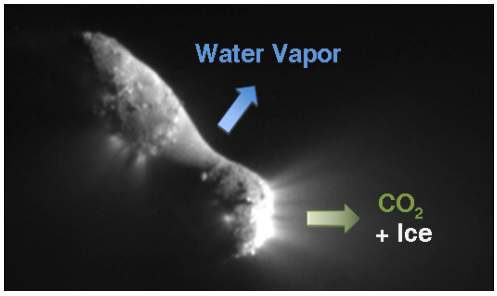
Comet Secrets Revealed!

Two very cool Discovery Program comet missions — Deep Impact and Stardust — each flew a highly capable, very reliable, and pretty amazing spacecraft. After accomplishing their prime missions in 2005 and 2006, NASA followed through on the Reduce, Reuse, Recycle trend with a fourth R — Retarget. Both spacecraft were re-targeted to new cometary destinations in 2007, and both have now accomplished their second incredibly successful mission.

EPOXI Reveals Cosmic Snowstorm During Comet Flyby

On November 4, 2010, the EPOXI mission, using the Deep Impact spacecraft, flew by comet Hartley 2 and returned spectacular images of this small, peanut-shaped active comet. The images showed it to be unlike any other comets we've seen close up before.

The images reveal a cometary snowstorm created by carbon dioxide jets spewing out tons of golf-ball to basketball-sized fluffy ice particles from the comet's rocky ends. At the same time, a different process caused water vapor to escape from the comet's smooth mid-section. The smooth area of comet Hartley 2 looks and behaves like most of the surface of comet Tempel 1, with water evaporating below the surface and percolating out through the dust.



Comet Hartley 2 from a distance of about 435 miles. Jets are streaming out of the 1.2-mile-long nucleus. Carbon dioxide, dust, and ice are emanating from the same areas, while water vapor appears to be from a different source. Credit: NASA/JPL-Caltech/UMD

Carbon dioxide appears to be a key to understanding Hartley 2. This information sheds new light on the nature of comets and even planets, showing that Hartley 2 acts differently than the four other comet nuclei that have been imaged by spacecraft: comets Halley, Borelly, Wild 2, and Tempel 1.

The finding that carbon dioxide is powering the many jets could only have been made by traveling to a comet, because ground-based telescopes can't detect CO_2 and current space telescopes aren't tuned to look for this gas.

More detailed analysis will continue, looking to determine whether the difference in outgassing between the smooth and rough regions of the comet is the result of a mixing of dry-ice-rich clumps with dry-ice-poor clumps during the comet's formation 4.5 billion years ago or whether the difference is due to more recent evolutionary changes. Early results will be reported at the Lunar and Planetary Science Conference in March.

View more images here.

Stardust-NExT Unveils New Views of Tempel 1

Stardust-NExT had a Valentine's Day rendezvous with comet Tempel 1, flying past the original target of the Deep Impact mission to capture the changes since 2005. On February 14, 2011, the spacecraft made its closest approach to Tempel 1 at a distance of 111 miles. Stardust took 72 high-resolution images of the comet and gathered 468 kilobytes of data about the dust in its coma. See the images here.

The Stardust-NExT mission achieved its goals, which included observing changes in surface features since 2005, imaging new terrain not seen before, and viewing the crater generated by Deep Impact's impactor. Scientists saw many unexpected and intriguing features in their first views of the comet. Further analysis will reveal much greater details in the findings.

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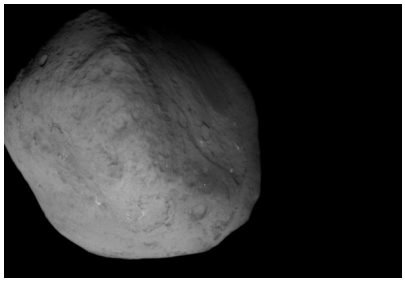


Previously unseen area of Tempel 1 taken by Stardust-NExT. Credit: NASA/ JPL-Caltech/ Cornell

Some of the visible changes between 2005 and 2011, during which the comet made a trip around the Sun, include areas of smooth terrain that is at a higher elevation than the more textured surface around it and cliffs that have been eroded. Some depressions previously seen have merged together over time from erosion. The erosion is caused by volatile substances evaporating away from the comet when it nears the Sun.

