Jet Propulsion Laboratory

Universe

SEPTEMBER 2011
VOLUME 41
NUMBER 9

Moon mission on the way

By Mark Whalen

GRAIL orbiter will precisely measure gravity field; liftoff due Sept. 8

Photo: Dutch Slager / JPL Photo Lab

Above: GRAIL Principal Investigator Maria Zuber (left) and Project Manager David Lehman

The mysteries hidden below the surface of the moon are soon to be revealed as JPL's Gravity Recovery and Interior Laboratory, or GRAIL, mission prepares for its launch Thursday, Sept. 8 from Kennedy Space Center. GRAIL will create the most accurate gravitational map of the moon to date.

GRAIL comprises twin satellites that will launch together on a Delta II rocket, separate shortly thereafter then begin to fly independent paths to the moon before converging next New Year's Day to begin an 82-day science phase from 55 kilometers (34 miles) above the lunar surface.

JPL built the payload and also provides project management and mission assurance services, and is mission operations lead. Lockheed Martin built the spacecraft and will support mission operations.

Project Manager David Lehman said the mission's major challenge involves very precise formation flying. "Our mission operations team has been working for about four years developing the concept to accomplish that," he said.

Lehman, a retired U.S. Navy Reserve officer, compared GRAIL's precision to the formation flights by the Blue Angels, a popular U.S. Navy flight demonstration squadron that performs at military and civilian airshows.

Lehman noted that JPL developed GRAIL's lunar gravity ranging system instrument, which will send and receive the signals needed to accurately and precisely measure the changes in range between the two orbiters. The device is similar to the one employed on JPL's Gravity Recovery and Climate Experiment, or GRACE, whose twin orbiters have precisely measured Earth's gravitational field since 2002.

"From GRACE, we have both hardware and people heritage," said Lehman, noting that a few JPLers worked on both projects. Charlie Dunn, deputy manager of the Tracking Systems and Applications Section 335, led the lunar gravity ranging system effort for GRAIL through the delivery to the assembled spacecraft.

The two orbiters will travel to the moon via the sun-Earth Lagrange point 1, a spot where the gravity between the two bodies balances the centrifugal force experienced at those points while orbiting with the bodies. This low-energy transfer was chosen to reduce the size of the rocket required to place GRAIL on its correct trajectory, allow more time for spacecraft check-out and increase the number of days available in the launch period.

Lehman said the plan calls for the arrival of the GRAIL-A orbiter at the moon on Dec. 31, followed by GRAIL-B's arrival Jan. 1, 2012.

Besides providing an invaluable navigational aid for future lunar spacecraft—both human and robotic—accurate knowledge of the moon's gravity will also help in understanding broader evolutionary histories of the other rocky planets in the inner solar system: Mercury, Venus, Earth and Mars. GRAIL looks to improve our knowledge of the satellite's near-side gravity by 100 times and of far-side gravity by 1,000 times.

"I predict we are going to find something ... that is really, really going to surprise us and turn our understanding of how the Earth and other terrestrial planets formed on its ear," said Maria Zuber of the Massachusetts Institute of Technology, GRAIL's principal investigator.

Students will have an opportunity to participate in the mission through Moon Knowledge Acquired by Middle school students, or MoonKam, a program led by Sally Ride Science of San Diego that will allow classrooms to request pictures of the lunar surface from cameras on the twin satellites. Leesa Hubbard, a teacher in residence with Sally Ride Science, noted that the presence of MoonKam makes GRAIL the first planetary mission to have an instrument strictly dedicated to education and public outreach. She said that about 500 teachers have already registered their classes for participation. See *http://moonkam.ucsd.edu* for more information.

A prelaunch webcast for the mission will be streamed at noon on Wednesday, Sept. 7. To view the webcast or to learn more about the mission, visit *http://www.nasa.gov/GRAIL* and *http://GRAIL.nasa.gov*. The launch will also be streamed live, with a chat available, on *http://www.ustream.tv/nasajpl2*.

Ultra-accurate atomic clock proposal advances

JPLer will lead technology demo for precise navigation

By Mark Whalen

Todd Ely is principal investigator for the Deep Space Atomic Clock demo mission.

A JPL-led proposal is one of three recently selected by NASA as technology-demonstration missions to transform space communications, deep-space navigation and in-space propulsion capabilities.

A mission to fly and validate the Deep Space Atomic Clock, a miniaturized mercury-ion clock that is 100 times more stable than today's systems, will be led by Todd Ely of the Navigation and Mission Design System Engineering Group (343K).

