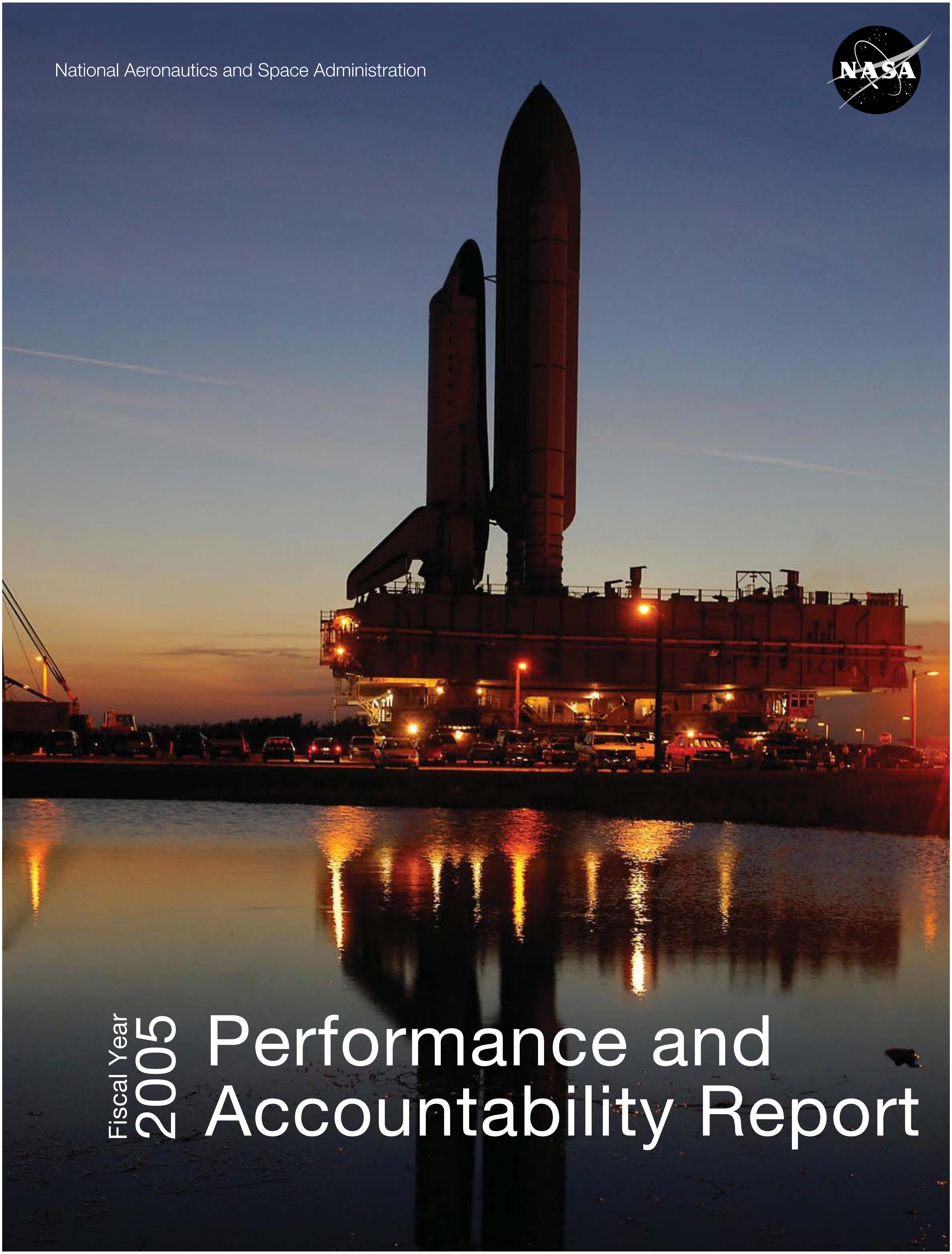
National Aeronautics and Space Administration



Fiscal Year 2005

Performance and Accountability Report

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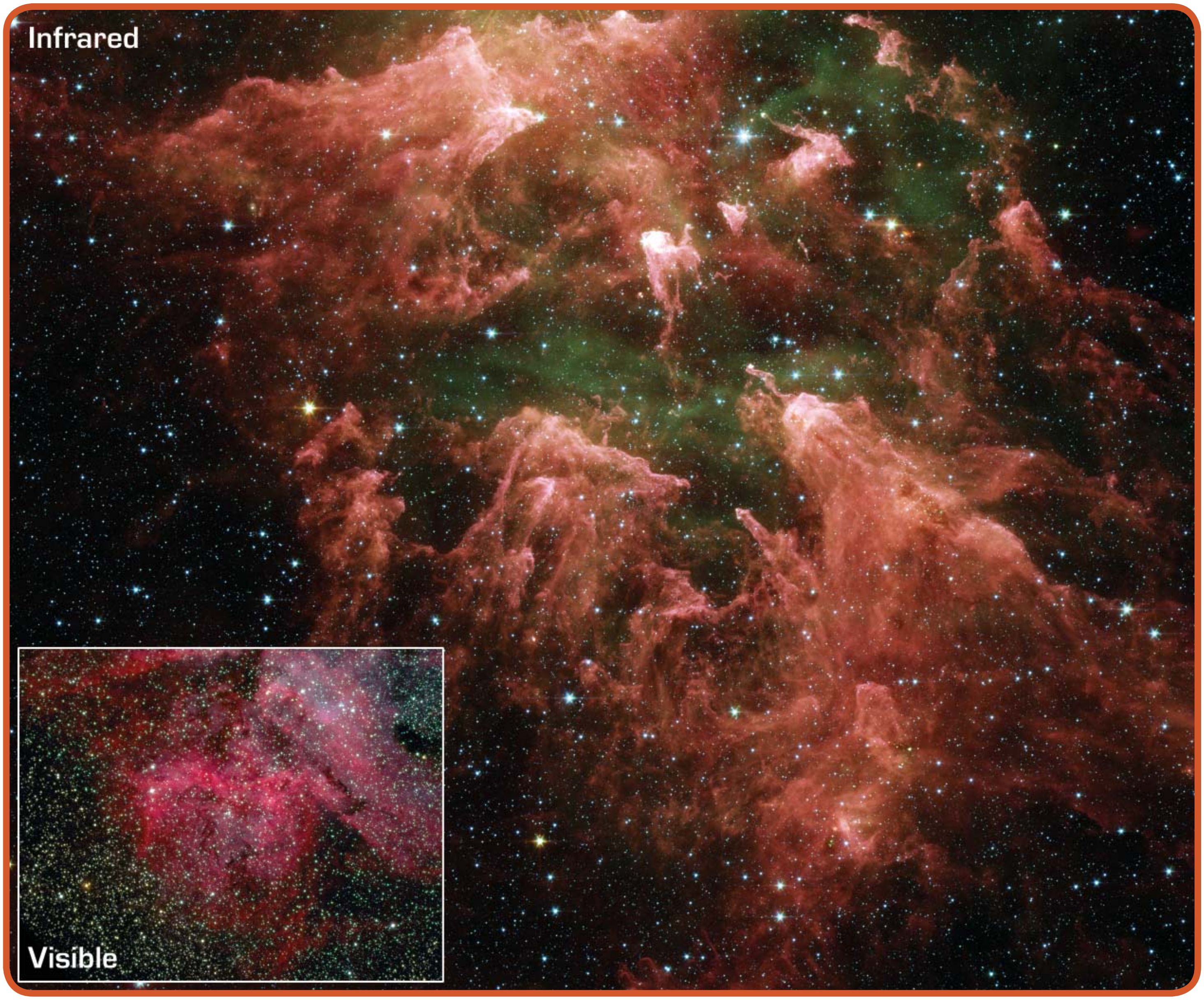
Part 2: Detailed Performance Data



Previous page: The Spitzer Space Telescope imaged the star-forming "bubble" RCW 79, found in the constellation Centaurus, in April 2005. The bubble is 70-light years in diameter, and probably took about one million years to form from the radiation and winds of hot young stars. Stars are born when the hot bubble expands into the interstellar gas and dust around it. RCW 79 has spawned at least two groups of new stars along the edge of the large bubble. Some are visible inside the small bubble in the lower left corner. Another group of baby stars appears near the opening at the top. (NASA/JPL–Caltech/E. Churchwell, Univ. of Wisconsin, Madison)

Above: In May, Spitzer captured this false-color image (large infrared image) of the "South Pillar" in the star-forming region called the Carina Nebula. Like cracking open a watermelon and finding its seeds, the infrared telescope "busted open" this murky cloud to reveal star embryos (yellow or white) tucked inside finger-like pillars of thick dust (pink). Hot gases are green and foreground stars are blue. The inset visible-light picture shows quite a different view. The dust pillars are fewer and appear dark because the dust is soaking up visible light. (Infrared: NASA/JPL–Caltech/N. Smith, Univ. of Colorado, Boulder; Visible: NOAO/AURA/NSF)

Introduction to NASA's Detailed Performance Data

To ensure that NASA pursues the Vision for Space Exploration in a systematic yet flexible manner, the Agency established 18 long-term research and development Objectives to guide NASA's course in 2005 and beyond. The Agency's FY 2005 Performance Plan Update is structured around these Objectives. NASA did not pursue Objectives 1, 9, 10, and 16 in FY 2005 and, therefore, they are not reflected in the Detailed Performance Data.

NASA's Objectives for FY 2005

2. Conduct robotic exploration of Mars to search for evidence of life, to understand the history of the solar system, and to prepare for future human exploration.
3. Conduct robotic exploration across the solar system for scientific purposes and to support human exploration. In particular, explore Jupiter's moons, asteroids, and other bodies to search for evidence of life, to understand the history of the solar system, and to search for resources.
4. Conduct advanced telescope searches for Earth-like planets and habitable environments around the stars.
5. Explore the universe to understand its origin, structure, evolution, and destiny.
6. Return the Space Shuttle to flight and focus its use on completion of the International Space Station, complete assembly of the ISS, and retire the Space Shuttle in 2010, following completion of its role in ISS assembly. Conduct ISS activities consistent with U.S. obligations to ISS partners.
7. Develop a new crew exploration vehicle to provide crew transportation for missions beyond low Earth orbit. First test flight to be by the end of this decade, with operational capability for human exploration no later than 2014.
8. Focus research and use of the ISS on supporting space exploration goals, with emphasis on understanding how the space environment affects human health and capabilities, and developing countermeasures.
11. Develop and demonstrate power generation, propulsion, life support, and other key capabilities required to support more distant, more capable, and/or longer duration human and robotic exploration of Mars and other destinations.
12. Provide advanced aeronautical technologies to meet the challenges of next generation systems in aviation, for civilian and scientific purposes, in our atmosphere and in atmospheres of other worlds.
13. Use NASA missions and other activities to inspire and motivate the Nation's students and teachers, to engage and educate the public, and to advance the scientific and technological capabilities of the Nation.
14. Advance scientific knowledge of the Earth system through space-based observation, assimilation of new observations, and development and deployment of enabling technologies, systems, and capabilities including those with the potential to improve future operational systems.
15. Explore the Sun–Earth system to understand the Sun and its effects on Earth, the solar system, and the space environmental conditions that will be experienced by human explorers, and demonstrate technologies that can improve future operational systems.
17. Pursue commercial opportunities for providing transportation and other services supporting International Space Station and exploration missions beyond Earth orbit. Separate to the maximum extent practical crew from cargo.
18. Use U.S. commercial space capabilities and services to fulfill NASA requirements to the maximum extent practical and continue to involve, or increase the involvement of, the U.S. private sector in design and development of space systems.

In FY 2004 and FY 2005, NASA also included in the Agency's Annual Performance Plan supporting multi-year Outcomes and Annual Performance Goals (APGs) to help the Agency address the difficult task of measuring annual performance against the 18 Objectives. The Outcomes enable NASA to focus and report on multi-year efforts more accurately, and the APGs enable the Agency to provide a clear picture of planned and actual annual performance.

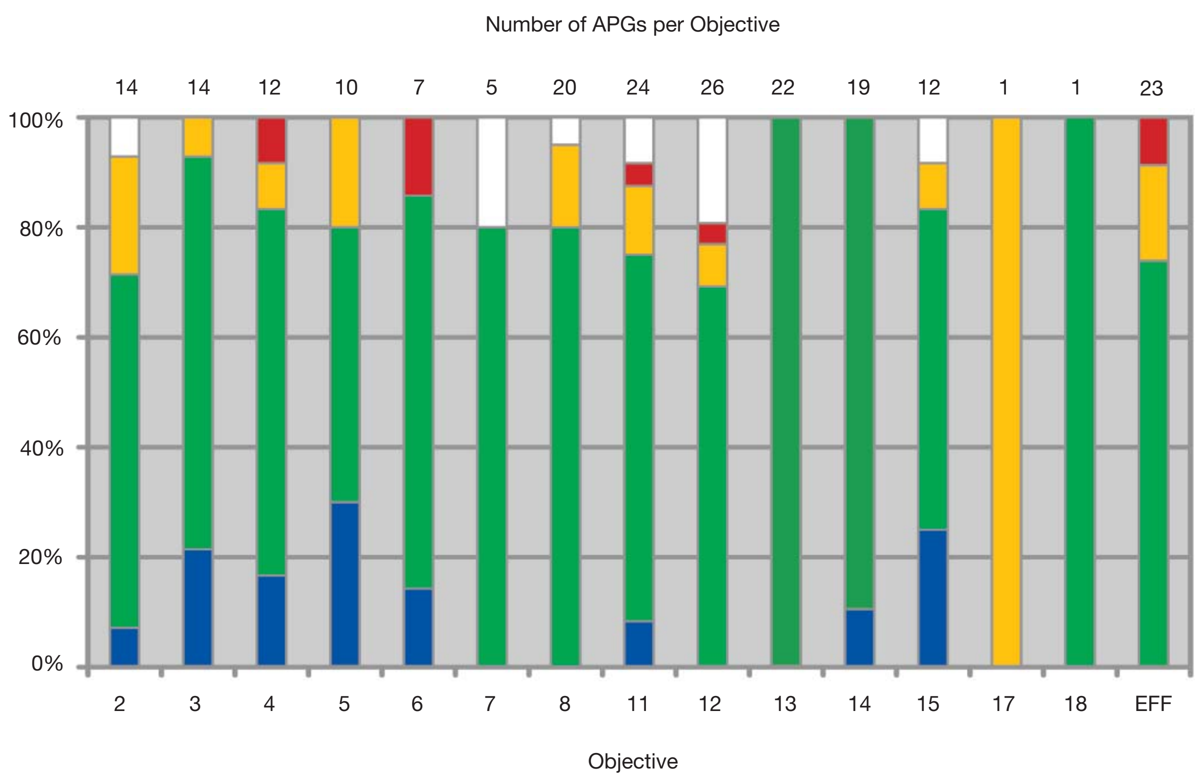
Part 2 of this report, "Detailed Performance Data," describes each of NASA's Objectives and provides a detailed performance report and color rating for each Outcome, including available trend data. Part 2 also includes color ratings for each APG, as well as APG trend data for up to four years, where applicable. (Performance ratings for NASA's Uniform Measures are located at the end of Part 2, preceded by a brief explanation of their purpose and organization.) Finally, Part 2 includes NASA's Performance Improvement Plan addressing all FY 2005 Outcomes and APGs that were not achieved fully.

The APG and Outcome ratings in Part 2 reflect NASA management's intense efforts to evaluate thoroughly and objectively the Agency's performance based on all data available as of September 30, 2005. Internal reviewers (NASA employees and managers at many levels across the Agency) reviewed the performance results and recommended APG color ratings to NASA senior officials. In some cases, external reviewers (e.g., highly qualified individuals, advisory boards, and advisory councils outside NASA) also assisted in this evaluation process by reviewing the same performance results and independently recommending specific APG color ratings. Following careful assessment of all performance data and results, as well as the color rating recommendations of both the internal and external reviewers, NASA senior management officials assigned color ratings to each APG using the following color rating criteria:

APG Rating Scale

Blue	Significantly exceeded the APG.
Green	Achieved the APG.
Yellow	Failed to achieve the APG, but NASA made significant progress and anticipates achieving the APG next fiscal year.
Red	Failed to achieve the APG, and NASA does not anticipate completing it within the next fiscal year.
White	This APG was postponed or canceled by management directive.

The figure below provides a summary of NASA's FY 2005 APG performance by Objective.



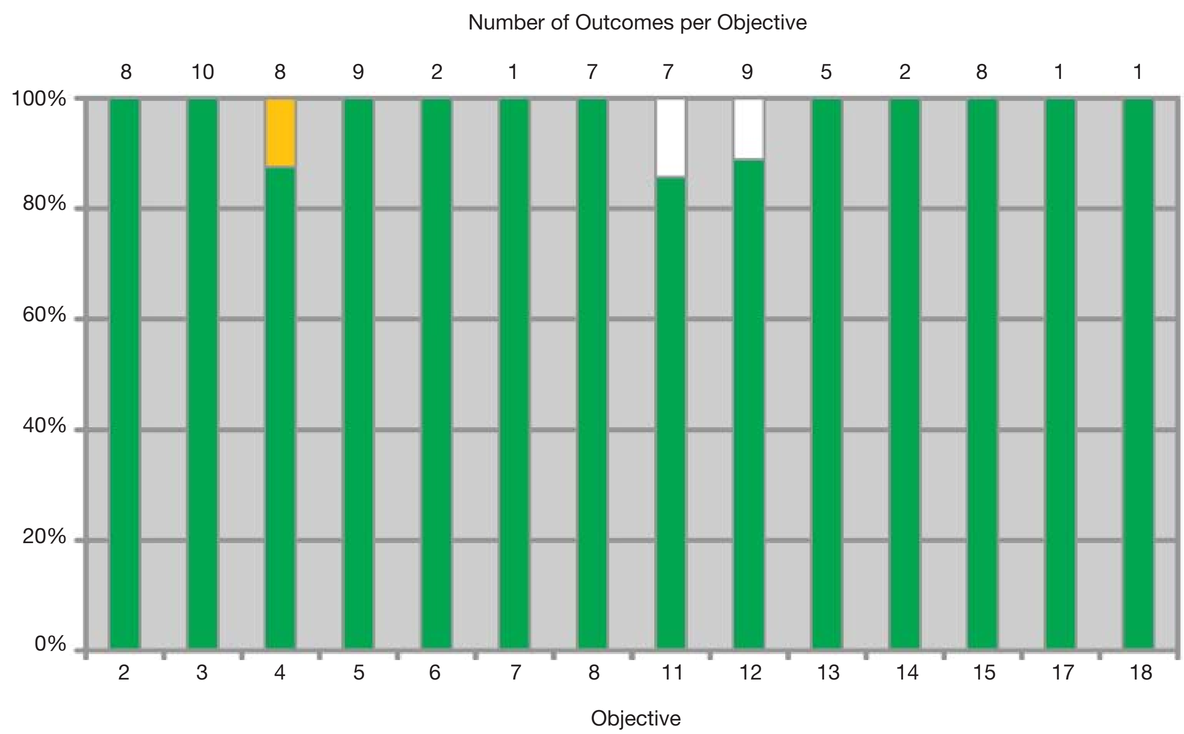
Next, aided again in many cases by recommendations from internal and external reviewers, NASA senior management assigned color ratings to each Outcome. (Please note that Outcome ratings are not averages of APG ratings, and they are not based solely on the Agency's performance in the current fiscal year. Outcome ratings are based on NASA's progress toward achieving the multi-year performance goal. Therefore, it is possible to have APGs rated Yellow or Red and still be on target to achieve an Outcome, as stated.)

NASA senior management officials assigned color ratings to each Outcome using the following color rating criteria:

Outcome Rating Scale

Green	Achieved most APGs; on track to achieve or exceed this Outcome.
Yellow	Progress toward the Outcome was significant, however, NASA may not achieve this Outcome as stated.
Red	Failed to achieve most APGs, and NASA does not expect to achieve this Outcome as stated.
White	This Outcome was postponed or canceled by management directive or this Outcome is no longer applicable based on management changes to the APGs.

The figure below provides a summary of NASA's FY 2005 Outcome performance by Objective.



NASA is including a Performance Improvement Plan in this year's report. This Plan addresses, in detail, each APG and Outcome that was not fully achieved (rated Green) in FY 2005. For each unmet Performance Outcome or APG, the Performance Improvement Plan presents an explanation as to why the metric was not met and how NASA plans to improve performance in this metric (or why NASA will be eliminating this metric) in the future. This Plan also demonstrates how future performance improvements will enable NASA to achieve many Outcomes in spite of current year APG ratings of Yellow or Red.

Objective 2: Conduct robotic exploration of Mars to search for evidence of life, to understand the history of the solar system, and to prepare for future human exploration.

WHY PURSUE OBJECTIVE 2?

Since NASA's Mariner 4 spacecraft took the first close-up picture of Mars in 1965, robotic missions to Earth's red neighbor have revealed a planet that is strangely familiar, yet different enough to challenge perceptions of what makes a planet work. After every mission, new discoveries send scientists back to the drawing board to revise existing theories about Mars and the solar system.

Mars shares many of Earth's features, including polar ice caps, seasonal weather patterns, clouds, volcanoes, and canyons. Recent NASA missions to Mars—the twin Mars Exploration Rovers, Mars 2001 Odyssey, and Mars Global Surveyor—found evidence of water, an essential element for life, in landscape formations and in the composition of some of its rocks. These findings indicate that rivers and lakes of liquid water once flowed across the red planet's now-desolate surface.

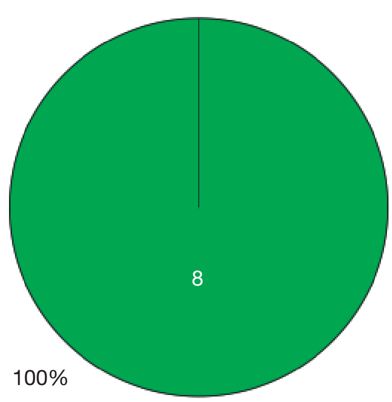
This discovery sparked many questions about what caused the differences and similarities between Earth and Mars. Does Mars have reservoirs of water under its surface? Did Mars once harbor life? Could life still exist in canyons or deep under the surface? If Mars has the potential to support life, could other planets or moons in the solar system support life? What can Mars tell scientists about the history of the solar system?

The Mars Reconnaissance Orbiter, launched in August 2005, continues NASA's efforts to answer these questions. As the spacecraft circles Mars, it will search remotely for water under the surface, analyze the planet's geology and atmosphere, and search for resources that could help humans explore Mars and places beyond. NASA also is planning future missions, like the Mars Science Laboratory, that will examine the red planet up close and in unprecedented detail.

Left: *Spirit* looks out across the Columbia Hills of Gusev Crater in this section of a panorama composed of pictures taken on August 24 to 26, 2005. In the center is the Inner Basin, where rover team members planned to send *Spirit* in the future. (Photo: NASA/JPL–Caltech/Cornell)

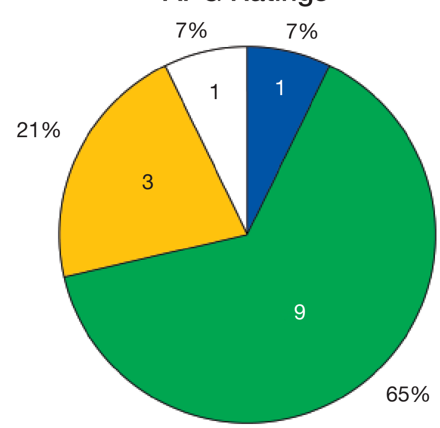
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 2, NASA is on track to achieve all 8 Outcomes.

APG Ratings



Under Objective 2 NASA achieved or exceeded 10 of 14 APGs.

Outcome 2.1: Characterize the present climate of Mars and determine how it has evolved over time.

FY 2005	FY 2004
Green	Green

(5.3.1)

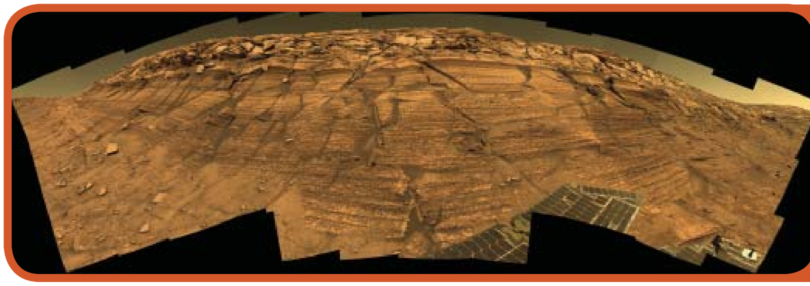
Mars Exploration Rovers continue to reveal Mars' climate secrets

In FY 2005, the Mars Exploration Rovers (*Spirit* and *Opportunity*) continued studying the present climate of Mars. The long life of the rovers has allowed them to monitor seasonal changes in the atmosphere. *Opportunity* saw frost and clouds marking the seasonal movement of water vapor from Mars' north pole to its south pole. From its perch near the top of Husband Hill, *Spirit* captured images of dust devils moving across the floor of Gusev Crater. The rovers' observations show that as the Martian summer nears and the area warms up, dust devil activity increases. The amount of dust varies with the season on Mars, and dust devils appear to play an important role in Martian weather because they inject dust into the atmosphere. NASA will use measurements from the rovers, the Mars Global Surveyor, and the Mars Odyssey to improve climate models in preparation for future robotic and human landed missions.

Opportunity glimpsed Mars' past by examining the layers of rock in Burns Cliff in the Endurance Crater. The sequence of rocks exposed there describes Mars' ancient changeable climate which varied repeatedly from desert conditions to wet periods with a fluctuating water table that saturated some of the rock layers.

Understanding the Martian atmosphere

The atmosphere of Mars undergoes rapid and drastic variations in density. Understanding these variations is essential to date the surface of Mars. One way to estimate the age of a planet's surface is by the number of impact craters created by falling meteorites. However, variations in a planet's atmospheric density could affect this analysis. If the atmosphere is thick, it will prevent smaller meteorites from reaching the surface, because the increased friction caused by the thicker atmosphere will heat many smaller meteorites until they disintegrate. By analyzing the relationship between Mars' atmospheric density and the rate at which craters are formed, researchers can gain a better view of the processes in the atmosphere and on the surface that shaped the Martian landscape.



NASA's Mars Exploration Rover *Opportunity* captured this view of Burns Cliff after driving to the base of this southeastern portion of the inner wall of Endurance Crater. The view combines frames taken by *Opportunity*'s panoramic camera from November 13 to 20, 2004. (Photo: NASA/JPL/Cornell)

	FY 2005 Annual Performance Goals	FY 2004	FY 2003	FY 2002
5MEP5 White	Successfully complete the Mission Concept Review and PMSR for the 2009 Mars Telesat Orbiter (NOTE: this APG supports all MEP research focus areas).	none	none	none
5MEP7 Green	Successfully demonstrate progress in characterizing the present climate of Mars and determine how it has evolved over time. Progress towards achieving outcomes will be validated by external review.	4MEP9 Green	none	none

Performance Shortfalls

APG 5MEP5: NASA did not hold the Preliminary Mission System Review for the 2009 Mars Telesat Orbiter. The Mars Telesat Orbiter was canceled as part of a reprioritization of science.

Outcome 2.2: Understand the history and behavior of water and other volatiles on Mars.

FY 2005	FY 2004
Green	Blue

(5.3.2)

Mars Exploration Rovers and the search for Mars' water

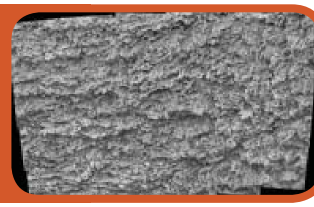
The Mars Exploration Rovers have explored the surface of Mars well past their design lifetimes, sampling regions not originally thought accessible. They continue to find evidence of past episodes of standing liquid water. These results, in part, led to the Mars rovers being declared "Breakthrough of the Year" by *Science* magazine in its December 17, 2004, issue.

After landing, *Spirit* found itself on a dry volcanic plain where the rocks had been slightly altered by small amounts of water. However, once the rover reached Columbia Hills, the rocks indicated that the ancient hills predating the lava flows were once bathed by large amounts of water. For several months, *Spirit* climbed a flank of Husband Hill, the tallest in the range, and examined the rocks along the way. Rocks from different layers share compositional traits, suggesting a shared origin. However, the degree to which minerals in rocks have been altered chemically by exposure to water or other processes varies greatly from outcrop to outcrop. The textures also vary greatly. The hypothesis that best fits these data postulates that the hills are a stack of volcanic ash or debris that erupted explosively from volcanoes and settled down into different environments. In some cases, additional interaction with water over time altered the rocks even more. *Spirit* also found that many of the rocks contained a large amount of sulfate salt, and the rover's spectrometer identified the mineral goethite in some rocks, a mineral that only forms in the presence of water.

Martian water—boiling and freezing at the same time?

Since their first discovery, orbital images of Mars suggested that the planet's gullies are relatively young and were formed by running water. Scientists find these results to be paradoxical because liquid water is unstable on the Martian surface. The surface temperatures and pressures at many of the gullies' locations are below the "triple point" where liquid water normally will boil or freeze spontaneously. Surprisingly, new numerical simulations indicate that these gullies formed in the low temperature and pressure conditions of present day Mars by the action of relatively pure liquid water boiling and freezing simultaneously.

This mosaic of 24 frames from *Spirit*'s microscopic imager shows the texture of a target called "Keystone" on the "Methuselah" outcrop of layered rock on Husband Hill inside Mars' Gusev Crater. The target area shows fine layers that may have been deposited by wind or water. The images were taken on April 28, 2005. (Photo: NASA/JPL/Cornell/USGS)



FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5MEP1 Green	Successfully complete assembly, test, and launch operations (ATLO) for the Mars Reconnaissance Orbiter mission.	none	none	none
5MEP2 Green	Successfully launch the Mars Reconnaissance Orbiter.	none	none	none
5MEP8 Blue	Successfully demonstrate progress in investigating the history and behavior of water and other volatiles on Mars. Progress towards achieving outcomes will be validated by external review.	4MEP10 Blue		

Spotlight: Rover Team Tests Mars Moves on Earth

For more than a year, the Mars Exploration Rover *Opportunity* stealthily dodged rocks and dunes as it explored Meridiani Planum, until April 26, 2005, when it became buried up to its wheel hubs in a ripple-shaped, soft-sand dune. A team of engineers at the Jet Propulsion Laboratory quickly began formulating a strategy to get *Opportunity* out of the trap.

The team created a simulated dune in a testing laboratory, but found their test rover had no trouble escaping the dune, even when it was sunk in up to its belly. They experimented with different sand mixtures—blends containing play sand for children's sandboxes, diatomaceous earth for swimming pool filters, and mortar clay powder—until they had more than two tons of simulated Mars sand for more realistic mobility tests. They tested every move carefully before sending directions to *Opportunity*.

After an intensive month of hard work, where the team directed the rover in cautious increments, *Opportunity* finally set its wheels on firm sand. The rover's next task was to examine the dune to provide the team a better understanding of what made that dune different from the dozens of similar ones the rover easily crossed. This new information will help the team plan a safer route as *Opportunity* continues to explore Mars' rugged terrain.

Rover engineers check how a test rover moves in material chosen to simulate the dune that bogged down *Opportunity* on April 26, 2005. They are working inside the In-Situ Instrument Laboratory at NASA's Jet Propulsion Laboratory. The team will use the information they gained from the tests and *Opportunity*'s observations of the dune to better direct the rover and to develop safer routes for future rover missions. (Photo: NASA)

Outcome 2.3: Understand the chemistry, mineralogy, and chronology of Martian materials.

FY 2005: Green | FY 2004: Blue (5.3.3)

Understanding Mars' geology—past and present

Dr. Jeff Moore of NASA's Ames Research Center and Dr. Mark Bullock of the Southwest Research Institute have been performing experiments simulating the formation of salts on the Martian surface. They found that synthetic Mars water, produced by the interaction of pure water with Mars-like basalts (a type of volcanic rock), has elemental abundances very similar to that of the soil measured by the Viking and Mars Pathfinder landers. They also found that when the water evaporates, salts are left behind that show striking similarities to the salt beds found by the Mars rover *Opportunity*. The chemistry of both the globally-distributed Martian soil and the sulfate deposits at Meridiani point to large-scale chemical reactions between basalt and water at some time in the past.

The European Space Agency's Mars Express spacecraft launches aboard a Russian Soyuz/Fregat launch vehicle from Baikonur, Kazakhstanin this photo taken in summer 2003. The United States is one of 12 countries participating in the mission. (Photo: ESA/S. Corvaja, Starsem)

Martian meteorites as a window into Mars' past

Analyses of tungsten and neodymium isotopes in the Martian meteorites revealed the chronology of crust and mantle formation on Mars. This study showed that the mantle sources of these meteorites were formed earlier than 4.525 billion years ago, possibly by solidification of an early magma ocean on Mars.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5MEP9 Green	Successfully demonstrate progress in studying the chemistry, mineralogy, and chronology of Martian materials. Progress towards achieving outcomes will be validated by external review.	4MEP11 Blue	none	none

Outcome 2.4: Determine the characteristics and dynamics of the interior of Mars.

FY 2005: Green | FY 2004: Green (5.3.4)

Researchers believe that Mars has a metallic core, but a lack of seismic data (due to the absence of any seismometers on Mars) has prevented them from confirming whether the core is solid or liquid. Other geophysical data, including magnetic measurements from Mars Global Surveyor (also known as MGS), suggest that early Mars possessed a magnetic field generated by a "planetary dynamo," caused by the movement of molten fluids in the planet's core. Measurements of tidal deformation, along with the inferred presence of a planetary dynamo, suggest that at least the outer part of the Martian core is liquid.

Understanding Martian volcanoes

An analysis of a tight ring of fractures around each of three Martian volcanoes in the Tharsis Rise (an ancient volcanic province that spans a quarter of the surface of Mars) suggests that the Tharsis Rise was not much warmer than the rest of Mars when the volcanoes formed. Previous mechanical models had difficulty explaining these rings, mainly because the rings are so close to the volcanoes and do not extend far. By modifying the models to include a phenomenon analogous to one that occurs in the crust beneath some of Earth's volcanoes, researchers are closer to understanding how the rings and Mars' surface formed.

This composite from the Mars Global Surveyor of images taken on July 6, 2005, shows an isolated water ice cloud extending more than 18 miles above the Martian surface. Clouds such as this are common in late spring over the terrain located southwest of the Arsia Mons volcano. Arsia Mons is the dark, oval feature near the limb, just to the left of the "T" in the "Tharsis Montes" label. The dark, nearly circular feature above the "s" in "Tharsis" is the volcano, Pavonis Mons, and the other dark circular feature, above and to the right of "s" in "Montes," is Ascraeus Mons. (Image: NASA/JPL/Malin Space Science Systems)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5MEP10 Green	Successfully demonstrate progress in determining the characteristics and dynamics of the interior of Mars. Progress towards achieving outcomes will be validated by external review.	4MEP12 Green	none	none

Outcome 2.5: Understand the character and extent of prebiotic chemistry on Mars.

FY 2005	FY 2004
Green	Green (5.4.1)

Looking for signs of life in Mars-like soils

Researchers studied Mars-like soils in the extreme arid region of the Atacama Desert in Chile. These soils have trace levels of organic compounds and extremely low levels of culturable bacteria. Incubation experiments with the soils show that non-biological processes actively decompose organic species. These experiments support the theory that the present lack of organic material on the surface of Mars is due to the high radiation and oxidizing environment.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5MEP4 Yellow	Successfully complete the Preliminary Mission System Review (PMSR) for the 2009 Mars Science Laboratory (MSL) mission.	none	none	none
5MEP6 Green	Successfully complete Preliminary Design Review (PDR) for Laser Communication Demonstration (NOTE: this APG supports all Mars Exploration research focus areas).	none	none	none
5MEP11 Yellow	Successfully demonstrate progress in investigating the character and extent of prebiotic chemistry on Mars. Progress towards achieving outcomes will be validated by external review.	4MEP13 Green	none	none

Performance Shortfalls

APG 5MEP4: NASA postponed the Preliminary Mission System Review for the 2009 Mars Science Laboratory. The review is scheduled for December 2005, with no impact to the mission launch date.

APG 5MEP6: Although there was no performance shortfall for this APG, the Laser Communication Demonstration was canceled, after the Preliminary Design Review was completed, as part of the reprioritization of NASA's science goals. NASA will complete several key technology elements, including ground system detectors and flight-like optical transmitter breadboard, due to their long-term scientific value. NASA also will catalog and archive the associated data so that the matured technologies can be applied in future development and possibly future missions.

APG 5MEP11: NASA did not make sufficient progress in investigating the character and extent of prebiotic chemistry on Mars due to a lack of currently operating flight missions designed to address this Outcome.

Outcome 2.6: Search for chemical and biological signatures of past and present life on Mars.

FY 2005	FY 2004
Green	Green (5.4.2)

Martian methane—a sign of life?

During FY 2005, several scientists, including those funded by NASA, detected very small amounts of methane in the Martian atmosphere. Some scientists also reported spatial and temporal variations in methane concentration. These observations may indicate the presence of current or extinct Martian life.

NASA and Michigan State University scientists found methane-generating bacteria living in young volcanic deposits, both hot and cold, on the Ploskii Tolbachik volcano, shown here, on Russia's Kamchatka Peninsula. Scientists using data from the European Space Agency's Mars Express spacecraft reported finding small amounts of methane in Mars' atmosphere. A potential source is volcanoes like Olympus Mons or methane-generating bacteria like those found on Earth. Scientists will continue to debate the topic and search for new and better ways to duplicate and improve measurements of methane on Mars. (Photo: NASA/MSU)

Searching for signs of life in Mars' past—here on Earth

Studies of the Martian meteorite ALH84001 suggest that magnetite crystals may be a biosignature, a chemical sign of life. On Earth, some bacteria use chains of small magnetite crystals to help them stay at an optimal depth in sediments. NASA-supported researchers are using state-of-the-art computations to understand which features of magnetite crystals are biosignatures and which are due to basic physics. These studies also are furthering the development of Ferromagnetic Resonance Spectroscopy as a tool for biosignature detection—a method that holds great promise for future missions to Mars.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5MEP3 Green	Complete science instrument selections for the 2009 Mars Science Laboratory (MSL).	none	none	none
5MEP12 Green	Successfully demonstrate progress in searching for chemical and biological signatures of past and present life on Mars. Progress towards achieving outcomes will be validated by external review.	4MEP14 Green	3S6 Green	2S6 Green

FY 2005	FY 2004
Green	Blue (5.5.1)

Outcome 2.7: Identify and understand the hazards that the Martian environment will present to human explorers.

