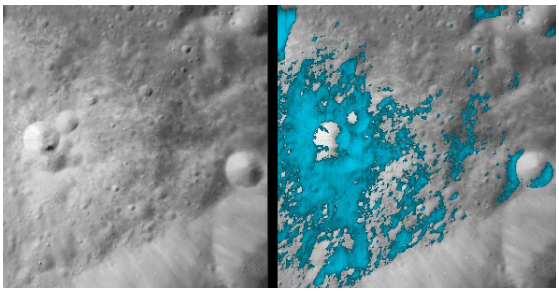
M3 Reveals Water Molecules on Lunar Surface

The Moon Mineralogy Mapper, or M3, instrument, has discovered water molecules in the polar regions of the moon. Reporting the finding at a NASA press briefing on Sept. 24, Dr. Carle Pieters, M3's principal investigator from Brown University, Providence, RI, said the M3 team found water molecules and hydroxyl at diverse areas of the sunlit region of the moon's surface. The findings were published in the Sept. 24 issue of the journal Science in a paper titled, "Character and Spatial Distribution of OH/H2O on the Surface of the Moon seen by M3 on Chandrayaan-1."



These images show a very young lunar crater on the side of the moon that faces away from Earth, as viewed by NASA's Moon Mineralogy Mapper on the Chandrayaan-1 spacecraft. On the left is an image showing brightness at shorter infrared wavelengths. On the right, the distribution of water-rich minerals (light blue) is shown around a small crater. Both water- and hydroxyl-rich materials were found to be associated with material ejected from the crater.
Credits: ISRO/NASA/JPL-Caltech/USGS/Brown Univ.

"For silicate bodies, such features are typically attributed to water and hydroxyl-bearing materials," said Pieters. "When we say 'water on the moon,' we are not talking about lakes, oceans or even puddles. Water on the moon means molecules of water and hydroxyl that interact with molecules of rock and dust specifically in the top millimeters of the moon's surface."

M3 was carried into space on Oct. 22, 2008, aboard the Indian Space Research Organization's Chandrayaan-1 spacecraft. Data from the Visual and Infrared Mapping Spectrometer, or VIMS, on NASA's Cassini spacecraft, and the High-Resolution Infrared Imaging Spectrometer on NASA's EPOXI spacecraft contributed to confirmation of the finding. The spacecraft imaging spectrometers make it possible to map lunar water more effectively than ever before.

Instruments aboard the three separate spacecraft revealed water molecules in amounts greater than predicted, but still relatively small. Hydroxyl, a molecule consisting of one oxygen atom and one hydrogen atom, also was found in the lunar soil.

The confirmation of elevated water molecules and hydroxyl at these concentrations in the moon's polar regions raises new questions about its origin and effect on the mineralogy of the moon. Answers to these questions will be studied and debated for years to come.

From its perch in lunar orbit, M3's state-of-the-art spectrometer measured light reflecting off the moon's surface at infrared wavelengths, splitting the spectral colors of the lunar surface into small enough bits to reveal a new level of detail in surface composition. When the M3 science team analyzed data from the instrument, they found the wavelengths of light being absorbed were consistent with the absorption patterns for water molecules and hydroxyl.

"The data from Cassini's VIMS instrument and M3 closely agree," said Roger Clark, a U. S. Geological Survey scientist in Denver and member of both the VIMS and M3 teams. For additional confirmation, scientists turned to the Discovery Program's EPOXI mission while it was flying past the moon in June 2009 on its way to a November 2010 encounter with comet Hartley 2. The spacecraft not only confirmed the VIMS and M3 findings, but also expanded on them.

"With our extended spectral range and views over the north pole, we were able to explore the distribution of both water and hydroxyl as a function of temperature, latitude, composition, and time of day," said Jessica Sunshine of the University of Maryland. Sunshine is EPOXI's deputy principal investigator and a scientist on the M3 team. "Our analysis unequivocally confirms the presence of these molecules on the moon's surface and reveals that the entire surface appears to be hydrated during at least some portion of the lunar day."

The Chandrayaan-1 mission ended earlier than planned when ISRO lost radio contact with the spacecraft on Aug. 29, after the mid-July failure of both star-sensors and some power supply systems. High levels of solar radiation in the moon's tenuous atmosphere had affected the units supplying power to two computers on board the spacecraft. With the loss of radio contact, no commands or data could be sent to or from the spacecraft.

The spacecraft completed 312 days and more than 3,400 orbits around the moon, providing a large volume of data from its sophisticated instruments, mapping approximately 90 percent of the lunar surface, and meeting most of the scientific objectives of the mission.

