AN OVERVIEW OF THE NASA AERONAUTICS RESEARCH MISSION DIRECTORATE BUDGET FOR FISCAL YEAR 2013

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

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AN OVERVIEW OF THE NASA AERONAUTICS RESEARCH MISSION DIRECTORATE BUDGET FOR FISCAL YEAR 2013

THURSDAY, APRIL 26, 2012

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC.

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

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6371
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Subcommittee on Space and Aeronautics

An Overview of the NASA Aeronautics Research Mission Directorate Budget for Fiscal Year 2013

Thursday, April 26, 2012

10:00 a.m.-12:00 p.m.

2318 Rayburn House Office Building

Witnesses

Dr. Jaiwon Shin,
Associate Administrator, Aeronautics Research Mission Directorate, National Aeronautics and Space Administration;

Ms. Marion Blakey,
Chair, Aeronautics Committee, NASA Advisory Council, and President, Aerospace Industries Association;

Dr. Wesley Harris,
Chair, Committee to Assess NASA's Aeronautics Flight Research Capabilities, National Research Council, and Charles Stark Draper Professor of Aeronautics and Astronautics, MIT; and

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SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

An Overview of the NASA Aeronautics Research Mission Directorate Budget for Fiscal Year 2013

Thursday, April 26, 2012
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

The purpose of the hearing is to review the Fiscal Year 2013 budget request submitted by NASA's Aeronautics Research Mission Directorate (ARMD) and to examine its programs and strategies. ARMD's request was submitted as part of the NASA budget in mid-February, seeking $551.5 million for FY2013, $17.9 million below its FY2012 funding level. The hearing will also discuss a report recently issued by the National Research Council, *Recapturing NASA's Aeronautics Flight Research Capabilities*, that looked into the efficacy and affordability of strengthening the agency's integrated flight research program.

Witnesses

- **Dr. Jaiwon Shin**, Associate Administrator, Aeronautics Research Mission Directorate, National Aeronautics and Space Administration;
- **Ms. Marion Blakey**, Chair, Aeronautics Committee, NASA Advisory Council, and President, Aerospace Industries Association;
- **Dr. Wesley Harris**, Chair, Committee to Assess NASA's Aeronautics Flight Research Capabilities, National Research Council, and Charles Stark Draper Professor of Aeronautics and Astronautics, MIT; and
- **Dr. John Tracy**, Chair, National Research Council's Aeronautics Research and Technology Roundtable, and Chief Technology Officer and Senior Vice President of Engineering, Operations and Technology, The Boeing Company

Background

From 1915 until 1958, the National Advisory Committee for Aeronautics (NACA) conducted much of the aeronautics research and development activities in the United States. From its charter, codified into law in 1915, the NACA mission was to "direct and conduct research and experimentation in aeronautics, with a view to their practical solution." In 1917, the NACA established the Langley Memorial Aeronautical Laboratory in Virginia, which became the most advanced aeronautical research and development facility in the world.

The NACA was involved in all areas of aeronautics, constructing wind tunnels and conducting airfoil testing to meet military research and development requirements, recommending the inauguration of airmail service, promoting safety in aerial navigation and advising the President on the Air Commerce Act of 1926, the first federal law regulating civil aeronautics. The NACA also established facilities dedicated to aeronautical research such as the Moffett Field Laboratory near San Francisco (renamed the Ames Aeronautical Laboratory), the Lewis Research Center near Cleveland Ohio, and the Wallops Flight Center on the eastern shore of Virginia.

During WWII, the NACA focused on military research such as high speed flight utilizing rocket powered aircraft and advanced supersonic wind tunnels. By the 1950s the NACA was already researching high altitude hypersonic flight, spaceflight, and reentry into the Earth's atmosphere. In 1958, with the creation of the National Aeronautics and Space Administration (NASA), all NACA activities and facilities became the nucleus of the new agency.

NASA's aeronautics programs are conducted by the Aeronautics Research Mission Directorate (ARMD) and continue to focus on long-term investments in fundamental aeronautics research. The ARMD includes four NASA centers: NASA Langley Research Center, VA; NASA Glenn Research Center, OH; NASA Ames Research Center, CA; and NASA Dryden Flight Research Center, CA.

The current generation of civil, general aviation, and military aircraft contain many technologies developed by NASA. Fly-by-wire, flight management systems, quiet and efficient turbine engines, airframe and wing designs, incorporation of composite materials into airframes and structures, are just a few examples. Aircraft manufacturers the world over have adapted NASA-developed technologies into their products.

Additionally, ARMD researches and matures technologies that underpin the Federal Aviation Administration's air traffic management system. It has provided software tools now used by FAA to enable more efficient routing of aircraft and increase the capacity and safety of our national airspace system. NASA (ARMD) is an essential partner with FAA in the development of the Next Generation Air Transportation System – NextGen.

The ARMD programs and associated activities [FY2013 budget request is in brackets] are:

- Aviation Safety Program – conducts research to improve safety attributes of current and future aircraft and air traffic management systems.
    - System-Wide Safety and Assurance Technologies [$29.7M];
    - Vehicle Systems Safety Technologies[$36.4M]; and
    - Atmosphere Environment Safety Technologies [$14.9M].

- Airspace Systems Program – addresses air traffic management research needs for the Next Generation Air Transportation System (NextGen).
  - NextGen – Concepts and Technology Development [$55.6M]; and
  - NextGen – Systems Analysis, Integration, and Evaluation [$37.6M].

- Fundamental Aeronautics Program – develops technologies, tools, and concepts for aircraft in all speed regimes enabling them to fly faster, cleaner, and quieter, and use fuel more efficiently.
  - Subsonic Fixed Wing [$77.9M];
  - Subsonic Rotary Wing [$24.1M];
  - High-Speed (supersonics and hypersonics) [$34.4M]; and
  - Aeronautical Sciences [$32.3M].

- Integrated Systems Research Program (ISRP) – conducts research at an integrated system-level on promising concepts and technologies. ISRP focuses specifically on maturing and integrating technologies into major vehicle and operations systems and subsystems for accelerated transition to practical application.
  - Environmentally Responsible Aviation [$73.5M]; and
  - Unmanned Aerial Systems Integration in the National Airspace System [$30.5M].

- Aeronautics Test Program – manages and invests in agency aeronautics test capabilities (major wind tunnels; propulsion test facilities; flight test assets) considered strategically important to NASA and the nation.
  - Aero Ground Test Facilities [$51.7M]; and
  - Flight Operations and Test Infrastructure [$26.4M].

- Aeronautics Strategy and Management – provides management of ARMD-level activities including a low-level innovative funding program, education, and outreach.
  - Innovative Concepts for Aviation [$10.0M];
  - Education and Outreach [$5.4M]; and
  - Cross Program Operations [$11.0M].

Over the last decade, the budget for ARMD has shrunk from a peak of approximately $1B to just $569.9M in FY12. The President's FY13 budget request is slightly lower at $551.5M and remains flat in the President's budget run-out over 5 years. As a share of NASA's budget, ARMD's percentage has dropped from ~ 7 percent in 2000 to ~ 3 percent in 2012.

Aeronautics Policy

NASA's Aeronautics Research Mission Directorate program receives policy guidance from Congress, the White House, and The National Research Council. Most recently the NASA Authorization Act of 2010 directed NASA to collaborate with the Department of Defense on aeronautics research and development and the Federal Aviation Administration on the Next

Generation Air Transportation Program (NextGen). The bill also directed ARMD to pursue three fundamental goals, including;

> (1) AIRSPACE CAPACITY.—NASA's Aeronautics Research Mission Directorate shall address research needs of the Next Generation Air Transportation System, including the ability of the National Airspace System to handle up to 3 times the current travel demand by 2025.
>
> (2) ENVIRONMENTAL SUSTAINABILITY.—The Directorate shall consider and pursue concepts to reduce noise, emissions, and fuel consumption while maintaining high safety standards and shall pursue research related to alternative fuels.
>
> (3) AVIATION SAFETY.—The Directorate shall proactively address safety challenges with new and current air vehicles and with operations in the Nation's current and future air transportation system.

In 2006, the National Research Council produced the *Decadal Survey of Civil Aeronautics: Foundation for the Future,* (http://www.nap.edu/catalog.php?record_id=11664#toc) proposing a portfolio of aeronautics research programs for NASA. The report made 8 programmatic recommendations and identified 51 technology challenges it deemed essential to ensuring a robust aeronautics R&D program responsive to industry and societal needs.

Executive Order 13419, "National Aeronautics Research and Development" issued December 2006, (https://www.federalregister.gov/articles/2006/12/26/06-9895/national-aeronautics-research-and-development) states in part: "Continued progress in aeronautics, the science of flight, is essential to America's economic success and the protection of America's security interests at home and around the globe."

Budget Request

NASA Aeronautics Research Mission Directorate
President's FY2013 Budget Request

Budget Authority, $ in millions

	FY2011 Actual	FY2012 Estimate	FY2013 Author.	FY2013 Request	FY2013 v FY2012 Est	FY2014 Notional	FY2015 Notional	FY2016 Notional	FY2017 Notional
Aeronautics TOTAL	**$533.5**	**$569.4**	**$590.0**	**$551.5**	**-$17.9**	**$551.5**	**$551.5**	**$551.5**	**$551.5**
Aviation Safety	67.3	80.1	*	81.1	1.0	81.0	81.4	81.9	82.5
Airspace Systems	87.2	92.7	*	93.3	0.6	92.6	91.9	91.2	90.5
Fundamental Aeronautics	206.3	186.3	*	168.7	-17.6	171.3	173.3	175.3	177.1
Aeronautics Test Program	76.4	79.4	*	78.1	-1.3	78.0	78.0	78.1	78.2
Integrated Test Systems	75.9	104.2	*	104.0	-0.2	102.3	101.2	100.1	98.8
Aero Strategy & Management	20.4	26.7	*	26.4	-0.3	26.2	25.7	25.0	24.4

(Numbers may not add due to rounding.)

*Authorization did not specify.

Comparing FY2012 with the FY2013 budget request, there is little variance across the programs, except for a $17.6 million reduction in Fundamental Aeronautics. Most of the decrease is attributable to diminished support for hypersonics research as well as the transfer of fundamental research in entry, descent and landing technologies to the Space Technology account. Topline outyear funding through FY2017 is held constant at the FY2013 level, similar to the profile received by all other NASA mission directorates.

In materials provided to committee staff, NASA identified its aeronautics priorities to be:

- Accelerate implementation and enhance the capabilities of NextGen (FAA's air traffic modernization program);
- Innovate to close critical gaps in both air traffic management 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.

National Research Council Report

Earlier this year the National Research Council issued a report, *Recapturing NASA's Aeronautics Flight Research Capabilities*. Dr. Wesley Harris, Professor of Aeronautics and Astronautics at MIT, chaired the committee that produced the report. He served as Associate Administrator for NASA's Aeronautics program from 1993 – 1995.

The report (http://www.nap.edu/catalog.php?record_id=13384) grew out of a request by ARMD to the NRC "to assess and make recommendations about how best to integrate flight research into the current Aeronautics Research Mission Directorate's (ARMD) fundamental research activities and integrated systems research activities." The NRC committee concluded "that the type and sophistication of flight research currently being conducted by NASA today is relatively low and that the agency's overall progress in aeronautics is severely constrained by its inability to actually advance its research projects to the flight research stage, a step that is vital to bridging the confidence gap. NASA has spent much effort protecting existing research projects conducted at low levels, but it has not been able to pursue most of these projects to the point where they actually produce anything useful. Without the ability to actually take flight, NASA's aeronautics research cannot progress, cannot make new discoveries, and cannot contribute to U.S. aerospace preeminence."

The report recommends that NASA dedicate $30 million - $50 million of its annual ARMD budget for focused flight research projects; to phase out lower-priority aeronautics projects as a budget offset; and to put each of its projects on a clearly defined path to flight testing in an appropriate environment.

Other of its recommendations include:

- NASA aeronautics should aggressively pursue collaboration with DOD, FAA, the U.S. aerospace industry, and international aeronautics research agencies. NASA should adopt management practices to facilitate effective collaboration and treat external organizations as customers and partners. NASA leadership should develop a formal process for regularly soliciting input from the U.S. aerospace industry and universities as well as key government agencies to assure the relevancy of its flight research programs to national needs.

- NASA aeronautics should become the nation's repository of flight research data and flight test results and should make these archival data readily accessible to key stakeholders—the engineers and scientists in industry, academia, and other government agencies. NASA should also require principal investigators in flight research projects to publish their results and provide funding for them to do so.

- NASA aeronautics leadership should study designating Dryden Flight Research Center as the primary flight research organization of NASA, with responsibility for the efficient use of NASA flight research aircraft, facilities, and other support resources. Dryden should adopt a customer-focused approach to flight research sponsored by NASA and external partners.

Overarching Questions

- Given its limited resources, can ARMD afford to support a broad research portfolio? Would ARMD be more effective by focusing its resources on high priority activities?
- How well does ARMD's research program align with mid- and long-term industry needs? Are there any research gaps?
- Are ARMD resources sufficient to mature technologies to a state of readiness that would enable their adoption by industry?
- How well does ARMD's research portfolio support implementation of NextGen? How effectively are NASA-developed technologies being transitioned from research to implementation at FAA?

Chairman PALAZZO. The Subcommittee on Space and Aeronautics will come to order.

Good morning, and welcome to today's hearing entitled "An Overview of NASA's Aeronautics Research Mission Directorate Budget for Fiscal Year 2013." In front of you are packets containing the written testimony, biographies and Truth in Testimony disclosures for today's witness panel. I recognize myself for five minutes for an opening statement.

Today's hearing will examine NASA's fiscal year 2013 Aeronautics Research Mission Directorate budget request. I first want to thank our witnesses for taking their time from their busy schedules to appear before the Space and Aeronautics Subcommittee. I realize you and your staff devoted considerable effort preparing for your appearance, and I want to assure you that your wisdom and expertise will be of immense help to our Committee today and in the months and years ahead.

Aeronautics research and development, and the technologies they spin off, are critical to our national security and to the ongoing success of our Nation's aerospace industrial base, which is our country's greatest source of exports. No other enterprise has played a greater role producing innovative aeronautics technologies than NASA.

Since its founding nearly 100 years ago as the National Advisory Committee for Aeronautics, NASA technologies have made possible today's domestic civil and military aerospace industries. Across the spectrum, from fundamental research in airfoil designs, materials research, and high-speed flight to highly integrated systems research activities such as turbine engines and innovations in air traffic management technologies, NASA's cadre of scientists and engineers have helped sustain the preeminence of American aerospace products, providing an enormous source of high-paying jobs.

Our position, though, is being challenged by the emergence of aerospace industries abroad. If our domestic industry is to maintain leadership in the years ahead, it is essential that research and development continue to produce more efficient, cleaner and robust aircraft, not only to distinguish our products from competitors, but to preserve the role of aviation as the safest, fastest, most convenient and most environmentally benign source of transport.

The growth of overseas competition occurs at a time when NASA's aeronautics research and development funding is on the decline and continues to shrink, chiefly for reasons related to agency budgets. The fiscal year 2013 request of $551 million is $18 million below current levels. Today's aeronautics spending accounts for about three percent of NASA's overall budget, compared to about seven percent of the budget in fiscal year 2000.

During the middle of the last decade, in an effort to address declining budgets, NASA aeronautics research and development was restructured to focus most of ARMD's portfolio on foundational research. In the years since, the agency has been able to leverage industry investment in a number of research areas, but a report recently issued by the National Research Council concludes that continuing down the path of emphasizing foundational research no longer makes good sense, and instead recommends that NASA reinstitute a cadence of relatively inexpensive flight research programs that are of a higher order of scale and sophistication than being currently flown.

To offset the costs of flight research, the NRC proposes that NASA phase out the majority of its lower-priority aeronautics activities. The report also stresses the intrinsic value of flight research, suggesting that the agency will be able to mature technologies to a higher level, thus ensuring their adoption by industry.

I look forward to discussing ARMD's research strategy and the NRC report, and gaining our witnesses' insights on the best path forward.

I want to again thank our witnesses for appearing here today. We have an excellent group of experts, and I look forward to hearing your testimony.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF SUBCOMMITTEE CHAIRMAN STEVEN M. PALAZZO

Good morning and welcome to today's hearing on NASA's FY 2013 Aeronautics Research Mission Directorate budget request. I want to thank our witnesses for taking time from their busy schedules to appear before the Space and Aeronautics Subcommittee. I realize you and your staff devoted considerable effort preparing for your appearance, and I want to assure you that your wisdom and expertise will be of immense help to our Committee today and in the months and years ahead.

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I look forward to discussing ARMD's research strategy and the NRC report and gaining our witnesses' insights on the best path forward.

I want to again thank our witnesses for appearing. We have an excellent group of experts, and I look forward to hearing your testimony.

Chairman PALAZZO. I now recognize Mr. Costello for his opening statement.

Mr. COSTELLO. Mr. Chairman, thank you, and I welcome our witnesses here today and look forward to hearing their testimony.

As Ranking Member of the House Transportation and Infrastructure Aviation Subcommittee, I am very much aware of NASA's importance to the U.S. aerospace and aviation, particularly with the development of NextGen, the next generation air traffic control system. Both Marion Blakey and I worked very closely together on NextGen, and I am looking forward to talking to her and asking her some questions about NextGen.

NASA's contributions have will make possible significant reduction in controller workload, and an estimated $300 million per year in fuel savings with fleet-wide deployment at the busiest airports. These contributions will save fuel and reduce noise by enabling more efficient arrivals and are evidence of how investments in research today will produce significant dividends tomorrow.

Through the 2010 NASA Authorization Act, Congress tasked NASA with maintaining a strong aeronautics research portfolio that focused on fundamental research through systems research. However, for the past several years, NASA has not received the necessary funding to fulfill those objectives. This is unfortunate, given NASA's integral role in enabling the strength of the U.S. aerospace industry and, in partnership with FAA, the safety of the flying public. Yet the industry faces continued challenges such as increasing congestion of the Nation's airspace system, maintaining safety in the face of increasing travel demand, and mitigating the negative impacts of aviation on the environment, whether noise, increasing energy consumption, or harmful emissions.

NASA's aeronautics research programs are addressing these challenges and have made significant progress. It is important to learn more about this progress because these challenges are at the crux of our transition to NextGen, and we must focus on NextGen research that will meet these challenges.

Our witnesses today will probably agree with me that carrying research to the level of maturity that allows the results to be transitioned to the users, whether private or public sector, is critical and requires a greater level of investment than is currently being made. If promising technologies and operational concepts aren't matured to the point that they can be transitioned to the users for further development or implementation, the Nation will never receive the full benefit of the investment that it has made in research. I understand that we are in tough economic times, but I hope that this hearing will illustrate how NASA's aeronautics research provides a sizable return on the taxpayer's investment. So I am eager to hear from our witnesses today on how we can ensure that NASA's aeronautics research remains vibrant, relevant to the Nation's needs, and contributes to maintaining U.S. leadership in the aviation world.

I thank you, Mr. Chairman, for calling this hearing and I look forward to hearing the testimony of our witnesses.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF RANKING MINORITY MEMBER JERRY F. COSTELLO

Good morning. Thank you, Mr. Chairman, for calling this important hearing on the FY 2013 budget request, challenges, and priorities for Aeronautics, and I welcome our witnesses.

