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Unmanned Aircraft Operations in Domestic Airspace: U.S. Policy Perspectives and the Regulatory Landscape

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Summary

Unmanned aircraft systems (UAS), often referred to as "drones," have become commonplace over the past few years. As UAS technology develops rapidly, the United States faces significant challenges in balancing safety requirements, privacy concerns, and economic interests.

The FAA Modernization and Reform Act of 2012 (FMRA; P.L. 112-95) required the Federal Aviation Administration (FAA) to develop and implement a comprehensive plan to integrate unmanned aircraft into the national airspace and issue regulations governing the operation of small unmanned aircraft used for commercial purposes. FAA has proposed regulations allowing routine operations of small commercial UAS weighing less than 55 pounds, but is still developing the guidelines and standards for federal, state, and local government agencies required by FMRA. Hundreds of thousands of small UAS are already being operated as recreational model aircraft and hobby drones that are permitted under a special rule for model aircraft established by FMRA. In addition, several hundred public agencies and more than 3,000 businesses have been granted approval to operate UAS on a case-by-case basis. Once regulations and guidelines are put in place, large growth in UAS operations is anticipated.

As UAS operations have increased, a number of safety concerns have emerged, particularly with regard to use of model aircraft and hobby drones. UAS flights have interfered with airline crews near busy airports and with aircraft fighting wildfires, and have posed safety and security hazards at outdoor events and in restricted areas. FAA has been addressing these concerns through user education initiatives and in limited cases by using its enforcement authority to sanction unauthorized and unsafe operations. In an effort to better monitor UAS operations and carry out enforcement actions as appropriate, FAA now requires that commercial and recreational UAS operators register all small UAS weighing between 250 grams and 55 pounds. Technology known as "geo-fencing" may play a future role in keeping UAS away from airports and other restricted airspace by overriding operator inputs and keeping UAS out of these areas.

UAS could potentially be used by criminals and terrorists for espionage and smuggling, or as a platform to launch a remote attack. To address both safety and security concerns, a number of technology solutions are being examined to detect airborne UAS and pinpoint the location of the operator. Technologies to disable, jam, take control over, or potentially destroy a small UAS are also being developed and tested.

Many of the commercial applications envisioned for UAS, such as express package delivery, remote monitoring of utilities and infrastructure, and imagery collection and analysis to support precision agriculture, most likely will not be viable without development of technological capabilities that allow for the complete integration of UAS in the national airspace. These include technologies to enable drones to sense and avoid other air traffic; manage low-altitude airspace and detect and prevent unauthorized use of airspace; mitigate risks to persons and property on the ground; provide secure command and control linkages between drone aircraft and their operators; and enable automated operations. There are also issues related to operator training and operator qualification standards. A number of bills introduced in the 114th Congress address UAS safety, and these topics may be considered in further detail in forthcoming FAA reauthorization debate.

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Introduction

In February 2012, President Obama signed the FAA Modernization and Reform Act of 2012 (FMRA; P.L. 112-95). The legislation mandated that the Federal Aviation Administration (FAA) develop a comprehensive plan to integrate unmanned aircraft systems (UAS) into the national airspace and begin implementing the plan starting in October 2015. FRMA also required FAA to issue regulations pertaining to small commercial drones and develop standards for the operation and certification of unmanned aircraft operated by federal, state, or local government. Deadlines for completing these actions have passed, but FAA has not yet finalized its UAS regulations and standards. However, FAA is granting approvals to government agencies and commercial operators to operate certain UAS on a case-by-case basis.

Under a special rule established by FMRA, model aircraft and hobby drones operated strictly for noncommercial recreational purposes are permitted to fly below 400 feet so long as they remain within sight of the operator, outside of restricted airspace, and away from airports unless appropriate prior notification has been given to airport operators and air traffic control towers. Under this rule, operations of hobby drones have proliferated, creating significant enforcement challenges for FAA.

Meanwhile, FAA has proceeded slowly and cautiously in complying with the FMRA mandate related to government and commercial operations. It has allowed government agencies and operators of small commercial drones to obtain permits on a case-by-case basis. In February 2015, FAA proposed regulations allowing for the routine operation of small commercial UAS; these rules are expected to be finalized in April 2016.[1] FAA's integration plan,[2] developed in response to FRMA requirements, indicates that procedures allowing public safety UAS routine access to airspace are forthcoming.

FAA's approach to regulation distinguishes between operations conducted within visual line of sight (VLOS) and those involving flight beyond (visual) line of sight (BLOS). This distinction does not depend on aircraft size. Some small UAS can achieve basic BLOS capability using a live feed from an onboard camera presented to the operator on a visual display. Larger UAS operated from dedicated control stations achieve BLOS capability through similar means, but also often include other sensing capabilities such as moving map displays, airborne radar information, and air traffic collision avoidance systems to enhance operator situational awareness.

So far, FAA is restricting commercial users and model aircraft operators to VLOS operations. The proposed rule for commercial UAS would maintain this restriction, a limitation that would rule out many potential uses of UAS, such as aerial surveying and inspections and package delivery. Furthermore, FAA requires that each UAS be controlled by a dedicated pilot operating one aircraft at a time, just as occurs with manned aircraft. It has proposed formal training requirements for commercial UAS operators similar to the certification process for pilots of manned aircraft. However, UAS technology is rapidly pushing in the direction of greater autonomy and automation. Operational concepts for potential BLOS applications envision systems that will involve minimal human input and interaction and minimal training to operate.

[1] Department of Transportation, *Report on DOT Significant Rulemakings*, January 2016.

[2] Joint Planning and Development Office, *Unmanned Aircraft Systems (UAS) Comprehensive Plan: A Report on the Nation's UAS Path Forward*, September 2013, http://www.faa.gov/about/office_org/headquarters_offices/agi/reports/media/UAS_Comprehensive_Plan.pdf.

Many of the anticipated uses envisioned for UAS, particularly those involving BLOS operations, will require that unmanned aircraft be integrated with manned aircraft within the national airspace system. At the current level of maturity, however, most UAS are being kept segregated from manned aircraft and controlled airspace through altitude restrictions and the establishment of strict airspace boundaries. In the future, it is anticipated that some UAS will share airspace, and potentially share facilities like airports and helipads, with manned aircraft. Technological innovations, as well as standardized procedures operators must follow, will be needed for full integration.

What Are UAS?

An unmanned aircraft is a vehicle designed for flight that does not have a human operator, a pilot, on board. Most unmanned aircraft are controlled from a ground station. The aircraft, its ground station, and command and control radio linkages between the two are collectively known as an unmanned aircraft system.[3] For small UAS, the ground station may be nothing more than a handheld radio control device with manual inputs. More sophisticated drones have ground control centers that look similar to cockpits of modern airliners.

Unmanned aircraft are generally classified based on their size and weight. FAA's initiatives to regulate small unmanned aircraft systems pertain to those weighing less than 55 pounds. FAA has also suggested a possible sub-category called micro-UAS, which would be limited to 4.4 pounds (2 kilograms) and thus might pose fewer safety concerns.[4] Unmanned aircraft 55 pounds and greater are categorized as large insofar as they do not meet the statutory or regulatory requirements to be considered small UAS. FAA has not proposed regulations relating to large UAS.

An unmanned aircraft's size and weight are generally correlated with both its operating altitude and its flight endurance. Small UAS operate at the lowest altitudes (typically below 1,000 feet) and have comparatively short endurance, usually 30 minutes or less. Many of the consumer drone products that fall into this category are battery-powered, and include rotary-wing designs, such as multi-copter drones, as well as more traditional fixed-wing airplane designs. Some larger designs are gasoline-powered and can operate up to several thousand feet. More capable gasoline-powered unmanned aircraft originally designed as military systems, like the fixed-wing ScanEagle and Fire Scout helicopter, and larger UAS like the Predator/Guardian and the jet-powered Global Hawk, can be deployed for several hours, have thousands of miles of effective range, and operate at medium and high altitudes (see **Figure 1**).

