UNMANNED AIRCRAFT SYSTEMS RESEARCH AND DEVELOPMENT

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTEENTH CONGRESS

FIRST SESSION

JANUARY 21, 2015

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January 21, 2015

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UNMANNED AIRCRAFT SYSTEMS RESEARCH AND DEVELOPMENT

TUESDAY, JANUARY 21, 2015

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

The Committee met, pursuant to call, at 2:35 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Lamar Smith [Chairman of the Committee] presiding.

LAMAR S. SMITH, Texas
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Congress of the United States

House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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Committee on Science, Space, and Technology

Unmanned Aerial Systems Research and Development

Wednesday, January 21, 2015
2:30 p.m. to 4:30 p.m.
2318 Rayburn House Office Building

Witnesses

Dr. Ed Waggoner, *Director, Integrated Systems Research Program, Aeronautics Research Mission Directorate, NASA*

Mr. James Williams, *Manager, UAS Integration Office, Aviation Safety Organization, FAA*

Dr. John Lauber, *Co-Chair, Committee on Autonomy Research for Civil Aviation, National Research Council*

Mr. Brian Wynne, *CEO and President, Association for Unmanned Vehicle Systems International (AUVSI)*

Mr. Colin Guinn, *Chief Revenue Officer, 3D Robotics, Small UAV Coalition Member*

Dr. John R. Hansman, *T. Wilson Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology (MIT)*

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

Unmanned Aircraft Systems Research and Development
CHARTER

Wednesday, January 21, 2015
2:30 p.m. – 4:30 p.m.
2318 Rayburn House Office Building

Purpose

On January 21, 2015, the Committee on Science, Space, and Technology will hold a hearing titled *Unmanned Aircraft Systems Research and Development.* The hearing will review research and development (R&D) performed by the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) in the area of Unmanned Aircraft Systems (UAS) and their integration into the National Airspace System (NAS). This hearing will inform FAA and NASA reauthorizations. The Science, Space, and Technology Committee has jurisdiction over civil aviation research and development.[1]

Witnesses

- **Dr. Ed Waggoner**, Director, Integrated Systems Research Program, Aeronautics Research Mission Directorate, NASA
- **Mr. James Williams**, Manager, UAS Integration Office, Aviation Safety Organization, FAA
- **Dr. John Lauber**, Co-Chair, Committee on Autonomy Research for Civil Aviation, National Research Council
- **Mr. Brian Wynne**, CEO and President, Association for Unmanned Vehicle Systems International (AUVSI)
- **Mr. Colin Guinn**, Chief Revenue Officer, 3D Robotics, Small UAV Coalition Member
- **Dr. John R. Hansman,** T. Wilson Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology (MIT)

Background

Unmanned aircraft systems (UAS) is a general and complete term which includes 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, commercial, and military applications. Current domestic use of UAS is limited to academic institutions, federal, state, and

[1] House Rules for the 113th Congress, http://www.gpo.gov/fdsys/pkg/HMAN-113/pdf/HMAN-113-houserules.pdf

local government organizations that receive a Certificate of Waiver or Authorization (COA) and private sector entities that receive special airworthiness certificates by the FAA, and hobbyists who may only operate under tight restrictions.[2] 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 Technology Testbed, or MUTT.[3] 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 several unmanned aircraft for academic research purposes.

Though military and civil government will likely dominate large UAS operations in the near term, the UAS market is dynamic and the commercial sector is poised for significant growth, particularly in the small UAS sector. 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 $6.4 billion in 2014 to $11.5 billion in 2024. Total worldwide spending for the period is forecast to amount to $91 billion. Throughout the forecast period, Teal expects the U.S. share of RDT&E to account for 65 percent of worldwide spending.[4]

In 2013, the Association for Unmanned Vehicle Systems International (AUVSI) estimated that between 2015 and 2025 103,776 jobs could be created in the U.S. as a result of UAS integration into the National Airspace System (NAS).[5] This does not include the tens of thousands of secondary jobs in sensor manufacturing, software development, and other complementary industries. The report also notes that delays in integrating UAS in the NAS could cost the U.S. more than $10 billion in economic growth annually.[6]

Congress directed that federal agencies accelerate the integration of UAS into the national airspace. The FAA Modernization and Reform Act of 2012 (FMRA) 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;

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[2] U.S. Department of Transportation, Federal Aviation Administration, "Unmanned Aircraft Systems (UAS) Operational Approval," National Policy Notice, serial N 8900.207 (Washington, DC, 2013).
[3] 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).
[4] Teal Group, Press Release for *World Unmanned Aerial Vehicle Systems: Market Profile and Forecast (Fairfax, 2014)*, cited in July 14, 2014.
[5] 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, 2013). http://qzprod.files.wordpress.com/2013/03/econ_report_full2.pdf
[6] Ibid.

- 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
- 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.[7]

Department of Transportation Inspector General Report

In June 2014, the Department of Transportation Office of Inspector General issued an audit report criticizing FAA for being significantly behind its efforts to integrate UAS into the National Airspace System. The report indicated that while the agency has made some progress in implementing the Congressionally mandated requirements from the FAA Modernization and Reform Act of 2012, they missed all their major milestones in doing so. Also, in November 2013, the FAA completed the first required roadmap for integrating UAS into the NAS. The IG audit concluded that it was not likely that FAA would reach the September 2015 deadline of integrating UAS into the NAS.[8]

National Academies Study

In August 2014, the National Research Council's Committee on Autonomy Research for Civil Aviation, Aeronautics and Space Engineering Board released a report titled *Autonomous Research for Civil Aviation: Toward a New Era of Flight.*[9] The report outlined concern about the technological readiness to safely integrate into the National Airspace System. It also recommended creation of a national UAS research agenda developed by FAA, NASA, and the Department of Defense (DOD), that include eight high-priority research projects:

- Behavior of Adaptive/Nondeterministic Systems
- Operation Without Continuous Human Oversight
- Modeling and Simulation
- Verification, Validation, and Certification
- Roles of Personnel and Systems

[7] FAA Modernization and Reform Act of 2012 (PL 112-95). https://www.congress.gov/bill/112th-congress/house-bill/658
[8] Department of Transportation Office of Inspector General, *FAA Faces Significant Barriers to Safely Integrate Unmanned Aircraft Systems into the National Airspace System*, AV-2014-061 (Washington, DC, 2014). https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Unmanned%20Aircraft%20Systems%5E6-26-14.pdf
[9] *sites.nationalacademies.org/cs/groups/depssite/.../deps_144680.pdf*

- Safety and Efficiency
- Stakeholder Trust

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.[10] 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.[11] 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.[12] 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.[13]

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[10] 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).
[11] 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).
[12] 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).
[13] "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).

Spectrum – The 2012 World Radiocommunication Conference allocated two bands of protected spectrum for UAS command and control.[14] 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.[15,16] 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)[17] 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.

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 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

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[14] 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).
[15] Ibid.
[16] 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."
[17] GBSAA is an air surveillance radar that provides positional information via a display of traffic information to the UAS flight crew.
[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

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]

Test Sites - Section 332 of the FAA Modernization and Reform Act of 2012 directs the FAA Administrator to establish six test sites for UAS.[24] Researchers use the sites to test UAS technologies, and the data collected through their research is given to FAA to aid the Administration in developing rules that ensure public safety throughout integration of UAS into the NAS.

In late 2013, FAA announced six teams to host the test sites including the University of Alaska, the state of Nevada, New York's Griffiss International Airport, North Dakota Department of Commerce, Texas A&M University in Corpus Christi, and Virginia Polytechnic Institute and State University. These teams then established test ranges in Hawaii, Oregon, Alaska, Nevada, Texas, North Dakota, New York, Massachusetts, Virginia, New Jersey and Maryland. The sites became operational in mid-2014.

Test site operators and researchers alike have been frustrated by their inability to test UAS at the test sites as researchers still need experimental certification from FAA to use the test sites, and the FAA certification process is slow.[25] For example, Nevada's test site opened in June 2014, but was only able to conduct its first UAS test last December.

Test sites are currently the most common means for the private sector to test UAS (other means include an FAA exemption under FMRA Section 333 or a Cooperative Research and Development Agreement). However, due to funding challenges, FAA indecision about the specific data test sites need to obtain from users, and private sector concerns about protecting intellectual property, the test sites are not being fully utilized. The long approval process to use a UAS test site has led some researchers to take their testing abroad, where rules on UAS testing are less restrictive.

Potential Loss of Jobs and Industry Growth to Lagging International Competitiveness– The FAA Modernization and Reform Act of 2012 allows companies to apply for an exemption of current regulations prohibiting commercial drones from flying in US airspace. However, the FAA's Sec 333 exemption application process, combined with the delay in its publication of new regulations for small UAVs, is impacting the pace of research,

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[22] Ibid.
[23] Ibid.
[24] H.R. 658
[25] http://motherboard.vice.com/read/the-faa-wont-tell-its-drone-test-sites-what-to-test

development, and testing of UAS technology.[26] It also may drive U.S.-based companies to move their R&D testing, resources, and high paying jobs to other countries, where UAS regulations are not as stringent as the United States.[27]

In July 2014, Amazon petitioned the FAA for an exemption under Sec. 333. Included in their petition was a request to use its own test facilities in Washington state, instead of taking the time and paying the expense to use one of the six test facilities in other parts of the country.[28]

Last September, the FAA began issuing exemptions under Section 333 of the FMRA. A few permits were granted to film companies, but Amazon's petition has yet to be addressed. In response to their inability to test their technology outdoors, Amazon has stated that more of its UAS research and development will have to be moved overseas. They have already begun flight testing in the United Kingdom, where regulations for UAS R&D and flight testing are less stringent.[29]

U.S. companies have UAS products that are in demand, but they are selling their products to customers in countries. For instance, one start up UAV company, based in Grand Forks, North Dakota, not far from one of FAA's UAS testing sites, sells most of their products to customers in Canada, South American countries, South Africa, the Czech Republic, and France. This is not a single case, and contributes to concern that the U.S. is losing its competitiveness in the growing UAS market.[30]

[26] U.S. Government Accountability Office, *Unmanned Aerial Systems: Efforts Made toward Integration into the National Airspace Continue, but Many Actions Still Required*, Testimony before the Subcommittee on Aviation, Committee on Transportation and Infrastructure, House of Representatives, GAO-15-254T, (Washington, DC 2014) http://www.gao.gov/assets/670/667346.pdf

[27] http://www.wsj.com/articles/amazon-warns-it-will-move-drone-research-abroad-1418076981

[28] http://www.washingtonpost.com/blogs/the-switch/wp/2014/07/11/amazon-wants-an-exemption-from-the-faas-drone-restrictions/

[29] http://www.wsj.com/articles/amazon-warns-it-will-move-drone-research-abroad-1418076981

[30] http://www.theguardian.com/world/2014/sep/29/drone-testers-faa-aviation-frustration-grows

Chairman SMITH. The Committee on Science, Space, and Technology will come to order. Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Before we go forward, I want to mention that at the Ranking Minority Member's request, we postponed the Science Committee's organizational meeting until next Tuesday at 11:00 a.m., and I ask unanimous consent to proceed with today's full Committee hearing under the Rules of the House, and without objection, so ordered. In other words, it is a little bit unusual for us to have a hearing before we have organized, but at the ranking member's request, we are going to postpone that organizational hearing.

Welcome to today's hearing titled "Unmanned Aircraft Systems Research and Development." In front of you are packets containing the written testimony, biography, and Truth in Testimony disclosures for today's witnesses. I will recognize myself for an opening statement and then recognize the ranking member as well.

Today's hearing will examine research and development of unmanned aircraft systems, also known as UAS. The hearing will also provide an overview of how UAS research, development and flight tests enable the integration of UAS into the National Airspace System. I am going to use the term "drone," since that is how most people refer to them. However, the term "unmanned aircraft systems" is a more complete and accurate term.

As the name suggests, UAS are complex systems made up of not only of the aircraft but also the supporting ground, air, and communications infrastructure. Drones come in a variety of shapes and sizes and can carry out a wide range of missions. In the past ten years, the public has become familiar with military drones. Less discussed are civilian and nonmilitary drones that have the ability to transform our everyday lives. Commercial drones have the potential to carry out a wide range of tasks across a broad range of sectors, including agriculture, weather, energy, and disaster relief.

The Teal Group, an aerospace and defense industry market intelligence firm, predicts America will spend over $11 billion on UAS research, development, testing, evaluation and procurement over the next decade. Total worldwide spending for the same period is projected to be $91 billion.

In 2013, the Association for Unmanned Vehicle Systems International estimated that in the next ten years, over 100,000 U.S. jobs could be created as a result of UAS integration into the National Airspace System. The report also notes that continued delays in integrating drones in the National Airspace System could cost the United States more than $10 billion per year, or $27 million per day, in potential earnings from investment in drones research and development.

In June 2014, the Department of Transportation Office of Inspector General released an audit report that criticized the FAA for being slow to integrate drones into the National Airspace System. The audit concluded it is unlikely that integration would be completed by the September 2015 deadline.

The FAA and NASA are working together to ensure safe and successful integration of drones in the National Airspace System. Some of the research being done seeks to ensure that drones have the technologies necessary to avoid mid-air collisions and the ability to be controlled from a central location.

Drones can greatly benefit our society. Farmers can use small drones to monitor their crops. Emergency responders could move quickly to access disaster areas to search for survivors. Energy companies could examine power lines and pipelines to assess damage or prevent leaks.

UAS experimentation and testing at high schools and universities might lead to technology breakthroughs as well as inspire students to enter STEM fields. However, due to the delays in integrating UAS into the National Airspace System, the public is not yet allowed to use drones to do many of these things.

Many other countries have developed a regulatory framework supportive of drone use for such activities. Consequently, some U.S.-based companies have moved research, development, testing and high-paying jobs offshore.

Our goal today is to better understand the research underway to overcome these barriers. We are particularly interested in hearing how government-funded and private sector UAS research and development informs, or should inform, the integration of UAS into the National Airspace System.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF CHAIRMAN LAMAR S. SMITH

Good afternoon and welcome to the Committee's first hearing of the 114th Congress. Today's hearing will examine research and development of unmanned aircraft systems, also known as UAS. The hearing will also provide an overview of how UAS research, development and flight tests enable the integration of UAS into the National Airspace System.

I'm going to use the term "drone," since that is how most people refer to them. However, the term unmanned aircraft systems is a more complete and accurate term. As the name suggests, UAS are complex systems made up of not only the aircraft, but also the supporting ground, air, and communications infrastructure.

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Our goal today is to better understand the research underway to overcome these barriers. We are particularly interested in hearing how government-funded and private sector UAS research and development informs, or should inform, the integration of UAS into the National Airspace System.

Chairman SMITH. That concludes my opening statement, but I want to mention before recognizing the Ranking Member that we are going to have a demonstration in a minute that to my knowledge will be the first such demonstration in this Committee room, and by the way, we had to get permission to fly a drone in the Committee room as well, so the rules are still pretty strict, but I appreciate the widespread interest in the particular subject.

By the way, hardly a week goes by where the subject of drones is not covered in some national publication or on the front of the local newspaper or leads the news, so this is a timely subject for lots and lots of reasons.

Also, without objection, I have a letter I would like to put into the record from the National Association of Realtors supporting what we are doing here today and supporting the integration as well.

[The information appears in Appendix II]

Chairman SMITH. With that, I will recognize the Ranking Member, Ms. Bonamici, the gentlewoman from Washington, for her comments.

Ms. BONAMICI. Thank you very much, Mr. Chairman. I join you in welcoming our distinguished panel of witnesses, and I look forward to your testimony.

I want to state that Ranking Member Johnson is currently detained at another committee and will join us shortly, as well as some of our other Members are currently in other Committees. The lack of other Members other than Representative Lofgren on this side does not indicate a lack of interest in the issue certainly.

And in the meantime, I want to start by thanking Chairman Smith for calling this hearing on unmanned aircraft systems research and development.

Because of the work in my home State of Oregon—it is close to Washington, Mr. Chairman——

Chairman SMITH. I am sorry. I was only one state off.

Ms. BONAMICI. I do want to make that clear because my home State of Oregon, I am particularly interested in hearing how we can provide universities with the flexibility they need for performing UAS testing in a safe and cost-effective manner, and private sector developers with the regulatory certainty necessary to support this growing industry.

So we, Oregon—that is why I needed to make this clear because we are a participant in the Pan-Pacific UAS Test Range Complex led by the University of Alaska-Fairbanks, and we have three test sites in Oregon.

The potential benefits of UAS technology to agriculture, environmental research, natural resource management and, I want to add that the Chairman acknowledged some of those—emergency disaster relief efforts—is really multiplied by expanding the workforce focused on the development of new products, which is creating, of course, new job opportunities throughout not only Oregon but in other test areas as well.

So I do look forward to hearing how we in Congress and across the Federal Government can help safely and responsibly support the development of this exciting industry with so much potential.

And I thank you, Mr. Chairman, and I yield back the balance of my time.

Chairman SMITH. Thank you, Ms. Bonamici.

And I will now introduce our witnesses today. Our first witness is Dr. Ed Waggoner. Dr. Waggoner is the Research Director of NASA's Integrated Systems Research Program's Office, which seeks to integrate NextGen technologies into vehicle and operational systems. In this capacity, Dr. Waggoner also oversees UAS integration into the National Airspace System. Dr. Waggoner has worked for NASA since 1982, where he began as a researcher in theoretical aerodynamics. We welcome you.

Our second witness today is Mr. Jim Williams. Mr. Williams is Manager of FAA's UAS Integration Office. As such, he is responsible for coordinating FAA's efforts to integrate UAS into the National Airspace System through rulemaking, standardization, and research and development. Before working on UAS, Mr. Williams served as the Director of FAA's Engineering Services and as the Director of the Air Traffic Control Communications Services Directorate. Mr. Williams received his bachelor's degree in aerospace engineering.

Our third witness today is Dr. John Lauber. Dr. Lauber was a Co-chair on the National Research Council's Committee on Autonomy Research for Civil Aviation. Dr. Lauber is now a private consultant, and he has previously served as Airbus's Senior Vice President of Product Safety. He has also served as a member of the National Transportation Safety Board. Dr. Lauber received his Ph.D. in neuropsychology from The Ohio State University.

Today's fourth witness is Mr. Brian Wynne, CEO and President of the Association for Unmanned Vehicle Systems International. Mr. Wynne formerly served as the President of the Electric Drive Transportation Association, CEO of the Association for Automatic Identification and Mobility, and held a leadership role at the Intelligent Transportation Society of America. Mr. Wynne received a bachelor's degree from the University of Scranton, a master's degree from the School of Advanced International Studies at Johns Hopkins University, and was a Fulbright Scholar at the University of Cologne in Germany.

Testifying fifth today will be Mr. Colin Guinn, Chief Revenue Officer of 3D Robotics, North America's largest personal drone company. Mr. Guinn is the Co-founder and former CEO of DJI North America and has been featured on 60 Minutes, Fox, and in Tech Crunch. Before working at 3D Robotics and DJI, Mr. Guinn founded a company that specialized in producing aerial photography, marketing materials for luxury home builders. Mr. Guinn received his bachelor's degree from the University of Texas in Austin and attended the University of Miami School of Business.

Our final witness is Dr. John Hansman, the T. Wilson Professor of Aeronautics and Astronautics at MIT, where he leads the Humans and Automation Division and serves as Director of the MIT International Center for Air Transportation. Dr. Hansman is a Fellow of the American Institute of Aeronautics and Astronautics and has received several awards including the 1997 FAA Excellence in Aviation Award, the 1994 Losey Atmospheric Award, the 1990 OSTIV, which is International Scientific and Technical Soaring Organisation Diploma for Technical Contributions, and the 1986 AIAA Award for best paper in thermophysics. Dr. Hansman received his Ph.D. from MIT.

Now, we thank the witnesses again for being here today, and Dr. Waggoner, we will begin with you.

TESTIMONY OF DR. ED WAGGONER, DIRECTOR, INTEGRATED SYSTEMS RESEARCH PROGRAM, AERONAUTICS RESEARCH MISSION DIRECTORATE, NASA

Dr. WAGGONER. Chairman Smith, Ranking Member Bonamici and Members of the Committee, thank you for the opportunity to testify on NASA's Aeronautics Research program and the R&D challenges associated with unmanned aircraft systems, or UASs, and autonomy.

NASA's aeronautics strategic thrust in Assured Autonomy defines our vision and approach for supporting the near-term integration of UAS into the National Airspace System, the NAS. This near-term research builds a foundation for the more extensive, transformative changes that autonomous systems will bring in the mid to the far term.

UAS and autonomous systems hold great promise for the transformation of our aviation system. We are witnessing the dawn of a new era in aviation innovation, ushering in flying vehicles and operations that are unimaginable today, opening up entirely new commercial markets, much the way that jet engines did 60 years ago.

NASA is performing research in transitioning our concepts, technologies, algorithms and knowledge to the FAA and other stakeholders to help them define the requirements, the regulations and standards for safe, routine NAS access.

Still, there are significant barriers and research challenges associated with the introduction of autonomous systems into our aviation system. This requires these complex systems to be comprehensively evaluated to verify and validate that they are operating as designed, thus allowing the FAA to establish operations and equipment standards.

The majority of NASA's near-term research work towards safe UAS integration is focused in three areas. In our sense-and-avoid research, we are helping to determine performance requirements for a certifiable sense-and-avoid system to ensure safe separation of UAS with all vehicles operating in the NAS. We are developing secure, robust, reliable communications systems and protocols as well as addressing the design of ground control stations and displays to maximize pilot effectiveness and safety.

To transfer our research findings, NASA has built effective partnerships with key customers: the FAA, the Department of Defense, Department of Homeland Security, RTCA Special Committee 228, as well as industry and academia. In these partnerships, NASA is playing a key role supporting critical activities from the executive level to our subject-matter experts.

For midterm applications, NASA is researching novel concepts and technologies to facilitate safe operation of UAS at altitudes that are not actively controlled today, for example, low-altitude operation of small, unmanned aircraft. Initial investigations into this trade space have drawn interest among a broad range of traditional and non-traditional aerospace companies and shows promise of opening up entirely new markets and operational models.

In order to safely enable widespread civilian UAS operations at lower altitudes, NASA is developing an air traffic management-like system called UAS Traffic Management. You can think of this as much like today's surface traffic management where vehicles operate under a rule-based system of roads, lanes, signs and traffic lights.

The growing UAS industry and the varied user base is a harbinger of potential changes that autonomous systems will bring to aviation but enabling these changes will require substantial research and experimentation to ensure the safety and efficacy of these systems. NASA's long-term research in autonomy will deliver technologies that demonstrate high payoff, integrated applications that advance the safety, efficiency and flexibility of the NAS and increase competitiveness of the U.S. civil aviation industry.

NASA's Aeronautics Research Mission Directorate is a national resource that through game-changing research advances enables a growing, sustainable and transformative aviation system. NASA is partnering with other government agencies, standards development organizations and industry to achieve routine UAS access into our National Airspace System. Our partnerships are built on clear roles and responsibilities, long and productive working relationships, and close and continuous collaboration and coordination for the specific needs of the UAS integration challenge.

As the challenges of UAS operations evolve and the broader implications of integration develop, NASA aeronautics will continue to advance the research and develop enabling technologies that will assure the safe realization of the transformative benefits of these systems.

Chairman Smith, Ranking Member Bonamici and members of the Committee, this concludes my prepared statement. I will be pleased to answer any questions at this time.

[The prepared statement of Dr. Waggoner follows:]

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UNTIL PRESENTED
BY WITNESS
January 21, 2015

Statement of

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

before the

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

Mr. Chairman and Members of the Committee, thank you for this opportunity to testify on NASA's Aeronautics Research program and the R&D challenges associated with Unmanned Aerial Systems and Autonomy.

Importance of Aviation

NASA's innovative aeronautics research and development portfolio is aimed at transforming the aviation industry through game-changing advances in the safety, capacity, and efficiency of the air transportation system, while minimizing negative impacts on the environment. NASA's FY15 aeronautics research portfolio is aligned with six strategic research thrusts to directly address the growing global demand for mobility, severe challenges to sustainability of energy and the environment, and technology advances in information, communications, and automation technologies.

NASA Aeronautics Research Mission Directorate (ARMD)'s strategic thrust in Assured Autonomy for Aviation Transformation defines ARMD's vision and approach for supporting the integration of Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS) in the near-term while pioneering the more extensive transformative changes that increasingly autonomous aviation systems will bring over the mid to far-term. Research to address this strategic thrust is primarily focused in two Programs – the Integrated Aviation Systems Program, and the Airspace Operations and Safety Program – although there will be implications of autonomy across the entire ARMD portfolio.

Unmanned Aerial Systems and Autonomy

UAS and more broadly inclusive autonomous systems and technologies hold great promise for the transformation of our future aviation system. All elements of an aviation system could possess some level of autonomy, ranging from flight vehicles to air traffic management, ground support vehicles, ground control stations and all other elements. We are witnessing the dawn of a new era of aviation innovation. The introduction of autonomous vehicles and technologies can usher in totally different flight vehicles and operations that are unimaginable today and open up entirely new commercial markets, benefitting consumers as well as manufacturers, much as jet engines did 60 years ago. Under Section 333 of the FAA Modernization and Reform Act of 2012 the FAA has granted regulatory exemptions for UAS operations for companies performing operations for aerial surveying, construction site monitoring, oil rig flare stack inspections, and film and video productions. NASA and US industry are actively exploring autonomy concepts and technologies specific to the aviation enterprise, as well as identifying advances in other sectors (automotive, electrical systems, or internet-of-things, to name a few) that could be adapted to aviation. The United States is not the only country seeing this opportunity – there is significant interest and research in aviation autonomy by our international counterparts as well, presenting strong competition and at the same time many opportunities for collaboration to advance the state-of-the-art in this field.

There are significant research challenges associated with the introduction of autonomous systems and technologies into our aviation system. Before becoming operational, autonomous systems will need to uphold the highest levels of safety and assurance. This requires the complex systems to be evaluated through new methods and approaches to verify and validate that these systems are operating as designed as well as certifying these systems for flight. New test and evaluation capabilities are required for the development, integration, and evaluation of these autonomous systems.

Introduction of UAS into the NAS is the first stepping-stone on the path toward the introduction of autonomous systems more broadly. Significant barriers exist for routine UAS access such as the lack of an on-board pilot to see and avoid other aircraft, the reliance on command and control communication frequencies used primarily by the military, and the wide variation in UAS size (e.g., Northrop Grumman Global Hawk, which has a 131 foot wingspan and has an empty weight of almost 15,000 pounds vs. AeroVironment Nano Hummingbird, which has a 6.3 inch wingspan and weighs less than an ounce) and performance characteristics (altitudes, speeds, and duration). Understandably, in order to continue to ensure safety of the NAS, 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.

NASA's Research and Development Approach

ARMD is not the end user of the concepts and technologies resulting from our research. NASA does not build and sell aircraft, engines, or air traffic management systems. Through the research we conduct and the research we sponsor with universities and industry, we help to develop the technology that enables continuous innovation in aviation.

Close coordination with our partners and stakeholders throughout the research process is essential if we are to successfully transfer new operational concepts and technologies for commercialization by industry, or adoption by the FAA and other federal agencies to help them meet their missions. By matching NASA mid- and far-term research with current problems and making a timely transfer of the needed technology, we are helping the FAA and other stakeholders to realize benefits in near term applications.

Over the last several years, NASA, the FAA and the five other federal agency members of the Joint Planning and Development Office (JPDO) together defined the vision for the Next Generation Air Transportation System (NextGen) and established a roadmap to get there over the long-term. The NextGen JPDO played an important role in helping to establish a common vision for NextGen across government and industry, and coordinate development of the future NAS architecture and concepts of operations. In addition, JPDO led the way in developing the first set of inter-agency UAS integration goals, a comprehensive plan and an attendant Research, Development and Demonstration Roadmap for UAS integration into the National Airspace System. This work established the foundation for subsequent interagency and industry collaboration that has led to the progress we have seen thus far. Since the FAA made a change in interagency coordination from the JPDO to the Interagency Planning Office (IPO), the NextGen IPO has continued to lead the coordination of several key technology focus areas including the prioritization of UAS related research and development across federal agencies.

One can characterize NASA's research and development efforts focused on autonomous systems into three time frames, near-, mid- and far-term. The following three sections describe NASA's work in these three time frames and the approach that NASA is taking to coordinate our work with the stakeholder community and transition research findings in an effective manner.

Near-Term - The UAS Integration in the NAS Project

The majority of NASA's research work toward near-term integration of UAS into the NAS is organized under the UAS Integration in the NAS Project, which is part of the Integrated Aviation Systems 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.

Sense and Avoid/Separation Assurance Interoperability (SSI)

Fundamental questions that must be addressed to effectively and safely integrate UAS in to the NAS include, but are not limited to: How can UAS sense other vehicles and avoid them? What are the appropriate variables needed 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 and that fulfills the requirement to "see" and avoid other aircraft.

- Determine the impact of these SAA system requirements on the NAS and whether procedures or standards should be modified to minimize the impact.

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)–228 Minimum Operational Performance Standards for Unmanned Aircraft Systems. RTCA SC-228 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.

Communications

Communication is another critical element for safe UAS operation. 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 such a communication system?

The UAS Communication work within 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 to consider spectrum for beyond line-of-sight (satellite) for UAS communications.

- NASA is testing 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.

- 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.

- NASA is conducting large-scale simulations of the UAS communication systems that would be needed for a NAS-wide deployment of UAS.

Human Systems Integration (HSI)

Given effective communications, humans will continue to play a role in highly-automated UAS operations. 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 (HSI) 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 tests 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.

- A prototype GCS is being developed and evaluated to present the required information to the pilot and support the tasks required.

The lessons learned from these Human Systems Integration evaluations will inform GCS design guidelines for operations in the NAS that will be vetted through RTCA SC – 228 leading to recommendations to the FAA.

Technology Transfer

The driving force behind NASA's UAS research is to be able to transfer tools and solutions for operation in the civil airspace to the UAS community. Transfer is enabled by the coordination and close working partnerships that form during the research process. Through our earlier involvement with the NextGen JPDO, NASA learned much about how to work efficiently and effectively across various federal agencies and with multiple industry partners and interests. We have applied those experiences and lessons to how we prioritize, execute and transfer our research findings to the stakeholder community.

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 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, NASA's R&D efforts require close coordination with the FAA's UAS Integration Office, industry standards organizations, and international organizations. The close working relationship with the FAA's UAS Integration Office is critically important to ensure that NASA's research provides validated findings that inform the FAA's policy and rule making processes. This includes the prioritization of key technologies to research, as well as the design of critical simulations and flight test campaigns.

Other formal and informal interfaces and forums are also vitally important for collaboration and coordination of inter-Agency research. Two key inter-government interfaces that NASA is involved in are the UAS Executive Committee (ExCom) and the Sense and Avoid Science and Research Panel (SAA SARP).

In response to integration challenges and the growing demand for UAS NAS access by government agencies, Congress created the UAS ExCom. The UAS ExCom was created in order to enable the DoD, the 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 composition of the UAS 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. Working closely with the ExCom, the FAA has streamlined the Certificate of Authorization (COA) application process and extended the length of the COA from 12 months to 24 months. In addition, the FAA has established expedited procedures to grant one-time COAs for time-sensitive emergency missions such as disaster relief and humanitarian efforts.

NASA supports and closely cooperates with the DoD chartered Sense and Avoid Science and Research Panel (SARP). The Office of the Secretary of Defense recognized that a key challenge to integrating UAS into the NAS is a means for UAS to sense and avoid other aircraft. To ensure sound technical approaches to overcome this challenge OSD has established a SARP composed of experts from organizations that are performing SAA research. The SARP's primary purpose is to promote partnerships between the DoD and the broader academic and science community on UAS NAS integration science and research initiatives. The stakeholder community benefits from these partnerships through a broader range and depth of scientific expertise applied to challenges that affect all aspects of potential UAS operations. Since inception, NASA has played key roles supporting the SAA SARP with subject matter experts and executive leadership.

NASA is collaborating with the DoD in several other key areas as well. NASA is working closely with the Air Force Research Lab to leverage research efforts associated with sense and avoid, particularly related to the Jointly Optimal Collision Avoidance 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 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. 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 further expand our collaborations with the DoD.

Industry Interfaces

In addition, NASA works closely with industry and other government agencies on the UAS Aviation Rulemaking Committee and RTCA Special Committee 228, which was described earlier. NASA is an integral contributor to the FAA's UAS Aviation Rulemaking Committee. 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.

Global Harmonization

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 (ICAO) activities as part of the U.S. delegation led by the FAA and the State Department, including the Flight in Non- Segregated Airspace work, the UAS Study Group, the Civil Air Navigation Services Organization, and various ICAO working groups.

Mid-Term – UAS Traffic Management/UTM concept

NASA also is researching novel concepts and technologies that may facilitate safe operation of UAS at altitudes that are not actively controlled today, such as low-altitude operation of small UAS (less than 55 pounds). Initial investigations in this trade space have drawn interest among a broad range of traditional and non-traditional aerospace companies, and show promise of opening up entirely new markets and operational models.

Many beneficial civilian applications of UAS have been proposed for operation in this airspace, from goods delivery, agricultural monitoring, and infrastructure surveillance, to civil emergency search and rescue. As some UAS operations may operate in the same airspace where a mix of general aviation aircraft, helicopters and gliders currently operate, there is a strong need to safely accommodate all of these vehicles at lower altitudes. Currently, there is no established infrastructure to enable and safely manage the widespread use of low-altitude airspace and UAS operations, regardless of the type of UAS.

In order to safely enable widespread civilian UAS operations at lower altitudes, NASA is initiating development of an air traffic management-like system called UAS Traffic Management (UTM), much like today's surface vehicles that operate within a system consisting of roads, lanes, stop signs, rules, and lights. The goal of UTM is to enable safe and efficient low-altitude airspace operations by providing critical services such as airspace design and geo-fencing, separation management, weather and wind avoidance, routing, and contingency management. UTM will support UAS ranging from those with minimal avionics capability, to those that are autonomous, and allow safe operations in presence of current vehicles (e.g., gliders, general aviation, helicopters). UTM is essential to enable the accelerated development and use of civilian UAS applications. UTM will provide structure such as corridors and geo-fences where absolutely necessary and flexibility where possible.

Two types of UTM systems are envisioned. The first type is a Portable UTM System, which would move between geographical areas and support operations such as precision agriculture and disaster relief. The second type of system is a Persistent UTM System, which would support low-altitude operations and provide continuous coverage for a fixed geographical area. The UTM will require persistent communication, navigation, and surveillance coverage to track, ensure and monitor conformance. Industry is considering a variety of options such as ground-based radars, cell phone, and satellite based Automatic Dependent Surveillance - Broadcast ADS-B for surveillance and tracking.

NASA's near-term goal is the development and demonstration of the UTM to safely enable low-altitude airspace and UAS operations within five years. For the longer-term (10 to 15 years in the future), the goal is to safely enable the anticipated dramatic increase in density and diversity of all low-altitude airspace operations. Working alongside with many committed government, industry and academic partners, NASA will lead the research, development, testing, and implementation of the UTM, exploring functional designs, concepts and technology development, and testing of proposed UTM systems utilizing a series of builds, each increasing in capability. NASA is using a spiral development approach targeting these four builds to be delivered at 12-16 months intervals.

During the UTM's development, NASA has collaborated closely with the FAA. The UTM system concept was presented in an all-stakeholder workshop in February 2014 that was attended by over 150 representatives from UAS manufacturers, operators, system integrators, test sites, as well as the FAA, NOAA, and DoD.

From the stakeholder workshop attendees there was solid support for the concept and NASA's role as a coordinator. Further, many organizations expressed interest in building partnerships with NASA to develop and test UTM. As a result, several Space Act Agreements have been developed. In order to ensure further inclusiveness, NASA issued a request for information on the federal business opportunities website to solicit further collaborators. To date, NASA has received over 100 potential collaboration requests. These collaborators represent UAS manufacturers, operators, software systems developers, communications companies, ADS-B manufactures, and airspace operations providers, to name a few.

NASA has also developed a research transition team (RTT) for UTM with the FAA. This collaboration and technical exchange management structure has successful roots in the delivery of several key air traffic management advanced technologies from NASA to the FAA over the last several years. The RTTs routinely engage FAA's NextGen, Aviation Safety, and Air Traffic Operations organizations, and the William J. Hughes Technical Center.

Interest from the UAS community has been very high, and anticipation of rapid progress in system development and implementation is equally high. The pace of collaborative research and demonstration planned for UTM is critical to address the demand of the UAS community.

After thorough testing, transfer of the technologies associated with a UTM prototype to the FAA is expected by 2019. The ultimate goal of this research is to assist all low-altitude operations (e.g., manned and unmanned) in an autonomous manner to accommodate future vehicles.

Far-Term –A Vision for Adopting Autonomy

The growing UAS industry and the varied user base is a harbinger of the potential for change that increasingly autonomous systems will bring to aviation. It has the potential to revolutionize existing transportation applications and enable fundamentally new uses of the National Airspace System. But enabling these changes will require substantial research and experimentation to ensure the safety and efficacy of these systems. As the National Research Council (NRC) Committee on Autonomy Research for Civil Aviation indicated in their recent report on the subject – "civil aviation is on the threshold of potentially revolutionary changes in aviation capabilities and operations associated with increasingly autonomous systems. These systems, however, pose serious unanswered questions about how to safely integrate these revolutionary technological advances into a well-established, safe, and efficiently functioning NAS."

NASA's long-term research in autonomy seeks to both answer those questions as well as to demonstrate high payoff, integrated applications that advance the safety, efficiency and flexibility of the NAS and increase competitiveness of the U.S. civil aviation industry. Through internal assessments and taking advantage of the previously mentioned NRC Committee's report, NASA has developed a set of research themes that are critical to enabling assured autonomy. These research themes include: advancing test, evaluation, verification and validation techniques; developing autonomous planning, scheduling and decision-making methods; developing the tools to design and analyze autonomous systems; and systems for integrated vehicle control, health management and adaptation.

While the ultimate outcomes of our autonomy research are long-term, the research is beginning today in synergy with other UAS research. For example, the Live, Virtual, Constructive – Distributed Environment being established for high fidelity flight testing and standards validation for the UAS in the NAS Project is being extended to the full NAS to enable shadow mode simulation and testing of advanced airspace architectures including research to achieve real-time, system-wide safety as well as autonomous system operations.

Another example is the later versions of the UAS Traffic Management test-bed that will test the ability to autonomously schedule safe, conflict free trajectories in very complex conditions with vehicles of varying performance. Both of these examples provide platforms for testing advanced verification and validation methods that will be required for confident application of increasingly autonomous systems.

Again, while the ultimate objectives of this research are long term, we also expect that initial applications of increasingly autonomous systems will be viable in the mid-term. Initial focus will be on autonomous functions that collaborate with humans to improve safety outcomes and UAS traffic management.

Conclusions

NASA's Aeronautics Research Mission Directorate is a national resource that, through game-changing research advances, enables a growing, sustainable and transformative aviation system. Increasingly autonomous aviation systems will both help solve evolving safety, efficiency, and sustainability challenges, and enable the type of transformative changes that UAS integration signals. For the near-term, NASA is playing an important role, in partnership with the FAA, DoD, standards developing organizations, and industry in general, to achieve the integration of UAS into the National Airspace System. This partnership is built upon clear roles and responsibilities among the partners, long and productive working relationships, and close and continuous coordination for the specific needs of the UAS integration challenge.

Moreover, because enabling the introduction of increasing autonomous systems is a major element of NASA's long-term aeronautics strategy, we are committed to sustaining this important partnership. As the challenges of UAS operations evolve and the broader implications of the integration of autonomy throughout the aviation system develop, NASA will continue to advance the research and enabling technologies that will assure the safe realization of the transformative benefits of these systems.

Biography

Image Credit: NASA/Paul Alers

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 SMITH. Thank you, Dr. Waggoner.
Mr. Williams.

TESTIMONY OF MR. JAMES WILLIAMS, MANAGER, UAS INTEGRATION OFFICE, AVIATION SAFETY ORGANIZATION, FAA

Mr. WILLIAMS. Chairman Smith, Ranking Member Bonamici, Members of the Committee, thank you for the opportunity to appear before you today to discuss unmanned aircraft systems, commonly referred to as UAS.

The Federal Aviation Administration has successfully integrated new technology into the National Airspace System for more than 50 years, while maintaining the safest aviation system in the world. Research and development is absolutely critical to the safe, efficient and timely integration of new technology like UAS.

Interagency partnerships with the Department of Defense, the Department of Commerce, the Department of Homeland Security, and NASA have allowed us to leverage our collective assets to advance research and development in the area of unmanned aircraft. Together with RTCA, a Federal advisory committee, the FAA is developing standards for command-and-control radios to detect and avoid systems. The FAA, DOD and NASA are working closely together to develop a technical standard for UAS detect and avoid systems that will allow UAS to remain well clear of other aircraft. The research, engineering and development contributions of the DOD and NASA have been essential to developing that standard.

Together with NASA and our industry partners, the FAA is developing standards for command-and-control radios. These radios provide the link between the pilot and the aircraft, and it is essential that they be secure and reliable. NASA and our industry partners are designing and building prototype radios to validate the standard. The FAA plans to use the NASA software to test the ability of those radios to function on a small UAS with size, weight, and power limitation.

The FAA is also actively supporting the research and development efforts undertaken by other government entities in the area of unmanned aircraft. Since 2012, the FAA has participated in the DOD joint test and evaluation effort for UAS airspace integration sponsored by NORAD NORTHCOM and the Army. The purpose of the test is to evaluate standardized procedures to effectively conduct manned and UAS operations in the airport environment. The FAA provided engineers, en route controllers, and laboratory assets at the William J. Hughes Technical Center to support DOD's Human-in-the-loop simulations. We are also supporting this effort by evaluating the joint test results for potential applicability at civil airports. We look forward to continuing these valuable partnerships and working together with industry and other government agencies to advance UAS research and development.

The FAA Technical Center is the Nation's premier air transportation system laboratory. It has a specialized UAS simulation laboratory for conducting integrated simulations through research and development UAS integration procedures and standards. The UAS lab has a variety of test assets including the ability to link FAA air traffic control systems with high-fidelity unmanned aircraft simulators provided by our industry partners through cooperative research and development agreements.

The Technical Center is also playing an important role in data collection from the six UAS test sites that were announced in 2013. A significant portion of the test site data analysis is being performed at the Technical Center. A data lead from the Technical Center regional representatives and research engineers are also visiting each UAS test site to evaluate how data is captured and maintained. This team will ensure the integrity of the data transferred to the FAA and determine whether additional data collection will facilitate meeting the FAA's research objectives. We continue to work with the test sites to obtain the most valuable information possible to help the FAA integrate UAS into the NAS.

We are tremendously grateful for the support and funding Congress has provided to establish a UAS Center of Excellence. Our goal is to create a cost-sharing relationship between academia, industry and government that will focus on research areas of primary interest to the FAA and the UAS community.

The Center of Excellence will perform short- and long-term basic and applied research through analysis, development, and prototyping activities. To that end, the FAA solicited proposals from accredited institutions of higher education with their partners and affiliates. We are currently in the process of reviewing proposals and will announce the award recipient within this fiscal year.

Together with Congress, we remain committed to the safe, efficient and timely integration of UAS technology into the national airspace. We look forward to continuing to work with our partners in government and industry to continue making steady progress toward that goal.

Mr. Chairman, this concludes my testimony for today, and I look forward to answering your questions.

[The prepared statement of Mr. Williams follows:]

STATEMENT OF JAMES H. WILLIAMS, UNMANNED AIRCRAFT SYSTEMS OFFICE MANAGER, FEDERAL AVIATION ADMINISTRATION, BEFORE THE HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLIGY, UNMANNED AIRCRAFT SYSTEMS (UAS) RESARCH AND DEVELOPMENT, JANUARY 21, 2015.

Chairman Smith, Ranking Member Johnson, Members of the Committee:

Thank you for the opportunity to appear before you today to discuss unmanned aircraft systems (UAS). The Federal Aviation Administration (FAA) has successfully integrated new technology into the National Airspace System (NAS) for more than 50 years, while maintaining the safest aviation system in the world. Research and development, conducted in coordination with our government and industry partners, is critical to the safe, efficient, and timely integration of UAS technology into the NAS.

The UAS Roadmap and Comprehensive Plan

Two key documents outline the path forward for UAS integration. The Integration of Civil UAS in the NAS Roadmap outlines the tasks and considerations necessary to integrate UAS into the NAS. The five-year Roadmap, updated annually, provides stakeholders with proposed agency actions to assist with their planning and development. The Roadmap also identifies research needs and priorities to enable UAS integration. The UAS Comprehensive Plan was prepared by the Joint Planning and Development Office (JPDO), in coordination with JPDO Board participants from the Departments of Defense (DOD), Commerce (DOC), Homeland Security (DHS), the National Aeronautics and Space Administration (NASA) and the FAA. The Comprehensive Plan details work that has been accomplished, along with future efforts needed to achieve safe integration of UAS into the NAS.[1] It sets overarching, interagency goals, objectives, and approaches to achieving integration.

