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Statement of
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Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today to discuss NASA research and development activities, with specific focus on the Agency's new initiatives in the area of Space Technology for FY 2011. I look forward to working with you on enactment of the President's pioneering direction in advanced technology and innovation.

The President's FY 2011 budget request for NASA is part of a larger national research and development effort in science, technology, and innovation that will lead to new products and services, new business and industries, and high-quality, sustainable jobs. For NASA, an enhanced technology and innovation focus responds to the input of the final report of the Review of the U.S. Human Space Flight Committee, recommendations from multiple National Research Council (NRC) assessments, and past Congressional hearings on this subject. As recognized by Congress and outlined in the America COMPETES Act (P.L. 110-69), our Nation's economic competitiveness and high standard of living are based on decades of investment in innovation. A focus on innovation and technology is required both to enable new approaches to NASA's current missions and allow the Agency to pursue entirely new missions. This investment also will allow NASA to participate in the development of technological solutions addressing broader national needs in energy, weather and climate, Earth science, health and wellness, and national security. NASA's new direction is well aligned with America COMPETES - innovative, high-risk, high-return research to improve America's economic competitiveness. As a research and development agency, NASA plays a vital role in America's innovation engine and, as such, its future economic prosperity and security. The President's FY 2011 budget request for NASA provides a renewed emphasis on research and development, which clearly recognizes the Agency as a long-standing and important catalyst for innovation and economic expansion in our Nation. Innovative research and technology, tied to exciting missions with national importance, is a strong motivator for students to pursue Science, Technology, Engineering and Mathematics (STEM) disciplines, and a strong attraction for new hires.

Given the importance of technology and innovation as a catalyst for encouraging STEM education, I wanted to say a few words about my background. For over 22 years I have pursued an aerospace engineering career in government and academia, and for 16 of those years, I served on the technical staff of the NASA Langley Research Center in Hampton, Virginia, where I developed advanced space exploration concepts, managed multiple technology development efforts, and contributed to the design, development, test and operation of several robotic Mars flight systems. I arrived at Langley through one of the Agency's educational programs. While at Langley, I earned both my Masters and PhD degrees through other NASA educational initiatives. So, I sit before you today, as a product of NASA STEM

activities, and I can assure you these programs were instrumental to my education choices and subsequent career. For the past six years, I have served on the faculty of the Daniel Guggenheim School of Aerospace Engineering at the Georgia Institute of Technology, where I led an active research and educational program focused on the design of advanced flight systems and technologies for planetary exploration. In my current capacity as the NASA Chief Technologist, I am honored to address this Committee on such an important topic.

NASA Response to Recent External Reviews

Several recent external reviews have addressed the issues of innovation and technology development at NASA, with a strikingly common set of themes. The Report of the Review of U.S. Human Space Flight Plans Committee (Augustine Committee) strongly endorsed an increased focus on innovative technologies and approaches to achieving broadly defined NASA and national goals. This recommendation is similar to one made by the Aldridge commission in 2004. The recently released National Research Council (NRC) report, *"America's Future in Space,"* specifically calls for NASA to create a capability to develop game-changing approaches to National challenges. Finally, last year's NRC report *"Fostering Visions for the Future: A Review of the NASA Institute for Advanced Concepts,"* for which I had the privilege of serving as a committee co-chair, recommended re-creating an early stage innovation engine like the NASA Institute for Advanced Concepts (NIAC). Each of these NRC reports emphasized the need for organizational independence from the mission-focused parts of the Agency in order to provide stability to the technology investment portfolio and a more risk-tolerant environment to foster innovation. They recommend a broad reach, across disciplines and organizations, to ensure the best ideas are brought forth and supported. All of these reports suggest that failure to invest in technology and innovation puts the Agency's future viability at great risk.

In recognition of the need to rebalance near-term mission and far-term technology and innovation investments, the Agency chartered an internal study team in 2009 to investigate approaches to improve innovation within NASA. The study team found NASA's investments in innovation and technology have been focused on the near term, especially in the space-related disciplines. They concluded the need for cutting edge technology and innovation is more important today than ever before as NASA develops missions of increasing complexity to understand the Earth, our solar system, and the universe. In addition, this team felt the Agency needed do a better job in engaging our partners from across academia, industry and other Government agencies in its technology development efforts.