Uses of Drone Aircraft

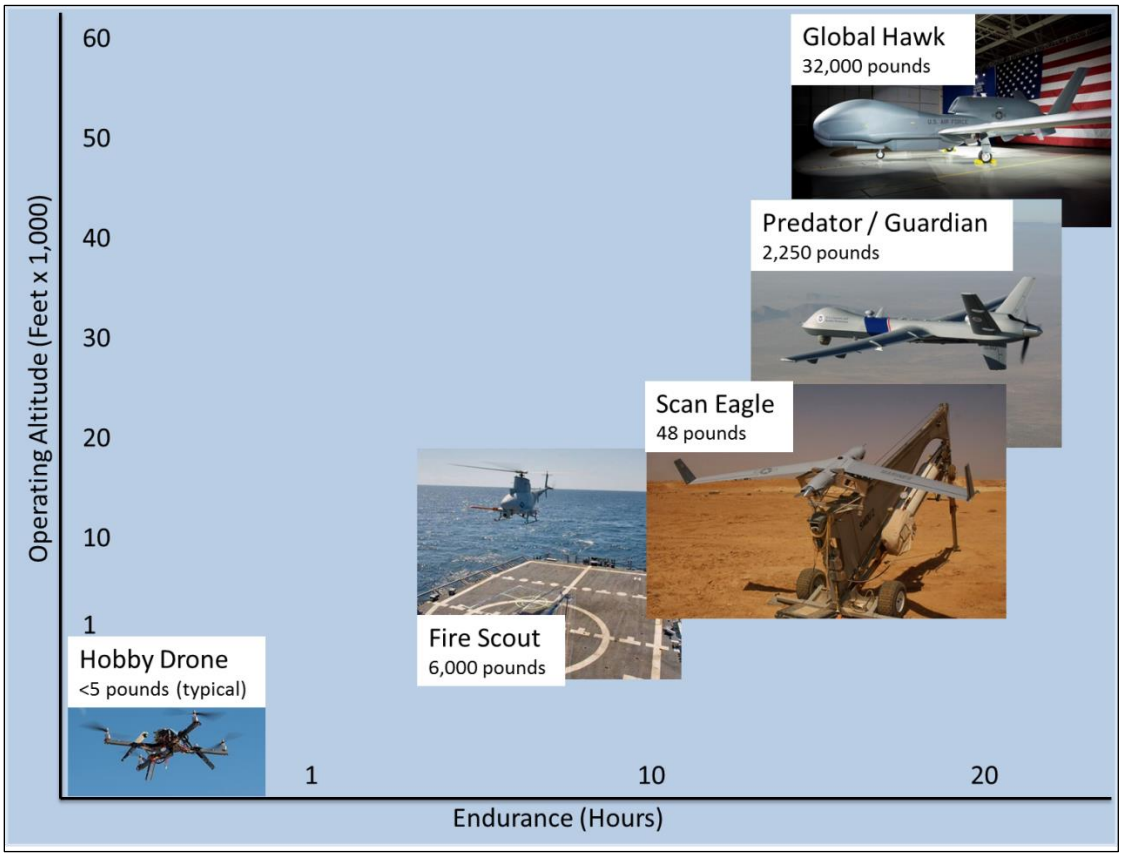
The history of unmanned aircraft goes back about a century, to the latter years of World War I, when prototype fixed-wing unmanned aircraft were developed. This research was important in the development of guided missiles and target drones during World War II and the Cold War era. In the 1980s, spurred by Israeli initiatives, the military developed more sophisticated unmanned systems with extensive ground-based command-and-control capabilities and more advanced

[3] While the military uses the term Unmanned Aerial System, the Federal Aviation Administration (FAA) has adopted the term Unmanned Aircraft System. Both terms use the acronym UAS. The term Unmanned Aircraft System is used in this report to be consistent with FAA usage.

[4] Federal Aviation Administration, "Operation and Certification of Small Unmanned Aircraft Systems," 80 *Federal Register* 9543-9590, February 23, 2015.

onboard imaging sensors. Unmanned aircraft were used by U.S. forces for intelligence missions in Kosovo in the late 1990s, and in Afghanistan and Iraq for reconnaissance and surveillance as well as, more recently, for combat missions.[5]

Figure 1. Operating Altitudes, Endurance, and Weight of Common UAS



Source: CRS analysis of operator and manufacturer data. Photograph credits: Hobby Drone (FAA); Fire Scout (U.S. Coast Guard); Scan Eagle (U.S. Marine Corps); Predator (CBP); and Global Hawk (U.S. Air Force).

Note: Figure not drawn to scale.

Interest in nonmilitary uses of UAS increased following the 9/11 terrorist attacks in 2001. In FY2004, Customs and Border Protection (CBP) began testing unmanned border surveillance missions, and in FY2005, CBP began operational use of UAS along the southern border. Such uses are allowed under certificates of authorization (COAs) issued on a case-by-case basis by FAA.

The Federal Bureau of Investigation (FBI) has deployed small unmanned aircraft on a limited basis to provide targeted aerial surveillance for search and rescue operations, kidnapping investigations, fugitive manhunts, anti-drug trafficking interdictions, and national security missions.[6] However, UAS have so far played a limited role in law enforcement. While there are about 18,000 police agencies in the United States, fewer than 50 have obtained FAA authorization

[5] For further information on military and intelligence UASs, see CRS Report R42136, *U.S. Unmanned Aerial Systems*, by Jeremiah Gertler.

[6] Office of the Inspector General, U.S. Department of Justice, *Audit of the Department of Justice's Use and Support of Unmanned Aircraft Systems*, Audit Division 15-11, March 2015, https://oig.justice.gov/reports/2015/a1511.pdf.

for unmanned flight operations.[7] Many federal, state, and local agencies involved in law enforcement and homeland security appear to be awaiting more specific guidance from FAA regarding the routine operation of public-use unmanned aircraft. Legal issues related to individuals' privacy interests protected under the Fourth Amendment have also slowed the adoption of drones for domestic surveillance and homeland security operations.[8]

Use of UAS by fire departments has been even more limited, even though there are about 30,000 fire departments in the United States.[9] To date, fire services have mainly used UAS for wildfire and search and rescue operations in remote areas. Applications in urban and suburban environments are being evaluated by several fire departments. The Fire Department of New York City envisions that a tethered UAS it is currently testing would be deployed at second alarm and greater fires and other emergency incidents to provide aerial surveillance to assess dangers to firefighters and other responders.[10]

Section 334 of FMRA directed FAA to address routine access to the national airspace by public safety agencies, and develop standards for operation and certification by such agencies by the end of 2015. However, this deadline has now passed, and it remains unclear what actions FAA may take to meet this mandate.

Federal government use of UAS includes other applications such as land management, wildfire monitoring, earth imaging and weather monitoring, and scientific research. Among federal agencies, research use by the National Aeronautics and Space Administration (NASA) currently accounts for almost half of the active UAS authorizations. Department of Homeland Security activities, predominantly CBP surveillance missions along U.S. borders and over territorial waters, comprised about 16% of active UAS authorizations as of January 2015. Other agencies using UAS include the National Oceanic and Atmospheric Administration (NOAA) and the Department of the Interior.[11] A small number of state agencies have obtained approvals to operate UAS for aerial surveying and to monitor the environment, highways, and other infrastructure. State university research programs currently are the largest nonfederal government use of UAS.

Many of the near-term applications of unmanned aircraft for both government and business involve data collection using a broad array of devices. Digital cameras are the most common data collection sensors aboard UAS. Additionally, UAS may be equipped with infrared sensors that provide night vision capability, more specialized imaging sensors such as synthetic aperture radar, light detection and ranging (LIDAR) systems that use laser scans to capture high-resolution contour maps and images, or multispectral imaging systems that capture a broad spectral range both within and beyond the limits of human vision.

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[7] CRS analysis of FAA Certificate of Authorization issuances for public UAS operations (see http://www.faa.gov/uas/public_operations/foia_responses/ for publicly released data).

[8] See CRS Report R42701, *Drones in Domestic Surveillance Operations: Fourth Amendment Implications and Legislative Responses*, by Richard M. Thompson II.

[9] Hylton J.G. Haynes and Gary P. Stein, "U.S. Fire Department Profile 2013," National Fire Protection Association, Quincy, MA: November 2014, http://www.nfpa.org/research/reports-and-statistics/the-fire-service/administration/us-fire-department-profile.

[10] Erin Durkin, "NYC Explores Drone Use for Everything from Disaster Response to Traffic Surveillance," *New York Daily News*, November 23, 2015, http://www.nydailynews.com/new-york/nyc-explores-drone-disaster-response-traffic-jams-article-1.2444023.

[11] CRS analysis based on Certificate of Authorization (COA) data provided by FAA.

Model Aircraft and Hobby Drones

Recreational model aviation using radio-controlled airplanes emerged as an organized hobby activity in the 1930s as enthusiasts sought to emulate some of the feats of the great air races of the time. It has remained a popular pastime ever since. The Academy of Model Aeronautics, the largest community-based national organization of model aircraft enthusiasts in the United States, has a current membership of more than 180,000 and has chartered about 2,400 local model aircraft clubs across the country.[12]

Modern-day hobby drones are a more recent development, primarily centered around recreational aerial videography and photography. Hobby drones incorporate a variety of consumer electronics technologies that may not be included in traditional model aircraft, including Wi-Fi communications, rechargeable batteries, small high-resolution digital cameras, global positioning satellite (GPS) receiver chips, accelerometer chips, and other miniaturized electronics advancements that came about in large part by the smartphone and portable electronic device industries that have advanced rapidly over the last decade.

The Market for Unmanned Aircraft

The demand to use UAS in domestic airspace has developed differently than many forecasters expected. The original impetus behind anticipated domestic UAS activity was the return of unmanned aircraft used for military and intelligence missions overseas, and the repurposing of those systems for nonmilitary governmental and commercial activities. Industry forecasts assumed that domestic UAS activities would develop as those relatively large aircraft were employed in the United States. Since that time, however, technology allowing smaller, low-cost UAS has developed quickly, leading to a rapid increase in the number of small hobby drones and commercial UAS. The proliferation of these systems has complicated FAA's efforts to develop regulations allowing for the integration of UAS into the national airspace.

