NASA AT 50: PAST ACCOMPLISHMENTS AND FUTURE OPPORTUNITIES AND CHALLENGES

HEARING

BEFORE THE

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July 30, 2008

NASA AT 50: PAST ACCOMPLISHMENTS AND FUTURE OPPORTUNITIES AND CHALLENGES

WEDNESDAY, JULY 30, 2008

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

The Committee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON SPACE & AERONAUTICS
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

NASA at 50: Past Accomplishments and Future Opportunities and Challenges

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

WITNESS LIST

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

NB: There will be a recorded audio message from Professor Stephen Hawking following witness testimony.

HEARING CHARTER

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

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 space flight 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 space flight, 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 space flight 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 space flight 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 space flight 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 space flight and exploration since the initiation of Project Mercury, from Alan Shepard's 15 minute sub-orbital 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 six-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 five 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 space flight 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 space flight project.

Following ASTP, it would not be until 1981 that NASA returned to human space flight. 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 space flight 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 space flight. 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 percent 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 CO_2 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 multi-billion 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 under-represented 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 space flight 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;

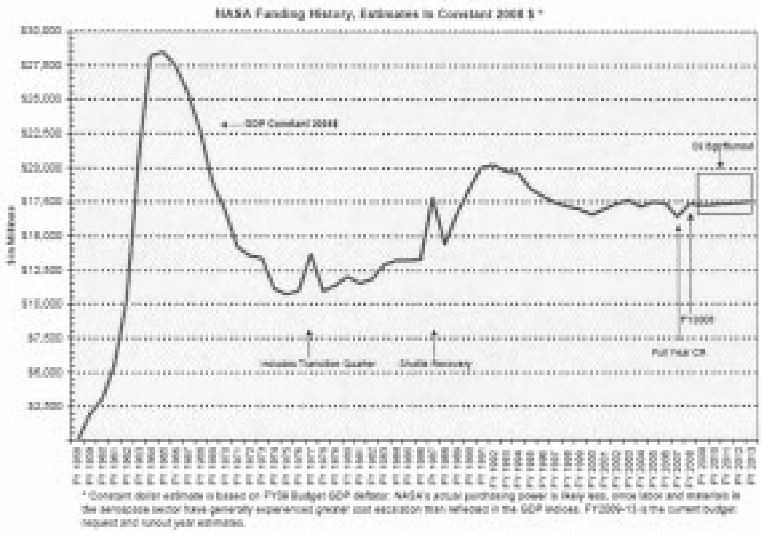
(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results, thereof; and

(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



Source: NASA

Chairman GORDON. Hearing will come to order. I hear the bells ringing, so it must be 10 o'clock, and I am following Senator Glenn's suggestion that, in his committees he knows how things are often hectic. You need to get started on time to encourage people to get here on time. We have Members at various other hearings that will be coming and going, but I want you also to know, and we want to welcome all of our web cast viewers today. We typically have, it is really hard to believe, but we will have two million or more individuals watching us on the web today. So we want to welcome all those, too.

And I will be brief in my opening remarks, because we have a very distinguished panel of witnesses, and I know that we all want to hear from them. However, I do want to provide some context for today's hearing.

As many of you know, this year marks the 50th anniversary of the creation of the Science and Technology Committee. We were one of Congress's responses to the Soviet Union's successful launch of Sputnik 1 in late 1957. Sputnik led to a national reexamination of America's educational system, our scientific research infrastructure, and our goals and capabilities for space exploration.

And this committee was given the responsibility of leading Congressional oversight of these issues.

1958 also marked the year that the National Aeronautics and Space Administration was established. In fact, yesterday, July the 29th, marked the 50th anniversary of President Eisenhower's signing of the *National Aeronautics and Space Act of 1958,* the legislation that created NASA.

So it is fitting that we take time to look back at what NASA has accomplished over the past 50 years, as well as look ahead to the opportunities and challenges facing the agency over the next 50 years.

We often forget how much we owe to the men and women of NASA who in many ways have helped create the world in which we live today. They have dramatically advanced our knowledge of our home planet Earth and of the universe at large through an amazing array of scientific research or spacecraft over the past five decades.

Indeed, it is no exaggeration to say that NASA's accomplishments have helped to rewrite the science textbooks more than once. NASA's men and women have also helped create the technologies that have made possible the commercial aircraft and the aviation system that contributes so much to our nation's economic viability, as well as technologies that have helped enable the military aircraft that defend our freedom.

Finally, NASA's men and women have led the way in helping humanity to move out into the solar system, including putting the first footprints on the Moon almost 40 years ago. In doing so they have inspired successive generations to seek to achieve challenging goals in science and technology.

In short, NASA has accomplished a great deal in its first 50 years.

Of course, the agency has also had its share of tragedies and missteps over that same period, and we will continue to address those issues whenever it is necessary as part of the Committee's ongoing oversight of NASA.

But at the end of the day, however, NASA and its programs are still recognized around the world as a shining symbol of America's preeminence in science technology, and we need to ensure that continues to be the case.

In that regard, I am pleased that the House of Representatives passed the Committee's bipartisan *NASA Authorization Act* by an overwhelming margin, because I believe the bill will help provide positive guidance to the next Administration regarding the importance of investing in our nation's civil space and aeronautics programs and investing at a level that is equal to the tasks we have asked the agencies to undertake.

I look forward to the Senate completing its work on the bill so that we can send it to the President for his signature before Congress adjourns.

I also want to express my deep appreciation to the noted physicist, Professor Stephen Hawking, for his submitting a pre-recorded message that will be played during this hearing. However, before we hear from the witnesses and Professor Hawking, I also want to recognize some special guests we have in the audience today. I am very pleased that two former Chairmen of the Science and Technology Committee, Bob Walker and Sherry Boehlert, are able to join us today.

In addition, I would also like to recognize NASA Deputy Administrator, Shana Dale, who has joined us today also. So welcome to each of you, and thank you for your contribution to this committee and to Congress and to NASA.

Now I would like to return to my friend and colleague, Ranking Member Hall, a long-time strong supporter of NASA, for any opening comments that he would care to make.

[The prepared statement of Chairman Gordon follows:]

Prepared Statement of Chairman Bart Gordon

Good morning.

I will be brief in my opening remarks, because we have a very distinguished panel of witnesses, and I know that we all want to hear from them.

However, I do want to provide some context for today's hearing.

As many of you know, this year marks the 50th anniversary of the creation of the Science and Technology Committee.

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In addition, I would also like to recognize NASA Deputy Administrator Shana Dale who has also joined us today.

Welcome to each of you.

Now I'd like to turn to my friend and colleague, Ranking Member Hall—a longtime strong supporter of NASA—for any opening comments he would care to make.

Mr. HALL. Mr. Chairman, I thank you, and you have made good comments, and it gives me great pleasure to be here today.

NASA has given us so many really great accomplishments and such pride and so many great American heroes, and today we are honored to have Senator Glenn here, who is certainly everyone's hero. Spent a lifetime serving this country, first as a Naval aviator, then as an American, the first American to orbit the Earth and serving 24 years as a U.S. Senator from Ohio. And I was proud to be on the John Glenn President for a long, long time in Texas, and they still, half the people there think he won. And the very lovely Mrs. Glenn, who would have made a great first lady. We are glad to have you with us.

I also am pleased to see other distinguished Americans on our panel today. Norm Augustine, a good friend and longtime supporter of everything that is good and great for NASA and for the American people. My recommendation to either of those Presidential aspirants for a Vice President, if we could push you into it, but I know we couldn't, because I suggested it to you, and you said you thought I was your friend.

Speaking of Norm, the American people really should feel at ease if we could accept this, would accept that second spot. We'll talk about that later.

Dr. Stephen Hawking, I also want to take a moment to welcome my good friends and former colleagues as Bart has done. Bob Walker and Sherry Boehlert, who, along with Jim Sensenbrenner, have ably chaired this committee. And also I would like to mention the Chairmen I have worked with here who could not make it here today, Don Fuqua, what a guy, and Robert Roe, and the late George Brown.

So it is really fitting to reflect on the accomplishments of both NASA and the Science and Technology Committee. Shana, we are happy to see you and glad to see that you are still running NASA. We look to you for leadership as you have given us for a lot of your years. I think the first time I ever saw you you were working for NASA, you were on a tricycle. That is how long you have been with us, so I won't mention the number of years. But welcome to you.

In the decade after World War II American leadership in science and technology was largely taken for granted, and we may have allowed ourselves to get too complacent. When the Soviets launched Sputnik in October of 1957, I well remember it. I watched it, and it was a real wakeup call for the country. In 1958, under House Speaker Sam Rayburn, whose Texas fourth district I proudly represent at this time, the Select Committee on Astronautics and Space Exploration was established. Shortly thereafter the Committee created NASA from what was then the National Advisory Committee on Aeronautics and the permanent House Committee on Science and Astronautics or our forerunner was chartered.

We rose to the challenge of Sputnik. We caught up with and then surpassed the Soviets, and in doing so we demonstrated to the world our American values of democracy and peaceful scientific achievements, but scientific and technological advantages tend to be short-lived, and they rely on a steady stream of education and innovation that must be nurtured.

While we celebrate and reflect on NASA's past accomplishments, it is also clear that the future challenges and opportunities are no less daunting, no less important, and no less inspiring than those of the last 50 years.

NASA's astronautical programs are vital as developing the next generation of aircraft and air traffic management systems that will help expand our economy through increased capacity with less frequent and less costly delays and by developing technologies that will enable safer and more efficient aircraft.

NASA's space science programs contribute to our knowledge of our solar system, the sun, and the universe. Space science has always been very practical and has had practical applications developing the means to monitor solar space weather events which can disrupt the transmission of GPS signals and satellite communications and interfere with ground-based systems such as our electricity grid or our military weapons targeting.

So finally, NASA's Earth Science programs have greatly advanced our understanding of our home planet. We are beginning to better understand the Earth and the ways that weather, the oceans, land masses, icecaps, and the atmosphere interact with one another. Through NASA-developed technology, we are also improving our ability to predict weather, help farmers increase crop production, give local governments the ability to better manage land use, fisheries, and many other practical uses.

And in human space exploration, NASA is completing construction of the International Space Station. The ISS is the largest international engineering and construction project ever undertaken, and research on-board Station holds the promise of life-changing medical breakthroughs. We will pursue many of our future space exploration challenges with our international friends and allies, and those arrangements offer the potential for sustained peaceful cooperation in both science and technology.

If America wants to retain its status in the world and the prestige and power that comes from leadership, we cannot be complacent. Other countries are making great strides, and American leadership is not guaranteed. We can succeed at whatever we put our minds to as long as we stay focused.

Mr. Chairman, I look forward to today's hearing. I look forward to celebrating some of our past successes. I also look forward to hearing from our panelists how we can all work together to ensure that the next 50 years are even better. I am proud to have been a part of the Science and Technology Committee for 27 years. Together we have accomplished amazing revolutionary things. You have given us good leadership as our Chairman. We are the leading Committee in the United States Congress on successfully transmitting bills that come before us and handle them properly, and I am confident that our finest hour is still ahead of us.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Mr. Chairman, it gives me great pleasure to be here today celebrating the 50th anniversary of the Science and Technology Committee, and honoring the great achievements of the men and women of NASA over the past 50 years. NASA has given us so many great accomplishments, and so many great American heroes.

Today we are honored to have Senator John Glenn, a true American hero who has spent a lifetime serving his country, first as a Naval Aviator, then as the first American to orbit the Earth, and then serving 24 years as a U.S. Senator from Ohio. Senator Glenn, it's an honor to have you with us today.

I would also like to welcome the other distinguished Americans on our panel today; Norm Augustine, and Dr. Maria Zuber. Speaking of Norm Augustine, the American people should feel at ease if he would accept the second spot on the Presidential ticket. We will also hear pre-recorded testimony from noted physicist and author, Dr. Stephen Hawking. I also want to take a moment to welcome my good friends and former colleagues, Bob Walker and Sherry Boehlert, who along with Jim Sensenbrenner, have ably chaired this committee in the past. I would also like to mention other Chairmen I have worked with but who could not make it today; Don Fuqua, Robert Roe, and the late George Brown.

It is fitting to reflect on the accomplishments of both NASA, and the Science and Technology Committee over the last half century because they were born of the same crisis. In the decade after World War II, American leadership in science and technology was largely taken for granted. We may have allowed ourselves to get too complacent. When the Soviets launched Sputnik in October 1957, it was a real wake-up call for the country.

In 1958, under House Speaker Sam Rayburn, whose Texas fourth district I now represent, the Select Committee on Astronautics and Space Exploration was established. Shortly thereafter, the Committee created NASA from what was then the National Advisory Committee on Aeronautics; and the permanent House Committee on Science and Astronautics—our forerunner—was chartered.

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Chairman GORDON. Thank you very much, Mr. Hall.

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

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Mr. Chairman, thank you for holding this hearing today. I am pleased that the Committee has taken time to honor the 50th anniversary of the establishment of the National Aeronautics and Space Administration (NASA) and review its accomplishments and examine its future challenges.

NASA's accomplishments have been numerous in its relatively short history, most notably multiple lunar landings beginning in 1969, international cooperation with Soviet and Russian space programs throughout the Cold War, and most recently, invaluable research and discovery on the planet Mars.

What is evident from NASA's accomplishments over the past decades is that they were achieved through a national commitment—through Sputnik, through President Kennedy's inaugural address challenging this country to put a man on the moon, and through the establishment of this committee and others.

Today NASA faces steep challenges—it continues to operate on a nearly stagnant budget and with the end of Shuttle flights, faces an operational gap before the next generation of space flight technologies become available. From this hearing and others honoring this anniversary, we must learn from our past, from mistakes we made and from what we were able to accomplish.

The Committee has a number of distinguished panelists today, witnesses that have been intricately involved with NASA's many accomplishments over its history. I look forward to our testimony today and I yield back the remainder of my time. Thank you, Mr. Chairman.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman. I want to welcome our distinguished witnesses: Senator John Glenn, Mr. Norman Augustine, and Dr. Maria Zuber.

Each of you has played an important role in directing and analyzing the state of our space and aeronautics efforts.

The National Aeronautics and Space Administration is critical to my home State of Texas, and the research it has supported has benefited all of mankind.

Today's hearing will assess NASA's 50 years of existence; analyze its current state of operations; and provide guidance for the Administration in the years ahead.

NASA celebrates 50 years since its establishment. For 50 years, NASA research has enabled scientists to continue to do ground-breaking research in a zero-gravity environment, with untold benefits.

For example, one of the many spinoff technologies from the Hubble telescope is the use of its Charge Coupled Device (CCD) chips for digital imaging breast biopsies.

The resulting device images tissue more clearly and efficiently than other technologies.

The CCD chips can detect the small differences between a malignant or benign tumor, without the need for a surgical biopsy.

This saves the patient weeks of recovery time, and the cost for this procedure is hundreds of dollars vs. thousands for a surgical biopsy.

With over 500,000 women needing biopsies a year, the economic benefits are tremendous, not to mention the reduction in pain, scarring, radiation exposure, time, and money associated with surgical biopsies.

Of course, this is just one of so many examples of NASA research that benefits society with broader applications.

NASA has played such a key role in outreach and education activities.

A well-educated technical workforce is essential to NASA's success, and it is imperative for the agency to continue to invest in education as well as its other activities.

