Liftoff

New Zealand's space exploration magazine

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Liftoff

Editor: **David Maclennan**

E-mail: **djmac@paradise.net.nz**

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New Zealand Spaceflight Association, Incorporated
P O Box 2945
Wellington 6140
New Zealand

Website: **http://www.nzspace.org.nz**

E-mail: **info@nzspace.org.nz**

NZSA News and Notices

Notice of Annual General Meeting

Notice is hereby given that the Annual General Meeting of the NZSA will be held on **Monday 6 December 2010** at 7:45 pm at MOTAT, Great North Road, Western Springs (entry via Stadium Rd).

A Statement of Accounts and President's Report will appear in the January-February 2009 issue of this magazine.

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Auckland meetings

The next Auckland meetings are on **6 December** (AGM, as noted above) and **7 February** at 7:45 pm at MOTAT, Great North Road, Western Springs (entry via Stadium Rd).

The Auckland Branch meets at MOTAT on the first Monday of each month (except January).

Wellington meetings

Good news for Wellington members! It is likely that meetings will resume at the Carter Observatory in the new year (probably February). Watch this space for details.

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Subscriptions 20010-2011 *(now reduced!)*

Subscription rates for 1 September 2010 to 31 August 2011 are as follows:

ORDINARY	$45
SENIOR CITIZEN	$40
STUDENT	$37.50

New subscriptions paid after 1 February 2010 may elect to receive *Liftoff* for only the second half year by paying half the above rates.

Note, too, that for each new member you introduce to the NZSA, providing they join for a full year and nominate you on their membership form, you will receive a credit of $5 against your next subscription. There is no limit to the number of credits you can qualify for.

Cover Photo: NASA

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Editor's Corner

It's the Year of the Solar System – at least according to NASA (and that's a Martian year, it seems, which is two Earth years).

To be sure, the next year or two look like being the most spectacular time ever in the history of solar system exploration. Things kicked off in late October with the flyby of Comet Hartley-2 by the EPOXI (formerly Deep Impact) spacecraft – more on that in the next issue. Other highlights in the next year include the MESSENGER spacecraft entering orbit around Mercury, the launch of the Mars Science Laboratory Curiosity, the launch of a new mission to Jupiter, and the Dawn spacecraft orbiting asteroid Vesta.

And that's just the US missions: also coming up are the orbiting of Venus by Japan's Akatsuki probe and Russia's Phobos-Grunt mission, designed to return samples from Mars' moon Phobos (this last mission will also carry a small Chinese Mars orbiter as a secondary payload).

Add to all this the ongoing work being carried out by missions such as Cassini, the Mars Exploration Rovers, and the US and European Mars orbiters, and you can begin to grasp the scale of things. In fact, over the next year or two, there will be spacecraft at, or en route to, every planet in the solar system (and some minor planets) bar Uranus and Neptune! Has there ever been a more exciting time in planetary exploration? I don't think so.

By contrast, human space exploration will be in the doldrums for some years to come. As I write this only two (or possibly three) Shuttle missions remain to be flown. After that, US human space flight faces an uncertain future, and the Republican gains in the recent US mid-term elections add further uncertainty. Look to Russia and China for most of the human spaceflight action for the foreseeable future (China, for example, plans to orbit a small space station by the end of the decade).

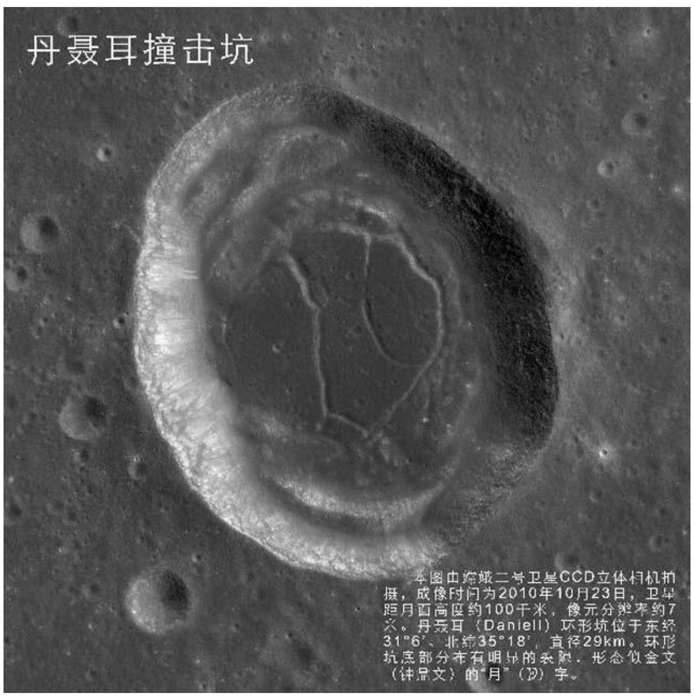
But with or without direct human participation, we are entering a golden age of exploration!

-- *David Maclennan*

China launches second Moon probe

On 1 October China launched its second Moon probe, Chang'e 2. Following a five-day journey (less than half the tim,e taken by its predecessor), the spacecraft entered lunar orbit at an initial altitude of about 100 kilometres. Eventually, Chang'e 2 will approach to within 15 kilometres of the surface.

The spacecraft was originally built as a ground spare for Chang'e 1, which launched in October 2007, in case that mission ran into problems. The US$134 million mission launched at 1059:57 GMT (6:59:57 a.m. EDT) on Friday 1 October from the Xichang space center in southwestern China's Sichuan province. The historic mission was broadcast live on CCTV, China's state-run television network. Crowds of well-wishers packed into Xichang, a facility normally off-limits to the public. Tourism groups sold tickets for up-close viewing of the launch, but visibility was limited by clouds in the area. Launch day was also National Day in China, marking the 61st anniversary of Communist rule.

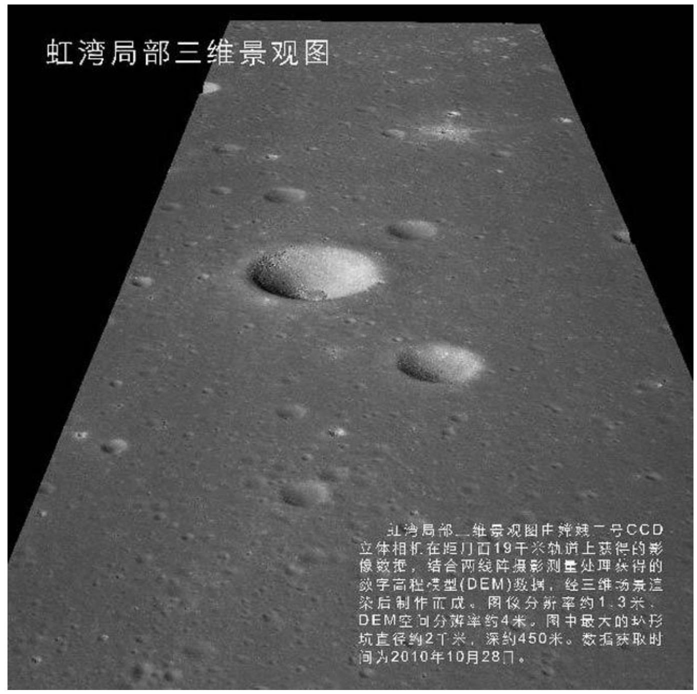


This photo, taken by China's Chang'e 2 lunar probe in October 2010, shows a crater in the moon's Bay of Rainbows. The image is one of the first released to the public by China's space agency. (China Lunar Exploration Program)

The three-stage Long March 3C rocket blasted off from Launch Pad No. 2 at Xichang, turning southeast from the space base and entering space a few minutes after liftoff. The launcher's hydrogen-fueled third stage fired twice to push the 2,494-kilogram craft into a transfer orbit toward the Moon.

The probe is designed to observe the Moon for at least six months, but it carries enough fuel to operate much longer. Its closest approach to the moon will be at an altitude of just 15 kilometres, according to China. Xinhua reports Chang'e 2's peak imaging resolution will be 10 metres. Chang'e 1's cameras could resolve objects 122 metres across. Chang'e 2's lower orbit around the moon will also contribute to the sharper imagery.

Chang'e 2 will map candidate landing sites in the Moon's Sinus Iridium region in preparation for the next mission in China's lunar program, which targets a robotic touchdown on the Moon after launch in 2013. Another project in China's long-term plans is a vehicle to return soil and rock from the moon back to Earth.



This 3-D map view of the moon's Bay of Rainbows was taken by China's Chang'e 2 lunar probe in October 2010. The mission is China's second robotic mission to explore the moon. (China Lunar Exploration Program)

After its baseline mission at the moon is finished, Xinhua reports Chang'e 2 could enter an extended phase. Officials are considering three scenarios for Chang'e 2's extended phase, including sending the spacecraft away from the Moon and into deep space, giving Chinese engineers practice in operations further from Earth. The satellite's propellant could also return Chang'e 2 to Earth orbit, according to Huang Jiangchuan, a chief designer quoted in Xinhua. Chang'e 2 could also continue circling the Moon, relaying more science data before attempting a landing or impact on the surface, officials said.

Corona watching camera on SOHO – 500,000 solar snapshots and counting

On 11 July, amateur astronomers from around the world trekked to remote islands in the South Pacific to witness a total solar eclipse. They watched in awe as the Moon completely covered the Sun and revealed wispy, incandescent streamers in our star's million-degree atmosphere, the corona.

These fleeting glimpses of the corona last just a few minutes and happen only every 19 months on average. But thanks to the Solar and Heliospheric Observatory, launched in December 1995, researchers can view the Sun's atmosphere any time they want, day or night, from the comfort of their computers. Developed jointly by NASA and the European Space Agency, SOHO and its 12 experiments monitor the Sun's brilliant disk and its corona in ways impossible from ground-based telescopes. Moreover, this sentinel's longevity has yielded observations over an entire 11-year cycle of solar activity, providing unprecedented insights about how our star works.

Remarkably, the concept of using a spacecraft to monitor the entire Sun continuously was not an easy sell, notes Joseph Gurman, Project Scientist for SOHO at NASA's Goddard Space Flight Center in Greenbelt, Md. "Earlier spacecraft were designed to follow flares and active regions on the Sun," he explains, because evidence from ground-based telescopes suggested that the solar corona changed little from day to day. But the corona proved to be anything but boring. Instead, it's actually a seething cauldron of superheated gases and intense magnetic fields that's constantly on the move. "We now realize," Gurman says, "that the corona changes on every time scale at which we've ever observed it."

One of SOHO's corona-watching cameras — the Extreme Ultraviolet Imaging Telescope (EIT) — has been critical to this epiphany. Built by specialists in France, Belgium, Germany, and the United States, EIT takes snapshots of the Sun at four ultraviolet wavelengths. Initially these views were beamed to Earth only twice per day. But over time mission managers increased this cadence dramatically, and eventually image sets were being taken every 12 minutes. Each of EIT's four spectral windows is attuned to invisible but very energetic photons of light emitted by ionized atoms in the corona. For example, ultraviolet light at a wavelength of 195 Ångstroms comes from iron heated to an amazing 2,700,000° F (1,500,000 K) — hot enough to strip eleven electrons from each atom.

How the lower corona gets so incredibly hot has puzzled solar physicists for decades. It's hundreds of times hotter than the Sun's light-producing "surface" layer, the photosphere, which has an average temperature of about 10,000 degrees F (5,800 K). Prior to SOHO's launch, physicists believed that countless tiny eruptions in the photosphere were driving up the corona's temperature. But EIT observations suggest that these "nanoflares" can't supply enough energy to make the corona so hot. Some other process must be involved.

Another revelation has come from watching the Sun spew enormous blobs of matter into space. These titanic eruptions, called coronal mass ejections or CMEs, propel a million tons of magnetized, superheated ions and electrons from the lower corona (where they're seen by EIT), up through its outer regions (where they're seen by another SOHO camera, the Large Angle and Spectrometric Coronagraph Experiment), and out into the solar wind. CMEs can arise several times each day during the Sun's peak in activity, and whenever one of these fast-moving super bubbles sweeps past Earth, our planet's protective magnetosphere recoils from the shock. The sudden assault of charged particles causes auroral displays to intensify and can sometimes damage orbiting satellites.

Apart from its scientific value, Gurman credits EIT with transforming the public's perceptions of the Sun and space weather. Ever since their debut in 1996, SOHO videos showing the Sun's dynamic face and its rotation have become tremendously popular. "In earlier missions we didn't get images of the Sun's entire disk," he explains. "There's a visceral reaction to seeing the Sun as a place, rather than just a hot ball of light."

All told, EIT has amassed more than 500,000 images during its 14½ years of operation. Except for a four-month hiatus in 1998, when a software glitch caused the spacecraft to veer away from the Sun and nearly doomed the mission, this long observing record has been unbroken. "It's the 24-hour coverage of the Sun's high-temperature corona that really has been revolutionary," observes Jay Pasachoff, a solar expert at Williams College in Massachusetts.

With the launch of NASA's Solar Dynamics Observatory last February, the task of keeping tabs on our dynamic star has passed to a newer and more capable spacecraft. Two SDO instruments, the Atmospheric Imaging Assembly (AIA) and the Extreme Ultraviolet Variability Experiment (EVE), are taking solar snapshots much more often and with far greater detail than was possible with SOHO. For example, AIA records the Sun at 10 different wavelengths every 10 seconds.

The changing of the solar guard began on in earnest on 1 August. That's when SOHO was commanded to start sending EIT images to Earth only twice per day, instead of every 12 minutes. This reduced frequency frees up radio bandwidth so that LASCO can provide enhanced imaging of the outer corona (SDO does not carry a comparable camera). Even in its diminished role, however, EIT remains crucial to SOHO's success: Since it's bolted directly to the spacecraft, it serves as the guide scope for all the other instruments.

A generation ago, solar specialists doubted the value of including EIT in SOHO's payload. The experiment's principal investigator, Jean-Pierre Delaboudinière, struggled to find the resources to construct the instrument. Today, however, its legacy is secure. "Had it not been for the success of EIT," Gurman observes, "I doubt there'd be any extreme-ultraviolet imagers on the Solar Dynamics observatory — or even an SDO mission.” *– J. Kelly Beatty, NASA Goddard Space Flight Center*

WMAP project completes mission to observe universe's oldest light

After nine years of scanning the sky, the Wilkinson Microwave Anisotropy Probe (WMAP) space mission has concluded its observations of the cosmic microwave background, the oldest light in the universe. The spacecraft has not only given scientists their best look at this remnant glow, but also established the scientific model that describes the history and structure of the universe. "WMAP has opened a window into the earliest universe that we could scarcely imagine a generation ago," said Gary Hinshaw, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md., who manages the mission. "The team is still busy analyzing the complete nine-year set of data, which the scientific community eagerly awaits."