UAS offer a unique capability to provide aerial surveillance and sensing capabilities at a much lower cost than manned aircraft operations. In addition, small UAS can sometimes provide imaging and sensing from a perspective that is not easily achievable using either manned aircraft or land-based systems such as cranes or poles. Flight missions considered to be "dirty, dull, or dangerous" are regarded as prime candidates for the use of unmanned aircraft. Examples include surveillance for homeland security, border protection, and law enforcement; highway traffic monitoring; forest fire scouting; disaster response; applications of pesticides; pipeline and transmission line inspection; surveying and geospatial imaging; atmospheric and environmental science; wildlife and natural resources management; scientific data collection; and severe storm monitoring. Some industry experts foresee eventual use of unmanned aircraft for cargo transport. At this point, however, passenger-carrying UAS are not on the horizon.

Industry analysts anticipate a robust market for unmanned aircraft systems, although the extent to which civilian sales will contribute to this market is highly dependent on how the regulation of civilian drones proceeds. In 2013, FAA forecasted that 7,500 commercial small UAS will be operational within five years after it finalizes proposed regulations on UAS.[13] More recently, FAA has backed away from projecting the potential size of the UAS market, noting only that once

[12] For additional information, see the Academy of Model Aeronautics (AMA) website at http://www.modelaircraft.org.

[13] Federal Aviation Administration, *FAA Aerospace Forecast, Fiscal Years 2013-2033*, http://www.faa.gov/data_research/aviation/aerospace_forecasts/media/2013_Forecast.pdf.

routine operations of small UAS are authorized, a surge in commercial uses of UAS is anticipated.[14]Already, more than 3,000 small UAS have been approved for a broad array of commercial uses under a special exemption process called for under the provisions of FMRA.[15]

A market study completed by the Department of Transportation's Volpe Center in 2013 concluded that future UAS markets are likely to follow an "S" shaped curve of technology adoption with three distinct phases: technological innovation, market growth, and market saturation (see **Figure 2**).[16] The study projected that public agencies will operate about 58,000 UAS by 2035, with federal agencies accounting for about 10,000 of those vehicles and the rest being operated by state and local entities. This market is likely to be driven primarily by state and local public safety agencies seeking to augment or acquire aerial surveillance and reconnaissance capabilities. Additional demand is anticipated from state universities using UAS for research, as well as from state highway, natural resource, and environmental protection agencies.

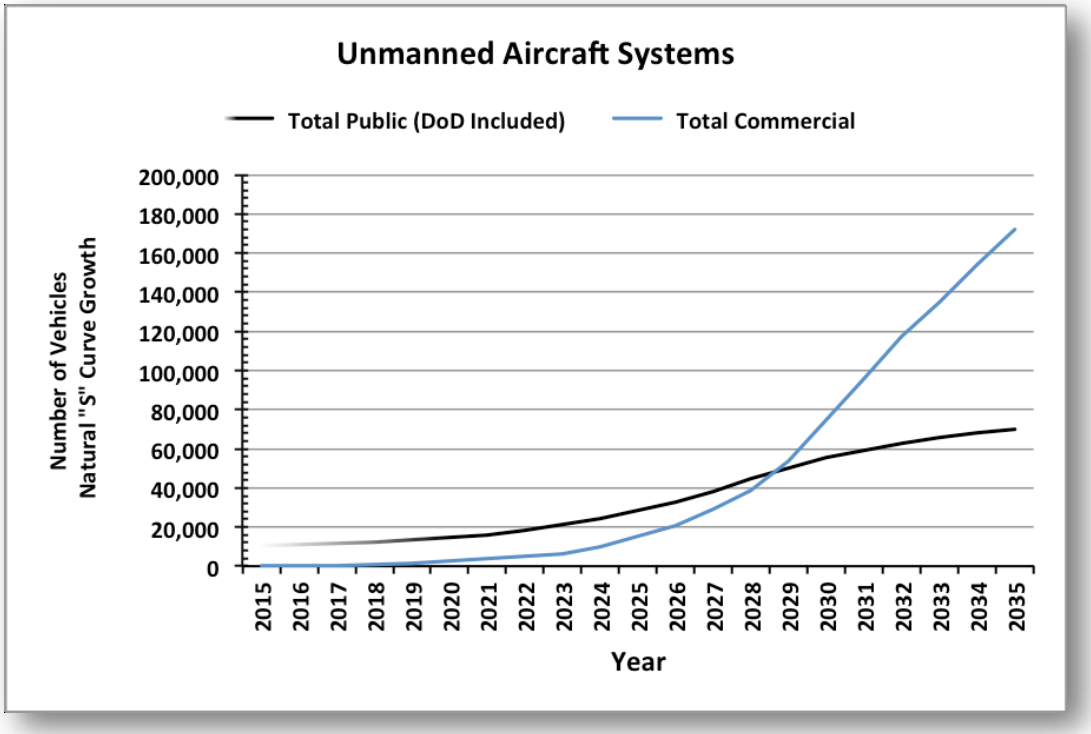
[14] Federal Aviation Administration, "Unmanned Aircraft Systems," in *FAA Aerospace Forecast, Fiscal Years 2015, 2035,* http://www.faa.gov/data_research/aviation/aerospace_forecasts/media/Unmanned_Aircraft_Systems.pdf.

[15] See http://www.faa.gov/uas/legislative_programs/section_333/.

[16] U.S. Department of Transportation, John A. Volpe National Transportation Center, *Unmanned Aircraft System (UAS) Service Demand 2015-2035: Literature Review & Projections of Future Use,* September 2013, DOT-VNTSC-DoD-13-01.

Figure 2. Projection of Technology Adoption of UAS by Public and Commercial Sectors

2015-2035



Source: U.S. Department of Transportation, John A. Volpe National Transportation Center, *Unmanned Aircraft System (UAS) Service Demand 2015-2035: Literature Review & Projections of Future Use,* September 2013, DOT-VNTSC-DoD-13-01.

The Volpe Center study anticipated that market growth for commercial UAS will start to expand exponentially as technology advances and regulations evolve to allow expanded access to the national airspace system. The study estimated that the number of commercial UAS in the United States would grow to about 45,000 by 2029, at which point the number of commercial UAS is expected to surpass the number of UAS operated by the military, federal, and state and local government entities combined. At that point, public-sector market growth is expected to taper off while commercial use continues to grow. The study projected that, by 2035, almost 250,000 UAS will be flying (not including model aircraft), about 170,000 of which would be commercial UAS. The overwhelming majority of these are anticipated to be classified as small or micro-UAS, and would be predominantly used for surveillance and imaging applications.

It is widely anticipated that among civilian uses, agriculture, and in particular precision agriculture applications that involve detailed imaging of crops and fields, will be the primary driver for commercial investment in UAS technology in the near term. Aerial spraying of small crop fields using radio-controlled helicopters began in Japan in the late 1980s, and today is commonplace.[17] Given the size of farm fields in the United States, however, widespread use of

[17] Association for Unmanned Vehicle Systems International, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States,* March 2013, http://www.auvsi.org/auvsiresources/economicreport.

UAS for pesticide spraying will probably not take off until regulations permit BLOS operations. Similarly, applications related to surveillance, monitoring, and inspection of infrastructure and utilities, such as highway systems, railways, pipelines, and electric lines, will face significant limitations until BLOS operations are approved. Current commercial UAS applications are confined to visual line of sight, such as aerial photography of properties for sale, aerial videography for motion pictures and television, and aerial surveys of construction sites, infrastructure, and buildings.[18]

The Regulatory Landscape

FAA distinguishes between three distinct classes of unmanned aircraft users:

- Public Operations, comprising federal, state, and local government users;
- Civil Operations, comprising primarily commercial entities; and
- Model Aircraft Operations, comprising users that fly unmanned aircraft strictly for hobby or recreational purposes.

The regulatory framework for each of these classes of users is unique, reflecting the differing operating characteristics of each of these classes as well as the unique statutory construction of provisions in FMRA. It is notable that this delineation closely parallels distinctions made by FAA for manned aircraft operations, which are subdivided into public aircraft operations, civil aircraft operations, and operations by recreational users of single-seat ultralight vehicles that must obey airspace regulations but do not require aircraft or operator certification or registration.[19]

Public/Governmental UAS Operations

Public UAS operators are granted authority to fly by FAA on a case-by-case basis. The mechanism for obtaining this approval is the certificate of authorization (COA). Operators seeking this authority must provide extensive details regarding the UAS, desired location, flight altitudes, other operational characteristics, and the qualifications of the operator. FAA requires that operators be licensed pilots.