Areas of the nucleus not seen before include three terraces of different elevations with dark, banded scarps, or slopes, separating them. The lowest terrace has two circular features that are about 500 feet in diameter.

A comparison of images of the area that was hit by the Deep Impact impactor show a crater that is estimated to be 500 feet in diameter. A brighter mound in the center of the crater was likely created when material from the impact fell back into the crater. Scientists believe this indicates the nucleus is fragile and weak based on how subdued the crater appears to be.

Don Brownlee, the Stardust mission principal investigator and member of the NExT team, said, "It really was a fantastic ending to the mission — far more so than I ever imagined because the pictures were just terrific and we got dust impact data from two different sensors. The only disappointment was that we didn't have another sample collection to return. That would have been the ultimate!"

Brownlee found the stereo images to be especially interesting. "Deep Impact didn't have stereo coverage," he said, "so this is a real eye opener, providing a lot more information than we had from the previous flyby. The backside is different; it has numerous big depressed areas, which must be where things have ablated off into space. I think that's very informative for how comets evolve." Brownlee mentioned the animation of the flyby on the Planetary Society blog was very well done.

Other early findings include data from the spacecraft's dust flux monitor that show consistencies among what was found at Wild 2, Hartley 2, and Tempel 1, in the way the ice shoots off the comets in bursts and pops and clusters. Large ice particles are released from the comet and disintegrate in space. This is the origin of what become meteor showers.

EPOXI and Stardust-NExT Education and Public Outreach Highlights

Pasadena-area students and teachers visited the Jet Propulsion Laboratory for both the Hartley 2 encounter on November 4 and the Tempel 1 flyby on February 14 to witness the excitement of space exploration firsthand. About 350 students and 25 teachers in total for both events heard from mission speakers about the missions and why these events were so significant. The students listened intently and asked very thoughtful questions. They witnessed the birth of a comet, made with dirt, sand and dry ice. The students visited JPL's Spaceflight Operations Facility and sat where the VIPs usually sit, watching the action in mission control. Students also made their own comet models, illustrating comet features with craft supplies.

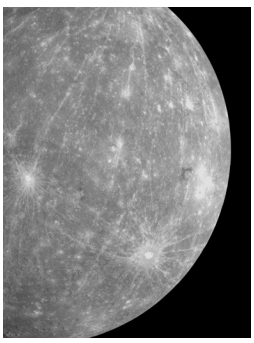
Solar System Ambassadors and Educators nationwide featured EPOXI and Stardust-NExT as they engaged students, teachers, and the public with talks, workshops, star parties, radio interviews, school visits, and newspaper articles.

The February issue of Science and Children, the National Science Teachers Association journal for elementary school teachers, contained an article by EPOXI and Deep Impact educators called "Inquiry Into the Heart of a Comet." The theme of the publication is Selecting an Inquiry Experience.

Mercury Orbit Almost Here

It's been a long and winding trajectory to Mercury for the MESSENGER mission. The Mercury orbiter was proposed to NASA in 1996 and selected as the seventh Discovery mission in 1999. Since its breathtaking launch against the dark Florida sky on August 3, 2004, the spacecraft has flown past Earth once, Venus twice, and Mercury three times, getting gravity assists needed to refine its path flight for orbit insertion. This incredible spacecraft has logged over 4 trillion miles since it set out for the planet closest to the Sun!

Now the excitement of the mission team is building as their patience is about to be rewarded — we are just weeks away from Mercury orbit insertion. Beginning on March 18, MESSENGER will spend an entire year studying the small planet with an array of seven instruments that could help answer fundamental questions about how planets form. During the 12-month orbital period, MESSENGER will obtain global mapping data and focus on targeted science investigations.



