U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY

HEARING CHARTER

NASA AT 50—PAST ACCOMPLISHMENTS, AND FUTURE OPPORTUNITIES AND CHALLENGES

Wednesday, July 30, 2008
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

The purpose of the hearing is to mark the 50th anniversary of the establishment of the National Aeronautics and Space Administration (NASA), review the accomplishments achieved since its creation, and examine its future challenges and opportunities.

Witnesses

Witnesses scheduled to testify at the hearing include:

Honorable John H. Glenn, Jr.
United States Senate [retired]

Mr. Norman R. Augustine
Chairman and Chief Executive Officer [retired]
Lockheed Martin Corporation

Dr. Maria T. Zuber

Department Head and E.A. Griswold Professor of Geophysics

Department of Earth, Atmospheric, and Planetary Sciences

Massachusetts Institute of Technology

Also, a special audio message from Professor Stephen Hawking, Lucian Professor of Mathematics, University of Cambridge, will be aired at the hearing.

Potential Issues

The following are some of the potential issues that may be discussed at the hearing:

- ***Which NASA accomplishments over the last 50 years have been the most significant in shaping the Nation's leadership in space and Earth science, aeronautics, and human spaceflight and exploration, and why?***

- ***What factors will be the most influential in shaping the next 50 years of civil space and Earth science, aeronautics, and human space flight and exploration, and why?***

- ***What are the most important steps that need to be taken today to ensure U.S. leadership in space and Earth science, aeronautics, human spaceflight, and exploration over the next half century?***

- ***What scientific discoveries or technological breakthroughs would dramatically change the current and future path of NASA?***

- ***What role can NASA play in engaging young people in science, technology, engineering, and mathematics (STEM) education and careers in space and aeronautics?***

- ***How can NASA maximize the effectiveness of its activities and missions in meeting societal needs?***

- ***How important has international cooperation been for NASA over the last 50 years, and what should be done to maximize the utility of future international partnerships in the civil space arena?***

- ***What impact will the emerging commercial space sector have on NASA's programs in the coming years, and how can NASA best make use of commercial space capabilities to support its missions?***

BACKGROUND

Overview

On July 29, 1958, President Eisenhower signed the National Aeronautics and Space Act that established the National Aeronautics and Space Administration (NASA). NASA formally came into existence on October 1, 1958. Since that time, NASA has made path-breaking contributions in the areas of aeronautics, human spaceflight and exploration, and space and Earth science. The space program has significantly advanced our understanding of the Earth and the Sun, our solar system and the Universe, and the role of microgravity in physical and biological processes. NASA has also tested and demonstrated space-based communications and meteorological monitoring techniques and fostered the applied use of Earth observations data to help to monitor natural resources, facilitate urban planning, and address societal challenges. NASA has pioneered aeronautical developments that have enabled more efficient and safer commercial air transportation as well as technologies to advance the capabilities of military aircraft. Finally, NASA developed and demonstrated the means to send humans into space, land them on the Moon, and return them home safely. NASA's further human spaceflight accomplishments include the development of a partially reusable Space Shuttle vehicle and leadership in developing and assembling the International Space Station.

NASA has built a workforce of highly educated and trained scientists and engineers who have contributed knowledge and technical capability that have helped to establish the Nation's leadership in technological innovation and competitiveness, a fact borne out by the 6,573 patents the agency holds for contributions by its employees and contractors. Today, NASA employs over 18,000 civil servants and some 40,000 contractors and grantees.

NASA has played a constructive role in providing opportunities to bring nations together in pursuit of peaceful and inspiring goals in science and technologies. These international activities have included data sharing and analysis at the scientist-to-scientist level; contributions of instruments to and coordination of space and Earth science missions to maximize observations; and contributions of major portions of space systems. The Apollo-Soyuz Test Project was an example of cooperation between the United States and the Soviet Union during the Cold War, and the International Space Station, which involves major contributions from the U.S., Russia, Europe, Japan, and Canada, is the largest and most complex space cooperative effort to date.

National Advisory Committee for Aeronautics: The Predecessor to NASA

Although NASA was established in 1958, its roots go back to the Advisory Committee for Aeronautics, later known as the "National" Advisory Committee for Aeronautics (NACA), which Congress created in 1915 "*to supervise and direct the scientific study of the problems of flight, with a view to their practical solution.…*". Its role was largely to coordinate, evaluate, and advise on ongoing aeronautical work.

