OPERATING UNMANNED AIRCRAFT SYSTEMS IN THE NATIONAL AIRSPACE SYSTEM: ASSESSING RESEARCH AND DEVELOPMENT EFFORTS TO ENSURE SAFETY

HEARING

BEFORE THE

SUBCOMMITTEE ON OVERSIGHT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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OPERATING UNMANNED AIRCRAFT SYSTEMS IN THE NATIONAL AIRSPACE SYSTEM: ASSESSING RESEARCH AND DEVELOPMENT EFFORTS TO ENSURE SAFETY

FRIDAY, FEBRUARY 15, 2013

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON OVERSIGHT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:01 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Paul Broun [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
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EDDIE BERNICE JOHNSON, Texas
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Congress of the United States
House of Representatives

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Subcommittee on Oversight

Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety

Friday, February 15, 2013
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Dr. Karlin Toner, Director, Joint Planning and Development Office, Federal Aviation Administration (FAA)

Dr. Edgar Waggoner, Director, Integrated Systems Research Program Office, National Aeronautics and Space Administration (NASA)

Dr. Gerald Dillingham, Director, Civil Aviation Issues, Government Accountability Office (GAO)

U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Oversight

HEARING CHARTER

Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety

Friday, February 15, 2013
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

On February 15, 2013, the Subcommittee on Oversight will hold a hearing titled "Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety." The hearing will examine challenges to integrating Unmanned Aircraft Systems (UAS) safely into the National Airspace System (NAS) and federal research and development (R&D) efforts to ensure the safe operation of UAS in the NAS.

Witnesses

- Dr. Karlin Toner, Director, Joint Planning and Development Office, Federal Aviation Administration (FAA)
- Dr. Edgar Waggoner, Director, Integrated Systems Research Program Office, National Aeronautics and Space Administration (NASA)
- Dr. Gerald Dillingham, Director, Civil Aviation Issues, Government Accountability Office (GAO)

Background

For most people, the term unmanned aerial vehicle (UAV) is closely associated with the U.S. Air Force's Predator or Global Hawk aircraft. Unmanned aircraft systems (UAS), however, is a more accurate and complete term which includes the aircraft as well as supporting ground, air, and communications infrastructure. UAS come in a variety of shapes and sizes and are viable for a broad range of civilian and commercial uses. Current domestic use of UAS is limited to academic institutions, federal, state, and local government organizations that receive a Certificate of Waiver or Authorization (COA) and private sector entities that receive special airworthiness certificates by the FAA.[1] Typical domestic applications of UAS include border patrol, scientific research, and environmental monitoring. For example, NASA has made extensive use of a myriad of advanced UAS to conduct aeronautics, meteorological, and environmental research over the years; from the Mini-Sniffers of the 1970s to the new high-altitude X-56A Multi-Use

[1] U.S. Department of Transportation, Federal Aviation Administration, "Unmanned Aircraft Systems (UAS) Operational Approval," National Policy Notice, serial N 8900.207 (Washington, DC, 2013).

Technology Testbed, or MUTT.[2] Also, the National Oceanic and Atmospheric Administration (NOAA) operates the RQ-4A Global Hawk platform for climate research, the Customs and Border Patrol (CBP) operates the MQ-1 Predator platform for border patrol, and public universities operate additional systems for academic research purposes.

Though military and civil government will likely dominate in the near term, the UAS market is dynamic and the commercial sector is poised for explosive growth. The Teal Group, an aerospace and defense industry market intelligence firm, forecasts worldwide annual spending on UAS research, development, testing, and evaluation (RDT&E) activities and procurement rising from $6.6 billion in 2013 to $11.4 billion in 2022. Total worldwide spending for the period is forecast to amount to $89.1 billion. Throughout the forecast period, Teal expects the U.S. share of RDT&E to account for 62 percent of worldwide spending, while U.S. procurement will amount to 55 percent of worldwide spending.[3] In 2010, the Association for Unmanned Vehicle Systems International (AUVSI) estimated that over the next 15 years more than 23,000 jobs, totaling $1.6 billion in wages, could be created in the U.S. as a result of UAS integration into the National Airspace System.[4] This does not include the tens of thousands of secondary jobs in sensor manufacturing, software development, and other complementary industries.

To make the most of this opportunity, Congress directed that federal agencies accelerate the integration of UAS into the national airspace. The FAA Modernization and Reform Act of 2012 contains provisions designed to promote and facilitate the use of civilian unmanned aircraft. These included mandates for:

- development of an integration plan that is to commence by the end of FY2015, if not sooner, along with a five-year roadmap for achieving integration objectives;
- selection of six test sites to study UAV integration into the NAS;
- designation of certain permanent areas in the Arctic where small unmanned aircraft may operate 24 hours per day for commercial and research purposes, including flights conducted beyond line-of-sight;
- a simplified process for issuing authorizations for entities seeking to operate public UAS in the NAS;
- incrementally expanding airspace access as technology matures and safety data and analysis become available and to facilitate public agency access to UAS test ranges;
- developing and implementing operational and certification requirements for public UAS by December 31, 2015; and

[2] Gary Creech, "Introducing the X-56a Mutt: Who Let the Dog Out?" http://www.nasa.gov/topics/aeronautics/features/x-56a_mutt.html (accessed February 8, 2013).
[3] Teal Group, *World Unmanned Aerial Vehicle Systems: Market Profile and Forecast (Fairfax, 2012)*, cited in U.S. Government Accountability Office, *Unmanned Aircraft Systems: Measuring Progress and Addressing Potential Privacy Concerns Would Facilitate Integration into the National Airspace System,* GAO-12-981 (Washington, DC, 2012).
[4] Association for Unmanned Vehicle Systems International, *Unmanned Aircraft System Integration into the United States National Airspace System: An Assessment of the Impact on Job Creation in the U.S. Aerospace Industry* (Arlington, 2010).

- an exemption from rules and regulations pertaining to the operation of unmanned aircraft for model aircraft weighing 55 pounds or less that are flown within visual line-of-sight strictly for hobby or recreation.[5]

Issues

UAS stakeholders have made progress toward completing the above requirements, but the GAO and Department of Transportation's Office of Inspector General have both assessed that significant technical obstacles and research gaps still exist.[6] Also, *The Washington Post* recently reported that at least nine U.S. UAS crashes occurred near civilian airports overseas as a result of pilot error, mechanical failure, software bugs, or poor coordination with air-traffic controllers.[7] While the operational environment for military UAS overseas is vastly different from UAS use domestically, these incidents are instructive. As UAS are integrated or accommodated into the NAS, several R&D challenges must be addressed.

Vulnerabilities in command and control of UAS operations – Ensuring uninterrupted command and control is critically important to safe integration of UAS into the national airspace. Unprotected data links can be hacked, spoofed or jammed to disrupt or gain control of the aircraft. For example, last summer a University of Texas (UT) at Austin research team demonstrated for the first time that it is possible to electronically hijack a UAV through Global Positioning System (GPS) spoofing. The team created false GPS signals to commandeer a small but sophisticated UAV about one kilometer away.[8] Redundant systems or encrypted communications would mitigate risks, but the costs, weight, and encryption issues make such additional equipage unfeasible for smaller UAS. NASA's five-year UAS Integration in the National Airspace System Project aims to: develop data and rationale to obtain appropriate frequency spectrum allocations to enable safe and efficient operation of UAS in the NAS; develop and validate candidate secure safety-critical command and control system/subsystem test equipment for UAS that complies with UAS international/national frequency regulations, recommended practices and minimum operational and aviation system performance standards for UAS; and perform analysis to support recommendations for integration of safety-critical command and control systems and air traffic control communications to ensure safe and efficient operation of UAS in the NAS.[9]

Homeland Security – In 2008 and again in 2012, the GAO assessed that Transportation Security Administration (TSA), a subordinate agency within the Department of Homeland Security, had

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[5] FAA Modernization and Reform Act of 2012 (PL 112-95)
[6] GAO-12-981, *Unmanned Aircraft Systems*
[7] Craig Witlock, "Drone crashes mount at civilian airports," *The Washington Post*, November 30, 2012, http://www.washingtonpost.com/world/national-security/drone-crashes-mount-at-civilian-airports-overseas/2012/11/30/e75a13e4-3a39-11e2-83f9-fb7ac9b29fad_story.html (accessed February 6, 2013).
[8] Melissa Mixon, "Todd Humphreys' Research Team Demonstrates First Successful Gps Spoofing of Uav," http://www.ae.utexas.edu/news/archive/2012/todd-humphreys-research-team-demonstrates-first-successful-gps-spoofing-of-uav (accessed February 6, 2013).
[9] "Unmanned Aircraft Systems Integration in the National Airspace System," National Aeronautics and Space Administration, http://www.nasa.gov/centers/dryden/news/FactSheets/FS-075-DFRC.html (accessed February 7, 2013).

not properly examined nor identified specific steps to mitigate potential security threats posed by routine UAS access to the national airspace.[10]

Spectrum – The 2012 World Radiocommunication Conference allocated two bands of protected spectrum for UAS command and control.[11] UAS stakeholders continue to develop hardware and standards to operate safely in allocated spectrum, while also working with the National Telecommunications and Information Administration and International Telecommunication Union to identify additional UAS-dedicated spectrum, particularly satellite spectrum, needed to assure continuous communication.

Inability to detect, sense, and avoid other aircraft – No suitable technology exists that would provide UAS with the capability to "sense and avoid" other aircraft and airborne objects in compliance with FAA regulations.[12,13] Most UAS, particularly small UAS, do not carry onboard systems to transmit and receive electronic identification signals. Solutions such as ground-based sense and avoid (GBSAA)[14] may offer a technical alternative to maintaining a human line-of-sight in the near-term before ultimately transitioning to Automatic Dependent Surveillance-Broadcast (ADS-B) and the satellite-based Next Generation Air Transportation System (NextGen). NextGen is due for implementation across the United States in stages between 2012 and 2025.

FAA's NextGen Integration Office and Joint Planning Development Office (JPDO) are working together to provide UAS stakeholders with a framework to collaborate and coordinate their UAS and NextGen R&D efforts. NASA is assessing how NextGen separation assurance systems, with different functional allocations, perform in real-world settings. For instance, in 2012 NASA researchers at Dryden Flight Research Center successfully tested an ADS-B transponder system on a UAS.[15, 16] Also, NASA, in collaboration with the FAA and U.S. Air Force Research Lab, is considering a two-tier, $1.5 million challenge – part of NASA's Centennial Challenge series – to develop reliable sense-and-avoid techniques to fly safely in congested airspace.[17]

Human Factors – Unmanned aircraft systems is a misnomer. Skilled human operators are critical to safe UAS operations. FAA defines human factors as the examination of interactions

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[10] GAO-12-981, *Unmanned Aircraft Systems*
[11] Julie Zoller, "NTIA Spotlight: Meeting Spectrum Needs At Home Takes Work Abroad," http://www.ntia.doc.gov/blog/2012/ntia-spotlight-meeting-spectrum-needs-home-takes-work-abroad (accessed February 7, 2013).
[12] Ibid.
[13] The 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."
[14] GBSAA is an air surveillance radar that provides positional information via a display of traffic information to the UAS flight crew.
[15] GAO-12-981, *Unmanned Aircraft Systems*
[16] ADS-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.
[17] "REQUEST FOR INFORMATION - CENTENNIAL CHALLENGES UNMANNED AIRCRAFT SYSTEMAIRSPACE OPERATIONS CHALLENGE," https://www.fbo.gov/?s=opportunity&mode=form&id=426438809b8348c157fa5b7120c18a45&tab=core&_cview=1 (accessed February 7, 2013)

between people, machines, and the environment for the purpose of improving performance and reducing error.[18] UAS stakeholders are examining ways to incorporate additional technical safeguards and regulations to mitigate the risks associated with remotely piloted aircraft, but according to a September GAO report, several issues remain: how pilots or air traffic controllers respond to the lag in communication of information from the UAS; the skill set and medical qualifications required for UAS operators; and UAS operator training requirements.[19] NASA is working to develop a research test bed and database to provide data and proof of concept for ground control station (GCS) and will coordinate with standards organizations, such as RTCA SC-203,[20] to develop human-factors guidelines for GCS operation in the NAS.[21]

Lack of technological standards – Minimum aviation system performance standards (MASPS) and minimum operational performance standards (MOPS) are needed in the areas of: operational and navigational performance; command and control communications; and sense and avoid capabilities. The complexity of the issues and the lack of data have hindered the standards development process. That said, according to the GAO, the FAA had not made the most of the data it possessed to develop such standards, according to a report issued in September 2012.[22] For instance, the FAA had not analyzed information collected as part of the COA process, nor had it used the seven years of operational and safety data provided by the Department of Defense because it lacked sufficient detail to be of much value. FAA officials have since more clearly defined and communicated data requirements, and the agency contracted with MITRE to address remaining data challenges. However, it remains to be seen if this will result in useful information.[23]

[18] GAO-12-981, *Unmanned Aircraft Systems*
[19] Ibid.
[20] 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.
[21] "Unmanned Aircraft Systems Integration in the National Airspace System," NASA
[22] Ibid.
[23] Ibid.

Chairman BROUN. The Subcommittee on Oversight will come to order.

In front of you are packets containing the written testimony, biographies, and Truth in Testimony disclosures of today's witness panel. I will recognize myself for five minutes for an opening statement.

Good morning, and welcome. This hearing, titled "Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety," is the first hearing for the 113th Congress's Subcommittee on Oversight. During our break, our name changed but our general and special investigatory authority to review and study, on a continuing basis, all laws, programs and Government activities dealing with or involving non-military research and development remains the same.

I would like to extend a warm welcome to our witnesses today. We really appreciate you guys being here. I also want to welcome our returning Members and our new Members, including the Subcommittee's Ranking Member, the distinguished gentleman from New York, Mr. Maffei. I look forward to working with you all, and Mr. Maffei, I look forward to working with you as my Ranking Member on this Committee.

Today's hearing focuses on integrating unmanned aircraft systems, or UAS, into the national airspace. As a pilot, I am extremely interested in this issue. Specifically, we hope to gain a better understanding of the safety risks, current technological obstacles and key research and development efforts being undertaken to overcome those obstacles. UAS has garnered a great deal of attention lately. In fact, if you watched the news this morning, there was a lot of news about this issue. In January, PBS's NOVA aired a documentary entitled, "Rise of the Drones." Last week's Time magazine cover carried the same title, and of course the Administration's use of drones for targeting terrorists to confront our war on terrorism has come to be a central issue in the confirmation hearing of the proposed CIA Director, the nominee John Brennan. However, privacy issues and military applications of UAS are beyond the scope of this hearing.

I use the term "unmanned aircraft systems" or UAS, instead of UAV or drone, because it is a more complete and accurate term. As the name suggests, UAS are complex systems made up of not only aircraft but as well as supporting ground, air and communications infrastructure. UAS comes in a variety of shapes and sizes and can carry out a wide range of missions.

Aviation has come a long way in a relatively short time thanks to American innovation and ingenuity. The list of American pioneers of aviation and aerospace is very long. You may not know the details of their achievements, but I am sure you will recognize names such as Clyde Cessna, James McDonnell and Donald Douglas, Howard Hughes, William Boeing, Charles Lindberg, Kelly Johnson, just to name a few. Unmanned aircraft are the next step in the evolution of modern aviation which all began with two American brothers at Kitty Hawk in 1903. Just as UAS has sparked a revolution in military affairs, they will also very likely transform civilian and commercial sectors.

The Teal Group, an aerospace and defense industry market intelligence firm, predicts America will spend over $49 billion on UAS just over the next decade. In 2010, the Association for Unmanned Vehicle Systems International estimated that over the next 15 years, more than 23,000 UAS jobs, totaling $1.6 billion in wages, could very well be created. This does not include the tens of thousands of secondary jobs in sensor manufacturing, software development and other complementary industries.

That said, the addition of thousands or tens of thousands of additional aircraft into the national airspace certainly poses safety concerns for all us. There is no guarantee that accidents will not occur, but we need to take every precaution to reduce the risks involved in the UAS integration.

Last year, Congress directed that federal agencies, including the FAA and NASA, collaborate in accelerating the integration of UAS into the national airspace. The FAA Modernization and Reform Act of 2012 contains provisions designed to promote and facilitate the use of civilian unmanned aircraft. We on this Subcommittee know you have been working hard and have made progress toward meeting the prescribed objectives, but we also know there are many unresolved issues, both technologically and regulatorily.