Working with the biomedical, advanced life support, advanced extravehicular activity, and advanced environmental monitoring and control communities, NASA began a comprehensive suite of studies to identify the potential hazards Mars poses to human explorers. These studies also will enable scientists to protect Earth from possible biological contamination from hardware and samples returned from Mars. The team published "Planetary Protection Issues in the Human Exploration of Mars" as a NASA Conference Publication. They also developed, in cooperation with the European Space Agency, requirements for life support and extravehicular activity systems to protect exploration crews—and Earth—from potential biological threats. The requirements include an overall strategy for avoiding Martian hazards (while also protecting Mars science, such as the search for biosignatures, from the influence of the human explorers) and specific requirements on crew support systems and operational practices for Mars missions.

Dust devils move from right to left across a plain inside Mars' Gusev Crater in this image taken on July 13, 2005, by the Mars Exploration Rover *Spirit* in hills rising from the plain. The number of dust devils the rover sees increase during Mars' spring. (Photo: NASA/JPL/Texas A&M)

Looking out for dust devils

Dust devils are vortexes in the atmosphere that act like vacuum cleaners, lifting dust from the surface. Although scientists have been aware of dust devils on Mars for some time, they did not know the amount of dust the devils injected into the atmosphere. Recent laboratory simulations and new observations from the Mars Exploration Rovers now show that dust devils lifted 42 tons of dust a day from the nine-square-mile area observed by *Spirit*. This activity is a function of Martian season and time of day. Therefore, Martian dust devils may play a significant role in generating larger dust storms on Mars, and they must be factored in as potential hazards for future surface operations for robotic and human explorers.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5MEP13 Green	Successfully demonstrate progress in identifying and studying the hazards that the Martian environment will present to human explorers. Progress towards achieving outcomes will be validated by external review.	4MEP15 Blue	3S8 Green	2S8 Blue

FY 2005	FY 2004
Green	Blue
	(5.5.2)

Outcome 2.8: Inventory and characterize Martian resources of potential benefit to human exploration of Mars.

Mars Reconnaissance Orbiter on its way to the red planet

The recently launched Mars Reconnaissance Orbiter (commonly known as MRO) will be able to identify and map mineral formations at a much finer scale than previous orbiters. It also will be able to determine whether the ice found by Mars Odyssey is the top layer of a deep ice deposit or a shallow layer in equilibrium with the current atmosphere and its seasonal cycle of water vapor.

This crescent view of Earth's Moon in blue–green wavelengths comes from a camera test by NASA's Mars Reconnaissance Orbiter spacecraft on its way to Mars. The mission's High Resolution Imaging Science Experiment camera took the image on September 8, 2005, while at a distance of about 6 million miles from the Moon. The Mars Reconnaissance Orbiter, launched on August 12, 2005, should reach Mars on March 10, 2006. (NASA/JPL/Univ. of Arizona)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5MEP14 Yellow	Successfully demonstrate progress in inventorying and characterizing Martian resources of potential benefit to human exploration of Mars. Progress towards achieving outcomes will be validated by external review.	4MEP16 Blue	3S8 Green	2S8 Blue

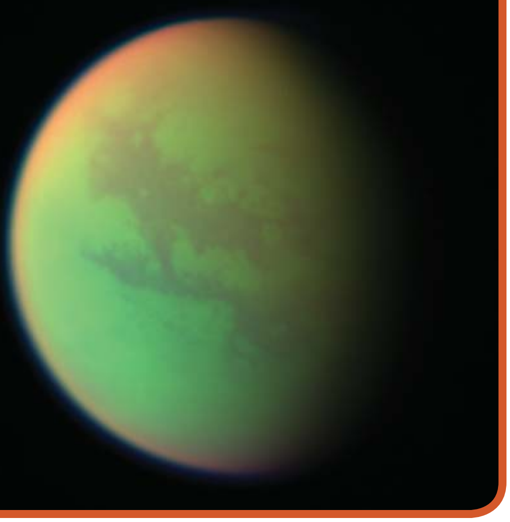
Performance Shortfalls

APG 5MEP14: NASA did not make sufficient progress in inventorying and characterizing Martian resources of potential benefit to human exploration of Mars due to a lack of currently operating flight missions designed to address this Outcome.

Resources

NASA's FY 2005 budgeted cost of performance for Objective 2 was $0.59 billion. NASA cannot provide FY 2005 budgeted cost of performance information at the Outcome level for this Objective.

Objective 3: Conduct robotic exploration across the solar system for scientific purposes and to support human exploration. In particular, explore Jupiter's moons, asteroids, and other bodies to search for evidence of life, to understand the history of the solar system, and to search for resources.



WHY PURSUE OBJECTIVE 3?

The solar system is a place of incredible variety: small, terrestrial planets, immense gas giants, rocky asteroids clustered together to form belts, and beautiful comets in eccentric orbits made of dust and ice. Each object seems enticingly unique. Yet, as scientists study the solar system, they discover astonishing similarities between Earth and its solar system neighbors, from signs of past oceans on Mars to the existence of organic compounds within the atmosphere of Saturn's moon, Titan.

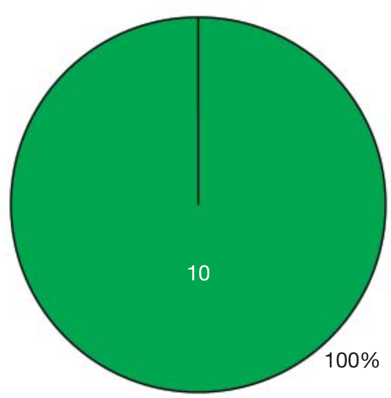
NASA conducts robotic missions of different complexities and scopes to answer fundamental questions about how the solar system formed and evolved, how Earth and this planet's life forms were created, and whether life exists elsewhere in the solar system. These missions also provide insight into how other, distant solar systems form and whether they may have the potential for life.

In the future, astronauts will explore the solar system. Today's robotic missions are laying the groundwork for this exploration by identifying potential targets, characterizing hazards, and searching for resources like oxygen and metals that will help astronauts safely journey farther from home.

Left: Titan's atmosphere glows blue and red in this false-colored image taken by the Cassini spacecraft during its April 16, 2005, flyby of Saturn's moon. Titan is enclosed by a thick, hazy atmosphere that is impenetrable by telescopes and cameras. The Huygens Probe, supplied by the European Space Agency and carried aboard Cassini, descended to the moon's surface in January 2005, giving the world its first glimpse of the mysterious moon beneath the haze. (Image: NASA/JPL/Space Science Institute)

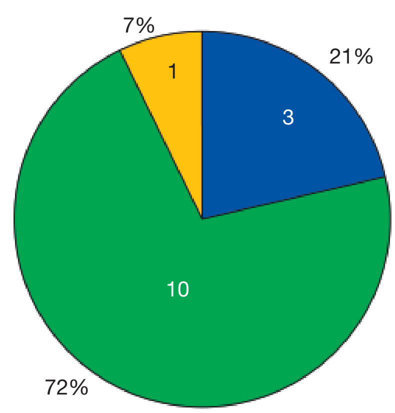
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 3, NASA is on track to achieve all 10 Outcomes.

APG Ratings



Under Objective 3, NASA achieved or exceeded 13 of 14 APGs.

FY 2005	FY 2004
Green	Yellow
	(5.1.1)

OUTCOME 3.1: UNDERSTAND THE INITIAL STAGES OF PLANET AND SATELLITE FORMATION.

Meteorites and the formation of the solar system

Detailed work on meteorites embedded with small, round granules of solar system materials called chondrules shows that the oldest materials preserved from the formation of the solar system are the calcium–aluminum-rich inclusions that formed a few million years before chondrules. Recently published work shows that at least some of these calcium–aluminum-rich inclusions remelted about two million years after their formation, revealing exquisite details about the processes and the timing of events during the formation of the solar system.

Understanding the formation of extra-solar systems

The discovery of over a hundred extra-solar planetary systems has profound implications for how Earth's solar system formed. The fact that Jupiter-mass planets appear to be commonplace around sun-like stars means that the formation mechanism for such gas giant planets must be fairly robust. Scientists have two competing theories explaining their formation: core accretion and disk instability. By examining disk instability models, scientists found that cooling of the dusty disk by vertical flows (similar to those in a boiling pot of water being heated at its bottom) created gravitational instability that can cause a gas giant planet to form.

Researchers in the Genesis Laboratory cleanroom at Johnson Space Center remove the concentrator targets and grid assembly from nitrogen storage to begin sample extraction. The Genesis mission sample return capsule crash landed in the Utah desert in September 2004 when its parachute failed to open. Despite this, its four collector arrays, vital to the scientific success of the mission, were in good shape and NASA expects to meet most of the mission's science objectives. Concentrators inside the arrays collected solar-oxygen ions blown by solar wind, which will provide clues to how the solar system was formed. (Photo: NASA)

Reaping the research of Genesis

The Genesis science team reported that the mission achieved most of its scientific goals despite the spacecraft's "hard landing" last year. This year, NASA made initial allocations of solar wind materials collected during the mission to science team members and announced the schedule for allocating samples to the outside science community. In addition, NASA made major progress on developing procedures for cleaning the surfaces of gross contaminants introduced by the impact of the sample return capsule with the Utah desert and of surface films from spacecraft degassing. Researchers also began measuring noble gas isotopic ratios that will provide clues to the solar system's age and processes that formed solar system objects. Researchers will publish scientific papers containing the mission's results in FY 2006.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE2 Green	Complete integration and testing for New Horizons/Pluto.	none	none	none
5SSE4 Green	Release a NASA Research Announcement (NRA) for in space power and propulsion technology development activities. (NOTE: this APG could potentially support multiple SSE research focus areas).	none	none	none
5SSE7 Green	Successfully demonstrate progress in understanding the initial stages of planet and satellite formation. Progress towards achieving outcomes will be validated by external review.	4SSE12 Yellow	none	none

FY 2005	FY 2004
Green	Green (5.1.2)

OUTCOME 3.2: UNDERSTAND THE PROCESSES THAT DETERMINE THE CHARACTERISTICS OF BODIES IN OUR SOLAR SYSTEM AND HOW THESE PROCESSES OPERATE AND INTERACT.

Unlocking the secrets of Saturn and its moons

The Cassini spacecraft (with 12 instruments) and its European-built companion, the Huygens probe (with six instruments), entered the Saturn system on July 1, 2004—almost seven years after launching from Cape Canaveral. On approach to Saturn, Cassini flew within 1,305 miles of its outermost moon, Phoebe. Analyzing Cassini's observations of Pheobe's surface composition and density, researchers have concluded that Phoebe is a captured object from the Kuiper Belt, the mysterious, debris-laden region beyond the orbit of Neptune.

While Cassini crossed Saturn's ring plane, the probe's instruments tracked lightning associated with storms, clouds, vertical wind shears, and thermal variations in the atmosphere. Observations of Saturn's kilometric radiation suggest that Saturn's rotation rate has slowed by about six minutes since Voyager observed it in 1981. Although more research is needed, scientists believe the slowing is due to momentum exchange between the rings, the magnetosphere, and the planet.

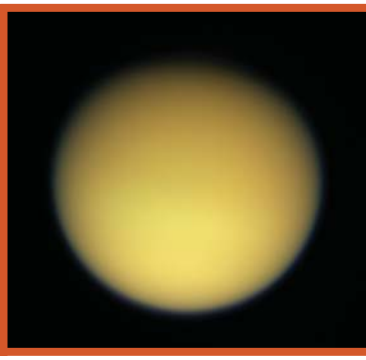
The Huygens probe was released from Cassini on Christmas Day 2004 and landed on Titan's surface on

January 14, 2005. The probe functioned perfectly, taking high-resolution images and other science data on its two-an-half-hour descent through Titan's atmosphere and landing intact in a marshy area. In defiance of all expectations, the probe continued to transmit data to the orbiting Cassini spacecraft until Cassini went below the horizon. Cassini then transmitted the data back to Earth.

During FY 2005, Cassini mapped 60 percent of Titan's surface using visible and infrared cameras. This is augmented by high-resolution, cloud-penetrating radar images of two percent of the surface. The surface appears to be relatively young and flat. It has only a few large and degraded impact craters and a striking variation in surface deposits. Together, these features indicate geological activity with active resurfacing and weathering by methane rain and perhaps snow formed from higher hydrocarbons. Cassini also found evidence for ammonia–water volcanism. Liquid methane appears to be flowing onto Titan's surface, resulting in lakes, rivers, and shorelines. Cassini's instruments identified more than a dozen simple hydrocarbons that are known to be necessary precursors for life.

New insight on the Moon

Researchers studying a lunar meteorite discovered in Africa found it to be only 2.9 billion years old, the youngest age date known for a lunar rock. This indicates that volcanism was active on the Moon for a significantly longer period than previously thought.

The European Space Agency's Huygens probe took this image (left) of Titan's surface—the first ever close-up view—on January 14, 2005. The image is colored, using data from the probe, to reflect the actual color. Telescopes and passing spacecraft are unable to view the surface because of Titan's smoggy atmosphere, shown in this natural-color image (right) taken by Cassini on February 15. (Huygens: NASA/JPL/ESA/University of Arizona; Cassini: NASA/JPL/Space Science Institute)

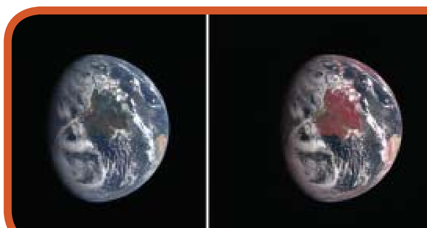
FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE8 Blue	Successfully demonstrate progress in studying the processes that determine the characteristics of bodies in our solar system and how these processes operate and interact. Progress towards achieving outcomes will be validated by external review.	4SSE13 Green	3S3 Green	2S3 Green

Outcome 3.3: Understand why the terrestrial planets are so different from one another.

FY 2005	FY 2004
Green	Green (5.1.3)

MESSENGER continues its journey to Mercury

NASA's MESSENGER spacecraft flew by Earth on August 2, 2005, one year after its launch, to use the pull of gravity to guide it towards Mercury's orbit (following two flybys of Venus and three of Mercury). The spacecraft will enter Mercury orbit in March 2011. MESSENGER then will conduct a one-year, in-depth investigation of the planet. The mission scientists and operations team used the Earth flyby to calibrate the remote sensing instruments. The MESSENGER project also completed the in-orbit check-out of the spacecraft and its instruments.



MESSENGER's Earth flyby on August 2, 2005, adjusted the spacecraft's path to Mercury and gave the science team an opportunity to calibrate the instruments. The composite on the left closely mimics the sensitivity of the human eye. Short wavelength light is scattered on Earth's atmosphere, producing blue skies, but also obscuring the surface. The image on the right is taken in the infrared wavelengths. Since infrared light is not easily scattered, the image shows more detail below the atmosphere. Land appears red due to the high reflectance of vegetation in the near-infrared. (Images: JHU/NASA)

A closer look at the Moon

Recent high-resolution Earth-based radar mapping of the Moon provided information on the properties of the lunar soil to depths of up to 164 feet. NASA mapped a large area of ancient mare basalt, extending westward from Oceanus Procellarum, that is now buried by ejecta (material ejected from an explosion like from a meteor impact or a volcanic eruption) from the Orientale basin. NASA also identified Orientale-derived impact melt deposits in many of the permanently shadowed craters near the Moon's south pole. These results emphasize the predominance of large-scale impact processes in the development of local soil layering for airless bodies like the Moon.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE9 Yellow	Successfully demonstrate progress in understanding why the terrestrial planets are so different from one another. Progress towards achieving outcomes will be validated by external review.	4SSE14 Green	3S5 Green	2S5 Green

Performance Shortfalls

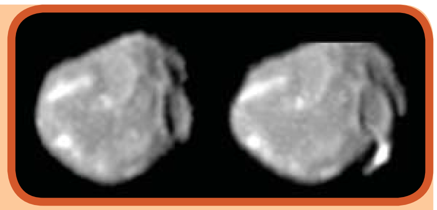
APG 5SSE9: NASA did not make sufficient progress in understanding why the terrestrial planets are so different from one another due to the lack of flight missions planned to address this Outcome in general and Venus in particular.

Spotlight: Icy Jupiter Moon Surprises Scientists

In May 2005, scientists studying data from NASA's Galileo spacecraft found that Jupiter's moon, Amalthea, is a pile of icy rubble less dense than water—not at all what they expected. Scientists expected moons closer to the planet to be rocky. The finding shook up long-held theories of how moons form around giant planets.

Current models imply that temperatures were high at Amalthea's current position when Jupiter's moons formed, but this is inconsistent with Amalthea being icy. This model is based on the theory that early Jupiter, like a weaker version of the early Sun, would have emitted enough heat to prevent volatile, low-density material from condensing and being incorporated into the closer moons. Jupiter's four largest moons fit this model, with the innermost of them, Io, made mainly of rock and iron. The new data suggest that either Amalthea was formed later than the major moons or it was formed farther from Jupiter and then was pulled in by the gas giant. Either of these explanations challenges current models of moon formation around giant planets.

Amalthea is a small, red-tinted moon that orbits about 112,468 miles from Jupiter, considerably closer than the Moon orbits Earth. Analysis of the moon's density, volume, shape, and internal gravitational stresses led the scientists to conclude that Amalthea is not only porous with internal empty space, but also contains substantial water ice.



Several years after the Galileo spacecraft took this image of Jupiter's irregularly shaped moon, Amalthea, the moon threw scientists a curve ball. Recent analysis shows that Amalthea consists largely of water ice, not rock as expected. Although blurry, this image taken in 1999 is among the highest-resolution images of the unusual moon. This "stereo pair" helped scientists study the topography of Amalthea's surface features. (Images: NASA/Cornell Univ.)

Outcome 3.4: Learn what our solar system can tell us about extra-solar planetary systems.

FY 2005	FY 2004
Green	Green (5.1.4)

Understanding the formation of gas giant planets

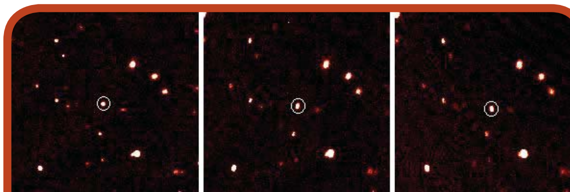
The orbits of the giant planets in Earth's solar system have changed significantly, and violently, since the planets formed. This is inferred from the results of a series of numerical simulations that, for the first time, reproduce much of the observed structure of the outer solar system. This new model envisions that the four giant planets (Jupiter, Saturn, Neptune, and Uranus) formed in a very compact configuration surrounded by a disk of planetesimals. The calculations indicate that the giant planets suffered dramatic orbital changes before settling into their present state. The model also explains many of the observed characteristics of the solar system and will help scientists understand processes that may subtly or dramatically change the orbits of extrasolar giant planets in multiple-planet systems.

Looking for Oort clouds

Computer simulations of synthetic planetary systems show that the number and arrangement of large outer planets can affect the size of a planetary system's Oort cloud (an area on the outer edge of the solar system believed to be the birthplace of most comets), thereby affecting the impact rate on the inner planets. The stability of the arrangement of outer planets also is important, as well, since instability in their orbits can trigger massive comet and asteroid bombardments of the inner planets, much like the Late Heavy Bombardment endured by Earth approximately 3.8- to 4-billion years ago.

Meteorites give insight into early solar system processes

Scientists believe that chondrules (small, round granules of solar system material) are the basic building blocks of planets in the inner solar system. Their rounded shapes imply that they were once flash-heated to melting temperatures, and their textures imply that they then cooled rapidly. Meteorite specialists have sought the mechanism behind this rapid heating for over 100 years. Recent calculations show that in any planet-forming disk capable of forming a Jupiter-mass planet, the spiral arms and clumps that accompany planet formation drive strong shock fronts that appear to be capable of shock-heating dust grains and turning them into chondrules. This process would have occurred early in Earth's solar system, as well as in other planetary systems containing Jupiter-like planets.



These time-lapse images, taken 90 minutes apart, were made on Oct. 21, 2003, using the Samuel Oschin Telescope at the Palomar Observatory near San Diego, California. The object, circled in white to distinguish it from background stars, was so far away that the research team did not identify it as a new-found planet until they reanalyzed the data in 2005. The team announced that the planet, located in the Kuiper Belt, is larger than Pluto. More observations are needed to fully characterize its size and orbit. (Images: Samuel Oschin Telescope, Palomar Observatory)

A new planet?

A new object discovered in the Kuiper Belt appears to be larger than Pluto. Using a 48-inch telescope on Mount Palomar, researchers first saw object "2003UB313" two years ago, but did not recognize it as a planet because its great distance from the Sun means that it moves slowly against the sky, making it difficult to track. Once researchers saw the motion and inferred the distance, they realized that 2003UB313—the third-brightest Kuiper Belt object—is at least as large as Pluto, depending on its intrinsic brightness. This discovery is a result of meticulous, ongoing surveys to discover Kuiper Belt objects, and 2003UB313 challenges the notion that the solar system is composed of only nine planets.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE10 Blue	Successfully demonstrate progress in learning what our solar system can tell us about extra-solar planetary systems. Progress towards achieving outcomes will be validated by external review.	4SSE15 Green	none	none

FY 2005	FY 2004
Green	Green (5.2.1)

Outcome 3.5: Determine the nature, history, and distribution of volatile and organic compounds in the solar system.

Understanding GEMS in the solar system

Extremely fine-grained aggregates called glass with embedded metal and sulfides, or GEMS, are an important and enigmatic component in interplanetary dust particles, commonly known as cosmic dust. GEMS are associated closely with organic carbon components in cosmic dust and probably present the best samples of pre-solar-system organic materials available. Researchers analyzed these materials with a new-generation electron microscope and found that they have spectral features that match those that have been observed by astronomers in the interstellar medium. As a result, researchers established an important link between primitive dust that can be sampled in Earth's solar system and the material present in interstellar space that is the repository of long-dead stars, planetary systems, and the raw material for new systems.

Understanding the origin of organic compounds in Titan's atmosphere

Researchers created a consistent picture of the origin of Titan's atmosphere using Cassini measurements of compounds present at the top of Titan's atmosphere and Huygens probe measurements at the bottom of the atmosphere. The measurements indicated that methane may have been manufactured within Titan from carbon dioxide or other carbon-bearing compounds. These results from Cassini represent new constraints for theories regarding the origin of Titan's atmosphere, specifying much more tightly the primordial material from which the atmosphere was derived.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE3 Green	Select the next New Frontiers mission (NOTE: this APG could potentially support multiple SSE research focus areas).	none	none	none
5SSE11 Green	Successfully demonstrate progress in determining the nature, history, and distribution of volatile and organic compounds in the solar system. Progress towards achieving outcomes will be validated by external review.	4SSE16 Green	none	none

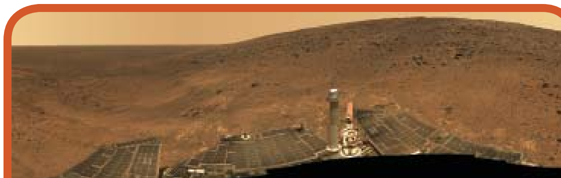
FY 2005	FY 2004
Green	Green (5.2.2)

Outcome 3.6: Identify the habitable zones in the solar system.

Looking for life's hiding places on Mars

Recent data from the Mars Exploration Rovers indicate that early Mars may have had highly acidic environments. Researchers began studies of similar environments on Earth to develop methods for exploring these types of environments and to define new biomarkers that can survive in this extreme environment. Research on the highly acidic Rio Tinto in Spain revealed an astounding, and previously unexpected, diversity of microbial life in the iron-rich river. In another research program, scientists began dissecting the structure and function of a microbial community living in the sulfuric acid- and metal-rich 108-degree Fahrenheit waters of an underground mine. This research used state-of-the-art genetic and chemical analysis tools to determine the genomes of the organisms inhabiting the community and the metabolic functions performed by those organisms.

Researchers interpreted two lines of evidence—remnant paleomagnetism (the magnetic field left over in rocks created by a planet's magnetic field when the rocks were initially formed) and the orientation of valley networks—as signs that the ancient Martian poles and equator were located far from the modern poles and equator. As researchers search for ancient rocks, possibly from warmer and wetter times, they will have to take into account where the poles and equator were at that time.



From the Columbia Hills, *Spirit* can see the peak of Husband Hills toward the right of this image, compiled from pictures taken in July 2005. During its climb to the peak, *Spirit* investigated rocks that appear to have been altered by exposure to water. (Image: NASA/JPL–Caltech/Cornell)

Looking for life's hiding places on Titan

Scientists are considering whether Titan could support life. Data from the Cassini/Huygens mission on the composition of Titan's atmosphere and surface, including the inventory of organic chemicals, will provide scientists with needed constraints on the possibility of life on Titan.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE12 Green	Successfully demonstrate progress in identifying the habitable zones in the solar system. Progress towards achieving outcomes will be validated by external review.	4SSE17 Green	3S6 Green	2S6 Green

FY 2005	FY 2004
Green	Green (5.2.3)

Outcome 3.7: Identify the sources of simple chemicals that contribute to pre-biotic evolution and the emergence of life.

The RNA (ribonucleic acid) World Theory speculates that during the evolution of life on Earth, RNA was the building block of basic biochemical functions for early life forms. This theory suggests that RNA molecules stored information and acted as catalysts to accelerate chemical reactions. Scientists long have thought that large RNA molecules are needed to achieve efficient chemical reactions. They have expended much effort trying to synthesize long RNA chains under plausible prebiotic (pre-life) conditions. Recent experiments, however, show that long RNA chains may not be needed, and that shorter RNA molecules provide the best catalysts.

One of the stumbling blocks to proving the RNA World theory has been the instability of ribose, the key sugar composing the RNA backbone, in water. Researchers now know, however, that the presence of low concentrations of borate minerals stabilizes ribose, making the RNA more resilient.

Meteorites give clues to early life on Earth

The larger portion of organic matter delivered to early Earth by meteorites was a complex macromolecule that is insoluble in water. Recent studies show that this insoluble material breaks down to produce a range of water-soluble organic compounds when exposed to conditions similar to those encountered at a hydrothermal vent (an undersea volcanic vent). These compounds include dicarboxylic acids, which researchers proposed as possible constituents of the earliest biological membranes.

Phosphorus is an element essential to life on Earth, but in the past, researchers believed that the interaction of rocks with water on early Earth did not liberate much of it. In FY 2005, research demonstrated that the amount of water-soluble phosphorus in carbonaceous meteorites, like the Murchison meteorite, may be much greater than that generated by the dissolution of common terrestrial crustal rock. This provides a new clue to the source of phosphorus on the early Earth.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE13 Green	Successfully demonstrate progress in identifying the sources of simple chemicals that contribute to prebiotic evolution and the emergence of life. Progress towards achieving outcomes will be validated by external review.	4SSE18 Green	3S6 Green	2S6 Green

Outcome 3.8: Study Earth's geologic and biologic records to determine the historical relationship between Earth and its biosphere.

FY 2005	FY 2004
Green	Green (5.2.4)

Understanding past mass extinctions on Earth

Using a novel combination of mineral deposit data and organism-specific biomarkers, researchers found clear evidence that during one of Earth's mass extinctions (in which up to 90 percent of marine species died), the upper regions of the ocean were not only oxygen-poor, but also full of sulfide. This suggests that sulfide toxicity helped drive the extinction and slowed the rate of recovery.

Understanding Earth's ancient atmosphere

The history of oxygen in Earth's atmosphere is crucial to understanding the evolution of life on Earth. Recent study results show that prior to 2.4 billion years ago, sulfur isotopes found in rocks were separated independently of their relative masses. This separation could only be produced in a nearly oxygen-free atmosphere. Moreover, experiments indicate that the precise details of the separation can be linked to particular microbial metabolisms, providing more clues to the early evolution of life on Earth.

Out of the sea

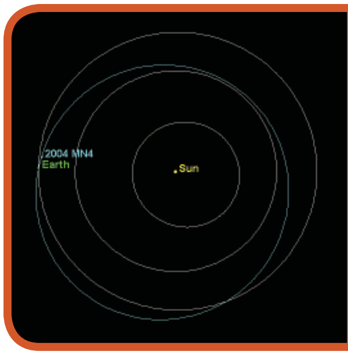
The ancestors of Earth's land-based life lived in the water. Recent research on the evolution of algae, the simplest green plants, uncovered genetic evidence that there may have been as many as 14 independent transitions from an aquatic lifestyle to a land-based lifestyle in the history of plants. If confirmed, this would alter researchers' current understanding of the difficulty of life's ancient transition from the water to the land.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE14 Green	Successfully demonstrate progress in studying Earth's geologic and biologic records to determine the historical relationship between Earth and its biosphere. Progress towards achieving outcomes will be validated by external review.	4SSE19 Green	3S6 Green	2S6 Green

Outcome 3.9: By 2008, inventory at least 90 percent of asteroids and comets larger than one kilometer in diameter that could come near Earth.

FY 2005	FY 2004
Green	Green (1.4.1)

In FY 2005, asteroid search teams funded by the Near Earth Object Observation Program found 57 large objects, bringing the total number known to 799 out of an estimated population of approximately 1,100. In addition,



2004 MN4's orbit around the Sun is shown in blue in the above illustration. Much of the asteroid's orbit lies within Earth's orbit, which is the outermost white circle. The positions of the asteroid and Earth are shown for December 23, 2004, when the object was about 9 million miles from Earth. Astronomers classified it as a near-Earth asteroid in December, when they confirmed that it would pass near Earth in 2029. Although there is no risk of collision during the 2029 pass, astronomers will continue tracking 2004 MN4 to determine its orbit in the more-distant future. (Image: NASA)

teams also found 466 smaller asteroids of less than one kilometer in diameter and three comets with orbits coming within Earth's vicinity, bringing the total number known to 3,582. The teams predict that none of the objects are likely to hit Earth in the next century, but 724 are in orbits that could become a hazard in the more distant future and warrant monitoring, and 153 are larger than one kilometer in diameter. Of these hazards, 89 were found this year alone, 10 of which are larger than 1 kilometer in diameter.

One very significant discovery this fiscal year was an asteroid designated 2004 MN4. Researchers predict that this object will approach Earth on April 13, 2029, coming within 20,000 miles of Earth's surface—inside the orbit of geosynchronous satellites. Using planetary radar observations, researchers eliminated any probability of impact on this pass. But future passes of the object bear watching, as it returns to Earth's vicinity about every six to seven years.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE5 Green	Successfully demonstrate progress in determining the inventory and dynamics of bodies that may pose an impact hazard to Earth. Progress towards achieving outcomes will be validated by external review.	4SSE10 Green	none	none

FY 2005	FY 2004
Green	Green (1.4.2)

Outcome 3.10: Determine the physical characteristics of comets and asteroids relevant to any threat they may pose to Earth.

Making a "Deep Impact" on the study of comets

On July 4th, the Deep Impact mission successfully rendezvoused with comet 9P/Tempel 1 and deployed Deep Impact's autonomous impactor. The impactor struck the comet nucleus at 1:52 AM EDT. The impact was monitored by the Deep Impact flyby spacecraft, the Hubble and Spitzer Space Telescopes, the Chandra X-ray Observatory, XMM–Newton, GALEX, FUSE, and Rosetta spacecraft, 60 ground-based observatories in 20 countries, and an international network of amateur astronomers. The results of these observations will provide the first analysis of material from the interior of a comet.

Studying asteroids to mitigate possible hazards to Earth

Understanding the structure of asteroidal bodies has implications for the hazards they pose and for how to mitigate such hazards. A recent investigation of the population of impact craters on asteroid 433 Eros indicates that while the interior of Eros is dense enough to transmit seismic energy over many miles, the exterior of the asteroid must be composed of relatively non-cohesive material. Therefore, any attempt to destroy or disrupt a potentially hazardous asteroid may have to penetrate it deeply to be effective.

The sun rises at Cape Canaveral Air Force Station, Florida, on January 12, 2005, where the Boeing Delta II rocket carrying the Deep Impact spacecraft waits for launch. (Photo: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSE1 Green	Successfully launch Deep Impact.	none	none	none
5SSE6 Blue	Successfully demonstrate progress in determining the physical characteristics of comets and asteroids relevant to any threat they may pose to Earth. Progress towards achieving outcomes will be validated by external review.	4SSE11 Green	3S8 Green	2S8 Blue

Resources

NASA's FY 2005 budgeted cost of performance for Objective 3 was $1.15 billion. NASA cannot provide FY 2005 budgeted cost of performance information at the Outcome level for this Objective.

Objective 4: Conduct advanced telescope searches for Earth-like planets and habitable environments around the stars.

WHY PURSUE OBJECTIVE 4?

Far beyond Earth's solar system, other planets have formed from the dusty debris surrounding distant stars. Thanks to NASA's eyes in the sky, including the Spitzer and Hubble Space Telescopes, and NASA-supported ground-based telescopes, scientists have discovered more than 150 extrasolar planets, including Jupiter-sized gas giants, or so-called "Super Jupiters," that dwarf any planet in Earth's solar system. The greater challenge for extrasolar planet hunters is to find small planets, particularly ones containing the necessary ingredients for life.

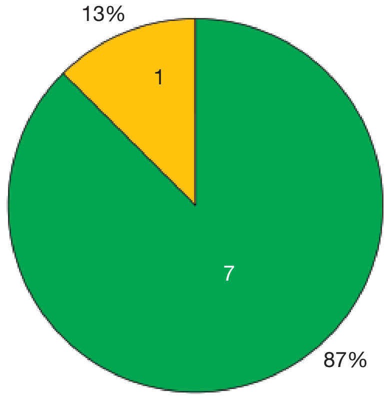
Scientists believe that life is unlikely on gas giants that have crushing gravity levels, toxic atmospheres, and no solid surfaces. To find life, scientists must find Earth-like planets. During FY 2005, NASA made great strides toward finding such extrasolar planets by perfecting current search techniques, like identifying organic molecules within planet-forming disks, and planning the next-generation of highly sensitive telescopes.

Humans have sought answers to fundamental questions for all of time. Are we alone? Is life abundant elsewhere in the universe? Can humankind safely venture beyond the solar system? Are there other planets in the vast universe that humans one day could turn into a second home? With the help of scientists worldwide, NASA is seeking answers to these questions.

Left: In this artist's impression, a hypothetical terrestrial planet and moon orbit the red dwarf star AU Microscopii. Although scientists have not spotted planets around the star, they have seen (via the Spitzer Space Telescope) a dusty disk capable of forming planets. The disk also is warped, possibly by the pull of one or more planets. The search for extrasolar planets is the search for subtle clues like this. Current telescopes are not powerful enough to see directly an extrasolar planet of any size. (Image: NASA/ESA/G. Bacon, STScI)

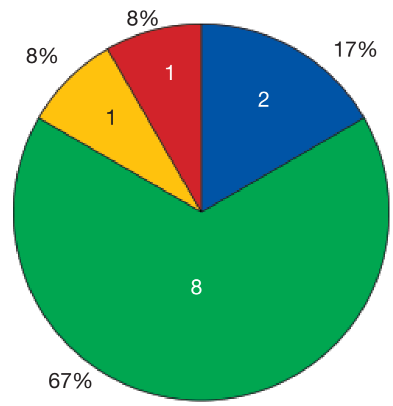
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 4, NASA is on track to achieve 7 of 8 Outcomes.

APG Ratings



Under Objective 4, NASA achieved or exceeded 10 of 12 APGs.

Outcome 4.1: Learn how the cosmic web of matter organized into the first stars and galaxies and how these evolved into the stars and galaxies we see today.

FY 2005 Green
FY 2004 Blue (5.8.1)

Hubble sees the most distant galaxies to date

Astronomers using the Hubble Space Telescope measured accurate distances for several faint, red galaxies seen in the Hubble Ultra Deep Field, confirming that three fourths of the objects in the observation are among the most distant galaxies yet studied. This is a milestone because the Hubble data provide spectra of objects 10 times fainter than have been studied with spectrometers on ground-based telescopes. The Hubble Ultra Deep Field allows researchers to probe the common galaxies in the early universe that scientists believe to be responsible for most of the energy output at that time and, perhaps, also for ionizing and heating the tenuous gas in between galaxies. Surprisingly, the distant galaxies are similar in many ways to their considerably closer descendants.

Hubble, Spitzer, and Keck work together to unveil some of the first stars to form in distant galaxies

U.K. and U.S. astronomers used the Spitzer Space Telescope and the Hubble Space Telescope to detect light coming from some of the first stars to form in some of the most distant galaxies. New evidence suggests that the formation of these distant, first galaxies may have begun earlier than previously thought. The 10-meter Keck telescope in Hawaii provided confirmation of these galaxies' extreme distance, approximately 13 billion light years from Earth. The Hubble images revealed the new-born stars, but the new infrared images taken with the Spitzer Space Telescope revealed that some of these galaxies were already 300 million years old when the universe was very young.

Chandra spots massive gas clouds

A Chandra X-ray Observatory image revealed a complex of several intergalactic hot gas clouds in the process of merging. Chandra's superb spatial resolution distinguished individual galaxies from the massive clouds of hot gas. One of the clouds that envelops hundreds of galaxies has an extraordinarily low concentration of iron atoms, indicating that it is in the very early stages of cluster evolution. This may be hot intergalactic gas in a relatively pristine state before it has been polluted by gas from galaxies. This discovery should provide valuable insight into how the most massive structures in the universe are assembled.

This Chandra X-ray Observatory image of the galaxy cluster Abell 2125 reveals a complex of several massive gas clouds in the process of merging. Chandra, the Hubble Space Telescope, and the Very Large Array ground-based radio telescope data show that several galaxies in the Abell 2125 core cluster (the bright object in upper left) are being stripped of their gas as they fall through surrounding high-pressure hot gas. This stripping process enriched the core cluster's gas in heavy elements such as iron. In contrast, the bright, large, and likely younger cloud on the lower right envelops hundreds of galaxies and has an extraordinarily low concentration of iron atoms. (Image: NASA/CXC/UMass/Q.D. Wang et al)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ASO4 Yellow	Demonstrate James Webb Space Telescope (JWST) primary mirror technology readiness by testing a prototype in a flight-like environment.	none	none	none
5ASO5 Green	Successfully demonstrate progress in learning how the cosmic web of matter organized into the first stars and galaxies and how these evolved into the stars and galaxies we see today. Progress towards achieving outcomes will be validated by external review.	4ASO9 Blue	3S3 Green	2S3 Green

Performance Shortfalls

APG 5ASO4 is rated Yellow because NASA only partially completed testing of the James Webb Space Telescope (JWST) primary mirror technology in a flight-like environment. NASA tested the demonstrator mirror for the advanced mirror system to operating temperature, but not to flight-like mechanical loads. NASA will test the prototype and flight spare engineering development units mirror segment to all flight conditions by summer 2006, bringing it to Technology Readiness Level 6.