NACA identified the need for civil aviation research as a priority for the post-World War I era, and it created the first U.S. aviation laboratory, the Langley Memorial Aeronautical Laboratory, in Virginia, in 1920, to conduct research and development work. Notably, NACA's work contributed significantly to the development of the engine cowling, refined wing design, laminar flow airfoils, and retractable landing gear. These features became standard on U.S. aircraft.

In response to continuing advances in European aviation and aeronautics, NACA and the Congress moved to establish additional U.S. aeronautics laboratories in the late 1930s and early 1940s, including the Ames Aeronautical Laboratory on Moffett Field in California and additional facilities at Langley. The need for research on aircraft engines led NACA to add a third center, the Aircraft Engine Research Laboratory (later named the Lewis Flight Propulsion Laboratory and now the John H. Glenn Research Center at Lewis Field), in Cleveland, Ohio. NASA's Dryden Test Flight Facility in California's Mojave Desert (at what was Muroc Army Air Field and is now Edwards Air Force Base) also traces its origins to NACA when aeronautics researchers began to use the air base for flight testing activities.

Following World War II, the U.S. focused on jet engines and supersonic flight capability, and the joint efforts of NACA and the Air Force led to the first supersonic flight on October 14, 1947, when Chuck Yeager broke the sound barrier while piloting the X-1 aircraft. During the Cold War, the Nation began to focus on military rocketry and NACA's infrastructure and personnel were tasked increasingly with missile research. In response to the Soviet Union's launch of Sputnik, the first artificial satellite deployed in space, the U.S. accelerated plans for launching satellites into space. NACA's experience in aeronautics, missile research, management of technical infrastructure and personnel, and its ability to help translate research developments into military and civil applications made it a fitting candidate to lead the Nation's civil space activities. Later, NACA's aeronautics research and development work was folded into a broader agency mission of space and aeronautics.

Dawn of the United States Space Program

The International Geophysical Year (IGY) of 1957-1958, a multinational program to coordinate global scientific investigations about the Earth system and the near-Earth space environment, included plans by the United States and Soviet Union for launching scientific satellites into space. However, the Soviet Union's launch of Sputnik on October 4, 1957 jolted the United States into a space race. The initial U.S. attempt, the launch of the Vanguard test rocket on December 7, 1957 failed, but on January 31, 1958, the launch of the Explorer I satellite succeeded and heralded America's entry into space.

Establishment of the House Committee on Science and Astronautics

As part of its swift response to the Soviet's early successes in space, the House of Representatives created a Select Committee on Astronautics and Space Exploration for the purpose of conducting "*a thorough and complete study and investigation with respect to all aspects and problems relating to the exploration of outer space…*", according to the book, Toward the Endless Frontier. In the following months, the Select Committee accomplished the monumental tasks of chartering a permanent House Committee on Science and Astronautics, working on the development of the Space Act which established NASA, and holding important hearings on the future of the Nation's space program. The House Committee on Science and

Astronautics, now known as the House Committee on Science and Technology, was authorized on July 21, 1958, and on January 3, 1959 became the first standing committee since 1892 to oversee an entirely new area. The Senate also established a space committee, the Committee on Aeronautical and Space Sciences.

The National Aeronautics and Space Act of 1958

On April 2, 1958, the Eisenhower Administration submitted a bill to Congress to establish a National Aeronautics and Space Administration (NASA). The House and Senate debated and made changes to the bill, including the addition of Congressional oversight, and provided a mechanism for international cooperation in the Act. On July 29, 1958 President Eisenhower signed into law P.L. 85-568, "The National Aeronautics and Space Act of 1958" (The Policy and Purpose section of the Act is included in Appendix A). NASA's workforce and facilities included those of its predecessor, NACA, as well as the space science staff from the Naval Research Laboratory, and later the Army Ballistic Missile Agency and the Jet Propulsion Laboratory, among parts of other organizations.

T. Keith Glennan, President of Case Institute of Technology, was selected as the first NASA Administrator. On October 1, 1958 at the Dolly Madison House, Glennan officially announced the end of NACA and the beginning of NASA. One week after NASA's birth, Glennan gave approval for work to start on Project Mercury, the country's first human spaceflight program.

Funding History (50 Years of NASA Budgets in Constant Year Dollars)

NASA's budget history since the creation of the agency in 1958 is shown in Attachment B. The budget reached an all-time high during the Apollo years and also saw an increase following the Challenger accident. Over the last decade, NASA's budget has been essentially flat.