Again, our goal here today is to better understand the research that is underway to overcome these technological issues and mitigate the risks involved with UAS integration into the national airspace system. We are particularly interested in hearing about any advances toward eliminating vulnerabilities in command and control communications, new sense and avoid capabilities, and agreements on technological standards.

The Washington Post recently reported that at least nine American UAS crashes occurred near civilian airports overseas as a result of pilot error, mechanical failure, software bugs, or poor coordination with air traffic controllers. In August of 2010, the New York Times reported that a Navy UAS violated airspace over Washington, D.C., when the operators lost contact due to a software issue. While this may be more acceptable in remote areas overseas, we need to do much better here in our own skies. The threat of command and control link jamming, GPS navigation signal spoofing, and system hacking is a real concern that has to be addressed before any UAS integration into the national airspace. Overcoming these challenges will require significant research and development investments by both the public and private sector. Given our Nation's current financial state, this demands more efficient coordination between all stakeholders.

[The prepared statement of Mr. Broun follows:]

PREPARED STATEMENT OF CHAIRMAN PAUL C. BROUN

Good morning and welcome. This hearing, titled "Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety," is the first for the 113th Congress's Subcommittee on Oversight. During the break, our name changed but our general and special investigatory authority to review and study, on a continuing basis, all laws, programs, and Government activities dealing with or involving non-military research and development remains the same.

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Again, our goal here today is to better understand the research underway to overcome these technological issues and mitigate the risks involved with UAS integration into the national airspace system. We are particularly interested in hearing about any advances toward eliminating vulnerabilities in command and control communications, new "sense and avoid" capabilities and agreements on technological standards.

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Chairman BROUN. I now recognize the Ranking Member, the gentleman from New York, Mr. Maffei, for an opening statement. You are recognized, sir, for five minutes.

Mr. MAFFEI. Thank you very much, Mr. Chairman. I am excited about the opportunity to work with you on this important Subcommittee. I particularly want to compliment you for your leadership in calling this hearing today. It hopefully won't surprise you

that on this issue I will be echoing a lot of your same comments, and I thought your opening statement very articulate.

Addressing the research and development efforts regarding the integration of unmanned aircraft systems, or UAS, into the national airspace is serious issue and presents daunting technical challenges, possible economic opportunities, as the chairman mentioned, but also potential threats to our civil liberties and safety.

I know firsthand what a complicated issue it is and the challenges it presents. An unmanned aerial vehicle unit operates out of my district at Hancock Field Air National Guard base on the military side. Now, while these are commonly referred to as drones, the future of unmanned vehicles goes far beyond what that word implies. There is a real human element to unmanned flight of this kind just as there is an increasing robotic element to manned flight. There are tremendous potential technical risks and public concerns associated with integrating UAS into the national airspace, and my constituents express those concerns on a daily basis. These aircraft represent an emerging technology with broad possible uses among many industries and government agencies. They could potentially provide benefits to many industries from our farmers to firefighters, search and rescue, researchers, meteorologists and scientists.

However, regardless of their specific use, we need to ensure that unmanned aerial systems operate in our national airspace safely and securely. But first they must overcome the technical challenges that exist, and indeed, there are many. A 2012 GAO report detailed several critical areas which must be addressed before UASs can fly safely in our skies. Chief among them is the stark reality that the technology to provide unmanned aircraft the ability to "sense and avoid" other aircraft and airborne objects does not currently exist, and this is a serious concern. Other technical challenges range from lost-link scenarios where communication between the pilot and UAS is severed as a result of environmental or technical causes or even by human actors whether they are inadvertent or intentional. Acquiring dedicated radio frequency spectrum in order to secure the continuous communication for UAS operations, particularly as the spectrum needs of the onboard sensors expand, is another challenge, and I look forward to our witnesses addressing some of these challenges in depth today.

There is a real and critical human element of unmanned flight of any kind. Highly skilled pilots who once sat in the cockpits now sit in ground stations detached from the sensation of flight and the G forces while remaining integrally connected to the outcome of the mission. We need to ensure that these human elements from proper training and medical certifications are appropriately incorporated into UAS integration as well.

A year ago, the FAA Modernization and Reform Act of 2012 was signed into law. It required the FAA to establish an integration plan permitting unmanned aerial systems to operate in the United States by September of 2015. I look forward to hearing from the FAA today on their progress in the last year as well as a realistic report on what challenges remain and where the FA stands in meeting these deadlines.

Now, 20 years ago, cell phone technology was in its infancy, and within ten years these devices have transformed from simple mobile phones to the pocket accessories used to help small businesses and owners expand. While security and safety concerns about the use and growth of these devices—they almost all have cameras on them now—have existed since the beginning, their proliferation and technical advancements have not slowed. Today, there are more than 315 million cell phones in the United States alone and most of these devices not only carry those cameras but also GPS, or global positioning satellite capabilities as well. And while these technical advancements have not been hindered or restricted, there are reasonable and legitimate limits on the use of cell phones in hospitals, secure facilities, on airplanes and while driving your car. So this should be an analogy to us.

Despite all the recognized challenges with UAS, whether we like it or not, for better or for worse, this technology is here and it is not going away. Both the public sector and commercial sector remains interested in this technology and that interest continues to evolve and expand. As a result, we must develop the necessary framework to handle UAS emergence safely and securely. We must also ensure the protection of individual rights and personal privacy in the air and on the ground. Like any new technology, it is impossible to predict the ultimate path UASs will take.

In tackling the tremendous task of ensuring the safe and secure operation and integration of UAS into the domestic airspace, we are once again presented with the challenge of balancing all these important issues. There are private sector issues which might help grow the economy. The government's interest is to provide domestic security, and we as representatives are charged with safeguarding the public's interest and protecting their civil liberties. Developing an effective regulatory framework could be an arduous process but this hearing is one step towards ensuring that this is happening in a timely and effective manner. It is our responsibility, and we don't take it lightly, to recognize the need for oversight, to ensure the proper steps are being taken, proper procedures are being created and federal agencies are meeting the critical timelines to address the rapid emergence of these UAS systems in our national airspace, and that is why I again want to compliment the chairman. Thank you for your leadership in calling this hearing today. I want to thank the witnesses, and I look forward to your testimony.

Thank you very much, Mr. Chairman.

[The prepared statement of Mr. Maffei follows:]

PREPARED STATEMENT OF RANKING MINORITY MEMBER DAN MAFFEI

Opening Statement
As prepared for delivery

Mr. Dan Maffei, Ranking Member
Subcommittee on Oversight
Committee on Science, Space & Technology

"Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety"

Friday, February 15, 2013
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2318 Rayburn

Thank you, Mr. Chairman. I am excited about the opportunity to work with you on this important oversight committee and I appreciate the necessity of this hearing you have called today. Addressing the research and development efforts regarding the integration of Unmanned Aircraft Systems or U-A-S into the national airspace is a serious issue that presents daunting technical challenges, possible economic opportunities and potential threats to individual civil liberties. I know firsthand what a complicated issue this is and the challenges it presents. A detachment of Unmanned Aerial Vehicles operates in my district at the Hancock Field Air National Guard Base.

While commonly referred to as "drones," the future of unmanned vehicles goes far beyond what this word implies.

There are tremendous potential technical risks and public concerns, associated with integrating UAS into the national airspace. My constituents express those concerns on a daily basis. These aircraft represent an emerging technology with broad possible uses among many industries and government agencies. They could potentially provide benefits to many different industries, from farmers to fire-fighters to search and rescue teams, researchers, meteorologists and scientists. However, regardless of their specific use, we need to ensure that Unmanned Aerial Systems operate in our National Airspace safely and securely. But first they must successfully overcome the technical challenges that exist. Indeed, there are many.

A 2012 GAO report detailed several critical areas which must be addressed before unmanned vehicles can fly safely in our skies. Chief among them is the stark reality that the technology to provide unmanned aircraft the ability to "sense and avoid" other aircraft and airborne objects does not currently exist. This is a serious concern. Other technical challenges range from "lost-link" scenarios where communication between the pilot on the ground and aircraft is severed as a result of environmental or technical causes or by human actors – either inadvertently or intentionally. Acquiring dedicated radio-frequency spectrum in order to secure continuous communication for unmanned aircraft operations – particularly as the spectrum needs of on-board sensors expands -- is another challenge. I look forward to our witnesses addressing some of those challenges in-depth today.

There is a very real and critical human element to unmanned flight of any kind. Highly skilled pilots who once sat in cockpits now sit in ground stations, detached from the sensation of flight

while remaining integrally connected to the outcome of every mission. We need to ensure that those human elements – from proper training to medical certifications – are appropriately incorporated into the UAS integration plan as well.

A year ago, the FAA Modernization and Reform Act of 2012 was signed into law. It required the FAA to establish an integration plan permitting unmanned aerial systems to operate in the United States by September 2015. I look forward to hearing from the FAA today on their progress in the last year, as well as a realistic report on what challenges remain and where FAA stands in meeting these deadlines.

Twenty years ago, cell phone technology was in its infancy. Within ten years these devices had transformed from simple mobile phones to pocket accessories used to help small business owners expand. While security and safety concerns about the use and growth of these devices have existed since the beginning, their proliferation and technical advancements have not slowed. Today, there are more than 315 million cell phones in the U.S. alone and most of these devices not only carry digital cameras but Global Positioning Satellite or GPS capabilities as well. While these technical advancements have not been hindered or restricted there are reasonable and legitimate restrictions on the use of cell phones in hospitals, secure facilities, on airplanes and while driving.

Despite all of these recognized challenges, commercial and public sector interests remain and this technology continues to evolve and expand. As a result, we must develop the necessary framework to handle the emergence of unmanned aircraft safely and securely. We must also ensure the protection of individual rights and civil liberties in the air and on the ground. Like any new technology it is impossible to predict the ultimate path unmanned aircraft will take.

In tackling the tremendous task of ensuring the safe and secure operation and integration of UAS into the domestic airspace we are once again presented with the challenge of balancing many interests. There are private sector interests which may help grow the economy. The government's interest is to provide domestic security. And we as Representatives must safeguard the public's interest and protect their civil liberties. Developing an effective regulatory framework is an arduous process, but this hearing is one step towards ensuring that is happening in a timely and effective manner. It is our responsibility to recognize the need for oversight to ensure that proper steps are being taken, proper procedures are being created and federal agencies are meeting critical timelines to address the rapid emergence of Unmanned Aircraft Systems in the National Airspace.

I want to thank Chairman Broun for calling this hearing today and I want to thank the witnesses for appearing before the Subcommittee this morning. I look forward to your testimony.

Chairman BROUN. Mr. Maffei, thank you so much and I look forward to working with you as we go forward through this Congress, and just from your statements, I can tell that you are I are going to be close colleagues protecting civil liberties and privacy issues, because those issues are extremely important to me and have been for a long time, well, since I have been here and before I came here.

At this time I would like to introduce our witnesses. Our first witness is Dr. Karlin Toner, who is the Director of the Joint Planning and Development Office at the Federal Aviation Administration. Our next witness is Dr. Edgar Waggoner, Director of the Integrated Systems Research Program Office at NASA. And the final witness today is Dr. Gerald Dillingham, Director of Civil Aviation Issues at the Government Accountability Office, or GAO.

As our witnesses should know, spoken testimony is limited to five minutes each after which the Members of this Committee will have five minutes each to ask questions.

I now recognize Dr. Toner to present her testimony. Dr. Toner.

STATEMENT OF DR. KARLIN TONER, DIRECTOR, JOINT PLANNING AND DEVELOPMENT OFFICE, FEDERAL AVIATION ADMINISTRATION (FAA)

Dr. TONER. Thank you, Mr. Chairman. Good morning, Chairman Broun, Congressman Maffei and Members of the Subcommittee. I appreciate the opportunity to appear before you today to discuss the Federal Aviation Administration's current research in support of unmanned aircraft systems integration into our national airspace system.

I am the Director of the Joint Planning and Development Office and will touch upon the role my office plays in facilitating and coordinating UAS research efforts throughout the government with partners including the Departments of Commerce, Defense, and Homeland Security, NASA, and the FAA.

I would also like to take this opportunity to speak to you about the solicitation the FAA announced yesterday that requested state and local governments, eligible universities, and other public entities to develop six UAS research and test sites around the country. This solicitation was done in accordance with the FAA Modernization and Reform Act of 2012, which directed the FAA to establish the test sites in order to conduct the critical research that will help determine how best to safely integrate these systems into our NAS. Once the sites are selected, which will be later this year, we expect to learn how UAS operate in different environments and how they impact air traffic operations. The test sites will also inform the agency as we develop standards for certifying unmanned aircraft and determine the necessary air traffic requirements.

In addition to the test sites, the FAA is publishing a notice in the Federal Register asking the public to review draft privacy language and provide input. The broad outline of FAA's privacy proposal will require each test site to ensure their privacy policies address the following: notice or awareness, choice and content, access and participation, integrity and security, and finally, enforcement mechanisms to deal with violations of these policies. The FAA

thinks the test sites will provide important information that will inform our UAS integration process moving forward.

With respect to FAA's research and development efforts, we are working in four areas: sense and avoid, control and communication, maintenance and repair, and human factors. Research in all four areas is critical, as the opening statements have mentioned. My written statement contains more details on each area, but I would like to take a moment to highlight the work we are doing with NASA in the area of control and communication.

The FAA is collaborating with NASA on prototype architecture that will be used to develop a high-level security risk assessment. Our joint work will define the network architecture and candidate security mechanisms for protecting the air-ground communications that can eventually be used to develop security standards and requirements. Likewise, all of our partner agencies have mission-related incentives for UAS integration to succeed. The JPDO enables leveraging the research being done by different agencies to ensure that all agencies are aware of and can benefit from the work being done throughout the Administration. This synergy, such as the FAA–NASA partnership I described, ensures that all research dollars are being used as effectively as possible to reach our common goal of safe UAS integration.

I certainly understand the desire to safely integrate UAS into the NAS. Because FAA's mission is to ensure the safety and efficiency of the NAS, integration can only occur to the extent the FAA is satisfied that the safety of the NAS will not be degraded by the introduction of these new aircraft. This is an extremely complex endeavor, but the FAA has been challenged with complex problems in the past, and the aviation safety record is a testament to the fact that we have been able to meet those challenges.

Mr. Chairman, this concludes my statement, and I will be happy to answer your questions.

[The prepared statement of Dr. Toner follows:]

STATEMENT OF DR. KARLIN TONER, DIRECTOR, JOINT PLANNING AND DEVELOPMENT OFFICE, FEDERAL AVIATION ADMINISTRATION, ON OPERATING UNMANNED AIRCRAFT IN THE NATIONAL AIRSPACE SYSTEM: ADDRESSING R&D EFFORTS TO ENSURE SAFETY, BEFORE THE HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY, SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT, FEBRUARY 15, 2013.

Chairman Broun, Congressman Maffei, Members of the Subcommittee:

Thank you for inviting me today to discuss the Federal Aviation Administration's (FAA) ongoing research and development efforts to ensure the safe integration of unmanned aircraft systems (UAS) into the national airspace system (NAS). As Director of the Joint Planning and Development Office (JPDO), I will discuss both the role of the JPDO in the coordination and collaboration of research efforts, as well as FAA's overall research efforts to achieve UAS integration.

The current NAS was developed to accommodate the capabilities of manned aircraft. While many procedures and principles used for manned aircraft apply to UAS, there are significant differences between the two types of operations in technological maturity, perception and acceptance, and operational experience. Joint efforts, including the development of NextGen, must deal with these differences because the demand for UAS operations has increased dramatically over the past few years, and is expected to continue to increase, due to the unique capabilities, and lower operating costs of UAS.

The FAA's mission is to ensure the safety and efficiency of the NAS. This means FAA will not integrate UAS unless and until we can be assured the safety of the NAS will not be degraded. JPDO is tasked with coordinating with public agencies, including the Department of Homeland Security, the Department of Defense, the Department of Commerce, the National Aeronautics

and Space Administration (NASA), and the FAA to understand the complexity of the airspace and to safely integrate the wide variety of UAS technology, sizes, and speeds into the NAS.