Education and Public Outreach Highlights

M3 participated in the public "Moonfest" held in concert with the 40th Anniversary of the Apollo 11 lunar landing events at NASA Ames Research Center on July 19, and took part in a lunar education

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workshop on July 20 in advance of the 2nd NASA Lunar Science Institute conference.

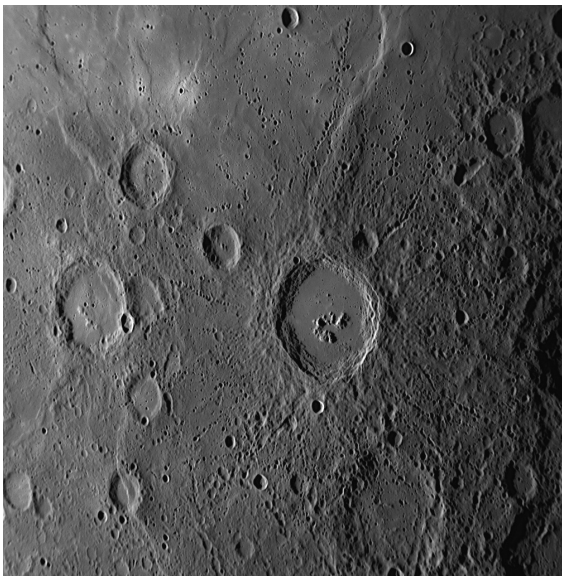
The project also participated in a Lunar Institute held at the Lunar and Planetary Institute in Houston, TX, at the end of July, presenting an overview of mission science and demonstrating spectral activities.

In August, Dr. Cass Runyon, M3 E/PO lead, was the invited keynote and closing speaker for a Women in Science event organized by the U.S. Embassy in New Delhi, India. She presented a talk on the Moon Mineralogy Mapper and Chandrayaan-1. Participants included female students (9th grade to undergraduate), teachers, and science faculty. The goal was to raise awareness about opportunities for women in STEM careers.

MESSENGER Completes Critical Gravity Assist

MESSENGER successfully flew by Mercury on Sept. 29, gaining a critical gravity assist that will enable it to enter orbit around Mercury in 2011 and capturing images of five percent of the planet never before seen. With more than 90 percent of the planet's surface already imaged, MESSENGER's science team had drafted an ambitious observation campaign designed to tease out additional details from features uncovered during the first two flybys. But an unexpected signal loss prior to closest approach hampered those plans.

The spacecraft passed by Mercury at an altitude of 142 miles and at a relative velocity of more than 12,000 miles per hour. As the spacecraft approached the planet, MESSENGER's Narrow Angle Camera captured this striking view, which shows examples of the multiple processes that have played important roles in shaping the geology of the planet's surface. This photo reveals that impact cratering has clearly been an influential process, with both old degraded craters and relatively young fresh craters visible. The area imaged is about 250 miles across.



Near the center is a large, fresh crater with a smooth floor, central peak structures, terraced walls, and many associated small secondary craters and crater chains. At the top of the image, smooth plains extend over a large area. Wrinkle ridges are visible on the plains. There is evidence that many of Mercury's smooth plains are volcanic in origin. In the lower left of this image, a scarp (cliff) can be seen cutting through a deformed impact crater.
Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

"This third and final flyby was MESSENGER's last opportunity to use the gravity of Mercury to meet the demands of the cruise trajectory without using the probe's limited supply of on-board propellant," said MESSENGER Mission Systems Engineer Eric Finnegan of the Johns Hopkins University Applied Physics Laboratory in Laurel, MD.

A portion of the complicated encounter was executed in eclipse, when the spacecraft is in Mercury's shadow and the spacecraft — absent solar power — was to operate on its internal batteries for 18 minutes. Ten minutes after entering eclipse and four minutes prior to the closet approach point, the carrier signal from the spacecraft was lost, earlier than expected.

According to Finnegan, the spacecraft autonomously transitioned to a safe operating mode, which pauses the execution of the command load and "safes the instruments," while maintaining knowledge of its operational state and preserving all data on the solid-state recorder.

"This third and final flyby was MESSENGER's last opportunity to use the gravity of Mercury to meet the demands of the cruise trajectory without using the probe's limited supply of on-board propellant."

Eric Finnegan
MESSENGER Mission Systems Engineer

"We believe this mode transition was initiated by the on-board fault management system due to an unexpected configuration of the power system during eclipse," Finnegan said. MESSENGER was returned to operational mode at 12:30 a.m. with all systems reporting nominal operations. All on-board stored data were returned to the ground by early morning and are being analyzed to confirm the full sequence of events."