Again, I want to congratulate NASA for 50 years of stellar work.

Thank you, Mr. Chairman. I yield back the balance of my time.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF REPRESENTATIVE MARK UDALL

Good morning. I am very pleased that we are holding today's hearing to commemorate the 50th anniversary of the National Aeronautics and Space Administration (NASA). NASA is one of the crown jewels of the Nation's research enterprise, and it has a positive "brand" that is known throughout the world. As Chairman Gordon has noted, this week marks the 50th anniversary of the signing of the *National Aeronautics and Space Act of 1958*—the legislation that established NASA, so it is quite appropriate that we hold this hearing now. I also want to welcome the very distinguished panel of witnesses that is appearing before us today. We appreciate your service.

The world is in many ways a far different place than it was a half century ago. Many of the technologies and capabilities that we take for granted today would have been considered to be in the realm of science fiction back in 1958. Moreover, I have little doubt that fifty years from now, many of *today's* technologies and accomplishments and scientific knowledge will be considered quaint at best. That is the dynamic reality of scientific and technological advance. And that advance can lead us to a brighter future, if we take the steps necessary to ensure that we harness the fruits of those advances in science and engineering for the benefit of society.

One of the significant engines of scientific and technological progress in America over the past fifty years has been NASA. Indeed, investments made in NASA since 1958 have produced achievements that have profoundly affected our daily lives, whether through the practical benefits of NASA's meteorological satellite R&D and its remote sensing satellites or by means of the innumerable improvements NASA has made to our civil and military aircraft technologies—improvements that have made them safer, faster, more efficient, and more environmentally friendly.

Yet NASA's impact has been even more profound, leading to extraordinary advances in our understanding of the universe—witness the amazing discoveries enabled by the Hubble Space Telescope—and of our Earth, especially in understanding the complex factors involved in climate change. NASA's human space missions have also fundamentally changed our world view, as people around the world saw Earth for the first time as a bluish-white globe suspended in the inky blackness of space while humans walked for the first time on the surface of another world nearly forty years ago. That change in world view has also been one of the fruits of the International Space Station project—a project involving some 16 nations in a complex and challenging cooperative mission. And it is a perspective that will produce benefits in the future as America leads cooperative efforts to explore our solar system with humans and robots.

As I note the amazing impact of NASA on our nation over the past fifty years, I am of course aware of the times when NASA's missions have not gone as planned, when missions have ended in tragedy, and when cost growth and technical problems have led to outcomes less successful than we would have liked. As Chairman of the Space and Aeronautics Subcommittee, I recognize those problems and have worked to help prevent their recurrence. That is the proper role of Congressional oversight, and I take that responsibility seriously.

Yet, that said, I think that as we look back at all NASA has accomplished over the past half century as well as what NASA is seeking to achieve even as we speak, I think we owe a debt of appreciation to all the men and women of NASA, its contractors, and the universities and research institutions that have made it all possible. So in conclusion, I would just like to say "Happy birthday, NASA—we look forward to many more years of accomplishments from you."

[The prepared statement of Ms. Richardson follows:]

PREPARED STATEMENT OF REPRESENTATIVE LAURA RICHARDSON

Thank you Chairman Gordon for holding this important hearing today. I would also like to thank our witnesses, in particular the former Senator from Ohio, and the first American to orbit Earth, Mr. John Glenn for their willingness to appear before this committee as we discuss the state of NASA moving forward.

This hearing marks the second in a series of three hearings celebrating the 50th anniversary of NASA and the creation of the Science and Technology Committee. Back in March this committee had a productive conversation with former Microsoft CEO Bill Gates about the state of American innovation. During that discussion Mr. Gates emphasized the need to focus our time and energy on our most precious resource, our children. Quite frankly any discussion about the future of NASA, American innovation, and our nation's standing in the global scientific community should include the youngest segment of the population responsible for ushering in the next era of creativity and advancement that has come to characterize NASA.

With the recent landing of the spacecraft Phoenix on Mars, coupled with my own opportunity to witness the launch of the Space Shuttle Endeavour, there is no doubt in my mind that we can continue to build upon our past achievements. However, we can not rest on our laurels to be leaders in innovation, we must also invest.

Back in February the Full Committee held a hearing on the NASA budget, and at that time I expressed concern with cuts to the budget in several areas. As Senator Glenn mentioned in his testimony, space flight has allowed the scientific community to perform critical research in zero gravity environments, and construct the International Space Station. However, absent a lack of funding, the United States will not have a viable means for space travel. Every effort to shorten this gap must be made to ensure that scientific progress in this country is not stymied.

In conclusion I want to reiterate my support for NASA, including past and present NASA personnel who conduct the activities which will keep us at the forefront of innovation. I look forward to a very productive discussion.

Mr. Chairman I yield back my time.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Mr. Chairman, thank you for hosting this monumental hearing to celebrate the 50th anniversary of the creation of the National Aeronautics and Space Administration (NASA).

The *National Aeronautics and Space Act* was signed into law 50 years ago yesterday, on July 29, 1958, establishing NASA. Our nation has witnessed extraordinary moments because of NASA's creation; we successfully and safely launched the first flight of humans into space and land them on the Moon. In fact, we have the first American to orbit the Earth before us today. Space exploration and aeronautical developments have enabled the creation of new technologies and capacities.

I am proud that our committee passed the NASA reauthorization bill this year. We must continue to adequately fund NASA's efforts, pushing the agency and Nation forward.

I was thrilled to witness a Space Shuttle liftoff this year in Florida. The excitement I felt must have been minimal compared to the awe of viewing the Earth while orbiting the planet for the first time, Senator. Yet, NASA continues to create a sense of national pride and personal inspiration for millions of Americans even without viewing a liftoff or orbiting the Earth first-hand.

I would like to thank today's witnesses, Senator Glenn, Mr. Augustine, and Dr. Zuber, for taking the time to appear before us. I look forward to hearing your testimonies.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF REPRESENTATIVE HARRY E. MITCHELL

Thank you, Mr. Chairman.

Thank you for holding this hearing to celebrate the 50th anniversary of the establishment of the National Aeronautics and Space Administration (NASA).

NASA conducts vital research and development projects that help us learn about our surroundings.

Arizona State University, which is located in my district, is home to researchers who on many of these important NASA research projects.

To maintain America's competitiveness in science and technology, we must do more than merely keep up. We must lead, and commit ourselves to providing the resources necessary to keep us at the forefront of this kind of cutting edge research and development.

I look forward to hearing more from our witnesses about NASA's accomplishments as well as its future challenges and opportunities.

I yield back.

Chairman GORDON. And at this time I will now introduce our witnesses. First up will be the Honorable John Glenn, who was the first American to orbit the Earth as part of the original Mercury 7 astronauts. He then served the State of Ohio as Senator for 24 years, and in 1998, Senator Glenn returned to orbit as the oldest person to fly in space as a crew member of the Space Shuttle Discovery. And Mr. Glenn, we welcome you here.

Secondly, we will have Dr. Norm Augustine, who was the Chairman and Chief Executive Officer of Lockheed Martin Corporation and went on to chair numerous advisory panels including the 1990, Advisory Committee on the Future of the U.S. Space Program, and most recently he chaired the Committee that authorized or authored the profoundly important National Academy's Report, *Rising Above the Gathering Storm.*

And finally, Dr. Maria Zuber, who is currently the Department Head and E.A. Griswold Professor of Geophysics in the Department of Earth, Atmospheric, and Planetary Sciences at the Massachusetts Institute of Technology. She also served on the President's Commission on Implementation of the United States Space Exploration Policy and is a member of the National Academy of Science. Welcome to you.

And we will begin with Senator Glenn.

STATEMENT OF HON. JOHN H. GLENN, JR., UNITED STATES SENATE (RETIRED)

Mr. GLENN. Thank you very much, Mr. Chairman and Members of the Committee.

To be asked to comment on NASA's first 50 years and then contemplate where we go from here for the next 50 years or more is a big order. It has been a wondrous half century to say the least. Mankind for the very first time learned to get off the surface of the Earth and make a lot of progress in getting into this new laboratory of space.

We can't help but remind ourselves of the losses along the way of good friends who are no longer with us who were sacrificed in this whole process, but we look forward to the coming days as memorial to those folks who were good friends who lost their lives.

Exploration comes, and this will be a summary of my longer remarks, which I ask would be put in the record if we could, please. This will be a summary of them.

Exploration comes down into two areas in my mind. One is macro, one is micro. Macro is going out deeper into space, going off Earth and going wherever we can learn how to travel. Micro to me is equally important in that it does the experimenting, the research that maximizes the research return for benefit of people right here on Earth. And that is an area that I will give special attention to.

In the first 50 years we had the Mercury Program, we had, that started us off. We had the Gemini Program in which we learned to rendezvous, Apollo that gave us that wondrous day, I certainly will never forget when Neil Armstrong made the first footprint on some place other than Earth.

We went on to use some old equipment and use Skylab. We built the Orbiter, which could then stay up for a 14-day period of time, and along with that we asked colleges, universities, and businesses to be involved with this, because we could now do research in space that we never were able to do before.

Beyond that we developed a Space Station for longer-term research because we thought it was that important, and the International Space Station then, when we asked 15 other nations to join us.

The number of projects that were, are illustrated by the fact that on STS–95, the flight of Discovery I was privileged to be on in '98, we had 83 different research projects, and *Columbia* before its demise had 90 research projects on that one flight.

So the community, the colleges, universities, and businesses had reacted very favorably to our proposals to let them or to encourage them to use space for this new research.

We had developed robotics along the way, which is amazing in its own. NASA set up a, they were enough into the research area that they set up a special research planning Office of Biological and Physical Research (OBPR). And they had five different areas under that in which they were looking forward to conducting very basic experiments; bio-technology, combustion, fluid physics, fundamental physics, and material science.

Now, there have been delays, and we look forward in those areas to longer-term research on the Station. There have been delays in completing the International Space Station because of *Columbia* and some of the other engineering problems, but those will be eventually solved.

Along the way George H.W. Bush, our 41st President, proposed a Mars Program, and there wasn't a whole lot of support for it, and when the Administration changed, the idea sort of died, but another proposal for the Mars Program, the *Vision for Space Exploration* was put forward by the current President, George Bush, in January of 2004. This time there was not a wait for support. The President just put a directive over to NASA to do it, and NASA responded.

Congress, this was not what Congress had really voted the appropriations for that time period, and Congress responded later on to this change of direction.

One note here that I would toss out to the Committee is I don't think we know yet, we don't have a clear definition of exactly what the ultimate objective of the Moon Project is going to be. In Cleveland in 2007, the President said, and I quote, "And, therefore, we set a new mission which is to go to the Moon and set up a launching there to further explore space." Now, I don't know that anyone has really addressed this yet, but if that is really our mission, it is to set up a launch facility on the Moon, that is a whole different complicated, expensive, and questionable safety-type proposal. So I think that needs to be ironed out.

I favored the VSE because I assumed that it was in addition to, not in place of, existing problems, existing programs. I assumed that money requests would follow. Instead what we got were cuts in other research to try and pay for this program, and it wound up in my view as the biggest unfunded mandate that we have in all government history. We had to do it, NASA had to do it. They were directed to do it, but it was out of the existing NASA budget, which is a huge job, enormous job.

Congressional consent and or consultation and international consultation was certainly lacking in this because there was consternation in some of those communities when this was announced. Not only would there be no increase in funding, but ongoing research at that time was cut by 1.2 billion over a five-year period.

Now, I think too often Mike Griffin, the current Administrator, catches some of the blame for this, because he is the one that has to implement it. I don't see that as being fair at all. I don't think it is his fault. He is as loyal a person as you could get, and if he is given a direction of doing something, he is going to do his level best to do it. He was a scientist at Johns Hopkins, headed up their space program, was formerly in the hierarchy of NASA in his earlier career, in fact, back when the first proposal to go to Mars was made.

So but he gets his direction from above, and he is a loyal soldier. He is going to do his level best to carry it out, and that is what he has been doing.

But I would say this. Someone once told me a long time ago in the Marine Corps, "Great plans without resources remain dreams." And nothing could be more true. Now, my colleague, the late Gus Grissom, put it in more understandable terms perhaps back in the days when a cut in the funding for the Project Mercury was being proposed. And Gus, being the person who could always sum things up well, they asked him for his comment on what the cuts would do, and he said, "No bucks, no Buck Rogers." And that, and so that did it.

The Shuttle has now been looked at as the source of money to continue with the program, because it costs some $400 million plus per launch, and so that was looked at, and so in 2010, the present plan is to terminate that program.

Then for five years before our own spacecraft are developed to where we can use them, for at least five years, it has already been extended one year, it may go out to more, for five years we will be dependent on the Russians to launch our people. We will have no man capability to go into space during that at least five-year period. U.S. astronauts and equipment will have to be launched from and returned to Russia to have access to our Station.

Now, I don't think that is a very pretty picture to put before the rest of the world, quite frankly, and I never thought I would see the day when the world's richest, most powerful, most accomplished space-faring Nation had to buy tickets from the Russians to get up to our Station. I think that is a bummer.

The Soyuz is not that great at the moment either, our transportation system, because it has had its own set of problems, and this all assumes that they will be able to work out the Soyuz problems. If not, we would be left with no way to get up there period. That would be it.

Way out, well, we have $100 billion invested in this. When the Station is completed, we will have over $100 billion. Our allied nations, the other 15 nations, will have about another $12 to $15 billion. So there is a $115 billion investment that we have here, and we are not maximizing. We could do that, we could keep the Shuttles going, start restoring research in those five areas that NASA was looking at previously, keep the Shuttle, restart research, and also keep the workforce we have, the most experienced launch engineering team, engineering and launch personnel ever developed anywhere. So it would keep that workforce alive also.

We have $100 billion investment, and if we put $2.8 to $3 billion per year additional into the program now, we could keep the Shuttles, keep the research, and keep the workforce. It is a huge investment for the most unique laboratory ever put together by anybody anywhere, and now it would cost that comparatively small amount to use it, use it properly. A lot of money? Yes.

But for this country with a $3 trillion budget just announced yesterday, $482 deficit that we owe $482 billion deficit, $10 billion a month going into Iraq, it would seem to me that we should be able to find enough money to maximize this thing which is so important for our future.

The reliability of the U.S. is at stake here also. We have scientists, college, university, the business, the international partners could all be brought back on stream as they originally signed on for.

This fits into a bigger picture, too. We are into a time of globalization. Tom Friedman has addressed that very well in his book about the flat Earth, and Fareed Zakaria has a new book out on that subject, too. But what they all sum up to me is this. A nation that leads in the future in education for our people, which we did in the past and which is down now, our K–12 education is not in good shape now compared to other nations, that our education and research. The second element is research. We learn the new things first, and with an educated citizenry, put them together, and NASA is a good example of that, and NACA, its predecessor that gave us the basis for the aircraft industry as we know it today.

Our spacecraft, our space program is admired as a symbol of a great nation willing to propose great projects and carry them out for the benefit of all mankind, and a true world leader defining what the future will be and in turn, making it happen.

NASA had a mantra at one time that said their goals were to improve life here, to extend life to there, to find life beyond. If we follow that prioritization, and I think we can do that and still do the VSE, if we have the will, but I would caution once again, "A great plan with resources remains a dream."

