HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
May 1, 2008

Statement of
Jaiwon Shin
Associate Administrator for Aeronautics Research Mission Directorate
National Aeronautics and Space Administration
Before the
Subcommittee on Space and Aeronautics
Committee on Science
U.S. House of Representatives

Chairman Udall and Members of the Subcommittee, thank you for this opportunity to appear before you today to provide an update on NASA's aeronautics research program and to address the issues raised by the Subcommittee concerning the R&D challenges in aeronautics; specifically, the Next Generation Air Transportation System (NextGen), promising new flight regimes, aviation safety, and aviation environmental impacts.

NASA has a long and successful history of conducting research and development (R&D) in technologies that have benefited our nation's aviation community. Today, NASA's Aeronautics Research Mission Directorate (ARMD) continues this tradition through its commitment to conducting long-term, cutting-edge research for the benefit of the broad aeronautics community. ARMD has put together a robust research portfolio that addresses the challenges facing our nation as it transforms its air transportation system to meet growing capacity needs. Furthermore, the portfolio ensures aeronautics research and critical core competencies continue to play a vital role in support of NASA's goals for both manned and robotic space exploration.

Growth in the air transportation system is vital to the well being of our nation. In order to realize the revolutionary changes required to meet forecasted capacity increases, a number of significant challenges must be overcome such as protecting the environment, ensuring safety, dramatically improving efficiency and revolutionizing the ways we manage the flow of aircraft. In the next two decades we must find ways to make advances that improve aircraft and system efficiency, reduce aviation's impact on the environment and allow more people to utilize air travel in ways that are more significant than all the gains realized over the last three decades. The research ARMD conducts today to address these issues will play a vital role in transforming the air transportation system of tomorrow.

ARMD Principles

Every successful organization can point to core principles that guide its strategic direction. Since the restructuring of NASA's aeronautics program in 2006, ARMD has been guided by three such core principles: 1) we will dedicate ourselves to the mastery and intellectual stewardship of the core competencies of aeronautics for the Nation in all flight regimes; 2) we will focus our research in areas that are appropriate to NASA's unique capabilities; and, 3) we will directly address the fundamental research needs of the NextGen while working closely with our agency partners in the Joint Planning and Development Office (JPDO). While the leadership of ARMD has changed, these principles remain core to our strategic decision making process and help to guide the direction of all of our programs. These principles ensure that NASA is focused on the most appropriate cutting-edge research to overcome a wide range of aeronautics challenges facing our nation's future air transportation system and space exploration missions. Lastly, these principles have helped ARMD structure a robust aeronautics program that is well aligned with the principles, goals and objectives of the recent National Aeronautics R&D Policy and Plan.

Program Descriptions

Four programs have been established under ARMD using our guiding principles: the Fundamental Aeronautics Program, the Aviation Safety Program, the Airspace Systems Program and the Aeronautics Test Program. While each program uniquely addresses critical challenges, the four programs integrate their research for a holistic approach to high level challenges such as NextGen. The following are brief descriptions of each program and how their research supports the broad aeronautic community.

ARMD's Fundamental Aeronautics Program (FAP) pursues long-term, cutting-edge research in all flight regimes (from subsonic to hypersonic) to produce data, knowledge, and design tools that will be applicable across a broad range of air vehicles. FAP focuses on creating innovative solutions for the technical challenges of the future which include 1) increasing performance (including fuel efficiency, range, speed, payload, take-off and landing distances) while meeting stringent noise and emissions constraints; 2) alleviating environmental and congestion/capacity problems through the use of new aircraft and rotorcraft concepts; 3) improving the speed of air transportation while maintaining strict standards for performance and environmental compatibility; and 4) facilitating access to space and re-entry through planetary atmospheres. FAP research will directly support the NextGen challenges of overcoming the environmental and performance barriers to projected increases in capacity. Research in new aircraft and rotorcraft concepts will also directly support NextGen goals of better utilization of the airspace.

ARMD's Aviation Safety Program (AvSP) builds upon NASA's unique research capabilities to improve aircraft safety, and to overcome safety limits that would otherwise constrain the full realization of the NextGen system. To meet these safety challenges, AvSP focuses on developing cutting-edge technologies to improve the intrinsic safety attributes of current and future aircraft and also on exploring how NextGen operations can improve upon the existing remarkable safety record of our current air transportation system. Examples of new technologies with direct application to NextGen include new sensors and methods to automatically detect and identify flight hazards, hidden anomalies or trends in aircraft systems, advanced materials, and flight control systems resilient in the face of failure and adverse flight conditions such as weather.