While the flyby did not go completely as planned, the primary objective, the gravity assist, was successful, putting the spacecraft on course for Mercury orbit insertion in March 2011. The science observations captured more areas of previously unexplored terrain and gathered new information on Mercury's exosphere.

Education and Public Outreach Highlights

Five MESSENGER Educator Fellows joined the team in mission control at the Applied Physics Lab in Laurel, MD, during the Mercury flyby and for two days afterward, attending briefings and science meetings and communicating their experiences with a national audience via Twitter, Facebook, blogs, and email. Dr Christina Dorr, OH; Gene Gordon, NY; Annette Iwamoto, CA; Sally Jensen, NH; and Julie Taylor, CA, also held videoconferences and a special live Twitter Q&A session with classrooms and communities nationwide with assistance from members of the science team to answer questions.

A public talk on the mission and the flyby took place on Oct. 1, with presentations by Principal investigator Sean Solomon, Project Manager P. D. Bedini, and science team member/geologist Louise Procktor.

MESSENGER now has 824 followers on Twitter (MESSENGER2011) and 1,158 friends on Facebook (Messenger mission). Weekly status reports and material published on the mission website are being used to provide regular updates on the mission, with followers and friends providing positive feedback on the postings.

Discovery and New Frontiers Bring NASA to Boaz, Alabama

An October visit to classrooms in Boaz, Alabama, coordinated by Shari Asplund for the Discovery and New Frontiers (D/NF) Programs became "NASA Week," reaching 2,000 students at all 5 city schools.

A team of 7 scientists and educators representing the D/NF missions visited intermediate, middle, and high schools to inspire and engage students in grades 4–12 with hands-on activities, spacecraft models, a cube of aerogel, information about careers at NASA, discussions on why Pluto was demoted, how Kepler will search for planets, if are we alone, and more.

Joe Davis, a branch chief at Marshall Space Flight Center, brought a space shuttle model, and D/NF chief engineer Judy Ballance shared her story about growing up on a farm near Boaz and changing careers until she found her place at NASA.

State Senator Hinton Mitchem and Superintendent Leland Dishman came out to show their support. "This brings the future to Boaz," Dishman said. Local media covered the events: NASA Reaches Out to Boaz Students, Boaz Students Participate in NASA Week, Igniting Interest, and Boaz Students Get a Taste of Space.

Boaz High School Assistant Principal Ann Landers said, "We have had very positive feedback from the students. I was very impressed to hear discussion about the activities in the hallways and at the lunch tables. Our kids enjoyed and learned from the participation."

Boaz Middle School principal Allen Johnson added, "Anytime we can bring in experts and expose our kids to their experiences, it's awesome. It's what learning is all about."

Even the youngest students got involved. "Having a special week like this enhances the science program," said kindergarten teacher Sonya Hester. "You actually get a week set aside for specific topics instead of trying to integrate it into your regular curriculum."

The NASA team also conducted a two-hour professional development workshop for 30 educators at the public library.

Boaz, located 55 miles south of Huntsville, has a population of about 8,200.

NASA representatives included Asplund, Jet Propulsion Laboratory; Alan Gould, Lawrence Hall of Science and the Kepler mission; John Ristvey, McREL, for Dawn and Stardust-NExT; Kay Tobola and Jaclyn Allen from the Astromaterials Research Office at Johnson Space Center; Wil Robertson, Penn State Aerospace Educator at MSFC; and Jennifer Reed-Taunton, NASA Explorer School Coordinator at MSFC.

Boaz High School was especially fascinated by the Kepler mission. Alan Gould spoke to an advanced math class that was using Kepler's online Exoplanet Transit Hunt simulation in the computer lab.

Students in the Civil Air Patrol's Aerospace Connections in Education program welcomed John Ristvey, Alan Gould, and Shari Asplund (center row) to their weekly meeting. The cadets were enthusiastic and loaded with questions. They learned about the D/NF missions and then designed their own. Seventh grader Jacob Elrod said, "The opportunity to get three extra lessons from these geniuses was 'scientastical!'"

High school students build and fire soda straw rockets.

Kepler's Human Orrery activity was a hit in grades 4–6.

