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Statement of

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Subcommittee on Aviation

Chairman DeFazio, Ranking Member Sam Graves, Chairman Larsen, Ranking Member Garret Graves, and members of the Subcommittee: thank you for this opportunity to testify on the vision of the National Airspace for 2050 and NASA's role in shaping future developments of the airspace.

Imagine with me for just a moment a vision of what our nation's transportation system could look like in 2050 and the possibilities that are unlocked for our citizens.

Imagine you are a business person in Arlington, VA. You wake up early in your home, then hold a quick virtual meeting with your staff. You hop in a ride share to the airport . . . car or air taxi, whichever is faster at the moment. A supersonic passenger jet takes you from DC to Seattle in about two hours. Upon arrival at the airport in Seattle, you fly from the airport to your meeting in an air taxi for a morning meeting.

You and your business partners order a fresh seafood lunch delivered by drone to a portal in the office building.

Perhaps you are studying wildfire damage in the state, with images sent in real time from first responders using unmanned vehicles flying over remote areas. Or you are reviewing construction of a new renewable energy infrastructure monitored by security drones. Or perhaps you are meeting with business leaders to discuss the new local manufacturing facility being built to assemble the new commercial aircraft for export around the world.

By early afternoon you wrap up your meeting and head back to the airport. On the plane ride home you remember you forgot to reorder your dog's heart medication, so you order an emergency shipment to be delivered by drone to your house, and it is waiting for you when you arrive.

That evening you are home in time for dinner with your family and a good night's sleep in your own bed.

This is a world enabled by aviation, where you can fly across the country in two hours, or to the other side of the world in five. A world with:

- Urban air taxis, drones delivering packages and collecting data, all available at your fingertips;

- New opportunities for mobility we haven't yet thought of across America and around the world benefiting consumers and passengers;
- Booming tourism and business travel fueled by inexpensive and quiet air travel for vacationers and business people alike; and,
- U.S. companies capitalizing on this vision to deliver these products and develop aviation services of the future, creating high quality manufacturing jobs.

This vision is closer than you might think. NASA and the U.S. aerospace industry currently are working on the technologies to make this vision a reality.

Today's aviation system moves the world – moving people and packages around the world contributing to jobs and trade. Today's aviation system is safe and efficient. It is centered around commercial air travel and airports. U.S. companies are global leaders in aircraft and engine manufacturing, commercial airlines and cargo delivery.

Aviation generates $1.6 trillion in total U.S. economic activity a year, and contributes about 5 percent of the U.S. Gross Domestic Product.[1] Aviation in the U.S. supports 10.6 million direct and indirect jobs,[2] and generates the largest positive trade balance of any manufacturing sector, over $84.8 billion per year.[3]

Tomorrow's aviation system will change the world. People and packages will move more quickly, and in new ways. Tomorrow's aviation system will still be safe and efficient, but now much more widely accessible to all citizens. Aviation enables new ways of living, working and connecting with others. Exciting new technology and changing consumer demand will change our relationship with aviation. Today's explosion of new business models for ground transportation (such as ride sharing and package delivery) is taking to the air, enabling an entirely new aviation mobility market and opportunity space for tomorrow.

These trends are real. Innovation and growing global economies will double global passenger air travel in the next twenty years as new products are introduced. Air travel will expand as economies grow and develop.[4] Boeing predicts demand of 42,730 new aircraft in the next twenty years and a market worth over of $6 trillion.[5] According to Airbus, there will be another $3 trillion in aftermarket services needed in that time period.[6] High speed flight – faster than the speed of sound – will open up new routes and new opportunities for air travel around the world.

This growth in aviation means jobs. Boeing has projected that aviation will need 790,000 new pilots by 2037 to meet growing demand, with 96,000 pilots needed to support the business aviation sector.[7] There will be similar growth in jobs for manufacturing, technicians, and aviation services, as well as new jobs created as a result of new economic opportunities which will be created.