Civilian Commercial UAS

UAS flights conducted for business purposes either by commercial entities or by individuals performing operations that are tied directly or indirectly to some form of commerce are fully regulated by FAA. Until comprehensive regulations governing such activities are issued, commercial UAS operations are approved by FAA on a case-by-case basis as an interim measure. All commercial applications approved to date have required unmanned aircraft to operate at low altitudes within the operator's visual line of sight. FAA's proposed regulations would maintain this requirement; regulations to allow operations beyond line of sight on a routine basis are not yet being considered.

[18] See CRS Report R44192, *Unmanned Aircraft Systems (UAS): Commercial Outlook for a New Industry*, by Bill Canis.

[19] For definitions of civil and public aircraft, see 14 C.F.R. 1.1. For further details on regulation of ultralight vehicles, see 14 C.F.R. Part 103.

Exemptions for Small Commercial Drones

Section 333 of FMRA required FAA to assess whether certain unmanned aircraft could be safely operated within the national airspace system in advance of completion of the required integration plan, and whether such aircraft would require airworthiness certification or be operated under a waiver and/or authorization. This assessment must be based on factors such as size, weight, speed, and type and location of operation. The law further required FAA to establish requirements for such operations if it determines that certain unmanned aircraft could be operated safely prior to the completion of the integration plan.

The process FAA established for reviewing and approving such operations is known as the Section 333 exemption process. Under this process, commercial drone operators may petition FAA for an exemption from FAA regulations. FAA reviews and grants such petition requests on a case-by-case basis.[20]

Initially, FAA required petitioners to apply for and obtain a unique COA designating a specific block of airspace within which they will conduct flights. However, in March 2015, FAA streamlined the Section 333 exemption process, allowing Section 333 exemption holders operating drones weighing less than 55 pounds to fly below 200 feet and away from airports under a blanket nationwide COA. A separate COA for the specific flights is not needed unless operators wish to exceed the 200-foot altitude restriction or operate near an airport. Before streamlining the process, FAA had issued fewer than 50 exemptions. By the end of 2015, however, more than 2,600 exemptions had been issued. Recently, exemptions have been approved at an average rate of about 300 per month.

FAA also allows certain commercial operations of UAS on a case-by-case basis by issuing special airworthiness certificates in either experimental or restricted categories. These have been issued to unmanned aircraft manufacturers and researchers for the purposes of research and development, flight testing, crew training, market surveys, and product demonstrations, and are not intended for other commercial purposes covered under Section 333 exemptions.

Proposed Rule for Small Commercial UAS

Section 332(b) of FMRA required FAA to issue a final rule on civilian small unmanned aircraft systems within 18 months of issuing its integration plan. According to the timeline set by FMRA, the integration plan was to have been submitted to Congress in February 2013 (one year after enactment), and the final rule was to have been issued by August 2014. While FAA has not kept to this schedule, in February 2015 it issued a Notice of Proposed Rulemaking on commercial small UAS operations. FAA anticipates that the final rule will be issued in late April 2016,[21] although the Government Accountability Office (GAO) recently reported that the final rule may not be issued until late 2016 or early 2017.[22]

The proposed rule would allow commercial unmanned aircraft operations of vehicles weighing less than 55 pounds. The regulations would restrict operations to those conducted within unaided visual line of sight of the operator or a visual observer. Operations would be allowed only between sunrise and sunset and only when visibility is at least three miles. Unmanned aircraft

[20] See http://www.faa.gov/uas/legislative_programs/section_333/.

[21] Department of Transportation, *Report on DOT Significant Rulemakings*, December 2015, http://www.transportation.gov/regulations/report-on-significant-rulemakings.

[22] U.S. Government Accountability Office, *Unmanned Aerial Systems: FAA Continues Progress toward Integration into the National Airspace*, GAO-15-610, July 2015.

operated under the proposed rule would be limited to flying below 500 feet above the ground at a maximum airspeed of 100 miles per hour (87 knots). Operations within controlled airspace would require air traffic control permission. Although small UAS would not require FAA airworthiness certification, they would have to be properly registered with FAA, and an operator would be required to maintain and inspect the aircraft before each flight to ensure that it is safe to operate.

Each small commercial UAS would have to be operated by an individual who has obtained an unmanned aircraft operating certificate with a small UAS rating after passing an FAA aeronautical knowledge test and undergoing a terrorism threat assessment administered by the Transportation Security Administration (TSA). Additionally, certificated operators would be required to pass a recurrent knowledge exam every 24 months. While operators would not require medical certification, they would not be able to operate UAS with a known physical or mental condition that could affect safety. Operators as well as visual observers, if used, would be restricted to flying or observing only one UAS at a time. Automated operation of small UAS without a human operator would not be allowed.

While FAA's formal proposal pertained to all UAS weighing less than 55 pounds, the agency sought comment on a less restrictive "micro UAS" classification for vehicles that weigh less than 4.4 pounds (2 kilograms) and are made of frangible materials that easily break apart on impact. FAA currently envisions that micro UAS, if treated separately in its final regulations, would be limited to flight in uncontrolled airspace, would be required to remain at least five miles away from any airport, would be restricted to airspeeds below 35 miles per hour (30 knots), and would have to remain within 1,500 feet of the operator and below 400 feet in altitude.

Recreational Model Aircraft

The regulatory framework for commercial UAS does not apply to operations of small UAS carried out strictly for hobby or recreation. These types of activities were excluded from such regulation under a special rule for model aircraft established in FMRA. Specifically, Section 336 of FMRA generally prohibits FAA from regulating model aircraft that are flown strictly for hobby or recreational use and operated in accordance with safety guidelines set by a community-based organization. Model aircraft weighing less than 55 pounds are generally covered under this special rule, while larger, heavier model aircraft can be covered under it if they are certified through a design, construction, inspection, flight testing, and operational safety program administered by a community-based organization.

While most radio-controlled model aircraft are powered by small propeller engines and weigh only a few pounds, model aircraft also encompass larger models, including some jet-powered scale models, some of which exceed the 55-pound maximum weight specified in the special rule for model aircraft and the proposed rule for small UAS. The legal distinction between model aircraft and small UAS is, therefore, largely based on an aircraft's use rather than its size or capabilities: vehicles classified as model aircraft are to be used strictly for recreational purposes.

In order to qualify for the Section 336 exemption, model aircraft must be operated in a manner that does not interfere with and gives way to manned aircraft, and cannot be operated within five miles of an airport unless the model aircraft operator gives prior notice to the airport operator and the airport control tower, if there is one.

The Academy of Model Aeronautics (AMA), a nationwide organization representing model aircraft enthusiasts headquartered in Muncie, IN, has developed a safety code[23] and other safety

[23] http://www.modelaircraft.org/files/105.pdf.

publications that address the requirements for "community-based" safety guidelines. Additionally, AMA, in partnership with the Association for Unmanned Vehicle Systems International (AUVSI), the Small UAV Coalition, and FAA, has promoted safety guidelines for recreational small unmanned aircraft systems through the *Know before You Fly* campaign to educate the public about the safe use of drones.[24] In general the safety guidelines for model aircraft specify that flights should

- remain below 400 feet above the ground;
- be operated within visual line of sight of the operator;
- remain clear of and not interfere with manned aircraft operations;
- stay at least five miles from an airport unless the airport authority or control tower is notified; and
- remain clear of people or stadiums.[25]

Additionally, FAA issued an updated advisory for model aircraft on September 2, 2015, to reflect the statutory requirements of FMRA.[26] That advisory outlines the requisite criteria to be considered a model aircraft operation as defined in Section 336 of FMRA and also

- notes that model aircraft that endanger flight safety, particularly those that operate in a careless or reckless manner or interfere with or fail to give way to manned aircraft, may be subject to FAA enforcement action;
- warns that model aircraft operators must comply with any temporary flight restrictions imposed due to disasters, reasons of national security, or for the management of air traffic around air shows, major sporting events, or other events;
- states that model aircraft must not operate in prohibited airspace, special flight rules areas, or the flight-restricted zone around Washington, DC, without specific authorization;
- states that model aircraft operators must be familiar with Notices to Airmen (NOTAMs) addressing operations near military installations and federal facilities, certain stadiums, various critical infrastructure facilities, national parks, and emergency service operations; and
- advises that model aircraft operators should follow best practices including limiting operations to below 400 feet above ground level.

Table 1 compares the FAA's current and proposed rules for various types of UAS. As this table illustrates, the same vehicles may be subject to different requirements and restrictions depending on whether they are being flown strictly for recreation or are being flown for commercial purposes. It is also possible that post-flight activities could retrospectively change the way in which a flight is categorized. For example, a hobbyist is free to take video from a model aircraft that carries a camera. However, should the hobbyist subsequently use that video in a commercial manner, such as by selling it or using it to market or promote a product, the flight may no longer qualify as a model aircraft flight.

[24] http://knowbeforeyoufly.org/.

[25] http://www.faa.gov/uas/model_aircraft/.

[26] Federal Aviation Administration, *Model Aircraft Operating Standards,* Advisory Circular 91-57A, September 2, 2015.