Interagency partnerships with DOD, DOC, DHS, and NASA have allowed us to leverage our collective assets and conduct research and development that benefits all users of the NAS as we integrate UAS. Through these partnerships and close collaboration, we are overcoming some of the largest barriers to UAS integration and ensuring the continued safety of the NAS.

Leveraging Interagency Partnerships

The FAA is actively collaborating with other government agencies and the UAS industry to leverage the assets of all stakeholders as we advance UAS integration and research. The FAA has collaborated with NASA on studies advancing air traffic control (ATC) interoperability with the future UAS use of detect and avoid systems in controlled airspace. We continue to collaborate with members of industry on flight tests to validate RTCA[2] standards for detect and avoid systems. And NASA, the FAA, and industry partners have successfully demonstrated a proof-of-concept airborne sense-and-avoid (SAA) system, marking a major milestone in the development of an Airborne Collision Avoidance System for Unmanned Aircraft (ACAS Xu).

The FAA, DOD, and NASA are collectively developing the technical standard that RTCA will evaluate and recommend as the appropriate minimum operational performance standards for UAS detect and avoid systems for UAS to remain clear of other aircraft. Without the Research, Engineering, and Development (RE&D) contributions of the DOD and NASA, the standard for

[1] The Integration of Civil UAS in the NAS Roadmap and Comprehensive Plan are available on the FAA UAS website at http://www.faa.gov/uas/publications/.
[2] RTCA, Inc. is not-for-profit organization that serves as a federal advisory committee to the FAA. *See* http://www.RTCA.org.

detect and avoid would have been delayed. We anticipate that the RTCA's recommended standards would satisfy the "see and avoid" regulatory requirements set forth in 14 C.F.R. Part 91.

Another key standard under development in RTCA is a minimum operational performance standard for command and control radios. These radios provide the link between the pilot and the aircraft and must be reliable and secure. NASA and our industry partners are playing a key role in development of this standard by designing and building prototype radios for validation. The FAA plans to use the NASA software and hardware to test the ability of those radios to function on smaller UAS with size, weight, and power limitations. Interagency partnerships are fundamentally important as we continue to develop safety standards for unmanned aircraft.

The FAA is also actively supporting the research and development efforts undertaken by other government entities. One example of this type of cooperation is the FAA participation in the DoD Joint Test and Evaluation effort for Unmanned Aircraft Systems Airspace Integration (UAS-AI), sponsored by North American Aerospace Defense Command (NORAD), U.S. Northern Command, and the Army. The purpose of the test is to standardize and evaluate procedures to effectively conduct manned and UAS operations in the airport environment. The FAA has provided operational subject matter expertise since the inception of this project in 2012. The FAA provided engineers, en route controllers, and high fidelity laboratory assets to support DOD's human-in-the-loop simulations in advance of three live UAS flight tests. The FAA has attended all three flight tests. The FAA is also supporting this effort by evaluating the associated

DOD Airspace Integration Joint Test results for potential applicability at civil airports and terminal facilities.

The FAA William J. Hughes Technical Center

Since 1958, the FAA William J. Hughes Technical Center has served as the core facility for modernizing the air traffic management system, and for advancing programs to enhance aviation safety, efficiency, and capacity. The Technical Center is the nation's premier air transportation system laboratory. The Technical Center's highly technical and diverse workforce conducts research and development, test and evaluation, verification and validation, sustainment, and ultimately, de-commissioning of the FAA's full spectrum of aviation systems. They develop scientific solutions to current and future air transportation safety, efficiency, and capacity challenges. Technical Center engineers, scientists, mathematicians, and technical experts utilize a robust, one-of-a-kind, world-class laboratory environment to identify integrated system solutions for the modernization and sustainment of the NAS and for integrating new operational capabilities and technologies, including UAS.

The Technical Center has a specialized UAS simulation laboratory for conducting integrated simulations to research and develop UAS integration procedures and standards. The UAS lab has a variety of test assets including the ability to link FAA Air Traffic Control systems with high Fidelity Unmanned Aircraft Simulators provided by our industry partners through cooperative research and development agreements. Important UAS research is currently underway in the area of sense and avoid multi-sensor data fusion strategies. This research focuses on the performance of sensors used to detect and avoid both cooperative and non-cooperative aircraft. The Technical Center is also evaluating specific UAS contingency operations and the associated impact to safety and efficiency of the NAS. Through that research, we consider contingencies that may arise in UAS operations, such as loss of the communication link between the pilot and aircraft, loss of pilot control of the aircraft (flyaway), and emergency flight termination procedures. The results of this research support the development of Air Traffic Control (ATC) requirements for providing services under contingency operations, as well as standard operational procedures for air traffic controllers. The Technical Center also conducted a real-time Human-In-The-Loop (HITL) simulation to examine the implications of a UAS pilot's inability to visually comply with applicable airspace regulations and ATC instructions. The simulation evaluated the impact that limitations of UAS would have on the safety and efficiency of the NAS to inform FAA policy and decision making regarding how to best integrate UAS into the NAS.

The Technical Center also provides strategic direction to the agency's RE&D portfolio and ensures that it is integrated, well planned, budgeted and executed. Successful Technical Center efforts have an impact across the country and indeed, around the world.

Much of the work performed at the Technical Center is in partnership with private industry, academic institutions, other agencies such as NASA and the DOD, and international organizations. The DHS and military entities also have space at the Technical Center. These other entities help to create a synergistic aviation-centered site that is without rival anywhere in the world.

NextGen is Enabling the Safe and Efficient Integration of UAS Into the NAS

The safe integration of UAS into the NAS will be facilitated by new technologies being deployed as part of the Next Generation Air Transportation System (NextGen). NAS Voice System (NVS), Data Communications (Data Comm) and System Wide Information Management (SWIM) will provide more information, flexibility, situational awareness and a greater ability to communicate. These features are necessary to enable safe and efficient integration of UAS into the NAS.

NVS will allow ground-based UAS pilots to communicate directly with the air traffic controllers – a key requirement in integration – over the ground-to-ground communications network. Safe integration will lead us from today's need for accommodation of UAS through individual approvals to a time when unmanned aircraft can "file and fly" in the NextGen environment. It will improve the efficiency and reliability of exchanges between the UAS flight crew and air traffic control. NVS networking capabilities enable greater flexibility in developing and using airspace/traffic assignments in all airspace. Additionally, a "party line" requirement integral to NVS adds to the overall situational awareness of UAS flight crews by allowing multiple participants to communicate.

Data Comm applications enable controllers to send digital instructions and clearances to pilots, and to exchange more complex four-dimensional (comprising latitude, longitude, altitude and time) trajectory data, including position, navigation and timing information. For UAS operators that elect to equip their ground control station, air traffic control messages and instructions will be exchanged via Data Comm to the pilot in control.

Network-enabled access to more timely and improved information throughout the NAS serves as a major enabler for future operations, including UAS. All information about a given flight (e.g., capabilities, constraints, preferences) is contained within the flight object and made available to system stakeholders and air traffic management service providers based on information needs and security protocol.

Data sharing is a key NextGen component – getting the right information to the right people at the right time. This is especially important when it comes to weather information. Common Support Services–Weather (CSS-Wx) will provide the FAA and NAS users with same-time access to a unified aviation weather picture via the SWIM network. This will enable collaborative and dynamic decision making among all users of the NAS, including UAS operators, and give them the flexibility to proactively plan and execute aviation operations ahead of weather impacts. These weather services are especially critical to UAS operations since the pilot typically will be exclusively dependent on ground-based weather products to avoid hazardous weather conditions encountered by the aircraft.

Technological developments achieved through NextGen will continue to facilitate the integration of UAS into the NAS. NextGen capabilities are continually being developed, tested, and deployed at the FAA Technical Center. We also work closely with the Mitre Center for Advanced Aviation System Development (CAASD), the FAA's Federally Funded Research and Development Center (FFRDC), to leverage all available technology for UAS integration.

UAS Test Sites

The six UAS test sites, announced by the FAA on December 30, 2013, also play a key role in our integration of UAS technology into the NAS. In selecting the sites, the FAA followed Congressional direction to consider geographic and climatic diversity and to consult with DOD and NASA. The FAA selected the University of Alaska Fairbanks, the State of Nevada, New York's Griffiss International Airport, the North Dakota Department of Commerce, Texas A&M University Corpus Christi, and Virginia Polytechnic Institute and State University (Virginia Tech) to serve as UAS test sites.

The FAA will utilize data from the test sites to help answer key questions and provide critical information about how UAS will interface with the air traffic control system. The information provided by the test sites will help the FAA to develop regulations and operational procedures for future civil commercial use of UAS in the NAS. Data from the test sites will also help identify elements of the certification and navigation requirements we will need to establish for unmanned aircraft.

UAS operational pre- and post-flight data is currently being collected from all test sites. The test sites are providing data about the types and sizes of aircraft, number of operations, number of flight hours, notable operating parameters (for example, whether the flight was within or beyond visual line of sight), and any incidents and accidents. Each site has also established its own research agenda. I would like to highlight just a few of the activities underway at each test site.

- The North Dakota Department of Commerce test site has conducted more than 84 flights, with research concentrated on wildlife census and precision agriculture studies.
- The University of Alaska Fairbanks test site encompasses 3,369 cubic miles of airspace in Alaska and Oregon. It is expanding flight operations into Kansas with the recent

approval of Kansas State University as a new team member. The research conducted at this test site includes forward-looking infrared technology to support surveying large land mammals and using UAS to meet operational firefighting needs and provide tactical police support.

- The State of Nevada's research will concentrate on UAS standards and operations, as well as operator standards and certification requirements. The Nevada Test Site was recently approved to issue Experimental Airworthiness Certificates on behalf of the FAA to enable better support to the UAS manufacturers.

- Griffiss International Airport has conducted 31 flights using three different vehicles. In cooperation with Lockheed Martin, Griffiss International Airport test site has conducted optional piloted (i.e., aircraft that can be flown from the ground or conventionally) aircraft research to test the utility of using of a rotorcraft both with and without an onboard pilot for firefighting.

- Texas A&M Corpus Christi created a fully operational UAS command center with advanced toolsets and is pursuing solutions that will incorporate air traffic control data to augment operational safety mitigation strategies. Research activities include precision agriculture and coastal monitoring.

- The Virginia Polytechnic Institute and State University (Virginia Tech) test site includes Virginia, Maryland, and New Jersey. Research in these three states will include agricultural spray equipment testing, developing training and operational procedures for aeronautical surveys of agriculture, and the development of aeronautical procedures for integration of UAS flights in a towered airspace.

We continue to work closely with the test sites to identify the data most useful to the FAA. A significant portion of test site data analysis is being performed at the Technical Center. A Data Lead from the Technical Center, regional representatives, and research engineers, are also visiting each UAS test site to evaluate how data is captured and maintained, ensure the integrity of data transferred to the FAA, and determine whether additional data collection would facilitate meeting the FAA's research objectives. We continue to work with the test sites to obtain the most valuable information possible to help the FAA integrate UAS into the NAS.

Center of Excellence

Under the Consolidated Appropriations Act of 2014, Congress directed the FAA to establish a UAS Center of Excellence (COE). The goal of this endeavor is to create a cost-sharing relationship between academia, industry, and government that will focus on research areas of primary interest to the FAA and the UAS community. We intend to forge a union of public sector, private sector, and academic institutions to create a world-class consortium that will identify solutions for existing and anticipated UAS-related issues. The COE will perform short- and long-term basic and applied research through a variety of analyses, development, and prototyping activities. To that end, the FAA solicited proposals from accredited institutions of higher education with their partners and affiliates. The FAA intends to enter into cooperative agreements with core university members, and will award matching grants for public benefit. Initially, grants will be awarded to university members to establish the COE, define the research agenda, and begin UAS research, education, training and related activities. We are currently in the process of reviewing proposals and look forward to establishing the COE.

The FAA has identified the following eleven initial research areas of current interest:

1) Air Traffic Control Interoperability
2) Airport Ground Operations
3) Control and Communication
4) Detect and Avoid (DAA)
5) Human Factors
6) Low Altitude Operations Safety
7) Noise Reduction
8) Spectrum Management

9) Unmanned Aircraft (UA) Crew Training and Certification, Including Pilots
10) Unmanned Aircraft Systems Traffic Management, and
11) UAS Wake Separation Standards for UAS Integration into the NAS.

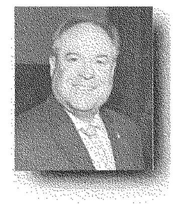
While our research needs may evolve over time, we look forward to the research and advancements that will emerge through the COE. The FAA has long had successful partnerships with the nation's academic research community, working with U.S. colleges and universities to foster research by COE faculty and students, industry, and other affiliates. These research efforts have provided the agency and the industry a high return on investments and have contributed significantly to the advancement of aviation science and technology over the past two decades. We look forward to continuing these partnerships with respect to UAS research as we establish the COE.

Conclusion

The FAA is committed to safely integrating UAS into the NAS. The FAA has made steady progress toward that goal and will continue to do so through partnerships with industry and other government agencies. Collaboration is critical to achieving safe integration and we look forward to continued collaboration with our federal, state, and industry partners.

The United States has the safest aviation system in the world, and our goal is to integrate this new and important technology while still maintaining safety as our highest priority. We are committed to ensuring that America continues to lead the world in the development and implementation of innovative aviation technology.

We look forward to continuing to work together with Congress as we continue to integrate UAS into the NAS. This concludes my statement. I will be happy to answer your questions at this time.



James (Jim) H. Williams
Manager, Unmanned Aircraft Systems Integration Office

Jim Williams is the Manager of the FAA's Unmanned Aircraft Systems (UAS) Integration Office. This office functions as the single agency focal point for all UAS-related activities and is uniquely positioned to develop and coordinate solutions to UAS challenges across the FAA and with external organizations.

UAS are often described as the most disruptive aviation technology since the invention of the jet engine, and the FAA's UAS Integration Office has the daunting challenge of accomplishing the safe, efficient, and timely integration of this technology into the National Airspace System (NAS), while balancing the political pressure and economic needs of the nation.

Before taking the helm of the UAS Integration Office in March 2012, Jim spent six years as the Director of Engineering Services in the FAA's NextGen Organization, where he led the coordination and integration of all systems engineering work needed to move the NAS toward NextGen. This work gave him a deep understanding of how FAA research progresses into a mature concept and eventually into the many technologies that become operational in the NAS. His office also led the development of the NAS Enterprise Architecture and NAS-level Requirements. Together these engendered a great appreciation for the interrelationships of the many systems which will be touched by the UAS integration effort.

During his long career with the FAA, Jim led the organization tasked with lifecycle management of all FAA communications systems and the implementation of the Safety Management System in the Technical Operations Service Unit. He has also worked with the FAA Command Center to transition personnel into the Air Traffic Organization, directed the team that developed, procured, and installed all air/ground communications services for the FAA, and led the team that designed, procured, and fielded the FAA's prototype Air/Ground Data Link Communications System. Jim also led the FAA Team that negotiated with other federal agencies to create a second civil GPS frequency.

Prior to 1998, Jim held various FAA positions related to the regulation and certification of avionics systems. During this time, he led the offices responsible for writing standards for all avionics installed in U.S. civil aircraft and the certification standards and guidance for all navigation systems used on U.S. civil aircraft.

Before coming to FAA Headquarters in Washington, DC, Jim worked in the Atlanta Aircraft Certification Office as a systems engineer where his responsibilities focused on approving the avionics installed in the Gulfstream G-IV airplane. He also worked on revisions to the RTCA standards for the development of computer software used in avionics.

Prior to joining the FAA, Jim was a flight test engineer and a production liaison engineer for the Lockheed Georgia Company's C5, C-141, and C-130 programs. He also worked for the National Aeronautics and Space Administration (NASA) in Mission Control during the initial U.S. Space Shuttle flights.

A native of Tennessee, Jim is a graduate of The Georgia Institute of Technology with a Bachelor's degree in Aerospace Engineering. He currently lives in Reston, VA, with his wife, son, mother-in-law, and two standard poodles. He enjoys umpiring Little League baseball.

Chairman SMITH. Thank you, Mr. Williams.
Dr. Lauber.

TESTIMONY OF DR. JOHN LAUBER, CO-CHAIR, COMMITTEE ON AUTONOMY RESEARCH FOR CIVIL AVIATION, NATIONAL RESEARCH COUNCIL

Dr. LAUBER. Thank you, Chairman Smith, Ranking Member Bonamici and Members of the Committee. Thanks for the opportunity to discuss with you today the work of the National Research Council's Committee on Autonomy Research for Civil Aviation, which I had the pleasure of co-chairing along with John Paul Clark from Georgia Institute of Technology.

Our final report was issued last summer after about 18 months of effort and was done at the request of NASA's Aeronautics Research Mission Directorate. We were specifically charged with developing a national agenda for research and development that would support the introduction of what we call increasingly autonomous elements into our civil aviation system. Copies of the summary of our report have been provided to you.

We recognized that several key characteristics of the civil aviation system set the context for our study, and first and foremost is safety. Our air transportation system operates at unprecedented levels of safety, and it is clear that the introduction of increasingly autonomous capabilities into that system will be acceptable only if they preserve or further enhance this high level of safety and reliability.

Secondly, we had to recognize the diversity of aircraft, ground systems and personnel that comprise our civil aviation system. Because so-called legacy aircraft and systems will continue to operate for the foreseeable future., it is clear that civil airspace must safety and efficiently accommodate everything from Piper Cubs designed in the 1930s to increasingly autonomous unmanned rotary and fixed-wing vehicles whose design and applications are continually evolving.

Today's aviation system sets the baseline for the system of tomorrow, and in this context, autonomy is a characteristic or feature of future aviation automation systems that enable operations over extended periods of time without direct human supervision or intervention. This has some profound implications for urgent research and development in machine vision, perception and cognition to provide the functional equivalent of a see-and-avoid capability, which is a cornerstone for collision avoidance in our national aviation system, and this is but one example of what we mean when we talk of increasingly autonomous systems, systems that will evolve to perform more and more of the functions presently provided by human pilots, controllers and other skilled aviation personnel.

Our report identifies eight technical barriers including such issues as cyber physical security, and we have also identified four barriers associated with regulation and certification, which include issues such as airspace access, and finally, we note in our report barriers related to public policy, law and regulation, and very importantly, social concerns about privacy and safety of autonomous systems.

Our recommended research agenda consists of eight broad tasks, which we consider the first four to be the most urgent and most difficult. These include fundamental issues about how to characterize the behavior of systems that change dynamically over time. Modeling and simulation will be of fundamental importance to the development and deployment of these systems, and finally, we discuss a wide range of research issues involving validation, verification and certification.

The remaining four research areas include issues having to do with the safe use of open-source hardware and software and reexamination and redefinition of the role of humans in the operation of these systems. We note in our report that this research program is best carried out by multiple government, academic and industrial entities and will require effective coordination at all levels.

Civil aviation is on the threshold of profound changes because of rapid evolution of increasingly autonomous systems. As often happens with rapidly evolving technology, early adapters sometimes get caught up in the excitement of the moment, greatly exaggerating the promise of things to come and greatly underestimating costs in terms of money, time, and in some cases, unintended consequences or complications. While there is little doubt that over the long run the potential benefits of increasingly autonomous systems in civil aviation will indeed be great, there should be equally little doubt that getting there while maintaining the safety and efficiency of U.S. civil aviation will be no easy matter.

We believe that the barriers in the research program we have identified is a vital next step, and that concludes my testimony. I will be happy to respond to questions. Thank you.

[The prepared statement of Dr. Lauber follows:]

Testimony of

Dr. John K. Lauber
Independent Consultant

Co-Chair, Committee on Autonomy Research for Civil Aviation
Aeronautics and Space Engineering Board
Division on Engineering and Physical Sciences
National Research Council
The National Academies

before the

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

January 21, 2015

Chairman Smith, Ranking Member Johnson, and members of the committee:

Thank you for the opportunity to appear before you today in my capacity as the Co-Chair the National Research Council's Committee on Autonomy Research for Civil Aviation. Together with my Co-Chair, John-Paul Clarke of the Georgia Institute of Technology, I had the pleasure of working with a distinguished group of scientists and engineers from a variety of disciplines and academic, industrial and government settings to develop a *national* research agenda to support the introduction of what we termed *increasingly autonomous* elements into our civil aviation system. This study was conducted at the request of NASA's Aeronautics Research Mission Directorate, and it was conducted over the course of about 18 months; our final report was issued last summer. Whereas our study was requested by NASA, we were asked not to provide recommendations to that one agency but moreover to identify and prioritize elements of a national agenda of research and development that could be pursued by government, academia, and industry. You have copies of the Summary of our report before you, and I will try to succinctly summarize our findings and recommendations below.

Before we get into the details of our findings, I want to summarize briefly the approach we took to this task. Because of our specific focus on civil aviation applications of increasingly autonomous systems, it was necessary to explicitly recognize a couple key characteristics of civil aviation that would set the context for our findings. First and foremost, one hallmark of our nation's civil aviation system is safety, especially in civil air transport operations. For a variety of reasons many decades in the making, our air transportation system operates at unprecedented levels of safety, and it is clear that the introduction of increasingly autonomous capabilities into that system will be acceptable only if they preserve or enhance this high level of safety and reliability. Secondly, we had to recognize the diversity of aircraft, ground systems, and personnel that comprise our civil aviation system. Because so-called "legacy" aircraft and support systems will continue to operate for the foreseeable future, it is clear that civil airspace must safely and efficiently accommodate everything from Piper J-3 Cubs designed in the 1930s to increasingly autonomous, unmanned rotary and fixed-wing vehicles whose designs and applications are continually evolving. These features and characteristics of civil aviation in the United States were key drivers of the elements of the national research agenda we recommended.

It is also important to understand how autonomous capabilities will be integrated over time into the National Airspace System (NAS). Our committee adopted the view that the civil aviation system of the future will evolve over time starting with a baseline defined by today's system, particularly with regard to levels of automation that are designed into present-day cockpits and air traffic management systems. *Autonomy*, in this context, is a characteristic or feature of future aviation automation systems that we use to refer to aviation systems that will be capable of *operations over extended distances and for long periods of time* ***without direct human supervision or intervention.*** As we point out in our report, this has some profound implications for urgent research in machine vision, perception, and cognition that must be developed to provide the functional equivalent of a "see-and-avoid" capability, which is the cornerstone for collision avoidance in our national aviation system. This is one key example of what we mean when we talk of *increasingly* autonomous systems—systems that will evolve to perform more and more of the functions presently provided by human pilots, controllers, and other skilled aviation personnel.

We started our task by identifying barriers to the increased use of autonomy in civil aviation systems and aircraft. Some of these barriers are technical, some are related to certification and regulation, and some are related to legal and social concerns. Our research agenda was developed to address these barriers.

The *Technology Barriers* we identified are as follows: (1) *Communications and data acquisition* requirements in an increasingly autonomous civil aviation system may push the boundaries of bandwidth and spectrum management necessary to support these operations; (2) *Cyberphysical security*, a topic of increasing concern generally, may be particularly critical to ensure the stability, reliability and functionality of the increasingly-autonomous civil aviation system of the future; (3) *Decision-making by adaptive, non-deterministic systems* is a critical element of autonomy in civil aviation systems, and there are significant challenges to the design, implementation and testing of such systems at present; (4) As I've previously mentioned, the *diversity of vehicles and systems* that must be accommodated in a civil aviation system will make it more difficult to incorporate increasingly autonomous systems; (5) advances in *human-machine integration* are needed because increasingly autonomous systems will require humans and machines to work together in new and different ways that have not yet been identified. (6) I've also mentioned machine *sensing, perception, and cognition* as a significant technological hurdle that must be addressed; (7) Increasingly autonomous systems will present new, and not well-understood challenges in terms of *system complexity* and the ability of the civil aviation system as a whole to resist precipitous declines in performance because of isolated failures in one part of the system; and finally, (8) Existing approaches to the formal *verification and validation* of systems are not adequate to address these requirements in increasingly autonomous systems. Each of these technical barriers is more fully-developed in the text of our report.

Four barriers in our report are related to *Regulation and Certification*: (1) *Airspace access for unmanned aircraft* is a significant barrier for present operations of unmanned aircraft; (2) Today's *certification process* doesn't adequately take into account the special characteristics of increasingly autonomous systems; (3) Many of the safety standards and requirements that are applied to increasingly autonomous systems were developed in the context of crewed, passenger-carrying aircraft, and it's not clear how well-suited they are to assure an *equivalent level of safety* for unmanned aircraft operations; and (4) Even if we had adequate processes and procedures for verification, validation, and certification of increasingly autonomous systems, the absence of *trust* in such systems will impose significant barriers to their widespread adoption and utilization.

Finally, our committee identified two other barriers that could seriously impede the degree and speed of adoption of increasingly autonomous technology in civil aviation: These are (1) *legal issues* associated with public policy, law. and regulation, and (2) *social issues*, especially public concerns about privacy and safety.

From a consideration of these technical, regulatory/certification, and social/legal barriers, our committee identified eight high-level research projects that collectively will enable the realization of our vision of increasingly autonomous civil aviation systems and operations. Our report discusses each of these in some depth, but in the interest of time this afternoon, I'll simply summarize and highlight our recommendations for a national research agenda. I would also point out that the committee feels that each of these research issues is important, but we consider the first four of these to be most urgent and most difficult.

1. **Behavior of Adaptive/Nondeterministic Systems:** Autonomous systems are characterized by their ability to learn from experience and to adapt to changing conditions. This means that the outputs of such systems can change over time, and that their response to a given set of conditions might be different over time as the systems gain experience. This poses significant technical challenges for design, testing and certification of these systems.

2. **Operation Without Continuous Human Oversight:** Another defining characteristic of increasingly autonomous systems is their ability to operate for extended periods of time without direct human oversight, that is, without the need for a human to monitor, supervise, and/or directly intervene in the operation of these systems in real time. This will require that the functions currently provided by human operators are accomplished by the increasingly autonomous systems during periods when the system operates unattended. Increasingly autonomous systems will need to respond safely to degradation or failure of aircraft systems as well as other high-risk situations encountered during a mission.

3. **Modeling and Simulation:** The committee recommends a significant undertaking to develop the theoretical basis and methodologies for using modeling and simulation to accelerate the development and maturation of increasingly autonomous systems and aircraft. Potential applications include component design, training and coaching of human operators, creating and enhancing human trust in increasingly autonomous systems, accident and incident investigation, and furthering our understanding of cybersecurity vulnerabilities and how to mitigate those risks.

4. **Verification, Validation, and Certification:** I've previously stated our committee's concerns about the inadequacy of present approaches to verification, validation, and certification of increasingly autonomous systems. It is important to recognize, however, that one of the key reasons for the previously-noted high levels of safety we experience

in civil aviation is because of the formal requirements imposed by the FAA for verification, validation, and/or certification of hardware, software and people, as appropriate.

5. **Nontraditional Methodologies and Technologies:** The active and growing community of hobbyists and prospective entrepreneurs developing increasingly autonomous unmanned aircraft and associated systems are relying heavily on open-source hardware and software, resulting in a proliferation of low-cost, highly-capable technology. We believe that such technologies will be a key element of the increasingly autonomous civil aviation system of the future, and urge research and development that will allow these technologies to be used safely and efficiently. This would include, in our view, the research that would allow the use of open-source intelligent software in safety-critical applications, including unlimited flight operations.

6. **Roles of Personnel and Systems:** There may be a tendency to believe that the advent of increasingly autonomous systems will lessen the need to assure proper consideration of human factors in the engineering of such systems. However, our committee believes quite the opposite. Because intelligent, adaptive/non-deterministic systems will require humans and machines to work together in previously unanticipated ways, it is imperative that research be undertaken to further understand the roles and responsibilities of humans and machines, and to address the question of how to safely and efficiently integrate these in an operational environment.

7. **Safety and Efficiency:** The committee believes that increasingly autonomous systems could enhance the safety and efficiency of civil aviation. Our report discusses a wide range of potential applications of increasingly autonomous technology that could greatly reduce the risk to humans involved in operations such as aerial fire-fighting operations. We also recognize that such technology might readily be applied to improve the safety of general aviation, especially with respect to single-pilot operations by, in effect, incorporating an "electronic co-pilot" that could provide needed, timely assistance to a human pilot. We recommend that this research project include an analysis of accidents and incidents to determine those instances where increasingly autonomous systems might have made a positive outcome possible. Such systems would not be susceptible to factors that adversely affect human performance, such as stress or fatigue. Effective development of increasingly autonomous systems could have a major impact on the need for highly-skilled, highly-trained people.

8. **Stakeholder Trust:** Increasingly autonomous systems can fundamentally change the relationship between people and technology, and one important dimension of that relationship is trust. Even if the necessary developments for verification, validation, and

certification are successfully accomplished, in the absence of trust, the potential benefits of increasingly autonomous systems cannot be realized. It is therefore necessary to understand what attributes of systems affect their trustworthiness and how this is communicated to the people who are responsible for their operation.

These then are the major recommendations for research developed by our committee. Although this study was done at the request of NASA's Aeronautics Research Mission Directorate, we were specifically directed to develop a national research agenda rather than a NASA research agenda. We thus recognize that the research we've recommended can and should be addressed by multiple organizations in the federal government, industry and academia. Clearly the FAA has a major role to play, particularly for those elements pertaining to verification, validation and certification. The Department of Defense, although primarily concerned with military applications of this technology, also has a requirement for at least some of their unmanned aircraft to be able to fit seamlessly into operations in the National Aviation System. Each of the high-priority research projects overlaps to some extent with one or more of the other projects, and each would be best addressed by multiple organizations working in concert. There is already some movement in that direction, however, we believe there is an ongoing need for active coordination of the research effort related to autonomy in civil aviation.

Civil aviation in the United States and elsewhere in the world is on the threshold of profound changes in the way it operates because of the rapid evolution of increasingly autonomous systems. Advanced systems will, among other things, be able to operate without direct human supervision or control for extended periods of time and over long distances. As happens with any other rapidly evolving technology, early adapters sometimes get caught up in the excitement of the moment, producing a form of intellectual hyperinflation that greatly exaggerates the promise of things to come and greatly underestimates costs in terms of money, time, and—in many cases—unintended consequences or complications. While there is little doubt that over the long run the potential benefits of increasingly autonomous systems in civil aviation will indeed be great, there should be equally little doubt that getting there, while maintaining or improving the safety and efficiency of U.S. civil aviation, will be no easy matter. Furthermore, given that the potential benefits of advanced systems—as well as the unintended consequences—will inevitably accrue to some stakeholders much more than others, the enthusiasm of the latter for fielding increasingly autonomous systems could be limited. In any case, overcoming the barriers identified in this report by pursuing the research agenda proposed by the committee is a vital next step. Even so, more work beyond the issues identified here will certainly be needed as the nation ventures into this new era of flight.

The Summary from our report is attached.

AUTONOMY RESEARCH FOR CIVIL AVIATION
TOWARD A NEW ERA OF FLIGHT

REPORT SUMMARY

Committee on Autonomy Research for Civil Aviation

Aeronautics and Space Engineering Board

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
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Summary

The development and application of increasingly autonomous (IA) systems for civil aviation (see Boxes S.1 and S.2) are proceeding at an accelerating pace, driven by the expectation that such systems will return significant benefits in terms of safety, reliability, efficiency, affordability, and/or previously unattainable mission capabilities. IA systems, characterized by their ability to perform more complex mission-related tasks with substantially less human intervention for more extended periods of time, sometimes at remote distances, are being envisioned for aircraft and for air traffic management (ATM) and other ground-based elements of the National Airspace System (NAS) (see Box S.3). This vision and the associated technological developments have been spurred in large part by the convergence of the increased availability of low-cost, highly capable computing systems; sensor technologies; digital communications systems; precise position, navigation, and timing information (e.g., from the Global Positioning System (GPS); and open-source hardware and software.

These technology enablers, coupled with expanded use of IA systems in military operations and the emergence of an active and growing community of hobbyists that is developing and operating small unmanned aircraft systems (UAS), provide fertile ground for innovation and entrepreneurship (see Box S.4). The burgeoning industrial sector devoted to the design, manufacture, and sales of IA systems is indicative of the perceived economic opportunities that will arise. In short, civil aviation is on the threshold of potentially revolutionary changes in aviation capabilities and operations associated with IA systems. These systems, however, pose serious unanswered questions about how to safely integrate these revolutionary technological advances into a well-established, safe, and efficiently functioning NAS governed by operating rules that can only be changed after extensive deliberation and consensus. In addition, the potential benefits that could accrue from the introduction of advanced IA systems in civil aviation, the associated costs, and the unintended consequences that are likely to arise will not fall on all stakeholders equally. This report suggests major elements of a national research agenda for autonomy in civil aviation that would inform and support the orderly implementation of IA systems in U.S. civil aviation. The scope of this study does not include organizational recommendations.

BARRIERS TO INCREASED AUTONOMY IN CIVIL AVIATION

The Committee on Autonomy Research for Civil Aviation has identified many substantial barriers to the increased use of autonomy in civil aviation systems and aircraft. These barriers cover a wide range of issues related

BOX S.1
Civil Aviation

In this report, "civil aviation" is used to refer to all nonmilitary aircraft operations in U.S. civil airspace. This includes operations of civil aircraft as well as nonmilitary public use aircraft (that is, aircraft owned or operated by federal, state, and local government agencies other than the Department of Defense). In addition, many of the IA technologies that would be developed by the recommended research projects would generally be applicable to military crewed and/or unmanned aircraft for military operations and/or other operations in the NAS.

BOX S.2
Increasingly Autonomous Systems

A fully autonomous aircraft would not require a pilot; it would be able to operate independently within civil airspace, interacting with air traffic controllers and other pilots just as if a human pilot were on board and in command. Similarly, a fully autonomous ATM system would not require human air traffic controllers. This study is not focused on these extremes (although it does sometimes address the needs or qualities of fully autonomous unmanned aircraft). Rather, the report primarily addresses what the committee calls "increasingly autonomous" (IA) systems, which lie along the spectrum of system capabilities that begin with the abilities of current automatic systems, such as autopiloted and remotely piloted (nonautonomous) unmanned aircraft, and progress toward the highly sophisticated systems that would be needed to enable the extreme cases. Some IA systems, particularly adaptive/nondeterministic IA systems, lie farther along this spectrum than others, and in this report such systems are typically described as "advanced IA systems."

BOX S.3
National Airspace System

The NAS is "the common network of U.S. airspace; air navigation facilities, equipment, and services; airports or landing areas; aeronautical charts, information and services; rules, regulations, and procedures; technical information; and manpower and material" (Integration of Civil Unmanned Aircraft Systems [UAS] in the National Airspace System [NAS] Roadmap, FAA, 2013). Some NAS facilities are jointly operated by the FAA and the Department of Defense. IA systems could be incorporated into airport ground systems such as snow plows. However, the greatest technological, social, and legal challenges to the use of IA systems in civil aviation are associated with their use in aircraft and air traffic management systems, and the report does not specifically address the use of IA systems in airport ground systems.

BOX S.4
Unmanned Aircraft/Crewed Aircraft

An unmanned aircraft is "a device used or intended to be used for flight in the air that has no onboard pilot. This device excludes missiles, weapons, or exploding warheads, but includes all classes of airplanes, helicopters, airships, and powered-lift aircraft without an onboard pilot. Unmanned aircraft do not include traditional balloons (see 14 CFR Part 101), rockets, tethered aircraft and un-powered gliders." A UAS is "an unmanned aircraft and its associated elements related to safe operations, which may include control stations (ground-, ship-, or air-based), control links, support equipment, payloads, flight termination systems, and launch/recovery equipment" (Integration of Civil Unmanned Aircraft Systems [UAS] in the National Airspace System [NAS] Roadmap, Federal Aviation Administration [FAA], 2013). UAS include the data links and other communications systems used to connect the UAS control station, unmanned aircraft, and other elements of the NAS, such as ATM systems and human operators. Unless otherwise specified, UAS are assumed to have no humans on board either as flight crew or as passengers. "Crewed aircraft" is used to denote manned aircraft; unless specifically noted otherwise; manned aircraft are considered to have a pilot on board.

to understanding, developing, and deploying IA ground and aircraft systems. Some of these issues are technical, some are related to certification and regulation, and some are related to legal and social concerns.

- Technology barriers
  —*Communications and data acquisition.* Civil aviation wireless communications are fundamentally limited in bandwidth, and the operation of unmanned aircraft in the NAS could substantially increase the demand for bandwidth.
  —*Cyberphysical security.* The use of increasingly interconnected networks and increasingly complex software embedded throughout IA air- and ground-based system elements, as well as the increasing sophistication of potential cyberphysical attacks, threaten the safety and reliability of IA systems.
  —*Decision making by adaptive/nondeterministic systems* (see Box S.5). The lack of generally accepted design, implementation, and test practices for adaptive/nondeterministic systems will impede the deployment of some advanced IA vehicles and systems in the NAS.
  —*Diversity of vehicles.* It will be difficult to engineer some IA systems so that they are backward-compatible with legacy airframes, ATM systems, and other elements of the NAS.
  —*Human–machine integration.* Incorporating IA systems and vehicles in the NAS would require humans and machines to work together in new and different ways that have not yet been identified.
  —*Sensing, perception, and cognition.* The ability of IA systems to operate independently of human operators (see Box S.6) is fundamentally limited by the capabilities of machine sensory, perceptual, and cognitive systems.
  —*System complexity and resilience.* IA capabilities create a more complex aviation system, with new interdependencies and new relationships among various operational elements. This will likely reduce the resilience of the NAS because disturbances in one portion of the system could, in certain circumstances, cause the performance of the entire system to degrade precipitously.
  —*Verification and validation (V&V).* Existing V&V approaches and methods are insufficient for advanced IA systems.
- Regulation and certification barriers
  —*Airspace access for unmanned aircraft.* Unmanned aircraft may not operate in nonsegregated civil airspace unless the Federal Aviation Administration (FAA) issues a certificate of waiver or authorization (COA).

BOX S.5
Adaptive/Nondeterministic Systems

Adaptive systems have the ability to modify their behavior in response to their external environment. For aircraft systems, this could include commands from the pilot and inputs from aircraft systems, including sensors that report conditions outside the aircraft. Some of these inputs, such as airspeed, will be stochastic because of sensor noise as well as the complex relationship between atmospheric conditions and sensor readings not fully captured in calibration equations. Adaptive systems learn from their experience, either operational or simulated, so that the response of the system to a given set of inputs varies and, presumably, improves over time.

Systems that are nondeterministic may or may not be adaptive. They may be subject to the stochastic influences imposed by their complex internal operational architectures or their external environment, meaning that they will not always respond in precisely the same way even when presented with identical inputs or stimuli. The software that is at the heart of nondeterministic systems is expected to enable improved performance because of its ability to manage and interact with complex "world models" (large and potentially distributed data sets) and execute sophisticated algorithms to perceive, decide, and act in real time.

Systems that are adaptive and nondeterministic demonstrate the performance enhancements of both. Many advanced IA systems are expected to be adaptive and/or nondeterministic, and issues associated with the development and deployment of these adaptive/nondeterministic systems are discussed later in the report.

BOX S.6
Operators

In this report, the term "operator" generally refers to pilots, air traffic controllers, airline flight operations staff, and other personnel who interact directly with IA civil aviation systems. "Pilot" is used when referring specifically to the operator of a crewed aircraft. With regard to unmanned aircraft, the FAA says that "in addition to the crewmembers identified in 14 CFR Part 1 [pilots, flight engineers, and flight navigators], a UAS flight crew includes pilots, sensor/payload operators, and visual observers, but may include other persons as appropriate or required to ensure safe operation of the aircraft" (Integration of Civil Unmanned Aircraft Systems [UAS] in the National Airspace System [NAS] Roadmap, FAA, 2013). Given that the makeup, certification requirements, and roles of UAS flight crews are likely to evolve as UAS acquire advanced IA capabilities, this report refers generally to UAS operators as flight crew rather than specifically as pilots.

—*Certification process.* Existing certification criteria, processes, and approaches do not take into account the special characteristics of advanced IA systems.

—*Equivalent level of safety.* Many existing safety standards and requirements, which are focused on assuring the safety of aircraft passengers and crew on a particular aircraft, are not well suited to assure the safety of unmanned aircraft operations, where the primary concern is the safety of personnel in other aircraft and on the ground.

—*Trust in adaptive/nondeterministic IA systems.* Verification, validation, and certification are necessary but not sufficient to engender stakeholder trust in advanced adaptive/nondeterministic IA systems.

- Other barriers
  —*Legal issues.* Public policy, as reflected in law and regulation, could significantly impede the degree and speed of adoption of IA technology in the NAS.
  —*Social issues.* Social issues, particularly public concerns about privacy and safety, could significantly impede the degree and speed of adoption of IA technology in the NAS.

The committee did not individually prioritize these barriers. However, there is one critical, crosscutting challenge that must be overcome to unleash the full potential of advanced IA systems in civil aviation. This challenge may be described in terms of a question: "How can we assure that advanced IA systems—especially those systems that rely on adaptive/nondeterministic software—will enhance rather than diminish the safety and reliability of the NAS?" There are four particularly challenging barriers that stand in the way of meeting this critical challenge:

- Certification process
- Decision making by adaptive/nondeterministic systems
- Trust in adaptive/nondeterministic IA systems
- Verification and validation

ELEMENTS OF A NATIONAL RESEARCH AGENDA FOR AUTONOMY IN CIVIL AVIATION

The committee identified eight high-level research projects that would address the barriers discussed above. The committee also identified several specific areas of research that could be included in each research project.

Recommendation. *National Research Agenda.* Agencies and organizations in government, industry, and academia that are involved in research, development, manufacture, certification, and regulation of IA technologies and systems should execute a national research agenda in autonomy that includes the following high-priority research projects, with the first four being the most urgent and the most difficult:

- ***Behavior of Adaptive/Nondeterministic Systems.* Develop methodologies to characterize and bound the behavior of adaptive/nondeterministic systems over their complete life cycle.**
- ***Operation Without Continuous Human Oversight.* Develop the system architectures and technologies that would enable increasingly sophisticated IA systems and unmanned aircraft to operate for extended periods of time without real-time human cognizance and control.**
- ***Modeling and Simulation.* Develop the theoretical basis and methodologies for using modeling and simulation to accelerate the development and maturation of advanced IA systems and aircraft.**
- ***Verification, Validation, and Certification.* Develop standards and processes for the verification, validation, and certification of IA systems, and determine their implications for design.**
- ***Nontraditional Methodologies and Technologies.* Develop methodologies for accepting technologies not traditionally used in civil aviation (e.g., open-source software and consumer electronic products) in IA systems.**
- ***Roles of Personnel and Systems.* Determine how the roles of key personnel and systems, as well as related human–machine interfaces, should evolve to enable the operation of advanced IA systems.**
- ***Safety and Efficiency.* Determine how IA systems could enhance the safety and efficiency of civil aviation.**
- ***Stakeholder Trust.* Develop processes to engender broad stakeholder trust in IA systems for civil aviation.**

FOUR MOST URGENT AND MOST DIFFICULT RESEARCH PROJECTS

Behavior of Adaptive/Nondeterministic Systems. Develop methodologies to characterize and bound the behavior of adaptive/nondeterministic systems over their complete life cycle.

Adaptive/nondeterministic properties will be integral to many advanced IA systems, but they will create challenges for assessing and setting the limits of their resulting behaviors. Advanced IA systems for civil aviation operate in an uncertain environment where physical disturbances, such as wind gusts, are often modeled using probabilistic models. These IA systems may rely on distributed sensor systems that have noise with stochastic properties such as uncertain biases and random drifts over time and varying environmental conditions. To improve performance, adaptive/nondeterministic IA systems will take advantage of evolving conditions and past experience to adapt their behavior; that is, they will be capable of learning. As these IA systems take over more functions traditionally performed by humans, there will be a growing need to incorporate autonomous monitoring and other safeguards to ensure continued appropriate operational behavior.

There is tension between the benefits of incorporating software with adaptive/nondeterministic properties in IA systems and the requirement to test such software for safe and assured operation. Research is needed to develop new methods and tools to address the inherent uncertainties in airspace system operations and thereby enable more complex adaptive/nondeterministic IA systems with the ability to adapt over time to improve their performance and provide greater assurance of safety.

Specific tasks to be carried out by this research project include the following:

- Develop mathematical models for describing adaptive/nondeterministic processes as applied to humans and machines.
- Develop performance criteria, such as stability, robustness, and resilience, for the analysis and synthesis of adaptive/nondeterministic behaviors.
- Develop methodologies beyond input-output testing for characterizing the behavior of IA systems.
- Determine the roles that humans play in limiting the behavior of adaptive/nondeterministic systems and how IA systems can take over those roles.

Operation Without Continuous Human Oversight. Develop the system architectures and technologies that would enable increasingly sophisticated IA systems and unmanned aircraft to operate for extended periods of time without real-time human cognizance and control.

Crewed aircraft have systems with varying levels of automation that operate without continuous human oversight. Even so, pilots are expected to maintain continuous cognizance and control over the aircraft as a whole. Advanced IA systems could allow unmanned aircraft to operate for extended periods of time without the need for human operators to monitor, supervise, and/or directly intervene in the operation of those systems in real time. This will require that certain critical system functions currently provided by humans, such as "detect and avoid," performance monitoring, subsystem anomaly and failure detection, and contingency decision making, are accomplished by the IA systems during periods when the system operates unattended. Eliminating the need for continuous cognizance and control of unmanned aircraft operations would enable unmanned aircraft to take on new roles that are not practical or cost-effective with continuous oversight. This capability could also improve the safety of crewed operations in situations where risk to a human operator is unacceptably high, workload is too heavy, or the task too monotonous to expect continuous operator vigilance.

