone was operating. A weight restriction also is appropriate. If a small drone weighing less than, say, ten pounds were to collide with an aircraft, survivability would be much greater than colliding with something any larger. Bird strikes are the number two accident cause with helicopters.[96] In one case the

---

[96] http://blogs.usda.gov/2013/06/06/helicopters-and-bird-strikes-results-from-first-analysis-available-online/; Washburn et al, Bird Strike Hazards and Mitigation Strategies for Military Rotary-wing Aircraft (31 December 2012) (Project No. 11-944), https://www.dodlegacy.org/Legacy/project/productdocs/FINAL%20OSD%20Legacy%20Report%20Joint %20RW%20Bird%20Strike%20Hazardswithcomments%20FINAL_ff16305b-b450-4d1c-9050-4404d614c07c.pdf [hereinafter "Bird Strike Study"]. Helicopters are much more likely to be damaged by bird strikes than fixed-wing aircraft. Bird Strike Study at 2.

pilot was incapacitated when a bird penetrated the bubble. In another, a larger bird impacted the main rotor causing it to separate and killing the occupants of the helicopter. Larger birds cause more damages and worse injuries.[97] Bigger birds have a mass similar to microdrones now on the market. The Phantom microdrone, for example, has a mass roughly equivalent to that of a mallard duck or a seagull.[98] An AR.Drone2.0 is similar to a rock pigeon.[99]

A weight limitation promotes safety by limiting the kinetic energy in the drone and therefore reduces the damage to another aircraft, ground objects, or persons on the ground if a collision or crash occurs. Engineering ballistics analysis backs this up and shows the relationship between drone weight and expected damage.[100]

A similar relationship between mass and damage to persons or objects on the the ground exists: the heavier the object, the more damage and the greater the hazard.

The current limit of 55 pounds seems too high, considering how much damage a 9.2 pound Canadian goose can do.

---

[97] Bird Strike Study at 17, 47. 200 bird strikes with U.S. civil helicopters were reported in 2011. Bird Strike Study at 41.

[98] Roger Nicholson, Kinetic Energy of Bird Strikes & Damage to Aircraft (Boeing technical paper).

[99] Id.

[100] Damage done when two objects collide depends on the kinetic energy of each when the collision occurs. Kinetic energy of a moving object is half of its mass times its velocity squared. If an aircraft collides with a hailstone, likely damage to the aircraft is modest. A small hailstone weighing one gram (0.002 pounds), has kinetic energy of 20.5 foot-poundals relative to a helicopter moving at 60 knots. The hailstone is not likely to have much horizontal velocity on its own. A 2.5-pound bird or microdrone has kinetic energy of 25,643 foot poundals. As mass increases, the kinetic energy increases linearly.

Even modest deformation of the aircraft skin or windshield can absorb all of that energy. Aluminum absorbs more energy before it fractures under impact than plexiglas. See Figure 16, http://www.kazuli.com/UW/4A/ME534/lexan%20VS%20Acrylic4.htm. Energy absorption of either is linearly proportional to thickness, for relatively thin structures. See David Roylance, Introduction to Fracture Mechanics at p. 11 (June 14, 2001), http://ocw.mit.edu/courses/materials-science-and-engineering/3-11-mechanics-of-materials-fall-1999/modules/frac.pdf [hereinafter "Roylance"].
On the other hand of 55 pound drone with a similar velocity would have 564,190 foot-poundals of energy, and a windshield or skin designed to withstand impacts with smaller objects cannot absorb that much energy without suffering penetration.

(3) The line of sight restriction

The purpose of the line of sight restriction is to increase controllability. So long as the DROP can see the microdrone, he can fly it so as to avoid collisions with other aircraft and ground objects. He can keep it under control and navigate by watching it, without reliance on more sophisticated video systems installed on the drone and in his console.

This restriction also makes it far more likely that the microdrone will remain within range of an inexpensive wireless control links at all times.

(4) Commercial use restriction

The statute, like the model-aircraft circular, excludes commercial operations. For commercial operations, a microdrone operator must obtain a special airworthiness certificate.[101] Such certificates require aircraft registration, limit operations to a defined geographic area, require pilots to be certified at the private or higher level, and require transponders, among other things.[102] Presently, special airworthiness certificates allow operations only for experimentation, data collection, and market development; not for routine operations.

The distinction between commercial and non-commercial aviation operations makes sense when the operations being regulated involve the carriage of passengers. Then, the more stringent requirements for commercial operations under Parts 119, 135, and 121 are necessary to protect paying passengers.

Drones, of course, do not carry passengers. So this justification is absent for more stringent regulation of commercial drone operations.

The scope of the existing regulations for commercial operations, however, suggests that the protection of passengers is not the only justification. Not only commercial passenger carriage, but also commercial cargo carriage, involves more stringent regulation.[103]

---

[101] Airworthiness Certification of Unmanned Aircraft Systems and Optionally Piloted Aircraft, Order 8130.34C, Para 11(b) (Aug. 2, 2013), http://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentID/1021706 [hereinafter "Special Airworthiness Order"].

[102] See Special Airworthiness Order § 1, para. 1 (registration); id., App. A, para. 3(b) (confined to defined area); id., App. A para 6(a) (pilot certification); id., App. A para. 7(b) (transponders).

[103] 14 C.F.R. § 1.1 defines "commercial operator" as a "person who, for compensation or hire, engages in the carriage . . . of persons or property . . . ." 14 C.F.R. § 119.1 subjects commercial operators to the more

Other justifications exist for applying higher standards to commercial operations. For one thing, economic incentives are likely to induce more operations. More aircraft will be flown and they will fly in more places.

For another, research into aviation safety makes it clear that a pilot or other decision-maker is more likely to fly into a risky situation when he does not want to lose the revenue for the flight, or face the prospect of losing his job or losing a contract if he makes to too many no-fly decisions. That is one of the justifications for introducing more stringent regulation of EMS operations in 2014, especially the requirement for operations control centers, limiting pilot authority to approve a flight on his own.[104]

2. Integration of machodrones

Machodrones will be regulated under an adaptation of the rules for manned aircraft including certification of aircraft types, pilots, mechanics and other crewmembers, and detailed flight rules. Differences also apparently will persist for regulation of "civil aircraft" as contrasted with "public aircraft" – those operated by units of federal, state, or local government.

The concern that necessarily will receive the most attention is the fear that collisions will result because machodrones and manned aircraft will be unable to see each other. Concerns about aircraft and pilot standards can be addressed in a relatively straightforward manner by adapting current aircraft airworthiness certification and airmen certification requirements. Adapting the rules for collision avoidance requires much more fundamental rethinking of current flight rules.

Developing flight rules necessarily invites close attention to features of machodrone flight that are unique, most obviously: the absence of a pilot in the cockpit. How can his sight picture, kinesthetic perception and control inputs be replicated from the ground? It is an extrapolation of fly-by-wire – over a very long wire, which is not even a wire.

The regulatory regime for machodrones will be based on adaptation of the elaborate system for manned aircraft, comprising detailed standards and testing requirements for

---

stringent requirements of Parts 121 (air carriers), 125 (large aircraft), or 135 (commuter and on-demand operations) in addition to the more general requirements of Part 91.

[104] See 79 Fed.Reg. 9932, 9935 (noting that time sensitivity of EMS flights puts pressure on pilots to fly); Id. at 9949 (discussion need for management approval of flights exceeding certain risk levels); Id. at 9949-9952 (discussing need for Operations Control Centers).

certification of specific models of aircraft ("types"), examination and licensing of those who want to become pilots and mechanics, and detailed flight rules. [105] In many respects, the process of adapting the existing rules will require rethinking many of them, some of which date back to the 1940s and 1950s. What risk are they meant to mitigate? Do they mitigate it in the most cost-effective manner, considering alternatives? Abundant opportunities for delay and controversy exist.

a) Certification of aircraft and DROPs

The 2012 Act requires the FAA to adopt rules to define standards for operation and certification of civil UAS. [106] Because the operating rules for microdrones and machodrones are almost certain to be quite different, the aircraft and airmen certification requirements should be different as well.

(1) Aircraft

Aircraft certification is intended to reduce the risk that that machodrone vehicles might be poorly designed or poorly manufactured, causing them to have unsafe flight characteristics or frequent failures of critical subsystems.

No person may operate an aircraft in the NAS unless the aircraft has a type certificate and a certificate of airworthiness.[107] The Roadmap says, "2. Civil UAS operating in the NAS obtain an appropriate airworthiness certificate while public users retain their responsibility to determine airworthiness.[108]

The FAA's aircraft certification process begins with application for a type certificate.[109] An applicant is entitled to a type certificate if the applicant submits design, flight-test

---

[105] The Roadmap says, "1. UAS operators [must] comply with existing, adapted, and/or new operating rules or procedures as a prerequisite for NAS integration." It also says, "5. UAS [must] meet performance and equipage requirements for the environment in which they are operating and adhere to the relevant procedures." The RTCA said, "And drone commercial operations will need to apply the operational control concept as appropriate for the type of operation, but with different functions applicable to drone operations." The Roadmap says, "9. No new classes or types of airspace are designated or created specifically for UAS operations."The RTCA said, "Drones will have access to the NAS, provided they have appropriate equipage and the ability to meet the requirements for flying in various classes of airspace . . . ." and "Routine drone operations will not require the creation of new special use airspace, or modification of existing special use airspace . . . ."

