

Statement of

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before the

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

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify on NASA's Aeronautics Research program and the R&D challenges in aeronautics.

Importance of Aviation

NASA continues to lay the foundation for the future of flight by exploring new ways to manage air traffic, build more fuel-efficient and environmentally friendly airplanes, and ensure aviation's outstanding safety record. Through the research we conduct and sponsor with universities and industry, we help to develop the technology that enables continuous innovation in aviation. Investments in aeronautics technology stimulate the economy, and contribute to the Nation's global competitiveness through the creation of new products and services.

To accomplish this comprehensive research agenda, NASA's budget provides \$551.5 million to the Aeronautics Research Mission Directorate (ARMD) in FY 2013. This budget continues support for conducting cutting-edge research at the fundamental and integrated systems levels to advance U.S. leadership in aeronautics R&D and to address national aviation challenges. We will continue research into improving aviation safety and minimizing the environmental impact of aviation, and we will also develop innovative air traffic management technologies and revolutionary vehicle technologies for the Next Generation Air Transportation System (NextGen). We will continue research into the integration of Unmanned Aerial Systems (UAS) into the National Airspace System (NAS) and the validation and verification of complex aviation systems. Funding is also provided to maintain and improve NASA's key aeronautics facilities.

State of the Market

With over 10 million commercial flights per year within the U.S. alone, aviation is an integral part of our daily lives, a critical part of the foundation of our economy, and a source of strength in the global market. On a typical day in the United States, there may be as many as 6000 commercial flights at one time in our skies during peak traffic hours.

A NASA simulation to visualize these traffic flows, using real data on airline flights, yields a real appreciation for the global complexity and interconnectedness of our global aviation market. During peak travel times the air traffic and airport systems in the United States are stretched to capacity. Problems introduced to congested airspace result in flight delays and cancellations, costing the country an estimated \$31 billion each year. Projected traffic growth will make this problem worse.

As busy as U.S. skies are, the future direction of the global air transportation system is increasingly being driven by growth and development outside the traditional North American and European markets. For example, the forecast for growth in the Asia Pacific region over the next five years is the addition of 350 million new passengers. China alone is planning to add at least 45 new airports in the next five years.

U.S. manufacturers of aircraft, helicopters, engines, and the hundreds of other technology and system suppliers play key roles in the large and growing market of civil aviation. U.S. companies currently enjoy strong positions in the global commercial aerospace market, introducing highly competitive products in recent years to satisfy this global demand. Technological superiority has been a key enabler for the U.S. aerospace manufacturing industry to be the world leader in the aviation sector, bringing a positive trade balance of over \$40 billion per year. In this time of continuing economic challenges, the aviation industry provides high-tech, highly rewarding, and high-paying jobs that Americans are proud to have, accounting for nearly 1 million jobs across the entire sector.

Just as operations become more global, aeronautics research and manufacturing capabilities are becoming more global—and more competitive. China is developing its own large commercial aircraft research and manufacturing capability, which is chiefly built to initially satisfy its national economic and transportation needs. Traditional regional jet manufacturers in Brazil and Canada – as well as new entrants to the market such as Japan and re-emerging Russia – are seeking to expand their market share, moving “up market” into large civil transports as opportunities allow.

The pressure for technological improvement is mounting. Despite impressive improvements to the overall fuel efficiency of the U.S. airline fleets, fuel has about doubled as a portion of their total costs to be the single largest direct operating cost today for airlines, as other operations costs have been reduced. Globally, airlines are demanding more highly efficient aircraft to counter rapidly rising energy costs and uncertainty over new environmental regulations. Airlines also are seeking more efficient air traffic management operations to meet growing demand, make better use of their existing fleets, and reduce operating costs.

National Level Challenges

Market factors such as those discussed above point to several key national level challenges facing the aviation industry:

A primary challenge is to ensure that our system continues to meet our demanding expectations of safety, even as new technologies find their way into the system and as air transportation grows around the world. This means changing the way we think about safety so our design methods and certification processes

match up with the new technologies entering the system—at the same time as we tackle continuing and emerging safety concerns.

