Liftoff

New Zealand's space exploration magazine

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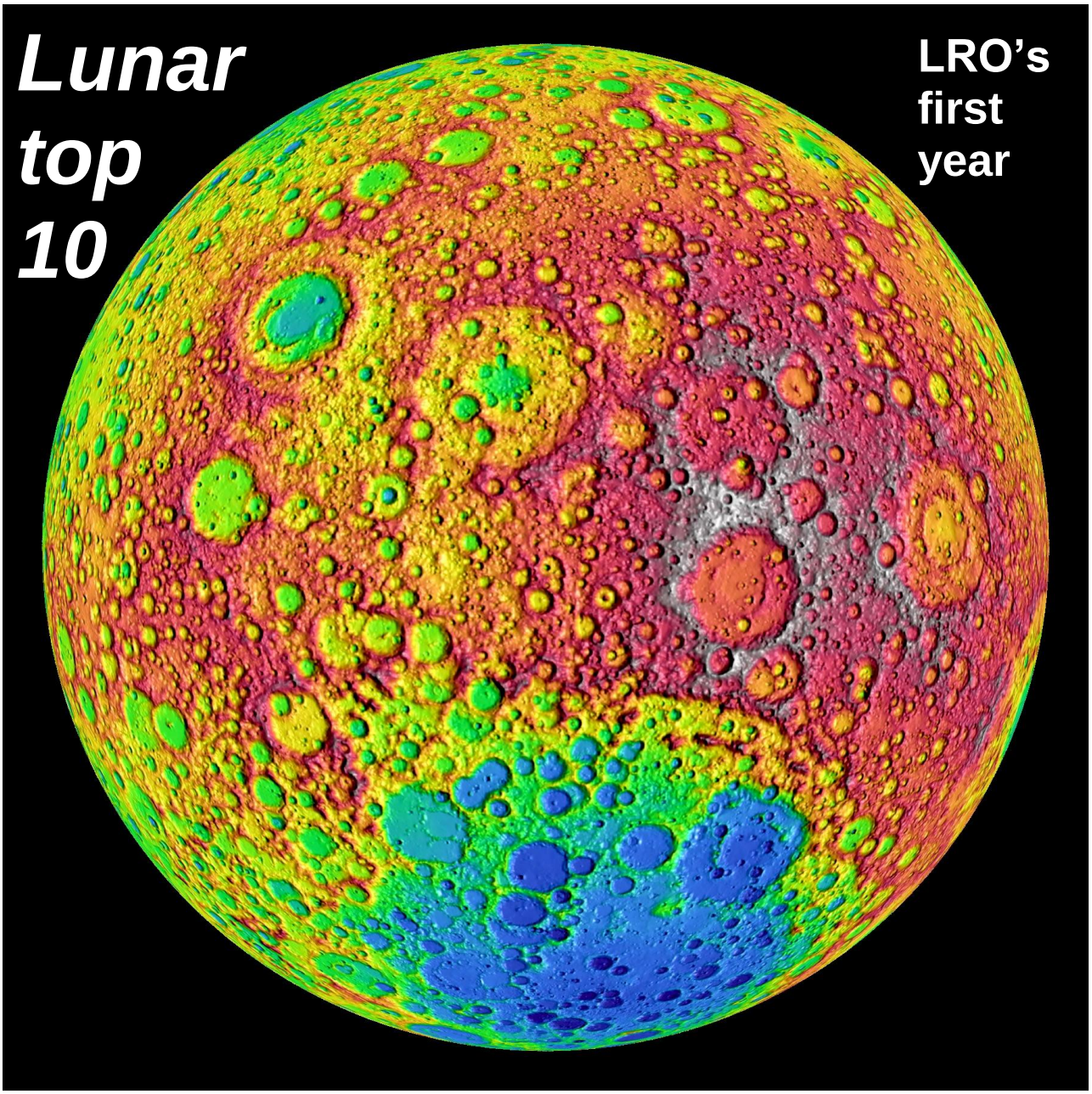

Also inside:

- **Latest Mars findings**
- **STS-132 report**

Liftoff

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Liftoff is published every two months by the New Zealand Spaceflight Association. Material for inclusion is always welcomed. Contributions must be in MS Word and should be e-mailed to the editorial address above.

Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Executive of the New Zealand Spaceflight Association.

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NZSA News and Notices

Auckland meetings

The next Auckland meetings are on **2 August** and **6 September** 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).

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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
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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: The image shows the moon's topography from the Lunar Reconnaissance Orbiter's LOLA instruments with the highest elevations up above 6,096 metres in red and the lowest areas down below -6,096 metres in blue. (NASA/Goddard).
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Editor's Corner

Since our last issue there have been further developments with President Obama's radical plans for NASA's future. In recent weeks, both the US Senate and House of Representatives have presented their authorization bills for the FY 2011 budget, and both bills present a compromise between retaining the Constellation programme in its entirety, and the Obama Administration's wishes.

Essentially, the two bills authorize development of commercial crew transportation, a key plank of the Obama proposal, but at substantially reduced funding levels. The bills also direct NASA to begin immediate work on a heavy-lift rocket capable of lofting payloads in the 75 to 100-tonne range (an Ares V-Lite, in other words), and to develop a government-owned crew vehicle for deep space missions (and presumably for space station missions also) – in other words, Orion. However, the Senate bill has this government-owned vehicle only as a backup for commercial vehicles, while the House bill envisages a vehicle that can service the ISS until commercial carriers are ready. The White House is apparently happy with the compromise, which makes you wonder just how committed the Obama Administration really is to their radical plans.

Continued operation of the ISS to at least 2010 is also authorized, as well as an additional Shuttle mission in mid-2011.

There is a big difference between the House and Senate bills when it comes to funding commercial crew-carrying vehicles. The House bill authorizes only $150 million in direct funding through 2013, with NASA providing another $100 million each year, for a total of $450 million, while the Senate bill offers $1.3 billion in commercial crew funding over the same period. Both sums are well south of the $3.3 billion the Obama Administration was asking for.

Where to now? Well, remember that these are only authorization bills, not appropriations bills. It will be up to the all-powerful appropriations committees of both houses to actually dole out the dosh, and you can expect to see a lot of horse-trading over the coming months as a compromise bill is hammered out that satisfies both the House and Senate.

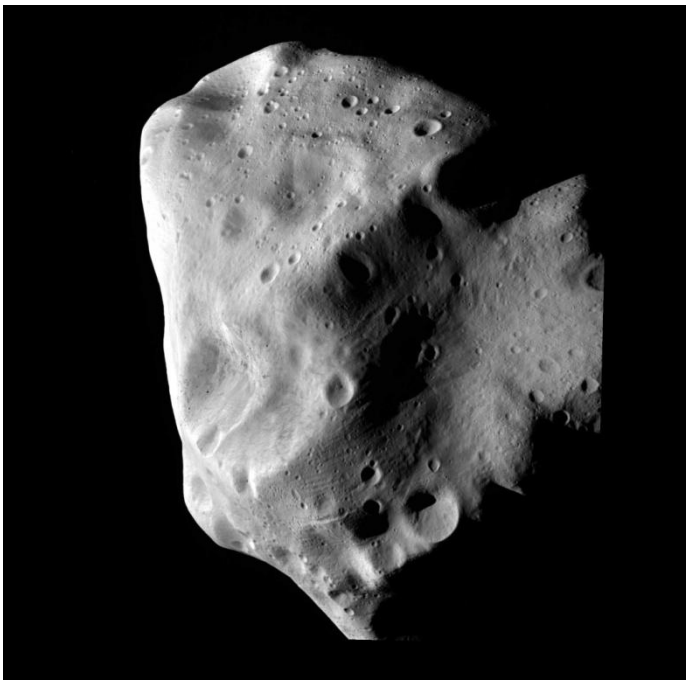
So, it would seem that while Ares I and the Altair lunar lander are definitely gone, something like Ares V and Orion will survive. That, at least, will help keep the dream alive.