ARMD's Airspace Systems Program (ASP) enables the development of revolutionary improvements to the national airspace system that allow sufficient capacity to meet increasing demand for air travel. ASP focuses on research to incorporate intelligent automation into the system with balanced roles for people and computers while preserving the high safety standard. Included in this is the development of automated aircraft trajectories that are safe, efficient and robust under a wide variety of traffic conditions. Solutions for enabling greater capacity at the busiest airports and in dense airspace integrate uncertainties, such as weather, into air traffic management decisions. The end result of ASP research is more efficient operations and reduced flight delays.

ARMD's Aeronautics Test Program (ATP) focuses on the support of both ground based facilities, such as wind tunnels and aero-propulsion test facilities, as well as the aircraft and flight test infrastructure. ATP makes strategic utilization, operations, maintenance, and investment decisions for major wind tunnels/ground test facilities at Ames Research Center in California, Glenn Research Center in Ohio, and Langley Research Center in Virginia, and supports selected mission support and test bed aircraft at Dryden Flight Research Center, also in California. ATP ensures the availability of world-class aeronautics test facilities and test aircraft for the benefit of the aeronautics community.

Addressing NextGen R&D Issues

Aviation in the United States is facing an exciting possibility for being on the verge of another renaissance. Demand for air travel is expected to double or even triple in the next two decades, which will require a revolutionary new air traffic management system. New technologies and design capabilities are making it possible to create entirely new vehicles that look radically different from the familiar "tube-and-wing" aircraft that are now so familiar. These new aircraft will bring remarkable new capabilities that may require entirely new operational procedures in the airspace. Aeronautics research is crucial to overcoming the numerous challenges that impede the growth of air travel. In addition, there is an inherent challenge of improving safety even as we increase capacity. NASA is focused on addressing these critical long term challenges.

It is difficult to identify the "most critical" barrier to NextGen. Thus, one clear focus for NASA is treating the entire system as an inter-related enterprise, mirroring the National Aeronautics R&D Policy, instead of segregating research into separate areas. Alignment with the National Aeronautics R&D Policy helps ensure that NASA is focused on the most important R&D issues.

NASA understands that the NextGen concept involves much more than just revolutionizing the air traffic management system; it also includes the advanced aircraft concepts that will populate the system over the next several decades. In particular, NASA is focusing on three generations of vehicles beyond the current generation, "N", represented by the Boeing 787 for the fixed wing subsonic class of aircraft. Generation "N+1" is presumed to enter into service in 2015, market permitting, and is envisioned to be a tube-and-wing configuration but equipped with more advanced technologies than Generation "N" aircraft. Generation "N+2" will employ revolutionary concepts to achieve simultaneous gains in fuel burn, noise, and emissions, with an Initial Operating Concept around 2020. Generation "N+3" will follow with much improved performance and reduced environmental impact.

We must ensure that the airspace in which these aircraft will operate allows them to make full use of their capabilities. Simultaneously, we must also ensure that safety is not compromised. Our system-wide view of the entire air transportation system is reflected in the recent cross-Program NASA Research Announcement (NRA) topic entitled: "Integration of Advanced Concepts and Vehicles into the Next Generation Air Transportation System."

To foster this thinking, ARMD's three research programs address issues of Air Traffic Management (ATM), avionics, advanced vehicles, safety, and environmental impact. The vast majority of what ARMD does is directly aligned with the NextGen vision that is clearly supported by the National Aeronautics R&D Policy. The following examples illustrate the alignment of ARMD programs with the National Aeronautics R&D Policy and the NextGen vision:

- The Airspace Systems Program directly addresses the Policy's first principle of "mobility through the air" by conducting air traffic management research that will develop concepts, capabilities, and technologies required to meet the Nation's anticipated growth in airspace operations, both in the air and on the ground. The Fundamental Aeronautics Program directly addresses this principle by conducting research that can enable the development of advanced aircraft systems that fly with higher performance, lower fuel consumption, and minimum environmental impact (noise and emissions) at a range of speeds and from a wide variety of airports.
- The core mission of the Aviation Safety Program directly addresses the Policy's third principle that states that aviation safety is paramount.
- The Fundamental Aeronautics Program simultaneously addresses the Policy's sixth principle of "assuring energy availability and efficiency" and seventh principle of "protecting the environment" by conducting research to improve aircraft performance, increase fuel efficiency, evaluate alternative fuels, lower emissions (including particulate matter) and reduce noise. In addition, the Airspace Systems Program also addresses these two principles by conducting research to improve efficiency and reduce environmental impact through better utilization of the airspace.