Successful development of an unattended operational capability depends on understanding how humans perform their roles in the present system and how these roles are translated to the IA system, particularly for high-risk situations. Eliminating the need for continuous human oversight requires a system architecture that also supports intermittent human cognizance and control.

Specific tasks to be carried out by this research project include the following:

- Investigate human roles, including temporal requirements for supervision, as a function of the mission, capabilities, and limitations of IA systems.
- Develop IA systems that respond safely to the degradation or failure of aircraft systems.
- Develop IA systems to identify and mitigate high-risk situations induced by the mission, the environment, or other elements of the NAS.
- Develop detect-and-avoid IA systems that do not need continuous human oversight.
- Investigate airspace structures that could support UAS operations in confined or pre-approved operating areas using methods such as geofencing.

Modeling and Simulation. Develop the theoretical basis and methodologies for using modeling and simulation to accelerate the development and maturation of advanced IA systems and aircraft.

Modeling and simulation capabilities will play an important role in the development, implementation, and evolution of IA systems in civil aviation because they provide researchers, designers, regulators, and operators with insights into component and system performance without necessarily engendering the expense and risk associated with actual operations. For example, computer simulations may be able to test the performance of some IA systems in literally millions of scenarios in a short time to produce a statistical basis for determining safety risks and establishing the confidence of IA system performance. Researchers and designers are also likely to make use of modeling and simulation capabilities to evaluate design alternatives. Developers of IA systems will be able to train adaptive (i.e., learning) algorithms through repeated operations in simulation. Modeling and simulation capabilities could also be used to train human operators. The committee envisions the creation of a distributed suite of modeling and simulation modules developed by disparate organizations with the ability to be interconnected or networked, as appropriate, based on established standards. The committee believes that monolithic modeling and simulation efforts that are intended to develop capabilities that can "do it all" and answer any and all questions tend to be ineffective due to limitations in access and availability; the higher cost of creating, employing, and maintaining them; the complexity of their application, which constrains their use; and the centralization of development risks. Given the importance of modeling and simulation capabilities to the creation, evaluation, and evolution of IA systems, mechanisms will be needed to ensure that these capabilities perform as intended. A process for accrediting models and simulations will also be required.

Specific tasks to be carried out by this research project include the following:

- Develop theories and methodologies that will enable modeling and simulation to serve as embedded components within adaptive/nondeterministic systems.
- Develop theories and methodologies for using modeling and simulation to coach adaptive IA systems and human operators during training exercises.
- Develop theories and methodologies for using modeling and simulation to create trust and confidence in the performance of IA systems.
- Develop theories and methodologies for using modeling and simulation to assist with accident and incident investigations associated with IA systems.
- Develop theories and methodologies for using modeling and simulation to assess the robustness and resiliency of IA systems to intentional and unintentional cybersecurity vulnerabilities.
- Develop theories and methodologies for using modeling and simulation to perform comparative safety risk analyses of IA systems.
- Create and regularly update standardized interfaces and processes for developing modeling and simulation components for eventual integration.
- Develop standardized modules for common elements of the future system, such as aircraft performance, airspace, environmental circumstances, and human performance.
- Develop standards and methodologies for accrediting IA models and simulations.

Verification, Validation, and Certification. Develop standards and processes for the verification, validation, and certification of IA systems and determine their implications for design.

The high levels of safety achieved in the operation of the NAS largely reflect the formal requirements imposed by the FAA for verification, validation, and certification (VV&C) of hardware and software and the certification of personnel as a condition for entry into the system. These processes have evolved over many decades and represent the cumulative experience of all elements of civil aviation—manufacturers, regulators, pilots, controllers, other operators—in the operation of that system. Although viewed by some as unnecessarily cumbersome and expensive, VV&C processes are critical to the continued safe operation of the NAS. However, extension of these concepts and principles to advanced IA systems is not a simple matter and will require the development of new approaches and tools. Furthermore, the broad range of aircraft sizes, masses, and capabilities envisioned in future civil aviation operations may present opportunities to reassess the current safety and reliability criteria for various components of the aviation system. As was done in the past during the introduction of major new technologies, such as fly-by-wire flight control system and composite materials, the FAA will need to develop technical competency in IA systems and issue guidance material and new regulations to enable safe operation of all classes and types of IA systems.

Specific tasks to be carried out by this research project include the following:

- Characterize and define requirements for intelligent software and systems.
- Improve the fidelity of the VV&C test environment.
- Develop, assess, and propose new certification standards.
- Define new design requirements and methodologies for IA systems.
- Understand the impact that airspace system complexity has on IA system design and on VV&C.
- Develop VV&C methods for products created using nontraditional methodologies and technologies.

ADDITIONAL HIGH-PRIORITY RESEARCH PROJECTS

Nontraditional Methodologies and Technologies. Develop methodologies for accepting technologies not traditionally used in civil aviation (e.g., open-source software and consumer electronic products) in IA systems.

Open-source hardware and software are being widely used in the rapidly evolving universe of IA systems. This is particularly, but not uniquely, true in the active and growing community of hobbyists and prospective entrepreneurs who are developing and operating small unmanned aircraft. Separately, the automotive industry is deploying IA systems using V&V methods different from the methods traditionally used in aviation. The committee believes that there are many potential safety and economic benefits that might be realized in the civil aviation environment by developing suitable methodology that would permit reliable, safe adoption of hardware and software systems of unknown provenance. Although these issues are closely related to issues of V&V and certification, the committee believes they merit independent research attention. This might open up new opportunities for the beneficial deployment of technologies that fall outside traditional uses and applications.

Specific tasks to be carried out by this research project include the following:

- Develop modular architectures and protocols that support the use of open-source products for non-safety-critical applications.
- Develop and mature nontraditional software languages for IA applications.
- Develop paths for migrating open-source, intelligent software to safety-critical applications and unrestricted flight operations.
- Define new operational categories that would enable or accelerate experimentation, flight testing, and deployment of nontraditional technologies.

The final phase of this research project would be accomplished by the VV&C research project as it develops certification standards.

Roles of Personnel and Systems. Determine how the roles of key personnel and systems, as well as related human–machine interfaces, should evolve to enable the operation of IA systems.

Effectively integrating humans and machines in the civil aviation system has been a high priority and sometimes an elusive design challenge for decades. Human–machine integration may become an even greater challenge with the advent of advanced IA systems. Although the reliance on high levels of automation in crewed aircraft has increased the overall levels of system safety, persistent and seemingly intractable issues arise in the context of incidents and accidents. Typically, pilots experience difficulty in developing and maintaining an appropriate mental model of what the automation is doing at any given time. Maintaining an awareness of the operational mode of key automated systems can become especially problematic in dynamic situations. Advanced IA systems will change the specifics of the human performance required by such systems, but it remains to be seen if cognitive requirements for human operators will be more or less stringent. Not only are there significant issues surrounding the proper roles and responsibilities of humans in such systems, but there are also important new questions about the properties and characteristics of the human–machine interface posed by the adaptive/nondeterministic behavior of these systems. The committee believes that in many ways, these are a logical extension of the age-old questions about duties, responsibilities, and skills and training required for pilots, air traffic controllers, and other humans in the system. However, advanced IA systems may permit, or even require, new roles and radical realignment of the more traditional roles of such human actors to achieve some of the benefits envisioned. The importance of these issues cannot be overstated, and, again, realization of projected benefits of autonomy will be constrained by failure to address the issues through research.

Specific tasks to be carried out by this research project include the following:

- Develop human–machine interface tools and methodologies to support operation of advanced IA systems during normal and atypical operations.
- Develop tools and methodologies to ensure effective communication among IA systems and other elements of the NAS.
- Define the rationale and criteria for assigning roles to key personnel and IA systems and assessing their ability to perform those roles under realistic operating conditions.
- Develop intuitive human–machine integration technologies to support real-time decision making, particularly in high-stress, dynamic situations.
- Develop methods and technologies to enable situational awareness that supports the integration of IA systems.

Safety and Efficiency. Determine how IA systems could enhance the safety and efficiency of the civil aviation system.

As with other new technologies, poorly implemented IA systems could put at risk the high levels of efficiency and safety that are the hallmarks of civil aviation, particularly for commercial air transportation. However, done properly, advances in IA systems could enhance both the safety and the efficiency. For example, IA systems have the potential to reduce reaction times in safety-critical situations, especially in circumstances that today are encumbered by the requirement for human-to-human interactions. The ability of IA capabilities to rapidly cue operators or potentially render a fully autonomous response in safety-critical situations could improve both safety and efficiency. IA systems could substantially reduce the frequency of those classes of accidents typically ascribed to operator error. This could be of particular value in the segments of civil aviation, such as general aviation and medical evacuation helicopters, that have much higher accident rates than commercial air transports.

Whether located on board an aircraft or in ATM centers, IA systems also have the potential to reduce manpower requirements, thereby increasing the efficiency of operations and reducing operating costs.

In instances where IA systems make it possible for small unmanned aircraft to replace crewed aircraft, the risks to persons and property on the ground in the event of an accident could be greatly reduced, owing to the reduced damage footprint in those instances, and the risk to air crew is eliminated entirely.

Specific tasks to be carried out by this research project include the following:

- Analyze accident and incident records to determine where IA systems may have prevented or mitigated the severity of specific accidents or classes of accidents.
- Develop and analytically test methodologies to determine how the introduction of IA systems in flight operations, ramp operations by aircraft and ground support equipment, ATM systems, airline operation control centers, and so on might improve safety and efficiency.
- Investigate airspace structures and operating procedures to ensure safe and efficient operations of legacy and IA systems in the NAS.

Stakeholder Trust. Develop processes to engender broad stakeholder trust in IA systems in the civil aviation system.

IA systems can fundamentally change the relationship between people and technology, and one important dimension of that relationship is trust. Although increasingly used as an engineering term in the context of software and security assurance, trust is above all a social term and becomes increasingly relevant to human–technology relationships when complexity thwarts the ability to fully understand a technology's behavior. Trust is not a trait of the system; it is the system status in the mind of human beings based on their perception of and experience with the system. Trust concerns the attitude that a person or technology will help achieve specific goals in a situation characterized by uncertainty and vulnerability.[1] It is the perception of trustworthiness that influences how people respond to a system.

Although closely related to VV&C, trust warrants attention as a distinct research topic because formal certification does not guarantee trust and eventual adoption. Stakeholder trust is also tied to cybersecurity and related issues; trustworthiness depends on the intent of designers and on the degree to which the design prevents both inadvertent and intentional corruption of system data and processes.

Specific tasks to be carried out by this research project include the following:

- Identify the objective attributes of trustworthiness and develop measures of trust that can be tailored to a range of applications, circumstances, and relevant stakeholders.
- Develop a systematic methodology for introducing IA system functionality that matches authority and responsibility with earned levels of trust.
- Determine the way in which trust-related information is communicated.
- Develop approaches for establishing trust in IA systems.

COORDINATION OF RESEARCH AND DEVELOPMENT

All of the research projects described above can and should be addressed by multiple organizations in the federal government, industry, and academia.

The roles of academia and industry would be essentially the same for each research project because of the nature of the role that academia and industry play in the development of new technologies and products.

The FAA would be most directly engaged in the VV&C research project, because certification of civil aviation systems is one of its core functions. However, the subject matters of most of the other research projects are also related to certification directly or indirectly, so the FAA would be ultimately be interested in the progress and results of those other projects as well.

The Department of Defense (DOD) is primarily concerned with military applications of IA systems, though it must also ensure that military aircraft with IA systems that are based in the United States satisfy requirements for operating in the NAS. Its interests and research capabilities coincide with all eight research projects, especially with those on the roles of personnel and systems and operation without continuous human oversight.

[1] J.D. Lee and K.A. See, 2004, Trust in automation: Designing for appropriate reliance, *Human Factors* 46(1): 50-80.

NASA supports basic and applied research in civil aviation technologies, including ATM technologies of interest to the FAA. Its interests and research capabilities also encompass the scope of all eight research projects, particularly modeling and simulation, nontraditional methodologies and technologies, and safety and efficiency.

Each of the high-priority research projects overlaps to some extent with one or more of the other projects, and each would be best addressed by multiple organizations working in concert. There is already some movement in that direction.

The FAA has created the Unmanned Aircraft Systems Integration Office to foster collaboration with a broad spectrum of stakeholders, including DOD, NASA, industry, academia, and technical standards organizations. In 2015, the FAA will establish an air transportation center of excellence for UAS research, engineering, and development. In addition, the NextGen Joint Planning and Development Office (JPDO), which is executing a multiagency research and development plan to improve the NAS, has issued a roadmap for UAS research, development, and demonstration.[2] Efforts such as these are necessary and could be strengthened to assure that the full scope of IA research and development efforts (not just those focused on UAS applications) is effectively coordinated and integrated, with minimal duplication of research and without critical gaps. In particular, more effective coordination among relevant organizations in government, academia, and industry would help execute the recommended research projects more efficiently, in part by allowing lessons learned from the development, test, and operation of IA systems to be continuously applied to ongoing activities.

The recommended research agenda would directly address the technology barriers and the regulation and certification barriers. As noted in Table 4.1, although several research projects would address the social and legal issues, the agenda would not address the full range of these issues. In the absence of any other action, resolution of the legal and social barriers will likely take a long time, as court cases are filed to address various issues in various locales on a case-by-case basis, with intermittent legislative action in reaction to highly publicized court cases, accidents, and the like. A more timely and effective approach for resolving the legal and social barriers could begin with discussions involving the Department of Justice, FAA, National Transportation Safety Board, state attorneys general, public interest legal organizations, and aviation community stakeholders. The discussion of some related issues may also be informed by social science research. Given that the FAA is the federal government's lead agency for establishing and implementing aviation regulations, it is in the best position to take the lead in initiating a collaborative and proactive effort to address legal and social barriers.

CONCLUDING REMARKS

Civil aviation in the United States and elsewhere in the world is on the threshold of profound changes in the way it operates because of the rapid evolution of IA systems. Advanced IA systems will, among other things, be able to operate without direct human supervision or control for extended periods of time and over long distances. As happens with any other rapidly evolving technology, early adapters sometimes get caught up in the excitement of the moment, producing a form of intellectual hyperinflation that greatly exaggerates the promise of things to come and greatly underestimates costs in terms of money, time, and—in many cases—unintended consequences or complications. While there is little doubt that over the long run the potential benefits of IA in civil aviation will indeed be great, there should be equally little doubt that getting there, *while maintaining or improving the safety and efficiency of U.S. civil aviation,* will be no easy matter. Furthermore, given that the potential benefits of advanced IA systems—as well as the unintended consequences—will inevitably accrue to some stakeholders much more than others, the enthusiasm of the latter for fielding such systems could be limited. In any case, overcoming the barriers identified in this report by pursuing the research agenda proposed by the committee is a vital next step, although more work beyond the issues identified here will certainly be needed as the nation ventures into this new era of flight.

[2] JPDO, NextGen UAS Research, Development and Demonstration Roadmap, Version 1.0, March 15, 2012, http://www.jpdo.gov/library/20120315_UAS%20RDandD%20Roadmap.pdf.

JOHN K LAUBER

John K. Lauber is an independent consultant. He served as Senior Vice President and Chief Product Safety Officer for Airbus SAS in Toulouse, France until his retirement in January, 2008. Prior to assuming this position in January 2005, Dr. Lauber was Vice President – Safety and Technical Affairs for Airbus North America in Washington, DC. From 1997 to 2000 he was Vice President–Training and Human Factors for Airbus Service Company, and prior to joining Airbus was Vice President - Corporate Safety and Compliance at Delta Air Lines. In 1985, Dr. Lauber was nominated by President Reagan and confirmed by the US Senate for a term as a Member of the National Transportation Safety Board. In 1990 he was re-nominated by President Bush and confirmed for a second term at the NTSB, which he served through 1994. Dr. Lauber has also served as Chief of the Aeronautical Human Factors Research Office for NASA Ames Research Center at Moffett Field, CA, where he was instrumental in the development of advanced flight crew training concepts such as Crew Resource Management (CRM) and Line Oriented Flight Training (LOFT) that are now used by airlines around the world. From 1969 until 1972, he was a Research Psychologist at the US Naval Training Devices Center in Orlando, FL. Dr. Lauber holds a Ph.D. degree in neuropsychology from Ohio State University (1969). He is a commercial pilot, with both airplane and helicopter ratings, and is type-rated in the B727 and the A320. He has received numerous awards, including NASA's Outstanding Leadership Award, the Flight Safety Foundation/Aviation Week and Space Technology Distinguished Service Award, the Industry/Public Service Award from Air Transport World, the Boeing/Flight Safety Award for Lifetime Achievement in Aviation Safety, and most recently, the Joseph T Nall award from the International Aviation and Transportation Safety Bar Association. He has served as President of the International Federation of Airworthiness (2004-2005) and the Association for Aviation Psychology (1984). He has also served on several NASA, FAA and NRC Boards and committees, including the Workshop on Assessing the Research and Development Plan for the Next Generation Air Transportation System, and the Committee on the Effects of Commuting on Pilot Fatigue; presently he is serving as Co-chair of the NRC committee on Autonomy Research for Civil Aviation. He is a member of the MITRE Aviation Advisory Committee and is the Vice Chairman of the Puget Sound Harbor Safety Committee (Public-at-Large member), and was recently appointed to the Safety and Reliability Review Board for Carnival Cruise Lines.

Chairman SMITH. Thank you, Dr. Lauber, and Mr. Wynne.

TESTIMONY OF MR. BRIAN WYNNE, CEO AND PRESIDENT, ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL (AUVSI)

Mr. WYNNE. Chairman Smith, Ranking Member Bonamici, and Members of the Committee, thank you for this opportunity to address the importance of UAS research and development. I am speaking on behalf of the Association for Unmanned Vehicle Systems International, the world's largest nonprofit organization devoted exclusively to advancing the unmanned systems and robotics community.

AUVSI has been the voice of unmanned systems for more than 40 years and currently we have more than 7,500 members, including over 600 corporate members. As you know, UAS increase human potential allowing us to execute dangerous or difficult tasks safely and efficiently. Whether it is assisting first responders with search-and-rescue missions, advancing scientific research, or helping farmers more efficiently spray their crops, UAS are capable of saving time, money, and most importantly, lives.

However, the benefits of this technology do not stop there. It has incredible potential to create jobs and stimulate the U.S. economy as well. In 2013, AUVSI released an economic impact study which found that within the first ten years following UAS integration, the UAS industry will create more than 100,000 new jobs and have an economic impact of more than $82 billion.

The benefits I just outlined can be recognized immediately once we put the necessary rules in place to enable commercial operations. We understand that a Notice of Proposed Rulemaking for small UAS from the Federal Aviation Administration is now expected any day. It cannot come soon enough.

Establishing rules will also eliminate the current approach of regulating by exemption whereby the FAA issues exemptions on a case-by-case basis for some commercial UAS operations under Section 333 of the FAA Modernization and Reform Act of 2012.

While we are here today to discuss the critical role of UAS research and development, the fact is, we don't need a lot of additional research to permit low altitude, line-of-sight operations. A variety of commercial applications can be safely authorized right away, and we look forward to working with the FAA to get this done as expeditiously as possible.

As we look forward—as we look beyond the initial phase of UAS integration, we will need robust research to further expand access to the airspace and address some of the challenges that exist to flying beyond line of sight. Areas requiring more research include sense and avoid, command and control, and autonomous operations.

The advancement of UAS technology needs to be a collaborative effort between industry and government. While the industry is investing millions in research and the Federal Government has various research projects underway, we can all do this better and in a more coordinated fashion. The challenges we jointly face call for a national leadership initiative that places UAS integration into the National Airspace System and all relevant R&D at the top of our country's priority list. Importantly, the benefits of this research extend well beyond UAS. It will make the entire National Airspace System safer for all aircraft, manned and unmanned.

A deeper national commitment to UAS R&D has three main components. First, the industry and its government partners need a holistic research plan that coordinates all UAS research. While the FAA designated test sites went operational in 2014, too many questions about the collection, sharing, and analysis of test data remain unanswered.

Second, the federal government needs more resources to coordinate UAS research. The FAA was given $14.9 million to support its UAS research this year, which is up from previous years. However, given the scope of the research needed to advance UAS integration, we feel this figure is insufficient.

Third, the government must have a transparent intellectual property protections—provide transparent intellectual property protections. Companies on the cutting edge of UAS innovations won't participate in FAA or other governmental research activities if their intellectual property isn't safeguarded. The FAA has taken significant steps to advance the UAS integration but much work remains to be done.

AUVSI members stand ready to collaborate with the appropriate government agencies to accelerate the needed R&D efforts that will allow for the safe integration of UAS into the national air space system.

Thank you again for this opportunity and I look forward to questions.

[The prepared statement of Mr. Wynne follows:]

AUVSI
ASSOCIATION FOR UNMANNED
VEHICLE SYSTEMS INTERNATIONAL

PREPARED STATEMENT OF BRIAN WYNNE
PRESIDENT AND CEO, ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

U.S. House of Representatives
Committee on Science, Space and Technology
"Unmanned Aircraft Systems (UAS) Research and Development"
January 21, 2015

Chairman Smith, Ranking Member Johnson, and members of the committee, thank you very much for the opportunity to address the importance of UAS research and development (R&D). I am speaking on behalf of the Association for Unmanned Vehicle Systems International (AUVSI), the world's largest non-profit organization devoted exclusively to advancing the unmanned systems and robotics community. AUVSI has been the voice of unmanned systems for more than 40 years, and currently we have more than 7,500 members, including over 600 corporate members.

As you know, UAS increase human potential, allowing us to execute dangerous or difficult tasks safely and efficiently. Whether it is assisting first responders with search and rescue missions, advancing scientific research or helping farmers more efficiently spray their crops, UAS are capable of saving time, saving money, and, most importantly, saving lives. However, the benefits of this technology do not stop there; this technology has incredible potential to create jobs and stimulate the U.S. economy as well.

In 2013, AUVSI released an economic impact study[1] which found that, within the first 10 years following UAS integration, the UAS industry will create more than 100,000 new jobs and more than $82 billion in economic impact. I would encourage everyone to take a look at it if you haven't already, as we even break out our figures state-by-state.

The benefits I just outlined can be recognized immediately, once we put the necessary rules in place to enable commercial operations. We understand that a notice of proposed rulemaking (NPRM) for small UAS from the Federal Aviation Administration (FAA) is now expected any day,

[1] www.auvsi.org/econreport

and it cannot come soon enough. Industries from agriculture and real estate to filmmaking and oil and gas are clamoring to use this technology. But until rules are created, these industries and many others will remain largely grounded. And for every day that UAS integration is delayed, the U.S. stands to lose $27.6 million in potential economic impact, according to AUVSI's economic impact study.

Establishing rules will also eliminate the current precedent of "regulating by exemption," whereby the FAA issues exemptions on a case-by-case basis for some commercial UAS operations under Section 333 of P.L. 112-95, the "FAA Modernization and Reform Act of 2012."

While we're here today to discuss the critical role of UAS research and development, the fact is, we don't need a lot of additional research to permit low-altitude, line of sight operations, which is generally what we expect the first phase of the integration will allow. These are low-risk flights in airspace where manned aircraft generally do not fly. A variety of commercial applications can be safely authorized right away, and we look forward to working with the FAA to get this done as expeditiously as possible.

As we look beyond the initial phase of the UAS integration, we will need robust research to further expand access to the airspace and address some of the challenges that exist to fly beyond-line-of-sight, for example. Current research needs include:

- Sense and avoid – How will unmanned aircraft that fly beyond line-of-sight sense and avoid other aircraft, both manned and unmanned?

- Command and control – What is the appropriate command and control – also known as "C2" – link between an unmanned aircraft and its control station? This includes determining the proper radio spectrum for UAS applications and the level of security needed to protect against jamming, spoofing and other attempts to interfere with UAS.

- Autonomous operations – How can UAS one day operate autonomously within the NAS and how will autonomous UAS interface with the air traffic control system?

The advancement of UAS technology, as with other technologies, will need to be a collaborative effort between industry and government. The industry is already leading the way, investing millions into R&D. All of us can become smarter faster if the industry and government work closely together – and the collaboration will also save the government from having to expend significant resources to conduct the necessary research itself.

As just a few examples of current industry research, companies like Airware are developing software that will interface with NASA's UAS traffic management (UTM) system and introduce new levels of safety and reliability in commercial operations. Lockheed Martin is working to make long-range UAS operations cleaner, greener and quieter. The company has developed a 20-pound propane fuel-cell powered aircraft that decreases carbon and lead emissions while virtually eliminating engine noise.

I would also like to credit our government partners for their role in advancing UAS research and development. While the small UAS rule has been delayed, the FAA has made some notable progress with regard to UAS research. In November 2013, the agency released its roadmap for UAS integration, which identified areas warranting further research, including sense and avoid, command and control and human factors. A month later, in December of 2013, the agency designated six UAS test sites to help to collect the data needed to safely and responsibly integrate UAS into the NAS. As of last fall, all of the test sites are operational, and the FAA continues to approve certificates of authorization for companies to use these sites.

While the industry is investing millions in research, and the federal government has various research projects underway, we can all do this better, and in a more coordinated fashion. The challenges we jointly face call for a national leadership initiative that places UAS integration into the NAS – and all relevant R&D – at the top of our country's priority list.

A deeper, national commitment to UAS R&D has three main components – a comprehensive industry-government UAS research plan, more resources for the federal government to coordinate UAS research and intellectual property protections for the companies that participate in UAS R&D.

1. First, the industry and its government partners need a holistic research plan that coordinates all UAS research. While the test sites are operational and each has been given specific areas to research, too many questions remain unanswered:
    - What type of data will the test sites collect, and in what manner?
    - Where will the data go, how will the data be used?
    - How will the soon-to-be-designated UAS Center of Excellence fit into the picture?
    - How will all of this be incorporated with NextGen?
    - How does NASA's UTM system – which could potentially manage flight approvals and aircraft deconfliction – fit into all of this?

Our industry wants to work with federal partners to help provide the answers and create a holistic research plan. In concert with better planning, it should be clarified who coordinates the various efforts, and at what level.

2. Second, the federal government needs more resources to coordinate UAS research. To be clear, the industry expects to shoulder the lion's share of the cost for UAS R&D, and the industry is already spending millions. But the FAA needs more resources to coordinate all of the various research efforts. The FAA was given $14.9 million (courtesy of a $6 million congressional increase) to support its UAS research this next year, which is up from previous years. However, when compared to other federal research efforts, this figure is insufficient. For example, the FAA's funding pales in comparison to the more than $50 million NASA received in Fiscal Year 2015 for UAS R&D in the Integrated Aviation Systems Program and UTM program under the Airspace Operations and Safety Program. UAS integration into the NAS should be a top national priority, and the relevant federal agencies and departments should have the financial resources commensurate with the task at hand.

3. Third, the government must have transparent intellectual property (IP) protections. Companies on the cutting edge of UAS innovations won't participate in FAA or other governmental research activities if we cannot guarantee that their intellectual property will be protected. Everyone stands to benefit from robust IP protections. Companies that are investing millions into new technologies would be encouraged to continue innovating. The FAA and other stakeholders would gain valuable data to guide the integration. There should be clarity about the government's responsibilities and obligations to protect proprietary data and processes. There also need to be clear IP policies from the entities designated to perform R&D functions on behalf of the government, such as the six federally designated test sites. These policies and protections would ease the concerns of manufacturers, software developers and other companies on the cutting-edge of UAS technology, and encourage them participate in UAS R&D.

The FAA has taken significant steps to advance the UAS integration, but much work remains to be done. If we are to fully realize the tremendous benefits of UAS technology, we need a national commitment supporting its advancement, including a comprehensive public-private research plan, more resources for the government to coordinate research, and intellectual property protections for the industry to participate.

AUVSI members stand ready to collaborate with the appropriate government agencies to accelerate the needed R&D efforts that will allow for safe integration of UAS into the NAS.

Thank you again for the opportunity to speak today. I look forward to answering any questions the committee might have.

AUVSI
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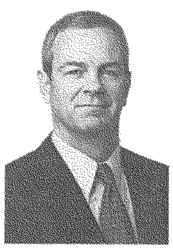

Brian Wynne

President and CEO
Association for Unmanned Vehicle Systems International

Brian Wynne is the President and CEO of the Association for Unmanned Vehicle Systems International (AUVSI), a position he began on January 12, 2015.

He came to AUVSI from the Electric Drive Transportation Association (EDTA), a post he held since April 2004. The organization promotes battery, hybrid, plug-in hybrid and fuel cell electric vehicles and infrastructure.

The Association for Unmanned Vehicle Systems International is the world's largest nonprofit organization dedicated to the advancement of unmanned systems. AUVSI represents more than 7,500 members from over 60 allied countries and 2,700 organizations involved in the fields of government, industry and academia.

Mr. Wynne brings in-depth experience in transportation and technology applications gained in leadership roles with trade associations and public-private partnerships. He has previously served as Senior Vice President for business and trade at the Intelligent Transportation Society of America (ITSA). Prior to that role, he led a global technology association as CEO of Association for Automatic Identification and Mobility (AIM). Mr. Wynne started his career as a legislative assistant to U.S. Senator Charles Percy and has served on several not-for-profit boards.

He holds a bachelor's degree from the University of Scranton, a master's degree from the School of Advanced International Studies at Johns Hopkins University, and was a Fulbright Scholar at the University of Cologne in Germany.

Updated January 2015

Chairman SMITH. Thank you, Mr. Wynne.

Let me say to Members, we have had a series of votes just called. We are going to try to finish our witness testimony before we go vote and then we will resume the hearing immediately after the last vote.

So we will go now to Mr. Guinn, who I think has the most fun job of the day, and you are recognized for your testimony.

TESTIMONY OF MR. COLIN GUINN, CRO, 3D ROBOTICS, SMALL UAV COALITION MEMBER

Mr. GUINN. Thank you very much, Chairman Smith and Ranking Member Bonamici. Thank you, Committee, here for having me. It is an honor to come speak to you guys about something that I am very passionate about.

And I think what I would like to do is just talk to you guys about kind of the stalemate that we are in today between, you know, no one is going to disagree to the benefits that UAS can provide to the economic, the efficiencies in business, the job creation, the revenue that can come into our country, and then at the same time, nobody is going to argue with the fact that we must be extremely thoughtful, considerate, and careful in integrating these systems into the national airspace because obviously the FAA has a second-to-none safety record and there is no question that we must maintain that.

So I guess for me today I would like to just talk a little bit about where can we start, what can we do now that allows us to bridge that gap between the chicken and the egg. So, you know, we have the FAA test sites, which are great, but at the same time it is a little bit of testing in a bubble. And to ask research and development companies to rapidly iterate their technology and have to every couple months figure out a time where they can get into a test site, travel with their entire engineering team, you know, did they accidentally leave the spectrum analyzer at the lab, now someone has to fly home to get that. You know, so it is—it doesn't allow for very rapid innovation, which is obviously not going to let us keep up with the other countries in this world that are absolutely reaping the rewards and the benefits of this technology.

Additionally, we must have—we must—testing in test sites is not necessarily going to give us the necessary data and the logged flight hours to figure out what the hurdles are, what the roadblocks are to safely integrating these systems into the NAS, and so I think what can be done in the meantime, and as you will see here—this is something I am going to talk about today—when it comes to very small systems, this is the Parrot Bebop, which weighs just over a pound and is actually an incredibly advanced UAV or drone.

And so what I wanted to talk about is I think we can start somewhere and instead of having to regulate and integrate 20-, 30-, and 40-pound systems or 50-pound systems into our national airspace all at one time, what I would at least bring to discussion is a possibility of taking very small lightweight systems, as many other countries in the world have done. You know, there is somewhat of a precedence around sub-2 kilogram systems because they carry the least amount of kinetic energy, they have the least risk-based approach that—the least chance of causing any harm, and so—all right. We all saw a drone fly. Fantastic. Incredible.

Chairman SMITH. I was hoping you would fly it over the whole room, not just in one location.

Mr. GUINN. Well, you said no haircuts. We could have——

Chairman SMITH. I said no haircuts earlier but I—he could have done it——

Mr. GUINN. We could have arranged that. No—I—so the point that I want to make today is that if we start somewhere, as many other countries have, with the smallest, lightest weight systems, we are basically using a proportional and risk-based system for regulation so that by integrating today or as soon as possible for commercial use small, sub-2 kilogram systems, we can now start gathering thousands of hours of flight time figuring out what are the issues when you are actually using these things in the national airspace, not just these FAA test sites. And I think that is something that could potentially bridge our gap while we are figuring out, okay, now how do we integrate the next heavier class? Great, we learned a lot from these little tiny ones——

Chairman SMITH. Um-hum.

Mr. GUINN. —and while we are learning a lot from the little tiny ones, we are capturing the vast majority of the economic benefit of commercial UAVs that can do power line inspection, that can have geo-fences set up, they can return to their home location and land themselves. They log every parameter of the flight in real time. These small systems can be saving wildfire firefighters' lives, they can be saving the lives of people that are flying full-scale helicopters over power lines simply to take pictures of the power lines. They can be used for a myriad of situations where they can save human lives.

So that is all I wanted to say today is that, you know, maybe we can start somewhere, integrate the lightweight systems, use that for data collection so that we can see what happens in the real world, and also satisfy some of that economic benefit that all those other countries are experiencing right now.

[The prepared statement of Mr. Guinn follows:]

Testimony of Colin Guinn
Chief Revenue Officer, 3D Robotics
Member, Small UAV Coalition

Before the House Committee on Science, Space, and Technology

"Unmanned Aircraft Systems (UAS) Research and Development"

January 21, 2015

Chairman Smith, Ranking Member Johnson, and members of the Committee, thank you for inviting me to testify on UAS Research and Development. My name is Colin Guinn, and I am the Chief Revenue Officer of 3D Robotics, North America's largest consumer drone manufacturer. We are known for pioneering advanced and easy-to-use consumer drone technology, and for the Pixhawk, the world's most popular universal autopilot platform. We are also a founding member of the Small UAV Coalition.

Today I'd like to focus my testimony on four points: (1) UAS research and development is important not only for integration of UAVs into the NAS, but for the U.S. economy as a whole; (2) Although the test sites are helpful, they are not enough; (3) the FAA must act quickly to maintain American competitiveness; and (4) allowing very small UAVs to operate commercially now will also serve as R&D for other UAVs.

I. Research and development for small UAVs is important not only for integration into the NAS, but for the U.S. economy as a whole.

3DR is at the forefront of research and development for small UAVs. For example, our autopilot is unlike any other on the market, in that it collects all of the information from every flight and saves it to the cloud. This is important because it helps us improve parts of operation that we may have not otherwise tested. We're working with NASA on the Urban SkyWays project, which will be the first end-to-end demonstration of a commercial drone network through four major cities. We're also partnering with NASA to develop an air traffic management system for UAVs, and developing new technology to help UAVs avoid objects. Finally, we've partnered with Intel on an amazing project to develop microcomputers. All of these projects are critical, because as we solve these technical issues, we will be able to speed up the safe integration of small UAVs into the national airspace.

This R&D has already produced enormous benefits. When our colleagues discover new sensors for precision agriculture, American farmers are able to increase their crop yields. Improvements in UAV platforms have benefitted the oil and gas industry, which uses drones to inspect live flare stacks. At 3DR, our drones have been used to gather data for ecological research and improve accuracy of search and rescue missions. As we improve and find new uses for our drones, we're creating efficiencies that will help us work smarter, save resources, and live sustainably.

II. Although the test sites are helpful, they are not enough.

Right now, American companies are not allowed to conduct research and development for UAS outside on their own property. Congress was well-intentioned in setting up the UAS Test Sites for this purpose, and we believe that the sites could be helpful for some companies. However, they are not enough to support our nation's entire UAV industry. First, for many smaller start-ups, they are cost-prohibitive. Second, some of our colleagues are iterating new platforms every few weeks – they don't have the time to navigate the bureaucracy of the test sites. Finally, companies don't want to move their entire teams of engineers to these test sites. Just like in other industries, UAS engineers want to test in their own labs.

These significant restrictions on R&D, as I'm sure you understand, are crippling. American companies are faced with either spending the time and money to operate at the UAS Test Sites, operating in the shadows, or moving R&D overseas. It is no small wonder that the epicenters of UAV research and manufacturing are now in France and China. Today, the FAA should allow companies to conduct R&D activities outside on their own property.

III. The FAA must act quickly to maintain American competitiveness.

This brings me to my third point. In order for the UAS industry to flourish, we have to have a sensible and risk-based regulatory system to support it. We hope the long-awaited sUAS rulemaking will open up R&D opportunities, but the pace of this rulemaking is just too slow to maintain American competitiveness. We believe the FAA has authority to authorize such R&D now on a broad scale, whether under section 333 (of the FAA Modernization and Reform Act of 2012) or its existing exemption authority (in section 44701(f) of the Federal Aviation Act).

IV. Allowing very small UAVs to operate commercially now will also serve as R&D for other UAVs.

My fourth point is that FAA can jump-start R&D by allowing the smallest UAVs to begin operating in the national airspace. R&D should not be relegated to test sites or testing at one's own facilities. And far too much R&D up to now has concentrated on large UAVs that are intended to operate in controlled airspace. Operating very small UAVs in the open environment –for commercial purposes in addition to testing – will also provide essential data for the safe development of other small UAVs. The U.S. can follow other countries such as France and Canada and expedite integrating the smallest UAVs – under 2 kilograms (about 5 pounds) to operate in the national airspace. With their very light weight, they pose a negligible risk should there be a collision with another aircraft or a person. And there are many commercial uses for the smallest UAVs, so that experience gained from these operations – with geo-fencing, fail-safe and go home capabilities, among other safety features – will provide lots of data to inform the development of other small UAVs up to 55 pounds, as well as larger UAVs.

Conclusion

Thank you again for inviting me to testify today. 3DR is proud to continue raising the bar for UAV technology and investing our energy in research and development. We need to work together in developing technology and regulations to quickly and effectively integrate sub-2 kg UAVs into the national airspace. I look forward to answering any questions.

Colin Guinn, CRO 3D Robotics

Colin joined 3D Robotics in 2014 after co-founding and serving as CEO of DJI North America, where he helped develop the first ready-to-fly consumer drone (the Phantom). He's one of the most interviewed experts on UAV technology in the world, and has been featured at premier industry conferences and in countless top-rated publications and newscasts, including *60 Minutes*, *TechCrunch*, *Fox* and *Fast Co*. At 3DR he is responsible for sales and marketing, strategic product development, and maintaining his role as a prominent advocate for the company and the industry at large.

Colin's uniqueness to the aerial cinematography world is that he understands the technology in two dialects: the granularity necessary to communicate to an engineer, and the simple, digestible language that's interesting to the average consumer. His excitement for this technology is palpable and contagious and puts UAVs in the light they deserve: powerful tools that help humanity in myriad ways, from sustainability to the creative arts to agriculture to capturing family vacations.

Colin has been foundational in propelling the global consumer drone market. His passion for UAVs and aerial cinematography began nearly a decade ago when he created a company that specialized in producing aerial photography marketing materials for luxury homebuilders. At that time he designed and built his own custom radio-controlled helicopters and specialized gimbals. This work led to the creation of his aerial cinematography company Avean Media, where Colin grew into one of the world's top UAV flight and design experts.

He lives with his family in Austin, Texas.

Chairman SMITH. Thank you, Mr. Guinn. Good suggestions.
Dr. Hansman.

TESTIMONY OF DR. JOHN R. HANSMAN, T. WILSON PROFESSOR OF AERONAUTICS AND ASTRONAUTICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

Dr. HANSMAN. Chairman Smith, Ranking Member Bonamici, Members of the Committee, thanks for the opportunity to be here today.

As you can see—it is sort of hard to follow the demo, but as you can see, UAVs are actually one of the most exciting areas in aerospace and particularly aeronautics today. You know, the same technologies that we use to enable these cell phones, the miniaturization of processing sensors, coupled with flight control algorithms, et cetera, enable incredible power in very—you can see in the stability of the vehicle high performance in very small packages.

Today in my office back at MIT in the basement I have two teams of students building new UAV concepts, so it is a real exciting area.

The thing to remember about UAV integration in the NAS is that there is a huge spectrum of UAV sizes ranging from a few grams up to, you know, hundreds of thousands of pounds. And it is important to note that one size isn't going to fit all. We have to have different concepts of operation for integrating different types of UAVs into the NAS.

I will break it into just four categories. We have the small UAS operating at low altitudes within line of sight of the operator. We actually know how to do that today. We have been doing it for years and we really just need to get going and get that enabled. That is what you have heard from some of this. But there are multiple other categories. You have high altitude UAVs, sort of the typical UAVs the military will want to operate. We also sort of know how to do that. We sort of developed operating rules. They are normally operating above where most of the manned airplanes are. It is not too tough a problem.

The two more challenging areas are small UAVs that are being operated beyond the line of sight of the operator so you don't have the visual feedback. You are going to rely more on algorithms. You are going to rely more on the technology. And the toughest area is actually UAVs whose missions require that they operate in the same airspace that manned airplanes need to operate. And frankly, we don't have good what we call concepts of operations for either the small UAS beyond line of sight or the larger UAS operating in that airspace.

There has been so much focus on the small UAS that we really haven't done the research to enable the concepts of operation. And you need concepts of operation in order to guide the research, to develop the standards, to work out the rules, to figure out the human factors. You know, for example, if we have UAVs operating as IFR aircraft in the system today, how does the air traffic controller think about that UAV? How do they communicate with them? Do they call them—do they call the operator up on a landline? Is there some relay? What happens when there is a loss of communication? How do they think about it? And it is actually a tough thing for the FAA because there are a lot of policy issues. For example, who do you give priority to? Do you give priority to the manned airplane or do you give the priority to the UAV airplane? While we would normally say give it to the manned airplane but what if the UAV airplane is doing a life-critical mission and the manned airplane is on a sightseeing tour? Who should have priority? So there are a lot of questions here.

So most of my comments are in my prepared remarks but I would just say I think the takeaway is that we really need to develop the con ops and we are really behind the eight ball. We really haven't been working the harder problems of the fully integrated UAS and some of these issues of the beyond line of sight. I would note that I am encouraged by, for example, the work that NASA has started on UTM concept, beyond line of sight, so they are starting to attack some of those problems.

So thank you for the opportunity.

[The prepared statement of Dr. Hansman follows:]

Statement of

R. John Hansman, Jr.
T. Wilson Professor of Aeronautics & Astronautics and Engineering Systems
Director, MIT International Center for Air Transportation
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before the

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

January 21, 2015

Chairman Smith, Ranking Member Johnson and Members of the Subcommittee:

Thank you for the opportunity to comment on the status and challenges of integrating Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS). I am a Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology and the Co-Chair of the FAA Research and Development Advisory Committee (REDAC). The REDAC is a Congressionally mandated committee which advises the FAA Administrator on research and development. I should note that while my testimony is informed by my participation on the REDAC, due to time constraints my comments have not been coordinated with my REDAC colleagues so I am speaking as an individual today.

The emergence of UAS technologies and potential operations are arguably the most exciting and innovative areas in aerospace today. The confluence high computational power and sensors in very small packages such as those in modern "smart phones" coupled with advanced flight control algorithms have opened the door to a broad spectrum of highly capable UAVs. From an aircraft design point of view entirely new performance regimes and configurations become possible when we don't have to worry about the limitations of the human occupants and their life support systems.

The spectrum of emerging UAVs is quite vast. Ranging from very small and maneuverable UAVs weighing only a few grams to large scale military UAVs such as the Predator and Global Hawk. From a technical point of view even large scale transport category UAVs are feasible today.

When considering integration of UAS into the NAS it is important to consider the diversity of potential UAS vehicles and applications as it is clear that a "one size fits all" approach will not work due to broad range of vehicle size, capability and types of potential UAS in the NAS operations.

For the purposes of this discussion I will identify 4 different operating categories where distinct Concepts of Operation (Con-Ops) and standards are required. For each of these operating categories it is necessary to develop a Con-Ops that allow safe UAS integration into the NAS. When considering UAS safety the traditional considerations of occupant safety which dominate requirements for manned aircraft do not apply. Instead the secondary considerations of avoiding injury or damage to property on the ground ("ground risk") or risks from midair collisions ("midair collision risk") drive the hazard analysis and system design.

Small UAS operating at low altitude in Line of Sight of the Operator (SUAS-LOS)

The easiest category to develop a Con-Ops for NAS integration is the Small UAS (SUAS) operating within Line of Sight (LOS) of the operator. Midair collision risk is minimized due to the low density of manned aircraft at low altitudes coupled with the UAS operators visual back up to land or avoid infrequent low altitude aircraft such as a Medevac helicopters. Ground risk is minimized by the small size of the vehicles and operator monitoring. New technologies such as "electronic bumpers" are being developed to improve the operators capability.

This category is the focus of the long anticipated and inexplicably delayed SUAS rule. We have a well established Con-Ops and years of experience based on radio controlled model aircraft which can, and should, provide the basis for this operating category. The delay in regulation has resulted in a somewhat perverse status where well informed, trained, responsible commercial and research operators are not allowed to fly while hobbyists with sometimes poor knowledge and limited experience are free to operate, often identical, SUAS.