WMAP was designed to provide a more detailed look at subtle temperature differences in the cosmic microwave background that were first detected in 1992 by NASA's Cosmic Background Explorer (COBE). The WMAP team has answered many longstanding questions about the universe's age and composition. WMAP acquired its final science data on 20 August. 20. On 8 September, the satellite fired its thrusters, left its working orbit, and entered into a permanent parking orbit around the Sun.

"We launched this mission in 2001, accomplished far more than our initial science objectives, and now the time has come for a responsible conclusion to the satellite's operations," said Charles Bennett, WMAP's principal investigator at Johns Hopkins University in Baltimore.

WMAP detects a signal that is the remnant afterglow of the hot young universe, a pattern frozen in place when the cosmos was only 380,000 years old. As the universe expanded over the next 13 billion years, this light lost energy and stretched into increasingly longer wavelengths. Today, it is detectable as microwaves.

The WMAP spacecraft (NASA)

WMAP is in the Guinness Book of World Records for "most accurate measure of the age of the universe." The mission established that the cosmos is 13.75 billion years old, with a degree of error of one percent. WMAP also showed that normal atoms make up only 4.6 percent of today's cosmos, and it verified that most of the universe consists of two entities scientists don't yet understand.

Dark matter, which makes up 23% of the universe, is a material that has yet to be detected in the laboratory. Dark energy is a gravitationally repulsive entity which may be a feature of the vacuum itself. WMAP confirmed its existence and determined that it fills 72% of the cosmos.

Another important WMAP breakthrough involves a hypothesized cosmic "growth spurt" called inflation. For decades, cosmologists have suggested that the universe went through an extremely rapid growth phase within the first trillionth of a second it existed. WMAP's observations support the notion that inflation did occur, and its detailed measurements now rule out several well-studied inflation scenarios while providing new support for others. "It never ceases to amaze me that we can make a measurement that can distinguish between what may or may not have happened in the first trillionth of a second of the universe," says Bennett.

WMAP was the first spacecraft to use the gravitational balance point known as Earth-Sun L2 as its observing station. The location is about 1.5 million kilometres away.

"WMAP gave definitive measurements of the fundamental parameters of the universe," said Jaya Bapayee, WMAP program executive at NASA Headquarters in Washington. "Scientists will use this information for years to come in their quest to better understand the universe."

Launched as MAP on 30 June 2001, the spacecraft was later renamed WMAP to honor David T. Wilkinson, a Princeton University cosmologist and a founding team member who died in September 2002.

Hubble captures first images of aftermath of possible asteroid collision

The Hubble Space Telescope has captured the first snapshots of a suspected asteroid collision. The images show a bizarre X-shaped object at the head of a comet-like trail of material.

In January, astronomers began using Hubble to track the object for five months. They thought they had witnessed a fresh asteroid collision, but were surprised to learn the collision occurred in early 2009. "We expected the debris field to expand dramatically, like shrapnel flying from a hand grenade," said astronomer David Jewitt of the University of California in Los Angeles, who is a leader of the Hubble observations. "But what happened was quite the opposite. We found that the object is expanding very, very slowly."

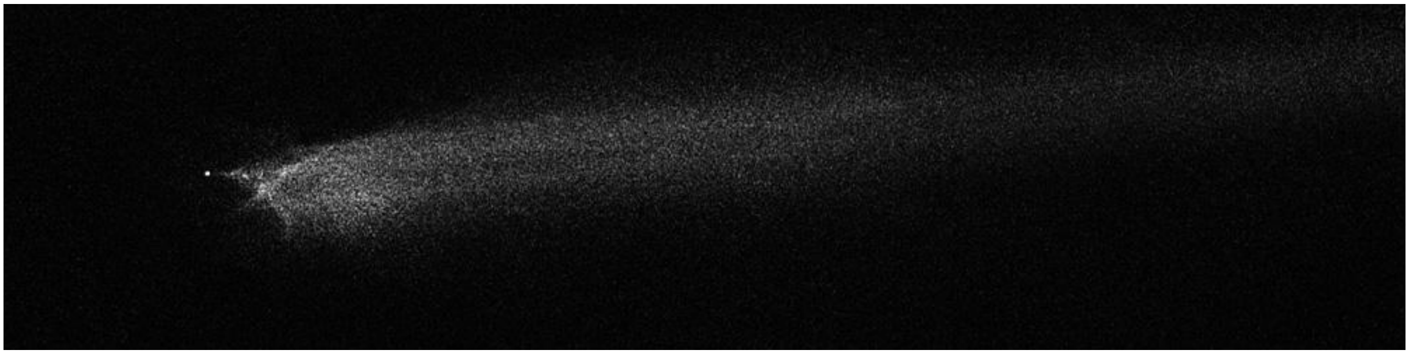
The peculiar object, dubbed P/2010 A2, was found cruising around the asteroid belt, a reservoir of millions of rocky bodies between the orbits of Mars and Jupiter. It is estimated modest-sized asteroids smash into each other about once a year. When the objects collide, they inject dust into interplanetary space. But until now, astronomers have relied on models to make predictions about the frequency of these collisions and the amount of dust produced.

Catching colliding asteroids is difficult because large impacts are rare while small ones, such as the one that produced P/2010 A2, are exceedingly faint. The two asteroids that make up P/2010 A2 were unknown before the collision because they were too faint to be noticed. The collision itself was unobservable because of the asteroids' position in relation to the sun. About 10 or 11 months later, in January 2010, the Lincoln Near-Earth Research (LINEAR) Program Sky Survey spotted the comet-like tail produced by the collision. But only Hubble discerned the X pattern, offering unequivocal evidence that something stranger than a comet outgassing had occurred.

Although the Hubble images give compelling evidence for an asteroid collision, Jewitt says he still does not have enough information to rule out other explanations for the peculiar object. In one such scenario, a small asteroid's rotation increases from solar radiation and loses mass, forming the comet-like tail. "These observations are important because we need to know where the dust in the solar system comes from, and how much of it comes from colliding asteroids as opposed to 'outgassing' comets," Jewitt said. "We also can apply this knowledge to the dusty debris disks around other stars, because these are thought to be produced by collisions between unseen bodies in the disks. Knowing how the dust was produced will yield clues about those invisible bodies."

The Hubble images, taken from January to May 2010 with the telescope's Wide Field Camera 3, reveal a point-like object about 121.9 metres wide, with a long, flowing dust tail behind a never-before-seen X pattern. Particle sizes in the tail are estimated to range up to 2.5 cm in diameter.

The 121.9-metre-wide object in the Hubble image is the remnant of a slightly larger precursor body. Astronomers think a smaller rock, perhaps 3 to 4.5 metres wide, slammed into the larger one. The pair probably collided at high speed, about 17,699 kilometres per hour, which smashed and vapourized the small asteroid and stripped material from the larger one. Jewitt estimates that the violent encounter happened in February or



This Hubble Space Telescope image shows the odd-shaped debris that likely came from a collision between two asteroids (NASA)

March 2009 and was as powerful as the detonation of a small atomic bomb. Sunlight radiation then swept the debris behind the remnant asteroid, forming a comet-like tail. The tail contains enough dust to make a ball 19.8 metres wide, most of it blown out of the bigger body by the impact-caused explosion.

"Once again, Hubble has revealed unexpected phenomena occurring in our celestial 'back yard," said Eric Smith, Hubble Program scientist at NASA Headquarters in Washington. "Though it's often Hubble's deep observations of the universe or beautiful images of glowing nebulae in our galaxy that make headlines, observations like this of objects in our own solar system remind us how much exploration we still have to do locally."

Astronomers do not have a good explanation for the X shape. The crisscrossed filaments at the head of the tail suggest that the colliding asteroids were not perfectly symmetrical. Material ejected from the impact, therefore, did not make a symmetrical pattern, a bit like the ragged splash made by throwing a rock into a lake. Larger particles in the X disperse very slowly and give this structure its longevity.

Astronomers plan to use Hubble again next year to view the object. Jewitt and his colleagues hope to see how far the dust has been swept back by the sun's radiation and how the mysterious X-shaped structure has evolved.

Europa’s hidden ice chemistry

The frigid ice of Jupiter's moon Europa may be hiding more than a presumed ocean: it is likely the scene of some unexpectedly fast chemistry between water and sulphur dioxide at extremely cold temperatures. Although these molecules react easily as liquids-they are well-known ingredients of acid rain-Mark Loeffler and Reggie Hudson at NASA's Goddard Space Flight Center in Greenbelt, Md., now report that they react as ices with surprising speed and high yield at temperatures hundreds of degrees below freezing. Because the reaction occurs without the aid of radiation, it could take place throughout Europa's thick coating of ice-an outcome that would revamp current thinking about the chemistry and geology of this moon and perhaps others.

"When people talk about chemistry on Europa, they typically talk about reactions that are driven by radiation," says Goddard scientist Mark Loeffler, who is first author on the paper being published in *Geophysical Research Letters*. That's because the moon's temperature hovers around 86 to 130 Kelvin (minus 300 to minus 225 degrees Fahrenheit). In this extreme cold, most chemical reactions require an infusion of energy from radiation or light. On Europa, the energy comes from particles from Jupiter's radiation belts. Because most of those particles penetrate just fractions of an inch into the surface, models of Europa's chemistry typically stop there.

"Once you get below Europa's surface, it's cold and solid, and you normally don't expect things to happen very fast under those conditions," explains co-author Reggie Hudson, the associate lab chief of Goddard's Astrochemistry Laboratory.

"But with the chemistry we describe," adds Loeffler, "you could have ice 10 or 100 meters [roughly 33 or 330 feet] thick, and if it has sulphur dioxide mixed in, you're going to have a reaction."

"This is an extremely important result for understanding the chemistry and geology of Europa's icy crust," says Robert E. Johnson, an expert on radiation-induced chemistry on planets and a professor of engineering physics at the University of Virginia in Charlottesville.

From remote observations, astronomers know that sulphur is present in Europa's ice. Sulphur originates in the volcanoes of Jupiter's moon Io, then becomes ionized and is transported to Europa, where it gets embedded in the ice. Additional sulphur might come from the ocean that's thought to lie beneath Europa's surface. "However," says Johnson, "the fate of the implanted or any subsurface sulphur is not understood and depends on the geology and chemistry in the ice crusts."

In experiments that simulated the conditions on Europa, Loeffler and Hudson sprayed water vapor and sulphur dioxide gas onto quarter-sized mirrors in a high-vacuum chamber. Because the mirrors were kept at about 50 to 100 Kelvin (about minus 370 to minus 280 degrees Fahrenheit), the gases immediately condensed as ice. As the reaction proceeded, the researchers used infrared spectroscopy to watch the decrease in concentrations of water and sulphur dioxide and the increase in concentrations of positive and negative ions generated.

Despite the extreme cold, the molecules reacted quickly in their icy forms. "At 130 Kelvin [about minus 225 degrees Fahrenheit], which represents the warm end of the expected temperatures on Europa, this reaction is essentially instantaneous," says Loeffler. "At 100 Kelvin, you can saturate the reaction after half a day to a day. If that doesn't sound fast, remember that on geologic timescales – billions of years – a day is faster than the blink of an eye."

To test the reaction, the researchers added frozen carbon dioxide, also known as dry ice, which is commonly found on icy bodies, including Europa. "If frozen carbon dioxide had blocked the reaction, we wouldn't be nearly as interested," explains Hudson, "because then the reaction probably wouldn't be relevant to Europa's chemistry. It would be a laboratory curiosity." But the reaction continued, which means it could be significant on Europa as well as Ganymede and Callisto, two more of Jupiter's moons, and other places where both water and sulphur dioxide are present.

The reaction converted one-quarter to nearly one-third of the sulphur dioxide into product. "This is an unexpectedly high yield for this chemical reaction," says Loeffler. "We would have been happy with five percent." What's more, the positive and negative ions produced will react with other molecules. This could lead to some intriguing chemistry, especially because bisulfite, a type of sulphur ion, and some other products of this reaction are refractory-stable enough to stick around for a while.

Robert Carlson, a senior research scientist at the Jet Propulsion Laboratory in Pasadena, Calif., who collaborates with the two researchers, notes that earlier hints of water and sulphur dioxide reacting as solids were found but not explained. "The Loeffler and Hudson results show that really interesting acidâ€“base reactions are going on," he says. "I am anxious to see what might happen when other species are added and how the minor concentrations of sulphur dioxide on the satellite surfaces affect the overall chemistry."

The ultimate test of the laboratory experiments will be whether evidence of any reaction products can be found in data collected during remote observations or future visits to Europa. Johnson agrees that if subsurface sulphur dioxide on Europa "reacts to form refractory species, as [the researchers] indicate, then the picture changes completely. " These results not only will affect our understanding of Europa, but can also be further refined and tested with the proposed Europa Jupiter System mission.

Spacecraft begin new exploration assignments

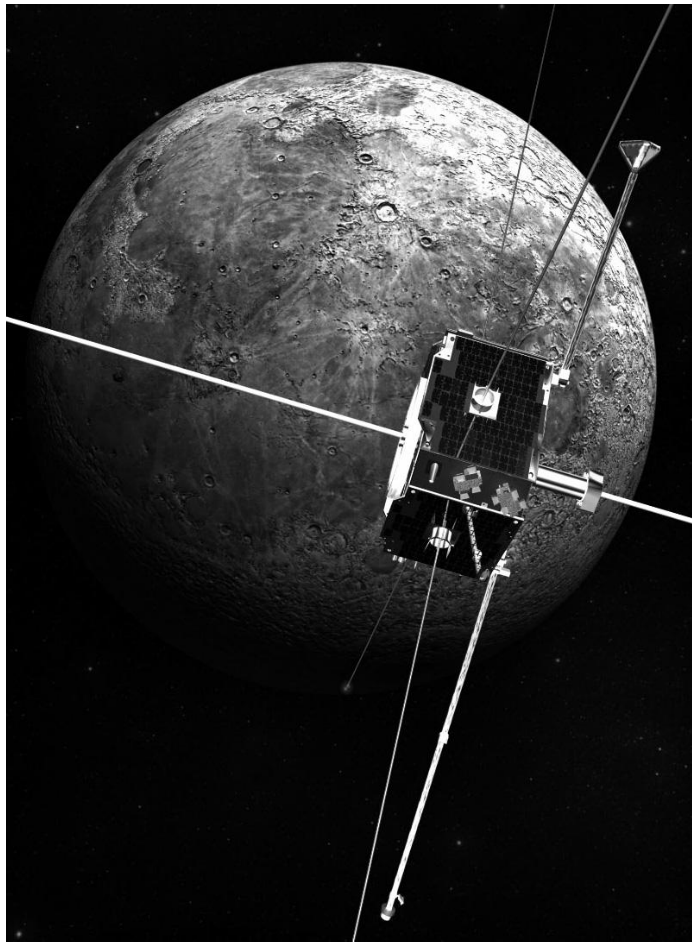
Two NASA spacecraft have been assigned a new mission after successfully completing their original science objectives earlier this year. The duo began making observations this week to study how solar wind electrifies, alters and erodes the Moon's surface. Data could reveal valuable information for future explorers and give planetary scientists a hint of what's happening on other worlds around the solar system.