The JPDO has developed a number of UAS national goals and related objectives in coordination with executive and working level representatives from NextGen partner agencies to provide a framework for interagency coordination and planning. The FAA is specifically focusing its current research efforts on four areas: sense and avoid technology; control and communication (including possible security risks associated with communication); aircraft certification, maintenance, and repair standards; and human factors associated with UAS integration. FAA research activities focus on new technology assessments, methodology development, data collection and generation, laboratory testing and field validation. The role of the JPDO is extremely important to enable leveraging the research being done by different agencies to ensure that no two agencies are conducting the same research, and that all agencies are aware of and can benefit from the work being done by other agencies. This interaction helps advance the goals and objectives agreed to within the Administration.

The FAA also recognizes the importance of non-safety related issues, such as privacy and national security which need to be taken into consideration as UAS are integrated into the NAS. The FAA plans to use the UAS test sites mandated by the FAA Modernization and Reform Act of 2012 to gather information on operational and technical issues, as well as privacy issues and potential of UAS to promote economic growth. Further, the FAA will continue to work with relevant U.S. government agencies to develop appropriate frameworks to address the privacy and national security questions brought about by the integration of UAS into the NAS.

UAS information systems security is needed to protect against the potential impact that a loss of confidentiality, integrity or availability would have on individuals and organizational operations and assets. We need to identify potential security features or mechanisms to protect UAS operations against threats, such as IT system threats, radio link threats, and human or physical threats. For example, FAA is currently collaborating with NASA on a UAS prototype architecture that will be used to develop a high-level security risk assessment. Our joint work will define a network architecture and potential security mechanisms for protecting air-ground communications for control and communication that are consistent with developed standards.

I want to assure you that UAS integration has the attention of individuals at the highest levels within the Administration. The President's budget request for FY 2013 reflects the FAA's commitment to UAS-related research. The request proposed a significant increase in FAA funding for this research. In addition, the interagency structure, such as the NextGen Senior Policy Committee, provides for Cabinet level input and review as required. All of the agencies involved in UAS integration have mission-related incentives for succeeding, which translate into the interest and support of key policy makers throughout the Administration.

The NextGen UAS Research and Development (R&D) Roadmap was published last year and is the first report that identifies relevant ongoing and planned NextGen UAS R&D activities. It is the joint product of more than 60 experts from the JPDO and our NextGen partners. The work was organized within four broad challenges which encompass research by the FAA and partner agencies and are common ways to think about identified barriers to UAS NAS integration. It is a blueprint for identifying and addressing technical challenges and establishes a set of research areas that must be addressed to permit routine UAS operations in a NextGen environment. The work brought together researchers, regulators and operators and led to an approach to link the

R&D activities of our partner agencies with the research needs of FAA. As a result of the Roadmap, we now have achieved an ongoing coordinated, multi-agency effort.

The challenges of integrating UAS into the NAS are extremely complex. It is on those challenges that FAA's research is focused. For example, in the area of command and control, we are conducting human factors research to determine the evaluation of criteria and guidelines related to UAS pilot and crew training and certification requirements. We also have eight ongoing Sense and Avoid activities in this area with the long term goal of replacing a pilot's see and avoid functions with technology or procedures that will meet the safety standards in our regulations.

In the area of Control and Communication, we are working with NASA on prototype architecture that is described above. The long term goal in this area is to develop baseline security standards that the prototype can be designed to meet.

Maintenance and Repair focuses on the differences between manned and unmanned aircraft. The FAA has implemented detailed safety standards for maintaining an aircraft in compliance with our regulations. Unmanned aircraft are a new and emerging technology. The FAA is working to identify whether unmanned aircraft require new and innovative safety approaches to address the differences in the operation and maintenance of these vehicles. Should different maintenance and repair requirements be identified, standards and requirements would be developed to ensure the same level of operational safety as manned aircraft.

Finally, there is the area of human factors. FAA has just initiated a study in this area that is intended to evaluate criteria for UAS control stations, pilot and crew training and certification requirements. In manned aircraft, a pilot can see, feel and even smell if something is not

functioning properly. An aircraft being flown by a pilot not collocated with the aircraft does not provide the same sensory access that a pilot in the aircraft has. We hope to use the information provided by the study to determine how best to mitigate this inequity.

Each of these safety research initiatives cannot be looked at in a vacuum, but rather as part of our overall strategy of transitioning to the NextGen capabilities necessary to meet the airspace demands of the future. It is abundantly clear that there are untold uses for the myriad of UAS and that their eventual integration into the NAS is both necessary and complicated. The FAA and its partners throughout the Administration will continue to work to make this happen seamlessly and, most importantly, safely. There is commitment to achieving the identified goals and objectives for integration at the highest levels of the Administration. The United States is the world leader for safety and technological innovation in aviation. The integration of UAS into the NAS is the latest of many challenges the FAA has faced, and like those we have seen in the past, we are confidently we will successfully and safely meet it.

The FAA looks forward to continuing working with Congress on this and other important aviation issues, and we thank you for the support Congress has provided thus far in assisting our work.

This concludes my prepared statement. I will be happy to answer any questions you have at this time.

Dr. Karlin Toner

Dr. Karlin Toner is the Director of the Joint Planning and Development Office (JPDO). As Director of the JPDO, Dr. Toner manages an interagency initiative charged with facilitating and coordinating the development of the Next Generation Air Transportation System (NextGen). Dr. Toner also serves as the Senior Staff Advisor to the Secretary of Transportation for NextGen, a role she has held since January 2009.

Dr. Toner has 20 years of experience with the National Aeronautics and Space Administration (NASA). From August 2006 to December 2008, she served as Director of the Airspace Systems Program at NASA Headquarters in Washington, DC. Prior to this, Dr. Toner held several key positions in aerospace and aeronautical planning and research while working at the NASA Ames Research Center in Moffett Field, California. From July 2005 to August 2006, Dr. Toner was the Associate Director for Aeronautics, charged with developing long-range technical and resource plans for aeronautical projects. Prior to that assignment, she established and managed the Aerospace Operations Modeling Branch. This organization provided a focal point for the modeling and simulation of air traffic operations within NASA.

Dr. Toner was a lecturer in the Aerospace Engineering Department at San Jose State University from 1991 to 1994. Her technical publications include papers on aircraft aerodynamics and design, computational physics, and the analysis of air traffic systems. Dr. Toner earned a NASA Exceptional Achievement Medal and is an Associate Fellow of the American Institute of Aeronautics and Astronautics. In 2011, Dr. Toner received the University of Florida's Department of Mechanical & Aerospace Engineering Outstanding Alumnus Award and the Distinguished Alumni Award from Indiana University of Pennsylvania.

Dr. Karlin Toner holds doctoral and master's degrees in Aerospace Engineering from the University of Florida and a bachelor's degree in Applied Mathematics from Indiana University of Pennsylvania.

Chairman BROUN. Thank you, Dr. Toner. I appreciate your staying within five minutes. That was perfect. Thank you so much. That is excellent.

Now I recognize Dr. Waggoner for five minutes.

STATEMENT OF DR. EDGAR WAGGONER, DIRECTOR, INTEGRATED SYSTEMS RESEARCH PROGRAM OFFICE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Dr. WAGGONER. Chairman Broun, Ranking Member Maffei and Members of the Subcommittee, I want to thank you for this opportunity to testify on NASA's research and development activities to ensure safety in the operation of unmanned aircraft systems, or UASs, in our national airspace.

There is a growing demand to routinely fly unmanned aircraft in the NAS, our national airspace system, and I am sure that you are aware that unmanned aircraft are increasingly being used for applications where it is not feasible or practical to rely on extended human-piloted flights. We often refer to these as dull, dangerous or dirty missions.

The application of unmanned aircraft to perform these missions is just part of what is driving the critical need for safe, less restrictive access to the NAS. Safe, routine access represents enhanced capabilities for the public sector but also the promise of new capabilities for commercial or civil aviation sectors as well. NASA is performing research in the Aeronautics Research Mission Directorate that provides an opportunity to develop and transition our concepts, technologies, algorithms and knowledge to the FAA and other stakeholders to help them define the algorithms, regulations standards for safe, routine NAS access.

In my testimony this morning, I want to make three key points. I will define the research that NASA is doing to help solve this problem, how we are working to transition our research results to the stakeholder community, and looking towards the future of what NASA considers some of the areas where additional research is required.

So one might ask, why aren't UAS routinely allowed in the NAS now? For unmanned aircraft, access to the NAS is hampered by various regulatory and operational challenges, making it difficult to establish common applicable standards and requirements. Now, the FAA has established a process for enabling public agencies to request a certificate or authorization (COA) or waiver in order to operate unmanned aircraft in the NAS. As a matter of fact, this is how NASA received permission to perform our science missions in flying the NAS. However, for civil, non-public UAS operations in the NAS, the FAA requires a special airworthiness certificate in the experimental category. Experimental certificates are limited to an individual vehicle rather than a class of vehicles and severely limit the uses of the UAS, for example, commercial operations are specifically excluded under an experimental certificate.

The majority of the research work that NASA is performing is organized under the UAS integration in the NAS project and it is focused in the following areas: sense and avoid separation assurance interoperability, developing reliable communication systems and

protocols, design of ground control stations and their displays for effective and safe operation, and the requirements necessary to define criteria for avionics communication systems and ground control station certification. In each of these areas, we are addressing critical research questions and delivering research results to our stakeholders.

Now, the work that NASA is performing is dependent on external government agency and stakeholder interfaces as well. I would like to identify three key interfaces where we are significantly involved: the UAS Executive Committee (UAS ExCom), the Joint Planning and Development Office (JPDO), and the UAS Aviation Rulemaking Committee (UASR). In each of these cases, NASA is playing a significant role in supporting the activities from the executive level down to our working level subject matter experts. In addition to this, we have built effective partnerships with the FAA, the Department of Defense and RTCA's Special Committee 203 that is focused on unmanned aircraft systems.

Finally, I would like to identify some future research areas where NASA is undertaking studies to evaluate the implications of safe integration of UAS into the Next Generation Air Transportation System (NextGen). So understanding the tradeoffs between remote control and computerized automation of unmanned aircraft, referred to as levels of autonomy, is a relatively immature research area that we think could generate some additional focus.

In addition, the second area I would like to point out is that of airborne-based sense and avoid. Issues associated with sense and avoid are particularly relevant when the aircraft involved are not under positive air traffic control. So we know about the work that the DOD has performed. We would like to assess that relative to civil applications.

So in conclusion, I would like to leave you with this thought. Granted, NASA doesn't build unmanned aircraft nor do we develop policy or the regulatory framework for their safe operation in NASA. However, through our research we conduct in cooperation with other government agencies, industry and academia, NASA is addressing barrier technology challenges for safe UAS integration in the NAS and ensuring that our research is effectively coordinated with and transitioned to the UAS stakeholder community.

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

[The prepared statement of Dr. Waggoner follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
February 15, 2013

Statement of

Edgar G. Waggoner, D.Sc.
Director, Integrated Systems Research Program
Aeronautics Research Mission Directorate
National Aeronautics and Space Administration

before the

Subcommittee on Oversight
Committee on Science, Space and Technology
U.S. House of Representatives

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify on NASA's Research and Development (R&D) efforts to enable safety in the operation of Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS).

Introduction

There is a growing demand to routinely fly UAS in the NAS. Unmanned Aircraft Systems are increasingly being used for applications where it is not feasible or practical to rely on extended human-piloted flights. Examples include long-duration scientific research, remote sensing, firefighting, land and crop monitoring and surveying, border protection, emergency management, and airborne communications. The application of unmanned aircraft to perform these national security, defense, scientific, and emergency management tasks is driving the critical need for broader integration of UAS into the National Airspace System.

Routine access of UAS to the NAS represents the promise of new capabilities for the government (public) and commercial (civil) aviation sectors. However, the Federal Aviation Administration (FAA) will not integrate UAS unless and until we can be assured the safety of the NAS will not be degraded. The growth

of this potential industry has not yet been realized because additional research must be done to determine what is required to safely operate UAS in the NAS. NASA is performing research in the Aeronautics Research Mission Directorate (ARMD) that provides an opportunity to transition concepts, technologies, algorithms, and knowledge to FAA and other stakeholders to help them define the requirements, regulations, and issues for routine UAS NAS access.

To be clear on the role that NASA Aeronautics plays in this effort—NASA does not build unmanned aircraft for the civil market nor develop the regulatory framework for their operation in the NAS. Rather, through the research we conduct, we address critical technology challenges for UAS integration in these key areas:

- Sense and Avoid/Separation Assurance Interoperability
- Communication
- Human Systems Integration
- Support of UAS Certification Requirements

Our research efforts and resulting deliverables are effectively coordinated with, and planned for seamless transition to, the UAS stakeholder community.

Barriers to Integration

Why aren't Unmanned Aircraft Systems allowed routine access to the NAS now?

Existing Federal Aviation Regulations (FAR) procedures and technologies do not allow routine UAS access to the NAS. Access to the NAS is hampered by challenges such as the lack of an on-board pilot to see and avoid other aircraft, the reliance on command and control (C2) communication frequencies used primarily by the military, and the wide variation in UAS size (e.g. Northrop Grumman Global Hawk vs. AeroVironment Nano Hummingbird) and performance characteristics (altitudes, speeds, and duration at which UAS operate). Understandably, the FAA needs to gather information in each of these areas, in order to determine the safety of these aircraft, and to set prudent operations and equipment standards before routine access is granted, in order to continue to ensure safety of the NAS.

The FAA has established a process enabling public agencies to request a Certificate of Authorization or Waiver (COA) to operate UAS in the NAS. Recently, the FAA has worked with government partners to streamline the COA application process and extended the length of the Authorization from 12 months to

24 months. In addition, the FAA has established expedited procedures to grant one-time Certificate of Authorization or Waivers for time-sensitive emergency missions such as disaster relief and humanitarian efforts.

For civil (non-public) UAS operations in the NAS, the FAA requires a special airworthiness certificate in the experimental category. Because of safety concerns, experimental Certificates (ECs) are limited to an individual vehicle, rather than to a class of vehicles. For example, commercial operations are specifically excluded under an EC.

The UAS Integration in the NAS Project

The majority of NASA's research work toward integration of UAS into the NAS is organized under the UAS Integration in the NAS Project, which is part of the Integrated Systems Research Program. The goal of the project is to contribute capabilities that reduce technical barriers related to the safety and operational challenges associated with enabling routine UAS access to the NAS.

Current work is focused in these areas that represent key barriers to UAS integration.

Research Area: Sense and Avoid/Separation Assurance Interoperability (SSI)

How can UAS sense other vehicles and avoid them? What are the appropriate variables necessary to evaluate the safe interoperability of manned and unmanned aircraft in the NAS? How do you quantify those variables in a way that could lead to aircraft certification minimum operating standards of the sense and avoid system?

This research area focuses on validating technologies and procedures for UAS to remain an appropriate distance from other aircraft and to safely and routinely interoperate with other aircraft in the NAS. NASA research will help determine the combination of technologies, systems, procedures and standards required to ensure that UAS operating in the NAS remain outside the separation minima defined by the FAA. To get to that point, we first need to:

- *Determine the performance requirements for a "certifiable" sense-and-avoid system (SAA) that replaces the pilot's eyes that fulfills the requirement to "see" and avoid other aircraft.* The existing requirement is intentionally vague to allow for pilot discretion in determining the "appropriate

distance" to remain from other aircraft but for UAS to contain a "certifiable" SAA system the requirements for remaining an "appropriate distance" cannot be vague and must be quantified. Otherwise it will be difficult to measure whether a given Target Level of Safety (TLOS) is achievable.

- *Determine the impact of these SAA system requirements on the NAS and whether procedures or standards should be modified to minimize the impact.* An SAA system that meets the TLOS will likely give the UAS pilot greater awareness about nearby traffic than has a manned pilot using only his or her eyes. This greater awareness may make a UAS pilot operate in different ways that impact the NAS differently than manned aircraft. For example, UAS pilots may contact Air Traffic Control more frequently to request maneuvers to avoid distant traffic, increasing controller workload. UAS in the NAS Project researchers will study the new impacts that a SAA-equipped UAS will have on the NAS and explore strategies (procedures, standards, technologies) to minimize those impacts.

NASA researchers will employ a suite of methodologies to address this safety goal including simulations and flight tests. Research results will be transitioned to various stakeholders including the FAA and Radio Technical Commission for Aeronautics (RTCA) Special Committee (SC) – 203 Unmanned Aircraft Systems. RTCA SC-203 will use results to support the development of recommendations for SAA system requirements and performance standards. NASA also anticipates that industry stakeholders will use these results to guide the design and implementation of new SAA systems.

Research Area: Communications

What frequency spectrum is appropriate for UAS? How do we develop and test a communication system? What are the security vulnerabilities that might exist in a communication system?