Small UAS operating at low altitude Beyond Line of Sight of the Operator (SUAS-BLOS)

For the second category when SUAS are operated Beyond LOS of the operator the Con-Ops and standards development are much less mature. The ground collision risk remains relatively low, particularly for low mass vehicles. However, controlling the flight trajectory to avoid people or property will require some level of autonomy or a high quality communications system if the operator needs to be part of the control loop. In addition, although SUAS operations are below the majority of manned operations, some sort of surveillance or traffic management will be required to monitor for the possible presence of manned aircraft. There are currently many open research questions in this area. The appropriate Con-Ops will depend on the technical capabilities of the vehicles as well as standards and performance of the communication and surveillance systems employed. For example, can current cell phone communication networks be employed to give communication and surveillance beyond line of sight, what is the appropriate level of autonomy for SUAS-BLOS?

Until recently there has been very little research in this domain by either NASA or the FAA. The current NASA efforts in Unmanned Traffic Management are starting to address this issue but the efforts are in the embryonic stage. There has been some development by the DOD and the private sector but a well accepted Con-Ops has yet to emerge.

High Altitude UAS

The High Altitude UAS category has received significant attention due to the interest of the DOD and the Con-Ops are more mature here. These vehicles are large enough and of sufficient value to justify sophisticated, heavy, power hungry avionics and high bandwidth satellite communications. Such aircraft spend most of the time at altitudes or locations in which they can be segregated from manned aircraft and only need to have a method to transit to their operating altitudes or locations. They must be able to satisfy the "sense and avoid" requirement to replace the vision of the human pilot and this has been the focus of much research in UAS either through onboard systems or external surveillance. It is unclear if the approaches developed for these relatively large, expensive systems will be applicable to smaller UAS due to size, cost and power limitations.

UAS Integrated with Manned Aircraft

The most challenging category of UAS operations are those where the UAS must routinely operate in the same airspace as manned aircraft. Many of the most valuable UAS applications such as emergency and disaster response will require that the vehicles operate near airports or in locations and altitudes where manned aircraft also operate. Clearly in this category the risks associated with mid air collision are higher due to the close proximity of the manned and UAS aircraft. This risk must be mitigated by procedural and/or technical solutions. While this is the most difficult problem it is also the one that has received the least attention. To my knowledge there is no clear Con-Ops that has been defined for this category of operations. There are an enormous number of open questions on how these operations will occur.

As an example, for Instrument Flight Rule (IFR) operations it is possible to consider Con-Ops where the UAS operates just like a manned IFR aircraft with additional communication systems. Even in this domain, it is unclear how controllers and the pilots of the manned aircraft will interact with the UAS particularly in non-normal events such as when the communication link to the UAS fails.

While full integration of UAS operating in the same airspace as manned aircraft may be further away and thus may have received less attention, it is a much more challenging environment than the other categories I have discussed above. We should be conducing the research now that will support developing the Con-Ops and standards for the future.

I will comment briefly on the specific questions you have asked me to address.

1. **What are the high priority and emerging issues associated with aviation safety resulting from the integration of Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS)?**

The fundamental issue which has emerged is the lack of clear Con-Ops for the various UAS operating categories to define the research requirements as well as the technical standards, procedures and regulations which would enable timely UAS integration in the

NAS. As I indicated above there must be multiple Con-Ops to account for the diversity of UAS vehicles and operating environments.

Many policy issues have also emerged. The integration of UAS into the NAS is very challenging for the FAA. The current system is exceptionally safe and the FAA is charged with maintaining and improving safety. Adding new types of vehicles and operations to the system adds new risk areas. There are legitimate policy questions on how to mitigate these risks and enable UAS access. Similarly there are policy issues about the relative importance of UAS vs. manned aircraft. Finally there are emerging concerns regarding the privacy implications of extensive UAS operations in the NAS.

From a research and technical perspective there are a number of generic issues which have emerged independent of the specific Con-Ops which are decided on. Some of these include:

- Communication architectures for low altitude UAS operations
- Development of autonomous systems for UAS operations
- Low cost, low power "detect and avoid" systems for aircraft and ground objects
- Applicability and limitations of ADS-B for UAS operations
- Interaction of ATC controllers with UAS systems and operators
- Loss of communication protocols
- Spectrum management
- UAS operator training requirements
- Emergency Procedures and non-normal operations
- Low altitude operations safety
- Certification of non-deterministic software
- Cyber security issues specific to UAS (e.g. Command uplink integrity)
- Alternatives to detect and avoid
- Ground risk based airworthiness standards for UAS

In considering the Con-Ops definition and technical issues it will be important to leverage the technical and operational capabilities of NextGen. For example, ADS-B should provide the basis for surveillance in UAS Con-Ops. In order to fully exploit ADS-B for SUAS, it will be necessary to develop standards for small, low power ADS-B systems and deal with potential issues of frequency congestion. System Wide Information Management (SWIM) will provide a mechanism for coordinating UAS and manned aircraft operations. Other areas such as Data Com may require UAS and SUAS specific solutions.

As a final issue, the delay in developing reasonable rules and inconsistencies in current guidance coupled with proliferation of low cost, highly capable vehicles has resulted in an effectively unregulated environment in the SUAS arena. In most cases the operations are responsible but there have been some cases of ill considered operations and some highly publicized interactions with manned aircraft or reported risks on the ground.

2. What does the FAA need to know before it can start initial UAS rulemaking and how does that knowledge relate to the high priority and emerging safety issues

you identified above? Are current plans and supporting projects for UAS research defined in such a way that they can provide FAA with the prioritized information conducive to making timely issuance of UAS rules? If not, what specific research needs to be done, how long will it take, and what is your estimate of the resources that are required?

The answer to this question varies by the category of UAS operations. For SUAS-LOS and probably for High Altitude UAS the FAA has what it needs to know to start initial UAS rulemaking. For the other categories of SUAS-BLOS and Integrated UAS there does not appear to even be an agreed upon baseline Con-Ops on which to base the research to support rulemaking.

From what I am aware of, the current plans and supporting projects for UAS research are not defined in such a way that they can provide the FAA with the prioritized information conducive to making timely issuance of UAS rules.

The FAA first needs to conduct research to inform decisions regarding Con-Ops and standards development. Once these Con-Ops and standards are defined this will provide the basis for prioritized research requirements to support the implementation of the Con-Ops.

I am not in a position to give a reliable estimate of the resources required but it is clear that the level of resources that the FAA has been able to devote to UAS integration in the NAS have not been sufficient to maintain the rate of progress that the Congress and the public have expected.

3. **How could a collaborative research effort combining federal, academic, and private sectors be leveraged to help fill research gaps? What organizational models could Congress consider for such a collaborative effort?**

I am encouraged by some recent activities by NASA and the FAA. The nascent NASA Unmanned Traffic System program has stimulated significant interest in industry and academia and is starting to work on key questions regarding SUAS-BLOS Con-Ops. The NASA effort should be encouraged and expanded to enable stronger participation by academia and industry and addressing a broader set of issues.

On the FAA side I am pleased that the FAA is in process to develop a Center of Excellence in UAS. The COE model is quite effective at developing collaboration between federal, academic and private sector researchers. It will be critical for the FAA to define research needs for the COE. This should include both research to support Con-Ops development and research to support implementation of those Con-Ops which have been defined.

I would note that is important to find ways to engage the DOD UAS research community in the FAA and NASA efforts. The DOD is one of the principal operators and has significant operational experience and research experience to bring to the table

I am less confident in the importance of the FAA test sites. There is a need for some experimental testing capability but the current 6 test sites appear to exceed the near term need. Selecting and managing the sites has been a drain on limited FAA UAS resources. It will be important to clearly define testing requirements to support Con-Ops development and implementation which should be the basis of a focused approach to the allocation of resources to test sites and the rapid approval of test plans.

Short Biography for

R. John Hansman

R. John Hansman is the T. Wilson Professor of Aeronautics & Astronautics at MIT, where he is the Director of the MIT International Center for Air Transportation. He conducts research in the application of information technology in operational aerospace systems. Dr. Hansman holds 7 patents and has authored over 250 technical publications. He has over 5900 hours of pilot in-command time in airplanes, helicopters and sailplanes including meteorological, production and engineering flight test experience. Professor Hansman chairs the US Federal Aviation Administration Research Engineering & Development Advisory Committee (REDAC). He is co-director of the national Center of Excellence in Aviation Sustainability Center (ASCENT). He is a member of the US National Academy of Engineering (NAE), is a Fellow of the AIAA and has received numerous awards including the AIAA Dryden Lectureship in Aeronautics Research, the ATCA Kriske Air Traffic Award, a Laurel from Aviation Week & Space Technology, and the FAA Excellence in Aviation Award.

Chairman SMITH. Okay. Dr. Hansman, thank you for those comments.

The Committee is going to stand in recess until after the series of three votes, and when we return, we will go immediately to our questions. And sorry for the inconvenience. I hope we are back within about 30 minutes if you all want to take a break until then.

[Recess.]

Chairman SMITH. The Science Committee will reconvene and we will now begin our questions, and I will recognize myself for that purpose.

Dr. Waggoner, Mr. Williams, let me direct my first question to you all, which is this: What is a realistic deadline for integrating the drones into the National Airspace System? I mentioned in my opening statement that it appears that the deadline has slipped but what can drone users and even the American people, the wider audience, what is a realistic deadline for that integration? Dr. Waggoner and then Mr. Williams.

Dr. WAGGONER. So, Chairman, I would answer that right now we do have a level of integration, so as—for public aircraft they are flying every day. We are—you know, NASA does research but we are also users and we have unmanned aircraft. So for civil applications, we are working very closely with the FAA and RTCA 228 to verify and validate these key technology barriers, the sense-and-avoid, the radio communications——

Chairman SMITH. Right.

Dr. WAGGONER. —the displays for the ground control stations to allow the FAA to determine these minimum operational performance standards.

Chairman SMITH. Okay. And, Mr. Williams, when might we expect the FAA to propose some rules?

Mr. WILLIAMS. Well, the FAA is working closely with our administration partners in the rulemaking process, and we are doing everything we can to get that small unmanned aircraft rule out. But our main focus is to get it right.

Chairman SMITH. Okay.

Mr. WILLIAMS. You know, we—the rulemaking process is deliberative——

Chairman SMITH. I understand. When do you think you might get that out?

Mr. WILLIAMS. I at this point can't give you a firm deadline. We are still working on the internal discussion——

Chairman SMITH. Do you have a goal in mind? I mean you have got a lot of people across the United States waiting and do you have any kind of working deadline or working goal?

Mr. WILLIAMS. Our goals are to get it out as quickly as we can as long as we get it out right——

Chairman SMITH. Okay. Is it likely to be this year or next year?

Mr. WILLIAMS. I can't speculate. My own personal hope is that we get it out as soon as possible, but, you know, it has got to go through the regulatory process that has been put in place by Congress and we are working our way through that.

Chairman SMITH. Okay. And I am going to pressure you one more time. You are slipping off my question here. How long does the regulatory process normally take in a situation like this?

Mr. WILLIAMS. Well, you have got to understand this is a very complex rulemaking. You are having——

Chairman SMITH. Never mind. Never mind. I can tell I am not going to get the answer that I was hoping for but we will take your word for expediting the process as much as we can.

Dr. Lauber, you mentioned this in your testimony a while ago, but what technology is needed to be prioritized before the NAS integration? What are the——

Dr. LAUBER. Well, I refer to what we believe is probably the highest, and I think a couple of the other witnesses also mentioned the need for technology that provides the equivalent of see and avoid, the sense and avoid technology that needs to be in place for full integration of a wide range of these vehicles into the aviation system. That would be the highest that I would——

Chairman SMITH. Okay. Thank you. Mr. Wynne and Mr. Guinn, what is the private sector contributing to this integration process? We have the government on one side—maybe not on one side but as a part of the process, we have the private sector as part of the process as well, but—so what are the contributions of the private sector to the integration?

Mr. WYNNE. My belief, Mr. Chairman, is that the industry is going to bring the lion's share of the technology solutions, as it should. You know, companies like 3D Robotics will—at the end of the day they are constructing the devices, they are developing the software, and not just directly in the industry, the microprocessor speeds are getting faster, et cetera, et cetera. So this was really—the spirit of my testimony was industry should really be doing the lion's share of this. We should be proving the concepts to the satisfaction of the regulators in this R&D process.

Chairman SMITH. Okay. Thank you, Mr. Wynne. Mr. Guinn, anything to add?

Mr. GUINN. Yeah. So it—not—to give a specific example, of course these companies are, you know, integrating and innovating these advanced technologies such as sense-and-avoid and, you know, geo-fencing and return-to-home technology, but to give a specific example of what 3D Robotics is doing is if I fly my drone today outside, you can log into droneshare.com and watch my entire flight automatically. So if I am—if I choose—any of our members around the world choose to make their profile public, every single time you fly, that log file is uploaded auto-magically from your smart device into the cloud to droneshare.com and we are able to now collect tens if not hundreds of thousands of hours of data on what are the fringe cases, right? That is what we have to figure out. What are the fringe cases when you actually start integrating, you know, hundreds of thousands of these systems into airspace?

Chairman SMITH. You mentioned the drone we saw a while ago in the room was a fairly sophisticated device. What did it cost? What is its range? What is its use?

Mr. GUINN. So that is more of a hobby-grade drone. It is called the Bebop. It is incredibly advanced in that it has got a full high definition camera that displays on your smart device. You can either fly with a smart device or with a long-range controller. It has got barometric altimeters, it has got optical flow sensors to look at the ground and maintain positioning, it has got accelerometers, gyroscopes, and a full computer that is a flight control system on board and it is $499.

Chairman SMITH. And what is the range?

Mr. GUINN. The range, depending on if you are using a smartphone, you are restricted to kind of, you know, Wi-Fi range——

Chairman SMITH. Yeah.

Mr. GUINN. —but if you use their controller, you can get up to, you know, a kilometer of range with something like that.

Chairman SMITH. Okay. Okay. Thank you.

Dr. Hansman, you mentioned during your testimony what your students are working on in the classroom and I just wondered if we can expect any kind of breakthroughs and some of you might give some examples of what they are working on as well, but you have obviously seen it from a hands-on approach.

Dr. HANSMAN. So I will just give you a couple quick examples. One vehicle that our students prototyped two years ago is a small UAV that can do a one-hour surveillance mission, which is launched out of an antimissile flare canister on a military airplane, so it is a two inch by two and a half inch by seven inch package. It gets shot out at 300 Gs. This was a concept that nobody in the Air Force thought would work. The students actually demonstrated it. It is now a developmental program where the vehicles they developed are being launched out of F–16s right now at Edwards.

Chairman SMITH. I hope that is not classified information.

Dr. HANSMAN. No.

Chairman SMITH. That is intriguing.

Dr. HANSMAN. Yeah.

Chairman SMITH. Well, thank you all for your answers and now I will recognize the gentlewoman from Oregon, Ms. Bonamici, for her questions.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and thank you to our very accomplished panel of witnesses.

As you heard in the opening remarks I gave, Oregon does have three test sites through the Pan-Pacific UAS test range led by the University of Alaska Fairbanks. We talked a lot about the benefits of the technology. One of the concerns that I have heard from constituents in Oregon who are working in the developing industry is that there are still some problems with advancing the testing of their products, especially true for small companies that don't have a solid revenue stream and the test range is—and I think Mr. Guinn suggested this—this test range is despite being set up to provide a space where the development can take place may be prohibitively expensive for small companies and prevent—there may be other logistical barriers.

So, Mr. Guinn, could you expand just a little bit on how the FAA could work with the test ranges to best address these concerns? And then I want to allow time for a couple other questions.

Mr. GUINN. Sure. So really quickly, right now there is not really a set understanding of how you even schedule a time to go to the range. You know, there is no way to log into the system and say when is the next available day? You know, it is not a matter of them being too busy because, quite frankly, there is not a whole lot of places—or companies using the test range. It is more a matter of what is the process? And there is a lot of bureaucracy surrounding getting even the approval to go to a test range and test fly for a few days so you don't know if that is going to be 30 days or 2 months.

Ms. BONAMICI. Well—and I am going to ask Mr. Williams about that, too, but first I want to ask Mr. Wynne a question.

Thanks for your association work and what you have been doing. I want to echo the comments already made by the Chairman and some of my colleagues about the concerns about the rulemaking, and I—somebody made a comment about the proposed—Notice of Proposed Rulemaking is expected so we are encouraged to hear that news. I actually sent a letter to Secretary Foxx joined by several colleagues who are concerned about the timeline. Of course we want this to be done right and we don't want to jeopardize safety, but we are concerned about not only workforce development and those challenges of recruiting people into this industry if we don't have the certainty, but also for these new companies attracting private investment.

So, Mr. Wynne, have you noticed some particular challenges because of the lack of certainty in attracting venture capital to the industry?

Mr. WYNNE. Oh, absolutely, ma'am, and I thank you for the question. There is—if I am investing money in a project like this, I want to know what the go-to-market strategy is, I want to know what the return on the investment is. If I don't know when I can fly and when I can pursue some of the commercial opportunities that are out there, it is a big barrier. So there is I think already—the fact that there is money flowing in, there is tremendous product being developed, says that this is a great investment opportunity and a great business opportunity and a job creator, which is something we need to be paying attention to. And so while we want to get this right and we want to do it once, you know, for the various levels and we are on a certain trajectory here, we think that there are opportunities immediately that require very little regulation and some of our—some of the countries abroad have demonstrated this success.

Ms. BONAMICI. Thank you. And I know Mr. Guinn talked about that.

So, Mr. Williams, you heard Mr. Guinn talk about some of the possible ways of moving forward. Of course it is not a one-size-fits-all because of the various sizes and capabilities and ranges, but I wanted to ask you first about the testing sites. Some companies have suggested maybe performing initial tests at a range where their safety can be demonstrated but then maybe performing additional tests closer to home. Could that outline potential changes—or could you talk about some potential changes that could allow some more flexibility, especially for the small developers? And then I also wanted you to respond to the concern about the small companies having access and being able to test.

Mr. WILLIAMS. So, first, the small companies have access to our experimental airworthiness approval process, which goes back to the manned aircraft process. It is the same regulations that are applied. We are in the process of updating that to make it a little more user-friendly for unmanned aircraft operators to get through that process.

On the test site front, we have set up a program to enable all of the test sites, should they choose to do so, to have the authority to issue experimental airworthiness certificates on behalf of the FAA, thereby streamlining the process of getting a new aircraft into the testing phase at one of the test sites. So we think that is a significant benefit that the test sites can offer to the industry and we are—you know, we are constantly looking at ways to streamline our processes and work to enable these new companies to test their aircraft in a safe and by-the-rules way.

Ms. BONAMICI. Thank you. And I see my time is expired so I will submit my Section 333 exemption question for the record.

Thank you, Mr. Chairman.

Chairman SMITH. Thanks, Ms. Bonamici.

The gentleman from Oklahoma, Mr. Lucas, is recognized for questions.

Mr. LUCAS. Thank you, Mr. Chairman.

And I would direct my question I guess to Dr. Waggoner and Mr. Wynne and Mr. Guinn and Mr. Hansman.

In recent years, agriculture has been one of the bright spots in our nation's economy. Can you speak for a moment about the potential applications in agricultural settings and what benefits these might provide for both producers and consumers? Whoever?

Dr. WAGGONER. Well, I could start. I have just a little bit of experience. And what we saw some high school students do this year who had the challenge of developing an unmanned aircraft to survey all—I think it was about a 100-square-mile farm, a large farm of corn for European corn borers. These kids, incredible kids from all over the country came up with a number of different solutions that they showed that there were viable solutions that were affordable, usable for the farmer, for precision agriculture where they could precisely locate where there were issues either with fertilizer or pesticides where they needed to be applied and could precisely do that.

So we saw that as an opportunity that shows that it is—there is a market out there for that work. And that was—that is part of what is behind our more midterm work on this UAS traffic management. So allowing the farmer or a commercial operation to go into a farm and do that kind of surveillance operation at low altitudes very safely and in a way that would be very cost effective.

Dr. HANSMAN. So ag applications are already ongoing in other parts of the world. In Japan, for example, where you have very small rice paddies, we are seeing applications there. It is considered one of the number one applications. There is significant interest on the part of agricultural departments to use these vehicles, and in fact they are frustrated by the rule like everybody else in that it is difficult for them to get exemptions to go off and do experiments. So it is one of the big opportunities spaces.

Mr. GUINN. So if I can maybe provide a specific example of a way that even one of these very small lightweight systems can provide real benefit to the farmer. So we had one of the top private vineyards in Napa Valley contact us and say, hey, we have been hearing about these drones; what can we do with them? And, you know, everyone talks about the super high-tech ability to do hyperspectral imagery and look for water damage and, you know, pesticide, but even if you just take it to the really simple level, most of these farmers have not ever seen a very high resolution look-down image of their vineyards.

So we went out, we took one of our sub-2KG systems, flew around, took a lot of pictures looking down in the back of the truck at the farm, stitched those together into a photo mosaic which allowed him to see a very high resolution image of the crop. And for the generations that they have had that vineyard, he looked down and said, wow, look over here in the corner of the vineyard here where—see how this is actually a little darker green that this whole area? Because you can't see that when you are walking the rows of the vineyard because when you are up close you don't see that minute differences in the green. This must be the fact that there is a slight elevation change there, which is sucking more water down to that area. That means we need to harvest these grapes 2 to 3 weeks earlier than the rest of the vineyard. He then walked us out, took some grapes from that area, took some grapes from the rest of the vineyard, squished them in a bag, and you could clearly taste the difference between the two sets. And he said, before today, we never knew that existed. And that happened in two hours.

Mr. WYNNE. Congressman, thank you for the question. The numbers that AUVSI put together in 2013, the $82 billion in the first ten years after we get access to the National Airspace System, we think as high as 80 percent of that could be agriculture.

Mr. LUCAS. Absolutely. Dr. Williams, I come from a State where the Chamber of Commerce likes for us to use the phrase "significant weather events" occur on a commonplace—in a common way, and my home State is making a lot of investments in weather-related research. And one of the things that I understand is a challenge is this requirement to obtain a Certificate of Authorization, COA, or a Section 333 exemption, which can be kind of challenging and cumbersome. What is the FFA—FAA doing to expedite the approval process for this kind of thing?

Mr. WILLIAMS. We are actually working in both areas to approve the processing of the approvals. Most of the—understand that Section 333 approvals are for the aircraft. The COA process is for the airspace. In order to operate unmanned aircraft you can't really comply with the see-and-avoid rule so we have to give you a waiver or authorization to do that. That is the COA process. That process is undergoing a revamp inside of the FAA. We are in the process of building new software to interact with the folks using it. We think that is going to be a major step forward.

We have achieved tremendous amount of progress with our public partners in accelerating their approvals. We have reduced the amount of overhead for many of the frequent users like NASA. They have a much easier way forward.

On the 333 side we are also working hard to streamline that process. We have put together a tiger team that is in the process of developing a streamlined and more efficient process to move those forward quicker. You have got to understand the exemption process was never intended as an approval mechanism. It was intended to deal with exceptions, special cases. So we are trying to have the—make that up as we go so to speak to figure out a way to accelerate it while still—it is a regulatory process so there are rules that have to be met as we go through it. So we are trying to find the right balance.

Mr. LUCAS. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Lucas.

The gentleman from Illinois, Mr. Lipinski, is recognized for his questions.

Mr. LIPINSKI. Thank you, Mr. Chairman. Thank you for holding this hearing, something we are all very interested in and it is critical that we get a handle on this. We don't want to—on the one hand, we want innovation to move forward and all the opportunities that are brought out for business purposes and others, other purposes from UAS, but we know that there is a lot of issues also that need to be dealt with.

And so I wanted to ask Mr. Williams, and anyone else can jump in after Mr. Williams if they have anything to add, I want to talk about the concern about the number of UAS near-misses being reported. My district includes Midway Airport so it is especially important to me, also Lewis University Airport is in my district. So given the rapid increase in number of small UAS in use for both for hobby and commercial purposes, what is being done to better understand the risk of UAS collision and what is being done to track near misses?

Mr. WILLIAMS. So we are in the process of building a tracking system modeled on the way we track the laser incidents that have been going on. We are also working hard on an education campaign to try to—we believe that most of the people that are flying these aircraft near airports just don't understand the area they are flying in and of the rules about where they can and can't fly. So we have—in partnership with the Small UAV Coalition; the Unmanned Aircraft Vehicles International, AUVSI; and the Academy of Model Aeronautics, we have a campaign ongoing called Know Before You Fly that we are working to find any means we can to educate the public about where they fly because, you know, primarily the FAA is interested in compliance with our rules, and we believe the best way to achieve that compliance is through education. So we are working hard to make that happen.

On the research side—I am sorry, you had another question about the research?

Mr. LIPINSKI. What is being better done to understand the risk of——

Mr. WILLIAMS. Right.

Mr. LIPINSKI. —UAS collision?

Mr. WILLIAMS. Right. So we actually have started this year a research initiative to look into what the potential is for—or really to assess the risk of an unmanned aircraft to a manned aircraft, and that project is just getting off the ground this year and we are accelerating it thanks to the additional funding that Congress provided us in our research budget this year. We should be able to accelerate that and move it forward more rapidly than we had been able to.

Mr. LIPINSKI. Anything else that any witnesses think should be done——

Mr. WYNNE. I just wanted——

Mr. LIPINSKI. —that are not being done?

Mr. WYNNE. I just wanted to emphasize that we thank the FAA for their help with this campaign to educate. I think in many instances it really is an education challenge today. Obviously commercial operations are not allowed at this stage until we get a rule, but the education campaign is really about keeping the UAS under 400 feet, 5 miles from the airport, within line of sight, stay away from crowds. It is basic common sense and we think that in many instances it is just a question of education. We have had tremendous response from the aviation community on this. We have got new partners in NBAA, EAA, et cetera. Many of the organizations are stepping in and helping us get that word out.

Mr. LIPINSKI. Thank you. One other thing I wanted to move on to before my time runs out is about test sites. The FAA established six test sites to enable UAS research, and these sites are operating under an agreement that may restrict the FAA's role in directing research. So I want to ask, Mr. Williams, what steps is the FAA taking to ensure that the test sites are being used to address the Nation's top research priorities, and are there any barriers that need to be addressed?

Mr. WILLIAMS. Back in the fall we released to the test sites a list of over 100 research areas that we believe we could benefit from having them look into. I think the—there has been a lot of misunderstanding about what they can and can't do at our behest. Our only rule is that, you know, through the procurement rules we have to—if we are going to direct one of our contractors—and the Other Transaction Agreements we have with them amount to a contract between them and us—if we are going to direct work, we have to pay for it. So—but we can also agree to work together with in-kind resources through these agreements.

So the—but the bottom line is to all of it, all we have to do is document it in those agreements and we can work together on any research project that is of interest to those test sites, and I believe that, you know, we have communicated that to them and I believe that we have—they understand the situation pretty well at this point.

Mr. LIPINSKI. All right, thank you. I have other questions that I will submit for the record.

I yield back. Thank you.

Chairman SMITH. Thank you, Mr. Lipinski.

On behalf of the new Member of the Committee, Barbara Comstock of Virginia, without objection I would like to put a letter from a Michael Kronmiller in the record. And without objection, so entered.

[The information appears in Appendix II]

Chairman SMITH. The gentleman from California, Mr. Rohrabacher, is recognized for questions.

Mr. ROHRABACHER. Thank you very much.

Now, let me see if I am getting all of this straight now. The FAA actually will approve Mr. Guinn's drones, their design, and their capabilities and approve them to actually go in the air before you are permitted to fly them, is that correct? Mr. Guinn? Mr. Williams? Who can answer that?

Mr. WILLIAMS. Sir, they are approved—the two processes run in parallel so that when the approval to fly the aircraft without an airworthiness certificate that is done through the Section 333 exemption process——

Mr. ROHRABACHER. You say that approval is based on the design of the aircraft and its capabilities, is that right?

Mr. WILLIAMS. Yes, and the operations. And then they——

Mr. ROHRABACHER. All right.

Mr. WILLIAMS. They come in and say, okay, we want to operate it in this particular area——

Mr. ROHRABACHER. Right.

Mr. WILLIAMS. —and our traffic organization assesses whether or not it is safe for them to operate, and so they are looking for, you know, conflicts with their manned aircraft.

Mr. ROHRABACHER. Okay. So this is both FAA in both cases? One is the safety of the equipment itself and then the safety of the actual instance that you—they want to use this specific situation. And where—are we having any trouble, Mr. Guinn, with the actual approval of the system itself meaning your crafts that you can bring before them for approval? Is that—am I understanding this, do you think that should be streamlined or——

Mr. GUINN. Yes, sir. So when one of our customers wants to use, say, a system for, you know, looking at photo mosaics of a farm so that they can see where the water is going and when to pick the grapes, they needed to take the system and get a Section 333 exemption, which is where the FAA determines is this aircraft——

Mr. ROHRABACHER. But once you have gotten that from this—to do that——

Mr. GUINN. Well, first you have to get that.

Mr. ROHRABACHER. That is what I mean——

Mr. GUINN. And so far, of all the companies——

Mr. ROHRABACHER. But after that you don't have to get it again, right? Is that correct?

Mr. GUINN. For the Section 333. So so far 14 have been granted.

Mr. ROHRABACHER. Out of how many?

Mr. GUINN. Is that correct, 14?

Mr. ROHRABACHER. Out of how many requests?

Mr. GUINN. Out of everyone in the country that wants to fly their drones.

Mr. ROHRABACHER. Oh, is that right, 14?

Mr. WILLIAMS. Right, but the process is being improved and they are going to be coming out a little more frequently——

Mr. GUINN. So it is difficult first to get it, 14 out of however many thousand——

Mr. ROHRABACHER. All right.

Mr. GUINN. —and then once you have a Section 333, you have to get the Certificate of Authorization to fly in a specific area, which is——

Mr. ROHRABACHER. So what we have here is technology and the technological capabilities are far surpassed the ability of making decisions about standards and rulemaking—general rulemaking, and that is what we have to catch up with. This isn't the first time that has happened in history, I am sure, and I hope that—can you tell me—can anyone here tell me which is more dangerous, a small privately owned airplane flying from here to there or a drone flying from here to there? Anybody want to——

Mr. GUINN. I have had several friends that have been in helicopter crashes, actually specifically test—you know, going out the side of the door, taking pictures of power lines. So, you know, I can't speak to the factual evidence here, but in my estimation, having a 2- or 3-pound drone flying over national grid power line taking photos, if they were to fail in any way, shape, or form, it doesn't have to worry about auto rotating down to the ground when they are already flying outside the chart. All it does is bounce off the power line, fall to the ground, you take another one out of the truck and keep inspecting. So my guess is that that would be much more safe and would allow us to start saving lives today.

Dr. HANSMAN. We have actually done analysis on this and it really depends on the size of the drone. So for a small drone, the risk to people on the ground and to people in the air is much lower.

Mr. ROHRABACHER. Has there ever been anybody hurt from a crashing drone, on the ground?

Mr. GUINN. I mean there has been ouch, you hit me in the head with that drone but——

Mr. ROHRABACHER. All right.

Mr. GUINN. —you know.

Mr. ROHRABACHER. Let me ask about the—how the FAA is planning to do this, these testing areas, test sites that have been established to help you try to determine whether or not these pieces of equipment should be approved. Could somebody tell me what they do at those test sites?

Mr. WILLIAMS. Well, the primary intention for the test sites is to provide an opportunity for manufacturers to do their developmental tests and evaluation in support of moving forward toward approval.

Mr. ROHRABACHER. And that is what the—that is what we have spent $11 million on that, providing that to you last year and now that budget has been increased, is that right?

Mr. WILLIAMS. No, sir. There has not been any appropriation to the FAA to directly support those test sites.

Mr. ROHRABACHER. Okay.

Mr. WILLIAMS. We funded it out of our existing appropriations.

Mr. ROHRABACHER. Is it possible that when we have these companies that are seeking profit, which is a good thing, and they have technology, which is a good technology, do you think that in order to facilitate and to move the process along that maybe it would be good to have the companies reimburse the government for the specific tests or be able to certify certain people to conduct those tests other than government employees?

Mr. WILLIAMS. I believe that is the actual intent of the test sites. The cost for running the test sites is currently being borne by the States who sponsored them and they are getting compensation from the companies who come to them for testing, or the government. In a couple cases there have been some government testing done there. The FAA doesn't fund the test site operating costs.

Mr. ROHRABACHER. Okay.

Mr. WILLIAMS. They are independently run.

Mr. ROHRABACHER. We only have 14 of these things approved so I can't imagine we have had much revenue so far, but I would hope that——

Mr. GUINN. So there is a small number of companies covering those costs, which is why it is prohibitively expensive to go to those sites to test——

Mr. ROHRABACHER. Well——

Mr. GUINN. —versus going to Canada or Mexico, our neighbors.

Mr. ROHRABACHER. All right. Thank you very much, Mr. Chairman.

And by the way, just to note, my family, which are catching a plane back to California, just happened to be coming in at the time when that drone was flying around and I guess they—my son got an interesting opinion of what his father does for a living so——

Dr. HANSMAN. And it kind of shows you how these vehicles actually stimulate the interest of the sort of next generation of young people.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Rohrabacher.

The gentlewoman from Connecticut, Ms. Esty, is recognized for questions.

Ms. ESTY. Thank you, Mr. Chairman, and to the Ranking Member for having this hearing today, and thank you all for your testimony.

Unmanned aircraft systems have already significantly impacted, as we have discussed today, particularly in the field of agriculture, changing the way farmers do business and increasing yields and decreasing the use of pesticides and this is all a very good thing. And coming from the State of Connecticut where we have been longtime leaders in aviation and aerospace, we are very excited about these opportunities. But we also live in an incredibly congested airspace and some of us that include Mr. Lipinski and I serve on the Transportation and Infrastructure Committee where we are having hearings on the same issue.

So I would like to turn to that a little bit and get you to help us understand how, on the R&D side, what are the risks we should be looking at? What should be the research priorities to avoid those issues which are a little different than the agricultural setting, those are the "what do you deal with LaGuardia to Logan" issues. And particularly as we follow up on the exciting possibility of improving our infrastructure, the grid, looking at lines, these are very important opportunities, but again, they do pose risks, particularly in the congested airspace.

So anyone who wants to jump in and help us guide through research capabilities, what are the risks we face, and on the R&D side what should we be prioritizing to address those risks outside of regulation, actually understanding?

Mr. GUINN. So—go ahead.

Dr. HANSMAN. So from a risk standpoint if you look at the risks of UAV operations, we don't have the risk to the passengers on board, so that two risk areas are ground impact hazard, people being hurt by drones coming out of the sky, or midair collision risk. The ground impact hazard, you can do the analysis, and it really scales significantly by vehicle mass. So we—and studies have been done and you can look at the risk versus the reliability required to compare those with manned airplanes and set standards there. From the airborne collision risk standpoint, it also scales with size.

So for very, very small UAVs we design airplanes so that they can take bird strikes. So an interesting research question is what is the threshold mass for UAV for which the existing regulatory guidance on bird strike criteria would allow you to work there? Above that size you need some method to separate the airplanes. The easy thing is to do segregation, okay, and that is where we are working now. The hard is to come up with, as I said before, concepts of operation that would allow you to operate in the same airspace and be coordinated in some way, and that is really where we have got to work is the concepts.

Mr. GUINN. And I would completely agree with that, and I think that is why many other countries have said, you know, if it is less than 2 KG, it is going to be similar to a bird strike which planes are already designed to handle in that worst-case scenario if that were to happen.

And I think the other thing that we need to do, like I said before is, you know, by going to FAA test sites with a team of Ph.D.'s flying a perfectly assembled drone, we are not figuring out what the fringe cases are. We are not figuring out what the real risks are when you integrate thousands of these systems. And the concept of integrating thousands and thousands of systems that are far beyond what would be considered a bird strike is extremely scary. So to me starting with those lightweight systems so that we can collect all that data and start figuring out, okay, here are the fringe cases, here are the failure points, here are the risks. Now, how do we mitigate those for the next set of heavier aircraft?

Dr. LAUBER. And I might add if I may that one of the four high priority most difficult research projects we identified in our study had to do with these very issues, the question of verification, validation, and certification and how you go about setting appropriate standards of risk that apply to these light small UAS systems in a world that was basically created to deal with manned aircraft systems of much larger mass. It is a very different world and demands very high priority in our view.

Dr. WAGGONER. And as Dr. Hansman mentioned, the harder problem of interoperability, particularly with a larger aircraft, so that is something that NASA has taken on and we are doing that research, so the sense-and-avoid work. But also, as you—the sense-and-avoid systems work, how you display that information to the pilot so that they can make informed decisions, and we are doing research in both of those areas in support of the FAA's standards development.

Ms. ESTY. Thank you. That is all very helpful. And those who have thoughts on how this might integrate with the NextGen system and if there are issues around UAS that we should be thinking about as we are addressing NextGen as part of the FAA authorization, I would love to follow up with——

Dr. HANSMAN. I would just say we need to leverage off of our investment in ADS–B and some of the communications architectures.

Ms. ESTY. Thank you very much.

Chairman SMITH. Thank you, Ms. Esty.

The gentleman from California, Mr. Knight, is recognized for his questions.

Mr. KNIGHT. Thank you, Mr. Chairman. Thank you for having this esteemed panel. I have just a couple statements, maybe a quick question.

You know, the UAS systems have helped quite a bit. I know that these aren't something new; they have been around for 50 or 60 years. I can remember the HiMAP program which helped us get into the fourth and fifth generation fighters that we have today. And also I appreciate what they do to help pilots have a safer flight. The G–CAST system that we are working on right now in the United States Air Force and the Navy, we put that on a UAS system because flying an airplane into the ground was not what a pilot wanted to do. So you put that on a UAS and hopefully the software worked, which it did, and the plane didn't crash, and then you might get a test pilot to do that.

But my questions are more in line with privacy and how Congress is going to move forward in the next 20 years, especially when it comes to law enforcement. And law enforcement has been part of the UAS discussion over the last ten years especially. If you have a helicopter that is chasing a bad guy and he flurs that area down there, we have decided that that is okay, but if you used a UAS, we have decided that that is probably not okay. And so the discussion is going to go—and I can already see—Mr. Williams, you probably want to answer this—is how do we go about that? How is the lawmaking? How is the rulemaking going to be when we talk about UAS in the law enforcement arena?

Mr. GUINN. I think that is a great question. Thank you. And I think for law enforcement it is probably the easiest to solve because you just simply say these are the rules for whether or not you can engage with a UAS and whether or not that evidence can be, you know, admitted into a hearing because obviously the point of law enforcement is to stop crime and the only way to stop crime is to be able to convict, and the only way to be able to convict is to use admissible evidence, right? So I think that one is pretty simple to say this is what is allowed, this is not—what is not allowed. You have Notice of Proposed Rulemaking, people vote on it, and decide.

I think the stickier point is the guy that is not being regulated, the hobbyist who is, you know, using these systems to peek into somebody's window, right? And there is a lot of people that have those concerns and they are valid concerns. But I would hearken this back to when they—when phone manufacturers started putting cameras in cell phones. People were very concerned about this. Samsung, as a matter of fact, there was a rule that you could not have a camera-equipped phone on the campus of Samsung, right? Now obviously every single employee has a camera in their pocket.

And so I think that people realize with this new technology that there is probably not tens of thousands of would-be criminals just waiting for this perfect technology to be able to spy on each other and I think this is a matter of education. You know, what can you get at the Apple Store? Wireless baby monitors and drop cams and things like that that could easily be set up silently and very small and not noticeable in somebody's house versus a loud, blinky, lit up drone flying out the window.

The reason—I mean that is—you know, so I think it is just a matter of education and a matter of saying, you know, let's leverage existing anti-invasion of privacy laws and make sure that those laws are, you know, applied to whatever technology is being used to invade somebody's privacy, and there should be consequences.

Mr. KNIGHT. And I guess what I would follow up on is that we already have an existing technology that does this, that chases bad guys from the air. So I guess, Mr. Williams, you can answer this. Would the FAA decide that they would follow the same exact rules as maybe an air unit does in today's law enforcement? Would they follow the same rules or would they be able to do different things because, you know, a helicopter can't fly like a UAS can, a helicopter can't do the things that a small UAS can do. So that is—I think will be a question for Congress is are we going to lax those rules to make it more available for the troops on the ground, the cops on the ground to use it in a different manner?

Mr. WILLIAMS. Well, one of the initiatives we took back in 2012 was to set up a special process called for in our reauthorization of 2012 for law enforcement and we have been working directly with individual law enforcement agencies around the country. There are some that have had some spectacular success with their aircraft and it is a priority for my office to continue to support law enforcement use of unmanned aircraft and find ways to approve their operation. And I have two individuals who do that as there full-time jobs so we very much support finding ways for law enforcement to use unmanned aircraft safely.

Mr. KNIGHT. Thank you.

Mr. WYNNE. Yeah, Congressman, I just wanted to point out that AUVSI, in an earlier effort, we did work with the International Association of Chiefs of Police to develop guidelines. I would be happy to submit those for the record.

Mr. KNIGHT. Thank you. Thank you, Mr. Chair.

Chairman SMITH. Thank you, Mr. Knight.

The gentleman from Washington, Mr. Newhouse, is recognized for his questions.

Mr. NEWHOUSE. Thank you very much, Mr. Chairman, and thank all of you for being here today to enlighten us about this very exciting and important subject.

Being in agriculture, I do share the vision for the future and how we can produce our crops more efficiently and effectively.

But a couple questions, I think that, Dr. Lauber, if I might start with you, I have heard a couple things, at least two today that talks about the potential of the unmanned industry as far as both public and privately, and then also the importance of safety of integrating these unmanned systems into the national airspace. And so speaking about that and the—and realizing the speed some of these innovations are happening, it certainly seems that safety should be a primary focus of what we are talking about. And so I am curious about the investment of harmonizing these systems with manned platforms, specifically talking about collision avoidance systems in general, perhaps specifically an ADS–B transponder, those kinds of things. If you could talk a little bit about that, I would be appreciative.

Dr. LAUBER. I think that you have already addressed several of the key considerations that we took up in our report. Clearly in order to achieve success in integrating these systems into the airspace and then realizing the potential benefits of these systems, we have to do it in such a way that safety is not adversely impacted. It will not fly, so to speak, to introduce these things in such a way that it imposes or adds risk to the system. Dr. Hansman has already outlined a couple of the key risks that have to be understood, collision with other aircraft and collision with the ground and trying to systematically understand those things is very important. And the FAA's effort to undertake a systematic analysis of risk as it applies to these systems is an equally vital part of this.

You know, one of the top four and most difficult research projects that we identified was what we called continuous operation without human intervention, and in order for UASs to do this, basically a UAS must have the capability of doing what any manned aviation system does in the present environment. So you have got to make up for all of the missing sensors, taking people's eyeballs out of the vehicle. You have to somehow substitute for that. The ability of humans to make decisions in real time based on unexpected or unanticipated situations, you have to be able to build that into the technology in order to maintain the levels of risk that we have now. So these are of fundamental importance as far as our study is concerned.

Mr. NEWHOUSE. Thank you.

And then just another question, I can't let the FAA off the hook totally, in a recent interview in Business Insider magazine, the CEO of Amazon Jeff Bezos was asked a question about when they might possibly be delivering packages using these systems, and maybe you have read that article, but it highlights some of the—perhaps some of the, lack of term, overregulation in the R&D of—in the United States. He answered a longer answer than I have time for but the technology is not going to be the long pole; the long pole will be regulation. And so, as was already talked about with, what, a dozen or 14 approvals already for commercial UAS, could you explain why there may be hundreds or even thousands in other countries that have been approved and here we lag behind so to speak?

Mr. WILLIAMS. Well, I am not sure I agree that we have lagged behind. Yes, we don't have a specific rule for small unmanned aircraft but we also have the most complex airspace in the world, we have the largest number of general aviation operators in the world, and it is a different regulatory and legal framework here than in some of the other countries. Part of my job is to interact with my counterparts from around the world and understand what they are doing and benefit from their experience so we are—and we are taking those things into consideration as we move forward.

There is a—there are multiple paths for commercial operations. We have two operators approved up in Alaska. We are using certificated aircraft that have gone through the manned certification process, adapted for use by—you know, for an unmanned aircraft. Obviously all the rules for unmanned—for manned aircraft didn't apply to them. But there are commercial operations available that way in addition to this new way we found through the Section 333 process that is designed to bridge us to that regulatory environment we are trying to achieve with the small unmanned aircraft rule.

Mr. NEWHOUSE. Thank you. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Newhouse.

The gentleman from Texas, Mr. Weber, is recognized.

Mr. WEBER. Thank you, Mr. Chairman.

And I don't know where to start. Are the permits issued from the—there has been—let me understand this. I came in late. So there has been 14 permits approved, is that right?

Mr. WILLIAMS. For small civil aircraft operators, yes. We have two certificated aircraft that are operating commercially in Alaska and there are a tremendous number of—over 700 public aircraft operators, in other words government operators that we have approved.

Mr. WEBER. Are they based on size, Mr. Williams? A category 1 might be that you could fly up to something that is 200 pounds, 500 pounds, or is there a weight limit?