Another important challenge is to improve mobility, both in terms of increasing capacity and saving fuel. This means using less fuel tomorrow to carry passengers and packages than we use to carry them the same distances today, by flying more efficient routes and using more fuel efficient aircraft. It also means increasing the number of flights which can be handled in existing airspace.

A related challenge is to limit the environmental footprint of aviation, which is a top tier concern related to maintaining U.S. industry economic health and avoidance of constraints on operations. Reduced fuel consumption directly reduces greenhouse gas emissions and pollution, but that is not enough. In addition to reducing the amount of fuel used, we must simultaneously reduce the emissions from the fuel that is used and minimize aircraft noise near increasingly busy airports. Translated into numbers, the challenge is to develop technology by 2020 to cut fuel consumption in half, reduce the area of objectionable noise around airports to one sixth of what it is today, and reduce Nitrous Oxide emissions to half that of the newest aircraft flying today

The critical challenge—and opportunity—facing manufacturers and airlines is to remain competitive in this growing and increasingly complex market through infusion of new technology. Aviation and aeronautics can enable whole new markets that can spur new avenues of economic growth and job creation. This is not limited to advances in traditional markets—new aircraft and technologies such as UAS, may bring radical changes to the way we think about and use aviation.

NASA's Approach

Business as usual is not going to guarantee the United States' pre-eminence in the global market, nor will it enable us to meet these challenges. We must stay with our proven formula of staying ahead with our technological superiority. NASA Aeronautics has a unique and important role in that formula.

NASA, the FAA and the five other federal agency members of the Joint Planning and Development Office (JPDO), together are defining the vision for the Next Generation Air Transportation System (NextGen) and establishing the roadmap to get there over the long-term. NextGen is being designed to deliver optimal aircraft flight trajectories with better coordinated and managed system-wide operations that will increase capacity and enable aircraft to minimize fuel burn and noise impacts, making it the most efficient aviation system possible.

NASA also has worked over the last five years with other federal agencies, and in consultation with our industry and academia stakeholders, to establish the National Aeronautics Research and Development Plan. We have identified critical gaps in technology which must be bridged if we are to make NextGen a reality, and we established far reaching goals for revolutionary advances in flight. We have also clarified the respective roles of the various federal agencies in achieving them, and established principles which govern how we interact with each other and the private sector.

To make NextGen a reality, NASA Aeronautics is having a tangible and compelling impact today, both through development of advanced air traffic management concepts and operations as well as through advancement of new aircraft technologies.

NASA Aeronautics seeks to:

- Accelerate research and development to enable the capabilities of the Next Generation Air Transportation System, or NextGen;
- innovate to close critical gaps in both Air Traffic Management (ATM) and vehicles to achieve the full potential of NextGen; and
- lead the country with a vision and revolutionary capabilities for the Nation's future aviation system.

NASA's role is to search for the most critical solutions to priority challenges – the “tall poles in the tent” – through world class, cutting edge research. NASA purposely pursues very challenging and high payoff aeronautics research goals to bring about revolutionary advancement, not incremental improvement, in technologies and concepts. With inherently high risk research, the potential for not meeting any specific research metric is always present. Nonetheless, NASA is committed to performing such research, and seeks to ensure that our research—no matter the outcome—provides valuable knowledge.

Over the past three years, our Aeronautics programs have changed structure or content in order to more effectively address the nation's research needs, and new programs and projects have been formed to address high-profile emerging challenges. We have developed a balanced portfolio, focusing on priority technical challenges in our fundamental research program to provide those new ideas and technologies which can be matured and graduated into our systems level research activities.

At the base is strategically-driven foundational research to advance concepts and technology development for key aviation challenges and opportunities. The long-term nature of these investments enables NASA Aeronautics to systematically develop knowledge, methods and the basic feasibility of technologies. We focus investments on specific Technical Challenges which have the greatest potential to solve the most pressing aviation challenges.