The new mission is called ARTEMIS, or Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with the Sun. ARTEMIS uses two of five in-orbit spacecraft from NASA's THEMIS, or Time History of Events and Macroscale Interactions during Substorms, mission. "Using two repurposed satellites for the ARTEMIS mission highlights NASA's efficient use of the nation's space assets," said Dick Fisher, director of the Heliophysics Division in NASA's Science Mission Directorate at the agency's headquarters in Washington.

ARTEMIS will measure solar wind turbulence on scales never sampled by previous missions. Solar wind is a stream of charged particles emitted from the upper atmosphere of the sun. "ARTEMIS will provide a unique two-point view of the Moon's under-explored space environment," said Vassilis Angelopoulos of the University of California in Los Angeles (UCLA), principal investigator of the THEMIS mission. "These two spacecraft are headed for an incredible new adventure."

One ARTEMIS spacecraft reached what is called the L2 Lagrange point on the far side of the Moon on 25 August. On 22 October, the other spacecraft entered the L1 Lagrange point on the Earth-side of the Moon. Lagrange points are places where the gravity of Earth and Moon balance, creating a sort of gravitational parking spot for spacecraft. NASA repositioned the two outermost THEMIS spacecraft using spare on-board fuel and a set of complex orbit maneuvers over the course of more than a year.

"ARTEMIS is going where no spacecraft have gone before," said Manfred Bester, Mission Operations manager from the University of California at Berkeley, where the spacecraft are operated. "We are exploring the Earth-Moon Lagrange points for the first time."



An artist's concept of the THEMIS spacecraft in orbit around the Moon. (NASA)

After six months at the Lagrange points, ARTEMIS will move closer to the Moon. The spacecraft will be approximately 62 miles from the surface at first, but will eventually move closer. From point-blank range, the spacecraft will look to see how the solar wind impacts a rocky world when there's no magnetic field to protect it. Earth is protected from solar wind by its magnetic field. However, the Moon is exposed because it has no global magnetism.

Launched in 2007, THEMIS was NASA's first five-satellite mission launched aboard a single rocket. The unique constellation of satellites provided scientists with data to help resolve the mystery of how Earth's magnetosphere stores and releases energy from the Sun by triggering geomagnetic substorms. The three remaining THEMIS satellites continue to study substorms that are visible in the Northern Hemisphere as a sudden brightening of the Northern Lights, or Aurora Borealis.

Hubble astronomers uncover an overheated early universe

During a period of universal warming 11 billion years ago, quasars – the brilliant core of active galaxies – produced fierce radiation blasts that stunted the growth of some dwarf galaxies for approximately 500 million years. This important conclusion comes from a team of astronomers that used the new capabilities of NASA's Hubble Space Telescope to probe the invisible, remote universe. The team's results are published in the October 10 issue of *The Astrophysical Journal*.

Using Hubble's Cosmic Origins Spectrograph (COS), the astronomers identified this era, from 11.7 to 11.3 billion years ago, when the ultraviolet light emitted by active galaxies stripped electrons off helium atoms. The process, known as ionization, heated the intergalactic helium from 18,000 degrees Fahrenheit to nearly 40,000 degrees. This inhibited the gas from ravitationally collapsing to form new generations of stars in some small galaxies.

Because of its greatly improved sensitivity and lower background "noise" compared to previous spectrographs in space, the COS observations were ground-breaking. The observations allowed scientists to produce more detailed measurements of the intergalactic helium than previously possible. "These COS results yield new insight into an important phase in the history of our universe," said Hubble Program Scientist Eric Smith at NASA Headquarters in Washington.

Michael Shull of the University of Colorado in Boulder and his team studied the spectrum of ultraviolet light produced by a quasar and found signs of ionized helium. This beacon, like a headlight shining through fog, travels through interspersed clouds of otherwise invisible gas and allows for a core sample of the gas clouds.

The universe went through an initial heat wave more than 13 billion years ago when energy from early massive stars ionized cold interstellar hydrogen from the big bang. This epoch is called reionization, because the hydrogen nuclei originally were in an ionized state shortly after the big bang.

The Hubble team found it would take another two billion years before the universe produced sources of ultraviolet radiation with enough energy to reionize the primordial helium that also was cooked up in the big bang. This radiation didn't come from stars, but rather from super massive black holes. The black holes furiously converted some of the gravitational energy of this mass to powerful ultraviolet radiation that blazed out of these active galaxies.

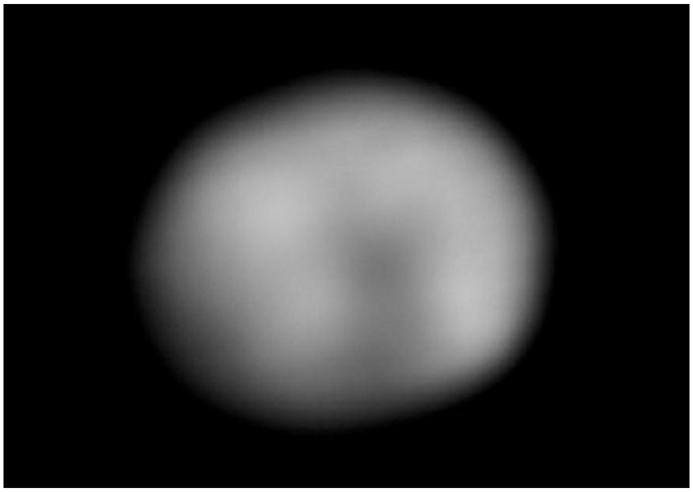
The helium's reionization occurred at a transitional time in the universe's history when galaxies collided to ignite quasars. After the helium was reionized, intergalactic gas again cooled down and dwarf galaxies could resume normal assembly. "I imagine quite a few more dwarf galaxies may have formed if helium reionization had not taken place," Shull said.

So far, Shull and his team only have one perspective to measure the helium transition to its ionized state. However, the COS science team plans to use Hubble to look in other directions to determine if helium reionization uniformly took place across the universe.

Asteroid mission gets help from Hubble

The Hubble Space Telescope has captured images of the large asteroid Vesta that will help refine plans for the Dawn spacecraft's rendezvous with Vesta in July 2011. Scientists have constructed a video from the images that will help improve pointing instructions for Dawn as it is placed in a polar orbit around Vesta. Analyses of Hubble images revealed a pole orientation, or tilt, of approximately four degrees more to the asteroid's east than scientists previously thought. This means the change of seasons between the southern and northern hemispheres of Vesta may take place about a month later than previously expected while Dawn is orbiting the asteroid. The result is a change in the pattern of sunlight expected to illuminate the asteroid. Dawn needs solar illumination for imaging and some mapping activities.

"While Vesta is the brightest asteroid in the sky, its small size makes it difficult to image from Earth," said Jian-Yang Li, a scientist participating in the Dawn mission from the University of Maryland in College Park. "The new Hubble images give Dawn scientists a better sense of how Vesta is spinning, because our new views are 90 degrees different from our previous images. It's like having a street-level view and adding a view from an airplane overhead."



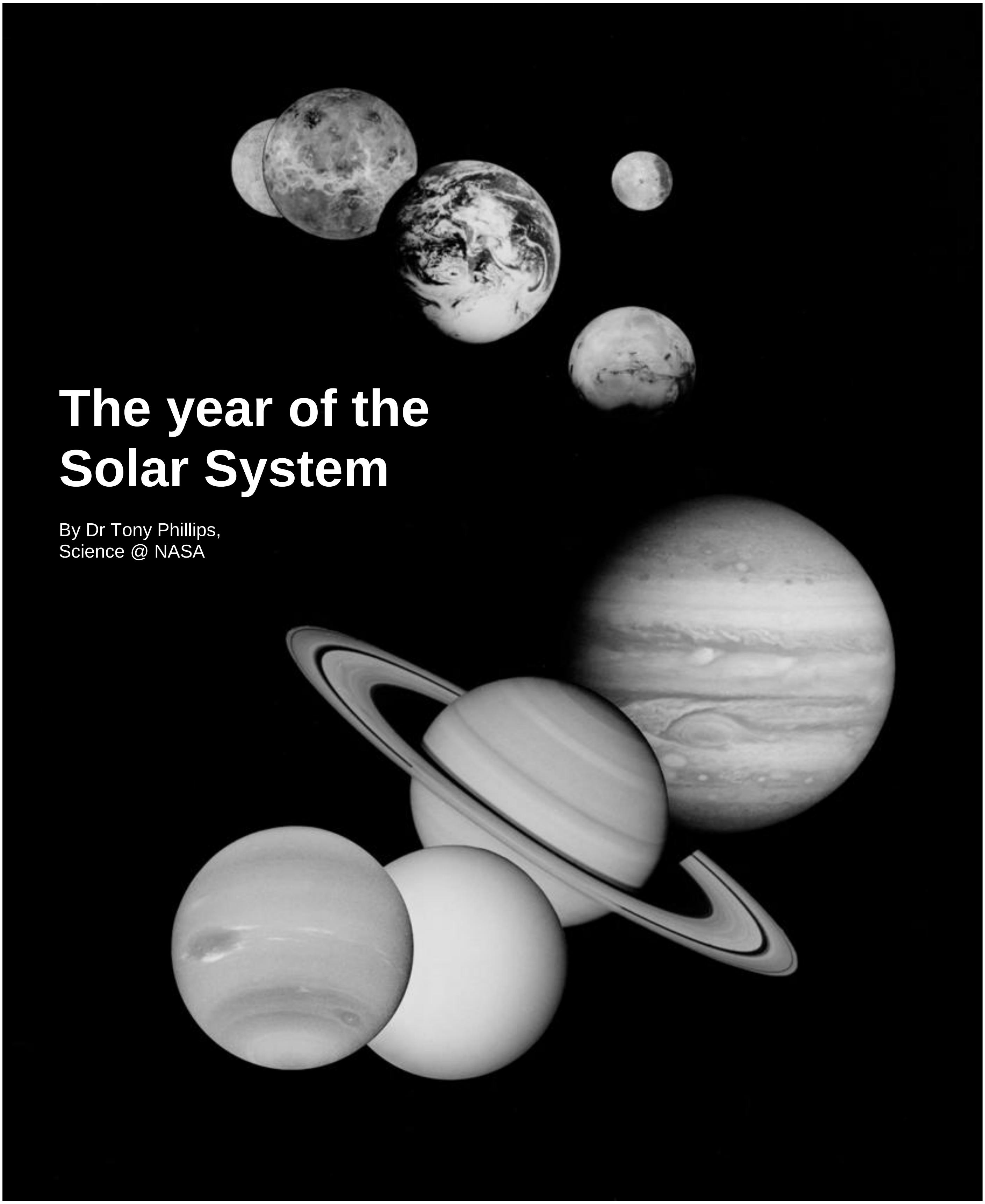
An image of asteroid Vesta taken by the Hubble Space Telescope in February 2010 (NASA)

The recent images were obtained by Hubble's Wide Field Camera 3 in February. The images complemented previous ones of Vesta taken from ground-based telescopes and Hubble's Wide Field and Planetary Camera 2 between 1983 and 2007. Li and his colleagues looked at 216 new images, and a total of 446 Hubble images overall, to clarify how Vesta was spinning. The journal *Icarus* recently published the report online.

"The new results give us food for thought as we make our way toward Vesta," said Christopher Russell, Dawn's principal investigator at the University of California, Los Angeles. "Because our goal is to take pictures of the entire surface and measure the elevation of features over most of the surface to an accuracy of about 10 metres, or the height of a three-story building, we need to pay close attention to the solar illumination. It looks as if Vesta is going to have a late northern spring next year, or at least later than we planned."

Launched in September 2007, Dawn will leave Vesta to encounter the dwarf planet Ceres in 2015. Vesta and Ceres are the most massive objects in the main asteroid belt between Mars and Jupiter. Scientists study these celestial bodies as examples of the building blocks of terrestrial planets like Earth. Dawn is approximately 216 million kilometres away from Vesta. Next northern summer, the spacecraft will make its own measurements of Vesta's rotating surface and allow mission managers to pin down its axis of spin.

"Vesta was discovered just over 200 years ago, and we are excited now to be on the threshold of exploring it from orbit," said Bob Mase, Dawn's project manager at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "We planned this mission to accommodate our imprecise knowledge of Vesta. Ours is a journey of discovery and, with our ability to adapt, we are looking forward to collecting excellent science data at our target."



The year of the Solar System

By Dr Tony Phillips,
Science @ NASA

To mark an unprecedented flurry of exploration which is about to begin, NASA has announced that the coming year will be "The Year of the Solar System" (YSS). "During YSS, we'll see triple the [usual] number of launches, flybys and orbital insertions," says Jim Green, Director of Planetary Science at NASA headquarters. "There hasn't been anything quite like it in the history of the Space Age.

Naturally, it's a Martian year.

"These events will unfold over the next 23 months, the length of a year on the Red Planet" explains Green. "History will remember the period October 2010 through August 2012 as a golden age of planetary exploration."

The action begins near the end of October 2010 with a visit to Comet Hartley 2. On 20 October, Hartley 2 will have a close encounter with Earth; only 17.6 million kilometres away, it will be faintly visible to the naked eye and become a splendid target for backyard telescopes. Amateur astronomers can watch the comet as NASA's Deep Impact/EPOXI spacecraft dives into its vast green atmosphere and plunges toward the icy core. On 4 November EPOXI will fly a mere 670 kilometres from Hartley's nucleus, mapping the surface and studying outbursts of gas at close-range.

