AERONAUTICS AND ASTRONAUTICS: A CHRONOLOGY: 2006

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PREFACE

This report is a chronological compilation of narrative summaries of news reports and government documents highlighting significant events and developments in U.S. and foreign aeronautics and astronautics. It covers the year 2006. These summaries provide a day-to-day recounting of major activities, such as administrative developments, awards, launches, scientific discoveries, corporate and government research results, and other events in countries with aeronautics and astronautics programs. Researchers used the archives and files housed in the NASA History Division, as well as reports and databases on the NASA Web site.

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JANUARY 2006

5 January

NASA announced the crew for International Space Station (ISS) Expedition 13, scheduled to launch aboard a Russian *Soyuz* spacecraft in March 2006. Russian cosmonaut Pavel V. Vinogradov would command the mission, and American astronaut Jeffrey N. Williams would serve as Flight Engineer and NASA Science Officer. Expedition 13 would also include the first Brazilian astronaut to fly in space, Marcos Cesar Pontes, who would engage in scientific experiments aboard the ISS for approximately one week. Williams had flown aboard Space Shuttle *Atlantis* STS-101 as Mission Specialist in May 2000, performing a spacewalk that lasted almost 7 hours. As Flight Engineer for the 1997 mission to the Russian *Mir* space station, Vinogradov had completed five spacewalks. NASA also announced the backup crew members for Expedition 13: American astronaut E. Michael Fincke and Russian cosmonaut Fyodor N. Yurchikhin.[1]

6 January

NASA announced plans to decommission the oceanography satellite known as the Topography Experiment for Ocean Circulation, or Topex/Poseidon, a joint mission between NASA and France's space agency, Centre National d'Études Spatial (CNES). Mission managers had decided to end the spacecraft's 13-year, 62,000-orbit mission, following the failure in October 2005 of its pitch-reaction wheel, which maintained the satellite's orientation. According to Lee-Lueng Fu, Project Scientist at NASA's Jet Propulsion Laboratory (JPL), the satellite had allowed scientists to compare models of ocean circulation with global observations and to improve climate predi os. Topex had also enabled the mapping of the elevation of the ocean's surface. Fu noted that, although Topex/Poseidon "was built to fly up to five years . . . it became history's longest Earth-orbiting radar mission."[2]

9 January

Researchers announced at a meeting of the American Astronomical Society (AAS) that, using NASA's Hubble Space Telescope (HST), they had been able for the first time to observe directly the close companion star to Polaris (the North Star). The newly observed star, one of two in the near vicinity of Polaris, is approximately 3.2 billion kilometers (2 billion miles) from Polaris and hundreds of times fainter. Polaris is Earth's nearest example of a Cepheid variable star. Scientists use the variations in the brightness of Cepheid stars to judge the distances of galaxies and the expansion rate of the universe. Imaging its companion star had enabled scientists to estimate Polaris's mass at 4.3 times that of the Sun, but future measurements of the companion star's motion during its 30-year orbit would enable scientists to make a more accurate determination of

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[1] NASA, "NASA Announces Next International Space Station Crew," news release 06-002, 5 January 2006, *http://www.nasa.gov/home/hqnews/2006/jan/HQ_06002_Expedition_13_crew.html* (accessed 14 September 2009); Tariq Malik, "NASA Announces Next Space Station Crew," *Space.com*, 5 January 2006, *http://www.space.com/ missionlaunches/060105_exp13_crew_announcement.html* (accessed 28 June 2010).

[2] John Antczak for Associated Press, "U.S.-French Oceanography Satellite Decommissioned After 13 Years," 6 January 2006; Ayinde O. Chase, "NASA Satellite Ceases To Operate," *All Headline News*, 6 January 2006; *CBC News* (Canada), "Ocean Satellite Ends 13-Year Mission," 6 January 2006.

Polaris's mass. Knowledge of mass size is critical to understanding the composition and evolution of Cepheids.[3]

10 January

Ohio University astronomers Thomas S. Statler and Steven Diehl, who had analyzed images of 56 elliptical galaxies, which NASA's Chandra X-ray Observatory had made, reported that the data from the images had revealed an unsuspected turmoil in the galaxies, which appear calm in optical light. Statler and Diehl had determined that the previously held assumption—that the equilibrium shape of the multimillion-degree gas clouds in these galaxies would correlate with the shape of its stars—had been erroneous. Searching for an energy source for the explosive activity, the astronomers had drawn a correlation between the shape of the hot gas clouds and the power produced at radio wavelengths by high-energy electrons. Scientists can trace this power output back to the centers of the galaxies, where supermassive black holes are located. Statler's and Diehl's analysis indicated that the phenomena of repetitive explosive activity, fueled by the in-fall of gas into central black holes—a process known to occur in giant elliptical galaxies located in galaxy clusters—was also occurring in isolated elliptical galaxies. According to Statler, "these results are part of an emerging picture that shows the impact of supermassive black holes on the environment is far more pervasive than previously thought."[4]

NASA awarded its Exceptional Scientific Achievement Medal posthumously to astronomer and astrophysicist John N. Bahcall, who had died in August 2005 of a rare blood disorder. NASA honored Bahcall for his work developing the HST, along with astronomers Lyman S. Spitzer Jr. and George B. Field, and for his "extraordinary service to NASA's astronomy program," including "groundbreaking work in the 1960s toward explaining the scientific mysteries of the sun." Bahcall had also received the NASA Distinguished Public Service Medal, and the National Medal of Science.[5]

11 January

NASA announced that the HST had captured an unprecedented look at the Orion Nebula, the region of massive star formation nearest Earth, at 1,500 light-years away. At the center of the Nebula is a group of four young, massive stars, known as the Trapezium, which radiate a stream of energetic x rays called a stellar wind. Stellar winds have blown out much of the dust and gas in which the stars form, thereby carving out a cavity that permits astronomers to view the Nebula. In a mosaic containing a billion pixels, Hubble's Advanced Camera for Surveys (ACS) had uncovered thousands of stars never seen before in visible light, including some that were only 100th the brightness of previously viewed Orion stars. Among the stars studied were young brown dwarfs and a small population of possible binary brown dwarfs (two brown dwarfs orbiting each other). According to observation leader Massimo Robberto, of the Space Telescope

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[3] NASA, "There's More to the North Star Than Meets the Eye," news release 06-004, 9 January 2006, *http://www.nasa.gov/home/hqnews/2006/ja/HQ_06004_hubble.html* (accessed 14 September 2009); Maggie McKee, "Hubble Reveals Pole Star's Closest Companion," *New Scientist*, 10 January 2006.

[4] Chandra X-ray Observatory, "NGC 0507: Black Holes Stir Up Galaxies," *http://chandra.harvard.edu/photo/2006/galaxies* (accessed 17 December 2009); NASA, "NASA's Chandra Finds Black Holes Stirring Up Galaxies," news release 06-006, 10 January 2006, *http://www.nasa.gov/home/hqnews/2006/jan/HQ_06006_Chandra_AAS_update.html* (accessed 14 September 2009).

[5] NASA, "NASA Honors Distinguished Astronomer with Medal," news release 06-005, 10 January 2006, *http://nasa.gov/home/hqnews/2006/jan/HQ_06005_Bahcall_AAS_Award.html* (accessed 14 September 2009).

Science Institute in Baltimore, Maryland, the information garnered from the Hubble survey, along with the ability to observe stars of all sizes in one dense area of space, would enable astronomers to calculate the masses and ages of the young stars in the Orion Nebula and to "get a general scenario of star formation in that region."[6]

12 January

NASA's Associate Administrator of the Aeronautics Research Mission Directorate, Lisa J. Porter, announced a comprehensive restructuring of NASA's aeronautics research programs. Speaking at an American Institute of Aeronautics and Astronautics conference, Porter stated, "NASA is returning to long-term investment in cutting-edge fundamental research in traditional aeronautics disciplines. We are investing in research for the long term in areas that are appropriate to NASA's unique capabilities and meeting our charter of addressing national needs and benefiting the public good." The four major programs restructured were fundamental aeronautics, aviation safety, airspace systems, and the aeronautics test program. Research in fundamental aeronautics was concentrated in four areas: hypersonics, supersonics, subsonic fixed wing, and subsonic rotary wing. The goal for research in fundamental aeronautics would be to produce knowledge, data, and capabilities for both civilian and military applications, and design tools to benefit a broad range of air vehicles. Research in the aviation safety program would address four areas: aircraft aging and durability, integrated vehicle health management, and integrated resilient aircraft control. The primary research responsibility of the airspace system program would be the development of concepts, capabilities, and technologies for high-capacity, efficient, and safe airspace and airport systems. The aeronautics test program would focus on the strategic use, operations, and maintenance of NASA's wind-tunnel and air-breathing propulsion test facilities at Ames Research Center (ARC), Glenn Research Center (GRC), and Langley Research Center (LaRC).[7]

15 January

NASA's Stardust mission return capsule landed at the U.S. Air Force Utah Test and Training Range at 5:10 a.m. (EST). The spacecraft, which had launched on 7 February 1999, flying 2.88 billion miles (4.63 billion kilometers) and circling the Sun three times, was the first to bring comet material from outer space. On 2 January 2004, Stardust had flown within 149 miles (239.79 kilometers) of comet Wild 2's nucleus, to collect microscopic dust particles. During the voyage, the spacecraft had captured bits of interstellar dust streaming into the solar system from other parts of the galaxy. NASA expected that the 100-pound (45.36-kilogram) capsule ejected from Stardust would contain approximately 1 million samples of comet and interstellar dust particles, trapped in a material like spun glass, called aerogel. NASA would transfer the capsule to a laboratory at its Johnson Space Center (JSC), where scientists would examine the samples. According to Principal Investigator for the mission, Donald E. Brownlee, of the University of

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[6] NASA, "NASA's Hubble Reveals Thousands of Orion Nebula Stars," news release 06-007, 11 January 2006, *http://www.nasa.gov/home/hqnews/2006/jan/HQ_06007_HST_AAS.html* (accessed 14 September 2009); Ker Than, "The Splendor of Orion: A Star Factory Unveiled," *Space.com*, 11 January 2006, *http://www.space.com/ scienceastronomy/060111_orion_news.html* (accessed 28 June 2010).

[7] NASA, "NASA Restructures Aeronautics Research," news release 06-008, 12 January 2006, *http://www.m\nasa. gov/home/hqnews/2006/jan/HQ_06008_ARMD_Restructuring.html* (accessed 14 September 2009); Lisa J. Porter, "Reshaping NASA's Aeronautics Program" (conference presentation, American Institute of Aeronautics and Astronautics, Reno, Nevada, 12 January 2006).

Washington, Seattle, "this has been a fantastic opportunity to collect the most primitive material in the solar system. We fully expect some of the comet particles to be older than the Sun."[8]

19 January

NASA launched the US$700 million New Horizons spacecraft aboard a Lockheed Martin Atlas 5 rocket, on a 3-billion mile (4.83-kilometer), 9-year journey to Pluto, at 2:00 p.m. (EST) from Cape Canaveral, Florida. The spacecraft left Earth's orbit at a speed of 36,000 miles per hour (57,936 kilometers per hour). After the spacecraft's planned February 2007 flyby of Jupiter, to receive a gravity-assisted velocity boost, NASA projected that it would reach a top speed of 47,000 miles per hour (75,639 kilometers per hour), thereby reducing the flight's duration by three to five years. NASA expected that the New Horizons spacecraft would have its closest approach to Pluto and its moons in July 2015. Powered by 24 pounds (10.9 kilograms) of plutonium, New Horizons carried seven scientific instruments. Three of these were cameras, which would capture visible-light, infrared, and ultraviolet images of the surfaces of Pluto and its moon Charon. Also on board were three spectrometers, to study the composition and temperatures of Pluto's thin atmosphere and surface features. After flying past Pluto, the spacecraft would penetrate deeper into the Kuiper Belt, an outer zone of the solar system comprising thousands of icy, rocky objects, including comets and small planets, such as Pluto.[9]

The European Space Agency (ESA) and Galileo Industries S.A. of Brussels, a consortium of European space-hardware manufacturers, signed a €950 million (US$1.15 billion) contract for the construction of four Galileo navigation-system satellites, planned for launch in 2008. ESA had created Galileo as a civilian-controlled operation, designed to increase Europe's strategic independence from the U.S. military's Global Positioning System (GPS) and to provide a more precise navigational tool. The first experimental Galileo satellite, Giove-A, which ESA had launched on 28 December 2005, had transmitted the first Galileo navigational signals on 12 January 2006.[10]

20 January

NASA announced that its Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite had ceased operations after a successful six-year mission. IMAGE had enabled researchers to study the global structure and dynamics of Earth's inner magnetosphere (the area of space around Earth that is controlled by Earth's magnetic field), as it responded to energy from solar winds. According to Barbara L. Giles, IMAGE Program Scientist at NASA

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[8] Guy Gugliotta, "Stardust Capsule Brings First Comet Sample to Earth," *Washington Post*, 17 January 2006; Warren Leary, "Space Capsule Bearing Comet Dust Lands in Utah," *New York Times*, 17 January 2006; NASA, "NASA's Comet Hunter on Final Approach for Sunday Landing," news release 06-028, 12 January 2006, *http://www.nasa.gov/home/hqnews/2006/jan/HQ_06028_stardust.html* (accessed 14 September 2009).

[9] Warren E. Leary, "NASA Launches Spacecraft on the First Mission to Pluto," *New York Times*, 20 January 2006; Mike Schneider for Associated Press, "Unmanned Spacecraft Hurtles Toward Pluto," 20 January 2006; *Spacewarn Bulletin*, no. 627, 1 February 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/ spx627.html* (accessed 14 September 2009).

[10] Agence France-Presse, "ESA, Galileo Industries Set Deal for First Four Galileo Satellites," 20 January 2006; European Space Agency (ESA), "Contract for In-Orbit Validation of Galileo System," press release 4-2006, 13 January 2006, *http://www.esa.int/esaCP/Pr_4_2006_p_EN.html* (accessed 5 October 2009); ESA, "First Galileo Signals Transmitted by GIOVE-A," press release 3-2006, 12 January 2006, *http://www.esa.int/esaCP/ Pr_3_2006_ p_EN.html* (accessed 5 October 2009); Peter B. de Selding, "Giove-A Permits Early Registration of Galileo Frequencies," *Space.com*, 20 January 2006.

Headquarters, "The IMAGE mission showed us space around the Earth is anything but empty, and that plasma clouds can be imaged and tracked just as we do from space for Earth's surface weather." The satellite had launched on 25 March 2000 and had provided data until December 2005, when its power supply subsystems had failed.[11]

23 January
NASA announced major personnel changes at three of its centers, Ames Research Center (ARC) in California, Kennedy Space Center (KSC) in Florida, and Stennis Space Center (SSC) in Mississippi. G. Scott Hubbard, Director of ARC, announced his resignation, stating that he had agreed to assume the Carl Sagan Chair for the Study of Life in the Universe at the SETI (Search for Extra-Terrestrial Intelligence) Institute in Mountain View, California. Hubbard had worked at Ames since 1987, serving as Director since 2002, and had previously served on the *Columbia* Accident Investigation Board and as the first Director of the NASA Astrobiology Institute. NASA appointed William W. Parsons Jr., Director of Stennis since 2005, as Deputy Director of KSC. Parsons's tenure at NASA had spanned 16 years. As Space Shuttle Program Manager after the *Columbia* accident, he had directed NASA's return-to-flight efforts, which had culminated, in the summer of 2005, in the successful flight of *Discovery* in STS-114. Parsons had also led NASA's recovery efforts after Hurricane Katrina. NASA appointed Richard J. Gilbrech, who had worked at Stennis since 1991, as Director of SSC. He had served as Deputy Director of LaRC in Virginia, as Deputy Director of NASA's Engineering Safety Center, and had worked at various NASA flight centers.[12]

24 January
Japan launched into space the Advanced Landing Observing Satellite (ALOS), known as Daichi, on an H-IIA rocket, from Tanegashima Space Center in Kagoshima in southern Japan, at 10:33 a.m. (JST). ALOS had the capability to produce maps of a scale of 25,000 to 1, without using reference points on Earth's surface. Japan would also use the satellite for precise regional land-coverage observation, disaster monitoring, and resource surveying. Three instruments aboard ALOS would accomplish these tasks: the Panchromatic Remote-Sensing Instrument for Stereo Mapping (PRISM), an optical camera measuring land elevation; the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), observing the material that covers land surfaces; and the Phased Array type L–band Synthetic Aperture Radar (PALSAR), enabling day-and-night and all-weather land observation. Japan had designed ALOS to operate for at least three years, with a program objective for a mission lasting up to five years.[13]

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[11] NASA, "Magnetospheres," *http://nasascience.nasa.gov/heliophysics/magnetosphere-ionosphere* (accessed 7 December 2009); NASA, "NASA Magnetic Field Mission Ends," news release 06-030, 20 January 2006, *http://www.nasa.gov/home/hqnews/2006/jan/HQ_06030_IMAGE_quits.html* (accessed 14 September 2009).
[12] NASA, "NASA Announces Senior Management Changes," news release 06-031, 23 January 2006, *http://www.nasa.gov/home/hqnews/2006/jan/HQ_06031_personnel_changes.html* (accessed 14 September 2009); *Picayune Item* (MS), "NASA Announces Management Changes at Stennis Space Center," 25 January 2006.
[13] Stephen Clark, "New Earth Observer Launched into Orbit," *Spaceflight Now*, 24 January 2006; Japan Aerospace Exploration Agency (JAXA), "Satellites and Spacecraft: Advanced Land Observing Satellite 'DAICHI' (ALOS)," 25 February 2009, *http://www.jaxa.jp/projects/sat/alos/index_e.html* (accessed 12 November 2009); *Spacewarn Bulletin*, no. 627, 1 February 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/ spx627.html* (accessed 14 September 2009).

30 January

Bruce T. Lundin, who had joined the Lewis Research Center (LeRC) in Ohio in 1943, and had served as its Director from 1969 to 1977, died at the age of 86. At Lewis, Lundin had conducted research on aircraft engine–cooling heat transfer; directed the development of turbojet engines, chemical rockets, and electric thrusters for spacecraft propulsion; and helped to develop electrical power–generating systems for spacecraft, using chemical, solar, and nuclear energy sources. According to NASA officials, Lundin's work during his tenure as the chief of the Engine Research Division had contributed to the increased performance and reliability of modern-day commercial transport and supersonic aircraft engines. Lundin had received NASA's Distinguished Service Medal twice.[14]

FEBRUARY 2006

1 February

An international team of astronomers, led by Frank Bertoldi of the University of Bonn and the Max-Planck-Institute for Radioastronomy, reported in the journal *Nature* that an object in the Kuiper Belt surrounding Pluto—2003 UB313—had a diameter greater than Pluto. Scientists had discovered 2003 UB313 in 2005 and had concluded from observations of its optical brightness that the object was larger than Pluto. Bertoldi's team had measured the object's heat radiation using the Spanish IRAM 30-meter (98.4-foot) telescope fitted with the Max-Planck Millimeter Bolometer detector. The team had observed the thermal emissions at a 1.2-millimeter (0.05-inch) wavelength, using the measurement to calculate 2003 UB313's size and surface reflectivity. The resulting diameter measurement of 3,000 kilometers (1,864 miles) indicated that the object was 700 kilometers (435 miles) larger than Pluto. Moreover, 2003 UB313 was the largest object discovered in the solar system since the 1946 discovery of Neptune. The object's size sparked a controversy among scientists, who were debating which criteria they should use to name objects as planets. The International Astronomical Union (IAU) would decide whether to name 2003 UB313 as the 10th planet or to demote Pluto from its planetary status.[15]

2 February

NASA's Deep Impact team of scientists, led by Michael F. A'Hearn of the University of Maryland, reported in the online edition of *Science* that they had found the first conclusive evidence of water ice on the surface of a comet. Jointly sponsored by NASA's JPL and the University of Maryland, Deep Impact had crashed a space probe into the comet Tempel 1 on 4 July 2005 and had taken samples of the resulting debris. Through a spectral analysis of data about the comet, which the probe had collected before the crash, the scientists had determined the existence of three patches of ice covering 300,000 square feet (27,871 square meters), approximately 6 percent of Tempel 1's total surface area. The team concluded that the exposed ice had come from larger reservoirs just below the comet's surface. While scientists had long known that ice is a component of comets, this report marked the first discovery of ice on a

[14] Wally Guenther, "Bruce Lundin, 86, Was Director of NASA Lewis Research Center," *Cleveland Plain Dealer* (OH), 30 January 2006.

[15] Guy Gugliotta, "At the Edge of Solar System, a 10th Planet May Lurk," *Washington Post*, 2 February 2006; Univeritätbonn and Max-Planck-Institut für Radioastronomie, "New 'Planet' Is Larger Than Pluto: Bonn Astronomers Measure Size of Recently Discovered Solar System Object," joint press release, 1 February 2006, www.astro.uni-bonn.de/~bertoldi/ub313/PR-UB313-E.doc (accessed 25 August 2010); see also Frank Bertoldi et al.,"The Trans-Neptunian Object UB313 is Larger Than Pluto," *Nature* 439, no. 7076 (2 February 2006): 563−564.

comet's exterior surface. Scientists speculate that comets might have been the first vector for the delivery of water and carbon-based molecules to Earth, providing the building blocks for life.[16]

6 February

President George W. Bush submitted his US$2.77 trillion budget for FY 2007, which included US$16.8 billion to fund NASA, a 3.2 percent increase over FY 2006. According to NASA Administrator Michael D. Griffin, the priorities established by this budget reflected NASA's commitment to implement the Vision for Space Exploration, to complete the assembly of the ISS with the fewest possible spaceflights, and to deliver an operational Crew Exploration Vehicle (CEV) no later than 2014. The budget provided for a reduction in funding for the Shuttle program, from US$4.78 billion in FY 2006 to US$4.06 billion in FY 2007, and a 3 percent increase in funding for the ISS, to US$1.81 billion. NASA had requested funds of US$3.98 billion for the Exploration Systems Mission Directorate, a 30 percent increase from the previous fiscal year. The Directorate would develop the CEV, two new launchers, and the lunar landers needed to return astronauts to the Moon by 2020. NASA had estimated the cost of completing ISS assembly with the minimum number of Shuttle flights, while ensuring the safety of Shuttle flights, and had calculated a budget shortfall of US$3–5 billion. To make up this shortfall, the FY 2007 budget would cut funding for aeronautics research by 18 percent, to US$724.4 million. In addition, the budget would cap the increase for NASA's science budget, which funded deep-space probes and Earth-observation satellites, at 1.5 percent in FY 2007, and at 1 percent annually for the following four years.[17]

8 February

NASA announced that the aviation industry, including the Boeing Company, was using the unique wind-tunnel technology that NASA had developed to test new aviation concepts before applying them in flight. Unlike conventional wind tunnels, the National Transonic Facility at NASA's LaRC used super-cold nitrogen gas at high pressure to duplicate true-flight aerodynamics capability, even with models as small as 1/50th the size of the typical test aircraft. According to facility chief aerodynamicist Richard A. Wahls, this capability "allows the aircraft manufacturers to produce better performing airplanes with less risk." Boeing had purchased wind-tunnel time to evaluate high-lift system designs for its new 787 jet aircraft.[18]

11 February

Adventurer J. Stephen Fossett broke the world's record for the longest nonstop flight in history. Virgin Atlantic's founder Richard Branson had financed the flight. Fossett had flown the

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[16] Reuters, "Deep Impact Probe Shows Ice on Comet's Surface," 2 February 2006; Brown University, "NASA's 'Deep Impact' Team Reports First Evidence of Cometary Ice," press release, 2 February 2006, *http://www.brown.edu/Administration/News_Bureau/2005-06/05-072.html* (accessed 27 August 2010); Ker Than, "Water Ice Detected on Comet's Surface," *Space.com*, 2 February 2006, *http://www.space.com/missionlaunches/060202_comet_ice.html* (accessed 31 August 2010); see also Jessica M. Sunshine et al., "Exposed Water Ice Deposits on the Surface of Comet 9P/Tempel 1," *Science* 311, no. 5766 (10 March 2006): 1453.

[17] NASA, "NASA Administrator's Statement About FY 2007 Budget," news release 06-056, 6 February 2006, *http://www.nasa.gov/home/hqnews/2006/feb/HQ_06056_Budget_Statement.html* (accessed 10 September 2010); Warren E. Leary, "Unexpected Costs Force NASA Cuts," *New York Times*, 7 February 2006; Brian Berger, "NASA Seeks 30-Percent Increase For Explorations Programs," *Space News*, 6 February 2006.