Congress has asked NASA to maintain, and I quote from the 2010 NASA Authorization Act, "*a strong aeronautics research portfolio ranging from fundamental research through systems research*." More importantly, the Act stresses NASA's need to perform research in airspace capacity, environmental sustainability, and aviation safety.

For the past several years, however, NASA has not received the necessary funding to fulfill those objectives. This is unfortunate, because NASA has an integral role in enabling the strength of the U.S. aerospace industry and, in partnership with FAA, the safety of the flying public.

As Ranking Member of the House Transportation and Infrastructure's Aviation Subcommittee, I am keenly aware of NASA's importance to U.S. aerospace and aviation. A strong aerospace industry enables the United States to defend itself, compete in the global marketplace, maintain a highly skilled workforce, and provide safe and secure travel to all Americans. According to the latest figures available, aviation manufacturing and services accounted for $445 billion in direct and indirect economic activity in 2006. Aviation provided the Nation with a trade surplus of $57.4 billion in 2008

The explosive growth of aviation over the last several decades has also brought its own set of challenges. These include dealing with the increasing congestion of the Nation's airspace system, the need to maintain safety in the face of increasing travel demand, and the need to mitigate the negative impacts of aviation on the environment—whether noise, increasing energy comsumption, or harmful emissions.

NASA's aeronautics research programs are addressing these challenges, and I hope to learn more about their progress, because these challenges are at the crux of the major transition underway in modernizing the Nation's air transportation system—NextGen. We must focus on NextGen research that will ensure that the Nation's air traffic management system will be able to meet anticiapted demand while preserving safety and making the whole experience a lot more pleasant than it is now for the average traveler. We also need to focus on developing technologies that can make aircraft much more energy efficient and produce lower levels of harmful emissions. And we need to focus on research that will ensure that we maintain the high level of safety that we have enjoyed in our aviation sector.

However, the continued decline in NASA's aeronautics funding is making it difficult to maintain an aeronautics research program that will be capable of stepping up to the challenges the Nation's aviation sector is facing.

Our witnesses today will probably agree with me that carrying research to a level of maturity that allows the results to be transitioned to the users—whether private or public sector—is critical and requires a greater level of investment than is currently made. If promising technologies and operational concepts *aren't* matured to the point that they can be transitioned to the users for further development or implementation, the Nation will never receive the full benefit of the investment that it has made in that research.

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So I am eager to hear from our witnesses on how we can ensure that NASA's aeronautics reseach remains vibrant, relevant to the Nation's needs, and contributes to maintaining U.S. leadership in aviation.

Mr. Chairman, we must keep aeronautics a priority.

I yield back the balance of my time.

Chairman PALAZZO. Thank you, Mr. Costello.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time I would like to introduce our panel of witnesses, and then we will proceed to hear from each of them in order.

Our first witness is Dr. Jaiwon Shin, Associate Administrator for NASA's Aeronautics Research Mission Directorate, a position he has held for four years. Previously, he served as Deputy Associate Administrator for Aeronautics for four years, and he served in research and executive positions at the Glenn Research Center in Ohio. Dr. Shin received a doctorate in mechanical engineering from Virginia Tech.

Our second witness is Ms. Marion Blakey, Chair of the NASA Advisory Council Aeronautics Committee. Ms. Blakey is currently President and Chief Executive Officer of the Aerospace Industries Association. Previously, she served as Administrator of the Federal Aviation Administration as Chairman of the National Transportation Safety Board and has held a number of other senior positions in the executive branch. Ms. Blakey is a graduate of Mary Washington College.

Our third witness is Dr. Wesley Harris, who chaired the National Research Council's Committee to Assess NASA's Aeronautics Flight Research Capabilities. Dr. Harris is the Charles Stark Draper Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology. He served as head of the Department of Aeronautics and Astronautics at MIT from 2003 to 2008 and prior to that served as NASA Associate Administrator for Aeronautics from 1993 to 1995. He earned his bachelor's degree in aeronautics engineering from the University of Virginia and his master's and doctorate degrees in aerospace from Princeton.

Our final witness will be Dr. John Tracy, who serves as Chair of the National Research Council's Aeronautics Research and Technology Roundtable. Dr. Tracy is Chief Technology Officer and Senior Vice President for Engineering, Operations and Technology for The Boeing Company. Dr. Tracy has spent most of his career at Boeing in a variety of senior management positions. He received his Ph.D. in engineering from the University of California-Irvine, and he is a Fellow of the American Society of Mechanical Engineers, the American Institute of Aeronautics and Astronautics, and the Royal Aeronautical Society.

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

I now recognize our first witness, Dr. Shin, to present his testimony.

STATEMENT OF DR. JAIWON SHIN, ASSOCIATE ADMINISTRATOR, AERONAUTICS RESEARCH MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. SHIN. Chairman Palazzo and Ranking Member Costello 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.

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. You are watching the visualization of actual airline flights around the globe and in the United States. This self-tour is called Future ATM Concepts Evaluation Tool, or FACET, developed by NASA, which won NASA'S 2010 Government Invention of the Year. This is a very important research tool that benefits both NASA and FAA for understanding and designing a more efficient

National Airspace System. In addition, it provides all of us a true appreciation for the complexity of today's air transportation system and challenges we are facing.

Although the Nation's air transportation system is safe and efficient, it faces several national-level challenges. Improving mobility is a challenge because it requires increasing capacity while saving fuel. Our Nation spent over $70 billion in 2010 on aviation fuels. A related challenge is to limit the environmental footprint of aviation. We must reduce the emissions and minimize aircraft noise. Today's air transportation system is the safest mode of transportation. It is essential to ensure that the current safety level is maintained and even improved as the system is becoming more complex and automated.

This short video shows how flights are placed in holding patterns as a storm system is moving into the very busy New York airspace. Some of the holds start as far away as the Pennsylvania and Ohio state line. Many of the incoming international flights with very low fuel left on board zigzag to delay their arrival into New York. Flight delays and cancellations are costing the country an estimated $31 billion each year.

To address these national-level challenges, the pressure for technological improvement is mounting. The U.S. aviation industry currently enjoys a strong position in the global market. Technological superiority has been a key enabler, bringing a positive trade balance of over $40 billion per year. The aviation industry provides high-tech and high-paying jobs that Americans are proud to have, accounting for nearly one million jobs. The critical challenge and opportunity facing the U.S. aviation industry is to retain this leadership in this growing and increasingly complex market through infusion of new technology.

NASA-developed technologies are in the DNA of almost all of the modern civilian and military aircraft. 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 record. Investment in aeronautics technology stimulates the economy and contributes 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 million to the Aeronautics Research Mission Directorate in fiscal year 2013. Our research agenda has been created in partnership with the broader aerospace community. NASA, the FAA and five other federal agencies together are defining the vision to the Next Generation Air Transportation System, or NextGen, and establishing the roadmap to get there. NASA aeronautics seeks to enhance implementation and the capabilities of NextGen, innovating both air traffic management 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.

To enhance implementation and the capabilities of NextGen, NASA and the FAA have established research transition teams, or RTTs, to develop joint research plans, fund our respective portions, and facilitate handoff from NASA to FAA of the research results.

A recent GAO report identified RTTs as a federal best practice for interagency collaboration.

One such RTT example is NASA's Efficient Descent Advisor technology. By enabling airplanes to descend on the optimal continuous path, this technology will save fuel and reduce noise for neighboring communities. NASA estimates $300 million in fuel savings per year if EDA is implemented fleet-wide at the Nation's busiest airports. This type of capability not only will help more efficient operations but also will show the airlines the return on investment they can achieve by equipping the aircraft with NextGen avionics.

NASA's innovative technologies such as lighter and more durable composite materials and structures; low-emissions combustor technologies; lightweight, durable, high-temperature alloys for turbine sections of engines; and chevron nozzles to reduce engine noise can be seen in new products entering the market today. These new vehicles hold the promise of reducing fuel consumption to 20 percent, longer operational life, and lower maintenance costs, all due to infusion of advanced technology.

Today, we are continuing our tradition of being the innovative engine in aeronautics R&D to help achieve the full potential of NextGen. For example, we are exploring new aircraft configurations like the hybrid wing body shown in this video, as seen from the chase-plane camera. Studies show that this kind of new configuration, combined with lightweight composite materials and advanced engines, can reduce fuel consumption by 50 percent and reduce the noise footprint to one-sixth of what it is today. We have successfully completed over 90 flights with this X–48 test bed.

We are also leading the country today with a fundamental understanding and new concepts to meet new emerging challenges 20 and 30 years from now. For example, NASA has funded industry-academia teams to develop new vehicle concepts that could achieve our aggressive efficiency and environmental goals in the future. Those teams also created technology development roadmaps to help NASA and industry to prioritize research investments in the coming years.

NASA does not build aircraft engines or air traffic management systems. Through our cutting-edge research, we develop the concepts, tools, and technologies that enable continuous innovation in aviation. We focus on priority research challenges of greatest relevance to the community where NASA has a unique contributing role and can have the greatest impact. We invest in a balanced portfolio of analytical research, research through high-fidelity stimulation, ground testing and flight demonstration and validation. We challenge the aeronautics community to think big and to reach far by developing new concepts for flights such as those represented on the table in front of me. 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 high-quality jobs, and enabling the United States to remain competitive in the global economy.

Thanks so much for allowing me to represent NASA aeronautics today. I will be glad to answer any questions you may have.

[The prepared statement of Mr. Shin follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
April 26, 2012

Statement of

Dr. Jaiwon Shin
Associate Administrator for Aeronautics Research
National Aeronautics and Space Administration

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.

Chairman PALAZZO. Thank you, Dr. Shin.

I now recognize Ms. Blakey for five minutes to present her testimony.

STATEMENT OF MS. MARION BLAKEY,

CHAIR, AERONAUTICS COMMITTEE,

NASA ADVISORY COUNCIL, AND PRESIDENT,

AEROSPACE INDUSTRIES ASSOCIATION

Ms. BLAKEY. Thank you, Chairman Palazzo and Ranking Member Costello. I am delighted to be here with you and other Members of the Committee. I also want to say how grateful I am to be able to discuss NASA's aeronautics budget and programs for the coming year because they are tremendously important.

I am Marion Blakey, President and Chief Executive Officer of the Aerospace Industries Association, the Nation's premier trade association for aerospace and defense manufacturers. However, today I am not here representing AIA but representing instead the chairmanship and committee of the NASA Advisory Council's Aeronautics Committee.

The Aeronautics Committee reports to NASA's Advisory Council and meets approximately three times a year. Our job is to review NASA's aeronautics research and testing programs and provide independent advice to the council and NASA leadership, including Dr. Shin. Although we review NASA's programs with an independent critical eye, we do have an excellent working relationship with Dr. Shin and his staff, and we appreciate their ongoing support.

Mr. Chairman, overall, ARMD provides important support to the Nation's aeronautics research efforts. NASA takes the lead in fundamental research into revolutionary aircraft concepts. They take a comprehensive, integrated look at systems-level solutions and they have unique testing facilities that really exist nowhere else. They push the boundaries of our aeronautical knowledge and transition new hardware and software to the marketplace.

You ask whether ARMD research matches up with the needs of industry. On balance, I do believe Dr. Shin's office is pursuing the right research with the right priorities. Let me touch on three examples, if I might: environmental research, UAS integration, and NextGen programs.

NASA is heavily involved in research to make our aviation system more environmentally friendly. U.S. manufacturers lead the world in developing quieter, more fuel-efficient aircraft. The industry has agreed to a cap on carbon dioxide emissions from aircraft, which is called carbon-neutral growth, by the year 2020. This is very aggressive and, believe me, is well beyond what any other global industry has agreed to, and NASA is helping us achieve those goals. For example, the Environmentally Responsible Aviation, ERA, project is developing advanced air vehicle concepts that could reduce fuel burn by 40 percent, cut aircraft noise to stage IV levels and below, and cut nitrous oxide emissions by 75 percent.

NASA aeronautics is also an important player in our efforts to develop and certify alternative jet fuels. NASA is also involved in unmanned aerial systems, UAS, and their integration into the national airspace. As you know, recent legislation requires that UAS systems be integrated into the NAS by the year 2015—very aggressive. NASA is working with the FAA to develop an interagency roadmap for UAS integration. Because this work is evolving so rapidly, the aeronautics committee that I chair established a special UAS subcommittee this past December, and we are going to have more to say on this as the committee works, but it wholeheartedly supports NASA's UAS activities.

The third and final area that I would like to highlight is NextGen. We see that there is real potential for NASA-developed technologies to contribute to NextGen and tools like NASA's Efficient Descent Advisor that Dr. Shin just mentioned, and the Airborne Merging and Spacing tool are very important parts of this effort. These technologies demonstrate NextGen's value in our terminal airspace and they are mature enough to transfer to operational use. In fact, EDA transitioned to FAA for operational use just last November.

Mr. Chairman, for a final moment, let me address NASA's fiscal year 2013 budget request. The request is $17.9 million below the current year, including a reduction of $20 million. This is in hypersonics research. In 2006, only six years ago, hypersonics programs were funded at $70 million. Under the President's budget for next year, it would be cut to $4.5 million. Maintaining an effective hypersonics program will be a challenge if additional funding is not provided. Therefore, we are very pleased to see that the House Appropriations Subcommittee has just recommended that these cuts be rejected because we believe hypersonics research is very important in today's world.

Mr. Chairman, that completes my summary, and I look forward to answering your questions. Thank you.

[The prepared statement of Ms. Blakey follows:]

Testimony of Marion C. Blakey

Chair, Aeronautics Committee, NASA Advisory Council

"Overview of the NASA Aeronautics Research Mission Directorate's

Budget Request for Fiscal Year 2013"

Subcommittee on Space and Aeronautics

House Committee on Science, Space, and Technology

April 26, 2012

Introduction

Chairman Palazzo and Ranking Member Costello, thank you for the invitation to discuss NASA's aeronautics budget request for next year. I am Marion Blakey, Chief Executive Officer of the Aerospace Industries Association (AIA), the nation's premier trade association representing aerospace and defense manufacturers. However, today I come not representing AIA, but instead in my role as Chair of the Aeronautics Committee of the NASA Advisory Council.

The Aeronautics Committee reviews NASA's aeronautics research and testing programs and provides advice to senior NASA leaders on those programs. As a standing committee of the Advisory Council, we meet approximately three times each year under Federal Advisory Committee Act (FACA) guidelines. Our advice spans all areas of aviation under the jurisdiction of the Aeronautics Research Mission Directorate (ARMD), including advanced air vehicle development, alternative fuels, UAS integration into our national airspace, and the Next Generation Air Transportation System (NextGen). The members I serve with have highly distinguished, world-class backgrounds in aeronautics, and it is an honor to work with them. We have an excellent working relationship with Dr. Shin and his staff, as well as the full Advisory Council, and we appreciate the support they provide to the committee.

Mr. Chairman, ARMD provides critical support to our nation's aeronautics research efforts. They have a strong track record leading complex, collaborative research with multiple federal agencies, academia, government labs, and industry. Military aeronautics research is focused on defense applications. FAA NextGen activities are focused on near- and mid-term engineering solutions. NASA, by contrast, integrates and adds to this research base. They take the lead in fundamental research into revolutionary concepts and technologies. They take a comprehensive, integrated look at systems-level solutions. And they operate and maintain unique testing facilities that exist nowhere else in the Federal Government. Simply put, they push the boundaries of our aeronautical knowledge, and bring together our best technical minds to push new technologies into the industry and into the global marketplace.

ARMD's Research Portfolio

You asked me to offer an opinion on how well ARMD's research matches up with the needs of our aerospace industry, and advise you of any gaps in that research. I am pleased to say that on balance I believe Dr. Shin's office is pursuing the right research and with the right priorities. Let me touch on three specific research areas where the Aeronautics Committee has been especially active: Environmental research, UAS integration, and the NextGen program.

Environmental Research

ARMD is heavily involved in research to make our aviation system more environmentally friendly – so-called "Green Aviation" research. Mr. Chairman, U. S. manufacturers are leading the world in developing quieter aircraft that are easier on our environment. The industry has committed to a cap on aviation-related CO^2 emissions -- "carbon neutral growth" -- by the year 2020. This is well beyond what any other global industry has agreed to, and we are working hard to achieve those goals.

NASA's "Green Aviation" research is a critical part of our overall effort to go beyond CNG 2020, to achieve even further greenhouse gas reductions, and to demonstrate to the world that the government and the aerospace industry are working overtime to address this issue. For example, the Environmentally Responsible Aviation (ERA) project is developing advanced air vehicle concepts that could reduce fuel burn by 40 percent, cut aircraft noise well below stage 4 levels, and nitrous oxide (NOx) emissions by 75 percent. And how will we do this? With new laminar flow concepts for reducing drag. With new composites that reduce weight. New engine combustor designs that cut emissions during takeoff and landing. And by implementing new air traffic management concepts.

NASA's Aeronautics program is also key to our government-wide efforts to develop and certify alternative jet fuels. This is a multi-agency effort, and each agency is responsible for a specific research area. In NASA's case, they are focused on engine performance and emissions from the use of alternate fuels. With their specialized facilities, NASA is conducting fundamental tests in combustion, exhaust plume experiments, and system-level engine testing. For example, the Aviation Alternative Fuel Experiment (AAFEX) – 2 used a NASA Dryden DC-8 to gather emissions test data comparing various alternative fuels to JP-8. This test not only provided data to help us model engine performance and emissions, it helped accelerate development of a standard for particulate data and sampling protocols.

The Committee is strongly supportive of ARMD's "Green Aviation" program. We believe NASA's technical expertise in this area can help the Environmental Protection Agency (EPA) in its standards setting and regulatory policy initiatives as they relate to aviation, and we have recommended that Dr. Shin and his office take a proactive approach in providing technical assistance to EPA.

Integrating Unmanned Aerial Systems into the National Airspace

If there is one emerging area where the Committee has become increasingly involved, it involves Unmanned Aerial Systems (UAS) and their integration into the National Airspace System (NAS). As you know, the recently-enacted FAA Modernization and Reform Act of 2012 required that UAS systems be integrated into the NAS by the year 2015 and required FAA to establish up to six test ranges to assist in this effort. UAS systems are coming, Mr. Chairman, and a lot of research needs to be done to meet the Act's milestones.

We believe NASA can play an important role in the development of standards, testing, and ultimately the approval of UAS systems. Right now, NASA is working with FAA's Joint Planning and Development Office (JPDO) to develop an interagency research, development and demonstration roadmap for UAS integration. Because this work is so important and evolving so rapidly, in consultation with ARMD the Committee established a UAS Subcommittee this past December. Dr. John Langford of Aurora Flight Sciences has agreed to chair the Subcommittee, and we have balanced representation from industry, academia, and government. We will have more to say on this subject in the future, but we wholeheartedly support NASA's activities in UAS and believe ARMD is uniquely suited to assist in this arena.