-- *David Maclennan*

Rosetta triumphs at asteroid Lutetia

On 10 July 2010, ESA's Rosetta mission returned the first close-up images of asteroid Lutetia, revealing a battered world of many craters, most probably a primitive survivor from the violent birth of the Solar System. The flyby was a spectacular success with Rosetta performing faultlessly. Closest approach took place at 18:10 CEST, at a distance of 3,162 kilometres.

The images show that Lutetia is heavily cratered, having suffered many impacts during its 4.5 billion years of existence. As Rosetta drew close, a giant bowl-shaped depression stretching across much of the asteroid rotated into view. The images confirm that Lutetia is an elongated body, with its longest side around 130km. The images come from OSIRIS instrument, which combines a wide angle and a narrow angle camera. At closest approach, details down to a scale of 60 metres can be seen over the entire surface of Lutetia. "I think this is a very old object. Tonight we have seen a remnant of the Solar System's creation," says Holger Sierks, OSIRIS principal investigator, Max Planck Institute for Solar System Research, Lindau.

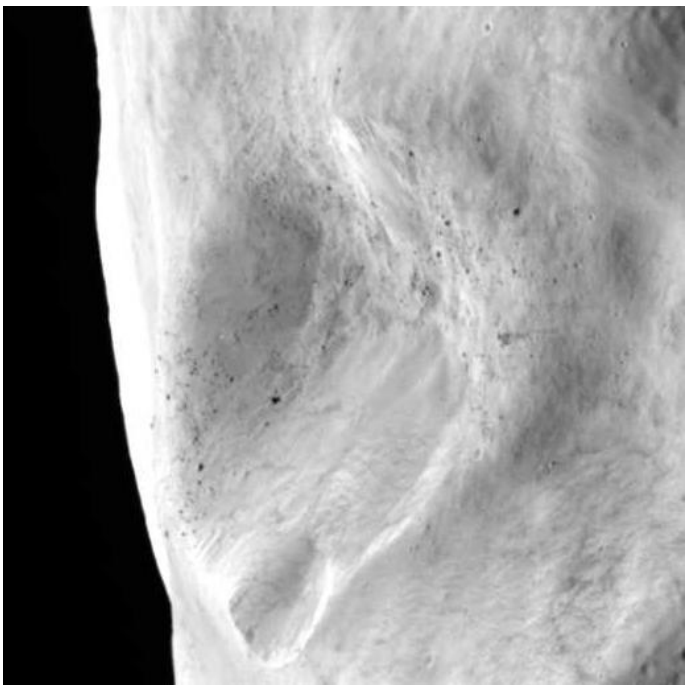


Lutetia close up (ESA)

Rosetta raced past the asteroid at 15 km/s completing the flyby in just a minute. But the cameras and other instruments had been working for hours and in some cases days beforehand, and will continue afterwards. Shortly after closest approach, Rosetta began transmitting data to Earth for processing.

Lutetia has been a mystery for many years. Ground-based telescopes have shown that the asteroid presents confusing characteristics. In some respects it resembles a C-type asteroid, a primitive body left over from the formation of the Solar System. In others, it looks like an M-type asteroid. These have been associated with iron meteorites, are usually reddish in colour and thought to be fragments of the cores of much larger objects. The new images and the data from Rosetta's other instruments will help decide, but not immediately. Compositional information will be needed for that.

Rosetta operated a full suite of instruments at the encounter, including remote sensing and in-situ measurements. Some of the payload of its Philae lander were also switched on. Together they looked for evidence of a highly tenuous atmosphere, magnetic effects, and studied the surface composition as well as the asteroid's density. They also attempted to catch any dust grains that may have been floating in space near the asteroid for on-board analysis. The results from these instruments will come in time.