[106] Id. sec. 332(a)(2).

[107] CITE.

[108] The RTCA said, "Except for some special cases, such microdrones with very limited operational range, all drones will require design and airworthiness certification to fly civil operations in the NAS . . . ."

[109] 14 C.F.R. § 21.15.

reports, and computations necessary to "show that the product to be certified meets the applicable airworthiness, aircraft noise, fuel venting, and exhaust emission requirements of this subchapter and any special conditions prescribed by the FAA," and that "no feature or characteristic makes it unsafe for the category in which certification is requested."[110]

For example, Part 27 prescribes the airworthiness standards for normal category rotorcraft.[111] It addresses flight requirements,[112] strength requirements,[113] design and construction,[114] powerplant,[115] equipment,[116] and operating limitations and information.[117] In the flight category, the aircraft must demonstrate takeoff at maximum gross weight, with the most critical center of gravity, without exceptioning piloting skill, in a manner that allows a safe landing if the engine fails.[118] Static longitudal and directional stability must be demonstrated.[119] The structure must be designed to protect the occupants in an emergency landing involving upward loading of 4 Gs, forward loading of 16 Gs, and sideward loads of 8 Gs.[120] A HV diagram must be constructed.[121]

In each case, the burden is on the applicant to show that the candidate aircraft meets the requirements and that the aircraft can perform safely within a defined flight envelope. The flight envelope is defined as a part of the certificate and information about it must be disclosed in the form of instructions, requirements and limitations for pilots and

---

[110]   14 C.F.R. § 21.21.

[111]   14 C.F.R. Pt. 27.

[112] Id. Subpart B.

[113] Id., subpart C.

[114] id. subpart D.

[115] Id. subpart E,

[116] Id., subpart F.

[117] Id., subpart G.

[118]   14 C.F.R. § 27.51.

[119] Id. §§ 27.171-27.177.

[120]   14 C.F.R. § 27.561(b)(3).

[121]   14 C.F.R.§ 27.87.

mechanics. Typically, a completely new design gets a type certificate, specific to that model, and then subsequent modifications to the model get new airworthiness certificates with reference to the type certificate. Typically, the submissions to the FAA comprise detailed design specifications, theoretical calculations and flight test results.

For example, height-velocity diagram familiar to all helicopter pilots results from flight tests in which the test pilot demonstrates his ability to set up an autorotation from various heights above the ground and ground speeds. His success in a series of maneuvers defines the outer envelope of the crosshatched or "avoid" area of the diagram.

Certification of navigation and control systems are a demanding part of the aircraft certification process.[122]

Familiar designs are easier to get accepted than completely novel ones. For example, the Learjet 85 has suffered delays in airworthiness certification because of the difficulty of proving acceptable characteristics of its composite-materials manufacturing process for the fuselage.[123]

Airworthiness certificates are available as a matter of course for new aircraft manufactured under a type certificate if " the FAA finds after inspection that the aircraft conforms to the type design and is in condition for safe operation."[124] The requirements for certification are quite detailed.[125]

In the Frequently Asked Questions section of its website, the FAA answered the following question:

---

[122] See generally Graham Warwick, Herk Works, Aviation Wk & Space Tech., Feb. 17, 2014 at p.35 (reporting that certification of civilian version of Lockheed-Martin's C-130J depends on system-by-system certification; engines and structure of aircraft already certificated).

[123] Matt Thurber, Learjet 85 schedule in doubt, Aviation International News, March, 2014, at p.6.

[124] 14 C.F.R. § 21.183(b).

[125] See, e.g. 14 C.F.R. §§ 27.2 (seatbelt and shoulder harness requirements); 27.33 (main rotor speed and pitch limits); 27.45 (specifying relative humidity and temperatures for calculation of performance figures); 27.75 (imposing requirement for landings without excessive vertical acceleration or tendency to bounce); 27.145 (prescribing speeds for which static stability must be demonstrated); 27.303 (prescribing factor of safety for structural design).

""Currently, there are no means to obtain an authorization for commercial UAS operations in the NAS. However, manufacturers may apply for an experimental certificate for the purposes of R&D, market survey and crew training."[126]

"How long does the process take to obtain an experimental certificate?

From our experience, depending on the system and operational complexity, the process may take from 60 to 90 days."[127]

For machodrones, their higher weight, and the idea that their operations would be integrated with manned aircraft, means that they should meet essentially the same certification requirements as manned aircraft, with the exception of those requirements that address the cockpit interface between pilot and aircraft. Those requirements should be replaced by suitable requirements for interface between drone and DROP display and between display and DROP.

The most straightforward way to address certification of drones and DROPS is to establish a new category of aircraft known as "UAS" in addition to the existing categories such as airplane, rotorcraft, and lighter than air. Then, microdrones and machodrones would be defined as classes with the category.

(2)   DROPS

Certification of pilots, mechanics and other crewmembers is intended to reduce the risk of insufficiently trained and disciplined operators, who can cause even well-designed aircraft to endanger the public. The 2012 Act requires the FAA to adopt rules to establish standards for licensing of UAS operators and pilots. [128]

The FAA aims at requiring UAS DROPs to satisfy manned-aircraft pilot standards to the extent feasible:

---

[126] http://www.faa.gov/about/initiatives/uas/uas_faq/#Qn4. See generally Airworthiness Certification of Unmanned Aircraft Systems and Optionally Piloted Aircraft, (Order No. 8130.34C) (Aug. 2, 2013) http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgOrders.nsf/0/10947CEE0052205886257BBE0057BD76?OpenDocument

[127] Id.

[128] Id. sec. 332(a)(2).

"UAS training standards will mirror manned aircraft training standards to the maximum extent possible, including appropriate security and vetting requirements, and will account for all roles involved in UAS operation. This may include the pilot, required crew members such as visual observers or launch and recovery specialists, instructors, inspectors, maintenance personnel, and air traffic controllers."[129]

Human factors issues in manned aviation are well known, but there needs to be further analyses regarding integration of UAS into the NAS. In the near-term, data will be collected to permit analysis of how pilots fly UAS, how controllers provide service involving a mix of manned aircraft and UAS, and how pilots and controllers interact with each other, with the goal of developing pilot, ATC, and automation roles and responsibilities concepts.

Airman certification should be structured similar to aircraft certification. A new category, "drone operator," would be established, paralleling the airplane, rotorcraft, and lighter than air category in the existing Part 61. Particular levels would be established within these categories, such as microdrone and machodrone, roughly paralleling single-engine and multi-engine ratings. An alternative would be simply to maintain the existing levels, recreational, private, commercial, and ATP, but the complexity of the throne and its control systems should matter more in the certification of airmen than the purpose for which it is flown.

The airmen certification requirements for a microdrone DROPs should emphasize the rules and procedures that are pertinent to microdrone operations: keeping the drone in sight, limiting its height, and alternating DROP reference between the video display and visual reference to the drone.

As for aircraft certification, the requirements for my machodrone DROP certification should resemble those for pilots of manned aircraft: with greater emphasis on procedures when the control link is lost and on use of the DROP's video display to spot other aircraft and maintain situational awareness.

b)   *Collision avoidance and NextGen*

Machodrone integration will be easier because of the basic requirements of the FAA's "NextGen" initiative. The Next Generation Air Transportation System ("NextGen") is a

---

[129] Roadmap § 3.6 at p.28.

comprehensive plan for updating the National Airspace System to reflect new technologies. The 2012 Act requires that drone integration be part of the NextGen plan.[130]

NextGen is defined in large measure by the essentiality of moving "from ground-based surveillance and navigation to more dynamic and accurate airborne-based systems and procedures . . . ."[131] A central part of the NextGen environment is Automatic Dependent Surveillance ("ADS").[132] Automatic Dependent Surveillance-Broadcast ("ADS-B") comprises two different services: ADS-B Out and ADS-B In. ADS-B Out periodically broadcasts information about the aircraft on which it is installed, including current position, altitude, and velocity, derived from GPS. This information is intended to be received by ATC ground stations and other aircraft. ADS-B In receives and displays information received from other aircraft's ADS-B Out broadcasts, ADS-R, and TIS-B.[133]

In a Final Rule promulgated in 2010[134] the FAA required all aircraft operating in Class A, B, or C airspace, above 10,000 in Class E airspace, and within 30 miles of certain high-density airports to be equipped with ADS-B Out.[135] The required equipment must be operated in transmit mode at all times,[136] and must transmit, once per second:[137]

---

[130] Sec. 332(a)(2)(I), 2012 Act.

[131] ADS-B Final Rule at 30161. See also See FAA Proposed Rules, Docket No. FAA-2011-1082, 77 Fed.Reg. 50420 (Aug. 21, 2012) (analyzing comments on FAA proposal to replace airways, routes, and procedures using VOR with RNAV and RNP systems).