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[1] The Economic Impact of Civil Aviation on the U.S. Economy," Federal Aviation Administration, November 2016, Page 20, PDF

[2] The Economic Impact of Civil Aviation on the U.S. Economy," Federal Aviation Administration, November 2016, Page 20, PDF

[3] Leading Indicators for the U.S. Aerospace Industry," International Trade Administration, March 13, 2018, PDF

[4] 2036 Forecast Reveals Air Passengers Will Nearly Double to 7.8 Billion," International Air Transport Association, October 24, 2017, Web Page

[5] https://www.boeing.com/commercial/market/commercial-market-outlook/

[6] https://www.airbus.com/newsroom/press-releases/en/2016/07/airbus-forecasts-3-trillion-commercial-aviation-aftermarket-services-over-the-next-20-years.html

[7] https://www.boeing.com/commercial/market/pilot-technician-outlook/2018-pilot-outlook/

Global competition is fierce in this sector as companies and countries seek to capture a larger share of this growing market and high wage jobs. U.S. and European companies traditionally have divided the global market for large civil aircraft and equipment. Now China is investing heavily in aerospace, starting up a new company to build large commercial aircraft to lure some of the large civil aircraft market share. Russia and Japan are seeking to break into the regional jet market, and companies from all around the world are seeking market share for smaller unmanned systems and vehicles.

NASA Aeronautics is uniquely positioned to be the catalyst for this exciting future, and to ensure that the U.S. maintains a strong leadership role. We have been a global leader in creating and realizing amazing advances in aviation for generations, developing new technologies and new concepts for how the aviation system can be better, faster, and more efficient. NASA Aeronautics research is in the DNA of every aircraft flying today. The United States has the safe, global air transportation system we have today in part because of NASA research.

NASA's cutting edge research today in areas such as composite materials, new airplane concepts, air traffic management, and safe routine integration of unmanned aerial systems (UAS) into the National Air Space is forging the path to this new vision for 2050.

NASA works with the U.S. aviation community and government partners to create opportunities for American businesses, raising the level of performance for all participants. NASA has a vision of what is possible, based on deep insight into the goals and needs of the aviation community and U.S. industry engagement early in the technology development cycle. We invest in aeronautics research to address the most critical challenges, always with an eye toward the practical application of the results. We bring the most promising technologies to flight to demonstrate them in a realistic environment, in collaboration with our U.S. industry partners whenever appropriate. Partners leverage NASA's investments through joint efforts that complement the agency's internal capabilities, provide access to a wide range of technologies beyond the traditional aeronautics portfolio, and facilitate technology transfer to more mature states of development and eventual implementation.

One critical government partner to NASA is the Federal Aviation Administration. We work closely with FAA leaders and technical experts in Washington and around the country, and the FAA Technical Center in Atlantic City to ensure our research meets their long term needs, and the results of our research can be transitioned and inform their investment decisions. Our successful model for collaboration is embodied in Research Transition Teams (RTTs), which are designed to enhance progress for NextGen advancements in critical areas and effectively transition advanced capabilities to the FAA for certification and implementation. RTTs serve as the bridge between NASA's long term, technology R&D, and FAA's near term R&D to support implementation and certification. Under RTTs, NASA and FAA develop joint research plans and fund their respective portions of the planned research according to the nature of the research, stage of research, and their relative capabilities. Data from our research results are used to develop standards and regulations through rulemaking committees and domestic and international standards bodies.

To achieve our vision for 2050, NASA is investing in discovery of new concepts and technologies in a few key areas.

Routine supersonic passenger travel will enable passengers to make current long journeys into day trips. However, current rules prohibit supersonic flight over land, the result of public objection to noisy supersonic Concorde flights in the 1970s. Over the past decade, NASA fundamental research and experimentation has demonstrated the possibility of supersonic flight with greatly reduced sonic boom noise, but the rules prohibiting over-land supersonic flights remain. In order for this sector to take off, regulators need to know how quiet the public will want these supersonic flights to be. NASA now is building a quiet supersonic experimental aircraft – X-59 QueSST – to help answer this question.