Thank you, Mr. Chairman.

[The prepared statement of Mr. Glenn follows:]

PREPARED STATEMENT OF JOHN GLENN

Mr. Chairman and Members of the Committee, thank you for inviting me to testify today.

Just 50 years ago, we were learning—for the first time in all human history—how to travel above the Earth's atmosphere at amazing speeds and remain there for increasing amounts of time. It has been a wondrous half-century.

We will always remind ourselves that progress was not without losses of some wonderful and dedicated friends along the way.

In the beginning:

My interest in NASA goes back to the 1950's when the first seven astronauts were starting what I viewed as a completely new service, akin in nature to the existing military services. The impetus for the manned space program back in those days was the cold war, but I felt that this was not just a short-term interest to be laid down when we prevailed in that confrontation with the Soviets. There would be new exploration, whether just out of the atmosphere, as we were contemplating in those days of Project Mercury, or deeper into space as a permanent and growing part of our national future. After all, people had looked up for thousands upon thousands of years and wondered what was up there and what we could do, what we could learn if we were there. Now, for the first time in all human history, we could go.

What was contemplated was exploration, to go where people had not gone before, and to exercise our innate and questing human spirit in ways never before possible.

Macro-Micro:

We could term that "macro" exploration to deeper space, but to me it's more than matched in importance by the opportunity, also for the first time in human history, to do on-board "micro" exploration, in a zero G environment. For the very first time we would be able to do unique experiments with medicines, pharmaceuticals, material, processes, physics and other research where astronauts could be working surrogates for the interest of the scientific community.

That dual view had the general interest, cooperation, and support of the successor administrations, our people, the Congress and scientific community, particularly in the area of micro-exploration.

From the earliest days of the space program, I believed that we served our nation best by maximizing the research return—*macro and micro*—at each new deeper venture into space. We would create maximum long-term public support as people realized and appreciated the personal value of this research to them and their families.

That concept was generally accepted through the years. In fact, we had experiments on-board even from the beginning flights in the space program. Even on our first orbital flight of Friendship 7 whose main purpose was to just prove we could do it successfully, I had special film for certain solar pictures as well as a spectrometer and other experiments.

Gemini taught us how to rendezvous.

And of course nothing can surpass Neil Armstrong's first step ever on someplace other than Earth. And the lunar? samples they brought back.

Skylab used leftover Apollo equipment and had varied research studies on a longer-term, but was not a vehicle that could remain in orbit permanently. By this time, the Shuttle with its fourteen-day limitation was used for expanded micro research. The Shuttle had much more space and capacity for research. NASA encouraged colleges, universities and private interest with "zero G" projects or experiments to submit their proposals for consideration along with NASA's own in-house developed research. A process of evaluation and review was set up to consider the hundreds of proposals. Although some Shuttle flights had dual purposes, all manifests were filled to the maximum with research projects. For example, on the STS–95 Discovery flight in 1998, we had 83 different research projects, and *Columbia,* before its ill-fated disaster, had 90 research projects on-board. Scientific, academic and corporate communities had responded very well to the challenge of doing experiments in micro-gravity. Space Station was conceived as a semi-permanent *long-term research* vehicle that could accommodate a normal crew of six. To date, crew size has been limited to two or three as construction has been delayed. The Shuttle would revert to its name and become principally the *builder-transport vehicle.*

And in a move that I supported, we asked fifteen other nations to become our international partners on what now became the *International* Space Station. Some would have their own research modules. In other words, this was envisioned as co-operative—rather than a competitive—space program.

Doing the macro-micro research—along with involvement with international partners—seemed to get the maximum return for every dollar spent on the space program and I still back that concept.

Robotics:

Meanwhile, as we proceeded with short-range exploration and research on-board, we would also have a robust robotic program to learn all we could about potential deeper space human destinations.

The concept of the ISS and its completely unique mission was well debated many times in the 1990's in Committees and on the House and Senate floors. I strongly supported this concept of the ISS and the NASA program and floor managed the Senate "pro" debate for several years. There was a long list of ISS potential benefits of space research. The Senate voted in favor of that, as did the House. The people of this country accepted that direction for the space program, and looked forward to benefiting from the research results.

Research Planning:

NASA established an Office of Biological and Physical Research (OBPR) that oversaw five areas of inquiry to receive special research priority on the ISS: Biotechnology, Combustion, Fluid Physics, Fundamental Physics, and Materials Science.

Delays:

Tragedies and engineering difficulties have delayed station completion. It has been partially manned all through this period, usually with a two-person crew, but will eventually have a crew of six. It is due to be completed within the next couple of years.

MARS (SEI):

The first President Bush (41st President) announced an intent to establish a Mars mission (Space Exploration Initiative—SEI), but it was very controversial and never was seriously considered or funded.

MARS (VSE):

In January of 2004, the current President George W. Bush (43rd President) announced what was called his *Vision for Space Exploration* (VSE). This came as a surprise and shock to most if not all Members of Congress since they had voted the NASA appropriations for a different purpose, to the space community and our international partners, who had not been part of the decision-making process. This time the President just directed NASA *"to do it"*—period.

The timing of the President's announcement I'll leave to your speculation. The new program, however, was to be a complete change of direction for NASA. It called for returning to the Moon, for extensive exploration, and then on to Mars at a later date. Those two objectives were to be the driving force of the program. *Everything* else was to be secondary or eliminated.

Recalling that decision in Cleveland in 2007, the President said, "And therefore, we set a new mission, which is to go the Moon and set up a launching there for which to further explore space."

If carried out, this proposal to *launch* from the Moon to Mars would be by far *the most complicated* and *expensive* compared to other Mars mission alternatives.

Presidential advice can come from many quarters, but it would be interesting to know just who advised the President on some of the VSE proposals.

Money:

Even with that, I was much in favor of this new program because I felt it added a new dimension, added new excitement for our young people and would engender new support from the American people. However, I presumed, as did most others, the *"vision" was in addition to* other scheduled NASA programs, *not in place of.* I naturally assumed there had to be a request for more money within the budgeting process to accomplish these new objectives.

My assumptions were incorrect. With no legislative change, the President's VSE had just unilaterally put into place an enormous "unfunded mandate."

Then Administrator Sean O'Keefe came to one of the National Advisory Council (NAC) meetings—of which I was a member—and informed us that the *VSE* would *come out of NASA's existing budget.* Therefore, all research on the ISS that did not apply directly to going to the Moon or Mars would be peremptorily cut. To say that I was amazed at this development is an understatement.

I was certainly in favor of the Moon/Mars VSE, but if the only way that could be done was by cutting out all research on the ISS—*the reason it had been built*—then that broke faith with what our people had accepted as the purpose of the program, what Congress had debated and approved, and what our allies had been promised from this great nation.

There had been little or no consultation with Congress before this change of direction or with the fifteen other nations involved. Just directing NASA from the White House into new priorities to the Moon and Mars completely altered the nature of the NASA job. It gave NASA an enormous task with no additional funding.

The changes announced by Administrator O'Keefe basically eliminated most research projects with colleges, universities and corporations unless those projects were specifically and directly connected with the Moon/Mars objectives. He said there would not only be no increase in funding, but there would even be a research cut of $1.2 billion over a five-year period.

New Administration:

The current NASA Administrator, Dr. Mike Griffin, is a broad-based scientist who headed up the space department at Johns Hopkins prior to becoming Administrator, and had been in the hierarchy of NASA many years ago, during the earlier Mars proposal. He is a loyal person trying to do the best job possible under the circumstances with the *directions he's been given from above.* He's taken hard criticism for the research cuts, both ISS and others, but the changed NASA mission he's been given and the lack of funding he is faced with comes from higher Administration decisions to not adequately fund the new NASA direction, and I presume is being enforced by whoever is in charge of the NASA account at OMB.

If we are to have new and expensive national objectives, then we must be willing to pay for them. With no change in budgeting policy, Dr. Griffin has been handed a near "mission impossible."

As someone said a long time ago,

> "Great plans without resources remain dreams."

My former astronaut colleague, the late Gus Grissom, put it in even more understandable terms when a cut was being proposed in Project Mercury:

> "No bucks, no Buck Rogers."

End of Shuttle:

Shuttle launches are expensive, running some four hundred million dollars plus per event.

The ISS is scheduled to be completed during 2009. To save money, Shuttle use will be terminated in 2010, leaving us with at least a five-year period in which the U.S. will not have a human space launch capability—until our newly designed Orion spacecraft has been tested and brought into operation. That assumes it will be operational on schedule.

During that five-year hiatus, we will be in the position of *buying* launch services *from the Russians.* A $750 million contract has already been signed to provide a specific number of Russian launches to ferry U.S. personnel and equipment to/from *our* ISS. We will not have a heavy-lift capability, up or down, as the Shuttle has. *Our astronauts and equipment will have to be launched from and return to Russia to maintain ISS access.* This assumes that recent re-entry problems of the Soyuz are corrected. If there would be further Soyuz difficulties, we will be left with no way to get to or from the ISS.

Correcting the Problem:

Additional funding of $2.8 to $3.0 billion per year could keep the Shuttle in operation until our new Constellation program equipment is ready, and at least partially restore the ISS research program.

Workforce:

Another major benefit of that process would be the preservation of the world's most experienced engineering and launch teams who could not be maintained with a five-year stand-down while we develop the Constellation concept. Personnel qualifications, training, and *experience* must be of great concern.

Investments:

With completion of the ISS, we will have invested just over $100 billion—*$100 billion*—and our colleague nations will have spent 12–15 billion to build and equip this most unique laboratory ever conceived. We should be doing everything we can to maximize its scientific utilization and extends its life, instead of just the opposite.

For the richest Nation on Earth with a budget of $3 trillion, to make a $100 plus billion investment and then not utilize it may be viewed as penny-wise, but is pound-foolish.

Unintended results:

There are other unintended results from the Shuttle termination decision.

Dr. Samuel Ting is a professor at MIT and Nobel Laureate recipient for his work in particle physics. When the underground Super-conducting Super-collider was canceled in 1993, he proposed an alternative concept that the Department of Energy supported and which NASA put on its flight manifest. It is the product of some 450 scientists in 50 institutions in 16 countries that would study cosmic rays, matter and anti-matter, with equipment weighing some 15,000 pounds and which would need on-board launch space of approximately one-third of the Shuttle cargo bay. It would then be mounted on trusses on the ISS for its operation.

$1.5 billion has been spent on the project to date, mostly from European and Asian researchers. A proof of concept prototype was successfully flown in 1998. NASA and DOE preparation teams have spent several tens of millions of dollars. With the cutback in Shuttle launches, the program has been put on what amounts to a permanent hold.

Reliability:

Changing direction in mid-stream has in effect pulled the rug out from under our own scientific community that worked very closely with NASA through the years. It has also pulled the rug out from under the colleges, universities, and businesses that took NASA seriously and cooperated with them. Perhaps even more dangerous, it's pulled the rug out from under our international partners, some of whom according to published reports are now looking at new space efforts by other nations for their cooperative plans in the future.

At a reception in Washington a short time ago, I met a foreign official high up in his country's space program—one of our ISS members—who told me they had trusted that the U.S. was serious about the Space Station and that they could not believe what the U.S. has done to them.

Globalization:

Another aspect to this that is very troubling for the long-term. We're into a period of globalization that will be extremely competitive. Our continued superiority in science and research is not one that is guaranteed. Tom Friedman's book, *"The World is Flat,"* outlines some of the difficulties and prospects.

A more recent book by Fareed Zakaria discusses how other nations are closing the scientific gap with the U.S.

U.S. Historical Strength:

If I were asked a question about what made this country great and gave us a position of international leadership in a comparatively short period of time, my answer would have to be two things.

Education:

One, we emphasized education, particularly in the hard sciences; math, science, technology, with K–12 education that became the norm for most of our people. Out of that came the best educated general citizenry in the world. Though not the major subject of this discussion, our K–12 education "system" is actually just over 14,700 school boards across the country, basically operating independently and too often more interested in saving money than in seeing that their children have a world competitive education.

Research:

The second element is basic research and this does apply to this discussion. Throughout our history, we put more effort into basic research, learned the new things first, and with that educated citizenry in a free democracy, new businesses were created, standard of living went up, and we were able to develop an economy that rapidly became the envy of the world.

Results:

A good example is the research impact of NASA's predecessor agency, the National Advisory Committee for Aeronautics (NACA). In the early days of aviation, NACA did the best aviation research in the world in structures, materials, aerodynamics, power plants, controls, etc. Utilizing that research, whole industries were formed in a short period of time. We became the world's leader with Boeing, Lockheed, Northrop Grumman, North American, Martin-Marietta, and others leading the way. They pioneered for the world the aviation travel and uses we depend on today. That would never have occurred without the kind of research that NACA did.

Today we find ourselves in the position of still being ahead in space research, but with the trends wrong. Our research seems to be leveling off—certainly government research has been reduced—at the same time other nations are increasing their research, so the trends for the long-teen are not good.

Those same basics apply for the future. World leadership for the future will still go to nations that lead in education, research and innovation.

Government Leadership:

For many years, some government agencies—NASA and DARPA for example—have been fountains of new and innovative "free thinking" type research. The Defense Advanced Research Projects Administration (DARPA) was the predecessor and inspiration for the Internet as we know it today. But DARPA, as I understand it, has now been restricted to only project-oriented research. I presume that means fewer innovation initiatives by some of the brightest minds in the world.

NASA has a network of some of the finest laboratories in the world with some of the best engineers and scientists anywhere who have worked for years getting ready for ISS research. Now research is cut in the most unusual and unique laboratory ever conceived. Granted, if we were doing the ISS over again, it would undoubtedly be done differently, but that's hindsight. We have it and its required an enormous investment. We should make the most of it.

Apollo:

With the VSE announcement in January of 2004, perhaps the President recalled the clearly enunciated Apollo goal that was successful, but that included an equally clarion call for enabling funds. In those days, the people and the Congress responded favorably. After January 2004, to the best of my knowledge, the President has never made another speech about the VSE.

Additional:

Addition of $3 billion to the yearly NASA budget is small when compared to other budget figures; to a $3 trillion national budget, to an announced $490 billion deficit, to a monthly $10 billion Iraq bill, and to other comparisons. But with this $3 billion investment, there is the potential of enormous return.

Additionally, we preserve *our* ability to travel in space and to *our* ISS.

We maintain a continuing engineering and launch workforce.

We restore the confidence of our international partners.

We make possible projects such as Dr. Ting's Alpha Magnetic Spectrometer.

Our space program will remain as a symbol of a great nation, willing to propose great projects and carry them out for benefit of all, a true world leader defining what the future *will* be.

At one time NASA's mantra was:

to improve life here
to extend life to there
to find life beyond

We can follow that prioritization and still do the VSE if we just have the will, but—

"A great plan *without resources* remains a dream."

Chairman GORDON. Thank you, Senator. You know, NASA as well as this committee was created by that so-called Sputnik moment, and I think that there is going to need another Sputnik moment before we are going to have those resources you speak about. I just hope that it is not when we have to, as you say, buy a ticket from the Russians to go to the Space Station or follow the Chinese back to the Moon, because once you have to, there is a lead time, and once you have to start catching up, you become years, years behind.

So thank you for your good advice.

And now we will hear from Norm Augustine.