[132] Ultimately, drone integration will also benefit from NextGen's goal of greater reliance on digital communications for air traffic control. As a part of NextGen, voice communications gradually will be replaced by digital communications through the Controller Pilot Data Link Communications ("CPDLC") system. MITRE paper at pp.1-1, 2-11.
Certain elements of CPDLC messages can be directly loaded to Flight Management Systems ("FMS"). MITRE Report at p.2-11. Flight Management Systems are enhanced autopilots.
As these digital systems are deployed, no particular technological challenge will be presented by integrating drones and providing for CPDLC messages to be exchanged with DROPs and drone autopilots. Full-scale deployment of CPDLC is not expected, however, until the 2020 timeframe.

[133] TIS-B collects information from primary and secondary ATC surveillance radars and broadcasts it for ADS-B In receivers. ADS-R collections traffic information from ADS-B Out broadcasts and rebroadcasts it for receipt by ADS-B In receivers. ADS-B Final Rule at 30161-30162 (describing ADS and its components).

[134] FAA, Automatic Dependent Surveillance-Broadcast (ADS-B) Out Performance Requirements To Support Air Traffic Control (ATC) Service, 75 Fed.Reg. 30160 (May 28, 2010) [hereinafter "ADS-B Final Rule"]

[135] 14 CFR § 91.225(a), (b), and (d). Specifically, the regulation requires specific operators to be equipped with Extended Squitter (ES) ADS-B and Traffic information Service-Broadcast (TIS-B) operating on the

- Three-dimensional position, including latitude and longitude
- Velocity
- Barometric pressure altitude
- Length and width of the aircraft
- Call-sign or registration number
- ATC-assigned squawk code
- IDENT when requested by ATC
- Capability to indicate radio failure, emergency, or unlawful interference[138]

The Rule also sets maximum error tolerances of 0.05 nautical miles for position and 10 meters per second for velocity.[139]

ADS-B is already having a significantly favorable impact on specialized domestic operations, such as helicopter support for oil and gas operations in the Gulf of Mexico.[140]

The 2010 Rule did not require ADS-B In capability, but that is likely eventually—at least for those aircraft that must have collision-avoidance systems.

In 2012, prices for a complete Garmin ADS-B Out and In package, installed, were about $23,000.

ADS-B is the key technology for integrating drones into the NAS, but it is only a traffic conflict detection system; collision avoidance depends either on pilot action or collision

---

frequency of 1090 Megahertz (MHz) and Universal Access Transceiver (UAT) ADS-B equipment operating on the frequency of 978 MHz by January 1, 2020.

[136] 14 C.F.R. § 225(f).

[137] The ADS-B Out broadcast occurs automatically, without the need for any query from a ground station or other aircraft. It also occurs without the knowledge of whether other aircraft or ground stations are receiving it. RTCA, Minimum Aviation System Performance Standards For Automatic Dependent Surveillance Broadcast (ADS-B) § 1.2.1 at p.3 (June 24, 2002), http://adsb.tc.faa.gov/WG6_Meetings/Meeting%2016/WG6-WP16-04-Working%20Draft_242B_Body_V1.pdf (description of ADS-B, its capabilities, and the infrastructures in which it can provide the basis for controlling air traffic).

[138] 14 C.F.R. § 91.227(d) (setting minimum message elements).

[139] 15 C.F.R. § 91.227(c).

[140] See FAA, NextGen is Platorm for Helicopter Flights, http://www.faa.gov/nextgen/snapshots/stories/?slide=21 (reporting on impact of ADS-B on 5,000-9,000 daily helicopter operations in Gulf of Mexico, enabling PHI to increase IFR flights from 1,500 hours annually to almost 20,000).

avoidance software layered on top of traffic conflict detection software. Airborne Traffic Collision Avoidance System ("TCAS") initially were developed and deployed before widespread availability of GPS,[141] based on transponder signals from the conflicting aircraft. Transponders, however, do not provide information on direction of flight.

Now GPS provides all the relevant data, including position, altitude, and direction and speed of flight. Two basic approaches have evolved. One gives urgent voice synthesizer commands to the flight crew. When the data is available, typical TCAS systems can issue synthetized voice commands such as:

"Traffic! Traffic! Climb, Climb – Now"

or

"Traffic! Traffic! Descend, Descend – Now"

And so on

The second basic approach is to command the aircraft to perform evasive maneuvers without pilot intervention. For the second approach to be available, the aircraft must be equipped with an autopilot. Pilots generally disfavor the automatic approach because they do not want their aircraft to be programmed to make some abrupt maneuver that they have no way of expecting.

With either approach, determining the protocols for collision avoidance is more challenging than programming the protocols into software. Suppose two aircraft are approaching head on. One of them dives to avoid the other, but the other dives as well and so they still collide. Lateral evasion is easier, as are head-on conflicts when there is some altitude separation or overtaking situations. For all of those, the FARs and the rules of the road prescribe what each aircraft must do.

Adapting this technology to drones is straightforward. The challenges of getting the collision avoidance protocols right remain, but either the voice synthesized approach or the automatic evasive action approach is conceptually feasible. The urgent voice-synthesized command can be given to the DROP, and he would fly the drone

---

[141] See James K. Kuchar & Ann C. Drumm, The Traffic Alert and Collision Avoidance System, 16 Lincoln Lab. J. 277 (2007), http://www.ll.mit.edu/publications/journal/pdf/vol16_no2/16_2_04Kuchar.pdf (summarizing history and development of TCAS).

appropriately, just has an onboard pilot would. Likewise, assuming the drone is equipped with autopilot, automatic evasive maneuvers can be triggered.

Collision avoidance systems for drones will surely piggyback off the ongoing development of traffic detection and collision avoidance systems for manned aircraft as part of the NexGen effort. The Roadmap says, "4. All UAS [must be] equipped with ADS-B Out and transponder with altitude-encoding capability. This requirement is independent of the FAA's rule-making for ADS-B Out.Traffic detection equipment promotes safety, especially if it is coupled with collision avoidance capability. It directly manages the risk of midair collisions, but it has nothing to do with avoiding threats to people or property on the ground, except by reducing the likelihood of collisions with other aircraft and resulting crashes of one or more of the aircraft

Several challenges exist, however, in implementing requirements for drones that will permit them to be integrated into the NAS before 2020. Identifying and installing the necessary equipment in drones is not a major problem, although it will increase weight and cost. The traffic detection and avoidance hardware and software will be the same as is being developed for manned aircraft and discussed in § ___. The physical design will have to be different, however. Manned aircraft solutions place a premium on good graphical video displays in the cockpit. For drones, good graphical displays will have to be available to the DROP, not in the drone itself. So the interface among transceiver, processor, and display components will be different: hardwired and physically proximate in manned aircraft; wireless and remote in drones. That has implications for the necessary bandwidth in the communications link. It's one thing for the drone to send frequent updates on its own position and velocity vector down to the DROP; it's another thing for it also to send large amounts of position and velocity vector information about other aircraft.

Second, is the question of how responsibility for collision avoidance will be divided between exercise of human judgment by the DROP and automatic evasive maneuvers programmed into the drone's flight control system. Collision avoidance algorithms for manned general aviation aircraft is still in its relative infancy as part of NexGen.

Exercise of human judgment for collision avoidance is feasible, but its effectiveness depends on the capabilities of what the DROP sees[142] and how quickly the drone can respond to his commands.[143]

c) ATC communications

The Roadmap preserves ATC authority to control access to airspace and ensure traffic separation, but without direct links to drones.[144] DROPS must "compl[y] with all ATC instructions and use standard phraseology . . . ." Drones must comply with ATC clearances and instructions, including instructions that require visual reference,[145] but the FAA identifies the following realities that must be considered:

"• The UAS pilot must depend on a data link for control of the aircraft. This affects the aircraft's response to revised ATC clearances, other ATC instructions, or unplanned contingencies (e.g., maneuvering aircraft);

"• UAS cannot comply with certain air traffic control clearances, and alternate means may need to be considered (e.g., use of visual clearances);

"• And some UAS launch and recovery methods differ from manned aircraft and require manual placement and removal from runways, a lead vehicle for taxi operations, or dedicated launch and recovery systems."[146]

A drone with a ground operator can deal with voice communications, most likely by equipping the drone with the appropriate transceiver and antenna for ATC and air to air communications and then inserting those communications on the down link to the ground operator. The ground operator's radio transmissions back to ATC or to other aircraft would be uplinked to the drone and transmitted by it.

For example, a drone approaching airport for might get a tower instruction that says, "Extend your downwind leg until cleared to start base. You're number two, to follow the Piper Arrow on long final. Advise when you have him in sight." The DROP would examine his video display showing live video captured by cameras on the drone and

---

[142] The DROP's visual capability is considered in § ___.

[143] Replicating a pilot's visual field of view is considered in § XXX.

[144] Roadmap, items 10-14. The RTCA said, "Drones will comply with ATC instructions, clearances, and procedures when receiving air traffic services . . . ."

[145] Roadmap at 17.

[146] Roadmap at 18-19.

respond by voice radio, "We'll extend downwind. We have the traffic in sight." Except for the two-stage radio link, and the fact that the DROP is on the ground, the transaction is the same as it would be for a manned aircraft in the same position.