Selected Accomplishments in Human Exploration

NASA accomplished a great deal in human spaceflight and exploration since the initiation of Project Mercury, from Alan Shepard's 15 minute suborbital flight in 1961 to the recent record breaking 377 days in space accomplished by astronaut Peggy Whitson. In the span of 47 years, NASA has gone from learning how to cope with operating in space without fear of temperature extremes and radiation to landing astronauts on the Moon and collaborating with other nations in building what will be a 925,000 pound research facility orbiting 200 miles above the Earth and occupied by a 6-person crew.

The *Mercury* project was NASA's first human space exploration effort. At that time, it was still uncertain whether a human could function in the hostile environment of space. Alan Shepard's flight on May 5, 1961 demonstrated that an astronaut could survive and work in space, albeit for a short period. Less than a year later, on February 20, 1962, NASA astronaut John Glenn became the first American to orbit the Earth. Glenn's flight in the *Friendship 7* spacecraft lasted just under 5 hours and made three orbits. Project *Gemini*, conducted from 1965 to 1966, involved a larger spacecraft with a crew of two. Goals were elevated as astronauts demonstrated the ability to rendezvous and dock with other spacecraft and conducted extra vehicular activities (EVAs), also known as spacewalks. Next was project *Apollo*, whose objectives were established by President John F. Kennedy on May 25, 1961, when he announced the goal of landing a man on the Moon and returning him safely to Earth by the end of the decade. The Apollo program was a demanding undertaking, one that resulted in the loss of the three astronauts of *Apollo 1* in a fire on the launch pad, and involved a series of challenging milestones including the development of the Saturn V rocket, a lunar module, and a series of manned flight demonstrations to validate systems. On July 20, 1969, President Kennedy's goal was achieved when two members of the crew of Apollo 11---Neil Armstrong and Edwin E. "Buzz" Aldrin Jr.---made a successful landing on the Sea of Tranquility. Over the next three and a half years, NASA successfully launched five more Apollo lunar landing missions to conduct scientific activities, collect lunar rock samples, and to explore regions of the Moon with the use of a lunar rover.

Evaluating the ability of humans to withstand long-term periods in space was the impetus behind three Skylab missions conducted from 1973 to 1974. Skylab was developed by converting an empty S IV-B stage into what was in essence the first U.S. space station. The first Skylab crew spent almost a month in space, doubling that previously experienced by a U.S. crew, and conducted experiments in solar physics, Earth resources, space medicine, and industrial processes.

During the late 1960s, acting NASA Administrator, Thomas Paine, sought increased cooperation in NASA's human space exploration activities. An offer to the Soviets to develop compatible rendezvous and docking systems that both nations could use in potential joint spaceflight activities was accepted. The Apollo-Soyuz Test Project (ASTP) involved joint docking of the two human spacecraft and crew exchange. The ASTP came to fruition on July 17, 1975 in the successful docking of the Soviet Soyuz and American Apollo spacecraft; it was the first ever international human spaceflight project.

Following ASTP, it would not be until 1981 that NASA returned to human spaceflight. The first Space Shuttle mission was launched on April 12, 1981. The next four shuttle flights demonstrated design and thermal characteristics, important confirmations since the orbiter was the first reusable spacecraft built by NASA. “Operational” shuttle flights began in November 1982 and included deploying communications satellite and scientific satellite payloads such as the Hubble Space Telescope. In 1983, the Shuttle launched the first European-built modular research laboratory, Spacelab---along with the first non-American astronaut, Ulf Merbold, as part of the Shuttle crew. From 1983-1998, Spacelab flew numerous times. The program involved scientific experiments and contributed valuable knowledge and experience to the International Space Station program.

The risk associated with human space exploration was made painfully apparent on two tragic occasions involving the Shuttle. On January 28, 1986, an O-ring failure in one of two solid rocket boosters attached to the Shuttle orbiter *Challenger* caused the main liquid fuel tank to explode seventy-three seconds after launch, killing all seven crew members. After the Shuttle successfully returned to flight in 1988, NASA flew eighty-seven successful missions before tragedy struck again on February 1, 2003, with the loss of the orbiter *Columbia* and its seven astronauts during reentry. Both accidents led to intense scrutiny and criticism of agency procedures and safety practices that were believed to have contributed to the accidents.

In 1984, Congress approved President Ronald Reagan's proposal for NASA to build a space station; Europe, Canada, and Japan were invited to participate and signed agreements in 1988. The space station program was technically and programmatically challenging for NASA to carry out and the program suffered significant cost growth and a number of restructurings.