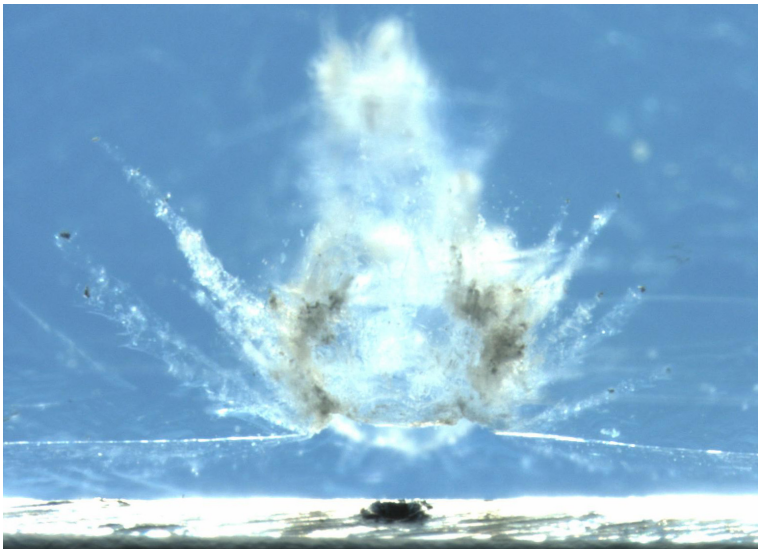
Stardust Discovers Amino Acid in Comet

As the Stardust spacecraft cruises toward comet Tempel 1 for the Stardust–NExT flyby in February 2011, the science team continues to plan for the upcoming encounter. They are comparing two models that predict the position of Tempel 1. Both models agree on the rotational period of the comet, however they differ in the duration of the required Time Of Arrival maneuver. Both will continue to be refined in preparation for a Jan. 7 science team meeting in Tucson.

Recent Hubble observations of Tempel 1 will be used in models to determine the comet's position at encounter. Current indications are that Temple 1 is behaving as predicted by the models.

Meanwhile, NASA scientists analyzing the comet dust samples returned by Stardust from comet Wild 2 have discovered glycine, a fundamental building block of life.

"Glycine is an amino acid used by living organisms to make proteins, and this is the first time an amino acid has been found in a comet," said Jamie Elsila of NASA's Goddard Space Flight Center in Greenbelt, MD. "Our discovery supports the theory that some of life's ingredients formed in space and were delivered to Earth long ago by meteorite and comet impacts."



This image shows a particle that penetrated the aluminum foil holding the aerogel block, leaving an impact crater in the foil and ejecta in the aerogel.

Elsila is the lead author of a paper on this research that was presented during the Aug. 16 meeting of the American Chemical Society in Washington, D.C. and published in the September 2009 journal. Meteoritics and Planetary Science.

Proteins are the workhorse molecules of life, used in everything from hair to enzymes, the catalysts that speed up or regulate chemical reactions. Just as the 26 letters of the alphabet are arranged in limitless combinations to make words, life uses 20 different amino acids in a huge variety of arrangements to build millions of different proteins.

"We analyzed aluminum foil from the sides of tiny chambers that hold the aerogel in the collection grid," said Elsila. "As gas molecules passed through the aerogel, some stuck to the foil. We spent two years testing and developing our equipment to make it accurate and sensitive enough to analyze such incredibly tiny samples."

"The discovery of amino acids in the returned comet sample is very exciting and profound," said Stardust Principal Investigator Donald E. Brownlee, a professor at the University of Washington, Seattle. "It is also a remarkable triumph that highlights the advancing capabilities of laboratory studies of primitive extraterrestrial materials."

Education and Public Outreach Highlights

In August, John Ristvey from Mid-Continent Research for Education and Learning (McREL) conducted a 30-minute presentation via Skype with Challenger Center students on the Stardust–NExT and Dawn missions.

The McREL E/PO team brought Stardust–NExT to STEMapalooza in Denver Oct. 16–17. The event supports Science, Technology, Engineering, & Math programs for students and educators. Students of all ages engaged in hands-on, minds-on activities, such as fast-track racing, robotics, gaming, rocketry, and more. A new Stardust–NExT activity called "Comet Chronicles" for students in grades 7–12 was beta-tested at the event to get feedback.

Stardust–NExT is offering web users an opportunity to make their opinions count, as well as be eligible to win a prize. Through Nov. 30, the mission is inviting web users to review the site and complete a short survey, with the goal of improving the site and providing a more robust web and mission experience. One hundred surveys will be selected at random to receive ice-cube sized pieces of aerogel or Stardust cookie cutters.

Genesis Team Reflects on Mission Outcomes

Members of the Genesis mission team gathered at JPL on Sept. 8 to celebrate the fifth anniversary of the sample return capsule's smashing return to Earth. A variety of speakers reviewed the mission's plans and the findings to date in a two-hour presentation. Everyone enjoyed a slice of Genesis cake, then adjourned for lunch.