Next Generation Air Transportation System (NextGen)

Mr. Chairman, on the NextGen front, the Committee is encouraged by the integrated air traffic management demonstrations being conducted through ARMD's Airspace Systems Program. We think there is major potential for NASA-developed technologies to make a critical contribution to successful implementation of the Automatic Dependent Surveillance – Broadcast (ADS-B) program. As you know, ADS-B is a fundamental building block of the NextGen program. And tools like NASA's Tailored Arrivals and Efficient Descent Advisor (EDA), Airborne Merging and Spacing tool (AMS), and Energy Navigation Concept (eNAV) are important parts of that effort. These technologies are mature enough to transfer to operational use, and will demonstrate the full potential of NextGen in our crowded terminal areas. We expect significant savings in aircraft fuel burn, flight time, and reduced noise, all of which will help make the business case for operators to equip with NextGen technologies. The Committee is working with NASA to calculate in detail the estimated fuel savings associated with these technologies, to support the business case and raise the level of near-term NextGen benefits.

One excellent example of the improved technology transition from NASA to FAA is the Efficient Descent Advisor program. This started in 2008 as a collaborative project between NASA, FAA, Boeing, and airline partners to develop an automation tool that could improve the efficiency of arrival operations in capacity-constrained situations. In testing, they found that EDA reduced the number of maneuver-related arrival clearances by almost two-thirds, reducing controller workload, and saved 180 pounds of fuel per flight. And this is not sitting in the lab -- it transitioned to the FAA last November, and is being planned for deployment.

We are continuing our review of NASA's NextGen work this year. However, since I have been chairman, I have been impressed at the contributions being made by NASA's ARMD team. We are also encouraging ARMD to establish a deeper understanding and collaboration with the international community in NextGen research, because we are not operating in a vacuum and it is critical that our global ATC systems be effectively timed and harmonized.

NASA's FY13 Aeronautics Budget Request

Mr. Chairman, NASA is requesting $551.5 million for Aeronautics research in FY13. This amount is $17.9 million below the current year, a decrease of 3.1 percent. The entire decrease is taken against fundamental aeronautics research. In fact, the overall number masks a reduction of $20 million in hypersonics research. This cut would leave approximately $5 million to continue that research next year.

NASA's existing hypersonics design capabilities and knowledge base was hard won through decades of investment – from early re-entry system development to the Next Generation Launch Technology program, which ended in 2004. Unfortunately, over the past few years NASA's investment in hypersonics has dropped substantially. In 2006, these programs were funded at approximately $70 million. This figure dropped to $25 million by 2012, and would be cut to $4.5 million in the fiscal year 2013 NASA budget request.

With NASA reducing its focus on hypersonic research so drastically, I am concerned about the overall future of U.S. government capabilities. From the X-15 program of the 1960's to the National Aerospace Plane of the 1980's and the Space Shuttle, NASA has helped develop a generation of engineers uniquely skilled in hypersonics systems design. If this engineering talent migrates to other disciplines, it will take many years to get it back. Hypersonics has a unique attraction for students, and continues to be a powerful focus of STEM education initiatives. And if successful, hypersonics technologies could lead to dramatic reductions in space launch costs and national defense capabilities that are not available today.

Although the Aeronautics Committee has not made specific recommendations on hypersonics, the trend toward extinction is certainly a cause for concern, and will be a real challenge for ARMD if additional funding is not provided in the appropriations process this year.

Conclusion

In summary, Mr. Chairman we believe NASA's aeronautics research plan is balanced and focused on the most critical areas. They are transitioning their research to industry at an appropriate pace. And they continue to push the frontiers of our fundamental knowledge. This is an important contribution that must be maintained if we are to maintain our global leadership in aeronautics and aerospace.

Thank you for allowing me to represent the Committee today, and I am glad to answer any questions you may have.

Chairman PALAZZO. Thank you, Ms. Blakey.

I now recognize Dr. Harris for five minutes to present his testimony.

STATEMENT OF DR. WESLEY HARRIS, CHAIR, COMMITTEE TO ASSESS NASA'S AERONAUTICS FLIGHT RESEARCH CAPABILITIES, NATIONAL RESEARCH COUNCIL, AND CHARLES STARK DRAPER PROFESSOR OF AERONAUTICS AND ASTRONAUTICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. HARRIS. Mr. Chairman, Ranking Member Costello, Members of the Committee, colleagues, I am Wesley Harris, Chair of the National Research Council's Committee to Assess NASA's Aeronautics Flight Research Capabilities. It is a pleasure to come before you to speak to you about the work of the committee. In 2011, NASA asked the National Research Council to undertake a study of NASA's flight research capabilities. I am here to report the results of that study.

Our committee consists of members of industry and academia, former NASA aerospace officials, aircraft designers, test pilots, and even an Apollo moon walker. We met several times throughout 2011. We visited NASA centers involved in flight research. We heard from numerous NASA and industry representatives. We received extensive cooperation from the agency for which we, the committee, are very grateful.

Many people may not be aware that unmanned aerial vehicles are a vital part of America's national security and a highly dynamic part of our aerospace industry, something and somewhere that the United States remains the world leader. What few people realize, however, is that during the 1990s, NASA played a major role in making this happen by supporting the development of multiple advanced UAV designs with efficient and effective aeronautical flight research, thereby spawning industry that is still active today. This was an industry where the United States was behind. It now leads. NASA played a major role in that, and we believe that NASA should receive recognition for this achievement.

Flight research is only one part of a healthy aeronautics research enterprise. It is absolutely vital. Flight research is vital. It stands in value equal to that of wind tunnel testing, to theory and simulation. A common-held misconception is that flight research is something that comes at the end of a research program. However, in many cases, it is necessary for that research to occur, that is, flight research to occur in the middle of the program. For instance, it is very common in the aeronautics R&D world to update sophisticated computer simulations based upon data collected by actually flying a vehicle.

Since the middle of the past decade, NASA has dramatically reduced its flight research to focus more on ground-based investigations and activities in what NASA describes as its fundamental research program. In the committee's opinion, most flight research today can be characterized as limited in scope, such as putting a new structure on or under the wing of an existing airplane, for example, an F–15, or flying a small-scale UAV. There are limited flight vehicles currently flying, that is, aircraft specifically designed for research such as the famed X planes. NASA has tremendous potential and capital resources. However, the committee concluded that those resources could be better used to conduct the kind of flight research that would expect and inspire more future generations of aeronautical engineers and that is required to make advances on the frontiers of knowledge and functionality.

Our committee recommended that NASA should start from two to five focused, integrated, high-risk, high-payoff programs with total budgets of $30 million to $50 million per vehicle per program over three years. In order to achieve progress of fundamental aeronautics as well as other relevant related military requirements, we recommend that these priority-focused programs should be drawn from the high-priority research areas identified in the 2006 NASA Research Council Decadal Survey of Civil Aeronautics.

The committee concluded that additional funding for aeronautics was not a prerequisite for NASA to be able to begin to implement these recommendations. This can be done if the agency begins to phase out its lower-priority aeronautics activities, a process that we believe would facilitate implementing two to three new vehicles. If aeronautics receives additional funding, NASA could implement three to five vehicles. Naturally, there is a tradeoff between size of individual projects and the number that the agency could pursue. An ambitious UAV project, for example, could be built at the lower end of the range, while a more ambitious pilot vehicle could be built at the higher end. We encourage the agency to aim high in its ambitions.

The committee also recommended NASA aeronautics research projects have a defined path to flight, essentially a roadmap that indicates how they intend to conduct actual flight research. The like of such roadmaps leads to many current projects being canceled before they can be pursued to the flight phase and their progress is subsequently lost.

Our committee notably did not recommend more money for NASA's aeronautics program. However, we do believe that it could benefit from additional funding. If NASA's budgets shift only one percent from its total funding to aeronautics research, it would enable substantial new research in several vital areas of prime national interest. But in the current fiscal environment, we also believe the aeronautics program could benefit from reordering its priorities, establishing focused goals and eliminating several lower-priority research programs if flight research is to be a priority activity.

During the course of the study, the committee received inputs from industry including Boeing, Lockheed Martin Skunk Works, Aurora Flight Sciences and other companies. Despite what I believe is a common perception that aeronautics is so mature that NASA's research role should be limited, it is not an attitude that we encountered when we receive input from industry. Quite to the contrary, the attitude that industry presented to us is one in which NASA can play a vital role in helping to develop technologies that industry is too risk-averse to address. They want NASA to be involved doing what NASA does best and what they believe industry cannot do.

When asked the question of why should NASA be involved in aeronautics research, particularly conducting flight research, the committee concluded that industry in these economic and political times cannot and will not take on full-cost risk of moving technologies from laboratory to operations. NASA's founding charter tasked the agency to help within this process. NASA's role is to develop requirements and asset capabilities for the next research vehicles and then work with industry to build and test those aircraft. NASA is a highly capable organization with many excellent people in the area of aeronautics research. The contributions the agency has made and continues to make in aeronautical research are significant and, in my personal opinion, quite important. NASA's aeronautics research directorate should be more broadly recognized for these contributions. We were asked, the committee, to look at the area of flight research, and having conducted our study, we believe that we as a Nation have an opportunity to accomplish much more in this research area of prime importance if given the opportunity. If we give NASA the tools to take flight, we believe, they will soar.

Thank you for the opportunity to testify. I would be happy to answer any questions the Subcommittee might have.

[The prepared statement of Mr. Harris follows:]

Testimony of

Wesley L. Harris
Charles Stark Draper Professor of Aeronautics and
Astronautics and Associate Provost
Massachusetts Institute of Technology
and
Chair, Committee to Assess NASA's Aeronautics Flight
Research Capabilities
Division Committee on Engineering and Physical Sciences
Aeronautics and Space Engineering Board
National Research Council
The National Academies

before the

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

April 26, 2012

Mr. Chairman, Ranking Member Costello, members of the committee, colleagues, I am Wesley Harris, Chair of the National Research Council's Committee to Assess NASA's Aeronautics Flight Research Capabilities. It is a pleasure to come before you today to speak to you about the work of our committee. The National Research Council (NRC) is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology. In 2011 NASA asked the NRC to undertake a study of NASA's flight research capabilities. I am here to report on the results of that study.

Our committee consisted of members of industry and academia, former NASA aerospace officials, UAV designers, test pilots, and even an Apollo moonwalker with a strong interest in flight research. We met multiple times throughout 2011, visiting NASA centers involved in flight research and hearing from numerous NASA and industry representatives. We received extensive cooperation from the agency for which the committee is very grateful.

Many people may be aware that unmanned aerial vehicles (UAVs), sometimes referred to as uninhabited aerial systems, are a vital part of America's national security and a highly dynamic part of our aerospace industry, something where the United States remains the world leader. What few people realize, however, is that during the 1990s NASA played a major role in making this happen by supporting the development of multiple advanced UAV designs, thereby spawning the industry that is so active today. This was an industry where the United States was behind, and now it leads. That was NASA's flight research in action, not in the distant past, but relatively recently and in my personal opinion NASA should receive recognition for this achievement.

Currently NASA often calls for "game changing" ideas. Our committee concluded that in order to achieve game changing results in aeronautics, the agency has to conduct useful, efficient aeronautical flight research. However, in the course of the study, we found that NASA is only conducting a low level of flight research and we concluded that they should, and they can, do much more.

Flight research is only one part of a healthy aeronautics research enterprise, but it is a vital part. A common analogy is that aeronautics research is like a three-legged stool. One leg is simulation and modeling, taking advantage of powerful computing technology. Another leg of the stool is wind tunnel testing. The third leg is flight research—flying aircraft to test new theories, test new combinations of technologies, validate existing computer and mathematical models, and demonstrating and validating technologies and concepts so that they can be adopted by commercial and military operators and manufacturers. Remove one leg of the stool and it topples over. A commonly held misconception is that flight research is something that comes at the *end* of a research program; however, in many cases it is necessary in the middle of a program in order to validate aspects of the research. For instance, it is very common in the aeronautics world to update sophisticated computer simulations based upon data collected by actually flying a vehicle.

Since the middle of the last decade NASA has dramatically reduced its flight research to focus more on ground-based investigations and activities in what NASA describes as its "fundamental" aeronautical research. Today we see the results of that development. If you visit a NASA center involved in flight research, you will see very few programs that involve actual flying. In the committee's opinion, most flight research today can be characterized as limited in scope, such as putting a new structure on or under the wing of an existing airplane such as an F-15, or flying a small-scale UAV. There are almost no unique flight research vehicles currently flying, that is aircraft specifically designed for research such as the famed X-planes. NASA has tremendous personnel and capital resources, however the committee concluded that it is not using those resources to conduct the kind of flight research we would expect would inspire future generations of aeronautical engineers, or that is required to make major advances on the frontiers of knowledge and functionality.

Our committee recommended that NASA should start from two to five focused, integrated, higher risk, higher payoff, and interdisciplinary programs with total budgets of $30 to $50 million (per vehicle/program) over three years. In order to achieve progress for fundamental aeronautics as well as other relevant related military requirements, we recommended that these priority focused projects should be drawn from the high priority research areas identified by the 2006 NRC decadal survey of civil aeronautics.

The committee concluded that additional funding for aeronautics was not a prerequisite for NASA being able to begin to implement this recommendation provided that the agency phases out the majority of its lower-priority aeronautics activities—a move that we believe would facilitate implementing two to three new vehicles. If aeronautics receives additional funding, NASA could implement three to five new vehicles. Naturally, there is a tradeoff between the size of the individual projects and the number the agency could pursue—that is, more, smaller projects versus fewer, larger projects. As stated, the committee estimated that to make significant progress in each of the selected areas, the $30 million to $50 million (total over three years) would be the appropriate scope for such activities. An ambitious UAV project could be built at the lower end of that range, while a more ambitious piloted vehicle could be built at the higher end. For example, Sikorsky's piloted X-2 helicopter, which recently won the Collier's Trophy, cost approximately $50 million.

Our committee specifically mentioned the Collier's Trophy as an aspirational goal for NASA's aeronautics program. The Trophy is awarded for outstanding aeronautics achievement in the previous year. NASA has won the Trophy in the past and is capable of doing so again. Although our report does not recommend this, I personally think that NASA should consider approving new projects on the basis of their ability to compete for such a prestigious prize. The agency should aim high in its ambitions.

The committee also recommended that NASA's aeronautics research projects have a defined "path to flight"—essentially a roadmap that indicates how they intend to conduct actual flight research. The lack of such roadmaps leads to many current projects getting canceled before they can be pursued to the flight phase and their progress is subsequently lost. In addition, by failing to define such a path, many projects never even get started because their advocates determine that they can never get sufficient funding to conduct flight research. Thus, many promising research subjects are never explored.

Our committee notably did not recommend more money for NASA's aeronautics program. However, we do believe that it could benefit from additional funding—if NASA's budget shifted only one percent of its total funding to aeronautics research it would enable substantial new research in several vital areas of prime national interest. But in the current fiscal environment we also believe that the aeronautics program could benefit from reordering its priorities, establishing focused goals, and eliminating lower-priority research programs if flight research is to be a priority activity.

The committee selected three areas of NASA aeronautical research as case studies. We selected these subjects because NASA has already made substantial progress in them—a fact the agency should be commended for—and we believed each of these areas are at the point where transitioning to flight research could produce significantly more progress. The detailed case studies enabled the committee to assess the essential strengths and weaknesses, challenges and opportunities in NASA aeronautical flight activities. These areas were environmentally responsible aviation, supersonics, and hypersonics.

Environmentally responsible aviation essentially involves developing highly fuel efficient aircraft that produce little noise. This is important because of rising fuel prices, and the encroachment of residential areas upon airports, as well as the increasingly strict noise and pollution regulations that are being imposed upon aircraft, particularly in Europe. If the United States is to remain a world leader in commercial aviation, we must be able to sell competitive aircraft to airlines around the world. The committee found that NASA could make substantial research leaps by developing a large scale aircraft that integrated many relevant technologies. Such aircraft might look radically different than those that people fly in today. NASA could develop this technology in concert with other government agencies as well as commercial industry.

In the area of supersonics, NASA is on the cusp of making a substantial leap that could create an entire industry of small supersonic passenger jets, just as NASA helped to create the modern UAV industry in the late 1990s. The agency has already performed considerable research into so-called low-boom technology, or aircraft that do not produce the loud sonic boom that prevents supersonic aircraft from operating over most of the United States. If NASA were to build a research aircraft, it could demonstrate that such vehicles could fly across the United States without producing loud sonic booms and with only a slight increase in fuel burn. This could put the United States at the forefront of such development.

Hypersonics is another area where NASA has developed great expertise over the years. We found that the agency could better focus its efforts on development of a hypersonic vehicle capable of high-speed, relatively long duration flight. Naturally, NASA would support DoD research in this area.

During the course of our study, the committee spoke with various representatives from industry, including people from Boeing, Lockheed Martin's Skunk Works, Aurora Flight Sciences, and other companies. Despite what I believe is a common perception that aeronautics is so mature that NASA's research role should be limited, that is NOT an attitude that we encountered within industry. Quite to the contrary, the industry representatives we talked to believed that NASA can play a vital role in helping to develop technologies that industry is too risk averse to address. They want NASA to be involved, doing what NASA does best, and what they believe industry cannot do.

When answering the question of "why should NASA be involved in aeronautics research, particularly conducting flight research," the committee concluded that industry in these economic times cannot and will not take on the full cost risk of moving technologies from the laboratory to operations. NASA's founding charter tasks the agency to help with this process. NASA's role is to develop requirements for the next research vehicles and then work with industry to build and test those aircraft.

Some of the potential areas that industry said NASA could help with are:

- Collecting high-altitude atmospheric data that could be used in the design of new high-altitude UAVs. This includes characterization of high-altitude turbulence, which is fundamental to understanding the aeroelastic effects on flight vehicles as well as characterizing the radiation environment at high altitudes, which could affect avionics systems. NASA currently has assets such as the U-2 and WB-57 high-altitude aircraft, as well as balloons, capable of gathering this data.
- Conducting research on pilotless commercial aircraft, perhaps starting with unpiloted cargo aircraft.
- Conducting research into electric aircraft propulsion and electric vehicle subsystems.
- A larger-scale experimental aircraft to explore ERA and N+3 technologies. This would be bigger than the X-48C, with a wingspan of perhaps 40 to 50 feet (compared to 21 feet for the X-48B). The cost of such a vehicle, according to an aerospace company with experience producing similar vehicles, could be in the range of $25 million to $60 million.
- Initiating programs to develop low-cost ($30 million to $50 million) innovative flight research vehicles, to demonstrate new technologies such as lift fan and fan-in-wing for a high-speed VTOL, or to gather useful data in the transonic or supersonic flight regimes.
- Conducting research on autonomous systems and the interaction between human operators and autonomous systems.

- Conducting research on hybrid propulsion, especially electric, quiet powered, distributed lift concepts, especially those enabled by hybrid electric systems, and quiet trans- and supersonic small aircraft for both commercial and military applications.

NASA cannot and should not go it alone. Our report contained the following recommendation:

> **Recommendation: NASA aeronautics should aggressively pursue collaboration with DOD, FAA, the U.S. aerospace industry, and international aeronautics research agencies. NASA should adopt management practices to facilitate effective collaboration and treat external organizations as customers and partners. NASA leadership should develop a formal process for regularly soliciting input from the U.S. aerospace industry and universities as well as key government agencies to assure the relevancy of its flight research programs to national needs.**

Although NASA is currently involved in numerous cooperative efforts, our committee heard from other government agency representatives that NASA often participates in cooperative efforts, but does not always bring its own resources to the table. In order to maximize its effectiveness, NASA should provide funding for all its cooperative efforts.