STATEMENT OF MR. NORMAN R. AUGUSTINE, CHAIRMAN AND CHIEF EXECUTIVE OFFICER (RETIRED), LOCKHEED MARTIN CORPORATION

Mr. AUGUSTINE. Thank you, Mr. Chairman and Members of the Committee. It is a distinct honor to appear before you today at this hearing that recognizes the 50th anniversary of NASA as well as of this committee itself. And it is particularly to do so in the presence of these colleagues.

I had the good fortune to be in the control room when Senator Glenn took his most recent flight, and that was a great occasion even to sit on the ground and watch. I probably should note at the outset that I am here today as a private citizen. I am not representing any of the organizations that I have been associated with along the way.

Some 50 years ago as a graduate student in aeronautical engineering, I was passing under the tower at Princeton's graduate college, and another student came running up to me and excitedly said that the Soviets had just launched a Sputnik, and frankly, my first words were, what is a Sputnik? I was soon to learn, and I recall feeling almost as if a body blow had been delivered to me. This was in the midst of the Cold War. America was supposed to be preeminent in science and technology, and the Russians had beaten us into space. So that was unfathomable.

And it, of course, carried enormous repercussions, economically, particularly militarily as well as in the space arena itself.

That was a period when America's leadership in science and technology was to a very large degree taken for granted. It had been little noted that the underpinnings of that leadership had been gradually eroding. Our investment in science and technology was not commensurate with the leadership position that we thought we had held. Our public schools were showing signs of neglect and deterioration, particularly when it came to the teaching of mathematics and science. And our production of scientists and engineers was stagnating.

As it turned out as you have noted, the Soviets inadvertently did us a very great favor. America was awakened, and America stayed awakened throughout the rest of the Cold War.

NASA was formed not only to assure leadership in aeronautics but now in space as well. This very committee as you have noted was formed to assure that the health of our nation's science and engineering enterprise was subjected to continuing attention by the Congress. The Advance Research Projects Agency was formed, and the Department of Defense. Our public schools took steps to improve the quality of the education that our children were receiving, particularly in the areas of science and technology. And more and more young people were attracted to the fields of science and engineering as we set new goals and in particular the Apollo Program.

Mr. Chairman and Members of the Committee, fast forward if you will 50 years to an era of globalization as mentioned by Senator Glenn, an era driven in no small part by advancements in science and technology. Americans by and large are very confident of our leadership in these fields. After all, who discovered the laser, the transistor, and the integrated circuit? Who sequenced the human genome, and who invented the personal computer or the Internet and the GPS and the iPod and so on?

NASA's former Administrator rather revealingly tells a story of, and I am referring to Dan Goldin, tells a story of being criticized by a citizen who thought that NASA was investing too much in Earth satellites, and the critic had asked, and I quote, "Why do we need meteorological satellites? We have the Weather Channel."

Little noticed today is that there are almost twice as many Bachelor's degrees granted in physics in the U.S. the year before Sputnik as there were last year. Little noticed is the number of engineers graduating with Bachelor's degrees declined by over 20 percent in a recent two-decade period with a modest up-tick the last two years, due in no small part to foreign students studying in this country. Or the number of Ph.D.s in engineering declined by 34 percent, the Ph.D.s granted to U.S. citizens declined by 34 percent in a little over a decade, again, with a slight up-tick due principally to foreign students increasing.

Further, our public schools mostly rank near the bottom of the class when it comes to international tests, particularly in math and science. We are surpassed by such nations as Azerbaijan and Latvia and Macao.

This time there is no Soviet Union to give us a precipitous wake-up call. China may do us the favor. More likely this time we will have to awaken ourselves. Once awakened, as we all know. Americans can do some truly remarkable things.

Not long after NASA was formed Senator Glenn, of course, greatly strengthened our national pride. In a time our nation badly needed encouragement, Neil Armstrong and Buzz Aldrin, aided by Mike Collins, gave us the ultimate list, lift. And soon ten more of my friends walked on the Moon, and all of them returned safely. As Buzz Aldrin has said, "It is amazing what one person and 100,000 of their friends can accomplish."

NASA's original charter, it is worth noting, emphasized the positive impact that space activity could have on education. In my own experience there is nothing that excites children more than space and dinosaurs, and we are short on the latter.

As a person who witnessed these past 50 years and was a member of the committee that was established by the White House and NASA to look at the future of the U.S. Space Program created not long after the *Challenger* accident, I think I have learned a lot of lessons along the way, and what I would like to do in the interest of time, Mr. Chairman, if you and the Committee would permit me to submit a full statement for the record, I have listed quite a number of those lessons that I think are important and that have a bearing on future space activities of our country.

I just conclude by observing that I think America could take enormous pride in what NASA has accomplished these past 50 years, all of which to our nation and NASA's great credit has been accomplished in the glare of the public spotlight. NASA, like any other organization that involves human beings, is not perfect, but if NASA sets perfection as a goal, I believe we have a great deal to look forward to in the next 50 years.

Thank you.

[The prepared statement of Mr. Augustine follows:]

PREPARED STATEMENT OF NORMAN R. AUGUSTINE

Mr. Chairman and Members of the Committee.

It is a distinct honor to appear before you at this hearing recognizing the 50th anniversary of NASA, as well as of the House Science and Technology Committee itself, and particularly to do so in the presence of such distinguished colleagues. I should perhaps note at the outset that I am appearing as a private citizen and not representing any of the organizations with which I am or have been affiliated.

Some fifty years ago, as a graduate student in aeronautical engineering, I was passing under the tower of Princeton's graduate college when another student excitedly called to me that the Soviets had just launched a "sputnik," Frankly, my first words were, "What's a 'sputnik?'" I was soon to learn-and I recall a feeling almost as if a body blow had been delivered to me. It was akin to learning of such events as the death of President Kennedy, the loss of *Challenger* and *Columbia,* the tragedy of *Desert One,* the *Apollo* fire, or 9/11. This was the midst of the Cold War; America was supposed to be preeminent in science and technology. That Russia had beaten us into space was unfathomable. And it carried broad repercussions.

It was a period when America's leadership in science and technology was largely taken for granted . . . it had been little noted that the underpinnings of that leadership were gradually eroding. Our investment in science and technology was not commensurate with the notion of world leadership. Our public schools were showing signs of neglect, particularly when it came to the teaching of mathematics and science. Our production of scientists and engineers was stagnating.

As it turned out, the Soviets had inadvertently done us a great favor. America was awakened . . . and remained awakened throughout the remainder of the Cold War. NASA was formed, not only to assure leadership in aeronautics but now in space as well. This very committee was formed to assure that the health of our nation's scientific and engineering enterprise would be subjected to continuing attention by the Congress. The Advanced Research Projects Agency was created within the Department of Defense. Our public schools took steps to improve the quality of education our children were receiving, particularly in mathematics and science. And more and more young people were attracted to the fields of science and engineering.

Mr. Chairman and Members of the Committee, fast-forward, if you will, fifty years . . . to an era of globalization, driven in no small part by the explosion in science and technology. Americans are once again confident of our leadership in these fields. After all, who discovered the laser, the transistor, the integrated circuit? Who sequenced the human genome? Who created the personal computer, the Internet, GPS and the iPod? NASA's former Administrator, Dan Goldin, tells of being criticized by a citizen for investing so much in Earth satellites. The critic asked, "Why do we need meteorological satellites . . . we have the weather channel?″

Little noticed is that there were almost twice as many Bachelor's degrees in physics awarded the year before Sputnik as now. Little noticed is that the number of engineers graduating with Bachelor's degrees declined by over 20 percent in the last two decades prior to a recent up-tick, the latter mostly due to an increase in foreign students; or that the number of Ph.D.s in engineering granted by U.S. universities to U.S. citizens had declined by 34 percent in a single decade. Or that nearly two-thirds of the Ph.D.s in engineering granted by U.S. universities go to foreign nationals; or that our public schools consistently rank near the bottom of the class in mathematics and science as compared with their global counterparts, surpassed by such nations as Azerbaijan, Latvia and Macao.

This time there is no Soviet Union to give us a precipitous wake-up call. China may do us the favor . . . more likely this time we must awaken ourselves. But once awakened, we all know that America can accomplish extraordinary deeds. Not long after NASA was formed, now-Senator Glenn strengthened our national pride. In a time when our nation badly needed encouragement, Neil Armstrong and Buzz Aldrin, aided by Mike Collins, gave us the ultimate lift. Soon, ten more of my friends walked on the moon-and all returned safely. As Buzz Aldrin has said, "It's amazing what one person and 100,000 of his friends can accomplish." NASA's original charter emphasized the positive impact the space program can have on education. In my own experience there is nothing that excites small children like space (and dinosaurs!).

As a witness to these past 50 years of effort in space and as a member of the committee that was established by the White House and NASA on the Future of the U.S. Space Program not long after the loss of *Challenger,* I believe I have learned many lessons. Perhaps I might share a few of them on this occasion. It, for example, has been my observation that:

- The most effective space program is a balanced space program, one that utilizes humans for those functions where humans excel and uses robots for those functions where robots excel. As the aforementioned White House/NASA committee noted in hindsight, we would not have risked the lives of seven humans to place a communications satellite on orbit. Nor, for that matter, would we expect a robot to have performed the repair of the Hubble Space Telescope.
- Given a balanced space program, first priority nonetheless goes to the conduct of research. It is here that the greatest return per dollar can frequently be realized and where fundamental new knowledge can be derived.
- The human space program is justified by the need of human beings and nations to explore the unknown . . . to push back frontiers. It cannot be justified solely by technological spin-offs or scientific returns, even though these benefits are often not insignificant. Sir Edmund Hillary standing atop Mount Everest is simply different from using a rocket to launch an instrument package to the top of Mount Everest.
- Transportation remains the primary stumbling block to a vigorous, affordable space program. Unfortunately, it is very difficult to justify the discounted cost, and risk, associated with developing a new launch vehicle based on future cost savings alone, particularly with any realistically foreseeable traffic model. Nonetheless, as our committee noted eighteen years ago, the nation badly needs a new, highly flexible heavy-lift-capable expendable launch vehicle in its inventory.
- The tipping point in affordability of near-Earth space operations will arrive when space *tourism* becomes commonplace. Unfortunately, this is a bit of a chicken and egg problem . . . but so, too, was the problem faced by the airline industry until the surge that was brought about by World War II. Although some years away, space tourism will one day become affordable to a not inconsiderable number of the Earth's inhabitants. That will change everything.
- The next logical centerpiece of the civil space program would seem to be a the landing of humans on Mars, probably with a return to the Moon as a precursor. Six robots built by NASA have of course already made successful landings on Mars and have done yeoman's work . . . but, eventually, humans will set foot on that planet. The only question is what flag or flags they will bear.
- In spite of the absence of a commitment to a major new project, there continues to be strong grassroots support among America's citizens for the space program. It would nonetheless be unwise to initiate a new "centerpiece" project without a strong national consensus for that specific undertaking, and a consensus that appears likely to endure. Any such pursuit will require the continued endorsement of *at least* six Congresses, three presidential administrations and twelve budget cycles. When a new centerpiece project, presumably involving human flight, *is* in fact initiated, no "date-certain" should be set for its accomplishment. Rather, a step-wise schedule should be established with the initiation of successive stages dependent upon successful completion of prior stages. One predictor of a successful space program is continuity: including continuity of funding, stability of objectives, and persistence of personnel.
- Major development projects should not be initiated until at least three conditions are satisfied: First, the mission concept is clear; second, only engineering—not new science—is required; and third, adequate funding can reasonably be expected to be available.

- There exists a critical mass in a nation's space program below which success becomes tenuous. Unfortunately, I am unable to define what that level is—but space activity is much like heart surgery: it is better to do a lot of it . . . or none of it.
- It is unwise to pursue space projects "on the cheap." It is, of course, essential to be efficient, particularly when entrusted with the taxpayers' resources—but space is highly unforgiving; it is intolerant of cutting corners. Projects are best served when "done right" . . . that is, conservatively . . . including extensive testing and, importantly, the provision of *reserves* in funding, technical approaches and, where applicable, in schedule. To do otherwise will almost always increase both cost and the probability of failure.
- The greatest challenge faced in the years ahead by the industry that supports NASA will be that of providing, and keeping, an adequate cadre of world-class scientists, engineers and engineering managers who choose to dedicate their careers to space activities. The same will be true of NASA.
- Finally, space is a risky business. We should never tolerate carelessness or neglect. Nor should we accept wastefulness of any type. But, as stated in the closing sentence of the report of the Advisory Committee on the Future of the U.S. Space Program, "If we as a nation are to place a greater premium on letting nothing go wrong, on not making errors, and on ridiculing those who strive but occasionally fail, than we place upon seeking potentially great accomplishments, then we have no business in space."

I believe that America can take enormous pride in what NASA has accomplished these past fifty years—all of which, to America's great credit, has been done in the glare of the public spotlight. NASA, like any other organization populated with humans, is not perfect—but if it sets perfection as a goal I am confident that we will have much to look forward to in the *next* fifty years.

Thank you for granting me this opportunity to share my views with you.

Chairman GORDON. Thank you, Mr. Augustine.

Now, Dr. Zuber, we would love to hear from you.

STATEMENT OF DR. MARIA T. ZUBER, DEPARTMENT HEAD AND E.A. GRISWOLD PROFESSOR OF GEOPHYSICS, DEPARTMENT OF EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Ms. ZUBER. Thank you. Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today at this notable event celebrating the 50th anniversary of NASA.

Exploration and discovery are human imperatives. Our efforts to investigate and understand the unknown found the foundation upon which our nation was built. NASA exemplifies the pioneering and innovative spirit that built our country into the world leader that it is today.

We all know the story of the Apollo Program and our nation's successful quest to send humans to the Moon. In parallel, NASA's Robotic Space Program got off to the same quick start. Progress continues today.

Both these endeavors contributed to NASA's Science Program. It was only two years from the launch of the first U.S. satellite, Explorer 1, in 1958, to the launch of the world's first weather satellite, TIROS–1, and two more years until the launch of the first planetary mission, Mariner 2, which successfully flew by Venus.

My written testimony, which I submit for the record, details the extraordinary achievements made by NASA in revealing the nature and workings of the Earth and the solar system and other planetary systems. These discoveries relate to the formation of our solar system, the violent bombardment of ancient planetary surfaces, the origin of the Moon, the thick, greenhouse atmosphere of Venus, water on Mars, winds on the giant planets, and ocean beneath the surface of Europa, hydrocarbon lakes on Titan, the discovery of an icy world larger than Pluto, and Voyager 1's trek to the edge of our solar system.

And while we rightly consider NASA to be the space agency, its history of discovery and Earth science is ironically out of this world. NASA can claim credit for the Van Allen and radiation belts, mapping the ocean circulation, biological ocean productivity, global wind patterns, the structure of hurricanes, and measurement of the direct measurement of the drift of the Earth's tectonic plates, water movement in subsurface reservoirs, and changes in atmospheric ozone that led to the discovery of the ozone hole.

But what is next? Because one doesn't know where the next significant discovery will arise, a balanced scientific program is essential. Opportunities need to be selected on the basis of strategic plans that are formed by community input that identify the most compelling science within the context of tractable implementation.

The Moon is a fascinating target for future study. Apollo produced a treasure trove of information in the lunar samples that are still being analyzed today, but they sampled only a half dozen locations. Many more scientific areas exist such as within dark polar craters that might contain water ice. As the most accessible planetary body, future study of the Moon will provide transformative advances in understanding the evolution of all terrestrial planets.

