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UNMANNED AIRCRAFT SYSTEMS

Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development

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G A O

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Highlights of [GAO-13-346T](#), a testimony before the Subcommittee on Oversight, Committee on Science, Space, and Technology, House of Representatives

Why GAO Did This Study

Unmanned aircraft systems are aircraft and associated equipment that do not carry a pilot aboard, but instead operate on pre-programmed routes or are manually controlled by pilot-operated ground stations. Although current domestic uses of UAS are limited to activities such as law enforcement, forensic photography, border security, and scientific data collection, UAS also have a wide range of other potential commercial uses. According to an industry forecast, the market for UAS is expected to grow and could be potentially worth \$89 billion over the next decade.

Concerned with the pace of UAS integration into the national airspace, Congress established specific requirements and set deadlines for FAA in the 2012 FAA Modernization and Reform Act (the 2012 Act).

This testimony discusses 1) the roles and responsibilities of and coordination among federal agencies and other UAS stakeholders involved in integrating UAS, 2) FAA's progress in complying with the 2012 Act's UAS requirements, and 3) research and development efforts by FAA and other entities to address challenges for safely integrating UAS.

This testimony is based on a 2012 GAO report. In past work, GAO analyzed FAA's efforts to integrate UAS into the national airspace, the role of other federal agencies in achieving safe and routine integration, and research and development issues. GAO also conducted selected interviews with officials from FAA and other federal agencies, industry, and academic stakeholders.

View [GAO-13-346T](#). For more information, contact Gerald L. Dillingham at (202) 512-2834 or dillinghamg@gao.gov.

February 15, 2013

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What GAO Found

While Congress has tasked FAA to lead the effort of safely integrating unmanned aircraft systems (UAS) in the national airspace, several federal and other entities also have a role. FAA has established various mechanisms to facilitate collaboration with these entities. For example, FAA has entered into formal agreements with the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) on obtaining appropriate safety data and coordinating research and development, respectively. FAA has also involved industry stakeholders and academia in the development of standards and research for UAS operations. FAA recently created the UAS Integration Office, within FAA, to coordinate all intra-agency UAS efforts and provide organizational leadership. Continued collaboration among UAS stakeholders will be critical to minimizing duplication of research and addressing implementation obstacles.

While FAA has made progress toward meeting the 2012 Act's requirements, as of January 2013, it has missed several of its deadlines. FAA continues to face challenges, with many of its efforts still in process. For example, the establishment of six test ranges for UAS operations, as required by the 2012 Act, is being delayed due to privacy concerns. Meeting the 2012 Act's requirements moving forward will require continued collaboration and significant work for FAA. In September 2012, GAO recommended that FAA incorporate mechanisms in its planning that allow for regular monitoring to assess its progress. Such mechanisms can help FAA identify what has been achieved and what remains to be done.

Research and development efforts are under way to mitigate obstacles to safe and routine integration of UAS into the national airspace. However, these research and development efforts cannot be completed and validated without safety, reliability, and performance standards, which have not yet been developed because of data limitations. GAO previously reported that FAA has not utilized the operational data it already possesses, such as data provided by the DOD.

Examples of UAS



Sources: Octatron Inc. and DHS.



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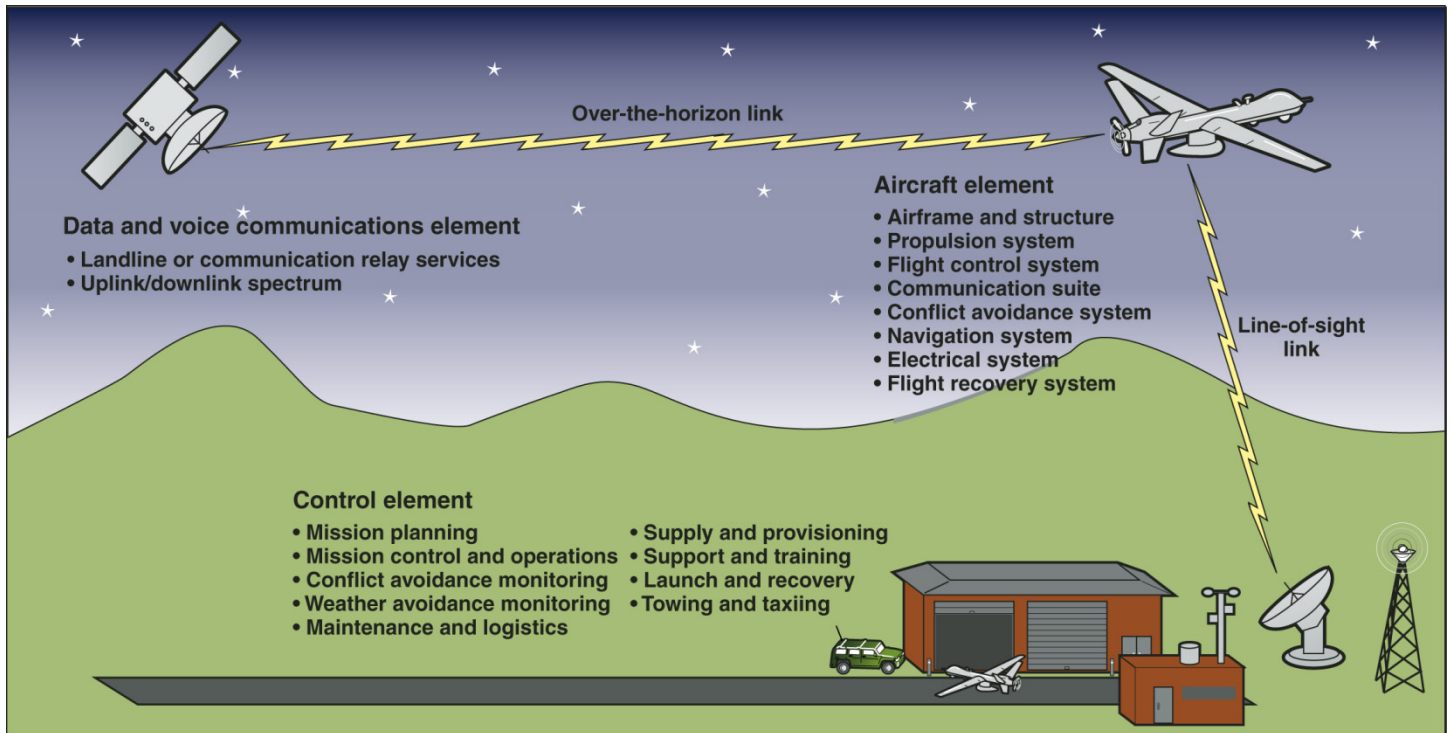
United States Government Accountability Office
Washington, DC 20548