Despite an outstanding history of NASA-led aeronautics flight research successfully transitioning to the U.S. aerospace industry, NASA could be more effective in identifying and communicating these accomplishments to key stakeholders within industry, government and academic institutions. One aspect of communication to stakeholders is the effective dissemination of technical data to relevant aerospace researchers after a flight research program is completed. Prior National Advisory Committee on Aeronautics (NACA—NASA's predecessor) reports, generated more than 50 years ago, are rich resources of information for the aerospace community to this day and are relatively accessible. However, more recent NASA aeronautics flight research programs have generated useful data that is relatively inaccessible to aerospace engineers and scientists. This led our committee to the following recommendation:

> **Recommendation: NASA aeronautics should become the nation's repository of flight research data and flight test results and should make these archival data readily accessible to key stakeholders—the engineers and scientists in industry, academia, and other government agencies. NASA should also require principal investigators in flight research projects to publish their results and provide funding for them to do so.**

NASA's flight research inventory is a mix of vehicles that are currently distributed across NASA centers, including Dryden Flight Research Center, Glenn Research Center, Ames Research Center, and Langley Research Center. NASA may be able to achieve greater efficiencies by designating a single center as the primary flight research center for the agency. We recommended that NASA study this possibility, fully aware that some flight research aircraft may be best supported at locations around the country. However, the current level of flight activity is so low that consolidation may free up valuable funds.

NASA is a highly capable organization with many excellent people in the area of aeronautics research. The contributions the agency has made and continues to make in aeronautical research are significant and in my personal opinion the importance of the work done by NASA's Aeronautics Research Mission Directorate should be more broadly recognized. However, we were asked to look at the area of flight research and having conducted our study we believe that we as a nation have an opportunity to accomplish much more in this research area of prime national importance if given the opportunity. If we give NASA the tools to take flight, we believe—I believe—they will soar.

Thank you for the opportunity to testify. I would be happy to answer any questions the Subcommittee might have.

Chairman PALAZZO. Thank you, Dr. Harris.

I now recognize our final witness, Dr. Tracy, for five minutes to present his testimony.

STATEMENT OF DR. JOHN TRACY, CHAIR, NATIONAL RESEARCH COUNCIL'S AERONAUTICS RESEARCH AND TECHNOLOGY ROUNDTABLE, AND CHIEF TECHNOLOGY OFFICER AND SENIOR VICE PRESIDENT OF ENGINEERING, OPERATIONS AND TECHNOLOGY, THE BOEING COMPANY

Mr. TRACY. Good morning, Chairman Palazzo, Ranking Member Costello, and Members of the Committee. On behalf of The Boeing Company, I thank you for your continued support of NASA. You have enabled NASA to create a balanced aeronautics portfolio that continues to enhance the safety, reliability, and efficiency of the world's aviation community. It is an honor to participate on this distinguished panel and provide Boeing's view on aeronautics research and the efforts of NASA's Aeronautics Research Mission Directorate.

In my role as Chief Technology Officer for Boeing, I have the great challenge to help our company identify how to invest in our future. The topic is central to Boeing's existence as we work to build on a 96-year legacy of technical achievement. These investments enable our role as a global leader in technology and innovation and ensure that our 172,000 employees design and create cutting-edge products sought by customers worldwide. We agree with the current NASA aeronautics policy, which states that the agency should focus on safer, more secure, efficient and environmentally progressive air transportation system. We also support the strategy of NASA's investments in the fundamental basic questions of how to improve the technology of our process to more complex systems-level questions of how best to integrate those new technologies in operational concepts.

My written testimony fully addresses the three questions that were asked by the Committee. For this hearing, I would like to summarize these responses. I will begin by discussing what I believe are the three biggest challenges in aerospace and how well ARMD's research portfolio and resources address them.

The first challenge is the wholesale change to the Air Traffic Management System. We are working with partners worldwide to improve today's global air traffic management system in order to enhance aviation safety, improve operational environmental efficiency, and enable continued growth in global air travel. Our view of a transformational system is based on satellite navigation that takes advantage of sophisticated airplane flight management systems and other advanced technologies. NASA is a critical member of the FAA NextGen team, which is implementing a plan for the ongoing transformation of the National Airspace System from ground-based to satellite-based.

The second challenge is aviation systems and solutions that are environmentally responsible. We at Boeing are committed to improving the environmental performance of our operations, our products and service and our factories. Our new 787 Dreamliner airplane burns 20 percent less fuel and has a noise footprint that is as much as 60 percent smaller than today's comparable airplanes. The technology areas in which we are engaged include fuel efficiency and noise reduction, sustainable aviation biofuels, more efficient flight operations, and airplane production and recycling. These areas align with the aims of NASA's environmentally responsible aviation program, whose goals include noise reductions of 42 decibels below current levels, a 75 percent reduction in emissions, and a 50 percent reduction in fuel burn below today's standards.

The third challenge is advanced testing and evaluation by analysis and simulation for integrating complex aviation systems and accelerating their verification and validation. A future NASA focus on fundamental technologies and multidisciplinary processes for faster and more efficient design and certification through high-fidelity virtual testing would increase opportunities to develop and field new vehicle systems. Software development and certification is a large and growing cost to civil aviation. This complex systems engineering including verification and validation and fundamental software engineering needs to be addressed through long-term research.

Now I would like to address ARMD's strategy of supporting a broad portfolio of research and the question as to whether ARMD at its current funding levels would be more effective by focusing its resources on high-priority activities such as flights that Dr. Harris mentioned. In our view, NASA has done an excellent job of addressing the critical subset of aviation issues in its broad portfolio. The agency continues to work with aeronautics stakeholders to prioritize current initiatives within budget constraints. This fundamental research is the seed corn that forms the basis for next-generation capabilities. But in light of current funding levels, NASA has been limited in its ability to do flight research, which is key to the next step in maturing its fundamental research into a dynamic flight regime. Based on historical costs associated with flight demonstration, further emphasis in this activity would need to be above and beyond the budget level that NASA ARMD receives for this critical research.

Lastly, I would like to offer my perspective on whether ARMD advances technologies to a state of maturity that enables their adoption by industry. The commercialization of aeronautics knowledge into products and services for the market is the responsibility of private industry. NASA has played an invaluable role in creating a foundation of knowledge that can be deployed by industry to serve the public. For instance, NASA, like its European counterpart, has been funding research into improving the Air Traffic Management System. It is critical, of course, that the collaborative NASA and industry research activity be consistent with the obligations of our trade treaties but there is much valuable work for NASA to promote within these bounds.

In closing, funding NASA's aeronautics activity in a balanced portfolio is, in our opinion, the right approach. NASA's work supports efforts to advance the safety, reliability, and efficiency of the Nation's aviation system and the work NASA is doing for improving the environmental footprint for aviation is absolutely critical for our country's future. The balanced portfolio will help America strengthen its global stature as a leader in technology.

I appreciate very much the opportunity to testify in front of this Committee today.

[The prepared statement of Mr. Tracy follows:]

Committee on Science, Space and Technology
'An Overview of the NASA Aeronautics Research Mission Directorate's Budget for Fiscal Year 2013'
Testimony of Boeing CTO and Sr VP EO&T, John Tracy

INTRODUCTION:

Good morning, Chairman Palazzo, Ranking Member Costello and members of the committee. On behalf of The Boeing Company, I wish to convey our gratitude for your continued support of NASA. Your efforts have enabled NASA to create a balanced aeronautics portfolio that continues to enhance safety, reliability, and efficiency of the world's aviation community. Without your committee's support, these continuing advancements would not be possible. It is an honor to be a participant on this distinguished panel and provide Boeing's view on aeronautics research and the efforts of NASA's Aeronautics Research Mission Directorate.

In my role as Chief Technology Officer for Boeing I have the great challenge to help our company identify how to invest for our future. This topic is central to the existence of Boeing, as we work to build on a 96-year-old legacy of awe-inspiring technical achievement. Our products include the revolutionary 787 Dreamliner airplane, the first true commercial jetliner of the 21st century. In 2011, our total research and development expense amounted to $3.9 billion. Our investments in future technologies will enable us to strengthen our role as a global leader in technology and innovation. And just as importantly, these investments will help ensure that our 172,000 employees design and create cutting-edge products that are sought by customers worldwide. We at Boeing are proud to be the Nation's No. 1 exporter, and our diligent, talented team is working hard to ensure we retain this esteemed rank.

I would like to discuss a forum that was initiated August 25, 2011, by the National Research Council. This forum is called the Aeronautics Research and Technology Roundtable, and I serve as its Chair. This forum convenes the senior-most representatives from government, industry, and universities to define and explore critical issues related to the nation's aeronautics research agenda that are of shared interest. It is designed to facilitate candid dialogue among participants, foster greater knowledge among the aeronautics community, and carry awareness to the wider public. This forum is just one source for NASA's Aeronautics Research Mission Directorate (ARMD) planning activities for the future of aeronautics. And as the Roundtable meetings continue, they will be a powerful forum for a range of industry stakeholders to contribute to the dialogue about the Nation's investment in aeronautics research.

We agree with the current NASA Aeronautics policy that the agency should focus on enabling a safer, more secure, efficient, and environmentally friendly air transportation system. We also support the strategy of NASA investments in the fundamental, basic questions of how to improve a technology or a way of doing something, to more complex, systems-level questions of how best to integrate those new technologies and operations concepts. The advances NASA makes, which are available for the benefit of the entire aeronautics industry, result in characterizing the maturity, efficacy, and applicability of technology to the entire aviation community. It is then up to industry to privately finance the development of products, systems, and services, with or without these technologies, for commercial markets.

We were asked today to comment to three questions about the future of aeronautics at NASA. I will discuss my thoughts on those now.

Question 1. What do you consider to be the three biggest challenges confronting the aerospace industry, and how well does ARMD's research portfolio, and its resources, address them?

First, the three biggest challenges we see for the aerospace industry in aeronautics research are:

1. a wholesale change for the Air Traffic Management system,
2. aviation systems and solutions that are environmentally responsible, and
3. improvement of analytical and simulation tools for integrating complex aviation systems and accelerating verification and validation for certifications.

I will talk about each of these areas in a little more depth to outline how we believe ARMD's research portfolio, and its resources, address them.

1. Air Traffic Management – Today's airspace users are grappling with the challenges of managing an ever-growing amount of air traffic. Outdated infrastructure and operating methods hamper the industry's ability to operate efficiently. So we are working with partners around the world to improve today's global air traffic management (ATM) system. These upgrades will enhance safety, improve operational and environmental efficiency, and prepare for the expected growth in global air travel. Our view of a transformational system is based on satellite navigation that takes advantage of sophisticated airplane flight management systems and other advanced technologies. Key elements of this system include digital command and control, trajectory-based operations, satellite-enabled technology and the integration of ground systems that support the capabilities of modern airplanes and secure network-centric operations. To advance the required technologies needed for a transformational system, we are involved in numerous global research and development contracts. They include, most notably, the Next Generation Air Transportation System (NextGen) with the U.S. Federal Aviation Administration (FAA) and Single European Sky ATM Research (SESAR) in Europe.

   NASA is a critical member of the FAA NextGen team which is implementing a plan for the ongoing transformation of the National Airspace System (NAS). NextGen represents the evolution from a ground-based system of air traffic control to a satellite-based system of air traffic management I mentioned before. As a part of their contribution we see the need for NASA to conduct extensive research on fundamental technology that will need to be integrated into future solutions for air traffic management. Safety is always a top focus item especially as automation and autonomy like that in Un-crewed Aerial Systems (UAS) enter the National Airspace System. Automation and autonomy are examples of key technologies that can be applied to all vehicle types and every sector of aviation that present high potential solutions for reducing cost, increasing performance, enhancing safety, driving efficiency and enabling new operational modes for the transportation industry.

2. Environmentally Responsible Aviation –We at Boeing are committed to improving the environmental performance of our operations, products and services. In the nearly 40 years of the jet age, fuel consumption and carbon emissions have been reduced 70% and jet noise footprints brought down 90%. And we intend to continue this progress by incorporating technologies that will make our products and operations even more environmentally progressive. As an example of this commitment, our new 787 Dreamliner airplane burns about 20% less fuel and has a noise footprint that's as much as 60% smaller than today's comparable airplanes.

   Our strategy is to lead the way in pioneering new technologies for environmentally progressive products and services – which we design, develop and build in an environmentally responsible manner. We are also committed to working together with customers, agencies, suppliers, and others to improve the aviation industry's environmental performance. We see this as critical to building a more sustainable future. The technology areas in which we are engaged include fuel efficiency and noise reduction, sustainable aviation biofuels, more efficient flight operations, and airplane production and recycling. These engagements have led to environmental achievements such as successful biofuel test flights on numerous commercial airplanes, as well as a U.S. Navy F/A-18E/F Super Hornet fighter jet; reductions in energy and water consumption across our company, even while we have increased production; and the opening of a new factory near Charleston, South Carolina, that was built to meet federal energy net-zero standards. And to quickly touch back on the benefits of upgrading our air-traffic management system, I'd like to note that if system improvements could reduce every flight by one minute, we could reduce carbon dioxide emissions by 4.8 million tons per year.

   In the NASA Environmentally Responsible Aviation (ERA) program it was recognized in 2010 that the combined reality of persistently strong growth in air traffic and the vital economic role of the air transport system result in continued demand for the progress of technology for the reduction of aircraft noise, emissions of oxides of nitrogen, and fuel burn. As stated for their goals in the program, ERA targets noise reduction of 42 decibels below current levels, a 75% reduction in emissions, and reduction of fuel burn of 50% below today's standards. This critical research includes evaluation of alternate aircraft configurations and in the future will need to include electric and hybrid propulsion systems which have high potential to be transformational enablers. NASA will complete the ERA Phase I investigations at the end of fiscal year 2012, and is expected to move directly into a three-year Phase II with continued inputs from industry, academia, and other government agencies.

3. Advanced Testing and Evaluation – Our journey at Boeing over the last few years has resulted in us integrating critical functions into one organization to support the enterprise – known as Engineering, Operations & Technology (EO&T) – to efficiently and effectively support our business. Among the integrated teams that serve our entire Boeing enterprise is Boeing Test & Evaluation, which ensures the safety and integrity of all Boeing products and services by validating that they operate as designed and meet the rigorous requirements of regulatory agencies and Boeing customers.

   Where NASA can be focused in the future is on fundamental technologies and multidisciplinary processes that can accelerate product development, test and evaluation through analysis and simulation to provide rapid validation and verification for quicker certifications with regulatory agencies. The activities NASA currently has in its portfolio include: Aeronautics Test Program, Airspace Systems Program, Aviation Safety Program, Fundamental Aeronautics Program, and Integrated Systems Research Program. As well, the agency is a partner with the FAA on the NextGen Program I discussed earlier. Within these programs, NASA has projects covering many critical areas including items for advanced air traffic management such as Concepts and Technology Development Project and Systems Analysis, Integration & Evaluation Project. In the Aviation Safety Program the agency has three research projects that cover the top 10 technical challenges for safety (Assurance of Flight Critical Systems; Discovery of Safety Issues; Automation Design Tools; Prognostic Algorithm Design; Vehicle Health Assurance; Crew-System Interactions and Decisions; Loss of Control Prevention, Mitigation, and Recovery; Engine Icing; and Airframe Icing). In the Fundamental Aeronautics Program, NASA researches four technology areas that promote future capabilities for configurations with subsonic fixed wing, subsonic rotary wing, supersonics, and hypersonics. Finally, the Integrated Systems Research Program includes two research areas, Environmentally Responsible Aviation Project, and UAS in the National Airspace System Project.

   In this third critical area people in our community have said that there is a continued need for research and technologies to achieve substantial structural, propulsive and aerodynamic efficiency improvements in all vehicle classes. For example, the transition to composite structures in commercial aviation provides extensive research opportunities to further advance and integrate materials, structures, and manufacturing processes. Faster and more efficient design and certification, through high fidelity virtual testing, would increase opportunities to develop and field new vehicle systems. Software development and certification is a large and growing cost for civil aviation, especially for complex, integrated software-intensive systems; this, complex systems engineering, including verification and validation, and fundamental software engineering need to be addressed through long-term research. Given the increasing integration of information systems in vehicle design and operations, future system architecture designs should account for cyber-security risks.

Question 2. What are your views about ARMD's strategy of supporting a broad portfolio of research? Given current funding levels, would ARMD be more effective by focusing its resources on high priority activities? How would you gauge their tolerance for risk across its research portfolio?

Part 1. What are your views about ARMD's strategy of supporting a broad portfolio of research?

In our view the portfolio of research underway with NASA covers the spectrum of critical issues facing general aviation today. NASA would be remiss in their responsibility to the flying public to address the challenges that still exist in our nation's air transportation system if the breadth of their current portfolio were reduced. NASA continues to work with aeronautics stakeholders to prioritize their current portfolio initiatives within budget constraints and has done an excellent job of addressing the critical subset of aviation issues. We support the intent to restore flight demonstrations to NASA's portfolio to compliment fundamental capabilities and technologies, as flight demonstrations provide the validation and a pathway to encourage further maturation and adaptation into general aviation.

Part 2. Given current funding levels, would ARMD be more effective by focusing its resources on high priority activities?

As we have learned within Boeing it is important to have a critical mass of investment to be able to accomplish technical objectives in research activities. We believe the research we see NASA performing and the way they are investing as appropriate for the funding levels they currently have. This fundamental research is the seed corn that forms the basis for next generation capabilities. Flight research is the next step in maturing NASA's fundamental research to validate analysis and wind tunnel results in a dynamic flight regime.

Based on historical costs associated with flight demonstration, further emphasis in this activity should be above and beyond the budget level that NASA ARMD already receives for the critical research it is already doing. Costs associated with flight research are directly related to the complexity of the demonstrator, and can be controlled by the limiting the inclusion of technologies to those deemed critical or enabling to the goals of the program. While fundamental flight research is a critical element in maturing aeronautics technologies, significant research and development efforts are still required before any of these technologies can be integrated into a commercial or military aircraft. As the results of NASA's fundamental research are shared openly to improve global aviation, the aviation industry looks to NASA to have responsibility for the preponderance of flight research funding.

Part 3. How would you gauge their tolerance for risk across its research portfolio?

They way NASA is investing today demonstrates that they have reviewed their risk factors to decide which technology areas make the most sense for them to engage. In their current funding level and the way the portfolio is laid out, they are able to manage risk well.

Question 3. From your perspective, does ARMD advance emerging technologies to a state of maturity that enables their adoption by industry?

Ultimately, the commercialization of aeronautics knowledge into products and services that serve the market is the responsibility of private industry. NASA has played an invaluable role in encouraging and helping to fund the development of a foundation of knowledge that can then be leveraged by industry to serve the public. For instance, NASA, like its European counterparts, has been funding critical foundational research into automating the air traffic management system with the goal, among other things, to increase safety and decrease the environmental impact of aviation. That kind of research is critical to future of the air travel and of our planet. It's critical of course that collaborative NASA and industry research activity be consistent with the obligations of our trade treaties, but there is much valuable work for NASA to promote within those bounds.