Returning samples from Mars from sedimentary and ice-rich environments with well-studied geological context should be the highest priority in future Mars exploration. Such samples will match the value of the Moon rocks in deciphering that planet's early and present environment.

The outer solar system offers numerous thrilling destinations for future study. For example, several of the icy moons may have accessible liquid water and organic materials, and they hold the possibility for harboring life. Future study of asteroids and comets is of both scientific and practical interest. A detailed study of the internal constitution of a near-earth asteroid would illuminate the challenges that would be faced regarding hazard avoidance in the event that such a body is one day discovered to be on a trajectory to impact the Earth.

There seems to be a spectrum of opinion both within and outside the agency as to how much NASA should be involved in Earth science. As head of a preeminent Earth science department, I have a strong opinion on this topic. The Earth is a complex, dynamic system that requires detailed, in situ study and precise global views repeated over time to unravel its workings. No other agency is capable of developing the kind of state-of-the-art sensors and observation techniques that NASA can provide. NASA simply must play a role in the essential mission of understanding the Earth.

Science goals of high merit in all fields of Earth science have been prioritized in a recent decadal study in which I participated along with many members of the scientific community. Programs to study solar and Earth radiation, changes in the heights of ice caps, land and ice surface deformation are justifiably recommended with high, near-term priority as they relate to climate change.

One of the most remarkable discoveries in space science over the past couple of decades has been the detection of planets around other stars known as extra solar planets. After years of unsuccessful searching, over 300 of these objects are now known, and their rate of discovery is rapid. Great challenge in the coming decades is to image Earth-sized planets in the so-called habitable zone of their stars where conditions favor Earth-like.

Investment in new technology will be required to take future giant steps. Technological hurdles tackled early in advance of mission selection are the best prevention against cost overruns. There is most worthwhile science to be done, and NASA can't afford to do it all. Prioritization based on community input and available resources will allow us to move productively forward. A stable funding profile in space and Earth sciences is essential to progress.

Here I acknowledge and in fact, applaud the efforts of the Committee and their strong support of NASA science, exemplified by the most recent NASA bill passed by the House.

The role of the Space Program in inspiring young people to pursue scientific and technical careers is often noted. But evidence is anecdotal and difficult to quantify. We don't know how many people inspired by the Space Program pursued a math, science, or technology degree who wouldn't have done so anyway. But much anecdotal evidence exists to suggest that the numbers are huge. Many of those inspired grew up to pursue technical careers in things such as computer science, the telecom industry, they are engineers, physicists, even biologists. Young people now fascinated with the latest discovery from Saturn or in driving Mars Rovers have the potential to take on the greatest societal changes in energy, the environment, and health care.

Students inspired to pursue scientific careers must then be trained. In my own university students interested in energy flock to me and other NASA-funded researchers to obtain experience in remote sensing chemical analysis, robotics, and instrument design. A stable funding base to universities, all awarded via peer review, is crucial for training scientific and technical professionals in the future.

Maintaining the best technical and scientific workforce will require access to the entire pool of top talent. We must work tirelessly to attract and engage all students with mathematical and scientific aptitude independent of gender, race, et cetera. We must provide opportunities to top scholars from the international community to participate in American Earth and space science endeavors, recognizing their potential for contributing to our technical preeminence.

In summary, NASA is the federal agency where dreams reside. Its can-do attitude and propensity for taking on tasks in President Kennedy's words, "because they are hard," exemplify so much of what is great about our country. Other nations emulate us, follow our lead, and partner with us in peaceful exploration of the solar system beyond, but I should say in closing almost every spacefaring nation on Earth currently is exploring or has plans to explore the Moon, and the rest of the solar system can't be far behind.

Will people really view the United States as the greatest Nation on Earth when Chinese astronauts are walking on the Moon when we are not?

I generally appreciate the forum that the Committee has provided to recognize the achievements of NASA, and I look forward to responding to your questions.

[The prepared statement of Dr. Zuber follows:]

PREPARED STATEMENT OF MARIA T. ZUBER

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today at this notable event celebrating the 50th Anniversary of the National Aeronautics and Space Administration (NASA). Exploration is a human imperative; indeed our efforts to investigate and understand the unknown form the foundation on which our nation was built. Our citizens are descended from those who dared to abandon familiar confines and safe harbors for the uncertain chance of a better life. Indeed, the impetus to explore is coded into our DNA. It certainly is for me. I spent endless evenings during my youth freezing in my backyard viewing the night sky with my homemade telescope. Now I explore the solar system from an office overlooking the Charles River where it is also my privilege to train the next generation of young people who will innovate, discover and lead our nation forward in scientific and technological endeavors. Today, I will address NASA's accomplishments in space and Earth sciences from both a scientific and educational perspective, and with an eye towards an even brighter future.

Accomplishments in Space and Earth Sciences

The list of scientific achievements in the space and Earth sciences that can be traced to NASA in the fifty years since its inception is as extensive as it is impressive, and my review must necessarily be illustrative rather than comprehensive. I apologize in advance for the numerous discoveries that I omit for brevity.

Beginning "next door," the Apollo Program revealed that the Moon, and by extension the rest of the solar system, is ancient, having formed over 4.5 billion years ago. Moon rocks, and later meteorites, analyzed in state-of-the-art geochemical laboratories provided the evidence for that discovery. The early solar system was a violent place; many planetary surfaces are saturated with impact craters that formed primarily due to impacts from debris left over from the disk of dust and gas encircling the Sun that condensed to form the planets.

Impacts, though they are low-probability events today, played a crucial role in shaping the planets. The Moon itself probably formed from the impact of a Mars-sized impactor into the Earth. An impactor larger than Pluto likely produced the low-elevation northern hemisphere of Mars, believed by many to be the former site of an ancient ocean. Another massive impactor may have stripped off much of the mantle of Mercury leaving a core that is three-quarters the size of the planet.

NASA missions revealed other important processes that shaped the terrestrial planets. The Magellan mission to Venus penetrated the thick atmosphere of that planet to show most of the surface was covered almost simultaneously (in a geologic sense) by volcanic flows about 600 million years ago. The surface also shows evidence of intense fracturing, rifting and folding that is the manifestation of dynamic forces within Venus' interior, the kinds of forces that produce earthquakes on our home planet. The closest planet to the Sun, Mercury, which was first imaged by flybys of the Mariner 10 spacecraft and more recently by MESSENGER, shows remarkably diverse evidence for wrinkling of the surface suggesting the planet cooled and contracted, and odd volcanic features including a fascinating spider-shaped volcanic center.

The advance in our understanding of the planet Mars over the past decade can be counted among NASA's greatest successes, both from a scientific and technological perspective. Landing on Mars is arguably the most difficult thing we do in the robotic space program. The remarkable descent vehicles that execute precisely timed events that collectively comprise the entry-descent and landing sequence are confounded by the planet's turbulent atmosphere and rocky surface. The combination of observations from orbiters, landers and rovers has established firmly the evidence for a more clement early climate and a watery past. The discovery of vast reservoirs or polar surface ice and subsurface ice has removed a major impediment to future human exploration of this most Earth-like of terrestrial planets.

NASA missions have revealed the nature of the solar system's small bodies—asteroids, comets, Kuiper Belt Objects. In addition to contributing toward the inventory and dynamics of these remnants of planet formation, NASA spacecraft have landed on an asteroid, (purposely) impacted a comet, and flown through a comet tail to sample the primitive icy materials. In addition, the New Horizons spacecraft is now en route to the most prominent Kuiper Belt Object—Pluto.

Other discoveries in the outer solar system have defied the imagination. The Pioneer, Voyager, Galileo, and most recently, Cassini missions have revealed the giant planets' massive cloud systems and their complex dynamics, as well as the prevalence of ring systems whose study has informed modeling of the formation of the solar system. The diversity of outer satellites is remarkable: active volcanism on Jupiter's moon, Io, and a likely subsurface ocean beneath Europa. Icy geysers on Neptune's moon Triton and Saturn's tiny, frozen moon Enceladus imply the presence of underground pockets of liquid water laced with organic molecules. In collaboration with European colleagues, Cassini-Huygens identified organic-rich rivers and lakes and atmospheric hazes on Saturn's active moon, Titan, the only other known planetary body with a nitrogen atmosphere like Earth's.

And the remarkably resilient Voyager 1 spacecraft continues its three-plus decade journey of discovery, observing the farthest limits of the solar system.

So many of NASA's greatest discoveries have been serendipitous. Perhaps the most striking example comes from NASA's astrobiology program. Originally conceived to address the plausibility of life beyond Earth, the program encouraged study the of the range of environmental conditions under which Earth-like life can survive. This program has been spectacularly successful in fueling progress in the field of life in extreme environments, and the research has also been instrumental in advancing our understanding the conditions under which life may have developed and proliferated on the early Earth.

NASA's contributions toward understanding the state and workings of our Earth has a tremendously rich history. The most innovative approaches used in remote satellite observation were developed by NASA or by the scientific and technological community under the auspices of NASA support. Satellites and analysis tools originally conceived and built by NASA are commonly distributed to other, more operational, government agencies, such as the National Oceanic and Atmospheric Association of the Department of Commerce, and the U.S. Geological Survey under the Department of the Interior. Among numerous accomplishments NASA can claim credit for the first measurements of the steady but minuscule motions of the Earth's tectonic plates, characterization of the ozone hole, the three-dimensional structure of hurricanes, the general circulation of the oceans, biological ocean productivity, rainfall patterns in the tropics, and the global wind pattern over the oceans and its relationship to wave distribution and height. Efforts are ongoing to study changes on the Earth on decadal time scales—sea level rise, the surface ice volume, and measurement of changes in water reservoirs.

NASA's studies of the Earth's plasma environment have been central in understanding the phenomenon of "space weather," as well as the magnetic character of the Sun and the nature of the solar atmosphere.

The contribution of NASA to scientific knowledge is truly impressive. The respected publication *Science News* indicates that five to ten percent of all scientific discoveries, worldwide, over the past decade, can be traced to NASA. I routinely tell my students that there has never been a better time to be a space or Earth scientist. The web page of NASA's Science Mission Directorate lists nearly a hundred missions currently operating or in development studying the Earth, our solar system, the heliosphere and beyond. With this record of scientific achievement is it any surprise that the rest of the world aspires to be like us? Nearly forty years after the first humans walked on the Moon, nearly every space-faring nation is either actively executing or planning missions to the Moon. Many of those same nations are planning missions to Mars. Can the rest of the solar system be far behind?

Most Exciting Possibilities and Opportunities for New Scientific Discovery

About a week before our team's laser altimeter experiment arrived at Mars I received a call from a member of the press asking me what I was going to discover. I explained that if I knew I could have saved others and myself the trouble of designing and building the instruments and spacecraft. But while I didn't know what I would discover I knew without question that our experiment was worth doing. Anytime that one has gone to a place no one has been before, or looked at a place visited earlier with a novel new sensor, discovery has been assured. There has never been an exception. Even high expectations are often surpassed by large measure. The beauty and complexity of the natural world exceeds our imagination. Beyond that realization, however, there are some simple rules that can guide a vibrant program.

First, one doesn't know where the next significant discovery will arise, so a balanced scientific program is essential. Destinations should be chosen on the basis of decadal studies and strategic plans forged by community input. Peer review must continue to be employed to identify the most compelling science within the context of tractable plans for implementation. A mix of smaller missions with focused objectives should be combined with flagship missions with ambitious objectives or challenging destinations.

The Moon is for a fascinating target for future scientific study. The Apollo Program provided a treasure trove of information in the lunar samples that are still being analyzed today, but they sample only a half-dozen locations. If one visited only a half-dozen locations in the United States how well would one understand our country? With numerous missions en route to, or planned for the Moon, including the Gravity Recovery and Interior Laboratory (GRAIL) mission which I am privileged to lead, the next decade or more will represent a golden age of lunar exploration. I feel about the Moon the same way that I felt more than a decade ago in advance of a suite of orbiter, lander and roving missions that redefined our view of the planet Mars. As the most accessible example of a primordial planetary body, future study of the Moon will provide transformative advances in our understanding of the early evolution of all terrestrial planets.

Returning samples from Mars—from sedimentary, volcanic and volatile environments with well-studied geological context—should be the highest priority in future Mars exploration. Such samples will match the value of Moon rocks in deciphering that planet's early and present environment.

The outer solar system offers numerous thrilling destinations for future study and I see the next steps motivated in large measure by information returned from the Cassini and Galileo missions. A number of the icy moons (Europa and Ganymede of Jupiter and Enceladus and Titan of Saturn) are characterized by the presence of liquid water and/or organic volatiles and they hold the possibility of harboring life. The choice of nearest-term targets should be driven by peer review analysis that indicates that discoveries considerably beyond the current state of the art are possible within the context of current technology and affordable technology development.

Reconnaissance and/or sampling of small bodies will be of great value. From a practical standpoint a detailed study of the internal structure and constitution of an asteroid would be informative regarding the challenges that would be faced by an near-Earth asteroid that might one day be recognized to be a potential Earth impactor.

Likewise there are numerous challenging questions about workings of Earth that are appropriate for study by NASA. There seems to be a spectrum of opinion both within and outside the agency as to how much NASA should be involved in Earth science. As head of a preeminent Earth Science Department with a view on the most challenging questions in contemporary Earth and atmospheric science and oceanography, I have a strong opinion on this topic. The Earth is a complex, dynamic, system of systems that requires detailed *in situ* study combined with precise global views over time to unravel its workings. From the point of view of remote observation, no other agency is capable of developing the kind of state-of-the-art sensors and observation strategies that only NASA can provide. NASA simply must play a role in the essential mission of understanding our Earth.

Science goals of high merit in solid Earth, atmospheric, oceanic, hydrologic and cryospheric science have been prioritized in a recent decadal study that forms the plan for moving ahead. The questions are of both purely scientific interest and practical regard, the latter associated with natural hazards and climate change. What is clear in both cases is that collection and analysis of high-quality data of global extent, with repeated observations over time, is essential if we are to understand the state and future of our Earth.

One of the most astounding discoveries in space science over the past couple of decades has been the detection of planets around other stars, also known as extrasolar planets. Over three hundred of these objects are known now and after years of unsuccessful searching their rate of discovery is now rapid. Detection of these objects is mostly indirect, by tiny perturbations of parent stars and dimming of such stars as the planets pass in front of them. But most recently spectra have been measured and the first atmosphere detected. Most of these objects are giant planets very close to their stars, inside the orbit of Mercury by analogy with our own solar system. But detection of "super-Earths," large terrestrial-like planets, is now becoming a reality. A very high-priority challenge in coming decade is to image Earth-sized planets in the so-called "habitable zone" of their stars, that is, where conditions are favorable for Earth-like life. Large space-based deployable optics and the realization of coordinated sensor arrays are key in realizing this exciting scientific objective.

Judicious investment in new technology will be required to take future scientific giant steps. Technological hurdles tackled early, in advance of mission selection, are the best prevention against cost overrun. A prime example of an enabling new technology is the transition from radio to optical communication to take advantage of much increased data rates enabled by the shorter wavelength of light compared to radio waves. Such a system would be required to realize, for example, near-real time streaming video from the surfaces of other planets. The challenge is how to balance new investment with transformative possibilities with maintaining current facilities and continuing operations that have excellent return.