Chairman Broun, Ranking Member Maffei, and Members of the Subcommittee:

I appreciate the opportunity to testify on several efforts to allow unmanned aircraft systems (UAS) to safely and routinely fly in the national airspace. UAS are aircraft and associated equipment that do not carry a pilot aboard, but instead operate on pre-programmed routes or are manually controlled by following commands from pilot-operated ground control stations. Figure 1 shows the components of a UAS, including the airframe, power plant, communications links, and ground control station. UAS are typically described in terms of weight, endurance, purpose of use, and altitude of operation. For the purposes of this testimony, we consider UAS in two broad categories: a *small* UAS is less than 55 pounds, while a *large* UAS is 55 pounds or more.¹

¹We have distinguished between small and large aircraft because a number of rules and requirements apply specifically to aircraft that weigh less than 55 pounds, which we discuss later in the report. According to an industry association, small UAS are expected to comprise the majority of UAS that will operate in the national airspace.

Figure 1: Conceptual Rendering of Unmanned Aircraft System



Sources: GAO and NASA.

Current domestic use of UAS is limited to activities such as law enforcement, search and rescue, forensic photography, border security, weather research, and scientific data collection. UAS also have potential commercial uses that include pipeline, utility, and farm-fence inspections; vehicular traffic monitoring; real-estate and construction-site photography; relaying telecommunication signals; film industry production; and fishery protection and monitoring. Concerned with the pace of progress toward integrating UAS into the national airspace, in February 2012, Congress established specific requirements and set deadlines for FAA to expedite UAS integration in the FAA Modernization and Reform Act (the 2012 Act).² In September 2012, we reported that FAA had taken steps to meet these requirements and deadlines, and raised concerns about when UAS

²Pub. L. No. 112-95, §§ 332 – 334, 126 Stat. 11 (2012).

integration in the national airspace will be achieved.³ We recommended that FAA incorporate regular monitoring of its efforts to measure progress toward fulfilling its statutory requirements. We also reported on a variety of obstacles that still must be overcome before UAS might be safely integrated in the national airspace.

My statement today is based on our September 2012 report, updated as appropriate, and discusses 1) the roles and responsibilities of and coordination among federal agencies and other UAS stakeholders involved in integrating UAS into the national airspace; 2) FAA's progress in complying with the 2012 Act's UAS requirements; and 3) research and development efforts by FAA and other entities to address challenges for safely integrating UAS. We reviewed and analyzed documents and interviewed relevant government, academic, and private-sector entities, as well as federal UAS users. More detailed explanations of the methods used to conduct our work can be found in the full report referenced above. We performed our work in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