[18] NASA, "Industry Uses NASA Wind Tunnels To Design New Airplanes," news release 06-060, 8 February 2006, *http://www.nasa.gov/home/hqnews/2006/feb/HQ_06060_LaRC_wind_tunnel.html* (accessed 14 September 2009).

lightweight Virgin Atlantic Global Flyer built by aircraft designer Burt Rutan, taking off from KSC in Cape Canaveral, Florida, on 9 February, and heading east. After circumnavigating the globe, Fossett had planned to cross the Atlantic a second time and to land at Kent International Airport outside London, thus breaking the world's record for the longest flight made by any aircraft. This achievement would have surpassed both the airplane distance record that Richard A. Rutan and Jeana Yeager had set in 1986, flying the Voyager aircraft, and the balloon distance record that the Breitling Orbiter 3 had set in 1999. However, Fossett had encountered several difficulties and had to make an emergency landing in Bournemouth, England, when his generator failed only a few miles shy of his intended destination. Fossett had completed his record-setting 26,389-mile (42,689-kilometer) journey in 76 hours and 45 minutes. Fossett's flight also marked the first time that a privately built experimental aircraft had taken off from a Cape Canaveral runway.[19]

14 February

Scientists led by University of Iowa professor Donald A. Gurnett, Principal Investigator for the Radio and Plasma Wave Science Investigation, announced that, since 23 January 2006, the team had been using instruments aboard NASA's Cassini spacecraft to track a lightning storm on Saturn. Cassini had detected radio emissions from the lightning but, at first, had been unable to image the storm because of the storm's position on the night side of the planet. Amateur astronomers had succeeded in capturing the first images of the storm, and Cassini had acquired subsequent images. Gurnett described the storm as larger than the continental United States, with lightning bolts over 1,000 times the strength of conventional lightning, the strongest lightening that his team had observed since Cassini entered Saturn's orbit in 2006.[20]

16 February

The House Committee on Science held a hearing on NASA's FY 2007 budget proposal, receiving testimony from NASA Administrator Michael D. Griffin. Griffin reiterated NASA's budgetary priorities, which he had outlined on 6 February when President George W. Bush submitted the federal budget to Congress. NASA had proposed using money previously allocated for science, lunar exploration, and aeronautics programs to fund the programs that would now take precedence, according to the Vision for Space Exploration. Priorities would include supporting human spaceflight programs, completing the assembly of the ISS, and placing the CEV in operation by 2014. Committee chair Sherwood L. Boehlert (R-NY) and ranking member Bart Gordon (D-TN) were equally critical of the proposed budget. Boehlert stated that the budget was "bad for space science, worse for Earth science, perhaps worse still for aeronautics. It basically cuts or de-emphasizes every forward looking, truly futuristic program of the agency to fund operational and development programs to enable us to do what we are already doing or have done before." Although he expressed support for the Vision for Space Exploration, Boehlert said that he saw no need to accelerate the deadline for an operational CEV to a date earlier than 2014. Gordon criticized the Bush administration for sending Congress a budget

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[19] NASA, "GlobalFlyer Departs From NASA's Kennedy Shuttle Runway," news release 06-059, 8 February 2006, *http://www.nasa.gov/home/hqnews/2006/feb/HQ_06058_Global_Flyer.html* (accessed 27 August 2010); Guy Gugliotta, "Fossett Sets Flight Distance Record," *Washington Post*, 12 February 2006; Associated Press, "Fossett Takes Off Seeking New Record," 9 February 2006.

[20] University of Iowa News Services, "UI Researchers, Colleagues Find Giant Lightning Storm at Saturn," news release, 14 February 2006, *http://news- releases.uiowa.edu/2006/February/ releases.uiowa.edu/2006/february/ 021406saturn_lightning.html*, (accessed 13 August 2010).

request for funding that was inadequate to implement NASA's exploration initiative and other programs.[21]

17 February

A team of scientists, led by Eric J. Rignot of NASA's JPL and Pannir Kanagaratnam of the University of Kansas Center for Remote Sensing of Ice Sheets, reported in the journal *Science* that, in the last 10 years, Greenland's glaciers had doubled the rate at which they were losing ice into the Atlantic Ocean, from 96 cubic kilometers (23 cubic miles) per year in 1996, to 220 cubic kilometers (53 cubic miles) in 2005. Using interferometric synthetic-aperture radar data that Canadian Space Agency's (CSA's) Radarsat-1 and ESA's Envisat Advanced Synthetic Aperture Radar and Earth Remote Sensing Satellites 1 and 2 had collected between 2000 and 2005, the researchers calculated the volume of ice breaking off the edges of the glaciers and falling into the ocean. They attributed the change in glacial ice flow to an increase in global temperature, suggesting that the resulting melting water was making the undersides of the glaciers more slippery and accelerating the pace at which the glacial ice was sliding into the ocean. This study represented the most comprehensive data on glacial ice flow to date. Researchers noted that, based on this research, scientists might need to revise previous computer models predicting the rate of ocean-level increase.[22]

18 February

Japan Aerospace Exploration Agency (JAXA) and Rocket System Corporation (RSC) launched the Multi-Functional Transport Satellite 2 (MTSAT-2) from the Tanegashima Space Center at 06:55 (UT) aboard an H2-A rocket. The Civil Aviation Bureau and the Japan Meteorological Agency jointly owned the 1,250-kilogram (2,756-pound) geostationary weather satellite, which carried an imaging telescope with detectors for five wavelength channels: visible band, micron infrared (IR1), micron (IR2), micron water vapor (IR3), and micron near infrared. After coming to rest over 145º east longitude, the satellite would commence its mission to capture data and images that scientists could use to determine weather patterns, and to relay that information to the Japanese Meteorological Agency.[23]

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[21] U.S. Congress, House of Representatives, Committee on Science, *NASA's Fiscal Year 2007 Budget Proposal*, 109th Cong., 2nd sess., 16 February 2006, *http://www.gpo.gov/fdsys/search/pagedetails.action?browsePath=109%2FHOUSE%2FCommittee+on+Science&granuleId=CHRG-109hhrg25937&packageId=CHRG-109hhrg25937&fromBrowse=true* (accessed 30 December 2010); U.S. Congress, House of Representatives, Committee on Science, "NASA's Stated Goals Don't Match Budgetary Realities," press release, 16 February 2006, *http://science.house.gov/press/PRArticle.aspx?NewsID=1044* (accessed 12 July 2010); Brian Berger, "Congress Criticizes NASA Budget Request," *Space.com*, 16 February 2006, *http://www.space.com/news/060216_griffin_nasa.html* (accessed 27 September 2010).

[22] Andrew Bridges, "Greenland Glaciers Dumping More Ice," *Washington Post*, 17 February 2006; NASA "Greenland Ice-Loss Doubles in Past Decade, Raising Sea Levels Faster," press release 06-066, 16 February 2006, *http://www.nasa.gov/home/hqnews/2006/feb/HQ_06066_Greenland_ice_melting_ corrected.html* (accessed 2 September 2010); see also Eric Rignot and Pannir Kanagaratnam, "Changes in the Velocity Structure of the Greenland Ice Sheet," *Science* 311, no. 5763 (17 February 2006): 986–90.

[23] *Spacewarn Bulletin*, no. 628, 1 March 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/spx628.html* (accessed 17 August 2010); JAXA, "Launch Result of the Multi-functional Transport Satellite 2 (MTSAT-2) by the H-IIA Launch Vehicle No. 9 (H-IIA F9)," press release, 18 February 2006, *http://www.jaxa.jp/press/2006/02/20060218_h2a-f9_e.html* (accessed 17 August 2010).

21 February

JAXA announced that it had successfully launched its ASTRO-F infrared astronomical satellite after a one-day weather delay. The 952-kilogram (2,099-pound) satellite blasted off from Uchinoura Space Center on an M-5 booster at 21:28 (UT). ASTRO-F carried a 67-centimeter-aperture (26-inch-aperture) infrared telescope, a Far-Infrared Surveyor, and the Infrared Camera. Its mission was to survey all the galaxies for infrared luminance indicating newly forming planets, stars, and protogalaxies, and to collect data on the structure, mass, and composition of new stars. This information would help scientists understand the formation process of stars, planetary systems, and galaxies. Part of a joint mission of JAXA, ESA, and Korean researchers, ASTRO-F was built to survey the cosmos at higher resolutions and with higher sensitivity than the world's first infrared satellite, the Infrared Astronomy Satellite, which had launched in 1983.[24]

23 February

A team of scientists, led by Harold A. Weaver Jr. of Johns Hopkins University, S. Alan Stern of the Southwest Research Institute, and Richard P. Binzel of the Massachusetts Institute of Technology, reported in *Nature* their discovery of two small satellites orbiting Pluto. The team had sighted the moons, which had diameters of an estimated 60 kilometers (37 miles) and 50 kilometers (31 miles), respectively, in May 2005, using the HST. Both small moons circle on the same orbital plane as Pluto's large moon Charon. In addition, the durations of all three bodies' orbital rotations are simple ratios of one another. These facts led scientists to conclude that the same collision event created all three moons. Furthermore, the evidence raised the possibility that the distant Kuiper Belt, which includes Pluto, could contain other multiple-body systems. The researchers also speculated that debris from impacts in the Pluto system could have formed rings or arcs around Pluto. Thus far, scientists have only documented ring systems around gas giant planets, such as Jupiter, Saturn, Uranus, and Neptune.[25]

28 February

International Launch Services (ILS), a joint venture of Lockheed Martin and Khrunichev State Research and Production Space Center in Moscow, announced that a rocket carrying an Arabsat 4A telecommunications satellite had failed to reach its proper orbit. The Russian Proton Breeze M rocket, which launched from Baikonur Cosmodrome in Kazakhstan at 3:10 p.m. (EST), failed to burn its upper-stage engine for as long as its designers had planned, leaving the satellite stranded in low orbit. EADS Astrium engineers had designed Arabsat to expand and optimize capacity for direct-to-home TV broadcasting, telephony, and data transmission over a coverage zone encompassing North Africa, the Middle East, and part of Western Europe. If the launch had

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[24] JAXA, "Infrared Imaging Satellite "AKARI" (ASTRO-F)," *http://www.jaxa.jp/projects/sat/astro_f/index_e.html* (accessed 14 September 2010); Tariq Malik, "Japan Launches New Observatory for Infrared Sky Survey," *Space.com*, 21 February 2006, *http://www.space.com/missionlaunches/060221_jaxa_astrof_lnch.html* (accessed 14 September 2010); *Spacewarn Bulletin*, no. 628, 1 March 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/spx628.html* (accessed 22 September 2010).

[25] Ker Than, "Pluto Might Have Rings," *Space.com* 22 February 2006, *http://www.space.com/scienceastronomy/060222_pluto_moons.html* (accessed 8 September 2010); see also H.A. Weaver et al., "Discovery of Two New Satellites of Pluto," *Nature* 439, no. 7079 (23 February 2006): 943‒945; S. A. Stern et al., "A Giant Impact Origin for Pluto's Small Moons and Satellite Multiplicity in the Kuiper Belt," *Nature* 439, no. 7079 (23 February 2006): 946‒948; and Richard P. Binzel, "Planetary Science: Pluto's Expanding Brood," *Nature* 439, no.7079 (23 February 2006): 924-925.

been successful, it would have placed Arabsat in a geostationary transfer orbit with an apogee of 36,000 kilometers (22,369 miles). ILS announced that it would form a failure-review oversight board "to review reasons for the anomaly and define a corrective action plan." An investigatory Russian state commission would conduct a similar review.[26]

MARCH 2006

2 March

Heads of the national space agencies of Canada, Europe, Japan, Russia, and the United States met at NASA's KSC in Florida to review plans for completing assembly of the ISS by the end of 2010. Since the grounding of the Space Shuttle fleet in 2003, in the wake of the *Columbia* disaster, the ISS had operated with two-member crews. However, the ISS partners planned to increase the crew to three members with the next Space Shuttle *Discovery* flight, scheduled for May 2006, and to increase the crew of the station to six members in 2009. Furthermore, NASA announced its plan to launch 16 Shuttle flights to allow completion of the ISS before the planned retirement of the Shuttles in 2010. To advance the assembly schedule, the Shuttles would transport ESA's Columbus laboratory module and JAXA's experiment module Kibo to the ISS during four missions in 2007 and 2008. The ISS partners issued a joint statement that "affirmed their plans to use a combination of transportation systems provided by Europe, Japan, Russia, and the United States in order to complete ISS assembly in a timeframe that meets the needs of the partners and ensures full utilization of the unique capabilities of the ISS throughout its lifetime."[27]

At a hearing on NASA's FY 2007 budget request for its Science Mission Directorate, the House Committee on Science received testimony from the Directorate's Associate Administrator Mary L. Cleave. NASA's FY 2007 budget request for science programs was US$3.1 billion less for fiscal years 2006 through 2010 than its FY 2006 budget request had projected. The request reflected NASA's decision to slow the rate of growth for scientific missions by 1.5 percent in 2007 and by 1 percent thereafter. Cleave defended this decision against concerns of the House committee that the policy would result in the delay or cancellation of numerous missions, and insufficient funds to initiate new missions. She stated that, to comply with NASA Administrator Michael D. Griffin's directive to provide "a robust and executable program that can be implemented in this resource-constrained environment," the Directorate would be "selecting, developing, and launching a slate of Science missions within cost and schedule targets." NASA would have to delay, but not abandon, new scientific missions, such as the mission to Jupiter's moon Europa. Democrats on the committee joined the scientists testifying before the House panel in opposing the proposed cuts to NASA's science programs, particularly in the areas of research and analysis. Opponents of the budgetary reduction argued vehemently that the cuts could potentially cause long-term damage to the health of NASA's science program, and that the

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[26] Sergi Manstov, "Proton Failure—Arian Re-sets," *NASASpaceFlight.com*, 1 March 2006; Jefferson Morris, "Proton Launch Failure Leaves Arabsat 4A Stranded," *Aerospace Daily and Defense Report*, 2 March 2006.
[27] NASA, "Joint Statement by International Space Station Heads of Agency," news release 06-084, 2 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06084_HOA_statement.html* (accessed 21 June 2010); Warren E. Leary, "Schedule To Complete Space Station Is Advanced," *New York Times*, 3 March 2006; Irene Klotz for Reuters, "NASA Has New Plan To Complete Space Station," 2 March 2006.

continuance of university-based research was critical to training the next generation of scientists and engineers.[28]

8 March

In a comprehensive survey published in the *Journal of Glaciology*, H. Jay Zwally, of NASA's Goddard Space Flight Center (GSFC) in Maryland, and a team of NASA scientists confirmed that climate warming was affecting Earth's largest storehouse of ice and snow. Results of studies measuring the ice sheets covering Greenland and Antarctica indicated that Greenland's ice sheets had experienced a net loss between 1992 and 2002—a reduction equivalent to 20 billion tons (18.14 tonnes or 18,143 kilograms) of water—along with a corresponding rise in sea level. The researchers had used a new satellite map showing the height of Greenland's ice sheets, based on data that two ESA satellites had captured. They had compared it with NASA's previous map of the edges of the ice sheets to determine the rate at which the thickness of the ice was diminishing. The survey documented for the first time the extensive thinning of the West Antarctic ice shelves, the increase in snowfall in the interior of Greenland, and the thinning at the edges of the ice shelves. Zwally remarked, "the contribution of ice sheets to recent sea-level rise during the decade studied was much smaller than expected, just 2 percent of the recent increase of nearly 3 millimeters a year." NASA would continue to monitor the polar ice sheets using data from the Ice, Cloud, and land Elevation Satellite (ICESat), which had launched in 2003.[29]

10 March

A team of researchers reported in the journal *Science* that images from NASA's Cassini spacecraft revealed evidence of towering plumes of water vapor and ice particles erupting from the surface of Saturn's moon Enceladus. Cassini had conducted three flybys of the moon in 2005. According to Carolyn C. Porco, leader of the Cassini Imaging Team at the Space Science Institute, Boulder, Colorado, the scientists surmised that Enceladus possessed water reservoirs under high pressure below its icy exterior. When the ice ruptured, the subsurface water shot out and froze into icy crystals. Porco stated that, if this assumption were correct, the discovery had "significantly broadened the diversity of solar system environments where we might possibly have conditions suitable for living organisms." The Imaging Team reported that the discovery of water plumes on Enceladus was unique because the "pockets of liquid water may be no more than tens of meters below the surface," whereas liquid-water oceans on other moons in Earth's solar system are covered by kilometers of icy crust.[30]

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[28] U.S. Congress, House of Representatives, Committee on Science, "NASA Budget Puts Key Science Priorities at Risk," news release, 2 March 2006, *http://science.house.gov/press/PRArticle.aspx?NewsID=1057* (accessed 12 July 2010); U.S. Congress, House of Representatives, Committee on Science, *NASA Science Mission Directorate: Impacts of the Fiscal Year 2007 Budget Proposal*, 109th Cong., 2nd sess., 2 March 2006, 3, 4, 24, *http://www.gpo.gov/fdsys/search/pagedetails.action?browsePath=109%2FHOUSE%2FCommittee+on+Science&granuleId=CHRG-109hhrg26204&packageId=CHRG-109hhrg26204&fromBrowse=true* (accessed 30 December 2010).

[29] NASA, "NASA Survey Confirms Climate Warming Impact on Polar Ice Sheets," news release 06-089, 8 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06089_polar_ice_sheets_melting.html* (accessed 14 September 2009); see also H. Jay Zwally et al., "Mass Changes of the Greenland and Antarctic Ice Sheets and Shelves and Contributions to Sea-level Rise: 1992–2002," *Journal of Glaciology* 51, no. 175 (December 2005): 509−527.

[30] NASA, "NASA's Cassini Discovers Potential Liquid Water on Enceladus," new release 06-088, 9 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06088_cassini_saturns_moon.html* (accessed 14 September 2009).

After a seven-month, 310-mile (498.9-kilometer) journey, NASA's Mars Reconnaissance Orbiter (MRO) completed the crucial step of entering orbit around Mars. To achieve initial capture by the planet's gravity, the orbiter fired its main propulsion engines for 27 minutes, thereby reducing its speed by 3,540 kilometers per hour (2,200 miles per hour). This placed the US$720 million spacecraft in a highly elliptical orbit. The next phase of the orbiter's mission would involve a seven-month "aerobraking" process. The spacecraft would dip into Mars's atmosphere hundreds of times, using the friction of atmospheric drag to move from an approximately 35-hour orbit, extending almost 35,000 miles (56,000 kilometers) above the planet, to a 2-hour polar orbit that skims only 190 miles (300 kilometers) above Mars's surface. A two-year phase of scientific study would follow the aerobraking phase. During those two years, the orbiter would use six instruments to study every level of Mars, from underground layers to the top of the atmosphere. The instruments would include the most powerful telescopic camera ever sent to another planet, an advanced mineral mapper to identify water-related areas, radar to probe beneath the surface for buried ice and water, and a weather camera that would monitor the planet daily. MRO Project Manager James Graf predicted, "this spacecraft will return more data than all previous Mars missions combined."[31]

13 March
Scientists announced preliminary findings from their evaluation of the dust samples of comet Wild 2, findings that NASA's Stardust spacecraft had returned to Earth in January 2006. Stardust had passed within 149 miles (239.79 kilometers) of Wild 2 in January 2004, trapping particles of the comet within an exposed gel. Because comets form in the frigid region beyond Neptune's orbit called the Kuiper Belt, the scientists were surprised to find that the samples of Wild 2 contained minerals that had formed near the Sun or near other stars, at temperatures higher than 1,100°C (2,012°F). These minerals included calcium, aluminum, and titanium, as well as olivine, a compound of iron and magnesium generally found in beach sand. Michael E. Zolensky, Stardust curator and co-investigator at NASA's JSC, concluded that comets appear to be composed of a mixture of materials formed "at all temperature ranges, at places very near the early Sun and at places very remote from it." According to Zolensky, finding high-temperature minerals in the comet provided support for a model of comet formation in which "strong bipolar jets coming out of the early sun propelled material formed near to the sun outward to the outer reaches of the solar system." Over 100 scientists, most associated with NASA's JSC, were continuing to study the sample particles to determine their chemical histories.[32]

16 March
Using data collected by NASA's Wilkinson Microwave Anisotropy Probe (WMAP) satellite, scientists announced the discovery of new evidence supporting the concept known as "inflation." Proposed 25 years before WMAP, inflation theory attempted to explain the distribution of matter and energy in the Big Bang, the theoretical beginning of the universe. Inflation theory posits that,

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[31] NASA, "Mars Reconnaissance Orbiter Arrival," press kit, March 2006, *http://marsprogram.jpl.nasa.gov/mro/files/mro/mro-arrival.pdf* (accessed 30 July 2010); Damian Carrington, "New Mars Probe Safely Enters Orbit," *New Scientist*, 10 March 2006; Warren E. Leary, "U.S. Spacecraft Enters Orbit Around Mars," *New York Times*, 11 March 2006.
[32] NASA, "NASA's Stardust Findings May Alter View of Comet Formation," news release 06-091, 13 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06091_Stardust_update.html* (accessed 14 September 2009); Irene Klotz for Reuters, "US Scientists Unearth Hot Rocks from Cold Comet," 14 March 2006; Warren E. Leary, "Hot Material Is Discovered in Icy Comets," *New York Times*, 14 March 2006.

at the outset of the Big Bang, approximately 13.7 billion years ago, the universe underwent a rapid expansion. According to WMAP researcher David N. Spergel, "during this growth spurt, a tiny region, likely no larger than a marble, grew in a trillionth of a second to become larger than the visible universe." The rapid inflationary expansion converted quantum fluctuations—short-lived bursts of energy at the subatomic level—into fluctuations of matter that ultimately enabled the formation of stars and galaxies. WMAP, first launched in 2001, was providing observations of the cosmic microwave background (CMB), the afterglow light produced when the universe was less than a million years old. The first WMAP data, released in 2003, had focused on the temperature variations of this light, providing an accurate age of the universe and insights into its geometry and composition. The new WMAP observations provided not only a more detailed temperature map, but also the first full-sky map of the polarization (the way light is changed by the environment through which it passes) of the CMB.[33]

17 March
NASA formed a five-member investigation board at NASA's KSC in Florida, to review the 4 March 2006 incident during STS-121 in which Space Shuttle *Discovery*'s remote manipulator system (robotic Shuttle arm) sustained damage. The arm, a 50-foot-long, jointed extension, was used to grapple payloads and to remove them from the payload bay, and to move spacewalking astronauts to various work platforms. Hugo M. Delgado Jr., Deputy Director for the Office of the Chief Engineer at KSC, would chair the board, which would investigate the facts surrounding the incident, determine its probable cause, assess the possibility of a recurrence, and recommend corrective actions. The 4 March incident was one in a series of accidents that had occurred at KSC in 2006, prompting Director of KSC James W. Kennedy to order a brief shutdown of operations. At that time, Kennedy had warned KSC employees that a major accident could derail NASA's plans to complete the ISS and to begin exploring the Moon and Mars.[34]

21 March
The United States and the Russian Federation signed an Agreement on Technology Safeguards Associated with the Activities under the Sea Launch Project. The Sea Launch Project, a Boeing-led consortium, comprising companies from Russia, Ukraine, and Norway, was using Russian Zenit carrier rockets to provide commercial launch services for U.S. and foreign satellite payloads from a launch platform in the international waters of the Pacific Ocean. The program, which had begun in 1999, had completed 19 launches. The U.S. Department of State, acting as signatory, stated, "Conclusion of this agreement highlights our ongoing bilateral partnership in this successful commercial endeavor and will facilitate Russian participation. It also increases

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[33] NASA, "NASA Satellite Glimpses Universe's First Trillionth of a Second," news release 06-097, 16 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06097_first_trillionth_WMAP.html* (accessed 14 September 2009); Ker Than, "Astronomers Detect First Split-Second of the Universe," *Space.com*, 16 March 2006, *http://www.space.com/scienceastronomy/060316_wmap_results.html* (accessed 12 July 2010); Dennis Overbye, "Astronomers Find the Earliest Signs Yet of a Violent Baby Universe," *New York Times*, 17 March 2006.
[34] NASA, "NASA Appoints Board To Investigate Shuttle Arm Incident," news release 06-100, 17 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06100_Shuttle_arm_board.html* (accessed 14 September 2009); *New York Times*, "Accident Involving Shuttles at Kennedy Space Center Prompt Safety Directive," 18 March 2006.

the potential for enhanced Russian participation and cooperation more generally in the sphere of commercial use of outer space for peaceful purposes."[35]

22 March

NASA launched the first three microsatellites in the Space Technology 5 (ST 5) mission, aboard a Pegasus XL rocket from Vandenberg Air Force Base in California, at 9:04 a.m. (EST). The ST 5 mission was part of NASA's New Millennium Program, created to identify, develop, build, and test innovative technologies and concepts for use in future missions. NASA launched the three satellites to a near-Earth polar elliptical orbit that would enable them to travel from approximately 300 kilometers (190 miles) to approximately 4,500 kilometers (2,800 miles) above Earth. Once in orbit, the satellites would form a row, with each satellite approximately 40 to 200 kilometers (25 to 125 miles) away from the others. Miniature boom-mounted magnetometers on each satellite would collect data enabling coordinated multi-point measurements of Earth's magnetic field. This type of measurement would be useful in future missions studying the effect of solar activity on Earth's magnetosphere, the bubble that protects Earth from harmful space radiation. The satellites would remain operational for approximately 90 days.[36]

24 March

Isabella Velicogna and John Wahr, scientists at the University of Colorado, Boulder, who had conducted the first-ever gravity survey of the entire Antarctic ice sheet, reported their findings in the journal *Science*. Using data from two of NASA's GRACE (Gravity Recovery and Climate Experiment) satellites, Velicogna and Wahr had determined that the ice sheet's mass had decreased significantly between April 2002 and August 2005—by 152 cubic kilometers (36 cubic miles) of ice annually, plus or minus 80. The scientists had concluded that the Antarctic melting, an indicator of climate change, was causing the global sea level to rise 0.4 millimeters (0.16 inches) per year. The twin GRACE satellites, which orbit Earth more than a dozen times each day at an altitude of 310 miles (498.9 kilometers), measure variations in Earth's mass and gravitational pull. Increases or decreases in the Antarctic ice sheet's mass alter the distance between the satellites as they fly in formation.[37]

29 March

The Russian federal space agency Roskosmos launched the crew of ISS Expedition 13 in a *Soyuz* spacecraft at 9:30 p.m. (EST) from Baikonur Cosmodrome in Kazakhstan. The members of Expedition 13 were Russian cosmonaut Commander Pavel V. Vinogradov and American

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[35] RIA Novosti, "Russia, U.S. Sign Technology Agreement Under Satellite Project," 22 March 2006; U.S. Department of State, "Launch TSA Signed on March 21, 2006," media note 289-2006, 21 March 2006, *http://2001-2009.state.gov/r/pa/prs/ps/2006/63459.htm* (accessed 20 April 2010).