The most promising technologies can be further matured and integrated in integrated systems research. In integrated systems research, NASA brings together individual components to ensure that they perform as well integrated as they did when developed individually. Given the “large scale” nature of the experimentation required in this type of research, we must be very selective and ensure close partnership with the aeronautics community in the research process. This ensures that we leverage partner investments, and maximize the potential for technology transition into the air transportation system.

To collect and support new ideas, we established the NASA Aeronautics Research Institute (NARI), a virtual institute hosted at NASA's Ames Research Center, to fund small competitively selected projects that represent new, promising ideas that need basic development and analysis of their feasibility. NARI funds ideas of NASA researchers, and in FY 2012 NARI is also funding externally solicited ideas. The funds managed by NARI come from our Aeronautics Strategy and Management Program and are similar to corporate Independent Research and Development (IR&D) funds which gave rise to critical technologies such as transistors and liquid crystals. For example, one concept currently being funded is the development of an array of electrical actuators each the size of a human hair that could be applied to an aircraft surface to shed ice as it attempts to adhere to the aircraft.

We conduct this research at four NASA Centers: Ames Research Center and Dryden Flight Research Center in California, Glenn Research Center in Ohio, and the Langley Research Center in Virginia.

In addition to direct spending on research and development, NASA Aeronautics also seeks to be a good steward of NASA's aeronautics research test infrastructure through prudent management of the Aeronautics Test Program portfolio. We ensure that the necessary facilities are available for NASA and

other customers to meet priority research objectives, and invest in new capabilities where necessary to ensure our infrastructure remains as relevant as our research programs. NASA leveraged American Recovery and Reinvestment Act funds to meet the objectives of the Act – support jobs and revitalize critical elements of the nation’s technology economy - by funding shovel-ready infrastructure projects such as investing \$50 million in facilities to create new capabilities tailored to evolving new challenges.

NASA Aeronautics takes a “get the basics right” philosophy to ensure excellence in broad-based research with robust mechanisms for aeronautics community participation. Disciplined research management provides assurance that the portfolio is relevant to National needs, is technically sound, and follows good project management principles. We have begun utilizing strategic systems and portfolio analysis to better ensure we are prioritizing our Technical Challenges to make the highest impact with our limited resources.

Since 2008, NASA Aeronautics has established more direct and active partnerships with external partners and other federal agencies to ensure that we are investing in the right areas, bringing in the best ideas from the aeronautics community, enhancing the transfer of our research results to the broadest possible community, and maintaining accountability for results.

Consultations with leaders in the aeronautics community during the establishment of new programs have ensured that we are focused on priority problems, that our research activities are structured as effectively as possible, and that the community has clear visibility into our planning processes to support research collaboration in the future. During the execution stage, our research goes through an extensive peer review process, and external experts are central to our annual program reviews. We receive regular advice and assessment of our technical and management capabilities from other experts in industry, academia and other federal agencies, such as through the Aeronautics Committee of the NASA Advisory Council (NAC), our chartered Federal Advisory Committee.

We have formalized and expanded our engagement with a broad range of community representatives through sponsorship of the Aeronautics Research Round Table (ARTR) organized by the National Research Council. This roundtable, populated by leaders throughout industry and academia, will be a regular part of our process of understanding the context that drives aviation and ensuring a common understanding of the leadership that is required for the U.S. to stay at the forefront of aviation.

Partnership in research is critical to our success. Through open competition, we solicit and fund proposals for foundational research by academia, industry, and non-profit organizations via NASA Research Announcements (NRAs) to seek the best new ideas in support of ARMD strategic goals and research objectives. NRAs provide NASA researchers access to fresh ideas, leverage our funds by fostering collaboration between government, industry and academia, and provide universities the opportunity to involve the next generation of engineers in working on today’s aeronautics technical challenges. NRA results often serve to identify the “trade space” related to a particular research topic, to identify solutions to particularly difficult problems, or to assist with technology transition. Since 2006 we have awarded over \$400M in research contracts and cooperative agreements to over 70 different academic and industrial organizations.