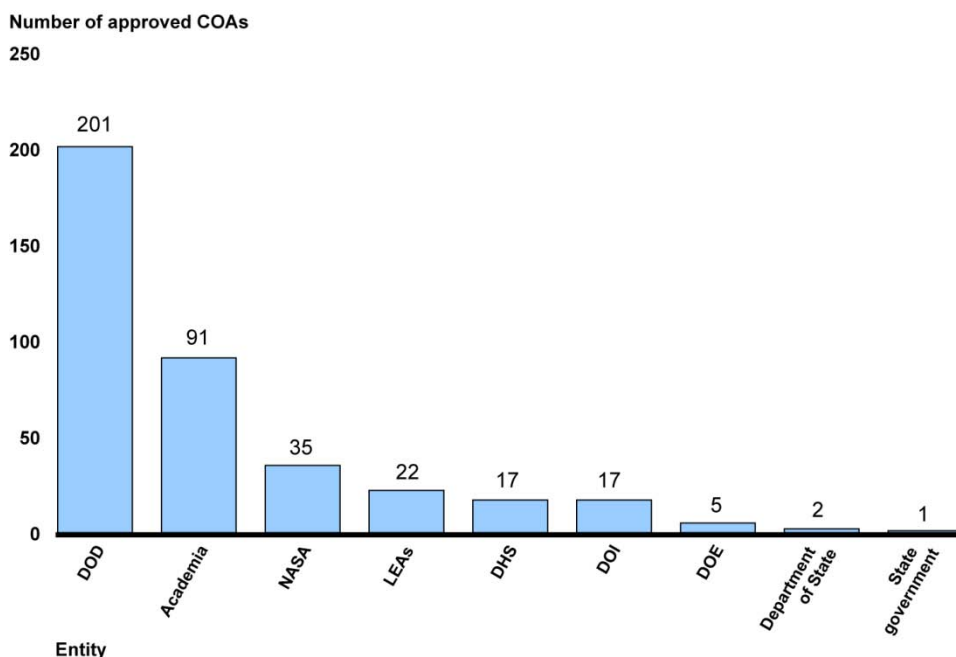
Currently, FAA authorizes all domestic military; public (academic institutions, federal, state, and local governments including law enforcement organizations); and civil (private sector entities) UAS operations on a limited basis after conducting a case-by-case safety review. Federal, state, and local government agencies must apply for Certificates of Waiver or Authorization (COA), while civil operators must apply for special airworthiness certificates in the experimental category. Because special airworthiness certificates do not allow commercial operations, there is currently no means for FAA to authorize commercial UAS operations.

Since FAA started issuing COAs in January 2007, 1,428 COAs have been issued. At present, under COA or special airworthiness certification,

³GAO, *Unmanned Aircraft Systems: Measuring Progress and Addressing Potential Privacy Concerns Would Facilitate Integration into the National Airspace System*, [GAO-12-981](#) (Washington, DC: Sept. 14, 2012).

UAS operations are permitted for specific time frames (generally 12 to 24 months); locations; and operations. So, one agency can be issued multiple COAs to operate one UAS for the same purpose. In 2012, FAA issued 391 COAs to 121 federal, state, and local government entities across the United States, including law enforcement entities as well as academic institutions (see fig. 2).⁴

Figure 2: Entities with COAs Approved from January 1, 2012, through December 31, 2012



Source: GAO analysis of FAA data.

Notes: DOD=Department of Defense, NASA=National Aeronautics and Space Administration, LEAs=Local Law Enforcement Agencies, DHS=Department of Homeland Security, DOI=Department of the Interior, and DOE=Department of Energy.

According to an industry forecast, the market for government and commercial use of UAS is expected to grow, with small UAS having the greatest growth potential.⁵ This forecast estimates that the worldwide

⁴These COA figures provided by FAA may not represent the number of active COAs because COAs issued prior to January 2012 may still be active and COAs issued during 2012 may have already expired.

⁵Teal Group Corporation, *World Unmanned Aerial Vehicle Systems* (Fairfax, VA: 2012).

UAS market could be potentially worth \$89 billion over the next decade. The majority of this estimate is for military-type products (primarily the U.S. military) with the associated research and development for production estimated to be \$28.5 billion over the next 10 years. As smaller UAS are expected to continue to improve in technology and decrease in price, their prevalence in the national airspace is expected to increase. The forecast also indicates that the United States could account for 62 percent of the world’s research and development investment for UAS technology over the coming decade.

FAA Is Responsible for Leading Coordination Efforts across Agencies and Industry to Achieve UAS Integration

Congress has tasked FAA to lead the effort of safely integrating UAS into the national airspace, but several other federal agencies—such as the Department of Defense (DOD), Department of Homeland Security (DHS), and the National Aeronautics and Space Administration (NASA)—also have a role. While DOD uses UAS for training and operational missions, DHS for border patrol, and NASA for scientific research, each agency provides FAA with safety, reliability, and performance data through the COA process. These agencies also participate in UAS integration forums as discussed later in this section. Table 1 provides an overview of key federal UAS stakeholders and their roles in integrating UAS.

Table 1: Key Federal UAS Stakeholders and Their Roles Integrating UAS into the National Airspace

Key stakeholders	UAS integration role
Federal Aviation Administration (FAA)	FAA’s UAS Integration Office is responsible for ensuring that UAS operate safely in the national airspace.
Department of Defense (DOD)	DOD provides FAA with UAS operational and safety data, as well as research and development support.
National Aeronautics and Space Administration (NASA)	NASA provides research and development and testing on UAS integration efforts.
Department of Homeland Security (DHS)	DHS’s Customs and Border Patrol has provided flight demonstrations to FAA’s Next Generation Air Transportation System (NextGen) Office.
General Services Administration (GSA)	The General Services Administration (GSA) is responsible for tracking the federal government’s UAS inventory. Federal agencies that own or lease UAS report their UAS inventory, cost and utilization data to GSA.
Department of Justice (DOJ)	DOJ’s National Institute of Justice is responsible, in part, for assisting the technology needs—including UAS—of local, state, and tribal law enforcement agencies.

Source: GAO analysis of FAA data.