Space Technology Program

Through the new Space Technology Program, led by the Office of the Chief Technologist, NASA will increase its support for research in advanced space systems concepts and game-changing technologies, enabling new approaches to our current mission set and allowing the pursuit of entirely new missions. Using an array of management, funding, and partnership mechanisms, this program will engage the brightest minds in private industry, across the NASA Centers, and throughout academia. This new program builds upon the success of the NASA Innovative Partnerships Program and directly responds to input from multiple NRC reports, as well as the Augustine Committee. The Space Technology Program will meet NASA's needs for new technologies to support future NASA missions in science and exploration, as well as the needs of other government agencies and the Nation's space industry in a manner similar to the way NASA's predecessor, the National Advisory Committee on Aeronautics (NACA), aided the early aeronautics industry. The broadly-applicable technologies proven and matured within the Space Technology Program complement the more mission-focused activities in NASA's mission directorates. Together, these programs ensure the development and infusion of innovative

technologies to reduce the cost and improve the performance of many important science and exploration missions. NASA will establish a deliberative panel of internal and external stakeholders—including stakeholders from industry and other government agencies—to review and advise on technology development priorities for the Space Technology Program through a transparent and balanced process.

The Office of the Chief Technologist provides a visible Agency entry point for technology transfer and commercialization, interagency coordination and joint activities, intellectual property management and partnership opportunities, providing additional value to external innovators, including a wide range of small businesses and the commercial space industry. The Space Technology Program will use open competitions such as NASA Research Announcements and Announcements of Opportunity, targeted competitions including those for small business and universities, while engaging early career scientists and engineers. NASA will also continue to use challenges and prizes to stimulate innovative new approaches to technology development and will encourage partnerships with both established and emerging commercial space industries. Through the three major elements of this program—Early-Stage Innovation, Game-Changing Technology, and Crosscutting Capability Demonstrations—a broad suite of management, funding and partnership mechanisms are employed to stimulate innovation across NASA, industry and academia.

Early-Stage Innovation

The Early-Stage Innovation program element sponsors a range of advanced space system concepts, and initial technology development efforts across academia, industry and the NASA Centers. This program element includes: (a) the Space Technology Research Grant program (analogous to the Fundamental Aeronautics program within NASA's Aeronautics Research Mission Directorate) that focuses on foundational research in advanced space systems and space technology; (b) re-establishment of a program akin to the NASA Institute for Advanced Concepts to engage innovators within and external to the Agency in accordance with the recommendations of the NRC's *Fostering Visions of the Future* report; (c) expansion of the Innovative Partnership Programs Seed Fund into a Center Innovations Fund to stimulate aerospace creativity and innovation at the NASA Centers; (d) the NASA Small Business Innovation Research/Small Business Technology Transfer Research (SBIR/STTR) program to engage small businesses; and, (e) the Centennial Challenges Prize Program to address key technology needs with new sources of innovation outside the traditional aerospace community. Competitive selection is a major tenet of all the activities within this program element.

While a broad range of activities are planned in this program element, a few examples include Nanotube Based Structural Materials, Flexible Power Arrays, Energy Storage Systems, Formation Flying Spacecraft Systems (Swarm Operations), Extreme Environment (Temperature/Radiation) Sensors and Mechanisms, Safe Despin/Detumble Approaches for Large Non-operational Spacecraft, Material/Structural Concepts to Mitigate Impact of Small Debris, and Precision Timing and Navigation Using Only Celestial Objects. Early-Stage Innovation efforts not only benefit NASA, but can spur innovation and job growth in the broader economy. For example, NASA's Centennial Challenges has led to the formation of new companies such as FLAGSuit LLC started by our first winner, Peter Homer of Maine. FLAGSuit is now developing commercial pressure suits and gloves. In addition, our most recent Centennial Challenges winner, LaserMotive of Seattle, Washington, recently announced plans for commercial expansion based on the laser power-beaming technologies developed to win the Power Beaming Challenge.