Mr. WILLIAMS. Well, the FAA in general takes a risk-based approach to all our approvals and so we have—the reason there are different levels of approval is there are different levels of risk. So for these very small ones that we are now approving through an exemption process, we are essentially—because of their size, weight, and operating environment, approving—basically waiving most of the manned aircraft rules so they don't have to comply.

Mr. WEBER. So what is a small weight?

Mr. WILLIAMS. Under 55 pounds was legislated in the—in our 2012 reauthorization—was defined as small under that legislation.

Mr. WEBER. Are there approved operators that get above 55 pounds?

Mr. WILLIAMS. Yes, sir. The—on the public aircraft operations side they go up to—the Global Hawk aircraft that both NASA and the DOD fly is approximately the same size as a 727.

Mr. WEBER. Are they able to cross into Mexico and Canada without violating airspace issues?

Mr. WILLIAMS. I believe the DOD flies around the world with their unmanned aircraft and they are following the ICAO rules for manned aircraft the same way as they do for——

Mr. WEBER. What about private companies? Have they crossed from the United States into Canada?

Mr. WILLIAMS. We currently don't have any approved private companies that are operating across the borders, and there is a committee—or what they call a panel has been formed at ICAO to develop the international standards and recommended practices for unmanned aircraft crossing between countries. So that regulatory framework internationally is being developed.

Mr. WEBER. So when a company gets approval, has—it is permitted or licensed? What do you call it?

Mr. WILLIAMS. Well, we called the pilots—getting certificated I guess would be the correct term.

Mr. WEBER. Certificated, okay. Does that process of certification get reviewed after one year, 2 years?

Mr. WILLIAMS. From a standpoint of—if the aircraft is approved through a type certificate, then it is indefinite. There is no restriction on that.

Mr. WEBER. So——

Mr. WILLIAMS. For the processes that we are doing through the exemptions, those are good for 2 years.

Mr. WEBER. Okay. So if a UAV—if one of these units falls out of the sky and hits a car on the ground, the liability insurance—do people market insurance for these things?

Mr. WILLIAMS. Yes, sir. There is insurance available through the multiple different insurance companies.

Mr. WEBER. Okay. The little cameras on it—and I know, Mr. Guinn, you talked about the high-definition camera. Are they able to transmit back video back on the ground? Is that standard—pretty much standard?

Mr. GUINN. Yes, absolutely. Even what Baptiste was flying today from Parrot it transmits high-def video back to your tablet.

Mr. WEBER. Is it captured, for lack of a better term, in a little black box? Does it record its own?

Mr. GUINN. There is a myriad of ways to do it so we can actually record on the ground, at the same time we are recording a much higher bit rate stream on the camera in the air. So for later review if you need to zoom into an image and check a power line or something like that——

Mr. WEBER. But you said it had a computer on it. Does it have the capability of storing that right on board?

Mr. GUINN. Absolutely. Yeah. Most of the cameras that are on board have their own memory card slots and you are storing it right on the memory card.

Mr. WEBER. Has—and I know this is getting way out there, what are people able—I mean you think about people hacking in to different things. Are they going to be able to hack into these and commandeer these?

Mr. GUINN. That is a good question. I think that, you know, probably for Dr. Lauber a much better question.

Dr. LAUBER. I will just add that cyber physical security is one of the key issues that we identify in our report. It is a concern and it needs to be addressed from the outset.

Mr. WEBER. How many drone manufacturers are there? Ten, twenty——

Mr. GUINN. At least hundreds.

Mr. WEBER. Hundreds?

Mr. GUINN. Um-hum. Yes.

Mr. WEBER. How many in the United States?

Mr. GUINN. Much less than anywhere else in the world, so I mean——

Mr. WEBER. Okay.

Mr. GUINN. —3D Robotics, our company is the largest and then that is——

Mr. WEBER. One final question. You see planes fly over with the number on the bottom of it, you can identify the number. Are the drones numbered, identified?

Mr. GUINN. They are not today but that is one of the considerations, especially for the heavier systems, to have a tail number.

Mr. WILLIAMS. Well——

Mr. WEBER. Okay. And let me go one more question if I may, Mr. Chairman. So Google has a car that they can drive they say wherever without—can you program one of these drones to go somewhere and back and basically never have a—never touch it?

Mr. GUINN. Absolutely, yes, just right from your smartphone if you need to.

Mr. WEBER. Thank you. I yield back.

Chairman SMITH. Thank you, Mr. Weber.

The gentleman from Florida, Mr. Posey, is recognized.

Mr. POSEY. Thank you, Mr. Chairman. And I would like to thank all the witnesses for showing up today and bringing their great testimony. I had the opportunity to read the written testimony. This is one of those days where another committee meeting with votes required conflicted with the early part of the schedule so some of us didn't get to see the demonstration of your vehicle. And if the Chairman would indulge us, I would be interested and I think some of the others would be interested in seeing it.

Chairman SMITH. Do we still have the vehicle and the pilot?

Mr. GUINN. Yeah, we can get it back up in the air in just about 1 minute.

Mr. POSEY. All right. That will work.

Chairman SMITH. All right. Let's have another quick brief demonstration but perhaps you can use more airspace this time, too.

Mr. GUINN. He is going to get saucy with it, Baptiste.

Chairman SMITH. And we will define haircuts within 2 feet of someone's head, so if you can stay above that, that will be——

Mr. GUINN. He is going to show you leaf blower mode with your papers on your desk.

Chairman SMITH. We didn't give you much advanced notice here but——

Mr. GUINN. It will take him about 30 seconds or 45 seconds to connect to the Wi-Fi network before he can take off.

Chairman SMITH. Okay.

Mr. GUINN. Did you have any quick questions in the meantime?

Mr. POSEY. Silence is golden in this committee, too.

Mr. GUINN. Okay. Perfect. Sounds good. Another fun fact is that he will be piloting this drone from his iPhone, as well as seeing a live HD feed right on his phone that is being digitally stabilized, so pretty cool for 500 bucks.

Mr. POSEY. We will all have one by the next time you come and testify here.

Chairman SMITH. Well——

Mr. GUINN. My kids got them for Christmas. And that is your worst-case scenario, oh, my gosh——

Chairman SMITH. You know, maybe——

Mr. GUINN. —drone crash. Drone crash.

Chairman SMITH. Maybe we won't fly over people.

Mr. GUINN. Yeah, well, while he is flying over, you just do this just in case.

Chairman SMITH. Yeah.

Mr. GUINN. A fringe case is when you are asked to fly a drone in 60 seconds in front of Congress.

Chairman SMITH. Yeah.

Mr. GUINN. This is the kind of data we need to be collecting out in the real world.

Chairman SMITH. We need to make allowances for this. Tell you what, just to take the pressure off of you, maybe we ought to—okay.

Mr. GUINN. All right. Here we go.

Chairman SMITH. Oh, there we go. Okay. Okay. Can you head towards Mr. Posey and just keep it right out of—there we go.

Mr. GUINN. Leaf blower mode, here we go. Baptiste, can I push it around a little bit, show its stability or do you want to? Yes, in a very French and stylish way. Thank you.

Chairman SMITH. Thanks again for that.

Mr. Posey, anything else?

Mr. POSEY. Thank you, Mr. Chairman.

Chairman SMITH. Okay. The gentleman from Illinois, Mr. Hultgren, is recognized.

Mr. HULTGREN. Well, thank you all for being here. This is important and interesting and I really do appreciate the work that you are doing and we do want to be helpful in making sure we do this well.

With development and usage, I know of UAS expanding it certainly is crucial that we understand the research our government is doing, especially the research that will affect the rulemaking process FAA is currently undergoing. From a competitive standpoint, it is also crucial that we do this right so that we are not encouraging businesses to move elsewhere or denying access to researchers for the best, most cost-effective tools that they need to do their work.

To be frank, sometimes I don't—I find the FAA's process to be a little bit confusing and I agree certainly with the need for public safety, that should always be our top goal, but right now my fear is—in the name of safety I am afraid we are stifling innovation and research opportunities by keeping pretty harmless UASs out of the sky. At the same time, on an unrelated topic but one that is important to me, I have been trying to get answers from the FAA about their air traffic controller hiring practices, which were recently changed, and I believe could jeopardize the safety of airline passengers across the country. And we are going to continue to try and get answers there from the FAA.

But getting to questions, Mr. Williams, in early December 2014 the Association of American Universities and Association of Public Land Grant Universities wrote a letter to FAA stating, "there is no timely workable mechanism for both public and private universities to secure FAA approval to conduct important research utilizing small unmanned aerial systems, or sUAS, technology." I wondered, has FAA considered issuing a rule to make it easier for universities to research sUASs such as allowing universities to research sUASs on their own property below 400 feet?

Mr. WILLIAMS. Well, we believe that our small rule will address the needs of the universities. We also believe that—and I have had discussions with several universities about this, that they can move forward using our Section 333 process to conduct their training, research, et cetera. And I have had discussions with several universities about the possibility of doing that and I think they are interested.

Mr. HULTGREN. Okay. So in the meantime there is some opportunities there but also you expect that the rule would give them this ability to do some of the research that they are looking to do?

Mr. WILLIAMS. Um-hum.

Mr. HULTGREN. Mr. Williams, roughly how much interest is there in the FAA test sites in terms of calls, meetings, and website visits? How many organizations have actually used the test sites?

Mr. WILLIAMS. I don't have the data with me, sir. We can certainly get back to you——

Mr. HULTGREN. Could you? That would be great. If you can maybe get that back to us or to the Committee, that would be terrific.

Mr. Wynne and Mr. Guinn, how would you organize the FAA UAS test sites to best accommodate industry's R&D needs?

Mr. WYNNE. Sir, we are—we want to get this word out. I think the—you know, it is early days for the test sites so we have got to make the—I think them more accessible. We have discussed earlier the need for greater transparency, getting the costs down, et cetera. I think there is also a need to focus the research on the specific areas that we have been all agreeing needs to be advanced, so I think those are the primary elements that we have been looking at.

Mr. HULTGREN. Do you have anything to add?

Mr. GUINN. I would take the six FAA test sites that exist in remote locations and expand that to test sites that might be on your company's private property that have, you know, strict regulations around what you are allowed to do, geo-fenced. You know, the drones with a geo-fence will not cross that barrier. They have that level of intelligence today. So sub 400 feet, you know, don't cross the geo-fence, remain line of sight, and now that test site can be on your own company's property.

Mr. HULTGREN. Are they—have you heard if they are open to that, looking into that?

Mr. GUINN. Are you guys open to that?

Mr. HULTGREN. Mr. Williams?

Mr. WILLIAMS. I believe that we have the experimental process that could accommodate that type of operation. We have experimental airworthiness certificates that we issue for development, research, et cetera, that have been taken advantage of by other companies to do exactly that. So that process does remain available to anyone who chooses to use it.

Mr. GUINN. And I hear that a lot and that is the same—is that the same airworthiness certificate that there has been 14 total granted so far in the country of all the people that want to fly drones?

Mr. WILLIAMS. No, we have issued quite a few more experimental certificates.

Mr. GUINN. So the Section 333, is that—that is what is required for a private drone operator to be able to operate and do test flights?

Mr. WILLIAMS. That is for commercial use. I mean the experimental process is for the developmental use.

Mr. GUINN. Okay. So I guess I am talking about more for private sector versus government. Is that——

Mr. HULTGREN. Let me ask you this real quick because I am running out of time, but on that, how do you see other countries openness to doing this versus the United States, your members? Have you seen similar openness here as in other countries or do you see greater challenge? And I am out of time.

Mr. GUINN. Well, there is a huge disparity, and I think in other countries they just use a simple, you know, proportional risk-based system to say if the drone is very lightweight and being flown low altitude, line of sight, there is a lot less regulation than a heavy drone being flown out of line of sight at higher altitudes. So it is pretty logical.

Mr. HULTGREN. It makes common sense. Yeah.

Mr. GUINN. Pretty logical.

Mr. HULTGREN. Hopefully we can see what other countries have been doing, doing safely, and we can do the same thing here.

Thank you, Chairman, for your indulgence. I yield back.

Chairman SMITH. Thank you, Mr. Hultgren.

And the gentleman from Alabama, Mr. Palmer, is recognized for questions.

Mr. PALMER. Thank you, Mr. Chairman.

I was called away to another meeting so I missed a lot of this. And thank you for the demonstration. I might ask for one of those for Christmas myself.

A couple of things, I don't know if this has been asked, but has anyone done an estimate of economic impact in the context of what it would be worth to the U.S. economy for—if we had the design and engineering done here in the United States, if we do the construction here—manufacture, I should say the manufacture of the—well, if you are doing UAS as—did you say as large as a 727? Is that what you said?

Mr. WILLIAMS. [Nonverbal response.]

Mr. PALMER. So you would be doing design engineering and construction. Has anyone looked at what the economic impact of that might be?

Mr. WYNNE. Yes, sir. The numbers that my organization have put together in 2013 suggest that after we have access to the national airspace the economic impact amounts to about $82 billion and 100,000 jobs, 100,000 plus jobs. Those numbers were put together in 2013. We think they probably—we are going to update those numbers. They probably understate the opportunity.

Mr. PALMER. Now, that is just the design, engineering, construction? That is my question.

Mr. WYNNE. And ancillary.

Mr. PALMER. So that would be the commercial use?

Mr. WYNNE. No, that does not include commercial use.

Mr. PALMER. Okay.

Mr. WYNNE. Profitability for other business——

Mr. PALMER. All right. All right. Are we losing any technological advantage by the delays in approval for testing, in other words, if this is—if this goes offshore?

Mr. WYNNE. For the design and test, and those numbers I think, yes, sir. I think that is an important distinction. The markets that we—the end user community such as the insurance industry, the agriculture community, et cetera, they will still want to utilize the technology. The question is whether or not they will be using American-built technology.

Dr. LAUBER. And if I may add to that, during the course of our study, we heard presentations from many in the industry. Many of them told us that they could not conduct the kind of research and development that they needed to do in the United States and that they were taking their operations offshore.

And if I may briefly add in November I participated in a meeting sponsored by the National Air and Space Academy in France and one of the key things that came out of that conference was the fact that the DGAC, the French FAA, in 2012 issued a risk-based set of regulations covering the very small UASs, I think 2–1/2 kilos. They put those in place. As of the time of the conference, which was in November, there were over 1,000 certified operators, more than 1,600 vehicles in French airspace alone, and there were multiple manufacturers and others participating in this. It was really quite interesting to see this industry taking off there.

Mr. GUINN. And those numbers for France, that—France has approximately 90 percent the populous of Texas, is that right? So, yeah, we could probably get some pretty amazing economic benefit for the whole country.

Mr. PALMER. Going back to the size of these things is, you said a 727. Do you foresee a company like Federal Express or one of the big commercial carriers utilizing these for high-capacity transports?

Dr. HANSMAN. There is interest on the part of Federal Express explicitly and several other particularly cargo operators. It—this is going to be a long time in the future. These capabilities will first come through in the military, demonstrated, and the risk issues will be demonstrated. But 50 years from now, 60 years from now there will be UAVs. We can do it technically today. The issue is to work out all the operational details.

Mr. PALMER. And one of those operational details, I would assume, would be ensuring that the guidance systems cannot be hacked?

Dr. HANSMAN. Exactly. That is the comment that Dr. Lauber talked about. One of the key research areas are the cybersecurity issues particularly associated with the uplink—command uplink.

Mr. PALMER. My last question has to do with utilizing these for high altitude subspace, maybe even, you know, launch and return capabilities, high altitude subspace for, say, weather evaluations, things like that. Do you—is that something that is on the drawing board?

Dr. HANSMAN. One of the biggest potential markets is actually the use of these vehicles for high altitude relay for basically internet on the surface. So you can have long persistence vehicles at high altitude that can now act effectively as satellites and be doing broadband distribution to the ground.

Mr. PALMER. And I guess my B part of the last question would be, for instance, an unmanned flight to the International Space Station, would you—do you foresee having the capability for launch and return for a mission like that?

Dr. HANSMAN. Well, we do today. That is—we have unmanned vehicles that are flying cargo missions to the Space Station today.

Mr. PALMER. All right. Thank you, Mr. Chairman.

Chairman SMITH. And thank you, Mr. Palmer.

And let me thank all of our witnesses today. This has been a particularly interesting and informative panel. We wish Mr. Williams, however, the FAA had told us when they might have the rule ready, but with that possible exception, I appreciate all your contributions.

And this has really been helpful, I think, to members of the Science Committee and we look forward to hearing from you all in the future and to waiting and watching to see how the development goes with the integration and with the use of drones both in the private sector and in the commercial sector as well.

So thank you all again for being here.

[Whereupon, at 4:58 p.m., the Committee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Ed Waggoner

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Unmanned Aircraft Systems Research and Development"

Questions for the record, Dr. Edgar Waggoner, Director, Integrated Systems Research Program, Aeronautics Research Mission Directorate, NASA

Questions submitted by Rep. Lamar Smith, Chairman

QUESTION 1:

Which agency is responsible for ensuring that command, control, and navigational links are secure, reliable, and robust? What agency is responsible for conducting Research and Development (R&D) to advance these efforts?

ANSWER 1:

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 National Airspace System (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 command and control (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-228, leading to control communication Minimum Operational Performance Standards (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 are being used to develop the UAS C2 MOPS and will be shared with the FAA.

Other NASA R&D related to UAS communications include the following:

- The UAS in the NAS 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 to consider spectrum for beyond line-of-sight (satellite) for UAS communications.
- NASA is conducting large-scale simulations of the UAS communication systems that would be needed for a NAS-wide deployment of UAS.

QUESTION 2:

What major technological obstacles remain to safe integration of UAS into the National Airspace System (NAS), and what research and development (R&D) efforts are planned to overcome those obstacles?

ANSWER 2:

The majority of NASA's research work toward near term integration of UAS into the NAS is organized under the UAS Integration in the NAS Project, which is part of the Integrated Aviation Systems 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 three 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? What are the 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" detect and avoid (DAA, formerly sense and avoid (SAA)) that replaces the pilot's eyes that fulfills the requirement to "see" and avoid other aircraft.

- Determine the impact of these DAA system requirements on the NAS and whether procedures or standards should be modified to minimize the impact.

Research Area: Communications

Communication is another critical element for safe UAS operation. 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 such a communication system? The UAS Communication work within 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 to consider spectrum for beyond line-of-sight (satellite) for UAS communications.

- NASA is testing 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.

- 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.

- NASA is conducting large-scale simulations of the UAS communication systems that would be needed for a NAS-wide deployment of UAS. 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)

Given effective communications, humans will continue to play a role in highly-automated UAS operations. 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 (HSI) is achieving this through: 1) identifying the tasks and requirements that allow a pilot to operate safely; 2) developing a prototype research ground control station (GCS) that supports those tasks and requirements; and 3) demonstrating this capability in simulation and flight tests 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.

- A prototype GCS is being developed and evaluated to present the required information to the pilot and support the tasks required.

The lessons learned from these Human Systems Integration evaluations will inform GCS design guidelines for operations in the NAS that will be vetted through RTCA SC – 228 leading to recommendations to the FAA.

QUESTION 2a:

Are there any R&D gaps?

ANSWER 2a:

This question is better answered by the FAA.

QUESTION 3:

Please discuss some of the immediate benefits that would come from integrating UAS into the NAS.

ANSWER 3:

This question is better answered by the FAA.

QUESTION 4:

Should UAS that operate in the NAS be encrypted the same way as military UAS?

ANSWER 4:

A FAA security analysis has determined that UAS user data and sensitive communication link information shall be encrypted. NASA, working in partnership with the FAA, has recommended the encryption shall be at least as strong as FIPS 140-2 accredited cryptographic algorithms.

QUESTION 4a:

If so, will this be for both large and small UAS (sUAS)?

ANSWER 4a:

NASA's research on UAS control communication systems is focused on UAS larger than sUAS, and as such has not analyzed or developed recommendations for security of sUAS control communication systems.

QUESTION 4b:

If so, how will the government manage these encrypted systems, particularly for the private sector?

ANSWER 4b:

The research to date, conducted by NASA and the FAA has been based on the ability of the UAS control communication system security to be managed by the UAS operator or by a private sector communication system service provider, and that the encryption shall meet the requirements of the Command and Control (C2) MOPS. It has not been determined that it would be necessary for the government to manage these encrypted systems.

QUESTION 4c:

What kind of research is being done to address concerns about individuals hacking, jamming, and spoofing sUAS?

ANSWER 4c:

To address hacking and spoofing of the UAS control communication system, NASA, working in partnership with the FAA, has developed a security architecture based on the analysis of UAS security threats and vulnerabilities. This architecture was instantiated in both laboratory and flight environments, in order to validate operation of recommended security mitigations in a relevant UAS flight environment. The results from the tests were used to develop security requirements in the C2 MOPS.

To address jamming of UAS control communications, a trade study was conducted by NASA and reviewed by industry and other government agencies. This study concluded that due to the limited allocation of UAS frequency spectrum anti-jam communication waveforms would not be effective. The development and use of UAS operations procedures would be necessary to overcome a jammer (i.e. switch to an alternate frequency band, employ lost-link procedures, etc.)

QUESTION 5:

Please explain how FAA, NASA, the Department of Homeland Security, and the Department of Defense (DoD) coordinate to identity R&D gaps.

a. How do agencies decide who will fund projects to address these gaps?

ANSWER 5a:

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 Sense and Avoid Science and Research Panel 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) consisting of DOD, DHS, NASA and the FAA. 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 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 DoD chartered Sense and Avoid Science and Research Panel (SARP). The Office of the Secretary of Defense recognized that a key challenge to integrating UAS into the NAS is a means for UAS to detect and avoid (DAA, formerly sense and avoid (SAA)) other aircraft.

To ensure sound technical approaches to overcome this challenge OSD has established a SARP composed of experts from organizations that are performing DAA research. The SARP's primary purpose is to promote partnerships between the DoD and the broader academic and science community on UAS NAS Integration science and research initiatives. The stakeholder community benefits from these partnerships through a broader range and depth of scientific expertise applied to challenges that affect all aspects of potential UAS operations. Since inception, NASA has played key roles supporting the DAA SARP with subject matter experts and executive leadership.

NASA research outcomes to be delivered in the next two years will address near-term barriers to integration through the support of RTCA's Special Committee 228 (SC-228), chartered by the FAA to address two distinct near-term phases or scenarios. SC-228 will develop Minimum Operational Performance Standards (MOPS) for DAA equipment and command and control (C2) data link solutions. The initial phase of standards development focuses on civil UAS equipped to operate in Class A airspace under Instrument Flight Rules (IFR), hence positive air traffic control. The operational environment for the MOPS is the transit of a UAS from Class A or special use airspace to Class D and E airspace. The second phase of MOPS development will specify DAA equipment to support extended UAS operations in Class D and E airspace, during which the UAS will interoperate with other UAS as well as manned aircraft. NASA is providing critical, research based data for the FAA and SC-228 to use to develop the MOPS for each of these civil UAS operational scenarios. Establishment of the MOPS and subsequent operational rules will provide the framework for initial, near-term civil UAS operations in the National Airspace System.

NASA also works as an integral contributor to the FAA's UAS 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.

QUESTION 6:

Is there any aspect of DoD's research (as outlined in the UAS Executive Committee Annual Report) that is not considered "military" R&D? For instance, is DoD conducting civil research that is not exclusive to the military?

ANSWER 6:

The DoD's UAS R&D portfolio is primarily focused on military purposes. Although the DoD is not directly performing civil research, many of the technologies that have been developed for military purposes have shown promise to transition into the civil industry. For instance, Ground Based Sense and Avoid technologies were developed as means for DoD to move UAS between facilities and perform training. Ground Based Sense and Avoid technologies are now broadly considered a means for the civil industry to perform similar activities. There are several other similar examples in the UAS Executive Committee annual report that document DoD research performed for military purposes that can also have a benefit on the civil community.

QUESTION 6a:

If so, how is this research shared with other agencies, such as FAA, NASA, and DHS?

ANSWER 6a:

The DoD has been open about sharing its research activities with agencies such as FAA, NASA and DHS. There are several forums in which DoD regularly provides updates on their research activities, and even supports agencies such as NASA in development of their own research agendas. The UAS Executive Committee Senior Steering Group (SSG), FAA Interagency Planning Office, and RTCA Special Committee 228 (developing Detect and Avoid Performance Standards) are a few primary examples of where the DoD shares research and technologies in open agency forums.

QUESTION 6b:

How is this research shared with private industry?

ANSWER 6b:

This question is better answered by the DoD.

QUESTION 7:

Are there any additional federal agencies or organizations that should coordinate with FAA to safely integrate UAS into the NAS?

ANSWER 7:

This question is better answered by the FAA.

QUESTION 8:

Given the magnitude of the task of developing a plan to integrate UAS into the NAS by this year, are the deadlines outlined in the FAA Modernization and Reform Act reasonable?

ANSWER 8:

This question is better answered by the FAA.

QUESTION 9:

FAA has been directed to integrate UAS into the NAS while the U.S. transitions to the Next Generation Air Transportation System (NextGen). What challenges and opportunities does this present?

a. How are resources coordinated between NextGen and stand-alone UAS research?

b. How is this complicated by the cancellation of the Joint Planning and Development Office (JPDO)?

ANSWER 9:

These questions are better answered by the FAA.

QUESTION 10:

What is the state of human factors research?

ANSWER 10:

The state of Human Factors research in UAS Integration is strong. NASA has a well planned and funded research effort focused on how the pilot interfaces with the UAS. NASA is evaluating in a realistic environment displays offering various levels of information and decision support to assist the pilot in maneuvering around other vehicles in the vicinity. The displays and decision support tools are being evaluated from the perspective of the pilot/operator and the air traffic controller assessing the amount of information and the format that data are presented to the pilot/operator. The pilot/operator is assessing how well the information helps them made a decision relative to safe maneuvers. The air traffic controller is evaluating any response differences from the pilot based on the information and format used in the various displays.

QUESTION 10a:

What agency is taking the lead on this topic?

ANSWER 10a:

NASA is leading a multi-agency effort including the FAA, DoD and industry.

QUESTION 10b:

Does this research incorporate both pilot and Air Traffic Control challenges?

ANSWER 10b:

Work has focused on displays and alerts to support the detect and avoid function in support of RTCA SC-228. These displays/alerts have been evaluated by trained UAS pilots (supplied by the Air Force and Air National Guard) in conjunction with FAA supplied Air Traffic Controllers. Additional investigations have assessed the impact of contingency management (e.g., lost link) and pilot responses to differing levels of automation.

QUESTION 11:

How many R&D programs and projects relating to UAS does NASA fund?

ANSWER 11:

NASA's FY 2015 direct investment in UAS integration related research and development is $47.87M.

QUESTION 11a:

Please provide these for the record, as well as the FY15 funding levels for each project.

ANSWER 11a:

The Safe Autonomous Systems Operations Project is investing $11.0M and the UAS Integration in the NAS Project is investing $36.7M.

QUESTION12:

Please identify any projects jointly funded by FAA and NASA with any other agency, as well as the FY15 funding levels for those projects.

ANSWER 12:

NASA is not jointly funding any UAS related research with any other agency.

QUESTION 13:

How does the research conducted by NASA and FAA inform the FAA's regulatory process and UAS integration efforts?

ANSWER 13:

NASA's research informs the FAA's regulatory process for UAS integration efforts into the NAS through two primary forums. Plans for the work that needs to be done and coordination and prioritization of activities is a key focus of the UAS ARC. That body brings together stakeholders from government and industry (both manufacturers and operators) to assess the integration of UAS into the NAS holistically. The UAS ARC has developed a comprehensive plan of what activities need to be accomplished to inform the FAA's rulemaking process and shared these plans as recommendations to the FAA. NASA is a member of and contributor to the UAS ARC, regularly presenting research findings and sharing research plans. In addition, NASA uses information gleaned from the UAS ARC deliberations to inform its research strategy.

NASA's research is also guided by RTCA Special Committee 228. RTCA 228 is developing Minimum Operational Performance Standards (MOPS) for two important UAS integration scenarios involving interoperation of UAS and manned aircraft in the NAS. NASA is conducting research that will verify and validate (V&V) these proposed MOPS for the FAA. These V&V activities as well as NASA's research supporting the development of the MOPS informs the FAA of the effect of various parameters related to detect and avoid, communications and pilot displays on the efficiency and safety of operating UAS in the NAS.

QUESTON 14:

What UAS research currently not conducted by FAA or NASA should be conducted by FAA and NASA?

ANSWER 14:

This question is better answered by the FAA.

QUESTION 15:

How has the elimination of JPDO affected coordination between agencies in regards to integrating UAS into the NAS? Has the Interagency Planning Office accomplished the same level of coordination and communication that JPDO did?

ANSWER 15:

Over the last several years, NASA, the FAA and the five other federal agency members of the Joint Planning and Development Office (JPDO) together defined the vision for the Next Generation Air Transportation System (NextGen) and established a roadmap to get there over the long-term. The NextGen JPDO played an important role in helping to establish a common vision for NextGen across government and industry, and coordinated development of the future NAS architecture and concepts of operations. In addition, JPDO led the way in developing the first set of inter-agency UAS integration goals, a comprehensive plan and an attendant Research, Development and Demonstration Roadmap for UAS integration into the National Airspace System. This work established the foundation for subsequent interagency and industry collaboration that has led to the progress we have seen thus far. Since the FAA made a change in interagency coordination from the JPDO to the Interagency Planning Office (IPO), the NextGen IPO has continued to lead the coordination of several key technology focus areas including the prioritization of UAS related research and development across federal agencies.

QUESTION 16:

The Department of Transportation's Office of Inspector General reported that there are outstanding questions among government partners and industry stakeholders about the organization and transparency of the UAS Integration Office. How does the delay and disorganization of establishing FAA's internal UAS office potentially affect the timeline for meeting integration deadlines?

ANSWER 16:

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.

QUESTION 16a:

How does it affect the R&D process, particularly for government partners and industry stakeholders?

ANSWER 16a:

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, NASA's R&D efforts require close coordination with the FAA's UAS Integration Office, industry standards organizations, and international organizations. The close working relationship with the FAA's UAS Integration Office is critically important to ensure that NASA's research provides validated findings that inform the FAA's policy and rule making processes. This includes the prioritization of key technologies to research, as well as the design of critical simulations and flight test campaigns.

QUESTION 17:

FAA has emphasized that U.S. airspace is the busiest in the world, and that this is the reason FAA is taking longer to integrate UAS into the NAS than similar agencies abroad. But sUAS are oftentimes used for research at very low altitudes and at least five miles from an airport where manned aircraft are exceedingly rare or non-existent. Why can't sUAS research be conducted safely right now at low altitudes, on private property, or with similar limitations for safety?

ANSWER 17:

This question is better answered by the FAA.

QUESTION 18:

How does the FAA regulatory process affect UAS R&D, and vice versa?

ANSWER 18:

This question is better answered by the FAA.

QUESTION 19:

Please provide us with examples of progress made on developing sense and avoid technology.

ANSWER 19:

A variety of state-of-the-art technologies (e.g., sensors, ground-control stations, and guidance algorithms) currently exist that will enable UAS pilots to safely avoid other aircraft, known as detect and avoid (DAA, formerly sense and avoid (SAA)).

Three key advancements in the development of detect and avoid technology are (1) quantitative definition of well clear, (2) execution of collaborative flight test, and (3) modeling and simulation work.

Well Clear

One of the two main functions of a DAA system is to remain "well clear" of other aircraft. While human pilots determine "well clear" subjectively, an unambiguous quantitative definition of well clear is needed for UAS DAA systems. The UAS Sense and Avoid Science and Research Panel (SARP) brought together key experts, aligned research efforts from NASA, the Massachusetts Institute of Technology (MIT) Lincoln Laboratory, and the U.S. Air Force Research Laboratory, and a produced a quantitative definition for well clear that was recommended to and accepted by the RTCA Special Committee 228 for use in developing DAA system MOPS.

Flight Test

A flight test was executed utilizing NASA's Predator-B unmanned aircraft in collaboration with the FAA and industry partners to evaluate three potential DAA platforms and their ability to effectively inform the UAS pilot of proximate traffic and remain well clear of other aircraft in realistic flight conditions.

Modeling and simulation

Overall a half a dozen modeling and simulation experiments of increasing capability and fidelity have been executed to collect data that support the development of DAA MOPS. These simulations and planned simulations building on these efforts are crucial to developing and validating the MOPS requirements that will ensure effective UAS DAA systems.

QUESTION 20:

Please provide us with examples of progress in preventing "lost link" disruptions.

ANSWER 20:

Communication link robustness is being addressed during the development of control communication performance requirements in the C2 MOPS. The C2 MOPS performance requirements will be validated based on NASA flight testing in relevant UAS flight environments, as well as within simulations utilizing link models validated by flight testing.

QUESTION 21:

How have your relationships with international partners, such as the International Civil Aviation Organization, informed NASA UAS R&D?

ANSWER 21:

The UAS Integration in the NAS Project is currently supporting the International Civil Aviation Organization (ICAO) Remotely Piloted Aircraft Systems (RPAS) Panel in the areas of Human Factors and Airspace Integration. Through our support of this panel, the Project will inform the ICAO RPAS panel on technology developed under the Project. Additionally, the Project will collect information from the Panel that will influence and inform the Project's technology developments. An example of this collaboration is the development of an "information paper" on human performance issues in RPAS. The draft will be presented at the June 2015 symposium. The Project also supports ICAO's Frequency Spectrum Management Panel, providing information on the Project's communication technology developments and air-ground channel measurement and modeling efforts, and receiving comments and guidance from the Panel's members.

Additionally, the Project is supporting the International Telecommunication Union – Radiocommunication (ITU-R) 2015 World Radiocommunication Conference for spectrum analysis and recommendations to support UAS command and control, by providing frequency spectrum sharing studies and other technical support in obtaining global radiofrequency spectrum allocations supporting unmanned aircraft communications.

QUESTION 22:

As the number of UAS operations increase, so too will UAS operators' demand for spectrum. What R&D is being conducted to either minimize the amount of spectrum needed, or to increase the efficiency of spectrum used by UAS?

ANSWER 22:

The development of the C2 MOPS includes the ability to size the frequency usage according to the amount of data necessary to safely fly the aircraft. A set of UAS control communication data rates have been developed in order to perform an analysis of the number of UAS that could be in operation using a prototype communication waveform. The sizing of the frequency channels, as written in the C2 MOPS, allows the usage of more efficient control communication waveforms as communication technologies evolve in the future, thus allowing more UAS to operate.

QUESTION 23:

Will UAS operations require additional satellite spectrum to ensure safe operations?

ANSWER 23:

An analysis was conducted within RTCA Special Committee (SC-203), to determine the requirements for terrestrial and satellite UAS spectrum, prior to any spectrum being allocated for UAS communication. This analysis took into account different types of UAS, their missions, and an estimate of the number of UAS, in order to determine the overall amount of spectrum required. This analysis also separated the spectrum requirements between terrestrial and satellite, based on the ability of the aircraft to carry necessary SatCom equipment. Given the amount of spectrum allocated for UAS terrestrial frequencies at the 2012 World Radiocommunication Conference, there is still a need for satellite spectrum in order to meet the needs for the anticipated number of UAS operations. NASA, industry partners, and other government agencies are currently conducting studies to support the allocation of necessary satellite spectrum for UAS at the 2015 World Radiocommunication Conference.

QUESTION 24:

Much attention has been paid to the challenges of securing command and control links for UAS. What other challenges exist that may not receive as much attention (and therefore as much R&D support)?

ANSWER 24:

NASA is addressing the development of UAS Minimum Operational Performance Standard supporting the challenges of Command and Control and Detect and Avoid. There may well be other challenges that exist relative to UAS integration but they would be outside NASA's expertise and knowledge to assess or to offer comments against.

Questions for the Record from Ranking Member Johnson
Full Committee Hearing
January 21, 2015
"Unmanned Aircraft Systems Research and Development"

Dr. Edgar Waggoner
National Aeronautics and Space Administration

QUESTION 1:

What is the scope and timeframe of the work being conducted by NASA, FAA, and NIST to analyze and develop mitigations to potential security vulnerabilities of the UAS control communication system?

ANSWER 1:

The UAS Communication work within NASA's UAS Integration in the National Airspace System (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 to consider spectrum for beyond line-of-sight (satellite) for UAS communications.

- NASA is testing 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.

- NASA is conducting large-scale simulations of the UAS communication systems that would be needed for a NAS-wide deployment of UAS. NASA and the FAA are working in partnership to analyze and develop mitigations to potential security vulnerabilities of the UAS control communication system.

QUESTION 2:

What are the key challenges associated with NASA's near-term goal of developing and demonstrating a UAS Traffic Management system to safely enable low altitude airspace and UAS operations within five years?

ANSWER 2:

The following are main challenges associated with NASA's near term goals of developing and demonstrating a UAS Traffic Management (UTM) system to safely enable UAS operations at low-altitude airspace within five years.

- The final safety case will require detailed understanding of the vehicle performance and airspace integration considerations. We are making conservative estimates about vehicle performance regarding trajectory prediction, sense and avoid, weather forecasting at low altitudes, sensor/software/hardware technologies that will support operations all the way to one's doorstep. NASA is exploring National UAS Standardized Testing and Rating (NUSTAR) capability for assessing vehicle performance. With NUSTAR capability, comprehensive assessment of vehicle performance characteristics will be possible which will enable establishment of more accurate separation, sense and avoid performance, weather forecasting precision, and safety assessment of operations all the way to door step.

- Cyber security continues to be a challenge in the UTM environment.

- All stakeholders also need to continue to focus on approaches to address privacy, legal, national security, and policy considerations beyond testing to enable daily use.

QUESTION 3:

How should Congress ensure that it gets the most out of the UAS test sites? What, if anything, does Congress need to do to maximize the use of these test sites for their intended purpose? Are there any barriers that need to be addressed, and if so, what are they?

ANSWER 3:

This question is better answered by the FAA.

"Unmanned Aircraft Systems Research and Development"
January 21, 2105

Representative Dan Lipinski – Questions for the Record

QUESTION 1:

We as a nation are supporting a variety of research efforts spread across several agencies. How can we (the committee) ensure that work being done by NASA, and others, is being utilized by the FAA?

ANSWER 1:

NASA's research informs the FAA's regulatory process for UAS integration efforts into the National Airspace System (NAS) through two primary forums. Plans for the work that needs to be done and coordination and prioritization of activities is a key focus of the UAS Aviation Rulemaking Committee (ARC). That body brings together stakeholders from government and industry (both manufacturers and operators) to assess the integration of UAS into the NAS holistically. The UAS ARC has developed a comprehensive plan of what activities need to be accomplished to inform the FAA's rulemaking process and shared these plans as recommendations to the FAA. NASA is a member of and contributor to the UAS ARC, regularly presenting research findings and sharing research plans. In addition, NASA uses information gleaned from the UAS ARC deliberations to inform its research strategy.

FAA has chartered the RTCA Special Committee 228 (RTCA SC-228) to address UAS issues. RTCA Special Committees (SCs) leverage the expertise of the aviation community to generate recommendations in response to requests (Taskings) from the FAA to address technical topics including generating minimum performance standards which often form the basis for FAA regulatory requirements. RTCA 228 is developing Minimum Operational Performance Standards (MOPS) for two important UAS integration scenarios involving interoperation of UAS and manned aircraft in the NAS. NASA is conducting research that will verify and validate (V&V) these proposed MOPS for the FAA. These V&V activities as well as NASA's research supporting the development of the MOPS informs the FAA of the effect of various parameters related to detect and avoid, communications and pilot displays on the efficiency and safety of operating UAS in the NAS.

QUESTION 2:

Many countries have segmented UAV rules by weight, as smaller UAVs can access more areas safely, while heavier UAVs have the potential to do more harm. What research is being conducted to better understand how multiple weight classes under 55 pounds could impact operator qualifications, device certifications, and operational limits?

ANSWER 2:

Initial studies at NASA, completed in 2014, identified a number of attributes important to UAS classification, but did not focus exclusively on small UAS. That work was published in a technical report "A Review of Current and Prospective Factors for Classification of Civil Unmanned Aircraft Systems," NASA/TM-2014-218511. NASA's current portfolio does not include any research activities, at this time, examining the potential for subdivisions of the small UAS category, by weight or other attribute.

QUESTION 3:

Public agencies are beginning to find valuable uses for UAS technology, such as responding to natural disasters and inspecting infrastructure. What technology transfer efforts are FAA and NASA taking to promote and implement these technologies at public agencies?

ANSWER 3:

Both NASA and the FAA are heavily focused on developing standards for safe and efficient UAS integration in the NAS. NASA and the FAA are developing Detect and Avoid (DAA), Command and Control (C2), and UAS Ground Control Station technologies that will assist public agencies and civil entities to obtain full access to the NAS in support of natural disaster, infrastructure inspection, and many other UAS missions. UAS certification standards will allow UAS owners to apply for FAA approval against predefined certification and operational procedures. The primary standards that the NASA UAS Integration in the NAS project is focused on relate to RTCA Special Committee 228 Detect and Avoid and Command and Control standards. These standards represent NASA and FAA transfer of technology and demonstrate significant progress towards allowing UAS to perform missions on-demand to support broad user defined needs.

NASA is also in the initial development stages to determine feasibility of a UAS Traffic Management (UTM) system designed to support UAS at lower altitudes. As the UTM is developed, it will include many industry partners and the FAA. As the system develops and becomes functional, industry will be expected to leverage the system in coordination with the FAA to ensure safe low altitude UAS operations per the UTM use case. Both industry and government agencies can benefit from the use of a UTM.

Both NASA and the FAA stay well coordinated on all technology development efforts with the primary expected user group of UAS across the government agencies. Groups such as the FAA Aviation Rulemaking Committee, the joint agency UAS Executive Committee (ExCom) and UAS Senior Steering Group (SSG), and FAA Interagency

Planning Office are a few primary examples of where both the FAA and NASA share research and technologies in open agency forums. The NASA UAS projects also regularly interfaces with many other government agencies.

QUESTION 4:

UAS is a growing industry that will require workers with technical skills and experience. As a co-chair of the STEM Education Caucus, I would like to know if there any issues on STEM education and workforce training specific to UAS.

ANSWER 4:

NASA does not directly target STEM Education initiatives for UAS, but the Agency does support broader initiatives promote STEM Education. We have not identified any workforce training issues specific to UAS.

QUESTION 5:

Our veterans possess many of the skills required in the burgeoning UAS industry. For example, many veterans hold pilots licenses. How can we (the committee) and the federal agencies help put our veterans to work in the UAS industry?

ANSWER 5:

NASA supports and fully complies with Federal law and regulation concerning hiring of veterans. The Agency does not have a role in promoting veterans' employment in the UAS industry.

QUESTION 6:

If these aircraft are going to share the airspace with airliners, what is the FAA's position on the requirement for UAS aircraft to be equipped with collision avoidance capability? TCAS? ADS-B?? Is industry in full agreement? If not, why not?

ANSWER 6:

This question is better answered by the FAA.

QUESTION 7:

Comment on the difficulty of developing "sense and avoid" technology that effectively replicates the ability of a pilot to continuously search the area around his or her aircraft and react immediately and effectively to any perceived threat.

ANSWER 7:

A variety of state-of-the-art technologies (e.g., sensors, ground-control stations, and guidance algorithms) currently exist that will enable UAS pilots to safely avoid other aircraft, known as Detect and Avoid (DAA, formerly Sense and Avoid (SAA)).

One key challenge is integrating these technologies into a DAA system that replicates the ability of an onboard pilot to "see and avoid" other air traffic, and safely interoperates within our current National Airspace System (NAS). Seamless integration of DAA-equipped UAS into the NAS is being addressed through experimental evaluations of both the Air Traffic Control environment, and interoperability with the Traffic Alert and Collision Avoidance System II (TCAS-II).

A second challenge is the establishment of DAA minimum operational performance standards (MOPS). The establishment of MOPS is being led by the RTCA Special Committee 228. This Special Committee is on track for delivering Draft DAA MOPS in July 2015, and Final DAA MOPS in July 2016.

Responses by Mr. James Williams

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Unmanned Aircraft Systems Research and Development"

Questions for the record, Mr. James Williams, Unmanned Aircraft Systems Integration Office, Aviation Safety, Federal Aviation Administration

Questions Submitted by Rep. Lamar Smith, Chairman

1. What agency is ultimately responsible for ensuring that command, control, and navigational links are secure, reliable, and robust? What agency is responsible for conducting R&D to advance these efforts?

The FAA will set the standards for these technical requirements along with other partner agencies (e.g. National Aeronautics and Space Administration (NASA), Department of Defense (DoD)). The FAA is working to conduct research to advance these efforts. Designers, manufacturers and operators will then need to meet these standards.

2. What major technological obstacles remain to safe integration of UAS into the National Airspace System (NAS), and what FAA research and development (R&D) efforts are planned to overcome those obstacles?
   a. Are there any R&D gaps?

The most significant technological obstacles to the safe integration of UAS in the NAS include the development of reliable detect and avoid (DAA) and command and control (C2) capabilities on the unmanned aircraft itself as well as in the ground control station and supporting NAS infrastructure. The FAA and its NASA and DoD partners are planning a number of research efforts to validate the RTCA phase 1 technical standards for these systems and develop the supporting infrastructure for both DAA and C2 to allow equipment employing these standards to be used in safe and efficient NAS operations. Additional efforts will be necessary as RTCA continues to develop additional DAA and C2 capabilities in the second phase of its technical standards development activities.