In addition, in 1992, President George Bush and Russian President Boris Yeltsin signed an agreement which included involving a U.S. astronaut on a long-duration Mir mission and the flight of a Russian cosmonaut on the Shuttle. Later in 1992, NASA Administrator Daniel Goldin and Yuri Koptev, Director General of the Russian Space Agency (RSA), signed an agreement detailing further human spaceflight cooperation with Russia, including a Russian cosmonaut joining a Shuttle crew as a mission specialist and a U.S. astronaut launching in a Soyuz spacecraft, spending more than 90 days on the Mir, and returning in a Shuttle, among other activities. The program established a level of trust between NASA and the Russian Space Agency, and provided a basis of understanding and interaction that led to the U.S. invitation, in 1993, to Russia to join the U.S. and its partners in the International Space Station. In 1998, the U.S., Russia, members of the European Space Agency, Japan, and Canada signed an Intergovernmental Agreement on Space Station Cooperation.

The first element of the International Space Station, the Russian-built and U.S. funded Functional Cargo Block reached orbit in November 1998. Since then, the International Space Station has grown with the addition of modules, trusses, solar arrays, and laboratories contributed by the U.S., Russia, Europe, and Japan. Permanent habitation of the ISS began when the Expedition One crew arrived in 2000 and the ISS has been continuously occupied ever since. The ISS, scheduled for completion in 2010, will be the largest human-made object ever to orbit the Earth.

While work on developing the space station was underway, President George W. H. Bush, in 1989, announced a Space Exploration Initiative that included the Space Station and plans to send astronauts back to the Moon and, eventually, on to Mars. The Initiative, however, failed to garner support, and the Clinton Administration did not continue it. In 2004, President George W. Bush announced a Vision for Space Exploration that entailed sending humans back to the Moon and on to Mars by retiring the Shuttle after completion of the ISS, planned for 2010, and developing the follow-on Constellation program. The latter includes a new, multipurpose Orion crew exploration vehicle as well as new crew and cargo launchers, known as Ares I and Ares V. Scheduled to transport six crew members to the International Space Station in 2015, Orion, supplemented by the Altair lunar lander module, is intended to return U.S. astronauts to the Moon by no later than 2020, budgets permitting, and provide the core capability for future travel to other bodies in the solar system.

While human space exploration during much of NASA's first 50 years was managed, in large part, by the federal government, the contributions of the aerospace industry and private sector companies have increased significantly over time, and contractors currently carry out the bulk of the development work in the Constellation program. In addition, NASA is planning to procure commercial cargo, and eventually crew, transportation services to the International Space Station, should the private sector demonstrate the capability to provide those services. The private sector is also pursuing a potential market in personal human spaceflight. Further opportunities for commercially-provided space services may emerge from innovation prize competitions, including a challenge to develop, land, and operate a rover on the Moon, all based on private funding.

Selected Accomplishments in Aeronautics

Building on the pioneering accomplishments of NACA, NASA has continued to enable aeronautical advances that encompass a wide range of developments in aerodynamics, aircraft structure, and experimental design. Many of the technologies that have emerged from NASA research have found their way into both military and civilian aircraft and have significantly improved aircraft performance and fuel efficiency and enhanced the safety of the national airspace.

During the 1940s and 1950s, problems with aircraft drag were causing excessive use of fuel and problems in aircraft control. A NASA scientist, Dr. Richard Whitcomb, discovered the “area rule,” a revolutionary concept that helped aircraft designers to avoid the disruption in air flow caused by the attachment of wings to the fuselage. By removing the equivalent wing cross-sectional area from that of the fuselage cross-sectional area, scientists were able to improve the distribution of flow across the longitudinal area of the aircraft. The benefits were immediate and the so-called “Coke bottle” fuselage revolutionized fighter designs and high performance aircraft for the years to come.

During the late 1950s and the 1960s, NASA’s aeronautics research and development program, the X-15 experimental rocket-powered aircraft, made significant contributions. On August 22, 1963, the X-15 reached a record 354,000 feet in altitude and achieved a speed of Mach 6.7 on October 3, 1967. The X-15 program produced valuable data on aerodynamic heating, high-temperature materials, reaction controls, and space suits, some of which was later used in the Space Shuttle program. Other “X-planes” contributed important data in other areas of aeronautical research and development.

During the 1960s and 1970s, NASA scientists and researchers developed the "supercritical airfoil" shape, which delayed the drag rise that normally accompanies transonic airflow and help to improve aircraft cruise efficiency. At the same time, NASA also helped develop and flight test the digital "fly-by-wire" system. This replaced heavier and less reliable hydraulics systems with a digital computer and electric actuators. Such technologies are now commonplace on military and commercial aircraft.