The project will demonstrate ultra-precision timing in space and its benefits for one-way radio navigation. "JPL's John Prestage invented the mercury ion-trap technology more than 20 years ago and has steadily improved and miniaturized it to the point where we're ready to use it as the basis for a small deep-space atomic clock," said Ely. "John and Bob Tjoelker are my co-investigators and we will lead a team of engineers taking the clock in the lab and build a flight version that will operate in space. Clocks are fundamental components to the radiometric tracking systems that we use to navigate almost all of our spacecraft."

Ely said the clock will have a mass of under 3 kilograms and small size that make it ideal for an onboard application. "That is the game changer," he said. "Since the spacecraft can now emit a signal that is as stable as the ground reference there really isn't a need to turn the signal around to collect high-quality tracking data for navigation. This opens up whole new ways of operating—multiple spacecraft can be tracked and navigated with a single antenna without having to divide time on the link, making navigation operations at Mars more efficient. It also yields more tracking data especially for deep-space users because tracking time is not reduced by round-trip light times."

The team's intended application is for deep-space missions. But the device has great benefits near Earth as well. Indeed, since the technology improves on GPS clock stabilities by 100 times, the ion-clock technology would be ideal for use on future GPS satellites. "These types of stabilities would greatly improve the performance of the constellation for everyone who uses it, and play an important role in extending GPS's autonomous operation, period," said Ely.

"It is our plan to launch as a hosted payload on an Iridium Next spacecraft in 2015," he said. "While on orbit we will be able to collect radiometric tracking data from the forward-looking antenna to the GPS satellites that are in view. We'll be able to do this, essentially, continuously. This provides a rich data set for us to confirm the stability of the clock, and demonstrate its utility for precision navigation."

Teachers' internships pay off

By Susan Braunheim

From left are JPL summer intern teachers Shin Adachi (Synergy Quantum Academy), Andrew Giang (Los Altos High School), Skyler Lassman (Orcutt Academy High School), Jessica Potter (Arroyo Valley High School) and Adorina Moshava (Taft High School).

Out of the many student programs and internships offered at JPL, only one focuses entirely on future math and science teachers, the individuals directly responsible for responsible for introducing critical thinking skills and essential content matter to the next generations of students.

The Science Teacher and Researcher (STAR) Program does just that. It provides aspiring science and math teachers with paid summer internships in national, independent and university laboratories allowing participants to pursue a prestigious dual "teacher-researcher" career path.

Out of the 12 undergraduate and graduate school interns participating in the program at JPL this summer, five have been offered teaching positions for the fall. The seven other interns are continuing their education.

"Providing research opportunities for STAR participants is one of many ways JPL adds to science, technology, engineering and mathematics, or STEM, education in California and nationwide," said Petra Kneissl-Milanian, a JPL education program specialist who coordinates the program on Lab. "Our scientists and engineers enable these aspiring science and math teachers to experience real, hands-on science, and absorb the culture of JPL specifically, and the scientific environment in general. These young teachers will carry this excitement into their future classrooms, teaching and inspiring learners.

The STAR program is offered by the California State University in partnership with government agencies that include the U.S. Department of Energy, the National Science Foundation and NASA, as well as private research organizations. Over the past five summers, the program has offered 222 placements at 15 research sites in California, Colorado, Maryland, Tennessee and Washington. JPL has hosted 28 interns during its three years of participation.

The full text of this article is posted on Lab at *http://jplspace*.

NASA center directors visit Lab

The directors of several NASA centers visited JPL Aug. 15 to discuss with managers the agency's next steps in the post-shuttle era. On hand, from left, were JPL Director Dr. Charles Elachi; Ray Lugo, director of the Glenn Research Center; Lesa Roe (Langley Research Center); Robert Lightfoot (Marshall Space Flight Center); Pete Worden (Ames Research Center) and David McBride (Dryden Flight Research Center). Elachi told JPLers, "We have an opportunity to shape the future." The center directors' meeting is available at *http://goto/center-directors*.

Visionary breakthroughs on the way

JPLers named to lead studies in NASA's Innovative Advanced Concepts Program

By Mark Whalen

Four JPL-led proposals were among 30 selected in August for funding under NASA's Innovative Advanced Concepts Program. These concepts—the first for the program—were chosen based on their potential value to the agency's future space missions and operational needs and are 10 years or more from mission infusion. Each proposal will receive about $100,000 for one year to advance its innovative space technology concept. Below is an overview of concepts led by JPL principal investigators.