Enforcement Authority over Model Aircraft Operators

While Section 336 of FRMA limits FAA regulatory authority over model aircraft, FAA has asserted that it retains enforcement authority against users of the national airspace system, including model aircraft operators who fly in a careless and reckless manner or otherwise endanger the safety of the national airspace system. FRMA provides that the special rule for model aircraft is not to be construed to limit FAA's authority to pursue enforcement action against model aircraft operators who endanger the safety of the national airspace system.[27]

FAA has stated that it does not regard FMRA as limiting its ability to apply safety and security rules to operators of model aircraft along with other airspace users. Moreover, FAA has interpreted the special rule for model aircraft as not limiting its ability to rely on its existing safety regulations to carry out enforcement actions against model aircraft operators. These existing rules prohibit careless and reckless operations and govern rights-of-way among converging aircraft, operational requirements in various classes of airspace, and temporary flight restrictions issued for safety or security reasons.[28]

For example, FAA has kept the flight-restricted zone within a 15-nautical-mile radius of Ronald Reagan National Airport near Washington, DC, off limits to UAS operators. Additionally, in December 2015, FAA extended that restriction to airspace within 30 nautical miles of Ronald Reagan National Airport. Within that radius, all aircraft are required to broadcast position using transponders and remain in radio contact with air traffic controllers, criteria that small UAS and model aircraft are not equipped to meet.[29]

[27] See P.L. 112-95, §336(b).

[28] Federal Aviation Administration, "Interpretation of the Special Rule for Model Aircraft," 79 *Federal Register* 36171-36176, July 25, 2014.

[29] Faiz Siddiqui, "FAA tells local drone and model aircraft clubs: Cease and desist," *Washington Post*, December 31, 2015.

Table 1. Comparison of Model Aircraft, Section 333 Exemptions, and Proposed Regulations Under the Small UAS Notice of Proposed Rulemaking

	Special Rule for Model Aircraft and Related Guidelines	Section 333 Exemptions Covered Under the Blanket Certificate of Authorization[a]	Small UAS Notice of Proposed Rulemaking
Aircraft weight	Less than 55 pounds or certified through a design, construction, inspection, flight test, and operational safety program administered by a community-based organization	Less than 55 pounds	Less than 55 pounds
Maximum aircraft speed	Not specified	Not specified	100 miles per hour (87 knots)
Maximum altitude[b]	400 feet	200 feet	500 feet
Operator qualifications	None, although some FAA guidance material encourages operators to take lessons and learn to fly safely	A current pilot with an FAA airman certificate and either a valid FAA medical certificate or a U.S. driver's license	FAA unmanned aircraft operator certificate with small UAS rating requiring aeronautical knowledge tests every 24 months Transportation Security Administration terrorism threat assessment
Aircraft registration, certification, and airworthiness determination	Except for vehicles weighing less than 250 grams (0.55 pounds), the operator must register with FAA using an online form for small unmanned aircraft, and the assigned registration number must be affixed to the model aircraft	UAS must be registered with the FAA using a paper registration process prior to applying for the Section 333 exemption. After March 31, 2016, applicants will be able to register using the online registration form	Registration required and registration number must be displayed in standard size or as large as possible[c] No FAA airworthiness certification required, but operator must properly maintain the UAS and carry out pre-flight inspections to ensure it is safe to operate
Airspace and operational limitations	Within visual line-of-sight Clear of stadiums and people Not within five miles of an airport without prior notification	Within visual line-of-sight From sunrise to sunset with visibility of three miles or more At least five nautical miles (NM) from an airport with an operating control tower, three NM from an airport with a published instrument procedure but no operational tower, or two NM from a heliport with a published instrument procedure or an airport with no published instrument procedures	Within visual line-of-sight (may use an observer) May not fly over people not directly involved in flight operations A first-person view camera is permitted, but cannot be used to operate beyond visual line of sight or to satisfy see-and-avoid requirements

Source: CRS analysis of information available at http://www.faa.gov/uas.

a. While petitioners granted a Section 333 exemption are automatically covered under the blanket COA, they may apply for and be granted a more permissive COA for certain operations in certain geographic locations.

b. 14 C.F.R. Section 91.117 generally restricts aircraft speeds to 250 knots below10,000 feet, and 200 knots when operating below 2,500 feet near towered airports (class C or D airspace), or whenever in or under Class B airspace.

c. Sizes of aircraft registration markings are specified in 14 C.F.R. Section 45.29. However, since the requirements generally specify that marks must be at least 12 inches high, it would not be feasible to meet this requirement on most small UAS.

Safety Concerns

The slow pace of UAS regulation in the United States thus far reflects, in part, many of the uncertainties about the potential risks of unmanned aircraft operations. Since UAS are new and have not been integrated into complex airspace, the potential safety hazards to manned aircraft and to persons and property on the ground have not been thoroughly evaluated and are difficult to evaluate.

Consider the possibility of a drone being ingested into the jet engine of a large commercial airliner.[30] The extent to which such an event would render the engine inoperable is uncertain, and would likely depend on the size, materials, and construction of the unmanned aircraft, as well as the size of engine and the phase of flight.

The mere presence of drones in congested airspace around major airports raises additional concerns over possible pilot distraction. Numerous airline flight crews have reported sightings of UAS in close proximity to airport approach and departure paths, where they may distract pilots during critical phases of flight. In August 2015, FAA stated that pilots reported 238 sightings of UAS in calendar year 2014 and more than 650 through the first seven months of 2015.[31] Additionally, UAS flights in the vicinity of wildfires disrupted aerial firefighting activities and led to the cancellation of some manned flights conducted in support of firefighting activities in the summer of 2015.[32] Several UAS have been spotted over sporting events, and in some instances drones have crashed at public events such as football games and tennis matches. In some of these instances, operators have faced criminal charges in addition to potential FAA enforcement action.

User Education

Educating UAS operators regarding the potential hazards of drones has been a major focus of efforts to curtail unsafe practices. In partnership with FAA, leading UAS and model aircraft organizations created a website, KnowBeforeYouFly.org, to disseminate information regarding responsible UAS practices. In November 2015, FAA released an "I Fly Safe" checklist aimed at recreational hobby drone and model aircraft operators (see **Figure 3**). The checklist highlights key safety considerations outlined in the special rule for model aircraft and the set of community-based safety guidelines outlined in the Academy of Model Aeronautics' safety code. The educational campaign was launched in advance of the 2015 holiday season in anticipation that many small hobby drones would be received as gifts.

[30] See House Subcommittee on Aviation, Committee on Transportation and Infrastructure, *Hearing: Ensuring Aviation Safety in the Era of Unmanned Aircraft Systems,* October 7, 2015, http://transportation.house.gov/calendar/eventsingle.aspx?EventID=399335.

[31] Federal Aviation Administration, "Pilot Reports of Close Calls With Drones Soar in 2015," http://www.faa.gov/news/updates/?newsId=83445&omniRss=news_updatesAoc&cid=101_N_U.

[32] "Agencies Urge Public Not To Fly Drones Over or Near Wildfires To Prevent Accidents and Disruption of Suppression Operations," National Interagency Fire Center, Boise, ID.

Figure 3. FAA's 2015 "I Fly Safe" Unmanned Aircraft Safety Checklist

Source: Federal Aviation Administration.

Besides these broader safety campaigns, FAA and others have disseminated targeted messages in an effort to curtail certain unsafe practices. For example, in the summer of 2015, FAA, the U.S. Forest Service, and some state firefighting agencies launched public education campaigns warning UAS operators not to fly in the vicinity of firefighting operations (see **Figure 4**).

In addition to concerns about flights in the vicinity of wildfires, UAS activity over sporting events and other outdoor gatherings has been a particular problem. Despite existing security restrictions prohibiting flights over professional sporting events, including professional and college football games, over certain outdoor venues such as Disney theme parks, and over national security-sensitive sites, like the White House, UAS, mostly hobby drones, have been spotted in all of these areas. In response, FAA has released public safety materials to convey that temporary flight restrictions (TFRs) also apply to UAS, and TFR areas are "No Drone Zones."[33] FAA has also launched a public education campaign with the assistance of National Football League teams urging fans to leave their drones at home and not to fly over stadiums or people, or near airports, airplanes, and wildfires.[34]

Figure 4. U.S. Forest Service Educational Poster

Source: U.S. Forest Service.

Educating operators, particularly recreational operators covered under the special rule for model aircraft, about operational safety and airspace regulations continues to pose a particular challenge. Another challenge is assuring that these users are able to obtain, understand, and comply with relevant airspace warnings and restrictions.

In August 2015, FAA began testing a smartphone application, B4UFLY, designed to help UAS operators determine whether there are any restrictions or special requirements in effect in the area where they want to fly. The app obtains location information to provide users of the current status of airspace and any upcoming restrictions in the current or planned flight location. It also provides links to additional FAA UAS resources and regulatory information.[35]

[33] Federal Aviation Administration, *No Drone Zone*, http://www.faa.gov/uas/no_drone_zone/.