FY 2005	FY 2004
Green	Green
	(5.8.2)

Outcome 4.2: Understand how different galactic ecosystems of stars and gas formed and which ones might support the existence of planets and life.

This image composite compares visible-light and infrared views from NASA's Spitzer Space Telescope of the glowing Trifid Nebula, a giant star-forming cloud of gas and dust located 5,400 light-years away in the constellation Sagittarius. Visible-light images taken with the Hubble Space Telescope (left, inset) and the National Optical Astronomy Observatory (left, larger image) show a murky cloud lined with dark trails of dust. Data of this same region from the Institute for Radio-astronomy millimeter telescope in Spain revealed four dense knots, or cores, of dust (outlined by yellow circles) that are "incubators" for embryonic stars. Astronomers thought these cores were not yet ripe for stars until Spitzer spotted the warmth of rapidly growing massive embryos tucked inside. (Images: NASA/JPL–Caltech/J. Rho, SSC/Caltech)

Spitzer sees embryonic stars

NASA's Spitzer Space Telescope uncovered a hatchery for massive stars. A new image from the infrared telescope shows a vibrant cloud called the Trifid Nebula dotted with glowing stellar "incubators." Tucked deep inside these incubators are rapidly growing, warm embryonic stars detected for the first time by Spitzer's powerful heat-seeking instruments. The new view offers a rare glimpse at the earliest stages of massive star formation.

Chandra catches a glimpse of super X-ray flares

New results from NASA's Chandra X-ray Observatory imply that X-ray super-flares torched the young solar system. Such flares likely affected the planet-forming disk around the early Sun and may have enhanced Earth's chances of survival. By focusing Chandra on the Orion Nebula almost continuously for 13 days, a team of scientists obtained the deepest X-ray observation ever taken of any star cluster. These data provided an unparalleled view of 1,400 young stars, 30 of which are prototypes of the early Sun. The team discovered that these young stars erupt in enormous flares that dwarf in energy, size, and frequency anything seen from the Sun today. The difference between young, energetic stars and older, docile ones like the Sun may affect the fate of small, rocky planets like Earth. According to recent theoretical work, X-ray flares can create turbulence when they strike planet-forming disks, preventing rocky planets from rapidly migrating towards the young star and plummeting into it.

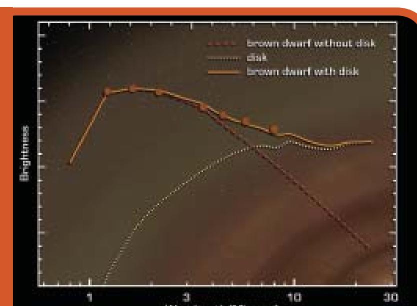
FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ASO6 Green	Successfully demonstrate progress in understanding how different galactic ecosystems of stars and gas formed and which ones might support the existence of planets and life. Progress towards achieving outcomes will be validated by external review.	4ASO10 Green	none	none

FY 2005	FY 2004
Green	Green
	(5.8.3)

Outcome 4.3: Learn how gas and dust become stars and planets.

NASA's Spitzer Space Telescope spotted a dusty disk of planet-building material around an extremely low-mass failed star known as a brown dwarf. The brown dwarf is only 15 times the mass of Jupiter. Previously, the smallest brown dwarf known to host a planet-forming disk was 25 to 30 times more massive than Jupiter. The finding will help astronomers better understand how and where planets form.

This graph of data from NASA's Spitzer Space Telescope shows that an extraordinarily low-mass brown dwarf is circled by a disk of planet-building dust. The brown dwarf is only 15 times the mass of Jupiter, making it the smallest known brown dwarf to host a planet-forming disk. Whereas a brown dwarf without a disk (red dashed line) radiates infrared light at shorter wavelengths, a brown dwarf with a disk (orange line) gives off excess infrared light at longer wavelengths. This surplus light comes from the disk itself and is represented here as a yellow dotted line. Actual data points from observations of the brown dwarf are indicated with orange dots. (Image: NASA/JPL–Caltech/Harvard–Smithsonian CfA)



Astronomers also determined the inner accretion disk sizes and temperatures for four solar-type stars using observations from the Keck Interferometer in Hawaii. These inner disk measurements help researchers determine the location of possible, Earth-like planet formation, as well as potential mechanisms for halting giant planet migration within a planetary system.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ASO7 Green	Successfully demonstrate progress in learning how gas and dust become stars and planets. Progress towards achieving outcomes will be validated by external review.	4ASO10 Green	3S3 Green	2S3 Green

Spotlight: NASA Scientist Finds World with Triple Sunsets

In FY 2005, a NASA-funded astronomer discovered a world where the sun sets over the horizon, followed by a second sun and then a third. The new planet, called HD 188753 Ab, is the first known to reside in a classic triple-star system.

"Before now, we had no clues about whether planets could form in such gravitationally complex systems," said Maciej Konacki of the California Institute of Technology, who found the planet using the Keck I telescope atop Mauna Kea in Hawaii. The findings suggest that planets are more robust than previously believed and that they could form in unusual, multi-star systems.

The tight living quarters of the circus-like trio of stars throw theories of hot Jupiter formation into question. Astronomers had thought that hot Jupiters form far away from their parent stars before migrating inward. The discovery of a world under three closely placed suns, where there is no room in the outskirts for a planet to form, contradicts this scenario. HD 188753 would have sported a truncated disk in its youth, due to the disruptive presence of its stellar companions. That leaves no room for HD 188753's planet to form—and raises a host of new questions.

This artist's concept shows the view from a hypothetical moon in orbit around the first known planet to reside in a tight-knit triple-star system. The gas giant planet zips around a single star that is orbited by a nearby pair of pirouetting stars. (Image: NASA/JPL–Caltech)

FY 2005	FY 2004
Green	Blue
	(5.8.4)

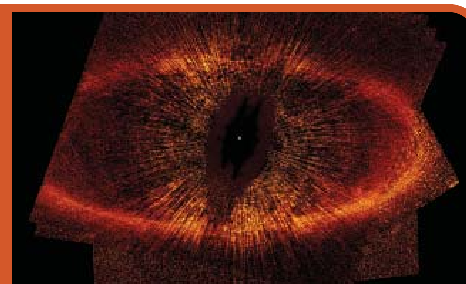
Outcome 4.4: Observe planetary systems around other stars and compare their architectures and evolution with our own.

Planets evolve from massive collisions between rocky bodies as big as mountain ranges. New observations from NASA's Spitzer Space Telescope reveal surprisingly large dust clouds around several stars that likely flared up when rocky, embryonic planets smashed together. (Earth's Moon may have formed from such a collision.) Prior to these observations, astronomers thought planets were formed under less chaotic circumstances.

Hubble looks for a hidden planet

An image taken by NASA's Hubble Space Telescope is the most detailed visible-light image ever taken of a narrow, dusty ring around the nearby star Fomalhaut. The image offers the strongest evidence yet that an unruly and unseen planet may be tugging gravitationally on the ring. Although part of the ring is outside the telescope's view, Hubble shows that the center of the ring is 1.4 billion miles away from the star. Clearly, the geometrically striking ring, tilted obliquely toward Earth, is not being influenced by Fomalhaut's gravity alone.

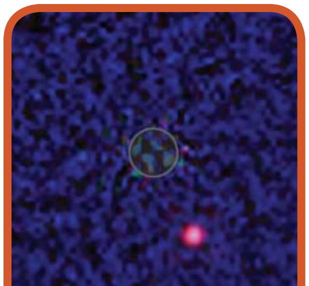
This image taken by the Hubble Space Telescope is the first visible-light image of a dust ring around the nearby young, bright star Fomalhaut (blocked from the center of the image). Astronomers believe that an unseen planet moving in an elliptical orbit is reshaping the ring. Only Hubble has the optical resolution to "see" that the ring's inner edge is sharper than its outer edge, a telltale sign that an object is gravitationally sweeping out material like a plow clearing away snow. (Image: M. Clampin, NASA/ESA/P. Kalas and J. Graham, Univ. California, Berkeley)



FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ASO3 Green	Demonstrate system-level instrument pointing precision consistent with SIM's flight system basic performance requirements, as specified in program plan.	none	none	none
5ASO8 Green	Successfully demonstrate progress in observing planetary systems around other stars and comparing their architectures and evolution with our own. Progress towards achieving outcomes will be validated by external review.	4ASO12 Blue	3S4 Blue	2S4 Green

FY 2005: Green — FY 2004: Blue (5.8.4)

Outcome 4.5: Characterize the giant planets orbiting other stars.



The Hubble Space Telescope captured this false-color, near-infrared-light view of a brown-dwarf star (located within the circle at center) and a giant companion (magenta spot), which may be a planet. Scientists estimate that the possible companion planet is five times the mass of Jupiter. Scientists will conduct more observations to see if the two objects are gravitationally bound. (Image: NASA/ESA/G. Schneider, Univ. Arizona)

Spitzer confirms the presence of extrasolar planets

NASA's Spitzer Space Telescope captured for the first time the light from two known planets orbiting stars other than the Sun. The findings marked the beginning of a new age of planetary science in which the surface temperature of extrasolar planets can be measured and compared. Previously, all confirmed extrasolar planets were discovered indirectly by observing their "gravitational tug" on their parent star. In the new studies, Spitzer directly observed the warm infrared glows of two previously detected "hot Jupiter" planets, extrasolar gas giants that zip closely around their parent stars soaking up ample starlight to shine brightly in infrared wavelengths.

Hubble tracks down a planetary companion

The Hubble Space Telescope's near-infrared vision spotted a possible planetary companion to a relatively bright young brown dwarf located 225 light-years away in the southern constellation Hydra. Astronomers at the European Southern Observatory's Very Large Telescope in Chile used infrared observations to detect the planet candidate, which is dimmer and cooler than a brown dwarf (a failed star), in April 2004. No planet beyond the solar system had ever been imaged directly at this point, so astronomers used Hubble's unique capabilities to validate this remarkable observation.

Spotting a strange, new world

A strange new-found planet as massive as Saturn appears to have the largest solid core known. The planet orbits a Sun-like star, taking just 2.87 days to complete its orbit. That makes it hot—about 2,000 degrees Fahrenheit on the star-facing side. Modeling shows it has a solid core approximately 70 times Earth's mass.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ASO8 Blue	Successfully demonstrate progress in characterizing the giant planets orbiting other stars. Progress towards achieving outcomes will be validated by external review.	4ASO13 Green	3S4 Blue	2S4 Green

FY 2005: Green — FY 2004: Green (5.9.2)

Outcome 4.6: Find out how common Earth-like planets are and see if any might be habitable.

Scientists reported the discovery of two new Uranus/Neptune-sized planets in another planetary system. More than a third of the planets discovered so far beyond the solar system are Jupiter-size giants that orbit their star closer than the planet Mercury orbits the Sun, making them hot. They can hold on to an extensive atmosphere in spite of the heat only because of their large size and strong surface gravity. These two new planets are much smaller, however, with masses only about one-tenth that of Jupiter. Although scientists know that these planets are hot, they do not know whether the planets have sufficient gravity to hold a massive atmosphere or to permit large amounts of ice in their interiors, as is the case for Neptune and Uranus.

Astronomers spot the smallest extrasolar planet to date

An artist's concept shows two possible versions of the planet found circling star Gliese 876. With a mass halfway between Earth and Uranus, the planet could be rocky (left) or composed of gas and ice (right). (Image: NSF)

Taking a major step forward in the search for Earth-like extrasolar planets, a team of astronomers announced the discovery of the smallest extrasolar planet yet detected. About seven-and-a-half times as massive as Earth, with about twice the radius, it may be the first rocky planet ever found orbiting a normal star similar to the Sun. Previously, all the extrasolar planets astronomers detected were larger than Uranus. The newly discovered extrasolar planet orbits its star in two days and is so close to the star's surface that its dayside temperature probably tops 400 to 750 degrees Fahrenheit—oven-like temperatures far too hot to support life. The team estimated that the minimum mass is 5.9 Earth masses. NASA, the University of California, and the Carnegie Institute of Washington supported the team's work, conducted at the Keck Observatory in Hawaii.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ASO2 Green	Successfully complete the Kepler mission Preliminary Design Review (PDR).	none	none	none
5ASO10 Blue	Successfully demonstrate progress in finding out how common Earth-like planets are and seeing if any might be habitable. Progress towards achieving outcomes will be validated by external review.	4ASO14 Green	none	none

Outcome 4.7: Trace the chemical pathways by which simple molecules and dust evolve into the organic molecules important to life.

FY 2005	FY 2004
Yellow	Green
	(5.9.3)

Understanding the building blocks for life in the universe

Polycyclic aromatic hydrocarbons (PAHs) are a class of stable organic molecules made up of carbon and hydrogen. Experts believe that they are distributed widely throughout space in many forms. NASA researchers are interested in PAHs because these molecules could point to possible life-supporting locations in the galaxy, so scientists are using spectral analysis to understand the different types of PAHs and how they are distributed. Researchers believe that greater understanding of PAHs will reveal how likely it is that other places within the galaxy could support life.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ASO1 Red	Deliver the SOFIA Airborne Observatory to Ames Research Center for final testing.	none	none	none
5ASO11 Green	Successfully demonstrate progress in tracing the chemical pathways by which simple molecules and dust evolve into the organic molecules important for life. Progress towards achieving outcomes will be validated by external review.	4ASO15 Green	3S6 Green	2S6 Green

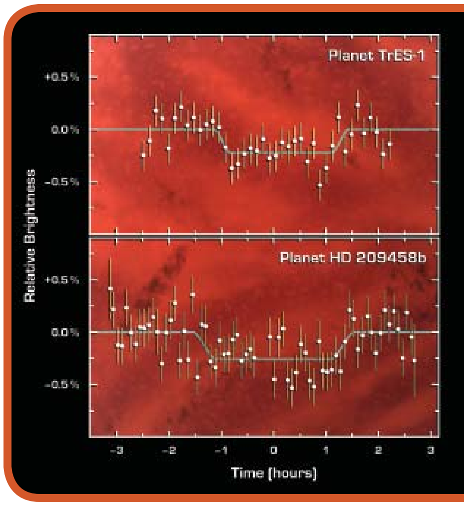
Performance Shortfalls

Outcome 4.7 and APG 5ASO1 are rated Yellow and Red respectively because NASA has not delivered the Stratospheric Observatory for Infrared Astronomy (SOFIA) Airborne Observatory to Ames Research Center for final testing. The SOFIA mission delays over the last several years resulted from a variety of causes acknowledged and explained in prior years' performance reports. Delivery to Ames for final testing will occur in FY 2007.

Objective 4.8: Develop the tools and techniques to search for life on planets beyond our solar system.

FY 2005	FY 2004
Green	Blue
	(5.9.4)

NASA Astrobiology Institute scientists led one of two teams that announced the first measurements of light from



This graph of data from NASA's Spitzer Space telescope shows changes in the infrared light output of two star–planet systems (one above, one below) located hundreds of light-years away. The data were taken while the planets disappeared behind their stars in what is called a "secondary eclipse." The dip seen in the center of each graph represents the time when the planets were eclipsed, and tells astronomers exactly how much light they emit. (Images: Top: NASA/JPL–Caltech/ D. Charbonneau, Harvard–Smithsonian CfA; Bottom: NASA/JPL–Caltech/D. Deming, GSFC)

planets around other stars. The Spitzer Space Telescope detected infrared emissions from these two planets, a new technique to detect and study extrasolar planets. Previously, extrasolar planets were detected by their gravitational pull on their parent stars and by the dimming of the stars as the planets crossed in front of them.

Getting a closer look at Earth-sized extrasolar planets

The principal goal of NASA's Terrestrial Planet Finder and the European Space Agency's Darwin mission concepts is to detect and characterize extrasolar terrestrial planets. NASA expects that these missions will provide measurements that will allow researchers to inspect a planet's surface and, possibly, its atmosphere. Scientists used Mars to test one model.

<table>
<tr><th colspan="2">FY 2005 Annual Performance Goals</th><th>FY 2004</th><th>FY 2003</th><th>FY 2002</th></tr>
<tr><td rowspan="2">5ASO12
Green</td><td rowspan="2">Successfully demonstrate progress in developing the tools and techniques to search for life on planets beyond our solar system. Progress towards achieving outcomes will be validated by external review.</td><td rowspan="2">4ASO16
Blue</td><td>3S4
Blue</td><td>2S4
Green</td></tr>
<tr><td>3S6
Green</td><td>2S6
Green</td></tr>
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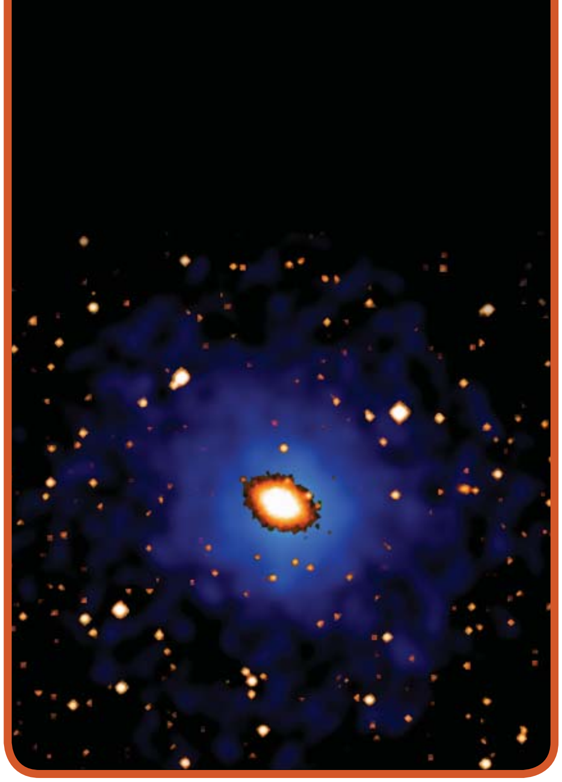
Resources

NASA's FY 2005 budgeted cost of performance for Objective 4 was $1.10 billion. NASA cannot provide FY 2005 budgeted cost of performance information at the Outcome level for this Objective.

Objective 5: Explore the universe to understand its origin, structure, evolution, and destiny.



WHY PURSUE OBJECTIVE 5?

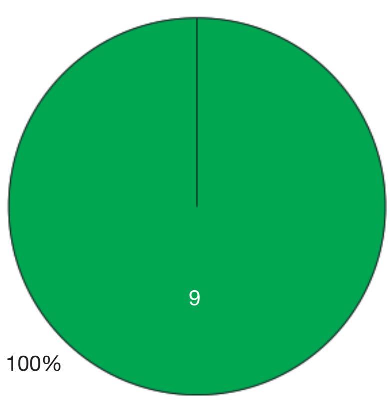
Since the Big Bang gave birth to the universe 12 to 14 billion years ago, the universe has been expanding and evolving slowly. Much of what goes on in space is invisible to the naked eye. Gravity and energy interact with surrounding matter, shaping the universe and influencing the destiny of stars, planets, solar systems, and galaxies. And, while the universe's slow-motion evolution does not affect the daily lives of those on Earth, it is part of humankind's story. As the late astronomer Carl Sagan said, "We are starstuff," suggesting that the matter that makes up the stars and planets is the same matter that gave rise to life on Earth. Therefore, humans are naturally curious about the forces and processes that made this happen.

NASA's research into the origin, structure, evolution, and destiny of the universe focuses on these powerful forces. From black holes (contorted knots with no volume, but infinite density that affect time itself) to dark matter (matter of an unknown type that does not emit light, but does exert gravitational pull on surrounding, visible objects), NASA-supported research is filling in the universe's "gaps" and showing a web of invisible matter and energy that helped build Earth's cosmic neighborhood.

Left: Researchers used the Chandra X-ray Observatory and the European Space Agency's XMM–Newton X-ray Observatory to image this "fossil galaxy," an ancient galaxy group in which large galaxies have merged to form one central giant galaxy. The researchers discovered a remarkable concentration of dark and normal matter in the core of such fossil galaxies as compared to the mass distribution within normal galaxy clusters. Dark matter, which makes up about 80 percent of the universe, has never been detected directly, but its presence is inferred through its gravitational influence on ordinary matter. This image was released on April 7, 2005. (Image: H. Khosroshahi)

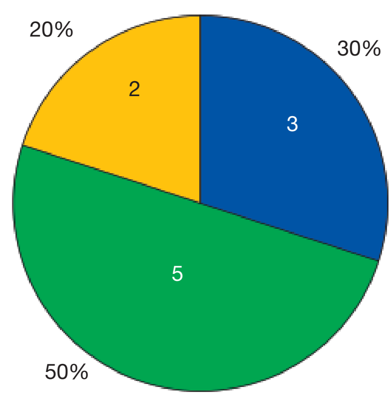
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 5, NASA is on-track to achieve all 9 Outcomes.

APG Ratings



Under Objective 5, NASA achieved or exceeded 8 of 10 APGs.

FY 2005	FY 2004
Green	Green
	(5.10.1)

Outcome 5.1: Search for gravitational waves from the earliest moments of the Big Bang.

A team consisting of NASA, the Department of Energy, and the National Science Foundation completed a report on a technology development program that will lead to a space-based full-sky measurement of the polarization of the cosmic microwave background. This background contains the signature of primordial gravitational radiation produced during the inflationary epoch of the universe. Detection of this signature will reveal when the inflationary period of the universe began, and it should provide the best measure of early universe physics. Through the detection of this gravitational radiation, researchers will view the universe at the earliest moments of its existence, at an age of approximately 10 to 40 seconds.

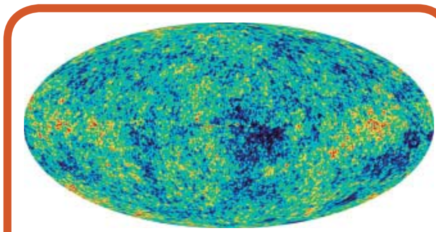
FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU4 Green	Successfully demonstrate progress in search for gravitational waves from the earliest moments of the Big Bang. Progress towards achieving outcomes will be validated by external review.	4SEU9 Green	none	none

FY 2005 Green | FY 2004 Green (5.10.1)

Outcome 5.2: Determine the size, shape, and matter-energy content of the universe.

Scientists worldwide use data from the Wilkinson Microwave Anisotropy Probe (WMAP) for analysis of the cosmic microwave background and what it reveals about the origin, size, shape, and matter-energy content of the universe. The data obtained by WMAP was more revealing about the history of the universe than expected, enabling measurement of the universe's beginning and events in its evolution. The primary WMAP results paper is now one of the most referenced papers in physics.

In FY 2005, hundreds of scientists worldwide used WMAP data in their independent, published papers on the cosmology of the universe. Theorists continue to use WMAP data to advance understanding of cosmology, as evidenced by the number of publications in FY 2005. Although they may be working with data obtained in earlier years, many of these theorists and data analysts are supported by funding from NASA's data analysis programs, giving them the opportunity to analyze the data and ultimately publish new results, continuing progress toward determining the size, shape, and matter–energy content of the universe.



WMAP supplied the data used to compile this full-sky map of the oldest light in the universe. The microwave light captured in this picture is from 379,000 years after the Big Bang, over 13 billion years ago. Red indicates warmer spots and blue represents the colder spots. The temperatures vary only by millionths of a degree. (Image: NASA)

WMAP successfully completed its analysis of fluctuations in the cosmic microwave background, with results that inaugurated a new era of "precision cosmology." The entire cosmology community has been waiting for WMAP's analysis of the polarization pattern of the cosmic microwave background, however, this analysis is far more complex than anticipated, causing a delay in its release. The data being collected by WMAP in its extended mission ultimately will significantly enhance the quality of the cosmic microwave background fluctuation and polarization results and understanding the history of the universe.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU5 Blue	Successfully demonstrate progress in determining the size, shape, and matter-energy content of the universe. Progress towards achieving outcomes will be validated by external review.	4SEU10 Green	3S1 Blue	2S1 Green

FY 2005 Green | FY 2004 Blue (5.10.3)

Outcome 5.3: Measure the cosmic evolution of dark energy.

The NASA/Department of Energy Joint Dark Energy Mission Science Definition Team evaluated various methods for investigating dark energy during a space-based mission. This included the expanded search for "standard candle" supernovae (supernovae that have known luminosity due to some characteristic quality possessed by all the supernovae like it), weak lensing, X-ray clusters, and baryon oscillations. The team considered each method's efficacy, complementarity, and likely systematic errors. The team also prepared a set of standard cosmological and dark energy parameter values that all future proposers must use in demonstrating the power of their mission implementation.

NASA also issued a call for proposals for mission concept studies. The Agency will offer one or two two-year awards for the development of competing collaborations for a future dark energy mission. This will help insure that alternative methods for investigating dark energy have a chance for selection if they can provide superior discrimination between competing models of dark energy.

The NASA/Department of Energy/National Science Foundation Dark Energy Task Force is preparing its advice for presentation in December 2005 to the participating agencies on a program structure optimizing the investigation of dark energy. The task force will tackle the question of how much ground-based observatories (and possibly balloon missions) can characterize dark energy and what the needs are for a space-based mission. The task force also will help quantify the science return for a given dark energy parameter-measurement error and will recommend minimum performance measures for both the ground-based Large Sky Telescope and Joint Dark Energy Mission.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU6 Green	Successfully demonstrate progress in measuring the cosmic evolution of the dark energy, which controls the destiny of the universe. Progress towards achieving outcomes will be validated by external review.	4SEU11 Blue	none	none

FY 2005	FY 2004
Green	Green (5.11.1)

Outcome 5.4: Determine how black holes are formed, where they are, and how they evolve.

A swarm of 10,000 or more black holes may be orbiting this galaxy's central supermassive black hole, according to results from the Chandra X-ray Observatory. This would represent the highest concentration of black holes anywhere in the galaxy, confirming predictions of a dense stellar graveyard at the galactic center. The results will help scientists better understand how some supermassive black holes grow.

Chandra discovered four bright, variable X-ray sources (circles) within three light years of Sagittarius A* (the bright source just above Source C) at the center of the Milky Way galaxy. The lower panel illustrates the strong variability of Source A. This variability, which is present in all the sources, is indicative of an X-ray binary system where a black hole or neutron star is pulling matter from a nearby companion star. The observed high concentration of X-ray binaries is strong circumstantial evidence that a dense swarm of 10,000 or more stellar-mass black holes and neutron stars has formed around Sagittarius A*. (Image: NASA/CXC/UCLA/M.Muno et al.)

Chandra found that distant galaxies undergoing intense bursts of star formation are fertile growing fields for the largest black holes in the universe. Collisions between galaxies in the early universe may be the ultimate cause of both accelerated star formation and the growth of supermassive black holes. Combining this deepest X-ray image ever taken with ground-based observations, a consistent picture arises in which galaxy mergers drive large quantities of gas to the central region of the galaxies, dramatically enhancing star formation while simultaneously feeding the growth of their central black holes with gas and dust.

In a related survey, a deep Chandra X-ray survey found that supermassive black holes may have an upper mass limit of approximately 100 million solar masses. The long-exposure images found black holes that would otherwise have gone unnoticed, because many of the black holes with masses smaller than this are shrouded by large quantities of gas and dust. The picture that emerges is one in which black holes either can feed quickly on gas and stars until the mass limit of 100 million solar masses is reached, at which point the supply of "food" has been exhausted, or they can "graze" more slowly. The birthrate of stars also tracks the growth rate of supermassive black holes.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU7 Green	Successfully demonstrate progress in determining how black holes are formed, where they are, and how they evolved. Progress towards achieving outcomes will be validated by external review.	4SEU12 Green	none	none

FY 2005	FY 2004
Green	Green (5.11.2)

Outcome 5.5: Test Einstein's theory of gravity and map space-time near event horizons of black holes.

Chandra sees white dwarfs dancing

The Chandra X-ray Observatory found evidence that two white dwarf stars are orbiting each other in a death grip, destined to merge. Due to the close proximity of the white dwarf pair, and consequently their rapid orbits around each other, they are emitting a large amount of gravitational radiation. This added energy loss causes the spiral rate of the pair to increase. Chandra observed this increase and found it to be consistent with the rate predicted by Einstein's General Theory of Relativity. This white dwarf pair may be the largest source of gravitational radiation in the Milky Way Galaxy, and it may be the first source detected by NASA's Laser Interferometer Space Antenna when it launches in 2015.

This artist's concept depicts hot iron gas riding a ripple in space–time around a black hole. The observation, made with NASA's RXTE spacecraft, confirms an important theory about how a black hole's extreme gravity can stretch light. It also paints an intriguing image of how a spinning black hole can drag the fabric of space around with it, creating a choppy sea of space that distorts all that passes through it on a descent into the black hole. (Image: NASA)

NASA's Rossi X-ray Timing Explorer catches black holes warping the fabric of space

An observation of a stellar-mass black hole 4,000 light-years away by NASA's Rossi X-ray Timing Explorer (also known as RXTE and now in its tenth year of operation) found streams of gas that appear to be surfing on a wave of space as the gas falls toward the black hole. This is compelling evidence for an exotic prediction of Einstein's General Theory of Relativity: that a spinning black hole can drag the fabric of space around with it, creating a choppy sea of space that distorts all that passes through it on a descent into the black hole.

Gravity Probe-B successfully completes science operations

The Gravity Probe B mission completed its science operations phase with the payload and spacecraft in good condition. It will take close to a year of additional data analysis for researchers to determine whether the "frame-dragging" effect, the twisting of space–time around a rotating, massive object like Earth, matches the numerical prediction of Einstein's General Theory of Relativity.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU8 Yellow	Successfully demonstrate progress in testing Einstein's theory of gravity and mapping space–time near event horizons of black holes. Progress towards achieving outcomes will be validated by external review.	4SEU13 Green	3S2 Green	2S2 Green

Performance Shortfalls

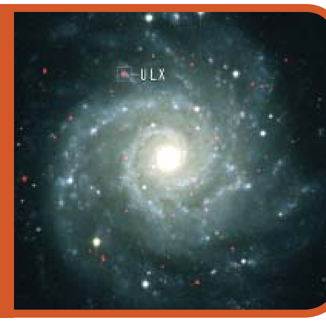
APG 5SEU8: The Japanese mission Astro-E2/Suzaku was launched successfully on July 10, 2005. The prime instrument, a new-generation X-ray spectrometer, the XRS-2 provided by NASA, initially worked well. However, it ceased functioning on August 6, 2005, when it prematurely ran out of helium for reasons not yet fully understood. The high spectral resolution of XRS-2 would have enabled it to study elemental abundances and bulk motion in both point and extended sources, but the spectrometer's failure significantly affected NASA's progress in testing Einstein's Theory of Gravity and mapping space–time near event horizons of black holes.

FY 2005	FY 2004
Green	Green (5.11.3)

Outcome 5.6: Observe stars and other material plunging into black holes.

Chandra X-ray Observatory data on peculiar outbursts of X-rays coming from a black hole called M74 provided evidence for a new class of black holes. The black hole's quasi-periodic outbursts, recorded at approximately two-hour intervals, helped scientists determine that this black hole has a mass of about 10,000 Suns, placing it in a new class of intermediate black holes.

Chandra discovered the most powerful eruption ever seen in the universe. It was produced by a supermassive black hole in the galaxy cluster MS 0735.6+7421, which grew at a remarkable rate, consuming about 300 million solar masses of material over a period of more than 100 million years. The result of this explosion is a huge



This composite X-ray (red) and optical (blue and white) image of spiral galaxy M74 highlights an ultraluminous X-ray source (ULX) shown in the box. ULX sources are distinctive because they radiate 10 to 1000 times more X-ray power than neutron stars and stellar-mass black holes. Chandra observations made in 2001 of this ULX provided evidence, released in a study in 2005, that its X-radiation is produced by a disk of hot gas swirling around an intermediate-size black hole, a new class of black hole. (Image: X-ray: NASA/CXC/U. of Michigan/J. Liu et al.; Optical: NOAO/AURA/NSF/T. Boroson)

cavity of more than a million light years in size, swept clean by the enormous energy release generated by the black hole's feeding. It substantiates the significant effect inferred by scientists of black holes on the evolution of the universe.

NASA scientists also used X-ray measurements from the European Space Agency's XMM–Newton X-ray Observatory to observe a supermassive black hole in a galaxy, Markarian 766, more than 170 million light years away. The researchers clocked three separate clumps of hot iron gas whipping around the black hole at 20,000 miles per second, more than 10 percent of light speed. This marks the first time scientists could trace individual blobs of shredded matter on a complete journey around such a black hole.

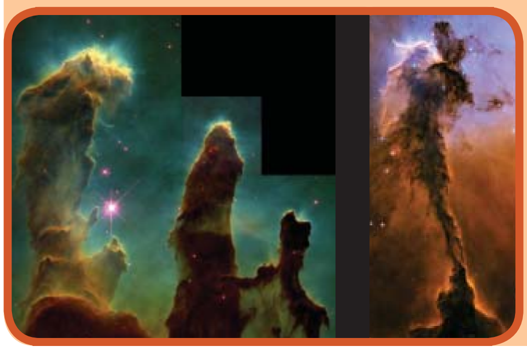
FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU9 Blue	Successfully demonstrate progress in observing stars and other material plunging into black holes. Progress towards achieving outcomes will be validated by external review.	4SEU14 Green	none	none

Spotlight: Hubble Celebrates 15th Anniversary with Spectacular New Images

NASA's Hubble Space Telescope has orbited Earth for 15 years and has taken three-quarters of a million photos of the cosmos—images that have awed, astounded, and even confounded astronomers and the public alike.

On April 25, 2005, NASA celebrated Hubble's 15th anniversary by releasing new views of two of the most well-known objects Hubble has ever observed: the Eagle Nebula and spiral galaxy M51, known as the Whirlpool Galaxy. The two images, the sharpest Hubble has ever taken, could be enlarged to billboard size and still retain all of their stunning details.

The Space Shuttle Discovery placed Hubble into Earth orbit on April 25, 1990, opening a brand new era in astronomy. The telescope's false-colored images, in which different gases are colored to bring out shapes and details, also have changed the way the public views space. Once depicted as a black and white place of vast, empty distances, space is now—thanks to Hubble—a place of color, texture, and curious, delicate-looking objects of gas, dust, and energy. Hubble has helped confirm the existence of a strange, elusive dark energy, discovered the existence of supermassive black holes, and has imaged beautiful celestial objects such as galaxies, dying stars, and the birth of stars in giant gas clouds.



In 1995, the Hubble Space Telescope captured its most famous and, arguably, its most beautiful image (left). The image showed the world newborn stars emerging from finger-like columns of cold gas and dust in the Eagle Nebula (also called M16). Inside the gaseous columns, the interstellar gas is dense enough to collapse under its own weight, forming bright, young stars. For Hubble's 15th anniversary, scientists revisited the Eagle Nebula to capture this billowing tower. Looking like a winged fairy-tale creature, the tower is approximately 57 trillion miles high, about twice the distance from the Sun to the next closest star. (Images: 1995—NASA/ESA/STScI/J. Hester and P. Scowen, U. Arizona; 2005—NASA/ESA/The Hubble Heritage Team)

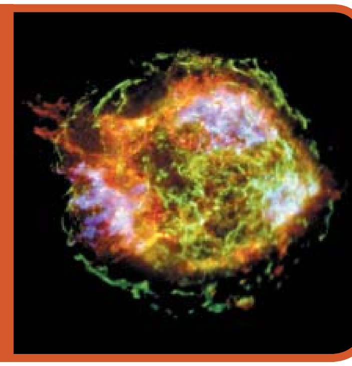
FY 2005	FY 2004
Green	Green (5.12.1)

Outcome 5.7: Determine how, where, and when the chemical elements were made, and trace the flows of energy and magnetic fields that exchange them between stars, dust, and gas.

The Chandra X-ray Observatory made a spectacular new observation of the 340 year-old supernova remnant

Cassiopeia A that shows the presence of two bipolar (oppositely directed) jets that extend to 10 light years from the remnant. The jets are rich in silicon, but not in iron, in contrast to the clouds of iron near the remnant produced in the central regions of the parent star. This suggests the jets were not the cause of the explosion.

This spectacular image of the supernova remnant Cassiopeia A is the most detailed image ever made of the remains of an exploded star. The one-million-second image shows a bright outer ring (green) 10 light years in diameter that marks the location of a shock wave generated by the supernova explosion. A large jet-like structure that protrudes beyond the shock wave can be seen in the upper left and lower right. (Image: NASA/CXC/GSFC/U. Hwang et al.)



FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU10 Green	Successfully demonstrate progress in determining how, where, and when the chemical elements were made, and tracing the flows of energy and magnetic fields that exchange them between stars, dust, and gas. Progress towards achieving outcomes will be validated by external review.	4SEU15 Green	none	none

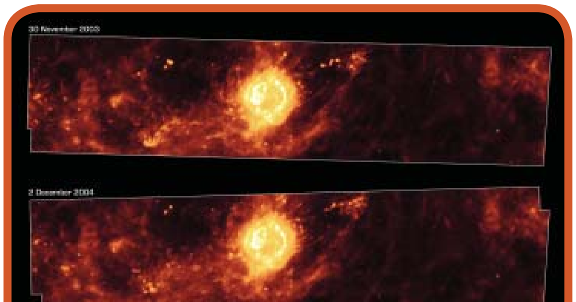
Outcome 5.8: Explore the behavior of matter in extreme astrophysical environments, including disks, cosmic jets, and the sources of gamma-ray bursts and cosmic rays.

FY 2005: Green | FY 2004: Green (5.12.2)

Swift tracks down gamma-ray bursts

NASA successfully launched the Swift satellite on November 22, 2004. Its goal is to enhance current understanding of gamma-ray bursts, explosions that signal the birth of black holes. Shortly after its launch, Swift detected its first gamma-ray burst, rotating quickly to image it within 200 seconds of its initial flare and providing the first image of a long-duration gamma-ray burst while it was still exploding.