Conclusion

In closing, funding NASA's aeronautics activities in a balanced portfolio is the right approach to advancing the safety, reliability, and efficiency of the aviation system. The world needs to upgrade the Air Traffic Management system to support the economic growth that comes from a robust commercial aviation industry and to reap the environmental benefits of a more effective system. Our future is going to include automated systems in the National Air Space and NASA is contributing hugely to efforts to enable that to happen. The work NASA is doing for improving the environmental footprint for aviation is critical for our country's green future. This balanced portfolio will help America strengthen its global stature as a leader in technology.

Chairman PALAZZO. Thank you, Dr. Tracy, and I thank the panel for their testimony. I will remind members that Committee rules limit questioning to five minutes. The Chair will at this point open the round of questions. The Chair recognizes himself for five minutes.

Dr. Shin, I am going to have three related questions. First, how does NASA ensure that its portfolio of fundamental research projects remains relevant and that research projects don't become stale? Second, what mechanism does NASA have in place to determine when fundamental research should be advanced to a higher level or, alternatively, to cease further investment in research results if they are disappointing? And third, as you look across your portfolio, what is an appropriate balance between fundamental and higher integrated levels of research?

Dr. SHIN. Thank you, Chairman. I think, on the first question, we have now several national-level guidance documents starting from national aeronautics R&D policy and plan, which we as a Nation never had for almost 100 years since the Wright brothers powered flight was accomplished. So that policy and plan was developed by all the departments and agencies that have any stake in aeronautics R&D and certainly NASA, DOD, FAA and Commerce and Homeland Security are pretty major players there. So out of those goals and objectives identified in the national-level document, we have constructed our research portfolio aligned with that and also we have Joint Planning and Development Office, the JPDO, which is consisted of seven Federal Government agencies. So I think, in terms of identifying the national challenges, many of the witnesses spoke about the same kind of areas for national needs—safety, NextGen, environmental impact and energy-efficient aircraft. I would be happy to report to you, Chairman, the NASA programs are well aligned with those national-level challenges. To further the relevance, we have reorganized aviation safety program and airspace systems program in the last three years and we are also reorganizing, in the process of reorganizing fundamental aeronautics program this year. So we are far more focused and streamlined and much more relevant to users' needs, and there are ample evidence that we are transferring technologies to the users. So a longwinded answer but that would be my response to the first question.

And higher-level activities, if we don't produce intended results from sort of low-technology readiness-level research, how do you phase that out or cancel that activity? I think that was your second question. I would like to describe our research portfolio and endeavor as organic. Certainly, the research needs to be nimble because we don't know how the research will pan out. That is the major high risk of high-payout research. So we do have a rigorous review process both at the research centers and headquarters periodically, and as I am speaking, we are actually conducting a six-month review at headquarters of all our projects. So going through these reviews, we make sure that progress is being made, and if we don't make the intended progress, we certainly take the lessons out of it and then we phase the activities. We have done many of those to date.

In terms of balance between fundamental research and a little higher level of research, I believe within the given budget that Congress graciously allowed us to have $570 million this year. Within that budget, I believe the proportion between fundamental research and integrated system-level research is about right from all the community inputs and discussions we had, and given my experience, having been in aeronautics for 20-some-odd years, I think it is very important to note that maintaining fundamental research is crucial for the future of our aviation industry as Dr. Tracy pointed out, that you don't want to eat your seed corn to beef up higher-level research if the funding is such that you have to make a balance. Sorry for the long answer.

Chairman PALAZZO. No, thank you, Dr. Shin.

I now recognize Mr. Costello for five minutes.

Mr. COSTELLO. Mr. Chairman, thank you. We all recognize that we are facing many challenges with the federal budget because of deficits, but I think we also recognize, at least most people in the industry, that the historical decline of NASA's aeronautics budget has had a negative impact on the industry. And I am wondering if the aeronautics program at NASA was given sustained funding over a period of time as opposed to just an infusion of funds in one fiscal year, what would be the most productive use of the additional funding? And I would ask Dr. Shin, what would you do with the additional funding if you knew that you were going to see an increased funding level over the next five years as opposed to the infusion of funds one year and then a reduction the following year? What would the number one priority be?

Dr. SHIN. Thank you, Ranking Member Costello. I think the number one priority would be in my view, again, doing more flight research and bringing X plane into our research mix. We do have a few test paths, but I think we can certainly do more. So that would be my most priority, sir.

Mr. COSTELLO. Ms. Blakey, I would ask the same question of you. One, first, would you agree with most in the industry that the historical decline of aeronautical funding has had a negative impact, number one, and number two, if, over the next five years or so, if we saw an increased level of funding to NASA, what do you think the number one priority should be for the agency to do with the additional funding?

Ms. BLAKEY. Certainly there is no doubt about the fact that our technological advances, which is what this country is known for, would have gone much faster, and it is hard to know what we don't know, what we didn't do because of the rather precipitous decline in NASA's budget. As we all understand, they were well above $1 billion for many years and over $2 billion, and now we are in the $500 million range. You cannot have that kind of reduction without having a major impact in terms of our innovation and technologies across the aviation and aeronautics industry. Flight research is critical. There is nothing that substitutes for building it and flying it.

And in the area that I highlighted, hypersonics, there is tremendous potential. I will show you something because I saved this. This is a brochure from 1986, and it shows our plans for the national aerospace plane. It is a beautiful thing, and this is what our country had in mind and President Reagan called for, but we simply were not able to engage in this at the time, and hypersonics still offers a potential for continent-to-continent rapid flight, propulsion into space and really inspiring young people in a way that we haven't seen since the Apollo program. So I would suggest, let us not leave this behind; it is a part of fundamental research and it should be a part of flight test.

Mr. COSTELLO. Let me ask another question of you, Ms. Blakey. You and I have worked together on NextGen through the Aviation Subcommittee. One of the problems that the FAA has had, and it has been cited as to why NextGen has fallen behind on the schedule, on the proposed schedule, by both the FAA and the JPDO, is that the FAA underestimated the complexities of the software development to implement NextGen. With NASA's vast knowledge in developing automated systems, I wonder if there is anything in your opinion that NASA could be doing to help the FAA with this problem?

Ms. BLAKEY. Well, I will be honest about this, because I was there at the early stages of NextGen when we were looking for more research capability out of NASA, and because NASA at that point had a very strong emphasis on fundamental basic research and not taking it to the higher TRL levels, we found a gap, and I talked to Mike Griffin about it and others at the time because I think that would have helped FAA advance itself much more quickly.

I will say this. As you know, in my current position, I have reason to work with a lot of very fine minds in the defense arena, and I have heard more and more their comments about NextGen, saying it is the most complex development program they have run across, and you know what the military in this country has done. So it is not easy. I do want to caution on that, and I think there are inevitably, therefore, schedule slips that occur.

But that said, NASA's current approach to transferring software that works in terms of a lot of the capabilities of NextGen, it really is a vital asset. So I hope we will be able to keep it up.

Mr. COSTELLO. Dr. Harris, you mentioned in your testimony that the Committee didn't recommend additional funding. I wonder, going back to my first question, if the agency knew that over the next five years that they were going to receive sustained funding and increase, what would be the number one priority in your opinion? Where should they direct that money?

Dr. HARRIS. Thank you for the question. The Committee was, I thought, very firm in its position in terms of a focus on flight research that would lead to substantial advancement of aeronautics for the less. We examined three cases in depth. We also looked across all of the programs within ARMD. We firmly believe that resources should be directed toward those highly focused, highly integrated projects that require flight research that would lead to a spawning of an industry.

For example, business jets. How do we move NASA to flight research to ensure that we can fly within limits of the sonic boom that it is not a nuance or a noise inhibitor? That, we believe, is a major breakthrough that we are on the edge of, and if we move forward with that and similar kinds of research, we will enable the development of more high-skilled, high-wage jobs, more market share for our industry, a positive return to our taxpayers' investment.

If NASA were to obtain sustained funding, it should continue to focus or should focus on high-payoff flight research that leads to an advancement of our industry.

Chairman PALAZZO. I now recognize the gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. I am a bit perplexed by this; we all are. We have half the budget for the federal budget is being borrowed now. We are spending that much more than we are taking in. It is over $1 trillion a year. So I imagine everybody in this room knows that something has to be done, and it seems that every time you are a member of a committee that focuses on one aspect of the budget, it is always the other guys who need to be cut.

I think $500 million is a lot of money, and I know it is less than what we had before. It was less than the $1 billion that we had before. First of all, let me ask Dr. Shin. How many people will be laid off as a result of this?

Dr. SHIN. No one would be laid off, sir, because the current budget has been stable for the past three or four years. So we have budgeted or constructed our work and the work force to the budget. So no one will be laid off. This budget reduction that some of the witnesses mentioned happened years ago.

Mr. ROHRABACHER. Okay. So actually the reduction from $1 billion to $551 million will not result in a layoff of federal employees?

Dr. SHIN. No, sir.

Mr. ROHRABACHER. Well, I think that is important. I mean, I don't understand why it is when the private sector has to cut back that people are let go, realizing that they can no longer afford their work, but we can't seem to let go of any federal employees.

Let me ask about the private sector here, especially Boeing company. First of all, if Boeing was going to have this reduction in the amount of money available to Boeing, I would imagine there might be a few layoffs, is that correct?

Dr. TRACY. Mr. Rohrabacher, in a commercial setting, I think that is true. If there are reductions in budget, then you have to find ways to balance the books.

Mr. ROHRABACHER. You might even reduce the number of projects that you were working on.

Dr. TRACY. Yes, sir, that is true. I am an engineer, not an economist, sir, so forgive me. My feeling is that the NASA budget that we are talking about here is an investment to try and drive, from our perspective, a large sector of the economy. I believe that commercial aviation is probably the largest contributor to positive balance of trade, and it literally is a significant fraction——

Mr. ROHRABACHER. No doubt about it.

Mr. TRACY [continuing]. Of major post-domestic product. So that is why we are interested, because this research does make a great contribution to that.

Mr. ROHRABACHER. Well, I am not sure. If we can actually cut the budget and you don't have to let anybody off, I mean, this is— I know you are an engineer, and engineers, maybe if you could make the same thing with fewer people, I mean, we are keeping the same people. Usually you would say you are going to have to be doing less. If you have less money, you have less personnel.

Let me just suggest that there is a lot of research going on in the private sector, and maybe Ms. Blakely could tell us about that, research that is going on in the private sector. Can they pick up, can companies like Boeing and others pick up hardware costs? It sounds like to me if you are not going to reduce the number of people working, what we are reducing is wind tunnels and things such as that. Is it possible that the private sector could pick up those capital costs that are now being funded by the government?

Ms. BLAKEY. Well, Congressman Rohrabacher, as you know from a number of the companies that you know very well, they do tremendous amounts——

Mr. ROHRABACHER. They do.

Ms. BLAKEY [continuing]. Of R&D work. And they also work in close partnership with NASA. They lease the use of those wind tunnels, pay good private-sector money to be able to take advantage of what essentially is an investment the government made to make this early innovation happen. Tremendous amounts of R&D go from our companies into the air and fly. What they are not able to do though is this very fundamental basic research which is where government always has had an important role. That then translates to the kind of technological advantage we enjoy worldwide. But it has always come, almost always, and I won't say always because there were the Wright brothers. I don't think they were working on a government grant. But the fact of the matter is a great deal has come from the military's research and from research at NASA.

Mr. ROHRABACHER. Mr. Chairman, I would suggest that while I am very supportive of the development technology, that my guess sometimes when people cut back, sometimes it makes different operations demand more efficiency. That is what happens in the private sector. It is a little bit disconcerting to know that we are cutting back, and there isn't any change in personnel. That does not reflect to me the way things should go.

And one last note and that is if we spent $551 million on this research, my guess also is that we are providing a subsidy to those countries that steal our technology and steal the research. Thus, we are not just carrying the load for our own businesses. We are carrying the load for China's new space program. Hunky dory. Thank you very much, Mr. Chairman.

Dr. SHIN. Sir, could I offer just one thought?

Mr. ROHRABACHER. Sure, go right ahead.

Dr. SHIN. I want to make——

Mr. ROHRABACHER. Proceed.

Dr. SHIN. Yes, I want to make sure that my response earlier was not misunderstood. When aeronautics budget was close to $1 billion or a little bit over $1 billion back in late 1990s, of course we had a lot more people working on aeronautics. So I want to make sure that the response that I provided to you, sir, was for $570 million level budget, that has been going on three or four years. And because of that, the reduction happened many years ago and the number of workforce working on aeronautics has come down quite a bit.

Mr. ROHRABACHER. Yeah, I don't quite understand that. I thought we were talking about budget reduction here.

Dr. SHIN. That budget reduction happened many years ago, several years ago.

Mr. COSTELLO. I wonder if my friend from California would yield?

Mr. ROHRABACHER. Well, actually, it is the Chairman's time. Mr. Chair.

Chairman PALAZZO. We are being pretty flexible with the five-minute rule today, so if Mr. Rohrabacher wants to——

Mr. ROHRABACHER. Sure, go right ahead.

Chairman PALAZZO [continuing]. Give you what time he has left.

Mr. COSTELLO. I want to clarify a point here just for my information, because I think Mr. Rohrabacher makes some pretty good points here, but one is that this isn't a $500 million reduction from one year to the next. This has gone back three or four years. Two, I don't know the level of funding that NASA uses out of when you were at $1 billion or if you are at $551 million. How much of that money actually stays in the agency and supports employees in-house versus what you contract out to many private-sector companies that are members of Ms. Blakey's association? Am I wrong about that? Is all the $551 million, if that is what the funding level is, does that all stay in house or you contract out with Boeing and many other companies to do research with NASA, is that correct?

Dr. SHIN. Yes, that is very correct. We do support in-house capability because that is one of the charters for NASA aeronautics. But roughly I think about 40 to 45 percent goes out to out-of-house to certainly industry and universities and others.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

Chairman PALAZZO. I now recognize the gentlelady from Maryland, Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman, and to our witnesses today. I just want to point a couple of things out for the record, that in 2004 the research budget was roughly seven percent of the overall agency budget, and by this time, it has leveled off to three percent. That is more than double a reduction in the research budget, at a time when in 2006 the Decadal survey actually recommended enhancing areas of research that we are focused on today, and I think that that is an important reminder to us, that we had a Decadal survey done of the needs in civil aeronautics with recommendations, and we have done exactly the opposite in terms of funding those areas of recommendation that we paid for in 2006. So I don't really get that but I offer that for the record.

Dr. Harris, in your testimony, you indicated the maturity of the industry, and I think that that is true. But the question for me really is about the future of our leadership in aeronautics and in whether we are able to, in a robust way, develop new and innovative technologies that are dependent on core research to continue our competitive advantage. And so to me these are questions that are really about the future.

And I think, you know, going to some other issues that are not the jurisdiction of this committee about expanding and making permanent research and development tax credits and enhancing a domestic manufacturing credit that I think would greatly benefit both the stability of what we are doing in research but also the growth in aeronautics. Now, that said, there is something about fundamental core research that each of you has offered testimony for our record. Dr. Tracy, I think in your testimony you indicate that Boeing spent about $3.9 billion in R&D. How much of that is fundamental research?

Dr. TRACY. Congressman Edwards, that amount you mentioned does include both product development and technology. We don't publically break out the split between the two, but it is a substantial number measured in billions, the amount that goes toward technology.

Ms. EDWARDS. But that goes toward fundamental research, toward basic research?

Dr. TRACY. Yes, ma'am.

Ms. EDWARDS. And so would you say, though, Ms. Blakey, that in the industry, I mean, as you have indicated, that part of the reason that you are able to spend, that a lot of the industry is able to spend money on its core research is also because you are dependent on the research that comes out of NASA and out of the aeronautics research, and if that had to be then put onto the backs of the industry, is it your view, Ms. Blakey, that the industry would be able to do all of that?

Ms. BLAKEY. Well, Boeing, of course, is in a very powerful position to make these kinds of investments. But remember, the industry is populated by thousands and thousands of smaller businesses. Innovation in this country is driven significantly by small businesses, but they are not able to do the kinds of things that involve big investments and test facilities and work at the most academic level that really is undertaken by NASA with the university community. That is not what a small business can do, but they can pick up the advances there and then bring them into the marketplace. And that is what is a very exciting chain that goes on.

Ms. EDWARDS. Dr. Tracy?

Dr. TRACY. Congresswoman Edwards, Dr. Harris talked about the maturity of the field, because it is 100 years old, but there is no shortage of things to work on. The progress that we are making today in aviation, aeronautics in particular, is absolutely outstanding and it is astounding. And so we count on being able to work jointly with NASA to investigate some of the higher-risk things. It probably won't see commercial use for 20 years, but we need to have work going on them today to make sure that the pipeline is filled, and some of these very advanced technologies will be ready when companies like ours are able to commercialize them.

Ms. EDWARDS. And I think that you draw the same conclusion that if we don't do that, we will look 100 years down the line and not have made the kinds of advancements that will actually allow our domestic industry to be at the top of its game the way that it is today, isn't that right?

Dr. TRACY. Yes, ma'am, I agree completely.

Ms. EDWARDS. And then I just want to ask Dr. Shin about the hypersonic research program because there has been an indication that perhaps the Department of Defense would then assume some of that or all of that research agenda. Can you tell me whether you really believe that that is appropriate and perhaps, Ms. Blakey as well, if you could indicate whether there have been some issues or challenges with fully marrying a DOD agenda with what needs to take place in the civilian sector.

Dr. SHIN. Yes, Congresswoman. I think the first point I would like to convey to you is our relationship with DOD in hypersonic area has been very prosperous in the past couple decades, to say the least. So with the priority exercise that we have gone through with the NASA budget in proposing reduction in hypersonic doesn't mean that we didn't know each other and didn't work together and all of a sudden something will fall off the cliff.

So I will propose one good example which was U.S. Air Force program called X–51, and that was built upon the technological accomplishments that NASA made through X–43 program. I am sorry to throw all these numbers. But X–43 for the first time in history demonstrated that we can fly supersonic and self-ignited combustion could happen in a hypersonic regime. So someone mentioned to me, an expert in the hypersonic area mentioned to me, that igniting the combustor in this hypersonic speed would be like trying to light a candle in the hurricane. I think that is a very good analogy.

So we flew 10 seconds in hypersonic, self-ignited mode. U.S. Air Force built upon that technology, and now X–51 flew minutes and especially on not hydrogen fuel but carbon fuel, hydrogen fuel that is a conventional fuel, and be able to build upon the technology.

So to getting to your question, we have been in good collaboration with DOD for years, so with this reduction on the NASA part, certainly the partnership needs to be elevated into higher level, more like reliance level. But we have been discussing—I personally am engaged in several discussions with officials in DOD and Air Force, and we are doing our best not to damage the collaboration, certainly with DOD and for the competency for the country.

Ms. EDWARDS. Thank you, Mr. Chairman.