The UAS Communication work with NASA's UAS Integration in the NAS Project addresses safety aspects of UAS communications when operating in the NAS.

- The Project is working with the International community to identify spectrum bands to enable safe control of UAS. NASA assisted the community to identify spectrum for line-of-sight (terrestrial) UAS communications and the consider spectrum for beyond line-of-sight (satellite) for UAS communications at the 2012 World Radio Conference. NASA is currently conducting analyses to

assist in identifying additional beyond-line-of-sight frequency bands for UAS communications at the 2015 World Radiocommunication Conference.

- NASA is developing a prototype control communication radio system to allow the validation of proposed UAS communication system requirements in a relevant environment, utilizing frequency bands identified for UAS operations. This effort is in partnership with an established aircraft avionics manufacturer, Rockwell Collins, who has developed and fielded numerous radio systems certified by the FAA. NASA is conducting flight validation of a prototype UAS communication system as a full end-to-end system test, incorporating systems and algorithms from other UAS in the NAS sub-projects. The testing of this system in a realistic flight environment enables the proposed communication system requirements to be rigorously evaluated, in order to establish a basis for the minimum performance standards necessary for a FAA-certified UAS control communication system.

- NASA is working in partnership with the FAA and National Institute for Standards and Technology (NIST) to analyze and develop mitigations to potential security vulnerabilities of the UAS control communication system. The security analysis follows applicable NIST security standards, guidelines and processes. The developed security mitigations are being validated through flight tests of a full end-to end system.

- NASA is conducting large-scale simulations of the UAS communication systems considering a NAS-wide deployment of UAS. These simulations are being utilized to validate the ability to scale the prototype communication system to future anticipated UAS traffic levels, as well as exploring the effect the UAS communication system may have on manned aircraft traffic.

NASA and the FAA are working in partnership to analyze and develop mitigations to potential security vulnerabilities of the UAS control communication system.

Research Area: Human Systems Integration (HSI)

How does the NAS accommodate a UAS pilot who is on the ground compared to a pilot in the cockpit? How do we design Ground Control Station displays to maximize pilot effectiveness and safety?

NASA researchers in this focus area are working to ensure that the unmanned aircraft pilot operates as safely in the NAS as a manned aircraft pilot. Human Systems Integration is achieving this through; 1)

identifying the tasks and requirements that allow a pilot to operate safely, 2) developing a prototype Ground Control Station (GCS) that supports those tasks and requirements, and 3) demonstrating this capability in simulation and flight test and in both nominal and off-nominal conditions. The results of this work will be the basis for developing guidelines for GCS designed to operate in the NAS.

The HSI element is performing a systematic evaluation of the task and information requirements ultimately including consideration of FAA Federal Aviation Regulations (FARs) for design and safe operation in the NAS. Three information requirements analyses have been conducted to fulfill this objective: 1) analysis of the phase of flight of the aircraft; ground operations, departure, cruise and approach and landing; 2) a functional analysis, i.e., aviate, navigate and communicate; and 3) a requirements study carried out in conjunction with the FAA focused on evaluating applicability of current FARs to UAS.

When the requirements are well understood, a prototype Ground Control Station (GSC) will be developed to present the required information and support the tasks required. A survey of over 100 existing Ground Control Stations has been conducted to ensure the industry lessons learned and state of the art for GCS design are well documented. Further, a similar analysis of applicable manned aircraft technologies is underway to make use of the decades of superior aeronautical engineering. Human factors best practices will be employed in the development of the prototype GCS.

The lessons learned from these Human Systems Integration evaluations will inform GCS design guidelines for operations in the NAS that will be vetted through Radio Technical Commission for Aeronautics (RTCA) Special Committee (SC) – 203 leading to recommendations to the FAA.

Research Area: Support of UAS Certification Requirements

What data needs to be collected on the road to developing guidelines for UAS aircraft certification? What criteria are critical for avionics, communication and GCS certification?

To help identify what role certification can play in safe integration of UAS in the NAS, NASA Aeronautics is: (1) collecting and analyzing data on safety-related hazards from UAS operations, and (2) analyzing risk factors that underlie development of system safety standards for UAS.

Work is underway to collect incident, accident, and system failure data to increase our understanding of UAS failure modes and hazards experienced to date. The majority of data on UAS incidents and accidents comes from military and public-use operations, where the quality and availability of data records are extremely variable, making comprehensive analysis difficult. NASA Aeronautics is currently acquiring data across many of NASA's science missions that employ UAS and data that has been made publicly available from the FAA's COA process. Various modeling and data mining techniques are being applied to analyze that data and to advance data collection and analyses methods, with the goal of facilitating proactive identification of UAS safety issues.

Work is also underway to analyze how risks inherent in the design and operation of UAS affect the specification of airworthiness standards; that is, aircraft and system-specific design and performance standards that promote safe flight. To attain routine access to the NAS, minimum standards must be established or adapted from current standards for manned aircraft that provide confidence in system reliability and safe operation.

NASA's UAS Integration in the NAS Project is examining the degree to which existing design standards and reliability requirements may serve as an appropriate certification basis for UAS, and sharing the results of this examination with FAA. That degree depends, at least in part, on whether aviation hazards or other risk factors significantly change based on operational or physical attributes of the UAS, such as the separation of the cockpit and pilot of the aircraft from the vehicle itself. Even in the most conventional UAS designs, significant new hazards may arise from ground control stations, communication links, and specialized avionics. The effect of failures in these elements, separately or in combination, can bring a new twist to long-established hazards such as loss of aircraft control and loss of situational awareness. Evaluation of various risk factors, coupled with lessons learned from incidents and accidents, is intended to support development of a well-founded safety case for integrating UAS into the NAS.

Technology Transfer

As stated earlier, the driving force behind NASA's UAS research is to be able to transfer tools and solutions for operation in civil airspace to the UAS community. Transfer is enabled by the coordination and close working partnerships that form during the research process.

Inter-Government Interfaces

The work that NASA is performing to support the safe integration of UAS into the NAS is dependent on external government agency interfaces to coordinate ongoing work as well as to transfer research deliverables. To this end, three key inter-government interfaces that NASA is involved in are the UAS Executive Committee (ExCom), the Joint Planning and Development Office (JPDO), and the UAS Aviation Rulemaking Committee (ARC).

In response to integration challenges and the growing demand for UAS NAS access by government agencies, Congress created the UAS Executive Committee (UAS ExCom). The ExCom was created in order to enable DOD, DHS, and NASA to obtain routine UAS access to the NAS in order to execute their agency missions of national defense, security, and scientific research. The expectation is that the experience gained by these agencies may enable the FAA to extend normalized or routine operational procedures to other public UAS operators and eventually civil UAS operators. The final composition of the ExCom includes senior executives from all four agencies. NASA also supports the work of the UAS ExCom through participation on its Senior Steering Committee and associated Working Groups.

NASA supports and closely cooperates with the Joint Planning and Development Office in cross-agency efforts to coordinate integration activities and document governing consensus to support UAS integration. The NASA Administrator is a member of the Senior Policy Committee and the Associate and Deputy Associate Administrator for the Aeronautics Research Mission Directorate are active JPDO Board members. NASA also supports UAS integration efforts at JPDO through active participation in various working level efforts that focus on specific integration challenges. NASA is supporting the JPDO on developing the UAS Comprehensive Plan, a national roadmap for civil UAS access (in conjunction with the FAA's UAS ARC), identifying specific NASA contributions to a Research Development and Demonstration Roadmap, and developing national goals and objective for UAS integration.

NASA also works as an integral contributor to the FAA's UAS Aviation Rulemaking Committee (ARC). This committee was formed to provide a forum for the Nation's aviation community to discuss UAS related issues, and provide recommendations to the FAA for various UAS rulemaking projects. This includes providing information and input to the FAA to help develop the means to continue integration of UAS with manned NAS operations that address safety, capacity, and efficiency objectives consistent with global aviation. NASA is involved at the executive level as a member of the UAS Aviation Rulemaking Committee and provides subject matter experts to support various working groups.

In addition to the formal interfaces described, the work NASA is performing requires close coordination with the FAA's UAS Integration Office, industry standards, organizations, and international organizations in an effort to ensure that the research products NASA delivers are well aligned across the multi-agency, multi-national efforts to enable routine UAS access to national and global airspace.

Partnerships and Agreements

The UAS community is both broad and deep. NASA and DoD have extensive experience in flying UAS in segregated and non-segregated airspace over the past 40+ years. Other government agencies, such as DHS, have been flying UAS during the past decade. In addition to operating UAS, many governmental and industry entities have been conducting research in areas of sense and avoid, communications, pilot/aircraft/controller interactions, and other areas related to UAS access to the NAS.

Since there are a multitude of operational and research experiences across the UAS community, it is imperative that NASA fosters partnerships and collaborations in order to ensure that the research products that NASA delivers are both relevant and not unnecessarily duplicative.

Even before the onset of establishing the UAS Integration in the NAS Project, NASA began to build partnerships with the two key customers, the FAA and RTCA SC-203, for critical deliverables. With the FAA, NASA is leveraging formal agreements from the past, and has established a new UAS specific agreement to ensure full collaboration at both the management and technical levels. Key personnel from NASA and the FAA have met and will continue to meet routinely to ensure that our deliverables will reduce or eliminate technical barriers for routine civil UAS access to the NAS. With RTCA's SC-203, NASA is represented on all of the Work Groups. NASA is developing research products that will validate the SC-203 standards recommendations to the FAA.

In addition to the partnerships with the FAA and SC-203, NASA is collaborating with the DoD in several key areas. NASA is working closely with the Air Force Research Lab (AFRL) to leverage research efforts associated with sense and avoid, particularly related to the Jointly Optimal Collision Avoidance (JOCA) research and on human factors efforts related to UAS access. The Project is working with US Northern Command in their flight test efforts to validate the DoD Concept of Operations for UAS access. NASA is working with the Navy Broad Area Maritime Surveillance (BAMS) Program on safety case analysis in addition to sense and avoid testing. This will again provide specific additional data related to routine access for both public and civil aircraft. Based on a request from the UAS ExCom, NASA is validating specific flight test data for Class D airspace. NASA is also coordinating research activities

with the DoD Policy Board for Federal Aviation and the Office of the Secretary of Defense's UAS Task Force to expand our collaborations with the DoD further.

Our involvement with industry has primarily been through NASA Research Announcements (NRAs) or contracts. NASA does have a specific cost sharing arrangement with Rockwell Collins on the development of a prototype UAS communications system.

A final area of collaboration in which NASA is engaged is global harmonization. The data and research findings that are being developed in the Communications activity are being shared with the international community through the International Telecommunication Union meetings associated with the World Radio Conference. NASA is also involved in several International Civil Aviation Organization activities as part of the U.S. delegation led by FAA and the State Department, including the Flight In Non-Segregated Airspace work, the UAS Study Group, the Civil Air Navigation Services Organization, and Working Group.

The Reality of Research Gaps

NASA has diligently worked to identify and address the most critical challenges associated with the routine operation and integration of UAS into the NAS. However, two future areas of research have been identified where NASA is undertaking studies to evaluate the implications of safe integration of UAS into the Next Generation Air Transportation System.

Level of Autonomy

As mission complexity and environmental complexity increase, automation technologies can augment piloted control of UAS in much the same manner as in manned aircraft. However, understanding the tradeoffs between remote control and computerized automation of unmanned aircraft systems is relatively immature. As civil UAS interoperate with manned aircraft in the NAS, levels of acceptable automation may well remain a critical obstacle for routine UAS integration and dictate the pace of expansion of the UAS commercial market.

Airborne Based Sense and Avoid (ABSAA)

As previously described, one of the critical challenges for routine UAS access to the NAS is the risk associated with the lack of having an onboard pilot to "see and avoid" other aircraft. This is particularly relevant when one or both aircraft are not under positive control from air traffic controllers. Current

mitigation strategies require a ground based observer or an observer in a chase aircraft maintaining visual contact with the UAS. Significant research has been performed supporting DoD operations that should be assessed for civil UAS applications. This includes addressing research issues of self-separation, collision avoidance, and aircraft detection.

Conclusion

In summary, NASA does not build unmanned aircraft for the civil market nor develop the regulatory framework for their operation in the NAS. However, through the research we conduct in cooperation with other government entities, industry and universities, we are addressing barrier technology challenges for UAS integration into the NAS. This includes critical research being performed in the areas of:

- Sense and Avoid/Separation Assurance Interoperability
- Communication
- Human Systems Integration
- Support of UAS Certification Requirements

NASA is working diligently on various fronts to insure that the research we are delivering is effectively coordinated with and transitioned to the UAS stakeholder community.

The research being conducted by NASA Aeronautics in support of integration of UAS into the NAS supports NASA Aeronautics' core principles of:

- Valuing innovation and technical excellence;
- Aligning our research to ensure a strong relevance to national needs;
- Transferring technology in a timely and robust manner;
- Maintaining strong partnerships with other government agencies, industry and academia; and
- Inspiring the next generation of engineers and researchers.

Our planned research for the upcoming years will continue to provide valuable benefits to the aviation community and the Nation.

Dr. Edgar G. Waggoner
Director of the Integrated Systems Research Program

As director of the Integrated Systems Research Program Office, Ed Waggoner is responsible for the overall planning, management and evaluation of the directorate's efforts to conduct integrated, system-level research on promising vehicle and operational technologies in a relevant environment that meet energy, environmental and mobility objectives.

In addition, he supports the associate administrator in a broad range of mission directorate activities, including strategic and program planning; budget development; program review and evaluation; and external coordination.

Previously he was on assignment to the Joint Planning and Development Office in Washington, DC, where he served as director of the Interagency Architecture and Engineering Division responsible for technical leadership in the development of the Next Generation Air Transportation System (NextGen) Enterprise Architecture, Concept of Operations, and Integrated Work Plan. While on this assignment, he served as a co-author of the Mobility chapter for the National Aeronautics R&D Plan.

Waggoner began his NASA career in 1982 as a researcher in the theoretical aerodynamics discipline at NASA's Langley Research Center. He eventually held management positions in Langley's transonic and subsonic aerodynamics branches responsible for planning and supervision of applied computational and experimental research directed at developing aerodynamics technology for advanced civil and military vehicles.

Prior to NASA, Waggoner worked as a researcher and project engineer with Vought Corporation in Dallas, Texas, where he worked on advanced wind tunnel testing techniques and performed foundational work in the emerging field of computational fluid dynamics.

He has been awarded several NASA Group Achievement Awards and NASA Special Act or Service Awards and has authored or coauthored 44 NASA technical papers, journal articles and conference publications on computational and experimental aerodynamics, and advanced airspace systems concepts. He is an associate fellow of the American Institute of Aeronautics and Astronautics.

Waggoner received a bachelor's degree in aerospace engineering from Auburn University, a master's degree in mechanical engineering from Southern Methodist University, and master's and doctoral degrees in engineering management from George Washington University.

Chairman BROUN. Thank you, Dr. Waggoner. I appreciate it very much. Excellent testimony from both you guys, and I am sure Dr. Dillingham is going to give us an equally excellent testimony.

Sir, you are recognized for five minutes. Thank you, Dr. Dillingham.

STATEMENT OF DR. GERALD DILLINGHAM, DIRECTOR, CIVIL AVIATION ISSUES, GOVERNMENT ACCOUNTABILITY OFFICE (GAO)

Dr. DILLINGHAM. We will do what we can, Mr. Chairman.

Ranking Member Maffei, Members of the Subcommittee, as you requested, my testimony addresses three areas related to integrating UAS into the national airspace system.

First, the roles, responsibilities and coordination among the key stakeholders; second, Faa'sprogress in complying with the UAS requirements in the 2012 FAA Reauthorization Act; and third, R&D efforts by FAA and others to address key integration challenges.

With regard to the first area of stakeholder roles, responsibility and coordination, Congress has tasked the FAA to lead the effort of integrating UAS into the national airspace system, and successful integration requires the involvement of several other agencies including DOD, DHS and NASA as well as industry stakeholders. FAA has taken several important steps to facilitate collaboration among the stakeholders. For example, they have established several working groups, various memorandums of understanding and Cooperative Research and Development Agreements to address a range of integration issues. FAA has also recently created the UAS Integration Office with one executive to coordinate UAS efforts across the FAA. Although we did not evaluate the effectiveness of these efforts, our work on other federal and industry collaborations, such as the implementation of the Next Generation Air Transportation System, has shown that early and continuous involvement of stakeholders is critical to project success.