A crater on Lutetia (ESA)

The flyby marks the attainment of one of Rosetta's main scientific objectives. The spacecraft will now continue to its primary target, comet Churyumov-Gerasimenko. It will rendezvous with the comet in 2014, mapping it and studying it. It will then accompany the comet for months, from near the orbit of Jupiter down to its closest approach to the Sun. In November 2014, Rosetta will deploy Philae to land on the comet nucleus. "Wunderbar!" says David Southwood, ESA Director of Science and Robotic Exploration, "It has been a great day for exploration, a great day for European science. The clockwork precision is a great tribute to the scientists and engineers in our Member States in our industry and, not least, in ESA itself. Roll on 2014 and our comet rendezvous."

But for now, analysing the Lutetia data will now become the focus for the Rosetta instrument teams. Before the flyby, Lutetia was a distant stranger. Now, thanks to Rosetta, it has become a close friend.

MESSENGER spacecraft reveals new information about Mercury

The first spacecraft designed by NASA to orbit Mercury is giving scientists a new perspective on the planet's atmosphere and evolution. Launched in August 2004, the Mercury Surface, Space Environment, Geochemistry and Ranging spacecraft, known as MESSENGER, conducted a third and final flyby of Mercury in September 2009. The probe completed a critical maneuver using the planet's gravity to remain on course to enter into orbit around Mercury next year.

Data from the final flyby has revealed the first observations of ion emissions in Mercury's exosphere, or thin atmosphere; new information about the planet's magnetic substorms; and evidence of younger volcanic activity than previously recorded. The results were reported in three papers published online in the 15 July edition of *Science Express*.

The distribution of individual chemical elements that the spacecraft saw in Mercury's exosphere varied around the planet. Detailed altitude profiles of those elements in the exosphere over the north and south poles of the planet were also measured for the first time. "These profiles showed considerable variability among the sodium, calcium, and magnesium distributions, indicating that several processes are at work and that a given process may affect each element quite differently," said Ron Vervack, lead author of one of the papers and the spacecraft's participating scientist at the Johns Hopkins University Applied Physics Laboratory (APL), in Laurel, Md.

Emission from ionized calcium in Mercury's exosphere was observed for the first time during the flyby. The emission was concentrated over a relatively small portion of the exosphere, with most of the emission occurring close to the equatorial plane.

During its first two flybys of Mercury, the spacecraft captured images confirming that the planet's early history was marked by pervasive volcanism. The spacecraft's third flyby revealed a new chapter in that history within an impact basin 289.6 kilometres in diameter that is among the youngest basins yet seen. The basin, recently named Rachmaninoff, has an inner floor filled with smooth plains that differ in color from their surroundings. These sparsely cratered plains are younger than the basin they fill and apparently formed from material that once flowed across the surface.

"We interpret these plains to be the youngest volcanic deposits we have yet found on Mercury," said Louise Prockter, one of the spacecraft's deputy project scientists at APL and lead author of one of the three papers. "Other observations suggest the planet spanned a much greater duration volcanism than previously thought, perhaps extending well into the second half of solar system history."

For the first time, the spacecraft revealed substorm-like build-up, or loading, of magnetic energy in Mercury's magnetic tail. The increases in energy measured in Mercury's magnetic tail were very large. They occurred quickly, lasting only two to three minutes from beginning to end. These increases in tail magnetic energy at Mercury are about 10 times greater than at Earth, and the substorm-like events run their course about 50 times more rapidly.

Magnetic substorms are space-weather disturbances that occur intermittently on Earth, usually several times per day, and last from one to three hours. Earth substorms are accompanied by a range of phenomena, such as the majestic auroral displays seen in the Arctic and Antarctic skies. Substorms also are associated with hazardous energetic particle events that can wreak havoc with communications and Earth-observing satellites. "The extreme tail loading and unloading observed at Mercury implies that the relative intensity of substorms must be much larger than at Earth," said James A. Slavin, a space physicist at NASA's Goddard Space Flight Center in Greenbelt, Md., and a member of the spacecraft's science team and lead author of another paper. The new measurements give fresh insight on the time duration of Mercury's substorms. Scientists await more extensive measurements when the spacecraft is in orbit.