In addition to the long-duration burst (greater than one second) detected shortly after its launch, Swift also detected and pinned down the location of a short gamma-ray burst (much less than a second) in May 2005. Scientists believe that long gamma-ray bursts are generated during the supernovae of very massive stars. Before Swift, short gamma-ray bursts were a mystery because the bursts were too fast to be measured directly. Swift's measurement of the rapid decay of the gamma-ray burst X-ray afterglow supports the theory that the explosion is due to the merger or collision of two neutron stars or black holes.



These Spitzer Space Telescope images, taken one year apart, show the supernova remnant Cassiopeia A (yellow ball) and surrounding clouds of dust (reddish orange). The pictures illustrate that a blast of light from Cassiopeia A is spreading outward through the dusty skies, an "infrared echo" that began when the remnant erupted about 50 years ago. (Images: NASA/JPL–Caltech/O. Krause, Steward Observatory)

Chandra sees a dense, young pulsar

The Chandra X-ray Observatory's long look at a young pulsar revealed unexpectedly rapid cooling that suggests it contains much denser matter than previously expected. The pulsar's cool surface temperature, and the vast magnetic web of high-energy particles that surrounds it, have implications for the theory of nuclear matter and the origin of magnetic fields in cosmic objects.

Spitzer sees the light

The Spitzer Space Telescope observed a light echo around Cassiopeia A, a quiet neutron star produced by a supernova over 300 years ago. The spherical shell of light (the echo) was produced when an expanding shock wave from the neutron star energized the medium surrounding it. The energetic event that created this halo occurred only 50 years ago, suggesting that this is a very rare type of neutron star, a magnetar, with magnetic field strengths thousands of times higher than common neutron stars. Huge energy releases occur when the neutron star's magnetic field restructures itself to a lower energy configuration, causing a massive "neutron star quake."

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU1 Yellow	Complete the integration and testing of the Gamma-ray Large Area Space Telescope (GLAST) spacecraft bus.	none	none	none
5SEU11 Blue	Successfully demonstrate progress in exploring the behavior of matter in extreme astrophysical environments, including disks, cosmic jets, and the sources of gamma-ray bursts and cosmic rays. Progress towards achieving outcomes will be validated by external review.	4SEU16 Green	3S2 Green	2S2 Green

Performance Shortfalls

APG 5SEU1: The GLAST spacecraft bus integration and testing has not been completed. Delays were due to schedule problems with the primary instrument on the GLAST observatory, the Large Area Telescope (LAT). The LAT experienced both engineering design and electrical parts problems, which required a project schedule and cost re-baseline. In 2005, the spacecraft structure was completed and tested, the spacecraft harness was installed, and subsystems were being assembled and tested in progress toward completing integration and test of the bus.

FY 2005	FY 2004
Green	Green (5.12.3)

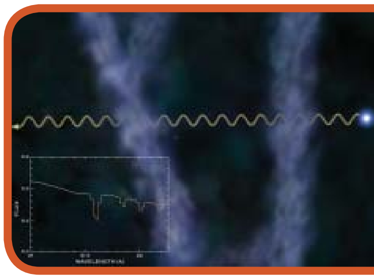
Outcome 5.9: Discover how the interplay of baryons, dark matter, and gravity shapes galaxies and systems of galaxies.

Chandra finds missing atoms and searches for dark matter

Scientists using the Chandra X-ray Observatory discovered two huge intergalactic clouds of diffuse hot gas, providing the best evidence to date that a vast cosmic web of hot gas contains the missing half of the atoms in the universe. Since all the atoms (and ions) in stars and gas inside and outside of galaxies account for only half of the known atoms present in the universe, Chandra's observation helps confirm the presence of the other half in a universal, cosmic web.

A Chandra survey of the nearby Fornax galaxy cluster also showed that this galaxy is being pulled by an underlying super-structure of dark matter. Scientists believe that most of the matter in the universe is concentrated in long, large filaments of dark matter, with galaxy clusters forming at their intersections. The Fornax picture is one of the best matches to date with high-resolution simulations.

An observation by Chandra and the XMM–Newton X-ray Observatory of six "fossil galaxies" showed a concentration of dark matter and normal matter in the cores of these isolated systems. Fossil galaxies began as ancient galaxy groups that gradually merged to form one giant, central galaxy. The highly dense concentration of dark matter in these galaxies implies that they collapsed long before typical groups of galaxies formed.



This illustration shows the absorption of X-rays from the quasar Mkn 421 by two intergalactic clouds of diffuse hot gas, and a portion of the X-ray spectrum of the quasar observed by the Chandra X-ray Observatory. The spectrum provides evidence that three separate clouds of hot gas are filtering out or absorbing X-rays from Mkn 421. Dips in the X-ray spectrum are produced when some of the X-rays are absorbed by ions of oxygen in the hot gas clouds, which are located at various distances from Earth. The clouds are likely part of a predicted diffuse, web-like system of gas clouds—the cosmic web—from which galaxies and clusters of galaxies are thought to have formed. (Image: NASA/SAO/CXC/F.Nicastro et al.; Illustration: NASA/CXC/M.Weiss)

XMM–Newton tracks the "perfect cosmic storm"

Scientists using XMM–Newton observed a head-on collision of two galaxy clusters. The clusters smashed together thousands of galaxies and trillions of stars creating what NASA scientists leading the study called "the perfect cosmic storm." It is one of the most powerful events ever witnessed because such collisions are second only to the Big Bang in total energy output. This unprecedented view of a merger in action crystallizes the theory the universe built its hierarchal structure from the "bottom up" through mergers of smaller galaxies and galaxy clusters into bigger ones.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEU12 Green	Successfully demonstrate progress in discovering how the interplay of baryons, dark matter, and gravity shapes galaxies and systems of galaxies. Progress towards achieving outcomes will be validated by external review.	4SEU17 Green	3S1 Blue	2S1 Green

Resources

NASA's FY 2005 budgeted cost of performance for Objective 5 was $0.38 billion. NASA cannot provide FY 2005 budgeted cost of performance information at the Outcome level for this Objective.

Objective 6: Return the Space Shuttle to flight and focus its use on completion of the International Space Station, complete assembly of the ISS, and retire the Space Shuttle in 2010, following completion of its role in ISS assembly. Conduct ISS activities consistent with U.S. obligations to ISS partners.

WHY PURSUE OBJECTIVE 6?

Two and a half years after the loss of Space Shuttle *Columbia* on February 1, 2003, the Space Shuttle fleet returned to flight with the launch of Space Shuttle *Discovery* on mission STS-114 on July 26, 2005. This safe return to flight was NASA's most significant accomplishment in FY 2005 because it represents the first major step in executing the Vision for Space Exploration.

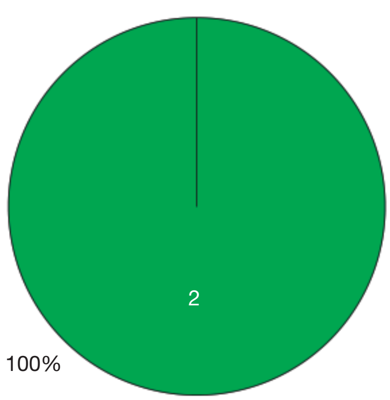
The Shuttle is the largest human-rated space vehicle in the world, capable of delivering over 50,000 pounds of crew and cargo to low Earth orbit. This capacity makes it critical to completing the International Space Station. While the Shuttle was grounded, our Russian partners helped us maintain a continuous presence on the Space Station by launching all crew and cargo on the Russian Soyuz and Progress vehicles. Because the Russian vehicles are smaller, however, NASA had to reduce the Station crew size and halt assembly. Still, the Station crews continuously performed research that will be critical to future human space exploration beyond Earth orbit.

Once the Shuttle returns to regular service, NASA will increase the number of crewmembers and deliver new facilities and components to enable completion of the Space Station and to meet its commitments to the Station's international partners.

NASA's crawler takes *Discovery* (STS-114) to the pad on June 15, 2005, as the morning sun paints the Florida sky bright orange. (Photo: NASA)

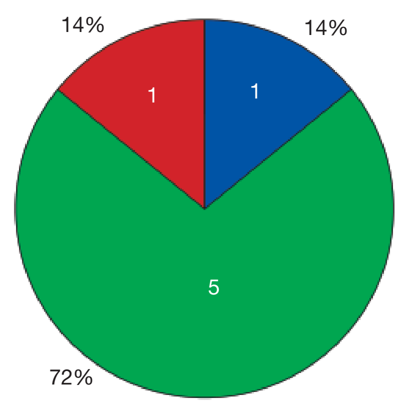
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 6, NASA is on track to achieve both Outcomes.

APG Ratings



Under Objective 6, NASA achieved or exceeded 6 of 7 APGs.

OUTCOME 6.1: ASSURE PUBLIC, FLIGHT CREW, AND WORKFORCE SAFETY FOR ALL SPACE SHUTTLE OPERATIONS, AND SAFELY MEET THE MANIFEST AND FLIGHT RATE COMMITMENT THROUGH COMPLETION OF SPACE STATION ASSEMBLY.

FY 2005	FY 2004
Green	Green (8.3.1)

The Shuttle returns to flight

The Space Shuttle fleet returned to flight with the launch of Shuttle *Discovery* (STS-114) on July 26, 2005. NASA completed return to flight-related modifications and engineering analyses as called for by the Columbia Accident Investigation Board (CAIB) and NASA's self-initiated "raise the bar" requirements. The independent Return to Flight Task Group finished its final assessment of NASA's implementation of the 15 CAIB recommendations and

Discovery shows its belly in this photo taken by Station crew as the Shuttle backflips on July 28, 2005. The maneuver was added to Shuttle procedure so the Station crew could scan the heat shield for any damage caused during launch. The image was overexposed to bring out details of the individual black heat shield tiles, helping Station and ground crew search for anomalies. (Photo: NASA)

NASA's Space Shuttle Program Action 3, "Shuttle Contingency Crew Support." The Task Group deferred on fully closing out three CAIB recommendations regarding external tank thermal protection system modifications, orbiter hardening, and thermal protection system on-orbit inspection and repair, noting that these recommendations represented substantial technical challenges (more so, perhaps, than even CAIB had anticipated). The Task Group noted, too, that NASA had made significant progress in addressing these challenges and confirmed that its assessment was not a statement on the overall readiness of STS-114 for launch.

STS-114 validated nearly all return to flight-related improvements scheduled for demonstration during the mission. In particular, a new suite of cameras and sensors provided far more data on the condition of *Discovery* than has ever been available before on a spaceflight mission. The new imaging system and procedures spotted two gap fillers that had slipped partially out from between the silicon tiles underneath the orbiter. These gap fillers might have disrupted the aerodynamic flow during reentry, so Shuttle astronauts successfully removed the gap fillers during the mission's third spacewalk. This was the first time such a procedure had been done on-orbit. The Shuttle astronauts also successfully completed other test objectives, including validating on-orbit tile and reinforced carbon–carbon repair techniques. STS-114 delivered approximately 15,000 pounds of logistics and hardware to the International Space Station, augmenting the Station's supplies and restoring a number of Station systems to full operational capability.

The Shuttle program is preparing for the second return to flight mission, STS-121, and resumption of International Space Station assembly flights in FY 2006.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SSP1 Green	Achieve zero Type-A (damage to property at least $1M or death) or Type-B (damage to property at least $250K or permanent disability or hospitalization of three or more persons) mishaps in FY 2005.	4SSP2 Yellow	3H06 Red	2H7 Green
5SSP2 Red	Achieve an average of eight or fewer flight anomalies per Space Shuttle mission in FY 2005.	none	none	none
5SSP3 Green	Achieve 100 percent on-orbit mission success for all Shuttle missions launched in FY 2005. For this metric, mission success criteria are those provided to the prime contractor (SFOC) for purposes of determining successful accomplishment of the performance incentive fees in the contract.	4SSP3 White	3H08 Green	2H09 Green

Performance Shortfalls

APG 5SSP2: There was one Space Shuttle mission in FY 2005—STS-114. For this mission, there were approximately 185 in-flight anomalies reported. This number is approximate since post-STS-114 hardware inspections and analyses continue; these results could generate additional in-flight anomalies as the process unfolds.

FY 2005	FY 2004
Green	Green
	(8.3.1)

Outcome 6.2: Provide safe, well-managed, and 95 percent reliable space communications, rocket propulsion testing, and launch services to meet Agency requirements.

In FY 2005, NASA's Space Communications Architecture Working Group continued developing an integrated space communications and navigation architecture that will support the Agency's exploration and science missions through 2030. The Working Group developed techniques for identifying, evaluating, and selecting architectures to recommend to management and studied lunar and near-Earth communications architectures that are scaleable, evolvable, and capable of meeting the projected changing needs of future missions. In developing the architectures, the Working Group defined criteria against which all architecture alternatives are scored. They also identified cost estimation tools to provide risk-based cost estimations for the architectures.

NASA successfully manages expendable launch vehicle launches

In FY 2005, NASA's Launch Services Program maintained a high level of mission success: 98.7 percent (75 out of 76) for NASA missions using commercial launch services. All five NASA-managed launches of primary payloads on expendable launch vehicles deployed to their required orbits.

The Mars Reconnaissance Orbiter launch was the first U.S. government launch using the new Atlas V-401 vehicle. The launch successfully completed the certification process for the Atlas V.

An Atlas V-401 launch vehicle, with the two-ton Mars Reconnaissance Orbiter on top, roars away from the pad at Cape Canaveral Air Force Station, Florida, on August 12, 2005. This was the first U.S. government launch using the new Atlas V, which was developed for the U.S. Air Force's Evolved Expendable Launch Vehicle program. NASA conducted extensive research, including an in-depth risk analysis, before selecting the vehicle for the mission. (Photo: NASA)

Cape Canaveral Launches

- Swift on a Delta II, November 20, 2004
- Mars Reconnaissance Orbiter on an Atlas V-401, August 15, 2005
- Deep Impact on a Delta II, January 12, 2005

Vandenberg Air Force Base Launches

- DART on a Pegasus, April 15, 2005
- NOAA-N on a Delta II, May 20, 2005

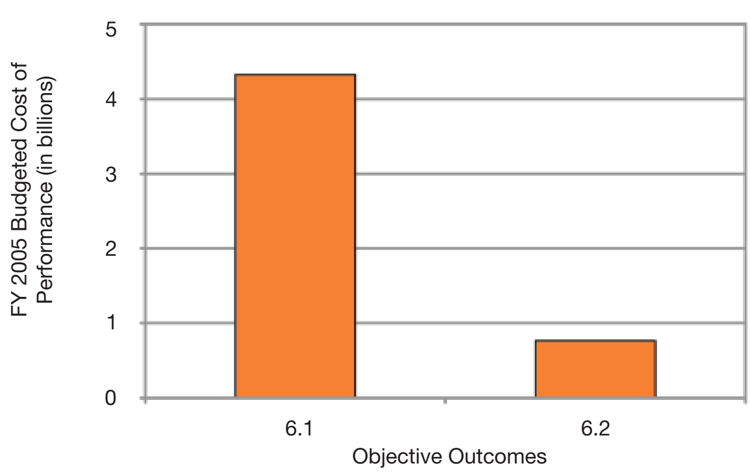
Selecting launch vehicles for the Vision for Space Exploration

NASA performed numerous studies in FY 2005 to identify requirements for crew and cargo launch vehicles needed to achieve the Vision for Space Exploration. The studies examined more than 63 launch vehicle options and assessed each architecture for characteristics like crew safety, mission success, cost, performance, schedule, and extensibility. These preliminary studies were the foundation for the Exploration Systems Architecture Study effort.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SFS8 Green	Establish the Agency-wide baseline space communications architecture, including a framework for possible deep-space and near-Earth laser communications services.	4SFS8 Green	none	none
5SFS15 Green	Maintain NASA success rate at or above a running average of 95% for missions on the FY 2005 Expendable Launch Vehicle (ELV) manifest.	4SFS4 Green	3H03 Blue	2H3 Green
5SSP16 Blue	Achieve at least 95% of planned data delivery for the International Space Station, each Space Shuttle mission, and low Earth orbiting missions in FY 2005.	4SFS5 Blue	3H14 Blue	none
5SFS19 Green	Define and provide space transportation requirements for future human and robotic exploration and development of space to all NASA and other government agency programs pursuing improvements in space transportation.	none	none	none

Resources

NASA's FY 2005 budgeted cost of performance for Objective 6 was $5.09 billion.



Objective 7: Develop a new crew exploration vehicle to provide crew transportation for missions beyond low Earth orbit. First test flight to be by the end of this decade, with operational capability for human exploration no later than 2014.

WHY PURSUE OBJECTIVE 7?

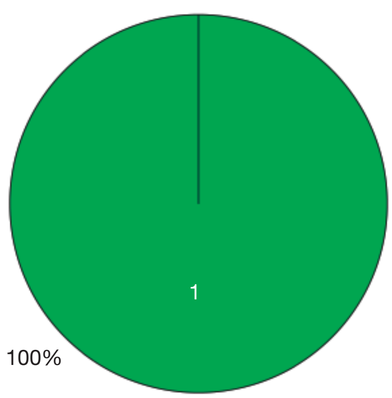
With the Space Shuttle's retirement scheduled for 2010, NASA must acquire or develop next-generation space transportation for crew and cargo. In September 2005, NASA released the Agency's planned Exploration System Architecture Study, including the concept for a crew launch and exploration system. The new system will use reliable elements from the Apollo and Shuttle systems, but it also will incorporate the latest in shielding, computer technologies, and support systems. The goal is to create an exploration infrastructure that is sustainable, affordable, reliable, and safe. NASA will use the new spacecraft to deliver crew and cargo to the International Space Station and to explore beyond low Earth orbit.

NASA's next-generation space transportation system is crucial to achieving the Vision for Space Exploration. The new system will support increased Station crew sizes and enhanced research capacity. In addition, next-generation transportation systems will support plans to return astronauts to the Moon in preparation for travel to Mars and beyond.

Left: NASA's planned crew exploration vehicle, shown approaching the International Space Station in this artist's concept, will deliver crew and cargo to and from the Station, carry up to four astronauts to the Moon, and support up to six astronauts during a mission to Mars. (Image: John Frassanito and Associates)

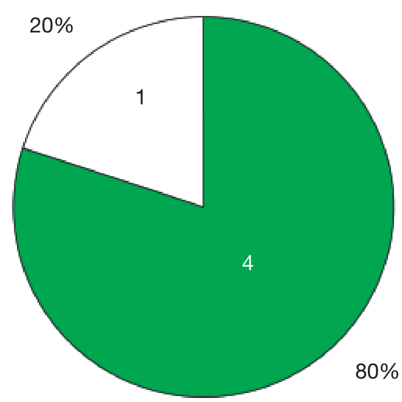
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 7, NASA is on track to achieve the single Outcome.

APG Ratings



Under Objective 7, NASA achieved 4 of 5 APGs.

Outcome 7.1: By 2014, develop and flight-demonstrate a human exploration vehicle that supports safe, affordable and effective transportation and life support for human crews traveling from Earth to destinations beyond LEO.

FY 2005	FY 2004
Green	Green
	(9.5.1)

Creating NASA's exploration architecture

In May 2005, NASA's Administrator established an Exploration System Architecture Study team. The team developed a detailed concept for a new Crew Exploration Vehicle (CEV) as a part of NASA's overall exploration architecture. The team reviewed and assessed past programs and technologies for best practices and incorporation into a new vehicle design. The CEV operational deadline has been changed to 2012 to minimize the gap in U.S. access to space once the Shuttle fleet is retired in 2010.

The Exploration System Architecture Study team accepted the Mars Design Reference Mission 3.0 for architecture planning purposes. The architecture's requirements will determine how NASA will develop its lunar outpost in terms of habitat, surface power, and crew rotation.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5TS1 Green	Conduct a detailed review of previous vehicle programs to capture lessons-learned and appropriate technology maturation; incorporate results into the human exploration vehicle requirements definition process.	none	none	none
5TS2 Green	Develop and obtain approval for human exploration vehicle Level 1 and Level 2 Requirements and the resulting Program Plan.	none	none	none
5TS3 Green	Complete preliminary conceptual design(s) for the human exploration vehicle, in conjunction with definition of an integrated exploration systems architecture.	none	none	none
5TS4 Green	Develop launch vehicle Level 1 Requirements for human-robotic exploration within an integrated architecture, and define corresponding programs to assure the timely availability of needed capabilities, including automated rendezvous, proximity operations and docking, modular structure assembly, in-space refueling, and launch vehicle modifications and developments.	none	none	none
5TS5 White	Conduct a preliminary conceptual design study for a human-robotic Mars exploration vehicle, in conjunction with definition of an integrated exploration systems architecture.	none	none	none

Resources

NASA's FY 2005 Budgeted Cost of Performance for Objective 7 was $0.06 billion, all of which was allocated to Outcome 7.1.

Objective 8: Focus research and use of the ISS on supporting space exploration goals, with emphasis on understanding how the space environment affects human health and capabilities, and developing countermeasures.

WHY PURSUE OBJECTIVE 8?

The International Space Station plays a unique role in human space exploration. It is the only facility where researchers can study the effects of space travel on human health and performance in an actual space environment over long periods of time.

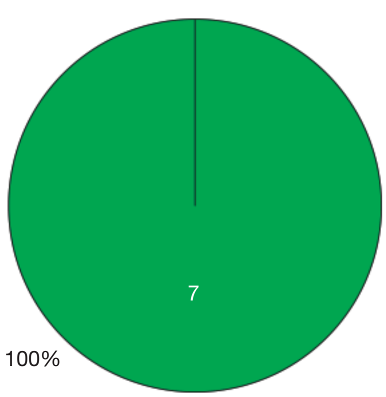
In July 2005, Space Shuttle *Discovery* (STS-114) delivered to the Station new equipment, including a second Human Research Facility that contains tools for studying human health. Over the next five years, until the Shuttle's retirement by 2010, the Shuttle will deliver additional components and equipment to support a larger crew and more research capabilities.

Much of the research being conducted on the Space Station focuses on activities that support NASA's exploration goals. The Agency will continue to use the Station to study the effects of living for long periods of time in space, and researchers will develop countermeasures for problems like muscle atrophy, bone loss, and changes to the cardiopulmonary and immune systems. The Station also will be a test bed for new technologies, system performance, and logistical support crucial to NASA's plans to achieve human space travel beyond low Earth orbit.

Left: Leroy Chiao, Expedition 10 commander and NASA science officer, poses for a photo with Russian Orlan spacesuits during preparations for a spacewalk outside the Station on March 28, 2005. NASA will use the Station to evaluate advanced extravehicular activity systems, including suits optimized for use on lunar and planetary surfaces. (Photo: NASA)

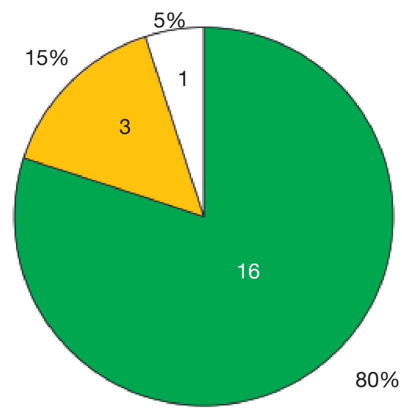
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 8 NASA is on track to achieve all seven Outcomes.

APG Ratings



Under Objective 8 NASA achieved 16 of 20 APGs.

OUTCOME 8.1: BY 2010, COMPLETE ASSEMBLY OF THE ISS, INCLUDING U.S. COMPONENTS THAT SUPPORT U.S. SPACE EXPLORATION GOALS AND THOSE PROVIDED BY FOREIGN PARTNERS.

FY 2005	FY 2004
Green	none

In May 2005, NASA convened the Shuttle/Station Configuration Options Team. The team evaluated options for completing International Space Station assembly within the parameters of the Vision for Space Exploration and assessed the related number of flights needed by the Shuttle before it is retired. The scope of the study spanned Station assembly, operations, and use, and it considered such factors as international partner commitments, research utilization, cost, and sustainability. The team evaluation results were integrated with a parallel Exploration Systems Architecture Study and will serve as central elements in the NASA FY 2007 budget proposal to the White House.

A worker at Kennedy Space Center helps load the Human Research Facility 2 into the Shuttle's Multi-Purpose Logistics Module Raffaello on March 8, 2005, for flight on STS-114. The large research rack, a component of the U.S. Destiny research module, was too large to be launched on a Russian vehicle and had to await the Shuttle's return to flight. The Shuttle is the only vehicle capable of delivering to orbit large Station components, including modules developed by the Agency's international partners. (Photo: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ISS5 Yellow	Obtain agreement among the International Partners on the final ISS configuration.	4ISS5 Green	none	none

Performance Shortfalls

APG 5ISS5: The ISS International Partnership Heads of Agency met in January 2005 to endorse the Multilateral Coordination Board-approved the Station configuration. However, in May 2005, NASA's Administrator initiated a 60-day study on options for completing International Space Station assembly within the parameters of the Vision for Space Exploration. The decision based on the study requires NASA to reopen discussions with its partners. By the end of the fiscal year, NASA had begun these discussions with the International Partners.

Outcome 8.2: Annually provide 90 percent of the optimal on-orbit resources available to support research, including power, data, crew time, logistics, and accommodations.

FY 2005	FY 2004
Green	none

The International Space Station has been crewed continuously since November 2000. While the Space Shuttle fleet was grounded, the international partnership maintained a continuous presence of two crewmembers aboard the Station throughout FY 2005. The Station hosted three crews who performed all necessary housekeeping and maintenance activities and conducted a range of scientific investigations. The planned on-Station science was limited by the reduced crew size and the cargo delivery limitations of Progress and Soyuz spacecraft. However, NASA is maximizing the Station's research capability through scheduling, standby launch reserve, and on-orbit reserve. During FY 2005, the crew conducted 246 hours of research onboard the Station. Overall, the Station's performance has surpassed expectations, given the grounding of the Shuttle fleet. (Operating the Space Station with a two-person crew and a limited re-supply capability actually is helping NASA plan future missions to destinations like the Moon or Mars, for which logistic options will be limited.)

Left photo: On August 2, 2004, Expedition 9 crewmembers Gennady Padalka (left) and Edward (Mike) Fincke pose for a picture with the Russian Orlan spacesuits in the Station's Pirs docking compartment. Their stay began during FY 2004 and extended into the first month of FY 2005. Center photo: On November 6, 2004, Expedition 10 crewmembers Leroy Chiao (left) and Salizhan Sharipov add their mission patch to the Unity module's growing collection of insignias representing crews who have worked on the Station. Right photo: Expedition 11 crewmembers John Phillips (left) and Sergei Krikalev pause for a photo while working on the Treadmill Vibration Isolation System on September 7, 2005. Their expedition extended into FY 2006. (Photos: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ISS1 Green	In concert with the ISS International Partners, extend a continuous two-person (or greater) crew presence on the ISS through the end of FY 2004.	4ISS1 Green	none	none
5ISS2 Yellow	Achieve zero Type-A (damage to property at least $1M or death) or Type-B (damage to property at least $250K or permanent disability or hospitalization of 3 or more persons) mishaps in FY 2005.	4ISS2 Yellow	3H11 Green	2H10 Green
5ISS3 Green	Based on the Space Shuttle return-to-flight plan, establish a revised baseline for ISS assembly (through International Core Complete) and research support.	4ISS3 Green	3H02 Yellow	none
5ISS4 Yellow	Provide at least 80% of up-mass, volume, and crew-time for science as planned at the beginning of FY 2005.	4ISS4 Green	none	none
5ISS6 Green	Continuously sustain a crew to conduct research aboard the ISS.	4ISS6 Green	none	none

Performance Shortfalls

APG 5ISS2: Although there were no Type-A mishaps in FY 2005, NASA failed to achieve this APG due to the occurrence of one Type-B mishap at a Station subcontractor facility. In June 2005, the pre-cooler assembly, part of the Environmental Control and Life Support System flight hardware, was damaged at the Honeywell plant. This damage rendered the pre-cooler assembly unrecoverable, and as a result, NASA will request additional unit(s) from the Station Program. NASA estimated the damage at approximately $350,000; there were no injuries. The Mishap Investigation Board is conducting an investigation.

APG 5ISS4: While NASA did not meet 80 percent as planned at the beginning of the fiscal year for these metrics, NASA did meet 97 percent of the science objectives during Increment 10 (October 2004 through March 2005) and expects a similar achievement for Increment 11 (March 2005 through October 2005).

NASA did not pursue Outcome 8.3 in FY 2005.

Outcome 8.4: By 2006, each Research Partnership Center will establish at least one new partnership with a major NASA R&D program to conduct dual-use research that benefits NASA, industry, or academia.

FY 2005	FY 2004
Green	none

The Research Partnership Centers are on track for completing this outcome in 2006, although the number of Shuttle flights may impact the ability to put hardware to use.

In FY 2005, the Research Partnership Centers implemented a new database that includes pertinent data regarding all projects and current spaceflight hardware. The Centers made copies of the complete database available to the Department of Defense and industry.

NASA's Space Partnership Development Program implemented a multi-faceted system for sharing flight hardware with potential users outside NASA. The program developed an exhaustive list of flight hardware that contains descriptions of over two dozen flight hardware units for performing a variety of research in space. The program also established a Web-based system listing ground and flight hardware accessible to all Research Partnership Centers and participating Space Act Agreement companies. The Spacecraft Technology Center Research Partnership Center developed a Web-based forum that includes news announcements, discussion threads, document posting, and a vendor information exchange. The system features a flight hardware database through which users can describe their flight hardware systems and components available for use and exchange available or needed parts.

NASA's partnership programs help companies develop technologies for space flight and then turn those technologies into commercially available products. For example, one of the partners that collaborated on a plant growth chamber for space-based research, held by Station Expedition 5 crewmember Peggy Whitson in the left photo, turned the light-emitting diodes that provided light to the plants into several health-related products, including a device that kills anthrax spores, a probe that activates tumor-treating drugs, and a device (shown in the right photo) that provides temporary relief of minor muscle and joint pain. (left: NASA; right: Quantum Devices, Inc.)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5RPFS4 Green	Promote availability of RPC-built spaceflight hardware throughout NASA utilizing the new database.	none	none	none
5RPFS5 Green	Implement hardware sharing system.	4RPFS6 Green	none	none
5RPFS6 Green	Identify and develop a working relationship with at least one new non-SPD user of RPC-built spaceflight hardware.	none	none	none

Outcome 8.5: By 2008, develop and test the following candidate countermeasures to ensure the health of humans traveling in space: bisphosphonates, potassium citrate, and mitodrine.

FY 2005	FY 2004
Green	none

During FY 2005, NASA-funded researchers published papers on ground-based studies of bisphosphonate, a medication used to slow bone loss. While bisphosphonate is used on Earth to combat osteoporosis, NASA has not validated fully its use as a countermeasure for spaceflight-induced bone loss. (Other papers based on flight-based studies were reviewed and accepted by journals and are awaiting publication in FY 2006.)

NASA continues space-based studies of potassium citrate, a potential countermeasure for spaceflight-induced renal stones, and midodrine, a potential countermeasure for treating spaceflight-induced low blood pressure. Although these studies were delayed by the *Columbia* accident and the Agency's change in direction to pursue the Vision for Space Exploration, NASA has completed most of the planned testing.

Expedition 10 crewmember Leroy Chiao gives a thumbs up on his way to launch aboard a Russian Soyuz TMA-5 spacecraft on October 5, 2004. Astronauts experience dizziness when they stand up (called orthostatic intolerance) after returning to Earth due to lowered blood volume—and therefore low blood pressure—from being in space. During reentry, astronauts wear full-body pressure suits underneath their spacesuits to help move blood from the feet up to the head, but this alone is not enough to prevent orthostatic intolerance. While in space, Chiao took mitodrine, a medication that NASA is testing as a potential countermeasure. (Photo: B. Ingallls/NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5BSR7 Green	Increase the use of space flight analogs on the ground to better define hypotheses for flight experiments.	none	none	none
5BSR8 Green	Publish final results of Bioastronautics experiments conducted during ISS Increment 8 and preliminary results from Increments 9 and 10.	4BSR9 Green	none	none
5BSR9 Green	Maintain productive peer-reviewed research program in Biomedical Research and Countermeasures, including a National Space Biomedical Research Institute that will perform team-based focused countermeasure-development research.	4BSR10 Green	none	none
5BSR10 White	Under the Human Research Initiative (HRI) increase the number of investigations addressing biomedical issues associated with human space exploration.	none	none	none
5BSR11 Green	Conduct scientific workshops to fully engage the scientific community in defining research strategies for addressing and solving NASA's biomedical risks.	none	none	none
5SFS20 Green	Certify the medical fitness of all crew members before launch.	4SFS10 Green	none	none

Performance Shortfalls

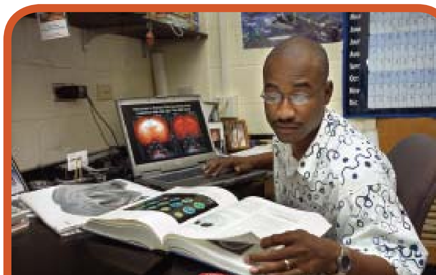
APG 5BSR10: The number of investigations addressing biomedical issues associated with human space exploration was not increased. Anticipated Human Research Initiative funding was reduced.

Outcome 8.6: By 2008, reduce the uncertainties in estimating radiation risks by one-half.

FY 2005	FY 2004
Green	Blue
	(9.1.2)

Through annual solicitations, NASA's Space Radiation Program expands the radiation research community by funding approximately 10 to 14 new, high-quality research projects each year. Between 2003 and 2005, the program increased from 51 research projects to 76. The selections in FY 2005 included 11 new individual projects, 10 of which were from researchers not funded previously through the Space Radiation Program.

Since the NASA Space Radiation Laboratory began full operations in October 2003, the Space Radiation Program has exceeded utilization plans. Original plans included 650 hours of beam time the first year, growing to 1,200 hours by 2007. During the first two years of operations (FY 2004 to FY 2005), the laboratory provided 2,251 hours of beam time to NASA- and Department of Energy-funded investigators performing research in radiation health and shielding. The October 2005 special issue of Radiation Research will include 18 papers containing the first published results from the NASA Space Radiation Laboratory. Laboratory researchers revised the methodology for assessing radiation risks and the uncertainties in projections and will apply it to new data sets in FY 2006.



A member of the Space Radiation Summer Student Program, hosted by NASA's Space Radiation Laboratory, conducts research. Since it opened in summer 2003 at Brookhaven National Laboratory, the laboratory has been an important venue for conducting radiobiology experiments for the U.S. space program. (Photo: Brookhaven National Laboratory)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5BSR12 Green	Expand the space radiation research science community to involve cutting edge researchers in related disciplines by soliciting, selecting, and funding high quality research.	4BSR11 Green	none	none
5BSR13 Green	Use 1000 hours/yr of beam time at the National Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory (BNL) to measure survival, genetic mutation (mutagenesis), and chromosome aberrations in cells and tissues to improve understanding of the biological effects of the space radiation environment.	none	none	none
5BSR14 Green	Integrate research data collected over the past two years at NSRL, with existing database to develop more accurate predictions resulting in improved biological strategies for radiation risk reduction.	none	none	none

Outcome 8.7: By 2010, identify and test technologies to reduce total mass requirements for life support by two thirds using current ISS mass requirement baseline.

FY 2005	FY 2004
Green	Green
	(9.2.1)

Future long-duration space exploration demands systems that are smaller, lighter, and more efficient than what NASA currently uses aboard its vehicles. By 2010, NASA seeks to reduce by two thirds the total mass of the advanced life support systems currently used aboard the Station. As life support technologies improve and become more compact, NASA moves incrementally toward achieving this target. Every year, NASA assesses the available technologies and determines how small and light NASA engineers can make support technologies (mass requirement) while still providing necessary life support to the Station: NASA reduced the mass requirement by 32 percent by the end of 2003 and 51 percent by the end of 2004, as defined by the advanced life support mass metric developed by NASA engineers.

This photo shows the water recovery system for the International Space Station's Environmental Control and Life Support System in 2000. NASA engineers are developing smaller, lighter, and more efficient technologies to reduce the mass of all life support systems for the Station and future space exploration spacecraft and surface habitats. (Photo: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5BSR17 Green	Demonstrate, through vigorous research and technology development, a 55% reduction in the projected mass of a life support flight system compared to the system baselined for ISS.	4BSR17 Green	3B2 Green	2B2 Green

FY 2005	FY 2004
Green	Green (9.2.1)

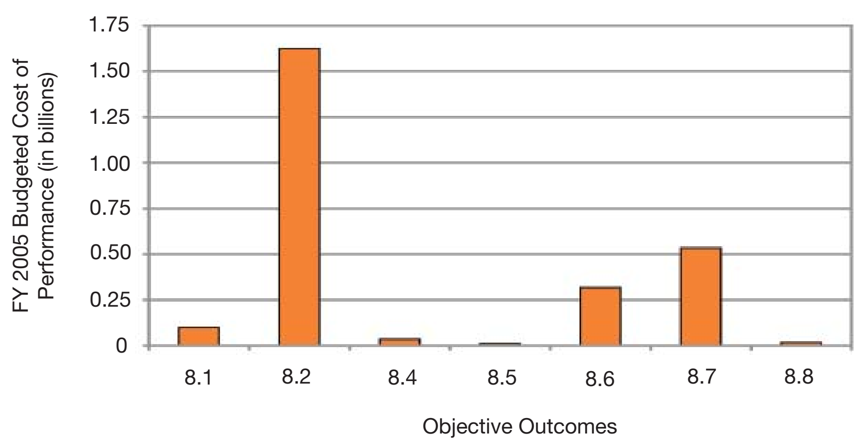
Outcome 8.8: By 2008, develop a predictive model and prototype systems to double improvements in radiation shielding efficiency.

NASA researchers are accumulating data on the radiation shielding effectiveness for a number of candidate shielding materials in anticipation of the 2008 milestone. NASA will narrow this set of candidate materials down to a select few that must meet specific requirements, including mechanical and environmental properties, before qualifying as multifunctional materials. So far, NASA has selected at least two candidate materials for further development.