[36] NASA, "NASA's Space Technology 5 Satellites Soar into Space," news release 06-104, 22 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06104_ST5_Successful_Launch.html* (accessed 14 September 2009); NASA, "Space Technology 5: Mission Overview," *http://www.nasa.gov/mission_pages/st-5/main/index.html* (accessed 4 January 2010).

[37] Juliet Eilperin, "Antarctic Ice Sheet Is Melting Rapidly," *Washington Post*, 3 March 2006; NASA, "NASA Mission Detects Significant Antarctic Ice Mass Loss," news release 06-085, 2 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06085_arctic_ice.html* (accessed 14 September 2009); see also Isabella Velicogna and John Wahr, "Measurements of Time-Variable Gravity Show Mass Loss in Antarctica," *Science* 311, no. 5768 (24 March 2006): 1754−1756.

astronaut Jeffrey N. Williams. The two men would replace the crew of Expedition 12, which comprised American astronaut Commander William S. McArthur Jr. and Russian cosmonaut Valery I. Tokarev. The ISS partners planned for the new crew to stay at the station for six months. In NASA's second return-to-flight mission, STS-121, scheduled for July 2006, *Discovery* would bring ESA astronaut Thomas A. Reiter to the ISS to join the crew of Expedition 13. The Russian spacecraft also transported astronaut Marcos C. Pontes of the Brazilian space agency, Agência Espacial Brasileira (AEB), who had joined NASA as an international astronaut in 1998. Pontes, the first Brazilian to fly in space, would conduct scientific experiments under a commercial contract with Roskosmos, returning to Earth with the Expedition 12 crew on 8 April 2006.[38]

NASA's JPL awarded Lockheed Martin a preliminary start-up contract for the design and concept of the aeroshell system for Mars Science Laboratory (MSL). Scheduled for launch in the fall of 2009, MSL would support NASA's exploration for water on Mars, in preparation for human exploration missions. The aeroshell system, which Lockheed Martin had built, included the thermal protection system (heat shield) that would encapsulate and protect the MSL rover from the intense heat and friction generated during the system's descent through the Martian atmosphere. In addition, the aeroshell system included a parachute system and a crane, which would lower the rover to a soft landing on the surface of Mars.[39]

30 March

Scientists with NASA's Cassini-Huygens Mission reported in *Nature* the detection of a new class of small moonlets within Saturn's rings. The Cassini spacecraft's camera had detected four faint, propeller-shaped moonlets, measuring 100 meters (300 feet) across, in a small fraction of the mid A-ring, a bright section in Saturn's main rings. Based on this observation, scientists speculated that the total number of Saturn's moonlets could be approximately 10 million. Previous measurements, including those that NASA's Voyager spacecraft had made in the early 1980s, had shown that Saturn's main rings are composed predominantly of water-ice particles, ranging from approximately 1 centimeter (0.39 inch) to approximately 10 meters (32.8 feet) in radius. Two previously identified embedded ring moons, known as Pan and Daphnis, have a radius measuring several kilometers. Based on the discovery of the smaller moonlets, scientists concluded that Pan and Daphnis were likely the largest members of the ring population. The verification of the moonlets' existence would also help answer the question of whether Saturn's rings had formed when a larger moon exploded, or were remnants of the swirling discs of gas, dust, and debris from which Saturn and its moons had formed.[40]

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[38] NASA, "International Space Station Status Report SS06-013," 29 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_SS06013_ISS_Status_Report.html* (accessed 24 September 2009); NASA, "International Space Station Status Report: SS06-014," 1 April 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_SS06014_ISS_Status_Report.html* (accessed 25 September 2009); Tariq Malik, "Orbital Rendezvous: Fresh Crew, Brazilian Astronaut Arrive at ISS," *Space.com*, 1 April 2006, *http://www.space.com/missionlaunches/060401_exp13_docking.html* (accessed 7 July 2010).

[39] Lockheed Martin, "Lockheed Martin Awarded Contract To Design the Mars Science Lab Aeroshell," 29 March 2006, *http://www.lockheedmartin.com/news/press_releases/2006/LOCKHEEDMARTINAWARDEDCONTRACTDESIGN.html* (accessed 21 April 2010); Associated Press, "Lockheed Martin Making Mars Heat Shield," 30 March 2006.

[40] NASA, "Cassini Finds 'Missing Link' Moonlet Evidence in Saturn's Rings," news release 06-130, 29 March 2006, *http://www.nasa.gov/home/hqnews/2006/mar/HQ_06130_cassini_moonlets.html* (accessed 14 September 2009); Ker Than, "Saturn's Rings Created by Collision," *Space.com*, 29 March 2006, *http://www.space.com/scienceastronomy/*

APRIL 2006

5 April

Pratt & Whitney Rocketdyne announced the completion of the assembly of the first Common Extensible Cryogenic Engine (CECE) demonstrator, a deep-throttling 15,000-pound-thrust-class engine, fueled by a mixture of liquid oxygen and liquid hydrogen. Built in support of NASA's Vision for Space Exploration, the CECE would validate key component technologies that high-energy, in-space propulsion systems would require for future space exploration. The CECE program would focus on descent propulsion for the Lunar Surface Access Module, as well as demonstrating technologies for other applications, such as the Earth Departure Stage and in-space transfer systems. In June 2005, NASA had awarded Pratt & Whitney Rocketdyne the first portion of a US$40 million four-year contract to develop CECE.[41]

Speaking at the 22nd National Space Symposium, in Colorado, Vice Administrator of China National Space Administration (CNSA) Luo Ge reviewed the landmark achievements of the People's Republic of China and outlined its ambitious future space exploration plans. Luo Ge recapped China's accomplishments to date—46 consecutive successful launches since 1996, including 23 satellites and six Shenzhou spacecraft, the most recent of which were crewed missions. He stated that China's total annual investment in space programs was equivalent to US$500 million. China planned to achieve a lunar flyby in 2007, to develop a nonpolluting launch vehicle by 2010, to land a rover on the Moon's surface by 2012, to establish an orbiting space laboratory by 2015, and to launch robotic lunar-sample-return missions by 2017. Furthermore, Luo Ge stated that China expected to launch approximately 100 Earth-orbiting satellites over the next five to eight years, ranging from oceanographic, navigation, and telecommunications satellite systems to constellations of Earth-observing and disaster-mitigation spacecraft.[42]

7 April

Imke de Pater of the University of California, Berkeley, and a team of astronomers, reported in *Science* that they had determined that the outermost ring of the planet Uranus is bright blue. Saturn is the only other planet in the solar system known to possess a blue outer ring. In December 2005, astronomers Mark R. Showalter and Jack J. Lissauer, had reported the discovery of two of Uranus's moons—Mab and Cupid—and of two new rings. At that time, the astronomers had only determined the color of the innermost red ring. To determine the color of the planet's outermost ring, the team had combined the ground-based, near-infrared observations of the W. M. Keck Telescope in Hawaii with visible-light images captured by the HST. They had analyzed the properties of Uranus's outermost ring and had drawn a parallel with the blue ring of

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060329_saturn_moonlets.html (accessed 25 August 2010); see also Matthew S. Tiscareno et al., "100-Metre-Diameter Moonlets in Saturn's A Ring From Observations of 'Propeller' Structure," *Nature* 440, no. 7084 (30 March 2006): 648−650.

[41] Pratt & Whitney, "Pratt & Whitney Rocketdyne Completes Assembly of First Common Extensible Cryogenic Engine Demonstrator," press release, 5 April 2006, *http://www.pw.utc.com/Media+Center/Press+Releases/Archive+-+2006* (accessed 27 April 2010).

[42] Leonard David, "China Unveils Ambitious Space Plans at National Space Symposium," *Space.com*, 5 April 2006, *http://www.space.com/news/060405_nss_china.html* (accessed 24 June 2010); Xinhua News Agency, "China Reveals Space Exploration Plans," 6 April 2006.

Saturn. The astronomers speculated that Saturn's blue ring of small particles was the result of meteoroid impacts on the surface of Saturn's moon Enceladus, impacts that had scattered debris into the moon's orbit. The largest particles had remained within Enceladus's orbit, but various forces, including pressure from sunlight, had pushed the smallest particles out of the moon's orbit, causing Saturn's broad ring of smaller scattered particles, which reflect predominantly blue light. De Pater explained that this explanation of the color of Saturn's outer ring was directly applicable to the blue ring observed around Uranus. However, he cautioned that astronomers did not yet "understand the details of the process."[43]

8 April

The crew of ISS Expedition 12, American astronaut Commander William S. McArthur Jr. and Russian cosmonaut Valery I. Tokarev, returned to Earth aboard a Russian *Soyuz* spacecraft, landing at 7:48 p.m. (EDT) in Kazakhstan. The two men had spent nearly 190 days in space, conducting two spacewalks and using every Russian docking port on the complex. They were the first ISS crew to dock at all the Russian ports. Accompanying McArthur and Tokarev on their return was Brazil's first astronaut Marcos C. Pontes, who had spent eight days on the ISS conducting scientific experiments, under a commercial agreement with the Russian federal space agency Roskosmos.[44]

11 April

Five months after launch, ESA's Venus Express spacecraft entered orbit around Venus. The path of the spacecraft's initial nine-day "capture orbit" would follow a long ellipse, ranging from 350,000 kilometers (217,480 miles) at its furthest point from Venus (its apocentre), to less than 400 kilometers (248 miles) at its closest point to the planet (its pericentre). This elliptical orbit would afford the Venus Express a view of the entire disc of the planet. Over the next four weeks, the spacecraft would be brought into its operational 24-hour polar orbit, ranging from 250 kilometers (155 miles) to 66,000 kilometers (41,000 miles) above Venus. From this vantage point, the spacecraft would conduct in-depth observations of the structure, chemistry, and dynamics of Venus's atmosphere, continuing to capture data for at least 486 Earth days.[45]

14 April

An Orbital Sciences Corporation Minotaur rocket launched from Vandenberg Air Force Base in California at 9:40 p.m. (EDT), carrying six Taiwanese-American weather microsatellites. The launch of the weather satellites was part of a US$100 million mission known in the United States as COSMIC (Constellation Observing System for Meteorology, and Climate) and as

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[43] Robert Sanders, "Blue Ring Discovered Around Uranus," University of California at Berkeley press release, 6 April 2006, *http://berkeley.edu/news/media/releases/2006/04/ 06_bluering.shtml* (accessed 25 June 2010); see also Imke de Pater et al., "New Dust Belts of Uranus: One Ring, Two Ring, Red Ring, Blue Ring," *Science* 312, no. 5770 (7 April 2006): 92−94.

[44] NASA, "International Space Station Status Report: SS06-016," 8 April 2006, *http://www.nasa.gov/home/hqnews/ 2006/apr/HQ_SS06016_ISS_Status_Report.html* (accessed 25 September 2009).

[45] ESA, "Europe Scores New Planetary Success: Venus Express Enters Orbit Around the Hothouse Planet," news release 13–2006, *http://www.esa.int/esaCP/Pr_13_2006_p_EN.html* (accessed 2 April 2010); ESA, "Venus Express' Initial Orbit Matches Expectations," 11 April 2006, *http://www.esa.int/esaMI/ Venus_Express/SEMY1SNFGLE_ 0.html* (accessed 2 April 2010); Peter B. de Selding, "Second from the Sun: European Probe Enters Venus Orbit," *Space.com*, 12 April 2006, *http://www.space.com missionlaunches/060411_venusexp_arrival.html* (accessed 24 June 2010).

FORMOSAT 3 in Taiwan. Taiwan's National Science Council and National Space Organization had provided primary funding for the project, with contributions from the U.S. National Science Foundation (NSF) and its partners, including NASA. After an initial orbit approximately 300 miles (500 kilometers) above Earth, the satellites would achieve their final circular orbits 13 months later, orbiting between 435 and 500 miles (700 and 800 kilometers) above Earth. The principal instrument on each of the 155-pound (62-kilogram) satellites would be a GPS receiver, originally developed by NASA's JPL. Working together with other on-board instruments, GPS antennas would track the extent to which the GPS signals bend when they pass through (are occulted by) the Earth's atmosphere. Measuring the degree to which the signals bend would enable scientists to evaluate atmospheric conditions, such as air density, temperature, moisture, and electron density. According to Jay S. Fein, Program Director in the NSF's Division of Atmospheric Sciences, the satellites would obtain new information that would "have a tremendous impact on geosciences research and weather prediction, and would be an important contribution to global Earth observations."[46]

15 April

The orbiting capsule of the *Shenzhou 6*, the piloted spacecraft that CNSA had launched on 12 October 2005, returned to Earth after completing 2,920 orbits. The mission's crew had returned to Earth on 17 October 2005. According to China's state news agency Xinhua, the orbiting capsule had successfully gathered scientific data during its 180-day mission and had laid a "solid foundation" for China's future space engineering projects, such as its planned mission to the Moon.[47]

19 April

Albert Scott Crossfield, legendary test pilot and aeronautical engineer, died at the age of 84, when his single-engine Cessna plane crashed. During his five-year tenure (1950–1955) as a research pilot for NASA's forerunner, the National Advisory Committee for Aeronautics (NACA), Crossfield had flown most of the experimental aircraft tested at Edwards Air Force Base in California. In 1953, at the controls of a Douglas D-558-2 Skyrocket, he had been the first person to fly at twice the speed of sound, achieving a speed of Mach 2—more than 1,320 miles per hour (2,124 kilometers per hour). Crossfield had later become the chief test pilot for North American Aviation, where he was the consultant for the revolutionary X-15 rocket-powered airplane. One of his two-dozen flights aboard the X-15 had reached Mach 2.97, almost three times the speed of sound. In 1993 Crossfield had received the NASA Distinguished Public Service Medal for his contributions to aeronautics research and development. NASA Administrator Michael D. Griffin described Crossfield as "not only one of the greatest pilots who ever flew," but also "an expert aeronautical engineer, aerodynamicist, and designer who made significant contributions . . . to systems testing, reliability engineering, and quality assurance for the Apollo command and service modules and Saturn V second stage."[48]

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[46] Leonard David, "COSMIC Constellation To Study Atmosphere," *MSNBC.com*, 14 April 2006; Tariq Malik, "Minotaur Rocket Orbits COSMIC Constellation To Scan Earth's Atmosphere," *Space.com*, 14 April 2006, *http://www.space.com/missionlaunches/060414_ cosmic_mino_ launch.html* (accessed 24 June 2010); Justin Ray, "Mission Status Center," *Spaceflight Now*, 15 April 2006.

[47] *Space Daily*, "Orbiting Chinese Space Capsule Returns to Earth," 17 April 2006.

[48] Dennis McLellan, "Scott Crossfield, 84; 1st Man To Fly at Twice the Speed of Sound Helped Craft X-15 Rocket Plane," *Los Angeles Times*, 21 April 2006; NASA, "NASA Administrator Statement Regarding the Tragic Loss of Aviation Pioneer A. Scott Crossfield," news release 06-191, *http://www.nasa.gov/home/hqnews/2006/apr/HQ_*

20 April

An Atlas 5 rocket launched from Cape Canaveral, Florida, at 4:27 p.m. (EDT), carrying the 4.3-tonne (4,300-kilogram or 4.74-ton) geostationary Astra 1KR telecommunications satellite. Lockheed Martin had designed and built the satellite for Luxembourg-based SES ASTRA. International Launch Services (ILS), a joint venture between Lockheed Martin and Khrunichev State Research and Production Center in Moscow, had marketed the mission. Once the satellite had achieved its final orbital slot over the equator at 19.2° east longitude, its 32 Ku-band transponders would transmit analog, radio, and digital television signals, as well as Internet and multimedia services throughout Europe.[49]

21 April

NASA announced the appointment of retired U.S. Air Force Brigadier General Simon P. "Pete" Worden as Director of NASA's ARC in California. Worden, a research professor of astronomy at the University of Arizona, Tucson, had served as Director and Deputy Director at the U.S. Air Force Space Command and had specialized in advanced satellite and launch concepts. He had also served as second deputy for technology at the Strategic Defense Initiative Organization, where he had received NASA's Outstanding Leadership Medal for directing the 1994 Clementine lunar probe mission.[50]

25 April

NASA Administrator Michael D. Griffin testified before the U.S. Senate Commerce, Science and Transportation Subcommittee on Science, Technology, and Space. Griffin outlined highlights of NASA's FY 2007 budget request and discussed "the strategic direction for NASA in implementing the priorities of the President and Congress within the resources provided." Griffin stated that NASA's first priority must be to honor its March 2006 commitment to its international partners on the ISS. NASA had pledged to conduct an adequate number of Space Shuttle flights to complete the assembly of ISS by the end of the decade. Toward this end, NASA had reallocated funds budgeted for its scientific and exploration missions for fiscal years 2007−2011, transferring the projected funds to the budget for the Space Shuttle and the ISS. Griffin urged that NASA's second priority should be constructing the new CEV, which would transport humans to the ISS after NASA retired the Space Shuttles in 2010. Griffin said that the CEV must be operational "not later than 2014 and possibly much sooner." According to Griffin, NASA would have to delay several new scientific missions because fulfilling NASA's commitment to the ISS and the CEV was a higher priority. Redirecting funds budgeted for Exploration Systems, in order to provide additional funds for aeronautics research or science

06191_Crossfield_death.html (accessed 25 September 2009); David Stout, "Scott Crossfield, Fabled Test Pilot, Dies at 85," *New York Times*, 21 April 2006.

[49] United Press International, "ASTRA Satellite Ready for Thursday Launch," 20 April 2006; Justin Ray, "Atlas 5 Rocket Launches TV Broadcasting Craft for Europe," *Spaceflight Now*, 20 April 2006; *Spacewarn Bulletin*, no. 630, 1 May 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/spx630.html* (accessed 1 March 2010).

[50] NASA, "NASA Names Worden New Ames Director," news release 06-193, *http://www.nasa.govhome/hqnews/2006/apr/HQ_06193_Worden_named_director.html* (accessed 25 September 2009); Warren Ferster, "Worden Named Director of NASA Ames," *Space.com*, 21 April 2006.

missions, would directly affect "NASA's ability to effectively and efficiently transition the workforce and capabilities from the Space Shuttle to the new CEV system."[51]

27 April

The U.S. Government Accountability Office (GAO) issued its report, "NASA's Deep Space Network: Current Management Structure Is Not Conducive To Effectively Matching Resources with Future Requirements." The report concluded that, although Deep Space Network (DSN) "is able to meet most of the requirements of its current workload, serious questions exist as to whether it will be able to keep up with both near-term and future demands." The report also found that "system infrastructure, which has been marked by extensive deferred maintenance, is aging and is likely to become increasingly fragile and subject to breakdown at a time when demand is anticipated to increase." Managed by NASA's JPL, DSN comprised communications antennas measuring up to 70 meters (229.6 feet), located in California, Australia, and Spain. Established in 1959, DSN supported an average of 35 to 40 deep space missions each year. However, the number of new deep space missions continued to increase, and existing "legacy" missions, such as Voyager missions, had remained in operation longer than initially planned. Therefore, NASA projected that, by 2020, DSN would have to support twice as many missions as currently. In a written response to GAO's report, NASA Deputy Administrator Shana L. Dale stated that, although "no mission had been unable to meet its mission requirements due to a lack of capability in the DSN, NASA shared GAO's concerns about the future capacity and capabilities of the system." She also noted that NASA had initiated a study to review the management structure for all of NASA's space communications activities.[52]

28 April

NASA launched two meteorological satellites, CloudSat and CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations), aboard a Boeing Delta 2 rocket, at 11:02 (UT) from Vandenberg Air Force Base in California. The satellites would eventually circle 438 miles (705 kilometers) above Earth in a Sun-synchronous polar orbit. CloudSat, an experimental mission designed to study the effects of clouds on climate and weather, was 1,000 times more sensitive than typical weather radar, using millimeter-wavelength radar to measure the altitude and properties of clouds. CALIPSO carried three instruments to study the role that clouds and atmospheric aerosols (airborne particles) play in regulating Earth's weather, climate, and air quality. The two satellites would become part of a constellation of Earth-observing satellites known as the A-train, joining the satellites Aqua, Aura, and PARASOL.[53]

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[51] U.S. Congress, Senate, Committee on Commerce, Science and Transportation, Subcommittee on Science and Space, *NASA Issues and Challenges*, 109th Cong., 2nd sess., 25 April 2006, 2–4 (statement of NASA Administrator Michael D. Griffin), *http://commerce.senate.gov/pdf/griffin-042506.pdf* (accessed 21 January 2010).

[52] U.S. Government Accountability Office, "NASA's Deep Space Network: Current Management Structure Is Not Conducive To Effectively Matching Resources with Future Requirements" (report no. GAO-06-445, Washington, DC, 27 April 2006), 2, 22, *http://www.gao.gov/new.items/d06445.pdf* (accessed 24 June 2010); Brian Berger, "GAO Warns Deep Space Network Ill-Equipped To Meet Future Demands," *Space News*, 23 May 2006.

[53] *Spacewarn Bulletin*, no. 630; NASA, "NASA Launches Satellites for Weather, Climate, Air-Quality Studies," news release 06-190, 28 April 2006, *http://www.nasa.gov/home/hqnews/2006/apr/HQ_06190_Cloudsat_CALIPSO_launch.html* (accessed 25 September 2009); Jesco von Puttkamer, "Space Flight 2006—The Year in Review," July 20, 2007, *http://www.nasa.gov/directorates/somd/reports/2006/us.html* (accessed 3 March 2010).