3. Please discuss some of the immediate benefits that would come from integrating UAS in the NAS?

Integration of UAS into the NAS will be incremental. Full scale integration that enables routine beyond line-of-sight operations is several years away. Key technical challenges, such as DAA and C2 must be addressed before this is possible. However, we are moving forward today with enabling small UAS operations within line-of-sight. The small UAS proposed rule has been published and we received over 4500 public comments on the proposal. We will work toward finalizing the rule as quickly as possible. In the meantime, we are authorizing limited commercial operations via exemption under authority granted under section 333 of the FAA's 2012 Reauthorization. We have received over 1000 petitions for exemption and have granted authorization to almost 400 petitioners as of May 18, 2015. These civil commercial operations generate economic benefits and address operational needs for jobs that are dull, dirty, or dangerous. Right now, we are seeing benefits and advances in many industries, such as precision agriculture, and aerial surveillance and filmmaking.

4. Should UAS that operate in the NAS be encrypted the same way as military UAS?
   a. If so, will this be for both large and small UAS (sUAS)?
   b. If so, how will the government manage these encrypted systems, particularly for the private sector?

While commercially available UAS for hobby or recreational use generally come with some level of encryption to maintain contact between the operator and the aircraft, industry standards for encryption for UAS that have to be certified for other non-hobby or recreational uses have not yet been established. Industry groups such as RTCA and ASTM are working with the FAA on developing standards for certification. We expect to have these standards established in 2016.

5. What kind of research is being done to address concerns about individuals hacking, jamming, or spoofing sUAS?

The FAA, NASA, and aerospace industry have partnered in research to develop performance standards for UAS C2 radio link security and UAS ground network security to address hacking.

Multi-constellation GNSS technology, GPS with tightly coupled inertial device, and secured C2 radio link are areas of ongoing research and standards development to address jamming and spoofing of sUAS.

6. Please explain how FAA, NASA, the Department of Homeland Security, 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 FAA, NASA, and DoD coordinate through collaborative relationships that support RTCA standards development, UAS Executive Committee (ExCom) initiatives, and ongoing prioritization efforts such as the Sense and Avoid Science and Research Panel (SARP). Research efforts are aligned with each agency's capabilities. Collaboration in technical interchange meetings and standards development forums helps avoid duplication of effort. Funding prioritization is based on the availability of sufficient resources from each agency and an alignment with individual agency interests and agreed joint interests. The SARP holds quarterly forums to discuss the progress on joint research interests and to re-prioritize research needs based on current progress and continuing needs of the partner agencies. The FAA and the Department of Homeland Security (DHS) partner in the evaluation of the usability and capability of sUAS through FAA support to the evaluation procedures that DHS has used effectively in its Robotic Aircraft for Public Safety program.

7. 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 has had one face-to-face meeting and one telecon in the last year. A face-to-face meeting is being scheduled for early summer. As stated in the charter, the UAS ExCom will meet regularly face-to-face and by teleconference.

8. Is there any aspect of DoD's research (as outlined in the UAS Executive Committee Annual Report) that is not considered "military" R&D? For instance, is DoD conducting civil research that is not exclusive to the military?

The DoD is conducting research that supports RTCA technical standards development, principally in the validation of DAA standards and related safety evaluations.

9. Which federal agencies and organizations should coordinate with FAA to safely integrate UAS into the NAS?

Through the UAS ExCom, a body established by Congress, the FAA coordinates with key agencies, such as DoD, NASA, the Department of Commerce, and DHS on UAS integration.

10. The FAA Modernization and Reform Act directed the FAA to take a number of steps toward integrating UAS into the NAS. In June 2014, the Department of Transportation's Office of Inspector General released an audit of FAA's UAS integration activities and determined that FAA is behind on meeting several milestones.
    a. Please explain which milestones you are behind on and provide a notional schedule for their completion.

The Office of Inspector General's Report included 11 recommendations. Currently, we are behind on three of these recommendations, which are listed below, along with their associated timelines:

1) Publish a report annually detailing ongoing research activities and progress FAA and other entities are making in their respective areas of responsibility to resolve technical challenges to safe integration of UAS. **Action:** FAA is developing a detailed inventory of past and ongoing research activities. 9/30/15
2) Establish a timeline for developing standardized training and procedures for air traffic controllers responsible for UAS operations. **Action:** A timeline for providing standardized training for air traffic controllers is being developed. 9/30/15
3) Develop a mechanism to verify that the UAS Integration Office, all FAA lines of business, and field safety inspectors are effectively coordinating their UAS efforts. **Action:** The FAA will make research planning and execution information available to government and industry research stakeholders. 9/30/15 We strongly desire their participation in keeping areas of research they are addressing current and up-to-date.

Research, planning, and execution information from NASA, DoD, MITRE and other research partners is captured by the FAA in its UAS Research Inventory and Mapping (RIM) database. This research inventory database is being refined with input from MITRE CAASD to improve its consistency and usability.

11. Given the magnitude of the task of developing a plan to integrate UAS into the NAS by this year, are the deadlines outlined in the FAA Modernization and Reform Act reasonable?

The deadlines in the FAA Modernization and Reform Act are generally reasonable. However, these deadlines must consider that UAS integration into the NAS must be incremental. Since the FAA is charged with safely integrating UAS into the largest, most complex aviation system in the world, the safety of current NAS users as well as people and property on the ground must be the FAA's primary focus. We are moving forward deliberately and steadily to expand authorized UAS operations. In 2015 alone, the FAA has been able to significantly increase access for commercial operations and to streamline the exemption process to authorize these operations. In addition, we have significantly expanded our research and development budget and associated activities to answer many of the difficult questions that must be addressed before UAS operations in the NAS, including beyond line-of-sight operations, are routine.

12. FAA was directed to integrate UAS into the NAS while the U.S. transitions to the Next Generation Air Transportation System (NextGen). What challenges and opportunities does this present?
    a. How are resources coordinated between NextGen and stand-alone UAS research?
    b. How is this complicated by the cancellation of the Joint Planning and Development Office (JPDO)?

Examples of NextGen technologies to support UAS Integration into the NAS are:

- Airborne Collision Avoidance System (ACAS-Xu): In order for many unmanned aircraft to operate safely in shared airspace, we must develop technologies that enable them to "detect and avoid" other airborne vehicles. The agency is researching and developing a collision avoidance system specifically designed for unmanned aircraft called ACAS-Xu.

- Automatic Dependent Surveillance-Broadcast (ADS-B): ADS-B helps achieve more precise surveillance – and separation – of both manned and unmanned aircraft in the same vicinity where the FAA provides separation and improved situational awareness in the other radar airspace.

- National Airspace System Voice System (NVS): Another NextGen technology that will support unmanned aircraft is NAS Voice System. NVS modernizes the voice communication capabilities that we use for air traffic services. It will enable controllers to communicate with the ground pilot of an unmanned vehicle.

Examination of UAS in other than integrated operations and airspace in which the FAA does not provide radar service also is ongoing, especially through cooperate activities with NASA.

a. In 2011, NextGen appointed an UAS Portfolio Manager to unify and manage all UAS research and development efforts under a cohesive portfolio. This ensures that there are no stand-alone UAS research initiatives. The UAS R&D Portfolio includes the UAS Center of Excellence, interagency UAS partnerships (with NASA, DOD, DHS, and the Department of the Interior, etc.), UAS flight demonstrations, and all of the aviation safety research defined by the FAA's UAS Integration Office and funded by the FAA's UAS RE&D budget line item.

Looking forward, the Interagency Planning Office (IPO) is working with its partner agencies to develop a multiagency federated UAS vision that will help guide research planning for far-term outcomes through 2030 and beyond.

b. Following the cancellation of the JPDO, NextGen created the Interagency Planning Office (IPO) to maintain connectivity with the FAA's government partners and to focus on key aviation domains in the long-term such as UAS. The IPO conducts monthly interagency meetings with NextGen's UAS Advisor to facilitate discussions among agency partners. The IPO is also leading the development of an interagency UAS Vision in the 2030+ time frame. This activity includes biweekly meetings of a multiagency working group, and governance through a partner agency NextGen Executive Board, continuing the interagency coordination and communication practices that were established by the JPDO.

In addition to the IPO coordination on research, the multi-agency UAS ExCom for nearer term coordination continues and provides the link between the now and the future that the IPO team represents.

13. What is the state of human factors research?
   a. What agency is taking the lead on this topic?
   b. Does this incorporate both pilot and air traffic control challenges?

The FAA, NASA, and DoD are effectively collaborating to address human factors research of common interest. NASA is taking the lead in RTCA standards developments for the controls, displays, and alerting needs of both DAA and C2 systems, and the FAA and DoD are in close collaboration with NASA. The FAA is taking the lead in human factors research related to air traffic control considerations and new controller displays and procedures for UAS integration, but DoD and NASA are key collaborators and DoD has provided leadership in developing airspace integration procedures and charting that may have potential application at civil airports and terminal control areas.

14. How many R&D programs and projects relating to UAS does FAA fund?
a. Please provide these for the record, as well as the FY15 funding levels for each project.

There are 6 R&D domains related to UAS which are funded by the FAA. The following list reflects those domain areas, and their FY15 planned/estimated funding level:

1) Detect and Avoid - $4,113,000
2) Command and Control - $2,472,000
3) Human Factors - $344,000
4) Aircraft Safety - $1,092,000
5) Test Sites - $451,000
6) UAS Research Center of Excellence - $4,000,000

PC&B and other costs are not included.

15. Please identify any projects jointly funded by FAA with any other agency, as well as the FY15 funding levels for those projects.

FAA is jointly funding the following project with DoD/Navy:

- Control Non Payload Communication testing (CNPC) – Under the command and control research domain for UAS, the FAA is partnered with DoD/Navy to conduct a flight demonstration in FY15 to examine the basic feasibility to use a small form factor radio in a composite Small Unmanned Aircraft Systems (sUAS) airframe at point-to-point (P2P) ranges that allow flexible employment of sUAS.

Funding Levels:
FAA: $855K
Navy: $35K (plus 2 ScanEagle UASs, UAS pilots, flying time and engineering personnel).

In addition, FAA is collaborating with NASA in the domain areas of Detect and Avoid Technology and Human Factors, as well as Communications and Certification. FAA will leverage NASA project outcomes and findings to further expand on its efforts in these areas. Two major NASA projects are:

- NASA Unmanned Aircraft Systems (UAS) Integration in the National Airspace Systems (NAS) – This project will demonstrate solutions in specific technology areas that address operational and safety issues related to UAS access to the NAS. NASA, the FAA, and industry partners have successfully demonstrated a proof-of-concept airborne sense-and-avoid (SAA) system of an Airborne Collision Avoidance System for unmanned aircraft.
-

Funding Levels:

NASA: $32M

- UAS Traffic Management - This project seeks to enable safe and efficient low-altitude airspace operations by providing services such as airspace design, corridors, and dynamic geofencing without human operators monitoring every vehicle continuously.

Funding Levels:
NASA: $10M

16. How has elimination of the JPDO affected coordination between agencies in regards to integrating UAS into the NAS? Has the Interagency Planning Office accomplished the same level of coordination and communication that JPDO did?

As a result of the ongoing biweekly meetings of the multi-agency working group, and the governance through a partner agency Senior Policy Committee and NextGen Executive Board, there has been no practical change in coordination and communication due to elimination of the JPDO.

17. When staff asked for an FAA briefing on integrating UAS, they requested an organizational chart of the UAS Integration Office. Likewise, the Department of Transportation's Office of Inspector General recommended that FAA create a mechanism to delineate their coordination efforts across the agency. Has this been done?

The UAS Strategic Working Group is in the process of establishing a mechanism to measure the effectiveness of coordination efforts based on an OIG recommendation. It is anticipated that this process will be approved and implemented by the end of July 2015. The current version of the UAS Integration Office organizational chart is attached.

18. In 2013, FAA published the first edition of the five-year UAS integration roadmap. Based on the mandate in the FAA Modernization and Reform Act of 2012, this roadmap is supposed to be updated annually with more details about how UAS integration will occur. However, there was no update for 2014. When will the next update be released?

We are working on the 2015 edition of the Roadmap and plan to deliver it for Executive Branch coordination by August 30, 2015.

19. The Department of Transportation's Office of Inspector General reported that there are outstanding questions among government partners and industry stakeholders about the organization and transparency of the UAS Integration Office. How does the delay and disorganization of establishing this office potentially affect the timeline for meeting integration deadlines?
    a. How does it affect the R&D process, particularly for government partners and industry stakeholders?

The UAS Integration Office was officially created in January 2013. The creation of a focal office within the FAA has ultimately fostered greater levels of efficiency and effectiveness by streamlining processes, policies, and procedures. As the office and the environment matures, the level of effort needed to maintain the level of safety required becomes more complex, potentially causing delays to the integration timeline. These delays are not due to disorganization, however. Safety is the FAA's top priority, and as such, cannot be compromised as we continue to move forward into this new and challenging landscape.

20. Does FAA plan to separate UAS into more than two size and weight classes? What are the pros and cons of doing so?

In the recently published sUAS notice of proposed rulemaking (NPRM), the FAA solicited comments on a smaller class of UAS (micro) that are under 4.4 pounds. The FAA is evaluating the more than 4500 public comments received in response to the NPRM and will consider designating additional classes of UAS as we finalize the small UAS rule.

21. How long will it take FAA to review all the public comments on the Small UAS Notice of Proposed Rulemaking? How will that timeline affect UAS R&D in both the public and private sectors?

The public comment period on the proposed small UAS rule closed on April 24, 2015. Issuing a small UAS final rule is one of the FAA's and the Department of Transportation's highest priorities, however the timing to promulgate the final rule will depend heavily on the quantity and substance of comments we receive.

Today, a person seeking to conduct private sector R&D may apply for a section 333 exemption and a Certificate of Waiver or Authorization (COA) issued by the FAA Air Traffic Organization to use specific airspace and to conduct specific operations. An alternative avenue available today would be to apply for a special airworthiness certificate in the experimental category to conduct private sector R&D operations. Public aircraft operations would only need a COA permitting the R&D activities.

22. Is it a violation of FAA regulations for a professor and a student to fly a small model helicopter, a paper airplane, or a rubber band-powered airplane on a campus 5 feet above ground in connection with coursework or a class project?

Any device that meets the definition of Aircraft as defined in 49 USC 40102(a)(6), and the definition of Unmanned Aircraft or Unmanned Aircraft System as defined in Section 331 of Pub. L. 112-95 must either operate with FAA authorization or within the parameters established in Section 336. If a UAS operation in question is strictly for hobby or recreation and meets the elements of the definition of Model Aircraft found in section 336(c), then no further FAA authorization is required.

23. A two-pound DJI Phantom flown for research is just as dangerous as a two-pound DJI phantom flown as a hobby. Why it illegal to fly a DJI phantom for research, but not as a hobby?
    a. Is a risk-based regulatory approach based on potential damage a smarter way to regulate UAS when compared to the current FAA regulatory approach that is at least partly based on a UAS-operator's purpose for flying?

In Section 336 of the FAA Modernization and Reform Act of 2012, the FAA was effectively prohibited from making new regulations for model aircraft operations. UAS flights that were not for recreation or hobby, such as those for research, require additional authorization. These types of flights may be authorized to operate under a Section 333 exemption, as authorized by the FAA Modernization and Reform Act of 2012, or via a Special Airworthiness Certificate, Experimental Category.

24. In early December, 2014, the Association of American Universities and Association of Public Land-grant Universities wrote a letter to FAA stating "there is no timely, workable mechanism for both public and private universities to secure FAA approval to conduct important research…utilizing small UAS technology." Has FAA considered issuing a rule to make it easier for universities to research sUAS, such as allowing universities to research sUAS on their own property, below 400 feet?

Universities, both public and private, may submit a petition for exemption under Section 333 of the FAA Modernization and Reform Act of 2012 to operate for research. The FAA recently streamlined the COA process, which accompanies a Section 333 Exemption grant, to enable operators to operate below 200 feet over their own property, provided they are a specified distance from airports. Additional details may be found at: http://www.faa.gov/news/updates/?newsId=82245.

The sUAS proposed rule would also permit universities to operate sUAS under its proposed framework without having to first obtain an exemption or COA from the FAA.

25. When do you expect to determine the safety, reliability, and performance data guidelines needed for R&D conducted at test sites?

The FAA is not providing safety, reliability, and performance data guidelines for R&D conducted at the Test Sites. In September 2014, at the 2nd Technical Interchange Meeting, FAA gave a presentation on potential research areas to the Test Sites. FAA also provided the document itself, which contains 7 broad categories that totaled over 120 potential research areas. Research includes the areas of certification (including sense and avoid, maintenance, security, environmental, communications and airworthiness), flight planning, operational approvals, operations and safety. This research will assist FAA (and industry) in determining safety, reliability and performance guidelines for UAS in the NAS. Further, research considerations were presented for each of the potential research areas. These research areas are not static and will evolve as UAS integration matures to support operational scenarios and policy issues.

26. How useful can the test sites be if they haven't been given research guidelines?

The FAA worked across agency lines of business to prepare Potential Research Areas for UAS Test Sites associated with the previously developed UAS concept of operations. The topics were presented in September 2014, at the 2nd Technical Interchange Meeting representing areas FAA believes require further research that involves flight testing that would be appropriate for all Test Sites for integration. The Agency briefed this topic and in October 2014 provided the Potential Research Areas for UAS Test Sites document to the Test Sites. This document presented research in seven (7) broad categories that totaled over 120 potential research areas. These research areas are not static and will evolve as UAS integration matures to support operational scenarios and policy issues. The Potential Research Areas for UAS Test Sites document, marked "Sensitive - Not for Distribution", demonstrates FAA collaboration with the Test Sites as this information is not for the general public and has not been released outside the FAA.

In 2015, test sites plan to continue UAS research, development, testing, and evaluation to support integration of UAS into the NAS, including DAA research and testing; investigation of lost link causes and resolution; and evaluation of the adequacy of air traffic control and communications procedures. Coupled with aviation research will be the exploration of commercial applications such as emergency response, utility company infrastructure inspection, wildlife census and precision agriculture.

27. When do you expect to determine the safety, reliability, and performance data guidelines needed for R&D conducted at test sites?

The FAA is not providing safety, reliability, and performance data guidelines for R&D conducted at the Test Sites. In September 2014, at the 2nd Technical Interchange Meeting, FAA gave a presentation on potential research areas to the Test Sites. FAA also provided the document itself, which contains 7 broad categories that totaled over 120 potential research areas. Research includes the areas of certification (including sense and avoid, maintenance, security, environmental, communications and airworthiness), flight planning, operational approvals, operations and safety. This research will assist FAA (and industry) in determining safety, reliability and performance guidelines for UAS in the NAS. Further, research considerations were presented for each of the potential research areas. These research areas are not static and will evolve as UAS integration matures to support operational scenarios and policy issues.

28. FAA test sites were created to help FAA develop regulatory standards and integrate UAS into the NAS. Have the test sites successfully aided FAA in developing these standards?
    a. If so, which standards have been developed thanks to research performed at FAA test sites? Please include an example of research at a test site that has contributed to developing regulatory standards.

b. If not, what changes in research policy would make the test sites useful to FAA?

FAA continues to work with industry on the development of RTCA Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS) to shape the certification of the safety and efficiency of new equipment. One example of planned and on-going activities includes UAS Control and Non Payload Communications (CNPC). This includes validation of levels of safety anticipated from using a dual band approach for detect and avoid and CNPC to reduce collision likelihood. As standards are developed the test sites could conduct live trial testing e.g., CNPC flights could be conducted at the test sites.

29. How many organizations have actually used the test sites, and in how many instances have these organization used them?

The Test Sites were asked by the FAA to provide information to respond to this question posed by Congressman Hultgren at the January 21, 2015 House Committee on Science, UAS Research and Development Hearing. FAA received the following response on March 18, 2015. "While none of the test sites directly tracked inquiries after their selection was announced some had estimates or tracked contacts they initiated. One contact campaign identified over 100 contacts to follow up after reaching out. Another estimated roughly 900 inquiries in the months immediately following selection, counting telephone calls, meetings, and website visits. A third listed 884 calls, 985 meetings, which resulted in 52 signed non-disclosure agreements, but had no way to track website visits. Similar differences were provided in contracts signed vs documents completed, or actual operations. Those who reported state the phones continue to ring off the hook, which results in significant dedication of time to pursuing early contacts, few of which convert to actual work."

The following table was also provided in the test site response:

Contacts	Meetings	NDAs	Contracting	Contracts	Used	333
>900	included	unk	unk	7	7	NR
884	985	52	4	4	2	NR
>100 OR + unk	included	29	~ 8	~ 8	4	several
~800	included	20	6	3	3	At least 6
179	167	NR	NR	NR	170	NR
>800	>40	~15	~15	~6	~4	1 in process

Unk means unknown
NR means no report.
~ means interpreted to fit within this category.

30. What is the average cost of using a test site for the user?
    a. Does this cost include the cost of paperwork and overcoming regulatory hurdles?
    b. Is the cost prohibitive to small businesses?

The FAA is unable to respond to this question. Test Site fees are proprietary in nature and have not been shared with the FAA.

31. Are there altitude, airspeed, line-of-site, or other restrictions at these test sites?
    a. If so, is there any concern that these restrictions limit research and development? Why or why not?

Test Sites submit COA applications predicated on their specific research and operational objectives. These applications specify unique parameters identified by the test site including: altitudes, airspace needs, aircraft type, research planned, flight parameters (with or without a chase plane) and day vs. night operations.

As each Test Site submits its requirements, the FAA approves the operational parameters submitted. Therefore, it is the test site that establishes the operational limits.

32. What data has been collected from the test sites?
    a. Is any of the data from the test sites publicly available?
    b. Can private companies access that data?
    c. How is that data protected?

The FAA tracks Test Site activities including: number of flights; missions/operations; type of aircraft; ground control stations; time of day; type of operation—line-of site or beyond-line of site; other aircraft in vicinity; incident and accidents; and classes of airspace. The requirement for submitting this data is included in the Test Site Operator's COAs. Reported data is reviewed and evaluated for accuracy.

The William J. Hughes Technical Center is playing an important role in data collection; a significant portion of test site data analysis is being performed there. A Data Lead from the William J. Hughes Technical Center visited each test site to evaluate how data is captured and maintained. The test sites made an estimated 550 comments on current data collection procedures which the FAA is currently reviewing. This has enabled the FAA to identify several areas where it can provide assistance to the test sites by defining and clarifying relevant terminology; improving data structures and format; and offering a more intuitive means of reporting. These comments also helped the FAA identify potential research opportunities with the test sites that may contribute to the larger mission of UAS Integration into the NAS.

The FAA plans to review the research to be conducted to understand the relevant data the FAA may independently or collaboratively analyze. A UAS Test Site data retention plan is under development to securely warehouse data.

The FAA has been testing an automated mission logging system since February 11, 2015 at the North Dakota and Texas Test Sites. These two test sites have provided over 120 comments, suggestions, issues, and enhancement requests to the FAA. When fully deployed at all test sites, each test site will be able to log aircraft flight concurrent with the actual flight, and the information will be automatically stored for data analysis purposes by the test site and FAA. Initial operational capability at all test sites is scheduled to be completed by summer 2015.

Test Sites control access to their data for economic reasons such as intellectual property, and the proprietary and/or competition sensitive nature of the data. FAA may provide a consolidated data snapshot in public briefings.

Data provided to the FAA is protected by implementing government and industry standards based security practices for information systems.

33. Do you provide any of the following to assist test site users with testing: infrastructure such as GPS and accuracy evaluation for takeoff, flight, and landing; RF monitoring for testing communications; infrastructure for testing sense and avoid systems; maintenance facilities; safety equipment for hazards; weather monitoring; or UAV tracking services to locate UAVs in the case of fly-aways or other incidents?
    a. Could you provide these services on a reimbursable basis?
    b. Do you believe that providing this kind of support would improve FAA's data from the test sites in a way that would accelerate integration of UAS into the NAS?

FAA does not provide infrastructure such as GPS and accuracy evaluation for takeoff, flight, and landing – GPS is provided as a free service by the U.S. Government. It is operated and maintained by the DoD. Further, FAA does not provide RF monitoring for testing communications; infrastructure for testing sense and avoid systems; maintenance facilities; safety equipment for hazards; weather monitoring; or UAV tracking services to locate UAVs in the case of fly-always or other incidents. We do not believe it is feasible for the FAA to charge test site users for those services it does not charge other NAS users.

Having the FAA provide this additional level of support would not necessarily accelerate integration as there is no guarantee that the Test Site users would require or use such capabilities. Development of these types of services would be best left to the Test Sites themselves to develop their capabilities and value proposition in response to customer requirements and market needs.

34. FAA has no public standard for certificates of authorization (COAs) or Section 333 exemptions for UAS. As a result, researchers are unsure if they should take the time to apply for a COAs or a Section 333 exemption because they have no idea if their applications will be approved. This discourages many researchers from even applying for FAA exemptions that would allow them to fly UAS. Has FAA published guidelines

that would help researchers and others to know whether or not their COA or Section 333 exemption applications might be approved?

a. If not, why not?
b. What is the earliest date by which FAA could feasibly publish these guidelines?

Guidelines for both the COA and Section 333 exemption process, including qualifications and how to apply, are available to the public online at www.FAA.gov/UAS.

35. Researchers have said they don't know how FAA decides which UAS will get a COA, and which UAS will not. Because of the uncertainty involved in the COA process, UAS researchers have had trouble deciding which technologies to research; they don't want to waste their time researching new software for a UAS if they won't be able to test it because their COA application is denied. Has FAA looked into making the COA application process more transparent for researchers so they can submit applications that are more likely to result in a COA?

The determination on the approval or denial of a Certificate of Waiver/Authorization (COA) is based upon ensuring the operation proposed by the applicant does not pose any unnecessary risk to the National Airspace System (NAS). That determination cannot be made until the applicant provides sufficient information so as to allow for a determination to be made. Providing sufficient information early in the COA process will allow for a more timely response. During the COA process, the requested airspace is evaluated and a determination is made on whether the UA can safely operate in that airspace. The UA is also evaluated for its airworthiness, etc. A holistic approach is used to determine if a COA is approved. The type of operation requested, the airspace location, or the UA may be the determining factor if a COA is denied.

Researchers who are seeking to operate UAS as public aircraft also need to comply with the public aircraft statute. The FAA has issued guidance on public aircraft operations generally (Advisory Circular 00-1.1A) and on the meaning of the term "aeronautical research" in the public aircraft statute to provide information to potential users.

36. After applying for a special airworthiness certificate for operation at a test site, how long does it take for a researcher to have their application approved?
    a. After approval, how long does it take them to actually use the test site?

Special Airworthiness Certificates are governed under the FAA's Airworthiness Certification of Unmanned Aircraft Systems and Optionally Piloted Aircraft Order 8130.34C. The processing of an application is based upon the completeness of the submitted documentation and the nature of the UAS operations being proposed and its impact to the NAS.

37. If a researcher receives a COA or a Section 333 exemption, but then changes a piece of technology on their UAS, do they then need to re-apply for a COA or Section 333 exemption?

If there is a change to the UAS, the researcher will have to go back through the exemption process and get an amendment to the exemption. Depending on the change, an amendment or a new COA may also be required. The timeline for an amended COA is less than 30 days.

38. FAA issued 313 certificates of authorization, or COAs, in 2011. In 2012, Congress directed FAA to expedite the COA process. But FAA only issued 257 COAs in 2012 and 545 COAs in 2013. How many COAs were issued in 2014?
    a. What feedback have you received from government partners about the new COA process?
    b. Has FAA considered allocating greater resources to speed up the COA process? What resources would FAA need to accelerate this process?

The FAA issued 609 COAs in 2014. Feedback from our government partners has been very supportive of the progress the FAA has made in the timeliness of the processing of COAs since the inception of the program. The FAA is constantly looking for ways to streamline the COA process and recently hired additional personnel to assist with COA processing.

39. FAA has emphasized that U.S. airspace is the busiest in the world, and that this is the reason FAA is taking longer to integrate UAS into the NAS than similar agencies abroad. But sUAS are often used for research at very low altitudes and at least five miles from an airport where manned aircraft are exceedingly rare or non-existent. Why can't sUAS research be conducted safely right now at low altitudes, on private property, or with similar limitations for safety?

On March 23, 2015, the FAA established an interim policy to speed up airspace authorizations for certain commercial UAS operators who obtain Section 333 exemptions. The new policy helps bridge the gap between the past process, which evaluated every UAS operation individually, and future operations after we publish a final version of the proposed small UAS rule. Under the new policy, the FAA will grant a Certificate of Waiver or Authorization (COA) for flights at or below 200 feet to any UAS operator with a Section 333 exemption for aircraft that weigh less than 55 pounds, operate during daytime Visual Flight Rules (VFR) conditions, operate within visual line of sight (VLOS) of the pilots, and stay certain distances away from airports or heliports. Additional details may be found at: http://www.faa.gov/news/updates/?newsId=82245

40. Please provide us with examples of progress made on developing sense and avoid technology. What is FAA doing to address these challenges?

RTCA is on schedule to complete draft technical standards for DAA technology in 2015 and a one-year standards validation period is currently planned to complete the needed standards validation activities prior to completion of the RTCA DAA standards. The FAA supports RTCA with subject matter experts in air traffic control, pilot procedures, and avionics certification. The FAA also supports research and analyses required to draft the DAA standards and validate the standards to ensure they can be used in a safe and efficient manner in the NAS.

41. Please provide us with examples of progress in preventing "lost link" disruptions. What is FAA doing to address these challenges?

RTCA is developing technical standards for command and control to provide reliable link connectivity between the remote pilot controlling the aircraft from a ground control station and the unmanned aircraft itself. These standards will be completely drafted in 2015 and a one-year validation period is currently planned to mature the standards prior to their publication and use in type certified UAS. The FAA is also conducting air traffic control research to address how to effectively address "lost link" events when they occur by improving air traffic controller interfaces and procedures and standardizing the flight paths flown by future UAS when they lose their C2 link.

42. How have your relationships with international partners, such as the International Civil Aviation Organization, informed FAA UAS R&D?

Currently a Memorandum of Cooperation exists between FAA and Single European Sky Air Traffic Management (ATM) Research (SESAR). Through this cooperative agreement each party seeks to coordinate and concentrate all research and development activities in Air Traffic Management (ATM). Coordination Plan (CP) 1.9 (Remotely Piloted Aircraft Systems) has been initiated. This plan coordinates and prioritizes the activities necessary to support the evolution of remote piloted aircraft system (RPAS) or Unmanned Aircraft System (UAS) as legitimate airspace users that are able to operate from an ATM perspective in a manner analogous to manned aircraft.

Action Plan 24: Unmanned Aircraft Systems (UAS) - Under this plan, EUROCONTROL and the FAA will be proactive in areas such as research and development (R&D) and development of certification requirements and regulatory material. The range of activities which will need to be coordinated is extensive and complex. Action Plan (AP) 24 has been incorporated into CP 1.9 (mentioned above) and will focus on strategies to support the resolution of Human Factors Issues, Sense and Avoid and Collision Avoidance Issues, Command and Control and ATC Communications (C3), and ATM Integration issues. In addition, UAS certification and operational regulations will need to be addressed from the perspective of equivalent and existing regulations for manned aircraft, as a means of achieving ATM system transparency.

Activity on RPAS by other institutions such as RTCA, EUROCAE, EASA, JARUS and ICAO will derive significant benefit from guidance and leadership provided by the coordinated contributions of FAA and SESAR as outlined above.

Such contributions, particularly with regard to technical and operational development strategies, will result in convergence of ATM provisions for RPAS/UAS ATM integration, thereby supporting eventual full global RPAS inter-operability.

Regular technical interchange meetings are held where current UAS R&D briefings are provided to inform stakeholders on respective research activities to help avoid duplicative efforts.

Frequency Spectrum has been specifically reserved for UAS use at the International Telecommunications Union ITU. The availability of this spectrum drives the R&D on command and control links.

43. As the number of UAS operations increase, so too will UAS operators' demand for spectrum. What R&D is being conducted to either minimize the amount of spectrum needed, or to increase the efficiency of spectrum used by UAS?

The FAA is working closely with RTCA, MITRE and others on performing research and evaluation of command and control link standards that minimize the bandwidth required to operate and maximize spectrum efficiency.

44. Will UAS operations require additional satellite spectrum to ensure safe operations?

The International Telecommunications Union (ITU) has established for both terrestrial and satellite based aviation protected spectrum for the control and communication (C2) for unmanned aircraft. The FAA is continuing to evaluate alternatives for the optimal management and use of this spectrum for safe operation of UAS. The focus is to provide C2 service provision to UAS to the highest levels of safety. It is currently undetermined as to whether the available spectrum will provide sufficient spectrum for all operations as reliable data on future market demand for UAS C2 spectrum is unavailable.

45. Much attention has been paid to the challenges of securing command and control links for UAS. What other challenges exist that may not receive as much attention (and therefore as much R&D support)?

The challenge of providing C2 frequencies and radio communication coverage over the entire NAS has not received as much attention as research and development efforts for DAA and C2 systems on UAS. The FAA is currently reviewing potential service provision options for C2 and will conduct research to analyze service provision options and associated governance structures.

46. It is our understanding that FAA has solicited bids for the creation of a Center of Excellence (COE) for UAS R&D in the areas of sense and avoid and command and control technologies.
    a. Which stakeholders were represented in the bidding process?
    b. When does the agency expect to announce the winner(s)?
    c. How will the COE be funded?
    d. How much money will be expended on the COE?
    e. Is the COE a greater funding priority than test sites?

a. NASA, DOD and DOI contributed to the research focus areas listed in the public solicitation.

b. On May 8, 2015, the FAA announced the team led by Mississippi State University was selected and will focus on research, education and training in areas critical to safe and successful integration of UAS into the nation's airspace. The team brings together 15 of the nation's leading UAS and aviation universities that have a proven commitment to UAS research and development and the necessary resources to provide the matching contribution to the government's investment.

c. Congress appropriated $1M for the COE in FY14 and $4M in FY15 in the FAA's UAS R,E&D Budget Line Item. Partner agencies have the option to fund the COE to support their research initiatives.

d. The FAA has committed a minimum of $500K per year to fund the COE. Congress appropriated $1M for the COE in FY14 and $4M in FY15 in the FAA's UAS R,E&D Budget Line Item. These funds will be expended on the COE.

e. Congress appropriated $1M for the COE in FY14 and $4M in FY15 in the FAA's UAS R,E&D Budget Line Item. In contrast, the FAA has not been appropriated funds for the test sites.

47. How does domestic UAS R&D compare with foreign UAS R&D?

The United States has conducted more research to develop DAA and C2 standards in support of RTCA than other nations have conducted to support other international standards bodies such as EUROCAE or SAE in their development of DAA and C2 standards.

Questions Submitted by Rep. Mo Brooks

1. Mr. Williams, there seems to be an unlevel playing field today. There have just been a handful of section 333 exemptions granted to a few private sector companies, but scores of Certificates of Authorization ("COAs") have been granted to government agencies and universities. Many of the government agencies and universities are using their COAs to fly UAVs on projects that are actually commercial in nature and in some cases they are compensated, reimbursed, for their services.
   a. Can you provide for the record the FAA's opinion, its standard, its legal analysis of the difference and distinction between a public aircraft, flown by a government agency or university, versus a commercial aircraft, for UAV operations, and tell us if the FAA intends to expand the opportunity for the private sector to provide these services?

The FAA has streamlined its process for issuing 333 exemptions and has significantly increased the rate at which we are authorizing commercial UAS operations.

Under the public aircraft statute (49 U.S.C. § 40125) a public aircraft operation must be conducted using a public aircraft for one of the governmental functions identified in the law.

This statute does not allow operations for compensation and would therefore not be applicable for commercial operations.

Questions Submitted by Rep. Eddie Bernice Johnson, Ranking Member

1. As you are aware, a few days after the hearing, a drone was reported to have been found on White House grounds. Would regulations currently contemplated by the Administration have diminished the likelihood of such a situation from happening? What can be done to prevent similar situations from occurring in the future?

It is against FAA regulations to fly into restricted areas, such as the Washington DC Area Flight Restricted Zone (FRZ), without the appropriate authorization. The proposed rule for small UAS would also limit flights in prohibited or restricted areas, such as the FRZ.

The FAA is working to educate the public about safe operation of model aircraft. Also, recognizing that local law enforcement is in the best position to respond quickly, we recently posted guidance for first responders on recommended actions for handling unauthorized or unsafe operations.

We have partnered with industry and the UAS community in a public outreach campaign called "Know Before You Fly." This campaign is targeted at providing basic do's and don'ts to the public for safe model aircraft operations. As part of the campaign, we produced a video to alert Super Bowl spectators that the game was a "No Drone Zone." On May 13, in cooperation with a number of other partners in the National Capital Region, the FAA announced a public awareness campaign to educate unmanned aircraft users that the National Capital Region is a No Drone Zone. No Drone Zone materials target both DC-area residents and the many international tourists who visit the region, and are designed to be easily understood. Messaging for the DC-area No Drone Zone campaign reminds unmanned aircraft operators that they may face civil and criminal penalties for operating in the DC area.

2. How will the data gathered from the UAS test sites help inform the development of regulations? Could you describe how this will work in practice? What are the other sources of data that FAA is using to inform the development of regulations?

The FAA plans to review the research to be conducted to understand the relevant data the FAA may independently or collaboratively analyze.

Data gathered at the UAS Test Sites, specifically flight information, will aid in the development of RTCA Documents including avionics specific Minimum Aviation Safety Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS). These documents shape the certification standards for safe and efficient new equipment and provide a competitive market for the implementation of these technologies. MASPS and MOPS are frequently referred to by the FAA in Technical Standard Orders and Advisory Circulars and, thereby, provide a partial basis for the certification of equipment. RTCA documents are also used by the private sector for development, investment, and other business decisions.

Before the FAA issues a final small UAS rule, the agency will consider information and data submitted by the public as comments on the proposed rule.

3. How can Congress ensure that it gets the most out of the UAS test sites? What, if anything, does Congress need to do to maximize the use of these test sites for their intended purpose? Are there any barriers that need to be addressed, and if so, what are they?

Continued congressional support of the FAA's approach and execution of The Integration of Civil UAS in the NAS Roadmap and the UAS Comprehensive Plan will facilitate getting the most out of UAS Test Sites, specifically in achieving the goals of the FAA Modernization and Reform Act of 2012. These documents set overarching interagency goals, objectives, and approaches to achieving integration. Leveraging interagency partnerships along with working with industry includes using the Test Sites to conduct flight operations supporting a significant segment of research, development, testing and engineering required to integrate UAS into the NAS more efficiently.

4. Mr. Guinn indicated in his prepared statement that the establishment of UAS test sites is not enough to support the entire UAS industry. He proposes that FAA allow companies to conduct R&D activities outside on their own property. What safety measures must FAA enforce before it allows such a proposal?

Current processes exist for companies to conduct research and development activities outside on their own property. FAA Order 8130.34C explains the process for issuance of special airworthiness certificates for UAS in the experimental category for research and development, market survey, or crew training. Additionally, a company could petition for a section 333 exemption to conduct similar research and development for a particular UAS. The measures in these processes ensure the safety of other operations occurring in the NAS and the safety of persons and property on the ground.

5. Given the importance of small UAS to university education and research, is there any risk associated with giving institutions a blanket exemption governing such use, provided that these institutions ensure that research and educational uses are conducted in a manner that does not encroach upon the safety and integrity of the National Airspace System? What liability rules would apply under such an exemption?

Universities are eligible to obtain section 333 exemptions for flights that cannot be conducted as public aircraft operations. The agency recently implemented improvements to streamline the exemption review process by increasing the use of summary grants. Petitions that are similar to exemptions the agency has previously granted can be processed through this streamlined process.

Novel requests require additional review. Additionally, the FAA is granting a "blanket" Certificate of Waiver or Authorization (COA) with each exemption and has modified the pilot certification and medical certificate requirements from the earlier exemptions.

Conditions and limitations in an exemption and the provisions in a COA enable safe operation. If not operating a UAS as a model aircraft for hobby or recreation, an operator of a UAS must comply with the conditions and limitations of an exemption and COA. Public aircraft operators must also obtain a COA.

6. Should students be free to test fly their latest small unmanned vehicle, sensor, or software at low altitudes above an open field in uncontrolled airspace in the same way early experimenters of piloted aircraft were able to in the past? What are the risks of providing students with such a capability? Could such an approach be extended to small UAS commercial operators? Why or why not?

The FAA would evaluate each instance individually. Unmanned aircraft flights that can be operated as model aircraft, as defined in section 336 of the 2012 FAA Modernization and Reform Act, do not need FAA authorization. Flights that are not for hobby or recreational purposes would require FAA authorization.

7. Civil operators are applying in growing numbers for an exemption, allowed under section 333 of the 2012 Act which requires the Secretary of Transportation to determine if certain UAS may operate safely in the NAS prior to the completion of the UAS rulemakings.
   a. What lessons has FAA learned from granting such exemptions? To what extent are these lessons informing the development of UAS regulations?
   b. Will FAA be developing a database on the exempted user operations to track and gain insight into any trends in problems, anomalies, or safety issues? If not, why not?
   c. Has FAA considered the utility of a tool capable of capturing user experiences and mission data into a shared database, along the lines described by Mr. Guinn regarding 3D Robotics' Droneshare application, for conducting research to inform the promulgation of UAS regulations?

a. The FAA has developed a standardized exemption process to significantly expedite the time in which the agency is approving exemptions to allow civil UAS use. Petitions that are similar to exemptions the agency has previously granted can be processed through this streamlined process. Lessons learned from granting exemptions will continue to inform the development of policies for safe UAS integration.

b. Yes, the database is currently receiving information and the FAA considers such information as it refines conditions and limitations of exemptions. That information may ultimately affect the final rule to come from the small UAS NPRM.

Currently, exemption holders are required to report any incident, accident, or flight operation that transgresses the lateral or vertical boundaries of the operational area as defined by the applicable COA. In addition to the exemption reporting requirements, the new streamlined process associated with the COA requires monthly reports of the following information:

1. The proponent must submit the following information through Mail to: 9-AJV-115-UASOrganization@faa.gov on a monthly basis:

   a. Name of Proponent, Exemption number and Aircraft registration number

   b. UAS type and model

   c. Number of flights (per location, per aircraft)

   d. Total aircraft operational hours

   e. Takeoff or Landing damage

   f. Equipment malfunctions. Reportable malfunctions include, but are not limited to the following:

      (1) On-board flight control system

      (2) Navigation system

      (3) Powerplant failure in flight

      (4) Fuel system failure

      (5) Electrical system failure

      (6) Control station failure

2. The number and duration of lost link events (control, performance and health monitoring, or communications) per aircraft per flight.

c. The data outlined above is intended to inform our policymaking in this area. Requiring the capture of data from tools such as that described by Mr. Guinn would need to be explored from various perspectives, may require additional rulemaking, and could be subject to other administrative review requirements.

Questions Submitted by Rep. Suzanne Bonamici

1. We have been in contact with the academic community and are interested in helping them educate the next generation of students on unmanned aerial systems technology. In turn, we know there will be a developing commercial industry that will need a skilled workforce on which it can rely. As I understand it, any UAS flight conducted for a reason

> other than a "hobbyist flight" must be approved by FAA, and that approval understandably takes time. Recognizing that the first priority of the FAA is safety, and that a thorough review of UAS flight applications is in the best interest of the public, I am concerned that the time required to gain FAA approval may present unintended barriers for capable educational institutions to effectively — and safely — train the next generation workforce.
>
> To what extent are you working with universities to understand their unique needs for offering UAS-focused training and educational experiences for students as you develop your draft regulations on integrating UAS into the national airspace? Is there a hierarchy of preference when it comes to reviewing applications for UAS flights from universities, test sites, or private operators?

Universities are eligible to obtain section 333 exemptions for flights that cannot be conducted as public aircraft operations. The FAA has streamlined its process for issuing 333 exemptions and has significantly increased the rate at which we are authorizing commercial UAS operations.

The FAA would evaluate whether a flight is conducted as a model aircraft operation individually. Unmanned aircraft flights that can be operated as model aircraft, as defined in section 336 of the 2012 FAA Modernization and Reform Act, do not need FAA authorization. Flights that are not for hobby or recreational purposes would require FAA authorization.

For operations that qualify under the statute as a public aircraft operation, the FAA generally issues Certificates of Waiver or Authorization within 60 days.

2. Does FAA provide, or intend to provide, technical assistance or guidance targeted to educational institutions interested in securing FAA approval for a UAS flight? Are there different considerations or requirements for FAA approval for flights conducted for the purpose of research or testing than those conducted for the primary purpose of educational and training purposes?

Whether FAA authorization for flights would be required depends on whether the flights could be conducted as public aircraft operations or whether they are conducted for hobby or recreational purposes. The FAA has issued an Advisory Circular and legal interpretations related to public aircraft operations. The FAA has also issued guidance through its legal interpretation of the Special Rule for Model Aircraft (Section 336 of the 2012 FAA Modernization and Reform Act).