Principal investigator **Marco Pavone** (Advanced Robotic Controls Group) and his team (Julie Castillo-Rogez, JPL scientist; Issa Nesnas, JPL roboticist; and Jeffrey Hoffman, MIT professor and former astronaut) propose to develop a mission architecture for the systematic and affordable in-situ exploration of small solar-system bodies such as asteroids, comets and Martian moons.

The idea is to have a mother spacecraft deploy on the surface of a small body one or more robotic mobility platforms that would behave as spacecraft/rover hybrids, capable of accessing most destinations on virtually any small body. Each platform would be sealed in an enclosure and would have minimal internal actuation, critically enabled by the microgravity environment. Once deployed, the hybrids would perform attitude-controlled hops for long-range travel (about 10 meters per hop) and would tumble to reach specific locations.

Through hybrid mobility, the deployed platforms would quickly travel to targeted locations. In turn, the mother spacecraft would act as a communication relay to Earth and would perform remote measurements complementing those taken in-situ by the hybrids. Pavone says the hybrids would allow multi-asset missions where not only specific targets could be closely observed, sampled and cached, but also high-risk, high-payoff measurements could be taken, since the loss of one hybrid would not spell the end of the mission. Missions envisioned for this architecture range from the exploration of active comets, to the detailed analysis of wet asteroids, to the emulation of astronauts with manned maneuvering units.

Flexible printed electronics have revolutionized consumer products such as cell phones and PDAs, allowing greater functionality with decreasing size and weight. But who could imagine a similar process creating a self-contained, end-to-end, flexible spacecraft?

Kendra Short and Dave van Buren did. Short and van Buren, both from the Mechanical Systems Division 350, are co-investigators for this architectural concept of designing and fabricating a spacecraft based entirely on flexible substrate printed electronics. Short and her team see opportunities to leverage the current consumer electronics industry investment by augmenting its capabilities with advanced materials and engineering research performed by universities, industry and NASA centers. The team will explore the viability of printed technologies for creating small two-dimensional spacecraft, including mission concepts, architectures, materials, subsystems, integration and manufacturing. They will inventory relevant sensors and subsystem elements—identifying gaps between what is currently available in industry products and what is required for space applications—and develop a strategy for technology investments needed to fill those gaps.

With this revolutionary capability, Short says, NASA would be able to dramatically improve performance, flexibility, weight, cost, schedule, reliability and operational simplicity for many scientific missions and support for human exploration.

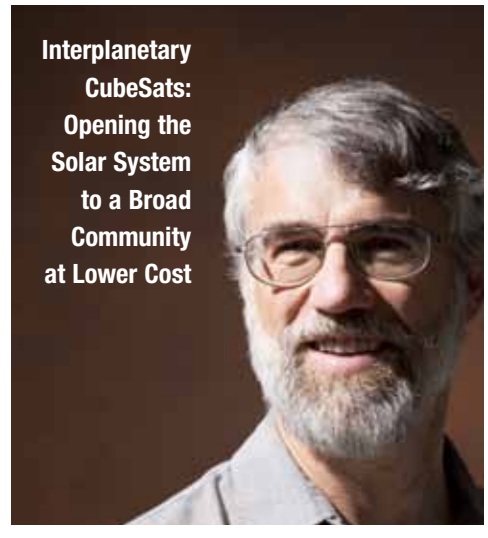
Principal investigator **Dmitry Strekalov** and his team, including JPL co-investigators Baris Erkmen and Nan Yu, propose a revolutionary concept in applying optical "ghost imaging" techniques in astronomy and astrophysics.

Potential benefits include enhanced resolution and better imaging of space objects such as Earth-like planets (including those near bright stars), black holes and dust or gas clouds.

Ghost imaging is a process in which cameras measure light beams to create images of objects otherwise difficult to image directly. Other researchers have used artificially generated light and correlations between pairs of photons to build up a ghost image of the target object.

Rather than use this traditional approach, Strekalov's team will try to answer whether the concept can also be used for natural sources of illumination such as the sun and stars, which give off their own light.

The team's technique employs feature detection—looking for signatures that reveal certain features of objects. It can be used to suppress unwanted light, particularly useful for exoplanet imaging. While not focused on one mission or type of observation, the concept provides a technology that will complement traditional large telescopes while offering special properties that conventional imaging systems do not provide. It can be used for ground- or space-based telescopes, or a combination of both.



Dutch Slager / JPL Photo Lab

In much the same way that CubeSats weighing a few pounds have dramatically increased low-cost access to experimentation in low-Earth orbit, a team led by **Robert Staehle** will develop six technologies in unison to enable dramatically lower-cost solar system exploration.