MAY 2006

1 May

Eileen M. Collins, who had joined the astronaut corps in 1990, announced her retirement from NASA. In February 1995, Collins had served as NASA's first female Shuttle pilot on Space Shuttle *Discovery* STS-63, the first Shuttle mission to rendezvous with the Russian *Mir* space station. In May 1997, she had served as pilot on Space Shuttle *Atlantis* STS-84 flight to *Mir*, and in July 1999, she had become NASA's first female Shuttle commander on Space Shuttle *Columbia* STS-93, which had launched the Chandra X-Ray Observatory. In July–August 2005, she had served as commander of Space Shuttle *Discovery* STS-114, the first Shuttle flight since the 2003 loss of Space Shuttle *Columbia* and its crew. NASA Administrator Michael D. Griffin described Collins as a "brave, superb pilot," and NASA Flight Crew Operations Director Kenneth D. Bowersox called her a "gifted leader."[54]

2 May

NASA announced the crew for ISS Expedition 14, a six-month mission scheduled to launch aboard a Russian *Soyuz* spacecraft in September 2006. American astronaut Michael E. Lopez-Alegria would command the mission and serve as NASA's station science officer, and Russian cosmonaut Mikhail V. Tyurin would serve as Flight Engineer. American astronaut Sunita L. Williams, making her first spaceflight, would join Expedition 14 in progress, after traveling to the ISS on Space Shuttle *Discovery* STS-116, scheduled for December 2006. ESA astronaut Thomas A. Reiter would travel to the ISS aboard Space Shuttle *Discovery* STS-121, scheduled for summer 2006, serving as the third astronaut on Expedition 13 and later joining the Expedition 14 crew until Williams's arrival. Lopez-Alegria had served on board Space Shuttle *Columbia* STS-73 in 1995, on Space Shuttle *Discovery* STS-92 in 2000, and on Space Shuttle *Endeavour* STS-113 in 2002, conducting five spacewalks during the assembly of the station complex. Tyurin had served as Flight Engineer of ISS Expedition 3 in 2001. NASA also announced the backup crew members for Expedition 14, American astronauts Peggy A. Whitson and Clayton C. Anderson.[55]

3 May

A Soyuz-U rocket launched from the Plesetsk Cosmodrome in northern Russia at 17:38 (UT), carrying Kosmos 2420, a Russian military satellite. The Russian federal space agency Roskosmos stated that "the launch took place in the interests of the Defense Ministry." Observers in the United States speculated that Kosmos 2420 might be a spy satellite intended to bolster Russia's declining military-intelligence presence in space.[56]

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[54] NASA, "NASA Astronaut Eileen Collins Completes Career of Space Firsts," news release 06-208, 1 May 2006, *http://www.nasa.gov/home/hqnews/2006/may/HQ_06208_Collins_retires.html* (accessed 1 October 2009); Tariq Malik, "NASA's First Female Shuttle Commander Retires from Spaceflight," *Space.com*, 1 May 2006, *http://www.space.com/news/060501_collins_retirement.html* (accessed 18 June 2010).

[55] NASA, "NASA Announces 14th International Space Station Crew," news release 06-209, 2 May 2006, *http://www.nasa.gov/home/hqnews/2006/may/HQ_06209_14th_ISS_crew.html* (accessed 16 March 2010); Tariq Malik, "NASA Announces Next Space Station Crew," *Space.com*, 3 May 2006.

[56] *Spacewarn Bulletin*, no. 631, 1 June 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/spx631.html* (accessed 17 March 2010); Stephen Clark, "Russian Soyuz Rocket Launches New Spy Satellite," *Spaceflight Now*, 3 May 2006; RIA Novosti, "Russia Launches Kosmos Military Satellite from Plesetsk Base," 3 May 2006.

4 May

An international team of scientists led by Giacomo Giampieri of NASA's JPL reported in *Nature* the results of their study measuring Saturn's rotation period. Using magnetic field data collected by NASA's Cassini spacecraft in 2003 and 2004, the researchers estimated that the rotation rate of Saturn is almost 8 minutes longer than the 10 hours, 39 minutes, and 22.4 seconds calculated in 1980. Scientists had based the 1980 measurement on the Voyager spacecraft's observations of the radio waves generated when solar radiation hits Saturn's atmosphere. Whereas scientists were able to measure the rotation period of other planets by comparing their magnetic and rotational axes, they could not use this procedure for Saturn, because its rotational axis is nearly identical to the axis of its magnetic field. Instead, scientists had measured distortions in the radio signals that Saturn emits—distortions that they believed were related to the planet's magnetic field—to estimate the planet's rotation rate. According to Giampieri, a planet's rotation rate indicates the amount of centrifugal force acting on the interior of the planet, data that provides "a very important ingredient for planetary modeling."[57]

The National Research Council Space Studies Board released its study, *An Assessment of Balance in NASA's Science Programs*, concluding that NASA "does not have the necessary resources to carry out the tasks of completing the ISS, returning humans to the Moon, maintaining vigorous space and Earth science and microgravity life and physical sciences programs, and sustaining capabilities in aeronautical research." Study chair Lennard A. Fisk, University of Michigan space scientist and former NASA Associate Administrator, stated that the study committee was "particularly concerned that the shortfall in funding for science has fallen disproportionately on small missions and on funding for basic research and technology. These actions run the risk of disrupting the pipeline of human capital and technology that is essential for the future success of the space program." The conference report (H. Rep. No.108-792), which accompanied H.R. 4818 (Pub. L. No.108-447), the bill appropriating FY 2005 funds for NASA, had mandated the study.[58]

Using images from the HST, astronomers at the Space Telescope Science Institute in Baltimore, Maryland, were able for the first time to witness the birth of a second red spot (dubbed Red Spot Jr.) on the planet Jupiter. The Great Red Spot, which dates at least to the seventeenth century, is a storm rising as high as 5 miles (8.05 kilometers) above Jupiter's cloud level. The Great Red Spot is large enough to contain two or three planets the size of Earth. The new red spot, roughly half the diameter of the Great Red Spot, had begun as three white ovals—cooler, upper-level storms. Observers had first seen two of the ovals in 1915, and astronomers had seen the third in 1939. The three storms had merged between 1998 and 2000. Astronomers believed that Red Spot Jr., like the Great Red Spot, rises above the top of the main cloud deck on Jupiter. Scientists had theorized that the change in color of the oval to red, which occurred earlier in 2006, was the

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[57] Giacomo Giampieri et al., "A Regular Period for Saturn's Magnetic Field that May Track its Internal Rotation," *Nature* 441, no. 7089 (4 May 2006): 62–64; Ker Than, "Length of Saturn's Day Updated Based on Mystery Signal," *Space.com*, 3 May 2006.

[58] Guy Gugliotta, " NASA Underfunded, Panel Reports," *Washington Post*, 5 May 2006; National Academy of Sciences, Office of News and Public Information, "NASA Lacks Resources To Sustain Vigorous Science Program," news release, 4 May 2006, *http://www8.nationalacademies.org/ onpinews/newsitem.aspx?RecordID=11644* (accessed 16 March 2010); National Research Council, Space Studies Board, *An Assessment of Balance in NASA's Science Programs* (Washington, DC: National Academies Press, 2006), 29, *http://www.nap.edu/catalog.php?record_id=11644* (accessed 16 March 2010).

result of the storm's exposure to the Sun's ultraviolet light. They surmised that, when the storm dredged up material deep below Jupiter's clouds and lifted it above Jupiter's cloud deck, the Sun's ultraviolet light chemically altered the material, giving it a red hue. Astronomers also speculated that the HST images could indicate a major climate change in Jupiter's atmosphere, related to the new spot.[59]

5 May

At the National Space Society's International Space Development Conference, NASA Deputy Administrator Shana L. Dale announced NASA's sponsorship of the Lunar Lander Challenge competition, with prizes totaling US$2.5 million, to develop rockets capable of landing on the Moon. The X Prize Foundation would manage the competition and award the Lunar Lander Challenge prizes at the presentation of the X Prize Cup in October 2006. The challenge would have two levels of difficulty, with prizes awarded at each level. Level 1 would require a vehicle to take off from a designated launch area, rocket to an altitude of 150 feet (50 meters), hover for 90 seconds, and land on a pad 100 meters (320.08 feet) from the launch point. Level 2 would require the same launch altitude and the same distance between launch and landing pad, but the rocket would have to hover for 180 seconds and to land on a rocky site simulating the lunar surface. California entrepreneur Peter H. Diamandis, founder of the X Prize competition, stated that "entrepreneurial companies can build the lunar space ships [necessary for achieving NASA's goal of returning people to the Moon in the next decade], and a Lunar Lander Challenge can stimulate the required technology in an efficient and rapid fashion."[60]

7 May

Less than one month after insertion into orbit, and after achieving 16 loops around the planet Venus, ESA's Venus Express spacecraft reached its final operational elliptical orbit—a 24-hour polar orbit at a range of 66,000 kilometers (41,000 miles) to 250 kilometers (155 miles) over Venus. Venus Express Project Scientist Håkan Svedhem stated that this orbit was "designed to perform the best possible observations of Venus, given the scientific objectives of the mission," including "global observations of the Venusian atmosphere, of the surface characteristics and of the interaction of the planetary environment with the solar wind. It allows detailed high resolution observations near pericentre and the North Pole," enabling scientists to "study the very little explored region around the South Pole for long durations at a medium scale."[61]

9 May

In Bangalore, India, NASA Administrator Michael D. Griffin and G. Madhavan Nair, Chair of the Indian Space Research Organisation (ISRO), signed two Memoranda of Understanding (MOUs), agreeing to cooperate on India's first uncrewed lunar mission—Chandrayaan 1—

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[59] HubbleSite, "Hubble Snaps Baby Pictures of Jupiter's 'Red Spot Jr.'" news release STScl-2006-19, 4 May 2006, *http://hubblesite.org/newscenter/archive/releases/2006/2006/19* (accessed 26 March 2010); John Johnson Jr., "Astronomers See Spot's Runt, Clue of Jupiter Climate Change," *Los Angeles Times*, 5 May 2006; *Space Daily*, "Hubble Takes Sharpest Shot Yet of New Red Spot on Jupiter," 5 May 2006.

[60] Maggie McKee, "Lunar Lander Is NASA's Biggest Challenge," *New Scientist*, 5 May 2006; X Prize Foundation, "X Prize Foundation and NASA Offer $2.5 Million Lunar Lander Challenge Competition To Take Place at '06 X Prize Cup in Las Cruces," 4 May 2006, *http://www.xprize.org/llc/press-release/x-prize-foundation-and-nasa-offer-2-5-million-lunar-challenge-competition-t* (accessed 23 March 2010).

[61] ESA, "Venus Express Has Reached Final Orbit," 9 May 2006, *http://www.esa.int/esaMIVenus_Express/SEM3308ATME_0.html* (accessed 2 April 2010).

scheduled to launch in late 2007 or early 2008. The mission would fly two NASA scientific instruments—the Moon Mineralogy Mapper, to track the mineral and chemical composition of the Moon, and the mini synthetic-aperture radar (Mini-SAR) to map ice deposits in the Moon's polar regions. Chandrayaan 1 would also carry three scientific instruments from European research centers. At the signing ceremony, Griffin said that he hoped that "as we extend the reach of human civilization throughout our solar system, the United States and India will be partners on many more technically challenging and scientifically rewarding projects."[62]

15 May

NASA's DART (Demonstration of Autonomous Rendezvous Technology) Mishap Investigation Board (MIB), chaired by NASA engineer Scott D. Croomes, released a summary of its findings and recommendations regarding the DART spacecraft's failure to complete its critical technology mission objectives. The MIB did not make the complete text of the official report public because it contained information protected by U.S. International Traffic in Arms Regulations and Export Administration Regulations. NASA had designed DART, successfully launching it on April 2005, to rendezvous with MUBLCOM (Multiple Paths, Beyond-Line-of-Sight Communications) and to perform maneuvers in proximity to that satellite. However, less than 11 hours into the mission, DART had collided with MUBLCOM. The MIB concluded that an error in the spacecraft's global-positioning receiver had prevented DART from accurately determining its distance and speed in relation to MUBLCOM. Because of the incorrect on-board navigational data regarding its velocity, DART had failed to take effective action to avoid a collision and had responded with repeated excessive thruster firings. Shortly after the collision, the craft had determined that its pressurized nitrogen gas maneuvering fuel was low, and had initiated preprogrammed departure and retirement maneuvers. The MIB also found that "a lack of training and experience led the [DART] design team to reject expert advice because of the perceived risks involved in implementing the recommendations." This error had "led to inadequate navigation system design and testing." The MIB reported that the DART team could have addressed many of DART's shortcomings if the team had reviewed and applied the documented data and experience of previous missions.[63]

18 May

A team of European astronomers, led by Christophe Lovis of the Observatoire de Genève in Switzerland, reported in *Nature* their discovery of a new system of three extrasolar planets in the constellation Puppis. The discovery of the three planets orbiting the Sun-like star HD 69830, which is approximately 41 light-years from Earth, marked the first time that astronomers had identified a system composed of several planets, each planet possessing a mass approximating that of Neptune. Theoretical calculations of the complexion of the three planets had indicated

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[62] NASA, "NASA Agrees To Cooperate with India on Lunar Mission," news release 06-219, 9 May 2006, *http://www.nasa.gov/home/hqnews/2006/may/HQ_06219_griffin_india.html* (accessed 1 October 2009); Gavin Rabinowitz for Associated Press, "Indian Mission To Carry NASA Devices," 10 May 2006; Paul Watson, "U.S. To Piggyback on India's Mission To Orbit the Moon," *Los Angeles Times*, 10 May 2006.

[63] NASA, "NASA Releases Accident Report Summary," media advisory M06-081, 15 May 2006, *http://www.nasa.gov//home/hqnews/2006/may/HQ_M06081_dart_report.html* (accessed 1 October 2009); NASA, "Overview of the DART Mishap Investigation Results," *http://www.nasa.gov/pdf/148072main_DART_mishap_overview.pdf* (accessed 1 October 2009); Tariq Malik, "NASA Releases Summary of DART Mission Mishap," *Space.com*, 16 May 2006, *http://www.space.com/news/060515_dart_mishap_summary.html* (accessed 24 June 2010; *Space Daily*, "Lots of Little Errors Caused DART Spacecraft Mishap," 17 May 2006.

that the two closest to HD 69830 have a rocky composition similar to the planet Mercury. The astronomers reported that the outermost planet likely has a significant gaseous envelope, surrounding a core composed of rock or ice or a combination of the two, and that the temperatures of the planet are moderate enough to allow the existence of liquid water. The team had discovered the planets using the European Southern Observatory's 3.6-meter (11.8-foot) telescope at the La Silla Observatory in Chile. The telescope was equipped with a precise spectrograph to detect small wobbles induced by the Puppis planets in the HD 69830 star. The technique of detecting and studying these wobbles enabled astronomers to measure the gravitational influence of a planet on its parent star and, thereby, to infer the planet's presence.[64]

24 May

After months of delays due to various technical difficulties, the Geostationary Operational Environmental Satellite–N (GOES-N) launched successfully aboard a Boeing Delta-4 rocket from Cape Canaveral, Florida, at 6:11 p.m. (EDT). GOES-N, which would be renamed GOES-13 after completing its destination orbit, was the latest in a series of Earth-monitoring satellites that provided the kind of continuous monitoring necessary for intensive data analysis. GOES satellites circled the Earth in a geosynchronous orbit—they orbited the equatorial plane of the Earth at a speed equal to the Earth's rotation—allowing GOES satellites to hover continuously over one position on the Earth's surface and to appear stationary. GOES satellites remained constantly vigilant for atmospheric triggers of severe weather conditions, such as tornadoes, flash floods, hailstorms, and hurricanes. GOES-N would carry enhanced imaging and sounding instruments, enabling meteorologists to pinpoint the location of severe weather within 1.5 kilometers (0.9 miles), as well as a solar imager designed to detect and precisely to locate solar flares and coronal mass ejections (CMEs) soon after their occurrence. After reaching its geosynchronous orbit of 22,300 miles (35,888 kilometers), GOES-N would enter on-orbit storage mode, so that it could rapidly replace any existing GOES satellite, in case of failure.[65]

27 May

An Ariane 5-ECA rocket launched from the space center in Kourou, French Guiana, at 21:09 (GMT), placing two telecommunications satellites into geostationary transfer orbit at 36,000 kilometers (22,400 miles) above Earth's equator. The two satellites, Mexico's Satmex 6 and Thailand's Thaicom 5, had a combined mass of 8.2 tonnes (8,200 kilograms or 9.04 tons), the largest payload ever carried by a European rocket. Satmex 6 would provide telecommunications and television services to North America and South America, and Thaicom 5 would provide those services throughout the Asia-Pacific region.[66]

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[64] Christophe Lovis et al., "An Extrasolar Planetary System with Three Neptune-Mass Planets," *Nature* 441, no. 7091 (18 May 2006): 305–309; Dennis Overbye, "Planet Group Similar to Solar System Is Found," *New York Times*, 18 May 2006; Ker Than, "Planets Found in Potentially Habitable Setup," *Space.com*, 17 May 2006, *http://www.space.com/scienceastronomy/060517_neptune_planets.html* (accessed 24 June 2010).

[65] Stephen Clark, "Weather Observatory for Americas Ascends to Space," *Spaceflight Now*, 25 May 2006; Von Puttkamer, "Space Flight 2006"; *Spacewarn Bulletin*, no. 631.

[66] *Space Daily*, "Ariane 5 Rocket Launches Two Satellites into Orbit," 30 May 2006; ESA, "Ariane 5 ECA Carries Record Payload Mass to GTO," news release, 28 May 2006, *http://www.esa.int/easCP/SEMXIO9ATME_index_).html* (accessed 26 March 2010); *Spacewarn Bulletin*, no. 631.

JUNE 2006

2 June

NASA's KSC selected Lockheed Martin Commercial Launch Services to build the Atlas V rocket that would launch the Mars Science Laboratory (MSL) mission. The mission, scheduled for launch in fall 2009 from Cape Canaveral, Florida, would carry to Mars a six-wheeled rover, equipped with cameras mounted on a mast. Twice as long and three times as heavy as the Mars Exploration rovers Spirit and Opportunity, MSL would explore Mars for two years, collecting Martian soil samples and rock cores and analyzing them for organic compounds and for environmental conditions capable of supporting microbial life, now or in the past. Mars Reconnaissance Orbiter (MRO), which had entered Mars's orbit in March 2006, had transmitted to Earth images that NASA scientists would use to select a landing site for MSL. MRO would serve as a communications relay for MSL after the rover landed on the Martian surface.[67]

During a spacewalk of 6 hours and 31 minutes, which lasted longer than scheduled, ISS crew members Pavel V. Vinogradov and Jeffrey N. Williams performed several tasks to repair, retrieve, and replace hardware on the U.S. and Russian segments of the space complex. Vinogradov replaced the clogged nozzle of a valve that helped vent hydrogen into space from the Elektron oxygen-generator in the Zvezda service module. Vinogradov and Williams replaced a faulty video camera on the ISS's Mobile Base System, which rests upon a rail car that moves up and down the station's truss, to position the robotic arm for assembly work. The two crew members also photographed navigation antennas on the aft side of the service module that the European Automated Transfer Vehicle (ATV) would use in the future for unpiloted docking.[68]

5 June

NASA awarded Pratt & Whitney Rocketdyne a contract in the amount of US$50 million to initiate conceptual design, development, testing, and evaluation of the J-2X engine. The engine would power the Crew Launch Vehicle (CLV) upper stage and the Earth-departure stage of the Cargo Launch Vehicle (CaLV). The contract, which would run through 30 November 2006, would support two scheduled reviews of associated vehicles—a Systems Requirements Review in September 2006, and a Systems Design Review in October 2006.[69]

The National Academies' National Research Council (NRC) Steering Committee for the Decadal Survey of Civil Aeronautics issued a report recommending a long-term strategy for the federal government's involvement in civil aeronautics, with particular emphasis on NASA's future research priorities. NASA had sponsored the report. According to the committee, the next 10

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[67] Chris Bergin, "Another Mars Rover—Atlas V Chosen," *NASASpaceflight.com*, 2 June 2006, *http://www.nasaspaceflight.com/2006/06/another-mars-rover-atlas-v-chosen* (accessed 9 August 2010); Lockheed Martin, "Lockheed Martin's Atlas V Selected To Launch Mars Science Laboratory in 2009," news release, 6 June 2006, *http://www.lockheedmartin.com/news/press_releases/2006/LOCKHEEDMARTINSATLASVSELECTEDLAUNCH.html* (accessed 9 August 2010).

[68] Tariq Malik, "Extended EVA: Astronauts Make ISS Repairs in Long Spacewalk," *Space.com*, 2 June 2006, *http://www.space.com/missionlaunches/060602_exp13_eval.html* (accessed 13 August 2010); NASA, "International Space Station Status Report no. SS06-026," 2 June 2006, *http://www.nasa.gov/home/hqnews/2006/jun/HQ_SSO6026_station_stauts.html* (accessed 15 April 2010).

[69] NASA, "NASA Announces Engine Development Contract," contract release C06-032, 5 June 2006, *http://www.nasa.gov/home/hqnews/2006/jun/HQ_06032_J2X_engine_selection.html* (accessed 22 February 2010).

years of U.S. civil aeronautics research and technology should provide a foundation for achieving six strategic objectives, including improved safety and reliability and increased capacity, efficiency and performance. The report provided a list of 51 high-priority aeronautics research and technology challenges for NASA. To achieve the goals outlined in the report, the committee recommended that NASA cooperate more with public and private organizations, to share facilities and tools for key projects, and with other federal agencies that support aeronautics research, such as the National Oceanic and Atmospheric Administration (NOAA) and the Federal Aviation Administration (FAA).[70]

6 June

NASA's CloudSat meteorological satellite, which had launched on 28 April 2006, began sending early images, indicating that the satellite was observing all types of major cloud systems. CloudSat carried a millimeter wavelength radar called the Cloud-Profiling Radar, a type of radar never used before. Scientists had concluded that the new radar was penetrating through all but the heaviest rainfall. According to CloudSat Deputy Principal Investigator at JPL Deborah Vane, scientists were "no longer looking at clouds like images on a flat piece of paper, but instead [were] peering into clouds and seeing their layered complexity." CloudSat's radar had enabled scientists to observe for the first time clouds and snowstorms over the Antarctic, as well as providing new views of sloping, frontal clouds and thunderstorms over Africa, both as individual storms and as part of larger tropical storm systems.[71]

8 June

The House Committee on Science held a hearing to address the results of the statutorily mandated Nunn-McCurdy review of the National Polar-Orbiting Operational Environmental Satellite System (NPOESS). NOAA, NASA, and the U.S. Department of Defense (DOD) jointly managed NPOESS, which would provide data and imagery to help weather forecasters, climatologists, and the military map and monitor changes in weather, climate, the oceans, and the environment. The Nunn-McCurdy amendment to the Defense Authorization Act of 1983 (10 U.S.C. 2433) provided that Congress must review any DOD-funded program that was more than 25 percent over budget, to determine whether and in what manner it should continue. In January 2006, the Secretary of the Air Force had notified Congress that the NPOESS program would exceed the 25 percent Nunn-McCurdy threshold. The three NPOESS managing agencies had reviewed the program and determined that it should continue. However, NPOESS must reduce the number of its satellites from six to four and eliminate five sensors, including three for climate research. The agencies would postpone the first NPOESS satellite launch until 2013 and discontinue work on the key weather sensor known as Conically Scanning Microwave Image/Sounder (CMIS). The United States would temporarily rely on Europe for the data that CMIS would have collected, including ocean wind speeds. NASA Administrator Michael D. Griffin testified regarding NASA's compliance with the mandates of the Nunn-McCurdy recertified NPOESS program, emphasizing that NASA would continue to provide cost-effective

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[70] National Academies Office of News and Public Information, "U.S. Should Strengthen Foundation for Future of Air Transportation," press release, 5 June 2006, *http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=11664* (accessed 15 September 2010); see also National Research Council, *Decadal Survey of Civil Aeronautics: Foundation for the Future* (Washington, DC: National Academies Press, 2006), *http://www.nap.edu/catalog/11664* (accessed 16 September 2010).