Later in November, NASA astrobiologists will launch O/OREOS, a shoebox-sized satellite designed to test the durability of life in space. Short for "Organism/ORganic Exposure to Orbital Stresses," O/OREOS will expose a collection of organic molecules and microbes to solar and cosmic radiation. Could space be a natural habitat for these "micronauts?" O/OREOS may provide some answers. As a bonus, the same rocket that delivers O/OREOS to space will carry an experimental solar sail. NanoSail-D will unfurl in Earth orbit and circle our planet for months. Occasionally, the sail will catch a sunbeam and redirect it harmlessly to the ground below where sky watchers can witness history's first "solar sail flares."

On 7 December 2010, Japan's Akatsuki (Venus Climate Orbiter) spacecraft grabs the spotlight when it enters orbit around Venus. The mission aims to understand how a planet so similar to Earth in size and orbit went so terribly wrong. Venus is bone-dry, shrouded by acid clouds, and beset by a case of global warming hot enough to melt lead. Instruments on Akatsuki will probe Venus from the top of its super-cloudy atmosphere all the way to the volcano-pocked surface below, providing the kind of detailed information researchers need for comparative planetary studies.

"Take a deep breath," says Green, "because that was just the first three months of YSS!"

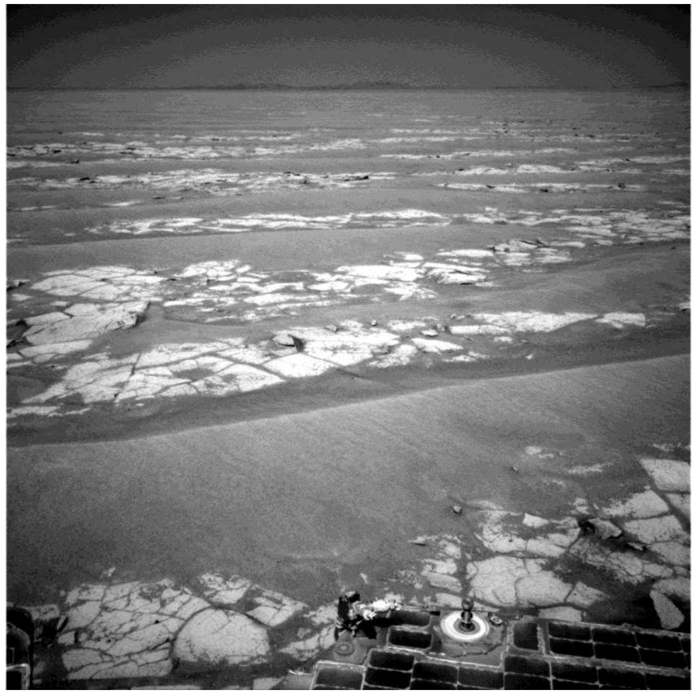
The action continues in 2011 as Stardust NExT encounters comet Tempel 1 (14 February), MESSENGER enters orbit around Mercury (18 March), and Dawn begins its approach to asteroid Vesta (May).

"For a full month Dawn will be able to see Vesta even more clearly than Hubble can," marvels Green. "The only way to top that would be to go into orbit." And that is exactly what Dawn will do in July 2011: insert itself into orbit for a full-year study of the second-most massive body in the asteroid belt. Although Vesta is not classified as a planet, it is a full-fledged alien world that is expected to mesmerize researchers as it reveals itself to Dawn's cameras.

Next comes the launch of the Juno spacecraft to Jupiter (August), the launch of GRAIL to map the gravitational field of the Moon (September), and the launch of a roving science lab named "Curiosity" to Mars (November).

"The second half of 2011 will be as busy as some entire decades of the Space Age," says Green. Even then, YSS has months to go.

2012 opens with Mars rover Opportunity running the first-ever Martian marathon. The dogged rover is trundling toward



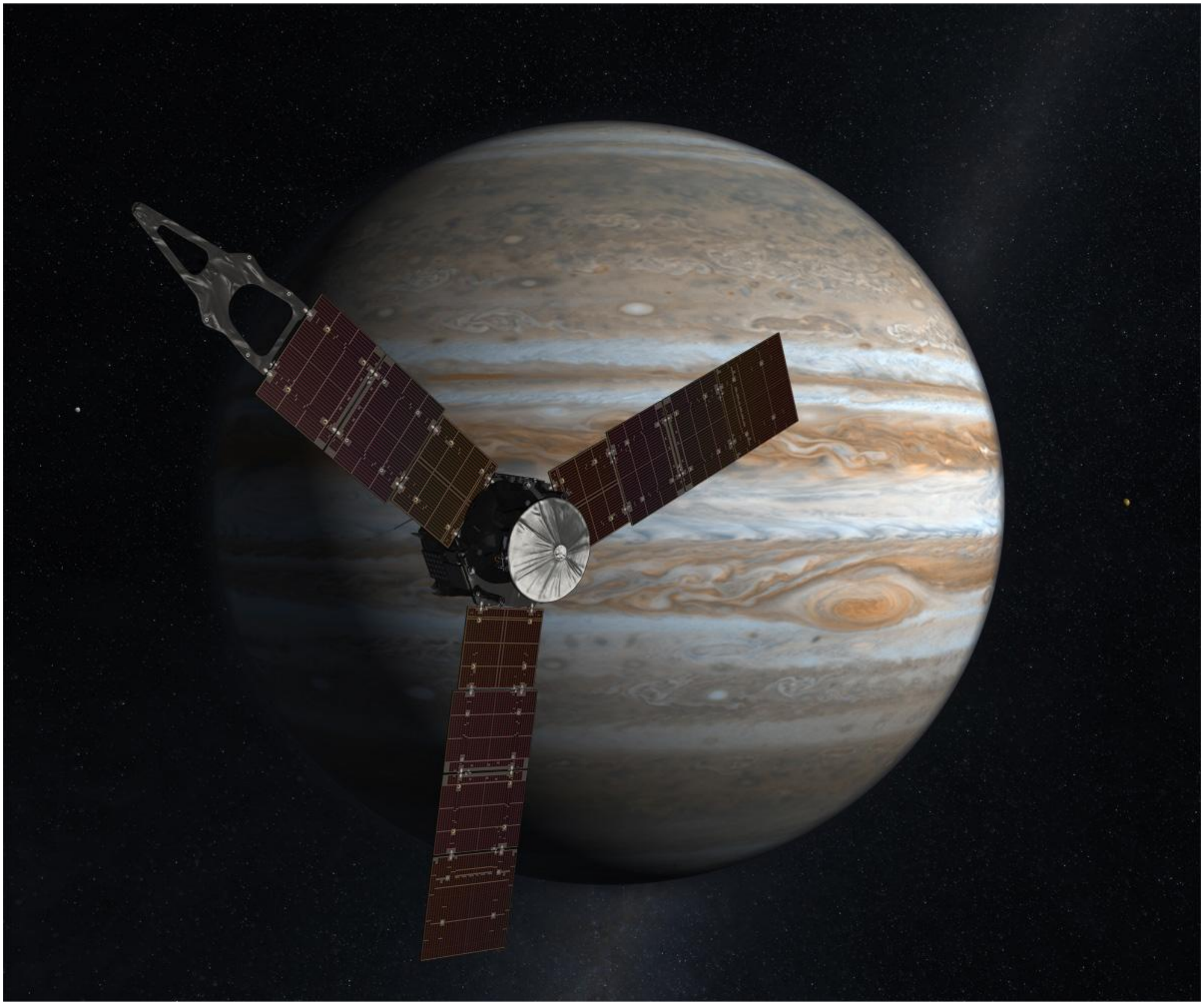
Endeavour crater is seen in the distance in this recent view from the Opportunity rover as it traverses the Meridiani Planum region of Mars (NASA/JPL)

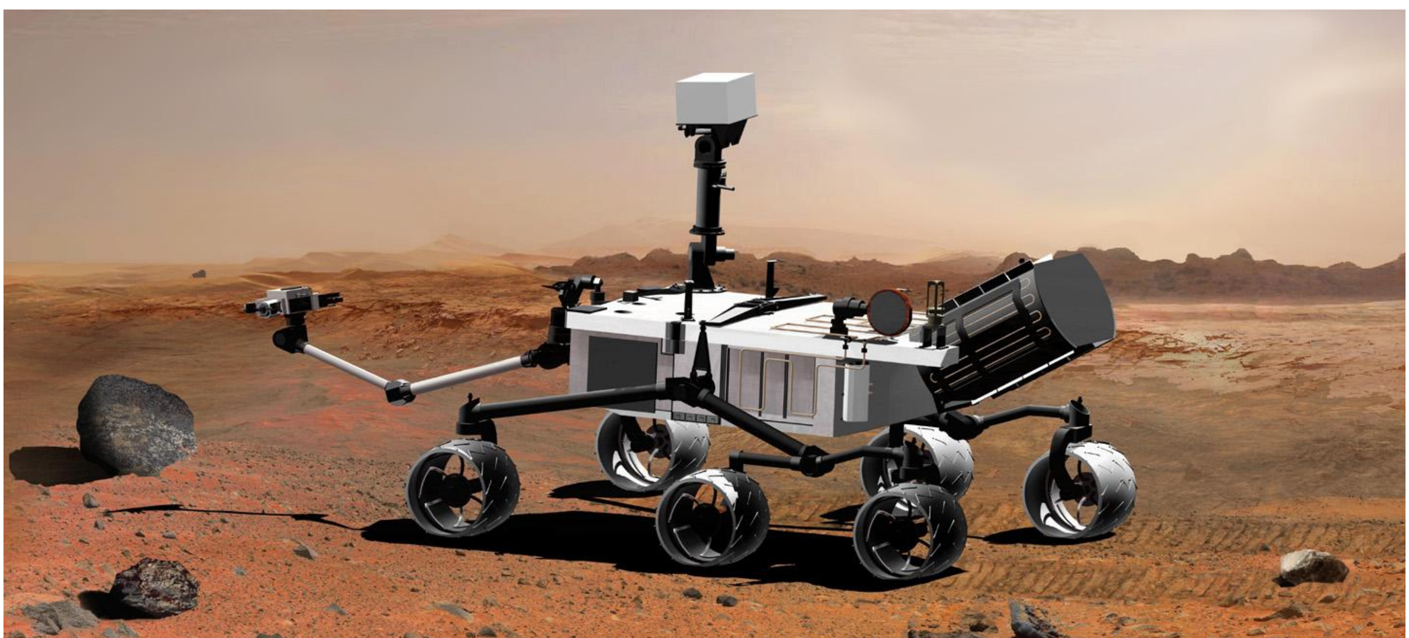
the heart of Endeavour Crater, a city-sized impact basin almost two dozen miles from Opportunity's original landing site. "Opportunity is already under the influence of the crater," says Green. "The ground beneath the rover's wheels is sloping gently down toward its destination—a welcome feeling for any marathoner." Sometime in mid-2012, Opportunity will reach Endeavour's lip and look over the edge deeper into the heart of Mars than any previous robotic explorer. The only thing more marvelous than the view will be the rover itself. Originally designed to travel no more than 0.6 miles, Opportunity's rest stop at Endeavour will put it just miles away from finishing the kind of epic Greek run that athletes on Earth can only dream about.

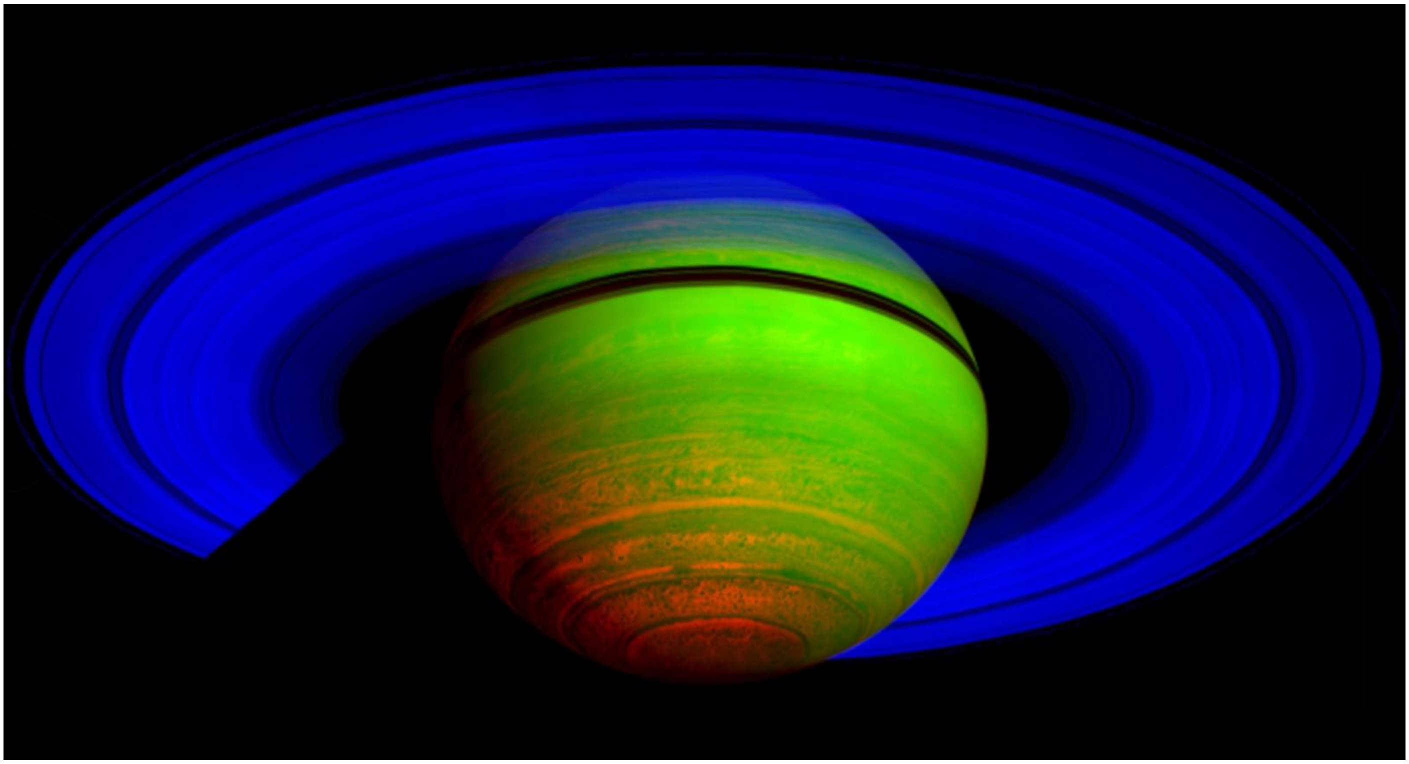
Meanwhile, halfway across the solar system, Dawn will fire up its ion engines and prepare to leave Vesta. For the first time in space history, a spacecraft orbiting one alien world will break orbit and take off for another. Dawn's next target is dwarf planet Ceres, nearly spherical, rich in water ice, and totally unexplored.