FAA has established various mechanisms to facilitate collaboration with its partner agencies, and private sector entities to safely integrate UAS (see table 2). For example, given its unique role in managing partnerships among federal agencies for the Next Generation Air Transportation

System (NextGen), FAA's Joint Planning and Development Office (JPDO) was tasked by the Office of Management and Budget to, in conjunction with partner agencies, develop a strategic interagency UAS Research, Development, and Demonstration Roadmap.⁶ This roadmap provides a framework for interagency and private sector coordination on UAS research and development efforts. Several working groups have also been formed, such as the UAS Executive Committee, to facilitate collaboration between agencies. FAA has also entered into memorandums of understanding (MOU) with some of these federal agencies. FAA signed MOUs with NASA and DOD regarding research and development and the availability of safety data, respectively. FAA has also involved industry stakeholders and academia through the UAS Aviation Rulemaking Committee and RTCA SC-203. For example, the RTCA SC-203 (a standards-making body) is developing safety, reliability, and performance standards for UAS operations.

⁶NextGen is a complex undertaking that requires acquiring new integrated air traffic control systems; developing new flight procedures, standards, and regulations; and creating and maintaining supporting infrastructure to create a more automated aircraft-centered, satellite-based air transportation system. JPDO's primary responsibility is for overseeing and coordinating NextGen research activities within the federal government and ensuring that new technologies are used to their fullest potential in aircraft and the air traffic control system.

Table 2: Examples of UAS Collaboration across Agencies or in Industry

Forums for collaboration	UAS integration role
JPDO	FAA's JPDO provides a framework for UAS stakeholders to collaborate and coordinate on their UAS integration efforts.
UAS Executive Committee ^a	The UAS Executive Committee—composed of senior executives from federal agencies including FAA, DOD, NASA, and DHS—is responsible for identifying solutions to the range of technical, procedural, and policy concerns arising from UAS integration into domestic airspace.
UAS Aviation Rulemaking Committee ^b	The UAS Aviation Rulemaking Committee was chartered in 2011 to provide a mechanism for industry and academic stakeholders as well as other federal, state, and local government entities to provide recommendations and standards to FAA on issues related to UAS integration.
RTCA SC-203 ^c	RTCA is a private, not-for-profit organization consisting of industry experts. SC 203 is responsible for developing consensus-based recommendations and standards regarding UAS communications, navigation, surveillance, and air traffic management system issues that are provided to FAA.
ASTM International Committee F38 ^d	ASTM International Committee F38 is a private organization, consisting of industry experts that are responsible for developing standards and consensus-based recommendations to FAA for small UAS integration into the national airspace and worldwide.

Source: GAO analysis of FAA data.

^aThe UAS Executive Committee was formed as a result of the National Defense Authorization Act (NDAA) for Fiscal Year 2010 (Pub. L. No. 111-84, 123 Stat. 2190 (2009)). Section 935 of 2010 NDAA states that “The Secretary of Defense and the Secretary of Transportation shall, after consultation with the Secretary of Homeland Security, jointly develop a plan for providing expanded access to the national airspace for unmanned aircraft systems of the Department of Defense” and requires that the Executive Committee members to provide Congress with, among other things, a communication plan, specific milestones for expanded access to the national airspace, and that the Committee report on their efforts.

^bFAA also chartered a small UAS Aviation Rulemaking Committee in 2008, which made recommendations for the standards and regulations for the operation of small UAS in the national airspace.

^cRTCA, formerly the Radio Technical Commission for Aeronautics, serves as a federal advisory committee, and its recommendations are the basis for a number of FAA’s policy, program, and regulatory decisions.

^dASTM International, formerly known as the American Society for Testing and Materials, works to deliver the test methods, specifications, guides, and practices that support industries and governments worldwide.

FAA also has agreements with a range of industry, federal research entities, universities, and international organizations to conduct research. These research and development agreements, known as Cooperative Research and Development Agreements and International Agreements, typically require the agency, organization, or company to perform types of research and provide FAA with the data in exchange for funding. For example, in 2009 FAA established an agreement with the European Union to initiate, coordinate, and prioritize the activities necessary for supporting the development of provisions required for the evolution of

UAS to full recognition as a legitimate category-of-airspace user.⁷ In addition, FAA partners with federally funded research and development centers on UAS integration efforts.⁸

Within FAA, steps have also been taken to increase collaboration and provide the organizational leadership needed to safely accelerate UAS integration. FAA recently created the UAS Integration Office under one executive to provide stable leadership and focus on the FAA UAS integration efforts.⁹ The office will coordinate all intra-agency collaboration efforts. At this time, some UAS responsibilities are being handled in other offices throughout FAA. For example, some of the research and development efforts and analysis of operation and safety data are being performed by the Air Traffic Office and the Accident, Investigation, and Prevention Office, respectively. The UAS Integration Office reports directly to the Director of the Flights Standards Service, which provides visibility for the office. At this time, several planning efforts are under way in the office. However, because the reorganization has only recently been implemented, it remains unclear whether the office will provide the support needed to guide a collaborative effort given the complexities of safely integrating UAS into the national airspace.