Driven by the need to find ways to reduce fuel consumption, NASA developed winglets during the 1970s and 1980s. These vertical endplates, seen on many aircraft wings today, help to reduce vortices and drag and to improve airflow and fuel efficiency, and represent one of the agency’s most important aeronautical achievements. Over the last few decades, NASA’s work in aeronautics resulted in several air traffic management simulation tools, which today are greatly improving aircraft flow and air traffic safety.

With adequate funding, NASA will be a significant contributor to the advances in future civilian aircraft technologies that will be needed to deal with projected increases in air transportation capacity, without imposing adverse effects on the environment. The agency is building on its aircraft engine efficiency, emissions and noise research to help develop technologies that will maximize fuel consumption and minimize harmful environmental impacts—including those on the Earth's climate. Prior NASA research such as the Energy Efficient Engine Project developed and demonstrated technologies capable of reducing fuel consumption by 15% relative to the best commercial aircraft engines in service at that time. These accomplishments also enabled the development of jet engines such as those powering today's Boeing 777. Pratt & Whitney's prior collaborative research with NASA is enabling the company to bring to market a geared turbo fan engine which is projected to burn less fuel, emit less CO2 emissions and be cheaper to use then most other jet engines.

The Nation's latest military aircraft have also benefited from technologies developed by NASA. For example, the Air Force's C-17 transport owes several of its key elements to NASA research including the supercritical wing and externally blown flap, the latter enabling the heavy transport to make slow, steep approaches with heavy cargo loads. Another example is the F-22 fighter aircraft, which can maneuver in ways unlike most fighters due to the thrust vectoring of its engine nozzles, a feature successfully demonstrated by NASA on a number of test aircraft, most notably the X-31.

Selected Accomplishments in Space Science

Since Explorer I's inauguration of our Nation's civil space program on January 31, 1958, the world has witnessed stunning achievements by NASA scientific spacecraft. Explorer I's main experiment led to the discovery of radiation belts surrounding the Earth, an achievement that provided new scientific understanding of the near-Earth environment and its hazards to human space exploration. NASA scientific spacecraft have continued to make discoveries that have rewritten textbooks, led to Nobel prizes, and captivated our youth and the public.

Planetary Exploration

NASA's interplanetary exploration began with the launch of Mariner 2 in 1962, which passed within 21,000 miles of Venus. From that point on, NASA's planetary spacecraft, including Pioneers, Mariners, Voyagers, Cassini, Magellan, Galileo, Messenger, Mars missions, and smaller probes, have visited and explored eight planets and their moons as well as comets and asteroids. Mariner 9 was the first probe to successfully orbit Mars in 1971, and the Pioneer 10 and 11 spacecraft, launched in 1972 and 1973, were the first spacecraft to pass through the harsh asteroid belt and to explore the outer planets of Jupiter and Saturn (Pioneer 11). In 1983, Pioneer 10 became the first robotic object to leave the solar system. The Voyager 1 and 2 spacecraft, launched over 30 years ago in 1977, studied Jupiter, Saturn, and their moons. Voyager 2 went on to discover previously undetected moons orbiting Uranus when it flew by the planet and became the first spacecraft to observe Neptune. The Voyager probes, now beyond the solar system and en route to interstellar space, have sent back data that have changed scientists' understanding about what happens at the edge of the solar system where the solar wind blowing outward from the Sun meets energetic particles from interstellar space. The Cassini-Huygens mission, a collaborative mission with the European Space Agency, was launched in 1997, and has been the first to study the Saturn system of rings and moons and included the first probe (Huygens) sent into the atmosphere of Titan.

NASA's Viking 1 and 2 spacecraft touched down in a "soft landing" on the Chryse Planitia and Utopia Planitia areas of Mars respectively in 1976. Viking's ambitious scientific objectives included the search for life. Although the results were inconclusive, the Viking mission were followed in later decades by a series of integrated investigations of Mars by orbiters, landers, and rovers that have significantly changed scientists' understanding of the Martian world. The landing of the Mars Pathfinder lander and its rover, Sojourner, on July 4, 1997 created an unprecedented appetite for the images of and scientific news reported from the Red Planet. Subsequent Mars orbiters, landers and probes, including those operating today, have revealed that Mars once had liquid water and that areas of the planet harbor water ice beneath its surface.