The Year of the Solar System concludes in August 2012 when Curiosity lands on Mars. The roving nuclear-powered science lab will take off across the red sands sniffing the air for methane (a possible sign of life) and sampling rocks and soil for organic molecules. Curiosity's advanced sensors and unprecedented mobility are expected to open a new chapter in exploration of the Red Planet.

"So the end," says Green, "is just the beginning. These missions will keep us busy long after YSS is history."



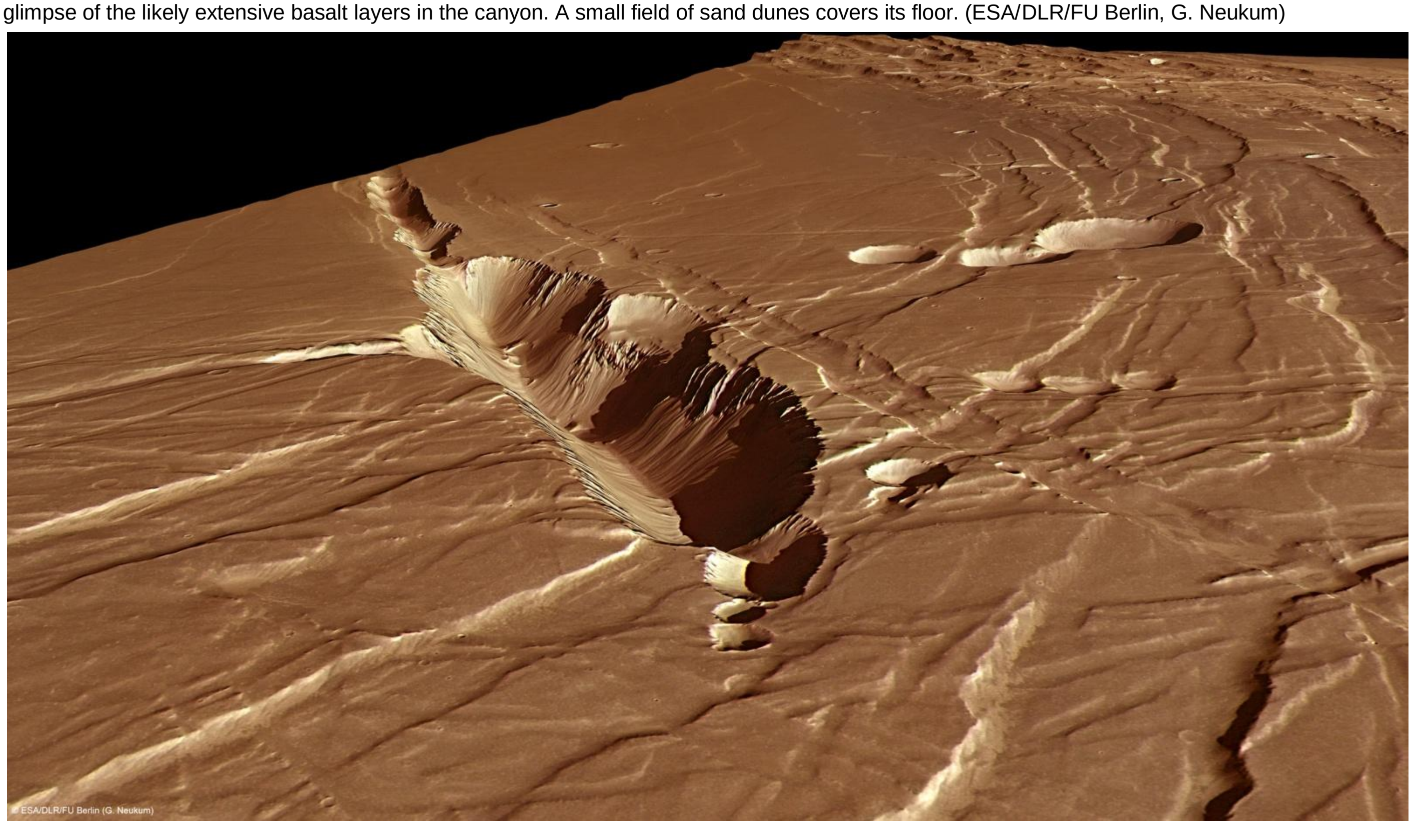




Preceding page: NASA's Juno mission to Jupiter (top) and Curiosity Mars rover will both launch in 2011 (NASA photos)

This page: (Top) This false-color composite image, constructed from data obtained by NASA's Cassini spacecraft, shows Saturn's rings and southern hemisphere. The composite image was made from 65 individual observations by Cassini's visual and infrared mapping spectrometer in the near-infrared portion of the light spectrum on 1 November 2008 (NASA/JPL)

(Bottom) This prominent collapse feature in Mars' Phoenicis Lacus sinks to a depth of about 3 km below the surrounding terrain. Its walls give a glimpse of the likely extensive basalt layers in the canyon. A small field of sand dunes covers its floor. (ESA/DLR/FU Berlin, G. Neukum)



Dawn one year away from Vesta

By Ed Case

Let the countdown begin! NASA's Dawn spacecraft is less than one year away from giant asteroid Vesta.

"There's nothing more exciting than revealing an unexplored, alien world," says Marc Rayman, Dawn's chief engineer at the Jet Propulsion Laboratory. "Vesta," he predicts, "is going to amaze us."

Dawn is slated to enter orbit around Vesta in late July 2011. As the first breathtaking images are beamed back to Earth, researchers will quickly combine them into a movie, allowing us all to ride along. "It will look as though the spacecraft is hovering in one place while Vesta rotates beneath it," says Rayman.

Previous missions have shown us a handful of asteroids, but none as large as this hulking relic of the early solar system. Measuring 563 kilometres across and containing almost 10% of the mass of the entire asteroid belt, Vesta is a world unto itself. "It's a big, rocky, terrestrial type body – more likely similar to the moon and Mercury than to the little chips of rocks we've flown by in the past," continues Rayman. "For example, there's a large crater at Vesta's south pole, and inside the crater is a mountain bigger than asteroid Eros."

Dawn will orbit Vesta for a year, conducting a detailed study and becoming the first spacecraft to ever orbit a body in the asteroid belt. Later, Dawn will leave Vesta and go on to orbit a second exotic world, dwarf planet Ceres – but that's another story.

Many scientists consider Vesta a protoplanet. The asteroid was in the process of forming into a full fledged planet when Jupiter interrupted its growth. The gas giant became so massive that its gravity stirred up the material in the asteroid belt so the objects there could no longer coalesce.

"Vesta can teach us a lot about how planets formed," says Christopher Russell of UCLA, the mission's Principal Investigator. "There is a whole team of scientists sitting on the edge of their seats waiting for that first glimpse of Vesta."

Dawn's official Vestian approach, which Rayman also calls the "Oh man this is so cool phase" of the mission, begins next May. Unlike most orbital insertions, however, this one will be comparatively relaxing. "This may be the first planetary mission that doesn't cause its mission team members to bite their nails while their spacecraft is getting into planetary orbit," says Rayman.

A conventional spacecraft's entry into a flight path around a celestial body is accompanied by crucial periods during which maneuvers must be executed with pinpoint precision. If anything goes wrong, all can be lost. But Dawn, with its gentle ion propulsion, slowly spirals in to its target, getting closer and closer as it loops around. "Dawn's entire thrust profile for its long interplanetary flight has been devoted largely to the gradual reshaping of its orbit around the Sun so that by the time the spacecraft is in the vicinity of Vesta, its orbit will be very much like Vesta's."

With just a slight change in trajectory, the spacecraft will allow itself to be captured by Vesta's gravity. "Even that gentle ion thrust will be quite sufficient to let the craft slip into orbit. It's like merging into traffic on an interstate – only gradual acceleration is needed. Dawn won't even notice the difference, but it will be in orbit around its first celestial target."

Dawn's first survey orbits will be high and leisurely, taking days to loop around Vesta at altitudes of about 1700 miles. After collecting a rich bounty of pictures and data from high altitude, Dawn will resume thrusting, spiraling down to lower and lower orbits, eventually settling in a little more than 160 kilometres high – lower than satellites orbiting Earth.

Parts of the surface may be reminiscent of features on Earth or the Moon with craters and perhaps even volcanoes. "We don't expect to see active volcanoes," notes Carol Raymond, the mission's Deputy Principal Investigator at JPL, "but there could be ancient volcanic features still recognizable among the craters."

Meanwhile, "other sights could be completely unlike anything we've imagined," says Rayman. "It'll be pure excitement!"

Moon's buried treasures uncovered

Nearly a year after announcing the discovery of water molecules on the Moon, scientists have revealed new data uncovered by NASA's Lunar CRater Observation and Sensing Satellite, or LCROSS, and Lunar Reconnaissance Orbiter, or LRO. The missions found evidence that the lunar soil within shadowy craters is rich in useful materials, and the Moon is chemically active and has a water cycle. Scientists also confirmed the water was in the form of mostly pure ice crystals in some places. The results are featured in six papers published in the 22 October issue of *Science*.

"NASA has convincingly confirmed the presence of water ice and characterized its patchy distribution in permanently shadowed regions of the Moon," said Michael Wargo, chief lunar scientist at NASA Headquarters in Washington. "This major undertaking is the one of many steps NASA has taken to better understand our solar system, its resources, and its origin, evolution, and future."

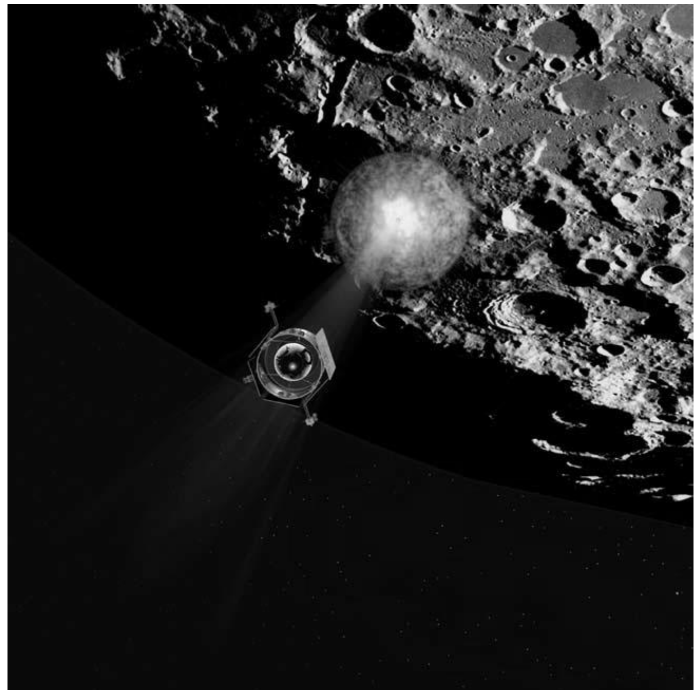
The lunar rocks brought back to the Earth by the Apollo astronauts were found to have very little water, and to be much drier than rocks on Earth. An explanation for this was that the Moon formed billions of years ago in the solar system's turbulent youth, when a Mars-sized planet crashed into Earth. The impact stripped away our planet's outer layer, sending it into orbit. The pieces later coalesced under their own gravity to form our Moon. Heat from all this mayhem vaporized most of the water in the lunar material, so the water was lost to space.

However, there was still a chance that water might be found in special places on the Moon. Due to the Moon's orientation to the Sun, scientists theorized that deep craters at the lunar poles would be in permanent shadow and thus extremely cold and able to trap volatile material like water as ice perhaps delivered there by comet impacts or chemical reactions with hydrogen carried by the solar wind.

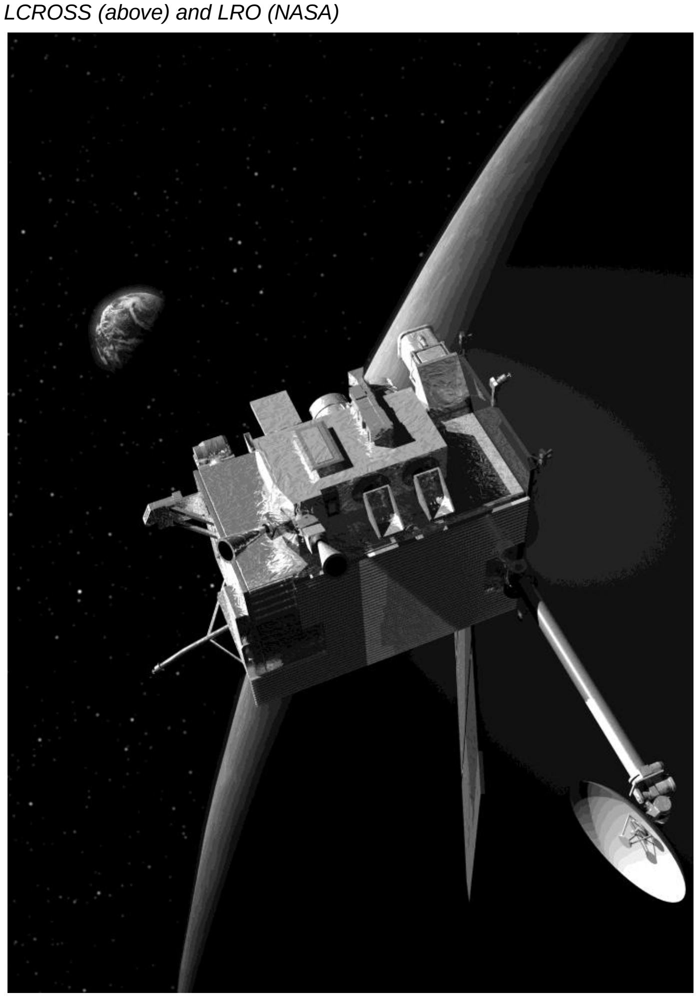
The twin impacts of LCROSS and a companion rocket stage in the Moon's Cabeus crater on 9 October 2009, lifted a plume of material that might not have seen direct sunlight for billions of years. As the plume traveled nearly 16 kilometres above the rim of Cabeus, instruments aboard LCROSS and LRO made observations of the crater and debris and vapor clouds. After the impacts, grains of mostly pure water ice were lofted into the sunlight in the vacuum of space.

"Seeing mostly pure water ice grains in the plume means water ice was somehow delivered to the Moon in the past, or chemical processes have been causing ice to accumulate in large quantities," said Anthony Colaprete, LCROSS project scientist and principal investigator at NASA's Ames Research Center in Moffett Field, Calif. "Also, the diversity and abundance of certain materials called volatiles in the plume, suggest a variety of sources, like comets and asteroids, and an active water cycle within the lunar shadows."