Ms. BLAKEY. One thought to add to that from the vantage point of looking at the situation of DOD very closely as we do every day, the Budget Control Act has taken $487 billion out of the DOD budget. The upcoming prospect of sequestration is another half-trillion. We know that the operational aspects of DOD's budget will continue to require to be funded and that therefore means that it is the investment accounts, the R&D, which is where those cuts will take place. I believe, as Dr. Shin outlined, that there is the best intent in the world to try to keep so much going that supports it. But in the reality of the world that we are facing in terms of DOD's own budget, it is an extremely bleak picture. So I think we should bear that in mind.

And things such as you are highlighting, the R&D tax credit, that could make a real difference. The United States has dropped to 16th in the world in terms of the way we support private-sector R&D. So looking outside the federal budget but trying to be supportive, I would urge this Committee to keep that in mind.

Chairman PALAZZO. Go ahead, Doctor.

Dr. HARRIS. Mr. Chairman, may I speak to Congresswoman Edwards' concern regarding DOD's support for hypersonics? First of all, of all the flight regimes, it is hypersonics that requires, that cannot make advances without flight research. There is no way you can advance hypersonics with ground testing facilities or computations, simulations alone. Flight test is absolutely critical.

In terms of the budget or the responsibility being shifted entirely to DOD, I would recommend that that is not a capital idea, that NASA needs to maintain a capability in hypersonics. Why? It is such a critical field that once you leave it, the cost to rebuild it is enormous and it costs money as well as time. I firmly believe NASA should maintain a presence in hypersonics.

Chairman PALAZZO. I now recognize Mr. Clarke from Michigan.

Mr. CLARKE. Thank you, Mr. Chair. I appreciate it. Just a general question to any panel member. It is regarding opportunities that you see in NASA's aeronautics research that could be easily commercialized, any low-hanging fruit that can help us create jobs in the near future.

Dr. HARRIS. May I take that one? Sir, the committee that reviewed NASA's flight research capabilities identified an area of great opportunity, mainly the development of a supersonic business jet. The requirement in terms of flight research is to demonstrate a reduction in the impact of the sonic boom. We feel that the Nation, industry and NASA has progressed to a point where we are able to do that in a reasonable length of time. That would generate an opportunity to build business jets, a new industry, one that would lead to high-skilled, high-wage jobs that would have a tremendous impact on our economy, and I would say would offer opportunities to sell such airplanes worldwide.

Mr. CLARKE. Dr. Harris, is there anything that needs to be done to help advance this commercialization?

Dr. HARRIS. Well, yes. I think we have to demonstrate through flight tests that we can fly supersonic biz jets over land without being a nuisance in terms of the sonic boom produced. And that is a flight test requirement that it has to be demonstrated in flight, and I think NASA should have the opportunity to demonstrate that.

Mr. CLARKE. Thank you. Anyone else have any suggestions?

Ms. BLAKEY. There is tremendous potential in the unmanned aerial systems in domestic use of air space, cargo, all sorts of security, homeland security monitoring. This is an area that we will see a proliferation of vehicles if we could just get over a few problems that we are trying to solve right now. So that would be one.

And I would also say alternative jet fuels that NASA is working on. There is a huge market there because we are going to be moving to that, and we would like to see that those companies in distribution come out of the United States.

Mr. CLARKE. What are the difficulties you think we need to overcome right now to best commercialize that research?

Dr. SHIN. I think as Dr. Harris and Ms. Blakey mentioned, NASA aeronautics has been really diligently working with industry to make sure that technologies are transferred effectively and timely. During my oral testimony, we showed many of the NASA technologies that have been transferred to industry and turned into commercial products for the past several decades. We are continuing that role, and Ms. Blakey mentioned about UAS. We have a project, started last year, trying to make the UAS access to national air space, civil UAS. That is what I am talking about, not military UAS, and so many of the NASA capabilities and concepts and tools will be able to work with FAA to help speeding the access of UAS into NASA. And now the opportunities are just really limitless there, as Ms. Blakey just alluded, that from high altitude, long endurance, observation to—some people even conceive even a pizza delivery, but I think that is a little too far-fetched.

But the opportunities are just boundless. So I think that is what we would like to do. We push the boundary and develop new capabilities to open up the market so our country stays ahead of all this aviation sector, not just dwelling in what we do best right now, but keep on investing in the future, as Congresswoman Edwards so accurately pointed out, pushing the boundary and putting it out there in the future so industry can stay and remain in the leadership position for decades to come.

Mr. CLARKE. When it comes to the development of these unmanned surveillance vehicles, what is the timeframe that you think we—how long would it take before this could be commercialized?

Dr. SHIN. Yes. So our project has a plan to make impact from 2015 to next 10 years. So that is our target, and we do need to remember that DOD has an enormous amount of experience operating UAS. So we got to build upon that experience and knowledge to transition to a civil UAS, and I think working with FAA, DOD, and also Homeland Security, we are up to the task, and we certainly will do our best to make that impact from 2015 and out.

Mr. CLARKE. Thank you, Mr. Chair. Thank you.

Chairman PALAZZO. Thank you, Mr. Clarke. At this time we are going to go into a second round of questions, and I now recognize myself for one question.

There is a lot of discussion this week on certain cyber security bills. When you talk to a lot of our military leaders, they say the things that keep them up at night is a short list, and cyber security and cyber warfare is one of those.

So Dr. Tracy, some of your comments about the future system architecture designs in your testimony was noteworthy. You go on to say current and future generation aircraft, their flight management systems and ATM systems, are highly dependent upon highly complex software and hardware, digital system to operate. What is being done today to protect current generations of automation systems, and how severe a threat is cyber security? And where does our Nation's expertise reside for this type of research?

Dr. TRACY. Chairman Palazzo, thank you for the opportunity to talk about cyber security. We and all of the industry take the threat as very serious. We invest significant resources in understanding what the threats are, where they are coming, and we work very hard to mitigate them. The threats could be toward our infrastructure, which is used to run the company or any other company, and then also you have to always be on the alert that people aren't trying to attack systems that you might have on the airplane.

We go to a great extent to verify that the network architecture on all our platforms is secure and that software can't be injected into those systems through some unapproved path.

We work jointly with the Department of Defense and other government agencies to both understand the threat and come up with mitigation plans for taking care of those threats in both our infrastructure and in our platforms.

Chairman PALAZZO. Thank you. I now recognize Mr. Costello for a question.

Mr. COSTELLO. Mr. Chairman, thank you. Dr. Shin, you and Ms. Blakey touched on the unmanned aircraft system, the UAS. They are playing more of a role every day in public missions with border patrol, military training, weather monitoring, and we are seeing companies that are being created and jobs being created today and for the future for our unmanned aircraft. As you know, after 23 extensions, we finally have an FAA reauthorization bill that was passed by the Congress and signed into law by the President, and it requires the FAA, by the middle of next month, to determine how to expedite the licensing process of certain government unmanned aircraft. But it also requires the FAA to develop a plan later this year, a comprehensive plan, for the integration of private, unmanned aircraft systems into the U.S. airspace system by 2015.

So my question, Dr. Shin, is NASA currently working with the FAA in order for them to implement what is required under the FAA reauthorization bill, and is there anything that you are doing now or can be doing in the future to meet these timelines?

Dr. SHIN. Yes, sir. A NASA project is working on separation assurance, piggybacking and collaborating with—the DOD has been working very hard, and also communication. We talked about cyber security a little bit, and I think UAS has a big importance when keeping that communication line secure and safe and also the certification end of it that we are working with FAA to support that. And then also human factors, man and machine interaction in those areas.

So these are all very critically important areas, research areas, that NASA is working to provide support to the community and in particular FAA. But I am also a member to UAS executive committee as you are well aware of. The DOD, FAA, Homeland Security and NASA, the founding members, and I think we have made a lot of progress, the special permit process between DOD and FAA, and also NASA has been working with FAA, UAS office and the safety office there to make sure that we are connected in identifying the critical issues that FAA has been working on.

So as an example, last year on the JPDO's oversight, Department of Defense, NASA and FAA and a couple other agencies also participated. But three agencies were the main workhorses to generate this interagency, national UAS research, technology, and demonstration roadmap. So that is a very important piece of work that will guide all these participating members in the Federal Government. But we have to build upon that. That shouldn't be the end of our interagency efforts.

So through X–COM, through JPDO, I think there are structures in place for our government agencies to work together.

Chairman PALAZZO. I now recognize Mr. Rohrabacher for a question.

Mr. ROHRABACHER. Thank you very much. First of all, Ms. Blakey, what is the depreciation schedule for your industry in terms of purchasing new equipment, new machines?

Ms. BLAKEY. I will have to get back with you for that. I don't have it.

Mr. ROHRABACHER. Maybe our gentlemen?

Dr. TRACY. Same answer. I will have to get that.

Mr. ROHRABACHER. Let me just note, depreciation schedules are really important for innovation, and perhaps even more important than a direct subsidy to a specific company for a specific research job. It is an enabler, and I understand that the Japanese have a depreciation schedule that permits them to write off the cost of new equipment and machines immediately and that our companies are faced with a much greater burden. But I certainly would like to know the statistics on that. There is some reform that we could do that would have some dramatic impact and not have a major impact on the budget.

Let me suggest this, Mr. Chairman. We are sort of taking a microscope and looking at the impact of trying to balance the budget. Well, maybe we don't need a microscope. Maybe we just sort of step back and take a look at the picture here, and I don't think that we would have any trouble financing any of these research projects and keeping all of this equipment that we need to help our private sector verify the technological things, that they are research projects. They are the wind tunnels and the various electronics that provide basic research verification, et cetera. I don't think we would have a lack of money if we perhaps weren't spending $3 billion a year on a huge, huge rocket that may never go into service. $3 billion. The SLS Orion project which will take an incredible amount of time, and if you look at other NASA projects of this scope, we will probably be way over budget. Anyway, just take a step back because we have this mammoth program staring us right in the face, and that is what is draining the money here. It is not even a balanced budget. It is having grandiose plans when we can't take care of fundamentals.

We also have a telescope project now that is almost $700 million a year. That is over $3.5 billion being extracted out of the NASA budget. These are huge expenditures, and while I certainly support the telescope and we have seen these incredible expansions of the actual cost that we were promised on these things.

Anyway, I would hope that we are a little bit more cautious when we get ourselves involved in mega-projects because they will impact on micro-projects like this.

One last thought on drones. Drones are going to really—you got the radical left in this country who decided that having a drone in the air is more of a threat to their privacy than to having a helicopter pilot in the air in a helicopter. This type of irrationality is up to us to combat, and that doesn't cost a penny. Thank you very much, Mr. Chairman.

Chairman PALAZZO. Thank you. I thank the witnesses for their valuable testimony and the Members for their questions. The Members of the Subcommittee may have additional questions for the witnesses, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments and statements from Members. The witnesses are excused, and this hearing is adjourned.

[Whereupon, at 11:34 a.m., the Subcommittee was adjourned.]

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Questions for Dr. Jaiwon Shin
From Subcommittee Chairman Steven M. Palazzo
April 26, 2012
An Overview of the NASA Aeronautics Research Mission Directorate's Budget for Fiscal Year 2013

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1. The NRC report, *Recapturing NASA's Aeronautics Flight Research Capabilities*, states that NASA Aeronautics has not done a good job disseminating research results. What is your response to this assertion?

   In order to transition research results into use by government and private sector stakeholders, NASA Aeronautics does currently disseminate its research results, concepts, and design methods as widely as possible through a variety of mechanisms. NASA Aeronautics has disseminated the results of its research by publishing our results in peer-reviewed journals and NASA Technical Reports. Furthermore, we have established technical working groups within projects to engage industry and academic partners on a regular basis in order to facilitate knowledge transfer. Space Act Agreements are also used to establish intellectual partnerships with industry that enable NASA to leverage industry's unique systems-level expertise while enabling industry to quickly acquire research results and establish close working relationships with the researchers both internal and external to NASA who contribute to the research. One example of a successful NASA Aeronautics' mechanism is the DASHlink virtual laboratory the aviation safety research community uses to share results and collaborate on research problems in health management technologies for aeronautics systems. (https://c3.nasa.gov/dashlink/) Research Transition Teams (RTTs) established between NASA and the FAA are another key mechanism for transition of our results, cited by GAO as a best practice for government collaboration. RTTs improve progress for NextGen advancements in critical areas and efficiently transition advanced capabilities to the FAA for certification and implementation. 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.

   In addition, NASA Aeronautics disseminates information about the purposes, progress and ultimate benefits of its research to public audiences through Web feature stories, images and videos published at *nasa.gov* and at *aeronautics.nasa.gov*. NASA Aeronautics also introduces the public, including other researchers, students and educators, to specific areas of research and the people conducting that research through live Web chats, educational materials, and hands-on activities at major outreach events.

2. What percentage of ARMD's budget pays for personnel, for infrastructure, and for overhead; and what portion does ARMD put out in the form of research grants? In your opinion, are the personnel and infrastructure expenses appropriate for the size of your program?

   Approximately 35% of the FY 2012 ARMD budget is allocated for civil servant labor, and about 20% of the budget is for contractor labor. Costs for general center infrastructure and overhead are paid out of the Cross Agency Support appropriation and are not a part of the ARMD budget.

ARMD does fund the Aeronautics Test Program (ATP) with an annual budget of approximately $75M. ATP ensures the strategic availability, accessibility, and capability of a critical suite of aeronautics ground test facilities and flight operations assets to meet Agency and national aeronautics testing needs. These assets are utilized by all NASA Mission Directorates and external customers.

ARMD does not award grants, but through our NASA Research Announcement (NRA) process we award approximately $75M a year of contracts and cooperative agreements to academia and industry. These agreements allow us to work collaboratively with our research partners to ensure the most effective technology development and transfer for the aeronautics community. In our opinion, the personnel and infrastructure expenses are appropriate for our current budget level and research portfolio.

3. What is NASA's response to the NRC's recommendation to consolidate flight research activities at Dryden Flight Research Center?

   NASA has a very broad range of flight research objectives and believes that flight research tests should be conducted using the aircraft and test locations that are best suited to meeting the objective of each research project. The Dryden Flight Research Center aircraft, facilities, and resources are particularly well-suited to some current research projects such as the development of low-boom supersonic commercial aircraft and unmanned aerial vehicles (UAV). Such projects rely on the restricted access of the Western Aeronautical Test Range that is maintained by Dryden to enable their flight tests. Other flight research needs to be performed in environments far from Dryden. For example, we are currently equipping a research aircraft to measure ice crystal properties in the vicinity of tropical convective storms near Darwin, Australia. Such storms occur primarily in the tropics and cause engine power loss events which are not well understood and which pose a hazard to trans-oceanic commercial aircraft operations. We are also interested in the effects of alternative aviation fuels on the formation of contrails, which require flight tests in northern latitudes that are conducive to contrail formation. Flight tests aimed at improving performance of air vehicles ranging from helicopters to hypersonic aircraft are often accomplished by leveraging the assets of our partners such as the Army, the Air Force, the FAA, and commercial entities using platforms and test sites, which are determined by our partners. NASA will continue to invest in and utilize the resources of the Dryden Flight Research Center when they are the most appropriate to achieving our mission to enhance aircraft safety and performance across all speed regimes.

4. Looking to the future, how will NASA and industry be able to afford building a flight research vehicle that would be of an appropriate scale to demonstrate and validate new designs and technologies, if the cost ranges into the hundreds of millions of dollars? Does NASA foresee the day that such a large flight demonstration vehicle would be necessary?

   An important aspect of bringing a new aircraft technology to maturity is the safe and successful integration of that technology into an aircraft system. In other words, the performance benefits of a new concept demonstrated in a ground test facility or wind tunnel must be proven to be achievable in flight, to be safe, and to be certifiable by the FAA. There are two approaches to demonstrating such systems integration. The first approach is the design, construction, and flight test of a purpose-built full-scale or sub-scale flight demonstration vehicle that can simultaneously incorporate several new aerodynamic, structural, and propulsion technologies. Recent studies of such an approach for subsonic commercial aircraft conducted by the NASA Environmentally Responsible Aviation Project show that the cost would indeed be several hundred million dollars. The second approach is to demonstrate a particular new concept by flight testing that concept using an existing aircraft. Such an approach is currently being utilized by the FAA Continuous Lower Energy, Emissions, and Noise (CLEEN) program which is accelerating the maturity of new environmentally-friendly aircraft technologies in order accelerate their certification and entry into the fleet. A similar approach was utilized in 2005 by the Quiet Technology Demonstrator Two (QTD2) program conducted by Boeing, General Electric Aircraft Engines, Goodrich Corporation, NASA, and All Nippon Airways. The QTD2 flight tests enabled the incorporation of several new technologies on Boeing's latest 787 and 747-8 aircraft. Given the current budgetary realities it is not likely that a purpose-built flight demonstration vehicle can be funded, even through multi-participant partnership, in the near future. For the immediate term, the second approach of modifying existing aircraft to demonstrate new concepts is the most realistic. In the longer term new concepts such as low-boom supersonic aircraft, which will rely on the unique shape of the entire aircraft configuration to achieve acceptable sonic boom levels, will require a purpose-built flight demonstration vehicle.

Questions for Dr. Jaiwon Shin
From Ranking Member Jerry Costello
April 26, 2012 Hearing on
An Overview of the NASA Aeronautics Research Mission Directorate's Budget for Fiscal Year 2013

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1. What are the key steps in how ARMD selects the highest priority aeronautics research initiatives? How is stakeholder input weighed and incorporated in this prioritization process? When did NASA start using the current prioritization scheme? Are any changes to the prioritization scheme envisioned in the near future?

   Aeronautics uses a combination of systems analysis, inputs from research stakeholders, and judgment of our subject matter experts to formulate priorities for research initiatives. First, the input of our subject matter experts is critical to projecting the timeframe and potential for advancement to the state-of-the-art across the aeronautical disciplines. With that understanding, systems analysis can provide insight into the relative merits of those advancements in a total systems context. Systems analyses can also help determine top-down "goal posts" for technology advancements in order to achieve key system metrics derived from strategic assessment of aviation needs.

   While expert judgment and analysis provides key insights into our investment trade-offs, we also look to understand the priorities of research stakeholders, such as manufacturers and operators. They bring substantial real world insight into aeronautical challenges, at the system-of-systems, system and technology levels. Their inputs are received through participation in our systems analyses, through dialogue at technical interchange meetings, at the Aeronautics Research and Technology Roundtable and other executive level discussions.

   Overall, this is a continual process of assessing the portfolio content and enabling decision-making as a part of the budget process. This current process has been developing over the last several years and we don't envision major changes to it at this time. However, we will continue to improve our analysis process and dialogue with our stakeholders.

2. How is NASA determining if the Aeronautics Research and Technology Roundtable is an effective way for stakeholders to provide input to NASA? When does NASA expect to provide Congress with its first report on the roundtable?

   Through two full meetings of the Aeronautics Research and Technology Roundtable, we have engaged in valuable dialogue with stakeholders and believe that it is one effective way for NASA to garner input. We have already received a very good perspective on future cross-cutting needs for the aeronautics community as was discussed in the bi-annual report provided to Congress on May 16, 2012.

3. One of the goals of the Environmentally Responsible Aviation project is to enable, twenty years from now, a simultaneous reduction of fuel burn, noise, and emissions. With current technology, reducing fuel burn might increase some emissions. What breakthroughs in technology are needed to accomplish those simultaneous reductions?