[34] Federal Aviation Administration, *San Francisco 49ers Tackle Drone Safety*, September 21, 2015, http://www.faa.gov/news/updates/?newsId=83785.

[35] Federal Aviation Administration, *B4UFLY Smartphone App*, http://www.faa.gov/uas/b4ufly/.

National Park Service Restrictions

Besides curbing UAS use near airports, in restricted areas, and above crowds of people, steps are being taken to limit their use on public lands, particularly park lands where UAS use could interfere with others' enjoyment. The National Park Service released an interim policy in June 2014 observing that UAS may create noise and visual distractions in natural areas, disturb wildlife, and interfere with rescue operations. Until these impacts can be more fully evaluated, the National Park Service has prohibited launching, landing, or operating unmanned aircraft within park lands and waters unless approved in writing by a park superintendent.[36]

State and Local Restrictions

Some states and local areas have also restricted UAS operations on public lands. For example, except for pre-designated areas for model aircraft, the state of New Jersey prohibits the use of UAS on its designated state park lands without prior approval, in a manner similar to the interim policy released by the National Park Service.[37]

State and local jurisdictions have authority over land use, and can restrict or prohibit certain activities, such as launching, operating, or recovering a UAS, on lands owned by the state or a municipality. However, given FAA jurisdiction over airspace, state and local laws and ordinances generally may not restrict UAS overflights of public lands so long as the UAS is operated from beyond the boundaries of the publicly owned area. Airspace restrictions would have to be coordinated with and disseminated by FAA.

In addition, some private entities have worked with FAA to establish flight restrictions over certain lands, usually based on security concerns. Airspace over Disney theme parks, for example, is restricted from the surface to 3,000 feet.[38] This restriction applies to UAS as well as to manned aircraft. Several ski resorts, on the other hand, have established policies restricting UAS without involving FAA.[39] However, such policies, particularly as they pertain to UAS launched or operated from outside resort boundaries, raise unresolved legal issues over whether a private entity has any right or authority to limit the use of low-altitude airspace over its land, or whether such actions are strictly under the purview of FAA.

Enforcement

At present, UAS, and small UAS in particular, are largely segregated from manned aircraft operations as a safety measure. This is accomplished through altitude restrictions that keep UAS below controlled airspace and flight restrictions that keep UAS away from airports and other restricted areas. Enforcement of these restrictions is an important tool for FAA to assert its authority over model aircraft and UAS and to promote safe operations. FAA has stated that it has

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[36] Jonathan B. Jarvis, Director, *Policy Memorandum 14-05: Unmanned Aircraft – Interim Policy*, National Park Service, http://www.nps.gov/policy/PolMemos/PM_14-05.htm.

[37] New Jersey Department of Environmental Protection, Division of Parks and Forestry, State Park Service, *Unmanned Aerial Vehicles*, Policy Number 2.38, July 8, 2015, http://www.state.nj.us/dep/parksandforests/parks/docs/policy_2.38_unmanned_aerial_vehicles-drones.pdf.

[38] Federal Aviation Administration, NOTAM FDC 4/3634, Temporary Flight Restrictions for Special Security Reasons: Disney World Theme Park, Orlando, Florida; Federal Aviation Administration, NOTAM FDC 4/2625, Temporary Flight Restrictions for Special Security Reasons: Disneyland Theme Park, Anaheim, California Near Seal Beach VORTAC (SLI).

[39] Drone Policies at US Ski Areas, *UAS Vision*, http://www.uasvision.com/2016/01/11/drone-policies-at-us-ski-areas/.

launched a number of investigations of unauthorized UAS operations and has imposed civil penalties in some cases. In October 2015, it announced a proposed fine of $1.9 million against a commercial UAS operator.[40] FAA alleged that the operator conducted unauthorized operations for the purpose of commercial photography in New York, NY, and Chicago, IL, between March 2012 and December 2014.

Previously, in November 2014, the National Transportation Safety Board (NTSB) upheld FAA's authority to pursue enforcement action against UAS and model aircraft operators, finding that such vehicles fit the statutory and regulatory definition of an aircraft, and are therefore subject to applicable general flight regulations such as the prohibition on careless and reckless operations. In that case, FAA had fined an individual for careless and reckless operation of a fixed-wing UAS being used for aerial videography of the University of Virginia campus in Charlottesville, VA.[41] The FAA action was upheld by the NTSB on appeal.

However, despite its authority to act against unauthorized and unsafe UAS and model aircraft operations, carrying out enforcement actions has proved challenging for FAA. This may be partly due to difficulty in identifying possible violators. Additionally, FAA has limited resources to investigate and pursue regulatory action against violators. It has requested the support of state and local law enforcement agencies, and has developed guidance for them to follow in the investigation of suspected UAS violations.[42]

UAS Registration

FAA requires operators of all UAS flown under a Section 333 exemption or in authorized test ranges to register their unmanned aircraft. On October 19, 2015, FAA asserted its authority to require all UAS operators, including operators of model aircraft, to register their aircraft. It formed a task force to develop recommendations.[43] In December 2015 FAA announced an Internet-based application process for UAS incorporating several of the task force recommendations.[44] Effective December 21, 2015, all operators of model aircraft and hobby drones weighing between 250 grams and 55 pounds are required to register with FAA. Operators of small UAS to be used exclusively as model aircraft must comply by February 19, 2016. The cost of registration is $5, although those who registered by January 20, 2016, had their registration fee refunded.[45] After March 31, 2016, commercial UAS operators will also be able to use the online registration. Before then, those applying for Section 333 exemptions must use FAA's mail-in paper registration process for aircraft. Among other things, FAA expects that registration will simplify the task of identifying individuals who operate a UAS in an unsafe manner.

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[40] Federal Aviation Administration, Press Release – FAA Proposes $1.9 Million Civil Penalty Against SkyPan International for Allegedly Unauthorized Unmanned Aircraft Operations, October 6, 2915, http://www.faa.gov/news/press_releases/news_story.cfm?newsid=19555.fs.

[41] National Transportation Safety Board, *Michael P. Huerta v. Raphael Pirker*, NTSB Order EA-5730, Served November 18, 2014, Docket CP-217, http://www.ntsb.gov/legal/alj/Documents/5730.pdf.

[42] Federal Aviation Administration, *Law Enforcement Guidance for Suspected Unauthorized UAS Operations*, http://www.faa.gov/uas/law_enforcement/.

[43] Department of Transportation, Office of the Secretary and Federal Aviation Administration, "Clarification of the Applicability of Aircraft Registration Requirements for Unmanned Aircraft Systems (UAS) and Request for Information Regarding Electronic Registration for UAS," 80 *Federal Register* 63912-63914, October 22, 2015.

[44] Federal Aviation Administration, "Registration and Marking Requirements for Small Unmanned Aircraft," 80 *Federal Register* 78593, December 16, 2015.

[45] See http://www.faa.gov/uas/registration/.

Technology to Curtail Airspace Violations

FAA and UAS manufacturers are examining technologies that could override operators and prevent flights into airspace where UAS are not permitted. The technology, broadly referred to as "geo-fencing," relies on up-to-date onboard geospatial databases that include information about the location of airports, prohibited and restricted areas, and temporary flight restrictions established by FAA. To be fully effective, the operator must assure that the data are current before a launch. Once airborne, the UAS will constantly compare precise location data, usually derived from onboard GPS receivers, against information in the prohibited flight area database. If the operator attempts to fly the UAS into an area designated as off limits in the database, the UAS would override the operator's inputs and keep the aircraft outside of the restricted area.

Some major manufacturers of small UAS are already equipping new systems with these capabilities or, in some cases, offering to retrofit current UAS. There has been some interest in Congress in making geo-fencing a mandatory feature for newly manufactured consumer UAS and in requiring that UAS without geo-fencing capabilities be upgraded when it is feasible to do so.[46]

There are also efforts under way to use video analytics, acoustic sensors,[47] and other detection technologies to provide warning of drone intrusions into restricted airspace. Such systems could be used to detect and locate airspace violators to carry out regulatory enforcement measures.

Security Concerns

In addition to safety concerns, UAS pose a potential threat to security. Small UAS can be used by criminals and terrorists for espionage, surveillance, and intelligence gathering at critical government and industrial facilities. Criminals are also using unmanned aircraft to smuggle drugs and contraband across U.S. borders and over prison walls and fences.[48] Somewhat larger UAS could be used to carry out terrorist attacks by serving as platforms to deliver explosives or chemical, biological, radiological, or nuclear weapons. Chemical and biological agents pose a particular concern, as UAS used for aerial pesticide applications could readily serve as platforms to carry out attacks.[49] Small UAS could similarly be used to disperse small amounts of certain agents that may be lethal in minute quantities. Even a hoax attack—for example, releasing a powdery substance and making false claims that it contains anthrax virus—could cause widespread panic. UAS could also be used as platforms for firearms or other weapons.