Astrophysics

NASA's first astrophysics satellites were launched in the late 1960s. The Orbiting Astronomical Observatory (OAO)-2 provided the first ultraviolet images of stars and discovered a supernova. Its successor, OAO-3, conducted in collaboration with the United Kingdom, went on to discover several pulsars. During the 1970s, NASA began to launch a series of High Energy Astronomy Observatories (HEAO) to survey the sky in the x-ray band. In 1989, NASA launched the Cosmic Background Explorer (COBE), which measured microwave radiation from the early Universe. The scientific analysis of COBE data confirmed the theory of the Big Bang. The importance of this result was recognized by Dr. George Smoot and Dr. John Mather (a NASA civil servant) being awarded the 2006 Nobel Prize in physics.

During the 1990s and 2000s, NASA completed and launched the so-called "Great Observatories"—the Hubble Space Telescope, Spitzer Space Telescope, Chandra X-ray Observatory, and the Compton Gamma Ray Observatory. Together these observatories, which have observed the Universe through multiple wavelengths of light, have peered back in time to examine the early evolution of the Universe and the development of stars, galaxies, and planets. In July of 1994, Hubble was able to obtain images of Comet Shoemaker-Levy's impact with Jupiter, the first collision of two bodies in the solar system to be observed. NASA's astrophysics spacecraft also contributed to confirming the 1998 discovery that the expansion of the Universe was accelerating and that a mysterious "dark energy" was counteracting the forces of gravity to increase the pace of expansion of the Universe.

Solar and Space Physics

In the area of solar physics and space physics, the earliest science satellites of the late 1950s provided data that helped scientists to create the initial maps of the magnetosphere and confirm the existence of the solar wind (the energetic particles that blow out from the Sun) and observe the interplanetary magnetic field. A series of Orbiting Solar Observatory (OSO) spacecraft, launched during the 1960s and 1970s, conducted solar physics investigations during a full solar cycle, mapped the ultraviolet, x-ray, and gamma radiation in the sky, and collected the first images of a solar flare. The data on solar activity were used to develop warnings of heightened solar activity and to conduct satellite operations in space. The planetary missions of the 1970s and 1980s enabled significant advances in studies on magnetic fields in the planets of the solar system.

In 1995, the Solar and Heliophysics Observatory, a large cooperative mission between the European Space Agency and NASA, was launched. Among its many contributions, SOHO recently helped confirm a thirty-year old theory about solar flares and has made significant contributions to the study of the Sun and solar activity. NASA's solar and space physics satellites continue to collect data to improve understanding of the Sun-Earth connection, the physical processes of the heliosphere, the dynamics of the solar corona and its heating processes, among other research areas. NASA's solar and space physics research advances basic knowledge and contributes to improving the prediction of space weather events, which can disrupt space-based activities including the transmission of GPS signals and satellite communications and interfere with ground-based assets such as the electricity grid.

Selected Accomplishments in Earth Science

NASA's long record of Earth observations, beginning with its earliest scientific satellites, has become critical in understanding changes to the Earth and its climate on a global level and for facilitating applied uses of the data to help address societal challenges. The Vanguard I satellite launched in 1958 gave us new information about the shape of the Earth. The Explorer 7 satellite that operated from 1959-1961 enabled the first measurements of the energy coming into and going out of the Earth, a key component of climate study. The launch of NASA's TIROS 1 in 1960, the first weather satellite, revealed features such as ocean storms and the structures of hurricanes and typhoons, the flows of ice over water, and the temperature patterns of oceans and land--information that had direct societal value. The immediate recognition of TIROS's value to the Nation led to the continuation of the program and its eventual inclusion in an operational weather satellite program housed in what is now the National Oceanic and Atmospheric Administration (NOAA).

The Nimbus series of satellites, starting in 1964, became a standard NASA platform for observing the Earth and provided the first global images of clouds and weather systems. The Nimbus 7 satellite, which operated from 1978-1994, carried an instrument that collected the first precision measurements of the total solar irradiance, an important measurement for understanding long-term climate change. Instruments on Nimbus satellites also provided the first data from space on changes in the color of the ocean from space, which enable scientists to quantify and map the concentration of chlorophyll, estimate global marine biomass, and provide insight on ocean biomass as a carbon sink.