Similarly, for IFR operations, the question is not whether the drone autonomously can fly an IFR flight plan; it probably can, assuming it has a state-of-the-art autopilot. The question is how amended clearances would be transmitted—digitally to the drone, or verbally to the operator.

d) *See and avoid*

The core principle for reducing the risk of mid-air collisions between aircraft is "see-and-avoid." Pilots must keep a lookout for other aircraft and comply with various right-of-way rules to avoid them. When weather conditions do not permit visual observation of other aircraft, a distinct regulatory regime shifts responsibility for traffic separation to air traffic controllers. Visual Flight Rules ("VFR") use see-and-avoid, supplemented by ATC instructions at busier airports and differing weather criteria for different types of airspace, depending on traffic density.[147]   Instrument Flight Rules ("IFR")[148] apply when the weather is bad, or when a qualified pilot prefers to yield some of his autonomy to ATC. Each of these presents different challenges for integrating drones into the flow of manned aircraft traffic. The 2012 Act requires the FAA to adopt rules to require that all civil UAS include a "sense and avoid capability."[149]

Under VFR,[150] pilots may fly wherever they want, at whatever speeds and on headings they want. Certain geographically specific restrictions are imposed, however. A handful of prohibited areas exist, such as those over certain national facilities in Washington and over certain national defense facilities. Operation in prohibited areas requires advance permission from a controlling authority.

IFR flight is permitted only pursuant to an IFR clearance,[151] which specifies the precise route of flight, altitudes, and, in some cases, speeds. Typically, a pilot files an IFR flight

---

[147] 14 C.F.R. § 91.XXX.

[148]   14 C.F.R. § 91.XXX.

[149] Id. sec. 332(a)(2). See Roadmap at 18-19 (identifying challenges).

[150] A pilot may elect to fly VFR whenever sky conditions provide more than three statute miles of visibility and ceilings of 1,000 feet above ground level or better.

[151] Pilots who have instrument ratings may fly IFR in IFR-equipped aircraft even when conditions are VFR. In Class A airspace, that airspace above 18,000 feet, only IFR is permitted.

plan through the Internet, on the telephone—or at a rapidly diminishing number of Flight Service Stations, by filling out a printed form and submitting it in person. Then, when he is ready to take off, he calls ATC on a frequency known as Clearance Delivery and receives his clearance, which may be the same as that filed or different. A typical IFR flight plan would read:

It is not unusual for a pilot to receive one or more amendments to his IFR clearance enroute, to accommodate potentially conflicting traffic and changing weather conditions.

The challenge for integrating drones into either VFR or IFR traffic is, not so much how to design and deploy systems that enable onboard computers to detect and to decide how to avoid traffic, but rather to understand what the human operator can perceive through his video link, whether he can detect conflicting traffic visually, or with the aid of onboard collision avoidance systems alerting him through the video link, and how quickly the data link will allow him to take evasive action.

Instrument flight rules will be easier to adapt for machodrones then visual flight rules. See-and-avoid is not so central to IFR as it is to VFR. To sit in the cockpit, scan gauges and provide appropriate control imputs is not all that different from sitting on the ground doing the same thing. Of course the nature of the control link differs, extended much further, and rewiring on wireless radio instead of wired signals or mechanical linkages.

The capability of drones to fly IFR flight plans does not mean, however, that IFR flight plans should be required. The Roadmap says, "3. All UAS must file and fly an IFR flight plan." This is manifestly infeasible if full drone capabilities are to be available. Filing and adhering to an IFR flight plan is completely incompatible with useful law-enforcement or ENG missions. Instead of being point-to-point flights of relatively long distances, well-suited for IFR clearances, law-enforcement and ENG machodrones must follow unpredictable routes and be able to change position quickly. Requiring them to obtain an amended IFR clearance every time they want to move around would make mission performance impossible.

e)　　　*Special drone arrival and departure procedures*

The National Airspace System can handle drone traffic with proper procedures. Special rules of the air exist, much like rules of the road, to keep the flow of traffic moving efficiently, and, more importantly, special procedures limit risk in congested airspace.

Currently aircraft arrival and departure procedures are used 24/7 to keep the flow of air traffic flying smoothly in the vicinity. Such procedures expedite the flow of traffic and minimize radio congestion in and around busy airports. Airborne routes such as instrument approaches map a route for aircraft to fly into airports providing altitudes, headings and speeds. These instrument approaches provide terrain and obstacle clearance.

Drone arrival routes would be structured similar to that of an instrument approach or departure procedure. Utilizing a "plate" a DROP would simply taxi the drone to a pre-approved departure point on the airfield. When ready for departure the DROP would call ATC providing a tail number and name of the departure plate. ATC would clear the aircraft for the departure. From then on very limited radio communication, if any, would be needed. Traffic, obstacle separation would not be an issue because of the pre-determined route.

Depicted arrival/departure procedures would be published by the same methods under which current charts are published.[152]

The basic concept resembles that presently in the FARs for helicopter flight into and out of and in the vicinity of airports with significant fixed wing traffic.[153] Typically, at a tower-operated airport, helicopters receive clearances to operate directly from ramps and taxiways, while fixed wing aircraft use the runways. These helicopter rules are not mandatory and usually are defined on an ad hoc basis in radio communications between an air traffic controller and helicopter pilot.

---

[152] See generally FAA, Aeronautical Information Manual § 5-4-1 (STARs); id. § 5-2-8 (DPs) (2014).

[153] For example, 14 CFR § 91.126(b) prescribes traffic patterns for fixed wing aircraft operating at airports without control towers, while simply saying that helicopters must be operated so as to "avoid the flow of fixed wing aircraft." 14 C.F.R. § 91.126(b)(2).

Also, in major cities, the FAA publishes helicopter charts that show nonbinding "preferred routes" over expressways or other prominent ground features which ease the burden on air-traffic controllers and pilots when helicopters fly these routes.[154]

These special rules for helicopters embrace the idea that aircraft with significantly different flight characteristics can be separated without much burden on either type of aircraft. They represent a model for doing the same thing with drones.

f) *Fail-safe protocols*

For about 80 years, a central philosophy of traffic separation in the NAS has been based on knowing what to expect from other aircraft. This is a philosophy inherited from rules of the road for maritime navigation. It is as important that the vessel with the right-of-way assert its right-of-way[155] as it is for the vessel obligated to give way to alter course. In its application to aviation, an aircraft being overtaken has the right-of-way, and the overtaking aircraft must alter course to the right. The overtaken aircraft, having the right-of-way, must maintain its course.

So also when in-flight emergencies or less urgent incidents occur. An IFR flight losing radio communications is obligated to fly the last clearance.[156] An aircraft experiencing an emergency necessitating deviation from an ATC clearance may deviate as necessary,[157] but must inform ATC by radio as soon as it can do so safely.[158]

One of the challenges for integrating drones into the NAS is to prescribe rules for drones experiencing emergencies that let everyone else – other aircraft and controllers – know what to expect. The first step an outlining such an approach is to identify what might happen that would constitute an emergency. The following incidents clearly belong to any list:

- Propulsion plant failure

---

[154] See, e.g. FAA, Chicago Helicopter Route Chart (21 October 2010) (depicting "Des Plaines" standard route through O'Hare Class B airspace).

[155] See http://www.boatus.com/foundation/guide/navigation_3.html (stand-on vessel--the one with the right of way--must maintain current course and speed until burdened vessel has passed).

[156] 14 C.F.R. § 91.185(c).

[157] 14 C.F.R. § 91.3(b).

[158] FAA, Airman's Information Manual ("AIM") § 1 at p. 835.

- Loss of control link
- Loss of control while the control link is maintained
- Impairments to visibility
- Loss of navigational datalink
- Loss of voice communications through the drone

The responses should be different depending on whether the DROP is still able to control the drone. If he is unable to control the drone because of a loss of the control link or for other reasons, three options are possible.

- The drone lands immediately
- The drone returns to its starting point
- The drone follows the last flight plan that was agreed to with ATC.

Whether returning to base or continuing to fly the flight plan is feasible depends on endurance remaining. The DROP should know remaining endurance before he lost contact.

Landing immediately or returning to the starting point represents a deviation from what is expected by nearby users of the airspace. That means that some mechanism is necessary to alert the others to the drone's intentions or at least to alert them to the fact that the drone is in distress. A standard way of doing that for manned aircraft is for the pilot to transmit a radio call, either "Mayday, Mayday Mayday," for a serious emergency or "Pan, Pan, Pan," for a less urgent incident. In addition, if the aircraft is transponder equipped, the pilot must squawk 7700 for an emergency or 7600 for a radio communications failure.[159] Any drone capable flying outside the line of sight of the DROP will be transponder equipped, and its on board flight control systems can be programmed to set a special transponder code when one of the listed incidents occurs.

A lost communications link is one obvious trigger for an emergency procedure. Indicative of the FAA's approach to lost-link procedures is this passage from the order for special airworthiness certificates:

"In the event of lost link, the UA must provide a means of automatic recovery that ensures airborne operations are predictable and that the UA remains within the flight

---

[159] AIM § 6-2-2.

test area. The chase aircraft or observer, all other UAS control stations, and the appropriate ATC facility must be immediately notified of the lost link condition and the expected UA response. Comply with the following provisions:

"(1) If lost link occurs within a restricted or warning area, or the lost link procedure takes the UA into a restricted or warning area, the aircraft will not exit the restricted or warning area until the link is re-established.