Volatiles are compounds that freeze and are trapped in the cold lunar craters and vaporize when warmed by the sun. The suite of LCROSS and LRO instruments determined as much as 20% of the material kicked up by the LCROSS impact was volatiles, including methane, ammonia, hydrogen gas, carbon dioxide and carbon monoxide. The instruments also discovered relatively large amounts of light metals such as sodium, mercury and possibly even silver. Scientists believe the water and mix of volatiles that LCROSS and LRO detected could be the remnants of a comet impact. According to scientists, these volatile chemical by-products are also evidence of a cycle through which water ice reacts with lunar soil grains.



LCROSS (above) and LRO (NASA)



LCROSS was a companion mission to the LRO mission. The two missions were designed to work together, and support from LRO was critical to the success of LCROSS. During impact, LRO, which is normally looking at the lunar surface, was tilted toward the horizon so it could observe the plume. Shortly after the Centaur hit the Moon, LRO flew past debris and gas from the impact while its instruments collected data.

"LRO assisted LCROSS in two primary ways -- selecting the impact site and confirming the LCROSS observations," said Gordon Chin of NASA's Goddard Space Flight Center, Greenbelt, Md., LRO associate project scientist. "Since observatories on Earth were also planning to view the impact, there were a lot of constraints on the location -- the impact plume had to rise out of the crater and into sunlight, and it had to be visible from Earth," added Chin.

Prior to the impact, LRO's instruments worked together to map and provide details on the polar regions, according to Chin. For example, LRO's Lunar Orbiter Laser Altimeter (LOLA) instrument built up three-dimensional (topographic) maps of the surface. This data was plugged into computer simulations to see how shadows change as the Moon moves in its orbit, so that regions in permanent shadow could be identified. The Lunar Reconnaissance Orbiter Camera (LROC) helped by making images of the actual regions of light and shade, which were used to verify the simulation's accuracy. Finally, LOLA measured the depths of polar craters to find areas where the impact could still be seen from Earth.

Since hydrogen is a component of water, maps of lunar hydrogen deposits are useful for finding areas that might hold water. Preliminary hydrogen maps were provided by the spacecraft's Lunar Exploration Neutron Detector (LEND) instrument. Regions that had relatively high amounts of hydrogen were identified as the most promising for the impact.

"Over a year ago, we formally suggested Cabeus to the LCROSS principal investigator," said LEND principal investigator, Igor Mitrofanov of the Institute for Space Research, Moscow. "According to our current data, the regolith within the Cabeus impact crater may have the highest content of water anywhere on the Moon, perhaps up 4.0% weight."

"Originally, the LCROSS team was going with a site further north than the Cabeus crater, because it was better for Earth visibility," said Chin. "However, LEND revealed that the area did not have a high hydrogen concentration, but Cabeus did. Also, Diviner showed that Cabeus was one of the coldest sites, and LOLA indicated it was in permanent shadow. So, we were able to inform the decision to aim for Cabeus further south -- while it was a little less visible from Earth, Cabeus was ultimately better for what we were trying to find."

Temperature maps from LRO's Diviner instrument were also crucial to identify where the coldest places were. David Paige, principal Investigator of the Diviner instrument from the University of California, Los Angeles, used temperature measurements of the lunar south pole obtained by Diviner to model the stability of water ice both at and near the surface.

"The temperatures inside these permanently shadowed craters are even colder than we had expected. Our model results indicate that in these extreme cold conditions, surface deposits of water ice would almost certainly be stable," said Paige, "but perhaps more significantly, these areas are surrounded by much larger permafrost regions where ice could be stable just beneath the surface.

"We conclude that large areas of the lunar south pole are cold enough to trap not only water ice, but other volatile compounds (substances with low boiling points) such as sulfur dioxide, carbon dioxide, formaldehyde, ammonia, methanol, mercury and sodium," Paige added.

UCLA graduate student and Diviner team member, Paul Hayne, was monitoring the data in real-time as it was sent back from Diviner. "During the fly-by 90 seconds after impact, all seven of Diviner's infrared channels measured an enhanced thermal signal from the crater. The more sensitive of its two solar channels also measured the thermal signal, along with reflected sunlight from the impact plume. Two hours later, the three longest wavelength channels picked up the signal, and after four hours only one channel detected anything above the background temperature."

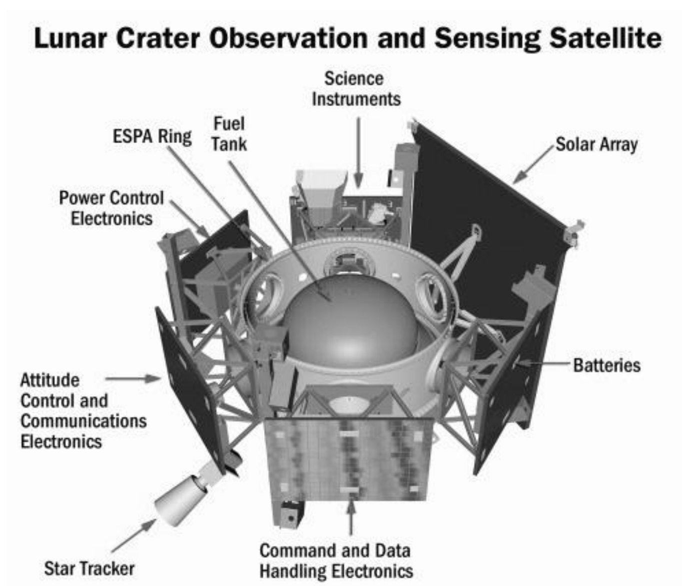
Scientists were able to learn two things from these measurements: first, they were able to constrain the mass of material that was ejected outwards into space from the impact crater; second, they were able to infer the initial temperature and make estimates about the effects of ice in the soil on the observed cooling behavior.

Another LRO instrument, the Lyman-Alpha Mapping Project (LAMP), used data on the gas cloud to confirm the presence of the molecular hydrogen, carbon monoxide and atomic mercury, along with smaller amounts of calcium and magnesium, all in gaseous form. "We had hints from Apollo soils and models that the volatiles we see in the impact plume have been long collecting near the Moon’s polar regions," said Randy Gladstone, LAMP acting principal investigator, of Southwest Research Institute (SwRI) in San Antonio, Texas. "Now we have confirmation."

"The detection of mercury in the soil was the biggest surprise, especially that it’s in about the same abundance as the water detected by LCROSS," said Kurt Retherford, LAMP team member, also of SwRI.

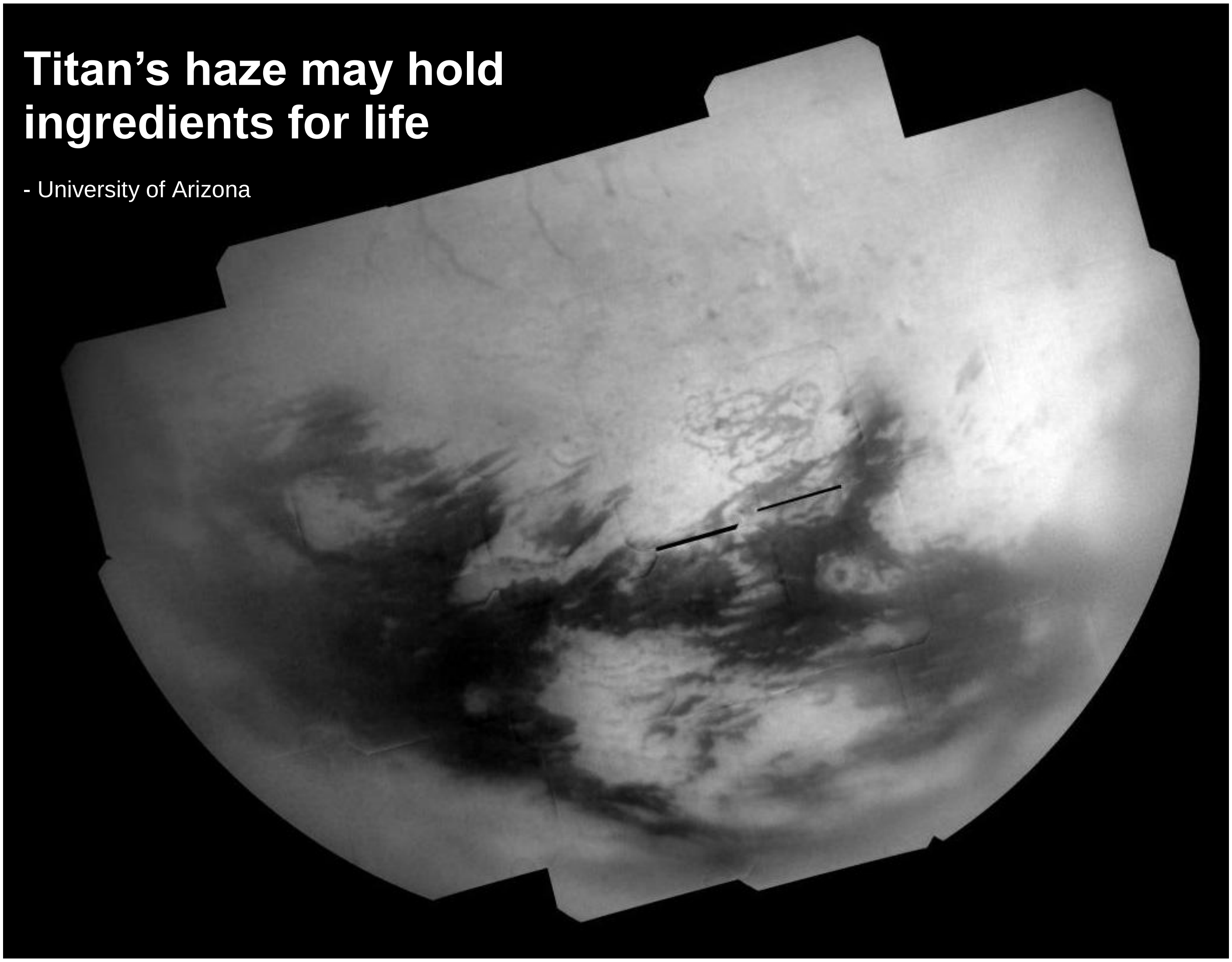
"The observations by the suite of LRO and LCROSS instruments demonstrate the Moon has a complex environment that experiences intriguing chemical processes," said Richard Vondrak, LRO project scientist at NASA Goddard. "This knowledge can open doors to new areas of research and exploration."

LCROSS launched with LRO aboard an Atlas V rocket from Cape Canaveral, Fla., on 18 June 2009. – *Compiled from NASA sources*



Titan's haze may hold ingredients for life

- University of Arizona



A mosaic of Cassini images of Saturn's largest moon, Titan (NASA/JPL)

In an experiment exploring the chemical processes that might be going on in the hazy atmosphere enshrouding Saturn's largest moon, a University of Arizona-led team of scientists discovered a variety of complex organic molecules - including amino acids and nucleotide bases, the most important ingredients of life on Earth. "Our team is the first to be able to do this in an atmosphere without liquid water. Our results show that it is possible to make very complex molecules in the outer parts of an atmosphere," said Sarah Hoerst, a graduate student in the UA's Lunar and Planetary Lab, who led the international research effort together with her adviser, planetary science professor Roger Yelle.

The molecules discovered include the five nucleotide bases used by life on Earth to build the genetic materials DNA and RNA: cytosine, adenine, thymine, guanine and uracil, and the two smallest amino acids, glycine and alanine. Amino acids are the building blocks of proteins. The results suggest not only that Titan's atmosphere could be a reservoir of prebiotic molecules that serve as the springboard to life, but they offer a new perspective on the emergence of terrestrial life as well: Instead of coalescing in a primordial soup, the first ingredients of life on our planet may have rained down from a primordial haze high in the atmosphere.

Oddball of the solar system

Titan has fascinated - and puzzled - scientists for a long time. "It's is the only moon in our solar system that has a substantial atmosphere," Hoerst said. "Its atmosphere stretches out much further into space than Earth's. The moon is smaller so it has less gravity pulling it back down."

Titan's atmosphere is much denser, too: On the surface, atmospheric pressure equals that at the bottom of a 15-foot-deep pool on Earth. "At the same time, Titan's atmosphere is more similar to ours than any other atmosphere in the solar system," Hoerst said. "In fact, Titan has been called 'Earth frozen in time' because some believe this is what Earth could have looked like early in time."

When Voyager I flew by Titan in the 1970s, the pictures transmitted back to Earth showed a blurry, orange ball. "For a long time, that was all we knew about Titan," Hoerst said. "All it saw were the outer reaches of the atmosphere, not the moon's body itself. We knew it has a an atmosphere and that it contains methane and other small organic molecules, but that was it."

In the meantime, scientists learned that Titan's haze consists of aerosols, just like the smog that cloaks many metropolitan areas on Earth. Aerosols, tiny particles about a quarter millionth of an inch across, resemble little snowballs when viewed with a high-powered electron microscope.

The exact nature of Titan's aerosols remains a mystery. What makes them so interesting to planetary scientists is that they consist of organic molecules - potential ingredients for life. "We want to know what kinds of chemistry can happen in the atmosphere and how far it can go." Hoerst said. "Are we talking small molecules that can go on to becoming more interesting things? Could proteins form in that atmosphere?"

What it takes to make life's molecules

For that to happen, though, energy is needed to break apart the simple atmospheric molecules - nitrogen, methane and carbon monoxide - and rearrange the fragments into more complex compounds such as prebiotic molecules. "There is no way this could happen on Titan's surface," Hoerst said. "The haze is so thick that the moon is shrouded in a perpetual dusky twilight. Plus, at -192 degrees Fahrenheit, the water ice that we think covers the moon's surface is as hard as granite." However, the atmosphere's upper reaches are exposed to a constant bombardment of ultraviolet radiation and charged particles coming from the sun and deflected by Saturn's magnetic field, which could spark the necessary chemical reactions.

To study Titan's atmosphere, scientists have to rely on data collected by the spacecraft Cassini, which has been exploring the Saturn system since 2004 and flies by Titan every few weeks on average. "With Voyager, we only got to look," says Hoerst. "With Cassini, we get to touch the moon a little bit."

During fly-by maneuvers, Cassini has gobbled up some of the molecules in the outermost stretches of Titan's atmosphere and analyzed them with its on-board mass spectrometer. Unfortunately, the instrument was not designed to unravel the identity of larger molecules - precisely the kind that were found floating in great numbers in Titan's mysterious haze. "Cassini can't get very close to the surface because the atmosphere gets in the way and causes drag on the spacecraft," Hoerst said. "The deepest it went was 900 kilometers (560 miles) from the surface. It can't go any closer than that."