Additional examples of specific challenges and the NASA strategy to address them are provided in the following sections.

Safety Issues Facing the Nation

The current US air transportation system is among the safest modes of transportation ever. Throughout the implementation of NextGen it is imperative that we maintain or preferably improve on this impressive safety record. However, there is no single safety issue upon which to focus our efforts. Instead, we need to continually analyze for and predict safety issues as NextGen is implemented.

We do know that there are many complex aspects of NextGen that present research challenges accepted by all ARMD research programs. For example, a major challenge will be the proper design, integration, and use of automation in both ground-based and airborne systems. Meeting this challenge will require advances in human-machine integration capabilities, better decision-making through data and knowledge mining systems, and intelligent systems that adapt to failures and hazardous flight conditions. Another challenge is the need for improved software verification and validation techniques to prevent against anomalies that could propagate across highly integrated systems with unintended consequences. In addition, new aircraft create challenges for effective maintenance and continued airworthiness assurance of advanced materials and lightweight structures when exposed to typical operational hazards and aging effects.

Consequently, NASA's Aviation Safety Program conducts fundamental research across its four project areas to address both established and emerging safety barriers to the full realization of NextGen. For example, one aspect of the research portfolio is investigating human-machine integration issues to include the best use of automation. We also know that a myriad of new aircraft materials will be used, so NASA is working to predict the long term aging effects to understand the fundamental characteristics of advanced materials and aircraft structures, with the intent to design and mitigate against aging related hazards. NASA is also looking at mitigating unknown issues that may develop in flight by designing intelligent on-board systems that can respond to and reliably mitigate against failures and flight in adverse conditions such as icing. Finally, NASA is also researching new data mining techniques to predict future failures from trends in current operations. This involves a fundamental shift away from a forensic approach of trying to understand why an accident occurred to a prognostic approach to safety that allows unsafe conditions to be identified before they become tragic. NASA continues to work with the Commercial Aviation Safety Team and other stakeholders to identify current and emerging aviation safety issues.

The Impact of Aviation on the Environment

As NextGen evolves to meet the projected growth in demand for air transportation, NASA’s Fundamental Aeronautics Program is working to answer two major questions: (1) how will we continue to reduce the environmental impact of aviation (in terms of noise, local and global emissions, and local air quality) despite growth? and, (2) what kinds of advanced vehicles will be required to satisfy both forecasted demand and environmental compliance? Furthermore, the Airspace Systems Program is ensuring that today's fleet and new generations of vehicles can operate within the NextGen in a manner minimizing aviation's environmental impact. These efforts represent significant investments in "green" aircraft research initiatives being led by NASA ARMD.

As the number of flight operations at many of the largest airports in the nation continues to increase, environmental concerns over noise and emissions will limit the capacity of those airports, and therefore limit the capacity of the entire system. Concerns over global emissions (mostly over greenhouse gases) may radically change air transportation as we know it: without new and innovative aircraft concepts and air traffic management concepts that can provide unprecedented levels of performance and environmental compliance, the overall capacity of the system will be significantly hampered. By 2025, the demand for air transportation will be satisfied by a variety of classes of aircraft. The Fundamental Aeronautics Program is developing "green" ideas, technologies, and tools to enable the development of highly efficient and environmentally friendly aircraft (including subsonic aircraft; supersonic aircraft; and aircraft with the ability to take-off and land on short runways, yet cruise efficiently at transonic speeds) and rotorcraft to meet the performance and environmental requirements that will be demanded by the public. Below are some specific examples of NASA's ongoing work to mitigate the environmental (and global climate) impact of aviation:

1. NASA has set aggressive goals for fuel burn, noise, and emissions reductions for three generations of vehicles (referred to as "N+1", "N+2", and "N+3") and is pursuing technologies that can achieve each of these goals.
2. Advancement of hybrid wing-body vehicle ("N+2") technologies for low noise, higher performance, and better engine/airframe integration. These efforts have the potential of enabling aircraft that, unlike conventional tube-and-wing aircraft, can simultaneously achieve significantly reduced noise, emissions, and fuel burn.
3. System-level understanding of laminar flow control techniques for application in "N+1" and "N+2" concepts. Laminar flow technology can significantly decrease the fuel burn of both conventional and unconventional aircraft and, therefore accomplish significant CO_2 emissions reductions (up to 50% better than the current state of the art).
4. Aggressive weight reduction technologies using advanced materials and structural concepts for both aircraft and engine structures with significant reduction of CO_2 emissions due to decreases in fuel burn.
5. Studies into the necessary technologies and integration approaches to realize significantly improved gas turbine engines with higher efficiency (resulting in lower CO_2 emissions) and lower NO_X emissions.
6. Efforts to assess the validity and applicability of biofuels / alternative fuels of various different sources to aviation applications.
7. Approaches to improve the viability of both supersonic transports and advanced rotorcraft in the NextGen incorporating environmental constraints.