With regard to the implementation status of the FAA reauthorization provisions, our written statement contains a chartof selected requirements and the status of FAA's efforts to meet them. Most of the requirements must be achieved between May 2012 and December 2015. Our work shows that while FAA has efforts underway to meet these requirements, they have completed only two of the nine requirements with completion deadlines that have passed as of this morning. Of the deadlines missed, FAA has not yet established a program for the six UAS test sites or released a comprehensive plan. Stakeholders including the Congress consider these actions among the key gateways to moving closer to safe and efficient UAS integration. While it could be argued that some of the provisions are complex undertaking that requires significant amount of effort by FAA and the partner agencies, meeting established deadlines can help increase stakeholder confidence in FAA's ability to lead the UAS integration effort and contribute to the continued participation and collaboration among all stakeholders.

Regarding research and development efforts, FAA's UAS R&D roadmap identifies the various organizations that have efforts underway to mitigate obstacles that prevent UAS from being allowed to operate safely and routinely in the NAS. Some of these obstacles

and related research include vulnerabilities to UAS operations such as sense and avoid, command and control including lost link, GPS jamming and spoofing, and human factors. While progress is being made to address these obstacles, the lack of necessary data has seriously hampered the development of safety, reliability and performance standards which are needed to validate the R&D efforts. In addition to the technical and R&D obstacles that I have cited, government and industry will need to work together to address issues related to the public acceptance of UAS in the NAS, especially as it relates to privacy and homeland security concerns.

Mr. Chairman, Ranking Member Maffei and Members of the Subcommittee, the potential impact of this industrial sector on the Nation's aerospace industry and overall global competitiveness could be significant. As the Chairman noted, in addition to their life protection and lifesaving potential, according to an industry forecast, over the next decade, the worldwide market for government and commercial use of UAS could potentially grow to be worth $89 billion, and the United States could account for nearly two-thirds of the $28 billion projected R&D investment for UAS technologies. With this kind of growth, it will be critical for FAA to continue to make progress in integrating UAS into the national airspace system, and oversight hearings such as this one highlight the importance of issues that need to be addressed.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Dillingham follows:]

United States Government Accountability Office

GAO

Testimony

Before the Subcommittee on Oversight, Committee on Science, Space, and Technology, House of Representatives

For Release on Delivery
Expected at 10:00 a.m. EST
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UNMANNED AIRCRAFT SYSTEMS

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

Statement of Gerald L. Dillingham, Ph.D.
Director, Physical Infrastructure Issues

GAO-13-346T

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Highlights

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

UNMANNED AIRCRAFT SYSTEMS

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

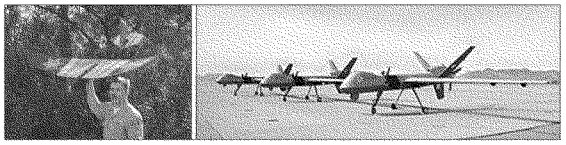
What GAO Found

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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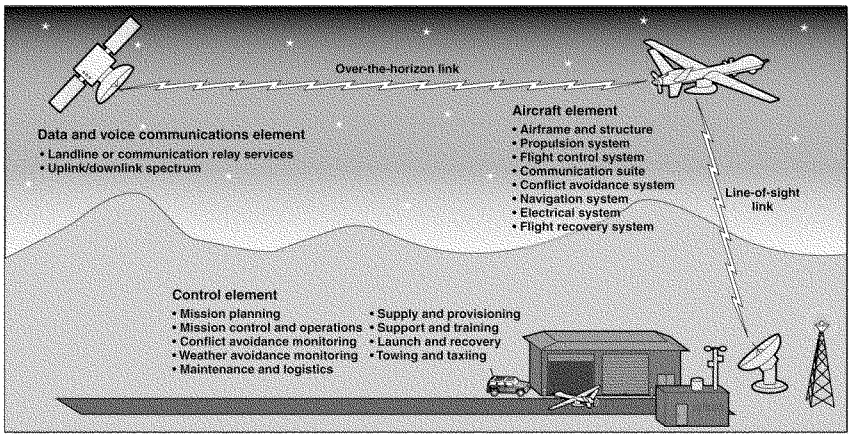
United States Government Accountability Office
Washington, DC 20548

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]

[1]We 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

[2]Pub. 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

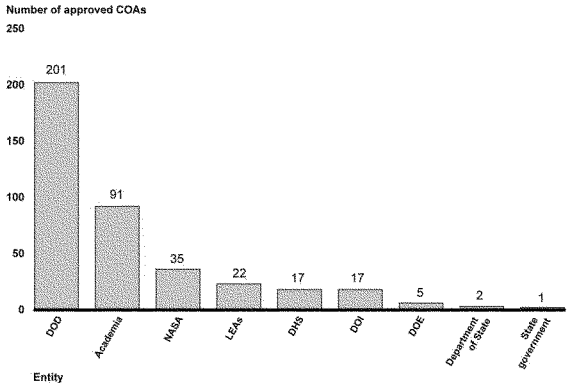
Currently, FAA authorizes all domestic military; public (academic institutions, federal, state, and local governments including law enforcement organizations); and civil (private sector entities) UAS operations on a limited basis after conducting a case-by-case safety review. Federal, state, and local 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,

[3]GAO, *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

[4]These 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.

[5]Teal 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.

[6]NextGen 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.

[a]The 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.

[b]FAA 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.

[c]RTCA, 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.

[d]ASTM 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

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

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

[9]The 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.

[10]The 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 *Federal Register* the Final Rule on small UAS.	In process
08/14/2014	Publish in the *Federal Register* a Notice of Proposed Rulemaking to implement recommendations of the comprehensive plan.	None to date
08/14/2014	Publish in the *Federal Register* 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 *Federal Register* 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.

- *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

[11]Additionally, 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.

[12]The 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.

[13]A 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

[14]The 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."

[15]MITRE 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.

[16]ADS-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.

[17]Ikhana 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.

[18]Air 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.

[19]Jamming 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.

[20]The 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

[21]For 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.

[22]In 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

For further information on this testimony, please contact Gerald L. Dillingham, Ph.D., at (202) 512-2834 or dillinghamg@gao.gov. In addition, contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this statement. Individuals making key contributions to this testimony include H. Brandon Haller, Assistant Director; Heather Krause, Assistant Director; Cheryl Andrew; Colin Fallon; Rebecca Gambler; Geoffrey Hamilton; Daniel Hoy; Brian Lepore; Sara Ann Moessbauer; Faye Morrison; Jeffrey Phillips; Nalylee Padilla; and Melissa Swearingen.

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Dr. Dillingham is currently the Director of Civil Aviation Issues at the U.S. Government Accountability Office (GAO) in Washington, D.C.—the investigative arm of the U.S. Congress. As such, he oversees all program evaluation and policy analysis related commercial and general aviation safety, airport and airline finance, the environment, air traffic control, airport development, and international aviation issues.

Dr. Dillingham is recognized as an expert on aviation issues, program evaluation, and policy analysis. He has appeared as an expert witness before numerous committees of the U.S. Congress. He also served on the National Commission on Terrorist Attacks Upon the United States (The 9/11 Commission). Dr. Dillingham holds a Ph.D. and master's degree from the University of Chicago in Sociology, and a postdoctoral certificate in Evaluation Research from the University of California-Los Angeles.

Chairman BROUN. Thank you, Dr. Dillingham. You did an excellent job also, and all three witnesses, I appreciate you all being here and the excellent testimony and hopefully Dr. Dillingham's questions that they brought up at GAO are going to be answered not only through this hearing but also through written questions that we will ask you all as we go along.

Reminding Members that Committee rules limit questioning to five minutes each, the chair at this point will open the first round of questions and the chair will recognize himself for five minutes.

On December 4, 2011, the United States lost an RQ–170 Sentinel near Iran. Iranians claim to have spoofed the global position system, GPS, signal that was in operation with that Sentinel. Last summer, Professor Humphreys from the University of Texas at Austin demonstrated that it is possible to spoof the GPS signals to take control of an unmanned aircraft. GAO's testimony states that military GPS signals, unlike the non-military GPS signals, unlike the military GPS signals, are not encrypted and transparency and predictability make them vulnerable to being counterfeited or spoofed. I ask, what R&D is being conducted to address this concern, and are there any R&D gaps that you are aware of? Dr. Toner, if you could start off answering those questions, and Dr. Waggoner, if you could fill in any gaps that Dr. Toner leaves out.

Dr. TONER. Thank you, Mr. Chairman.

You mentioned the very careful experimentation that was conducted by Dr. Humphreys and his students in Texas. We are aware of the experiments. Believe me, the security of the communication and control system is one of the key challenges we have looked at for UAS. I mentioned in my testimony projects that we are working on. What I want to point out about Dr. Humphreys' experiments is that I believe in his paper he even points out that they were very carefully conducted and would be hard to repeat. That said, we must be cognizant. The FAA has initiated a group that is looking at spoofing and jamming. There is also a position navigation and timing excom that looks across the government at GPS systems and would be concerned in that area. We are working on multiple levels to address it.

Chairman BROUN. Dr. Waggoner?

Dr. WAGGONER. Yes, sir. We are also aware of the work that Dr. Humphreys did at the University of Texas. Just to frame this problem, the issue with GPS is far bigger than just UAS. I mean, this would have economic implications. Our economy is run on GPS actually now. So we are aware of this. We are certainly in our work that we are working to make sure that there is adequate redundancies in any systems that we would test so positioning is not only reliant on the GPS signal and other situation awareness issues associated with that as well. Our focus is more on security at the command and control signal to the vehicle and making sure that within these frequencies that we are operating in, that those are secure and the data that we are transmitting is reliable and is valid data. So from that point of view, we have a very robust research effort going on in that.

As far as spoofing of the GPS signal, we are aware of it. We are cognizant of what Dr. Humphreys did, and as part of our knowledge base and the constraints that we are operating under but we

don't have any particular research efforts going towards spoofing of the GPS signal.

Chairman BROUN. Certainly, this is of great concerns to Americans not only because of the safety just generally but also because if Dr. Humphreys and his students can spoof the GPS system, what could other nation-states or terrorist groups do also.

Will civil and commercial UAS operating in the national airspace use encrypted command, control and navigation links? Dr. Toner?

Dr. TONER. The military today uses encrypted links, and I believe that solution may not be as viable for the commercial market. That is the reason so much research is being done today.

Chairman BROUN. Dr. Waggoner, do you have any additions?

Dr. WAGGONER. No, sir.

Chairman BROUN. My time is just about out, so please answer this question. In 2010, the Navy lost control of a Fire Scout UAS, which eventually violated the airspace here in Washington, DC. What work is being done to address the challenge of ensuring the safety in the event of a lost link? Anyone?

Dr. WAGGONER. So the work that we are doing, there would be certain lost-link protocols that would come into play so that's where autonomy would take over if there was a loss of the command control link to the UAS so that the UAS would either go to a predetermined position in order to reestablish the link or return to base.

Chairman BROUN. Weren't there protocols in place for this particular incident, though, and we still had a problem. Is that correct?

Dr. WAGGONER. That is correct in that case.

Chairman BROUN. Okay. Well, hopefully we can have that taken care of so that this doesn't occur anymore. I am sure it caused a lot of consternation here in D.C.

With that, my time is up. Mr. Maffei, you are recognized for five minutes.

Mr. MAFFEI. Mr. Chairman, thank you, and I found your questions and answers very enlightening. Clearly, there are some real national security and homeland security elements to this, and of course, on 9/11, it was not military airplanes that were taken over, it was the civilian airliners, and the same thing could be true; our biggest threat on these may not be a military craft being taken over in the Middle East but maybe a civilian one being taken over here. So we want to look at those things.

Dr. Toner, you said in your testimony that the FAA will not integrate UAS unless and until we can be assured that the safety of the national airspace will not be degraded, and I assume you mean in all these respects, and Dr. Waggoner echoed that. But given the fact, Dr. Toner, that we have a very aggressive timeline set out for you and the FAA has already missed many of those deadlines, do you believe that you will be able to safely and effectively integrate the UAS into the national airspace by the current deadline of September 2015, and if you are not sure you can, are there things that you need from us in Congress to help make that happen or expedite it?

Dr. TONER. Our approach is a phased in approach, and we are very cognizant that the FAA Act of 2012 called for safe integration by 2015. We view that as a beginning. If you look at aircraft such

as the F-22 today, it is a manned aircraft but it is not fully integrated into the air traffic control system. We are taking a phased-in approach. In 2015, we will have integration beginning, but as we move towards the NextGen system, there will be new capabilities that make this an even more efficient integration for more varieties of aircraft. So, I think it is important that we consider a rolling approach as we focus on the safe integration and safe interaction of manned and unmanned aircraft.

Mr. MAFFEI. Well, what do you need from us? Nothing?

Dr. TONER. Congress has given us a lot of attention and support. We would ask for the opportunity to continue to explain the difficulties and challenges and our progress as we move forward.

Mr. MAFFEI. Okay. Thank you very much.

The chairman and I both have expressed concerns about privacy and civil liberties related to the equipment on board of these UAS aircraft, surveillance sensors, et cetera, and then I think there is—well, let me ask you this. Who is responsible for regulating these issues such as privacy concerns? Dr. Dillingham, do you have an idea of that? Everyone can answer if you have opinions.

Dr. DILLINGHAM. Mr. Maffei, we looked into this, and I think at best we can say, it is unknown at this point. When we did our work, we asked FAA about it, and FAA said our area is safety and that is what we are going to focus on, and of course there are already existing a number of different privacy regulations and laws but none of them have been tested with regard to UAS. I think the recent SIR that was put out by FAA to seek comments on privacy issues will be a start on that. From our perspective, that is one of the big obstacles to integration, that is, public acceptance, public education, and public concern about how that data will be used.

Mr. MAFFEI. The other two witnesses are free to answer, but if you want to also address that public acceptance issue because it also seems there is no agency that is working on education of the public, et cetera.

Dr. DILLINGHAM. Not so much an agency but some of the industry associations, some of the model airplane associations are trying to educate the public or at least inform the public. One of the things that we keep in mind is, no matter what kind of technology is out there for good, there will be some who will find a way to misuse that technology, so it becomes very important that the public recognize those issues as well.

Mr. MAFFEI. Anything to add from the other two witnesses? I have one more question, so quickly.

Dr. WAGGONER. Yes, sir, just real quickly, while I am not an attorney or certainly a legal expert on this, we go to a lot of forums where this subject is discussed, and sort of the consensus opinion that I have drawn from this is that yes, privacy is not the FAA's responsibility. They are focused on safety. There are legal precedents that are set relative to technology and surveillance if these exist, and the legislators and the community really need to identify what the ethical issues are and how these differ from a UAS to a manned aircraft relative to flight operations. Then this issue that Dr. Dillingham mentioned, the public and the media really need to be educated about UAS operations and missions.

Mr. MAFFEI. Dr. Toner, do you have anything to add? You don't have to. Okay. Thank you very much, and Mr. Chairman, you and I may have to roll up our sleeves and do a little bit of bipartisan work to maybe set a legislative beginning to it, I don't know, but I would like to look into that with you.

One quick question, and it can be answered in writing, but Dr. Toner, I really appreciate the fact that the FAA took the first formal step in selecting the six UAS test sites yesterday by releasing the screening information request document to the public. While I realize that this may not be your exact area, nonetheless, can I—I may have some additional questions on it once we sort of review it in terms of trying to get more precision on what you are really looking for. After you get a chance, can I get your commitment that we will receive timely written responses to that?

Dr. TONER. We will provide a timely response, sir.

Mr. MAFFEI. Thank you very much, Dr. Toner. Thank you, Mr. Chairman.

Chairman BROUN. Mr. Maffei, all the Members of the Committee will have the opportunity to give written questions to the witnesses and hopefully—in fact, I have already talked with them about that and they are all willing to give us those expeditious answers to all these questions because I know all of us have questions and all of us have concerns about this. The American public are just frightened, frankly, about the use of the UAS to possibly have invasions of their privacy and invasions of their civil rights, and I am extremely interested in making sure that we protect those privacy issues and civil rights issues. It is something that I have been focusing on for a long period of time not only in this issue but through cybersecurity and everything else. I am eager to work with you on this issue. Mr. Maffei?

Mr. MAFFEI. Me too, and certainly, Mr. Chairman, I think you will agree, we have to at least figure out who the go-to person is in the Administration so that, you know, we have—it doesn't fall through the cracks.