While collaboration mechanisms have been developed to help facilitate UAS integration into the national airspace, continued collaboration among UAS stakeholders will be critical to minimizing duplication of research and addressing implementation obstacles. For example, as we previously reported in our September 2012 report, federal agencies have not yet stepped forward to proactively address the growing concerns regarding the potential security and privacy implications of UAS.¹⁰ We recommended that DOT, DHS, and the Attorney General initiate

⁷FAA's International Agreements include ones with the Netherlands, the German Aerospace Center, and the European Union.

⁸FAA's Federally Funded Research and Development Centers are located at MITRE, MIT's Lincoln Lab, and the Air Force Research Lab.

⁹The UAS Integration Office was formally created in January 2013. However, work was being performed on UAS integration prior to operations being formalized. For example, the FAA appointed the Executive in March 2012.

¹⁰The Congressional Research Service has issued a report assessing the use of UAS under the Fourth Amendment. Congressional Research Service, *Drones in Domestic Surveillance Operations: Fourth Amendment Implications and Legislative Responses*, R42701 (Washington, D.C.: September 2012).

discussions, prior to the integration of UAS into the national airspace, to explore whether any actions should be taken to guide the collection and use of UAS-acquired data. As we discuss later in this statement, FAA and DOD will need to continue to work together to determine how to leverage DOD's operational and safety data to help develop UAS operations standards, which is a critical step in the integration process. While we did not evaluate the collaboration mechanisms already in place, stakeholders told us that collaboration was occurring, but efforts could be improved. Specifically, stakeholders told us they would like to see additional leadership from FAA.

Meeting the 2012 Act's Requirements Will Continue to Challenge FAA

FAA has several efforts under way to satisfy the 2012 Act's requirements, most of which must be achieved between May 2012 and December 2015. See table 3 for a list of selected requirements and the status of FAA's efforts to meet them. FAA has made progress toward these selected requirements. Of the seven deadlines that had passed, however, FAA had completed two as of January 2013.

Table 3: Selected Requirements and Status for UAS Integration under the FAA Modernization and Reform Act of 2012, as of January 31, 2013

Deadline	FAA Modernization and Reform Act of 2012 requirement	Status of action
05/14/2012	Enter into agreements with appropriate government agencies to simplify the process for issuing COAs or waivers for public UAS.	In process
05/14/2012	Expedite the issuance of a COA for public safety entities.	Completed
08/12/2012	Establish a program to integrate UAS into the national airspace at 6 test ranges. This program is to terminate 5 years after date of enactment.	In process
08/12/2012	Develop an Arctic UAS operation plan and initiate a process to work with relevant federal agencies and national and international communities to designate permanent areas in the Arctic where small unmanned aircraft may operate 24 hours per day for research and commercial purposes.	Completed
08/12/2012	Determine whether certain UAS can fly safely in the national airspace before the completion of the Act's requirements for a comprehensive plan and rulemaking to safely accelerate the integration of civil UAS into the national airspace or the Act's requirement for issuance of guidance regarding the operation of public UAS including operating a UAS with a COA or waiver.	In process
11/10/2012	Develop a comprehensive plan to safely accelerate integration of civil UAS into national airspace.	In process
11/10/2012	Issue guidance regarding operation of civil UAS to expedite COA process; provide a collaborative process with public agencies to allow an incremental expansion of access into the national airspace as technology matures and the necessary safety analysis and data become available and until standards are completed and technology issues are resolved; facilitate capability of public entities to develop and use test ranges; provide guidance on public entities' responsibility for operation.	In process

Deadline	FAA Modernization and Reform Act of 2012 requirement	Status of action
02/14/2013	Approve and make publically available a 5-year roadmap for the introduction of civil UAS into national airspace, to be updated annually.	In process
02/14/2013	Submit to Congress a copy of the comprehensive plan.	In process
08/14/2014	Publish in the <i>Federal Register</i> the Final Rule on small UAS.	In process
08/14/2014	Publish in the <i>Federal Register</i> a Notice of Proposed Rulemaking to implement recommendations of the comprehensive plan.	None to date
08/14/2014	Publish in the <i>Federal Register</i> an update to the Administration's policy statement on UAS in Docket No. FAA-2006-25714.	None to date
09/30/2015	Achieve safe integration of civil UAS into the national airspace.	In process
12/14/2015	Publish in the <i>Federal Register</i> a Final Rule to implement the recommendations of the comprehensive plan.	None to date
12/31/2015	Develop and implement operational and certification requirements for public UAS in national airspace.	In process

Source: GAO analysis of FAA Modernization and Reform Act as well as FAA progress.

These requirements can be considered under four categories: (1) developing plans for integrating UAS into the national airspace; (2) changing the COA process; (3) integrating UAS at six test ranges; and (4) developing, revising, or finalizing regulations and policies related to UAS. The following provides additional information on the status of FAA's efforts to meet the requirements under these four categories:

- Comprehensive plan and roadmap for UAS integration.* FAA, with the assistance of JPDO, is developing several planning documents required by the 2012 Act, including a 5-year roadmap and comprehensive plan to outline steps toward safe integration. As of January 2013, FAA officials told us they were in the final stages of reviewing and approving these documents and expected to make them publically available by the February 14, 2013 deadline. In light of the timeframes and complicated tasks involved in achieving the requirements, in September 2012, we recommended that FAA incorporate mechanisms in its 5-year roadmap and comprehensive plan that allow for regular monitoring to assess progress toward safe and routine access of UAS into the national airspace. Incorporating regular monitoring can help FAA understand what has been achieved and what remains to be done and help keep Congress informed about this significant change to the domestic aviation landscape. While FAA concurred with our recommendation, because these documents were not publically available as of January 2013, it remains unclear whether they include mechanisms for monitoring progress.