Through Space Act Agreements, we partner with large and small manufacturers to conduct fundamental research, test novel new concepts and technologies, and leverage their own investments to transition advancements from the laboratory into the field. Through Small Business Innovative Research (SBIR) contracts, we fund innovation by small businesses in foundational aeronautics disciplines in line with our portfolio.

We transfer results of fundamental and systems-level research to the aerospace community through dissemination of research results, concepts, and design methods. In some instances, companies may build on specific technologies and capabilities developed through NASA research, investing their own research and development dollars to take those last steps to become a commercialized product. In other instances, NASA provides design methods and understanding used by companies in developing new products. By maturing new technologies and validating design methods, NASA research can buy down the risk of incorporating new technologies and systems in aircraft, shortening the path through safety certification in the FAA and speeding the transition of new technologies into the fleet.

We also directly transfer new operational concepts and technologies for adoption by the Federal Aviation Administration and other federal agencies to help them meet their missions. By matching NASA mid- and long-term research with current problems and making a timely transfer of the needed technology, we are helping the FAA to realize benefits in near term applications.

In addition, NASA and the Department of Defense (DoD) coordinate investments in research portfolios and the nation's aeronautics research test infrastructure through the U.S. Air Force/NASA Executive Research Committee and the National Partnership for Aeronautical Testing (NPAT).

Implementing NextGen

NASA is investing in cutting edge research to further the implementation of NextGen in several ways.

Air traffic controllers currently rely on simple decision support tools to safely separate and maintain an orderly flow of aircraft within the National Airspace System (NAS). As the volume of air traffic grows, greatly enhanced tools will be needed to maintain and increase system performance. To help controllers keep up with the anticipated heavy workload, NASA is developing advanced automation tools that will provide controllers with more accurate predictions about the Nation's air traffic flow, weather, and routing. NASA's Air Traffic Management (ATM) research and development ensure that these tools work well together, and demonstrate the potential of widespread use of new procedures throughout the system.

For example, NASA has developed the Ground Delay Program (GDP) that combines National Weather Service real-time data with Air Traffic Control departure scheduling. FAA, along with NASA's support, conducted trials of this new capability at San Francisco International Airport (SFO) last summer and demonstrated a significant reduction in ground delays due to morning fog compared with the current ground delay policy at SFO, which often leads to excessive and unrecoverable delays affecting the entire country.

Looking to the near future, we are partnering with the FAA, manufacturers, airlines and airports to conduct a near-term demonstration of fuel-saving air traffic management concepts enabled by the satellite navigation capability of NextGen through the ATM Technology Demonstrator-1 or ATD-1 activity. A complex, integrated set of ground-based and flight deck technologies will be demonstrated in a series of simulations and flight trials by 2015, showing the airlines the return on investment they can achieve by equipping their aircraft with NextGen avionics such as Automatic Dependent Surveillance – Broadcast (ADS-B) equipment.

Where we have a longer-term focus, NASA and the FAA have established Research Transition Teams (RTTs) to improve 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, game-changing technology R&D and the FAA's R&D to support near term 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 and their relative capabilities. To a limited extent, the FAA provides funding to NASA to perform specific studies or simulations through reimbursable agreements. A recent GAO report (D11604) identified RTTs as a federal best practice for interagency collaboration.

This model for cross-agency collaboration and cost sharing has been very effective, resulting in several recent demonstrations of advanced technology benefits. One such RTT example is NASA's Efficient Descent Advisor (EDA) technology which will save fuel by enabling more efficient arrivals into congested airports. EDA was developed and field tested through a three-year collaborative effort between NASA, FAA, Boeing, MITRE, Sensis/SAAB, and United Airlines and Continental Airlines under a NASA-FAA RTT, and then transferred to the FAA on November 30, 2011, for certification and integration into mid-term (2014-2018) NextGen operations. NASA estimates \$300 million in fuel savings per year during descents if EDA is implemented fleet-wide at the nation's busiest airports.