In 1972, NASA launched the Earth Resources Technology Satellites (later renamed Landsat), which opened new opportunities to study natural and human-induced changes of the Earth's surface and land cover such as deforestation, urbanization, and ice flows and their implications. Unlike purely science-oriented missions, Landsat grew out of the interests of both non-scientist stakeholders and scientists who wanted to use the data for monitoring crops, managing natural resources, and mapping forest fires, among other uses. The Landsat program has continued through successive satellite launches and data collection over the last 36 years; the program holds the longest unbroken record of data collected on the Earth's surface from space. Landsat 7 data have recently been used to create a map of Antarctica at a resolution ten times better than the previous maps. Landsat was also one of the NASA Earth observing spacecraft that contributed to the dramatic images of the collapse of the Larsen B Ice Shelf in western Antarctica during January-March 2002.

Not all of NASA's Earth science contributions have come from satellite observations. A NASA-funded airborne survey to explore reported losses of stratospheric ozone over Antarctica "*demonstrated unequivocally that ozone was destroyed by chlorine and bromine radicals*," according to a National Academies report, *Supporting Research and Data Analysis in NASA's Science Programs.* The survey helped establish that chlorofluorocarbons were destroying the ozone, results that helped lead to the Montreal Protocol of 1987 and the agreement among industrialized nations to stop producing chlorofluorocarbons.

During the 1980s, NASA initiated the Earth Observing System program to provide measurements of the Earth as an integrated system. NASA launched its Earth Observing Satellites—Terra, Aqua, and Aura--during the late 1990s and early 2000s. These and other NASA Earth observations satellite have made important contributions to environmental and climate change research.

Data collected by the Aqua satellite, for example, has been used in weather prediction models and helped to improve "*the accuracy range of experimental six-day Northern Hemisphere weather forecasts by up to six hours, a four percent increase*", according to a 2005 NASA and NOAA news release.

Early Developments in Satellite Communications

NASA's research and development activities on satellite communications during the 1960s and 1970s demonstrated the ability to redirect transcontinental and intercontinental telephone, radio, and television signals with the first passive communication satellite, Echo 1; to amplify and retransmit up to 60 two-way telephone conversations simultaneously with NASA's launch of the first orbiting commercial communications satellite, AT&T's Telstar 1; and the routine use of ground station technology with the RCA-developed Relay 1 satellite, which NASA launched. In 1963, NASA launched the first geosynchronous communications satellite, Syncom 2, which enabled the development of a global communications satellite system.

NASA's Applications Technology Satellites Program (ATS) program tested communications experiments, including the use of search and rescue location transmitters, emergency communications links, and satellite navigation, and demonstrated new applications such as long-distance education. Many of these early demonstrations helped foster what has grown to be a multibillion dollar commercial communications satellite and services market.

Education

From the early 1960s through 1970, NASA funded graduate studies for 5,000 scientists and engineers---an investment of more than $100 million. NASA has continued to support a graduate fellowship program and also supports undergraduate fellowships, internships, cooperative education opportunities, museum and outreach activities, and education projects to inspire students at all levels to study space-related disciplines and to provide training and educational opportunities for America's youth, including women and underrepresented minorities. In addition, many of NASA's science missions include education and outreach activities. Through its education and related program activities, NASA is working to foster student interest in and pursuit of science, technology, engineering and mathematics (STEM) education and careers that serve the Nation's and NASA's workforce needs.

Looking Ahead

While NASA's past accomplishments are reason for celebration and reflection this year, it is also clear that the future will provide challenges and opportunities no less daunting and inspiring than those of the past half century. Challenges for NASA's aeronautical programs include the national effort to develop of a next generation air transportation system, research to mitigate aviation's impact on the environment, and the development of innovative vehicle concepts that can provide new capabilities for civil and military aviation.

In human space exploration, NASA is seeking to exploit the research opportunities of the International Space Station, develop a new crew and cargo launch system, and continue to plan for returning astronauts to the Moon, all of which will help build the capabilities required for human visits to other destinations in the solar system.

In the area of science, space-based investigations of "dark energy", the ongoing search for extant and extinct life beyond Earth, as well as the search for Earth-like planets orbiting stars like the Sun and the prospects for collecting samples on Mars and returning them back to Earth represent some of the exciting challenges that lie ahead. The need to sustain measurements of the Earth and climate are critical to understanding changes to the Earth; these data also offer the potential for new and expanded uses of the data to benefit society. In addition, the threat of space radiation remains a significant hazard to human space exploration and requires scientific research that can help lead to approaches for mitigating radiation effects to astronauts. Finally, better understanding and characterizing the properties and potential threat posed by near-Earth objects will continue to be a challenge for the agency.

Many of these challenges will be pursued with international partnerships, due to their cost and complexity and the opportunities that they offer for sustained peaceful cooperation in science and technology. The potential pathways for such cooperation will continue to emerge as many nations with increasing space capabilities seek to expand their presence in outer space.