Chairman BROUN. Absolutely. No matter who is in the White House and whatever the Administration is, this is an extremely important issue and it is a constitutional issue for me.

Mr. Cramer, you are recognized for five minutes.

Mr. CRAMER. Thank you, Mr. Chairman, and thank you to all of the witnesses. You really have done an excellent job of both efficiently and thoroughly answering the questions in the charter, so I appreciate that very much. I especially appreciate the opportunity to meet you before the hearing, and Dr. Toner, to have somebody who has actually spent New Year's Eve in Hazen, North Dakota, as a witness on my first hearing is extraordinarily fortuitous for me because, as you know, in North Dakota we were quite pleased yesterday when the SIR was released. It has been a long wait. Nonetheless, we are grateful for the opportunity to be one of at least the 26 states that applied for the designation, and I would say, given that you spent New Year's Eve in Hazen, North Dakota, at one point, you understand how extreme our climate can be and I hope you take that into account if you are on the team that chooses where a good place would be to test extreme weather. But I also assure you that in the summertime, the other extreme is the same.

I would be interested in just exploring a little further this juxtaposition of the privacy issue with the safety issue because as I understand it, while the SIR has a—is it a 60-day window for public comment on the privacy question? Am I correct in that, Dr. Toner? Do you know?

Dr. TONER. Yes, that is correct.

Mr. CRAMER. But does that—thank you. And does that have anything to do then with the designation of the test sites? In other words, is it part of the SIR but not part of the criteria to be considered?

Dr. TONER. We are looking to get public input on the privacy policy. We will be evaluating the test site proposals as called for in the SIR. We are looking to make sure that we are doing a good job, and that the authors are doing a good job in meeting the criteria in the SIR.

Mr. CRAMER. And so then getting back to some of your earlier criteria, I guess in your opening statement about the collaboration, the coordination and cooperation of various institutions, that would certainly, I think, fit into some of that.

Dr. TONER. I cannot comment on the collaboration in terms of the proposals themselves. However, from my office's perspective, we need everybody rowing in the same direction on this issue since it is so complex.

Mr. CRAMER. Sure. Well, the point of the question is probably to make the statement given that you have answered all the questions, the technical questions, so well. Again, going back to the criteria, we are in North Dakota, again, speaking for my constituents who are very interested in this topic because we are a big aviation state. As you know, we have the School of Aerospace Sciences, Dr. Waggoner at the University of North Dakota and the aviation school that is very much a part of a team that the governor has put together called the Airspace Integration Team. This is a state effort to do exactly—unify all of the institutions under one collaborative effort to try to get this designation, and that we think is second probably to the extreme weather in terms of the criteria. I would have a question, though, about our proximity to Canada. Is that—would you consider that a concern or an asset, being a border state, and what kind of collaboration do we have, if any, with the Canadian government if the—as we test the airspace, national airspace, realizing we deal with a lot of international airspace.

Dr. TONER. We have laid out in terms of the test sites what we believe are a wide range of criteria that we hope will attract a wide variety of offers including North Dakota. I could not comment today on the interaction with Canada and any international implications, and I could get back to you if you needed.

Mr. CRAMER. If you could, that would be great.

And Mr. Chairman, again, they have done such a great job answering the questions that I had earlier that I think I will yield back.

Chairman BROUN. Thank you, Mr. Cramer.

They have just called votes. We have some time. We will try to get through as many questions as we can. Mr. Peters, you are recognized for five minutes.

Mr. PETERS. Thank you, Mr. Chairman, and thank you for the opportunity to serve with you and Mr. Maffei on this Committee. I look forward to it.

I had a pretty simple question about spectrum. You know, San Diego supports more than 7,100 jobs in the UAS industry, and we are interested in seeing these vehicles being able to be used for environmental monitoring and scientific research. We think they have got great application there. In addition, we are also the home to Qualcomm and interested in the wireless industry. That is our largest private employer. So my question is about the bulk of spectrum resources required from the use of these aircraft and whether any of you has reviewed what the potential spectrum need will be for the various unmanned aerial systems operating in the United States 5, 10, 15 years down the road.

Dr. TONER. The FAA worked with the FCC to reserve some spectrum for the command and control of UAS. We could get you the specifics on our work. We believe, based on our assessment of the market for operation today, that spectrum should be adequate. However this is a point that we will continue to study to ensure adequacy down the road.

Mr. PETERS. I think that is fair, and I appreciate in addition to looking at the privacy concerns raised by the previous gentleman who spoke previously, I would appreciate an update on that as we go along.

Mr. Chairman, I appreciate the opportunity and yield back.

Chairman BROUN. Thank you, Mr. Peters.

Mr. Posey is next in line but he said he is not interested in asking questions. We appreciate you joining us. Oh, he has one question. Okay.

Mr. POSEY. Mr. Chairman, I just want to apologize for being late. We rolled votes from yesterday in the Financial Services Committee and I had to go do that first.

Chairman BROUN. Thank you for being here. So Mr. Schweikert, you are recognized for five minutes.

Mr. SCHWEIKERT. Thank you, Mr. Chairman.

This is one—when you are from Arizona and, you know, we actually have a number of manufacturers producing products and those things. I have a couple different questions. First one, particularly for the FAA, sort of the R&D roadmap and the deadlines and the mechanics that are supposed to be built in there, where are we time-wise? What should our expectations be of deliverabilities? What do we expect to see in the next year or two out of that?

Dr. TONER. Thank you. That is a great question, and I will probably run out of time to explain the answer. I am assuming you are talking about the UAS research, development and demonstration roadmap that we published about a year ago. At that time we said that the challenges we had identified were a good start, they were a snapshot in time, and that we would need additional vetting and additional insurance that we would be meeting the needs of the regulatory folks with our research program. During the past year, we have worked tirelessly along with the government partners. We are, I think, very close to the coordination of a set of national goals and objectives of getting a single point of view, or concept of operations, that we can use as a measuring stick for our progress. We

have set up a framework for how we can prioritize the R&D challenges. We know we have many of them. We want to make sure we cover them all. Quite frankly, we are looking forward to the point where we can share that with the full community.

Mr. SCHWEIKERT. Mr. Chairman, as you go through those sort of challenges, are you going to be publishing updates saying look, here is what we are seeing, you know, here is our latest status? And I know that is always hard around here. One of the things we have great frustration with is the number of missed deadlines. I think you had one, what was it, September that you missed?

Dr. TONER. Yes. In our roadmap report, we did push ourselves a little bit and promised some September data.

Mr. SCHWEIKERT. Would we be seeing some incremental updates, some incremental publications telling us where you are at?

Dr. TONER. We have not released incremental publications because it is very important to us, and the five agencies that we have been working with as partners, that we have coordinated with the agencies. We are in the last steps of coordination, and then we think we can release a very comprehensive package.

Mr. SCHWEIKERT. All right. My friend from civil aviation?

Dr. DILLINGHAM. Is that me?

Mr. SCHWEIKERT. Yes.

Dr. DILLINGHAM. I just wanted to add to Dr. Toner's comments that we did a report a couple of years ago and we made a recommendation that when the comprehensive plan is developed, that it also include the ability to show progress, to monitor progress towards goals, and we have not seen that comprehensive plan yet. It has been delayed as well. But if our recommendation is adhered to, the kinds of things that you are interested in and asking for should be included.

Mr. SCHWEIKERT. Okay. Doctor, a slight lark but it sort of ties in. Being from Arizona, and I actually have this gentleman as a constituent who is a high-end engineer, has lot of resources, has built himself about a nine-foot-size flying wing with constant uplink, and I appreciate it when he flies over my house and sends me a text message with photos of my house and what I am doing in my backyard. What are we seeing also from the hobbyist world? Are they running ahead of us? Are they heading towards a dangerous conflict? What is going on there, and are we about to see also some clash of cultures of people going off on their own?

Dr. DILLINGHAM. This is a very sensitive and difficult area but let me try and respond. The 2012 FAA Reauthorization Act actually prohibited FAA from making regulations related to model aircraft, and persons who operate model aircraft. There are existing regulations that suggest that if you operate it in accordance with the principles that are now inforce, that that would be okay, and there is a way for FAA to intervene if you operate them dangerously. The Model Aircraft Association has issued some guidelines, though voluntary, that their membership, which I think is over 150,000, adhere to, but it is a different world in terms of modeling and, you know, how they are going to come together is to be determined.

Mr. SCHWEIKERT. Well, I know I am beyond time but, Mr. Chairman, what you and I grew up thinking of as a model airplane,

these things ain't model airplanes anymore. They are stunning in scale and complexity. So thank you, Mr. Chairman.

Chairman BROUN. Absolutely, and the American public are very fearful, concerned, and that is the reason that the news media has been focusing on this issue so long, and I appreciate you, Dr. Dillingham. I wasn't trying to ignore you and neither were any of these Members, but I trust that you guys are going to continue to monitor and report back to us on an ongoing basis what you find, and please keep us informed.

Also, Dr. Waggoner, if you would, please provide for the record all of NASA's UAS R&D projects as well as the FY 2012 and 2013 funding levels for each project. The FAA has been kind enough to provide those for us but we have not got those records from NASA, so if you would, please provide those—that information to us in an expeditious manner.

I thank all the witnesses for you all's excellent testimony today. It is not only interesting but extremely valuable for us. Members of the Committee may have additional questions, as I have talked to you all in private. We ask for you to respond to those very expeditiously in writing to us. The record will remain open for two additional weeks for additional comments and for written questions from Members. I thank you all. I am disappointed that we have a vote on that is going to interrupt this extremely interesting topic for me and for the Members of the Committee, for Americans all over the country, and I thank C–SPAN for coming and helping to broadcast this to the American public so we can get that information out and you all's valuable testimony. Thank you so much for being here.

The witnesses are excused and the hearing is now adjourned.

[Whereupon, at 10:59 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Karlin Toner

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON OVERSIGHT

"Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety"

Questions for the Record for Dr. Karlin Toner, Director, Joint Planning and Development Office,
Federal Aviation Administration

Questions submitted by Dr. Paul Broun, Chairman

1) Please explain how agencies such as the Federal Aviation Administration (FAA), Department of Homeland Security (DHS), National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD) coordinate to identify R&D gaps.
   a. How do agencies decide who will fund projects to address these gaps?

The Joint Planning and Development Office (JPDO) is mandated by P.L. 112-95 to coordinate research goals and to create multi-agency roadmaps for the Next Generation Air Transportation System (NextGen). The JPDO began the prioritization of R&D topics with the NextGen UAS Research, Development and Demonstration (RD&D) Roadmap. Developed in 2011, the NextGen UAS RD&D Roadmap is a catalog of ongoing and planned R&D efforts being conducted by the NextGen partners supporting the integration of UAS operations into the NAS. Subject matter experts from the partner agencies – FAA, NASA, DoD, DHS, and the Department of Commerce – contributed to the NextGen UAS RD&D Roadmap, identifying planned and ongoing work and critical R&D challenges in their areas of expertise. The NextGen UAS RD&D Roadmap defined 23 challenges within the four technical tracks of Communications, Airspace Operations, Unmanned Aircraft, and Human Systems Integration.

Building on that effort, the JPDO continued coordination during FY12 to agree on a methodology to prioritize UAS research. The FY13 JPDO-led effort is reviewing the data collected in FY11, updating the UAS R&D needs and R&D inventory, conducting an initial gap analysis, and will collaborate on priority gaps. Continuing coordination among the JPDO and its partner agencies concerning UAS R&D, builds on the cooperative process established to formulate the UAS Comprehensive Plan, including the UAS National Goals, concluded earlier this fiscal year. The process included determination of agency needs based on published documents and resolution of issues through formal review, adjudication, and vetting. The same steps will be used to identify critical gaps in ongoing and planned R&D and categorize them with respect to criticality and goals being supported. This process is intended to be an on-going effort to ensure that priority research is identified. This structured coordination also allows for information sharing and greater efficiencies in demonstrations and analyses.

The coordination process will include a review of progress in filling the gaps, as well as identification of new and emerging needs and gaps. The results of these reviews, along with indications of actions that may be required, will be made available to the partner agencies for programming considerations. Interagency coordination on UAS research is also taking place through several efforts.

To cite a particular example, the FAA has partnered with DHS, Customs and Border Protection, in support of NextGen demonstration activities. The FAA also continues to partner with NASA in support of the multi-year "UAS in the NAS" project, and with DoD in support of their "Airspace Integration Joint Test." The agencies are committing resources and subject matter expertise to support research and analysis required to address known research challenges while identifying research gaps.

2) How often does the UAS Executive Committee meet to coordinate efforts?
   a. How many times has it met in the last year?

The UAS ExCom meetings are normally scheduled quarterly. In 2012, the UAS ExCom only had three formal meetings due to schedule conflicts (19 January, 8 May and 28 August). However the ExCom principals also had several informal telecons to discuss issues and progress.

3) Are there any federal agencies or organizations that are not satisfactorily fulfilling their role in

addressing UAS safety concerns?

The FAA is not aware of any agencies that are not adequately addressing safety concerns related to UAS. The FAA's main partners who assist with UAS safety concerns are NASA and DoD. Both have been engaged with the FAA on addressing safety concerns. Intra-agency working relationships have been established at all levels with these two Agencies. There is a formal outlet for decision making and escalation through the UAS Executive Committee (ExCom).

4) Are there any organizations that should be involved that currently are not?

Those organizations with interest in current safety related issues are involved.

5) Please explain the relationship between the FAA and DHS as it pertains to safety and security.
   a. Understanding that you cannot speak for DHS, what is your understanding of what DHS is doing in this regard?

The FAA has an excellent working relationship with DHS and each agency has clear expectations and understanding of their respective roles and responsibilities. Both agencies understand the need to cooperatively develop solutions that meet individual requirements. DHS is proactively working to develop Unmanned Aircraft Systems capabilities and Operational Missions requirements while meeting FAA safety standards and documentation within coordination time frames.

   b. What is the FAA responsible for? What is the DHS responsible for? How does this differ?

The FAAs role is to ensure the safe operation of aircraft within the National Airspace System. DHS has the National Security Mission responsibility for protecting U.S. borders in a safe manner so as to avoid unnecessary damage or harm/injury to individual citizens and property.

   How are decisions like this made?

Together, the FAA and DHS cooperate to ensure DHS' priority missions are given timely NAS access while meeting the FAA's safety requirements and minimizing the impact to operations.

   c. How involved has the Transportation Security Administration (TSA) been in the process?

The FAA interacts with TSA and other DHS agencies as appropriate in carrying out our mission to ensure safe operations.

6) A late 2012 GAO report suggests that the FAA has failed to act on a 2008 GAO recommendation to utilize the operational data it has collected on UAS as part of its Certificate of Waiver or Authorization (COA) to develop safety, reliability, and performance standards. Why has FAA failed to act?

The FAA has been challenged with turning the limited safety data provided via the Certificate of Waiver or Authorization (COA) process into tangible performance standards, aircraft certificate standards, or operational integration standards. In response, the FAA has charted a plan to acquire the needed data through Research and Development (R&D) Projects, both joint with interagency partners, and independently. The goal of these research projects is to ensure that developed standards meet rigid safety standards and fall within the parameters of our NextGen Modernization Program.

   a. If this assessment is inaccurate, please describe how the FAA has utilized data it received from COA recipients such as NASA, DHS, and public universities.

The FAA has used the limited data available to help define the requirements for future R&D strategy development which will serve as an input for our safety standards development.

   b. Has the FAA utilized data from UAS manufacturers that received special airworthiness certificates?

Yes, the FAA has used the data collected from the COA holders as well as experimental certificate holders to identify adverse trends and assess operational risks imposed by the accommodation of UAS in the NAS.

7) RTCA's Special Committee 203 has been working on Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS) for unmanned aircraft. How critical are these processes in advising us what research and development work is needed?

These processes are very important in advising the FAA on what R&D work is needed.

a. When are these standards likely to be finalized?

RTCA provides the FAA with recommendations on technical standards for all types of avionics. RTCA is working on developing standards for Detect and Avoid (DAA) equipment and Command and Control (C2) radio equipment. The DAA system is designed to replace the functionality of the pilot on manned aircraft to "see and avoid" other aircraft in the airspace. This capability is a key enabler for integration of Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS). C2 radios are also key to approval of UAS by the FAA. This standard will allow aircraft equipment manufacturers to build radios for controlling UAS that meet FAA safety requirements.