"(2) The UA lost link mission will not transit or orbit over populated areas.

"(3) Lost link programmed procedures will avoid unexpected turn-around and/or altitude changes and will provide sufficient time to communicate and coordinate with ATC.

"(4) Lost link orbit points will not coincide with the centerline of published airways."[160]

B. Six FAA test regions

The 2012 Act requires the FAA to establish pilot projects at six test ranges [161] to conduct research and development in operational settings to support its eventual requirements for aircraft and airman certification and flight rules. The test range program is to continue until 2017, with a report to Congress within 90 days after its termination.[162]

On 30 December 2013, the FAA selected six test sites for drone research and development.[163] Each has a particular area of focus

- University of Alaska-standards for unmanned aircraft categories, state monitoring and navigation, and UAS operations.
- State of Nevada- UAS standards and operations, operator standards and certification requirements; evolution of air traffic control procedures.
- New York's Griffiss International Airport- test, evaluation, verification and validation processes under FAA safety oversight; sense and avoid capabilities.

---

[160] Airworthiness Certification of Unmanned Aircraft Systems and Optionally Piloted Aircraft, Order 8130.34C, Para 11(b) (Aug. 2, 2013),
http://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentID/1021706.
[161] § 332(c)(1) Pub.L. 112–95
[162] Roadmap at 60.
[163] http://www.faa.gov/news/press_releases/news_story.cfm?newsid=15576.

- North Dakota Department of Commerce- airworthiness essential data, validation of high reliability link technology; and human factors research.
- Texas A&M University – Corpus Christi- system safety requirements and protocols and procedures for airworthiness testing.
- Virginia Polytechnic Institute and State University (Virginia Tech)- failure mode testing and identification of operational and technical risks areas.[164]

The test site approach is logical and should result in much useful data and analysis, helping to crystallize regulatory approaches. It will be an impediment, however, if the FAA defers all other proposals for drone testing until 2017.

Moreover, if the FAA requires the six test site operators to obtain certificates of airworthiness for microdrone testing, and if it is inflexible in adapting the published requirements,[165] the test site program may not provide much useful information about microdrones.[166]

C.   Regulatory timeline realities

As of early 2014, the FAA had released its Congressionally mandated Comprehensive Plan for integrating drones into the NAS,[167] its first annual "UAS Roadmap," summarizing regulatory steps to integrate drone operations into the national airspace,[168] a final privacy policy for the six UAS test sites,[169] and conducted an online public-engagement session on privacy issues arising from drone use.

Serious drone-related activity by manufacturers, operators and end users will not occur until the regulatory framework for drones exists. While the 2012 Reform Act imposes

---

[164] Id.

[165] See § ___.

[166] See § XXX regarding unsuitability of current special airworthiness requirements for microdrones.

[167] See Joint Planning and Development Office, Unmanned Aircraft Systems (UAS) Comprehensive Plan: A Report on the Nation's UAS Path Forward (Sep. 2013) [hereinafter "Comprehensive Plan"], http://www.faa.gov/about/office_org/headquarters_offices/agi/reports/media/UAS_Comprehensive_Plan.pdf. The Committee comprised representatives from the Department of Transportation, the FAA, the Department of Defense, the Department of Homeland Security, the Department of Commerce, NASA, and the Executive Office of the President.

[168] http://www.faa.gov/about/initiatives/uas/.

[169] Id.

various deadlines for the FAA's integration of drones into the NAS, it is not uncommon for agencies to miss statutory deadlines for rulemaking.[170]

The FAA's Comprehensive Plan sets the following deadlines:

- Routine public small UAS (microdrone) Visual Line-of-Sight (VLOS) operations in the NAS without COAs, by 2015. These operations would be permitted only outside of Class B/C airspace and not over populated areas.
- Routine civil microdrone VLOS operations in the NAS without special airworthiness certificates, by 2015. Such operations would not be allowed in Class B/C airspace or over populated areas.
- Routine public drone operations in the NAS by 2015, initially using mitigation to comply with 14 CFR Part 91 requirements, and eventually under revised operating requirements addressing unique drone attributes.
- Routine civil UAS Operations in the NAS by 2020, initially using mitigation to comply with 14 CFR Part 91 requirements, and eventually meeting revised operating requirements addressing unique drone attributes. [171]

The FAA Roadmap sets a goal of 2014 for release of a Notice of Proposed Rulemaking ("NPRM").[172] The FAA might meet this deadline, so December 31, 2014 is a reasonable estimate for release of the NPRM. From that point forward, it is reasonable to use the timing of the FAA's most recent final rule making significant changes in the FARs as a baseline from which to project timing for the drone-integration rule. The FAA issued its NPRM for air ambulance operations on October 12, 2010, with a comment deadline about 90 days later, on January 10, 2011.[173] It then took three years and one month to consider the comments and to promulgate the final rule.

---

170 For example the 2012 Act set a deadline of July 1, 2012 for air ambulance rules, but the final rules were not promulgated until February 21, 2014. See Helicopter Air Ambulance, Commercial Helicopter, and Part 91 Helicopter Operations, 79 Fed. Reg. 9932 (Feb. 21, 2014) [hereafter "Air Ambulance Rules"] (referring to Congressional deadline).

171 Comprehensive Plan at pp. 9-10.

172 Comprehensive Plan at p. 15. An NPRM is the first formal step in the promulgation of regulations by an administrative agency. See 5 U.S.C. § 553 (providing for "notice and comments" rulemaking).

173 Air Ambulance Rules, 79 Fed. Reg. at 9936.

Extrapolating from this experience to the drone-integration rulemaking,[174] one could expect the following:

NPRM released	31 December 2014[175]
Comment period closes in 90 days	1 April 2015
Evaluation of comments takes six months to three years[176]	
Final Rule	1 October 2015 to 31 January 2018

Drone proponents are not going to remain passive while the rulemaking proceeds. They will continue their development and testing work, many in conjunction with test-site operators. Some operators and end users will participate in these activities and refine their economic and operational analyses as more data becomes available. The existence of the advisory committee represents a channel through which the FAA's evolving intentions will be relatively transparent to the most interested parties, as the agency evaluates comments, which are unlikely to deviate much from the RIAC consensus guidelines. As draft regulations become more specific, however, agreement on broad principles is likely to erode and sharper disagreements to emerge.

In any event, commercial and public use drone operations will not be legal, except under one-off COAs and special airworthiness certificates until late 2015, and perhaps not until early 2018.

---

[174] While the drone-integration rules are more sweeping than the Air Ambulance Rules, they affect new entrants more directly than existing participants in the NAS, and thus the prospect of intense opposition to protect vested interests is less likely than for the Air Ambulance Rules, which stiffened requirements imposed on existing operators. Both rulemaking activities were and are supported by well-structured industry advisory committees. The drone-integration committee already has reached consensus on the basic features of drone integration. See § ___ (describing RIAS and summarizing its guidelines). Likewise an Aviation Rules Committee was convened for the Air Ambulance Rules made consensus recommendations to the FAA in 2005. Air Ambulance Rules 57 Fed. Reg. at 9935.

[175] The Roadmap calls for release of a microdrone NPRM in early 2014 and release of a more general NPRM for drone integration in 2014. Roadmap at 58-59.

[176] It is possible that the FAA would issue a final rule on some issues, and ask for further comments on other parts of it. If that occurs, it could reduce the evaluation period toward the six-month low end for some aspects of the rule and extend it beyond the high end for other aspects. It also is possible that judicial review over some aspects of the rule would delay its implementation further.

IV. Realities

How soon drones become a regular feature of air commerce depends on a complex interplay among technology development, regulatory constraints, entrepreneurship, demand and supply interaction, and politics.

A. Supply chain

The market is in its infancy. A handful of suppliers are selling rotary wing microdrones to law enforcement agencies and advertising them for ENG and pipeline and powerline patrol. The civilian category currently comprises only microdrones. It is likely to stay that way until certification requirements for larger civilian drones crystallize in the 2018-2019 time period.

Even before the FAA finalizes the safe harbor for microdrones and well before requirements for machodrones crystallize, however, the pipeline is beginning to fill. Flint Hills Systems, for example, offers a family of drones, from microdrones at the low-end to two machodrones. It is actively promoting them for powerline patrol, law enforcement, and ENG. The designs are conventional, in the sense that they involve one main rotor and the tail rotor in all four configurations.[177]

The level of activity is greater for fixed-wing machodrones. In October, 2013, the FAA granted a special airworthiness certificate to Applied Research Associates, Inc. for its Nighthawk IV fixed-wing microdrone operating at its Randolph, VT location for the purposes of research and development, customer demonstrations, and crew training.[178] The company is advertising the availability of the Nighthawk IV for public safety agencies that can use data generated by the manufacturer to expedite issuance of a COA.[179] Earlier in 2013, the FAA issued restricted category type certificates for the Scan Eagle X200 and Aero Vironment's PUMA permitting them to conduct aerial reconnaisance pertinent to wildlifre surveillance and oil spill monitoring, and ice flows and migrating whales in Arctic oil exploration areas. The drones are fixed-wing and weigh about 55 pounds.[180]

---

[177] http://fhsllc.com/

[178] http://www.prweb.com/releases/2013/10/prweb11228997.htm.