CubeSats measure about 4 inches, with a volume of about 1 quart, and weigh no more than 2.2 pounds. The team's study will show how combining upgraded CubeSat elements can host small, capable instruments and optical telecommunications on an example mission to map the composition of a sequence of near-Earth asteroids. The six technologies combine to enable a new architecture, yielding many mission possibilities:

- CubeSat electronics and subsystems extended to operate in the interplanetary environment
- Optical telecommunications to enable very small, low-power uplink/downlink over interplanetary distances
- Solar sail propulsion to enable rendezvous with multiple targets using no propellant
- Navigation of the "interplanetary superhighway" to enable multiple destinations over reasonable mission durations and distances
- Small, highly capable instrumentation enabling acquisition of high-quality scientific and exploration information
- Onboard storage and processing of raw instrument data and navigation information

The work includes a miniature imaging spectrometer based on instruments currently being built at JPL, as well as an optical telecommunications flight terminal based on JPL laser telecommunications development.

News Briefs

Rosaly Lopes

Lopes named vice chair

JPL senior research scientist Rosaly Lopes has been named vice chair of the Division for Planetary Sciences of the American Astronomical Society, the world's largest organization of professional planetary scientists. She begins her term in October, and will become chair of the organization one year later.

Lopes is deputy manager of the Planetary Science Section (322) and supervisor of the Geophysics and Planetary Geosciences Group. She is also the investigation scientist for the radar team on Cassini.

A volcanologist and planetary geologist, Lopes joined JPL in 1989 and two years later became a member of the Galileo project, working on the near infrared mapping spectrometer. In the years to follow, she investigated volcanoes on Jupiter's moon Io, finding many that were previously unknown.

In 2005, Lopes was awarded the Carl Sagan Medal by the AAS Division for Planetary Sciences in recognition of her significant efforts in public outreach and education, particularly among Hispanic groups and young women. In 2006 she was honored in the Guinness Book of World Records for having discovered the greatest number of active volcanoes anywhere.

JPLers complete systems engineering leadership

Jason Gates of the Electronics Design Group (3455) and Jane Oh of the Software Assurance and Assurance Research Group (525) recently completed NASA's Systems Engineering Leadership Development Program, a yearlong effort that included 20 systems engineers from across NASA.

Through mentoring, coaching and technical training, participants learned the qualities of a systems engineering leader: creativity, curiosity, self-confidence, persistence and an understanding of human dynamics. Participants also took on systems-engineering roles at a new NASA center that challenged them to incorporate new knowledge and skills in an unfamiliar setting.

Gates' assignment at Kennedy Space Center with the NASA Safety and Mission Assurance Division's Launch Services Program allowed him to work several launch-vehicle risk items for Taurus and Atlas rockets. "This experience gave me a better understanding of assessing and accepting flight risks for the spacecraft we develop," said Gates, who has worked on development of the flight avionics for the Mars Exploration Rovers, Dawn and Mars Science Laboratory spacecraft.

At Marshall Space Flight Center, Oh participated in reviews of NASA flight projects in their implementation phase, including JPL's Gravity Recovery and Interior Laboratory mission, due for launch Sept. 8. She also spent time at NASA Headquarters, where she interacted with associate administrators and program executives. "I learned great lessons about making critical decisions, about working with multiple organizations and cross-agency projects, and about bi-directional communication with hundreds or thousands of people engaged in a highly technical activity," she said.

Birur earns kudos

Gajanana Birur, a principal engineer in the Thermal and Cryogenic Engineering Group, has been honored with the Society of Automotive Engineers International Forest R. McFarland Award.

The award recognizes individuals for their outstanding contributions to the planning, development and dissemination of technical information. Birur is one of 26 mobility-engineering professionals to receive the recent honor.

High honors for Neilan

JPL's Ruth Neilan, center, is flanked by (from left) Fernando Sanso, Italy; Gerhard Beutler, Switzerland; Chris Rizos, Australia; and Michael Sideris, Canada. Rizos is the current president of the International Association of Geodesy; the other men are former presidents of the organization.

Ruth Neilan of the Communications, Tracking and Radar Section has received a major award in recognition of her international efforts related to the geodetic and geophysical applications of the Global Positioning System and her distinguished service to the International Association of Geodesy.

Neilan, with JPL since 1984, was awarded the association's Levallois Medal, which honors Jean-Jacques Levallois, former secretary general of the organization. Neilan becomes the first American in more than 30 years—and the first female—to win the award.