NASA transferred the research results from another RTT to the FAA in July 2011 regarding tools and methods for in-flight Flow-Based Trajectory Management (FBTM) in the NextGen. The concept of FBTM demonstrated an effective method for successful management of future aircraft traffic densities at levels 30 percent greater volume of flights than today without additional controller resources.

Joint work continues under two other RTTs, and NASA and the FAA are now building on the RTT model to enhance planning and cooperation in other research areas.

NASA R&D is helping to further NextGen through transfer of technology to industry as well. For example, the analysis of flight recorder data to ensure safety and improve operational efficiency is another enormous challenge in NextGen implementation. New data mining software from NASA automates the process of sifting through vast arrays of data to identify trends, leading to improved operational practices for the airlines, saving time and fuel. NASA has open-sourced key data mining software for analyzing flight data recorder output through a collaborative website known as DASHlink, where over 300 researchers can share their latest developments. In one example of early success, Southwest Airlines (SWA) acquired two advanced anomaly detection techniques through DASHlink and put them through a trial application which uncovered flight events that were not detected by SWA's existing operational analysis methods. Events flagged by these software tools are being added to SWA's daily operations review to improve operational performance. With over 1 million flights per year, a fuel savings in the tens of gallons per flight can be significant to Southwest's bottom line.

Innovation to Close Critical Gaps for Air Traffic Management (ATM) and Air Vehicles

Today, NASA is investing to support continued innovation, so that new technologies are in the pipeline to close critical gaps in both ATM and air vehicles to achieve the full potential of NextGen.

The United States enjoys a leadership role in the global aviation community because of our demonstrated ability to bring into the market new technology and new ideas. NASA-developed technologies are in the DNA of many of the civil and military aircraft the U.S. industry has developed and marketed to date. NASA technologies can be seen in new products entering the market today as well, such as the new 787 intercontinental passenger airplane, and advanced versions of the 737 using next generation aircraft engines. These new vehicles hold the promise of reducing fuel consumption up to 20 percent, longer operational life, and lower maintenance costs—all due to infusion of advanced technology.

The technological advances that enabled introduction of these new products were not achieved overnight. NASA research over the last 20 years factored into the design of the following products:

- Low-emissions combustor technologies developed within the Advanced Subsonic Transport program provided the foundation for today's low-emissions combustors.
- NASA's composite research in the 1980s and 1990s, focused on reducing weight, reducing manufacturing costs, and increasing the durability of composite materials and structures, which provided a foundation of knowledge that enabled commercialization and widespread use of this technology.
- New lightweight high-temperature alloys developed under our Enabling Propulsion Materials program have found their way into the turbine sections of engines, reducing the weight and parts count and increasing the durability of the engine component that has the shortest life and requires the most maintenance.
- Research on engine noise developed the understanding that guided the design of chevrons, which are the serrated trailing edges of the engine cowlings that initially were put into service on some regional jets in 2002, and now are highly visible on the Boeing's new 787 and 747-8 aircraft. These chevrons reduce the noise levels within and outside the aircraft by one third.
- NASA propulsion aerodynamics research enabled the fan design for Pratt & Whitney's new Geared Turbofan engine, which is anticipated to be the quietest and most fuel efficient engine in its class when it enters service in 2 years.
- A NASA-based icing simulation tool, LEWICE-2D, is widely accepted by manufacturers and the FAA as the premiere tool to rely on when certifying aircraft designs and vehicle sub-systems under icing conditions.

Today, we have technologies in the R&D pipeline to help achieve the full potential of NextGen as they are introduced in vehicles over the coming decade.