This high-resolution mosaic shows Mercury after the second flyby. It features the spectacular rays of Hokusai crater extending great distances across Mercury's surface. Credit: NASA/ Johns Hopkins University Applied Physics Laboratory/ Carnegie Institution of Washington

The mission team at the Applied Physics Laboratory near Baltimore has been extremely busy in recent months preparing for this monumental event. Since the last deep-space maneuver almost a year and a half ago, the team's primary focus has been to get ready for the orbit-insertion maneuver and orbital operations. Numerous tests and reviews have been conducted to assure success, including three full-team rehearsals using the hardware simulator to practice all activities for the upcoming maneuver. A Deep Space Network Operational Readiness Test was carried out using the antenna configuration that will be in place for orbit insertion. All commands to the spacecraft and all data returned from it go through this amazing array of antennas. The instruments have been tested and calibrated and are good to go!

Education and Public Outreach Highlights

"Mission Design" is a new educational module that places space exploration in the greater context of the history of human exploration. Students investigate how scientists and engineers today plan missions to study worlds in the solar system and extend their exploration even farther across the universe.

A new educational product called Mosaic Post Cards features images of Mercury's surface that were captured during MESSENGER's three flybys of the planet. To help students and teachers better understand this revealing new look at Mercury, a series of images each highlight a small "slice" of Mercury, such as a crater or fault. The individual cards can then be pieced together, puzzle-style, on a poster-sized grid to reveal a larger mosaic view of the planet, helping students understand scientific concepts related to and revealed by MESSENGER's journey.

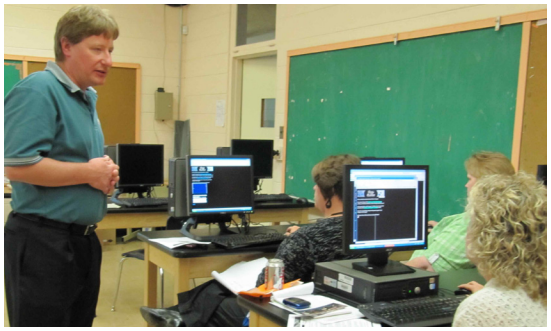
Dawn Counting Down to Vesta

Dawn passed its third anniversary of flight on September 27, on its way to investigate the two most massive objects in the main asteroid belt, Vesta and Ceres. The mission is anticipating arrival at Vesta in July, where it will begin a year-long orbit. Dawn is the first spacecraft ever to rendezvous with a main belt asteroid, to orbit two targets, and to visit a dwarf planet. Dawn's ion propulsion system, which is key to its ability to accomplish its lofty goals, has executed over 19,000 hours of thrusting since launch.

In November, mission controllers radioed new parameters to the spacecraft to allow it to use less of its hydrazine propellant. Hydrazine is fired through the small reaction control jets to help the spacecraft hold stable or rotate in the zero-gravity of spaceflight.

Also in November, the entire Dawn mission team gathered in Albuquerque, New Mexico. Twenty new participating scientists from all over the world were welcomed to the mission science team. Participants shared status reports and team updates, presented and listened to papers on key topics, and discussed planning strategies for data collection and analysis. They visited the University of New Mexico meteorite collection and Meteoritics Lab. Tim McCoy, the Curator-in-Charge of the meteorite collection at the Smithsonian Institute, gave a presentation on asteroids and meteorites.

In December, as Dawn continued to make excellent progress to Vesta, mission controllers commanded the spacecraft to switch from ion thruster #2 to thruster #3. After not being operated in two and a half years, #3 resumed thrusting smoothly and efficiently. All thrusters remain healthy.



Dawn education team member John Ristvey demonstrates computer-based activities at an educator workshop.

In January, the spacecraft executed a rehearsal of one of the activities it will need to perform in its low-altitude mapping orbit at Vesta. The test successfully demonstrated that even during times when Vesta blocks the starlight used by a sensor to help orient it in the zero-gravity of spaceflight, an alternate kind of sensor can be used.