The Genesis samples have provided data leading to important scientific insight into questions related to planetary materials, or cosmochemistry. The first result came from researchers in Germany who surmised that the "Solar Energetic Particles" inferred from some past lunar and meteorite data did not exist. The bizarre isotopic compositions were simply an artifact of the mechanism by which solar wind implants into solid materials.

Noble gas analyses from research based at Washington University in St. Louis observed enriched $^{36}Ar/^{38}Ar$ ratios in Genesis samples and interpreted these ratios as possible evidence for atmospheric losses early in the Earth's history. Perhaps most interesting was a progress report on oxygen isotopic measurements out of the MegaSIMS laboratory at the University of California Los Angeles that suggested a simple, homogeneous, equilibrium model of our solar nebula was not sufficient; rather, there was at least one kinetic process (such as isotope-selective photochemical shielding or, perhaps, the addition of extra-solar material from nearby stars) that differentially affected parts of our solar nebula.

Judy Allton, Genesis Solar Wind Sample Curator at the Astromaterials Acquisition and Curation Office at the Johnson Space Center, talks about the efforts to catalog, document, and disseminate samples.

Genesis solar material was collected concurrently with in situ data from other spacecraft monitoring the sun. This provides an opportunity for Genesis data to assist in the understanding of solar physics mysteries. Researchers are using Genesis sample data to test multiple hypotheses to better understand how material is ejected from the Sun.

Education and Public Outreach Highlights

McREL, a Denver-based nonprofit that served as the education partner for Genesis during most of the mission, has received funding from the U.S. Department of Education's Institute for Education Science for a three-year project called "Cosmic Chemistry." The curriculum will be based on real world science from the Genesis mission.

The summer science program aims to encourage ninth and tenth grade students to enroll in high school chemistry. Cosmic Chemistry will use the real-world context of space science to set high expectations, build background knowledge, and motivate students, with the ultimate goal of increasing their science achievement.

The goal of the program is to help students learn complex science concepts while building their confidence to take higher level science courses. It will teach students to think and communicate like scientists by identifying questions, generating hypotheses, and conducting investigations to test their hypotheses.

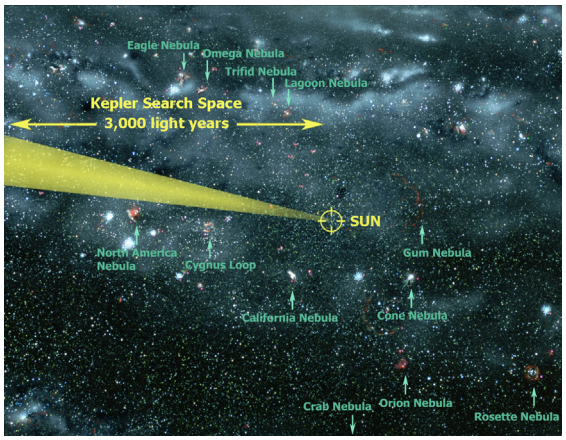
The Genesis mission partnered with the Voyager, Ulysses, and STEREO missions to host a Sun Educator Conference, "Exploring the Center of Our Universe," at JPL on Oct. 17. Forty-five teachers attended and heard talks from speakers representing each mission. They also learned activities based on mission science.

The Genesis mission education and public outreach effort concluded at the end of October. The web site was archived so will have no further updates. Check the Discovery Program web site for ongoing reports of science findings.

Kepler Delights with Early Science Results

The exoplanet-hunting Kepler space telescope has detected the atmosphere of a known giant gas planet, demonstrating the telescope's extraordinary scientific capabilities. The discovery was published in the August 7 issue of Science.

Kepler team members say these new data indicate that the mission, launched March 6, 2009, from Cape Canaveral, Florida, is indeed capable of finding Earth-size planets, if they exist. Kepler will spend the next 3-1/2 years searching for planets as small as Earth, including those that orbit stars in a warm zone where there could be water. It will do this by looking for periodic dips in the brightness of stars, which occur when orbiting planets transit, or cross in front of, the stars.



Kepler's target region in the Milky Way.
Image Credit: NASA/JPL

"When the light curves from tens of thousands of stars were shown to the Kepler science team, everyone was awed; no one had ever seen such exquisitely detailed measurements of the light variations of so many different types of stars," said William Borucki, the principal science investigator.