However, as the Committee's oversight activities have demonstrated, NASA is likely to continue to face hurdles in carrying out all of these challenges. Controlling costs; executing programs efficiently; maintaining a balanced set of aeronautics, science, and human spaceflight and exploration programs; dealing with an aging workforce, and coping with a constrained fiscal environment are all likely to continue to be imperatives for the agency's leadership in the years ahead.

Appendix A
Declaration of Policy and Purpose of the National Aeronautics and Space Act of 1958 as enacted in 1958 (Unamended)

DECLARATION OF POLICY AND PURPOSE

Sec. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201 (e).

“(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes.

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere.

(6) The making available to agencies directly concerned with national defenses of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

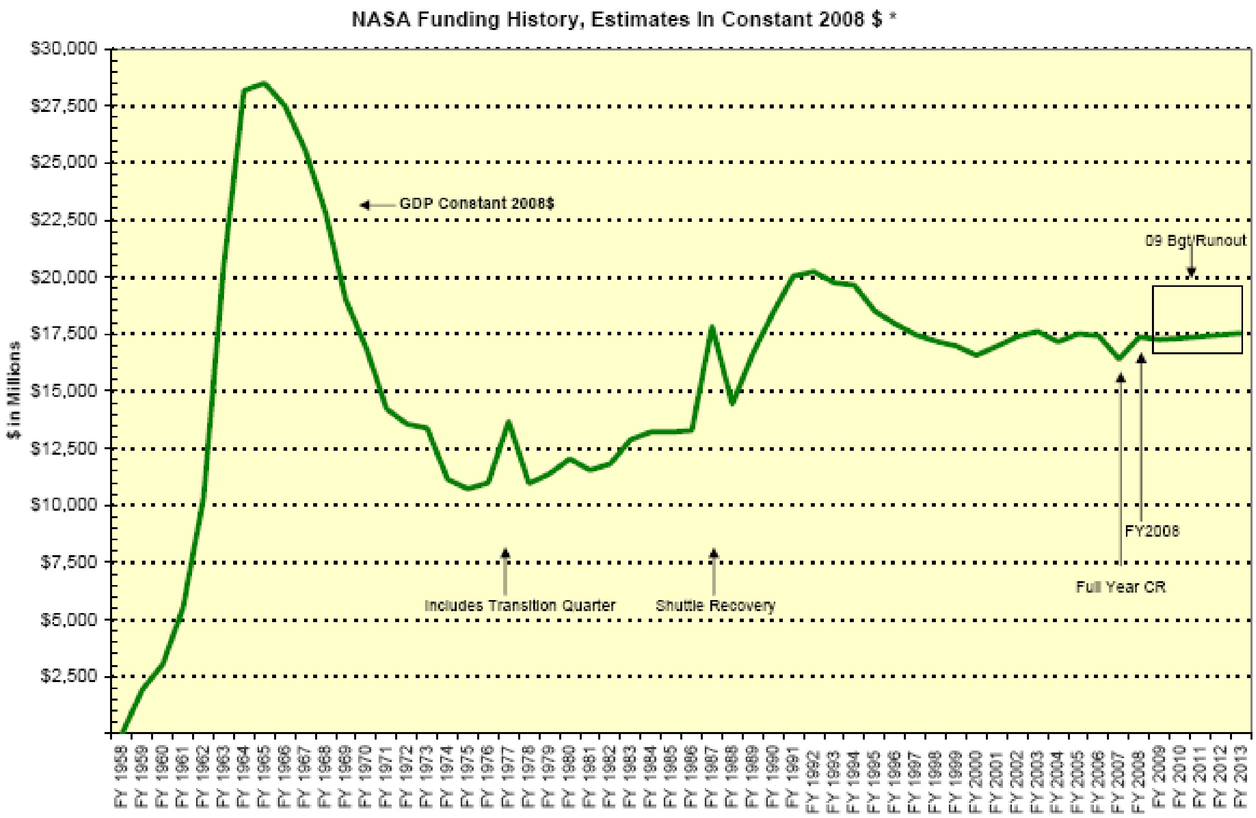
(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results, thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

(d) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), and (c).”

Attachment B

NASA Budget History 1958-2008



* Constant dollar estimate is based on FY09 Budget GDP deflator. NASA's actual purchasing power is likely less, since labor and materials in the aerospace sector have generally experienced greater cost escalation than reflected in the GDP indices. FY2009-13 is the current budget request and runout year estimates.

Source: NASA