There is much worthwhile science to be done, but NASA cannot afford to do all of it. Prioritization needs to occur in order to move productively forward. Strategic plans must be developed and implemented, with flexibility to respond to discovery or enabling technology advances. A stable funding profile in space and Earth science is essential to progress. Here I acknowledge and in fact applaud the efforts of the Committee for their strong support of NASA science, exemplified by the most recent NASA bill passed by the House.

Inspiring the Next Generation

In 2003 I had the privilege of serving on the Presidential Commission to develop an implementation plan for the *Vision for Space Exploration.* One of the most eye-opening experiences of my participation on the Commission was reading the commentary of the general public with regard to space science and exploration, and traveling around the country talking to citizens about space. A remarkable outcome of the Apollo Program is how many children of the Apollo era grew up to study science or engineering because they were thrilled and amazed by the quest to reach the Moon. By and large, only a small percentage of these folks (present company on the Committee excluded) grew up to participate directly in the space program. Most of them grew up to pursue other disciplines, and today they are computer engineers, telecom engineers, chemists, physicists, etc. Last week on telling a friend that I would be testifying about the accomplishments of NASA, he told me: "Talk about inspiration. There's no doubt that I became a scientist because of my fascination with the space program when I was a kid." This individual is a molecular biologist who was elected this year to the National Academy of Sciences.

This anecdote highlights a key attribute of the space program, namely, its ability to inspire young people to pursue scientific and technical careers. But it is important to mention that the evidence is anecdotal and difficult to quantify. We don't know how many people inspired by the space program pursued a math, science or technology degree who wouldn't have done so any way. Many of the young people now fascinated with the latest discovery from Saturn or in driving Mars rovers have the potential to take on the greatest societal challenges in energy, the environment, and health care to name a few. Students inspired to pursue scientific careers must then be trained. We do know that college-level students are making use of NASA data to assist in their training for a range of professional careers. In my own university students interested in energy flock to me and other NASA-funded researchers to obtain experience in remote sensing, chemical analysis, robotics, and instrument design to name but a few. A stable funding base to universities, all awarded via peer review, is crucial for training the scientific and technical professionals of the future.

Attracting the best technical and scientific workforce will require access to the entire pool of top talent. We must work tirelessly to attract and engage all students with mathematical and scientific aptitude independent of gender, race, etc. We must provide opportunities to top scholars from the international community to participate in the American Earth and space science endeavor, recognizing their potential for contributing to our technical preeminence.

Because NASA is the agency of discovery, its potential for outreach is extraordinary. Few can fail to appreciate the stark beauty of an alien landscape revealed for the first time, or the difficulty of designing a spacecraft to fly close to the Sun. But there is no perfect measure of engagement. In outreach programs it is possible to measure web hits or museum attendance, both useful indicators, but far more difficult to measure when a child has been sufficiently inspired to take the harder math course or to consider science for a career for the first time. We must trust in the power of scientific discovery to motivate in its own right.

NASA does not have the scope, mandate or resources to solve all education problems in our country. But the agency most assuredly has the ability to nudge those with the "right stuff" in the direction of careers in science and technology. There is nothing like hands on experience on a difficult problem that better brings out the joy of learning. There must be room for creative, hands-on programs that complement broader programs with wide reach. On my GRAIL mission America's First Woman in Space, Sally Ride, and I have teamed to offer an innovative student project. Leveraged by an ongoing program called EarthKAM that Sally and her educator colleagues currently operate on the International Space Station, our MoonKAM program will place up to five cameras on each of two spacecraft sent to orbit the Moon. These cameras will be used entirely for educational and public outreach. By decoupling the experiment from the formal science objectives of the mission and making everything about the experiment "best effort" rather than measurable success, it is possible to implement the program in an affordable manner and on a non-interference basis. Middle school students across the United States will have the opportunity to study the Moon and propose targets to image, and selected images will be sequenced by a team of competitively selected undergraduate students supervised by trained professionals. Our collective conviction about the inspirational value of a space-based imaging experiment solely dedicated to outreach is great. We are absolutely certain that the experience will extend the NASA tradition of changing lives and motivating future careers.

In summary, NASA is the federal agency where dreams reside. Its can-do attitude and propensity toward taking on tasks, in President Kennedy's words, "because they are hard" exemplifies so much of what is great about our country. Other nations emulate us, follow our lead, and partner with us in peaceful exploration of the solar system and beyond. I sometimes wonder how I managed to be so fortunate to be born at a time that allowed me the opportunity to pursue my penchant for scientific discovery in the solar system. I do believe in a bright future for NASA, one in which young people with similar inclination will feel as I do fifty years from now at NASA's centennial celebration.

I genuinely appreciate the forum that the Committee has provided to recognize the achievements of NASA, and I look forward to responding to your questions.

Chairman GORDON. Thank you very much, Dr. Zuber. Before we begin with questions of our witnesses, as I noted earlier, the noted physicist and author, Dr. Stephen Hawking, has graciously provided a pre-recorded message for today's hearing, and we would like to hear that message now.

[Recording played.]

Chairman GORDON. I hope Dr. Hawking is one of the two million plus watching this on web cast today, and if so, we want to thank him for his testimony, and more importantly, for his great contribution to the universal body of knowledge.

DISCUSSION

Chairman GORDON. At this point we will now open our first round of questions, and the Chair recognizes himself for five minutes, but I want to try to be brief because we have a lot of Members here, and I want to get onto their questions.

But I do, would like to ask one question, just one question of the Committee at large, following up on Dr. Zuber, as she talked about the potential for, not potential, but the asset that NASA has in being able to inspire, particularly inspire our youth.

What do we need to encourage NASA to do to be more effective using that inspiration to try to get young folks into the STEM education programs and then hopefully after that into careers in science technology?

So we will, Dr. Zuber, we will start with you, and welcome anything that Senator Glenn or Mr. Augustine might have to say.

Dr. ZUBER. Okay. Well, I would like to press for the ability to pursue creative programs. Some of our most inspirational things as I related to in my testimony don't have metrics of success. Okay. In my testimony I mentioned how people who watch rings of Saturn swirling, who watch Mars rovers, we don't know how many of those people are going into science.

In NASA education programs there tends to be an emphasis on doing things where you can measure what the success is, and some of those things are excellent and keep doing them, but we should also encourage creative programs where you can't necessarily measure the success but you know that the success is there.

Mr. GLENN. I would just like to back up on what Dr. Zuber is talking about here. I think that the nation that leads in education for all their people and in basic research, those two very fundamental things have built this country, whoever leads in that is going to lead the world in the future. We still lead in those areas except K–12. Our K–12 education system is not in good shape now as we all know. But I think we should be trying to set up the best education system possible and the best research we can, and that is the reason that I think we should be doing the maximum research we can on all the, with NASA's efforts.

Their funding in that area as far as research goes has been cut. I ran into a statement in the *Aviation Week and Space Technology* of a year ago, July 20, 30 issue, in which they said, according to a National Academy Space Science Board tabulation NASA pulled the funding plug on 59 percent of its human research program investigators, the ones who would have dealt with basic long-term research concerns, as well as 88 percent of fundamental space biology investigators, along with 84 percent of its physical science investigators. They go on to discuss why this was, but it is because we did not provide the money to follow the presence of VSE, *Vision for Space Exploration.* We cannibalized within NASA itself out of other programs to provide the money to do that.

And that is what I have proposed to correct it. So——

Chairman GORDON. Mr. Augustine.

Mr. AUGUSTINE. I would just add that it has been my observation that if one wants to inspire young people, one has to have accomplishments that they can see and relate to and are, become excited about. But that is only half, I think, what is needed.

The other is to have clearer, longer-term programs and goals that they believe in, that they think that they might be able to become involved in as they get older. And when I was young, the Cold War, that was, if you were a scientist or engineer, you wanted to help win the Cold War. Then the Space Program drew that kind of excitement, and it was the information revolution, now it is the biosciences, I think.

And not only do you have to have immediate accomplishments, but one has to have goals in the future that young people can really believe in and embrace.

Chairman GORDON. Thank you, all of our panel members.

And then, Mr. Hall, you are recognized for five minutes.

Mr. HALL. Mr. Chairman, I thank you.

Senator Glenn, I am very interested in your comments about the fact that Shuttle launches are expensive and then you go on to say the ISS is scheduled to be completed during 2009, and to save money Shuttle use will be terminated in 2010, leaving us at least a five-year period in which the U.S. will not have a human space launch capability. That concerns me, and it seems to concern you.

I know money, you know, ask us the value of money, and somebody said, well, it is not much, but it sure keeps you in touch with your kids. Well, I think we, that money is a matter here that we need to discuss, and we need to think of somewhere that we are expending money or doing something that is way less important than it is to be, have the leadership in space exploration.

I would like for you to go a little further on that. You know, I would even like to suggest that we cancel any foreign aid to those who would vote against us 90 percent of the time in the U.N. or things like that. That has never worked before. Maybe we ought to look at that again, but I would like your idea on some of the things we could do without or how we could lessen it or how we could provide that thing called money that NASA has to have to make those and not rely on Russia or some fallibility in our own ability to get from here to Russia or from here to the Moon or to Mars to wherever we are trying to go.

Mr. GLENN. Thank you, Mr. Hall. I appreciate that, and we are, that is the direction we are going right now, is we will be dependent on the Russians for launch. Our people will go over there for their launch and any equipment we have will have to go up. It will not be a heavy launch capability because they can't put up the same loads that we can on the Shuttle. But I just thought I would never see, as I said earlier, I thought I would never see the day when we would be buying a ticket on the Russian system to get our people to our International Space Station, yet that is what we are doing right now.

I think we have already signed contracts as a matter, as I understand, some 700 and some million dollars for launch services from the Russians already. But I just think that is the wrong way to go for the world's greatest space-faring Nation.

Mr. HALL. And you say that additional funding of $2.8 to $3 billion per year could keep the Shuttle in operation until their new Constellation program equipment is ready and at least partially restore the ISS research program?

Mr. GLENN. That is what I have been told, Mr. Chairman, and you would want to flush that out with NASA I am sure and get the details of exactly, exact amount. But those are approximate amounts, and that would keep us with our own launch capability as I understanding it.

Mr. HALL. I am not only concerned, but I am really astounded that we are going to go four years without the ability to visit our own station.

Mr. GLENN. Five. Five years——

Mr. HALL. Five.

Mr. GLENN.—now, and we had a one-year slippage, and there may be more slippage beyond that. Of course, as our new, this is, that five-year estimate is dependent on our new equipment working out perfectly and being available at a certain time. If we have any delays in it, then the, our dependence on the Russians will go even further.

Mr. HALL. I think that is one of the major problems we have in the program.

Mr. GLENN. Yes.

Mr. HALL. Thank you, John.

Mr. GLENN. Thank you.

Chairman GORDON. Mr. Miller is recognized from North Carolina for five minutes. All right. Ms. Giffords is next up. All right. Ms. Edwards, our newest Member of the Committee, is recognized for five minutes.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you to our witnesses. I listened with fascination about the Space Program. I had the great privilege of working for Lockheed actually out at Goddard Space Flight Center, supporting Space Lab and TEDRIS and LandSat, and you know, the early days of the development of the space telescope.

And I had the benefit also of learning from engineers who, engineers and scientists who started out with NASA in 1958, who were my mentors, and one of the concerns I have is about this sort of resident experience within NASA at the highest levels of, you know, our scientists and people who understand technology, both for their oversight role but also for the value they play in the long-term sustainability of NASA and its resident knowledge.

And so I wonder about your comments about that, and then because I am out in a community that supports the Goddard Space Flight Center, what I notice is that so many people actually don't even know that that is a jewel in our community. It hasn't been exploited in nearly the way that it can, both as an engine for economic development but also for the value to our schools and our young people.

And so I am curious as to whether any of you have comments about what we can do to really tell the story of NASA and the Space Program and exploration and the real valuable, tangible value to our communities and ways that we can inspire our young people to get the, to reap the benefits of that technology.

Dr. ZUBER. I will address that. I used to be a Goddard civil servant, so first of all, with respect to the NASA civil servant workforce, I feel your pain. It seems like there is always a hiring freeze at NASA, and it is very difficult to hire. There are freezes on hiring, and a lot of expertise is brought in from general areas just for short periods of time to do small jobs when there are engineers and scientists who would love to have these jobs. They are not the highest-paying jobs that can be had, but people would love to have them.

I am actually on an advisory committee to the Science Director at Goddard in dealing with improving the role and maximizing the contribution of women at Goddard, and one thing that you find is that people would love to have that job because of the quality of life that is associated and the prestige that is associated with working for the Space Program. And the salary and compensation, people need a good wage to make a living, but beyond that people are much more excited about a situation where they can contribute to the Space Program and deal with their family responsibilities.

So first of all, making flexibility for family situations is one thing that would be more attractive, but anything that the government could do to make hiring more civil servants there a possibility would be great, and this is a place where maybe that committee could help.

Mr. AUGUSTINE. Ms. Edwards, you raised two I think very important points. Pardon me. I share the concern about the aging of the workforce and the talent in the Space Program, and I think the biggest problem that our industry, the industry element of the Space Program is likely to face in the decades ahead will be a shortage of engineering and science talent.

And it has also been my observation that the Space Program, it is a risky business, and it is a lot like performing heart transplants. You either do a lot of it or none of it, and I have noticed when we start phasing down people, we start having trouble because we have inexperienced people.

So I think you raise an important point. The only thing I would add to your second point would be that I believe our corporations and our universities and our national labs could do an awful lot more in terms of working with young people and getting them involved in what they are doing, given the summer jobs. There are other organizations I am sure you are familiar with like the Challenger Center that does a lot, and these entities are there waiting for people to support them.

Chairman GORDON. The gentlelady's time has expired.

As you know, Mr. Augustine, part of the COMPETES Bill was to use our national labs more to bring those teachers and students in, and we are starting to see them implement some of that.

Now we have the former Chair of the Space and Aeronautics Subcommittee, Mr. Rohrabacher, is recognized for five minutes.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. It has been my honor to be on this committee for 20 years, and I was elected to this committee the first year, and let me just note George Brown was the Chairman at that time, and he worked with the Members, the leadership that we had over the years, and George Brown and we got Bob Walker with us and Sherry Boehlert as well today, and let me just add, Mr. Chairman, that I believe that you are conducting yourself and providing the leadership that we can respect and admire of you.

To set the record straight, I believe that Senator Glenn was not a Naval aviator but a Marine aviator if I am——

Mr. GLENN. Well, both.

Mr. ROHRABACHER. Right. And my father actually served with Senator Glenn when he was in the Marine Corps, something he talked about a lot and was very proud of.

Let me ask a certain, get to certain questions here, because I do want to ask some questions.

Dr. Zuber, I was very appreciative of your statement today, because you mentioned, not only did you mention asteroids and comets, but you also mentioned the word, prioritization. Those areas have a special interest for me.

First of all, let me ask you, and I am going to ask the panel just very quickly can you please name one area that you would cut that we could make a few billion dollars in cutting so that we can actually accomplish the mission that I think Senator Glenn has told us is an important priority for us to accomplish, which is making sure we have that capability for launch capability. Is there an area that we can cut, and we can focus the money on that?