NASA researchers will measure public acceptance of the technology by flying the X-59 over a handful of U.S. cities. This data will be delivered to the Federal Aviation Administration and the International Civil Aviation Organization to allow these organizations to develop new regulations that permit commercial supersonic flight over land under conditions acceptable to the general public. This capability will position the U.S. aviation industry to supply global customers with future supersonic aircraft products.

As we push for ever faster flight we may even see initial applications of hypersonic flight. The challenges are enormous for commercially feasible hypersonics, but with NASA's productive partnership with the Department of Defense, we continue to make progress on key technical challenges that may one day unlock a high-value commercial market.

Subsonic aircraft will still carry the majority of passengers in 2050, but those aircraft will be different from today. Large leaps in aircraft efficiency coupled with reductions in noise and harmful emissions are critical to the environmental sustainability of aviation. Future aircraft will look different, will be made from different materials, will be powered differently, and will even be designed and manufactured differently.

NASA is collaborating with U.S. industry to investigate innovative technology for subsonic aircraft such as advanced configurations and wing design, transformative structures, propulsion-airframe integration, and small core turbine engines.

NASA also is leading research into new components, technologies and powertrain architectures for electric or hybrid electric systems that can bring about revolutionary improvements in small and large transport aircraft. NASA work on the X-57 Maxwell aircraft – an all-electric, general aviation size plane – already is delivering to the community important lessons about designing, building and operating an all-electric system.

Ground tests this year and flight tests next year will provide valuable insights into the challenges and opportunities of electric aircraft and serve as the building blocks for industry to create future safe and certifiable aircraft designs.

NASA recently completed single-aisle transport aircraft concept studies with industry to develop hybrid gas-electric propulsion concepts and assess the potential benefits for larger vehicles such as regional transports and airplanes as large as a Boeing 737.

Building on these activities, NASA has begun a multi-year effort to solve the technical challenges of a 1-Megawatt (MW) power electric propulsion system – enough energy to power 165 homes. NASA will refine concepts and technologies and validate new electric systems through ground and flight tests. High power electric propulsion systems represent a potential major change for aviation propulsion similar to moving from turbojets to modern turbofan engines. Realizing a practical 1-MW electric propulsion system has never been accomplished and is an area of notable international competition. To support this work, NASA has developed a world-leading NASA Electric Aircraft Test Facility (NEAT) capable of conducting full scale ground test of high-power electric propulsion systems.

Aerospace design and manufacturing processes in 2050 will be more efficient, reducing the time and cost required to build aircraft. Future computational design and certification capabilities of advanced materials required for emerging aeronautical vehicle applications are identified in NASA's "Vision 2040: A Roadmap for Integrated, Multiscale Modeling and Simulation" report. Next year, NASA will complete the Advanced Composites Project, a six-year focused effort with industry to significantly reduce the time needed to develop and certify new composite structures for aerospace applications.

Autonomy and increased automation bring new opportunities to do the things we already do even better, but also hold the potential to open new markets and create new benefits that are not yet possible.

In 2050, UAS will be fully integrated into the airspace. These could be large, high altitude UAS providing communications relays or gathering scientific data; mid-sized drones delivering cargo through mid-altitude airspace; or small surveillance drones operating at low altitude. An increasing number of UAS will operate safely and securely over cities, suburban areas and in congested skies.

NASA is developing the building blocks for safe UAS integration:

- the ability to detect and avoid other aircraft, currently the ultimate responsibility of the pilot on board an aircraft;
- assured secure command and control communications between the UAS and the operator on the ground;
- human systems integration capabilities; and,
- approaches to determining airworthiness requirements.

NASA is developing this technology for the most basic business case - one remote pilot, one UAS, one mission. In this model, FAA manages the UAS operations like that of any other aircraft, or requires to UAS to operate entirely separate from other aviation traffic, such as low altitude operations over a farmer's field or surveying a historical building or inspecting a power plant.