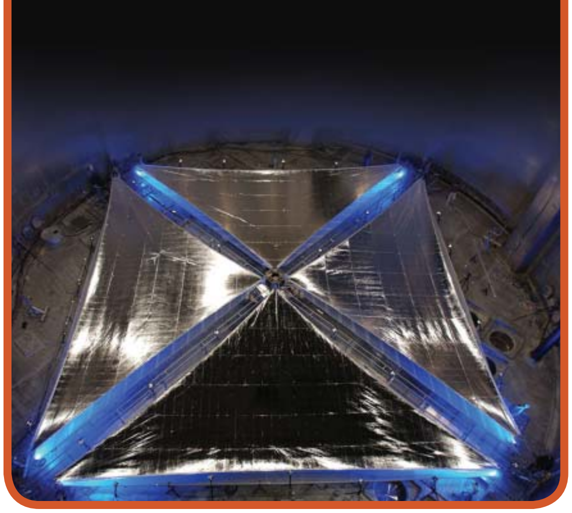
FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5BSR9 Green	Continue accumulating data on radiation effects on materials properties and initiate the assessment of the performance of multifunctional materials.	none	none	none

Resources

NASA's FY 2005 budgeted cost of performance for Objective 8 was $2.64 billion.



Objective 11: Develop and demonstrate power generation, propulsion, life support, and other key capabilities required to support more distant, more capable, and/or longer duration human and robotic exploration of Mars and other destinations.



WHY PURSUE OBJECTIVE 11?

To push the boundaries of robotic and human space exploration, NASA continuously must improve the systems that support this exploration. These systems cover a wide range of capabilities: batteries that work reliably in the extreme cold of deep space; propulsion systems that generate more power and speed with less fuel; dexterous robots that can explore autonomously or serve as astronaut helpers; mobility systems that astronauts can use in near-weightlessness and on planetary surfaces; modular life support and habitation systems; better scientific instruments and sensors; in-situ resource utilization technologies; improved communications and navigation systems; and advanced computing, modeling, simulation, and analysis technologies.

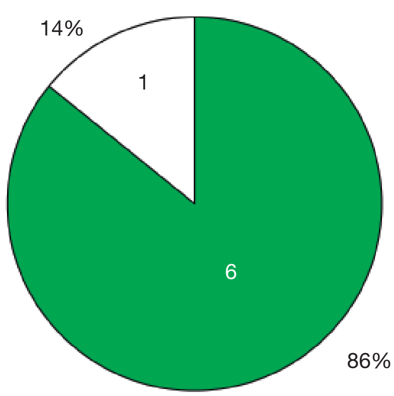
NASA's goal is to develop the best possible exploration architecture—one that is flexible, affordable, reliable, and safe—to help the Agency achieve the Vision for Space Exploration. This means refining requirements, conducting rigorous cost and risk analysis, and thoroughly testing systems. These capabilities will evolve in stages as technologies reach maturity.

NASA partners with other government agencies, U.S. industry, and academia to develop capabilities for the space program. NASA also provides the capital funds and facilities to help small businesses develop and produce their space-related technologies for commercial and government use. These partnerships are beneficial to all involved and help maintain vigorous technology research, development, and manufacturing within the United States.

Left: A four quadrant, 20-meter solar sail system is fully deployed during testing at NASA Glenn Research Center's Plum Brook facility in Sandusky, Ohio. The tests were a critical step toward developing the unique propulsion technology, where sunlight pressure provides the necessary thrust to propel the spacecraft toward its destination. (Photo: NASA)

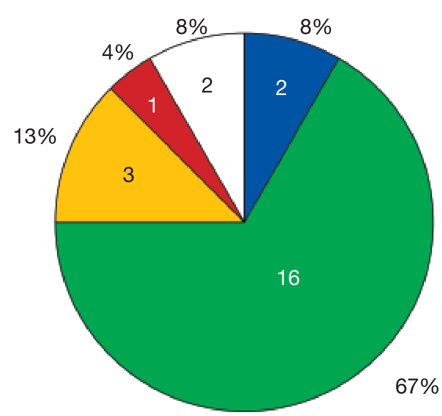
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 11, NASA is on track to achieve six of seven Outcomes.

APG Ratings



Under Objective 11, NASA achieved 18 of 24 APGs.

NASA DID NOT PURSUE OUTCOMES 11.1 OR 11.2 IN FY 2005.

	FY 2005	FY 2004
Outcome 11.3	Green	Green (9.4.1)

Outcome 11.3: By 2015, identify, develop, and validate human-robotic capabilities required to support human-robotic exploration of Mars and other destinations.

In FY 2005, NASA established a strategy-to-task technology research and development planning process and identified and developed programs that support technology concepts, International Space Station utilization, and analysis for human–robotic lunar missions. Using its advanced technology lifecycle analysis system tools, NASA tested and validated reference architectures, modeling capabilities, and potential future technologies. The Agency also held a series of technical interchange meetings focused on helping designers, developers, and customers quantify a variety of technologies and customer needs while helping NASA select different approaches for ongoing system and technology planning for lunar missions. NASA also tested and validated over 20 reference architectures and relevant technologies identified in the Advanced Technology Life-cycle Analysis System, a system to help NASA identify and use available space exploration technologies and systems and plan mission architectures.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT1 Green	Establish an integrated, top-down strategy-to-task technology R&D planning process to facilitate the development of human-robotic exploration systems requirements.	4HRT1 Green	none	none
5HRT2 Green	Execute two systems-focused Quality Function Deployment exercises through an Operational Advisory Group (including both technologists and operators) to better define systems attributes necessary to accomplish human-robotic exploration operational objectives.	4HRT2 Green	none	none
5HRT3 Green	Execute selected R&D-focused Quality Function Deployment exercises through an external/internal Technology Transition Team to review candidate human-robotic exploration systems technologies, and provide detailed updates to human-robotic technology road maps.	4HRT3 Green	none	none
5HRT4 Green	Test and validate preferred engineering modeling and simulation computational approaches through which viable candidate architectures, systems designs, and technologies may be identified and characterized. Select one or more approaches for ongoing use in systems/technology road mapping and planning.	none	none	none
5LE1 Yellow	Identify and define preferred human-robotic exploration systems concepts and architectural approaches for validation through lunar missions.	none	none	none
5LE2 Red	Identify candidate architectures and systems approaches that can be developed and demonstrated through lunar missions to enable a safe, affordable, and effective campaign of human-robotic Mars exploration.	none	none	none
5LE6 Yellow	Identify preferred approaches for development and demonstration during lunar missions to enable transformational space operations capabilities.	none	none	none
5LE7 Green	Conduct reviews with international and U.S. government partners to determine common capability requirements and opportunities for collaboration.	none	none	none

Performance Shortfalls

APG 5LE1: NASA has not completed the results, only preliminary concepts, for APG 5LE1. NASA's near-term focus is on lunar site selection and characterization, rather than human-robotic linkages. Future architecture and long-term linkages will flow from the Exploration Systems Architecture Study results announced in August 2005.

APG 5LE2: NASA shifted its near-term focus to lunar exploration and, therefore, has deferred linkages to Mars exploration to re-allocate resources for Constellation Systems development.

APG 5LE6: NASA performed limited analysis of space operations. NASA's near-term focus for robotic exploration is on site selection and characterization. NASA will derive the linkage to transformational operations from the Exploration Systems Architecture Study results and architecture development.

	FY 2005	FY 2004
Outcome 11.4	Green	Green (9.4.2)

Outcome 11.4: By 2015, identify and execute a research and development program to develop technologies critical to support human-robotic lunar missions.

NASA established a research and development program to support human–robotic lunar missions. The program includes subsystem technology development efforts and a Robotic Lunar Exploration Program that will launch its first mission, the Lunar Reconnaissance Orbiter (currently in development), in late 2008. The second mission, a lander, is in program formulation and planned for launch by 2010.

NASA also identified, analyzed, and executed viable technology candidates critical to program development in support of human–robotic lunar missions, including self-sufficient space systems, habitation and bioastronautics, and space assemblies.

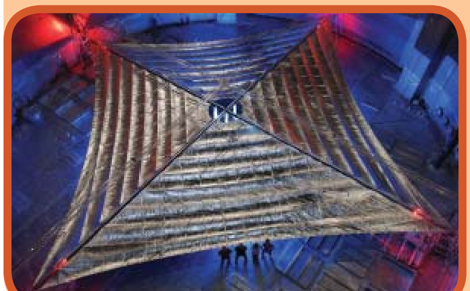
This artist's concept shows vehicles exploring the surface of the Moon. Throughout FY 2005, NASA formed a phased capability and advanced technology architecture to meet future robotic and human lunar exploration needs. (Image: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT5 Green	Identify and analyze viable candidates and identify the preferred approach to sustained, integrated human-robotic solar system exploration involving lunar/planetary surfaces and small bodies, and supporting operations. Validate a focused technology R&D portfolio that addresses the needs of these approaches and identifies existing gaps in technological capabilities.	none	none	none
5HRT6 Green	Establish and obtain approval for detailed R&D requirements, road maps, and program planning in key focused technology development areas, including self-sufficient space systems; space utilities and power; habitation and bioastronautics; space assembly, maintenance, and servicing; space transportation; robotic networks; and information technology and communications.	none	none	none
5LE3 Green	Establish a baseline plan and Level 1 requirements to utilize the robotic lunar orbiter(s) and robotic lunar surface mission(s) to collect key engineering data and validate environmental characteristics and effects that might affect later robotics, astronauts, and supporting systems.	none	none	none
5LE4 Green	Identify candidate scientific research and discovery opportunities that could be pursued effectively during robotic lunar missions.	none	none	none
5LE5 Green	Establish a viable investment portfolio for development of human support systems, including human/machine extravehicular activity (EVA) systems, locally autonomous medical systems, and needed improvements in human performance and productivity beyond low Earth orbit (LEO).	none	none	none

Spotlight: NASA and Partners Test a Solar Sail System

In June 2005, NASA reached a milestone in the testing of solar sails when engineers successfully deployed a 20-meter solar sail system that uses an inflatable boom deployment design. NASA and its commercial partner deployed the system at the Space Power Facility, the world's largest space environment simulation chamber, at Glenn Research Center's Plum Brook Station in Sandusky, Ohio. The complete test ran 30 days.

Solar sail technologies use energy from the Sun to power a spacecraft's journey through space. Sunlight bounces off giant, reflective sails made of lightweight material 40- to 100-times thinner than a piece of writing paper. Because the Sun provides the necessary propulsive energy, solar sails require no onboard propellant, making them lighter than traditional propulsion systems and increasing their range of mobility or their ability to hover at a fixed point for longer periods of time. This new type of propulsion system could enable more ambitious missions within the inner solar system.



NASA engineers, visible near the bottom of the photo, look at a 20-meter solar sail and boom system after it is fully deployed during testing at NASA's Space Power Facility. Red and blue lights help illuminate the four triangular sail quadrants as they lie outstretched. The sail material is supported by a series of inflatable booms that become rigid in the space environment. The system extends via remote control from a central stowage container about the size of a suitcase. (Photo: NASA)

Outcome 11.5: By 2016, develop and demonstrate in-space nuclear fission-based power and propulsion systems that can be integrated into future human and robotic exploration missions.

FY 2005	FY 2004
White	Green
	(9.4.3)

Recently, NASA identified a logical and affordable path to realizing the Vision for Space Exploration through the recently completed Exploration Systems Architecture Study. The review did not identify a near-term need for nuclear fission systems, so Outcome 11.5 is no longer applicable. NASA, however, will focus on nuclear research and technology studies, including development of nuclear systems strategic plans and formulation of program and nuclear technology development objectives, to meet longer-term exploration and science needs.

NASA will still need a longer-term nuclear capability for extended human presence in space, whether on the Moon, Mars, or in transit. Extended human stays on the Moon, even where there is plenty of sunlight, will require power support for the 14-day-long lunar nights. A surface nuclear reactor power system would provide adequate power to support human exploration on the lunar surface or on the surface of Mars. Such a system also could provide the large amounts of power needed support in-situ resource utilization to process surface resources such as lunar soils for oxygen. For long duration stays on the surface, oxygen could be very important for sustaining human existence on the surface and also useful as a source of rocket propellant and other consumables.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT7 Green	Develop Level1/Level 2 requirements for nuclear power and propulsion systems in support of selected human and robotic exploration architectures and mission concepts.	none	none	none
5HRT8 White	Complete a validated road map for nuclear power and propulsion R&D, and related vehicle systems technology maturation.	none	none	none
5HRT9 Green	Formulate a demonstration mission plan for Jupiter Icy Moons Orbiter that will test and validate nuclear power and propulsion systems for future human-robotic exploration missions.	none	none	none

Outcome 11.6: Develop and deliver one new critical technology every two years in each of the following disciplines: in-space computing, space communications and networking, sensor technology, modular systems, robotics, power, and propulsion.

FY 2005	FY 2004
Green	Green
	(9.4.4)

Researchers for NASA's Advanced Space Technology Program developed two technologies that will be used for Mars missions: a 100-Watt Ka-band traveling wave tube amplifier for the 2009 Mars Telecommunication Orbiter and a micro sun sensor for the Mars Science Laboratory. The new transmitter has 10 times the output capability than existing deep space communication devices, and the new transmitter will increase significantly the rate of data return from Mars. NASA will use the micro sun sensor to navigate the Mars Science Laboratory rover across the surface of Mars by measuring the position of the Sun. The micro sun sensor weighs less than 0.35 ounces and is about 10 times smaller than conventional sun sensors.

This photo shows a 100-Watt Ka-band traveling wave tube amplifier designed for NASA's 2009 Mars Telecommunication Orbiter mission. (Photo: NASA)

NASA's Centennial Challenges Program continues

NASA's Centennial Challenges Program continued to reach out to the best and brightest in the Nation through four challenges announced in FY 2005: the 2005–2006 Tether Challenge, the 2005–2006 Beam Power Challenge, the MoonROx Challenge, and the 2006 Astronaut Glove Challenge. NASA awaits Congressional authorization to announce Challenges with larger purses.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT15 White	Complete an Advance Space Technology Program technology road map that interfaces appropriately with technology planning of NASA's Mission Directorates.	none	none	none
5HRT16 Green	Deliver at least one new critical technology in each key area (including in-space computing, space communications and networking, sensor technology, modular systems, and engineering risk analysis) to NASA's Mission Directorates for possible test and demonstration.	none	none	none
5HRT17 Blue	Prepare and announce the Centennial Challenge Cycle 2 major award purses, including competition rules, regulations, and judgment criteria.	none	none	none

Outcome 11.7: Promote and develop innovative technology partnerships, involving each of NASA's major R&D programs, among NASA, U.S. industry, and other sectors for the benefit of Mission Directorate needs.

FY 2005	FY 2004
Green	Blue
	(10.3.1)

In FY 2005, NASA signed 85 technology partnerships to benefit each of NASA's major research and development and Mission Directorate needs. However, NASA did not sign any partnerships using the Enterprise Engine concept. As of the third quarter of FY 2005, 100 percent of 185 signed innovative technology infusion partnership agreements demonstrated their value to NASA.

The patented, portable hyperspectral camera and its applications were developed by the Institute for Technology Development, a NASA Research Partnership Center at NASA's Stennis Space Center. The Environmental Protection Agency teamed with NASA to use the hyperspectral imaging technology to improve crop management by helping growers easily distinguish between a traditional and a bioengineered crop. Hyperspectral imaging also can be used in treating astronaut wounds in space. The Institute for Technology Development is working on a portable, handheld camera that an astronaut could use to capture an image of a wound site. The goal of all research partnerships is to create technologies that are beneficial to NASA and the public. (Photo: NASA/SSC)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT12 Yellow	Establish three partnerships with U.S. industry and the investment community using the Enterprise Engine concept.	4HRT8 Yellow	none	none
5HRT13 Green	Develop 12 industry partnerships, including three established using the Enterprise Engine, that will add value to NASA Mission Directorates.	4HRT9 Blue	none	none

Performance Shortfalls

APG 5HRT12: NASA did not form any partnerships with industry or the investment community using the Enterprise Engine concept in FY 2005. NASA's Administrator canceled the program. However, the Agency did create partnerships through other means, keeping NASA on track to achieve the Outcome.

Outcome 11.8: Annually facilitate the award of venture capital funds or Phase III contracts to no less than two percent of NASA-sponsored Small Business Innovation Research Phase II firms to further develop or produce their technology for industry or government agencies.

FY 2005	FY 2004
Green	Green
	(10.3.2)

NASA's Alliance for Small Business Opportunity (NASBO) Program awarded contracts to two Small Business Innovation Research firms, WaveBand Corporation and Tao of System Integration, Inc.

WaveBand Corporation applies millimeter wave technology to autonomous landing applications. The first collaboration was a follow on flight test conducted by WaveBand/Sierra Nevada Corporation and a major airplane manufacturer, resulting in a $3 million contract to certify the technology. The end result may be the inclusion of the radar technology in commercial aircraft.

Tao of System Integration, Inc., provides software to characterize broad platform flow. Tao's first support from NASBO was to identify and introduce a major aerospace firm interested in licensing Tao's technology, but difficulty in coming to terms with intellectual property ownership prevented the deal from being signed. NASBO then enrolled Tao in its eight-week Sales Acceleration workshop series. Tao benefited from this hands-on approach: the company changed its business model, identified a single application of many possibilities, and is committing 60 percent of management's resources to the applications' launch. Currently Tao is in negotiations with Boeing for its first sale. Tao also is working actively with the Dryden Flight

NASA's F-15B #837 (painted red, white, and blue) participates in a flight test on the Intelligent Flight Control System while its stablemate, F-15B #836, serves as a chase plane on July 22, 2005. From June through August 2005, NASA's Dryden Flight Research Center also conducted experimental flight tests with sensors and electronics developed by Tao to determine unsteady aerodynamic characteristics of an F-15B tail instrumented with strain gages and hot-film sensors. (Photo: C. Thomas/NASA)

Research Center to infuse into its technology the recent results of an F-15 flight test.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT14 Green	Achieve through NASBO the award of Phase III contracts or venture capital funds to no less than two SBIR firms to further develop or produce their technology through industry or government agencies.	4HRT10 Green	none	none

NASA did not pursue Outcome 11.9 in FY 2005.

Outcome 11.10: By 2005, demonstrate two prototype systems that prove the feasibility of resilient systems to mitigate risks in key NASA mission domains. Feasibility will be demonstrated by reconfigurability of avionics, sensors, and system performance parameters.

FY 2005	FY 2004
Green	Green

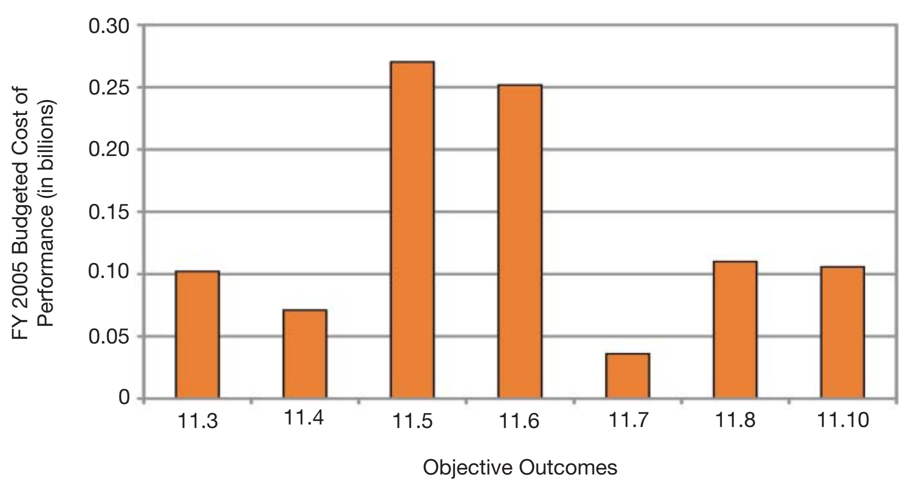
(10.1.1)

NASA demonstrated two prototype systems tools via the development of the prototype Function-based Failure Design Tool and the Investigation Organizer. The Function-based Failure Design Tool helps engineers identify potential failures during the earliest stages of design, when solutions are incomplete and only loosely specified by functions. Xerox is commercializing the Investigation Organizer. The Investigation Organizer is an automated software tool developed by NASA ARC to collect different types of data and put this data into an organizational structure that is more easily interpreted and used. Investigation Organizer provides a central information repository that can be used by mishap investigation teams to store digital products. NASA used the tool to support the *Columbia* accident investigation.

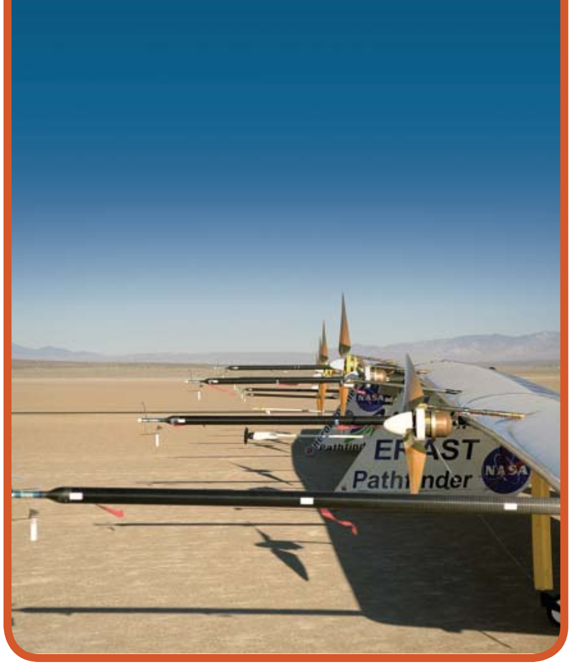
FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT10 Green	Develop prototype design and organizational risk analysis tools to do risk identifications, assessments, mitigation strategies, and key trade-off capabilities not only between risks, but between risks and other mission design criteria.	none	none	none
5HRT11 Blue	Develop a robust software tool for accident investigation that can help identify the causes of spacecraft, airplane, and/or other mission hardware accidents.	none	none	none

Resources

NASA's FY 2005 budgeted cost of performance for Objective 11 was $0.96 billion.



Objective 12: Provide advanced aeronautical technologies to meet the challenges of next-generation systems in aviation, for civilian and scientific purposes, in our atmosphere and in atmospheres of other worlds.



WHY PURSUE OBJECTIVE 12?

NASA's predecessor, the National Advisory Committee for Aeronautics, responded to the Nation's urgent need to learn about the science of flight. That research contributed to the design of every American aircraft of the time, commercial and military. Today, NASA meets the Nation's urgent need to transform its air transportation system to benefit the public by developing barrier-breaking technologies for aircraft and supporting systems that are safer, more secure, more efficient, and friendlier to the environment.

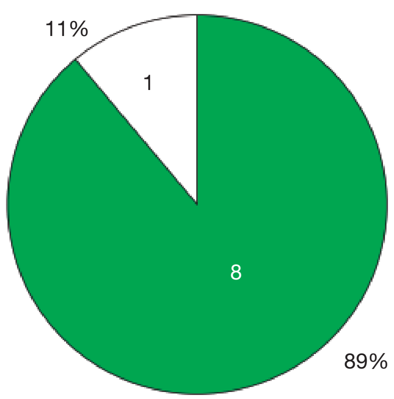
NASA's aeronautics program has five goals: protect air travelers and the public; protect the environment from polluting emissions and excessive noise; increase the mobility of travelers and goods; partner with other government agencies, academia, and the commercial sector for national security; and explore revolutionary aeronautical concepts to develop the next generation of aircraft and support systems.

NASA also is exploring ways to apply its aeronautical technologies to the Agency's space exploration goals. For example, NASA's technologies to pilot remotely uncrewed aircraft may be applied to robotic planetary vehicles, and supersonic, oxygen-breathing jets like the X-43A may offer a low-cost way to deliver crews and cargo to orbit.

Left: Sensitive instruments mounted on booms extending forward of the wing measure air turbulence and its effect on stability on NASA's Pathfinder–Plus solar-electric flying wing, shown parked at Rogers Dry Lake, adjoining Dryden Flight Research Center, California. NASA and AeroVironment, Inc., teamed up in 2004 through 2005 to conduct research flights on the lightweight solar aircraft. (Photo: T. Tschida/NASA)

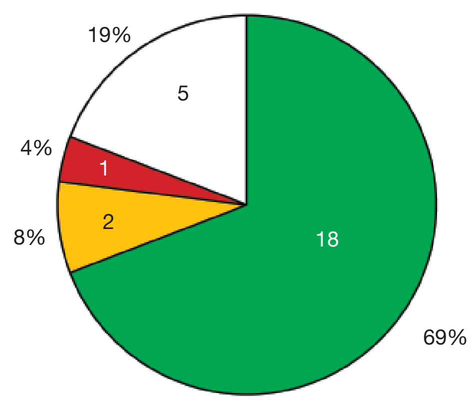
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 12, NASA is on track to achieve eight out of nine Outcomes.

APG Ratings



Under Objective 12, NASA achieved 18 out of 26 APGs.

FY 2005	FY 2004
Green	Green (2.1.1)

Outcome 12.1: By 2005, research, develop, and transfer technologies that would enable the reduction of the aviation fatal accident rate by 50 percent from the FY 1991-1996 average.

NASA's research and development program to reduce the fatal aircraft accident rate focuses on preventing accidents involving hazardous weather and icing conditions, controlled flight into terrain, and mechanical or software malfunctions. NASA also seeks to decrease injuries and fatalities when accidents do occur. Flight tests in FY 2005 resulted in significant improvements in pilot situational awareness and confidence in the Weather and Synthetic Vision Systems. NASA developed and transferred to the Federal Aviation Administration information technologies needed to build a safer aviation system—supporting pilots and air traffic controllers—and information to assess situations and trends that might indicate unsafe conditions before they lead to accidents. NASA's extensive safety and cost benefit analysis indicates that if these technologies had been applied to the 1990–1996 National Transportation Safety Board set of accident causes, they would have had either a direct or indirect impact on reducing the accident rate for over 80 percent of accident causes.

The Tropospheric Airborne Meteorological Data Report, or TAMDAR, instrument, shown here installed aboard a Masaba Airlines aircraft, allows aircraft flying below 25,000 feet to sense automatically and report atmospheric conditions. Observations are sent by satellite to a ground data center. The center processes and distributes up-to-date weather information to forecasters, pilots, and those who brief pilots. (Photo: Masaba Airlines)

	FY 2005 Annual Performance Goals	FY 2004	FY 2003	FY 2002
5AT1 Green	Evaluate and flight validate selected next generation cockpit weather information, communications, airborne weather reporting, turbulence prediction and warning technologies, Synthetic Vision System and Runway Incursion Prevention System display concepts. The flight demonstration will illustrate the increased safety of integrating selected concepts in support of fleet implementation decisions. (AvSSP)	none	none	none
5AT2 Green	Demonstrate through applications and simulations safety-improvement systems that will illustrate the increased safety of integrating selected concepts in support of fleet implementation decisions. (AvSSP)	none	none	none

FY 2005	FY 2004
Green	none

Outcome 12.2: Develop and validate technologies (by 2009) that would enable a 35 percent reduction in the vulnerabilities of the National Airspace System (as compared to the 2003 air transportation system).

NASA continued its progress toward reducing the vulnerability of the National Airspace System through formal research agreements with the Transportation Security Administration, the Federal Air Marshall Service, and the Department of Homeland Security Science and Technology Directorate. Members of those organizations joined the Aviation Safety and Security Subcommittee within NASA's Aeronautics Research Advisory Committee. NASA defines additional activities monthly in cooperation with the Next Generation Air Transportation System Joint Program and Development Office. During FY 2005, NASA and its partners developed a new anonymous incident reporting system, analyzed threat assessments, and developed a concept for surveillance of protected areas.

	FY 2005 Annual Performance Goals	FY 2004	FY 2003	FY 2002
5AT3 Green	Create and establish a prototype data collection system for confidential, non-punitive reporting on aviation security by functional personnel in the aviation system.	none	none	none
5AT16 Green	Develop a preliminary joint research plan with the Transportation Security Administration (TSA). (AvSSP)	none	none	none

FY 2005	FY 2004
Green	none

Outcome 12.3: Develop and validate technologies that would enable a 10-decibel reduction in aviation noise (from the level of 1997 subsonic aircraft) by 2009.

NASA completed testing for the following noise reduction test articles in August 2005: a jointless acoustic barrel for the inlet; an acoustically-treated inlet lip; a fan thrust reverser with chevrons; variable geometry chevrons for fan thrust reverser; primary chevron; aligned landing gear; and toboggan landing gear fairing. NASA researchers also gathered acoustic data in the cabin for cruise and take-climb-out conditions as well as community noise data for takeoff, approach, and airframe noise. NASA validated noise-reduction projections for the selected concepts. These projections, when combined with benefits anticipated from aircraft operations in an aircraft-system-level noise assessment, will reduce aircraft noise sufficiently to fully meet the 10 dB noise reduction goal.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5AT4 Green	Using laboratory data and systems analysis, complete selection of the technologies that show the highest potential for reducing commercial air transportation noise by at least 50%. (Vehicle Systems)	none	none	none

Spotlight: NASA Works to Quiet the Skies

A huge ball of microphones that looks like a robotic porcupine may help make airplane cabins quieter for passengers and flight crews. Technicians at NASA's Langley Research Center installed the microphones and other sensor arrays on a B-757 "flying laboratory" to measure interior noise and assess the effectiveness of sound deadening materials.

A NASA research team installs a sphere containing 50 sensitive microphones in the cabin of a 757 jet to isolate the sources of noise that are irritating to aircraft crew and passengers. This testing helps engineers develop planes that are quieter and more comfortable. (Photo: NASA)

"The goal of NASA's Quiet Aircraft Technology project is to reduce the impact of aircraft noise on all our citizens . . . those on the ground and those in the air," said Mike Marcolini, Quiet Aircraft Technology project manager. "We've already had some success reducing engine noise. We're working on making engines even quieter and tackling the noise that airplane structures, like landing gears, make."

Sensitive microphones were placed inside the cabin to isolate the sources of irritating cabin noise, while sensors placed on the outer skin of the B-757 measured the pressure fluctuations of the air passing closest to the fuselage, also known as the turbulent boundary layer, and transmitted that information to data systems inside the aircraft. Computers recorded data from all sensors and microphones simultaneously providing data so researchers can begin to explore best methods for pinpointing and measuring noise sources. The researchers also compared how well current insulation and wall treatments were able to reduce noise. Future research will emphasize new materials that might be used to reduce sound even further.

Outcome 12.4: By 2010, flight demonstrate an aircraft that produces no CO_2 or NOx to reduce smog and lower atmospheric ozone.

FY 2005	FY 2004
White	none

The engine shown above demonstrated a 50 percent reduction in NOx emissions during past tests conducted by NASA's program partner, Pratt & Whitney. (Photo: NASA)

A reduction in FY 2005 funding severely impacted the Ultra-efficient Engine Technology program, including the Low-NOx Combustor Detailed Design Review milestone originally planned for completion in the second quarter of FY 2005.

While engine technology is the major contributor to CO_2 and NOx reduction, improvements to aerodynamic performance also reduce emissions. NASA researchers achieved two significant aerodynamic performance improvements in FY 2005—completing key studies on advanced fuel cell and hybrid systems, and testing a low-drag slotted wing concept at flight-design conditions.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5AT5 Red	Demonstrate 70% reduction NOx emissions in full-annular rig tests of candidate combustor configurations for large subsonic vehicle applications. (Vehicle systems)	none	none	none
5AT6 Green	Based on laboratory data and systems analysis, select unconventional engine or power systems for technology development that show highest potential for reducing CO_2 emissions and/or enabling advanced air vehicles for new scientific missions. (Vehicle Systems)	none	none	none
5AT7 Green	Complete laboratory aerodynamic assessment of low-drag slotted wing concept. (Vehicle Systems)	none	none	none
5AT27 White	Demonstrate through sector testing a full scale CMC turbine vane that will reduce cooling flow requirements and thus fuel burn in future turbine engine system designs. (Vehicle Systems)	none	none	none

Performance Shortfalls

Outcome 12.4: NASA discontinued the Ultra-efficient Engine Technology program in the FY 2006 Budget Request, due to a change in Agency focus, so it is unlikely that NASA will achieve this Outcome.

APG 5AT5: NASA funded three companies to demonstrate 70 percent NOx reduction. However, a reduction of FY 2005 funding severely impacted the Ultra-efficient Engine Technology project, including the Low-NOx Combustor detailed design review milestone that was planned for completion in 2005. One contractor did complete a detailed design review of their concept and is continuing with testing as remaining Ultra-efficient Engine Technology project funds run out. Final termination decisions and notices are pending.

APG 5AT27: This effort was deleted from the Ultra-efficient Engine Technology portfolio. Budget constraints during the re-planning of the Vehicle Systems Program did not allow for this effort from earlier Propulsion and Power Project efforts to be included into the Ultra-efficient Engine Technology portfolio.

FY 2005	FY 2004
Green	Green (2.3.2)

Outcome 12.5: By 2005, develop, demonstrate, and transfer key enabling capabilities for a small aircraft transportation system.

During FY 2005, NASA conducted integrated flight experiments demonstrating the technical and operational feasibility of the four Small Aircraft Transportation System project operating capabilities: higher volume operations, en-route integration, lower landing minima, and single-pilot performance.

Visitors pack into the main tent of the SATS 2005: A Transformation of Air Travel technology demonstration in Danville, Virginia, to catch a glimpse of the possible future of personalized air travel by small plane. In addition to technology demonstrations, the three-day event for professionals and enthusiasts featured advanced small aircraft, interactive exhibits, and flight simulators. (Photo: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5AT10 Green	Complete experimental validation of airborne systems with concept vehicle development.	none	none	none

FY 2005	FY 2004
Green	none

Outcome 12.6: Develop and validate technologies (by 2009) that would enable a doubling of the capacity of the National Airspace Systems (from the 1997 NASA utilization).

NASA made significant progress toward doubling the capacity of the National Airspace Systems in FY 2005. As part of this effort, NASA defined three different configurations to meet requirements for the Civil Heavy Lift Vertical Takeoff and Landing mission.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5AT8 Green	Complete development of WakeVAS concept of operations and downselect WakeVAS architecture.	none	none	none
5AT9 White	Complete human-in-the-loop concept and technology evaluation of shared separation. (Airspace Systems)	none	none	none
5AT11 Green	Complete analysis of capacity-increasing operational concepts and technology road maps with VAST models, simulations, and Common Scenario Set. (Airspace Systems)	none	none	none
5AT12 Green	Develop display guidelines that exploit new understanding of perceptual systems and cognitive and physiological determinants of human performance. (Airspace Systems)	none	none	none
5AT13 White	Establish the fluid dynamics mechanism for alleviating wake through experimental and computational fluid mechanics studies. (Airspace Systems)	none	none	none
5AT14 White	Complete System-Wide Evaluation and Planning Tool initial simulation and field demonstration. (Airspace Systems)	none	none	none
5AT15 White	Complete communications, navigation, and surveillance requirements analysis. (Airspace Systems)	none	none	none
5AT17 Green	Complete NASA/industry/DoD studies of heavy-lift Vertical Take Off and Landing (VTOL) configurations to provide strategic input for future decisions on commercial/military Runway Independent Vehicles. (Vehicle Systems)	none	none	none
5AT22 Yellow	Using laboratory data and systems analysis, complete selection of the technologies that show the highest potential for reducing takeoff/landing field length while maintaining cruise Mach, low speed controllability, and low noise. (Vehicle Systems)	none	none	none

Performance Shortfalls

APG 5AT9: This APG was not completed in FY 2005 and was delayed to FY 2006 due to FY 2005 budget constraints. FY 2005 accomplishments include completion of initial air-ground human-in-the-loop simulation environment, concept simulation demonstration of UPS Louisville hub operations, and establishment of NASA/FAA/Boeing partnership to develop a tailored arrivals test plan.

APG 5AT13: This APG was not completed in FY 2005 and was delayed to FY 2006 due to FY 2005 budget constraints. FY 2005 accomplishments include completion of initial tests of wake vortex-alleviating configurations and presentation of research paper at "Principles in Wake Vortex Alleviation Devices" workshop in Toulouse, France.

APG 5AT14: This APG was not completed in FY 2005 and was delayed to FY 2006 due to FY 2005 budget constraints. FY 2005 accomplishments include deployment of System-Wide Evaluation and Planning Tool (SWEPT) Reroute Conformance Monitoring algorithms in FAA's Enhanced Traffic Management System, license of Future ATM Concepts Evaluation Tool (FACET) to Flight Explorer, and reception of NASA Space Act Award for FACET development.

APG 5AT15: This APG was not completed in FY 2005 and was delayed to FY 2006 due to FY 2005 budget constraints. FY 2005 accomplishments include completion of draft mobile communications network architecture definition documents review, completion of application analysis and identification of airport surface ICNS network architecture definition, completion of FAA Radio Frequency Interference (RFI) analysis at Cleveland Hopkins Airport, and completion of C-band channel sounding and interference tests at two Cleveland, OH, airports and at two Miami, FL, airports.

APG 5AT22: This APG was not completed in FY 2005 due to FY 2005 budget constraints. NASA is conducting limited internal studies. External technology trade studies did not take place in FY 2005, but work is expected to be completed in FY 2006.

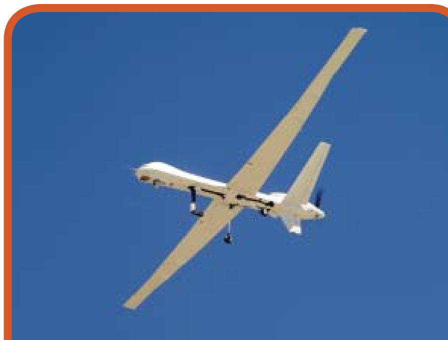
NASA did not pursue Outcomes 12.7 or 12.8 in FY 2005.

FY 2005	FY 2004
Green	Green
	(10.5.1)

Outcome 12.9: Develop technologies that would enable solar powered vehicles to serve as "sub-orbital satellites" for science missions.

NASA completed a series of research flights at Dryden Flight Research Center for the Pathfinder–Plus solar-electric flying wing to investigate the effects of turbulence on lightweight, flexible wing structures. The flights marked the end of an era in solar-powered flight research for the 23-year-old craft which is due for retirement shortly.

Flown by crews from AeroVironment, Inc., owner and builder of the unique experimental aircraft, the Pathfinder–Plus made two low-altitude flights over the northern portion of Rogers Dry Lake at Edwards Air Force Base in California. The first was a three-hour flight on August 31, followed by a more-than two-hour mission on September 14. Both missions flew on a combination of solar and battery power.