We are exploring the ability of new aircraft configurations to help us reach our NextGen goals, such as through flight test of the X-48B, a 1/12th scale model of a hybrid wing body (HWB) aircraft. The HWB is a radical new aircraft architecture in which the wings blend into a wide body. This architecture may help us meet our aggressive targets of a 50% reduction in fuel consumption and 42 decibel reduction in noise for future aircraft. Because HWB aircraft do not have the tails seen on conventional aircraft, we had to develop new flight control methods to maintain stable flight and we have done that through a series of 92 flights of the X-48B at the NASA Dryden Flight Research Center.

Building on our long history of icing research, we are tackling another gap – the high-altitude engine icing phenomenon which has surfaced over the last ten years. Occurring primarily in equatorial regions at high cruise altitudes, this icing has resulted in over 100 significant commercial aircraft main engine power loss events in the last 15 years. These conditions cannot be duplicated in any existing ground test facility. Therefore, in 2009 NASA initiated an effort with American Recovery and Reinvestment Act funding to modify the Propulsion Systems Laboratory (PSL) at the Glenn Research Center to enable research on ways to mitigate the effects of high-altitude icing and develop new engine certification procedures. NASA research using this new test capability will enable us to understand and seek to mitigate high altitude engine icing phenomena, and, in turn, inform the development of improved engine icing certification standards by the FAA.

NASA continues to make significant progress to reduce the impact of sonic booms and to make practical overland supersonic flight a reality. If we are successful in fully demonstrating the design of low sonic boom aircraft and determining the impact of low boom signatures at that level on people on the ground, we may be able to open up entirely new markets and applications. A significant portion of the research is focused on tools used in aircraft design and shaping that are needed to achieve a low-boom signature. There has also been significant progress in the testing of new, advanced configurations in wind tunnels.

Through flight tests, we are making very good progress on understanding the human perception of low boom signatures on the ground. By working with domestic and international aviation regulators in our research, we hope to speed the transition of our results into new rules on supersonic flight.

In FY 2011, NASA initiated a new research activity in the verification and validation (V&V) of the functionality of the complex software systems in aircraft and air traffic management systems. It now costs more to prove today's flight-critical systems are safe than it does to design and build them. For example, it is estimated that the software verification associated with the safety certification of the 787 aircraft cost Boeing \$4.5 billion dollars. Current techniques for certifying complex systems are inadequate to provide V&V of highly automated, non-deterministic software systems which are expected to be a major component of NextGen in the long-term. The V&V of complex flight systems was identified as a critical gap to realize the NextGen vision by the JPDO, and NASA started its investment of about \$20M per year in FY 2011 to develop methodologies and concepts to effectively test, validate and certify software-based systems that will perform reliably, securely, and safely as intended.

A five-year, focused NASA project began in FY 2011 to close critical gaps related to enabling the safe operation of Unmanned Aerial Systems (UAS) in the National Airspace System (NAS). UAS could support public and commercial needs ranging from communications to remote sensing to search and rescue among others. According to industry forecasts, UAS operations will increase exponentially in a variety of key military and civil areas once they are fully integrated to the NAS. NASA's research will support development of a JPDO-led Concept of Operations (ConOps) for UAS in NextGen; facilitate certification of new technologies and operations; leverage new NASA research in verification and validation (V&V); and leverage existing systems engineering experience and technical capabilities to address new challenges.

Also in 2011, NASA, DoD, FAA, and other federal agencies developed a joint research, technology, and demonstration roadmap for enabling UAS access to the NAS, and strengthened coordination on UAS operational issues through the UAS Executive Committee (EXCOM) that is composed of senior executives from DoD, FAA, DHS, and NASA.

NASA is working with FAA to facilitate maturing aircraft and engine technologies from the early stages of research and development to ready for implementation in a product in the near term via coordinated efforts among the FAA Continuous Lower Energy Emissions and Noise (CLEEN) Program and NASA efforts.

NASA is investing in a range of other tools and technologies, such as composite materials and structures, which are the critical capabilities we must retain in the U.S. to enable continued leadership of our industry in the global aerospace sector.