The ERA project is focused on technology maturation in five key areas that will enable achieving the goal of simultaneous reduction of fuel burn, noise, and emissions. The first area is drag reduction, which will contribute to fuel burn reduction. Required technology development includes advanced wing technologies, such as high aspect ratio swept wings, and active control of flow that would reduce drag and weight. The second area is weight reduction, which also contributes to fuel burn improvements and will be enabled by continued advances in composites technology. We are developing an efficient approach to building lightweight, damage arresting, unitized structures that will reduce weight and part count and enable more efficient airframe configurations through high aspect ratio wings and alternate architectures. The third key area is propulsion technology. Both propulsor and core engine efficiency gains are needed to simultaneously reduce engine fuel burn and noise. The development of high thermal efficiency compression systems and lower speed fans is key to the realization of next generation ultra high bypass (UHB) turbofan engines. The fourth key area, emissions reduction, will be enabled by new lean-burn combustor design architectures that improve the management of fuel and air mixing to reduce the formation of nitrogen oxides (NOx) within the combustor. The final key technology area combines the efficient integration of the propulsion system and airframe with airframe noise improvements. Successful engine-airframe integration will simultaneously improve propulsion system performance and reduce community noise. Airframe noise reduction will be enabled by streamlining landing gear and developing new concepts for high lift systems such as flaps and slats needed during landing and takeoff.

Comprehensive systems analyses indicate that advancements in each of the five key areas described contribute to the achievement of the aggressive ERA project goals. In addition, it appears that the efficacy of the integrated benefits of these technologies is dependent on the configuration. That is, analyses indicate that these advanced technologies when integrated on some unique configurations potentially offer more benefits that those same technologies integrated on an advanced conventional, tube-and-wing configuration.

The ERA project is currently identifying the most promising technologies from these areas to down select for further research and integration in phase 2 of the project.

4. What factors go into establishing the proper balance between fundamental research and flight research? Have advances in ground testing reduced the amount of flight-testing that must be conducted?

Flight research is performed at all levels of technical maturity – from very early concept and technology exploration through large-scale demonstrations in relevant environments. Therefore, it is not a question of fundamental research versus flight research, but of where is flight research the best tool for the type of research to be performed – whether that is fundamental research or integrated, systems-level research. The types of factors that need to be considered are whether flight provides access to conditions that cannot easily be replicated in other experimental environments, the level of uncertainty in physics-based simulations for the key areas of technical interest, and the level of fidelity that is required to answer the research question.

Advances in numerical simulation, ground test and flight test have changed the relationship between the three. High fidelity numerical simulation allows ground test and flight test to be more targeted and therefore require less overall test time. At the same time, sensor and measurement technology advancements have enabled more detailed information to be gathered in ground and flight test that enables more precise validation of numerical methods. In some cases, flight test becomes more important than ground test since the often complex, integrated and non-linear conditions that can be achieved in flight are the conditions least suited to high confidence numerical simulation.

5. One of the significant changes in your FY 2013 budget request is the proposed restructuring of the hypersonics work and the elimination of research in air breathing hypersonic propulsion systems.

    - What NASA capabilities and expertise will be lost as a result of the restructuring the hypersonics work? Has NASA been engaging in discussions with DOD to determine the fate of this research? What has DOD told you?

      NASA partners with the DOD in many aspects of hypersonics research, and NASA expertise and facilities have been instrumental in DOD hypersonics efforts such as the X-51. NASA plans to maintain the LaRC 8-ft High Temperature Tunnel and some of the related research capability to support such work. Prior to the reduction, NASA was a joint sponsor with the DOD in air breathing hypersonic research, but this responsibility falls primarily to the DOD moving forward.

      NASA is engaging with the DOD at multiple levels to minimize impacts. The NASA-USAF Executive Research Council and the National Partnership for Aeronautical Testing are forums for the two organizations to meet at a senior level to address such issues. ARMD program and project leaders have also held meetings with DOD counterparts to discuss how to continue as much research as possible. These meetings will continue throughout the summer to further develop the partnerships and plans.

      The DOD has expressed a concern because they did not anticipate having to allocate their funds for acquiring NASA expertise to support their air breathing hypersonics programs. However, they support NASA's decision to focus remaining hypersonic funding on the LaRC 8-ft High Temperature Tunnel and related research.

    - Why were Entry, Landing and Descent activities transferred out of the aeronautics budget and what will that transfer mean for aeronautics capabilities?

      Responsibility for fundamental research associated with Entry, Descent, and Landing (EDL) technologies will be transitioned to Space Technology in FY 2013. This research is critical for developing future systems that the Agency may employ to land payloads either on Earth or other planets, and the change aligns the EDL research more closely with related space flight in the Space Technology portfolio. NASA's EDL capabilities will be retained, but funded through Space Technology instead of ARMD.

6. An increasing number of aircraft manufacturers are moving towards composite materials because of weight savings.

- Does NASA have any composite materials research that addresses progressive damage analysis, aging, inspection and repair techniques?

- What type of research could help us better understand how operating fluids and mechanical loads interact with composite materials over time? Is this type of research currently being performed? If not, why not?

Background:
The understanding of the material properties of metals and the ability to predict the load-carrying capability of metallic structures is highly advanced within the aeronautics community and is an enabler for the performance of modern aircraft. Composites are rapidly making their way into aircraft because of their superior strength-to-weight advantage over metals and their resistance to fatigue and corrosion. However, current composite structures are conservatively designed because we don't have a first-principles capability to model composite material properties and to analyze the load-carrying capability and fatigue resistance of composite structures. To take full advantage of composites and accelerate their future use in aircraft requires improved composite materials modeling, structural analysis, and manufacturing technology. Further details provided below.

Does NASA have any composite materials research that addresses progressive damage analysis, aging, inspection and repair techniques?
Efforts in the Aviation Safety Program have included demonstration of self-healing composite materials, which can restore compressive strength of a composite material that has been subjected to impact. Complementary efforts include computational modeling to simulate discrete composite matrix cracks. Research is also looking for methods of preparing surfaces for adhesive bonds and non-destructive methods for measuring integrity of bonds. The significance of efforts such as these is that future composite materials designers can predict the conditions under which the cracks may form, develop designs to avoid these conditions, and provide knowledge for effective repairs.

Composites research in the Fundamental Aeronautics Program is primarily focused on models to enable the design of new composite materials and structural components for future air vehicles. Improved computer models of composite materials behavior offer great potential to simulate failure modes accurately and to predict the residual strength of composite structures. We are also conducting limited efforts on in-situ non-destructive evaluation (NDE) for progressive damage analysis to reveal when there is growing delamination inside composite structures.

The Integrated Systems Research Program currently conducts research to enable advanced composites for weight reduction while simultaneously improving damage tolerance. The goal of the Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS) research effort is to demonstrate that stitching technology is an efficient approach to building lightweight, damage arresting, unitized structures to reduce part count while providing the improved mechanical load-carrying capability needed to enable improved airframe efficiency through concepts such as high aspect ratio wings and alternate architectures. However, there is limited research on the long-term aging aspects or repair of this type of structure.

What type of research could help us better understand how operating fluids and mechanical loads interact with composite materials over time? Is this type of research currently being performed? If not, why not?

NASA does not conduct research specifically focused on the long-term interaction of operating fluids with composite structures. Such research is best accomplished by the manufacturers of engines and aircraft. The safety-related research described above also helps us better understand how mechanical loads interact with composite materials over time.

For the past several decades NASA has been engaged with partners in academia and industry to develop new technology in composites. A general limitation on the advancement of composites technology is the inability of the aeronautics community to accelerate the design and certification processes for composite structures and materials. There is significant potential in increasing our efforts to apply computational analysis techniques to the design of composite materials and structures. Improved computer models would enable the community to eliminate a significant portion of the testing currently required to develop and certify composite structures, thereby greatly reducing the time and expense of developing these new materials and structures.

7. What areas of aviation safety research do you consider the most promising that could lead to new capabilities in the next five to 10 years and why?

The aviation community is investigating potential future risks and proactively managing increasing system complexity, while at the same time continuously seeking to maintain and improve safety, by mitigating known hazardous conditions and keeping vehicles healthy. As a member of the community, NASA research is supporting these issues with new capabilities.

NextGen's ability to provide the benefits of reduced fuel, emissions, and delays, will depend on advanced systems and operation capabilities. The verification and validation of these complex systems is an integral part of the system safety assurance process. With current methods, verification and validation can cost more than all other design and implementation costs combined, effectively prohibiting advancements, which would otherwise increase operational safety and efficiency while reducing environmental impact. NASA research will provide verification and validation tools, methods, and technologies that are essential for FAA and industry to enable those NextGen innovations.

In order to maintain and improve on the aviation system's excellent safety record, the community is relying on data mining to understand current and future hazards and risks before they can become serious. NASA has developed data mining algorithms and concepts for system-wide knowledge discovery that have already produced capabilities and are being utilized by aviation operators and the FAA. NASA's aviation safety researchers will continue to push the state-of-the art in order to enable the automated discovery of precursors to aviation safety incidents by mining massive heterogeneous (i.e.: discrete, numerical, and textual) data sets.

One example of understanding a future risk is flight through high ice-water content clouds. Although no accidents have been caused by it, incidents in which turbofan engines' operation is interrupted due to flight through ice crystals in high ice-water content clouds have occurred. A proactive team, involving NASA, the FAA, other government agencies and manufacturers, is currently developing the knowledge base to characterize conditions of high ice-water content and understand its accretion on engines. This will also support NASA's development of analysis tools and ground simulation capabilities, which will be used by the FAA and manufacturers to support their engine icing certification requirements in the future.

The transition to NextGen will also include new operational scenarios and an increased role for automation, and thus pilots' interaction with automated systems will change. NASA research into enabling pilots to better understand and respond with correct decisions in complex situations will provide the community with design concepts and guidelines for advanced cockpit systems that improve situation awareness and proper engagement with automation. These future capabilities will be important to realizing NextGen.

New or emerging hazards are not the only ones being addressed. Flight conditions leading to loss-of-control have been under scrutiny for some time. Current airline flight crew training simulators are not certified nor validated for out-of-envelope flight conditions (i.e.: upsets and fully developed aerodynamic stalls). Consequentially, current training only emphasizes stall recognition, rather than recovery. NASA's research in the state-of-the-art of aerodynamic modeling, including extensive wind tunnel testing, will provide an aerodynamic database and model under these conditions for application to flight simulators. This will enable historical changes in pilot training for prevention of loss-of-control accidents due to inadvertent aerodynamic stall.

While the safety record of modern aircraft systems is excellent and they are designed so that precursors to failure are found during periodic inspections, real-time knowledge and diagnosis of vehicle and system health on new and existing designs is important. NASA and its partners are evaluating structural and gas-path sensors, sensor management systems, and performance algorithms inside an engine under realistic operating conditions. Upon completion of a series of tests, advanced capabilities to diagnosis the state of engine health will be demonstrated in a relevant environment to the partners who are also end-users of the technologies.

QUESTIONS FOR THE RECORD
FROM SUBCOMMITEE CHAIRMAN STEVEN M. PALAZZO
TO MARION BLAKEY
APRIL 26, 2012

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1. The NRC report, *Recapturing NASA's Aeronautics Flight Research Capabilities*, recommends that NASA drop low-priority research in order to provide budget offsets for ramping up a flight research program that, they argue, provides greater scientific return. What are your thoughts about this recommendation? Do you agree?

> In an ideal world, ARMD would have robust funding for both fundamental research and flight testing. However, today's budget reality requires the agency to pursue a lean but balanced program. Ten years ago NASA had a $1.4 billion aeronautics budget. This year it is $569 million. That 60% drop in funding has forced ARMD to focus carefully on what research is most important. In its report, the National Research Council did not specify which projects it considered "low priority", so it is impossible to know what they would eliminate or curtail. However, the Aeronautics Committee is in overall agreement with ARMD's existing portfolio.

2. Over the last decade, NASA has begun to mothball or demolish wind tunnels and other expensive – and oftentimes outdated – test facilities. Do you agree with their actions? Is NASA being prudent? Are we at risk of losing critical testing capabilities?

> NASA and ARMD have the difficult challenge of maintaining cutting-edge industrial and testing capabilities while dealing with significant budget constraints. The Committee looked into this issue in 2010. In fact, one of my first site visits as chairman was to the wind tunnels at Langley Research Center. In April 2010, the Aeronautics Committee made the following recommendation to the Advisory Council: "The Committee observes that the utilization data for Aeronautics Test Program facilities continues a downward trend. This trend, left unabated, is a "going out of business" trend. The cost gap is increasingly difficult to close. Some of these facilities will be essential for future national air and space priorities, and computational fluid dynamics is not a sufficient replacement . . . It is urgent that an agency-wide plan be developed to stabilize, and where possible reverse, the situation, including supporting and improving the technical capabilities and operations of the most critical facilities, and de-accessioning some facilities through sale or gift." NASA needs to maintain core capabilities in simulation and scale testing to support key technologies under development. We believe the underutilization and high operating

cost of test facilities is an agency-wide issue that is not totally resolved. The Aeronautics Committee will review NASA's response to our 2010 recommendation in the coming year.

3. Unmanned aircraft systems appear to be the next major evolution of aircraft in our National Airspace System. What are the biggest technical and operational challenges that must be solved before UAS operations become commonplace, and how confident are you that government and industry have a plan in place to solve these challenges?

Congress has mandated the integration of UAS systems into the National Airspace System (NAS) by the year 2015, a date which poses significant challenges. Technical questions concerning loss of communications between the aircraft and its satellite or ground station ("lost link") and the aircraft's ability to monitor and avoid other traffic ("sense and avoid") need to be resolved to the satisfaction of FAA's safety and certification staff. On the operational side, FAA will need to develop and promulgate clear performance standards for UAS systems and components, including specifications for reliability and emergency modes of operation. The FAA has asked RTCA to assist in this effort, and RTCA Special Committee 203 is actively working this issue now with input from aerospace manufacturers. And finally, integrating UAS systems into the NAS will require FAA to promulgate new standards for pilot qualifications and training; operational security; and interface with FAA en route and terminal air traffic management systems.

The Joint Planning and Development Office (JPDO) and the NextGen Institute have made UAS integration a top priority for the coming year. The Senior Policy Committee, headed by Secretary LaHood, has tasked JPDO to develop a draft of the national UAS plan by September 30, 2012. JPDO and the Institute recently brought together more than 40 subject matter experts in a series of workshops to discuss the goals and milestones for UAS integration, what "full integration" means, and the major challenges to meeting Congressional goals. JPDO and the Institute's focus on UAS integration, and NASA's continued involvement with these organizations, will help ensure that government-wide issues are fully evaluated in this process.

It was only a few months ago that Congress gave clear guidance for UAS systems to be integrated into our airspace. Just last year, Congress mandated the establishment of up to six UAS test sites around the nation. It is fair to say that the civil use of UAS systems has gotten an important "jump start" from these initiatives of Congress. Industry is responding rapidly, and we believe UAS systems can and will operate as safe, productive elements of our air transportation system in the not too distant future. We look forward to reviewing and commenting on FAA's "UAS Roadmap" later this year, and rolling out the UAS test sites over the next year or so. I am confident that, working together, FAA, airspace users, and industry will make UAS integration a reality.

QUESTIONS FOR THE RECORD
FROM SUBCOMMITEE RANKING MEMBER JERRY COSTELLO
TO MARION BLAKEY
APRIL 26, 2012

1. What needs to be done to ensure that NASA's aeronautics research program is relevant to the Nation's needs and contributes to maintaining U. S. leadership in aviation?

It is important that NASA continue to coordinate its research program with other affected entities such as the FAA, the DOD, and the Joint Planning and Development Office, and communicate regularly with airspace users and equipment manufacturers. It is also critical for the agency to monitor and respond to global aerospace trends in areas such as unmanned aerial systems and environment and energy. The civil aerospace market is global in nature, and the U. S. will need to be competitive in emerging markets to maintain our global leadership over the long-term. Thirdly, the agency needs an independent source of advice as a sounding board for its plans and ideas. Today, the NASA Advisory Council provides NASA executives this important, independent view on priorities and long term needs. And finally, the agency must receive adequate funding to carry out its aeronautics research program. ARMD's research budget has been reduced substantially over the years, and we believe the budget should not be reduced below the FY12 enacted level.

2. How can NASA work most effectively with industry and the universities to carry out a meaningful aeronautics R&D program? Can you provide examples or models that have worked well in the past?

NASA's Aeronautics Research Mission Directorate works effectively with industry today under the auspices of the NASA Advisory Council's Aeronautics Committee and the ARMD Aeronautics Research and Technology Roundtable. These venues provide important opportunities for industry to gain information on ARMD projects and to provide valuable feedback on those efforts. One successful example involves ARMD's "Green Aviation" research portfolio, which involves manufacturers, airlines, and others in a highly collaborative project to reduce fuel consumption, noise, and aircraft emissions.

3. Your prepared statement indicates your Committee is encouraged by the integrated air traffic management demonstrations being conducted through ARMD's Airspace Systems Program.

- How effective has NASA been in advancing NextGen technologies and in assisting the Federal Aviation Administration (FAA) to implement these air traffic management technologies expeditiously?
- What more, if anything, should NASA be doing within its role on NextGen given its resource constraints?

NASA's Efficient Descent Advisor and Airborne Merging and Spacing Tool are just two examples of how the agency has assisted the FAA in NextGen. The agency has begun to work more closely with FAA in the past few years, a positive development that is now bearing fruit. NASA has also been a key member of the NextGen Joint Planning and Development Office (JPDO), an office that was given greater responsibilities and a seat at FAA's Joint Resources Council in recent legislation. NASA should continue its active involvement in JPDO activities to ensure its NextGen programs are "hard wired" into FAA system architecture and resource plans.

NextGen will enable the safe and efficient integration of UAS into the National Airspace System. This is a top priority in the recently-enacted FAA Modernization and Reform Act of 2012 (Public Law 112-95). As UAS activities accelerate and test sites are commissioned, NASA will need to ensure that its aeronautics program pays adequate attention to this emerging technology and how NextGen capabilities support it. The agency has unique capabilities at its research centers and test facilities to investigate and validate the safety of integrating UAS systems into commercial airspace. Because of its importance, the Aeronautics Committee recently established a UAS Subcommittee, chaired by Dr. John Langford, to monitor and provide advice on NASA's UAS activities.

4. You state in your prepared statement that your NAC committee is encouraging ARMD to establish a deeper understanding and collaboration with the international community in NextGen research. What would you envision in such an expanded international collaboration? Do you have a concern that current efforts are insufficient?

Historically, aeronautics and air traffic management research have been centered in the United States or Europe. This is likely to broaden in the coming years, as the highest percentage of air travel growth in coming decades will shift to emerging markets. This will provide powerful incentives for those nations to develop or bolster their own aircraft manufacturing and air traffic management technologies. It is critical for our NextGen systems to be synchronized and harmonized with SESAR and similar systems being developed internationally. It is just as important for us to establish deeper collaborations with the international research community, including the emerging economies. Current technical disagreements between the U. S. and Europe over the measurement and effect of volcanic ash are but one example of the need for stronger and deeper collaborative research with our international counterparts. And as UAS systems become certified for use in U. S. airspace, our ability to export those systems internationally will depend on how easily the specifications and standards mesh with the requirements of other countries. International collaboration up front can pay big dividends down the road, especially in emerging areas of technology.