[179] Id.

[180] http://rt.com/usa/us-drones-civilian-use-685/

It is likely that major manufacturers such as Boeing, Lockheed Martin, and Grumman will adapt their military versions for civilian application but the nature of these adaptations is still murky.

For the near-term, the greatest level of product design and sales activity will be limited to the microdrone segment. Then, as regulatory aircraft certification, airmen certification, and flight rules for operations mature, manufacturers will be able to crystallize their plans for machodrones.

B.   Labor market

Significant deployment of civilian drones depends also on the availability of DROPs and other qualified personnel. Presently, the view is that DROPs need essentially the same training as pilots for manned aircraft. Embry-Riddle Aeronautical University has added UAS training and degrees to its long-standing aviation education programs.[181] The curricula of the handful of other universities-- Kansas State,[182] Northern Michigan,[183] and the University of North Dakota[184] are offering UAS degrees[185]-- that have established degree programs for DROPS are similar to Embry-Riddle's: they are modifications of traditional pilot-oriented degree programs with the addition of three or four courses specifically concerning unmanned aircraft systems. The pipeline will be augmented, of course, by DROPs being discharged from the armed forces.

The equilibrium between supply and demand in the labor market for the relevant skills is hard to estimate until more progress is made on regulatory initiatives and until manufacturers ramp up their production. Prices and capabilities in the product market will, of course, influence demand in the law-enforcement, ENG, and utility-industry segments. They have to decide how active their drone operations will be before they know their hiring plans.

---

[181] See http://daytonabeach.erau.edu/coa/aeronautical-science/undergraduate-degree/unmanned-aircraft-systems-science/index.html(describing pilot and non-pilot tracks and degrees); http://catalog.erau.edu/daytona-beach/aviation/bachelors/unmanned-aircraft-systems/ (listing specific course requirements).

[182] http://www.salina.k-state.edu/aviation/uas/Salina%20uas.pdf

[183] https://www.nmc.edu/programs/academic-programs/aviation/uas-courses.html

[184] http://aviation.und.edu/ProspectiveStudents/Undergraduate/uasops.aspx.

[185] See also http://www.nytimes.com/2013/02/03/education/edlife/universities-offer-degrees-in-unmanned-aircraft-systems.html?_r=0.

The aviation community has already entered a period of pilot shortages, as the Viet Nam era generation of pilots accelerates its retirement and fewer young people are beginning pilot training. This means that drone operators and the institutions the train DROPs will have to compete with manned flying opportunities for the same pool of potential commercial pilots. There is a possibility, that the lure of flying drones will attract a new group of people are not interested in becoming pilots of manned aircraft, but this is entirely speculative, and even if such attraction exists, demanding training requirements may discourage the potential new entrants.[186]

The labor market for DROPS will be significantly influenced by the attitudes of helicopter pilots toward drones. Pilots have outsized, but not determinative, influence on public policy relating to aviation. They have enormous influence on young people considering careers in aviation. The pilot community is generally opposed to drones, because of a perception that their use will diminish opportunities for pilots, and pilots enjoy flying manned aircraft. In the context of this article, helicopter pilots fear that their jobs are in jeopardy if drones gain a toehold. And they are not drawn in the least to DROP jobs. "Who wants to sit on the ground and fiddle with a videogame console while the aircraft flies around without you?"

The fear that their jobs are at risk is neither in their self interest nor backed up by reality. For the first few years of operational drone use, no pilot's job will be at risk. It will be years or decades before any customer starts canceling helicopter contracts or selling helicopters because its needs can be covered by drones.

Attitudes toward new technologies are generational. Already a new generation is ready to enter the pilot workforce. They have grown up with drones being part of any conversation about aviation and aviation careers. The generation ahead of them feels blindsided by the threat of drones just as they get a leg up on getting paid to be in the cockpit. The reaction of the two groups is likely to be quite different. Older generations of pilots—those in their forties and fifties have retirement within their planning horizons. Their attitude is likely to be, "Just stave off the drones until I am ready to retire."

---

[186] It may turn out that microdrones operating within line of sight and at limited altitudes likely will be operated by regular police officers, reporters, or utility inspection personnel with modest on-the-job training. This would ease the barriers to recruitment in the microdrone segment.

C.   Political factors

The pace with which drones will be deployed will depend as much on politics and privacy concerns as on technology and FAA regulation.

1.   Privacy concerns

The privacy community is up in arms about the potential for drones to expand intrusion into private affairs by law enforcement, foreign intelligence, and journalistic organizations. The FAA's online telephonic session on privacy issues relating to the test sites illustrated some of the concerns.

Those focusing on privacy identified the perceived threats:

> *"[U]se as evidence in a criminal court of law, . . .videotaping the facial expressions of people on the ground from hundreds of feet in the air. [It] will usher in a new age of surveillance in our society. No person, whether he is at a political rally, exiting a house of worship or simply walking around downtown will be safe from the prying eyes of these devices."*[187]

EFF summarized the privacy threats:

> *"UAS are capable of highly advanced and near-constant surveillance through live-feed video cameras, thermal imaging, communications intercept capabilities, and backend software tools such as license plate recognition, GPS tracking, and facial recognition. . . . They can amass large amounts of data on private citizens, which can then be linked to data collected by the government and private companies in other contexts."*[188]

CDT summarizes it this way:

> *"Surveillance-capable UASs are quite different than manned aircraft and other types of surveillance activities for a number of reasons. First, platforms for UAS based surveillance are increasingly inexpensive, with small systems costing a few hundred dollars, compared to many thousands of dollars per hour of operation for manned surveillance aircraft such as airplanes and helicopters. Because of their small size and lack of an on-board human pilot, UASs are capable of going many places manned aircraft*

---

[187] Michael Covari, FAA UAS Online Listening Session,
http://www.faa.gov/about/initiatives/uas/media/uastranscription.pdf [hereinafter "Privacy Transcript"] at p.4.

[188] Maas, Three Requirements.

cannot (such as between narrow buildings) and capable of operation in environments that humans cannot (such assuring high-g tactical maneuvers, high altitudes and long times aloft). UASs, like manned surveillance aircraft, are capable of unique vantage points from which ground-based individuals may not expect surveillance systems to observe. Finally, the nexus of these considerations result in aerial surveillance platforms that may be very difficult – if not impossible – to visually identify, such that many types of UAS surveillance are possible with no notice to ground-based individuals."[189]

Another privacy concern is that widespread use of drones will make it easy to monitor crowds and other public gatherings that have First Amendment implications.

Support is growing for a requirement that drone operators file and adhere to data collection and management plans. Such plans would include:

"• The purpose for which the UAS will be used and the circumstances under which its use will be authorized and by whom,

"• The specific kinds information the UAS will be capable of collecting, including whether that information is personally identifiable or not,

"• The length of time for which the information will be retained (in a manner that preserves identifying data),

"• Methods used to minimize or aggregate data and delete old data,

"• Parties with which information will be shared,

"• The possible impact on individuals' privacy,

"• The specific steps the operator will take to mitigate the impact on individuals' privacy, including protections against unauthorized disclosure,

"• The individual responsible for safe and appropriate use of the UAS, and

"• An individual point of contact for citizen complaints."

---

[189] CDT, Comments to the Federal Aviation Administration on Unmanned Aircraft System Test Site Program 1-2 (Apr. 23, 2013), https://www.cdt.org/files/file/CDTComments_FAA-UAS.pdf [hereinafter "CDT Privacy Comments"].

Many critics would require search warrants.[190] This may not provide much protection, however, because search warrants are required only of governmental entities, and the "open fields" doctrine says that warrants are not required to conduct surveillance of activities going on in public areas.

Widespread support exists for making data collection and distribution transparent. Some would require that any downlink be unencrypted and represented in standard data structures so that anyone could see what is being collected.

Others would make metadata about drone collection available on the web, perhaps for each flight--route of flight, time and date, targets of collections efforts, and amount of data being collected.

EPIC recommends a searchable database for drones and drone operators.[191]A more modest proposal, not aimed at data collection itself, but rather at drone flights, would simply require drones to have ADS-B Out capability, which would permit anyone to track them.

Significantly, CDT would exempt microdrones:

"Certainly, the traditional exemptions for model aircraft operation and the current unregulated airspace below 400 feet should still allow relatively simple UAS operations without such equipment requirements; however, if the UAS has sufficient power and recording capability, it should also be able to generate an ADS-B Out signal.

Privacy fears will continue to dominate the political calculus. In many respects, the privacy concerns are unfocused, reflecting a lingering conspiracy theory about "black helicopters" as the wedge of a crushing state intruding into individual activities. But

---

[190] The Fourth Amendment to the United States Constitution protects against governmental invasions of privacy; no such legal provision protects against private invasion. Accordingly, the legal framework for privacy protection with respect to law-enforcement use of drones is more robust than it is otherwise. The basic concept of the Fourth Amendment is that the government may not intrude into areas clothed with a "reasonable expectation of privacy" without a search warrant, absent other circumstances that make the intrusion "reasonable." Search warrants may be obtained only upon showing a probable cause to believe that evidence pertinent to a criminal investigation will be obtained by the search and only then subject to conditions that minimize the intrusion.