NASA will conduct a series of test flights next year and will deliver data on these UAS technologies to FAA rulemaking committees to serve as the basis for certifying UAS for safe flight.

The potential benefits of UAS grow greatly if multiple aircraft can safely perform the same mission simultaneously or if UAS can be used for a broad diversity of missions. This means enabling one pilot to control multiple UAS, or removing the pilot entirely from fully autonomous vehicles. In this model, it is impossible for the FAA to manage the UAS operations like all other aircraft – there are too many vehicles to control, and there may not even be pilots to talk to.

NASA has developed a concept called UAS Traffic Management or UTM to overcome this challenge. UTM enables widespread low altitude UAS operations by providing air traffic management services to UAS operators, as an intermediary between the FAA and UAS operators. NASA has collaborated with industry and the FAA to develop and test the UTM system through increasingly complicated flight trials at FAA test sites across the U.S. The final demonstrations – flying UAS in dense urban environments – will take place in Reno, Nevada, and Corpus Christi, Texas, this summer. Companies participating in these demonstrations are maturing and proving their technical capabilities. Industry-led domestic and international standards development organizations and trade groups have established working groups focused on UTM Services and supporting UAS technologies utilizing NASA research, prototypes, and specifications to form the basis for UTM standards.

Data from these demonstrations inform FAA rulemaking, technology development and investments. NASA's UTM Flight Information Management System (FIMS) is being used for FAA's UTM Pilot Program, and NASA partner-developed UTM services are being used at most of the awarded test sites for the DOT UAS Integration Pilot Program. The FAA has adopted the UTM architecture and deployed the first operational UTM service, low altitude authorization and notification capability (LAANC), which reduces UAS airspace access approval from weeks to near real-time. NASA has provided the FAA requested information and research results to inform upcoming rulemaking activities (e.g. Remote UAS Identification, Operation over people, etc.)

As a result of these technical innovations and a clear path to implementation, we have jump started a fledgling U.S. industry of UTM service providers and drone manufacturers and operators.

These efforts provide the foundation for another major transformation of the aviation sector being led by NASA – creation of an urban air mobility or UAM system that is safe, economical and environmentally friendly to move people and packages in population centers, forever changing how citizens around the world benefit from aviation. UAM vehicles might range from small delivery drones to passenger-carrying air vehicles that have electrically-powered Vertical Take Off and Landing (eVTOL) capability.

NASA is preparing a series of "Grand Challenges" that will provide a means to assess the maturity of key systems for Urban Air Mobility. Through these Grand Challenges, NASA will serve as a catalyst for companies to rapidly develop and demonstrate their capabilities, while setting the course for the research and investment needed to realize the potential of UAM. One key objective of the Grand Challenges is to provide the means and opportunity to develop and test UAM innovations in the U.S. so that U.S. companies don't have to go overseas to test their vehicles and systems. Another is to provide opportunities for close collaboration among NASA, FAA, industry and local authorities to understand and overcome together the challenges facing UAM, enabling innovation to take place within our borders.

Although initial UAM operations are likely to use piloted vehicles, autonomy and increased automation will be a game changer for UAM, making it truly accessible to all citizens. The demand for ride-sharing or ride-hailing aviation operations is likely to be constrained by a lack of certified pilots available to operate the vehicles.

The aviation community will need new technologies and operational concepts to manage this higher operational tempo air travel. The UTM system provides a look at what the future might bring for the entire airspace in 2050. UTM has a user service-oriented architecture where third party service providers deliver the various services that make up the airspace environment. A similar federated, user service-oriented architecture for the National Airspace, where third party service providers play critical roles in a collaborative air traffic management structure, provides the scalability to accommodate the large number of expected operations in the airspace in 2050. This new system will need to provide seamless access to the airspace for all users and missions ranging from traditional operations to on-demand UAM, UAS and to emergent scheduled services such as supersonic travel and space launch. It will be scalable for increased demand across users and missions, flexible whenever possible, and will provide structure only when necessary. The system of the future will also be collaborative through integrated information exchange, and resilient to uncertainty, degradation, and disruptions.