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- *Changes to the COA process.* FAA has changed the existing COA process in response to the 2012 Act, including taking steps to expedite COAs for public safety entities and developing agreements with government agencies to expedite the COA or waiver process. To help expedite COAs for public safety entities, FAA extended the length of UAS authorization from a 12-month period to a 24-month period so that those entities receiving COAs do not have to reapply as frequently. In addition, FAA made additional changes to simplify the COA application process, including automating the application process through an online form. FAA also worked with DOJ's National Institute of Justice to develop an MOU to meet the operational requirements of law enforcement entities, which are expected to be early adopters of small UAS. Officials from both FAA and DOJ have reached agreement on a draft version of the MOU establishing this process. However, this MOU is still under legal review at FAA and DOJ.¹¹
 - *Test ranges.* FAA has taken steps to develop, but has not yet established, a program to integrate UAS at six test ranges, as required by the 2012 Act. As part of these ranges, FAA must safely designate airspace for integrated manned and unmanned flight operations, develop certification standards and air traffic requirements for UAS, ensure the program is coordinated with NextGen, and verify the safety of UAS and related navigation procedures before integrating them into the national airspace. FAA expects data obtained from these test ranges will contribute to the continued development of standards for the safe and routine integration of UAS.¹² In March 2012, FAA issued a Request for Comments in the Federal Register and received a number of comments. FAA officials told us they are still working to meet all of the specified requirements for the test ranges and had expected to issue a Screening Information Request to initiate the competitive bid process for selecting the six

¹¹Additionally, FAA has signed a letter of agreement with the Department of the Interior and is in the process of establishing additional agreements with other agencies, such as DOD and NASA.

¹²The designation of permanent areas of operation for UAS in the Arctic, also required by the 2012 Act, could provide FAA with another source of data. In November 2012, FAA finalized an Arctic Implementation Plan to expand small UAS use in the Arctic and has assigned a program manager who will officially assume his position in February 2013.

test ranges in July 2012.¹³ However, because of privacy concerns regarding the collection and use of UAS-acquired data expressed by commenters, the internal review process of the Screening Information Request was delayed. FAA officials said they hired a privacy expert to help develop a strategy to address these concerns and are working to incorporate this strategy in its Screening Information Request. As of January 2013, officials noted that FAA expects to release the Screening Information Request in the next 4 to 6 weeks.

- *Rulemaking.* While FAA has efforts under way supporting a rulemaking for small UAS, as required by the 2012 Act, it is uncertain whether FAA will meet the August 2014 deadline. In fact, the agency's rulemaking efforts for UAS date back more than 5 years, when it established the small UAS Aviation Rulemaking Committee in 2008. In August 2011, FAA initially provided the Secretary of Transportation with its draft Notice of Proposed Rulemaking (NPRM). FAA officials told us in January 2013 that the FAA is still internally reviewing the draft and working to agree on the NPRM's language. According to the officials, FAA has not determined when it might issue the NPRM.

Standards and Data Needed to Guide UAS Research and Development Efforts for Agencies

As we reported in 2012, many entities have research and development efforts under way to mitigate obstacles before UAS are allowed to operate safely and routinely in the national airspace. Some of these obstacles and related research include vulnerabilities in UAS operations, such as sense and avoid; command, control, and communications, including lost link, dedicated radio-frequency spectrum, and Global Positioning System (GPS) jamming and spoofing; and human factors. However, these research and development efforts cannot be completed and validated without safety, reliability, and performance standards, which have not yet been developed because of data limitations.

¹³A Screening Information Request is a request by the FAA for documentation, information, presentations, proposals, or binding offers concerning an approach to meeting potential acquisition requirements established by the FAA.

Elements of UAS Research and Development

Sense and Avoid

To date, no suitable technology has been deployed that would provide UAS with the capability to sense and avoid other aircraft and airborne objects and to comply completely with FAA regulatory requirements of the national airspace.¹⁴ However, research and development efforts by FAA, DOD, NASA, and MITRE, among others, suggests that potential solutions to the sense and avoid obstacle may be available in the near term.¹⁵ Since 2008, FAA and other federal agencies have managed several research activities to support meeting the sense and avoid requirements. DOD officials told us that the Department of the Army is working on a ground-based sense and avoid system that will detect other airborne objects and allow the pilot to direct the UAS to maneuver to a safe location. The Army has successfully tested one such system, but it may not be useable on all types of UAS. Another potential system to address this obstacle is an airborne sense and avoid system, which could equip UAS with the same GPS-based transponder system that will be used in FAA's NextGen air-traffic-management system and with which some manned aircraft are starting to be equipped. In 2012, NASA researchers at Dryden Flight Research Center successfully tested an automatic dependent surveillance-broadcast (ADS-B) transponder system on its Ikhana UAS.^{16 17} An airborne sense and avoid system could include ADS-B, along with other sensors such as optical/infrared cameras and radar.