[71] NASA, "First Images from NASA's CloudSat Have Scientists Sky High," news release 06-234, 6 June 2006, *http://www.nasa.gov/home/hqnews/2006/jun/HQ_06234_CloudSat_First_Light.html* (accessed 22 February 2010).

technologies for two key components of this program—the NPOESS Preparatory Project (NPP) and the continuity of long-term climate measurements.[72]

A team of international astronomers, led by Aki Roberge of NASA's GSFC, reported in *Nature* that, using NASA's Far Ultraviolet Spectroscopic Explorer (FUSE) telescope, they had discovered that the disc surrounding the Beta Pictoris star, initially discovered in 1984, is extremely rich in carbon. Beta Pictoris is approximately 60 light-years away from Earth and relatively young—8 to 20 million years old. The HST's earlier observations had indicated that a Jupiter-like planet might have already formed in the star's disc and that rocky terrestrial planets might be forming. Roberge's team reported that the disc contained nine times as much carbon as oxygen, which is twice the ratio found in the Sun or in Beta Pictoris itself. The scientists proposed one possible explanation for the high carbon content: that the disc is in a transient, carbon-rich phase. In its earliest period of development, Earth's solar system could have gone through a phase similar to that of the disc surrounding Beta Pictoris. Alternatively, if researchers were to discover in the future that the asteroids and comets orbiting Beta Pictoris contained large amounts of carbon-rich material, such as graphite and methane, such a finding could indicate the formation of carbon planets very different from Earth.[73]

13 June

The House Science Subcommittee on Space and Aeronautics held a hearing to assess whether NASA's current workforce strategy was developing the tools needed to meet NASA's future needs. Subcommittee Ranking Member Mark Udall (D-CO) expressed concern that the proposed budget reductions to its aeronautics, microgravity life and physical sciences, and space and Earth sciences programs would further complicate NASA's efforts to create a workforce with an appropriate balance of civil servants and private contractors. NASA's Assistant Administrator for Human Capital Management Toni Dawsey testified that the overall objective of NASA's workforce strategy, submitted to Congress in April 2006, was "to transform the composition of NASA's workforce so that it remained viable for the long-term goals of NASA's missions." She stated that NASA was addressing its two most pressing workforce challenges— "uncovered capacity, caused by program changes and cancellations and budget constraints, and retaining Space Shuttle employees through its retirement in 2010." NASA was maintaining sufficient work in house to protect and strengthen its core capabilities and had established a Shuttle Human Capital Working Group to oversee the complex Shuttle workforce issues. David C. Black, co-chair of the NRC committee that NASA had asked to explore "long-range science and technology workforce needs to achieve the Nation's long-term space exploration vision," also testified. In its interim report, the committee planned to recommend that NASA work with other

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[72] U.S. House of Representatives, Committee on Science, *The Future of NPOESS: Results of the Nunn-McCurdy Review of NOAA's Weather Satellite Program*, 109th Cong., 2nd sess., 8 June 2006, 3−6, 22−25, *http://www.gpo.gov/fdsys/search/pagedetails.action?browsePath=109%2FHOUSE%2FCommittee+on+Science&granuleId=CHRG-109hhrg27970&packageId=CHRG-109hhrg27970&fromBrowse=true* (accessed 20 December 2010); NOAA, Center for Satellite Applications and Research (STAR), "STAR Acronyms," *http://www.star.nesdis.noaa.gov/star/acronyms.php* (accessed 5 October 2010).

[73] Maggie McKee, "Star's Dusty Disc Could Create Exotic Worlds," *New Scientist*, 8 June 2006; NASA, "NASA's Fuse Finds Infant Solar System Awash in Carbon," news release 06-236, 7 June 2006, *http://www.nasa.gov/home/hqnews/2006/jun/HQ_06236_FUSE_0607_final.html* (accessed 23 August 2010); see also Aki Roberge et al., "Stabilization of the Disk Around β Pictoris By Extremely Carbon-Rich Gas," *Nature* 441 (8 June 2006): 724−26.

government agencies involved in space-related work, as well as with the private sector, including universities, to "assess the nature, scope, and possible solutions for its skill mix."[74]

NASA's Genesis Mission Mishap Investigation Board, chaired by Michael Ryschkewitsch of NASA's GSFC, released its findings on why the drogue parachute and parafoil systems had failed to deploy properly, to slow the Genesis Sample Return Capsule's re-entry. With nothing to slow its descent, the capsule had crashed into Utah's desert landing zone on 8 September 2004. The fifth in its series of Discovery missions, NASA had launched Genesis on 8 August 2001, to collect samples of solar wind and to return them to Earth. The Board had determined that the proximate cause of the mishap was an erroneous design, namely, the installation of the G-switch (gravity-switch) sensors in an inverted position, rendering them "unable to sense sample return capsule deceleration during atmospheric entry and [to] initiate parachute deployments." The report identified root causes of the accident, as well as major contributing factors. It cited JPL project managers' lack of critical oversight during Lockheed Martin Space Systems' design, review, and testing of the spacecraft. The report also found that NASA's systems engineering processes were inadequate and recommended "adding a thorough review of all project Systems Engineering progress, plans, and processes as part of existing major milestone reviews." Furthermore, the Board criticized NASA's decision to use its "faster, better, cheaper" approach to select and develop the Genesis mission, an approach that NASA had previously applied in other failed missions. The Board found that this approach had impaired JPL's insight into the project's technical progress and increased the element of risk.[75]

14 June

NASA announced the appointment of two new Flight Directors, Ron Spencer and Heather Rarick, who would direct human spaceflights from Mission Control at NASA's JSC. The appointments increased to 28 the number of active Space Shuttle and ISS flight directors, including those in training. From 1990 to 1994, Spencer had worked as a contractor at JSC, during which time he had developed the space station assembly sequence for the Space Station Program Office. In 1994 he had become a NASA civil servant, and, beginning in 1997, he had worked in Mission Control as a Shuttle flight dynamics officer. Rarick had also worked as a contractor for NASA in various capacities until 2001, including working as the operations lead and Russian interface officer in the International Liaison Office of Mission Control. She had become a NASA employee in 2001, continuing her previous assignment, as well as assuming the technical lead for the Russian interface officers. In 2003 NASA had named Rarick chairperson of the Russian Joint Operations Panel, which would address long-term resolution of U.S.-Russian

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[74] U.S. House of Representatives, Committee on Science, Subcommittee on Space and Aeronautics, *The NASA Workforce: Does NASA Have the Right Strategy and Policies To Retain and Build the Workforce It Will Need?* 109th Cong., 2nd sess., 13 June 2006, 14, 17, 81, 84, *http://www.gpo.gov/fdsys/search/pagedetails.action?browsePath=109%2FHOUSE%2FCommittee+on+Science&granuleId=CHRG-109hhrg27971&packageId=CHRG-109hhrg27971&fromBrowse=true* (accessed 21 December 2010); U.S. House of Representatives, Committee on Science, "What Will NASA's Future Workforce Look Like?" news release, 13 June 2006, *http://science.house.gov/press/PRArticle.aspx?NewsID=1140* (accessed 4 February 2010).

[75] Amir Alexander, "Genesis Mishap Investigation Board Releases Final Report," *The Planetary Society*, 13 June 2006, *http://www.planetary.org/news/2006/0613_Genesis_Mishap_Investigation_Board.html* (accessed 22 February 2010) 14 June 2006; NASA, "Genesis Mishap Investigation Board Report," (Washington, DC, June 2006), *http://www.nasa.gov/pdf/149414main_Genesis_MIB.pdf* (accessed 22 February 2010); NASA, "NASA Releases Genesis Accident Report," media advisory M06-097, 13 June 2006, *http://www.nasa.gov/home/hqnews/2006/jun/HQ_M06097_Genesis_update.html* (accessed 22 February 2010).

operational issues. NASA Flight Director Office Chief Phil Engelauf praised Spencer and Rarick as "possessing the leadership skills necessary to ensure NASA accomplishes the near-term exploration goals of completing the space station, safely flying the shuttle through retirement and returning to the moon."[76]

15 June

Russia launched the Resurs DK1 satellite aboard a Soyuz-U rocket at 4:00 a.m. (EDT) from the Baikonur Cosmodrome in Kazakhstan. The civilian Earth-observation satellite would operate for three years, the first in an upgraded series of spacecraft with improved capabilities in imaging resolution and communications. Navigating with a system based on Russia's global navigation system Glonass, Resurs would be capable of surveying up to 700,000 square kilometers daily. Unlike previous Russian civilian remote-sensing craft, Resurs DK1 would carry an advanced communications system enabling it to quickly download recent images of natural resources, natural disasters, sea-ice conditions, and polar weather to Russian ground stations. Russian government agencies would use the images, making them available to national and international organizations, as well as private commercial customers. The satellites would have two attached instruments—Italy's Payload for Anti-Matter Exploration and Light-Nuclei Astrophysics (PAMELA), which would monitor cosmic rays, and a Russian particle detector, which would identify probable electromagnetic precursors of earthquakes.[77]

19 June

NASA announced the crew for the Space Shuttle *Discovery* STS-120 mission, scheduled to launch an Italian-built U.S. module for the ISS in summer 2007. The Node 2 module would interconnect the research, habitation, control, and docking modules of the ISS. American astronaut Pamela A. Melroy, the second woman to command a Shuttle, would command the mission, and American astronaut George D. Zamka would serve as Pilot. Melroy had served as Pilot of Space Shuttle *Discovery* STS-92 in 2000 and as Pilot of Space Shuttle *Atlantis* STS-112 in 2002. Other crew members would be American astronauts Scott E. Parazynski, Douglas H. Wheelock, and Michael J. Foreman, and Italian astronaut Paolo A. Nespoli of ESA. NASA and the Italian space agency, Agenzia Spaziale Italiana (ASI), had arranged Nespoli's mission within the framework of a MOU. According to the terms of the MOU, Italy would supply three pressurized Multi-Purpose Logistic Modules (MPLM) to the United States, which would assign to Italy flight opportunities and the use of the ISS.[78]

22 June

An independent scientific panel, convened by the National Academy of Sciences' (NAS's) NRC, issued a report evaluating the results of a controversial 1999 study conducted by climatologist

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[76] NASA, Johnson Space Center, "Two New Flight Directors Chosen To Lead NASA's Mission Control," news release J06-069, 14 June 2006, *http://www.nasa.gov/centers/johnson/news/releases/2006/J06-069.html* (accessed 11 August 2010).

[77] NASA, *Spacewarn Bulletin* no. 632, July 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/spx632.html* (accessed 6 August 2010); Stephen Clark, "Civil Remote Sensing Craft Launched by Russia," *Spaceflight Now*, 16 June 2006; RIA Novosti, "Survey Satellite Launched from Baikonur," 16 June 2006.

[78] ESA, "ESA Astronaut Paolo Nespoli Assigned To Crew for Shuttle Flight STS-120," news release 19-2006, 19 June 2006, *http://www.esa.int/esaCP/Pr_19_2006_p_EN.html* (accessed 8 June 2010); NASA, "NASA Assigns Crew for Shuttle Mission," news release 06-242, 19 June 2006, *http://www.nasa.gov/home/hqnews/2006/jun/HQ_06242_crew_shuttle.html* (accessed 8 June 2010).

Michael E. Mann. Mann and his researchers had concluded that the warming of the Northern Hemisphere during the last decades of the twentieth century had no precedent within the past 1,000 years, and that the 1990s—particularly 1998—were the warmest years during that period. The study included a graph that had acquired the nickname "hockey stick," becoming an environmentalist icon. The graph depicted little temperature variation in the Northern Hemisphere for almost 1,000 years, followed by a sharp upward hook representing recent rising temperatures. NAS had prepared the report, *Surface Temperature Reconstructions for the Last 2,000 Years*, at the request of House Science Committee Chairman Sherwood L. Boehlert (R-NY). The panel had found "sufficient evidence from tree rings, retreating glaciers, and other 'proxies' of past surface temperatures to say with a high level of confidence that the last few decades of the twentieth century were warmer than any comparable period in the last 400 years." Although this conclusion vindicated the main argument of Mann's study for the most part, the panel cautioned that scientists had found less empirical evidence proving that Northern Hemisphere warming had no precedent before 1600. The panel also stated that "because of larger uncertainties in temperature reconstructions for decades and individual years, and because not all proxies record temperatures for such short timescales," they had less confidence in the team's conclusions about the 1990s.[79]

23 June
The International Astronomical Union (IAU) announced the official naming of Pluto's newest small moons—Nix and Hydra, names from Greek mythology. The HST had discovered Nix and Hydra, previously known as S/2005 P1 and S/2005 P2, in May 2005. The two moons are approximately 5,000 times fainter than Pluto and approximately two to three times farther from Pluto than its larger moon Charon, discovered in 1978. The first initials of the two moons—N and H—are the same as the initials of the NASA spacecraft New Horizons, which launched in January 2006 toward the Pluto system. Scientists expected that New Horizons would map Nix and Hydra in detail when the spacecraft flew by Pluto in summer 2015.[80]

30 June
NASA's three orbiting ST 5-mission microsatellites, launched on 22 March 2006, concluded operations. The mission had demonstrated the benefits of using a constellation of spacecraft to perform scientific studies of the auroral displays that occur near Earth's polar regions. Using miniature magnetometers, the spacecraft had simultaneously traversed electric current sheets and measured the magnetic field. According to Guan Le, ST5 Mission Project Scientist at Goddard, "taking measurements at the same time in different locations allowed scientists to better estimate the thickness of current sheets and how they vary over time." Previously, no single spacecraft had been capable of doing this. Project scientists would analyze the mission's magnetometer data

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[79]Juliet Eilperin, "Study Confirms Past Few Decades Warmest on Record," *Washington Post*, 23 June 2006; National Academies Office of News and Public Information, " 'High Confidence' That Planet Is Warmest in 400 Years; Less Confidence in Temperature Reconstructions Prior to 1600," press release, 22 June 2006, *http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=11676* (accessed 9 August 2010); Andrew C. Revkin, "Panel Supports a Controversial Report on Global Warming," *New York Times*, 23 June 2006; see also National Research Council Committee, *Surface Temperature Reconstructions for the Last 2,000 Years* (Washington, DC: National Academies Press, 2006), *http://www.nap.edu/catalog/11676.html* (accessed 1 October 2010).
[80] Kenneth Chang, "Moons of Pluto Renamed," *New York Times*, 23 June 2006; NASA, "Pluto and Its Moons: Charon, Nix and Hydra," 23 June 2006, *http://www.nasa.gov/mission_pages/hubble/plutos_moons_prt.htm* (accessed 23 August 2010).

over the next few months to assess the satellites' performance. The mission also demonstrated an innovative communications technology that used miniature spacecraft-radio transponders, coupled with antennas, for space-to-ground communications and tracking.[81]

JULY 2006

3 July

One of the largest asteroids ever to have flown by Earth passed the planet harmlessly at a distance of nearly 269,000 miles (433,000 kilometers), which is close for a cosmic object. In 2004 scientists had discovered the asteroid designated 2004 XP14, but they had calculated that it was unlikely to pose any danger to Earth. However, its close pass by Earth had received substantial press coverage, because the asteroid was large enough to destroy a geographic area roughly equivalent to a region of the United States. Astronomers estimated that the asteroid's width is in the range of 0.25 to 0.5 miles (0.4 to 0.8 kilometers). Scientists believed that an asteroid with a width of 1 mile (1.6 kilometers) could potentially threaten the existence of life on earth.[82]

4 July

NASA launched the Space Shuttle *Discovery* (STS-121) from NASA's KSC at 2:37 p.m. (EDT). The mission was NASA's second Return to Flight mission since the 2003 *Columbia* tragedy. *Discovery*'s crew planned to continue testing safety equipment and procedures that NASA had introduced on the first Return to Flight Mission (STS-114), which *Discovery* had flown in 2005. Other objectives of the mission included delivery of equipment, experiments, and supplies to the ISS and the transport to the ISS of a third crew member, ESA astronaut Thomas A. Reiter. STS-121 crew members included Commander Steven W. Lindsey, Pilot Mark E. Kelly, and Mission Specialists Michael E. Fossum, Lisa M. Nowak, Piers J. Sellers, and Stephanie D. Wilson.[83]

8 July

Discovery crew members Michael E. Fossum and Piers J. Sellers performed the first of two scheduled extravehicular activities—spacewalks—for Mission STS-121. During the 7.5-hour spacewalk, the two astronauts performed several tasks to ensure the continued operation of a data, power, and video cable on the station's exterior. In addition, the two men tested *Discovery*'s robotic arm and Orbiter Boom Sensor System, components that astronauts could use to repair a damaged orbiter if necessary.[84]

10 July

ISRO's launch of a Geosynchronous Satellite Launch Vehicle (GSLV) failed when the GSLV malfunctioned, taking with it an INSAT-4C communications satellite. ISRO had created the

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[81] NASA, "NASA's Micro-Satellites Complete Technology Validation Mission," news release 06-254, 29 June 2006, *http://www.nasa.gov/home/hqnews/2006/jun/HQ_06254_microsatellites.html* (accessed 22 February 2010).
[82] Associated Press, "Large Asteroid Zips Harmlessly Past Earth," 3 July 2006; *Times* (London), "Cosmic Near-Miss," 28 June 2006.
[83] NASA, "NASA's Shuttle Discovery Launch Provides Spectacular Fireworks," news release 45-06, 4 July 2006, *http://www.nasa.gov/centers/kennedy/news/releases/2006/release-20060704.html* (accessed 15 March 2010); NASA, "STS-121," *http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/archives/sts-121.html* (accessed 25 January 2010).
[84] NASA, "STS-121."

GSLV series of rockets to put heavy satellites weighing 2.0–2.5 tonnes (2,000–2,500 kilograms or 2.2–2.8 tons) into geosynchronous orbit. The Indian National Satellite system, INSAT, is a series of domestic communications satellites. ISRO launched the rocket (formally designated GSLV-F02) from the Satish Dhawan Space Center in Sriharikota, an island off the coast of the southern state of Andhra Pradesh in India. Soon after liftoff, the GSLV's first stage failed to separate, causing the rocket to veer from its trajectory, falling into the Bay of Bengal. The unsuccessful launch, ISRO's fourth launch of a GSLV, was the first GSLV launch ever to fail.[85]

Michael E. Fossum and Piers J. Sellers performed a second spacewalk for Mission STS-121. In the course of the spacewalk, which lasted almost 7 hours, the two astronauts restored the ISS's mobile rail transporter car to full operational status and replaced a damaged component of the station's electrical power system. That component, called the trailing umbilical system, had sustained damage during earlier operations.[86]

12 July

Astronauts Michael E. Fossum and Piers J. Sellers performed their third and final spacewalk for Mission STS-121. The mission's management team had delayed the return flight to Earth by one day to conduct the spacewalk, so that the crew could test repair techniques and a thermal imaging camera. During the spacewalk, Fossum and Sellers tested a technique in which they made repairs to *Discovery*'s damaged thermal protection panels, using an experimental sealant called nonoxide adhesive experimental (NOAX). NOAX was a preceramic polymer sealant containing carbon-silicon carbide powder. In addition, Fossum and Sellers installed a grapple bar on an ammonia tank inside the ISS's S1 truss, so that the crew could move the tank later.[87]

A privately funded experimental spacecraft called Genesis I launched from Russia's Ural Mountains at 12:53 (UT). The launch was the first for Bigelow Aerospace, a United States–based company founded by American Robert T. Bigelow. The company had designed Genesis I as an inflatable spacecraft. Bigelow Aerospace planned to launch similar spacecraft and to connect them to Genesis I to form an expandable space station. The company reportedly planned to use the completed structure as a hotel, scientific laboratory, or sports arena, providing services for a commercial spaceflight business.[88]

14 July

Discovery crew members used the orbiter's robotic arm to check *Discovery*'s wing for damages. This marked the first time that astronauts had used an orbiter's robotic arm to conduct such an inspection. NASA believed that *Discovery* might have sustained damage during its docking at

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[85] Indian Space Research Organization (ISRO), "Chandrayaan-1's Orbit Closer to Moon," press release, 10 July 2006, *http://www.isro.org/ pressrelease/scripts/pressreleasein.aspx?Jul10_2006* (accessed 14 September 2010); ISRO, "GSLV," *http://www.isro.org/Launchvehicles/GSLV/gslv.aspx#* (accessed 14 September 2010); Von Puttkamer, "Space Flight 2006."

[86] NASA, "STS-121."

[87] NASA, "STS-121"; NASA Mission Control Center, "STS-121 Mission Control Center Status Report #17," NASA status report STS-121-17, 12 July 2006, *http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts121/news/ STS-121-17.html* (accessed 28 June 2010).

[88] Alicia Chang, "Private Spacecraft Takes Off," *Houston Chronicle*, 13 July 2006.

the ISS and wanted to assess the orbiter before its scheduled return to Earth the following day. The inspection revealed no obvious damage to protective material on the spacecraft's exterior.[89]

17 July

NASA's *Discovery* returned to Earth, landing at NASA's KSC at 9:14 a.m. (EDT) to complete the 13-day Mission STS-121. During STS-121, the crew had tested the use of *Discovery*'s robotic arm boom extension as a work platform, performed repairs to the exterior of the ISS, delivered 14 tons (12.7 tonnes or 12,700 kilograms) of equipment and supplies to the orbiting space station, and transported ESA astronaut Thomas A. Reiter to the ISS. Reiter joined Russian Pavel V. Vinogradov and American Jeffrey N. Williams as an ISS crew member, marking the first time since May 2003 that the ISS had three crew members. *Discovery* crew had also tested improved safety procedures and equipment for the Shuttle. Furthermore, the flight had verified the safety of a significant aerodynamic modification to the Shuttle's external fuel tank. More specifically, NASA had removed protuberance air load ramps from the external fuel tank, because a piece of foam had jettisoned from that area of the tank during *Discovery*'s launch for the Return to Flight Mission (STS-114) in 2005.[90]

GAO released a report criticizing NASA's plans to acquire rockets and spacecraft for the Vision for Space Exploration program and recommending that the U. S. Congress restrict some of its funding until NASA had completed its review of the program. NASA expected to finish the review during the following year. The report addressed NASA's plans to sign long-term agreements with the contractors for the project in late 2006. NASA planned for the contractors to design, develop, and produce both the CEV—the the crew exploration vehicle, which would replace the Space Shuttle—and the rocket that would launch it. The report stated that NASA had not completed the first phase of its ongoing design and cost estimates for these projects, and that signing the contracts would place the projects at risk for cost, performance, and schedule problems. GAO recommended postponing the contracts until after NASA had completed its preliminary design reviews for those projects. NASA expected to complete the final phase of the ongoing review by March 2008. The report specifically recommended that Congress restrict NASA's appropriations and obligations for the CEV, providing only the funds needed to complete the preliminary review.[91]

18 July

The National Research Council (NRC) released a study of civil aeronautics research and technology priorities that NASA and other government agencies should pursue in the coming decade. The U.S. Congress and NASA had requested the NRC to produce a report identifying aeronautics technologies that would support and improve the U.S. air transportation system. In its report, the NRC stated that NASA and other agencies should pursue aeronautics research and technology that advances the U.S. air system's capacity, safety, reliability, efficiency, and performance, and reduces the system's energy consumption and environmental impact. The

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[89] Warren E. Leary, "Shuttle and Station Wrap Up Joint Tasks," *New York Times*, 15 July 2006.

[90] NASA, "NASA Welcomes Space Shuttle Crew Back to Earth," news release 06-280, 17 July 2006, *http://www.nasa.gov/home/hqnews/2006/sep/HQ_06321_Atlantis_lands.html* (accessed 15 March 2010).