3. Another concern I have heard from the academic research community is the potential narrow interpretation of "aeronautical research" in your upcoming regulations. Have you done outreach to universities to help inform your interpretation of what comprises "research" for purposes of your draft regulations?

The FAA Office of the Chief Counsel issued a publically available legal interpretation on June 13, 2014 that addresses the meaning of the term "aeronautical research" as used in the public aircraft context.

4. Some have raised concerns about Section 333 exemptions at FAA that allow some private entities to operate UAS for commercial purposes, and meanwhile companies continue to line up to seek these Section 333 exemptions from FAA.

Any "person" can petition for exemption. This applies to both private entities and companies.

The FAA has better learned what applications are in immediate demand for UAS applications. The FAA has developed standardized exemption processing to significantly expedite the time in which familiar uses of UAS under similar conditions and limitations can occur. The agency recently implemented improvements to streamline the exemption review process by increasing the use of summary grants. Petitions that are similar to exemptions the agency has previously granted can be processed through the summary grant. Novel requests require additional review. Additionally, the FAA is granting a "blanket" Certificate of Waiver or Authorization (COA) with each exemption and has modified the pilot certification and medical certificate requirements from the earlier exemptions.

5. This hearing is about research and development, and we all concede there is a lot we don't know about UAS and how this technology will change aviation and commerce, among other things. In this context: When FAA grants exemptions under Section 333, are you gaining any new knowledge about the big questions we are discussing here today: safety of UAS technology; integration into the National Air Space; and other key issues?

Yes. Under the Certificate of Authorization that each operation must comply with, each operator submits a monthly status report providing valuable operating information to the FAA such as: number of flights and flight hours, equipment malfunctions, and number and duration of lost link events. Further, each grant of exemption requires operators to report incidents or accidents and any occurrence of when a UAS transgresses outside of the approved operational boundaries. This data informs FAA regulatory and standards development activities which ensure the highest levels of safety.

Questions Submitted by Rep. Dan Lipinski

1. We as a nation are supporting a variety of research efforts spread across several agencies. How can we (the committee) ensure that work being done by NASA, and others, is being utilized by the FAA?

The FAA recognizes the outstanding capabilities and substantial resources of NASA, DoD, and other government agencies and is leveraging them wherever possible to address research needs and expedite UAS integration in the NAS. The FAA has compiled past research that addressed integration requirements and is continuing to compile and inventory all relevant research conducted by its partners. This inventory helps the FAA understand how various integration requirements have been addressed by research so that the relevant research can be brought to the attention of FAA policy makers for use in procedures development, NAS architecture decisions, and regulatory efforts.

2. Many countries have segmented UAV rules by weight, as smaller UAVs can access more areas safely, while heavier UAVs have the potential to do more harm. What research is being conducted to better understand how multiple weight classes under 55 pounds could impact operator qualifications, device certifications, and operational limits?

The FAA has conducted research to understand key characteristics of UAS (size, weight, shape, other safety features, etc.) that can be used to mitigate the risk of UAS to people on the ground. This research continues in 2015 and will be supported by additional analysis so that the resulting knowledge and understanding may be used to adjudicate comments made by the public on the sUAS Notice of Proposed Rulemaking (NPRM). The principal purpose of this research is to address comments on whether sUAS operations are acceptable as proposed at weights up to 55 pounds and whether any other lower weight category might be acceptably safe for operations over people with operational conditions proposed by those who comment on the sUAS NPRM.

3. Public agencies are beginning to find valuable uses for UAS technology, such as responding to natural disasters and inspecting infrastructure. What technology transfer efforts are FAA and NASA taking to promote and implement these technologies at public agencies?

The FAA, NASA, and DoD are supporting RTCA standards development efforts for DAA and C2 and the technical standards for hardware, software and operational procedures will be available to enable safe UAS operations in the NAS. NASA has signed a research technology transfer agreement with the FAA for its UAS traffic management research and is partnering with many industry customers to ensure the low altitude traffic management equipment and procedures are usable in both urban and rural low altitude airspace. These technologies will be usable for other public agencies and also for the public at large.

4. UAS is a growing industry that will require workers with technical skills and experience. As a co-chair of the STEM Education Caucus, I would like to know if there any issues on STEM education and workforce training specific to UAS.

UAS reaches across all of the STEM disciplines—Science, Technology, Engineering and Mathematics. The basic STEM issue is the forecasted shortfall of STEM candidates entering college, ergo the workforce.

5. Our veterans possess many of the skills required in the burgeoning UAS industry. For example, many veterans hold pilots licenses. How can we (the committee) and the federal agencies help put our veterans to work in the UAS industry?

Under the proposed small UAS rule, pilots of a small UAS would need to pass an initial aeronautical knowledge test at an FAA-approved knowledge testing center and obtain an unmanned aircraft operator certificate with a small UAS rating. Under the proposal a veteran who operated UAS in the military would be able to take the more limited recurrent aeronautical knowledge test when seeking an unmanned aircraft operator certificate. The FAA is considering public comments on the small UAS Notice of Proposed Rulemaking. The comment period closed on April 24, 2015.

The FAA has attained considerable success in recruiting and hiring veterans to fulfill a variety of its mission critical needs. A total of 2,677 veterans were hired in 2014 contributing to the Agency's current population of approximately 15,000 veterans onboard. This segment makes up over 30 percent of the FAA's total workforce.

As the Agency implements the next generation of technologies in the National Airspace System, including Unmanned Aircraft Systems, we will continue to seek out the talent of our highly skilled veterans to support these mission critical functions. Far beyond the holding of pilot licenses, the Agency recognizes value across a myriad of military skillsets to include airspace management, air traffic control, aviation maintenance, military aviation safety managers, attorneys, as well as current DOD consumers of unmanned aircraft services to name a few.

6. If these aircraft are going to share the airspace with airliners, what is the FAA's position on the requirement for UAS aircraft to be equipped with collision avoidance capability? TCAS? ADS-B?? Is industry in full agreement? If not, why not?

The FAA has existing, established rules for the equipage of airborne transponders, ADS-B, TCAS I and TCAS II airborne equipment for certain types of aircraft operations and, in some cases, in specifically designated airspaces. As UAS are aircraft, they must comply with established equipage rules as specified for applicable aircraft operating rules. No UAS specific rulemaking for UAS equipage of collision avoidance airborne equipment has been identified as a requirement at this time. We have received comments on the proposed small UAS rule on collision-avoidance equipage. We are currently considering all comments filed in response to the Notice of Proposed Rulemaking.

7. Comment on the difficulty of developing "sense and avoid" technology that effectively replicates the ability of a pilot to continuously search the area around his or her aircraft and react immediately and effectively to any perceived threat.

Much discussion and disagreement has occurred in the past about whether Detect and Avoid (DAA) (previously referred to as Sense and Avoid) technology needed to be equivalent to the capability of a pilot in a manned aircraft to see and avoid other aircraft. The disagreement has included what field of view the DAA technology needed to sense and how a "sense and avoid" system could reliably and predictably analyze when the unmanned aircraft was becoming too close to another aircraft. RTCA SC-228 has addressed these difficulties by creating a technical standard for the separation that an unmanned aircraft must maintain in terms of closure rate and minimum lateral and vertical distances. RTCA has used this technical standard to define equipment standards and associated pilot procedures to remain well clear from other aircraft. The performance of the DAA system is being assessed in terms of a safety assessment that will ensure the DAA system, as used, will meet both airspace safety and efficiency needs.

Responses by Dr. John Lauber

General Note: The questions below, which were directed to Dr. Lauber, are generally focused on UAS as a whole. The National Research Council report, *Autonomy Research for Civil Aviation: Toward a New Era of Flight,* which is the basis for Dr. Lauber's testimony, is focused on the development of increasingly autonomous technologies and systems for advanced UAS as well as crewed aircraft. The responses below are framed accordingly.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Unmanned Aircraft Systems Research and Development"

Questions for the record, Mr. John Lauber, Co-Chair, Committee on Autonomy Research and Communication, Aeronautics and Space Engineering Board, National Research Council

Questions submitted by Rep. Lamar Smith, Chairman

1. What major technological obstacles remain to safe integration of UAS into the National Airspace System (NAS), and what private sector research and development (R&D) efforts are planned to overcome those obstacles?

Response: The 14 barriers detailed in Chapter 3, *Barriers to Implementation*, consist of technological, regulatory, social, or legal barriers that should be addressed during the process of developing and integrating advanced UAS with autonomous capabilities into the NAS. The 14 barriers are listed below, and a brief description of those barriers appears on pages 3-5 of the report.

- Technology Barriers
  — Communications and data acquisition,
  — Cyberphysical security,
  — Diversity of aircraft,
  — Human–machine integration,
  — Decision making by adaptive/nondeterministic systems,
  — Sensing, perception, and cognition,
  — System complexity and resilience, and
  — Verification and validation.
- Regulation and Certification Barriers
  — Airspace access for unmanned aircraft,
  — Certification process,
  — Equivalent level of safety, and
  — Trust in adaptive/nondeterministic increasingly autonomous systems.
- Additional Barriers
  — Legal issues and
  — Social issues.

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a. Are there any R&D gaps?

Response: Many R&D gaps must be overcome to overcome these obstacles/barriers. At a top level, they are represented by the eight research projects listed below. More detailed research gaps are described in the discussion of each research project in Chapter 4.

Question for the Record—Responses from Dr. John Lauber

- Behavior of Adaptive/Nondeterministic Systems
- Operation without Continuous Human Oversight
- Modeling and Simulation
- Verification, Validation, and Certification
- Nontraditional Methodologies and Technologies
- Roles of Personnel and Systems
- Safety and Efficiency
- Stakeholder Trust

2. Please discuss some of the immediate benefits that would come from integrating UAS into the (NAS).

Response: At a top level, the greatest potential benefits relate to safety and reliability; costs; and UAS operational capabilities. More details on the potential benefits in each of these areas appear in the sections by the same name on pages 20-23.

3. Should UAS that operate in the NAS be encrypted the same way as military UAS?
   a. If so, will this be for both large and small UAS (sUAS)?
   b. If so, how will the government manage these encrypted systems, particularly for the private sector?

Response: Cyberphysical security is one of the barriers discussed in Chapter 3 (see page 31). The committee did not investigate specific levels of security that would be needed for different classes of UAS nor did it hypothesize on whether the level of encryption used by the military would be needed for civilian UAS.

4. What private sector research is being done to address concerns about individuals spoofing sUAS?

Response: The committee did not survey the private sector to identify ongoing research in this area.

5. Which federal agencies or organizations should coordinate with FAA to safely integrate UAS into the NAS? How can the private sector better coordinate R&D efforts with the federal government?

Response: The report does not directly addresses this question, though it does address coordination of or research and development by industry, academia, the Federal Aviation Administration (FAA), the Department of Defense (DOD), and NASA in a section titled Coordination of Research and Development on pages 59-61 of the report.

6. Given the magnitude of the task of developing a plan to integrate UAS into the NAS by this year, are the deadlines outlined in the FAA Modernization and Reform Act reasonable?

Question for the Record—Responses from Dr. John Lauber

Response: The process of integrating advanced UAS with autonomous capabilities is a very difficult challenge that will extend far beyond the end of this year given the need to complete the research projects specified in the study report. The exact timeframe is directly related to the level of sophistication of the autonomous systems to be incorporated in any particular UAS.

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7. What is the state of human factors research?
    a. What agency is taking the lead on this topic?
    b. Does this research incorporate both pilot and Air Traffic Control challenges?

Response: The report does not summarize the state of research in particular disciplines. Neither does the report specify which agency should take the lead; that is an issue to be resolved in the process of establishing a coordinated effort to address the research projects detailed in Chapter 4 and in the recommendation on a national research agenda on page 63.

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8. How is UAS R&D divided across NASA, FAA, and other agencies? Who sets priorities for UAS R&D across the federal government? How could this process be improved?

Response: As detailed in the report section titled Coordination of Research and Development (see page 59), NASA would support basic and applied research in civil aviation tools, methods, and technologies (including ATM technologies of interest to the FAA), the FAA would be most directly engaged in the verification, validation, and certification research project, and DOD is primarily concerned with military applications. The same section discusses ongoing interagency efforts that are necessary and could be strengthened to assure that the full scope of increasingly autonomous research and development efforts (not just those focused on UAS applications) are effectively coordinated and integrated, with minimal duplication of research and without critical gaps. In particular, more effective coordination among relevant organizations in government, academia, and industry would help execute the recommended research projects more efficiently, in part by allowing lessons learned from the development, test, and operation of increasingly autonomous systems to be continuously applied to ongoing activities. A more timely and effective approach for resolving the legal and social barriers could begin with discussions involving the Department of Justice, FAA, the National Transportation Safety Board, state attorneys general, public interest legal organizations, and aviation community stakeholders.

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9. The Department of Transportation's Office of Inspector General reported that there are outstanding questions among government partners and industry stakeholders about the organization and transparency of the UAS Integration Office. How does the delay and disorganization of establishing FAA's internal UAS office potentially affect the timeline for meeting integration deadlines?
    a. How does it affect the R&D process, particularly for government partners and industry stakeholders?

Response: The study did not address the issues raised in this question.

Question for the Record—Responses from Dr. John Lauber

10. FAA has emphasized that U.S. airspace is the busiest in the world, and that this is the reason FAA is taking longer to integrate UAS than similar agencies overseas. But sUAS are oftentimes used for research at very low altitudes and at least five miles from an airport where manned aircraft are exceedingly rare or non-existent. Why can't sUAS be allowed for research right now at low altitudes on private property?

Response: One of the issues raised in the report is trust; as applied to this situation, it would involve trust that the sUAS system (hardware plus operator) would remain within the intended operating area.

11. What are the impacts to UAS R&D and U.S. competitiveness if FAA does not separate UAS into more than two size and weight classes?

Response: The committee did not investigate the issues addressed by this question.

12. How does the FAA regulatory process affect UAS R&D, and vice versa?

Response: As detailed in the section titled Airspace Access for Unmanned Aircraft (page 38ff), under current regulations there is no routine way to accommodate unmanned aircraft operations in nonsegregated civil airspace. Such operations have been possible only with (1) a certificate of authorization issued by the FAA on a case-by-case basis to public organizations or (2) a special airworthiness certificate in the experimental category. These certificates include operational restrictions that limit the utility and mission effectiveness of the affected unmanned aircraft. This has been a problem for commercial operations as well as R&D, particularly for non-public institutions (that is, for industry and private universities).

13. Please provide us with examples of progress made on developing sense and avoid technology? What is the private sector doing to address these challenges?

Response: The report does not include the information asked for in this question.

14. Please provide us with examples of progress in preventing "lost link" disruptions. What is the private sector doing to address these challenges?

Response: The report does not include the information asked for in this question.

15. What R&D should NASA perform that is not currently being performed? Is there any UAS-related R&D that NASA is conducting, but should not be?

Response: The report's recommendation on a national research agenda specifies the eight research projects that should be the top priority for autonomy research efforts by NASA and others. However, the committee was not tasked with assessing research programs by NASA in autonomous systems or UAS research. The study plan anticipated that NASA and other interested parties would consider these priorities in making plans for new research. As part of the report dissemination process, we facilitated that process by briefing the report to staff from NASA, the Federal Aviation Administration, and the Air

Question for the Record—Responses from Dr. John Lauber

Force (at the Pentagon and at the Air Force Research Laboratory in Dayton). We also raised the visibility of the report by holding panel discussions at a UAS conference in Dayton and at a national AIAA conference.

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16. What is the effect of U.S. companies moving their R&D activities overseas because of delays in FAA regulations?

Response: The report discusses this issue in the section titled Unmanned Aircraft Systems (see page 25), although it does not specially identify the consequences, such as the loss of economic activity and the missed opportunity to work with U.S. customers during the development and test phases of product development.

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17. According to GAO, "a 2014 MITRE study found that Japan, Australia, the U.K., and Canada have progressed further than the U.S. with regulations that support commercial UAS operations." Why, in your opinion, has FAA fallen behind other nations' regulatory progress?
    a. What can FAA do to catch up to countries like Canada, which have exempted UAS weighing 55lbs or less from needing special approval for commercial operations?

Response: The report does not assess why the FAA has been so slow to act, nor does it describe activities, such as adopting UAS regulations that mirror Canadian regulations, that would allow the U.S. to catch up to countries such as Canada.

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18. Based on the findings and recommendations in *Autonomy Research for Civil Aviation: Toward a New Era of Flight (2014),* do you believe the U.S. is maintaining its competitive position globally in UAS R&D?

Response: As noted in the findings and recommendations Chapter 5 (page 62), there are many substantial barriers to the increased use of autonomy in civil aviation systems and aircraft, and if the United States fails to address these barriers in a timely fashion (that is, if it fails to establish a vigorous program to execute the recommended research projects), the United States will cede the field to any other nation that chooses to do so.

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19. Are exemptions to Section 333 of the FAA Authorization and Reform Act of2012, effectively meeting the needs of the UAS community, while the FAA determines ways to integrate UAS into the NAS?

Response: The committee did not investigate the impacts of exemptions to Section 333.

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20. Of the eight major research areas recommended in Autonomy Research for Civil Aviation: Toward a New Era of Flight (2014), which areas are most developed in regards to the R&D needed to safely integrate UAS into the NAS? Which areas are least developed in

Question for the Record—Responses from Dr. John Lauber

this regard?

Response: The following four areas are the most urgent and most difficult with regard to the integration of advanced UAS that incorporate autonomous systems:

- Behavior of Adaptive/Nondeterministic Systems. Develop methodologies to characterize and bound the behavior of adaptive/nondeterministic systems over their complete life cycle.
- Operation without Continuous Human Oversight. Develop the system architectures and technologies that would enable increasingly sophisticated and autonomous systems and unmanned aircraft to operate for extended periods of time without real-time human cognizance and control.
- Modeling and Simulation. Develop the theoretical basis and methodologies for using modeling and simulation to accelerate the development and maturation of advanced, increasingly autonomous systems and aircraft.
- Verification, Validation, and Certification. Develop standards and processes for the verification, validation, and certification of increasingly autonomous systems, and determine their implications for design.

The other four areas are still of a high priority, although not as urgent and difficult. They are:

- Nontraditional Methodologies and Technologies. Develop methodologies for accepting technologies not traditionally used in civil aviation (e.g., open-source software and consumer electronic products) in increasingly autonomous systems.
- Roles of Personnel and Systems. Determine how the roles of key personnel and systems, as well as related human–machine interfaces, should evolve to enable the operation of advanced, increasingly autonomous systems.
- Safety and Efficiency. Determine how increasingly autonomous systems could enhance the safety and efficiency of civil aviation.
- Stakeholder Trust. Develop processes to engender broad stakeholder trust in increasingly autonomous systems for civil aviation.

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21. The aforementioned National Academies' report mentions the need to investigate the relationship between use, acceptance, and trust of UAS technology. Would you please expand on the importance of that relationship?

Response: As noted in the section titled Stakeholder Trust (page 58ff), trust is based on both analysis and intuition. Fostering an appropriate level of trust in new aviation systems is critical to overcoming barriers to adoption and acceptance by the broad stakeholder community, which includes operators, supervisors, acquirers, patrons, regulators, designers, insurers, the operating community, and the general public. An individual operator who interacts with an advanced UAS with autonomous systems but harbors unwarranted skepticism about the reliability and performance of autonomous systems in general might fail to capitalize on their capabilities and instead rely on less efficient approaches. At the societal level, unwarranted skepticism might cause patrons to seek other services, and the public might even push for legislation that unnecessarily limits the pace of innovation. On the other hand, excessive

Question for the Record—Responses from Dr. John Lauber

trust could lead to failures to adequately supervise imperfect increasingly autonomous systems, potentially resulting in accidents and a subsequent loss of trust that could be very difficult to regain. Trust influences how people respond to increasingly autonomous systems across various organizational levels, circumstances, and timescales. Although closely related to V&V and certification, trust warrants attention as a distinct research topic because formal certification does not guarantee trust and adoption. This is very similar to how extended-range twin operations (ETOPS) have been managed: As confidence in the reliability of engines and other aircraft systems has grown, the FAA has granted air carriers the authority to operate twin-engine commercial transports along routes with flight segments that are increasingly distant from airports to which such aircraft could be diverted in the case of an engine malfunction enroute.

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22. Are there other areas of research, aside from the eight areas mentioned in the National Academies' report, that could inform UAS research? For instance, how could research being conducted on autonomous cars, including sense and avoid technology, be applied to UAS?

Response: As noted in the sections titled Ground Applications (page 27ff), and Space Regulations (page 29ff), although ground vehicle applications of autonomy for the most part differ substantially from civil aviation applications, there are also several parallels and opportunities to build joint expertise on responding to the challenges of increased autonomy:

- The drivers of cars and the pilots of general aviation aircraft would both benefit from relatively inexpensive, increasingly autonomous systems that could to some degree serve as copilots, alerting the driver or pilot of hazards that have been overlooked and taking corrective action in extremis.
- Verification and validation of automobiles with increasingly autonomous systems face challenges similar to those faced by civil aviation. The National Highway Traffic Safety Administration (NHTSA) does not regulate or certify vehicle designs in the way that FAA regulates and certifies aircraft designs—and FAA certification standards tend to be much more rigorous than the safety standards that must be met before increasingly autonomous systems can be introduced into cars. Even so, NHTSA and the FAA may benefit from sharing information regarding their efforts to assure that increasingly autonomous systems are safe and reliable. In particular, the FAA may benefit from operational data collected on the performance of advanced increasingly, autonomous systems deployed in cars.
- Because both aircraft and ground vehicles operate in challenging physical, electromagnetic, and social environments, they may face similar vulnerabilities. These vulnerabilities range from unusual electrical failures (e.g., tin whisker shorts) to cyberphysical security.
- Issues related to coordination of control in ground vehicles may be relevant to aircraft. The safety and performance of automobiles depend on the surrounding vehicles. The network effects of vehicle automation that propagate across a traffic stream could dominate vehicle response in some situations. This may become an even stronger influence with the connected vehicle concept, which provides data links among different vehicles and between vehicles and the infrastructure. Civil aviation may face a similar situation as aircraft communicate and interact more directly with one another.

Question for the Record—Responses from Dr. John Lauber

Similarly, space applications of autonomy may contribute new algorithms for a variety of functions that would benefit the civil aviation community. These include route planning, autonomous navigation, obstacle avoidance, autonomous landing site selection, and automation of lower-level maintenance and operational functions. Another contribution will come in the form of the crewing concepts needed to manage a constellation of vehicles versus the single platform model now widely used. Space systems already employ a different crewing paradigm than typical crewed systems. Perhaps the most significant application of autonomy to civil aviation will come from the technologies used to deal with the long time delays between the ground and the spacecraft. The space domain has learned to use robust software algorithms to successfully operate spacecraft without continuous human inputs.

23. Please provide your analysis of FAA's recently-released Small UAS Notice of Proposed Rulemaking.

Response: The committee did not have the opportunity to consider the proposed rules.

24. Do you believe the current state of technology related to UAS is sufficient to provide for safe integration into the NAS?
    a. If so, what is preventing integration?
    b. If not, what time frame do you believe is reasonable to expect UAS integration?

Response: The current state of technology is not sufficient to safely integrate advanced UAS with autonomous capabilities into the NAS because of the 14 technical, regulatory, and social and legal barriers detailed in Chapter 3. A brief description of those barriers appears on pages 3-5. The time necessary to overcome these barriers will depend largely on the sophistication of the autonomy on any particular aircraft.

Question for the Record—Responses from Dr. John Lauber

Questions for the Record from Ranking Member Johnson
Full Committee Hearing
January 21, 2015
"Unmanned Aircraft Systems Research and Development"

Dr. John Lauber

- How should Congress ensure that it gets the most out of the UAS test sites? What, if anything, does Congress need to do to maximize the use of these test sites for their intended purpose? Are there any barriers that need to be addressed, and if so, what are they?

Response: The committee did not investigate the issues addressed by this question.

- Your panel pointed out the complexity of the aviation system. How does the integration of UAS into the airspace affect that already complex national aviation system? Does the nature of UAS affect how we need to think about the aviation system and the national airspace, and are there any implications for the types of research needed as a result of this changing environment?

Response: Incorporating increasingly autonomous capabilities into the NAS will make a complex system even more complex, with new interdependencies and new relationships among various operational elements. One of the likely consequences will be a reduction in the resilience of the civil aviation system, because disturbances in one portion of the system could, in certain circumstances, cause the performance of the entire system to degrade precipitously.

- The FY2015 appropriations for FAA's research in Unmanned Aircraft Systems is about $15 million. Is this sufficient to address the research and development priorities aimed at ensuring the safe integration of UAS into the national airspace system? If not, where are the shortfalls, and why? Is FAA's research program well defined and matched to UAS research priorities?

Response: The study did not assess the current research programs of the FAA or other federal agencies, nor did it estimate the cost necessary to complete its recommended research projects. Without question, executing the research agenda set forth in the report would require significant resources from multiple federal agencies and research organizations. Even so, substantial advances could be achieved using currently available resources.

- Should FAA give consideration to establishing a risk-based system with regards to promulgating UAS regulations, an approach already used by other countries? How can the differences in airspace environment between the U.S. and these other countries be properly considered if a risk-based approach is utilized? How would one go about

Question for the Record—Responses from Dr. John Lauber

establishing such a system?

Response: The report notes that the FAA will need to develop technical competence in increasingly autonomous systems (for both unmanned and crewed aircraft) and issue new guidance material and regulations to enable safe operation of all classes and types of increasingly autonomous systems and aircraft. The report also notes that many existing safety standards and requirements, which are focused on assuring the safety of aircraft passengers and crew on a particular aircraft, are not well suited to assure the safety of unmanned aircraft operations, where the primary concern is the safety of personnel in other aircraft and on the ground. However, the report does not specifically assess the merits of establishing a risk-based system with regards to promulgating UAS regulations.

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"Unmanned Aircraft Systems Research and Development"
January 21, 2105

Representative Dan Lipinski- Questions for the Record

- We as a nation are supporting a variety of research efforts spread across several agencies. How can we (the committee) ensure that work being done by NASA, and others, is being utilized by the FAA?

Response: The report's primary recommendation is that agencies and organizations in government, industry, and academia that are involved in research, development, manufacture, certification, and regulation of increasingly autonomous technologies and systems should execute a national research agenda in autonomy. A collaborative effort to implement this recommendation by the FAA, NASA, Department of Defense, and other agencies would help ensure that work being done by NASA and others is being utilized by the FAA

- Many countries have segmented UAV rules by weight, as smaller UAVs can access more areas safely, while heavier UAVs have the potential to do more harm. What research is being conducted to better understand how multiple weight classes under 55 pounds could impact operator qualifications, device certifications, and operational limits?

Response: This study focused on issues associated with the use of increasingly autonomous systems on crewed and unmanned aircraft; it did not investigate issues related to the weight of UAS.

- Public agencies are beginning to find valuable uses for UAS technology, such as responding to natural disasters and inspecting infrastructure. What technology transfer efforts are FAA and NASA taking to promote and implement these technologies at public agencies?

Response: The committee did not investigate UAS technology transfer issues apart from the primary recommendation for collaboration by government, industry, and academia in addressing key research projects, a process which would inherently facilitate transfer of new technologies arising from that research.

- UAS is a growing industry that will require workers with technical skills and experience. As a co-chair of the STEM Education Caucus, I would like to know if there any issues on STEM education and workforce training specific to UAS.

Response: The committee did not identify any STEM issues specific to UAS. However, this is not an issue that the committee investigated in detail.

- Our veterans possess many of the skills required in the burgeoning UAS industry. For example, many veterans hold pilots licenses. How can we (the committee) and the federal agencies help put our veterans to work in the UAS industry?

Response: The committee did not investigate the issue addressed by this question.

- If these aircraft are going to share the airspace with airliners, what is the FAA's position on

Question for the Record—Responses from Dr. John Lauber

the requirement for UAS aircraft to be equipped with collision avoidance capability? TCAS? ADS-B? Is industry in full agreement? If not, why not?

Response: The committee is not aware that the FAA has taken a position on what the minimum equipage requirements would be for UAS to conduct routine operations in shared airspace.

- Comment on the difficulty of developing "sense and avoid" technology that effectively replicates the ability of a pilot to continuously search the area around his or her aircraft and react immediately and effectively to any perceived threat.

Response: Development of a sense-and-avoid system suitable for UAS will require the development of new technologies. Developing such systems will be particularly difficult for advanced, autonomous UAS with the ability to operate without continuous human oversight. Such systems will have to handle deconfliction scenarios with other aircraft that are not equipped with ADS-B and with aircraft whose pilots respond inappropriately.

Responses by Mr. Brian Wynne

House Committee on Science, Space, and Technology

"Unmanned Aircraft Systems Research and Development"

Questions for the record, Mr. Brian Wynne, President and CEO, Association for Unmanned Vehicle Systems International (AUVSI)

Questions submitted by Rep. Lamar Smith, Chairman

1. What major technological obstacles remain to safe integration of UAS into the National Airspace System (NAS), and what private sector research and development (R&D) efforts are planned to overcome those obstacles?
    a. Are there any R&D gaps?

    As we look to beyond-line-of-sight operations and plan to allow more transformational uses of the technology, there are technological challenges that exist, and which require more research and development now. We need to develop standards for sense and avoid. We need to figure out how UAS will interact with air traffic control systems. We need to determine the appropriate command and control standards to ensure the security of the communications links between UAS platforms and ground stations.

    All of these technological issues are resolvable and the industry is leading the way to develop solutions. But we also need a deeper national commitment to UAS R&D that includes a more comprehensive industry-government research plan, more government resources to coordinate UAS R&D and intellectual property protections for the companies that are at the forefront of UAS innovations.

2. What private sector research is being done to address concerns about individuals spoofing small UAS (sUAS)?

    We don't have visibility into every company's research on spoofing and, as I'm sure you can appreciate, for both competitive and security reasons. That said, the UAS industry takes the potential for "spoofing" seriously.

    Many unmanned aircraft have alternate navigation systems, such as radio links and backup inertial systems, which provide redundancy to GPS. Other backup technologies exist – or are being developed – that autonomously guide unmanned aircraft to a safe landing at a pre-determined location in the unlikely event of interference with navigation signals. Other "spoofing" countermeasures have been proposed since the 1990s, some of which are relatively simple software changes to the civilian GPS system.

3. Are there any additional federal agencies or organizations that should coordinate with FAA to safely integrate UAS? How can the private sector better coordinate R&D efforts with the federal government?

   There are a number of federal agencies already using and researching UAS that can coordinate with the FAA on research efforts. For instance, NASA has done extensive research on the concept of a UAS Traffic Management (UTM) system. All of this research needs to be coordinated with the FAA.

   In addition, researchers at NOAA and USGS have been using UAS for years for scientific research in a variety of settings. Their experience, expertise and the data they've collected can also help to improve the FAA's integration process.

   A holistic research plan from the FAA is needed to coordinate all research. It is still unclear what data will be collected by the FAA-designated test sites, or how the UAS Center of Excellence fits into this. Once the needed research and the plan for collecting it is in place, industry can better coordinate its work with the government's research needs. The FAA and other federal agencies need to create this plan so the private sector can work to support the integration process.

4. The Department of Transportation's Office of Inspector General reported that there are outstanding questions among government partners and industry stakeholders about the organization and transparency of the UAS Integration Office. How does the delay and disorganization of establishing FAA's internal UAS office potentially affect the timeline for meeting integration deadlines?
   a. How does it affect the R&D process, particularly for the government partners and industry stakeholders?

   Delays have been a big issue and, as a result, the FAA will not meet the congressionally-mandated September 2015 deadline for UAS integration. The delays have taken several forms. Notably, the small UAS rulemaking has been delayed for four years. While we finally have a Notice of Proposed Rulemaking (NPRM) as of February 2015, this process could have, and should have, started much sooner.

   The lack of an operational UAS regulatory environment here in the U.S. encourages companies to seek out more favorable regulatory environments in other countries, and several other countries are faster to grant access to their airspace for UAS research and development. For example, it was recently reported that Amazon had already tested a UAS platform in Canada and determined it wasn't viable by the time the FAA approved Amazon to test the same model in the U.S.

5. Have industry groups told FAA that they are willing to consolidate their comments on the Notice of Proposed Rulemaking (NPRM) to reduce the total number of comments and speed up the regulatory process?
    a. If so, how will the effort be coordinated?

AUVSI can only speak for our organization; we intend to submit comments on behalf of our more than 7,500 members, including more than 600 corporate members. It's possible some of our member companies may also submit separate comments.

There are a plethora of UAS stakeholders and immense interest in the technology. We believe it is important that everyone who wants a voice in the process gets the opportunity to be heard.

6. FAA has emphasized that U.S. airspace is the busiest in the world, and that this is the reason FAA is taking longer to integrate UAS into the NAS than similar agencies abroad. But sUAS are oftentimes used for research at very low altitudes and at least five miles from an airport where manned aircraft are exceedingly rare or non-existent. Why can't sUAS research be conducted safely right now at low altitudes, on private property, or with similar limitations for safety?

Small UAS can and are already being flown for research under these circumstances, but the industry is limited by the FAA's delayed regulations and lack of resources to expedite those requests. In order to fly for research outside of a test site, an individual or entity needs to apply for a certificate of authorization (COA), which can be a very timely process. We can, and should, look at expanding and expediting the ability for research in these low-risk environments in order to gather the data that will inform the next stages of the integration process.

7. What are the impacts to UAS R&D and U.S. competitiveness, if FAA does not separate UAS into more than two sizes and weight classes?

It is not immediately clear what impact a tiered regulatory structure might have on UAS R&D. However, the current pace and proposed rules that the FAA is pursuing will not meet the needs of the entire UAS industry.

That is why AUVSI has been socializing the concept of a "risk-based, technology neutral" approach for future legislative and regulatory actions. What this means is having the FAA and/or Congress establish a regulatory environment that is able to accommodate UAS innovation via flexible responsibility, reliability, security, and compliance standards, rather than continually putting new rules forward for different UAS platforms and operations.

8. Please provide us with examples of progress made on developing sense and avoid technology. What is the private sector doing to address these challenges?

   One option for airborne sense and avoid is through the use of ADS-B (automatic dependent surveillance-broadcast) transponders. ADS-B will soon replace radar as the primary means of managing U.S. air traffic and the FAA will require the majority of manned aircraft operating in U.S. airspace to be equipped with ADS-B by January 1, 2020. This is part of the transition to the Next Generation (NextGen) Air Transportation System.

   It is possible ADS-B technology could be applied to unmanned aircraft as well, broadcasting their locations in real time and directing UAS away from any other air traffic that may pose a conflict. However, there may be other solutions that industry is actively working on and have yet to unveil.

9. Please provide us with examples of progress in preventing "lost link" disruptions. What is the private sector doing to address these challenges?

   When looking at preventing "lost link" scenarios, there are companies currently engaged in ensuring backup systems and contingency plans, via operating software, that allow for the UAS to safely return to the ground. In some cases, the platforms are programmed to fly a pre-determined course while attempting to re-establish the communications link with the operator. In other cases, the UAS can be programmed to land at pre-determined location in the event of a disruption.

10. How would you organize the FAA UAS test sites to best accommodate the nation's R&D needs?

    While the FAA's UAS Test Sites have been active for over a year, one way that Congress could elevate their stature and provide indicators to industry that the FAA intends to actually utilize their work, is to make them eligible for federal funding under current FAA offices and programs that are engaged with UAS activities. This would not specifically add new funding for the test sites, rather it could allow for them to receive federal funding and give industry some guidance and incentive on better utilization of the test sites.

11. What is the effect of U.S. companies moving their R&D activities overseas because of delays in FAA regulations?

    AUVSI has not specifically quantified the impact of U.S. companies testing abroad, but we have quantified the economic benefits of UAS integration in the U.S. Our economic impact study found that the industry is poised to create more than 100,000 jobs and $82 billion in economic impact in the U.S. in the first decade after integration. Clearly not all of those jobs will be lost if more testing moves abroad, but the numbers provide a sense for what's at stake.

12. How does domestic UAS R&D compare with foreign UAS R&D?

We do not have specific numbers to compare domestic R&D vs. foreign R&D at the moment, but we believe the U.S. remains one of the top countries for UAS R&D, if not the global leader. That said, as other countries put more favorable regulations in place, there's the risk that more and more research will move overseas. When we have more specific numbers on domestic and foreign R&D, we will be sure to share those with the committee.

13. As the number of UAS operations increase, so too will UAS operators' demand for spectrum. What R&D is being conducted to either minimize the amount of spectrum needed, or to increase the efficiency of spectrum used by UAS?

Later this year, the 2015 World Radiocommunication Conference (WRC-2015) is expected to consider the use of frequency bands allocated to the fixed-satellite service for the control and non-payload communications of unmanned aircraft systems in non-segregated airspaces. We expect for this to have a major impact on the global harmonization of UAS spectrum standards and technologies moving forward.

14. Please provide an analysis of FAA's recent release of its Small UAS NPRM.

This proposed rule is a critical milestone in the UAS integration process, and one that is long overdue. UAS technology has largely remained grounded while many prospective users wait for the regulatory framework to catch up. This is a good first step in an evolutionary process that brings us closer to realizing the many societal and economic benefits of UAS technology. As an industry we believe it is important that the final rule enables the many civil and commercial uses for UAS technology in a safe and responsible manner and without being unnecessarily restrictive

AUVSI is in the process of drafting its formal comments and once our comments are finalized, we will ensure that the committee receives a copy.

15. What are some of the challenges associated with using the test sites?
    a. Are there any incentives that could be given to encourage increased use of test sites?
    b. What are your recommendations for improvements in the design and use of test sites? What kinds of data should FAA collect from test sites?

The purpose of the sites was to conduct critical research into how best to safely integrate UAS systems into the national airspace over the next several years. The research conducted at the sites should also help establish the certification, navigation and other standards needed for the integration. However, a lot remains to be done in order to achieve those goals.

As stated previously, while the FAA's UAS Test Sites have been active for over a year, one way that Congress could elevate their stature and provide indicators to industry that the FAA intends to actually utilize their work, is to make them eligible for federal *funding under current FAA offices and programs that are engaged with UAS activities. This would not specifically add new funding for the test sites, rather it could allow for them to receive federal funding and give industry some guidance and incentive on better utilization of the test sites.*

16. According to GAO, "a 2014 MITRE study found that Japan, Australia, the U.K., and Canada have progressed further than the U.S. with regulations that support commercial UAS operations." Why, in your opinion, has the FAA fallen behind other nations' regulatory progress?
    a. What can FAA do to catch up to countries like Canada, which have exempted UAS weighing 55lbs or less from needing special approval for commercial operations?

The FAA has fallen behind because the agency has not kept up with the congressionally mandated timeline laid out in the FAA Modernization and Reform Act of 2012. The FAA has not fully explained the reasons behind these delays.

Now that the rule has been proposed, the FAA must focus on producing a final rule as soon as possible. It is important that this rule enable as many commercial and civil applications as possible, as quickly as possible, in a safe and responsible manner.

Right now the only way for industries to fly UAS commercially is by applying for a Section 333 exemption and obtaining a COA. However, the exemption process has been fraught with delays. As of March 20, the FAA had received more than 600 exemption requests, but only approved 69. The FAA needs to expedite these exemptions so more businesses can being using this technology before the sUAS rule is final.

Lastly, the FAA should use the authority granted under Section 333 to begin granting exemptions for use beyond visual line of sight. This will both begin to allow broader use of this technology, as well as allow the FAA to collect data to inform the next phase of integration.

Questions for the Record from Ranking Member Johnson

Full Committee Hearing

January 21, 2015

"Unmanned Aircraft Systems Research and Development"

Mr. Brian Wynne

AUVSI

- Dr. Waggoner states in his prepared statement that NASA's near-term goal is to develop and demonstrate a UAS Traffic Management system to safely enable low altitude airspace and UAS operations within five years. Is NASA projected goal of 2019 compatible with AUVSI members' needs, and if not, what can industry do to help NASA and FAA in moving that date forward?

  There is a need to have a UTM concept deployed immediately, given the time it will take to have a fully operational system in place, to ensure compatibility with the current air traffic control system, and establish any multi-agency and industry coordination necessary. The current estimated timelines for initial operating capability needs to be sped up.

  In order to fly beyond-line-of-site we would need to integrate UAS into the air traffic infrastructure and this is where NASA's UTM system could serve a valuable purpose. We support NASA's research into its UTM system and believe the agency should be given the resources it needs to not only meet its stated goal, but also accelerate that goal to the extent possible.

- Please expand on what you see is needed to show a deeper national commitment to UAS R&D, and specifically what you mean by "a holistic research plan that coordinates all UAS research." Who should be in charge of this coordination?

  A deeper national commitment to UAS R&D is more than just a comprehensive industry-government research plan; it also includes establishing intellectual property protections for the companies participating in UAS R&D and devoting more government resources to the coordination of UAS R&D.

  With regard to the comprehensive plan, there's already a vast amount of research underway, for which industry is investing millions. We believe this research can be better coordinated with our partners in the federal government to ensure that the research is addressing the questions we need answered. A comprehensive plan would, among other things, identify gaps in research, avoid duplication of effort and lay out timetables and milestones for addressing technological challenges.

- How should Congress ensure that it gets the most out of UAS test sites? What, if anything, does Congress need to do to maximize the use of these test sites for their intended purpose? Are there any barriers that need to be addressed, and if so, what are they?

  The purpose of the sites was to conduct critical research into how best to safely integrate UAS systems into the national airspace over the next several years. The research conducted at the sites should also help establish the certification, navigation and other standards needed for the integration. However, a lot remains to be done in order to achieve those goals.

  While the FAA's UAS Test Sites have been active for over a year, one way that Congress could elevate their stature and provide indicators to industry that the FAA intends to actually utilize their work, is to make them eligible for federal funding under current FAA offices and programs that are engaged with UAS activities. This would not specifically add new funding for the test sites, rather it could allow for them to receive federal funding and give industry some guidance and incentive on better utilization of the test sites.

"Unmanned Aircraft Systems Research and Development"

January 21, 2015

Representative Dan Lipinski – Questions for the Record

- We as a nation are supporting a variety of research efforts spread across several agencies. How can we (the committee) ensure that work being done by NASA, and others, is being utilized by the FAA?

  As mentioned in AUVSI's testimony, we need a comprehensive industry-government research plan, which should include work being done across all federal agencies. NASA and others are doing research that is important to the integration of UAS into the National Airspace System, and they should be working in concert with the FAA and industry to ensure that all stakeholders are coordinating appropriately. In addition, the research plan should encompass the FAA-designated test sites, the UAS Center of Excellence and, where possible, include research efforts already underway in the private sector.

- Many countries have segmented UAV rules by weight, as smaller UAVs can access more areas safely, while heavier UAVs have the potential to do more harm. What research is being conducted to better understand how multiple weight classes under 55 pounds could impact operator qualifications, device certifications, and operational limits?

  We're not aware of specific research related to how weight classes impact operator qualifications.

- Public agencies are beginning to find valuable uses for UAS technology, such as responding to natural disasters and inspecting infrastructure. What technology transfer efforts are FAA and NASA taking to promote and implement these technologies at public agencies?

  There are a number of federal agencies already using and researching UAS. Researchers at NOAA, the U.S. Geological Survey and the Bureau of Land Management have been using UAS for years for scientific research in a variety of settings. Public safety agencies are using the technology for a variety of purposes, and public universities across the country are using UAS for everything from agriculture to weather research. Their experience, expertise and the data they have collected can help to improve the FAA's integration process, and should be included in the industry-government research plan.

- UAS is a growing industry that will require workers with technical skills and experience. As a co-chair of the STEM Education Caucus, I would like to know if there are any issues on STEM education and workforce training specific to UAS.

  Many of the occupations created by this industry will require STEM education. AUVSI's economic impact report found that 100,000 jobs will be created by UAS manufacturing in the first decade after integration, but does not include the many other specialized jobs that will be required in the industry.

  As the integration process continues, the industry will also need increasingly more UAS-specialized individuals. We should support such programs to ensure that we have the best and most qualified people available to work in this industry and fill the many jobs it will create.

- Our veterans possess many of the skills required in burgeoning UAS industry. For example, many veterans hold pilots licenses. How can we (the committee) and the federal agencies help put our veterans to work in the UAS industry?

  The committee and federal agencies can help ensure that our service members, especially those that already have the technical skills needed to serve in the UAS industry, have access to this increasing job market. According to an AUVSI economic report, this industry is projected to create more than 100,000 jobs and $82 billion in economic impact in the first decade after integration. AUVSI and its members are committed to doing our part to make sure that veterans also reap the benefits of this growing industry.

- If these aircraft are going to share the airspace with airliners, what is the FAA's position on the requirement for UAS aircraft to be equipped with collision avoidance capability? TCAS? ADS-B? Is industry in full agreement? If not, why?

  At this time, the FAA does not have an agreed upon standard for UAS collision avoidance, otherwise known as sense and avoid. This is one of the technological issues industry and government must resolve.

  One option for airborne sense and avoid is through the use of ADS-B (automatic dependent surveillance-broadcast) transponders. ADS-B will soon replace radar as the primary means of managing U.S. air traffic and the FAA will require the majority of manned aircraft operating in U.S. airspace to be equipped with ADS-B by January 1, 2020. This is part of the transition to the Next Generation (NextGen) Air Transportation System.