In addition, NASA has recently issued a solicitation for the "N+3" generation of advanced vehicles (see http://www.aeronautics.nasa.gov/fap) that will have dramatically improved environmental performance to the point that emissions of CO_2 will be reduced by up to 70% and the noise of such aircraft will be barely noticeable outside airport boundaries.

To facilitate the transition of advanced ideas and technologies into the aircraft fleet, NASA is partnering with the Federal Aviation Administration's (FAA) Continuous Low Emissions, Energy and Noise (CLEEN) program to guide efforts to mature technologies that have already shown promise to the point where they can be adopted by the current and future aircraft fleet. This collaboration with the FAA is only one of the many joint activities that both agencies are pursuing to ensure that the environmental impact of aviation is significantly reduced in the presence of net growth.

Finally, NASA actively participates in Aviation Climate Change Research Initiative (ACCRI) to better understand and assess the global climate impact of current and future advanced vehicles. In fact, the "N+3" solicitation is specifically addressing some of the leading issues in global climate.

It is widely recognized that 90-95% of the environmental gains in the current air transportation system have resulted from improvements in aircraft and aircraft technologies. NASA's Fundamental Aeronautics Program is ensuring that, in the future, dramatic improvements can be derived from the next generation of aircraft.

New Flight Regimes

NASA is not fixated on developing new capabilities in just one flight regime, but instead believes that an ideal situation will exist when multiple vehicle types exist, each suited for a particular use, operating in an air transportation system that is flexible enough to accommodate a wide range of vehicles without limiting performance. Examples of some of the most promising concepts for large improvements in aviation include:

- Advanced subsonic/transonic transports with nearly half the fuel burn of current vehicles (and therefore half the greenhouse gas emissions), a noise footprint that can be confined to the boundary of the airport, and local emissions that are far below those encountered today. These gains will require revolutionary changes in the airframe and propulsion plant and the way in which they are integrated into a single system. Alternative sources of energy are likely to play a significant role in the development of these vehicles.
- Advanced supersonic transports with comparable performance to their subsonic/transonic counterparts and with low sonic boom characteristics so that the aircraft may be allowed to fly supersonically over land. In addition, take-off and landing noise will be significantly reduced to meet or exceed Stage 4 requirements.

- Cruise-Efficient Short Take-Off and Landing (CESTOL) aircraft that cruise with very high performance and low environmental impact, yet can take off and land from very short runways.
- Advanced rotorcraft (large civil tiltrotors and variable-speed compound concepts) that allow vertical or short take-off and landing with vastly improved range and performance and reduced environmental impact (mainly from noise).

Knowledge / Technology Transfer

NASA believes "knowledge transfer" is critical and deserves high priority attention and a concerted effort to ensure it happens in a timely manner. Emphasizing "technology transfer" only drives a tendency to focus on devices and widgets, rather than on the knowledge enabling their creation. To ensure broad benefits to the community, the knowledge that underpins any new technology must be transferred to the community such that technology can be broadly applied. This "transfer" occurs at many levels ranging from the exchange of fundamental ideas to the adoption of new systems. We have created a number of mechanisms to enable such an exchange. For example, we have established technical working groups to engage industry and academic partners on a regular basis in order to facilitate knowledge transfer. Space Act Agreements are used to enable NASA to leverage industry's unique systems-level expertise while enabling industry to quickly acquire research results.

A new process has been established to help ensure that NASA's fundamental research can be transitioned for implementation in NextGen systems and concepts. NASA Aeronautics, the FAA, and the JPDO are working collaboratively to establish this process, which ensures research is sufficient and appropriate to enable NextGen. The new process has top-level commitment from the NASA Associate Administrator for Aeronautics and the FAA Vice President for Operations Planning Services, Air Traffic Organization. A coordinating committee that includes both FAA and NASA representatives oversees four initial Research Transition Teams (RTT) that are organized around the NextGen Concept of Operations framework. This framework connects the FAA's Operational Evolution Partnership elements with NASA research. The JPDO has an important role in the transfer in which they inform the Integrated Work Plan as work progresses. The teams are working to plan near-term R&D transition in areas such as surface management and long-term transition in areas such as dynamic airspace allocation. With regards to the initial collaborative RTT activity, more than 35 participants from FAA service units, NASA, MITRE/CAASD, and industry attended a workshop in Washington, DC in February 2008 to focus on integration of NASA and FAA research plans, schedules, roadmaps, and coordinated simulations for near-term NextGen Trajectory Management objectives.