One of Dawn's reaction wheel assemblies has experienced problems and has been removed from operations. The project is investigating ways to recondition it and has operational workarounds in place for operations at Vesta if reconditioning fails.

The operations team spent a week handling simulated problems during the approach phase to Vesta. The exercise included a wide variety of creative complications, including hypothesized damage to the spacecraft, unexpected characteristics of Vesta, loss of some planned Deep Space Network coverage, and unavailability of two members of the team. This "operational readiness test" is an important component of preparing for real operations.

Education and Public Outreach Highlights

With Vesta orbit insertion drawing near, the mission is planning Vesta Fiesta events nationwide in early August. Stay tuned for more details. Also be sure to check out Dawn's newly redesigned website.

Dawn joined EPOXI and Stardust-NExT to bring thematic small bodies events to a wide variety of audiences in recent months:

- Mission materials were on display and handed out to over 10,000 participants at the Colorado STEMapalooza on October 8–9.
- Thirty educators attended a full-day Small Worlds workshop at the Denver Museum of Nature and Science on October 16.
- Mission materials were part of a Discovery Space display at the Central Library in Aurora, CO this fall.

Dawn materials were distributed at the Chamberlin Observatory in Denver, the Florida Association of Science Supervisors fall meeting, and the Northwest Vision Conference in Madison, Wisconsin.

The Dawn E-News is distributed to over 6,000 subscribers. Sign up here.

New Horizons Passes Halfway Mark

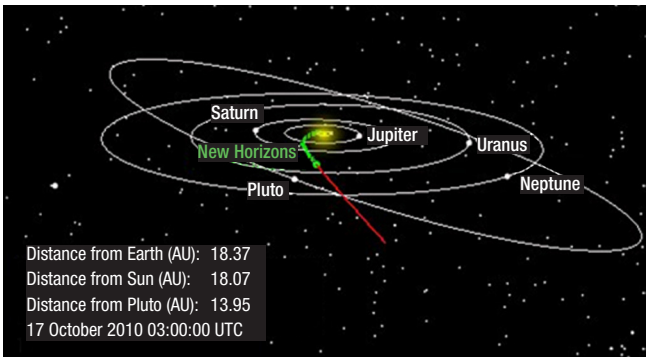
On October 17, 2010, at 3:24 Universal Time, New Horizons passed the halfway mark in the number of days from launch to Pluto encounter. The spacecraft is rapidly approaching the orbit of Uranus, which it will cross on March 18, 2011 — the same day the MESSENGER mission enters orbit about Mercury.

An unplanned event occurred in October when the monthly check of telemetry data from the spacecraft showed that no signal had been received on the ground. Fortunately, the problem wasn't on the spacecraft but rather was a misconfiguration of the receiving antenna. The problem was resolved and the telemetry was received, showing that New Horizons was functioning just fine.

In October, as New Horizons passed the 18 AU (astronomical unit) mark from the Sun, the Student Dust Counter (SDC) claimed the record for being the farthest operating dust detector ever from the Pioneer 10 and 11 spacecraft, whose dust detectors quit operating at this distance in the early 1980s. The SDC is now exploring uncharted territory for cosmic dust science.

Keeping with the mission's standard plan of a long wakeup from hibernation for a summertime checkup and two short wakeups in fall and winter, New Horizons was awakened in November and January to re-point the communication antenna to account for the motion of the Earth around the Sun and to gather tracking data for the navigation team. Science data from the SDC was transmitted back to Earth during both wake-up sessions.

The mission team continues planning for the Pluto encounter, concentrating primarily on the days just prior to and after the nine-day closest approach period. They are studying ways to increase the science studies of the space environment of the outer solar system by taking measurements while the spacecraft hibernates. They have also begun planning for next summer's annual checkout,



Progress on the way to the Pluto system, captured near the halfway mark.