The long, slender wings of the General Atomics Altair Predator-B remotely operated aircraft stand out against the bright blue sky during a climatic and environmental monitoring mission conducted in spring 2005. The aircraft was developed by General Atomics under NASA's Environmental Research Aircraft and Sensor Technology project. In addition to environmental research, NASA uses the Predator-B to validate technologies for high-altitude, long-endurance remotely operated aircraft. (Photo: T. Tschida/NASA)

NASA completes requirements for remotely operated aerial vehicle

In FY 2005, NASA completed and captured requirements for the Predator-B aircraft, an extended-wingspan civil variant of the turboprop-powered military QM-9 Predator B remotely operated aerial vehicle being developed by General Atomics Aeronautical Systems. The systems-level vehicle architecture will address all systems on-board: propulsion, airframe, avionics, flight controls, health management, and mission management. General Atomics will use NASA's requirements to build the research avionics that will be installed on the Predator in FY 2006 to support major flight experiments in FY 2007. The new aircraft is designed to meet payload, duration, and altitude requirements for NASA's Earth science missions. It also will serve as a testbed to demonstrate operational reliability and systems redundancy necessary to allow remotely operated aircraft to fly in the national airspace.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5AT20 Yellow	Complete flight demonstration of a second generation damage adaptive flight control system. (Vehicle Systems)	none	none	none
5AT21 Green	Define requirements for a robust, fault-tolerant avionics architecture that supports fully autonomous vehicle concepts. (Vehicle Systems)	none	none	none
5AT24 Green	Complete laboratory aerodynamic assessment of low-drag slotted wing concept. (Vehicle Systems)	none	none	none
5AT25 Green	Based on laboratory data and systems analysis, select unconventional engine or power systems for technology development that show highest potential for reducing CO_2 emissions and/or enabling advanced air vehicles for new scientific missions. (Vehicle Systems)	none	none	none
5AT26 Green	Complete initial flight series for validation of improved HALE ROA aero-structural modeling tools used to reduce risk and increase mission success. (Vehicle Systems)	none	none	none

Performance Shortfalls

APG 5AT20: NASA is making good progress in the technical development of second-generation adaptive flight control system software. However, a reduction of $1.25 million in funds impacted the completion of this APG. The result was that NASA delayed the schedule for software delivery and the start of the second-generation flight demonstration. NASA also will reduce the scope of the flight demonstration to limited flight envelope testing and will not demonstrate the full capability of the damage adaptive control system. However, NASA anticipates that this APG will be achieved in FY 2006.

Outcome 12.10: By 2008, develop and demonstrate technologies required for routine Unmanned Aerial Vehicle operations in the National Airspace System above 18,000 feet for High-Altitude, Long-Endurance (HALE) UAVs.

FY 2005	FY 2004
Green	Green
	(10.5.2)

NASA worked toward routine unmanned vehicle operations in the National Airspace System by finalizing requirements for a cooperative collision avoidance demonstration. The Agency selected a vehicle and equipment and integrated collision avoidance systems into the vehicle.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5AT23 Green	Demonstrate integrated technologies and policies for UAV flight operations above FL400. (Vehicle Systems)	none	none	none

FY 2005	FY 2004
Green	none

Outcome 12.11: Reduce the effects of sonic boom levels to permit overland supersonic flight in normal operations.

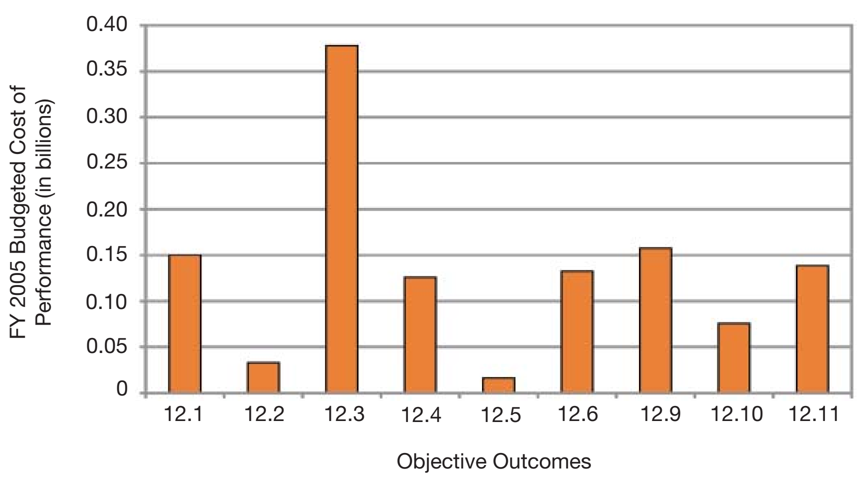
NASA competitively selected industry teams to perform a system study to define the inlet requirements and identify key technologies for a small quiet supersonic vehicle like a supersonic business jet. The Integrated Inlet Propulsion Systems Study compared two different engine cycles: high-bypass ratio and variable cycle as part of the assessment. The key technologies identified greatly enhance the range for this vehicle class with the potential to make it economically viable. NASA also identified key technologies needed to enable a highly-integrated inlet/propulsion system and created technology development plans.

Along with the propulsion activities, NASA researchers conducted a number of flight and system demonstrations to assess methods of demonstrating low-boom–no-boom technologies. ("Boom" refers to the characteristic sound generated by an aircraft traveling in excess of the speed of sound). NASA accomplished many flights in the area of Low Boom testing. NASA also studied the feasibility of repeatedly producing sonic booms at a specific geographic location using a surrogate F-18 aircraft. During 10 flights this year using a diving technique, 45 low booms were produced, all at the testing location.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5AT19 Green	Complete supersonic inlet design requirements study that will identify technology gaps and priorities required for design of future efficient long-range supersonic propulsion systems. (Vehicle Systems)	none	none	none

Resources

NASA's FY 2005 budgeted cost of performance for Objective 12 was $1.21 billion.



Objective 13: Use NASA missions and other activities to inspire and motivate the Nation's students and teachers, to engage and educate the public, and to advance the scientific and technological capabilities of the Nation.

WHY PURSUE OBJECTIVE 13?

For nearly 50 years, NASA has opened new frontiers for the Nation and the world. The Agency's landmark journeys in air and space, made possible by scientific excellence and technical innovation, have deepened humankind's understanding of the universe while yielding down-to-Earth advances in air travel, health care, electronics, computing, and more.

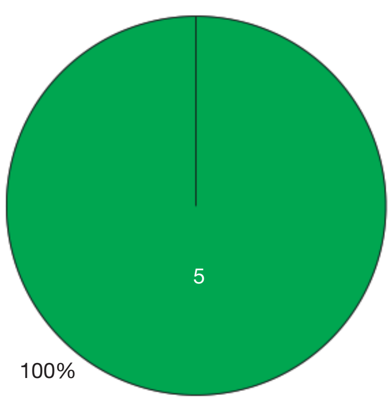
These achievements ultimately share a single source—education. Every person who has contributed to the advancement and strength of the Nation was inspired with a passion to explore and discover. NASA uses its unique mission and vast scientific and technical experience to inspire and motivate America's next-generation of leaders. The Agency's education programs develop educational tools and materials around the themes of space exploration, aeronautics, health, engineering, and Earth science to encourage interest and academic achievement in science, technology, engineering, and math. NASA also helps prepare undergraduate, graduate, and post-graduate students for NASA-related careers through opportunities for hands-on experiences like internships, fellowships, and grants.

NASA's education programs do not stop with students. NASA provides tools and training opportunities for teachers. The Agency collaborates with informal education groups like youth programs, museums, and science centers, to create stimulating programs and exhibits. Through its Web site, special events, publications, and exhibits, NASA also shares the Agency's mission and discoveries with the public, bringing the world along for the ride as NASA returns to flight, explores distant planets, and gazes into the vast universe.

High-school students conduct an experiment inspired by the Gravity Recovery and Climate Experiment, a joint mission of NASA and DLR, the German Aerospace Agency. NASA develops education and outreach programs to translate its Mission and the Vision for Space Exploration into inspiring and motivational products and opportunities for students, teachers, science and technology professionals, and the general public. (Photo: Texas Space Grant Consortium)

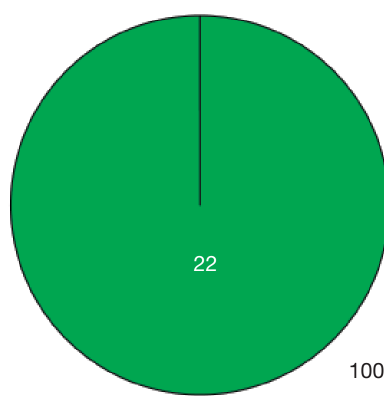
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 13, NASA is on track to achieve all five Outcomes.

APG Ratings



Under Objective 13, NASA achieved all 22 APGs.

Outcome 13.1: Make available NASA-unique strategies, tools, content, and resources supporting the K-12 education community's efforts to increase student interest and academic achievement in science, technology, engineering, and mathematics disciplines.

FY 2005	FY 2004
Green	none

NASA education programs inspire future space explorers by providing unique learning experiences that encourage students to examine science, technology, engineering, and math (STEM) concepts as they apply to NASA's diverse and complex missions. These experiences also stimulate student interest in pursuing careers in the STEM fields.

In FY 2005, NASA Explorer Schools served 150 school-based teams led by more than 750 teachers offering students engaging educational experiences and providing teachers with science curricula content for their classrooms and professional development opportunities targeted to their special needs. Explorer School teams consistently rated their Explorer School experiences highly and reported that the program rejuvenated student achievement and interest in STEM subjects.

NASA education program managers also pursue relationships with organizations and institutions that support education initiatives. By the end of FY 2005, NASA had partnerships with coalitions of educators, business leaders, and policy officials in all 50 states. Through these partnerships, NASA served more than 279,000 students and 39,000 teachers and engaged family members in more than 19,000 activities and events.

A NASA education specialist gives students a lesson on technology using a remote-control rover. The lesson was part of NASA's Explorer Schools program, a unique educational program that reaches elementary to high-school pupils in all 50 states, Puerto Rico, and the District of Columbia. The program partners NASA Centers with school teams composed of students, teachers, and administrators to develop and implement strategic plans for staff and students. The plans promote and support the use of NASA content and programs to address the teams' local needs in science, technology, engineering, and mathematics education. (Photo: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ED1 Green	Increase NASA student participation by 5% above baseline.	none	none	none
5ED2 Green	Increase NASA teacher participation by 5% above baseline.	none	none	none
5ED3 Green	Increase existing NASA-sponsored family involvement activities and existing and potential partners by 5% over baseline.	none	none	none
5ED4 Green	25% of NASA elementary and secondary programs are aligned with state or local STEM educational objectives.	none	none	none

Outcome 13.2: Attract and prepare students for NASA-related careers, and enhance the research competitiveness of the Nation's colleges and universities by providing opportunities for faculty and university-based research.

FY 2005	FY 2004
Green	none

To prepare the future aerospace workforce, in FY 2005, NASA's Higher Education Program provided career-enhancement and development opportunities to more than 18,000 faculty members and more than 70,000 students, of whom about 12,000 were at the graduate or post-doctoral level.

First, NASA offered 20 core-funding programs and 35 research awards through the Experimental Program to Stimulate Competitive Research (EPSCoR) Program. Each year, approximately 325 university faculty, 330 graduate students, 200 undergraduate students, and 65 post-doctoral students participate in the EPSCoR Program. Through research awards, EPSCoR provides seed grants at an average of $25,000 each.

Second, the Space Grant Fellowship Program continued to support 52 state-based consortia (one per state, plus the District of Columbia and Puerto Rico) that develop programs in education, research, and public service responsive to their state's needs (within the guidelines and constraints of the Space Grant Program). This program includes 850 affiliated organizations, 550 colleges and universities, 80 industry affiliates, 40 government affiliates, and 180 nonprofit and other educational entities. Each consortium has a mandatory fellowship/scholarship component that offers five-year awards to more than 2,000 students per year (75 percent undergraduate and 25 percent graduate).

Robert Lee Howard, Jr., has had eight different hands-on education appointments at NASA's Johnson Space Center. The first four were as a participant in the NASA Scholars Program while working toward a bachelor's in general science from Morehouse College and another in aerospace engineering from the Georgia Institute of Technology. He continued on to NASA's graduate co-operative program while working on his master's and Ph.D. NASA's student programs provide students with valuable learning opportunities while training the Nation's next generation of science and engineering professionals. (Photo: NASA)

Maricela Villa, a high-school student interested in studying physics in college, poses in front of a microscope in a materials testing laboratory at NASA's White Sands Test Facility in Las Cruces, New Mexico. In 2005, she and other students participated in the Las Cruces Public Schools Career Education Office and NASA EXCEL Aerospace Science Program at the facility. The semester-long, two-credit program gave students the opportunity to work alongside NASA and contractor aerospace scientists, engineers, and support personnel who directly support space flight. (Photo: NASA)

Third, the Graduate Student Research Program stimulates research among students pursuing degrees in space and aeronautics disciplines. The program annually offers three-year, $24,000 awards to approximately 300 students representing U. S. accredited colleges and universities. NASA Center and Mission Directorate scientists and engineers select the research opportunities, which may be renewed for a maximum of three years. Of the more than 200 awards made in FY 2005, 91 percent supported doctoral programs and 9 percent supported master's degrees.

Finally, the Undergraduate Student Research Program provided nearly 75 summer and fall merit-based internships at NASA Centers to encourage undergraduate students in their junior and senior years to pursue NASA-related careers.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ED5 Green	Establish a NASA-wide baseline of the diversity of NASA-supported students.	4ED8 Green	none	none
5ED6 Green	Use existing higher education programs to assist and encourage first time faculty proposers for NASA research and development opportunities.	none	none	none
5ED7 Green	Establish a baseline of institutions receiving NASA research and development grants and contracts that link their research and development to the institution's school of education.	none	none	none
5ED8 Green	Establish a baseline of the number and diversity of students conducting NASA-relevant research.	none	none	none

Outcome 13.3: Attract and prepare underrepresented and underserved students for NASA-related careers and enhance competitiveness of minority-serving institutions by providing opportunities for faculty and university- and college-based research.

FY 2005	FY 2004
Green	none

NASA created the Minority University Research and Education Program to increase the participation of underrepresented and underserved students in science, technology, engineering, and mathematical disciplines and NASA-related careers, and to enhance the research and academic infrastructure of minority-serving institutions. NASA collects data on the effectiveness of the program on a calendar-year (CY) basis; CY 2004 data is the most current available. In CY 2004, NASA conducted eight technical assistance workshops at minority-serving institutions to provide faculty and students with information on opportunities for grants, scholarships, and internships. More than 5,000 students and faculty attended these workshops.

In CY 2004, students and faculty supported by the Minority University Research and Education Program

A mock rover shows off its flexibility by gently rolling over students in this photo taken on September 29, 2005. Students from local schools visited NASA's Jet Propulsion Laboratory during this year's La Familia Technology Space Day. The event was part of La Familia Technology Week, a National public awareness campaign that informed Hispanic students and parents about the value of science and technology and raised awareness about careers in those fields. NASA strives to ensure that underrepresented and underserved students, teachers, faculty, and researchers participate in NASA education and research opportunities. (Photo: NASA)

generated 980 professional publications, made more than 1,100 presentations at professional conferences, and were awarded 11 patents. Supported faculty also submitted 472 research proposals to funding agencies, resulting in 227 awards. In addition, through the Harriett Jenkins Pre-doctoral Fellowship Program, NASA annually awards 20 graduate fellowships. In 2004, NASA received 525 applications for this program, the highest number in the program's history.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ED9 Green	Increase NASA underrepresented/underserved student participation by 5% over baseline.	none	none	none
5ED10 Green	Increase NASA underrepresented/underserved teacher/faculty participation in NASA STEM-related learning environments by 5% over baseline.	none	none	none
5ED11 Green	Increase the numbers of underserved/underrepresented researchers and minority serving institutions competing for NASA research announcements by 5% above baseline.	none	none	none
5ED12 Green	Establish a baseline of family involvement in underrepresented/underserved NASA-sponsored student programs.	none	none	none

Spotlight: First NASA Education Facility Opens on Native American Reservation

On June 25, 2005, NASA opened the door to a new era in education with the dedication of its first Science, Engineering, Mathematics, and Aerospace Academy program housed at a Tribal College on a Native American Reservation. John Herrington, the first Native American to walk in space, was among the dignitaries to attend the opening of the Academy at Oglala Lakota College, located on the Pine Ridge Reservation in Kyle, South Dakota.

Through this innovative program, students will have access to unique learning experiences, such as taking a trip to the International Space Station, designing an aircraft, and plotting its flight across the country, via a state-of-the-art, computerized Aerospace Education Laboratory. In addition, the program gave the new Academy a portable planetarium that can be used to teach astronomy throughout the state.

Sponsored by NASA's Glenn Research Center, in partnership with Oglala Lakota College, the Academy offers three eight-week sessions during the academic year and four one-week sessions during the summer. The middle- and high-school students meet during school, after school, and on Saturday mornings to participate in hands-on sessions that encourage independent, inquiry-based discovery. The Aerospace Education Laboratory also is available, at no cost, to local teachers, faculty members, parents, and other community members.

A teacher helps a student fly high using a flight simulator at the NASA-sponsored Science, Engineering, Mathematics, and Aerospace Academy program at Oglala Lakota College, South Dakota. (Photo: SEEMA/Oglala Lakota College)

Outcome 13.4: Develop and deploy technology applications, products, services, and infrastructure that would enhance the educational process for formal and informal education.

FY 2005	FY 2004
Green	none

NASA's Learning Technologies Program funds the creation of innovative technologies for teaching science and math. These programs produce valuable software technologies that enhance learning experiences for both school-age children and the general public.

In FY 2005, NASA Learning Technologies Program continued classroom testing of four immersive technologies: What's the Difference?, MathTrax, Virtual Lab, and Scientific Visualization Studio/World Wind. These pilots resulted in improvements to all four applications, making them ready for transfer and commercialization in FY 2006.

A student participating in the Digital Learning Network gives a presentation to an instructor via video. This coordinated digital learning network allows students and educators at the pre-college and university levels across the Nation and around the world to share in the unique NASA experience without having to travel to a NASA Center. (Photo: NASA)

NASA responded to increase citizen demand for the Agency's learning services in other ways, too. For example, NASA Educational Technology Services attached metadata to over 200 Agency educational television program descriptions to enhance user Web capabilities and improve search results. In addition, this year NASA tested the Agency's Digital Learning Network, and NASA's Central Operation of Resources for Education expanded its collection of video materials for hearing and sight-impaired students.

NASA continues to seek additional project collaborations, partnerships, and funding opportunities for these educational technology initiatives. (The final reports for each project are available at *http://learn.arc.nasa.ogv/app*.)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ED13 Green	Implement 1 new advanced technology application.	none	none	none
5ED14 Green	Evaluate the 50 pilot NASA Explorer Schools, utilizing a design experiment approach.	none	none	none
5ED15 Green	Develop a plan for establishing a technology infrastructure.	none	none	none

Outcome 13.5: Establish the forum for informal education community efforts to inspire the next generation of explorers and make available NASA-unique strategies, tools, content, and resources to enhance their capacity to engage in science, technology, engineering, and mathematics education.

FY 2005	FY 2004
Green	none

In FY 2004, NASA initiated a new national project called the NASA Explorer Institutes to provide engaging experiences, opportunities, materials, and information to members of the informal education community, including science centers, museums, planetariums, parks, youth groups, and community-based organizations. In FY 2005, NASA funded six workshops and eleven focus groups, all sharing similar goals: improving the public's understanding and appreciation of science, technology, engineering, and math (STEM) disciplines; establishing linkages that promote new relationships between providers of informal and formal education; providing opportunities to excite youth, particularly those who are underrepresented and underserved, about STEM disciplines; and, expanding STEM informal education programs and activities to communities/locations that have been underserved by such opportunities. Over 300 individuals representing more than 150 informal education organizations participated in these professional-development workshops. And, more than 400 experts from the informal education community participated in the focus groups and reviewed the Institute concept.

The team shown here, representing two schools from Johannesburg, South Africa, was one of four teams that tied for second place in the high-school division in this year's Planetary Aircraft Design Competition. (Photo: NASA)

NASA brings aviation wonders to students

NASA' s Dreams of Aviation, an eight minute video featurette, introduces audiences to the topic of aviation and the impact of breakthrough aeronautics technologies on America. To date, this featurette has earned four national awards: Gold Aurora Awards in the categories of Convention/Exhibition and Aerospace; the Silver Crystal Vision Award in the non-broadcast category of Aviation; and the Bronze Telly Award in the category of Government Relations.

In FY 2005, NASA also sponsored the Planetary Aircraft Design Competition during which students developed concepts for planetary flight vehicles serving science and exploration objectives. In the high-school division, four teams (one from Iowa, two from New Jersey, and one from Illinois) tied for first place. Six universities also participated, and NASA invited the winning University of Virginia team and the runner up University of Texas team to present their concepts to the Agency in July 2005.

Finally, NASA is developing Ultra-Efficient Engine Technology through a grant with North Carolina A&T State University. The grant will support student development and research efforts in the areas of aerodynamic simulations, fault diagnosis for propulsion systems, and computational tool development. And, for students in grades K–12, NASA hosted a day of hands-on engineering and science competitions focused on providing a sense of excitement about aeronautics and space while fostering teamwork.

Sharing the Vision for Space Exploration

In FY 2005, NASA expanded its outreach activities to reach minority and underrepresented sectors of the public to make them aware of the Vision for Space Exploration.

- In October 2004, NASA displayed an exhibition at the American Association of Retired Persons annual convention that focused on the benefits of the space program, specifically highlighting areas that were applicable to the senior community. NASA experts spoke on topics related to the items highlighted in the exhibit to supplement the exhibition.
- In March 2005, NASA unveiled a "NASA Touches Your Life" Exhibit. The exhibit underscores the extent to which NASA-developed or NASA-sponsored technology has made its way into the lives of all Americans. The exhibit was developed to reach the general public, especially those in underserved, non-traditional communities. NASA unveiled the new exhibit at the National Space Society conference in March, displayed it at NASA Headquarters for the month of June, and used it at the Urban League Convention in July.
- In March 2005, NASA co-sponsored the National Space Society Space Product Development Conference and hosted a track highlighting the benefits of the space program. This track included a series of sessions with panelists who were involved in the development of specific technology, were end users of the technology, or were representatives from industry sectors benefiting from the technology.
- NASA also unveiled a Vision for Space Exploration traveling exhibit in July 2005. The exhibit was displayed at the Summer 2005 National Boy Scouts Jamboree (over 6,000 visitors) and at the NASCAR Brickyard 400.

The Vision for Space Exploration exhibit demonstrates NASA's short- and long-term goals, covering such subjects as the Shuttle's return to flight, the Crew Exploration Vehicle, robotic and human missions to the Moon and Mars, and further exploration of the solar system. The exhibit features two semi-circular trusses with interchangeable graphic light boxes, audio and video, and six free-standing kiosks for display of models, hardware, and artifacts. (Photo: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ED16 Green	Implement Phase 1 of a plan to increase appreciation of the relevance and role of NASA science and technology.	none	none	none
5ED17 Green	Develop a plan to assess and prioritize high-leverage and critical informal education programs and educational involvement activities.	none	none	none
5ED18 Green	Develop a plan to assess current NASA professional development programs for relevance to the targeted informal learning environments.	none	none	none
5AT18 Green	Partner with museums and other cultural organizations and institutions to engage non-traditional audiences in NASA missions.	none	none	none
5ESA11 Green	Provide in public venues at least 50 stories on the scientific discoveries, the practical benefits, or new technologies sponsored by the Earth Science programs.	4ESA6 Green	none	none
5ESS10 Green	Post the most exciting imagery and explanations about Earth Science on the Earth observations/ Science Mission Directorate website.	4ESS13 Green	3Y25 Green	2Y24 Green
5RPFS9 Green	Expand outreach activities that reach minority and under-represented sectors of the public, through increased participation in conferences and community events that reflect cultural awareness and outreach. Each fiscal year, increase the previous year baseline by supporting at least one new venue that focuses on these public sectors.	4RPFS10 Green	none	none

Spotlight: Smart Skies

In the minds of many students, mathematics is usually associated with addition, subtraction, geometry, algebra, and formulas. However, for some students in the San Francisco Bay area, mathematics now conjures up images of airplanes, runways, pilots, and air traffic control towers. These students have experienced "Smart Skies," one of NASA's newest math-related educational products.

International mathematics testing shows that U.S. students perform poorly relative to students in other countries on standardized mathematics tests related to solving reality-based problems. To help remedy this, NASA developed Smart Skies, a series of hands-on educational activities related to solving interesting and challenging real-world problems in air traffic control.

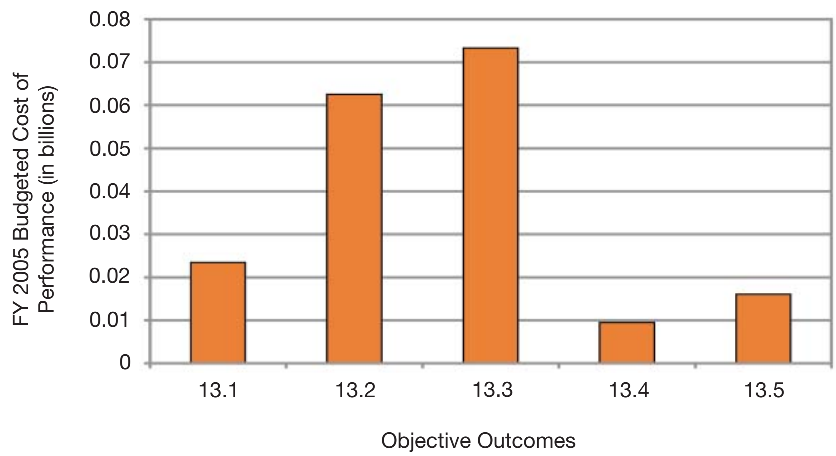
The Smart Skies project encourages students to explore and understand mathematics and its applications in daily life using a variety of instructional materials, including instructor-guided paper-and-pencil activities, Web-based simulations, and hands-on simulations. NASA released the paper-and-pencil activities in April on the NASA education portal. Early in 2005, NASA gave students in grades five through nine the opportunity to participate in evaluating the web-based and hands-on simulation activities. Using the Web-based simulator in their classrooms or computer labs, the students learned how to apply their math to solve realistic air traffic problems.

For the hands-on component of the Smart Skies evaluation, students traveled to NASA's Ames Research Center and assumed the roles of air traffic controllers, and pilots, to solve simulated air traffic problems related to distance, rate of speed, and time. The student pilots moved electronically instrumented model aircraft along a designated route of flight laid out on the floor. Student controllers watched the aircraft movement on a computer screen that displayed speed and distance information broadcast from the model aircraft. Students then used the mathematics knowledge learned from the print-based and web-based instructional materials, to determine if and when the airplanes would fly too close to each another. If problems arose, they radioed the student pilots to adjust their speed or route. Both retired and active Federal Aviation Administration air traffic controllers from the Oakland Center volunteered as docents and gave guidance and support to the students.

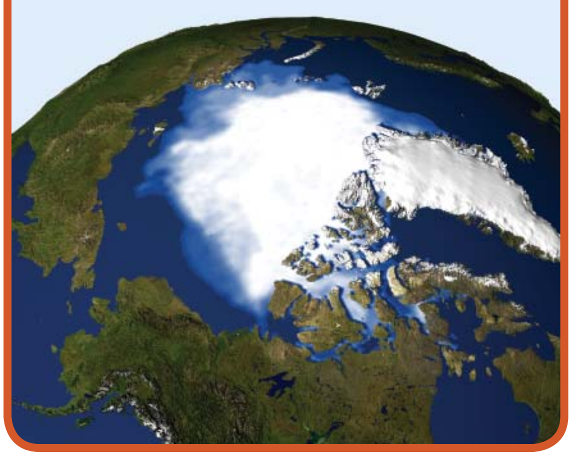
Students at Crittenden Middle School in Mountain View, California, exercise their math and problem-solving skills during a Smart Skies project, where they become pilots, air-traffic controllers, and NASA scientists in simulated air traffic scenarios. Smart Skies also teaches about the National Airspace System and those involved who make air travel efficient and safe. (Photo: NASA)

Resources

NASA's FY 2005 budgeted cost of performance for Objective 13 was $0.19 billion.



Objective 14: Advance scientific knowledge of the Earth system through space-based observation, assimilation of new observations, and development and deployment of enabling technologies, systems, and capabilities, including those with the potential to improve future operational systems.



WHY PURSUE OBJECTIVE 14?

NASA's space capabilities provide a unique opportunity to observe Earth from above the atmosphere. From this vantage point, satellites can gather data on changes, developments, and processes that cannot be observed fully on the ground. NASA uses satellites in low, medium, and high Earth orbits to help researchers better understand and predict climate change, weather, and natural hazards. Closer to Earth, NASA uses aircraft, including advanced aircraft developed by NASA's aeronautics programs, to conduct research and monitor natural hazards like wildfires.

NASA partners with the National Oceanic and Atmospheric Administration, the Federal Emergency Management Agency, the Environmental Protection Agency, the U.S. Geological Survey, the U.S. Department of Agriculture, and other government agencies to provide essential services to the Nation: improved weather prediction; disaster preparedness and recovery; environmental protection; resource monitoring and management; Earth science education; and homeland security. Through collaborations and agreements, NASA also shares its Earth system data and observation capabilities with other agencies, universities, and international organizations.

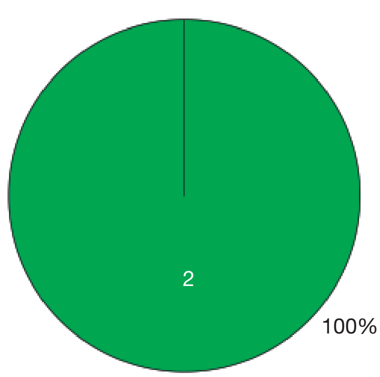
To enable its Earth observation efforts, NASA develops advanced sensors, instruments, and telescopes for use on the Agency's satellites and aircraft. NASA uses some of these Earth observation technologies to study the atmospheres and topography of other planets, too. The Agency also develops and implements information systems to organize, analyze, and distribute Earth science images and data and to create improved models of different Earth system processes. The goal is to ensure that Earth observation information is thorough, reliable, and accessible to diverse providers and users.

Left: In September 2005, the Arctic sea ice coverage shrank to 2.05 million square miles (shown in this artist's concept), the smallest coverage since satellites began monitoring sea ice in 1978. Arctic sea ice typically reaches its minimum in September, at the end of the summer melt season. During the last four Septembers (2002–2005), sea ice extents have been 20 percent below the mean September sea ice extent for previous years. NASA scientists are studying arctic sea ice to determine if the decreased coverage is due to naturally occurring climate variability or human-influenced climate changes. The scientists used data from NASA's Nimbus-7 satellite and the Defense Meteorological Satellite Program Special Sensor/Microwave Imager. (Image: NASA)

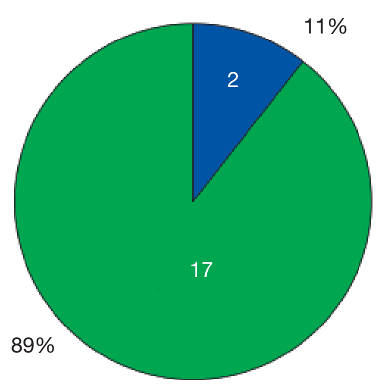
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Under Objective 14, NASA is on track to achieve both Outcomes.

Outcome Ratings



APG Ratings



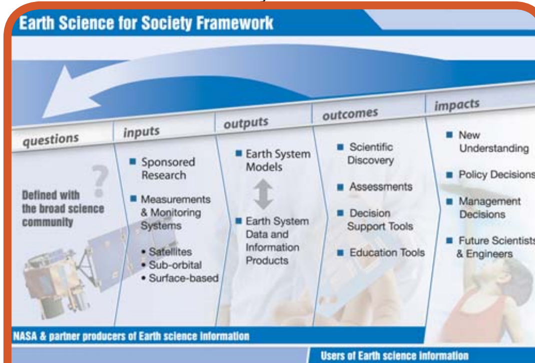
Under Objective 14, NASA achieved or exceeded all 19 APGs.

NASA did not pursue Outcomes 14.1 or 14.2 in FY 2005.

Outcome 14.3: Develop and implement an information systems architecture that facilitates distribution and use of Earth science data.

FY 2005	FY 2004
Green	none

In the course of advancing knowledge of the Earth–Sun system, NASA uses an information systems architecture that serves the scientific community and helps NASA assess the potential of research results to improve future operational systems. NASA assesses and develops both observational data (primarily from spacecraft) and predictive capability data from models, in cooperation and consultation with Earth science experts. NASA provides full access to these data to help researchers understand and predict climate change, weather, and natural hazards. NASA also benchmarks the use of these data to expand and accelerate economic and social benefits of Earth–Sun system scientific research.



NASA has adopted a science-driven and results-oriented planning and information framework, illustrated above, that supports a continuum from science to applications for the public good. (Image: NASA)

The Earth Observation System Data and Information System (EOSDIS) is a major contribution to accomplishing NASA's Earth information systems architecture, and a large community now uses data and information products from EOSDIS. The data holdings of EOSDIS are growing at a rate of over 3.5 terabytes per day. (One terabyte equals 1,024 gigabytes or 1 trillion bytes.). At the end of FY 2005, the archives of EOSDIS held over 4 petabytes of data. (One petabyte equals 1,024 terabytes or 1 quadrillion bytes.) To date, users have accessed EOSDIS data over 2.4 million times, and according to a federal survey conducted in 2005, users are satisfied with EOSDIS.

Using data from EOSDIS's archive at the University of Colorado's National Snow and Ice Data Center, scientists confirmed that the floating cap of sea ice on the Arctic Ocean shrank in the summer of 2005 to what is probably its smallest size in at least a century of record keeping, continuing a trend toward less summer ice.

The Near Real Time Image Distribution Server (NEREIDS) at the Jet Propulsion Laboratory's Physical Oceanography Distributed Active Archive Center provides satellite images for sea surface temperature, ocean topography, ocean wind, and land and sea ice. This system provides information that helps fishermen range as much as 2000 miles while making fishing safer and more cost effective.

In FY 2005, NASA began to evolve its distributed Earth System Science data and information system (including EOSDIS) with new information technologies and approaches while engaging the science user community to provide the observational information strategy for Earth information systems of the future. A study team examined several ideas for evolving EOSDIS elements and is preparing an implementation plan for FY 2006. Observational collections are moving "from missions to measurements" as an organizational focus to improve the study of Earth system processes over seasons, years, and decades.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ESA1 Green	Crosscutting Solutions: Work within the Joint Agency Committee on Imagery Evaluation and the Commercial Remote Sensing Policy Working Group through partnerships with NIMA, USGS, NOAA, and USDA to verify/validate at least two commercial remote sensing sources/products for Earth science research, specifically with respect to land use/land cover observations for carbon cycle and water cycle research.	none	none	none
5ESA2 Green	National Apps: Benchmark measureable enhancements to at least 2 national decision support systems using NASA results, specifically in the Disaster Management and Air Quality communities. These projects will benchmark the use of observations from 5 sensors from NASA research satellites.	none	none	none

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ESA3 Green	Crosscutting Solution: Expand DEVELOP (Digital Earth Virtual Environment and Learning Outreach Project) human capital development program to increase the capacity for the Earth science community at a level of 100 program graduates per year and perform significant student-led activities using NASA research results for decision support with representation in 30 states during the fiscal year.	none	none	none
5ESA4 Green	Crosscutting Solutions: Benchmark solutions from at least 5 projects that were selected in FY03 REASoN program to serve national applications through projects that support decision support in areas such as agriculture, public health, and water quality. These projects will benchmark use of observations from at least 5 sensors from NASA research satellites.	none	none	none
5ESA5 Green	The DEVELOP (Digital Earth Virtual Environment and Learning Outreach Project) program will advance the capacity of our future workforce with students from at least 20 states working to develop and deliver benchmark results of at least 4 rapid prototype projects using NASA Earth science research results in decision support tools for state, local, and tribal government applications.	none	none	none
5ESA6 Green	Crosscutting Solutions: Benchmark solutions associated with at least 5 decision support systems that assimilate predictions from Earth system science models (e.g., GISS, GFDL, NCEP, SpoRT, and the Earth Science laboratories).	none	none	none
5ESA7 Green	National applications: Benchmark enhancements to at least 2 national decision support systems using NASA results, specifically in the Disaster Management, Public Health, and Air Quality communities. These projects will benchmark the use of observations from 5 sensors from NASA research satellites.	none	none	none
5ESA8 Green	Crosscutting Solutions: Verify and validate solutions for at least 5 decision support systems in areas of national priority associated with the FY03 selected REASoN projects.	none	none	none
5ESA9 Green	Benchmark the use of predictions from 2 NASA Earth system science models (including the GISS 1200 and NCEP weather prediction) for use in national priorities, such as support for the Climate Change Science Program (CCSP) and Climate Change Technology Program (CCTP) and the NOAA National Weather Service.	none	none	none
5SEA10 Green	Benchmark the use of observations and predictions of Earth science research results in 2 scenarios assessment tools, such as tools used by the Environmental Protection Agency (specifically in the Community Multi-scale and Air Quality (CMAQ) Improvement Program tools) and the Department of Energy.	none	none	none

Outcome 14.4: Use space-based observations to improve understanding and prediction of Earth system variability and change for climate, weather, and natural hazards.

FY 2005	FY 2004
Green	none

NASA's space-based capabilities and sponsored research contributed to many substantial advances in Earth science over the last year, which will lead to improved predictions of the Earth's environment.

Weather prediction

NASA scientists worked with experimental data from the Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua satellite in collaboration with National Oceanic and Atmospheric Administration (NOAA) scientists at the Joint Center for Satellite Data Assimilation. The AIRS instrument takes three-dimensional infrared pictures of atmospheric temperatures, water vapor, and trace gases. Researchers found that incorporating the instrument's data into numerical weather prediction models improves the accuracy range of experimental six-day Northern Hemisphere weather forecasts by up to six hours, a four-percent increase. According to the National Weather Service, the AIRS instrument has provided the most significant increase in forecast improvement in this time range of any single instrument since a four-percent increase in forecast accuracy at five or six days normally takes several years to achieve. NOAA has incorporated the instrument data into its National Weather Service operational weather forecasts.