In April 2008, NASA and FAA program, project, and senior researchers attended a RTT kick-off workshop focused on Surface ATM concepts. The primary goal of this RTT is to jointly collaborate on near- and mid-term objectives to reduce the risk of development of an Integrated Airport Surface/Arrival/Departure system concept for NextGen. Furthermore, NASA and FAA personnel are scheduled to conduct two additional RTT workshops early in the summer of 2008. In a fully collaborative effort, one workshop will work to define the far-term NextGen objectives of the dynamic airspace allocation concept, and the second will contribute to the definition of mid-term NextGen roles, responsibilities and objectives for the Multi-Sector Planner concept.

Following completion of the four pilot RTT workshops, NASA, FAA, and JPDO will make improvements to the RTT process based on lessons learned, and continue the collaboration of researchers and implementers to ensure that the research needed for NextGen is identified, conducted, and transitioned.

Building on NASA's Research Heritage

It is important to remember that NASA has a long heritage of conducting revolutionary research. The following are examples of NASA research that are making a difference in aviation today.

- NASA completed the first test of a digital fly-by-wire system in a modified F-8 Crusader aircraft in 1972. It was the forerunner of the fly-by-wire flight control systems now used on the Space Shuttle and on today's military and civilian aircraft to make them safer, more maneuverable and more efficient.

- Winglets are one of the most successful examples of NASA aeronautical innovation being utilized around the world on all types of aircraft. Winglets are vertical extensions of wingtips that improve an aircraft's fuel efficiency and cruising range.

- The FAA is engaged in national deployment of the NASA-developed Traffic Management Advisor (TMA) tool. TMA is now a component of the FAA's Free Flight program to increase the capacity of the nation's airspace. The application enables en route air traffic controllers and traffic management specialists to develop complete arrival-scheduling plans. These plans help maximize an airport's use of available capacity by making early runway assignments for arriving aircraft and spacing aircraft so that they reach the airport at appropriate intervals.

- NASA's work improved aviation safety in hazardous weather conditions caused by wind-shear. In collaboration with industry and the FAA, NASA developed and validated onboard aircraft wind-shear sensors that could detect and measure the intensity of wind-shear conditions ahead of the aircraft, such that a pilot could be alerted in time to safely avoid a hazardous weather condition.

Figure 1 at the end of this testimony depicts some of these improvements along with others that have made a difference in the way we safely travel today.

Recent Accomplishments

After undergoing a thorough reformulation period, all of ARMD's programs are now in full implementation. The most important "thing" that these programs generate is knowledge. To validate our accomplishments and disseminate our results, we have placed a renewed emphasis on publication in peer-reviewed references and Program planning accounts for the effort needed to document research results. While there are too many success stories over the past two years to list, here are a few examples of recent accomplishments.

- In partnership with Boeing and the Air Force Research Laboratory (AFRL), the Fundamental Aeronautics Program successfully completed several flight tests of a blended wing body (BWB) aircraft, named X-48B, which has the potential to provide increased capacity, increased fuel efficiency and decreased noise compared to today's aircraft. The X-48B was cited as one of the "Best Innovations of the Year 2007" by Time Magazine.
- The Fundamental Aeronautics Program successfully demonstrated, in partnership with Pratt & Whitney, the feasibility of a high-efficiency fan design for an ultra-high bypass ratio turbofan engine that, in combination with other technologies, has the potential for achieving significant noise reduction for aircraft.
- The Aviation Safety Program developed new data-mining tools to integrate and analyze large quantities of operational flight data to detect potential systemic problems across a fleet of aircraft. The ability to automatically detect and identify hidden anomalies or trends in aircraft systems will enable corrective action to be taken in a timely manner before an unsafe situation occurs.
- The Aviation Safety Program designed and built a new silicon carbide circuit chip that has exceeded 6,000 hours of continuous operation at 500 degrees Celsius (C) in a laboratory environment. The highly durable packaging of circuit chips is being developed to enable extremely functional but physically small and resilient circuitry that can provide constant engine health monitoring, even in the harsh conditions in the hot sections of jet engines.
- To better enable effective decision-making essential for NextGen, the Airspace Systems Program developed an aircraft-level flow control model to examine the impact of constraints (such as ground-delay decisions due to congestion) on flows into and out of New York area airports. The study examined variations in the geographical location of constraints, magnitude of constraints, and flow prioritization approaches, and found that prioritizing New York flows through congested sectors is possible without increasing system delays.
- The Airspace Systems Program developed an initial concept for Airspace Super Density Operations that meets the multiple objectives of NextGen terminal airspace operations: significantly increased capacity, robustness to varied and chaotic weather conditions, reduced environmental impact, and coordination of arrival and departure operations to/from multiple proximate airports. Initial assessments of core elements were conducted including: closely-spaced approach procedures, continuous descent arrival operations, 4D trajectory navigation, delegated spacing function and dynamic routing to avoid adverse weather.