ACO-5, which will include checkouts of all backup systems, upgrades to fault protection software, and powering up and checking out all seven scientific instruments.

Dr. Robin Canup, scientist and associate vice president of the Planetary Science Directorate at Southwest Research Institute, recently published findings in the Astronomical Journal from her research on the possibility that all three of Pluto's moons could be traced back to a giant collision. An impact has long been suspected for the origin of Charon, Pluto's largest moon, but impact simulations show that Nix and Hydra, two much smaller satellites discovered in 2005, may be debris from the same collision.

In Memory of Rick Grammier

Rick Grammier, director for solar system exploration at JPL, passed away unexpectedly on Jan. 23. Rick held many important positions during his 21 years at JPL, none more challenging than becoming the fourth manager of the Deep Impact project to comet Tempel 1 one year before launch.

In an interview with the *Discovery and New Frontiers News* in December 2004, just prior to the January 2005 launch, Rick talked about taking over as project manager. "It was more than a huge challenge," he said, "it was probably the biggest challenge I've ever had to deal with. And I've had to deal with some big challenges. When you come into a project that's been in trouble and you only have a year to turn it around, it takes a lot of time."

He continued, "This is really tough because we have such a short mission. We have a lot of activity crammed into the six-month cruise time, and we still have a lot of tweaking and additional testing to do for the encounter. It's not going to slow down very much."

Rick's leadership resulted in the spectacular success of the mission. The mission "hit a bullet with a bullet," as he described it, just perfectly. Earlier in his career, Rick served as the project engineer and deputy manager of the Stardust mission, playing a key role in the success of that comet sample return project. Now that the Stardust spacecraft just completed its flyby of Tempel 1 on Feb. 14, it is very sad that someone who provided such significant leadership on both missions was not here to witness this unprecedented return. Many people had Rick in their thoughts on the day of the encounter, with great appreciation for his legacy on these groundbreaking missions.

Rick went on to become the Juno project manager, but JPL management recognized his exceptional talents and abilities, promoting him to deputy director for solar system exploration and then director. He was awarded the NASA Exceptional Achievement Medal for Cassini, as well as two NASA Outstanding Leadership Medals for his accomplishments on Stardust and Deep Impact.

Here is advice Rick had for students who are interested in a career in space exploration: "Work hard at your education and don't limit yourself to excel in just one subject. Space exploration isn't limited to just a few areas; the possibilities are boundless. Explore different subjects and find out what you like. Then figure out where and how to apply it to your space exploration desires. You must like what you do, because you are going to spend a long time doing it. Listen to advice and think about it, but you must decide your direction. No one else can do that for you."

Rick Grammier's remarkable career took him all over the solar system. He will be fondly remembered and greatly missed here on Earth.

Program Office News

Teachers — Join us for Thrill of Discovery Workshop

Celebrate NASA's Year of the Solar System by attending a Thrill of Discovery workshop on March 19, 2011, in four locations: Pasadena, Calif.; Houston, Texas; Champlin, Minn.; and Laurel, Md. Each site will offer special speakers, hands-on activities for K–12 and out-of-school-time educators, and resource packets full of free educational resources, including the "Space School Musical" DVD. A webinar option is available for those unable to attend in person.

- See Sights Never Before Seen on Mercury: MESSENGER
- Get Up Close and Personal with Asteroids and Comets: Dawn, Stardust-NExT, and EPOXI
- Map the Moon's Gravity with Twin Satellites: GRAIL
- Peer through Jupiter's Clouds: Juno
- Cruise to the Outer Reaches of the Solar System: New Horizons

Register now — go to http://dawn.jpl.nasa.gov/discovery/thrill_of_discovery.asp

Scientists Gather at Workshop

A Discovery Program Science Workshop was held on December 1–2 at the Westin Washington DC City Center Hotel. The session was well attended by representatives from past and present Discovery missions, as well as one Lunar Quest mission: ASPERA-3, Dawn, Deep Impact, EPOXI, GRAIL, Kepler, LADEE, MESSENGER, Moon Mineralogy Mapper, and Stardust-NExT.