Responses by Dr. Wesley Harris

Questions From Subcommittee Chairman Steven M. Palazzo

QUESTION

Looking to the future, how will NASA and industry be able to afford building a flight research vehicle that would be of an appropriate scale to demonstrate and validate new designs and technologies, if the cost ranges into the hundreds of millions of dollars? Does NASA foresee the day that such a large flight demonstration vehicle would be necessary?

RESPONSE

Speaking personally, I would note that we have done that before, so it is not impossible. If we, as a nation, wanted to do it again, the proper approach would be as a joint project between NASA and other partners, including the U.S. Air Force and industry and possibly even international partners. That said, our committee thought that NASA could and should work on less-costly projects.

As an example of how well this can work, I would specifically note that by the mid-1990s the United States was no longer the world leader in UAVs, a technology that we had pioneered. But after NASA initiated a UAV research program that totaled less than $100 million, and pursued innovative cooperative projects with industry that required various degrees of industry investment, by the early 2000s the United States was once again the world leader in UAVs, a position that we retain today. This agency, and this nation, can do great things, and it does not have to cost hundreds of millions of dollars.

QUESTION

2. Your committee recommended that lower priority aeronautics activities be phased out to free-up spending for flight research projects. While the committee did not take on the task of identifying such projects, can you offer examples of the sorts of activities that would fit this description?

RESPONSE

In my personal opinion, a quick response would be any project that does not currently have, or can easily define, a path-to-flight testing within a relatively short span, such as five to ten years, should be considered low priority and eliminated. It does not have to make its way into a commercial or military aircraft within that span of time, but if it is not going to fly, then we should not do it. The reason is simple: we need to avoid projects that spend all their lives in the laboratory and do not reach the field, and flight research is an important step to reaching operational use. Also, I would personally recommend eliminating those programs that have a low probability of impacting (1) the production of new aviation systems, (2) the efficient operation of aviation systems, and (3) the environment favorably.

QUESTION

3. Unmanned aircraft systems appear to be the next major evolution of aircraft in our National Airspace System. What are the biggest technical and operational challenges that

must be solved before UAS operations become commonplace, and how confident are you that government and industry have a plan in place to solve those challenges?

RESPONSE
The biggest challenge is efficient, timely, and accurate communications between the operators of the UAS systems and the air space controllers. UAVs need to have the ability to safely operate with other aircraft. Below 18,000 feet this is often called "See and Avoid." What systems, with what capabilities do UAVs need to have to replace the pilot? Figuring that out is challenging. As for having a plan for solving those challenges, I personally do not believe that we have a plan, although there is some discussion of developing a plan. I can say, however, that if the United States does not get out ahead in this area, other countries, such as China, will do this on their own and we will either have to catch up or be left behind.

QUESTION
4. Over the last decade, NASA has begun to mothball or demolish wind-tunnels and other expensive - and oftentimes outdated - test facilities. Do you agree with their actions? Is NASA being prudent?

RESPONSE
Our committee did not address this issue, so I can only offer a personal opinion. NASA has made some tough, but also prudent choices, about eliminating existing ground facilities. In some ways, this could serve as a model for eliminating lower priority projects in aeronautics and redirecting their funds. I personally agree with NASA's decisions to take off line several ground test facilities.

QUESTION
Are we at risk of losing critical testing capabilities?

RESPONSE
Yes. As our report states, NASA is clearly at risk of losing critical flight testing capability in hypersonics. Hypersonics is an area where flight research is the only reliable method for validation and verification of proposed aviation systems. This is an area where the United States leads the world, but we may lose our capabilities and our position.

QUESTION
5. Your committee concluded that NASA could pursue flight vehicle research programs at a cost of$30 million - $50 million each. How was this estimate derived?

RESPONSE
This was the range that many committee members—many of whom have recent experience developing flight research aircraft—believed was realistic and productive. If

you look at figure 1.8 of our report (p. 17), you see a graph comparing development costs of several experimental aircraft to their empty weight. Our recommendation was essentially for vehicles in the middle range of that graph.

From Ranking Member Jerry Costello

An Overview of the NASA Aeronautics Research Mission Directorate's Budget for Fiscal Year 2013 indicated that your committee estimated that $30 million to $50 million in total over three years would enable NASA to make significant progress in flight research. As an illustration, your committee stated that Sikorsky's piloted X-2 helicopter, which recently won the Collier's Trophy, cost approximately $50 million.

QUESTION
What was the basis for your estimate of $30 million to $50 million in total costs over three years? What were the major components of this estimate and what key assumptions were made?

RESPONSE
First, our recommendation was that this would be $30-$50 million per project, not total for all flight research. The recommendation was based upon the experience of the committee members, many of whom have worked on experimental flight research projects and are familiar with the costs, including UAS/UAV systems. The committee notes, for example, that in the 1990s NASA's ERAST program operated for less than $100 million total, and funded four different flight vehicles. In addition, the Boeing/NASA X-48B and AFRL's X-56A are examples of low cost flight research as well as the concept of cost as an independent variable design.

The committee also received presentations about what was possible in the flight research field. For example, one presenter told the committee that he had been in discussions with a well-known experimental aircraft developer and they had suggested to him that a piloted, scale aircraft capable of testing many fuel efficiency techniques for larger transport aircraft could be developed for a cost that was actually in the low end of that range. The committee was quite confident that significant capabilities could be demonstrated with aircraft that are not very expensive. While we want to see NASA back in the business of flying research aircraft, we also do not believe that these have to be—or should be—expensive programs.

QUESTION
Did Sikorsky provide you with its cost estimate and did your committee attempt to verify it?

RESPONSE

The cost estimate was obtained from public sources. The committee did not attempt to verify it. However, the committee has no reason to distrust the public source, and the committee also included members who had direct knowledge about the X-2 program.

QUESTION
Dr. Harris, your prepared statement indicated that your committee concluded that additional funding for aeronautics was not a prerequisite for NASA being able to begin to implement your recommendation for enhancing flight research opportunities, provided that NASA phases out the majority of its lower-priority aeronautics activities.

How does the panel suggest this phasing-out be done?

RESPONSE
One possible way to phase out projects would be for NASA to evaluate each one according to some specific standards, and if the project fails, to eliminate it. In my personal opinion, one way to do this would be to ask if the project has a defined path-to-flight testing. If it does not, ask if such a path could be developed at reasonable cost. If the answer to both questions is "no," then eliminate that project. After all, if the project is not going to get into the air, why should NASA do it?

NASA, and other science agencies, already conduct "senior reviews" in areas such as astronomy and astrophysics. Those reviews involve external experts who evaluate a group of projects (such as telescopes and spacecraft) and rank them. Another approach, which is slightly different, but probably more applicable to NASA aeronautics, is what is known as a "portfolio review." These kinds of reviews, adapted to the unique requirements of the Aeronautics Research Mission Directorate, could determine which projects to continue and which ones to end.

However, our committee believed that if NASA adopted certain more ambitious goals that one consequence would be that it would become clear within the agency which projects needed to be ended and their personnel and resources redirected toward the new goals.

As to how to specifically eliminate the projects, that is easier if there are clearly articulated, focused projects that the agency is starting that it can direct its personnel to work on. People want to work on exciting projects, and will gladly leave boring and unproductive ones to do so.

QUESTION
What criteria would you suggest NASA use to establish lower-priority aeronautics activities?

RESPONSE

See my previous response. I think that NASA could establish an external review group to identify lower-priority aeronautics activities. But I also think that this is within the agency's ability to do on its own, and eliminating lower-priority projects would be simplified if the agency established some challenging goals.

QUESTION
Dr. Harris, in referencing the Decadal Survey of Civil Aeronautics and the 51 challenges it identified, your panel said that NASA has made limited progress in achieving these goals. The pane1 concluded that "this number is too high for NASA to achieve meaningful progress, given existing resources."

Are the 51 challenges sufficiently detailed for NASA to address? If so, what would it take to address all 51 challenges indentified in the Decadal Survey?

RESPONSE
Yes, the 51 challenges listed in the Decadal Survey are sufficiently detailed for NASA to address. To address all 51 challenges simultaneously NASA must develop a detailed research program, including flight testing as appropriate; the research plan must be fully resourced with personnel, facilities and budget for 5 to 7 years. More money may be required, but I believe that this will become evident only after the research program is developed.

QUESTION
The list of 51 challenges was developed by the National Academies, not NASA. Given that, do you have any suggestions on how NASA might prioritize and reduce the number of challenges it addresses to achieve the meaningful progress you advocate?

RESPONSE
See my reply to Chairman Palazzo's second question.

Questions for Dr. John Tracy
From Subcommittee Chairman Steven M. Palazzo
April 26, 2012
An Overview of the NASA Aeronautics Research Mission Directorate's Budget for Fiscal Year 2013

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1. Looking to the future, how will NASA and industry be able to afford building a flight research vehicle that would be of an appropriate scale to demonstrate and validate new designs and technologies, if the cost ranges into the hundreds of millions of dollars?

   While flight testing is an expensive undertaking, there are technical and programmatic approaches to ensure a best value product for a given investment.

   On the technical side, the percent scale selected for the demonstrator vehicle is a first order driver of cost; the smaller the demonstrator scale the less it will cost. To determine the best value scale of the demonstrator aircraft, cost would be traded against the technical gains achieved at various scale sizes as not all scales will provide the same quality of data. Typically as the demonstrator aircraft size is decreased, the quality of data for the full scale version can be degraded by design constraints. Piloted versus unpiloted scales provide a clear example of this. An unpiloted version allows for a small scale demonstrator, but doesn't provide the valuable pilot feedback and typically drives higher cost by requiring more advanced computer controls. A small scale piloted demonstrator could be influenced by the geometry of the cockpit and canopy which could create a deviation from the intended demonstrator configuration. While both configurations provide valuable data, this needs to be traded to ensure the selected scale provides the best value to the full scale vehicle development.

   Programmatically increasing the number of participants involved with a demonstrator program lessens the financial burden for each participant, so selecting technologies that have broad applicability will help enable this dynamic. Theoretically NASA's Environmentally Responsive Aircraft program has such appeal for reducing fuel consumption, noise and emissions. These attributes could create interest in other government agencies such as the Federal Aviation Administration, Department of Defense, Department of Energy, and the Environmental Protection Agency. If such a coalition of support is either persuaded or directed by legislation, flight testing costs could be shared with a broader set of users for any matured technologies.

2. Unmanned aircraft systems appear to be the next major evolution of aircraft in our National Airspace System. What are the biggest technical and operational challenges that must be solved before UAS operations become commonplace, and how confident are you that government and industry have a plan in place to solve those challenges?

   Below is a list of the major issues currently being addressed by the UAS community. Technical challenges do abound relative to UAS airspace integration, but for the most part can all be solved. The wide range of system designs, mission variations, and performance related to UAS make singular solutions to the technical challenges impractical. Specific roadblocks to NAS integration include:

- Improvement in system reliability.
- Development of acceptable sense-and-avoid technology permitting the safe integration of unmanned and manned aircraft in both the current and future air traffic control environment.
- Interference-protected spectrum for UAS command, control, and data transmission.
- GPS anti-spoofing technology to prevent unauthorized access, and/or a reliable back up for GPS navigation.
- Development of technology solutions that are cost-effective and improve affordability.
- System/aircraft certification requirements.
- Pilot and crew certification and medical requirements.
- Human factors issues – i.e. ground control station design, user interface, workload, etc.
- Definition of "acceptable level of safety" for UAS flight in the national airspace.
- International harmonization of UAS flight safety standards.
- Operational procedures/regulations that do not conflict with other users of the airspace. Specifically, how will "off nominal" events be handled so as not to pose risk to others.

Both government and industry are hard at work to address the challenges of integrating UAS in the NAS. Active dialogues are occurring between the government stakeholders themselves (FAA, NASA, DoD, DHS), between government and industry stakeholders (including industry associations with UAS interests), and between industry stakeholders. Our universities across the country are also engaged in this process. Although there is no plan in place today, planning is taking place with government, industry and academia support in working groups such as the UAS Aviation Rulemaking Committee, RTCA SC203, and ASTM F38, and across a broad number of forums and organizations. The FAA has multiple plans in progress internally as well, including defining the UAS concept of operations, a roadmap for integration, and how UAS will fit into the NextGen air traffic management system. Those efforts will, hopefully, result in a coherent, interagency plan or, at least, the synchronization of several plans that will result in the integration of UAS in the NAS. Importantly, we support the Congressional mandates for UAS integration in the NAS within the FAA Modernization and Reform Act of 2012 and they provide some clear guidance to the FAA as the leader in this effort. However, the lack of targeted appropriations for this purpose have created an additional set of challenges for the FAA in meeting these mandates by 2015, putting at risk UAS in the NAS integration within that timeline.

Questions for Dr. John Tracy
From Ranking Member Jerry Costello
April 26, 2012 Hearing on
An Overview of the NASA Aeronautics Research Mission Directorate's Budget for Fiscal Year 2013

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1. What needs to be done to ensure that NASA's aeronautics research program is relevant to the Nation's needs and contributes to maintaining U.S. leadership in aviation?

   Over the past six years, administration policy in the form of budget reductions and technical guidance have shaped NASA's current portfolio, primarily focused on fundamental aeronautics. Through this transformation the breadth and depth of NASA Aeronautics including fundamental research has been reduced to minimum levels. Trading fundamental research for flight research in a zero-sum manner will eventually drain the innovation pipeline and jeopardize future U.S. leadership in aeronautics.

   The magnitude of budget increase recommended by the NRC study would reinvigorate NASA's flight research program and would preserve the pipeline of fundamental research. What the NRC recommendation fails to address is the zero-sum game within the NASA budget at a time when the Agency is making tough decisions across their entire portfolio. We support additional funding for NASA Aeronautics, but this should be as a top-line increase to the overall NASA budget.

   Current fiscal constraints for NASA's flight research impede the maturation process for technologies that are ready to transition to general aviation. Significant maturation and integration efforts remain after the transition from NASA for inclusion into commercial and military aircraft. Increased expenditures in this area would speed NASA's portion of the lifecycle development process.

2. How can NASA work most effectively with industry, universities, and other federal agencies in carrying out a meaningful aeronautics R&D program? Can you provide examples or models that have worked well in the past?

   The Aeronautics Research and Technology Roundtable, which was initiated by the National Research Council on August 25, 2011, and for which I serve as its chair, is turning out to be a powerful forum for informing NASA on a meaningful aeronautics R&D program. This forum convenes the senior-most representatives from government, industry, and universities to define and explore critical issues related to the nation's aeronautics research agenda that are of shared interest. It is designed to facilitate candid dialogue among participants, foster greater knowledge among the aeronautics community, and carry awareness to the wider public. This forum is just one source for NASA's Aeronautics Research Mission Directorate (ARMD) planning activities for the future of aeronautics. And as the Roundtable meetings continue, they will enable a range of industry stakeholders to contribute to the dialogue about the Nation's investment in aeronautics research.

Otherwise NASA is engaged with aviation interests globally to identify future technologies and create roadmaps. In the past, the bigger question has been how well these will be funded. A general rule of thumb is it takes approximately 20 years from technology identification until the time it is included in production aircraft. Theoretically NASA is developing the technologies which will be integrated into future aircraft right now. Your efforts to ensure policy and budget so NASA maintains a healthy pipeline of technologies to continue U.S. aeronautics leadership provide the support that enables these relationships to continue.

3. How successful have the Research Transition Teams (RTTs) established by FAA and NASA been in ensuring that R&D needed for NextGen implementation is identified, conducted, and effectively transitioned from NASA to FAA?

In our experience, some Research Transition Teams (RTTs) have shown success in ensuring that needed NextGen R&D efforts are not duplicative or counterproductive and projects are successfully transferred from NASA to the FAA. For example, we believe a core air traffic management advancement that shows great promise is in the area of Trajectory Based Operations (TBOs). The clearest example of success with RTTs involves the FAA's Three Dimensional Paths for Arrival Management (3D PAM) project. 3D PAM is a collaborative effort between the FAA, NASA, Boeing, the airlines, and other industry partners to use ground and airborne automation to calculate and execute advisories to allow for conflict-free efficient descent trajectories from cruise altitude to fixed, time-based metering fixes outside of Terminal Radar Approach Control (TRACON) boundaries. This replaces the current inefficient transition between cruise and TRACON airspace that involves inefficient leveling off and "stepping down" that wastes time and fuel, which causes greater emissions and minimizes throughput. The critical component to 3D PAM is the Efficient Descent Advisor (EDA), which has been refined and matured by NASA and passed along to the FAA on schedule. Without EDA, 3D PAM would not be possible. The efficient transfer of this technology from NASA to the FAA is what makes this program possible.

With that success in place, the FAA's implementation of efforts such as EDA, Trajectory Arrivals, Required Navigation Performance procedures and other NextGen ATM initiatives requires NASA's ATM Technology Demonstration (ATD1) and the FAA's Terminal Sequencing and Spacing research to converge. This will further challenge FAA and NASA leadership to shepherd these efforts while insuring projects mature and enter into service in a timely manner, all while ensuring that industry partners are included and used as a resource in the beginning of these efforts.

4. Are Roundtable participants concerned that capabilities will be lost as a result of NASA's proposed reduction of its hypersonics work? What is the basis for this concern?

   At the present time hypersonics continues to be a future aeronautics challenge, and given the current financial constraints is best served through a continued effort with a general expectation of applications 25+ years in the future. We are concerned by NASA's recent reduction of hypesonics research.

   First, the proposed on-going research at NASA will focus primarily on re-entry, descent and landing for planetary exploration. While this has some applicability to hypersonics research in general, it does nothing to advance the propulsion and other areas of hypresonics needed for aviation.

   Secondly, NASA has played a key role in the continuity of hypersonics research. It is feared that without this, U.S. research in this area will lapse and erode. Furthermore reconstitution of hypersonics research would create an additional hurdle to overcome. Our impression is the level of hypersonics research is a very small fraction of NASA's budget and should be preserved.

5. Are there aspects to the increasing use of composite materials by aviation manufacturers that warrants NASA research? How significant would such research be to aviation manufacturers, both in the near-term and in the long-term? When would results be needed?

   We believe there remains room for innovation in developing ways to incorporate composites into aircraft. Some of these methods require fundamental research which would not likely be undertaken by commercial interests. We are supporting NASA Langley Research Center working group discussions addressing composites. To date, that group has generated three themes that cut across the community: 1) accelerated testing and certification, 2) advanced simulation of materials and failure, and 3) value of materials. Key areas of interest discussed during the last working group session were: test methods, damage tolerance, material characterization, standardization of methods and databases, and accelerated testing. There does not appear to be a consensus that there is an imperative today on most of these issues, but most agree over the long-term there is a need to figure out how to design and certify more quickly and with less cost. Such a technology roadmap, to design and certify faster and cheaper in the future, may be an element of an overarching initiative that could call for more flight research by NASA.