While many attack scenarios involving UAS may sound far-fetched, most are technically feasible with already-available technology, and some have been contemplated in terrorist plots. In September 2011, FBI disrupted a homegrown terrorist plot to attack the Pentagon and the Capitol

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[46] Senator Dianne Feinstein, *Feinstein Introduces Bill to Improve Safety of Consumer Drones*, Press Release, June 18, 2015, http://www.feinstein.senate.gov/public/index.cfm/2015/6/feinstein-introduces-bill-to-improve-safety-of-consumer-drones; Keith Lang, "Schumer Moves To Require Geo-Fencing on Drones," *The Hill*, September 14, 2015, http://thehill.com/policy/transportation/253565-schumer-moves-to-require-geo-fencing-on-drones.

[47] See "Boston Police Set Up 'Drone Shields' Along the 2015 Marathon Route, *Motherboard*, April 22, 2015, http://motherboard.vice.com/read/boston-police-set-up-drone-shields-along-the-2015-marathon-route.

[48] Sophie Jane Evans, "Two Men, Ages 18 and 19, Facing Up To 20 Years in Prison After Admitting Smuggling 30 lbs. of Heroin from Mexico by Drone," *Daily Mail (UK)*, August 13, 2015; Alison Knezevich and Ian Duncan, "Drone Intercepted Near Maryland Prison, Officials Say," *Baltimore Sun*, August 25, 2015.

[49] See Subcommittee on Oversight and Management Efficiency, House Committee on Homeland Security, *Hearing: Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies*, March 18, 2015.

with large model aircraft filled with explosives.[50] In 2012, the investigation culminated in the sentencing of 27-year-old Rezwan Ferdaus, who had ordered a remote controlled model aircraft from a Florida distributor under a false identity and had sought to acquire explosives from an undercover agent. Ferdaus also sought to acquire assault rifles and grenades to be used in a second phase of his attack plot to target personnel evacuating the buildings hit by the explosives-laden model aircraft.

Since 2012, other security incidents have raised concerns over potential security threats posed by UAS. Widely publicized drone incidents include an unauthorized flight at a political rally in Dresden, Germany, in September 2013 that came in close proximity to German Chancellor Angela Merkel; a January 2015 crash of a small drone on the White House lawn in Washington, DC; and a series of unidentified drone flights over landmarks and sensitive locations in Paris, France, in 2015.

Conversely, UAS may be vulnerable to attack from the ground. UAS could be targeted by terrorists or cybercriminals seeking to tap into sensor data transmissions or to cause mayhem by hacking or jamming command and control signals. Signal jamming or hacking could result in a crash or hostile takeover, as command and control systems typically use unsecured radio frequencies. Some experts have recommended that unmanned aircraft systems be required to have spoof-resistant navigation systems and not be solely reliant on signals from global positioning system equipment, which can be easily jammed.[51] While TSA has broad statutory authority to address a number of aviation security issues, it has not formally addressed the potential security concerns arising from unmanned aircraft operations in domestic airspace.

UAS Detection and Countermeasures

The persisting security threats of UAS, along with safety concerns about unauthorized operations in restricted areas and near airports, has generated increasing interest in technology solutions to detect and, potentially, to disable unauthorized UAS activity. A number of technology solutions have been developed to address this emerging need.

In October 2015, FAA announced that it was working with a private firm to test a system designed to detect radio transmissions between an unmanned aircraft and its operator and pinpoint the operator location.[52] A number of other systems using precision radar combined with analytics are capable of distinguishing small UAS from birds. Some available technologies also offer the potential of destroying, disabling, jamming, or taking over control of an unmanned aircraft to mitigate safety dangers or inhibit security threats.[53] There is interest in deploying these

[50] U.S. Attorney's Office, Massachusetts, "Ashland Man Sentenced for Plotting Attack on Pentagon and U.S. Capitol and Attempting to Provide Detonation Devices to Terrorists," Press Release, November 1, 2012, http://www.justice.gov/archive/usao/ma/news/2012/November/FerdausRezwansentencing.html.

[51] Todd Humphreys, "Statement on the Vulnerability of Civil Unmanned Aerial Vehicles and Other Systems to Civil GPS Spoofing," Submitted to the Subcommittee on Oversight, Investigations, and Management of the House Committee on Homeland Security, July 19, 2012; U.S. Government Accountability Office, "Unmanned Aircraft Systems: Use in the National Airspace System and the Role of the Department of Homeland Security," Statement of Gerald L. Dillingham, Ph.D., Director, Physical Infrastructure Issues, Before the Subcommittee on Oversight, Investigations, and Management, Committee on Homeland Security, House of Representatives, July 19, 2012, GAO-12-889T.

[52] William Garvey, Jessica A. Salerno, and Molly McMillin, "FAA Will Test UAV Detection System," *Business and Commercial Aviation*, October 27, 2015, http://aviationweek.com/bca/faa-will-test-uav-detection-system.

[53] Angus Batey and Bill Sweetman, "Detection and Protection against UAS Threats," *Aviation Week & Space Technology – Defense Technology Edition*, October 9, 2015, http://aviationweek.com/defense/detection-and-protection-against-uas-threats.

systems near security-sensitive locations and flight-restricted areas, including major commercial airports.

Research Activities to Support Integration

The effort to integrate UAS into the national airspace system has highlighted a number of technological challenges. These include

- developing capabilities to detect, sense, and avoid other air traffic, including both manned and other unmanned flights;
- mitigating risks to persons and property on the ground;
- preventing unauthorized use of airspace;
- providing adequate and adequately secure radiofrequency spectrum for command and control linkages and sensor payloads; and
- addressing human factors considerations including approaches to system automation, human-system interfaces, and operator training and qualification standards.

Much of this research is still in its early stages, and while the research is intended to inform FAA decisionmaking regarding future operation and regulation of UAS in the national airspace, anticipated benefits have not yet been realized.

A key requirement for enabling integrated UAS operations is the development of "sense-and-avoid" capabilities to allow unmanned aircraft and unmanned aircraft operators to reliably detect and maneuver around other aircraft, both manned and unmanned. While "sense-and-avoid" technologies are critical for beyond-line-of-sight operations that are not yet being considered in FAA regulations, they may also have application in visual-line-of-sight operations, particularly when the command-and-control links between the aircraft and its ground station are lost. FAA, in partnership with NASA and aerospace companies, has carried out demonstrations of prototype proof-of-concept sense-and-avoid systems.[54] However, the Department of Transportation Office of Inspector General found last year that there is a lack of mature detect-and-avoid technology to avoid collisions, and noted that industry experts consider this "the most pressing technical challenge to integration yet to be mitigated."[55] Even if suitable technologies are developed, their cost is likely to make them impractical for installation on small hobbyist UAS, at least initially.

FAA Designated Test Sites

FRMA required FAA to select six test sites to conduct research to inform FAA on integrating UAS into the national airspace system.

The test sites are to conduct research addressing the various challenges associated with integrating UAS into the national airspace system. While the test sites must agree to share data and findings with FAA to help develop regulations and procedures for UAS integration, the test

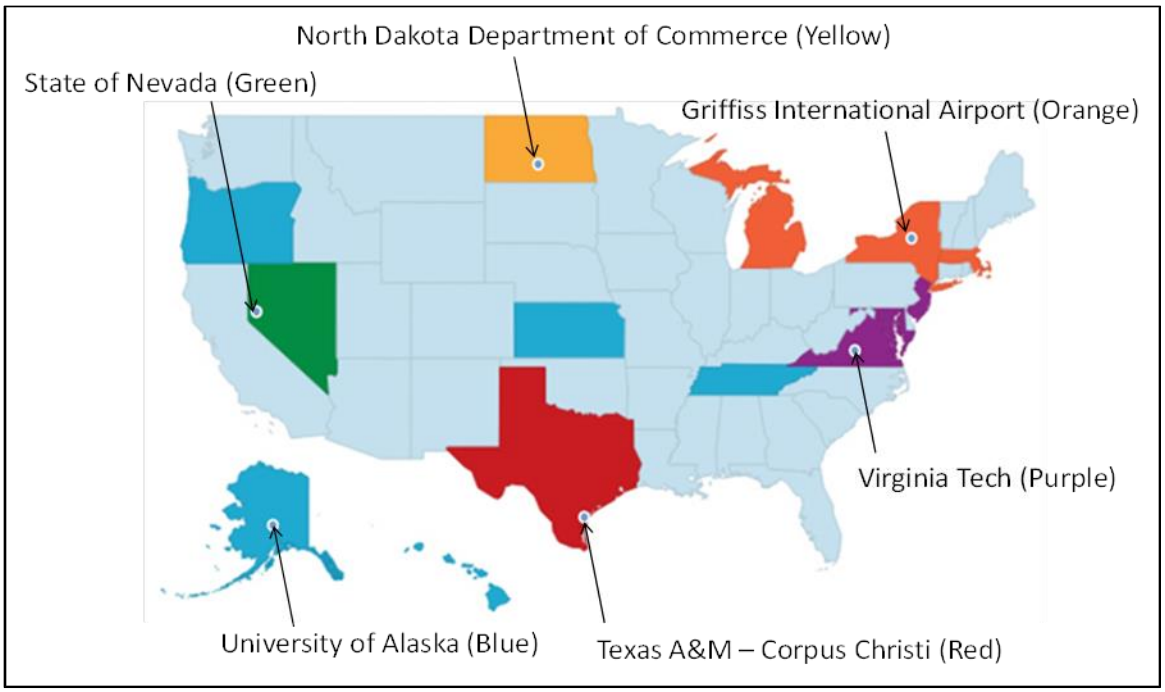
[54] National Aeronautics and Space Administration. "NASA, FAA, Industry Conduct Initial Sense-and-Avoid Test," Press Release, January 25, 2015, http://www.nasa.gov/centers/armstrong/Features/acas_xu_paves_the_way.html.