To find answers, Hoerst and her co-workers had to recreate Titan's atmosphere here on Earth. More precisely, in a lab in Paris, France. "Fundamentally, we cannot reproduce Titan's atmosphere in the lab, but our hope was that by doing these simulations, we can start to understand the chemistry that leads to aerosol formation," Hoerst said. "We can then use what we learn in the lab and apply it to what we already know about Titan."

Like a spy in a movie

Hoerst and her collaborators mixed the gases found in Titan's atmosphere in a stainless-steel reaction chamber and subjected the mixture to microwaves causing a gas discharge - the same process that makes neon signs glow - to simulate the energy hitting the outer fringes of the moon's atmosphere.

The electrical discharge caused some of the gaseous raw materials to bond together into solid matter, similar to the way UV sunlight creates haze on Titan. The synthesis chamber, constructed by a collaborating group in Paris, is unique because it uses electrical fields to keep the aerosols in a levitated state. "The aerosols form while they're floating there," Hoerst explains. "As soon as they grow heavy enough, they fall onto the bottom of the reaction vessel and we scrape them out."

"And then," she added, "the samples went on an adventure."

To analyze the aerosols, Hoerst had to use a high resolution mass spectrometer in a lab in Grenoble, about a three-hour ride from Paris on the TGV, France's high-speed train. "I always joke that I felt like a spy in a movie because I would take our samples, put them into little vials, seal them all up and then I'd get on the TGV, and every 5 minutes I'd open the briefcase, 'Are they still there? Are they still there?' Those samples were really, really precious."

Analyzing the reaction products with a mass spectrometer, the researchers identified about 5,000 different molecular formulas. "We really have no idea how many molecules are in these samples other than it's a lot," Hoerst said. "Assuming there are at least three or four structural variations of each, we are talking up to 20,000 molecules that could be in there. So in some way, we are not surprised that we made the nucleotide bases and the amino acids.

"The mass spectrometer tells us what atoms the aerosols are made of, but it doesn't tell us the structure of those molecules," Hoerst said. "What we really wanted to find out was, what are all the formulas in this mass spectrum?

"On a whim, we said, 'Hey, it would be really easy to write a list of the molecular formulas of all the amino acids and nucleotide bases used by life on Earth and have the computer go through them.'

"I was sitting in front of my computer one day - I had just written up the list - and I put the file in, hit 'Enter' and went to go do something," she said. "When I came back and looked at the screen, it was printing a list of all the things it had found and I sat there and stared at it for a while. I thought: That can't be right. I ran upstairs to find Roger, my adviser, and he wasn't there," Hoerst said with a laugh. "I went back to my office, and then upstairs again to find him and he wasn't there. It was very stressful.

"We never started out saying, 'we want to make these things,' it was more like 'hey, let's see if they're there.' You have all those little pieces flying around in the plasma, and so we would expect them to form all sorts of things."

In addition to the nucleotides, the elements of the genetic code of all life on Earth, Hoerst identified more than half of the molecular formulas for the 22 amino acids that life uses to make proteins.

Titan: A window into Earth's past?

In some way, Hoerst said, the discovery of Earth's life molecules in an alien atmosphere experiment is ironic.

Here is why: The chemistry occurring on Titan might be similar to that occurring on the young Earth that produced biological material and eventually led to the evolution of life. These processes no longer occur in the Earth's atmosphere because of the large abundance of oxygen cutting short the chemical cycles before large molecules have a chance to form. On the other hand, some oxygen is needed to create biological molecules. Titan's atmosphere appears to provide just enough oxygen to supply the raw material for biological molecules, but not enough to quench their formation.

"There are a lot of reasons why life on Titan would probably be based on completely different chemistry than life on Earth," Hoerst added, "one of them being that there is liquid water on Earth. The interesting part for us is that we now know you can make pretty much anything you want in an atmosphere. Who knows this kind of chemistry isn't happening on planets outside our solar system?"

Cassini latest

Raisin’ mountains on Saturn’s moon Titan

This mosaic, made from radar images obtained by NASA's Cassini spacecraft, shows parallel mountain chains on Saturn's moon Titan. The mountains appear along the northwest border of a region known as Xanadu, two degrees south latitude and minus 127 degrees west longitude. The tallest features in this image, which were mapped by the radar instrument, are about 1,900 meters taller than the surrounding plains. Scientists believe the structures rose up because the lithosphere, the outermost layer of the surface, folded up during deformation of the outer water ice shell. (NASA/JPL-Caltech)

Saturn's moon Titan ripples with mountains, and scientists have been trying to figure out how they form. The best explanation, it turns out, is that Titan is shrinking as it cools, wrinkling up the moon's surface like a raisin. A new model developed by scientists working with radar data obtained by NASA's Cassini spacecraft shows that differing densities in the outermost layers of Titan can account for the unusual surface behavior. Titan is slowly cooling because it is releasing heat from its original formation and radioactive isotopes are decaying in the interior. As this happens, parts of Titan's subsurface ocean freeze over, the outermost ice crust thickens and folds, and the moon shrivels up. The model is described in an article now online in the *Journal of Geophysical Research*.

"Titan is the only icy body we know of in the solar system that behaves like this," said Giuseppe Mitri, the lead author of the paper and a Cassini radar associate based at the California Institute of Technology in Pasadena. "But it gives us insight into how our solar system came to be." An example of this kind of process can also be found on Earth, where the crumpling of the outermost layer of the surface, known as the lithosphere, created the Zagros Mountains in Iran, Mitri said.

Titan's highest peaks rise up to about two kilometres, comparable to the tallest summits in the Appalachian Mountains. Cassini was the first to spot Titan's mountains in radar images in 2005. Several mountain chains on Titan exist near the equator and are generally oriented west-east. The concentration of these ranges near the equator suggests a common history. While several other icy moons in the outer solar system have peaks that reach heights similar to Titan's mountain chains, their topography comes from extensional tectonics -- forces stretching the ice shell -- or other geological processes. Until now, scientists had little evidence of contractional tectonics -- forces shortening and thickening the ice shell. Titan is the only icy satellite where the shortening and thickening are dominant.

Mitri and colleagues fed data from Cassini's radar instrument into computer models of Titan developed to describe the moon's tectonic processes and to study the interior structure and evolution of icy satellites. They also made the assumption that the moon's interior was only partially separated into a mixture of rock and ice, as suggested by data from Cassini's radio science team. Scientists tweaked the model until they were able to build mountains on the surface similar to those Cassini had seen.

They found the conditions were met when they assumed the deep interior was surrounded by a very dense layer of high-pressure water ice, then a subsurface liquid-water-and-ammonia ocean and an outer water-ice shell. So the model, Mitri explained, also supports the existence of a subsurface ocean.

Each successive layer of Titan's interior is colder than the one just inside it, with the outermost surface averaging a chilly 94 Kelvin (minus 290 degrees Fahrenheit). So cooling of the moon causes a partial freezing of the subsurface liquid ocean and thickening of the outer water ice shell. It also thickens the high-pressure ice. Because the ice on the crust is less dense than the liquid ocean and the liquid ocean is less dense than the high-pressure ice, the cooling means the interior layers lose volume and the top "skin" of ice puckers and folds.

Since the formation of Titan, which scientists believe occurred around four billion years ago, the moon's interior has cooled significantly. But the moon is still releasing hundreds of gigawatts of power, some of which may be available for geologic activity. The result, according to the model, was a shortening of the radius of the moon by about seven kilometres and a decrease in volume of about one percent.

"These results suggest that Titan's geologic history has been different from that of its Jovian cousins, thanks, perhaps, to an interior ocean of water and ammonia," said Jonathan Lunine, a Cassini interdisciplinary scientist for Titan and co-author on the new paper. Lunine is currently based at the University of Rome, Tor Vergata, Italy. "As Cassini continues to map Titan, we will learn more about the extent and height of mountains across its diverse surface."

See beautiful Ontario Lacus: Cassini's guided tour

Ontario Lacus, the largest lake in the southern hemisphere of Saturn's moon Titan, turns out to be a perfect exotic vacation spot, provided you can handle the frosty, subzero temperatures and enjoy soaking in liquid hydrocarbon.

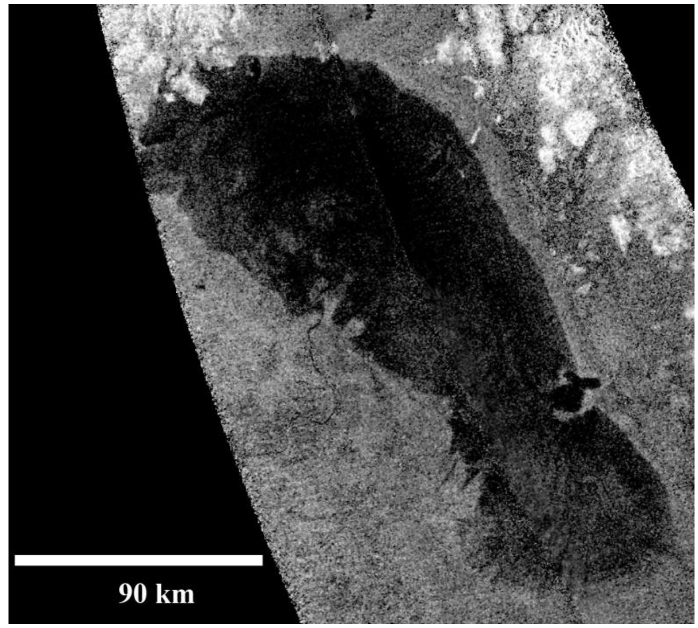
Several recent papers by scientists working with NASA's Cassini spacecraft describe evidence of beaches for sunbathing in Titan's low light, sheltered bays for mooring boats, and pretty deltas for wading out in the shallows. They also describe seasonal changes in the lake's size and depth, giving vacationers an opportunity to visit over and over without seeing the same lake twice. (Travel agents, of course, will have to help you figure out how to breathe in an atmosphere devoid of oxygen.)

Using data that give us the most detailed picture yet of a lake on another world, scientists and animators have collaborated on a new video tour of Ontario Lacus based on radar data from Cassini's Titan flybys on 22 June 2009, 8 July 2009, and 12 January 2010.

"With such frigid temperatures and meager sunlight, you wouldn't think Titan has a lot in common with our own Earth," said Steve Wall, deputy team lead for the Cassini radar team, based at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "But Titan continues to surprise us with activity and seasonal processes that look marvelously, eerily familiar."

Cassini arrived at Saturn in 2004 when the southern hemisphere of the planet and its moons were experiencing summer. The seasons have started to change toward autumn, with winter solstice darkening the southern hemisphere of Titan in 2017. A year on Titan is the equivalent of about 29 Earth years.

Titan is the only other world in our solar system known to have standing bodies of liquid on its surface. Because surface



Cassini radar view of Ontario Lacus (NASA/JPL-Caltech)

temperatures at the poles average a chilly 90 Kelvin (about minus 300 degrees Fahrenheit), the liquid is a combination of methane, ethane and propane, rather than water. Ontario Lacus has a surface area of about 15,000 square kilometres, slightly smaller than its terrestrial namesake Lake Ontario.

Cassini first obtained an image of Ontario Lacus with its imaging camera in 2004. A paper submitted to the journal Icarus by Alex Hayes, a Cassini radar team associate at the California Institute of Technology in Pasadena, and colleagues finds that the lake's shoreline has receded by about 10 kilometres. This has resulted in a liquid level reduction of about 1 metre per year over a four-year period.

The shoreline appears to be receding because of liquid methane evaporating from the lake, with a total amount of evaporation that would significantly exceed the yearly methane gas output of all the cows on Earth, Hayes said. Some of the liquid could also seep into porous ground material. Hayes said the changes in the lake are likely occurring as part of Titan's seasonal methane cycle, and would be expected to reverse during southern winter. This seasonal filling and receding is similar to what occurs at the shallow lakebed known as Racetrack Playa in Death Valley National Park, Hayes said. In fact, from the air, the topography and shape of Racetrack Playa and Ontario Lacus are quite similar, although Ontario Lacus is about 60 times larger.

"We are very excited about these results, because we did not expect Cassini to be able to detect changes of this magnitude in Titan's lakes," Hayes said. "It is only through the continued monitoring of seasonal variation during Cassini's extended mission that these discoveries have been made possible." Other parts of the Ontario Lacus' shoreline, as described in the paper published in *Geophysical Research Letters* in March 2010 by Wall, Hayes and other colleagues, show flooded valleys and coasts, further proof that the lake level has changed.

The delta revealed by Cassini radar data on the western shore of Ontario Lacus is also the first well-developed delta observed on Titan, Wall said. He explained that the shape of the land there shows liquid flowing down from a higher plain switching channels on its way into the lake, forming at least two lobes. Examples of this kind of channel switching and wave-modified deltas can be found on Earth at the southern end of

Lake Albert between Uganda and the Democratic Republic of Congo in Africa, and the remains of an ancient lake known as Megachad in the African country Chad, Wall said.

The radar data also show a smooth beach on the northwestern shore of Ontario Lacus. Smooth lines parallel to the current shoreline could be formed by low waves over time, which were likely driven by winds sweeping in from the west or southwest. The pattern at Ontario Lacus resembles what might be seen on the southeastern side of Lake Michigan, where waves sculpt the shoreline in a similar fashion.

"Cassini continues to take our breath away as it fills in the details on the surfaces of these far-off moons," said Linda Spilker, Cassini project scientist based at JPL. "It's exhilarating to ride along as it takes us on the ultimate cold-weather adventure."

Saturn's icy moon may keep oceans liquid with wobble

Saturn's icy moon Enceladus should not be one of the most promising places in our solar system to look for extraterrestrial life. Instead, it should have frozen solid billions of years ago. Located in the frigid outer solar system, it's too far from the sun to have oceans of liquid water -- a necessary ingredient for known forms of life -- on its surface.

Some worlds, like Mars or Jupiter's moon Europa, give hints that they might harbor liquid water beneath their surfaces. Mars is about 6,758 kilometres across and Europa almost 3,218 kilometres across. However, with a diameter only slightly more than 482 kilometres, Enceladus just doesn't have the bulk needed for its interior to stay warm enough to maintain liquid water underground.