NASA and the FAA are conducting supporting research for both DAA and C2 standards. In addition, the USAF Research Lab is leading the effort to create DAA systems and is playing a key role in the development of RTCA standards. In an effort to ensure that RTCA SC-203's efforts are aligned with the strategic needs of the FAA, the Governing Board that oversees all FAA standards writing special committees will revise the tasking for SC-203. After the tasking has been revised, RTCA in collaboration with the FAA will publish new timelines for completion of these standards.

8) Many who follow this issue argue that a "one-size-fits-all" approach to regulation will not be effective given the wide range of systems.
   a. What is your recommendation for categorizing the systems? By size (i.e. weight)? Payload? Capabilities? Mission? Complexity?

The UAS Aviation Rulemaking Committee (ARC) addressed this question through the Terminology and Classification Action Team (TCAT), and anticipates the delivery of their final recommendations to the FAA in Spring 2013. At this time, it is expected that the TCAT will recommend that large UAS follow the existing categorization used for manned aircraft. A category for small UAS is being addressed as part of the small UAS rulemaking activity.

   b. How does this impact R&D investments? Do you see a greater need for R&D on smaller or larger systems?

FAA UAS research is currently studying various sizes of UAS. In addition to physical size and weight differences, small and large UAS operations may differ in other ways, such as in flight profiles, operational missions, performance characteristics, and crew composition. These differences all have the potential to significantly impact National Airspace System (NAS) operations. UAS integration will require that UAS impacts on the safety of the NAS be well understood, such that appropriate mitigations (in the form of standards, regulation, policies, procedures, etc.) can be identified and put into place. Therefore, research should encompass as many of these operations—and UAS sizes--as possible.

   c. What is the status of a final rule regarding the certification and operation of small (i.e., ultralight, low-speed, short-life) UAS?

The small UAS Notice of Proposed Rulemaking (NPRM) is in coordination with FAA and DOT. The FAA is targeting release of the NPRM for 2013.

   d. What sort of training or certification will be required of civilian UAS operators?
      1. Would certification be universal or system-specific?

It is anticipated that certification will generally be universal. The FAA currently has a legacy system in place which may be used. This system consists of an aeronautical knowledge exam and a practical examination whereby a person demonstrates competency on flying the aircraft. Through using this process, a UAS pilot would have a certificate for the operation of an unmanned aircraft and its associated system(s).

2. What training opportunities currently exist for want-to-be civilian UAS operators?

Currently, several universities and UAS manufacturers offer training in unmanned aircraft systems.

3. Will proof of training be required to purchase a UAS? Would there be penalties (e.g., fines, revocation of license) for operating a UAS without proper credentials?

There is no required training to be able to purchase a UAS. However, training is required to operate a UAS in the NAS. Penalties currently exist for operations without proper certification of the Airman.

4. Will current air traffic controllers require any new or supplemental training to familiarize themselves with UAS operations?

As with all emerging technologies (e.g. ADS-B, and other NextGen systems) the Air Traffic workforce will require updated training on system capabilities, new procedures or work processes, as well as new standards or performance characteristics as they relate to UAS operations.

9) GAO's Dr. Dillingham testified that "[e]nsuring uninterrupted command and control for both small and large UAS remains a key obstacle for safe and routine integration into the national airspace." Dr. Dillingham's testimony also states that "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..."
   a. Who is responsible for ensuring that command and control and navigational links are secure, reliable, and robust?

Information system security will be approved as a part of the aircraft certification process, which will include certification of a safe and secure command and control link. The FAA's Aircraft Certification Service will certify civil UAS using industry standards developed by RTCA. These standards are currently in development, and are not expected to be complete before 2016. These standards will be implemented using Technical Standard Orders.

10) Dr. Toner, in your statement you mentioned "perception and acceptance." There are a lot of misconceptions and associated fears with regard to unmanned systems. What can be done to change that?

Given the amount of recent publicity on UAS, there appears to be an opportunity for public outreach and education to specifically address public and media concerns head on and to act as the Administration's focal point for high-level UAS messaging. Partnership opportunities exist with Public (Governmental) UAS users, UAS Industry Groups, UAS Modeling Associations and Privacy Advocates; Who would be responsible for leading the development and execution of such a public outreach campaign is to be determined. The six UAS test sites, as required by the *FAA Modernization and Reform Act of 2012*, will provide the FAA with information that may be used in the future to support educational opportunities.

11) Please identify any projects jointly funded by FAA and NASA with any other agency, as well as the FY13 funding level for those projects.

The FAA and NASA are collaborating on the NASA-funded "UAS in the NAS" project. The FAA is providing subject matter expertise, but no funding, in support of various sub-projects: 1) Separation Assurance and Sense and Avoid Interoperability; 2) Human-System Integration; 3) Communications; 4) Certification; and 5) Integrated Test and Evaluation. The FAA is providing NASA with technical and operational expertise to provide input into research objectives, methodologies, test plans, and reports, and is also sharing with NASA results from FAA-led research.

12) Is current funding sufficient to meet the Congressional mandate for full integration of UAS by 2015? Is this timetable reasonable?

UAS Integration is expected to be incremental and will take a number of years, starting in 2015, with the integration of small UAS in the National Airspace System. The aggressive timeline in the *FAA Modernization and Reform Act of 2012*, which called for the safe integration of civil unmanned aircraft systems into the national airspace system as soon as practicable, but not later than September 30, 2015, did not provide for additional resources. The loss of staff hours and contract support due to sequestration further complicates the Agency's timetables. .

13) FAA's report titled "NextGen UAS Research, Development and Demonstration Roadmap" indicated that it would be updated regularly. How is this document used to make investments at FAA? How often do you plan on updating this report? Do you believe this document is sufficient to coordinate R&D investments?

The NextGen UAS Research, Development and Demonstration Roadmap is a catalog of ongoing research projects from partner agencies – FAA, NASA, DoD, DHS, and DOC. This baseline document can be used to compare against the UAS research needs to enable gaps to be identified. The RD&D Roadmap is being used, in addition to updated information received from each of the partner agencies, to form a complete view of ongoing research for UAS as of FY13, which will then be used by the partners to determine where their research efforts (ongoing and new) fit into the UAS priorities. The updated catalog of research, the agreed-upon research priorities, and the enhanced relationships among the various research groups will improve the coordination of R&D investments.

Responses by Dr. Edgar Waggoner

"Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety"

Questions for the Record for Dr. Edgar G. Waggoner, Director, Integrated Systems Research Program Office, National Aeronautics and Space Administration

1. **Please explain how agencies such as the Federal Aviation Administration (FAA), Department of Homeland Security (DHS), National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD) coordinate to identify R&D gaps.**
    a. **How do agencies decide who will fund projects to address these gaps?**

A: Several formal forums exist for coordination of agency efforts to address research gaps and to ensure no unnecessary duplication of effort. These include the Unmanned Aircraft System (UAS) Executive Committee and the Senior Steering Committee, RTCA Special Committee 203 and associated Working Groups, the Joint Planning and Development Office, and the UAS Aviation Rulemaking Committee. All of the subject Agencies are involved in each of these forums and each forum focuses on a particular aspect of UAS integration, e.g. the ExCom focuses on public UAS access. In addition, there are ad hoc on going dialogues among and between the various agencies focused on specific research activities.

In particular during FY 2011, the JPDO sponsored an effort to catalogue the UAS related activities of the subject agencies. The NextGen UAS Research, Development and Demonstration (RD&D) Roadmap was published in 2011. This report accomplished the following objectives:

- Documented an initial set of critical R&D challenges that need to be addressed to enable routine access for UAS in the NextGen NAS;
- Developed an approach to linking the R&D activities of the partner agencies with the R&D needs of the FAA to support integration of UAS in the NAS;
- Established an approach to coordinating R&D activities of the participating agencies in order to address those challenges;
- Identified relevant ongoing and planned R&D projects to serve as a baseline for the NextGen UAS RD&D Roadmap; and
- Set forth a series of next steps toward achieving a responsive, vetted Roadmap, monitoring progress, and identifying actions needed.

The UAS RDD Roadmap has assisted the JPDO partner agencies in sharing information to leverage the research investments of other agencies. Funding decisions to address UAS research gaps are made at the agency level based on priorities, capabilities and available resources.

2. **How often does the UAS Executive Committee meet to coordinate efforts?**
    a. **How many times has it met in the last year?**

A: The ExCom meets approximately quarterly. Since January 2012 the ExCom has met on the following dates: January 19, 2012, May 8, 2012, August 28, 2012, November 20, 2012, and January 9, 2013.

3. Are there any federal agencies or organizations that are not satisfactorily fulfilling their role in addressing UAS safety concerns?

A: The UAS RD&D Roadmap identifies responsibilities of federal agencies to conduct the R&D required to address UAS safety concerns associated with the enabling UAS routine access to the NAS. Federal agencies are fulfilling their respective roles as identified in the roadmap.

4. Are there any organizations that should be involved that currently are not?

A: The UAS RDD Roadmap is a comprehensive assessment of the roles of federal agencies in conducting related R&D. All agencies with a role in this effort are identified appropriately in the Roadmap.

5. RTCA's Special Committee 203 has been working on Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS) for unmanned aircraft. How critical are these processes in advising us what research and development work is needed?

a. When are these standards likely to be finalized?

A: The MASPS and eventually the MOPS being developed by RTCA Special Committee 203 will provide the minimum safety standards for the UAS system and two critical UAS technologies necessary for the safe introduction of UAS into the NAS for civil operations. These two critical areas for UAS civil standards are Sense and Avoid (SAA) and Control and Communications (C2). The MASPS and MOPS under development for the UAS system, SAA and C2 are very critical in advising what research and development work is needed. NASA's UAS Integration in the NAS Project continues to work closely with RTCA to support development of these standards and their associated data requirements to validate system-level performance recommendations.

The current plan within RTCA calls for the UAS System MASPS to be completed and released in May 2013. The date for the SAA and C2 MASPS is in flux.

6. Many who follow this issue argue that a "one-size-fits-all" approach to regulation will not be effective given the wide range of systems.

a. What is your recommendation for categorizing the systems? By size (i.e. weight)? Payload? Capabilities? Mission? Complexity?

A: The categorization of the systems is the responsibility of the FAA. The UAS Integration in the NAS Project is currently evaluating the impact of size, payload, capabilities, mission, and complexity to support proposed categorization of UAS and associated operations. Research to date has identified numerous factors, including weight, complexity, and various operational capabilities that may have a significant

influence on categorizing UAS. Initial work designed to determine the scope of the issue was recently published in a NASA Technical Memorandum titled "Perspectives on Unmanned Aircraft Classification for Civil Airworthiness Standards", NASA/TM–2013-217969. The outcomes of NASA research will be shared with the FAA through the end of the Project in FY 2016 to assist them with their rulemaking responsibilities.

b. How does this impact R&D investments? Do you see a greater need for R&D on smaller or larger systems?

A: NASA is conducting research on sense-and-avoid requirements applicable to UAS irrespective of size, since we do not see a difference in sense-and-avoid R&D needs in relation to large or small UAS.

With respect to airworthiness standards, the answer is not as clear. The classification research described in 6(a) indicates that further R&D investments are needed to address the unique aspects of unmanned systems that may introduce unacceptable risks, including the reliability and design assurance of equipment such as communication links for command and control, sense and avoid sensors, and ground control stations.

c. What is the status of a final rule regarding the certification and operation of small (i.e., ultralight, low-speed, short-life) UAS?

A: The FAA has not released the final small UAS rule for public comment as of this writing.

7. GAO's Dr. Dillingham testified that "(e)nsuring uninterrupted command and control for both small and large UAS remains a key obstacle for safe and routine integration into the national airspace." Dr. Dillingham's testimony also states that "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…"

a. Who is responsible for ensuring the command and control and navigational links are secure, reliable, and robust?

A: In the United States, it is the responsibility of the FAA to establish the civil certification requirements for secure, reliable, and robust UAS communications. For integration in the NAS, civil UAS will need to utilize FAA certified communications equipment operating in protected safety spectrum for control communications.

To address security of the UAS control communication system, NASA is working in partnership with the FAA to analyze and develop mitigations to potential C2 security vulnerabilities to inform related FAA security requirements for civil UAS. Reliability and robustness are being addressed during the development of control communication performance requirements in RTCA SC-203, leading to control communication MASPS and MOPS. NASA has partnered with Rockwell Collins to develop a prototype UAS control communication system and perform a series of flight tests to evaluate the

prototype in relevant flight environments. Results of these evaluations will be shared with the FAA.

8. Dr. Toner's statement mentioned "perception and acceptance." There are a lot of misconceptions and associated fears with regard to unmanned systems. What can be done to change that?

A: NASA's research to develop technical solutions to real challenges related to safety and security can contribute to public confidence that UAS will be at least as safe and secure as manned aircraft before they can access the National Airspace on a routine basis.

9. Please identify any projects jointly funded by FAA and NASA with any other agency, as well as the FY 2013 funding level for those projects.

A: Relative to research and development associated with integrating UAS into the NAS, NASA is cooperating on various activities across several stakeholder agencies. The majority of these cooperative activities do not require any exchange of funds. However, there are two activities where NASA is supporting the funding of specific, focused integration efforts.

The UAS Integration in the NAS Project is working closely with the FAA UAS Integration Office to deliver relevant data. The Project is currently planning to augment the FAA's contracted effort to develop the National Airspace System Enterprise Architecture (EA) at the FY 2013 funding amount of $500K. The NASA contribution will focus on integration of essential source materials (FAA UAS ConOps, FAA Roadmap for Integration of Civil UAS in the NAS, Aviation Rulemaking Committee (ARC) Implementation Plan Working Group (IPWG) Implementation plan, and JPDO Comprehensive Plan) to reflect unique aspects of UAS operations in the NAS in the NextGen Architecture.

In addition, the UAS Integration in the NAS Project is working closely with the Air Force Research Lab (AFRL) at Wright Patterson Air Force Base to coordinate on Human Factors guidelines for ground control stations (GCS). The Project is jointly funding a contract with approximately $150K to acquire software support and maintenance from the AFRL contractor for common software that both NASA and AFRL are using in our respective UAS research efforts.

10. Is it important for the FAA to regularly update its report titled "NextGen UAS Research, Development and Demonstration Roadmap?" How often would you recommend this roadmap be updated? Do you believe this document is sufficient to coordinate R&D investments? How does this document influence R&D investments at NASA?

A: As discussed previously, the NextGen UAS RD&D Roadmap is an important document that catalogued JPDO partner agency activities as they were defined in FY 2011. Additional work is ongoing through the various coordination mechanisms described above to identify gaps between current plans and assess additional R&D needs. This includes the FAA's Comprehensive Plan and

the UAS Concept of Operations. Products resulting from the ongoing work need to be thoroughly assessed to understand how current investments toward UAS integration are aligned with the implementation strategy for UAS integration.

Responses by Dr. Gerald Dillingham

Enclosure

Subcommittee on Oversight
Committee on Science, Space, and Technology
"Operating Unmanned Aircraft Systems in the National Airspace System: Assessing Research and Development Efforts to Ensure Safety"
February 15, 2013
Additional Questions for the Record

The Honorable Dr. Paul Broun

1. Please explain how agencies such as the Federal Aviation Administration (FAA), Department of Homeland Security (DHS), National Aeronautics and Space Administration (NASA), and the Department of Defense (DOD) coordinate to identify research and development gaps?

- **How do agencies decide who will fund projects to address these gaps?**

UAS stakeholders—including FAA, DHS, and DOD—coordinate research and development (R&D) efforts through FAA's Joint Planning and Development Office (JPDO).[1] The JPDO provides the primary framework for coordination of UAS integration efforts and works to identify gaps in R&D. In 2012, JPDO published the *NextGen UAS Research and Development Roadmap—a* blueprint that identified stakeholders' roles and responsibilities for R&D efforts related to UAS integration and addressed challenges that must be addressed to permit routine UAS operations in a NextGen environment.

While each agency has different missions and provides its own funding for UAS-related projects, JPDO helps to leverage R&D to avoid duplicative efforts. Furthermore, our previous work has shown that agencies benefit from having one organization coordinate multi-agency efforts.[2]

2. How often does the UAS Executive Committee meet to coordinate efforts?

- **How many times has it met in the last year?**

The UAS Executive Committee (Committee) meets quarterly. However, in 2012, the Committee was able to hold only three formal meetings due to scheduling conflicts, according to FAA officials. Those meetings were held on January 19, May 8, and August 28. In addition to the formal meetings, the Committee members also held several informal teleconferences to discuss UAS issues.