Success Through Partnerships

NASA believes we should be in the leadership position to conduct fundamental research required to solve all the aeronautics challenges listed above. However, NASA also believes that we do this in close and strong partnerships with industry, academia and other government agencies in order to maximize the research capabilities of the nation. Because these partnerships are so important, NASA has put many mechanisms in place to engage academia and industry, including industry working groups and technical interchange meetings at the program and project level, Space Act Agreements for cooperative partnerships with industry, and the NRA process that provides full and open competition for the best and most promising research ideas. Cooperative partnerships with industry consortia can result in a significant leverage of resources for all partners and can provide opportunities to test the value of component-technology advances in full system-level contexts. All research results, whether generated by NASA internally or by its partners through the NRA, will be openly disseminated through archival publications and conference proceedings as well as NASA publications to benefit broad U.S. aeronautics community while ensuring the dissemination policy is consistent with national security and foreign policy guidelines.

ARMD is actively using the NRA mechanism to foster collaboration with academia, industry, and non-profit organizations. The first Research Opportunities in Aeronautics NRA was released in May 2006 and since then two more versions have been issued on an annual basis. The response to the NRA has been tremendous. As of the end of April 2008, more than 1380 proposals have been received resulting in more than 327 awards. An important aspect of these awards is that they are closely aligned with the research goals of internal NASA efforts. This results in a cooperative arrangement that is mutually beneficial to NASA and to the performing organization. The NRA is based on the principle of full and open competition and provides an ideal mechanism for bringing the best ideas from across the nation to bear on particular problems.

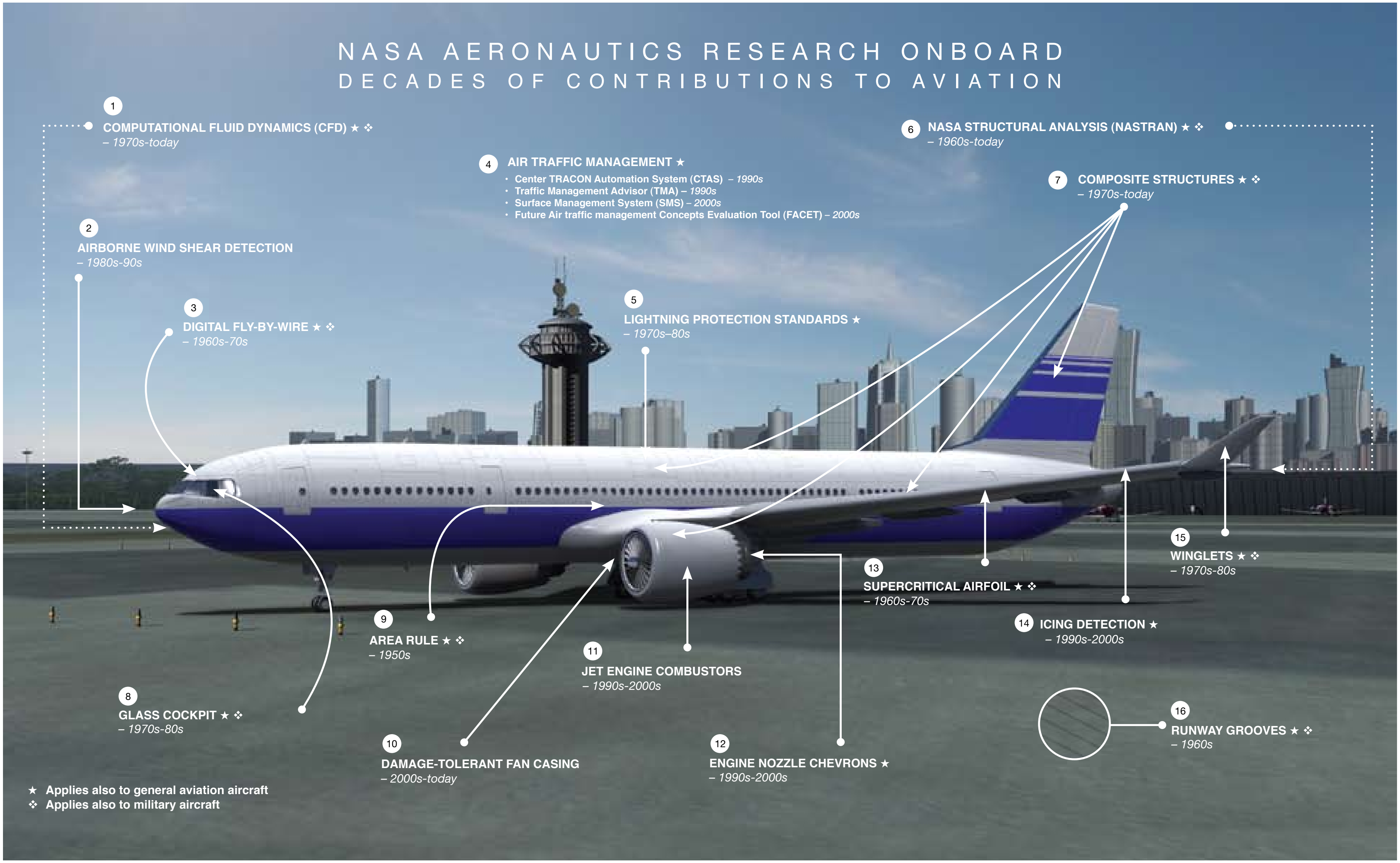
Last year, ARMD established over 30 Space Act Agreements with different members of the aerospace industry and, in some situations, with consortia of industrial participants. These collaborative opportunities have produced very significant research results at the system level where the expertise of industry and NASA come together to integrate technologies that can, one day, be incorporated into the aircraft fleet.