Command, Control and Communication Systems

Ensuring uninterrupted command and control for both small and large UAS remains a key obstacle for safe and routine integration into the national airspace. Since UAS fly based on pre-programmed flight paths

¹⁴The FAA regulations include 14 C.F.R. § 91.111, "Operating near other aircraft," with reference to "create a collision hazard," and 14 C.F.R. § 91.113, "Right-of-way rules."

¹⁵MITRE is a public interest company that works in partnership with the federal government applying systems engineering and advanced technology to address issues of national importance.

¹⁶ADS-B transponder system uses GPS signals along with aircraft avionics to transmit the aircraft's location to ground receivers. The ground receivers then transmit that information to controller screens and cockpit displays on aircraft equipped with automatic dependent surveillance-broadcast transponder system avionics.

¹⁷Ikhana is a large UAS that NASA has used for a number of research activities, such as monitoring and tracking wildfires and expects to use for an arctic mission to assess the surface sea ice next year.

and by commands from a pilot-operated ground control station, the ability to maintain the integrity of command and control signals are critically important to ensure that the UAS operates as expected and as intended.

Lost Link

In a “lost link” scenario, the command and control link between the UAS and the ground control station is broken because of either environmental or technological issues, which could lead to loss of control of the UAS. To address this type of situation, UAS generally have pre-programmed maneuvers that may direct the UAS to hover or circle in the airspace for a certain period of time to reestablish its radio link. If the link is not reestablished, then the UAS will return to “home” or the location from which it was launched, or execute an intentional flight termination at its current location. It is important that air traffic controllers know where and how all aircraft are operating so they can ensure the safe separation of aircraft in their airspace.¹⁸ FAA and MITRE have been measuring the impacts of lost link on national airspace safety and efficiency, but the standardization of lost link procedures, for both small and large UAS, has not been finalized. Currently, according to FAA, each COA has a specific lost link procedure unique to that particular operation and air traffic controllers should have a copy for reference at all times. Until procedures for a lost link scenario have been standardized across all types of UAS, air traffic controllers must rely on the lost link procedures established in each COA to know what a particular UAS will do in such a scenario.

Dedicated Radio-Frequency Spectrum

Progress has been made in obtaining additional dedicated radio-frequency spectrum for UAS operations, but additional dedicated spectrum, including satellite spectrum, is still needed to ensure secure and continuous communications for both small and large UAS operations. The lack of protected radio-frequency spectrum for UAS operations heightens the possibility that a pilot could lose command and control of a UAS. Unlike manned aircraft—which use dedicated, protected radio frequencies—UAS currently use unprotected radio spectrum and, like any other wireless technology, remain vulnerable to unintentional or intentional interference. This remains a key security and safety vulnerability because, in contrast to a manned aircraft in which the pilot has direct physical control of the aircraft, interruption of radio transmissions can sever the UAS’s only means of control.

¹⁸Air traffic controllers monitor and coordinate the movement of air traffic. They communicate with pilots of aircraft, including UAS, but do not directly control the operations of aircraft.

UAS stakeholders are working to develop and validate hardware and standards for communications operating in allocated spectrum. For example, FAA's UAS Research Management Plan identified 13 activities designed to mitigate command, control, and communication obstacles. One effort focused on characterizing the capacity and performance impact of UAS operations on air-traffic-control communications systems. In addition, according to NASA, it is developing, in conjunction with Rockwell Collins, a prototype radio for control and a non-payload communications data link that would provide secure communications.

GPS Jamming and Spoofing

The jamming of the GPS signal being transmitted to the UAS could also interrupt the command and control of UAS operations. In a GPS jamming scenario, the UAS could potentially lose its ability to determine its location, altitude, and the direction in which it is traveling.¹⁹ Low cost devices that jam GPS signals are prevalent. According to one industry expert, GPS jamming would become a larger problem if GPS is the only method for navigating a UAS. This problem can be mitigated by having a second or redundant navigation system onboard the UAS that is not reliant on GPS, which is the case with larger UAS typically operated by DOD and DHS.

Encrypting civil GPS signals could make it more difficult to "spoof" or counterfeit a GPS signal that could interfere with the navigation of a UAS. Non-military GPS signals, unlike military GPS signals, are not encrypted and transparency and predictability make them vulnerable to being counterfeited, or spoofed. In a GPS-spoofing scenario, the GPS signal going from the ground control station to the UAS is first counterfeited and then overpowered. Once the authentic (original) GPS signal is overpowered, the UAS is partially under the control of the "spoofer." This type of scenario was recently demonstrated by researchers at the University of Texas at Austin at the behest of DHS. During the demonstration at the White Sands Missile Range, researchers spoofed one element of the unencrypted GPS signal of a fairly sophisticated small UAS (mini-helicopter) and induced it to plummet toward the desert floor. The research team found that it was straightforward to mount an intermediate-level spoofing attack, such as controlling the altitude of the UAS, but difficult and expensive to mount a more sophisticated attack.

¹⁹Jamming and spoofing are problems that also affect other industries and projects.