The path toward this future airspace vision is being forged today as NASA develops software tools used by air traffic controllers and airlines to fly more efficiently in increasingly congested airspace. Through a series of Airspace Technology Demonstrations with the FAA, airlines and airport operators, NASA is demonstrating new capabilities for managing efficient airline operations. These capabilities are fundamental building blocks of the Next Generation Air Transportation System, or NextGen.

The first set of demonstrations focused on enabling efficient arrivals utilizing the FAA's precision navigation RNAV/RNP approaches into the most congested airports at peak traffic volume times. This essentially has eliminated the practice of airlines circling while waiting for a landing spot at a busy airport, saving fuel, time and reducing noise. The second set of demonstrations is delivering technologies to the FAA and airlines for efficient terminal area operations. This represents a significant step toward user preferred service options – where the airline gets to choose what they would like to do within the constraints set by the FAA. This is being demonstrated in Charlotte, NC, and soon Dallas, TX, in preparation for national deployment in FY2021. The third set of demonstrations is focused on providing services to airlines to allow them to fly around weather, and supporting efficient traffic flows from gate departure to gate arrival. In each of these cases, NASA is handing off these software tools and concepts to the FAA to inform their investment and rule-making decisions.

How do we get all of this innovation into the system? Commercial aviation is the safest mode of travel today, a result of decades of continuous improvement through proactive hazard management.
As I have described, aviation is on the verge of a significant transformation with the rapid evolution of new technologies, vehicles, and operations on the horizon. Maintaining a safe system will require recognition and timely mitigation of safety issues as they emerge, before they become hazards or lead to accidents. We must adopt a proactive risk mitigation approach, using aviation data, commercial data analytics methods, architectures, and the "internet of things" to monitor ongoing operations, assess operations in real-time for emerging risks, and provide in-time strategies to mitigate those risks.

We must also mature our ability to Verify and Validate (V&V) that these new systems are safe, of particular concern in light of significant technical challenges associated with certifying increasingly complex and autonomous systems. The methods to assure the safety of autonomous systems are in their infancy, and thus approaches will need to be investigated and evaluated for effectiveness. Given our past success in applying new safety assurance methods to autonomous systems for space missions, NASA is uniquely positioned to address this challenge. We have already performed initial demonstration of some valuable tools and capabilities in this area with industry partners, and are collaborating with other governmental agencies, like FAA and the Air Force, to map a course to our future vision.

The nature of the aerospace industry and workforce will also be different in 2050. The increasingly entrepreneurial nature of the aerospace industry enabled by increases in computing power, design tools and high-fidelity Multi-disciplinary Analysis & Optimization (MDAO) analytic tools will enables smaller teams to rapidly produce high-confidence, complex system designs. Advances in manufacturing such as additive manufacturing and robotic assembly will enable smaller and more agile manufacturing teams.

We need a next generation workforce with the mindset, system ideas, and capabilities to work in this future. NASA has a long history of collaboration with academia to explore new ideas and foster the next generation aerospace workforce. We have expanded and deepened this engagement through our University Leadership Initiative, where we provide opportunities for universities to identify the most important challenges facing aviation and collaborate across institutions and disciplines to develop solutions.

NASA will enable this future as a partner to government and industry, providing test infrastructure to evaluate and demonstrate new concepts in ground and flight tests, such as ranges at NASA's Armstrong Flight Research Center to test everything from unmanned systems and x-planes to high speed vehicles.

NASA is developing the technology that enables continuous innovation in aviation and leads us to reach this vision for 2050. U.S. companies are well positioned to build on discoveries and knowledge resulting from NASA research, turning them into commercial products that will enable this exciting vision of the future, benefiting the quality of life for our citizens, providing new high-quality engineering and manufacturing job opportunities, and enabling the U.S. to remain competitive in the global economy.