Sea Level Change

Earth's oceans have risen and fallen, and its land ice has shrunk and grown, as Earth has warmed and cooled over time. Sea level changes also are affected by the amount of water stored in lakes and reservoirs and the rising (uplift) and falling (subsidence) of land in coastal regions. Today, as in the past, global sea level has been rising at a rate of nearly two millimeters per year while regional subsidence and uplift continue. What is different today, however, is that tens—perhaps hundreds—of millions of people live in coastal areas that are vulnerable to changes in sea level. It is estimated that a one-meter increase in sea level potentially will impact over 100 million lives and cost hundreds of billions of dollars in the United States alone. NASA and its research partners have been using the TOPEX/Poseidon and Jason satellites to monitor the global sea surface height, as well as measurements from ICESat, that help explain the causes of sea level changes over the past decade.

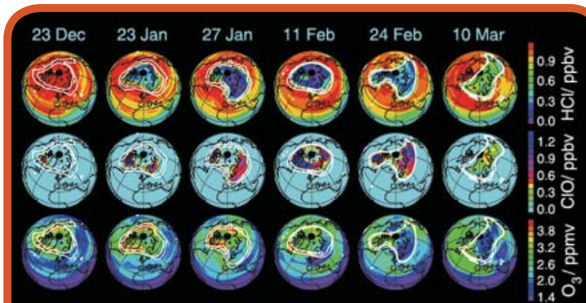
Recent peer-reviewed research indicates that the greatest contributors to change are the Earth's glaciers and ice sheets. Three-fourths of the planet's freshwater, or about 220 feet of sea level, is stored in glaciers and ice sheets. NASA-funded research published in an October 2004 article in *Science* offers further evidence that ice cover is shrinking much faster than thought, with over half of the recent sea level rise due to the melting of ice from Greenland, West Antarctica's Amundsen Sea, and mountain glaciers.

Observing the Earth's Mass Distribution Changes from Space (GRACE)

NASA's Gravity Recovery and Climate Experiment (also known as GRACE) successfully operated for three years and now researchers are beginning to report scientific breakthroughs resulting from the multi-disciplinary nature of GRACE observations.

GRACE is a two-spacecraft joint partnership of NASA and the German Aerospace Center, and the GRACE observations are 100 times better than previous measurements, the first-ever accurate enough to allow for measuring the time variability of the Earth's gravity. GRACE data reflected mass changes as water redistributed in oceans, atmosphere, and in soil, and NASA-funded research found that the shape of the Earth appears to be influenced by significant climate events that cause changes in the mass of water stored in oceans, continents, and atmosphere. Results published in the journal *Science* show that monthly changes in the distribution of water and ice masses could be estimated by measuring changes in Earth's gravity field. The GRACE data measured the weight of up to 10 centimeters (four inches) of groundwater accumulations from heavy tropical rains, particularly in the Amazon basin and Southeast Asia. Smaller signals caused by changes in ocean circulation were also visible.

A study led by the mission principal investigator at the University of Texas at Austin showed significant variations in the shape of the Earth, reflected by changes in Earth's gravity field during the past 28 years, might be linked in part to climate events. The study, published in 2005 in the *Journal of Geophysical Research*, examined Earth's oblateness, how much its rounded shape flattens at the poles and widens at the equator, and found that over the past 28 years, two large variations in Earth's oblateness were connected to strong El Niño Southern Oscillation events. Variations in mass distribution, which caused the change in the gravity field, were predominantly over the continents, with a smaller contribution due to changes over the ocean. The principal discovery, however, is that Earth's large scale transport of mass is related to long-term global climate changes.



These data maps from Aura's Microwave Limb Sounder depict levels of hydrogen chloride (top), chlorine monoxide (center), and ozone (bottom) at an altitude of approximately 490,000 feet on selected days during the 2004–2005 Arctic winter. The white lines demark the boundary of the winter polar vortex, a wintertime feature of the stratosphere where winds spin counterclockwise above the pole. The maps from December 23, 2004, show conditions shortly before significant chemical ozone destruction began. Based on various analyses of Aura data, NASA researchers participating in the Polar Aura Validation Experiment estimate that there was a maximum local ozone loss of approximately 2 parts per million by volume (approximately 60 percent) during the period from January 23, 2005, to March 10, 2005, with an average loss of approximately 1.5 parts per million by volume. (Image: NASA)

Tracking Arctic ozone

Researchers are using validated data from NASA's Aura satellite to unravel the complex interactions between variability and trends in Arctic stratospheric weather and the high chemical propensity for severe ozone depletion in the Arctic region. Aura's Microwave Limb Sounder found that by the beginning of March 2005, the ozone depletion had reached 50 percent at some altitudes, the second highest depletion level ever seen in the north polar stratosphere. Aura's Ozone Monitoring Instrument showed that by mid-March, however, the polar wind patterns shifted, dispersing the ozone-depleted air throughout the Northern hemisphere. Aura data from winter 2004–2005 points to a continuing potential for significant Arctic ozone depletion.

The effects of aerosols on climate change—from modeling to reality

The effects of aerosols on climate are not well quantified. However, after modeling the estimates of aerosol distributions and their effect on climate, NASA demonstrated that it is feasible to shift from largely model-based research to increasingly measurement-based research. NASA satellite and ground-based measurements, supplemented by model simulations of global chemical transport, improved scientists' ability to assess the climate effects of human-made aerosols.

Measuring pollutants around the world

In FY 2005, NASA researchers began releasing data from the Aura satellite's instruments via the Aura Validation Program. Data from the Tropospheric Emission Spectrometer, the Microwave Limb Sounder, and the Ozone Monitoring Instrument are providing new measurements of pollutants and greenhouse gases that will allow scientists to estimate the impact of regional pollution events on global air quality and climate. The Tropospheric Emission Spectrometer is providing the first-ever global measurements of the vertical distribution of pollutants, including ozone, in the lowest part of the atmosphere, the troposphere.

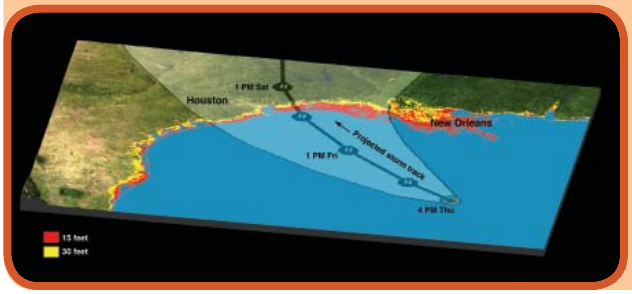
FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ESS1 Blue	Integrate satellite, suborbital, ground-based observations, coupled with laboratory studies and model calculations to assess potential for future ozone depletion in the Arctic. Characterize properties and distributions of clouds and aerosols as they relate to the extinction of solar radiation in the atmosphere. Specific output: first release of validated Aura data. Progress toward achieving outcomes will be validated by external review.	none	none	none
5ESS2 Green	Improve predictive capabilities of regional models using satellite-derived localized temperature and moisture profiles and ensemble modeling. Progress toward achieving outcomes will be validated by external review.	none	none	none
5ESS3 Green	Reduce land cover errors in ecosystem and carbon cycle models, and quantify global terrestrial and marine primary productivity and its interannual variability. Specific output: Produce a multi-year global inventory of fire occurrence and extent. Progress toward achieving outcomes will be validated by external review.	4ESS9 Green	3Y23 Green	none
5ESS4 Blue	Reduce land cover errors in ecosystem and carbon cycle models, and quantify global terrestrial and marine primary productivity and its interannual variability. Specific output: Release first synthesis of results from research on the effects of deforestation and agricultural land use in Amazonia. Progress toward achieving outcomes will be validated by external review.	4ESS9 Green	3Y23 Green	none
5ESS5 Green	Reduce land cover errors in ecosystem and carbon cycle models, and quantify global terrestrial and marine primary productivity and its interannual variability. Specific output: Improve knowledge of processes affecting carbon flux within the coastal zone, as well as sources and sinks of aquatic carbon, to reduce uncertainty in North American carbon models. Progress toward achieving outcomes will be validated by external review.	none	none	none
5ESS6 Green	Enhance land surface modeling efforts, which will lead to improved estimates of soil moisture and run-off. Specific output: launch Cloudsat. Progress toward achieving outcomes will be validated by external review.	4ESS9 Green	3Y23 Green	none
5ESS7 Green	Assimilate satellite/in-situ observations into variety of ocean, atmosphere, and ice models for purposes of state estimation; provide experimental predictions on variety of climatological timescales; determine plausibility of these predictions using validation strategies. Specific output: documented assessment of relative impact of different climate forcings on long-term climate change and climate sensitivities to those various forcings.	4ESS11 Green	3Y18 3Y5 3Y14 Green	2Y18 2Y5 2Y14 Green
5ESS8 Green	Assimilate satellite/in-situ observations into variety of ocean, atmosphere, and ice models for purposes of state estimation; provide experimental predictions on variety of climatological timescales; determine plausibility of these predictions using validation strategies. Specific output: An assimilated product of ocean state on a quarter degree grid.	4ESS11 Green	3Y18 3Y5 3Y14 Green	2Y18 2Y5 2Y14 Green
5ESS9 Green	Advance understanding of surface change through improved geodetic reference frame, estimates of mass flux from satellite observations of Earth's gravitational and magnetic fields, and airborne and spaceborne observations of surface height and deformation. Progress toward achieving outcomes will be validated by external review.	4ESS11 Green	3Y18 3Y5 3Y14 Green	2Y18 2Y5 2Y14 Green

Spotlight: NASA Goes "Down Under" for Shuttle Mapping Mission Finale

Culminating more than four years of data processing, NASA and the National Geospatial-Intelligence Agency completed in 2005 Earth's most extensive global topographic map. Researchers began compiling the data, which is extensive enough to fill the U.S. Library of Congress, during the Shuttle Radar Topography Mission in February 2000.

The digital elevation maps encompass 80 percent of Earth's landmass. They reveal for the first time large, detailed swaths of Earth's topography previously obscured by persistent cloudiness. The final maps completed for the mission covered Australia and New Zealand in unprecedented uniform detail. They also covered more than 1,000 islands comprising much of Polynesia and Melanesia in the South Pacific, as well as islands in the South Indian and Atlantic oceans. This was the first time many of the islands had their topography mapped.

The mission data benefits scientists, engineers, government agencies, and the public. Its uses are ever growing, ranging from land use planning to "virtual" Earth exploration. The data also will serve as a baseline for monitoring future global change.

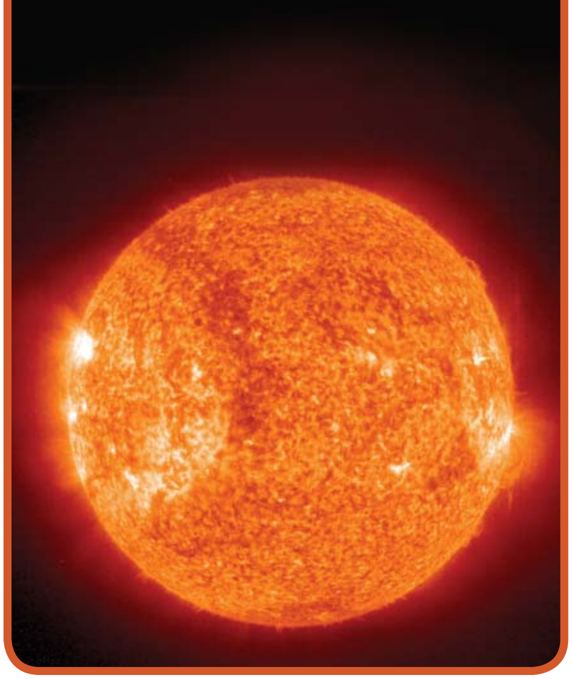


The Gulf Coast from the Mississippi Delta through the Texas coast is shown in this satellite image from NASA's Moderate Resolution Imaging Spectroradiometer overlain with data from the Shuttle Radar Topography Mission and the predicted storm track for Hurricane Rita. The prediction from the National Weather Service was published on September 22, 2005, as the hurricane approached shore. At-risk, low-lying terrain along the coast is highlighted using the mission elevation data, with areas within 15 feet of sea level shown in red and within 30 feet in yellow. The image illustrates one of the many ways Shuttle Radar Topography Mission data is used. (Image: NASA/JPL/NGA)

Resources

NASA's FY 2005 budgeted cost of performance for Objective 14 was $1.54 billion. NASA cannot provide FY 2005 budgeted cost of performance information at the Outcome level for this Objective.

Objective 15: Explore the Earth–Sun system to understand the Sun and its effects on Earth, the solar system, and the space environmental conditions that will be experienced by human explorers, and demonstrate technologies that can improve future operational systems.



WHY PURSUE OBJECTIVE 15?

In ancient times, many cultures worshipped the Sun. They honored it as a source of life and feared the wrath of its scorching heat. Today, scientists know that the Sun is critical to life on Earth, a giant ball of gas that radiates energy and anchors the solar system. Like the Sun worshippers of the past, modern scientists also know that the Sun's effects are not always kind. Powerful solar flares and coronal mass ejections can disrupt communications and navigation systems, damage satellites, and disable electric power grids. More important, solar disturbances can bombard humans who travel beyond Earth's protective ionosphere with health-damaging radiation.

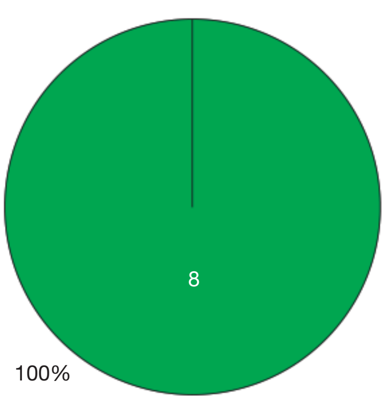
In an effort to protect humans and technology from the Sun's damaging effects, as well as those induced within Earth's near-space environment, NASA studies the interconnected Earth–Sun system that includes interacting magnetic fields, solar wind, energetic particles, and radiation. NASA's current and planned missions will provide a holistic view of space weather, from its starting point deep within the Sun step by step to Earth's surface, as scientists seek answers to fundamental questions: How and why does the Sun vary? How does the Earth system respond? What are the impacts on life and society?

NASA's space-based missions also provide an early warning system for space weather events. The Advanced Composition Explorer (ACE) and the Solar and Heliospheric Observatory (SOHO) missions offer real-time, uninterrupted views of the Sun from their orbit at the L1 Lagrangian point, a location that is never blocked by Earth or the Moon. These spacecraft spot solar disturbances long before their effects reach Earth, giving civil and military organizations time to enact mitigation plans.

Left: NASA's fleet of Earth–Sun system missions form an integrated observation network of sensors deployed in vantage points from Earth's ionosphere to deep space. The Solar and Heliospheric Observatory (SOHO), which took this image of the Sun in spring 2005, uses telescopes, spectrometers, and coronagraphs to observe the Sun's hot atmosphere and its inner and outer coronas, measure changes along its surface and in its interior, and study the energetic particles it emits. (Image: SOHO/ESA/NASA)

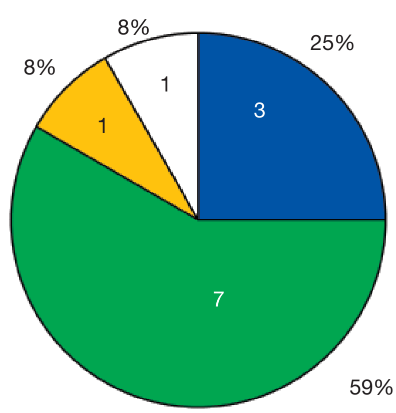
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



Under Objective 15, NASA is on track to achieve all eight Outcomes.

APG Ratings



Under Objective 15, NASA achieved 10 of 12 APGs.

FY 2005	FY 2004
Green	Green
	(1.3.1)

Outcome 15.1: Develop the capability to predict solar activity and the evolutiion of solar disturbances as they propagate in the heliosphere and affect Earth.

On January 20, 2005, a large solar flare generated the most intense burst of solar radiation in five decades. The flare tripped radiation monitors all over Earth and scrambled detectors on spacecraft only 15 minutes after the first sign of the flare. Researchers now know that such flares are preceded by a rotation of nearby sunspots. This rotation appears to build up magnetic stress that becomes the main source of the energy in the flares. Researchers demonstrated this new finding using data from the Transition Region and Coronal Explorer (or TRACE) and the Solar and Heliospheric Observatory (also known as SOHO), and it represents a major step toward predicting large solar flares.

Understanding solar particles

Solar energetic particles are associated with solar flares. Combined observations from the Advanced Composition Explorer (also known as ACE) and SOHO spacecraft are helping scientists understand why high-energy particles coming from the Sun are missing more electrons during solar flares than at other times. NASA researchers found that these high-energy particles do not come from a region of higher temperature within the Sun. Instead, they are accelerated low in the Sun's atmosphere and then stripped of more electrons through collisions with other particles as they stream outward toward space. By studying the composition and charge of these particles, researchers will understand better the mechanisms that produce solar flares and how to predict them.

Sunspot groups, like this one visible near the right edge of the Sun, are the source of the solar flare eruptions like the one on January 20, 2005. (Image: NASA/ESA/SOHO)

SOHO gives insight into coronal mass ejections

Coronal mass ejections are explosions in the Sun's atmosphere, or corona, that emit large quantities of solar particles. This year, NASA researchers made progress in understanding the structure and origin of coronal mass ejections by studying data from the Solar and Heliospheric Observatory (commonly known as SOHO). The researchers used brightness measurements of the solar corona to infer the three-dimensional structure and direction of coronal mass ejections to show that they are dominated by expanding arcades of magnetic loops.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC2 Green	Successfully complete Solar Dynamics Observatory (SDO) Critical Design Review (CDR).	none	none	none
5SEC3 Green	Successfully complete THEMIS Critical Design Review (CDR).	none	none	none
5SEC6 Green	Successfully demonstrate progress in developing the capability to predict solar activity and the evolution of solar disturbances as they propagate in the heliosphere and affect Earth. Progress towards achieving outcomes will be validated by external review.	4SEC8 Green	3S7 Green	2S7 Green

FY 2005	FY 2004
Green	Green
	(1.3.2)

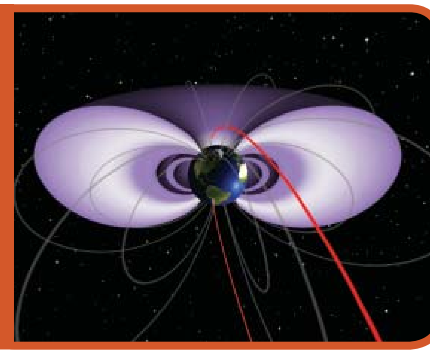
Outcome 15.2: Specify and enable prediction of changes to Earth's radiation environment, ionosphere, and upper atmosphere.

Satellite operators consider the "slot" region between Earth's two major radiation belts to be a safe zone for satellites since the region is swept clean of radiation regularly by lightning-induced wave action. However, new data from the Imager for Magnetopause-to-Aurora Global Exploration (also known as IMAGE), Solar, Anomalous, and Magnetospheric Particle Explorer (also known as SAMPEX), and Polar missions revealed that the slot region often becomes filled with intense radiation during solar storms. The radiation forms in this slot region when the outer boundary of Earth's plasmasphere (a donut-shaped region near the top of Earth's atmosphere) is eroded severely by nearby magnetic storms, and lightning-induced wave action is no longer present to scatter the radiation out of the trapping region.

New source for the aurora discovered

NASA also discovered a new method by which aurora are formed. Typically, energetic electrons from the Earth's magnetosphere stream into the atmosphere to form Earth's aurora, also known as the northern and southern lights. The TIMED and IMAGE missions recently demonstrated a direct connection between aurorae occurring at mid-latitudes and atoms raining down from Earth's ring current during magnetic storms. This is a new source for aurorae, in addition to the traditional electron precipitation source.

This illustration shows the donut-shaped Van Allen Radiation Belt around Earth. NASA research shows that a "safe zone" near the center of the Belt, near where the purple, ear-like shapes transition to white regularly fills with intense radiation. The red line extending toward the bottom of the illustration shows the orbit of the Imager for Magnetopause-to-Aurora Global Exploration (commonly known as IMAGE) spacecraft, which was used to confirm the theory about the safe zone. (Image: NASA/T. Bridgman)



Understanding mysterious flashes in Earth's atmosphere

Terrestrial gamma-ray flashes are short-lived blasts of gamma rays emitted into space from the top of Earth's atmosphere. In FY 2005, NASA's Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI) detected some of these mysterious bursts and discovered that they are much more powerful and prevalent than previously thought. A many as 50 flashes occur each day around the world. The gamma rays emitted by these flashes rival those seen from neutron stars and black holes. The mechanism that generates these flashes is still unknown, but researchers theorize that the energy to power the flashes comes from a build-up of electric charges from lightning storms.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC4 White	Complete Announcement of Opportunity (AO) selection for Geospace Missions far ultraviolet Imager.	none	none	none
5SEC7 Green	Successfully demonstrate progress in specifying and enabling prediction of changes to Earth's radiation environment, ionosphere, and upper atmosphere. Progress towards achieving outcomes will be validated by external review.	4SEC9 Green	3S8 Green	2S8 Green

Performance Shortfalls

APG 5SEC4: The Announcement of Opportunity selection for the first Geospace mission did not occur. A delay in releasing the Announcement of Opportunity resulted from a decision to reverse the order of Geospace missions. The Radiation Belt Mapper mission will be launched first, due to the particular relevance radiation physics has to the Vision for Space Exploration. NASA released the Announcement of Opportunity on August 23, 2005, with selection scheduled for mid-FY 2006.

FY 2005	FY 2004
Green	Green
	(1.3.2)

Outcome 15.3: Understand the role of solar variability in driving space climate and global change in Earth's atmosphere.

Understanding clouds

Polar mesospheric clouds are the highest clouds on Earth. They usually form over the polar caps at altitudes greater than 50 miles when temperatures fall below minus 350 degrees Fahrenheit. Over the past 40 years, polar mesospheric clouds have gotten brighter—a likely indicator of long-term global climate change. In FY 2005, NASA researchers developed a comprehensive model that predicts the global variability of polar mesospheric clouds. The model accurately predicts, as confirmed by observations, more clouds in the Northern Hemisphere than in the Southern Hemisphere and more clouds during solar minimum compared with solar maximum. NASA also discovered that large rockets and the Space Shuttle contribute considerable quantities of water to the upper mesosphere through their exhaust plumes. These plumes leave long-lasting clouds in the lower thermosphere that are transported from their launch sites across the equator to the Antarctic where they become an additional source of polar mesospheric clouds. Therefore, the increasing brightness of polar mesospheric clouds could be due, at least in part, to discharge from rocket launches. Researchers will use these results to predict longer-term changes that might arise from natural and human-induced changes.

NASA measures the Sun's effects on Earth's ozone

NASA researchers using the Upper Atmosphere Research Satellite (UARS) found evidence of a process that links precipitation of solar protons (from solar events like solar flares) deep into the polar cap with polar stratospheric ozone depletion during solar proton storms. The satellite found that the solar protons caused ozone depletions of up to 5 to 8 percent in the southern polar upper stratosphere lasting for days after the storm period.

A NASA first in weather observation

Researchers have assumed that vertical winds would move upwards over stable auroral arcs (phenomena seen in conjunction with auroral displays like the Aurora Borealis) due to heating. However, new measurements reveal downward-moving winds instead. A NASA sounding rocket, guided in a largely horizontal trajectory through a region generally inaccessible to weather balloons or satellites, revealed this surprise finding.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC8 Green	Successfully demonstrate progress in understanding the role of solar variability in driving space climate and global change in Earth's atmosphere. Progress towards achieving outcomes will be validated by external review.	4SEC10 Blue	none	none

FY 2005	FY 2004
Green	Green (5.6.1)

Outcome 15.4: Understand the structure and dynamics of the Sun and solar wind and the origins of magnetic variability.

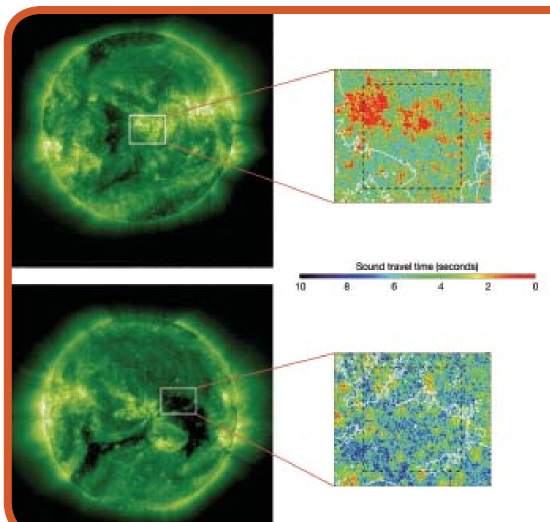
Understanding solar flares

Gamma- and X-ray observations of solar flares from NASA's Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI) revealed significant differences in the acceleration of electrons, protons, and heavier ions as they leave the Sun. Surprisingly, two of the largest flares revealed that electrons and ions release their energies in different locations separated by about 12,500 miles on the Sun's surface. These discoveries will help researchers understand where and how these different particle species are accelerated in solar flares.

Understanding the solar wind

NASA researchers found that solar magnetic and atmospheric structures associated with fast solar wind speeds extend well below the solar corona (the Sun's atmosphere), at least as far down as the chromosphere, the layer just above the "surface" of the Sun. They reached this conclusion by studying the time that sound waves take to travel between two layers of the lower solar atmosphere as seen by the Transition Region and Coronal Explorer (commonly known as TRACE) and the Advanced Composition Explorer (commonly known as ACE).

Researchers used data from the Ulysses mission to resolve the structure of the transition between fast and slow solar wind. Fast solar wind emanates from solar coronal holes and travels steadily at speeds between 600 and 800 kilometers per second. Solar wind is slower, denser, and more variable, exhibiting speeds between 200 and 600 kilometers per second with daily fluctuations. The slow solar wind's location of origin on the Sun is less well known. Scientists have discovered a fairly wide four-degree transition between these two types of solar wind,



Researchers measured areas of the Sun's upper atmosphere (shown approximately by the white outlines on the full Sun images) using observations by the TRACE satellite of a region with strong, closed magnetic field on July 7, 2003 (top), and another region with weaker, open magnetic field on September 18, 2003 (bottom). The areas in red in the top "time difference" image show a shallow, dense chromosphere beneath an area with slow, dense solar wind outflow. The areas in blue in the bottom image show a deep, less dense chromosphere below a "coronal hole" with fast, tenuous solar wind outflow. From such information on the chromosphere's structure, the researchers have been deriving an understanding of a continuous range of solar wind speeds. (Full Sun images: SOHO, ESA/NASA; images on the right: The Astrophysical Journal, Univ. of Chicago Press) now referred to as the coronal hole boundary layer. Not understanding the structure of this coronal hole boundary had been a critical impediment to understanding the physical origins of fast and slow solar wind. The Ulysses mission also discovered that the continuous motion of magnetic fields associated with these coronal hole boundaries deforms the general structure of the interplanetary magnetic field. Because of these discoveries, researchers are revising their fundamental understanding of the magnetic field that extends from the Sun and permeates the solar system.

Measurements from the Advanced Composition Explorer (commonly known as ACE) also provided the first direct evidence that magnetic reconnection, a phenomena in which magnetic fields break apart and then reconnect to release enormous amounts of energy and radiation, can occur in the solar wind itself. Observations revealed the physical nature of the plasma jets produced by the reconnection process and demonstrated that reconnection occurs frequently in the solar wind.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC1 Yellow	Complete Solar Terrestrial Relations Observatory (STEREO) instrument integration.	none	none	none
5SEC9 Blue	Successfully demonstrate progress in understanding the structure and dynamics of the Sun and solar wind and the origins of magnetic variability. Progress towards achieving outcomes will be validated by external review.	4SEC11 Green	3S7 Green	2S7 Green

Performance Shortfalls

APG 5SEC1: Instrument integration for the Solar Terrestrial Relations Observatory (also known as STEREO) was not completed. All U.S. instruments have been integrated on both spacecraft. The two Heliospheric Imager (HI) instruments being provided by an international partner remain to be integrated. The HI-A instrument was integrated in early October 2005. HI-B delivery is planned for November 2005.

FY 2005	FY 2004
Green	Blue
	(5.6.2)

Outcome 15.5: Determine the evolution of the heliosphere and its interaction with the galaxy.

NASA is investigating the nature of the solar system's interaction with its immediate interstellar neighborhood through observations of the flow of interstellar hydrogen and helium through the solar system. Researchers used data from the Advanced Composition Explorer (ACE), the Extreme Ultraviolet Explorer, the Solar and Heliospheric Observatory (SOHO), and Ulysses to show how interstellar helium penetrates close to the Sun and how this gas scatters solar ultraviolet light, produces ions, and joins with the solar wind. The Cassini spacecraft provided the first in situ observations to confirm the "interstellar hydrogen shadow" where hydrogen atoms streaming from the local interstellar medium are depleted in the region creating a shadow behind the Sun relative to the local interstellar flow. In addition, by looking at the difference between the directions of interstellar hydrogen and helium flowing into the solar system, researchers now have a clear indication of the nature of the magnetic field in interstellar space.

Voyager at the edge of the solar system

In FY 2005, NASA's Voyager 1 spacecraft entered the solar system's final frontier and became the farthest-traveled man-made object at nearly four billion miles beyond Pluto's orbit. On December 16, 2004, Voyager 1 entered the heliosheath, a region between the edge of the solar system and interstellar space. Voyager 1 continues to gather data and now is recording events unlike any encountered before in the mission's 26-year history.

The Voyager 1 spacecraft, shown here in an artist's concept (inset), has entered the heliosheath, the turbulent edge of the solar system near where the Sun's influence ends. As the heliosphere plows through interstellar space, a bow shock forms, much as forms in front of a boulder in a stream. The larger image, taken by the Hubble Space Telescope in February 1995, shows an arcing, graceful bow shock about half a light-year across created by wind from the star L.L. Orion's colliding with the Orion Nebula flow. Voyager's are the first in situ measurements of a stellar bow shock. (Image: STScI/AURA; Inset: NASA)

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC10 Blue	Successfully demonstrate progress in determining the evolution of the heliosphere and its interaction with the galaxy. Progress towards achieving outcomes will be validated by external review.	4SEC12 Blue	none	none

FY 2005	FY 2004
Green	Green

Outcome 15.6: Understand the response of magnetospheres and atmospheres to external and internal drivers.

(5.6.2)

NASA satellites give insight into water loss from Earth's atmosphere

In FY 2005, researchers observed oxygen flowing from Earth's atmosphere and gained new insight into the processes responsible for water loss from Earth's atmosphere using data gathered by the Fast Auroral Snapshot Explorer (commonly called FAST), IMAGE, and Polar missions. The observations revealed a number of phenomena connected to water loss from Earth's atmosphere: the outflows of water operate differently during the day and night; large geomagnetic storms influence these outflows; and they are enhanced when the interplanetary magnetic field points southward.

Cracking of Earth's protective shell

The four Cluster spacecraft provided clear evidence for the presence of fully-developed vortices that can transport solar wind plasma into the magnetosphere. This confirms theoretical predictions that solar wind plasma flowing along the flanks of the magnetosphere might be capable of exciting Kelvin–Helmholtz plasma instabilities, a special type of plasma mode capable of allowing plasma from the solar wind to penetrate the magnetosphere, Earth's protective layer.

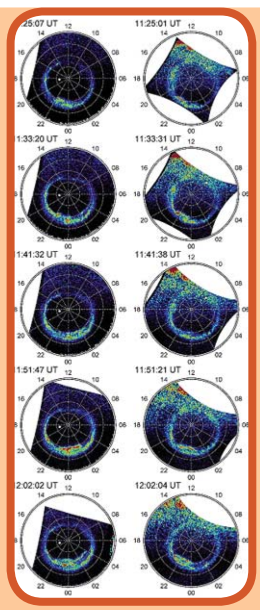
Auroral radios go quiet

Researchers from the Geotail mission, a joint endeavor of NASA and Japan's Institute of Space and Astronautical Science, found that the intense radio emissions caused by aurora disappear during magnetic storms. This surprising disappearance occurs when unusually large plasma sheet densities within the Earth's magnetosphere are present. Plasma is the fourth state of matter, where electrons are no longer trapped in orbit around an atom's nucleus. Earth's plasma sheet extends down the magnetotail, part of Earth's protective magnetic field, dividing

Spotlight: NASA Discovers the Consequences of Earth's Non-symmetric Aurora

Thanks to observations from the ground and satellites in space, scientists know that the North and South Poles light up at night with aurora because of magnetic storms induced by the solar wind, electrified gas continually flowing outward from the Sun at high speed. Aurora are created when charged particles become energized by storms within Earth's magnetosphere, and crash into the upper atmosphere, setting off a beautiful light display over the poles. NASA and university scientists studying Earth's northern and southern auroras were pleasantly surprised to discover the extent to which they do not mirror each other.

According to scientists, some of the new differences appear to be what occurs between the solar wind and Earth's protective magnetic field. From spacecraft observations made in October 2002, scientists noticed that these circular bands of aurora shift in opposite directions to each other depending on the orientation of the Sun's magnetic field, called the interplanetary magnetic field, which travels toward Earth with the solar wind flow. They also noted that the aurora shift in opposite directions to each other depending on how far Earth's northern magnetic pole is leaning toward the Sun.



This series of near-simultaneous auroras were observed on October 23, 2002. Observations were made of the northern (left) and southern (right) hemispheres by the IMAGE and Polar satellites, respectively. White dots indicate the geographic poles. Scientists analyzing the spacecraft images found that the auroras shift depending on the "tilt" of Earth's magnetic field toward the Sun and conditions in the solar wind. (Image: NASA)

Following a change in the orientation of the interplanetary magnetic field, the researchers noticed that the southern aurora shifted toward the Sun while the northern aurora remained in about the same location. They believe the southern aurora moved because the solar wind was able to penetrate into the magnetosphere in the southern hemisphere, but not in the northern hemisphere. What was most surprising was that both the northern and southern auroral ovals were leaning toward the dawn (morning) side of Earth for this event. The scientists suspect the leaning may be related to "imperfections" of Earth's magnetic field.

the two lobes of Earth's magnetic field. Researchers theorize that unusual densities in Earth's plasma sheet disrupt the process that normally generates the intense radio emissions.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC11 Green	Successfully demonstrate progress in understanding the response of magnetospheres and atmospheres to external and internal drivers. Progress towards achieving outcomes will be validated by external review.	4SEC13 Green	none	none

Outcome 15.7: Discover how magnetic fields are created and evolve and how charged particles are accelerated.

FY 2005: Green FY 2004: Green (5.7.1)

Understanding the release of energy within our solar system

Plasmas throughout the universe release enormous amounts of energy through the conversion of energy stored in magnetic fields into heated and flowing plasmas and energetic particles. NASA made significant progress in understanding these processes, enabling new simulations of the Sun–Earth system. The RHESSI spacecraft obtained X-ray evidence that reconnection of magnetic fields in the solar corona is the primary initiating mechanism by which particles are heated to high temperatures during solar flares. And, observations from the Cluster mission, together with simulations, showed that the particles in reconnection sites form electron "holes" containing strong electric fields, energetic electron beams, and large waves capable of accelerating plasma to high energies.

An artist conception of the SGR 1806-20, a magnetar that produced a flare brighter than anything detected beyond the solar system. The bright lines depict magnetic field lines rotating out and reconnecting, spinning out trapped positrons and electrons. The positrons and electrons destroy each other, producing hard gamma rays that can be detected by spacecraft like RHESSI. (Image: NASA)

NASA satellites catch a glimpse of a record stellar flare

Instruments onboard NASA's RHESSI and Wind spacecraft caught a glimpse of a giant stellar flare more luminous than any previously observed. Originating in the constellation Sagittarius, the flare released as much energy in its first 0.02 seconds as the Sun radiates in a quarter of a million years. The event unveiled the source of such short-duration hard x-ray radiation bursts to be extragalactic magnetars, a special kind of neutron star. The magnetic fields of these special neutron stars rotate quickly, twist, then break and reconnect in a process that sends trapped particles flying out from the star, annihilating each other in an explosion of gamma rays.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC12 Blue	Successfully demonstrate progress in discovering how magnetic fields are created and evolve and how charged particles are accelerated. Progress towards achieving outcomes will be validated by external review.	4SEC14 Green	none	none

Outcome 15.8: Understand coupling across multiple scale lengths and its generality in plasma systems.

FY 2005: Green FY 2004: Green (5.7.2)

Wave processes are important across all plasma systems

NASA made significant progress in understanding the space plasma waves that are the principals in many important space processes like particle acceleration and the scattering of particles into new regions. NASA's IMAGE spacecraft provided direct verification that wave-particle interactions in Earth's inner magnetosphere play a central role in the longevity of the near-Earth space radiation environment. The Cluster mission showed that some types of disruptive turbulence in the solar wind are kinetic Alfvén mode waves, a special type of plasma mode that can be damped out quickly by colliding solar wind electrons. And, contrary to earlier beliefs, researchers demonstrated that ultra low frequency wave turbulence that can affect over-the-horizon radar communication, can be stimulated solely within Earth's ionosphere without the need for special conditions to exist deeper in space.

Rare encounters

The Ulysses spacecraft made an unplanned crossing through the distant tail of a large comet and detected particles from the comet that were embedded in a fast moving coronal mass ejection from the Sun. The event is both rare and valuable for cometary studies and for understanding how particles can be transported through interplanetary space. Also, for the first time since space observations were possible, the planet Venus passed between Earth and the Sun. This once-in-122-year opportunity allowed NASA's TRACE, SOHO, SORCE, and other NASA spacecraft to study Venus' atmosphere, aiding the development of new techniques for the detection of extrasolar planets while supplying real-time viewing for the public.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5SEC13 Green	Successfully demonstrate progress in understanding coupling across multiple scale lengths and its generality in plasma systems. Progress towards achieving outcomes will be validated by external review.	4SEC15 Green	none	none

Resources

NASA's FY 2005 budgeted cost of performance for Objective 15 was $0.75 billion. NASA cannot provide FY 2005 budgeted cost of performance information at the Outcome level for this Objective.

Objective 17: Pursue commercial opportunities for providing transportation and other services supporting International Space Station and exploration missions beyond Earth orbit. Separate to the maximum extent practical crew from cargo.