[91] Mark Carreau, "GAO Warns NASA of Problems with Moon, Mars Strategy," *Houston Chronicle*, 27 July 2006; U.S. Government Accountability Office, "NASA: Long-Term Commitment To and Investment in Space Exploration Program Requires More Knowledge" (report no. GAO-06-817R, Washington, DC, 17 July 2006): 1−9, *http://www.gao.gov/new.items/d06817r.pdf* (accessed 22 January 2010).

report also suggested that civil aeronautics R&T should support the U.S. space program and take advantage of synergies with defense. In addition, the NRC outlined five areas of high-priority aeronautics R&T, areas that researchers at NASA and other U.S. agencies should pursue to attain the identified strategic objectives. Those areas included 1) aerodynamics and aeroacoustics; 2) propulsion and power; 3) materials and structures; 4) dynamics, navigation and control, and avionics; and 5) intelligent and autonomous systems, operations and decision making, human integrated systems, and networking and communications.[92]

21 July
The American company Space Adventures Limited announced that, in conjunction with the Russian space agency Roskosmos, it would offer spacewalks outside of the ISS for US$35 million. The fee included US$20 million for a space tourist to take a 10-day round-trip to the ISS on a *Soyuz* spacecraft and US$15 million for the traveler to make a spacewalk wearing a Russian spacesuit. Space Adventures Limited had previously sent three customers to the ISS, including Dennis A. Tito, who had become the first space tourist in 2001. The announcement was controversial because the approval of all 15 international partners in the ISS is required for plans of this type. A NASA spokesperson stated that Roskosmos had not yet informed NASA of its intent to sell spacewalks at the ISS.[93]

27 July
Scientists announced that images from the Cassini spacecraft had revealed the presence of lakes on Saturn's moon Titan, the first time that astronomers had located lakes anywhere other than Earth. Cassini, a joint mission of NASA and ESA, had captured the images during a 22 July flyby of a region of Titan called Xanadu. The pictures indicated that Titan might have topographic features similar to those found on Earth, such as hills, valleys, and rivers emptying into lakes. NASA scientists theorized that, because temperatures on Titan are approximately -180ºC (-292ºF), the liquid in the lakes is likely either methane or a combination of ethane and methane. Scientists speculated that the lakes could be the source of the hydrocarbon smog found in Titan's frigid and thick atmosphere. NASA and ESA had created Cassini to explore Saturn and its system of moons, and Titan's atmosphere was one of the mission's major research topics.[94]

AUGUST 2006

3 August
During a 6-hour spacewalk, ISS crew members Jeffrey N. Williams and Thomas A. Reiter completed both scheduled tasks and additional assignments. The scheduled tasks included installation of a device to minimize hazards associated with electrical currents and replacement of a computer on the ISS's S1 truss. In addition, the astronauts installed new samples of materials for the Materials on International Space Station Experiment (MISSE), an ongoing

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[92] National Research Council, *Decadal Survey of Civil Aeronautics: Foundation for the Future* (Washington, DC: National Academies Press, 2006).
[93] John Schwartz, "Walk in Space for $15 Million (Plus Airfare)," *New York Times*, 21 July 2006.
[94] Caitlin A. Griffith, "Planetary Science: Titan's Exotic Weather," *Nature* (London) 362, no. 1 (27 July 2006): 362–363, *http://www.nature.com/nature/journal/v442/n7101/full/442362a.html* (DOI 10.1038/442362a; accessed 15 March 2010); NASA, "Cassini Finds Lakes on Titan's Arctic Region," news release 06-274, 28 July 2006, *http://www.nasa.gov/home/hqnews/2006/jul/HQ_06274_cassini_lakes_itan_prt.htm* (accessed 15 March 2010).

experiment studying how prolonged exposure to an outer space environment affects various materials. The additional tasks included the removal of a malfunctioning GPS antenna and the installation of a vacuum-system valve on the station's Destiny laboratory, among other projects.[95]

7 August
NASA and the U.S. Air Force signed an agreement to create an aeronautics research partnership. According to the MOU, which NASA Administrator Michael D. Griffin and Secretary of the U.S. Air Force Michael W. Wynne signed, the two organizations would freely exchange research information, strive to reduce the duplication of research, and enhance their long-term research planning. The agreement covered several areas of aeronautics research, including advanced aircraft design, aviation safety, materials development, and propulsion management.[96]

9 August
James A. Van Allen, a major figure in physics and space exploration, died at the age of 91. Born in 1914, Van Allen had played a prominent role in early American rocket research, including the development of the radiation detectors contained in the United States' first successful satellite, Explorer 1. Launched January 1958, Explorer 1 had captured data revealing two belts of charged particles above Earth's magnetic field—phenomena later known as the Van Allen radiation belts. The finding was among the first major scientific discoveries of the early space age. In 1958 Van Allen had chaired a group of scientists who recommended that the United States create an independent national space agency by 1960 and launch a human mission to the Moon by 1968. Van Allen later became involved in several NASA projects, including the development of Galileo, Pioneers 10 and 11, and several Mariner spacecraft. During his lifetime, Van Allen had received numerous awards, including the National Medal of Science and NASA's Medal of Exceptional Achievement.[97]

10 August
NASA's Dryden Flight Research Center (DFRC) and the private company Gulfstream Aerospace conducted the first test of the Quiet Spike, a 24-foot-long (7.3-meter) retractable, lance-like rod, affixed to the nose of NASA's F-15B research aircraft and designed to suppress sonic booms during supersonic-jet flights. The term "sonic boom" refers to an accumulation of shock waves that develop around aircraft as they near the speed of sound (760 miles per hour or 1,223 kilometers per hour at sea level). Like an explosion, the sound energy generated by sonic booms can damage windows on the ground below a supersonic jet's path. The FAA prohibits supersonic-jet flight over land, except in designated military flight corridors. DFRC and Gulfstream had designed the Quiet Spike, which created three small shock waves, traveling

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[95] NASA, "International Space Station Status Report: SS06–036," status report SS06-036, 3 August 2006, *http://www.nasa.gov/home/hqnews/2006/aug/HQ_SS06036_ISS_status_report.html* (accessed 15 March 2010).
[96] NASA, "NASA, Air Force Agree To Aeronautics Cooperation," news release 06-289, 7 August 2006, *http://www.nasa.gov/home/hqnews/2006/aug/HQ_06289_air_force.html* (accessed 15 March 2010).
[97] Walter Sullivan, "James A. Van Allen, Discoverer of Earth-Circling Radiation Belts, Is Dead at 91," *New York Times*, 10 August 2006; NASA, "James A. Van Allen (1914–2006)," *http://history.nasa.gov/sputnik/vanallen.html* (accessed 5 March 2010).

parallel to one another to the ground, thereby reducing the noise produced when supersonic jets break the sound barrier.[98]

14 August

NASA announced that it had misplaced the original recordings of the first Moon landing, along with other tapes containing data from that same mission. NASA had initially transferred the tapes to the U.S. National Archives, later storing them at NASA's GSFC. NASA officials noted that NASA still had copies of all of the data on the tapes, including the footage of Neil A. Armstrong's historic first steps on the Moon. However, they also noted that the images on the copies were of lower quality than those on the original magnetic tapes, because NASA equipment had been incompatible with television technology when the first human mission to the Moon took place. NASA had displayed the original transmissions of the Moon landing on a monitor and pointing a television camera at the monitor to broadcast the images on television. NASA was continuing to look for the tapes.[99]

15 August

NASA's Voyager 1 achieved a milestone during its passage out of the solar system when it reached a distance of 100 Astronomical Units (AUs)—nearly 9.3 billion miles (15 billion kilometers) from the Sun. An AU is the average distance between Earth and the Sun, measuring approximately 93 million miles (150 million kilometers). Voyager 1 was already the most distant human-made object from Earth when it reached 100 AUs from the Sun. NASA had launched Voyager 1 and its twin spacecraft Voyager 2 in 1977 to explore Jupiter and Saturn and had continued to extend the operations of the two spacecraft. In the Voyagers' current mission—the Voyager Interstellar Mission (VIM)—the spacecraft would explore the environment of the outer solar system and, eventually, that of interstellar space.[100]

18 August

NASA awarded contracts to two companies to develop commercial orbital transportation services for the ISS, creating the possibility of a commercial space transportation industry. The agreements also marked the first time that NASA had hired contractors to build a space transportation system for private-sector use, rather than for government use. Under the agreements, NASA would invest up to US$287 million in Rocketplane Kistler and US$207 million in Space Exploration Technologies Corporation, also known as SpaceX, enabling the two companies to develop a spacecraft that could provide crew and cargo services for the ISS. NASA's provision of the funds would be contingent on the companies' completion of designated milestones—including launching and docking a spacecraft with the ISS. According to a NASA official, NASA hoped that private companies would be able to turn low-Earth-orbit services—

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[98] NASA, Dryden Flight Research Center, "Gulfstream, NASA Dryden Joust with Supersonic Shockwaves," news release 06-39, 5 October 2006, *http://www.nasa.gov/centers/dryden/news/NewsReleases/2006/06-39.html* (accessed 5 March 2010).

[99] Robert Colvile, "One Giant Slip-Up for Mankind, NASA Has Mislaid the Original Footage of Neil Armstrong's Historic Moon Landing," *Daily Telegraph* (London), 14 August 2006; *Washington Post*, "Tape of 1st Moon Landing Missing," 15 August 2006.

[100] Von Puttkamer, "Space Flight 2006"; NASA, Jet Propulsion Laboratory, "Voyager: Mission Overview," *http://voyager.jpl.nasa.gov/mission/mission.html* (accessed 14 September 2010).

such as transportation of people or cargo to the ISS—into a profitable venture, thereby enabling NASA to focus on other objectives, such as missions to Mars and the Moon.[101]

Scientists published research on the dimmest stars ever observed in a globular star cluster, including findings that revealed important information about the universe's age and provided supporting evidence for a theory of star transformation. Harvey B. Richer of the University of British Columbia, and his team of scientists, had used NASA's HST to observe faint light from white dwarf stars in the cluster NGC 6397. Astronomers often make estimates of the universe's age based on the age of stars. They are able to determine the age of stars because stars decline in temperature as they exhaust their available energy over their lifetimes. White dwarf stars, which are burned-out relics of stars and cool at predictable rates, are particularly useful for this purpose. However, white dwarves also become less visible as their radiation declines. According to the team's observations of the light from the white dwarves in NGC 6397, the cluster is almost 12 billion years old. The light from the cluster's white dwarf stars appears as faint as the light of a birthday candle on the Moon would appear to an observer on Earth. The HST images also revealed that the dimmest white dwarf stars in NGC 6397 have temperatures low enough to cause chemical changes in their atmospheres, making the stars appear blue rather than red. Scientists had theorized the existence of this phenomenon but had never observed it.[102]

21 August

Astronomers reported the first direct evidence of dark matter, an enigmatic substance whose existence scientists had debated. Various theories had suggested that dark matter composes most of the universe's matter and helps maintain cosmic structures by binding normal matter—such as galaxies' composite atoms and hot gas—between galaxies. Dark matter is, theoretically, an invisible substance, which scientists can only detect by its gravitational effects on visible matter and radiation. Therefore, scientists had acquired no direct evidence of it until astronomers, led by Douglas Clowe of the University of Arizona, Tucson, discovered such evidence in images that NASA's HST and other telescopes had captured. The images showed a collision between two galaxy clusters, an event that scientists believed might have been the most energetic event subsequent to the Big Bang. The collision of the clusters had created a wind, causing the formation of a gas cloud with a bullet-like shape. However, the astronomers determined that the gas cloud does not account for most of the matter in the clusters. Instead, a separate, relatively empty patch of space had exerted a gravitational pull on the gas, thereby slowing it down. Because alternative theories of gravity could not account for these results, the astronomers concluded that dark matter had exerted the gravitational pull from the apparently empty area of space.[103]

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[101] NASA, "NASA Selects Crew and Cargo Transportation To Orbit Partners," news release 06-295, 18 August 2006, *http://www.nasa.gov/home/hqnews/2006/aug/HQ_06295_COTS_phase_1.html* (accessed 15 March 2010); Mark Carreau, "Two Firms, Both Space Novices, Get Nod from NASA," *Houston Chronicle*, 19 August 2006.

[102] NASA, "Hubble Sees Faintest Stars in a Globular Cluster," news release *06-292*, 17 August 2006, *http://www.nasa.gov/home/hqnews/2006/aug/HQ_06292_HST_globular_clusters.html* (accessed 15 March 2010); Harvey B. Richer et al., "Probing the Faintest Stars in the Globular Star Cluster," *Science* 313, no. 5789 (18 August 2006): 936–940, *http://www.sciencemag.org/cgi/content/short/313/5789/936* (DOI 10.1126; accessed 29 June 2010).

[103] NASA, "NASA Finds Direct Proof of Dark Matter," news release 06-297, 21 August 2006, *http://www.nasa.gov/home/hqnews/2006/aug/HQ_06297_CHANDRA_Dark_Matter.html* (accessed 15 March 2010); Douglas Clowe et al., "A Direct Empirical Proof of the Existence of Dark Matter," *Astrophysical Journal Letters* 648, no. 2 (10

24 August
The IAU revised its definition of the term "planet," thereby stripping Pluto of its planetary status. The IAU, an organization of professional astronomers, establishes standards in the field of astronomy, such as definitions of astronomical constants and designations of celestial bodies. At a meeting in the Czech Republic, IAU members voted on a much publicized and debated resolution concerning the definitions of planets and other bodies in the solar system. The organization held the vote because new discoveries about celestial objects in the solar system had prompted debate among astronomers regarding the correct categorization of those objects. For example, astronomers had discovered that Pluto is far smaller than previous believed and has a more tilted orbit than the orbits of other planets. As a result of the vote, the IAU redefined the term "planet." According to the new definition, a planet is a celestial body that orbits the Sun, is large enough for its gravity to give it a nearly round shape, and "has cleared the neighborhood around its orbit," meaning that it has cleared other objects out of its orbital path and that its orbit does not cross the orbital paths of other objects. Because Pluto's orbit overlaps with that of Neptune, the IAU reclassified Pluto as a "dwarf planet," a new category of celestial object.[104]

29 August
The Russian space agency Roskosmos announced its plans to launch dozens of spacecraft between 2006 and 2015, including probes to conduct atmospheric and surface studies of Mars and Venus. Roskosmos also intended to launch 30 fixed communications-and-broadcasting satellites and 10 satellites to provide mobile communications services. In addition, Roskosmos planned to create a pair of geostationary satellites that would provide meteorological services, part of a satellite network under the auspices of the World Meteorological Organization.[105]

30 August
Scientists reported that the ozone outside of Earth's polar regions had begun recovering in 1997. This finding provided evidentiary support for international efforts to limit ozone-depleting substances. Researchers led by Eun-Su Yang of the Georgia Institute of Technology had examined ozone data that NASA satellites and other instruments had collected over a 25-year period. They had discovered that ozone in Earth's stratosphere—the layer of atmosphere from 11 to 50 kilometers (6 to 31 miles) above Earth's surface—had declined in thickness from 1979 to 1997 and then had ceased depleting. The results confirmed that the 1987 Montreal Protocol—an international treaty banning the production of ozone-depleting substances—had helped stop the loss of ozone, especially in the part of the stratosphere 18 kilometers (11.2 miles) above the surface of Earth. That stratospheric region contains the greatest concentrations of the chemicals banned by the treaty. The researchers also found substantial improvement of ozone in the stratospheric region below 18 kilometers (11.2 miles); they hypothesized that this alteration could be the result of changes in atmospheric winds.[106]

September 2006): L109–L113, *http://iopscience.iop.org/1538-4357/648/2/L109/* (DOI 10.1086; accessed 29 June 2010).

[104] International Astronomical Union (IAU), "Resolution B5: Definition of a Planet in the Solar System," *http://www.iau.org/static/resolutions/Resolution_GA26-5-6.pdf* (accessed 28 February 2010); Dennis Overbye, "Vote Makes It Official: Pluto Isn't What It Used To Be," *New York Times*, 25 August 2006.

[105] *Orlando Sentinel* (FL), "Russia Plans Space Probes To Explore Mars, Venus," 30 August 2006.

[106] NASA, "NASA, NOAA Data Indicate Ozone Layer Is Recovering," news release 06-300, 30 August 2006, *http://www.nasa.gov/home/hqnews/2006/aug/HQ_06300_Ozone.html* (accessed 15 March 2010); Eun-Su Yang et al.,

31 August
NASA announced its selection of Lockheed Martin as the primary contractor to design, develop, test, and evaluate NASA's new CEV, *Orion*, which would replace the Space Shuttle as the crew transportation vehicle. *Orion* would be able to carry four crew members to the Moon, to transport up to six persons to the ISS, and to support crew transfers for Mars missions. The contract's estimated value was US$3.9 billion. NASA expected work on *Orion* to occur between 8 September 2006 and 7 September 2013. Although all of NASA's 10 centers would provide technical and engineering support for the project, Lockheed Martin would perform the majority of the engineering work at NASA's JSC and would complete the final assembly at NASA's KSC. NASA planned for *Orion*'s first crewed launch to occur no later than 2014 and for the CEV's first human mission to the Moon to occur by 2020.[107]

SEPTEMBER 2006

3 September
ESA ended its Small Mission for Advanced Research in Technology (SMART-1) with a planned crash landing of the SMART-1 spacecraft into the Moon. The spacecraft impacted at a speed of 4,500 miles per hour (nearly 7,200 kilometers per hour) in a volcanic plain called the Lake of Excellence. ESA had planned the crash so that scientists could study the composition of the resulting dust and debris. SMART-1 had launched on 27 September 2003, orbiting the Moon many times to acquire data about the chemical and mineralogical composition of the lunar surface. ESA had also used the mission to test deep-space communications techniques, autonomous spacecraft–navigation techniques, and other innovative technologies, such as an ion-propulsion engine and various miniaturized instruments.[108]

9 September
NASA launched Space Shuttle *Atlantis* (STS-115) from NASA's KSC at 11:15 a.m. (EDT). The mission's principal objective was to deliver and install a girder-like structure to the ISS. That structure, called the Port 3/Port 4 (P3/P4) truss, contained arrays—large, wing-shaped solar panels—designed to increase significantly the station's power capability. The mission's crew members included Commander Brent W. Jett Jr., Pilot Christopher J. Ferguson, Mission Specialists Daniel C. Burbank, Heidemarie M. Stefanyshyn-Piper, Joseph R. Tanner, all U.S. astronauts, and CSA astronaut, Mission Specialist Steven G. MacLean.[109]

"Attribution of Recovery in Lower-Stratospheric Ozone," *Journal of Geophysical Research* 111, no. D17 (16 September 2006): D17309, *http://www.agu.org/pubs/crossref/2006/ 2005JD006371.shtml* (DOI 10.1029; accessed 29 June 2010).

[107] NASA, "NASA Selects Orion Crew Exploration Vehicle Prime Contractor," news release 06-305, 31 August 2006, *http://www.nasa.gov/home/hqnews/2006/aug/HQ_06305_Orion_contract.html* (accessed 15 March 2010).

[108] ESA, "Impact Landing Ends SMART-1 Mission to the Moon," news release 31-2006, 3 September 2006, *http://www.esa.int/esaCP/Pr_31_2006_p_EN.html* (accessed 16 April 2010); Nic Fleming, "The Dust Settles After Europe Lands a Mission on the Moon," *Daily Telegraph* (London), 4 September 2006.

[109] NASA, "STS-115," *http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/archives/sts-115.html* (accessed 11 March 2010).

12 September

Atlantis astronauts Heidemarie M. Stefanyshyn-Piper and Joseph R. Tanner performed the first of three planned spacewalks to install the P3/P4 truss. During the 6.5-hour spacewalk, the pair connected power cables to the truss, released launch restraints on the structure's components, and prepared those components for later operation. Another notable achievement of the spacewalk was the crew's use of a new procedure to acclimatize astronauts to the environment of outer space. Under the new procedure, called a "camp out," the astronauts followed a protocol requiring that they spend the night before the spacewalk shut inside the ISS's Quest airlock, under lowered air pressure. Sleeping in reduced air pressure speeds the removal of nitrogen from the astronauts' bodies, thereby helping them avoid decompression sickness—also known as the bends—during spacewalks.[110]

13 September

Atlantis crew members Daniel C. Burbank and Steven G. MacLean performed the second spacewalk for Mission STS-115. During the spacewalk, which lasted nearly 7 hours, the two astronauts further prepared the P3/P4 truss for installation, releasing locks on an automobile-sized component of the truss that would enable the ISS's solar arrays to track the Sun. The purpose of the locks was to secure the truss during launch.[111]

GAO released a report examining federal government agencies' progress toward implementing a government panel's recommendations to obviate anticipated problems in the U.S. aerospace industry. In 2002 the Commission on the Future of the United States Aerospace Industry had stated that the nation's aerospace industry could face various economic and security problems unless federal agencies performed several innovations. These included the creation of new aerospace technologies and the development of a space policy incorporating public-private partnerships. GAO stated that federal agencies had made preliminary efforts to implement some of the Commission's recommendations but had taken little action on others, such as the creation of a government-wide management structure for aerospace activities. The report noted that NASA had created a directorate to implement the Vision for Space Exploration. However, some aerospace experts believed that NASA's efforts to implement the Vision might have a negative effect on existing space exploration programs with demonstrated benefits.[112]

The IAU announced the official name of the second celestial body identified as a dwarf planet, calling it (136199) Eris and naming its moon Dysnomia. A team of astronomers led by Michael E. Brown of the California Institute of Technology had announced their discovery of Eris on 29 July 2005, based on data they had acquired in 2003. Initially, the astronomers had given the object the temporary name 2003 UB313 and the informal name Xena. The discovery team had subsequently proposed the formal name Eris, after the Greek goddess of discord and strife, to symbolize scientists' disagreements about the IAU's classification of celestial bodies in Earth's

[110] NASA, "STS-115."
[111] NASA, "STS-115."
[112] U.S. Government Accountability Office, "U.S. Aerospace Industry: Progress in Implementing Aerospace Commission Recommendations, and Remaining Challenges" (report no. GAO-06-920, Washington, DC, 13 September 2006), 1–5, *http://www.gao.gov/new.items/d06920.pdf* (accessed 17 March 2010).

solar system. In August 2006, IAU members had voted to strip Pluto of its planetary status, officially designating it a dwarf planet.[113]

14 September

Crew members of the ISS and *Atlantis* successfully unfolded two new solar arrays for the ISS's power system, thereby increasing the station's capacity for producing electricity. The 240-foot-long (73.2-meter-long) arrays were components of the station's truss structure. Astronauts had installed an identical set of arrays at the ISS in 2000, and NASA planned to install two additional arrays during Shuttle flights in 2007 and 2008. Although the new arrays were already generating electricity, the generated power would not feed into the station's power grid until the rewiring and activation of a related cooling system, which NASA had scheduled for completion in December 2006. NASA estimated that, once the crew had installed all of the arrays, the structures would double the ISS's electrical power to an estimated total power of 75 to 110 kilowatts. The ISS's international partners intended for the additional power to support European, Japanese, Russian, and U.S. laboratory modules and to enable the ISS's life-support system to support up to six astronauts.[114]

Scientists published research indicating that the number of galaxies in the universe had sharply increased 700 million to 900 million years after the Big Bang. The finding provided important information about the formation of galaxies and the composition of stars. Rychard J. Bouwens and Garth D. Illingworth of the University of California, Santa Cruz, had used data from NASA's HST to determine that, beginning 700 million years after the Big Bang, the number of galaxies had increased tenfold in 200 million years. Another team of researchers, led by Masanori Iye of the National Astronomical Observatory in Tokyo, had found a similar increase in galaxy formation during the same period. These findings supported a prevailing theory of galaxy formation, which held that luminous galaxies were rare in the universe's earliest times. As heavy elements, such as carbon, iron, and oxygen emerged, these new elements had formed the building blocks for stars and galaxies. The team cautioned that astronomers would need to make further observations to determine more certainly how galaxies had formed during the universe's nascent years.[115]

15 September

Astronauts Heidemarie M. Stefanyshyn-Piper and Joseph R. Tanner performed the third and final spacewalk for Mission STS-115. They powered up a cooling system for the newly unfolded solar arrays and replaced a radio antenna that provided backup communications between the ISS and the ground. The astronauts also completed additional work aimed at reducing workloads for future spacewalkers. Those tasks included installing insulation on communications antennas and testing an infrared camera designed to detect damage on Shuttles.[116]

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[113] International Astronomical Union, "IAU Names Dwarf Planet Eris," news release iau0606, 14 September 2006, *http://www.iau.org/public_press/news/detail/iau0605/* (accessed 17 March 2010).
[114] Mark Carreau, "NASA Unfurls Set of Solar Panels To Power Space Station," *Houston Chronicle*, 15 September 2006; NASA, "STS-115."
[115] Dennis Overbye, "The Boom in Galaxies After the Big Bang," *New York Times*, 14 September 2006; Rychard J. Bouwens and Garth D. Illingworth, "Rapid Evolution of the Most Luminous Galaxies During the First 900 Million Years," *Nature* 443, no. 7108 (14 September 2006): 189–192, *http://www.nature.com/nature/journal/v443/n7108/abs/nature05156.html* (DOI 10.1038/nature05156; accessed 29 June 2010).
[116] NASA, "STS-115."