  It is possible ADS-B technology could be applied to unmanned aircraft as well, broadcasting their locations in real time and directing UAS away from any other air traffic that may pose a conflict. However, there may be other solutions that industry is actively working on and have yet to unveil.

- Comment on the difficulty of developing "sense and avoid" technology that effectively replicates the ability of a pilot to continuously search the area around his or her aircraft and react immediately and effectively to any perceived threat.

  Developing sense and avoid technology will be one of the most important steps in the integration process, and the industry and government are already developing this technology. Computers may not only adequately replicate a pilot's ability, but computers may sometimes exceed a human pilot's ability to detect and avoid other aircraft.

Responses by Mr. Colin Guinn

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Unmanned Aircraft Systems Research and Development"

Questions for the record, Mr. Colin Guinn, Chief Revenue Officer, 3D Robotics

Questions submitted by Rep. Lamar Smith, Chairman

1. What major technological obstacles remain to safe integration of UAS into the National Airspace System (NAS), and what private sector research and development (R&D) efforts are planned to overcome those obstacles?

Effective sense and avoid is likely the biggest one. I know that most private companies are working on solving this problem, including us (3D Robotics), but we need to get systems into the world so we can collect data to help with the research.

   a. Are there any R&D gaps?

Only the inability to freely test lightweight systems in the US.

2. What private sector research is being done to address concerns about individuals spoofing small UAS (sUAS)?

Not my area of expertise, but there are several universities working on this.

3. Are there any additional federal agencies or organizations that should coordinate with FAA to safely integrate UAS into the NAS? How can the private sector better coordinate R&D efforts with the federal government?

Yes, if there's an organization that has a vested interest in adding safety and efficiency to getting images from the air. The FAA simply has no vested interest to get UAS integrated into the NAS.

4. The Department of Transportation's Office of Inspector General reported that there are outstanding questions among government partners and industry stakeholders about the organization and transparency of the UAS Integration Office. How does the delay and disorganization of establishing FAA's internal UAS office potentially affect the timeline for meeting UAS integration deadlines?

Well, the disorganization affects meeting the UAS integration deadline because they aren't actually trying to get anything done. If a private business tried to operate with this gross inefficiency, we'd be out of business within six months.

   a. How does it affect the R&D process, particularly for government partners and industry stakeholders?

Everything is slowed down...the longer they take to integrate UAS, even just sub-4kg systems, like the rest of the world, the longer it will be until true innovation can take place. Getting something to work in the lab - or in a closed off environment - is nothing like getting something to work anywhere and all the time. In order to truly test this technology for real world integration, you need thousands of systems in the hands of companies and customers to gather the necessary data.

5. Have industry groups told FAA that they are willing to consolidate their comments on the Notice of Proposed Rulemaking (NPRM) to reduce the total number of comments and speed up the regulatory process.

Yes, absolutely. The coalition we put together, call the Small UAV Coalition is coordinating efforts to consolidate our total number of comments.

a. If so, how will the effort be coordinated?

Aside from the above, there are several grassroots organizations that are willing to work in coordination with the FAA to try and make their jobs as easy as possible. But in my meetings with the FAA, they don't appear to have any idea of this—nor do they seem to really care.

6. FAA has emphasized that U.S. airspace is the busiest in the world, and that this is the reason UAS integration is taking so much longer for FAA than for our competitors overseas. But sUAS are oftentimes used for research at very low altitudes and at least five miles from an airport where manned aircraft are exceedingly rare or non-existent. Why can't sUAS research be conducted safely right now at low altitudes, on private property, or with similar limitations for safety?

Of course it can be! The problem is that the FAA is only tasked with mitigating any potential danger in the NAS. This means that anything that even slightly increases risk goes against their core assignment. Exactly as abstinence is the best form of birth control, not integrating UAS is the best way to make sure they don't pose a single safety risk. If they were charged with preventing the deaths of people in helicopters doing the work that UAS can easily do, then maybe they'd have a vested interest in actually making some progress.

7. What are the impacts to UAS R&D and U.S. competitiveness if FAA does not separate UAS into more than two size and weight classes?

We are quickly losing ground to almost every other first-world country. If the lightest weight category we have is 55lbs and less, we can only integrate sUAS once we feel confident these regulations will work for everything under 55lbs. Attached is a photo of a 55lbs UAS - it's very big and very dangerous. But if we add a third weight class for less than 2 kg - again, what most countries in the world have done - then we can quickly integrate these much safer systems (like the one we flew in the hearing). Once we have these systems integrated, we can meet 80-90% of the commercial demand for UAS. Additionally, US companies will be free to test, gather thousands of hours of valuable flight data, and stay competitive with the rest of the world—all while giving the FAA the time they need to integrate the heavier 4.4lbs - 55lbs system into NAS. This is so obvious it hurts my brain to have to type this again.

8. Please provide us with examples of progress made on developing sense and avoid technology. What is the private sector doing to address these challenges?

For us (3D Robotics) specifically - and this is very confidential for the time being: we have a new system coming out soon that has a built in 1Ghz processor-powered Linux computer on board. The HDMI video signal goes straight from a GoPro camera into this on-board computer and we can analyze the video stream in real time - and make real time decisions based on what the camera is seeing. That means that we'll soon be able to avoid objects that the GoPro is seeing (such as when doing a return to home, or doing follow-me). Then it's only a small step to add two more cameras to achieve a full 360 view.

9. Please provide us with examples of progress in preventing "lost link" disruptions. What is the private sector doing to address these challenges?

Our new system warns the user as she approaches the edge of her range. As the range is lost, the system will "retrace its steps" - taking a known safe flight path - back to where it last had a good signal. If it doesn't reconnect at that point, it will return home and land itself at the last known position of the operator - based on the GPS position of their mobile device.

10. How would you organize the FAA UAS test sites to best accommodate the nation's R&D needs?

Privatize them and run them like for-profit businesses. In fact, I'd give one site to each of six different companies; then they'd have to compete against each other to provide the best value proposition. This would motivate them to make them easy to access and not overly expensive. This would ensure the process for accessing these sites (i.e., giving these companies your money) would be very clear and easy to understand.

11. What is the effect of U.S. companies moving their R&D activities overseas because of delays in FAA regulations?

Less money being spent in the US, less jobs being created in this burgeoning industry in the US, other countries getting farther ahead of the US in this giant new industry, and the US getting farther and farther behind in innovation and technology.

12. How does domestic UAS R&D compare with foreign UAS R&D?

Domestic UAS R&D is basically non-existent when compared to foreign UAS R&D. So the difference is that these other countries seem to see some value in UAS and they are acting accordingly. My hunch is that this will pay off for them.

13. As the number of UAS operations increase, so too will UAS operators' demand for spectrum. What R&D is being conducted to either minimize the amount of spectrum needed, or to increase the efficiency of spectrum used by UAS?

Not sure what's been done here...but this is no different than cell phones and Wi-Fi. I'm confident this will not be a gating factor in getting these systems integrated in to NAS.

14. Please provide us with your analysis of FAA's recent release of its Small UAS NPRM.

It's a good start - but they MUST include a sub 4kg exemption (which they appear to be considering) if we want to stay in the mix with the rest of the world. We can literally accomplish 80-90% of the jobs and do 80-90% of the necessary R&D with sub-2kg systems. There are sub-2kg systems that are incredibly capable, and we should let the US private sector use them for commercial purposes so we can collect data from thousands of hours of flight time in the real world.

Questions for the Record from Ranking Member Johnson
Full Committee Hearing
January 21, 2015
"Unmanned Aircraft Systems Research and Development"

Mr. Colin Guinn
3D Robotics

- Dr. Waggoner states in his prepared statement that NASA's near-term goal is to develop and demonstrate a UAS Traffic Management system to safely enable low altitude airspace and UAS operations within five years. Is NASA's projected goal of 2019 compatible with the needs of your Coalition, and if not, what can industry do to help NASA and FAA in moving that date forward?

Meeting a 2019 date for a UAS Traffic Management system would be incredible. But we absolutely cannot wait until 2019 to integrate UAS - or the US will be left in the dust of all the other first-world countries that are integrating these systems today.

- In 2012, Congress mandated that FAA establish test sites for UAS integration into the national airspace. At present, six sites have been created at locations in Texas, Nevada, Virginia, New York, North Dakota, and Alaska. How should Congress ensure that it gets the most out of these test sites? What, if anything, does Congress need to do to maximize the use of these test sites for their intended purpose? Are there any barriers that need to be addressed, and if so, what are they?

It needs to be very easy to access the test sites - which may be impossible just because of the sheer distance most companies need to travel to use them. Really, companies need to be able to test systems "right outside" the lab. By giving an exemption to systems weighing less than 2kg - like most other countries have done - companies would be able to complete the vast majority of their testing in their own backyards, then only go to the test sites for their larger systems.

- In your prepared statement, you state that the experience gained from the operations of the smallest UAVs "will provide lots of data to inform the development of other small UAVs up to 55 pounds, as well as larger UAVs". Please explain how the data from using the smallest UAVs would be scalable to be pertinent to larger UAVs.

4-lb systems and 44-lb systems basically work identically. The only difference is the size of the payload (camera, sensor, etc.) that they can carry. The failures and what leads to them are the same, only with smaller motors and less inertia if there's a crash. The data collected from sub-2kg systems is precisely pertinent to heavier systems, because they work the same.

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Representative Dan Lipinski – Questions for the Record

- We as a nation are supporting a variety of research efforts spread across several agencies. How can we (the committee) ensure that work being done by NASA, and others, is being utilized by the FAA?

Wow, great question. I have no idea. The FAA needs to have a vested interest in integrating UAS into the NAS, otherwise it will never happen. Even though these systems will save many lives every year, the FAA only sees the potential risk to the NAS. Is there some risk introduced by integrating other flying systems into the NAS? Yes. Will there be many lives saved every year since humans won't have to sit in the back seats of helicopters just to take pictures of power lines? Absolutely.

- Many countries have segmented UAV rules by weight, as smaller UAVs can access more areas safely, while heavier UAVs have the potential to do more harm. What research is being conducted to better understand how multiple weight classes under 55 pounds could impact operator qualifications, device certifications, and operational limits?

I'm not sure exactly what research is being done to quantify the impacts of additional weight classes under 55lbs for the US, but most other countries have figured out that lighter-weight systems pose less risk (due to the lower amount of inertia they possess) and so they have incentivized companies and manufactures to utilize these safer systems by implementing less stringent regulations to fly sub-2kg systems.

- Public agencies are beginning to find valuable uses for UAS technology, such as responding to natural disasters and inspecting infrastructure. What technology transfer efforts are FAA and NASA taking to promote and implement these technologies at public agencies?

I really have no idea. I only know what the hundreds of companies who have spoken to me personally have said about how they want to use UAS to save time, money and lives.

- UAS is a growing industry that will require workers with technical skills and experience. As a co-chair of the STEM Education Caucus, I would like to know if there any issues on STEM education and workforce training specific to UAS.

I'm not 100% sure I understand the question exactly, but I'll take a crack at it. UAS are one of the absolute best ways to learn about all four STEM elements...and in an incredibly fun and engaging way for students. We are a huge supporter of STEM programs across the country and we either give away products or sell them at deep discounts when used for STEM programs. What better way to understand electricity, thrust, aerodynamics, radio frequency, micro processors, artificial intelligence, imaging, GPS, navigation and so much more than by flying around a small drone in a school yard?

- Our veterans possess many of the skills required in the burgeoning UAS industry. For example, many veterans hold pilots licenses. How can we (the committee) and the federal agencies help put our veterans to work in the UAS industry?

1) Tell me anytime there is a veteran with relevant skills looking for a job in the private sector. In the last six weeks, I've hired four veterans personally for my sales, marketing and training teams. We have a great deal of veterans working for 3D Robotics, and due to their training in the military, they

are generally extremely hard working individuals who have the ability to adapt to almost any situation, and to learn new jobs very quickly.

2) Create an organization specifically for veterans looking for jobs in the UAS industry. I know I would utilize this - as would many of my competitors.

- If these aircraft are going to share the airspace with airliners, what is the FAA's position on the requirement for UAS aircraft to be equipped with collision avoidance capability? TCAS? ADS-B?? Is industry in full agreement? If not, why not?

This may be a question more suited for the FAA, but I'll give you my take. I don't think sub-2kg systems should or would be sharing the airspace with airliners...which is why we should integrate these systems first. By doing this, we'll glean valuable information that will help us make systems that are larger (and may operate in the same airspace as airliners) and safe enough to comfortably integrate them. I think ATC visibility is an absolute must if drones are to be flying any where near airliners...I travel over 200k miles by air every year, so I know my wife and children would agree.

- Comment on the difficulty of developing "sense and avoid" technology that effectively replicates the ability of a pilot to continuously search the area around his or her aircraft and react immediately and effectively to any perceived threat.

As on-board computers and processing is getting lighter and more advanced, this is becoming less and less daunting. We can already analyze the video stream coming out of a GoPro camera in our on-board computer and make decisions based on what it sees. We'll soon be able to avoid hitting obstacles that are in the GoPro's field of view. From there, it's only a matter of adding a couple more imaging sensors and some additional processing power to get a 360-degree view.

Responses by Dr. John Hansman

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Unmanned Aircraft Systems Research and Development"

Questions for the record, Dr. John Hansman, T. Wilson Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology (MIT)

Questions submitted by Rep. Lamar Smith, Chairman

Questions submitted by Rep. Lamar Smith. Chairman

1. What major technological obstacles remain to safe integration of UAS into the National Airspace System (NAS), and what research and development (R&D) efforts are planned to overcome those obstacles?

We do not have a clear concept of operations for the operating domains of small UAS beyond line of sight or UAS integration into airspace with significant manned aircraft operations. There are many technical obstacles ranging from low cost – low power surveillance systems, control algorithms, operator and controller human factors, etc.

a. Are there any R&D gaps?

Yes, the largest gap is that there is very little work being done on the hardest problem which is the operation of UAS in airspace with manned operations.

2. What private sector research is being done to address concerns about individuals spoofing small UAS (sUAS)?

Much of the private sector research on cyber security and encryption has applications in the sUAS arena.

3. Given the magnitude of the task of developing a plan to integrate UAS into the NAS by this year, are the deadlines outlined in the FAA Modernization and Reform Act reasonable?

For sUAS operating within line of sight and for some other restricted operations the deadlines are reasonable although it is not clear if they will be met. For more difficult operations we are far away from making these deadlines.

4. What is the state of human factors research?
a. Which agency is taking the lead on this topic?
b. Does this research incorporate both pilot and Air Traffic Control challenges?

There is some research being done on UAS operator human factors principally by the DOD. There is very little work being done on the implications for Air Traffic Controllers. There have been a few very small exploratory studies by the FAA and NASA but these are just starting points and careful and focused controller studies have not been started in *part due to the lack of clear Concepts of Operations.*

5. How is UAS R&D divided across NASA, FAA, and other agencies? Who sets priorities for UAS R&D across the federal government? How could this process be improved?

Most of the focus on UAS research regarding integration in the NAS has focused on the problem of "sense and avoid". There is some coordination in this area NASA is starting an effort on air traffic management for sUAS and does some research on UAS applications. The DOD does significant focused research on their operational domains and operational systems. It is not clear if this is coordinated across the federal government.

6. Is FAA transparent to agency and industry partners working on UAS integration?
a. What has been your experience with FAA transparency as it relates to UAS integration?

The FAA has not been particularly transparent the strategy or requirements for UAS integration.

7. The Department of Transportation's Office of Inspector General reported that there are outstanding questions among government partners and industry stakeholders about the organization and transparency of the UAS Integration Office. How does the delay and disorganization of establishing FAA's internal UAS office potentially affect the timeline for meeting UAS integration deadlines?
a. How does it affect the R&D process, particularly for government partners and industry stakeholders?

Because there is not a clear set of potential concept of operations and requirements for UAS integration (other than the recent proposed rules for sUAS within Line of Sight of the operator, it is difficult to identify the R&D requirements. Some agencies and industry stakeholders are conducting research but it is difficult to make progress or integrated efforts.

8. FAA has emphasized that U.S. airspace is the busiest in the world, and that this is the reason FAA is taking longer than similar agencies overseas. But sUAS are oftentimes used for research at very low altitudes and at least five miles from an airport where manned aircraft are exceedingly rare or non-existent. Why can't sUAS research be conducted safely right now at low altitudes, on private property, or with similar limitations for safety?

There is nothing special about the U.S. airspace at low altitudes away from airports which would preclude safe UAS operations.

9. Why is using sUAS for research or commercial purposes deemed different from using sUAS as a hobby? What is the difference in regards to safety?

There is no difference if the sUAS are of similar type operated in a similar way. It is likely that the operation for commercial purposes would be less likely to cause safety concerns as the commercial operators are more likely to have trained and experienced operators, are more likely be aware of manned aircraft operations, and are more sensitive to liability concerns.

10. What are the impacts to UAS R&D and U.S. competitiveness if FAA does not separate UAS into more than two size and weight classes?

We are already seeing migration of the development of UAS technologies and operating testing overseas due to the current regulatory restrictions. I can't comment on the specifics of the implications of specific weight classes without knowing what they are and the operating limitation for each class.

11. How does the FAA regulatory process affect UAS R&D and vice versa?

The restrictions on operations have forced much UAS research in the US to be limited either to indoor or very restrictive operations with many months or years of delay to get approval. This clearly has a negative impact on innovation testing and development.

While there is significant R&D which would help defining the concepts of operation and potential regulatory processes the FAA has not been particularly receptive to input in this area. The one exception is in the well defined area of "sense and avoid" technologies.

12. Please provide us with examples of progress made on developing sense and avoid technology. What is the private sector doing to address these challenges?

There has been significant work done by the DOD and the FAA on sense and avoid using multiple technologies including optical detection, radar, and cooperative systems such as ADS-B or ACAS-X. Private industry is working on both sensing technologies and avoidance algorithms.

13. Please provide us with examples of progress in preventing "lost link" disruptions. What is the private sector doing to address these challenges?

For automated UAS the automation systems provide some robustness to short periods of lost link. For longer term lost link it is necessary to have a procedure which the vehicle will follow if it looses link. The current state of the art is somewhat limited. When a "lost link" occurs vehicles are normally programmed to either: return to base or a "rally" point or to intentionally crash to prevent leaving a safe test range. More advanced responses are possible but require an agreed upon procedure or concept of operations.

14. What R&D should NASA perform that is not currently being performed? Is there any

UAS-related R&D that NASA is conducting, but should not be?

The planned work by NASA on low altitude sUAS appears promising and will help define concepts of operations and procedures for low altitude beyond line of sight operations. I am less clear on what the objectives are for the work NASA is doing on larger UAS such as their Ikhana UAS.

15. In the Department of Transportation's Office of Inspector General report published in June 2014, it was reported that the Radio Technical Commission for Aeronautics (RTCA), a Federal Advisory Committee to FAA, had determined that their new UAS committee had prioritized sense and avoid and command and control links for large UAS that operate at higher altitudes. What was the motive for making larger UAS a higher priority than small UAS?

I do not know.

16. What are some of the challenges associated with using the test sites?
a. Are there any incentives that could be given to encourage increased use of test sites?
b. What are your recommendations for improvements in the design and use of test sites? What kinds of data should FAA collect from test sites?

Any testing, on a test site or not, should be based on clear research requirements which we currently do not have so this is a challenge. It is not clear if the current test site well match the research requirements and there are clearly more test sites then there is current research and development requiring testing.

The test sites are generally far away from much of the research community and there are not procedures yet for easy and inexpensive access.

For sUAS, unless there are significant safety issues or concerns, it would be more effective to have procedures to allow quick approval for limited test operation at the local level than to rely on large remote test sites. For larger UAVs with more risk the isolated test sites make sense.

17. According to GAO, "a 2014 MITRE study found that Japan, Australia, the U.K., and Canada have progressed further than the U.S. with regulations that support commercial UAS operations." Why, in your opinion, has FAA fallen behind other nations' regulatory progress?

The problem is somewhat simpler in countries like Australia and Canada which have lower aircraft and population densities than the US or in the U.K where there is less low altitude General Aviation activity. However I believe that the key reason that the U.S. has is concern of unintended consequences of broad and uncontrolled operation of UAS.

a. What can FAA do to catch up to countries like Canada, which have exempted

UAS weighing 55lbs or less from needing special approval for commercial operations?

Exempt UAS weighing 55 lbs. or less from needing special approval for commercial operations?

18. It is our understanding that FAA has solicited bids for the creation of a Center of Excellence (COE) for UAS R&D in the areas of sense and avoid and command and control technologies.
a. Which stakeholders were represented in the bidding process?
b. When does the agency expect to announce the winner(s)?
c. How will the COE be funded?
d. How much money will be expended on the COE?
e. Is the COE a greater funding priority than test sites?

Since MIT is participating on one of the bidding teams, I would defer this question to the FAA.

19. Are exemptions to Section 333 of the FAA Authorization and Reform Act of 2012 effectively meeting the needs of the UAS community while the FAA determines ways to integrate UAS into the NAS?

The number of exemptions issued at this point is much lower than the demand for UAS testing in the community. It is an option but is not fully meeting the needs.

20. Please provide us with your analysis of FAA's recent release of its Small UAS Notice of Proposed Rulemaking.

I think that the rule is reasonable and makes sense for sUAS within line of sight. It is basically what was expected. It does not meet the demands of many potential commercial operators who require beyond line of site operations. It does also not recognize the lower risk levels of very small use (eg below 2 lbs.).

Questions for the Record from Ranking Member Johnson
Full Committee Hearing
January 21, 2015
"Unmanned Aircraft Systems Research and Development"

Dr. R. John Hansman
MIT

• How should Congress ensure that it gets the most out of the UAS test sites? What, if anything, does Congress need to do to maximize the use of these test sites for their intended purpose? Are there any barriers that need to be addressed, and if so, what are they?

I think that the key issue is not the test sites but if it is possible to get the testing done both to enable UAS operations in the broader NAS but also to develop and test new UAV vehicles, technologies and missions. We need to reduce the barriers to exploration. The test sites have not yet delivered on this intended process and are just starting to get processes defined to approve tests. The key barriers are the slow process for test approval as well as geographical barriers as many test sites are remote. Cost may also be a barrier as it is not clear what the costs will be to test in the test sites.

• UAS is a growing area with potential commercial and research applications, as well as a growing industry that will require technical skills and experience. As a professor who has worked in the area of aviation and aeronautics, what are your perspectives on the opportunities for UAS to benefit STEM education and workforce training? Are there any issues for Congress on STEM education and workforce training specific to UAS that the Committee should consider?

We have found that small vehicle design (including model aircraft and sUAS) is a strong stimulant for STEM education. Small UAS offer the potential opportunity for students to innovate in the design, build, implementation and operation of UAS. The uncertainty and ambiguity in the sUAS operating rules has been a significant barrier. Students are unclear if a small model aircraft they design or a remotely controlled quad copter that they developed a sensor for can be flown and tested.

• The FY2015 appropriations for FAA's research in Unmanned Aircraft Systems is about $15 million. Is this sufficient to address the research and development priorities aimed at ensuring the safe integration of UAS into the national airspace system? If not, where are the shortfalls, and why? Is FAA's research program well defined and matched to UAS research priorities?

This level is unlikely to be adequate to insure that the key issues are addressed in a timely manner. It may be sufficient for one class of UAS operations (e.g. sUAS in line of sight) but it is clearly inadequate for the more difficult problems of sUAS beyond line of sight and larger UAS operating in airspace where manned aircraft are also operating.

• Mr. Guinn said in his statement that the experience gained from the operations of the smallest UAVs *"will provide lots of data to inform the development of other small UAVs up to 55 pounds, as well as larger UAVs"*. Do you agree that the data from using the smallest UAVs would be scalable to be pertinent to larger UAVs? If not, why not?

Any experience operating UAS in civil airspace will be useful if documented and monitored. The experience with very small UAS will probably scale to larger UAS if they are operating in similar airspace with similar restrictions, as many of the issues are not size related. However, only a part of the experience will transfer to different operating environments (e.g. beyond line of sight or non-segregated airspace).

"Unmanned Aircraft Systems Research and Development"
January 21, 2105

Representative Dan Lipinski – Questions for the Record

• We as a nation are supporting a variety of research efforts spread across several agencies.
How can we (the committee) ensure that work being done by NASA, and others, is being utilized by the FAA?

The best way to ensure that the FAA can use research from others is for the FAA to define clear research requirements and potential concepts of operations for UAS. In the absence of these agencies like NASA must speculate on potential research needs.

• Many countries have segmented UA V rules by weight, as smaller UAV s can access more
areas safely, while heavier UAVs have the potential to do more harm. What research is being
conducted to better understand how multiple weight classes under 55 pounds could impact
operator qualifications, device certifications, and operational limits?

A number of studies have been done to assess ground impact and mid-air collision risk as a function of vehicle size. There is a trade off as the smaller vehicles have less consequence if a mishap occurs but also have less capability. The technology is rapidly improving on sensors, communication and flight controls for very small vehicles so this picture is changing and is an area where research should be conducted to take advantage of these technology trends both for vehicle development and their implications for UAS operations in the NAS.

• Public agencies are beginning to find valuable uses for UAS technology, such as responding
to natural disasters and inspecting infrastructure. What technology transfer efforts are FAA
and NASA taking to promote and implement these technologies at public agencies?

The FAA has engaged in this area primarily with local and federal agencies who have an alternative certification path to commercial UAS users and are starting to approve commercial users. NASA has done some work in areas like forest fire assessment using existing UAV assets.

• UAS is a growing industry that will require workers with technical skills and experience. As
a co-chair of the STEM Education Caucus, I would like to know if there any issues on STEM
education and workforce training specific to UAS.

As I stated above, we have found that small vehicle design (including model aircraft and sUAS) is a strong stimulant for STEM education. Small UAS offer the potential opportunity for students to innovate in the design, build, implementation and operation of UAS. The uncertainty and ambiguity in the sUAS operating rules has been a significant barrier. Students are unclear if a small model aircraft they design or a remotely controlled quad copter that they developed a sensor for can be flown and tested.

• Our veterans possess many of the skills required in the burgeoning UAS industry. For example, many veterans hold pilots licenses. How can we (the committee) and the federal agencies help put our veterans to work in the UAS industry?

Reducing the barriers to development, testing and operation of UAVs should enable growth in the UAS industry. As you note, veterans are uniquely experienced in this area and should benefit from the growth.

• If these aircraft are going to share the airspace with airliners, what is the FAA's position on
the requirement for UAS aircraft to be equipped with collision avoidance capability? TCAS?
ADS-B?? Is industry in full agreement? If not, why not?

This is one area of development and research where the FAA has been active. Current TCAS is not designed for UAS maneuverability and there is an incompatibility between UAS and large aircraft maneuvers. This is being addressed. ADS-B offers significant promise as a common system where manned aircraft, UAS and Air Traffic Control can monitor traffic. In order to be most effective a small UAS ADS-B technical specification will be required as the current ADS-B technical specifications require more power and weight than would be practical for sUAS. Allowing low power ADS-B for sUAS would also help with concerns regarding ADS-B frequency congestion if the number of ADS-B aircraft and UAS were to suddenly increase.

• Comment on the difficulty of developing "sense and avoid" technology that effectively replicates the ability of a pilot to continuously search the area around his or her aircraft and
react immediately and effectively to any perceived threat.

There are a number of technical approaches under development both with remote surveillance (e.g. Radar) cooperative surveillance (e.g. ADS-B) or onboard monitoring (e.g. optical or LIDAR systems). The key challenge is to develop systems which will enable a broad class of UAS operations. This is particularly challenging for sUAS which have limited onboard capability and it is likely that the approach which works for large UAS will be different for sUAS. It is worth noting that many of the proposed technical requirements of Sense and Avoid likely significantly exceed the actual performance of a human pilot in the search and detection task.

Appendix II

ADDITIONAL MATERIAL FOR THE RECORD

STATEMENT SUBMITTED BY RANKING MEMBER EDDIE BERNICE JOHNSON

OPENING STATEMENT

Ranking Member Eddie Bernice Johnson (D-TX)
Committee on Science, Space, and Technology

"Unmanned Aerial Systems Research and Development"
Full Committee Hearing

January 21, 2015

Good afternoon. I want to welcome our witnesses to today's hearing.

As we will hear today, potential applications for Unmanned Aerial Systems are growing at an explosive rate, whether in agriculture, delivery services, environmental monitoring, and so forth. It is an exciting time for this emerging industry.

I want the UAS industry to grow, because it offers the promise of societal benefits, economic growth, and skilled jobs—and those are good things for our nation. However, this industry will only prosper if it is clear that UAS operations will be safe and not put at risk either the public on the ground or the airline passengers who will share the skies with some of those UAS vehicles.

This hearing offers us an opportunity to explore both the potential of UAS as well as the research that may be needed to ensure that safety will be maintained as these vehicles are integrated into the National Airspace System.

As you know, I serve on both this Committee and the Transportation & Infrastructure Committee. I anticipate that we will be working on reauthorizing FAA's activities in both Committees. I hope that this hearing will start the process of identifying any R&D issues that may need to be addressed in that legislation.

In closing, it is clear to me that UAS is one of the most interesting new developments in aviation, and I am glad we are holding this hearing. However, there are many other exciting things going on in aeronautics R&D that have the potential to transform air travel in the future. I hope that this Committee will use future hearings to look at aeronautics R&D more broadly so that Members can be informed about what is possible and what Congress can do to help promote that R&D.

Again, I want to thank our witnesses for appearing before our Committee, and I look forward to your testimony.

STATEMENT SUBMITTED BY REPRESENATIVE DONNA R. EDWARDS

STATEMENT FOR THE RECORD

Rep. Donna Edwards (D-MD)
Committee Member

"Unmanned Aircraft Systems Research and Development"

January 21, 2015

Good Morning, and welcome to our distinguished panel of witnesses. Mr. Chairman, thank you for calling this hearing on Unmanned Aircraft Systems Research and Development.

On March 3, 1915, Congress established the National Advisory Committee for Aeronautics, or NACA, "to separate the real from the imagined and make known the overlooked and unexpected" in the quest for flight. In 1958, the NACA's staff, research facilities and know-how were transitioned to the new NASA. So it is fitting, this year being the 100th anniversary of NACA, that the first aerospace related hearing by the Committee focuses on aeronautics.

Among the most dramatic events in aviation in the past ten years has been the growth of Unmanned Aircraft Systems (UAS). As most of my colleagues on the Committee know, I am a strong supporter of technology development and the innovation that it breeds. That is why I am so excited to see the explosive growth in the UAS industry and the potential it has to generate good jobs.

Initially limited to military applications and specialized federal civil uses such as border patrol, breakthroughs in miniaturization and other technological advances have resulted in broader UAS use and availability. UAS aircraft the size of a bird have prompted game-changing and widely publicized proposals, such as using UAS to support doorstep delivery of packages and meals.

But my colleagues also know that I am also a staunch advocate for safety. I was alarmed to read during the holidays that a Washington Post investigation had uncovered internal emails that were reported to show that FAA safety inspector concerns, surfaced during their review of applications for UAS exemption of certain FAA standards, were dismissed by the agency's senior management.

While I am aware that FAA Administrator Huerta has subsequently denied that FAA has been soft on its approval and enforcement policies, this report demonstrates the breadth of issues that need to be addressed in the Nation's quest to safely integrate UAS in the National Airspace System.

I repeat: safely integrate UAS in the National Airspace System. That's the challenge.

As you may recall, recognizing the significance of UAS and the need for a plan to facilitate the safe transition of UAS into the NAS, Congress had directed FAA in the "FAA Modernization and Reform Act reauthorization of 2012" to meet date-specific requirements and deadlines to achieve safe UAS integration.

Today, I hope to hear how well FAA is responding to Congress's directive as well as determine whether the agency is taking advantage of the expertise of NASA and academic institutions. We also need to hear if FAA believes that those deadlines need to be adjusted in order to assure continued airspace safety.

I am cognizant of user criticism that FAA is not moving fast enough. That is why I hope to better understand what is required to secure a sound foundation for FAA's UAS rulemaking and how research activities would be beneficial.

LETTERS SUBMITTED BY CHAIRMAN LAMAR S. SMITH

Michael C. Kronmiller
Great Falls, Virginia

January 21, 2015

Chairman Lamar Smith
House Committee on Science, Space, and Technology
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Chairman:

I am a student, in Eleventh Grade, who leads an international, collaborative research and development ("R&D") STEM—Science, Technology, Engineering, Math--project aimed at developing unmanned aircraft systems ("UAS") for disaster relief. I am seriously concerned about the legal and policy challenges facing me and anyone else in the United States, who engages in any similar endeavor, in secondary school or college. Your hearing offers the opportunity to explore these challenges and to set the stage for Congress to address them decisively.

R&D for UAS holds the promise of enormous contributions, not only to our national security and economy, but also to the international community at large. In this field of R&D, as in many others, the importance of our secondary schools and colleges as technological incubators cannot be overstated. Yet, America lacks the kind of legal and policy environment for UAS R&D flight testing that would allow these extraordinary national assets to be mobilized to their full potential.

I offer an example from my own experience. For the past thirteen months, I have been planning and organizing my STEM project for my school, here in the United States, and a school in Nepal. (*See* nepalrobotics.org.) The primary purpose is to develop drones deploying an array of sensors for disaster relief missions in that country. I chose Nepal, because it presents some of the most challenging conditions for disaster relief and has an active robotics community that can provide continuing technical support for drones. If sensor-equipped drones can be successfully employed for this purpose, in Nepal, then it is reasonable to expect that they can be readily adapted to conditions virtually anywhere else in the world, where technical support is, or can be made, available.

The immediate objective of the project is to develop drones to support rescue and recovery of avalanche victims. With that objective in sight of achievement, the project will set out to adapt drones to inspect vulnerable bridges and aerial lines and cables, which are vital links of transportation and communication in that country and others.

It is a tribute to U.S. experts in drone and sensor technologies, as well as in aviation, UAS law, and geological and computer sciences, that these individuals have so readily agreed to provide advice for this project. Without these advisers, I could not, nor could my fellow students, hope to achieve such ambitious STEM objectives.

Based on the advice already received, it appears feasible to find avalanche victims utilizing remotely piloted and autonomously operated quadcopters and octocopters equipped with high performance propulsion, guidance, and other subsystems, and payloads including optical (2-D and 3-D), tagging gear, ground penetrating radar, sonar, thermal imaging, and synthetic aperture radar. Environmental challenges, including high altitude, wind, snow, and ice and rock formations, while daunting, do not, now, appear to present technically insurmountable obstacles. To validate this tentative assessment, a program of thorough flight testing is required, but the fact remains that the technical requirements of this project cannot be adequately understood, much less met, without test flights for which the present U.S. legal and policy framework is unsuited.

Legal requirements applicable to commercial and governmental UAS R&D flight testing are not appropriate to educational UAS R&D and are too demanding for most high schools and many colleges. This activity is not commercial, although funding and other assistance by companies is important, if not essential. Likewise, such R&D, while sometimes supported by government funding and other assistance, is not exclusively or essentially governmental in nature. Characterizing UAS R&D by high schools and colleges as recreational is not appropriate, and the restrictions on that category are too constraining. The experimental category is not reasonably applied or even practicable for this activity. None of the approaches suggested by the Federal Aviation Administration ("FAA") on its website adequately takes account of the unique nature of educational UAS R&D. In the particular case of my STEM project, the remedy informally proposed by one FAA official is that flight testing be conducted entirely indoors, a restriction that would render this research and development impracticable.

The FAA, on January 9 of this year, posted on the Internet detailed guidance to law enforcement entities, "Unauthorized UAS Operations." http://www.faa.gov/uas/regulations_policies/media/FAA_UAS-PO_LEA_Guidance.pdf. How each among the vast multitude of law enforcement entities throughout the United States will interpret the flight rules described in the FAA document, and what enforcement practices will be employed based upon those interpretations, will not be known for an extended period of time.

This situation leaves students, faculties, and administrators in the position of having to make choices that do not facilitate, but instead, impede or even defeat, UAS innovation. At present, the choices are: securing special consideration from the FAA, on a complex, costly, and overly restrictive basis (exemptions and related waivers); working through the difficulties of utilizing the few, existing test ranges; attempting to interpret and apply broad rules in ways that allow at least some, though almost certainly inadequate, flight testing; or directing educational R&D to different, less preferred, and often less technologically promising, purposes.

My experience suggests that many secondary school and college administrators might find the obstacles to UAS R&D too great to justify the expenditure of resources, and the commitment of the time and effort of rising, young scientists, engineers, technologists, and mathematicians. Moreover, STEM students understandably might opt for other areas of R&D, where innovation is encouraged. These students not only serve their own personal ambitions, but also extend the boundaries of science, technology, engineering, and math in ways that serve the national interest.

My project is going forward, despite the serious problems posed by the current legal and policy situation. The project team could have chosen something far less difficult, but that would have been far less rewarding.

U.S. members of the project team are committed to visiting Nepal, in March, for consultations with Nepali counterparts and rescue pilots and organizations, and for initial, *in situ*, flight tests of our drones. Because very high altitude, associated weather conditions, and physical obstacles are critical areas of investigation for applying sensor-equipped, unmanned aircraft systems to avalanche response, one U.S. member will attempt to test fly one or two drones at the Everest Base Camp and Khumbu Icefall.

It will be possible to undertake, at lower altitudes and in more benign environmental conditions, other useful research. However, I cannot now count on being able to conduct methodical flight testing, here, that will be sufficient to reach the goal of fielding operational drones by June 2016. As things stand, in order to gather sufficient data to inform the design of the later, more advanced, operational drones, the initial test models will have to remain behind, in Nepal, for additional flight tests. Worse still, the legal and policy situation threatens to compel the project team to plan for confining its future, necessarily even more demanding flight testing effort, to Nepal. All of this is deeply disappointing for the American members of the project team, whose learning experience would benefit far more from flight testing development models, taking account of lessons learned and applying them on a continuing basis, in the United States. I can only hope that the offer by one of the project's advisers to help the team gain access to an FAA-authorized test site, for at least some flight testing in the national airspace system, will come to fruition.

All of this leads to an inescapable conclusion. Without decisive action by Congress, mine could a generation of secondary school and college students largely lost to this important field. I would like to offer suggestions, based on discussions with the project's advisers.

Legislation should provide specific guidelines allowing some reasonable degree of flexibility to meet particular research and development needs, while not compromising safety for which the FAA is responsible. Strict rules, from which no departure would be permitted, should be provided to address the most critical safety risks.

Legislation should leave it to each educational institution to develop its own flight testing plan, which the FAA would review for consistency with the new statute. Within 90 days of its submission, a plan would be deemed approved, if not found to be inconsistent with the safety provisions of the law. While the legislation should use small UAS as the basis for guidelines and rules, a clear, expeditious process should be provided for exceptions to accommodate more ambitious research and development flight testing, while providing for safety. Of course, the FAA should have appropriate oversight and enforcement authority.

I respectfully request that this letter, which does not necessarily reflect the views of my school, be included in the record of your Committee's January 21, 2015, hearing. Thank you.

Sincerely,

Michael C. Kronmiller

NATIONAL ASSOCIATION *of* REALTORS®

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January 20, 2015

The Honorable Lamar Smith
Chairman
House Science, Space, and Technology Committee
2409 Rayburn House Office Building
Washington, DC 20515

The Honorable Eddie Bernice Johnson
Ranking Member
House Science, Space, and Technology Committee
2468 Rayburn Office Building
Washington, DC 20515

Dear Chairman Smith and Ranking Member Johnson:

On behalf of the 1.1 million members of the National Association of REALTORS® (NAR), thank you for holding tomorrow's hearing, "Unmanned Aircraft Systems Research and Development," to address the growing innovation in the Unmanned Aircraft Systems (UAS) industry. NAR's membership includes REALTORS® who hope to utilize UAS technology, which is uniquely suited for photography and video of expansive or unique properties for marketing purposes. As the FAA works toward promulgating rules allowing the commercial use of UAS, working to make this technology as safe and reliable as possible is very important to our members.

The FAA Modernization Act of 2012 tasked the Federal Aviation Administration (FAA) with promulgating regulations for integrating small UAS into the National Air Space (NAS). Current FAA regulations ban any commercial use of UAS, but as the industry rapidly grows and innovates, we are hopeful that new developments to protect safety and privacy will propel the FAA along in their rulemaking. This technology-based industry can only succeed in the U.S. with effective regulation that protects citizen safety and privacy while allowing operators to use these machines for the multitude of purposes for which they were designed. As potential end-users of this technology, REALTORS® want clear regulation that permits the commercial application of UAS in a way that is affordable to users and safe for their communities, both on the ground and in the NAS.

Again, thank you for holding this hearing. NAR looks forward to working with Congress and the FAA to create a safe and reasonable regulatory environment for the commercial use of UAS.

Sincerely,

Chris Polychron
2015 President, National Association of REALTORS®

cc: Members of the House Science, Space, and Technology Committee

LETTER SUBMITTED BY RANKING MEMBER EDDIE BERNICE JOHNSON

Congresswoman
Eddie Bernice Johnson (D. TX)
Ranking Member
House Committee on Science, Space and Technology
2321 Rayburn House Office Building

Congressman
Lamar Smith (R. TX)
Chairman
House Committee on Science, Space and Technology
2321 Rayburn House Office Building

Dear Mr. Chairman Smith and Ms. Ranking Member Johnson

The Coalition of Airline Pilots Associations (CAPA) presents the following position paper on UAS governance going forward.

CAPA is a trade association composed of more than 25,000 professional pilots. CAPA's purpose is to address
safety, security, legislative and regulatory issues affecting the professional flight deck crew member on matters of common interest to the individual member unions. The members of CAPA are Allied Pilots Association (American Airlines), Independent Pilots Association (UPS Airlines), Teamsters Local 1224 (Allegiant Air, Atlas Air, Horizon Air, Hyannis Air, Kalitta Air, Miami Air, Omni Air, Silver Airways and Southern Air) and Teamsters Local 357 (Republic Airlines).

Members of CAPA are also involved in partnership with the FAA and industry in addressing risks to aviation safety through voluntary safety reporting programs, participation in developing and implementing future airspace redesign and cooperative safety data sharing programs such as Aviation Safety Information Analysis & Sharing (ASIAS). In partnership with our members and their FAA Certificate Management Offices, we have created a robust safety culture among our member pilots. The success of such industry wide cooperation has enhanced aviation safety immeasurably over the past two decades and is critical to the unprecedented commercial aviation safety record of the past 10 years.

CAPA has begun to receive reports from our line pilots regarding UAS encounters. Members of our Safety Committee, all current and qualified line pilots, are studying the issue closely via our various safety programs. As evidenced by recent media reports and the FAA's current focus on the issue, UAS aircraft are a rapidly evolving part of our airspace environment. While we work to understand the fine details involved in the issue it is apparent that there are some overarching ideas with which to begin addressing the concerns:

Oversight must be appropriate to the level of operation. UAS aircraft range from small consumer products up to and including systems that operate half way around the globe with lethal capabilities. Ultimately there may be remotely piloted vehicles (RPV) that are the size of commercial transport category aircraft or actual converted transport category aircraft. Any system put in place to govern these programs must account for this eventuality and provide the appropriate level of regulation for each. Our current commercial aircraft regulatory system was developed in the era of the Douglas DC-3 and has been patched and expanded to cover jet transports, which now saturate our airspace on a scale that was never anticipated. This is an opportunity to develop a regulatory schema, using the hard lessons learned over the past one hundred years, that has the long-range vision to be capable and integrated to handle the full spectrum of anticipated operations.

New airspace division and operating restrictions in controlled and uncontrolled airspace must be developed. The field of view in RPVs is very limited with no peripheral vision at all. In visual operations, as many airports operate during clear weather, pilots are responsible for their own separation from other aircraft during approaches. In instrument conditions close coordination and communication with Air Traffic Control is required to provide a minimum level of safety. Any lack of airspace division or traffic control could put RPVs and other aircraft in conflict. Part of the solution to this issue should lay in requiring UAS operations above a certain altitude (400' may be a natural choice due to current restrictions) to have minimum equipment requirements. The minimum standard would include anti-collision lighting, automatic dependent surveillance (ADS-B) system, and Traffic Collision Avoidance System (TCAS) with a mode S transponder.

Along with minimum equipment requirements there needs to be certification and training requirements for operators as well. As with manned aircraft the requirements should escalate with the size of the equipment and extent of the operations. Any UAS operator with a certificate would be subject to penalties and fines as are current airmen. As we've seen with the threat to aircraft from personal lasers there must be some protections that address misuse by those that are not licensed or operate outside the regulations.

Transport category aircraft currently undergo testing and certification to assess the risk and survivability of collision with wildlife. The 'miracle on the Hudson' attests to the validity of such a threat. UAS aircraft should be certified according to their size and range of operations. Should they suffer critical damage from such an encounter a small drone operating at low altitude within line of sight may not present as great a risk as a large RPV operating well beyond line of sight. For any small UAS systems operating with extended range consideration should be given to testing the survivability of passenger plane impact with such a vehicle. Larger RPVs would most likely have TCAS and be in communication with ATC which would mitigate the risk of collision.

Respectfully,
Captain Mike Karn
President Coalition of the Airline Pilots Association
Hall of States
Washington DC