In the early 1990s Neilan was a key player in the establishment of the International GPS Service (now called the International Global Navigation Satellite System Service). She has served in numerous leadership positions in the International Association of Geodesy, including currently as a member of the group's executive committee. She is also director of the International Global Navigation Satellite System's Central Bureau and vice president of the Global Geodetic Observing System, which provides geodetic infrastructure necessary for monitoring the Earth system and for global change research.

She has also contributed to, among others, the International Council of Science's World Data System Scientific Committee, United Nations Office of Outer Space Affairs, the World Climate Research Program and the U.S. Federal Advisory Board on Positioning, Navigation and Timing.

The International Association of Geodesy comprises about 200 organizations—mostly public, government and university research groups—with more than 400 permanent ground stations and data and analysis centers in more than 80 countries.

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Production
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JPL Photo Lab

Universe is published by the Office of Communications and Education of the Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

Passings

John Kolden, 83, a retired engineer and manager, died April 18.

Kolden worked at the Lab from 1963 to 1995. He served as integration and injection module manager for the International Solar Polar Mission and as integration and support manager for the Ulysses mission's 1990 launch from Space Shuttle Discovery. He also managed the Microwave Observing Project, part of the Search for Extraterrestrial Intelligence mission.

Kolden was awarded NASA's Exceptional Service Medal in 1977 and 1992.

Raymond Prizgintas, 74, a retired engineer and programmer, died May 23.

Prizgintas joined JPL in 1962 and retired in 2004. A graduate of UCLA, he programmed navigation equations developed for the Strapdown Electrostatic Aerospace Navigator, a late-1960s U.S. Air Force project funded by NASA's Office of Advanced Research and Technology. In 1989 he was named to lead the Test and Evaluation Subgroup in the Information Systems Engineering Section. He also later served as a software analyst for JPL's military contracts.

A member of JPL's search and rescue team, Prizgintas also volunteered for a Montrose rescue organization and for the Los Angeles County Sherriff's Department.

Prizgintas is survived by his mother, and sister Rita Gilmore.

Haskell (Hack) O'Brien, 75, a retired computer scientist and manager, died June 9.

O'Brien joined the Lab in 1961 and was a section manager for most of his 37 years with JPL, leading the Administrative Computing Section; General Purpose Computing Services Section; Communications, Computing and Network Services Section; Institutional Information Systems Section; and the Institutional Operations Process Office. He also served on the JPL Advisory Council on Minority Affairs. In 1997, O'Brien received NASA's Exceptional Service Medal.

He is survived by his wife, Emily; children Steven Solesbee, Stacey O'Brien and Gloria Fontenot; grandchildren Brittney Solesbee, Ashley Solesbee, Michael Marshall and Meagan Marshall; two brothers and his father.

Private services were held in Las Vegas.

Letters

I would like to thank my friends and colleagues in Division 173 and JPL for the beautiful plant. It was comforting during a very difficult time when my mother entered eternal sleep.

Paul and BJ Ottenfeld

My family and I would like to thank all of our friends and colleagues in Division 22 and Division 27 for their thoughtful condolences after the recent passing of my mother. Your flowers, plants and cards are beautiful and comforting. Your support is greatly appreciated.

Iris Young and family

On behalf of the Lopez family, I would like to thank JPL, Professional Development and those who sent e-mails, texts and letters of condolences for the passing of my father, Manuel. The tremendous support my family and I received from the Lab was very much appreciated and reminds me of how close of a community we have here at JPL. Thank you very much for the plant arrangement as that will live on as a remembrance of my father. With sincere appreciation,

Mark Lopez

I would like express my sincere gratitude to all my colleagues and friends in Section 2512 for their condolences at the recent loss of my father. It was so thoughtful of you to think of me during my time of sadness. Your sympathy card, plant and kind words are of great comfort to me as I grieve my father's death. Warm regards,

Cliff Fredericks

Retirees

The following JPL employees retired in August:

Donald Kurtz, 45 years, Section 8110; **Thomas Bicknell**, 42 years, Section 388B; **Yvonne Samuel**, 35 years, Section1800; **Doug Sanders**, 32 years, Section 1020; **Mark Schaefer**, 32 years, Section 337C; **Jan Gohlke**, 29 years, Section 318G; **Joseph Okonek**, 26 years, Section 334B; **Betty Preece**, 24 years, Section 252C; **Laura White**, 23 years, Section 2690; **Barbara Wilson**, 23 years, Section 1900; **Harold Minuskin**, 22 years, Section 173D; **Craig Peterson**, 21 years, Section 312A; **Sheldon Winnick**, 20 years, Section 2142; **Ramin Roosta**, 10 years, Section 5140.