With temperatures around 324 degrees below zero Fahrenheit, the surface of Enceladus is indeed frozen. However, in 2005 NASA's Cassini spacecraft discovered a giant plume of water gushing from cracks in the surface over the moon's south pole, indicating that there was a reservoir of water beneath the ice. Analysis of the plume by Cassini revealed that the water is salty, indicating the reservoir is large, perhaps even a global subsurface ocean. Scientists estimate from the Cassini data that the south polar heating is equivalent to a continuous release of about 13 billion watts of energy.

To explain this mysterious warmth, some scientists invoke radiation coupled with tidal heating. As it formed, Enceladus (like all solar system objects) incorporated matter from the cloud of gas and dust left over from our sun's formation. In the outer solar system, as Enceladus formed it grew as ice and rock coalesced. If Enceladus was able to gather greater amounts of rock, which contained radioactive elements, enough heat could have been generated by the decay of the radioactive elements in its interior to melt the body.

However, in smaller moons like Enceladus, the cache of radioactive elements usually is not massive enough to produce significant heat for long, and the moon should have soon cooled and solidified. So, unless another process within Enceladus somehow generated heat, any liquid formed by the melting of its interior would have frozen long ago.

This led scientists to consider the role of tidal heating as a way to keep Enceladus warm enough for liquid water to remain under its surface. Enceladus' orbit around Saturn is slightly oval-shaped. As it travels around Saturn, Enceladus moves closer in and then farther away. When Enceladus is closer to Saturn, it feels a stronger gravitational pull from the planet than when it is farther away. Like gently squeezing a rubber ball slightly deforms its shape, the fluctuating gravitational tug on Enceladus causes it to flex slightly. The flexing, called gravitational tidal forcing, generates heat from friction deep within Enceladus.

The gravitational tides also produce stress that cracks the surface ice in certain regions, like the south pole, and may be reworking those cracks daily. Tidal stress can pull these cracks open and closed while shearing them back and forth. As they open and close, the sides of the south polar cracks move as much as a few feet, and they slide against each other by up to a few feet as well. This movement also generates friction, which (like vigorously rubbing your hands together) releases extra heat at the surface at locations that should be predictable with our understanding of tidal stress.

To test the tidal heating theory, scientists with the Cassini team created a map of the gravitational tidal stress on the moon's icy crust and compared it to a map of the warm zones created using Cassini's composite infrared spectrometer instrument (CIRS). Assuming the greatest stress is where the most friction occurs, and therefore where the most heat is released, areas with the most stress should overlap the warmest zones on the CIRS map. "However, they don't exactly match," says Dr. Terry Hurford of NASA's Goddard Space Flight Center, Greenbelt, Md. "For example, in the fissure called the Damascus Sulcus, the area experiencing the greatest amount of shearing is about 50 kilometers (about 31 miles) from the zone of greatest heat."

Hurford and his team believe the discrepancy can be resolved if Enceladus' rotation rate is not uniform – if it wobbles slightly as it rotates. Enceladus' wobble, technically called "libration," is barely noticeable. "Cassini observations have ruled out a wobble greater than about 2 degrees with respect to Enceladus' uniform rotation rate," says Hurford. The team created a computer simulation that made maps of the surface stress on Enceladus for various wobbles, and found a range where the areas of greatest stress line up better with the observed warmest zones. "Depending on whether the wobble moves with or against the movement of Saturn in Enceladus' sky, a wobble ranging from 2 degrees down to 0.75 degrees produces the best fit to the observed warmest zones," said Hurford.

The wobble also helps with the heating conundrum by generating about five times more heat in Enceladus' interior than tidal stress alone, and the extra heat makes it likely that Enceladus' ocean could be long-lived, according to Hurford. This is significant in the search for life, because life requires a stable environment to develop.

The wobble is probably caused by Enceladus' uneven shape. "Enceladus is not completely spherical, so as it moves in its orbit, the pull of Saturn's gravity generates a net torque that forces the moon to wobble," said Hurford. Also, Enceladus' orbit is kept oval-shaped, maintaining the tidal stress, because of the gravitational tug from a neighboring larger moon Dione. Dione is farther away from Saturn than Enceladus, so it takes longer to complete its orbit. For every orbit Dione completes, Enceladus finishes two orbits, producing a regular alignment that pulls Enceladus' orbit into an oval shape. *– Bill Steigerwald , NASA Goddard Space Flight Center*

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License to Orbit: The Future of Commercial Space Travel – Joseph Pelton & Peter Marshall (Apogee Books, 2009; 97 pages). ISBN 978-1-894959-98-8

Right now, at an airfield in California's Mojave Desert, Virgin Galactic's SpaceShipTwo has begun its flight test programme, another indicator that commercial space travel is now only a few years from being a reality, after years of being something that was coming at some undefined point in the future. But Virgin Galactic is but one player in this field (albeit probably the leading one at present) – there is much more going on, as this timely book explains.

In this slim but information-packed volume, authors Pelton and Marshall give an overview of this burgeoning field and show that it's about much more than just providing joyrides for well-heeled adventure tourists. This is a brand-new business, and the sky is definitely *not* the limit.

The book begins with an overview of recent an current activities on the commercial space travel front, including the flights to the International Space Station by the likes of Dennis Tito, Anousheh Ansari and others, and the role of the Ansari X-Prize in stimulating commercial space access. They then move on to look at the billionaires who are backing this new commercial frontier – the likes of Richard Branson (Virgin), Elon Musk (SpaceX), and Robert Bigelow (Bigelow Aerospace) – and the companies in the field at the time the book was written. Almost inevitably, not all of these budding space tourism entrepreneurs will actually succeed in launching something, but it only needs a few success stories to kick-start a revolution.

Of course, once you have spacecraft then you need somewhere to launch and land them, and a number of spaceports are under development at the moment. The best-known at present is the Mojave Air and Space Port in California, where Scaled Composites, builders of SpaceShipOne and SpaceShipTwo, are based. This will soon be joined by Spaceport America in New Mexico, whose runway was recently dedicated. The authors look at these and other potential spaceports, as well as the regulatory issues surrounding such facilities.

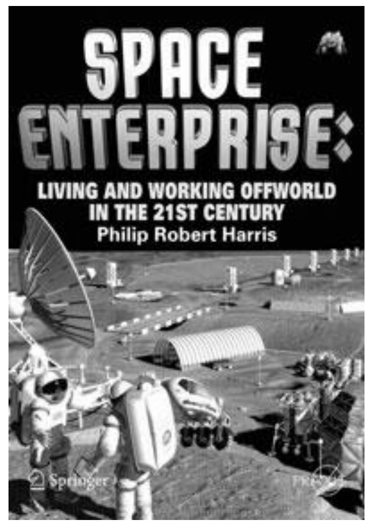
Space tourism, commercial space – call it what you like, but at the end of the day, it's a business – and like any business, it has to be profitable. In Chapter 6, Pelton and Marshall look at the business models and feasibility studies that have been carried out in this field. And if a space tourism business is to succeed, it must reduce the risk to would-be passengers as much as possible, and in Chapter 7 the authors examine the safety issues around this new industry.

Despite the optimism of entrepreneurs and designers like Richard Branson, Elon Musk and Burt Rutan, the budding commercial space industry faces many possible showstoppers, including environmental issues, regulatory issues, and even arms control issues. Chapter 8 takes a sober look at these, and the authors conclude by hoping that sanity will prevail among regulators.

In Chapter 10, the authors place space tourism in the wider context of human evolution and our desire for progress, and the challenges the new century will bring. Finally, in Chapter 11, the authors nicely round out the book with a "Top Ten" things to know about space tourism and the future of space.

Commercial space and space tourism is a rapidly evolving field, and doubtless much that the authors describe in this book will change. But if you want a concise introduction to the subject, this is as good a place to start as any.

Space Enterprise: Living and Working Offworld in the 21st Century – Philip Robert Harris (Springer-Praxis 2009, 616 pages). ISBN 978-0-387-77639-2



Given the Obama Administration's retreat from exploration through the cancellation of the Constellation programme, the concept of living and working off-world any time soon might seem like wishful thinking. Nevertheless, one day it will happen – in fact, aboard the International Space Station, it's already begun.

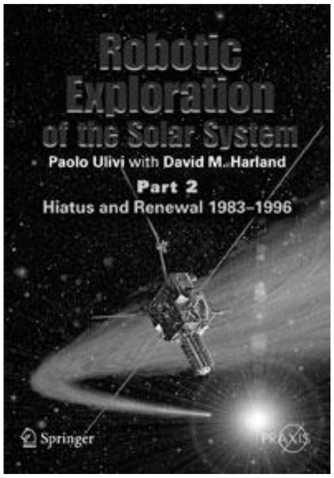
Author Harris, a behavioural psychologist and futurist, covers a lot of ground in this well-researched volume. In the opening chapter, he examines the space visions of the major space powers, which he views within the context of what he calls the "Cosmic Evolution". This leads into chapters on human space exploration and settlement in general, space habitability and the environment, and the cultural implications of space enterprise.

Harris brings his human resources expertise into play in Chapter 5, 'High-performing spacefarers', covering everything from learning from current spacefarers through to considerations of team performance, productivity, human/machine interfaces, and ergonomics and ecology.

Management and strategic planning for space activities are covered in Chapters 7-8, and in Chapter 9, Harris looks at the challenges to be faced in making off-world private enterprise a reality. The final chapter covers lunar enterprises and development, which Harris sees as the next step that the US and its international partners should undertake. However, in his view the mindset by which planners approach lunar exploration needs to change: Harris contends that such activity needs to be placed in a larger context; that there needs to be synergistic global cooperation in such an enterprise; and that it needs to be fully interdisciplinary and intersectoral in scope.

A number of appendices make up the last part of the book, providing more thought on governance issues, lunar development, health services in space, and lessons to be learned from today's space entrepreneurs.

In challenging some of the conventional thinking around space enterprise, Harris has written a thought-provoking book, and will be of interest to anyone concerned with where humanity is going in space.



Robotic Exploration of the Solar System – Part 2: Hiatus and Renewal 1983-1996 – Paolo Ulivi with David M Harland (Springer-Praxis, 2009; 535 pages). ISBN 978-0-387-78904-0

This is the second volume of a three-book series chronicling solar system exploration from the dawn of the space age to the present. The authors describe not only the missions themselves but also their design, management, and instrumentation and the political backdrop to the selection and execution of these missions – not to mention those that never flew at all.

The subtitle of this book is *"Hiatus and Renewal"*, referring to the fact that the 1980s were lean times for solar system exploration. As the authors state in their opening sentence, at the dawn of the decade the US solar system exploration programme was in some disarray. The Viking Mars missions were still operating, but no successors were planned. The Voyagers completed their reconnaissance of Jupiter and Saturn by late 1981, but again, no successors were planned other than the troubled Galileo mission, which by the time this book begins (1983) had already undergone several major redesigns.

1986 marked the return of Halley's Comet, a much-anticipated event the world over, yet the US, the world's leading space power, did not send a spacecraft to it. It was left to Europe, the Soviet Union and Japan to send a total of five spacecraft to the comet, of which ESA's Giotto was the most memorable.

Other ambitious US missions also fell by the wayside in the lean budget climate of the Reagan years, including the VOIR (Venus Orbiting Imaging Radar) and the CRAF (Comet Rendezvous/Asteroid Flyby) missions. Eventually, in the 1990s, pared-down missions would take their place, notably the Magellan mission to Venus, which made detailed radar maps of its surface.

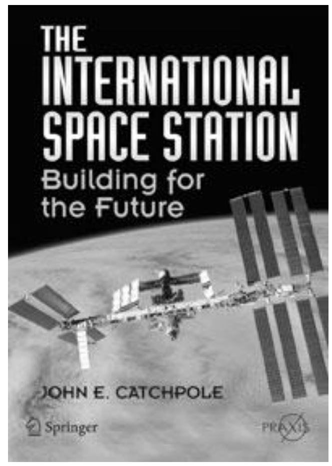
The one flagship mission that did survive was the Cassini mission to Saturn, which has been one of the most spectacular successes in the history of solar system studies, and it still going strong (see elsewhere in this issue). But that will be covered in the thir volume of this series.

The middle section of the book covers two of the big successes of the period in question, the Magellan and Galileo missions. Though not launched until 1990 and 1989, respectively, these missions fall within the period covered here because they were designed and built in the '80s, even though their missions were not carried out until the '90s.

The failed Soviet Phobos missions are also comprehensively described, as is the Mars-96 mission, also a failure. The Russian Space Agency is currently readying a new mission to Phobos for launch next year, which hopefully will have better luck.

In the last part of the book the authors look at NASA's controversial "faster, better, cheaper" philosophy, which had mixed success. The missions that did work well – Mars Global Surveyor, Mars Pathfinder and NEAR Shoemaker – are described here, but the next volume will doubtless chronicle the demise of "faster, better, cheaper" with the Mars debacles of 1999.

This is an excellent book and an excellent series. I look forward to the final volume.



The International Space Station: Building for the Future – John E Catchpole (Springer-Praxis, 2008; 389 pages). ISBN 978-0-387-78144-0

This book picks up where a previous book, *Creating the International Space Station* (2002), also written by Catchpole and co-author Harland, left off. That book covered the development and construction of the ISS and flight operations up to the end of the third crewed mission. This new volume picks up the story with the launch of STS-108 which delivered the Expedition 4 crew to the station in December 2001.

This new book covers all the subsequent flights and construction activity, including the unmanned supply flights, through to STS-120 in October 2007.

The period in question, of course, covers the period between the Columbia Shuttle disaster in February 2003, which brought ISS construction to a screeching halt, and the return to flight in July 2005 by STS-114. During this period, two-person caretaker crews kept the ISS ticking over until construction could resume. Science activities during this period were minimal, however (science activities overall have been limited during ISS construction until the crew size expanded to six).

Catchpole has given readers a good, detailed account of the missions and the construction activity, and the various problems inevitably encountered, which the crews and their support teams on Earth overcame. There are a good number of photos from the missions too.

There's also a short chapter at the end describing the Constellation programme, which is somewhat redundant now that the programme has been cancelled. Several appendices give a comprehensive list of acronyms used, and tables list all the flights to the ISS during the period, and spacewalks carried out.

All in all, a useful book, and doubtless there will be subsequent volumes that continue the story.

Reviewed by David Maclennan

Hey NASA, forgotten something?

No, this doesn't mean that budget cuts are getting so bad they're planning to launch Shuttles without the orbiter! A crawler-transporter is shown moving a mobile launcher platform with two solid rocket boosters perched on top from the Vehicle Assembly Building's (VAB) High Bay 1 to High Bay 3. Inside the VAB, the boosters will be joined to an external fuel tank in preparation for space shuttle *Endeavour*'s STS-134 mission to the International Space Station targeted to launch in February, 2011.