[55] Statement of Matthew E. Hampton, Assistant Inspector General for Aviation, U. S. Department of Transportation, *FAA's Progress and Challenges in Integrating Unmanned Aircraft Systems into the National Airspace System*, Department of Transportation, Office of Inspector General, CC-2015-002, Washington, DC, December 10, 2014, p. 4, https://www.oig.dot.gov/sites/default/files/UAS%20Statement_Master%20File_12-9-14_Final_508.pdf.

sites do not receive funding from FAA. The test site operators are required to manage the sites and give access to authorized research entities interested in using the sites for missions that will help advance UAS integration. Each test site operator must develop and adhere to safety standards and develop privacy policies for UAS operations within the test sites and data collection and retention by test site users.[56]

The six test site operators selected by FAA are the University of Alaska in Alaska, which includes additional sites in Hawaii, Oregon, Kansas, and Tennessee; the state of Nevada; Griffiss International Airport in New York, with additional test range locations in Massachusetts and Michigan; the North Dakota Department of Commerce; Texas A&M University—Corpus Christi, TX; and Virginia Tech, which includes additional test ranges in Maryland and New Jersey (see **Figure 5**).

Figure 5. UAS Test Sites



Source: CRS; Federal Aviation Administration.

Note: Figure shows states in which test site operators and test ranges are located, not the geographical boundaries of the test sites and ranges.

Center of Excellence

FAA has also designated a center of excellence for UAS research, education, and training to support UAS integration into the national airspace system. The center is a consortium of 15 universities led by Mississippi State University, and will focus on various UAS research topics including detect and avoid technologies; safety of low-altitude operations; control and communications; compatibility with air traffic control operations; spectrum management; training and certification of UAS operators; and human factors considerations.

[56] Federal Aviation Administration, "Unmanned Aircraft System Test Site Program," 78 *Federal Register* 68360-68364, November 14, 2013, http://www.faa.gov/uas/legislative_programs/test_sites/.

Under the Center of Excellence, Mississippi State University has created the Alliance for System Safety of UAS through Research Excellence (ASSURE), and has expanded the scope to include additional affiliate universities and additional research projects. ASSURE participants are using more than 300 UAS for this research.[57]

Arctic Demonstration

Section 332 of FMRA required FAA to develop and execute a plan establishing permanent areas in the Arctic where small unmanned aircraft may operate around the clock for research and commercial purposes. The act required FAA to include in its plan processes allowing for beyond-line-of-sight operations and over-water flights from the surface to 2,000 feet with ingress and egress routes from selected coastal launch sites. Under the resulting arctic implementation plan,[58] FAA issued restricted category type certificates to two UAS models, the Boeing Insitu ScanEagle and the AeroVironment Puma, and approved two energy companies to use these systems for arctic exploration, aerial surveys, and research, including studies on marine mammals and ice surveys. This marked the first time unmanned aircraft were certified for commercial purposes. Flights were initially limited to over-water operations, but were subsequently permitted over land based on safety assessments.[59]

Project Pathfinder

In May 2015, FAA launched a cooperative research and development partnership with industry, called Project Pathfinder, to address more advanced UAS operations beyond those outlined in the proposed rulemaking on commercial UAS. FAA is working with Cable News Network (CNN) to examine UAS news-gathering over populated areas; with a UAS developer to study beyond-line-of-sight operations for crop monitoring in precision agriculture operations; and with BNSF Railroad to explore challenges of using UAS to inspect rail system infrastructure.[60] In October 2015, FAA announced that it was expanding Project Pathfinder to include research on the detection of UAS in the vicinity of airports, addressing growing concerns regarding the operation of UAS in close proximity to landing and departing aircraft.[61]

NASA Initiatives

In addition to FAA, NASA has extensive ongoing research examining UAS integration. NASA has divided its UAS integration research into five distinct focus areas: separation assurance, communications, human systems integration, airworthiness certification, and integrated testing and evaluation.[62] Part of NASA's ongoing work is research into an air traffic management system for low-altitude airspace and small UAS operations it refers to as UAS traffic management

[57] http://www.assureuas.org/index.php.

[58] Federal Aviation Administration, *Expanding the Use of Small Aircraft Systems in the Arctic Implementation Plan, FAA Modernization and Reform Act of 2012*, http://www.faa.gov/uas/media/sUAS_Arctic_Plan.pdf.

[59] http://www.faa.gov/uas/legislative_programs/arctic/.

[60] Federal Aviation Administration, *Focus Area Pathfinders*, http://www.faa.gov/uas/legislative_programs/pathfinders/.

[61] Federal Aviation Administration, "FAA Expands Unmanned Aircraft Pathfinder Efforts," *News & Updates*, http://www.faa.gov/news/updates/?newsId=83927.

[62] National Aeronautics and Space Administration, *NASA Armstrong Fact Sheet: Unmanned Aircraft Systems Integration in the National Airspace System*, February 28, 2014, http://www.nasa.gov/centers/armstrong/news/FactSheets/FS-075-DFRC.html.

(UTM). NASA envisions that the system would be semi-autonomous, involving limited numbers of human managers to make strategic decisions while routine functions like dynamic geo-fencing and airspace configuration, route planning, separation management, and sequencing and spacing of low-altitude UAS could be performed with limited human involvement.[63] The system would need to work in tandem with onboard UAS technologies to provide lost link capabilities allowing autonomous vehicle recovery if command and control communications are lost. NASA envisions that prototype technologies capable of maintaining safe spacing between participating and nonparticipating UAS over moderately populated areas will be completed by 2018, and that the technology will be transitioned to FAA around 2019 for further testing and development.

Related Legislation

Unmanned aircraft operation in domestic airspace is the subject of a number of bills introduced in the 114th Congress.

- The Responsible Skies Act of 2015 (H.R. 798) would require that UAS flown under Section 333 exemptions remain below 400 feet and more than five miles from the perimeter of any airport that provides scheduled passenger air transportation.
- The Safe Skies for Unmanned Aircraft Act of 2015 (S. 387) would require FAA to develop procedures allowing beyond-line-of-sight operations for aeronautical research purposes conducted as public aircraft operations, including atmospheric and natural resources research, meteorological observations, and airborne astronomy. Similar language is contained in H.R. 819.
- The Commercial UAS Modernization Act (S. 1314) would establish an interim rule for small commercial UAS that would apply until FAA finalizes its proposed small UAS rulemaking. The interim policy described in the act would require aircraft registration and operator knowledge testing and certification. It would restrict operations to visual line of sight, below 500 feet, and away from towered airport controlled airspace without prior permission from air traffic control. The bill would give FAA explicit enforcement authorities and would require operators to report accidents resulting in injury or property damage other than to the small UAS itself. The act would also establish a position of deputy associate administrator for unmanned aircraft within FAA that would be responsible for overseeing the integration of UAS into the national airspace system, and develop strategies for unmanned aircraft spectrum issues, barriers to operating unmanned aircraft beyond line of sight, barriers to allowing payload carriage, and barriers to utilizing automated UAS. The bill also would direct FAA to expedite processing of exemptions to allow certain beyond-line-of-sight operations, programmatic exemptions based on previous analysis, extended visual-line-of-sight and marginal visual flight rules weather conditions, and heavier UAS. The bill also directs FAA to establish a joint data collection and analysis program at the William J. Hughes Technical Center in New Jersey to analyze test site data, implement an air traffic management pilot program for airspace below 1,200 feet,

[63] National Aeronautics and Space Administration, *Unmanned Aircraft System (UAS) Traffic Management (UTM)*, http://utm.arc.nasa.gov/index.shtml.

and create a partnership to test the management of small UAS operated at low altitude.

A number of other bills addressing privacy and security concerns of domestic UAS operations have also been introduced. Since multiyear authorization for FAA programs and funding under FMRA expired at the end of FY2015, many anticipate congressional deliberations on a new comprehensive FAA reauthorization measure during the second session of the 114th Congress. Safety, security, and privacy issues regarding domestic UAS operations and UAS integration are likely to be issues of particular interest in these deliberations.

Author Information

Bart Elias
Specialist in Aviation Policy

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