WHY PURSUE OBJECTIVE 17?

Since the beginning of the U.S. space program, NASA has partnered with industry to develop, build, and operate space transportation vehicles. NASA will continue this partnership to transport crew and cargo to and from the International Space Station and to develop and fly the vehicles that will take astronauts to the Moon, Mars, and beyond.

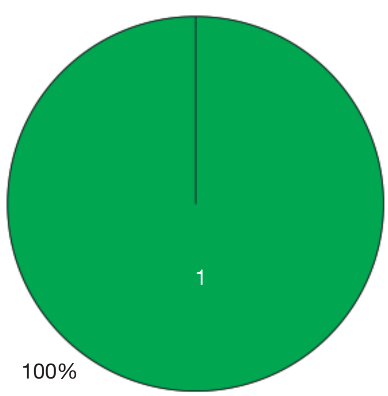
The benefit of partnerships is that NASA gets access to a wider variety of technologies than the Agency could develop in-house. NASA also can select the specific technologies and services that best fit the Agency's goals, schedules, and budget constraints.

In addition to partnerships, NASA may purchase from commercial providers launches to the Station that will meet or accelerate the Station completion schedule. In return, commercial providers have the opportunity to further develop technologies and services, like launch services for the satellite communications industry, which they could not afford without government support or would not pursue without the incentive of industry competition. This helps stimulate the commercial space industry while helping NASA achieve the Vision for Space Exploration.

Left: In September 2005, NASA announced its plans for a next-generation space transportation system, shown here in an artist's concept. Lockheed Martin Corporation and the team of Northrop Grumman Corporation and the Boeing Company will compete to build the Crew Exploration Vehicle, which would sit atop the Shuttle-derived, heavy-lift Crew Launch Vehicle. (Image: John Frassanito and Associates)

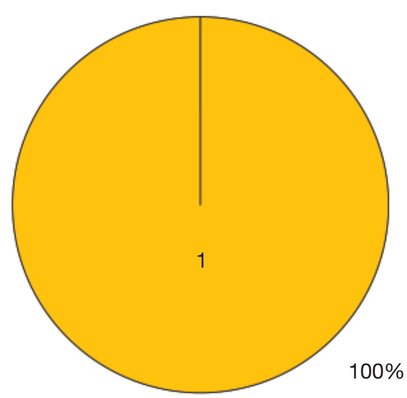
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



NASA is on track to achieve the Outcome under Objective 17.

APG Ratings

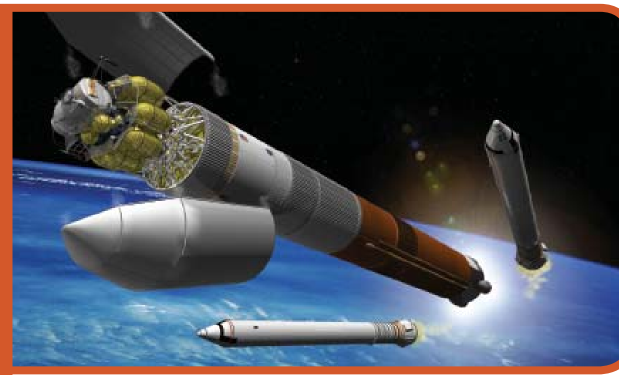


NASA made significant progress toward achieving the APG under Objective 17.

	FY 2005	FY 2004
Outcome 17.1: By 2010, provide 80 percent of optimal ISS up-mass, down-mass, and crew availability using non-Shuttle crew and cargo services.	Green	none

This year, NASA issued a Call for Improvement to the Crew Exploration Vehicle contractors that included requirements for cargo delivery services to the International Space Station. The Agency is developing a set of requirements for unpressurized cargo to support Station logistics and re-supply, while seeking strategies using commercial capabilities to meet Station requirements. These capabilities must be available to meet Station supply needs after the Shuttle's retirement.

During 2005, NASA announced its plan to develop a heavy-lift launch vehicle, shown here in an artist's concept. This vehicle would deliver cargo and crew, with modifications, to Earth orbit. NASA also is developing a smaller, crew-rated launch vehicle. Both would provide the up-mass NASA needs to pursue the Vision for Space Exploration after the Shuttle is retired in 2010. (Image: John Frassanito and Associates)



FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5ISS7 Yellow	Baseline a strategy and initiate procurement of cargo delivery service to the ISS.	none	none	none

Resources

NASA's 2005 budgeted cost of performance for Objective 17 is $0.00 billion.

Objective 18: Use U.S. commercial space capabilities and services to fulfill NASA requirements to the maximum extent practical and continue to involve, or increase the involvement of, the U.S. private sector in design and development of space systems.

WHY PURSUE OBJECTIVE 18?

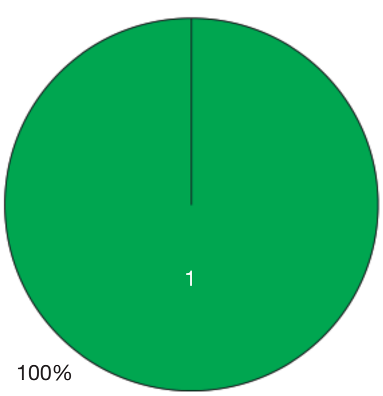
As missions move further into the solar system, NASA will rely more heavily on the private sector to provide supporting technologies and services. Through joint agreements, collaborations, and Centennial Challenge prizes for specific accomplishments that advance robotic and human exploration goals, NASA will expand its pool of creative thinkers and acquire the latest technologies at a competitive price.

To stimulate private sector participation, NASA has innovative partnership and commercialization programs that encourage companies to develop technologies and capabilities both for NASA and for commercial users. These programs also help companies transform unique NASA capabilities into products to benefit the public. The programs and initiatives are beneficial for all involved: NASA acquires valuable capabilities; the private sector is invigorated by increased competitiveness; small businesses gain visibility by partnering with the world's largest civil space organization; and the public benefits from the transfer of advanced NASA-derived technologies.

Left: In the early 1990s, Quantum Devices, Inc., began developing high-intensity, solid-state, light-emitting-diode lighting systems for NASA Space Shuttle plant growth experiments. In the late 1990s, NASA awarded the same company several Small Business Innovative Research contracts to investigate the effectiveness of the broad-spectrum diodes in medical applications. Since then, Quantum Devices, Inc., and the Medical College of Wisconsin have transitioned this space technology into an FDA-approved, non-invasive medical device, shown in the picture, that provides temporary relief from minor muscle and joint pain. (Image: QDI)

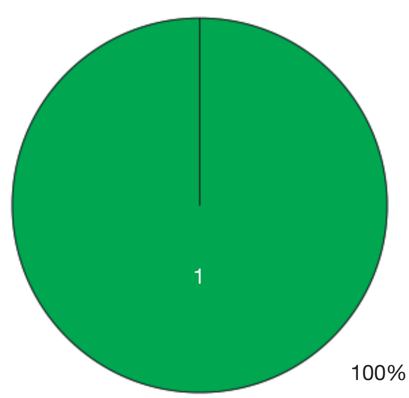
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2005

Outcome Ratings



NASA is on track to achieve the Outcome under Objective 18.

APG Ratings



NASA achieved the APG under Objective 18.

OUTCOME 18.1: ON AN ANNUAL BASIS, DEVELOP AN AVERAGE OF AT LEAST FIVE NEW AGREEMENTS PER NASA FIELD CENTER WITH THE NATION'S INDUSTRIAL AND OTHER SECTORS FOR TRANSFER OUT OF NASA DEVELOPED TECHNOLOGY.

FY 2005	FY 2004
Green	none

Data available as of October 21, 2005, shows that NASA Field Centers signed 61 partnership agreements with industrial and other sectors for dual use development transfer-in of technology to NASA. NASA Centers also signed 37 license agreements for transfer-out of NASA technology, for a total of at least 98 technology transfer agreements for FY 2005.

FY 2005 Annual Performance Goals		FY 2004	FY 2003	FY 2002
5HRT18 Green	Complete 50 technology transfer agreements with the U.S. private sector for the transfer of NASA technologies, through hardware licenses, software usage agreements, facility usage agreements, or Space Act Agreements.	4HRT6 Green	none	none

Spotlight: GlobalFlyer makes history with help from NASA

Steve Fossett and the experimental aircraft, Virgin Atlantic GlobalFlyer, made history in 2005 by safely completing the first solo, non-stop, non-refueled around-the-world airplane trip—with help from some NASA technology.

The flight tested NASA's advanced, experimental Tracking and Data Relay Satellite System transceiver, called the Low Power Transceiver, developed by NASA as a flexible, lower-cost way to relay information to and from spacecraft. NASA's transceiver allowed GlobalFlyer's mission control to communicate with Fossett for almost three days of flight through a live video connection.

NASA also loaned GlobalFlyer a Personal Cabin Pressure Monitor, a device invented by a NASA engineer that alerts pilots to reduced cabin pressure and oxygen deprivation. During those conditions, pilots can feel like they are functioning normally, while actually their mental capacity quickly diminishes. This is quickly followed by unconsciousness. Because Fossett's cockpit was too loud for an alarm, NASA engineers modified the device to vibrate to signal a problem.

On March 3, 2005, the Virgin Atlantic GlobalFlyer experimental aircraft completed the first solo, non-stop, non-refueled airplane flight around the world. On that historic day, Fred Gregory, acting NASA Administrator (center), and Vic Labacqz, NASA's Associate Administrator for Aeronautics (left), received a tour of the aircraft from GlobalFlyer Crew Chief Philip Grassa. (Photo: K. Peppard/FAA)

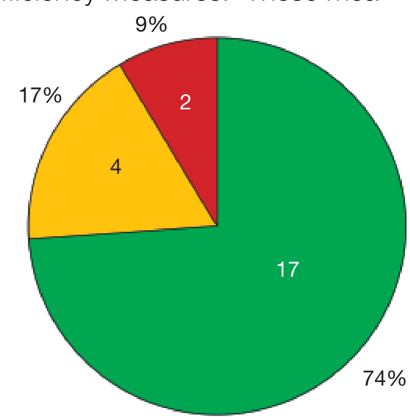
Resources

NASA's FY 2005 budgeted cost of performance for Objective 18 was $0.05 billion, all of which was allocated to Outcome 18.1.

EFFICIENCY MEASURES

In addition to tracking and reporting performance on NASA's 18 long-term Objectives, NASA also monitors and reports on the Agency's performance in a number of management goals called Efficiency Measures. These measures are not unique to NASA. They are organizational efficiency measures similar in purpose to the sound planning and management principles, practices, and strategies of all well-run organizations, and they are critical to NASA's achievement of the Agency's Objectives, Outcomes, and APGs.

NASA's Efficiency Measure APGs are organized according to the Agency's 12 Budget Themes (e.g., Solar System Exploration, Education Programs, Space Shuttle, etc.) to emphasize individual program area accountability.



In Efficiency Measures, NASA achieved 17 out of 23 APGs.

NASA's Progress and Achievements in FY 2005

NASA's progress in the Agency's Efficiency Measures is documented in the following tables. The NASA Performance Improvement Plan includes explanations for FY 2005 Efficiency Measure APGs that were rated Yellow, Red, or White.

FY 2005 Performance Measure		FY 2004	FY 2003	FY 2002
Solar System Exploration				
5SSE15 Yellow	Complete all development projects within 110% of the cost and schedule baseline.	4SSE1 Yellow	none	none
5SSE16 Green	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	none	none	none
5SSE17 Green	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	4SSE2 Green	none	none
5LE8 Green	The Robotic Lunar Exploration Program will distribute at least 80% of its allocated procurement funding to competitively awarded contracts.	none	none	none
The Universe				
5ASO13 Green	Complete all development projects within 110% of the cost and schedule baseline.	4ASO1 White	none	none
5ASO14 Yellow	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	none	none	none
5ASO15 Green	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	4SEU2 4ASO2 Green	none	none
Earth-Sun System				
5SEC14 Red	Complete all development projects within 110% of the cost and schedule baseline.	4ESS1 Green	none	none
5SEC15 Yellow	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	none	none	none
5SEC16 Green	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	4ESA8 Green	none	none
Constellation Systems				
5TS6 Green	Distribute at least 80% of allocated procurement funding to competitively awarded contracts, including continuing and new contract activities.	4TS5 Green	none	none
Exploration Systems Research and Technology				
5HRT15 Green	Distribute at least 80% of allocated procurement funding to competitively awarded contracts, including continuing and new contract activities.	4HRT13 Green	none	none

FY 2005 Performance Measure		FY 2004	FY 2003	FY 2002
Human Systems Research and Technology				
5BSR18 Green	Complete all development projects within 110% of the cost and schedule baseline.	4BSR18 Green	none	none
5BSR19 Green	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	4RPFS11 Green	none	none
5BSR20 Green	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	4BSR19 4PSR11 Green	none	none
Aeronautics Technology				
5AT28 Red	This Theme will complete 90% of the major milestones planned for FY 2005.	4AT3 Green	none	none
Education Programs				
5ED19 Green	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	4ED24 Green	none	none
International Space Station				
5ISS8 Green	Complete all development projects within 110% of the cost and schedule baseline.	4ISS7 Green	none	none
5ISS9 Green	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	none	none	none
Space Shuttle				
5SSP4 Yellow	Complete all development projects within 110% of the cost and schedule baseline.	4SSP5 Green	none	none
5SSP5 Green	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	none	none	none
Space and Flight Support				
5SFS21 Green	Complete all development projects within 110% of the cost and schedule baseline.	4SFS14 Green	none	none
5SFS22 Green	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	4RPFS11 Green	none	none

NASA'S PERFORMANCE IMPROVEMENT PLAN

The following table reports on APGs that NASA was unable to achieve fully in FY 2005 and Outcomes that NASA may not or will not achieve by the Outcome's targeted completion date. The table is organized by Strategic Objective. For each performance shortfall, the table includes an explanation of the specific performance problem, the reason(s) for less than fully successful performance, and NASA's plan and schedule to achieve or discontinue the Outcome or APG.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
2	APG 5MEP5	Successfully complete the Mission Concept Review and PMSR for the 2009 Mars Telesat Orbiter.	White	NASA did not hold the Preliminary Mission System Review (PMSR) for the 2009 Mars Telesat Orbiter.	The Mars Telesat Orbiter has been cancelled as part of a reprioritization of science.	Not applicable.	Not applicable.
2	APG 5MEP4	Successfully complete the Preliminary Mission System Review (PMSR) for the 2009 Mars Science Laboratory (MSL) Mission.	Yellow	NASA postponed the Preliminary Mission System Review (PMSR) for the 2009 Mars Science Laboratory.	NASA decided to delay in order to complete independent cost estimates prior to the review. The mission schedule allowed for this delay with no impact.	The PMSR currently is scheduled for December 2005, with no impact to the mission launch date.	Not applicable.
2	APG 5MEP11	Successfully demonstrate progress in investigating the character and extent of prebiotic chemistry on Mars. Progress towards achieving outcomes will be validated by external review.	Yellow	The external expert review determined that NASA did not demonstrate sufficient progress in investigating the character and extent of prebiotic chemistry on Mars.	The external expert review determined that NASA did not demonstrate sufficient progress due to a lack of currently operating flight missions designed to address this Outcome.	As noted by the external review, the Mars Science Laboratory, scheduled for launch in 2009, will address this Outcome.	Not applicable.
2	APG 5MEP14	Successfully demonstrate progress in inventorying and characterizing Martian resources of potential benefit to human exploration of Mars. Progress towards achieving outcomes will be validated by external review.	Yellow	The external expert review determined that NASA did not demonstrate sufficient progress toward achieving this APG.	The external expert review determined that NASA did not make sufficient progress due to a lack of currently operating flight missions designed to address this Outcome.	As noted by the external review, the Mars Reconnaissance Orbiter, launched in August 2005, will address this Outcome.	Not applicable.
3	APG 5SSE9	Successfully demonstrate progress in understanding why the terrestrial planets are so different from one another. Progress towards achieving outcomes will be validated by external review.	Yellow	The external expert review determined that NASA did not make sufficient progress toward achieving this APG.	The external expert review determined that NASA did not make sufficient progress due to the lack of flight missions planned to address this Outcome in general and Venus in particular.	NASA has included Venus investigations as an explicit target in the New Frontiers Program.	Not applicable.
4	APG 5ASO4	Demonstrate James Webb Space Telescope (JWST) primary mirror technology readiness by testing a prototype in a flight-like environment.	Yellow	NASA has completed only partial testing of JWST primary mirror technology in a flight-like environment.	NASA tested the advanced mirror system demonstrator (ASMD) mirror to operating temperature, but not to flight-like mechanical loads.	NASA will test the prototype and flight spare engineering development units mirror segment to all flight conditions by summer 2006, bringing it to Technology Readiness Level 6.	Not applicable.
4	Outcome 4.7	Trace the chemical pathways by which simple molecules and dust evolve into the organic molecules important for life.	Yellow	See 5ASO1 below.	See 5ASO1 below.	See 5ASO1 below.	Not applicable.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
4	APG 5ASO1	Deliver the SOFIA Airborne Observatory to Ames Research Center for final testing.	Red	SOFIA Airborne Observatory has not been delivered to Ames for final testing.	The SOFIA mission has experienced significant delays over the last several years from a variety of causes; the delay to completing the FY 2005 APG represents the effect of delays in prior years, acknowledged and explained in prior years' reports.	Delivery will occur in FY 2007.	Not applicable.
5	APG 5SEU8	Successfully demonstrate progress in testing Einstein's theory of gravity and mapping space–time near event horizons of black holes. Progress towards achieving outcomes will be validated by external review.	Yellow	The external expert review determined that progress toward achieving this APG was significantly affected by the loss of the XRS-2 instrument on the Astro-E2/Suzaku mission.	Progress toward achieving this APG was affected by the loss of the XRS-2 instrument on the Astro-E2/Suzaku mission.	A Mishap Investigation Board is assessing the causes of the failure. NASA may try to obtain the XRS science in the future, but NASA must evaluate this effort as part of the normal budget prioritization process.	Not applicable.
5	APG 5SEU1	Complete the integration and testing of the Gamma-ray Large Area Space Telescope (GLAST) spacecraft bus.	Yellow	NASA did not complete integrating and testing the GLAST spacecraft bus.	Delays were due to schedule problems with GLAST's primary instrument, the Large Area Telescope (LAT). The LAT experienced both engineering design and electrical parts problems, which required a project schedule and cost rebaseline.	NASA will integrate and test the spacecraft bus in FY 2006. The rebaseline resulted in a delay to the launch date, from May 2007 to September 2007.	Not applicable.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
6	APG 5SSP2	Achieve an average of eight or fewer flight anomalies per Space Shuttle mission in FY 2005.	Red	There was one Space Shuttle mission in FY 2005: STS-114. For this mission, there were approximately 185 In-Flight Anomalies (IFAs) reported. This number is approximate since post-STS-114 hardware inspections and analyses continue; these results could generate additional IFAs as the process unfolds.	A key contributor to the unusually large number of IFAs for STS-114 was a change in the definition of an IFA made during the Return to Flight effort. The change is documented in NSTS 08126, Problem Reporting and Corrective Action (PRACA) System Requirements, which became effective on August 27, 2004. Prior to this change in definition, IFAs were a small subset of problems reported in the PRACA system; with this change, any PRACA-reportable item during the launch preparation and execution timeframe automatically becomes an IFA. This change was made as part of the overall improvement to the Space Shuttle Program's problem tracking, IFA disposition and was documented in NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond. The Columbia Accident Investigation Board recommended anomaly resolution processes.	This performance goal has been eliminated for FY 2006.	The Space Shuttle program anomaly identification and resolution process depends upon actively encouraging anomaly reporting. Setting arbitrary metrics for the number of IFAs per flight (as APG 5SSP2 does) can potentially interfere with this process by implying that employees and contractors who report IFAs may be penalized for their findings. Although this performance goal is no longer being tracked in the Performance and Accountability Report, the Space Shuttle program will continue to review its IFA identification and disposition processes to ensure that problems reported during the launch preparation and execution time-frame are identified and dispositioned appropriately.
7	APG 5TS5	Conduct a preliminary conceptual design study for a human–robotic Mars exploration vehicle, in conjunction with definition of an integrated exploration systems architecture.	White	This APG was canceled by management directive. The timeline and approach for how NASA is going to define and develop a new architecture changed.	Not applicable.	Not applicable.	Not applicable.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
8	APG 5ISS5	Obtain agreement among the International Partners on the final ISS configuration.	Yellow	The ISS International Partnership Heads of Agency did meet in January 2005 to endorse the Multilateral Coordination Board-approved ISS configuration. However, in May 2005, Administrator Griffin initiated a 60-day study on options for completing ISS assembly within the parameters of the Vision for Space Exploration. The decision based on the study requires NASA to reopen discussions with its partners. By the end of the fiscal year, NASA began discussions with the International Partners on the way forward.	In May 2005, NASA initiated the Shuttle/Station Configuration Options Team study. This team conducted a 60-day study of the configuration options for the ISS and assessed the related number of flights needed by the Space Shuttle before it retires, no later than the year 2010. The scope of the team study spans ISS assembly, operations, and use and considers such factors as international partner commitments, research utilization, cost, and ISS sustainability. Decisions based on the study have required that NASA reopen discussions with its International Partners.	NASA proposed that the ISS Multilateral Coordination Board convene in late October 2005 to discuss the proposed configuration and assembly sequence and that the board, in turn, task and oversee the work of the Space Station Control Board to assess the technical aspects of this new approach. Following these detailed discussions, the partnership will meet at the Heads of Agency level.	Not applicable.
8	APG 5ISS2	Achieve zero Type-A (damage to property at least $1 M or death) or Type-B (damage to property at least $250 K or permanent disability or hospitalization of 3 or more persons) mishaps in FY 2005.	Yellow	Although there were no Type-A mishaps in FY 2005, NASA failed to achieve this APG due to the occurrence of one Type-B mishap.	The Precooler Assembly, part of the Environmental Control and Life Support System (ECLSS) flight hardware, was damaged during the tin plating process, damaging the protective braze layer. This breach rendered the assembly unrecoverable and will result in NASA requesting additional unit(s) from the ISS Program. The value of the loss is approximately $350 K. A Mishap Investigation Board is investigating the mishap.	NASA will review the ECLSS mishap investigation report for applicable lessons learned.	Not applicable.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
8	APG 5ISS4	Provide at least 80% of upmass, volume, and crew time for science as planned at the beginning of FY 2005.	Yellow	While NASA did not meet the 80% goal as planned at the beginning of the fiscal year on these metrics. NASA did meet 97% of the science objectives during Increment 10 (October 2004–March 2005) and expect a similar achievement for Increment 11 (March–October 2005). In addition, STS 114 delivered additional science capacity to the Station, bringing up the Human Research Facility-2 rack for the U.S. Destiny lab, deploying another set in an on-going material experiment, and flying three additional sortie experiments.	Due to the delay of Shuttle flight mission UF1 from March to July, the increase to three crewmembers was delayed from the scheduled date of May 2005 to a date to be determined in 2006, preventing achievement of the planned crew time and upmass for science goal.	A second successful test flight of the Space Shuttle will enable NASA to meet the planned science up-mass and volume goals, as well as an increase to three crewmembers.	Not applicable.
8	APG 5BSR10	Under the Human Research Initiative (HRI), increase the number of investigations addressing biomedical issues associated with human space exploration.	White	NASA has not increased the number of investigations addressing biomedical issues associated with human space exploration.	Anticipated HRI funding was reduced.	NASA hopes to re-engage the research community in robustly addressing biomedical issues associated with human space exploration within 5 to 7 years.	Biomedical research will be rephased in order to meet exploration mission requirements.
11	APG 5LE1	Identify and define preferred human–robotic exploration systems concepts and architectural approaches for validation through lunar missions.	Yellow	NASA does not have complete results, only preliminary concepts. NASA's near-term focus is on lunar site selection and characterization, rather than human–robotic linkages.	The architecture and long-term linkages must flow from the Exploration Systems Architecture Study results, which was completed in August 2005.	NASA intends to complete this APG in the third quarter of FY 2006.	Not applicable.
11	APG 5LE2	Identify candidate architectures and systems approaches that can be developed and demonstrated through lunar missions to enable a safe, affordable, and effective campaign of human–robotic Mars exploration.	Red	NASA's near-term focus has been lunar exploration; extensibility to Mars needs further work.	NASA deferred linkage to Mars in order to re-allocate resources for Constellation Systems development.	Although the schedule is unclear, NASA does not anticipate completing this APG before FY 2007.	This APG should be deferred until NASA can revisit the technology investment strategy for Mars exploration.
11	APG 5LE6	Identify preferred approaches for development and demonstration during lunar missions to enable transformational space operations capabilities.	Yellow	NASA has conducted limited analysis of space operations.	NASA's near-term focus for robotic exploration is on site selection and characterization. NASA will derive linkage to transformational operations from the Exploration Systems Architecture Study results and architecture development.	NASA intends to complete this APG in the third quarter of FY 2006.	Not applicable.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
11	Outcome 11.5	By 2016, develop and demonstrate in-space nuclear fission-based power and propulsion systems that can be integrated into future human and robotic exploration missions.	White	Although several APGs were met, this Outcome is no longer applicable due to Agency restructuring and program redefinition.	With NASA's restructuring and redefinition of its nuclear systems program, surface fission nuclear power for use on the Moon and Mars is now the primary goal for NASA's nuclear fission system development, while in-space nuclear fission-based power and propulsion development has been changed to a secondary goal.	At this time, NASA does not have plans to meet this goal. Missions requiring in-space nuclear fission-based power and propulsion systems have moved beyond the planning horizon. NASA is refocusing nuclear research and technology studies to meet longer-term exploration and science needs.	This Outcome is not practical since it is no longer a high-priority, near-term exploration need due to Agency restructuring and redefinition of the nuclear systems program. The responsible program recommends this Outcome be eliminated in FY 2006.
11	APG 5HRT8	Complete a validated road map for nuclear power and propulsion R&D, and related vehicle systems technology maturation.	White	NASA had not met this APG in May 2005 when the activity was canceled.	The activity was canceled before the strategic roadmap was complete.	Prometheus will generate program plans to meet exploration goals for lunar surface power pending acceptance of the Exploration Systems Architecture Study architecture.	Not applicable.
11	APG 5HRT15	Complete an Advanced Space Technology Program technology roadmap that interfaces appropriately with the technology planning of NASA's Mission Directorates.	White	NASA formed an Exploration Systems Research and Technology Coordination Group for this effort, but the group was placed on hold and eventually integrated into the Exploration Systems Architecture Study.	This effort was integrated into the Exploration Systems Architecture Study.	NASA will develop roadmap(s), as necessary, based on the results of the Exploration Systems Architecture Study.	Not applicable.
11	APG 5HRT12	Establish three partnerships with U.S. industry and the investment community using the Enterprise Engine concept.	Yellow	NASA did not form any partnerships with industry or the investment community using the Enterprise Engine concept in FY 2005.	Not applicable.	The program was restructured and is in place for FY 2006.	Not applicable.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
12	Outcome 12.4	By 2010, flight demonstrate an aircraft that produces no CO_2 or NOx to reduce smog and lower atmospheric ozone.	White	NASA rebaselined the combustor detailed design review (DDR) to the second quarter of 2005. This baseline, in turn, moved the completion of the annular rig test to the fourth quarter of 2006.	The curtailment of FY 2005 funding and the earmarks severely impacted the Ultra-Efficient Engine Technology (UEET) Project, including the Low-NOx Combustor DDR milestone that was planned for completion during the second quarter of 2005.	One contractor (P&W) did complete DDR of their concept in February 2005 and is continuing with testing as remaining UEET funds run out.	Following NASA's decision to levy Propulsion 21 earmark entirely against the UEET Project, stop-work orders were issued to RRNA/AADC. GE will continue low-NOx combustion work under the Propulsion 21 funding, but their schedule for DDR will slip into FY 2006. The P&W funding situation will be monitored. Final termination decisions and notices are pending official resolution of NASA's FY 2005 Operating Plan, but it is not expected that the RRNA/AADC effort will continue.
12	APG 5AT5	Demonstrate 70% reduction NOx emissions in full-annular rig tests of candidate combustor configurations for large subsonic vehicle applications. (Vehicle Systems)	Red	NASA originally funded three companies to demonstrate 70% NOx reduction, but only one successful annular rig test is needed to meet this APG's minimum success exit criteria. The curtailment of FY05 funding and the earmarks have severely impacted the UEET Project, including the Low-NOx Combustor DDR milestone that was planned for completion during the second quarter of 2005. One contractor (P&W) did complete DDR of their concept in February 2005 and is continuing with testing as remaining UEET funds run out.	Because of NASA's decision to levy Propulsion 21 earmark entirely against the UEET Project, stop-work orders were issued.	GE will continue low-NOx combustion work under the Propulsion 21 funding, but their schedule for DDR will slip into FY 2006. The P&W funding situation will be monitored. Final termination decisions and notices are pending.	Final termination decisions and notices are pending official resolution of NASA's FY 2005 Operating Plan, but it is not expected that the RRNA/AADC effort will continue.
12	APG 5AT27	Demonstrate through sector testing a full scale CMC turbine vane that will reduce cooling flow requirements and thus fuel burn in future turbine engine system designs. (Vehicle Systems)	White	This effort was deleted from the UEET portfolio.	Budget constraints during the replanning of the Vehicle Systems Program did not allow for this effort from Propulsion and Power to be included into UEET.	Not applicable.	Not applicable.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
12	APG 5AT9	Complete human-in-the-loop concept and technology evaluation of shared separation. (Airspace Systems)	White	This APG was delayed to third quarter of FY 2006 due to FY 2005 Congressional earmark impacts. The first in a series of planned FY 2005 simulations leading to a more mature concept demonstration had to be postponed until the second quarter of FY 2006 because of insufficient funds. However, NASA completed important supporting activities in FY 2005.	This goal was not met due budget impacts caused by FY 2005 Congressional earmarks.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.
12	APG 5AT13	Establish the fluid dynamics mechanism for alleviating wake through experimental and computational fluid mechanics studies. (Airspace Systems)	White	This APG was delayed to the third quarter of FY 2006 due to FY 2005 Congressional earmark impacts. Lack of timely and sufficient funding in FY 2005 caused the delay in completing the testing of more practical wake-alleviating configurations and ground and flight testing of various concepts. However, NASA completed important supporting activities in FY 2005.	This goal was not met due budget impacts caused by FY 2005 Congressional earmarks.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.
12	APG 5AT14	Complete System-Wide Evaluation and Planning Tool initial simulation and field demonstration. (Airspace Systems)	White	This APG was delayed to the third quarter of FY 2006 due to FY 2005 Congressional earmark impacts. During the schedule re-planning process, based on customer (e.g., FAA, airlines) needs, NASA revised the scope and focus of the Project's SWEPT efforts. As a result, initial simulation and field demonstration activity was re-scheduled to FY 2006. However, NASA completed important supporting activities in FY 2005.	This goal was not met due budget impacts caused by FY 2005 Congressional earmarks.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.

Objective	Performance Measure	Description	Rating	Explanation/ description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
12	APG 5AT15	Complete communications, navigation, and surveillance requirements analysis. (Airspace Systems)	White	This APG was delayed to the second quarter of FY 2006 due to FY 2005 Congressional earmark impacts. This resulted in a delay of two critical external requirements analyses for airport surface and oceanic requirements necessary to complete the related milestone. However, NASA completed important supporting activities in FY 2005.	This goal was not met due to budget impacts caused by FY 2005 Congressional earmarks.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.	Plans regarding this goal are pending details of re-alignment of Airspace Systems Program research efforts to NGATS JPDO capabilities requirements in FY 2006.
12	APG 5AT22	Using laboratory data and systems analysis, complete selection of the technologies that show the highest potential for reducing takeoff/landing field length while maintaining cruise Mach, low speed controllability, and low noise.	Yellow	This APG was not completed in FY 2005 due to substantially limited FY 2005 discretionary procurement budget that was caused by the requirement to fund Congressional Special Interest items. The work is expected to be completed in FY 2006. Limited internal studies are on-going.	NASA did not fund any external trade studies in FY 2005.	Progress toward achieving this detail is pending changes of Demonstration focus with the Vehicle Systems Program in FY 2006.	Not applicable.
12	APG 5AT20	Complete flight demonstration of a second generation damage adaptive flight control system. (Vehicle Systems)	Yellow	Although NASA is making good progress toward developing second-generation flight software, a reduction of $1.25 M in procurement funds, for Congressional Special Interest items, will impact completion of the APG. The result is a delayed software delivery schedule and the delayed start of the second-generation flight demonstration.	This APG was not met due to a $1.25 M reduction in available procurement funds.	NASA will reduce the scope of the flight demonstration to limited flight envelope testing. NASA will not demonstrate the full capability of the damage adaptive control system. However, NASA made signficant progress and plans to achieve the APG, based on the new scope, within the first quarter of FY 2006.	Not applicable.
15	APG 5SEC4	Complete Announcement of Opportunity (AO) selection for Geospace Missions far ultraviolet Imager.	White	NASA did not release the Announcement of Opportunity for the first Geospace mission.	A delay in releasing the Announcement of Opportunity resulted from a decision to reverse the order of Geospace Missions. The Radiation Belt Mapper (RBM) mission will be launched first, due to the particular relevance radiation physics has to the Vision for Space Exploration.	The Announcement of Opportunity for the Radiation Belt Mapper (RBM) was released on August 23, 2005, with selection scheduled for mid-FY 2006.	Not applicable.

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15	APG 5SEC1	Complete Solar Terrestrial Relations Observatory (STEREO) instrument integration.	Yellow	NASA completed over 90% of Instrument integration for STEREO. All U.S. instruments have been integrated on both spacecraft. Two Heliospheric Imager (HI) instruments being provided by an international partner must be integrated. The HI-A instrument has been delivered to the spacecraft, but technical problems have delayed integration until early October 2005. HI-B delivery is planned for November 2005.	The international partner encountered numerous technical problems associated with the Heliospheric Imager instruments, resulting in significant schedule slips.	The mission team is using schedule work-arounds, weekend work, and double shifts to minimize schedule delays. An HI mass model is being used on the "B" spacecraft so that observatory testing can proceed. The STEREO launch readiness date of April 2005 is unlikely due to these HI instrument delays.	Not applicable.
17	APG 5ISS7	Baseline a strategy and initiate procurement of cargo delivery service to the ISS.	Yellow	NASA completed the strategy, but has not initated procurement.	NASA is still awaiting detailed requirements from the Exploration Requirements Transition Team (expected in December).	NASA plans to initiate procurement by the second quarter of FY 2006.	Not applicable.
Efficiency Measure	APG 5SSP4	Complete all development projects within 110% of the cost and schedule baseline.	Yellow	Deployment of the Space Shuttle main engine Advanced Health Monitoring System (AHMS) slipped 21 months. Deployment to the fleet is now scheduled for July 2006. The project remains within overall budget.	Work on AHMS was interrupted to support testing and processing of Shuttle main engines for return to flight. The July 2006 date could also be delayed due to the effects of Hurricane Katrina on main engine testing facilities and delays in liquid hydrogen production and shipments to the Stennis Space Center in Mississippi.	Processing of the main engines for return to flight is complete, and testing facilities at the Stennis Space Center are coming back online after Hurricane Katrina. NASA is working with local and national distributors to secure shipments of liquid hydrogen fuel to complete AHMS certification testing.	Not applicable.
Efficiency Measure	APG 5AT28	This Theme will complete 90% of the major milestones planned for FY 2005.	Red	The Aviation Safety and Security Program was able to meet all its FY 2005 objectives by deferring the start of the aviation security technology developments that would support out-year goals. However, the magnitude of the change was significantly higher for both the Aviation Systems and Vehicle Systems Programs. As a result of canceled procurements, NASA only accomplished about 60% of the originally planned milestones in these two programs.	The funding of Congressional Special Interest items required approximately 1/3 of the funding planned for acquisitions associated with the accomplishment of program/project milestones. As a result, NASA did not accomplish the planned activities.	Not applicable.	Not applicable.

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Efficiency Measure	APG 5SSE15	Complete all development projects within 110% of the cost and schedule baseline.	Yellow	The Deep Impact mission was not launched within 110% of its schedule baseline.	Deep Impact did not meet its original launch readiness date of January 2004, and exceeded the cost baseline by 26%. Performance problems with the new, state-of-the-art spacecraft computers delayed their delivery for integration and test, which drove further delays to the spacecraft integration and test schedule, slipping the spacecraft delivery beyond the original launch date.	Deep Impact was launched successfully in January 2005.	Not applicable.
Efficiency Measure	APG 5ASO14	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	Yellow	The FUSE mission did not meet the 90% threshold for operating hours. (All other Theme missions met the threshold.)	On December 26, 2004, the z-axis reaction wheel assembly failed. This was the third of four assemblies to fail on the mission.	The project started a recovery effort immediately to recover control of the spacecraft. Because the spacecraft was designed to use a minimum of 2 reaction wheel assemblies, an entire motion control software had to be developed and tested, with final on-orbit tests in late June 2005. Science observations resumed on July 10, 2005.	Not applicable.
Efficiency Measure	APG 5SEC14	Complete all development projects within 110% of the cost and schedule baseline.	Red	The Cloudsat and CALIPSO missions were not completed within 110% of their cost and schedule baselines.	The CALIPSO and CloudSat missions are currently estimated to exceed baseline cost by more than 30% and schedule baselines by approximately 50%. The delays and associated costs resulted from a number of factors, including instrument problems on both missions. Delays have also resulted from external factors, such as co-manifest complexities, international partner deliveries, and significant launch vehicle-driven delays.	Cloudsat and CALIPSO are scheduled for launch in early FY 2006.	Not applicable.
Efficiency Measure	APG 5SEC15	Deliver at least 90% of scheduled operating hours for all operations and research facilities.	Yellow	The TOPEX/Poseidon mission did not meet the 90% threshold for operating hours. (The other Earth–Sun missions met the threshold, with the majority experiencing no loss at all.)	TOPEX does not have a working tape recorder, creating a limiting factor for TOPEX science. NASA expected the three recorders to fail after a decade of service on orbit. Despite this, TOPEX continues to provide vital science even though some subsystems no longer are available.	The most important aspect of science collections has to do with measurement of long-term variations of ocean surface topology. Intermittent interruptions, while undesirable, do not impact major science goals. NASA is compensating through real-time downlinking via the TDRSS communication satellite, where possible.	Not applicable.