An important aspect of the Space Technology Research Grants program is the competitive selection of U.S. citizen graduate student research that shows significant promise for future application to NASA missions. This effort will train the next generation of aerospace engineers and scientists by funding NASA-related graduate student research performed on campus during the academic year, as well as

research performed at NASA Centers during the summer months. Each student in this project will be matched to a NASA researcher who will serve as the student's NASA advisor. Through this experience, students will advance their STEM education, gain NASA experience, and learn the research and development processes.

Game-Changing Technology

The Game Changing Technology program element focuses on maturing advanced "push" technologies that may lead to entirely new approaches for the Agency's future space missions and solutions to significant national needs. Responsive to the NRC report, *America's Future in Space: Aligning the Civil Space Program with National Needs*, this program element demonstrates the feasibility of early-stage ideas that have the potential to revolutionize future space missions. Fixed-duration awards are made to Principal Investigator-led teams comprised of government, academia, and industry partners. These awards are evaluated annually for progress against baseline milestones with the objective of maturing technologies through ground-based testing and laboratory experimentation. NASA will draw from DARPA's experience to create and implement collaborative game-changing space technology initiatives. New technologies considered may include advanced lightweight structures and materials, advanced propulsion, power generation, and energy storage. With a focus on such potentially revolutionary technologies, success is not expected with each investment; however, on the whole, and over time, dramatic advances in space technology enabling entirely new NASA missions and potential solutions to a wide variety of our society's major technological challenges are anticipated.

Crosscutting Capability Demonstrations

A Crosscutting Capability Demonstrations program element matures a small number of technologies that are of benefit to multiple customers to flight readiness status. Technical risk, technology maturity, mission risk, customer interest, and proposed cost are discriminators planned for use in the selection process. For infusion purposes, proposing teams are required to have a sponsor or sponsors willing to cost share a minimum of 25 percent of the planned development effort. With objectives analogous to the former New Millennium Program, NASA will pursue flight demonstrations not only as standalone missions, but also as missions of opportunity on planned missions as well as international and commercial space platforms. Performing these flight demonstrations will advance the technology readiness of the selected systems, provide tangible products from the NASA innovation and technology program, and capture significant public interest and awareness. While a broad set of activities are possible in this program element, examples include optical communications, aerocapture, supersonic and hypersonic inflatable aerodynamic decelerators, formation flying, and advanced in-space propulsion. The Commercial Reusable Suborbital Research (CRuSR) Program (which provides suborbital flight opportunities for technology demonstrations, scientific research, and education); the Facilitated Access to the Space environment for Technology (FAST) program (which focuses on testing technologies on parabolic aircraft flights that can simulate microgravity and reduced gravity environments); and, the Edison Small Satellite Demonstration Missions project (which develops and operates small satellite missions in partnership with academia) are also included in this program element.

Partnership Development and Strategic Integration

Two key functions of the Space Technology Program are Partnership Development and Strategic Integration. Partnerships are an integral part of the NASA strategy for reinvigorating technology and innovation. Building upon the success of the Innovative Partnerships Program, NASA will pursue

partnerships with U.S. industry, academia, other Government agencies, and international partners. Partnerships provide rich sources of innovation to help address NASA's technical challenges, and also yield other applications of NASA-developed technologies that will benefit the public and contribute to economic growth. Each year, NASA documents 40-50 of the best recent examples of how the public benefits from NASA-derived technology in the annual *Spinoff* publication, with over 1,600 examples published and available online. One example from last year is the company Allocade, from Menlo Park, California. A NASA scientist founded Allocade then licensed Hubble Space Telescope scheduling technology and adapted it to help hospitals handle dynamic rescheduling issues with the On-Cue system. Efficiency is improving with this NASA technology. One hospital using the On-Cue system reported a 12 percent increase in procedure volume, a 35-percent reduction in staff overtime, and significant reductions in backlog and technician phone time. NASA technologies are also improving safety. The New York company Early Warning developed a new water analyzer—employing a carbon nanotube biosensor licensed from NASA—that can evaluate a water sample and alert operators to potentially dangerous biological contaminants in about two hours, a drastic improvement over typical laboratory-based water sampling, which can take several days.