[191] EPIC, Comments of the Electronic Privacy Information Center to the Federal Aviation Administration, Unmanned Aircraft System Test Site Program 10 (Apr. 23, 2013), http://epic.org/privacy/drones/EPIC-Drones-Comments-2013.pdf [hereinafter "EPIC Comments"]

some of them are more focused and susceptible of factual analysis. The starting point is to understand what drones are likely to do that manned aircraft are unlikely to do in the hands of the same types of operators.

There *are* differences. It is widely perceived that drones will be much cheaper than manned aircraft and therefore that there will be many more of them. As section XXX explains, however, these hopes are likely to be dashed on the shoals of regulatory reality. But that remains to be seen. If there are many more drones, the possibilities of using them to invade personal privacy increases linearly, in proportion to their numbers.

Of greater moment is the near certainty that drones will be flown much lower than manned aircraft. Prudent helicopter pilots stay at a height above ground level that permits a safe landing in the event of an engine failure. Flying higher also decreases the likelihood of colliding with obstructions such as radio antennas, water towers, electrical wires, and wind turbines. This particular safety concern is diminished with drones because an accident does not threaten the lives of the aircrew. It may, of course, from the lives of people on the ground. The prevailing view is that lower is better for drone flight to reduce potential conflicts with manned aircraft, most of which are flying higher. At least until low-flying drone accidents occur and the public demands minimum altitudes, flying low will be a reality.

The privacy concern is that, by flying lower, drones will be able to intrude more closely and private lives. The typical cartoon highlighting this concern depicts a small drone, hovering and looking through a bedroom window.

To some extent, the concern with height above ground is misplaced. Good onboard camera equipment is capable of zooming so that intimate detail of ground objects is clearly visible from heights of 1,000 feet AGL or so. On the other hand, to focus on the looking through the bedroom window fear, sight angles matter. ENG and law enforcement helicopters usually find it a 45° offset ideal to capture ground detail.[192] At that angle, one cannot see much through a bedroom window--except the floor.

---

[192] See Perritt, Sprague, and Cue at XXX.

In contrast, a drone hovering at 10 feet, 20 feet from the side of a single-family detached dwelling, can see almost anything going on inside a room through an unobscured window, if the drone is positioned at roughly the same height as an exterior window.

An important aspect of how the law protects privacy is the likelihood of detecting violations. Peeping toms are often caught, because they make noise, can be seen without too much difficulty, and can run only so fast when they try to get away. Drones, even small electrically powered ones, make a fair amount of noise, so detection is equally probable. On the other hand, they can fly away very fast, and the likelihood of catching them is low unless the victim is quick enough to capture detail and unless the regulatory system tracks their movements. It will be relatively easy to track the movements of larger drones – those equipped with ADS-B Out systems.[193] On the other hand, microdrones are unlikely to be required to have such systems and therefore the mechanism for tracking them will not be very robust.

Independently, privacy advocates are concerned about the use of data collected by drones. It is one thing for a trusted agency to have an inventory of data about a citizen; it is quite another if the same data fall into the hands of an employer, an insurer, or a blackmailer.

There will be continuing battles between privacy groups and ordinary citizens concerned about privacy and proponents of wider drone use. While the proposals for data collection plans and open access to ADS-B Out data are reasonable on their face, potential operators will oppose the data collection plans because they will impose additional paperwork burdens and restrict operations. Many of them also will oppose transparency in ADS-B Out data on law-enforcement-security or proprietary grounds. If anyone can know the exact flight path of law-enforcement drones, they can frustrate the law-enforcement mission. If competitors know the details of ENG drone flights, they can gain a competitive advantage. Indeed, such data meet most of the elements for trade secret status.[194] Whether the secrecy element can be met depends on how transparent the data transmissions are.

---

[193] See § XXX.

[194] See Henry H. Perritt, Jr., Trade Secrets for the Practitioner § ___ (2014) (summarizing elements of trade secret misappropriation: (1) information conferring competitive advantage because not generally known, (2) reasonable efforts to maintain secrecy, and (3) wrongful means to obtain).

2. The political calculus

It is early to predict with any confidence the values and variables in the political calculus for widespread drone use. Nevertheless, the FAA-sponsored "public listening session"[195] over the test sites provides a reasonable snapshot of the political equation as of the end of 2013 and early 2014. That session had the following characteristics:

Proponents and opponents of widespread drone use were about evenly split, with a slight tilt toward proponents.

All of the major privacy advocacy groups participated and demonstrated a high level of sophistication about the issues. They all made similar proposals with regard to privacy protection. Many of the concerns focused, however, not on privacy, but on safety—the prospect of drones falling out of the sky--as much as drones at the bedroom window.

> "At this point I am less concerned with the privacy issue. I am more concerned with safety with mid air collisions between a UAV and a manned aircraft and pieces of aircraft debris falling from the sky."[196]

> "[T]he thought of running into a 400 pound UAV that's 400 feet around my airport is very very scary and I don't want that to happen in my air space."[197]

> "How would you feel if a 45 foot wingspan drone came crashing to the ground in one of your elementary schools? . . . [think about] other accidents such as a 400 pound shadow drone crashing into a C130 Hercules transport plane."[198]

As is typical with such opportunities for general public participation, several of the individual participants had overblown concerns or fixations on bizarre solutions to general social problems. One participant, who called in twice, favored wider use of drones as instruments of the constitutional right to self defense, which, he claimed, would diminish gun violence and generally improve society.

Most of the proposals for privacy protections were rational, in the sense that they would diminish the opportunities for intrusion, or at least make targets aware of it. They

---

[195] See FAA UAS Online Listening Session, April 3, 2013, http://www.faa.gov/about/initiatives/uas/media/UAStranscription.pdf [hereinafter "Privacy Transcript"]

[196] Alice Sheflaw, Privacy Transcript at p.7.

[197] David Lemmon, Privacy Transcript at p.10.

[198] Shirley Mikinott, Privacy Transcript at p.7.

demonstrate a realization that the greatest threat comes from law-enforcement collection, and that considerable benefits result from other uses, such as for newsgathering.

Here is how the EFF summarized the status of state legislation in mid-2013:

"Some proposals floated so far, such as California's AB 1327, lay out a decent framework for limiting the use of drones by law enforcement. Few states, however, have adequately handled the use of drones by private individuals. Texas' recently passed (but so far unsigned) HB 912 manages to mess up both sides of the table by allowing cops to use drones without a warrant while also hampering the press' ability to use drones in newsgathering. The ACLU has a comprehensive breakdown of the legislation, along with analysis of the good and the bad and what has passed into law so far."[199]

EFF argues that the following principles should govern state legislation:

1. Law enforcement must be required to obtain warrants before using drones in investigations to protect the Fourth Amendment rights of citizens from overbroad or undue data collection.
2. Commercial drone operators must be held to established privacy standards and must disclose the details of their operations.
3. Legislation that regulates private and media use of drones must strike an appropriate balance between privacy and First Amendment protected activities such as newsgathering.

"EFF believes that the public has a right to know where drones are being used, what kind of information the surveillance technology records, how long the data will be stored, who has access to the data and whether the information can be used outside of the original, stated purposes."[200]

It is tempting to conclude that exciting new technologies cannot be held back, but they can. Political opposition based on noise and other environmental effects killed the

---

[199] Dave Maass, All Drone Legislation Must Meet These Three Requirements (June 3, 2013),https://www.eff.org/deeplinks/2013/06/all-drone-legislation-must-meet-these-three-requirements [hereinafter Maass, Three Requirements"].
[200] Maass, Three Requirements.

supersonic transport. XXX's book, THE GOD MACHINE, meticulously details how the prospects for helicopters and gyrocopters to be a pervasive part of everyday life have repeatedly been derailed by political opposition to noise, safety risks, and economic disparity.

But a coalition of supporters is possible. Significant to evaluating the political equation, however, is the fact that Congress has been pushing the FAA to accelerate drone integration rather than pulling it back. The inclusion of the push in the 2012 Reform and Revitalization Act suggests constituencies influential with the Aviation Committee are the most active. A review of testimony on the subject would be helpful. Drone manufacturers – both those who have supplied drones to the armed services, and new entrants—federal, state, and local law-enforcement agencies, potential operators, including those now in the ENG, pipeline and powerline patrol, and oil-and-gas exploration are pushing to accelerate drone use. Suppliers of wireless control systems, and DROP video displays see opportunities as well. Others, now at the margins, are commercial entities like Google that obviously could benefit from drone use for applications like Google Maps.

Local groups and national privacy advocates are pushing back. The most prominent privacy groups, however, are not implacably opposed to drone deployment; they have a more nuanced position. Significantly, CBT appears to favor ENG drone use. It reserves its strongest concerns for abuse by law enforcement and intelligence agencies.

V.   Forecast

As soon as the FAA relaxes further its COA[201] and special-airworthiness-certificate[202] requirements for microdrones[203]—and maybe even before--the deployment of these small systems will proliferate. They will transform the way law-enforcement and newsgathering organizations use aviation support. It will make aviation support more affordable for police departments and journalists, may flood the newsgathering marketplace with amateur-recorded imagery, much as cell-phone-acquired imagery has

---

[201] COAs ("Certificates of Authority") are available only to federal, state, and local governments.