Finally, NASA recognizes the importance of close coordination not just with industry and academia, but with its partners in other Government agencies as well. For example, NASA and the JPDO have established quarterly reviews to ensure close coordination, and NASA participates in all major JPDO planning activities. NASA and the FAA have developed a joint program plan for the Aviation Safety Information Analysis and Sharing (ASIAS) effort with well defined roles and responsibilities. NASA and the Department of Defense have signed an MOU to facilitate the establishment of an integrated national strategy for the management of their respective aeronautics test facilities. NASA and the U.S. Air Force have established an Executive Research Council that meets at least twice a year to ensure close coordination and collaboration. And lastly, NASA and the Army have signed a Memorandum of Understanding to coordinate research efforts on rotorcraft.

Conclusion

NASA Aeronautics is now in full execution of a robust fundamental research program that is well aligned with the National Aeronautics R&D Policy and directly supports the development of the NextGen system. NASA Aeronautics pursues long term, cutting-edge research to address new challenges in the nation's air transportation system and to support the Agency's space exploration vision. ARMD's commitment to technical excellence with strong partnerships with industry, academia and other government agencies will ensure our reputation as the world's premier aeronautics R&D organization.

National Aeronautics and Space Administration



1. Computational Fluid Dynamics (CFD)

During the 1970s, NASA developed sophisticated computer codes that could accurately predict the flow of fluids using complex simulations, such as air over an aircraft's wing or fuel through a space shuttle's main engine.

Those codes became CFD, which today is considered a vital tool for the study of fluid dynamics.

CFD greatly reduces the time required to test and manufacture nearly any type of aircraft.

2. Airborne Wind Shear Detection

During the 1980s and 1990s, NASA led the first comprehensive research program to discover the characteristics of microburst and wind shear hazards.

The resulting NASA technology base led to the manufacture of on-board sensors that alert pilots in advance of wind shear hazards.

3. Digital Fly-by-Wire

During the 1960s and 1970s, NASA helped develop and flight test the digital "fly-by-wire" system, which replaced heavier and less reliable hydraulics systems with a digital computer and electric wires to send signals from the pilot to the control surfaces of an aircraft.

"Fly-by-wire" is used today on new commercial and military aircraft, and on the space shuttle.

4. Air Traffic Management

Over the decades, NASA has developed a number of air traffic management simulation tools, including:

Center TRACON Automation System (CTAS)
CTAS is a suite of software tools developed by NASA in the 1990s that generates new information for air traffic controllers.

Traffic Management Advisor (TMA)
TMA software, developed in the 1990s, forecasts arriving air traffic to help controllers plan for safe arrivals during peak periods.

Surface Management System (SMS)
SMS software, developed in the 2000s, provides controllers with data to know when aircraft arrive on the ground or at the gate.