The observations were collected from a planet called HAT-P-7, known to transit a star located about 1,000 light years from Earth. The planet orbits the star in just 2.2 days and is 26 times closer than Earth is to the Sun. Its orbit, combined with a mass somewhat larger than the planet Jupiter, classifies this planet as a "hot Jupiter." It is so close to its star, the planet is as hot as the glowing red heating element on a stove.

The new Kepler data can be used to study this hot Jupiter in unprecedented detail. The discovery also demonstrates Kepler has the precision to find Earth-size planets. The observed brightness variation is just 1-1/2 times what is expected for a transit caused by an Earth-sized planet. Although this is already the highest precision ever obtained for an observation of this star, Kepler will be even more precise after analysis software being developed for the mission is completed.

The Kepler project has been transferred from the Discovery Program Office to the Exoplanet Exploration Office at JPL. It will not be included in future Discovery and New Frontiers newsletters.

Education and Public Outreach

Members of the Kepler Mission science and education teams continue to give talks and presentations about the mission in a variety of venues. The mission participated in an exhibit at NASA Ames Research Center's Science and Technology Showcase at the end of June and staffed a display and distributed mission materials at a star party at Ames in August.

Tying in with the International Year of Astronomy, Kepler scientists gave a public talk at Ames called "From Crystalline Spheres to the Modern Universe," highlighting the 400 year journey from Kepler's Laws and Galileo's Telescope to NASA's Kepler Mission.

Kepler offered 2 workshops at the Astronomical Society of the Pacific's annual meeting in San Francisco in September. The October meeting of the Northern California Northern Nevada Section of the American Association of Physics Teachers featured an invited talk by Kepler scientist Natalie Batalha.

Kepler is distributing their "Strange Planets" show kit to planetariums around the country.

New Horizons Checks Out, Enters Hibernation

The New Horizons mission team closed out a successful summer checkout, putting its Pluto-bound spacecraft back into hibernation on Aug. 27 after seven weeks of functional tests and system checks.

The mission's third annual checkout (ACO-3), which started July 7, "went very well," says Mission System Engineer Chris Hersman, of the Johns Hopkins University Applied Physics Laboratory. "New Horizons is in good shape."

New Horizons team bumper sticker

Principal Investigator Alan Stern, of the Southwest Research Institute, says ACO-3 was less "cluttered and complex" than previous ACOs, kept simple to let mission engineers and scientists focus on Pluto-encounter planning. But it was still productive: the team performed functional checkouts of all seven science instruments and every spacecraft subsystem, including the primary and backup hardware in each system; carefully tracked the spacecraft to refine its knowledge of New Horizons trajectory; and uploaded the instructions that will guide New Horizons through hibernation.

The Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI) and Solar Wind at Pluto (SWAP) instruments also each accumulated about a day's worth of data on the interplanetary gases and particles around the spacecraft.

In September, New Horizons reached the halfway point between the orbits of Saturn and Uranus. The spacecraft journeyed where only 5 previous spacecraft had traveled before — 14.1 astronomical units from the Sun, or 1.34 billion miles. "New Horizons is on its way to the farthest planetary encounter ever," said Stern, "at just over 32 astronomical units, which is a quarter-billion miles beyond the current planetary encounter record set at Neptune back in 1989."

The team will pull New Horizons out of hibernation for 10 days in November for a set of maneuvers that keep Earth in the beam of the spacecraft's antenna. It's an adjustment that is needed to make as Earth moves around the Sun and New Horizons moves farther along on its path toward Pluto.

Education and Public Outreach Highlights

The E/PO team continues to keep the public informed about the mission through web site updates and e-news mailings. Recent efforts include a "Girl Power" event for middle and high school girls and Maryland Summer Center for Space Science, both held at the Applied Physics Lab (APL), Laurel, MD, in partnership with the Maryland Department of Education. Other activities include participation in a Space Symposium in Colorado Springs with talks and exhibits for teachers, students and the public and a Space Academy for middle school students at APL with partners Discovery Science Channel and Comcast. The mission also joined in Maryland Science Center Space Day featuring exhibits and activities for the public and a Maryland Place in Space public event at the Baltimore Convention Center.

New Horizons also participated in undergraduate and graduate student internships at APL's Space Department over the summer.

Dawn Enters the Asteroid Belt

Dawn continues to make steady progress on its journey through the solar system. The spacecraft is thrusting with its ion propulsion system, heading toward a July 2011 rendezvous with asteroid Vesta. The project and the science team continue to refine the Vesta science plan to validate the design and operations processes.

On November 13, Dawn entered the asteroid belt where it will remain for the rest of its mission and well beyond. It will become a permanent inhabitant of that part of the solar system, the first emissary from Earth to take up residence in the main asteroid belt.