18 September

The Russian federal space agency Roskosmos launched a *Soyuz* TMA-9 passenger craft from Baikonur Cosmodrome in Kazakhstan at 04:08 (UT). The spacecraft carried two ISS crew members, American astronaut Michael E. Lopez-Alegria and Russian cosmonaut Mikhail V. Tyurin. Accompanying the two astronauts was the first female space tourist to the ISS, Anousheh Ansari, an Iranian-American entrepreneur who had paid US$20 million for the voyage. Ansari would perform blood and muscular experiments for ESA aboard the ISS.[117]

19 September

Russian space scientist Vladimir Sergevich Syromyatnikov died of leukemia in Moscow, Russia, at the age of 73. Syromyatnikov had begun working for Russia's S. P. Korolev Rocket and Space Corporation Energia (RSC Energia) in 1956. He had later developed several important space technologies, including the first piloted spacecraft, *Vostok*, which Yuri Gagarin had flown in 1961. Syromyatnikov had also worked on the *Voskhod* spacecraft, the Venera probe to Venus, and the docking system that had linked the Soviet *Soyuz* and the U.S. *Apollo* space vehicles in the Apollo-Soyuz Test Project of July 1975. Syromyatnikov had later developed the Androgynous Peripheral Assembly System—the docking system that connected NASA's Space Shuttles with Russia's orbital facility *Mir* and with the ISS.[118]

21 September

Space Shuttle *Atlantis* returned to Earth, landing at NASA's KSC at 6:21 a.m. (EDT) to complete its 12-day mission (STS-115). During that mission, the crew had resumed construction of the ISS after a four-year hiatus. The mission highlights included three spacewalks to install the P3/P4 truss on the ISS and to prepare new solar panels on that truss for future production of electricity at the orbiting space station.[119]

26 September

The House Science Subcommittee on Space and Aeronautics held a hearing on an NRC report recommending a strategy for the federal government's involvement in civil aeronautics, with particular emphasis on NASA's future research priorities. The NRC had released the report, *Decadal Survey of Civil Aeronautics: Foundation for the Future*, in June 2006. Major General William W. Hoover, co-chair of NRC's Committee on the Decadal Survey, testified that the NRC report would provide the executive branch with a "useful foundation" for developing a national aeronautics policy. Hoover urged NASA to allocate funding for research and technology more equitably, between NASA personnel and universities or industry, and to facilitate collaborative research with other federal agencies supporting aeronautics research, such as the FAA. Lisa J. Porter, Associate Administrator for NASA's Aeronautics Mission Directorate, testified that NASA's aeronautics-research portfolio aligned closely with the research priorities outlined in the report. Porter also stated that, although NASA had worked with private industry

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[117] Marc Kaufman, "As Shuttle Heads Home, NASA Lauds Mission," *Washington Post*, 18 September 2006; *Spacewarn Bulletin*, no. 635, 1 October 2006, *http://nssdc.gsfc.nasa.gov/spacewarn/spx635.html* (accessed 17 March 2010).

[118] Patricia Sullivan, "Vladimir Syromyatnikov; Designing Docking System for Space Capsules," *Washington Post*, 1 October 2006.

[119] NASA, "Mission Archives: STS-115."

in aeronautics research, NASA did not want to duplicate private-sector research or to pursue research that private industry was better equipped to conduct.[120]

28 September

The crew of ISS Expedition 13 returned to Earth. Commander Pavel V. Vinogradov and Science Officer Jeffrey N. Williams landed in their *Soyuz* TMA-8 spacecraft near the Russian city of Arkalyk. Accompanying Vinogradov and Williams was spaceflight participant Anousheh Ansari, who had flown to the ISS with the crew of Expedition 14 on 18 September 2006.[121]

The House Committee on Science held a hearing to examine NASA's development of the *Orion* CEV, NASA's planned replacement for the Space Shuttle. Hearing witness Allen Li of GAO testified that NASA had contracted with Lockheed Martin to develop *Orion* before it had established clear cost estimates and design requirements for the project. GAO had previously raised the same concerns in a July 2006 report. Li reported that, in response to the GAO report's criticism, NASA had made efforts to control the project's costs. However, he acknowledged that NASA needed to do more to control costs and to clarify the project's design requirements. The other hearing witness, NASA's Scott J. Horowitz, Associate Administrator of the Exploration Systems Mission Directorate, reported that *Orion*'s design relied on proven technologies, whereas earlier projects had relied on anticipated technological breakthroughs. He argued that NASA would therefore be able to control the costs of building *Orion* more easily than it had controlled the costs of previous projects. Furthermore, Horwitz pointed out that NASA was developing *Orion* for multiple applications over several decades. Committee members concluded that they would continue to monitor development of the CEV and other elements of NASA's exploration initiative to ensure the completion of those projects in a fiscally responsible manner that did not interfere with other NASA programs.[122]

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[120] U.S. House of Representatives, Committee on Science, Subcommittee on Space and Aeronautics, *The National Academy of Sciences' Decadal Plans for Aeronautics: A Blueprint for NASA?* 109th Cong., 2nd sess., 26 September 2006 (statement of Lisa J. Porter, Associate Administrator, Aeronautics Research Mission Directorate, NASA), *http://science.house.gov/commdocs/hearings/space06/sept%2026/Porter.pdf* (accessed 30 September 2010); U.S. House of Representatives, Committee on Science, Subcommittee on Space and Aeronautics, *The National Academy of Sciences' Decadal Plans for Aeronautics: A Blueprint for NASA?* 109th Cong., 2nd sess., 26 September 2006 (statement of William Hoover, National Research Council, the National Academies), *http://science.house.gov/commdocs/hearings/space06/sept%2026/Hoover.pdf* (accessed 30 September 2010).

[121] NASA, "International Space Station Status Report," status report SS06-042, 28 September 2006, *http://www.nasa.gov/home/hqnews/2006/sep/HQ_SS06042_station_status.html* (accessed 18 March 2010).

[122] U.S. Congress, House of Representatives, Committee on Science, "Democrats Call for Increased Oversight of NASA's Exploration Program," press release, 29 September 2006, *http://science.house.gov/press/PRArticle.aspx?NewsID=1200* (accessed 15 April 2010); U.S. Congress, House of Representatives, Committee on Science, *Implementing the Vision for Space Exploration: Development of the Crew Exploration Vehicle*, 109th Cong., 2nd sess., 28 September 2006, 48–53, *http://science.house.gov/commdocs/hearings/full06/Sept%2028/Horowitz.pdf* (accessed 15 April 2010); U.S. Government Accountability Office, "NASA: Sound Management and Oversight Key To Addressing Crew Exploration Vehicle Project Risks" (testimony of Allen Li before U.S. House Committee on Science; report no GAO-06-1127T, Washington, DC, 28 September 2006), *http://www.gao.gov/new.items/d061127t.pdf* (accessed 15 April 2010).

OCTOBER 2006

3 October

The Royal Swedish Academy of Sciences awarded the 2006 Nobel Prize in Physics to NASA scientist John C. Mather and University of California, Berkeley, scientist George F. Smoot. The pair received the award for research that strongly supported the Big Bang Theory as the definitive explanation of the universe's origin. Mather and Smoot had used data from NASA's Cosmic Background Explorer (COBE) to observe the universe 380,000 years after its inception. They had determined that the temperature of the cosmic microwave background—essentially, the Big Bang's afterglow—was approximately -455ºF. Their observations matched earlier predictions made by other scientists and indicated that nearly all of the universe's radiant energy—the energy of light and other electromagnetic waves—had been released during the first year after the Big Bang. The pair also discovered slight temperature variations in this relatively uniform light, indicating the density differences in matter that had led to the creation of stars, galaxies, and the universe's hierarchical structure.[123]

4 October

Data from NASA's HST revealed 16 objects, possibly the most distant planets ever observed by the HST. Scientists believed that the objects were extrasolar planets—planets located outside of Earth's solar system—orbiting various stars in the Milky Way's central region, 26,000 light-years away from Earth. Because of the distance and faintness of the objects' star systems, scientists could acquire mass measurements for only two of the planets. Therefore, they designated the objects as "candidate" extrasolar planets. The HST data also revealed that five of the newly discovered planets were Ultra-Short-Period Planets (USPPs), a type of planet not found in searches of neighboring areas of the Milky Way. USPPs orbit their stars in less than one Earth day.[124]

6 October

The U.S. Office of Science and Technology Policy publicly released the U.S. National Space Policy, which President George W. Bush had signed on 31 August 2006. The first full revision of overall U.S. space policy in 10 years, this policy superseded the previous National Space Policy of 14 September 1996. U.S. national security issues were a prominent feature of the new policy, with many of its stated principles and goals addressing U.S. defense and intelligence activities in space. The policy also supported private enterprise in space and the implementation of human and robotic space exploration to extend human presence across the solar system.[125]

Opportunity—one of NASA's robotic Mars rovers—began exploring the Victor Crater, an area of Mars that NASA scientists hoped would provide researchers with the most useful data yet

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[123] Nobel Foundation, "The Nobel Prize in Physics 2006," 3 October 2006, *http://nobelprize.org/nobel_prizes/physics/laureates/2006/press.html* (accessed 31 March 2010); NASA, "NASA Scientist John C. Mather Wins 2006 Nobel Physics Prize," news release 06-327, 3 October 2006, *http://www.nasa.gov/home/hqnews/2006/oct/HQ_06327_Mather_Nobel_prize.html* (accessed 31 March 2010).
[124] NASA, "Hubble Finds Extrasolar Planets Far Across Galaxy," news release 06-326, 4 October 2006, *http://www.nasa.gov/home/hqnews/2006/oct/HQ_06326_Extra_planets.html* (accessed 31 March 2010).
[125] Marc Kaufman, "Bush Sets Defense as Space Priority," *Washington Post*, 18 October 2006; U.S. Office of Science and Technology Policy, "U.S. National Space Policy," 31 August 2006, *http://www.whitehouse.gov/administration/eop/ostp/library/archives* (accessed 2 April 2010).

acquired about the planet's history. Arriving at the crater's rim, Opportunity began sending a volley of color panoramic images. However, before Opportunity actually entered the crater, NASA scientists planned for the robotic rover to circle it, determining a good location to enter and eventually to exit the site. The crater, which measures nearly 0.5 miles (0.8 kilometers) wide and 200 feet (61 meters) deep, is five times larger than any of the five craters the two Mars rovers, Opportunity and Spirit, had visited previously. Because of the crater's size and depth, it has many layers of exposed rock. The images that the rover captured would enable scientists to view and analyze the rock layers. The study of these layers would provide clues to the planet's geological and meteorological history, such as indications of when Mars had liquid water.[126]

12 October

Scientists using NASA's Spitzer Space Telescope (SST) reported the first measurements of day and night temperatures ever made on an extrasolar planet. Previously, astronomers had been able to measure extrasolar planets' global traits, such as mass and size, but had not been able to measure characteristics of particular portions of those planets. The scientists had observed a Jupiter-like gas giant, called Upsilon Andromedae b, which orbits very close to a star called Upsilon Andromedae. Gas giants are planets composed primarily of gas, rather than solid matter. The astronomers had discovered that Upsilon Andromedae b might be extremely hot on one side and extremely cold on the other. The observed temperature difference of 2,550ºF (1,400ºC) on the planet's two sides indicates that the planet's atmosphere absorbs and re-radiates sunlight rapidly, so that that gas circling the planet cools quickly, forming a stratosphere of cool gas.[127]

18 October

NASA and the Russian federal space agency Roskosmos announced the crew members for Expedition 15, the next expedition to the ISS: American astronauts Clayton C. Anderson and Daniel M. Tani and Russian cosmonauts Oleg V. Kotov and Fyodor N. Yurchikhin. The ISS partners had scheduled Kotov and Yurchikhin to fly to the ISS in March 2007; Anderson would travel to the ISS in June 2007, and Tani would go in August 2007. Yurchikhin would command Expedition 15, and the remaining three crew members would serve as flight engineers.[128]

19 October

ESA and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) launched the Meteorological Operational Satellite A (MetOP-A), Europe's first polar-orbiting weather satellite. MetOP-A, which represented a major advance in meteorological capabilities, launched on a Soyuz-Fregat rocket from Baikonur Cosmodrome in Kazakhstan at 16:28 (UT). Engineers had designed MetOP-A to quickly provide data of unprecedented accuracy and resolution, covering weather and climate variables ranging from temperature to concentrations of ozone gas. The satellite was the first of three scheduled for launch over the next 14 years. Collectively, the three satellites would ultimately form the space-based portion of EUMETSAT's Polar System (EPS). Polar-orbiting satellites were capable of highly detailed

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[126] Marc Kaufman, "Opportunity Panoramas of Martian Crater Thrill Scientists," *Washington Post*, 7 October 2006; Mark Carreau, "On Mars, NASA Finds a 'Tremendously Important Scientific Discovery," *Houston Chronicle*, 7 October 2006.

[127] NASA, "NASA's Spitzer Sees Day and Night on Exotic World," news release 06-334, 12 October 2006, *http://www.nasa.gov/home/hqnews/2006/oct/HQ_06334_spitzer_temps.html* (accessed 1 April 2010).

[128] NASA, "NASA Announced New International Space Station Crew," news release 06-337, 18 October 2006, *http://www.nasa.gov/home/hqnews/2006/oct/HQ_06337_new_station_crew.html* (accessed 20 April 2010).

Earth observation, because they orbited at relatively low altitudes—often at altitudes of 800 kilometers (nearly 500 miles), as opposed to the 36,000-kilometer-altitude (approximately 22,400-mile-altitude) orbits of many geostationary satellites. The EPS was Europe's contribution to a cooperative venture with NOAA, which had provided users worldwide with meteorological data from polar orbit for nearly four decades. In addition, NOAA and France's CNES had provided five of MetOP-A's 10 instruments.[129]

20 October
GAO released a report recommending that the U.S. Congress and the FAA reconsider the FAA's roles and responsibilities regarding the burgeoning commercial space tourism industry. In 2004 Congress had made the FAA responsible for regulations to ensure the safety of space tourists. However, Congress had also limited the FAA's ability to regulate crew and passenger safety until 2012, so that safety regulations would not stifle the budding space tourism industry. The GAO report noted that, although the FAA had performed well in its efforts to ensure that the space tourism industry followed safe procedures, the industry's rapid growth required the FAA to take a greater role than anticipated in creating safety regulations to for the period before 2012. The report suggested that, to accomplish its goal, the FAA would need additional funds and personnel, including staff with sufficient expertise to evaluate complex launch technologies. Furthermore, the report recommended that Congress reconsider the FAA's dual role in both regulating and promoting the industry, warning that this dual role presented a potential conflict of interest. The FAA and the Department of Transportation agreed with the report's findings and recommendations.[130]

24 October
NASA's Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) spacecraft performed the first of two scheduled flybys past the planet Venus, a maneuver intended eventually to steer the spacecraft to its final destination, Mercury. MESSENGER was the second spacecraft that NASA had launched to Mercury; the first had been Mariner 10, which had flown past the planet in 1974 and 1975. NASA had created MESSENGER to produce color maps of Mercury's surface and to conduct compositional analyses of the planet's atmosphere, magnetosphere, and surface. NASA had sent MESSENGER past Venus to collect new information about the planet—the closest planet to Earth—and to test equipment on the spacecraft. NASA had planned the Venus flyby as one of several planetary passages that, collectively, would help MESSENGER reach Mercury. During these planetary passages, the gravity of Venus and of the other planets would help decelerate MESSENGER, altering its trajectory so that the spacecraft would eventually attain orbit around Mercury. NASA planned for MESSENGER to fly past Venus again in June 2007, with the goal of reaching Mercury by 2011.[131]

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[129] ESA, "MetOP at a Glance: Overview," 16 November 2006, *http://www.esa.int/esaLP/ SEMN1FAATME_ LPmetop_0.html* (accessed 2 April 2010); *Spacewarn Bulletin*, no. 636, 1 November 2006, *http://nssdc.gsfc.nasa. gov/spacewarn/spx636.html* (accessed 2 April 2010).
[130] Mike Toner, "FAA Put on Guard for Space Tourism," *Atlanta Journal-Constitution* (GA), 30 October 2006; U.S. Government Accountability Office, "Commercial Space Launches: FAA Needs Continued Planning and Monitoring To Oversee the Safety of the Emerging Space Tourism Industry" (report no. GAO-07-16, Washington, DC, 20 October 2006), *http://www.gao.gov/new.items/d0716.pdf* (accessed 20 April 2010).
[131] Britt Norlander, "Dropping By," *Science World*, 23 October 2006, 6; Von Puttkamer, "Space Flight 2006."

26 October

NASA launched the Solar Terrestrial Relations Observatory (STEREO) mission from Cape Canaveral in Florida at 00:52 (UT). The STEREO mission consisted of two nearly identical observatories that would orbit the Sun, collecting data that scientists could use to predict the arrival of coronal mass ejections (CMEs) on Earth. CMEs, solar eruptions of matter, can disrupt satellites and power grids on Earth. NASA had designed the two spacecraft to conduct stereographic imaging of the Sun and its emissions, in order to trace the flow of energy and matter from the Sun to Earth. One spacecraft, STEREO-A (Ahead), would orbit the Sun ahead of Earth, while the other, STEREO-B (Behind), would orbit the Sun behind Earth. Scientists would be able to use the observatories' three-dimensional images of CMEs to predict with accuracy the arrival times of CMEs on Earth.[132]

28 October

CNSA launched the Sino Satellite Communications Company's (SinoSat's) satellite on a Long March 3B rocket from Xichang Satellite Launch Center at 16:20 (UT). The communications satellite, SinoSat-2, represented a major technological advance for the Chinese space program. The domestically developed satellite, capable of providing both analog and digital television broadcasts, was China's first satellite based on the Direct-From-Home-4 system, or DFH-4 bus. The DFU-4 bus enables individual households to receive television signals using their own satellite-dish antennas. SinoSat hoped that the satellite would improve the capacity and reliability of Chinese television broadcasting and help China serve the international spaceflight market. In addition, CNSA officials stated that the satellite's technology could prompt the Chinese government to eliminate regulations prohibiting Chinese citizens from installing their own satellite-dish antennas.[133]

31 October

NASA Administrator Michael D. Griffin announced that NASA would conduct a fifth and final crewed servicing mission to the HST, an expedition that would help extend and improve the observatory's capabilities through 2013. Griffin's announcement reversed previous NASA Administrator Sean O'Keefe's decision to cancel the servicing mission. The mission's main objective was to install two new instruments, the Cosmic Origins Spectrograph (COS) and Wide Field Camera 3 (WFC3). The COS would survey the universe's large-scale structure, known as the cosmic web. The gravity of dark matter and the spatial distribution of galaxies and intergalactic gas determine the structure known as the cosmic web. The WFC3 would observe objects in the solar system and in distant galaxies, providing scientists with information that would help them determine how those objects had formed. NASA announced that the mission's crew members would be Commander Scott D. Altman, Pilot Gregory C. Johnson, and Mission Specialists Andrew J. Feustel, Michael T. Good, John M. Grunsfeld, Michael J. Massimino, and K. Megan McArthur. NASA had tentatively scheduled the mission for 2008. The mission was controversial because it posed risks to astronauts. However, O'Keefe's cancellation had also

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[132] *Spacewarn Bulletin*, no. 636; NASA, "STEREO: Studying the Sun in 3-D," 17 February 2010, *http://www.nasa.gov/mission_pages/stereo/main/index.html* (accessed 2 April 2010).

[133] *Spacewarn Bulletin*, no. 636; Xinhua News Agency, "5th Ld-Writethru-China Exclusive: China Launches High-Power Communications, Broadcast Satellite," 29 October 2006.

engendered controversy, because failing to service the HST would have meant the end of the HST's mission by 2008.[134]

NOVEMBER 2006

1 November
JAXA released the most accurate images yet taken of the Large Magellanic Clouds (LMC), pictures that had the potential to provide important new information about the formation of stars and galaxies. Collectively known as the Magellanic Clouds (MC), the LMC and the Small Magellanic Clouds (SMC) are galaxies that orbit the Milky Way. Because of the slow, active star formation in the two galaxies, astronomers regard them as excellent sites for studying the evolution of galaxies and stars. JAXA's Akari satellite, also known as Astro-F, had captured multiple-wavelength images of the LMC as part of its mission to create images of the entire sky. The Akari images revealed stars forming within dust and gas clouds, numerous older stars outside of those clouds, and a distinct spindle-shaped cluster of stars in one area of the LMC. According to JAXA, the images of stars at different stages of their life cycles would help scientists study stellar evolution.[135]

7 November
NASA's Mars Reconnaissance Orbiter (MRO) began the primary science phase of its mission, a phase scheduled to continue until December 2008. NASA had designed MRO to conduct reconnaissance and exploration of Mars, while orbiting the planet, and had launched the orbiter in August 2005. During the primary science phase, MRO would produce high-resolution surveys of 15 percent of Mars's surface. NASA planned to use the images to identify particular areas for more detailed examination. NASA anticipated that data from MRO's surveys would enable scientists to examine changes in the surface of Mars occurring over time, including the effects of water and wind.[136]

9 November
NASA announced that its Cassini spacecraft had captured the first images ever taken of a hurricane-like storm on another planet. The images revealed a storm on Saturn with an eye ringed by towering clouds, winds blowing at a speed around 550 kilometers per hour (350 miles per hour), and a width of nearly 8,000 kilometers (5,000 miles)—nearly two thirds of the diameter of Earth. Despite its hurricane-like appearance, scientists did not classify the storm as a hurricane, because hurricanes on Earth form over water and drift around Earth's surface. The storm on Saturn remained at the planet's south pole and could not have formed over water, since

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[134] NASA, "NASA Approves Mission and Names Crew for Return to Hubble," news release 06-343, *http://www.nasa.gov/home/hqnews/2006/oct/HQ_06343_HST_announcement.html* (accessed 5 April 2010); Mark Carreau, "NASA to Repair Hubble Despite Potential Risks," *Houston Chronicle*, 1 November 2006.
[135] JAXA, "The Quest To Unravel the Mysteries of Galaxy Formation: Infrared Images of the Large Magellanic Cloud," press release, 1 November 2006, *http://www.jaxa.jp/press/2006/11/20061101_akari_e.html* (accessed 27 April 2010).
[136] NASA, Jet Propulsion Laboratory, "NASA's Newest Mars Orbiter Passes Communications Relay Test," 17 November 2006, *http://www.jpl.nasa.gov/news/features.cfm?feature=1230* (accessed 16 August 2010); NASA, "Mars Reconnaissance Orbiter Arrival" (press kit, March 2006), 8–18, *http://marsprogram.jpl.nasa.gov/mro/files/mro/mro-arrival.pdf* (accessed 16 August 2010).

Saturn is primarily composed of gases. Cassini had obtained the photographs over a 3-hour period on 11 October 2006.[137]

15 November
NASA produced the first live, high-definition television broadcasts from space, in cooperation with JAXA, American broadcaster Discovery HD Theater, and Japanese broadcaster Nippon Hoso Kyokai (NHK). During two 20-minute broadcasts, beamed live from the ISS, crew member Thomas A. Reiter filmed a narrated tour of the station, led by fellow crew member Michael E. Lopez-Alegria. The event was the result of a 2002 agreement between JAXA and NASA. Discovery and NHK had supplied the cameras and transmission equipment in exchange for first broadcast rights. NASA planned to use the equipment for educational and scientific purposes. NASA had produced high-definition footage during earlier missions but had possessed no equipment enabling broadcast from space.[138]

16 November
NASA announced the completion of the first systems requirements review (SRR) for its Constellation Program, a human spaceflight program aimed at sending astronauts to the Moon and possibly to Mars. NASA was conducting SRRs of human spacecraft systems to establish a foundation for the design, development, construction, and operation of those systems. NASA had completed its last review in August 1973 for the Space Shuttle program. The Constellation Program SRR examined the systems intended to replace the Shuttle systems, including the *Orion* spacecraft and the Ares I and Ares V launch rockets. The review confirmed numerous parameters of those systems, including *Orion*'s launch weight for lunar missions (61,000 pounds, or nearly 27,700 kilograms) and the Ares rockets' capacity to provide sufficient thrust to launch *Orion* into orbit. NASA also announced that it was preparing detailed project-level reviews of the Constellation Program's systems, scheduled for completion in early 2007. After completing those reviews, NASA would conduct another full review to reconcile information gained in the project-level reviews with the data from the first SRR.[139]

Scientists using NASA's HST reported research demonstrating how an enigmatic form of energy called dark energy has helped shape the universe's structure. Unable to observe dark energy directly, scientists analyze it by measuring its effects on matter. Previous research had revealed that dark matter causes the universe to expand by counteracting the collapsing gravitational pull of matter throughout the universe. However, several properties of dark matter had remained a mystery, such as how strong it is and when it began to exert its expansive effects. Attempting to solve some of these puzzles, a team of scientists, led by Adam G. Reiss of the Space Telescope Science Institute, had examined HST data on the luminosity distances of the farthest known supernovae—a type of ancient exploding star—to measure the universe's rate of expansion. The

[137] Will Dunham, "An Eye on Saturn Drawing the Focus of Astrophysicists," *Houston Chronicle*, 12 November 2006; NASA, Jet Propulsion Laboratory, "NASA Sees into the Eye of a Monster Storm on Saturn," 9 November 2006, *http://saturn.jpl.nasa.gov/news/newsreleases/newsrelease20061109/* (accessed 21 April 2010).
[138] Mark Carreau, "Space Station Transmits Live High-Definition TV Signals," *Houston Chronicle*, 16 November 2006; NASA, "NASA Schedules First Live HDTV Broadcast from Space," media advisory M06-176, 9 November 2006, *http://www.nasa.gov/home/hqnews/2006/nov/HQ_M06176_HDTV.html* (accessed 7 July 2010).
[139] NASA, "NASA Completes Milestone Review of Next Human Spacecraft System," news release 06-354. 16 November 2006, *http://www.nasa.gov/home/hqnews/2006/nov/HQ_06354_Constellation.html* (accessed 7 July 2010).

scientists found that dark energy had begun to accelerate the universe's expansion as long ago as 10 billion years, and that the expansive force of dark energy, although weak, had been sufficiently consistent to counteract gravity. In addition, the research supported Albert Einstein's theory of the existence of a "cosmological constant" that works against gravity to create equilibrium in the universe.[140]

17 November

The joint ESA-NASA Ulysses spacecraft commenced its third passage over the Sun's south pole, an event that scientists expected would reveal new information about changes in the Sun and the effects of those changes on space. Carried into space in 1990 by the Space Shuttle *Discovery*, Ulysses was on a mission to explore the heliosphere—the region of space influenced by the Sun and its magnetic field. Data gathered during Ulysses's orbit of the Sun, once every 6.2 years, was enabling scientists to study the Sun's 11-year cycle of maximum and minimum solar activity. Moreover, Ulysses had accomplished 17 years of orbit, making it possible for scientists to study the Sun during its entire 22-year magnetic cycle. The spacecraft had first passed over the Sun's south pole in 1994 and over its north pole in 1995, both passes occurring during a phase of minimum solar activity. Ulysses's second set of polar passes, in 2000 and 2001, had occurred during a period of maximum solar activity. The spacecraft's third passage over the Sun's south pole was occurring during another period of minimum solar activity, but this pass would provide new data because the Sun's magnetic field had reversed in polarity since the spacecraft's first passage over the south pole. Ulysses is part of the Heliospheric Network, a spacecraft fleet that includes NASA's Cassini, the joint ESA-NASA Solar and Heliospheric Observatory (SOHO), and other spacecraft.[141]

GAO released a report stating that the U.S. Department of Defense (DOD) needed to correct its unrealistic cost estimates for its major space acquisition programs. Analyzing six of the U.S. Air Force's ongoing space programs, GAO had found that the programs' estimated costs had increased by US$12.2 billion, 44 percent over initial cost estimates. The report attributed this cost growth to the DOD's practice of commencing programs before determining whether sufficient financial resources would be available to complete them. GAO suggested that this practice had developed because of pressures on the DOD to secure program funding. The report also stated that the DOD's unrealistic cost estimates had exacerbated its problems with acquisitions for the Air Force's programs. For example, the DOD had frequently had to move funds between programs to cover the costs of poorly performing programs. This had led to inefficiencies in meeting programs' costs and schedules. The DOD agreed with the report's findings and outlined specific steps it planned to take to make the Air Force's cost estimates more accurate.[142]

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[140] Adam G. Riess et al., "New Hubble Space Telescope Discoveries of Type Ia Supenovae at $z \geq 1$: Narrowing Constraints on the Early Behavior of Dark Energy," *Astrophysical Journal* 659, no. 1 (10 April 2007): 98–121, *http://iopscience.iop.org/0004-637X/659/1/98* (DOI 10.1086/510378; accessed 29 April 2010); Dennis Overbye, "9 Billion-Year-Old 'Dark Energy' Reported," *New York Times*, 17 November 2006.