NASA technology is also helping entrepreneurs pursue new space capabilities through technology licensing and partnerships, such as the inflatable structures technology licensed to Bigelow Aerospace and the advanced propulsion technology licensed to Ad Astra Rocket Company for their Variable Specific Impulse Magnetoplasma Rocket (VASIMR). The Strategic Integration function focuses on working with the Mission Directorates and the NASA centers to develop an Agency technology roadmap and measure the significance and performance of the Agency's technology investments. Agency-level technology coordination, integration, and prioritization assessments are performed. Technology roadmapping and portfolio planning activities are driven by the Agency's strategic goals, and coordinated with the technology development activities of our partners in industry, academia, and other government agencies.

Models of Success

NASA has a track record of success in the development of game-changing technologies and the transfer of its products and intellectual capital to industry. As an example, consider the Mars Pathfinder mission of the early 1990s. In addition to accomplishing its science and technology objectives, Mars Pathfinder established surface mobility and ground truth as important exploration principles, created a groundswell of interest and a foundational experience for a new generation of Mars scientists and engineers, re-engaged the public with Mars as a destination worthy of exploration, led to the creation of NASA’s Mars program and establishment of a Mars program budget line, and led to a wide spectrum of small missions to Mars, the asteroids, comets and other bodies in our solar system. As an early-career employee, I learned many lessons working on the Mars Pathfinder mission, and within a few years, I was applying these lessons learned to a wide range of more challenging flight systems. For the NASA robotic exploration program, Mars Pathfinder was clearly a game-changer.

In a more recent example, consider NASA’s improvements to ablative thermal protection system (TPS) materials through an Advanced Capabilities development project sponsored by the NASA Exploration Systems Mission Directorate. Over three years, a NASA-industry team raised the technological maturity of eight different TPS materials from five different commercial vendors, eventually selecting the system for the Orion heat shield. In addition to providing a heat shield material and design for Orion, this team identified a potentially catastrophic problem with the planned Mars Science Laboratory (MSL) heat shield and remedied the problem by providing a viable alternate heat shield material and design within stringent schedule constraints. From this effort, mature heat shield material and designs have been successfully transferred to the commercial space industry, including the material performance and modeling data for the SpaceX Dragon capsule heat shield with implications for a wide variety of customers.

Government-industry cooperation in the inflatable structures arena has also paid significant dividends. In 1996, the TransHab program began the development of large-scale inflatable structures suitable for space habitation. This technology was later transferred to the commercial sector through patents and intergovernmental personnel acts, enabling companies including Bigelow Aerospace to engage in space commerce. Bigelow Aerospace is now poised to take on the final challenge of producing human-rated inflatable space modules, capable of providing the habitation needs for a multi-person crew in low Earth orbit. As a stepping-stone on that path, NASA is presently investigating a proposal to attach a Bigelow Aerospace-produced inflatable module to the International Space Station.

NASA technology investments are of benefit to more than the Agency's missions and the aerospace industry. In 2000, NASA and the University of Arizona developed the Mars Oxygen Generator, a two-pound experiment designed to generate oxygen for life support and fuel production on Mars. The device used solid oxide electrolysis cells to convert carbon dioxide and water into oxygen and fuel. When operated in reverse as a fuel cell, this device has been shown to produce clean, reliable electricity here on Earth. Development and commercialization of this technology as a NASA spin-off by Bloom Energy, which is now largely supported by the private sector, is moving beyond the early demonstration phase, with the goal of generating electricity at prices lower than traditional methods while producing half the amount of greenhouse gases.

Beginning in FY 2011, the new NASA Space Technology Program aims to strengthen and broaden these successful innovation examples across a wide range of Agency and significant national needs.

The Role of STEM Education

NASA recognizes the important role that STEM education plays in developing the diverse scientific and technological workforce required to advance this Nation's economic leadership. Experience has shown that exciting and compelling NASA missions truly inspire the next generation of explorers, innovators, and leaders. The NASA Office of Education administers nationwide education efforts that draw on content from across the Agency in pursuit of its three primary education goals: (1) Strengthening NASA's and the Nation's future workforce; (2) Attracting and retaining students in STEM disciplines; and (3) Engaging Americans in NASA's mission. NASA leverages its unique program content, people, and facilities to spark interest, capture imaginations, and guide students toward careers in STEM fields while increasing their scientific and technological literacy to the benefit of the Nation. NASA accomplishes its STEM education goals through educational investments in Higher Education, Minority Research and Education, Elementary and Secondary Education, Education Technology and Products (e-Education), and Informal Education.