The research team recommended that spoof-resistant navigation systems be required on UAS exceeding 18 pounds.²⁰

Human Factors

UAS stakeholders have been working to develop solutions to human factor issues for both small and large UAS. According to FAA, human factors research examines the interaction between people, machines, and the environment to improve performance and reduce errors. Human factors are important for UAS operations as the pilot and aircraft are not collocated. The separation of pilot and aircraft creates a number of issues, including loss of sensory cues valuable for flight control, delays in control and communications loops, and difficulty in scanning the visual environment surrounding the unmanned aircraft. As part of its UAS Integration in the National Airspace System Project, NASA is working to develop human factor guidelines for ground control stations and plans to share the results with RTCA SC-203 to inform recommended guidelines. In addition, the Department of the Army is working to develop universal ground control stations, which would allow UAS pilots to fly different types of UAS without having to be trained on multiple configurations of a ground control station.

Development of UAS Safety, Reliability, and Performance Standards

The development of standards for UAS operations is a key step in the process of safe integration and supporting research and development efforts. Setting standards, certification criteria, and procedures for sense and avoid systems as well as protocols to be used for the certification of command, control, and communication systems will guide research and development efforts toward a specifically defined goal. Once the standards are developed, FAA will use the standards in UAS regulations. Currently, UAS continue to operate as exceptions to the regulatory framework rather than being governed by it. Without specific and permanent regulations for safe operation of UAS, federal stakeholders, including DOD and NASA, continue to face challenges and limitations on their UAS operations. The lack of final regulations could hinder the acceleration of safe and routine integration of UAS into the national airspace.

²⁰The presentation "Assessing the Civil GPS Spoofing Threat" by Todd Humphreys, Jahshan Bhatti, Brent Ledvina, Mark Psiaki, Brady O'Hanlon, Paul Kintner, and Paul Montgomery sought to assess the spoofing threat of a small civil UAS. The team built a civilian GPS spoofer and tested some countermeasures. They concluded that GPS spoofing is a threat to communications security and civil spoofing has not been the focus of research in open literature.

Standards-making bodies are currently developing safety, reliability, and operational standards.²¹ While progress has been made, the standards development process has been hindered, in part, because of FAA's inability to use safety, reliability, and performance data from DOD, the need for additional data from other sources, as well as the complexities of UAS issues in general. As we previously reported, while DOD provided FAA with 7 years of data in September 2011, FAA officials told us they have been unable to use this data to develop standards because of differences in definitions and uncertainty about how to analyze these data.²² To mitigate these challenges FAA has been working with DOD to develop an MOU and better identify what data are needed. Finally, FAA is also working with MITRE to develop a data collection tool that will allow officials to better analyze the data they receive from DOD.

The establishment of six test ranges, as previously discussed, and the designation of permanent areas of operation in the Arctic could provide FAA with two potential new sources of safety, reliability, and performance data for UAS. However, it is unclear when the test ranges and Arctic area will be operational. Use of these data will be important in developing safety, reliability, and performance standards, which are needed to guide and validate the supporting research and development efforts. According to an RTCA official, both DOD and NASA are sharing the results of their UAS flight experience and research and development efforts to assist RTCA in the standards development process. The RTCA official suggested that the standards-making process might be accelerated if it could start by producing an initial set of standards for a specific UAS with a clearly defined mission. The committee could then utilize those initial standards, along with the subsequent safety and performance data from those operations, to develop additional standards for increasingly complex UAS functions and missions.

FAA and NASA are taking steps to ensure the reliability of both small and large UAS by developing a certification process specific to UAS. Currently, FAA has a process and regulations in place for certifying any

²¹For example, RTCA, a standards-making body chartered by FAA, established a federal advisory committee to establish minimum aviation-system performance standards and minimum operational performance standards for FAA to use in developing UAS regulations.

²²In June 2011, FAA and DOD signed a memorandum of agreement that specified the data from this process that would be provided.

new manned aircraft type and allowing it access to the national airspace. FAA's Research and Development office is working to identify the substantive differences in how to meet the certification standards for manned and unmanned aircraft. According to its 2012 Research Management Plan, the office has six activities under way that support the development of UAS-specific certification and airworthiness standards.

In closing, UAS integration is an undertaking of significant breadth and complexity that touches several federal agencies. Congress has highlighted the importance of UAS integration by establishing statutory requirements and setting deadlines for FAA. FAA, as the lead agency, faces the daunting task of ensuring that all of the various efforts within its own agency, as well as across agencies and other entities, will align and converge in a timely fashion to achieve UAS integration within these deadlines. Because of concerns about the agency's ability to meet deadline requirements, we recommended that FAA incorporate regular monitoring of its efforts to assess progress toward fulfilling its requirements outlined in the 2012 Act. Incorporating regular monitoring will help to inform stakeholders and Congress about what has been achieved and what remains to be done and help FAA build stakeholder confidence in its ability to achieve UAS integration in a safe and timely manner. In addition, the various entities' research and development efforts require continued collaboration to address the critical issues that need to be resolved before UAS are allowed to operate safely and routinely in the national airspace. This collaboration will be important to help align research and development goals across federal agencies and minimize duplication of research or inefficient use of resources.

Chairman Broun, Ranking Member Maffei, and Members of the Subcommittee, this concludes my prepared statement. I would be pleased to answer any questions at this time.

GAO Contact and Staff Acknowledgments

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