Thanks to Dawn project system engineer Marc Rayman for this description of the asteroid belt, excerpted from this month's Dawn Journal: The asteroid belt consists of innumerable objects in orbit around the Sun between Mars and Jupiter. Dawn is aiming for Vesta and Ceres, the two most massive members of the belt.

There is no sharp edge to demarcate the boundary of the asteroid belt. Although most asteroids remain between the two planets, the orbits of some bring them closer to the Sun than Mars. One common definition says to be designated as a resident of the main asteroid belt, an object's orbit can bring it no closer to the Sun than 1.666 astronomical units (AU). It is not coincidental that this is the greatest distance that Mars travels from the Sun. Earth never reaches more than 1.017 AU from the Sun.

As with Earth, Mars, and asteroids, Dawn's orbit around the Sun is elliptical. The principal difference is that Dawn is constantly changing its course by emitting a high velocity beam of xenon ions. So far it has racked up more than 10,000 hours of powered flight, with much more thrusting ahead. The spacecraft's orbit grows larger as the mission progresses, bringing the explorer ever closer to its first destination.

Dawn is currently 1.25 AU (116 million miles) from Earth, or 485 times as far as the moon. Radio signals, traveling at the universal limit of the speed of light, take 21 minutes to make the round trip.

Education and Public Outreach Highlights

A new interactive on the mission web site explores how the Gamma Ray and Neutron Detector (GRaND) instrument works. A similar one for the Visible & Infrared Spectrometer (VIR) instrument will be available soon.

Whitney Cobb, McREL, demonstrates a computer game at STEMapalooza.

Dawn, Stardust–NExT, and EPOXI all participated in the 2nd annual STEMapalooza event in Denver on October 16–17 that drew nearly 10,000 students, parents, teachers, and business leaders. Exhibits featured robotics, gaming, film production, staging, rocketry, and solar energy to engage students and inspire them to develop the knowledge and skills necessary for careers that require math and science.

Mission E/PO staff from McREL in Denver had a fun and exciting booth where participants took part in a variety of hands-on, interactive activities. The most popular interactive was Stardust–NExT's educational "Design a Satellite" interactive, designed by the people of Littleton, Colorado. The Comet Chronicle was a big hit, featuring the differences between comets and cows. Visitors enjoyed the CSI investigations on the collision of the Deep Impact projectile with comet Tempel 1. The Discovery Program Space Thrills poster was an extremely popular hand out.

EPOXI Prepares for Hartley 2 Flyby

The EPOXI spacecraft performed a distant Earth flyby on June 29 and will do another in December. It continues on course for its flyby of comet Hartley 2 in November 2010.

In July, the EPOXI flight team completed the special Infrared (IR) Spectrometer calibration sequences. The sequences were successful in getting the data needed to fully understand the performance of this instrument. Having a complete characterization including flat field, dark levels, linearity, scattered light, and bad pixels, obtained within a short period of time is unprecedented.

Education and Public Outreach Highlights

E/PO partner McREL distributed EPOXI fact sheets at the Denver Museum of Nature and Science during Educator Night on September 15.

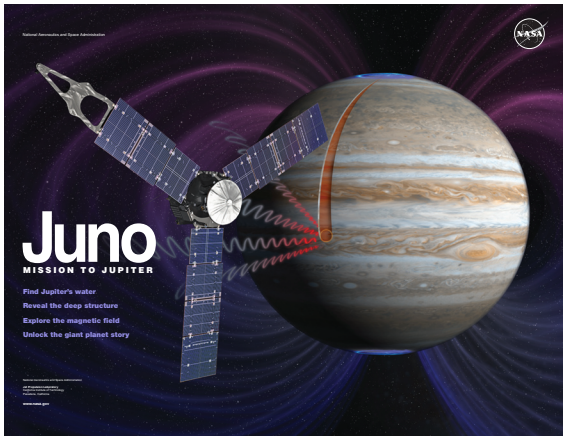
Tim Livengood, an EPOCh co-Investigator and the deputy E/PO lead, welcomed two high school interns from The Madeira School in McLean, Virginia, to work with EPOXI and with data resulting from the amateur-astronomy campaign.

EPOXI presented an E/PO poster at the 2009 Division for Planetary Scientists meeting in October.

Web site updates include a new Kids section with stories and puzzles, more team member biographies, and updated fact sheets.