Dr. ZUBER. I would be in big trouble if I—what I would say is new starts, that you can't start new things unless you finish what you are doing, and I think——

Mr. ROHRABACHER. Okay. That is fair.

Dr. ZUBER.—NASA has run into some troubles in this area.

Mr. ROHRABACHER. And new starts would be made for perhaps exploration new starts and where you were saying go explore this particular moon of Jupiter or whatever, and we shouldn't start that until we get something else done.

Dr. ZUBER. Well, we should be far enough along that we know that we can pay for things before we start new things.

Mr. ROHRABACHER. Dr. Augustine.

Mr. AUGUSTINE. I would certainly agree with that, that we should be measured by what we finish and not what we start. New starts are a candidate.

The other is that the really large consumer of funds is indeed the Shuttle, and sooner or later the Shuttle has to be replaced, and the commission that Chairman Gordon mentioned that I was involved in 18 years ago now made as one of its highest recommendations to build a replacement for the Shuttle. And we had forecasted our report that we would likely lose one or two more Shuttles before we were done. And unfortunately, we have been on that path.

So I think we have got to get a replacement to get up into space without using the Shuttle.

Mr. ROHRABACHER. Senator Glenn, do you have one area you would like to actually say is less important than another area?

Mr. GLENN. I have no particular one. It just seems to me when you have a $3 trillion budget, that is 3,000 millions or whatever it figures out to be, I just think this, or billions, that we can find 2.8 or three of them in there someplace that are better spent on maximizing this research return on a $100 billion investment we have made. We are not doing that now. We have empty racks going up into space now because we don't have the support for filling them.

Mr. ROHRABACHER. Actually, I have got some ideas where we could cut the budget myself, but no one ever listens to me. So, but let me ask one other question about prioritization.

There is a prioritization on the other side, and this is where Dr. Zuber's comments on asteroids and comments, comets come into play. I happen to believe, and I have been pushing this as you all know, that the idea that planetary defense is something that NASA should be focusing on because there could be a comet or an asteroid or a meteor that could hit, no one would be surprised if one of those was identified tomorrow as a potential threat to billions of people's lives on this planet.

Do you believe that, that planetary defense should be a priority mission for NASA? And just quickly down the line.

Dr. ZUBER. Well, I think that defense, the role of defense is in the Defense Department, but I do think that there are things that we can do in the study of comets and asteroids that are scientifically important but that would contribute significantly to the question about how to take action if action were ever needed to be taken.

Mr. ROHRABACHER. And the action should take place at the Department of Defense? Is that——

Dr. ZUBER. Well, the actual defense part should be done by Defense but——

Mr. ROHRABACHER. Okay. Dr. Augustine.

Mr. AUGUSTINE. If history is any precedent, this will be a problem at some point. Chances are it is in the distant future, so I think it is something that NASA should be concerned with, but I don't think it gets the highest priority of what they might do.

Mr. GLENN. I don't know that I would assign that to the Defense Department. They have their plate full right now. It would seem to me that the Defense Department normally deals with Earthbound threats to our country and our security. This is a little bigger than that. I would think that—and the question also arises, let us say we do find a trajectory that is coming toward Earth. What do we do about it? It is going to be very interesting, but you are probably going to increase church attendance considerably, but that is going to be about it for awhile.

It would seem to me unless we have some means of defense. Now, I know people have proposed that in something like this we might be able to actually go out into space, implant or take with us nuclear or powerful weapons of some kind that would be able to alter the course or destroy that asteroid on the way in or comet or whatever, or asteroid on the way in. But I think it would be, I would like to know that something like that is headed toward Earth certainly, and we can make observations of that.

Mr. ROHRABACHER. Thank you very much, and let me just note that in the next 50 years if we do, indeed, see an object headed toward the Earth that could cause millions of deaths of people and maybe even extinction of the planet, that maybe the most important thing that NASA will ever do will be to determine that object and to be able to help deflect it from its course.

Thank you very much, Mr. Chairman.

Chairman GORDON. The gentleman's time has expired.

The gentlelady from Arizona, Ms. Giffords, is recognized.

Ms. GIFFORDS. Thank you, Mr. Chairman. While I was basking in the brilliance of our panelists, I got called out, and I beg your forgiveness, to attend a meeting on homelessness from the State of Arizona, and it is sort of a reality check. I was thinking about how great it is being on this committee and how wonderful to have these panelists and then you have to step out to a meeting and talk to folks who represent your community of people that don't have enough food to eat and don't have shelter.

So it is a real challenge. I mean, I think about Dr. Hawking, who I had the chance to meet last year when you were presented the medal that was flown on STS–123, over at the Royal Society, which was amazing. Senator Glenn, you are an inspiration to all of us. I mean, the private and the public sector, and Dr., excuse me, Mr. Augustine, for everything you have done in the, with your work with the National Academies, of course, and in the private sector, and Dr. Zuber, thank you. We love having particularly women in science, as a woman in a non-traditional field as well. It is really important that we have everyone represented.

So I guess my question is, and I just want to cut straight, you know, down to it. How are we going to do this? Over the weekend I had a chance to present a state of the economy to a lot of people in my district. I talked about where we were in terms of debt and deficit, and I also wove in there a lot about math scores in Arizona and the country, fourth grade math scores, eighth grade math scores, twelfth grade.

I mean, we as a nation have to get going right now, and for the smartest people on this committee and our panelists, how are we going to do that? How are we going to say to the next generation, we are going to keep the standard of life, the beauty, the vision of this country, headed in the right direction?

And so I know we don't have a lot of time. You only have five minutes to answer those questions, but I turn it over to our panelists to tell us how we are going to make this happen.

Mr. AUGUSTINE. Let me begin. Great question. I guess I would begin by observing that 96 percent of the workforce in this country are not scientists and engineers, but the four percent that are the ones who create the jobs disproportionately that help solve homeless problems, provide the money. And so I think your question, what is it we should do, I will offer two highest priorities.

One is we ought to greatly increase the science budget in this country so that we have new discoveries that would create new products, create jobs for people. The second is that we need to get teachers in our classrooms all the way down to first grade who understand math and science and who have a primary degree in that core field, so that they can answer the questions the children ask so they can inspire them, so that they can tell them why what they are doing is relevant.

I think those are the two highest priority things that we should do.

Thanks for a great question.

Dr. ZUBER. Okay. Well, NASA itself can't solve all of the education problems in the country, but they can certainly contribute. The decision kids have to make and I think it comes when they are between elementary school and middle school is do they keep taking the harder math courses, or do they go the easier route. And they need to see something out there that gives them the feeling that putting in the extra effort to take the harder math course or the harder science course is worth their while.

So in that sense keeping discovery in space science, Earth science, and in fact, all science I think is key in that endeavor.

And I just want to echo Mr. Augustine's comment that having teachers in science and math who are actually science and math majors and who understand those disciplines deeply and who have opportunities for career enhancement in summer programs, that is, you know, one of the best investments that this country could make.

Mr. GLENN. This, it is a very good question, and it always comes up about whether we should solve the problems that exist now before we put money into research where we don't know for sure what the answer will be, is that wasteful, and that is basically the questions you asked, I think.

It seems to me that our research in this country, if there is one thing that we have learned throughout our history it is that money spent on research has a way of paying off in the future, usually beyond anything we see at the outset, and not every aspect of that research is productive, but enough of it is productive is that is how we moved ahead.

What we are saying by research is curiosity, and every single advance that humans have ever made has been because somebody was curious about how could we do things a new way and do them differently and whether it is a microphone or whatever it is, can we improve on this. And somebody had that kind of curiosity in looking into the unknown.

An example, you mentioned the problems of the homeless. I am very concerned about that, too, back in my home State of Ohio, but we, an example of this might be in feeding the homeless even in look what has happened in agriculture. In the early days of this country we had 95 or 96 percent of our people involved in agriculture to support the population. We are down now to about 2.8 percent of our people give surpluses that are enormous, so much so that we pay people not to produce. And that was because of research on hybrids and on soil and on fertilizer, seeds, just the whole, across the whole panoply about eight or nine things that go into that consideration in agriculture. And people thought maybe at that time it was goofy. Why did we have to do that kind of stuff? We were looking into fertilizers for heaven's sakes on the farm. It has always been okay, but yet we improved them enough that we have more increased production, and that does benefit the homeless now.

So it seems to me taking a long-term view of what may come out of research is the way we should go.

Chairman GORDON. The gentlelady's time has expired. And let me just point out, Ms. Giffords, in response to your question, I think there was concurrence that we need to be able to help educate our educators in terms of their core knowledge in the math and science areas, as well as make an increased investment within our science research.

Well, this committee and Congress has passed that legislation. The President signed it last year. We have that authorization in the COMPETES Bill. Now we need to fund it. We have got the roadmap.

And the gentleman from Washington State, Dr. Baird, is recognized for five minutes.

Mr. BAIRD. Thank you, Chairman. What a treat to be here with such distinguished individuals. Thank you for your service here today and for your many years of service to the country.

I am in a bit of a conundrum in that I share with great passion the belief articulated by Dr. Hawking, by the panelists today that part of our destiny is to explore and that I think part of our human destiny is to leave our solar system. We have to do it. Our curiosity drives us there, but our desire to preserve the species does as well.

So I believe that. I have followed the Space Program avidly since I was just a little child, but my concern is I am also on the Budget Committee, and we have a, we are approaching a $500 billion deficit. We got a $9.4 trillion debt. Our present value of our long-term commitments exceeds $52 trillion over the next 75 years.

And I look at pictures of the Mars Mission, and you know, here are sort of geodesic domes with astronauts walking about, et cetera, et cetera, and you know, those of us who watched the Star Wars movie, I sometimes wonder who the heck built those things, you know. You watch a Star Wars movie, there is these giant artificial planets that people live in. Somebody has got to be out there building this stuff, and where do they build it, and how do they fund it?

So my real question is this. We can make or revise laws, but we can't revise the laws of physics, and this notion that we are going to just put these big manufacturing plants on Mars somehow assumes that we have got the launch capacity to move a lot of junk a long ways at enormous expense. And who is going to say, Mr. President, that is a dandy vision, but here is what it is really going to cost.

And can you talk to us a little bit about what it would actually cost this country? I think maybe we should do it, but we are not prepared at all to make the sacrifices that it would require to do that. So can you talk to us a little about the realistic cost of putting these kind of stations up on Mars or wherever else to make this a reality?

Nobody wants it.

Dr. ZUBER. Okay. Let me start. First of all, nobody knows that cost. Okay. Nobody, we looked at, when I was on the Presidential Commission, and we looked at the cost of returning to the Moon and going to Mars, we used the analogy of the cost to cure cancer. Okay. Nobody when we decided in this country that we needed to attack cancer, nobody knew what it was going to cost. They only knew that it was worth doing.

Mr. BAIRD. When we decided to attack Iraq, nobody knew the cost, and they told us it would be less than $100 billion. I am very, with respect, concerned about that beginning point for an argument. I have seen the movie.

Dr. ZUBER. Okay. I, so we don't know what it costs. Okay. But what I can say is that in the robotic program to study Mars, we have learned an amazing amount about Mars in the past decade, which is providing the enlightenment needed to move ahead toward trying to understand what the costs would be.

And let me give you two examples. First of all, we have understood the structure of the atmosphere and the variability of the atmosphere, which is going to come into the issue of how do you land on Mars.

The second thing that we have learned is that sensors both on the surface and in orbit have detected vast amounts of frozen water in amounts that are so great that it can't be tied up in the mineral structures of rocks. And that means that water, ice in frozen form, exists in great amounts within a meter of the surface of Mars, and we know where.

So the most expensive thing you are going to take with you if you go to Mars is water. Okay. Now we know there is water there, so you don't have to take your own. So that discovery in itself has decreased the amount of launch capacity that is going to be needed to go, for humans to go and stay. Okay.

Now, these are two small examples, and there are a thousand other things that we currently don't know that we would need to know before we send humans to Mars. But I think that within the last decade of exploration of Mars, you know, those questions are being addressed, and the technical questions are being addressed, and it is going to take a lot more study to try to figure out what it is going to take.

Mr. GLENN. The question is: Is our objective to go to Mars? If that is our ultimate objective on this, then it seems to me the Moon is questionable as a way station. The President made a statement as I read into the record earlier when he was in Cleveland about a year ago, we go to the Moon and launch from the Moon to Mars. Now, if that is what we are doing, which I don't believe it is, but if that is what we are thinking about doing, that is enormously expensive. We are talking about taking thousands of tons of equipment literally from, with all the energy required to lift it off Earth, put it into Earth orbit, accelerate it on, go up and fall across this equi-gravisphere point where it then falls toward the Moon and then carry enough energy along to actually set it down to zero it out again on the Moon's surface. And then start all over again on a launch, granted, with one-sixth the gravity of Earth, that launched from there to Mars and check out spacecraft and do all the things that Cape Canaveral does right now, and do it in a vacuum on the surface of the Moon.

That is an enormous order, if that is the direction that we are going. Or are we going to go into Earth orbit, build up our vehicle to where it has, we have it built up to go to Mars, could be a good-sized vehicle as far as that goes, and then accelerate it out of Earth orbit.

It would seem to me that that would be the cheapest way to go, but NASA has done studies on all of these things, and you could get definite information from them on that.

For me to stay in Earth orbit or for anything to stay in Earth orbit you are talking about 4.8 miles per second, almost five miles per second. I believe I am correct that Neil, when he went to the Moon, had to get up, his escape velocity was around seven miles per second. Then falls up there, slows down, goes across that equi-gravisphere point, falls towards the Moon. To go directly from out of that Earth orbit to Mars, as I understand it, is about 7.4 miles per second.

So you have most of your energy expended in Earth orbit here and go and don't do all this complexity of going into the landing on the Moon and then have to put your launch sources together again and once again, launch from zero up to whatever speed you want to go to go to Mars.

So I think we need a better definition on this. I don't think it is real clear right now, and I am sure that Dr. Griffin and his people and Shana here can give us good information on that, but that is the way it appears to me right now in answer to your question.

Chairman GORDON. The gentleman's time has expired.

The gentleman from Ohio, Mr. Wilson, is recognized for five minutes.

Mr. WILSON. Thank you, Mr. Chairman.

First of all, thank you all for being here with the Committee. It is an honor to be able to discuss the issues that are going on today.

My question would be specifically to Senator Glenn, especially dealing with NASA Glenn and NASA Plum Brook in Ohio. Senator, I have been concerned for a long time as to why we don't get more credit for all the good work and the amount of jobs that are created, the economic development throughout the State of Ohio and the surrounding states with what goes on in Ohio.

So my question would be is how can we ratchet up the attention on the good work that is done, and I am sure it is done in many other states, but especially in our State of Ohio.

And then secondly, and I would be interested in comments from the other two members, too, Mr. Augustine and Dr. Zuber, that is what can we do in Congress to help foster this much-needed economic growth from the NASA Program?

Mr. GLENN. Good question. I think it goes back also to Ms. Edwards' comment about the appreciation for Goddard out here. The NASA centers around this country are amazing centers of scientists and engineers and very, very capable people. Many of them really free-thinking on some new ideas that are really, will redo the future for us. Our, the center there in Cleveland is a good example. In some of the areas of propulsion in particular, they have led the way, and they have some of the finest engineers in the country there.