[141] NASA, "NASA-European Spacecraft Swoops Under Sun's Pole," *http://www.nasa.gov/vision/universe/solarsystem/ulysses-20070207.html* (accessed 14 September 2010); ESA, "Ulysses Embarks on Third Set of Solar Passes," *http://www.esa.int/esaSC/SEMWPIUXJUE_index_0.html* (accessed 14 September 2010).

[142] U.S. Government Accountability Office, "Space Acquisitions: DOD Needs To Take More Action To Address Unrealistic Cost Estimates of Space Systems" (report no. GAO-07-96, Washington, DC, 17 November 2006), 1–6, *http://www.gao.gov/new.items/d0796.pdf* (accessed 29 April 2010).

21 November

NASA announced that its Mars Global Surveyor (MGS) was likely no longer operational. The spacecraft had ceased communications with NASA on 2 November 2006, and NASA's subsequent efforts to reestablish communications had failed. NASA did not officially terminate the spacecraft's mission. NASA had launched MGS in November 1996 to create a map of Mars. After completing its primary mission in January 2001, MGS had remained in operation, and NASA had decided to extend the spacecraft's mission. The MGS mission had eventually become the longest and most productive ever sent to Mars, producing nearly 240,000 images that revealed features of Mars never before seen, as well as the first strong evidence of the previous existence of water on the planet.[143]

22 November

To raise money for the Russian space program, ISS crew member Mikhail V. Tyurin drove a golf ball off the ISS during a spacewalk, an event that comprised a small, but highly publicized, part of the 5.5-hour spacewalk. Tyurin and American astronaut Michael E. Lopez-Alegria spent most of the spacewalk conducting serious tasks, such as installing a proton detector to monitor solar eruptions. NASA beamed imagery of the event to Mission Control, showing Tyurin using a 6-iron to drive a lightweight replica of a golf ball off a special spring-loaded tee. Element 21 Golf Company of Toronto, Canada, had paid the Russian federal space agency Roskosmos an undisclosed fee for the golf outing, and NASA had approved it after determining that the ball posed no threat to the ISS. NASA expected the ball to enter Earth's orbit and to incinerate in the upper atmosphere within a few days.[144]

30 November

Scientists released research indicating that a meteorite that had crashed to Earth in 2000 contained chemical compounds that were basic to all life forms already existing on Earth. A team of researchers led by Keiko Nakamura-Messenger of NASA's JSC had examined portions of the meteorite, which had landed in northern British Columbia's Tagish Lake. They had found that the meteorite was uncontaminated by organic material from Earth or from collisions with other space rocks but was, nevertheless, mostly composed of small carbon spheres, mixed with hydrogen and nitrogen—all organic material. The team's research also indicated that the meteorite's materials could be more than 4.5 million years old, more ancient than either the Earth or the Sun. The scientists postulated that the meteorite might have acquired the organic matter from the solar system's outer regions, which are sufficiently cold for the formation of hydrogen and nitrogen isotopes. However, the researchers also stated that further research was necessary to determine whether comets and meteorites had provided the building blocks for early life on Earth, as some scientists theorized.[145]

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[143] NASA, "NASA's Mars Global Surveyor May Be at Mission's End," news release 06-357, 21 November 2006, *http://www.nasa.gov/home/hqnews/2006/nov/HQ_06357_MGS_update.html* (accessed 7 July 2010); Thomas H. Maugh II, "Missing Mars Craft Appears To Be a Lost Cause," *Los Angeles Times*, 22 November 2006.

[144] Mark Carreau, "After Sending Golf Ball into Space, It's Down To Business," *Houston Chronicle*, 23 November 2006; Stefano S. Coledan, "From Outer Space, a Cry of Fore!" *New York Times*, 23 November 2006.

[145] Tom Spears, "Space Rock Might Tell Us How Life Began on Earth," *Gazette* (Montreal), 1 December 2006; Keiko Nakamura-Messenger et al., "Organic Globules in the Tagish Lake Meteorite: Remnants of the Protosolar Disk," *Science* 314, no. 5804 (1 December 2006): 1439–1442, *http://www.sciencemag.org/cgi/content/abstract/314/5804/1439* (DOI 10.1126/science.1132175; accessed 18 August 2010).

DECEMBER 2006

4 December

NASA released to the public two long-term strategies for placing humans on the Moon and Mars. The first of these was the Global Exploration Strategy, which NASA had written at the request of the U.S. Congress. The Global Exploration Strategy outlined NASA's plan for accomplishing the objectives established in NASA's strategic plan and in President George W. Bush's Vision for Space Exploration. In this document, NASA stated that it intended to pursue human and robotic exploration of the Moon, as well as explaining what the planned lunar exploration mission would do when it reached the Moon. The second strategic plan that NASA made public was its proposal for "lunar architecture," documenting requirements for implementing and enabling critical exploration objectives. The proposed architecture included robotic precursor missions to establish the operational infrastructure necessary for eventual human missions to the Moon and possibly to Mars. NASA anticipated that human journeys to the Moon would begin in 2020.[146]

6 December

Scientists published research based on photographs taken by NASA's Mars Global Surveyor (MGS). The images revealed the strongest evidence to date of occasional flowing water on the surface of Mars. MGS had begun orbiting Mars in 1997. NASA had used MGS repeatedly, to capture images of hundreds of sites on Mars, although in November 2006, NASA had announced that Surveyor's mission was likely at an end. A team of scientists led by Michael C. Malin of Malin Space Science Systems in San Diego, California, had compared MGS images taken in 2004 and 2005 with previous MGS images and had discovered sediment deposits in two gullies on Mars. The deposits had not been present in earlier MGS images of the site, suggesting that water had carried the sediment through the gullies at some point in the previous seven years. However, because of Mars's thin atmosphere and cold temperatures, liquid water is unlikely to remain on the planet's surface. The researchers hypothesized that water emerging from an underground source could remain in a liquid state long enough to transport debris down a slope before freezing. Scientists consider liquid water necessary for the existence of life and believe that its presence on Mars would indicate the possibility of microbial life on that planet.[147]

9 December

Space Shuttle *Discovery* launched at 8:47 p.m. (EST) from NASA's KSC on Mission STS-116. NASA anticipated that STS-116 would be one of the most complex missions ever made to the ISS. The crew of ISS and *Discovery* planned to reconfigure the station's electrical and cooling systems, making the solar arrays that the previous mission (STS-115) had delivered fully operational. In this unprecedented operation, the ISS's ground control would shut down and reroute the ISS's power in an iterative process. In addition, crew members would install the P5

[146] NASA, "NASA Unveils Global Exploration Strategy and Lunar Architecture," news release 06-361, 4 December 2006, *http://www.nasa.gov/home/hqnews/2006/dec/HQ_06361_ESMD_Lunar_Architecture.html* (accessed 7 July 2010).

[147] NASA, "NASA Images Suggest Water Still Flows in Brief Spurts on Mars," news release 06-361, 6 December 2006, *http://www.nasa.gov/home/hqnews/2006/dec/HQ_06362_Water_on_Mars.html* (accessed 8 June 2010); Michael C. Malin et al., "Present-Day Impact Cratering Rate and Contemporary Gully Activity on Mars," *Science* 314, no. 5805 (8 December 2006): 1573–1577, *http://www.sciencemag.org/cgi/content/abstract/314/5805/1573* (DOI 10.1126/science.1135156; accessed 8 June 2010).

truss (port side 5 truss) on the ISS's Integrated Truss Structure, a lattice-like structure on the station's exterior, which provided power, data, and other utilities for the station. *Discovery*'s seven-member crew included Commander Mark L. Polansky, Pilot William A. Oefelein, Flight Engineer Sunita L. Williams, and Mission Specialists Robert L. Curbeam Jr., Joan E. Higginbotham, Nicholas J. M. Patrick, and ESA's Christer Fuglesang. Williams would remain at the ISS as part of Expedition 14, replacing ESA astronaut Thomas A. Reiter, who would return to Earth with the *Discovery* crew.[148]

12 December
Astronauts Robert L. Curbeam Jr. and A. Christer Fuglesang performed the first extravehicular activity (EVA), or spacewalk, of Mission STS-116. During the 6.5-hour EVA, the two astronauts installed the girder-like P5 truss to the ISS's Integrated Truss Structure. Fellow astronauts Joan E. Higginbotham and Sunita L. Williams assisted them from inside the ISS, using the station's robotic arm (Canadarm2). The P5 truss would support a set of solar arrays, which NASA expected to attach during a Shuttle mission planned for 2007. The astronauts' other major task during the spacewalk was the retraction of the solar arrays on the station's P6 truss, so that the newer solar arrays on the P4 truss could begin tracking the motion of the Sun. Although NASA had designed the P6's arrays to fold up like an accordion, mechanical problems prevented crew members from fully retracting the device. Crew members of Space Shuttle *Atlantis* had installed the newer solar arrays during Mission STS-115 in August 2006.[149]

14 December
Astronauts Robert L. Curbeam Jr. and A. Christer Fuglesang conducted a second spacewalk for Mission STS-116, the 75th in the history of the ISS. During the near 6-hour excursion, the spacewalkers completed the first phase of the reconfiguration of the station's electrical system, a complex task that required the astronauts to plug in and unplug various cables, while simultaneously coping with the harsh environment of space. The second phase of the power reconfiguration would take place on 16 December. The rewiring was part of an extensive project to switch the ISS from its temporarily configured power system to a permanent arrangement. For the previous six years, the ISS had drawn its electrical power from one array of solar panels, but under the planned permanent configuration, the station would draw power from another set of solar arrays, which would rotate to face the Sun as the ISS orbited Earth.[150]

15 December
Scientists who had examined comet samples collected by NASA's Stardust spacecraft published research challenging currently held theories regarding comets and the solar system. Scientists believe that comets are ancient archives of relatively pristine material surviving from the solar system's inception. Therefore, they study comets to glean information about the solar system's formation. NASA had originally launched Stardust in 1999. In January 2004, the spacecraft had obtained particle samples from the comet Wild 2, returning the samples to Earth in January 2006.

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[148] NASA, "STS-116 Delivers Permanent Power," *http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts116/launch/sts116_summary.html* (accessed 7 June 2010).
[149] NASA, "STS-116 Delivers Permanent Power"; NASA, "Mission Archives: STS-115," *http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/archives/sts-115.html* (accessed 8 June 2010); Michael Cabbage, "Walk Add 2 Tons to Space Station; Truss Addition Paves Way for Solar Upgrade," *Orlando Sentinel* (FL), 13 December 2006.
[150] NASA, "STS-116 Delivers Permanent Power"; John Schwartz, "2 Spacewalkers Are Successful in Tricky Rewiring of the Space Station," *New York Times*, 15 December 2006.

Over 180 scientists had subsequently analyzed the particle samples, which had revealed a mixture of minerals from across the solar system. The discovery had challenged the prevailing idea that comets had formed in isolation, in the solar system's outer fringes. The particle samples contained material that derived from the inner solar system, raising questions about how the material had reached the solar system's far edge, and about how the solar system had formed. Moreover, Wild 2's compositional material suggested that comets are of different types. The comet's mélange of materials was different from the matter composing the comet Tempel 1, which NASA had analyzed in 2005, using its Deep Impact spacecraft. Researchers had found that Tempel 1 was largely composed of ice and dust.[151]

16 December
Astronauts Robert L. Curbeam Jr. and Sunita L. Williams conducted the third spacewalk for Mission STS-116, rearranging electrical channels on the station's exterior. The completion of that task finalized preparations for the planned additions of European and Japanese laboratory modules to the ISS. During the lengthy 7.5-hour spacewalk, Curbeam and Williams also made some progress on retracting a solar array, although they were unable to fold the device completely. NASA planned for a fourth spacewalk to continue work on the array.[152]

The first successful launch at a commercial spaceport in the United States took place when the Mid-Atlantic Regional Spaceport launched a rocket called the Minotaur, carrying two satellites. The state governments of Virginia and Maryland had funded the spaceport to serve the commercial space launch market. Other institutions contributing to the venture included Old Dominion University and several aerospace companies. The facility was located on land leased from NASA's Wallops Flight Facility (WFF) near Chincoteague, Virginia. Orbital Sciences Corporation of Dulles, Virginia, had built the rocket. One of the satellites it carried was a U.S. Air Force tactical surveillance satellite called TacSat-2. The other was a 10-kilogram (22-pound) NASA satellite called GeneSat 1, designed for experiments on E. coli bacteria.[153]

18 December
Astronauts Robert L. Curbeam Jr. and A. Christer Fuglesang conducted a fourth spacewalk for Mission STS-116. The goal of the 6.5-hour spacewalk was to retract the troublesome solar arrays on the P6 truss, located on the ISS's exterior. It constituted Curbeam's fourth spacewalk for STS-116, making him the first astronaut to conduct four spacewalks during a single mission. The retraction of the array would enable the astronauts to move the power-producing array to another location on the ISS and to install a permanent electrical grid for the orbiting station.[154]

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[151] Warren E. Leary, "Researchers Find Surprise in Makeup of a Comet," *New York Times*, 15 December 2006; Joanne Baker, "Look into the Seeds of Time," *Science* 314, no. 5806 (15 December 2006): 1707, *http://www.sciencemag.org/cgi/content/summary/314/5806/1707* (DOI 10.1126/science.314.5806.1707; accessed 8 June 2010).
[152] Mike Schneider, "4th Spacewalk Planned To Fix Panel," *Washington Post*, 17 December 2006.
[153] Michael E. Ruane, "At Va. Spaceport, Rocket Launches 1,000 Dreams," *Washington Post*, 17 December 2006; *Spacewarn Bulletin*, no. 638, 1 January 2007, *http://nssdc.gsfc.nasa.gov/spacewarn/spx638.html* (accessed 1 July 2010).
[154] Michael Cabbage, "Spacewalkers Retract Solar Array," *Orlando Sentinel* (FL), 19 December 2006; NASA, "STS-116 Delivers Permanent Power."

21 December

Scientists using data from NASA's Swift satellite published research on a newly discovered type of gamma-ray burst (GRB), designated GRB 060614. GRBs, which result from the collapse of stars, are the most powerful explosions in the universe. NASA had launched Swift in November 2004 to study this phenomenon. The satellite had been the first to observe a curious new type of GRB, which exhibited properties of the two known types of GRBs—long- or short-duration GRBs. Long GRBs often last two seconds or longer, whereas short GRBs typically last less than two seconds. The 102-second duration of the newly observed GRB resembled long GRBs. However, the explosion lacked the telltale supernova that follows long GRBs and had the luminosity and radiation characteristic of short GRBs. Scientists remained uncertain whether the newly discovered GRB was a variation of the two known GRB types or an entirely different category of GRB.[155]

22 December

Space Shuttle *Discovery* landed at NASA's KSC at 5:32 p.m. (EST), marking the end of the 13-day Mission STS-116, the 20th Shuttle flight to the ISS. The mission had been among the most challenging ever made to the space station. In addition to transporting 2.9 tons (2.6 tonnes or 2,631 kilograms) of equipment and supplies to the ISS, *Discovery*'s crew had rewired the ISS's power system and installed an additional truss segment to the station's Integrated Truss Structure. Rewiring the power system had proved particularly onerous because the crew had experienced difficulty retracting one set of solar arrays, to enable a different set of arrays to begin tracking the Sun's motion. Crew members had conducted four spacewalks to work on the exterior of the ISS.[156]

27 December

France's CNES launched the COROT (Convection, Rotation and planetary Transits) satellite on its mission to study stars and to discover exoplanets—planets outside of Earth's solar system. The French-Russian company Starsem launched COROT on a Soyuz-2 rocket from Baikonur Cosmodrome in Kazakhstan at 14:23 (UT). CNES had designed the satellite to conduct seismological analyses of stars, gathering data that would enable scientists to determine their age, composition, and internal structure. In addition, CNES had designed COROT to detect previously undiscovered exoplanets by searching for the dimming starlight that occurs when planets transit in front of the stars they are orbiting. CNES was the lead space agency for the COROT mission; the project's international partners included ESA and the space agencies of Austria, Belgium, Brazil, Germany, and Spain.[157]

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[155] Bing Zhang, "Astrophysics: A Burst of New Ideas," *Nature* 444, no. 7122 (21 December 2006): 1010−1011, *http://www.nature.com/nature/journal/v444/n7122/full/4441010a.html* (DOI 1189735951; accessed 6 July 2010); NASA, "Swift: Mission Update," *http://www.nasa.gov/mission_pages/swift/ launch/index.html* (accessed 6 July 2010).

[156] NASA, "STS-116 Delivers Permanent Power."

[157] Centre National d' Études Spatiales (CNES), "COROT: Discovering the Stars," *http://www.cnes.fr/web/CNES-en/1401-corot.php* (accessed 6 July 2010); ESA, "Europe Looks Forward to COROT Launch," press release 47-2006, *http://www.esa.int/esaCP/Pr_47_2006_p_EN.html* (accessed 6 July 2010); *Spacewarn Bulletin*, no. 638, 1 January 2007, *http://nssdc.gsfc.nasa.gov/spacewarn/spx638.html* (accessed 1 July 2010).

APPENDIX A: TABLE OF ABBREVIATIONS

AAS	American Astronomical Society
ACS	Advanced Camera for Surveys
AEB	Agência Espacial Brasileira
ALOS	Advanced Landing Observing
ARC	Ames Research Center
ASI	Agenzia Spaziale Italiana
ATV	Automated Transfer Vehicle
AU	Astronomical Unit
AVNIR	Advanced Visible and Near Infrared Radiometer
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CaLV	Cargo Launch Vehicle
CECE	Common Extensible Cryogenic Engine
CEV	crew exploration vehicle
Cloudsat	Cloud satellite
CLV	Crew Launch Vehicle
CMB	cosmic microwave background
CME	coronal mass ejections
CMIS	Conically Scanning Microwave Image/Sounder
CNES	Centre National d'Études Spatial
CNSA	China National Space Administration
COBE	Cosmic Background Explorer
COROT	Convection, Rotation and planetary Transits satellite
COS	Cosmic Origins Spectrograph
COSMIC	Constellation Observing System for Meteorology, and Climate
CSA	Canadian Space Agency
DART	Demonstration of Autonomous Rendezvous Technology
DFH	Direct-From-Home
DOD	U.S. Department of Defense
DSN	Deep Space Network
EDT	Eastern Daylight Time
EPS	EUMETSAT's Polar System
ESA	European Space Agency
EST	Eastern Standard Time
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites EVA extravehicular activity
FAA	Federal Aviation Administration
FUSE	Far Ultraviolet Spectroscopic Explorer
GAO	Government Accountability Office
GMT	Greenwich Mean Time

APPENDIX A: TABLE OF ABBREVIATIONS

GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GRB	gamma-ray burst
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
GSLV	Geosynchronous Satellite Launch Vehicle
G-switch	gravity-switch
HST	Hubble Space Telescope
IAU	International Astronomical Union
ICESat	Ice, Cloud, and land Elevation Satellite
ILS	International Launch Services
IMAGE	Imager for Magnetopause-to-Aurora Global Exploration
INSAT	Indian National Satellite
IR1	micron infrared
IR2	Micron
IR3	micron water vapor
ISRO	Indian Space Research Organization
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JST	Japan Standard Time
KSC	Kennedy Space Center
LaRC	Langley Research Center
LeRC	Lewis Research Center
LMC	Large Magellanic Clouds
MC	Magellanic Clouds
MESSENGER	Mercury Surface, Space Environment, Geochemistry, and Ranging
MetOP	Meteorological Operational Satellite
MGS	Mars Global Surveyor
MIB	Mishap Investigation Board
Mini-SAR	mini synthetic-aperture radar
MISSE	Materials on International Space Station Experiment
MOU	Memorandum of Understanding
MPLM	Multi-Purpose Logistic Modules
MRO	Mars Reconnaissance Orbiter
MSL	Mars Science Laboratory

APPENDIX A: TABLE OF ABBREVIATIONS

MTSAT	Multi-Functional Transport Satellite
MUBLCOM	Multiple Paths, Beyond-Line-of-Sight Communications
NACA	National Advisory Committee for Aeronautics
NAS	National Academy of Sciences
NHK	Nippon Hoso Kyokai
NOAA	National Oceanic and Atmospheric Administration
NPP	NPOESS Preparatory Project
NPOESS	National Polar-Orbiting Operational Environmental Satellite System
NRC	National Research Council
NSF	National Science Foundation
P3/P4	Port 3/Port 4
PALSAR	Phased Array type L–band Synthetic Aperture Radar
PAMELA	Payload for Anti-Matter Exploration and Light-Nuclei Astrophysics
PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping
RSC	Rocket System Corporation
SETI	Search for Extra-Terrestrial Intelligence
SinoSat	Sino Satellite Communications Company
SMART-1	Small Mission for Advanced Research in Technology
SMC	Small Magellanic Clouds
SOHO	Solar and Heliospheric Observatory
SpaceX	Space Exploration Technologies Corporation
SRR	systems requirement review
SSC	Stennis Space Center
SST	Spitzer Space Telescope
ST 5	Space Technology 5
STEREO	Solar Terrestrial Relations Observatory
STEREO-A	Solar Terrestrial Relations Observatory Ahead
STEREO-B	Solar Terrestrial Relations Observatory Behind
Topex	TOPography EXperiment for Ocean circulation
USPP	Ultra-Short-Period Planet
UT	Universal Time
VIM	Voyager Interstellar Mission
WFC	Wide Field Camera
WFF	Wallops Flight Facility
WMAP	Wilkinson Microwave Anisotropy Probe

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