Lead the Country with a Vision and Revolutionary Capabilities

Looking to the more distant future, through in-house research and partnerships we are developing today the fundamental understanding and new concepts that will be required to meet these and new emerging challenges 10, 20, and 30 years from now. For example, NASA's long-term research goals include enabling technologies that permit a 50% fuel reduction by 2025. This is an extremely difficult goal to achieve. As the 787 and other aircraft with similar technologies join the fleet between now and 2025, fuel consumption per flight may be reduced by an average of 8.5% – over 2 billion gallons of fuel saved per year!

NASA is pursuing aggressive research goals to simultaneously and dramatically reduce noise, fuel consumption and greenhouse gas emissions from civil aircraft. For example, we have funded studies with academia and industry that define new technologies to improve aircraft and engine fuel efficiency and reduce noise for aircraft envisioned to enter the marketplace 15 and 25 years from now. NASA funded three industry/academia teams to explore new vehicle concepts that could achieve those goals and enter into commercial service in 2025 (two generations after the current state-of-the-art aircraft). The teams created technology development roadmaps and identified critical technology demonstrations necessary to make those aircraft a reality. The results of these studies, released in January 2012, validate the aggressive vision for the future of civil aviation established by NASA, and are helping NASA and industry to prioritize research investments to make that vision a reality.

Similarly, NASA funded four subsonic aircraft teams and two supersonic aircraft teams to conduct concept studies of advanced aircraft concepts that can address even more aggressive performance and environmental goals for aircraft that may enter service in the 2035 timeframe. These studies pushed the thinking of the aircraft industry and academia to deeply and thoughtfully consider the advanced technology options and potential of advanced, highly-efficient aircraft with dramatically reduced noise and emissions. Results included uniquely-enabling aircraft concepts (strut/truss braced wing, double bubble aircraft, hybrid electric propulsion), advanced propulsion systems (small high efficiency core engines, variable flowpath systems), and highly integrated vehicle configurations to practically eliminate sonic boom.

Aeronautics Mission Directorate Program Structure

To accomplish this comprehensive research agenda, NASA's FY 2013 budget request provides \$551.5 million for the Aeronautics Research Mission Directorate (ARMD), an \$18 million decrease from the FY 2012 estimated level. The allocation among NASA Aeronautics' six programs is as follows.

- \$169 million is provided for the Fundamental Aeronautics Program (FAP) to develop technologies that can be infused into future subsonic aircraft. FAP also addresses key challenges to enable new rotorcraft and supersonic aircraft, and conducts foundational research to realize sustained hypersonic flight:
- \$104 million is provided for the Integrated Systems Research Program (ISRP) to evaluate and develop emerging engine and airframe concepts to advance environmentally responsible aviation. ISRP also addresses operational and safety issues related to the integration of UAS into the NAS.
- \$93 million is provided for the Airspace Systems Program (ASP) to conduct cutting-edge air traffic management research to enable the NextGen.
- \$81 million is provided for the Aviation Safety Program (AvSP), to develop methods for anticipating safety issues; mitigate the effect of hazardous weather; and develop techniques to verify and validate that the new and complex aviation systems meet the extremely high levels of safety required in the NextGen.
- \$78 million is provided for the Aeronautics Test Program (ATP) to sustain operations and to make strategic investments to ensure the continued availability of ground test facilities and flight assets at the four NASA Research Centers for NASA programs (aeronautics, space and science), other federal agencies, and the private sector to test and evaluate research concepts and technologies.
- \$26 million is provided for the Aeronautics Strategy and Management Program (ASM) to explore new and novel concepts and technologies in aeronautics through the Innovative Concepts for Aviation project. ASM also funds ARMD management expenses, including education and outreach activities.