Four missions (MESSENGER, NExT, GRAIL, and Dawn) presented an overview of their science goals and operations concepts, which served as the starting point for discussions and shared experiences by all participants. Those who attended expressed interest in maintaining a general forum to raise programmatic and science operations issues and share experiences and lessons learned. Organizers plan to explore holding such workshops on a regular basis and perhaps being able to expand participation.

Discovery and New Frontiers News Receives Award

The *Discovery and New Frontiers News*, published since 2000, has received a 2010–2011 Spotlight Award from the Society for Technical Communication in the informational materials competition.

The newsletter documents significant mission events and education highlights. The complete archive serves as a history of the Discovery and New Frontiers Programs.

Missions Bring NASA to Tennessee Students

On October 20–21, nine educators representing the Discovery and New Frontiers missions visited classrooms in Fayetteville, Tennessee, to bring STEM Exploration Week with NASA to students at all grade levels.

Coordinated by D/NF E/PO manager Shari Asplund on behalf of the Program Office at Marshall Space Flight Center, the educators reviewed current mission highlights, led hands-on activities, and discussed NASA career information with 1,300 students and 60 educators in grades 9–12. The team also offered a three-hour educator workshop for 30 pre-service and in-service teachers.

The event received front page coverage in the local Elk Valley Times newspaper and high praise from participating teachers and administrators. The team of NASA educators included Asplund, Jaclyn Allen, Kay Tobola, Wil Robertson, John Ristvey, Sandra Weeks, Dee McLellan, Leesa Hubbard, and Fabienne Bastien.

Other events during NASA Week included an "October Skies Event" with night sky viewing for fifth graders and their parents. Sixth grade students participated in a County Wide Egg Drop. Students in 8th grade learned about STEM careers. Younger students watched "Space School Musical" while others did technology activities.

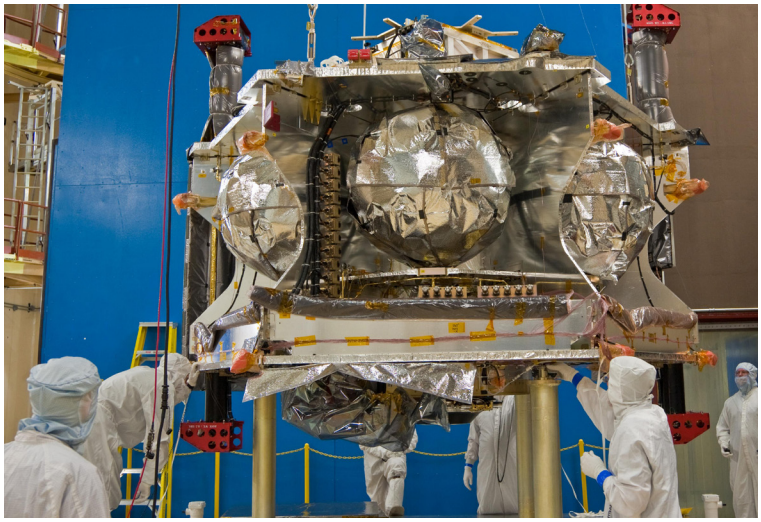
Juno Coming Together

Juno will improve our understanding of our solar system's beginnings by revealing the origin and evolution of Jupiter. With its suite of nine science instruments, Juno will investigate the existence of a solid planetary core, map Jupiter's intense magnetic field, measure the amount of water and ammonia in the deep atmosphere, and observe the planet's auroras.

Juno launch is scheduled for August 2011. It will take a five-year cruise, arriving July 2016 for a full year in orbit around the giant planet. New findings at Jupiter can provide critical knowledge for understanding planetary systems being discovered around other stars.

The spacecraft continues in assembly, testing, and launch operations, or ATLO, phase. All instruments have been delivered, and subsystems continue to make progress. Reviews are being conducted and issues being worked.