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[1]JPDO was created to plan for and coordinate a transition to the Next Generation Air Transportation System (NextGen)—a new satellite-based air traffic management system that will replace the current radar-based system. Given its unique role in managing partnerships among federal agencies for NextGen, the Office of Management and Budget tasked JPDO to coordinate UAS efforts.
[2]GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms*, GAO-12-1022 (Washington, D.C.: September 27, 2012).

3. Are there any federal agencies or organizations that are not satisfactorily fulfilling their role in addressing UAS safety concerns?

All agencies that are involved with safely integrating UAS into the national airspace system are satisfactorily participating and fulfilling their role in addressing UAS safety concerns, according to JPDO officials; however, as I noted in my statement, coordination could be improved.[3] Tasked by the Congress, FAA is the lead agency for UAS integration and its main responsibility in this area is for the safe integration of UAS.[4] As a result, coordinating with stakeholders to ensure safety has always been a top priority for the agency. With that said, challenges have arisen. For example, FAA officials told us that while all agencies meet their participating requirements, FAA has received conflicting input and reconciling various viewpoints can be difficult.

4. Are there any organizations or agencies that should be involved that currently are not?

At this point, all agencies and organizations that should be involved in the safe integration of UAS into the national air space are participating. However, as I said in my written statement, collaboration among agencies could be improved. For example, FAA's focus has been on safety, since that is its primary mission. Thus, other agencies could take the lead to coordinate on other issues, such as privacy, for instance. FAA officials have suggested that DHS or DOJ might be better positioned to address UAS privacy issues because privacy concerns generally stem from the operational uses of UAS for surveillance and law enforcement purposes.[5]

5. Please explain the relationship between the FAA and DHS as it pertains to safety and security.

- **Understanding that you cannot speak for DHS, what is your understanding of what DHS is doing in this regard?**
- **What is the FAA responsible for? What is the DHS responsible for? How does this differ? How are decisions like this made?**
- **How involved has the Transportation Security Administration (TSA) been in the process?**

As I noted in my written statement, FAA is responsible for the safety aspects and DHS is generally responsible for the security aspects of integrating UAS into the national airspace. To accomplish its' responsibilities, DHS's efforts—through TSA—include identifying and mitigating the security risks, threats, and vulnerabilities

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[3]See GAO, *Unmanned Aircraft Systems: Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development,* GAO-13-346T (Washington, D.C.: February 15, 2013).

[4]See, e.g., section 332 of the FAA Modernization and Reform Act of 2012, Pub. L. 112-95, 126 Stat. 11.

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

related to non-military UAS. TSA has been performing work related to UAS security since 2004. GAO has previously recommended that TSA examine the security implications of future, non-military UAS operations in the national airspace system and take any actions deemed appropriate.[6,7]

Security remains a significant issue that could be exacerbated with an increase in the number of UAS. TSA's practices might be sufficient in the current UAS environment of limited operations taking place under closely controlled conditions, but these controlled conditions will evolve as FAA and others continue to work toward allowing routine UAS operations in the national airspace system.

6. RTCA's Special Committee 203 has been working on Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS) for unmanned aircraft. How critical are these processes in advising us what research and development work is needed?

- **When are these standards likely to be finalized?**

The development of standards, such as MASPS and MOPS, is a critical step in supporting R&D efforts to safely integrate UAS into the national airspace system, but it remains unclear when the standards will be finalized. Setting standards, identifying 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 R&D efforts and identify and measure progress toward goals. It is unclear when standards will be finalized because of the complexities of the issues to be addressed and because the lack of operational and safety data have hindered the standards development process.

7. Many who follow this issue argue that a "one-size-fits-all" approach to regulation will not be effective given the wide range of systems.

- **What is your recommendation for categorizing the systems? By size (i.e. weight)? Payload? Capabilities? Mission? Complexity?**
- **How does this impact R&D investments? Do you see a greater need for R&D on smaller or larger systems?**
- **What is your understanding of the status of a final rule regarding the certification and operation of small (i.e., ultralight, low-speed, short-life) UAS?**
- **What sort of training or certification will be required of civilian UAS operators?**
    - **Would certification be universal or system-specific?**
    - **What training opportunities currently exist for want-to-be civilian UAS operators?**

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[6]While TSA agreed that security of UAS is important, the agency believes that existing procedures are sufficient and does not intend to implement GAO's recommendation.

[7]GAO, *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System,* GAO-08-511 (Washington, D.C.: May 15, 2008).

- **Will proof of training be required to purchase a UAS? Would there be penalties (e.g. fines, revocation of license) for operating a UAS without proper credentials?**
- **Will current air traffic controllers require any new or supplemental training to familiarize themselves with UAS operations?**

For our reporting purposes, GAO has used two broad categories of "small" and "large" to categorize UAS. A "small" UAS is less than 55 pounds; a "large" UAS is 55 pounds or more.[8] It will be up to FAA and other agencies, such as DHS, to determine how to categorize UAS for various regulatory and operational purposes. Alternatively we also heard from a NASA official that NASA's UAS Integration in the National Airspace System (NAS) Project is currently evaluating UAS categorization by size, payload, capabilities, mission, and complexity in coordination with FAA and expect to release a report in fiscal year 2016.

Investment in R&D and the identification of any R&D gaps is necessary to support the safe and routine integration of UAS into the national airspace regardless of size or categorization. For example, according to a NASA official, NASA does not see differences in the sense-and-avoid R&D needs between small or large UAS.

FAA has efforts under way supporting a rulemaking for the operation of small UAS, but it is unlikely that FAA will meet the August 2014 deadline for the final rule on small UAS required by the FAA Modernization and Reform Act of 2012. The agency's rulemaking efforts date back more than 5 years, when it established the small UAS Aviation Rulemaking Committee in 2008. FAA officials told us in January 2013 that FAA is still internally reviewing and finalizing the language of its draft Notice of Proposed Rulemaking (NPRM) for the regulation of small UAS.[9] FAA has not determined when it might issue the NPRM.

The training and certification requirements of civilian UAS operators have not yet been fully determined, though, according to FAA officials, training is required to operate a UAS in the NAS and penalties exist for operations without proper certification. FAA is in the process of formalizing aircrew certification and medical requirements, which could mirror requirements for operators of manned aircraft, as appropriate. For small UAS operators, FAA's rulemaking will likely establish what, if any, certification standards are needed for UAS operators.

Regarding air traffic controller training, FAA officials told us that as with all new technologies (e.g. NextGen systems) the Air Traffic workforce will require updated training on system capabilities, new procedures or work processes, as well as new standards or performance characteristics as they relate to UAS operations.

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[8]UAS are typically described in terms of weight, endurance, purpose of use, and altitude of operation. We have distinguished between small and large UAS because a number of rules and requirements apply specifically to aircraft that weigh less than 55 pounds.

[9]An NPRM, which is published in the *Federal Register* allows interested persons an opportunity to comment on the rulemaking process by providing written data, views, or arguments and gives the public an opportunity to provide information to agencies on the potential effects of a rule or to suggest alternatives for agencies to consider.

8. Dr. Dillingham, you testified that "ensuring uninterrupted command and control for both small and large UAS remains a key obstacle for safe and routine integration into the national airspace." Your testimony also states that "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..."

- **Who is responsible for ensuring that command and control and navigational links are secure, reliable, and robust"?**

FAA is responsible for ensuring that both command and control and navigational links are safe for UAS use. To accomplish this, FAA is working with RTCA SC 203 to develop MASPS and MOPS in the areas of operational and navigational performance; command and control communications; and sense and avoid capabilities.

9. There are a lot of misconceptions and associated fears with regard to UAS. What can be done to change that?

Mitigating misconceptions and fears associated with UAS will require public education and outreach. A main concern for the public regarding UAS is the privacy issue. Specifically, we have previously reported that concerns—by members of Congress, a civil liberties organization, and others—include the potential for increased amounts of government surveillance using technologies placed on UAS as well as the collection and use of such data.[10] While JPDO and FAA haven't done work in these areas, the Association for Unmanned Vehicle Systems International (AUVSI) and local UAS users, such as local law enforcement agencies, have started reaching out to the public through the media and community events. For example, AUVSI has recently published an industry code of conduct, which discusses privacy issues, safety, and professionalism. Some local law enforcement agencies have started reaching out to the public through the media and community events. For example, local law enforcement agencies have invited local media to a UAS demonstration with a question and answer period and held community acceptance panels when new technologies are deployed.

The possibility that the rate of technology advancements has outpaced regulations has exacerbated privacy fears regarding the use of UAS. For example, FAA has indicated that it will address privacy concerns in its' rule on small UAS and has yet to issue an NPRM soliciting comments regarding privacy concerns about the operation of small UAS. Through the rulemaking process, FAA will be able to solicit input through public comments and use that public input to craft its rules affecting privacy issues. Technology outpacing regulations is not a problem unique to UAS; similar privacy concerns have arisen over Smartphones and global positioning devices.

Finally, while the Supreme Court has not addressed privacy issues related to governmental UAS surveillance, the Court has upheld several instances involving

[10]GAO-12-981.

government aerial surveillance from manned aircraft. At this time, it is uncertain how such cases would be applied to governmental UAS surveillance.

10. Is current funding sufficient to meet the Congressional mandate for full integration of UAS by 2015? Is the current timetable reasonable?

None of the UAS stakeholders we spoke with identified funding as a key challenge for safely integrating UAS into the national airspace system. However, full UAS integration by 2015 will be challenging for FAA. As we stated in our September 2012 report, the FAA Modernization and Reform Act of 2012 set an aggressive timeframe for FAA to safely integrate UAS because many of the Act's requirements entail significant work on the part of FAA and its stakeholders. This work involves developing detailed steps for achieving safe and routine access to the national airspace system, including defining the characteristics of safe integration, identifying needed R&D to achieve integration, and identifying the information needed to issue regulations, among other tasks.

11. Is it important for the FAA to regularly update its report titled "NextGen UAS Research, Development and Demonstration Roadmap?" How often would you recommend this roadmap be updated? Do you believe this document is sufficient to coordinate R&D investments?

FAA's R&D roadmap provides a framework for interagency and private sector coordination on UAS R&D efforts, but the document lacks mechanisms and metrics that allow for regular monitoring to assess progress, as we recommended in September 2012. Including these metrics and regularly updating stakeholders on their progress will help build stakeholder confidence in FAA's UAS integration efforts.[11] Determining the frequency with which the Roadmap–or any other tracking document–will be updated should be done in consultation with stakeholders and focus on what would be necessary including, for example, identifying metrics and completion dates, to keep the Congress and stakeholders informed of progress and any related challenges. According to JPDO—which led the development of the roadmap for FAA—there initially were plans to upgrade the roadmap because JPDO realized that including performance metrics and completion dates would be needed to track progress. However, as of March 2013, JPDO has no formal plans to update the roadmap.

[11]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.

Appendix II

Additional Material for the Record

REQUESTED MATERIAL FOR THE RECORD SUBMITTED DR. EDGAR WAGGONER

Material requested for the record on page 43, line 968, by Chairman Broun during the February 15, 2013, UAS hearing.

Unmanned Aircraft System Integration in the National Airspace System Project
February 2013

Project Goal: Capitalizing on NASA's unique capabilities, the project will utilize integrated system level tests in a relevant environment to eliminate or reduce critical technical barriers of integrating Unmanned Aircraft Systems into the National Airspace System. NASA is performing research in the Aeronautics Research Mission Directorate (ARMD) that provides an opportunity to transition concepts, technologies, algorithms, and knowledge to Federal Aviation Administration (FAA) and other stakeholders to assist in defining the requirements, regulations, and issues for routine UAS NAS access.

Funding for NASA's UAS in the NAS Project:

FY12 Actual – $30.0M
FY13 Plan - $30.5M (Subject to final appropriation)

Descriptions of UAS in the NAS Project Activities:

Separation Assurance (SA) / Sense & Avoid (SAA) Interoperability

- **Requirements:** Assess UAS Interoperability in Air Traffic Control (ATC) Environments
- **Research Objectives:** 1) Assess the interoperability of UAS sense-and-avoid systems with the ATC environment, and 2) Assess the effects of UAS mission and performance characteristics, communications latencies and changes to separation roles and responsibilities on NAS operations. This research will help inform NAS UAS integration efforts and FAA regulatory and guidance proposals related to NAS operational procedures and/or proposed rulemaking.
- **Approaches:** NASA will analyze capacity, efficiency and safety impacts of SAA-equipped UAS in the ATC environment to validate the requirements for SAA and SA/SAA interoperability through analysis, simulation and flight tests. This research will likely result in recommendations to the FAA for development of further guidance and rulemaking.

Human Systems Interaction

- **Requirements:** Develop Ground Control Station (GCS) and Displays
- **Research Objectives:** 1) Develop a research test-bed and database to provide data and proof of concept for GCS operations in the NAS, and 2) Coordinate with the FAA and standards organizations to develop draft human factors guidelines for GCS operation in the NAS. This research will help inform NAS UAS integration activities and FAA regulatory and guidance proposals

related to NAS operational procedures and/or proposed rulemaking.

- **Approaches:** NASA will explore information display prototypes in the GCS through requirements analysis and simulation. Measured response and visual requirements for landing will be part-task and full-task simulated and the results fed back in to the prototype development. Further validation will occur through integrated simulations and eventually through integrated flight tests. This research will likely result in recommendations to the FAA for development of further guidance and rulemaking.

Communications

- **Requirements:** Assess Command Non-Payload Communications (CNPC) and ATC communications to promote safe and efficient operation of UAS in the NAS.
- **Research Objectives:** 1) Develop data and rationale to obtain appropriate frequency spectrum allocations; 2) Develop and validate candidate UAS CNPC system/subsystem test equipment which complies with UAS international/national frequency regulations, ICAO Standards and Recommended Practices, and FAA/RTCA Minimum Operational Performance Standards/Minimum Aviation System Performance Standards for UAS; 3) Perform analysis and propose CNPC security recommendations for public and civil UAS operations; and 4) Perform analysis to support recommendations for integration of CNPC and ATC communications.
- **Approaches:** NASA will: perform analysis to support National/International efforts within ICAO and ITU-R Working Party 5B to obtain terrestrial and satellite based spectrum for UAS CNPC systems, in preparation for World Radio Conferences 2012 and 2015; design, develop, and test a prototype communication system to validate proposed RTCA SC-203 CNPC performance standards and to recommend necessary modifications to these standards as a result of laboratory and flight testing in a relevant environment; perform analysis, develop, and test necessary mitigation techniques to risks and vulnerabilities of the CNPC system to assure risks and vulnerabilities are mitigated; and develop high fidelity communication system models and perform NAS-wide simulations of the CNPC system to assure communication system scalability and to minimize impact on aircraft traffic control communication, system delays, capacity, safety, and security. This research will help inform NAS UAS integration efforts and likely result in recommendations to the FAA for development of further guidance and rulemaking, as well as to ICAO and RTCA work groups for future standards development activities.

Certification

- **Requirements:** Develop a body of information to inform FAA's UAS airworthiness requirements and data to support FAA's development of certification standards and regulatory guidance.
- **Research Objectives:** 1) Determine a proposed methodology for Classification of UAS and Determination of Airworthiness standards for avionics aspects of UAS, and 2) Develop a body of hazard and risk related

data to support FAA's development of regulation.

- **Approaches:** NASA will explore alternate classification schemes for UAS and to define an approach for determining airworthiness requirements for any and all avionics that comprise UAS systems. Additionally, NASA will collect and analyze UAS hazard and risk related data to support safety case recommendations for certification/regulation development. The results of this research and data collection will be shared with the FAA for development of further guidance and rulemaking.

Integrated Test & Evaluation

- **Requirements:** Develop and assess a relevant testing environment for UAS
- **Research Objectives:** To develop an adaptable, scalable, and schedulable operationally relevant test infrastructure/environment for the integrated, simultaneous evaluation of all aspects of UAS integration in the NAS.
- **Approaches:** Develop and test a Live Virtual Constructive – Distributed Environment (LVC-DE) that incorporates connectivity to multiple live UAVs with ADS-B, ADS-B ground station and air surveillance radar, ground control stations, FAA tech center, simulation systems, other laboratories and the requisite connectivity infrastructure. This research will inform overall NAS UAS integration efforts and likely result in recommendations to the FAA for development of further guidance and rulemaking.

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