They have an outreach program, but I don't know. The press just doesn't seem to pick up on this. I don't know whether the complexities of science get beyond the average press person pretty fast, or that is probably not a fair statement to make. But we need something like that, and I think is it going to require another Sputnik? I hope not.

But that may be the answer. I don't know. NASA up there in Cleveland, though, has a, they have a program of outreach for schools. They have a lot of visits by schools and trying to encourage our young people into math and science and technology. But it is a jewel. It is a fountain of information for that neighborhood, particularly in this area of energy and energy use.

They had a program there some years ago called REDOX, which I was quite taken with, and we got some money for it through the Congress when I was here, but it involved large amounts of electrical energy storage. If we could make one breakthrough in energy, that might be the one we would wish for, because you could then take all your, every force of nature that we know how to put into electricity, we could then store it so we could bring it back onstream during that 6:00 to 10:00 time in the evening when we need it most. And it would, the theoretical part of that program was that we could get back about 70 percent of what we put into it, and it would take the output of 1,000 megawatt power plant in non-peak hours.

Now, that would be enormous.

Mr. WILSON. Sure would.

Mr. GLENN. We lost funding for that, and there were some complications with it, but those concepts are the kinds of things that our NASA labs work on all over this country and do a great job in and should get much more recognition for. Goddard you mentioned earlier, Ms. Edwards, and the others also.

Thank you.

Mr. WILSON. Thank you, Senator.

Mr. AUGUSTINE. I think your point is very correct. In this country we tend to undervalue science as compared with most other countries in the world that I have visited. The, for example, in China today of their nine top leaders eight are engineers, and they understand what science can do and the importance of it.

There is no question in my mind that one of the highest returned investments that this Congress could make is at basic research. There are many studies that support that. When it comes to getting a public that recognizes science and its importance, a lot of it comes back to our young people and trying to inspire them and help them. It is a long-term undertaking, but there is a great deal of anecdotal evidence that suggests that children, very young children as I said, are very excited about science, particularly about space. There is anecdotal evidence that we lose them by about fourth grade, that early. Usually for two reasons. One of two or both.

One is it is a father that tells their daughter that girls don't do math, and the second is that you have a physical education teacher who has been told to teach math or to teach science. And that, unfortunately, is the majority of the cases, not the minority. An overwhelming majority.

And so those are the things I think we have to solve.

Mr. WILSON. Thank you.

Mr. GLENN. Mr. Chairman, could I add to that just a moment?

Chairman GORDON. Certainly, Senator.

Mr. GLENN. Secretary Riley was Secretary of Education back in previous Administration, and he was very concerned about the TIMS Study, Third International Math and Science Study. And it showed that our kids up to about the fourth grade, which is the figure that Norm just used, up to about the fourth grade are in the top two or three nations in the world of 41 nations that were studied over a three-year period of time.

Now, these figures are about eight or nine years old. They are about almost 10 years old now, but I think they are still applicable. The, by the time our kids get out of high school, we are two or three from the bottom of 41 nations studied. And what happens in-between there is exactly what he was talking about here. What we found when we had our commission, I headed that commission for over a year, what we found was that 25 percent of the math teachers in high school, just average, across this country, were never trained to teach math. They are teaching out of field as they say in education. And 20 percent of our science teachers are the same way, teaching out of field.

Even more disturbing perhaps was the fact that 30 percent in both categories left the profession within three years, and 50 percent were gone in five years. They are off to AOL or Verizon or somebody that will offer them a lot more money than they could make teaching.

And so that is something, and what we are faced with is trying to do something about it is, the thing is overseeing, we call this an education system is not a system. At that time we had about 14,700 school boards in this country, each independent, each doing their own thing, with not much direction from above. And so until we solve some of those problems and get the, get that gap that occurs between the fourth grade and getting out of, and graduating from high school, until we solve that we are going to have big problems I think enticing people on into engineering and math and science and the scientific studies we would like to see some of them entering.

Chairman GORDON. Well, Mr. Augustine, through the *Rising Above the Gathering Storm,* brought that information up to the current, and unfortunately, things have gotten worse. It is, I think it is over 50 percent now of the math teachers in the middle schools have neither a certification or a degree in that subject, and it approaches 90 percent in the physical sciences.

And so as good as those teachers might be in teaching, if you don't have the core knowledge, it is hard to communicate that. And the reason it matters on a larger scale, Mr. Augustine said that only four percent of the public goes into the sciences. But not that that other 96, though, need to have that kind of background to work at a higher and more efficient level. And so to get the jobs for today and tomorrow, so that, you know, there are 6.5 billion people in the world. Half make less than two dollars a day. We can't compete that way. We don't want to compete that way, and so that other 96 percent has to be at least the base education to compete at a higher level.

And my time is expired. Your time is expired, and now Ms. Johnson is recognized.

Ms. JOHNSON. Thank you very much, Mr. Chairman. I apologize for being late. I had another emergency-called meeting, and I would like to ask unanimous consent to have my statement put into the record.

Chairman GORDON. Yes.

Ms. JOHNSON. And greetings, Mr. Walker. You served this committee with tenacity and leadership as Chair, and to our distinguished guests.

I believe that space exploration has offered us more through its research than any other research that we have ever been involved in, with breakthroughs and products. And I am very, very supportive of that continuing. And if I had to make a choice between research and immediate food, I think I would choose research and ask the churches to help us with food for awhile until we found a substitute or something.

I truly believe in research. I am so aware of the shortage we have in talent right now to help to continue it, and in my area we have some excellent schools. Texas Instruments has made that possible with this extra funding. And they do well. There is only 20 percent of the total student body in the district, and I wonder, Mr. Valentine, or is that, am I saying that right? Mr. Augustine, what does Lockheed Martin do to further education and invest in your own future frankly. That is what I tell Instruments they are doing. Invest in your future when you invest in education of our young people and our teachers.

Mr. AUGUSTINE. I want to be careful when I answer that question, because I have been retired from Lockheed Martin for 11 years, and so I can't speak for them today, but let me tell you——

Ms. JOHNSON. What were they doing back then?

Mr. AUGUSTINE. Yeah. Let me tell you some of the things they were doing. One is the company established with the help of the University of Tennessee a program where we could award fellowships to teachers to come to the University of Tennessee, work with the Oak Ridge National Labs and other organizations, summer programs to bring teachers up to speed with the latest developments. And this was all paid for by fellowships the company gave.

The company also has a number of local programs helping the boy scouts, the Challenger Center, the girl scouts, and community organizations of that type. The company is particularly able to do that because it has plants or some kind of facility in almost every state.

Ms. JOHNSON. Yes.

Mr. AUGUSTINE. So and in fairness I have to say that Lockheed Martin is not unique in that regard. There are a large number of companies that have contributed a lot in that same respect.

Ms. JOHNSON. I am so aware that we have so many teachers not really prepared teaching in these areas, and I believe that if some of the companies would offer some type of summer program for our teachers so they could see the environment and have an idea until we can find enough teachers that major in these areas.

I am critically concerned about this area, and I have spent a lot of energy trying to see if we could change it. And I don't see the progress I would like to see, and I don't think that the public understands the value of having these minds ready for this research and activity.

And if I could elicit your volunteer service in helping to speak on these areas, I would appreciate that. I am very indebted to Senator Glenn for his contributions, and so is this nation and the world because of the contributions he has made. And I know that he continues to speak out, and I appreciate that, Senator Glenn. I thank you so much for what you have offered.

But my, I know my time is about up, but I am getting my sermon done here, my concern is our future, because I really do think that it is our homeland security and maintaining our competitive edge that is going to cause this country to survive as an independent nation. And we can do it, but it is going to take a lot of public education, along with the students so that the public understands this need and have great expectations for our teachers and our students, because our students are not given that instruction to have those expectations. They take the easiest courses they can. It pains me every time somebody tells me they have a degree in political science if they are not going to get a Ph.D. or sociology if they are not going to get a Ph.D.

And I think that my time is up, but America COMPETES has addressed some of this and law. We didn't get the funding we wanted, but at least the President signed the authorization of $33.6 million, and that will help as the money comes. I don't see us coming out of a deficit until we have the skills to bring this money in.

And I hope that you will spend time, all of you, preaching my sermon on my behalf and the Nation's behalf, that we really do need this talent, and you have been in very key positions to understand what an important thing it is to have it.

And I thank you very much. My time is up. I could ask questions all day, but I mainly wanted to get that out. Thank you.

Chairman GORDON. Thank you, Ms. Johnson. I think we can all say amen, and I think it is appropriate that we complete our hearing with the last question from the gentleman from Texas, who physically represents the Johnson Space Flight Center, Nick Lampson.

Mr. LAMPSON. Thank you, Mr. Chairman, and I apologize for missing some of your testimony earlier, but we are certainly proud that all of you came today and help celebrate this 50th anniversary of this committee and NASA and all the accomplishments.

And one of the questions that or one of the things that I certainly remember was 1957. I am one of those that is old enough to remember listening to the beeps on the radio and to see what responded to, and there are a lot of people who are starting to say today that we are hearing similar kinds of beeps, but they are coming in different forms, accomplishments of other nations and their successes, and in some of those instances perhaps we should be more frightened with those successes in comparison to our own leadership capabilities and technological advances.

Let me start with Senator Glenn and just ask how should we view these growing space capabilities and plans of other nations, and then for everyone, what are you views as to whether we are on the verge of another space race? Can we make ourselves enter another space race, and how do we respond to it?

Mr. GLENN. Thank you. There is a recent book, I haven't read it yet by Fareed Zakaria, the international expert with *Newsweek,* I believe it is, and his theme in that, the summary I read of it the other day was that the, that we haven't laid down our mantle of leadership yet, but the trends are all wrong because other nations are now seeing what led this country into our successes, and they are putting more emphasis on education and research. While we have leveled off in some of these areas, they are coming up. And that doesn't portend very well for the future.

And so I think we are warned that we should get on with it. Earlier in the hearing China's efforts were mentioned and other nations, too, and we, on one of our trips to China back some years ago we met with Jiang Zemin, who was the President of China at that time, and I asked him then if they had considered joining our program with these 15 nations. And he told one of his staff people he wanted to look into that more. Well, nothing ever came from it.

But I think we can, we were the world's leader. We are the world's leader in this area, and if we by lack of support for these programs and for doing the research that is going to be the benefit to everybody here on Earth, I don't want to see us just seeing how far we can go in space, coming back, waving a Styrofoam finger in the air saying we are number one or something. It seems to me that the basis for a Space Program on a long-term basis support of our people comes as they see research returns coming back that benefit them and their children in many, many different areas. The five that I mentioned earlier that NASA had special, the OBPR Office had programs set up within to look in those areas. They seemed to be the most likely to be productive at that time.

So I think that, it is not so much that we are just laying down. It is whatever we are doing is not enough to keep us ahead of other people, as I see it, developing into the future.

Mr. LAMPSON. Mr. Augustine.

Mr. AUGUSTINE. My belief would be that we are not just in a space race. More importantly I think we are in a science and engineering race, not with any one country, but with a number of countries. Certainly the developing countries are committed to this area. You think of China and India and Brazil as leaders. We are all familiar with what China has been doing in space, including military space, and it is very impressive.

I think that today we are benefiting from the investments that this committee brought about 10 or 15 years ago, investments in basic research. And it is always a question as Senator Glenn said when you have a lot of problems today, it is very difficult to invest in the future.

But this nation could double or triple the investment in basic research. When you look at the overall curve of spending by our government, it wouldn't be the width of the line. That is the good news is we spend so little today that we could greatly increase it without an enormous impact.

So my highest priority would go to investing in basic research.

Mr. LAMPSON. Thank you. I wanted to bring the issue of international cooperation and particularly a project that we have been working on called the Alpha-magnetics Spectrometer, but I am going to run out of time, and I want you to comment in another area. So we will save that one.

But if you will both comment or discuss how NASA's aeronautic achievements have influenced the U.S. commercial aviation, maybe talk a little bit about what areas of aeronautics that you believe hold the greatest promise for advancing the Nation's aeronautical capabilities in yielding future benefits for the U.S. commercial aviation industry.

Both of you. If you don't mind, Senator Glenn, would you start?

Mr. GLENN. Let me respond first to your AMS, Alpha-Magnetics Spectrometer because that is one of Dr. Zuber's colleagues up at MIT, and it is a very interesting thing I think the Committee should be aware of that. When Dr. Ting up there, he is a Nobel Laureate, and after the superconducting supercollider was canceled in Texas back some years ago, he picked up the idea of doing this same kind of research on the Station. And could we put a huge magnet up there about 15,000 pounds, and they worked all this out. It has been over a period of time. He has put together a group that has raised one and a half billion privately, 450 science engineers, 50 institutions in 16 countries, and they were promised on NASA that they would put up the, they would put this up, it goes up on the Shuttle and then is mounted on the Station and makes its observations over about a three-year period.

This would be probably the most advanced particle research that has ever been done, and now he has been told that because of the cutbacks and because we have to stop the use of the Shuttle that

that project is now on, I guess you would call it a permanent hold. It is at least being held. They won't say the thing is canceled, but there is no place to put it. It requires about a third of the cargo bay and is about 15,000 pounds to put up there, but it has some of the greatest potential of our scientific community.

And it was backed by all the scientific groups that I am aware of. Dr. Zuber probably is familiar with that more than I am.

Dr. ZUBER. And it is basically built.

Mr. GLENN. Yeah, and it is built. It is ready to go.

Dr. ZUBER. It is built.

Mr. GLENN. And they even put up a smaller version of it in 1998, very successfully, to prove that this could be done. The tresses is already there, and NASA and Department of Energy, which is the administrator of this, have spent many tens of millions of dollars, I don't know exact figure, getting ready for this. Now it is canceled.

Chairman GORDON. Senator Glenn, let me just, I will point out if it is all right, in the authorization that this committee passed that is pending in the Senate now, we authorized one additional flight for the AMS.

Mr. GLENN. For AMS? Okay.

Chairman GORDON. So hopefully we will——

Mr. GLENN. I wasn't aware of that.

Chairman GORDON.—be able to proceed with that.

The gentleman's time has expired, but if the witnesses would like to make any closing comments, we would welcome that before we will adjourn.

Mr. AUGUSTINE. I would just say that it is my belief that investments in science are of enormous importance, investment in our children, particularly in math and science, K through 12, this committee has taken a leadership role. Your Chairman has been terrific in supporting these things, but you know, unfortunately, you can't spend authorizations. And that is our challenge now.

Dr. ZUBER. Yeah. I would just like to close by, again, thanking the Committee for all of their support on the scientific side, the technology and education. It has been crucial. We have fantastic young people in this country who have very bright futures. These are going to be the people who solve our problem in the future, and we need to get them engaged and get them going.

And so if you could keep continuing your support of these endeavors, we will be a better country for it.

Mr. GLENN. My view is that the Nation that leads in education and research, basic research in the future will lead the world. I think it is that simple.

Chairman GORDON. Well, thank you all the witnesses. This has been a very thoughtful hearing. It is one that we are going to be able to ponder and be able to probably, not probably but we will try to incorporate into our future efforts here.

And let me just close by saying that the record now will remain open for additional statements from Members and for answers to any follow-up questions that the Committee may have of the witnesses.

And this hearing is now adjourned. Thank you.

[Whereupon, at 11:55 a.m., the Committee was adjourned.]