[202] Drones may be operated as civil aircraft only pursuant to special airworthiness certificates.

[203] *sUAS* is the formal designation for what this article calls *microdrones*.

already transformed it. It will stimulate demand for relatively low levels of training for a large cadre of qualified DROPs.[204]

The timing and extent of use of microdrones will depend on the willingness of law-enforcement agencies, TV stations, and utilities to try them out. Their prices and capabilities are well-established. How far their will spread will depend, of course, on early experience with them and the responses of police officers, reporters, and utility inspection crews who try them out.

The development of machodrones will occur more slowly. They have essentially the same capabilities as manned helicopters, but stabilization of the regulatory regime will take another ten years. It is far from clear at this point that the weight and power-consumption requirements of equipment necessary to ensure safe integration into the NAS will offer any particular advantage in price or operating cost over manned helicopters. Anticipated labor cost savings will be largely nullified by requirements that DROPs have the same basic qualifications and certifications as pilots and system operators for manned helicopters.

Ultimately the revised FARs[205] applicable to certification of drones and their operations may result in prices and operating costs that are less favorable than those for manned helicopters.

The timing and extent of use for machodrones will depend mainly on cost and capabilities, influenced greatly by political reaction. They will used more widely for pipeline and powerline patrol than for law enforcement and newsgathering. This is so for several reasons: pipeline and powerline patrol can be carried out in remote areas, reducing political opposition; avoiding risks to flight crews is a bigger issue in powerline or pipeline patrol and repair; the finely tuned, ad hoc adjustments that

---

[204] DROP-DRone OPerator: the person who flies the drone from a remote ground station

DROSOP -DROne Systems Operator: the person who manages the drone's sensors and other non-flight equipment, e.g. cameras, searchlights, video downlinks

DROTOG -DROne phoTOG: a DSOSOP used in ENG

DROTSO -DROne TSO: a DROSOP used in law enforcement support

[205] FAA regulations applicable to aviation operations usually are referred to as the "FARs" ("Federal Aviation Regulations").

human pilots on board make is less for these applications than for law-enforcement and newsgathering.

None of this will happen tomorrow. As this article is written (early 2014) drone use in the civilian sector is illegal, except under tightly restricted model-airplane rules that preclude commercial purposes, and under hard-to-obtain COAs and special airworthiness certificates.[206]

The regulatory environment will evolve in three basic stages. The first is the present one, in which the FAA has sketched with reasonable specificity its basic intentions with respect to integration into the NAS, and is collecting and evaluating date from the six test sites. During this stage, however, drone use by either law enforcement or newsgathering organizations is illegal unless the users have special airworthiness certificates (for ENG or pipeline/powerline drones) or COAs (for law-enforcement drone operations).

In the second stage (as early as the end of 2015, or as late as early 2018),[207] general drone aircraft certification and operating rules will be on the books. That does not mean, however, that hundreds of drone operations will suddenly spring up. Instead, this will be a period of intense experimentation and market shakeout. Drone manufacturers will jockey to get airworthiness certificates for their products, new drone operators will apply for operating certificates under Part 135[208] or a comparable new part of the FAR applicable to drones, and end-users will embark on various test programs either with their own certificated drones or by contracting with certificated operators. Pricing and operating costs will become clearer.

During this period existing helicopter operators will decide whether they want to incorporate drones into their fleet or whether they will view them basically as a threat to their businesses.

---

[206] See Busting Myths about the FAA and Unmanned Aircraft, http://www.faa.gov/news/updates/?newsId=76240 (Feb. 26, 2014) (noting that only two special airworthiness certificates have been granted, both limited to Alaska, and lowering a 2011 FAA estimate of 30,000 operational drones by 2030 to the area of greatest expected growth, projecting 7,500 microdrones by 2018).

[207] See § ___ (projecting timeline for FAA drone-integration rulemaking).

[208] Recall that ENG operations are exempt from Part 135 because they constitute "aerial photography. See note ___, infra.

Most would-be manufacturers will discover they do not have capital, expertise, or patience to get their products certificated and then to invest what is necessary to sell them in quantities and at prices that level that will cover their costs and generate a return on investment.

Some end-user experiments will be successful, and these end-users will make substantial orders. Others will conclude, after their experimentation and tests that large-scale drone use does not offer benefits proportionate to costs. If the past is any guide, most existing helicopter operators will view drones only as a threat; they will expect their market share to diminish as drones move-in to some of their territory. Others will make strategic decisions to offer mixed fleets, including drones, to their customers.

The procedures for obtaining airworthiness certification will undoubtedly be divided by aircraft category, one, simplified, set for microdrones, and another, more demanding, set for machodrones.

A number of manufacturers and service providers are gearing up to exploit the market for both microdrones and machodrones. Already, civilian microdrones are flying under COAs for a limited amount of law-enforcement support. As the FAA moves to a regulatory framework for microdrone flight, instead of requiring COAs or special airworthiness certificates in every case, the use of microdrones on an exploratory basis will explode. Not all of these uses will turn out to be viable. As with the development of any new market, initial enthusiasm will be moderated by experience, as supply and demand gradually settle down to what is sustainable.

But it will be surprising if a number of microdrone uses like those sketched in this article do not prove to be viable. Therefore, by the end of 2018 or so, microdrones will regularly be flying missions for segments at the margin of pipeline, powerline, and railroad patrol, law-enforcement support, and ENG. Well before 2020, it is likely that a growing percentage of patrol officers will carry microdrones in the trunks of their squad cars and fly them to support localized tactical missions.[209] Similarly, televisions stations will be unable to resist the temptation to use videos acquired from microdrones by ordinary citizens—just as the widespread broadcast of iPhone-captured video is a mainstay of journalism. For example, on Thursday, 13 February 2004, WBBM, the local

---

[209] Aerobatic Solutions markets a microdrone, the Huntsman, very similar in weight an appearance to the Phantom for law-enforcement application. See http://www.aeroboticsolutions.com/products/.

CBS affiliate in Chicago featured a story about ice floes piling up on the southern shore of Lake Michigan, accompanying the report with video taken from a microdrone operated by the Indiana Department of Natural Resources.[210] Channel 7 in Chicago solicits viewer videos.[211]

Experimentation, especially with microdrones, will be decentralized. A particular police department or TV station—or more likely an individual police *officer* or *reporter*—will obtain possession of a drone and try it out. If success results, the word will spread and institutional interest will grow. If a negative incident occurs, the early, informal, adopter will get fired.[212]

Existing helicopter operators may participate in early drone evaluation, or they may decline to participate, limiting themselves to manned helicopter operations. If they decline, their customers are likely to undertake drone testing and—in some cases—drone deployment without involving the helicopter operators.

Early experimentation and evaluation will go much more smoothly if it takes place in remote areas where almost no one lives, works, or plays. Public outcry is going to be much less in the country than in the city.

Gradually, machodrones will find their way into law-enforcement and ENG fleets, but opponents will find it much easier to delay widespread use of machodrones than to block the proliferation of microdrones.. Their operations will be scrutinized, and inevitable accidents will provoke an outcry insisting on further restrictions. But then, at some point, a drone will find a lost child, and the political balance will tilt in the favorable direction.

It is hard to block new technologies, however, especially when an objective review of the technologies show that they can deal—for the most part—with concerns about traffic separation and keeping machodrones in the air and away from people on the ground. The trick is figuring out what "for the most part" means.

---

[210] The authors heard the story on the radio and watched the video clip on the web. It since has become unavailable, perhaps only to make room for more current news items.

[211] See http://abclocal.go.com/wls/feature?section=news/local&id=6549217

[212] See Draganfly—X4-ES First Look, Air Beat Magazine, Nov/Dec 2013 at 49 (describing successful experiments by Canadian and North Dakota agencies using a $25,000, 5.7 pound microdrone with a 1 km range and 20 minutes of endurance capable of flying Sony RS-100, Sony NEX5R Low Light, or FLIR Tau 640 thermal imager).

Anyone who flies both airplanes and helicopters, as the authors do, knows that helicopters are considerably harder to fly than airplanes. Helicopters require constant control inputs to keep them level; airplanes do not. In calm air, a pilot can take his hands entirely off the yoke and throttle, and the airplane just purrs straight ahead. A helicopter pilot almost never takes his hand off the cyclic stick. If he does, the aircraft reminds him in a second or two that he better put it back. It is relatively easy to set off pilot-induced oscillations in a helicopter and quite difficult in an airplane. Helicopter autopilots have become available much later than airplane helicopter autopilots and full-functioned autopilots capable of flying departures and landing approaches are only just being introduced.

Based on this experience it is counterintuitive to believe that rotary wing drones will have performance characteristics and safety features that put them at the leading edge of drone integration. Even if an engineer believes it, a pilot won't. All an opposition group needs is one or two helicopter pilots to testify that drones are inherently unsafe, and they can block almost anything.

Confidence on either side of the debate is misplaced. Who's talking today about ordinary people flying their own helicopters from their driveways?

The beast may be upon us, but it may all turn out, in the end, to have been merely a bad dream.