Future Air traffic management Concepts Evaluation Tool (FACET)
FACET, developed in the 2000s, maps thousands of aircraft trajectories to improve traffic flow across the United States.

5. Lightning Protection Standards

During the 1970s and 1980s, NASA conducted extensive research and flight tests to collect the first comprehensive data on intra-cloud lightning strikes and the effects of in-flight strikes.

NASA's knowledge base is used to improve standards for protection against lightning for aircraft electrical and avionics systems.

6. NASA Structural Analysis (NASTRAN)

In the 1960s, NASA partnered with industry to develop a common generic software program that engineers could use to model and analyze different aerospace structures, including any kind of spacecraft or aircraft.

Today, NASTRAN is an "industry-standard" tool for computer-aided engineering of all types of structures.

7. Composite Structures

NASA first partnered with industry during the 1970s to conduct research on how to develop high-strength, nonmetallic materials that could replace heavier metals and aluminums on aircraft.

Composite materials have gradually replaced metallic materials on parts of an aircraft's tail, wings, fuselage, engine cowlings, and landing gear doors.

Using composite materials can reduce the overall weight of an aircraft and improve fuel efficiency.

8. Glass Cockpit

During the 1970s and 1980s, NASA created and tested the concept of an advanced cockpit display that would replace the growing number of dial and gauge instruments that were taking up space on an aircraft's flight deck.

Called a "glass cockpit," the innovative approach uses flat panel digital displays to provide the flight deck crew with a more integrated, easily understood picture of the vehicle situation.

Glass cockpits are in use on commercial, military, and general aviation aircraft, and on NASA's space shuttle fleet.

9. Area Rule

In the 1950s, NASA scientist Richard Whitcomb discovered several fundamental solutions to key aerodynamics challenges. One of the most revolutionary was the "area rule," a concept that helped aircraft designers avoid the disruption in air flow caused by the attachment of the wings to the fuselage.

Whitcomb deduced that removing the equivalent wing cross-sectional area from that of the fuselage cross-sectional area avoided the abrupt bump and improved the distribution of flow across the longitudinal area of the aircraft.

By using the area rule, aircraft designers for decades have been able to allow aircraft to fly higher, faster, and farther.

10. Damage-Tolerant Fan Casing

In the 2000s, NASA began spearheading research into developing a cost-effective turbofan jet engine casing that could be lighter, but still protect against possible fan blade failure inside the engine.

The solution was a fan case made of braided composite material that can reduce overall engine weight, increase safety, and improve aircraft structural integrity.

11. Jet Engine Combustors

During the 1990s and early 2000s, NASA improved the technology associated with jet fuel combustion to help engines burn fuel more cleanly.

The improved combustion helps reduce polluting emissions from aircraft engines, making them more environmentally friendly.

12. Engine Nozzle Chevrons

During the 1990s and early 2000s, NASA used computer simulations to improve an asymmetrical scallop design of chevrons used on the nozzles of jet engines.

Ground and flight tests by NASA and its partners proved that the new chevron design reduced noise levels in the passenger cabin and on the ground.

Chevrons are being implemented on many of today's aircraft, including the new Boeing 787.

13. Supercritical Airfoil

During the 1960s and 1970s, NASA scientist Richard Whitcomb led a team of researchers to develop and test a series of unique geometric shapes of airfoils, or wing designs, that could be applied to subsonic transport to improve lift and reduce drag.

The resulting "supercritical airfoil" shape, when integrated with the aircraft wing, minimizes drag and helps improve the aircraft's cruise efficiency.

14. Icing Detection

During the 1990s and early 2000s, NASA was called upon by the FAA to identify the characteristics of a dangerous and little-understood icing phenomenon called Supercooled Large Droplets (SLD).

Results from NASA flight tests and research were compiled in a large database to improve weather models and instrumentation for detecting SLD.

15. Winglets

During the 1970s and 1980s, NASA studies led to the development of vertical endplates that are now seen on many aircraft wings, or "winglets."

Winglets reduce vortices and drag, therefore improving airflow and fuel efficiency.

The first aircraft to adopt winglets were within the general aviation and business jet communities. In the mid-'80s, Boeing produced the 747-400 commercial jetliner, which used winglets to increase its range.

16. Runway Grooves

During the 1960s, NASA conceived and developed a process for cutting grooves along runways to channel away standing water.

The grooves proved successful in helping aircraft make safe landings on pavement made slick from rain, snow, or ice.

NASA's groove process was later adapted for use on military base runways, U.S. public highways, and even swimming pool decks, playgrounds, and floors of refineries.

www.aeronautics.nasa.gov

NL-2008-10-004-HQ