NASA supports the objectives of the America COMPETES Act, as well as the Administration's STEM education teaching and learning improvement efforts through its education portfolio. This summer, NASA will launch *Summer of Innovation*, a new initiative that is aligned with both Congressional and Administration STEM education priorities in mind. *Summer of Innovation* will be an intensive STEM teaching and learning program targeted at the middle school level that includes follow-on activities during the school year. NASA content and products will be incorporated into evidence-based summer learning programs across participating states with the goal of improving student academic performance and motivating students to pursue further education and successful careers.

In addition to this new initiative, NASA's Experimental Program to Stimulate Research (EPSCoR) and University Research Centers (URCs) are long-standing examples of the Agency's commitment to the development of higher education academic research and development. EPSCoR targets states with

modest research infrastructure with the goal of enabling them to become more competitive in attracting research funding. The URCs expand the Nation's base for aerospace R&D and increase the number of underserved and underrepresented students studying STEM by increasing the competitive aerospace research capability among the Nation's minority institutions. These awards foster relationships with industries, enabling future research and development opportunities that advance NASA scientific and engineering mission priorities. The educational achievement of America's next generation is an issue that affects our Nation at all levels.

NASA will continue to partner with Federal, industry, state and local organizations and invest our resources toward a shared vision to secure those jobs critical to the 21st century workforce. This means not only inspiring the next generation and improving scientific literacy, but also providing educators with unique resources to aid in achieving national educational excellence in STEM.

Conclusion

Consistent with the objectives of the America COMPETES Act, many positive outcomes are likely from a long-term NASA advanced space systems concepts and technology development program, including a more vital and productive space future than our country has today, a means to focus NASA intellectual capital on significant national challenges and needs, a spark to renew the Nation’s technology-based economy, an international symbol of our country’s scientific and technological leadership, and a motivation for many of the country’s best young minds to enter into educational programs and careers in engineering and science. Major breakthroughs are needed to address our society's energy, health, transportation, and environmental challenges. While NASA investments alone will not solve these major challenges, the Agency has proven to have a unique ability to attract and motivate many of the country's best young minds into educational programs and careers in science, technology, engineering, and mathematics. A suite of game-changing space technology improvements are within our Nation's grasp. With a stronger focus on technology development, the intellectual capital at the NASA Centers will be utilized to deliver solutions to some of our Nation's greatest technological challenges.

The NASA FY 2011 budget request provides the civil space exploration enterprise with multiple exciting potential futures. Previously NASA was marching toward a single human exploration future, where it was leveraging Apollo, Shuttle, and other relatively mature technologies to return to the Moon. In doing so, the budget and schedule pressures from this effort left little room for NASA to invest in the next generation of space technologies. The future now holds a host of possibilities and opportunities, with humans going to the Moon, to asteroids, and eventually to Mars. We envision robotic explorers traveling throughout the solar system and into interstellar space; the identification of life on other planets and Earth-like worlds around other stars; an Earth observation system that can accurately forecast the emergence of major storms and natural disasters; and, NASA supporting an emerging commercial spaceflight industry and contributing substantially to solving our Nation's technological needs. Through the focus on innovation and technology represented in the President’s FY 2011 budget request, our Nation’s investment in NASA is much more likely to accomplish these potential futures.

Our Nation has made great progress throughout its history by innovating solutions to the enormously difficult challenges it has encountered. The grand challenge to build an intercontinental railway, or to land a man on the Moon and return him safely to the Earth, not only utilized our best talent, but also created new technologies and innovations. These achievements also inspired generations to pursue challenging goals, created new industries, and ultimately improved our country and the world. Similar opportunities are in front of us now.

Focusing NASA on these critical technological capabilities as we move forward is my challenge as NASA's Chief Technologist. I am pleased to be leading NASA's teams in this broadly applicable technological endeavor. In this manner, NASA can be an important catalyst for innovation and economic expansion in this Nation.

Mr. Chairman, I would be happy to respond to any questions you or the other Members of the Committee may have.