In October, the Juno magnetometers developed at NASA's Goddard Space Flight Center were delivered to Lockheed Martin in Denver.



Technicians position Juno for acoustical testing that simulates the intense vibrations of launch and other operations that take place while in flight.

This instrument will map the planet's magnetic field with great accuracy and observe its variations over time. It will provide a detailed picture of what the field looks like both around the planet and deep within it.

Jupiter's powerful magnetic field is nearly 20,000 times as strong as Earth's. The field is generated deep within the planet's atmosphere, where the intense pressure compresses hydrogen gas into an electrically conductive fluid. Fluid motion within the planet drives electric currents in this liquid hydrogen, and these currents generate the magnetic field. Jupiter's enormous magnetosphere extends nearly 2 million miles toward the Sun and as far as Saturn's orbit in the other direction.

This powerful magnetic environment also creates the brightest auroras in the solar system, as charged particles get trapped by the field and rain down into the atmosphere. Juno will directly sample the charged particles and magnetic fields near Jupiter's poles for the first time, while simultaneously observing the auroras at ultraviolet wavelengths of light. These investigations will greatly improve the understanding of this remarkable phenomenon and of similar magnetic objects, such as young stars that have their own planetary systems.

Education and Public Outreach Highlights

Juno participated in an Explore! Library workshop offered by the Lunar and Planetary Institute in Kentucky for 27 librarians. Juno scientists spoke about the mission and Jupiter.

Juno is featured in a new game on the SpacePlace website called JunoQuest.

GRAIL Continues Assembly and Testing

The Gravity Recovery and Interior Laboratory, or GRAIL, mission will send two spacecraft to orbit the Moon in tandem formation. The low-altitude, polar-orbiting twins will take precise gravity field measurements that will provide detailed information to determine the structure of the lunar interior from crust to core and understand the Moon's thermal evolution.

GRAIL will measure the gravity field of the Moon with unprecedented resolution, up to 1,000 times better than what we currently have for the far side. The mission will also answer longstanding questions about our Moon and provide scientists with a better understanding of how Earth and other rocky planets in the solar system formed. Launch is planned for September 2011, with orbit insertion in January 2012.

In October, the project delivered the Lunar Gravity Ranging System (LGRS) instruments and the MoonKAM cameras to Lockheed Martin. Installation and initial powered testing of the LGRS on GRAIL-A, one of the two spacecraft, was completed. Flight software was also delivered. A Mission Integration Working Group meeting was held in Denver and a Risk Management Board session was conducted.

The GRAIL Science Team met in November in Denver. An Environmental Test Readiness Review also took place. Random vibration and pyroshock testing on the Reaction Wheel Assembly Qualification Model was completed.

December accomplishments included completion of the GRAIL-A/GRAIL-B Deep Space Network Compatibility Test and initiation of Reaction Wheel Assembly Qualification Model life testing. Assembly and testing of the many spacecraft components and subsystems continues.

Education and Public Outreach Highlights

GRAIL educator workshops on Exploring Lunar Images with MoonKAM were presented at many venues in recent months, in-

GRAIL educator and Sally Ride Science teacher-in-residence Leesa Hubbard explains the MoonKAM to teachers at a workshop in Tennessee.

cluding Sally Ride Science (SRS) Festivals in Texas, National Science Teachers Association area conferences in Kansas City and Nashville, and the Space Explorers Education Conference in Houston. GRAIL educators conducted an eight-hour SRS educator institute in Tennessee featuring principal investigator Maria Zuber. A MoonKAM poster session was presented at the American Geophysical Union meeting.

Dr. Sally Ride, whose company Sally Ride Science leads the GRAIL E/PO effort, joined President Obama at the White House to launch Change the Equation, a corporate initiative dedicated to improving science, technology, engineering, and math (STEM) education. Dr. Ride is vice-chair for the initiative.

Discovery AND New Frontiers NEWS

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