Within the existing budget profile, this year NASA Aeronautics is reducing its investment in hypersonic air-breathing technologies, and focusing our resources on other civil aviation transportation priorities that will have greater benefit in the nearer term to those who use or benefit from the Nation's aviation system. NASA's Space Technology Program will assume responsibility for the fundamental research associated with Entry, Descent, and Landing (EDL) previously conducted through the ARMD budget.

Remaining hypersonic research in NASA Aeronautics will directly support the DoD. The early steps in hypersonics technology development will be military applications. Flight experience gained by the DoD will be leveraged by NASA and will be critical for advancing this field for civilian access-to-space applications. Specifically, NASA is reducing funding for hypersonics research related to air-breathing systems, including propulsion technologies and structurally integrated thermal protection systems. We are, however, maintaining some critical national capabilities related to scramjet propulsion and core competencies to provide support for both Agency and DoD missions. NASA Aeronautics' hypersonic investment will support the NASA Langley Research Center's 8-ft High Temperature Tunnel because it is a key facility for the DoD's hypersonic programs.

NASA is actively working with the DoD to minimize the impact of these decisions on their missions. NASA is aware of the DoD plans to expand research in hypersonic flight systems and is continuing to discuss options to optimize this collaboration. In the same way that NASA supported the development of the USAF X-51 system, we expect DoD collaboration and coordination to continue.

Programmatic and Management Challenges Facing ARMD

NASA ARMD is not introducing any new program initiatives in FY 2013. However, we are undergoing continuous evaluation to ensure management excellence and continued relevance to the aeronautics community.

A key management challenge is to retain an appropriate mix of investments among analytical research, research through high-fidelity simulations, ground testing, and flight demonstration and validation. Flight research – testing new concepts and technologies in a relevant flight environment – is now, and should continue to be, part of our portfolio because it can contribute significantly to the advancement of aeronautics state of the art through validation of concepts and technologies, and/or evaluate intended benefits in an integrated system level. To gain some additional perspectives, we chartered a committee from the NRC to identify those challenges where research program success can be achieved most effectively through flight research (in addition to, or as opposed to, other analytical or experimental approaches) across the entire ARMD research portfolio. We also asked the committee to consider the role of X-planes and demonstrator vehicles in research, and evaluate a balanced and effective flight research portfolio under different budget scenarios.

Another challenge is to maintain an appropriate investment portfolio in an increasingly global industry. Today's "open data" world and increasingly global aeronautics supply chain are leading us to consider carefully where we may find potential benefits of international collaboration. In certain situations, international cooperation enables NASA to take advantage of cutting-edge research already being done overseas, pool financial resources, and access foreign capabilities and/or expertise. In line with NASA policy, including export control regulations, ARMD engagement in international collaboration is conducted on a no-exchange of funds basis, and in line with existing NASA principles on Intellectual Property protection and access to results. Over the last two years, NASA has sought new partnerships to leverage emerging capabilities in other countries such as foundational research in supersonics with Japan, and rotorcraft research with South Korea.

Just last summer we joined other leading government aeronautics research and development agencies to create the International Forum for Aviation Research (IFAR). Through IFAR, NASA and our counterpart government-sponsored agencies will discuss and share ideas about priority aeronautics research challenges and potential solutions, and discuss opportunities for bilateral collaboration on precompetitive technical subjects.

Conclusion

In sum, NASA does not build aircraft, engines, or air traffic management systems. Through the research we conduct and research we sponsor with universities and industry, we help to develop the technology that enables continuous innovation in aviation. U.S. companies are well positioned to build on discoveries and knowledge resulting from NASA research, turning them into commercial products, benefiting the quality of life for our citizens, providing new high-quality engineering and manufacturing job opportunities, and enabling the United States to remain competitive in the global economy.

NASA Aeronautics has experienced tremendous success through the past years by committing to the core principles of:

- valuing innovation and technical excellence;
- aligning our research to ensure a strong relevance to national needs;
- transferring technology in a timely and robust manner;
- maintaining strong partnerships with other government agencies, industry and academia; and
- inspiring the next generation of engineers and researchers.

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