Juno Continues Development Work

In July, the Juno project conducted Critical Design Review briefings for NASA's Science Mission Directorate Program Management Council (PMC) and the Agency PMC. Both briefings were well received by the PMC members. A System Implementation Review is scheduled for March 2010. This marks the beginning of the assembly, test, and launch operations, or ATLO, phase of the mission. Launch is planned for August 5, 2011, with Jupiter orbit insertion in August 2016.



Building and testing of the spacecraft subsystems continue. In September the Juno team conducted a Test-As-You-Fly Workshop. The Juno Mission Operations team completed the Mission Operations Subsystem Critical Design Review.

In October, the Juno and the United Launch Alliance (ULA) teams conducted a Mission Integration Working Group meeting at the ULA-Denver facility. Development of the Launch Vehicle Interface Control Document was initiated.

In July, the Juno project conducted Critical Design Review briefings for NASA's Science Mission Directorate Program Management Council (PMC) and the Agency PMC. Both briefings were well received by the PMC members.

In November, the project successfully completed the Jupiter Energetic-particle Detector Instrument (JEDI) Test Readiness Review. The Juno mechanical structure successfully completed static test at the Lockheed Martin facility in Denver. After some minor mechanical

clean-up, the structure will be delivered to propulsion to start propulsion module integration.

Education and Public Outreach Highlights

The E/PO team has produced new posters, bookmarks, fact sheets, and banners for outreach purposes. Juno was featured in NASA's monthly "What's Up in the Night Sky" podcast as part of the International Year of Astronomy (IYA) focus on Jupiter in September. Juno will be participating in "Galilean Nights," a new IYA project focused on sidewalk astronomy with amateur and professional astronomers around the globe taking to the streets, pointing their telescopes to the wonders that Galileo observed 400 years ago.

GRAIL Completes Critical Design Reviews

The Gravity Recovery And Interior Laboratory, or GRAIL, will fly twin spacecraft in tandem around the moon to precisely measure and map variations in the lunar gravitational field. This detailed information will reveal differences in density of the moon's crust and mantle and will help answer fundamental questions about the moon's internal structure, thermal evolution, and history of collisions with asteroids. GRAIL is planning to launch in 2011.

In August, the GRAIL payload Critical Design Review (CDR) was completed. The Peer Board determined that the detailed design is compliant with the applicable requirements and unanimously approved the readiness of the instrument to proceed with implementation.

The project conducted 10 sub-system CDRs and 8 other critical reviews between September 15 and October 22. The system-level Critical Design Review was held November 9–13 at MIT in Cambridge, MA.

The GRAIL E/PO Peer Review Board plus project and program office representatives. Maria Zuber, GRAIL principal investigator, is at the front; to her left is Kathy Sullivan, review board chair; to her left is Sally Ride, who leads the E/PO effort.

Education and Public Outreach Highlights

The GRAIL E/PO Peer Review was held Oct. 21 at the University of California-San Diego to review the project's Education and Public Outreach Plan. GRAIL MoonKAM is the mission's signature education program facilitated by Sally Ride Science with undergraduate students from UCSD in partnership with the ISS EarthKAM.

GRAIL MoonKAM will engage hundreds of middle schools across the country in the GRAIL mission and lunar exploration. Tens of thousands of 5th to 8th grade students will plan and target images of the lunar surface and send their requests to the GRAIL MoonKAM Mission Operations Center. Once these images are downlinked they will be made available for public viewing in the Image Section of the MoonKAM web site. The middle school students will use their lunar images to study craters, highlands, and maria, while learning about other lunar features and future landing sites.

Strofio Project Begins Work

In May, NASA announced the selection of Strofio as a new Discovery Mission of Opportunity. Strofio will employ a unique mass spectrometer to reveal the composition of Mercury's thin atmosphere, or exosphere. The investigation will study the exosphere, which is formed from material ejected from its surface, to determine the composition of Mercury's surface. Strofio will fly aboard the European Space Agency's (ESA) BepiColombo mission, scheduled for launch in 2013.

Getting the necessary contracts in place to begin work took place over the summer. The Strofio Phase B Prime Contract was awarded to Southwest Research Institute (SwRI) on September 14, and SwRI awarded subcontracts to Smithsonian Astrophysics Observatory and Johns Hopkins Applied Physics Lab (APL) on Sept. 15.

Strofio developed a master integrated schedule that is being finalized. The science team will meet in late November at APL. The project is preparing for the Strofio Instrument Requirements Review in early December.

Strofio is part of the SERENA (Search for Exospheric Refilling and Emitted Natural Abundances) suite of instruments. The project continues to work mechanical and electrical interfaces with SERENA and with ESA.

Discovery and New Frontiers News

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