"Every time we've encountered Mercury, we've discovered new phenomena," said Sean Solomon, the mission's principal investigator at the Carnegie Institution of Washington. "We're learning that Mercury is an extremely dynamic planet, and it has been so throughout its history. After MESSENGER has been safely inserted into orbit around Mercury next March, we'll be in for a terrific show."

In addition to flying by Mercury, the spacecraft flew past Earth in August 2005 and Venus in October 2006 and June 2007. Approximately 98 percent of Mercury's surface has been imaged by NASA spacecraft. After this spacecraft goes into orbit around Mercury in 2011 for a yearlong study of the planet, it will observe the polar regions, which are the only unobserved areas of the planet.

Was Venus once a habitable planet?

ESA's Venus Express is helping planetary scientists investigate whether Venus once had oceans. If it did, it may even have begun its existence as a habitable planet similar to Earth.

These days, Earth and Venus seem completely different. Earth is a lush, clement world teeming with life, whilst Venus is hellish, its surface roasting at temperatures higher than those of a kitchen oven. But underneath it all the two planets share a number of striking similarities. They are nearly identical in size and now, thanks to ESA's Venus Express orbiter, planetary scientists are seeing other similarities too.

"The basic composition of Venus and Earth is very similar," says Håkan Svedhem, ESA Venus Express Project Scientist. One difference stands out: Venus has very little water. Were the contents of Earth's oceans to be spread evenly across the world, they would create a layer 3 km deep. If you were to condense the amount of water vapour in Venus' atmosphere onto its surface, it would create a global puddle just 3 cm deep.

Yet there is another similarity here. Billions of years ago, Venus probably had much more water. Venus Express has certainly confirmed that the planet has lost a large quantity of water into space. It happens because ultraviolet radiation from the Sun streams into Venus' atmosphere and breaks up the water molecules into atoms: two hydrogens and one oxygen. These then escape to space.

Venus Express has measured the rate of this escape and confirmed that roughly twice as much hydrogen is escaping as oxygen. It is therefore believed that water is the source of these escaping ions. It has also shown that a heavy form of hydrogen, called deuterium, is progressively enriched in the upper echelons of Venus's atmosphere, because the heavier hydrogen will find it less easy to escape the planet's grip. "Everything points to there being large amounts of water on Venus in the past," says Colin Wilson, Oxford University, UK. But that does not necessarily mean there were oceans on the planet's surface.

Eric Chassefière, Université Paris-Sud, France, has developed a computer model that suggests the water was largely atmospheric and existed only during the very earliest times, when the surface of the planet was completely molten. As the water molecules were broken into atoms by sunlight and escaped into space, the subsequent drop in temperature

probably triggered the solidification of the surface. In other words: no oceans. Although it is difficult to test this hypothesis it is a key question. If Venus ever did possess surface water, the planet may possibly have had an early habitable phase.

Even if true, Chassefière's model does not preclude the chance that colliding comets brought additional water to Venus after the surface crystallised, and these created bodies of standing water in which life may have been able to form.

There are many open questions. "Much more extensive modelling of the magma ocean–atmosphere system and of its evolution is required to better understand the evolution of the young Venus," says Chassefière. When creating those computer models, the data provided by Venus Express will prove crucial.

Juno armoured up to go to Jupiter

NASA's Juno spacecraft, scheduled for launch next year, will be forging ahead into a treacherous environment at Jupiter with more radiation than any other place NASA has ever sent a spacecraft, except the Sun. In a specially filtered cleanroom in Denver, where Juno is being assembled, engineers recently added a unique protective shield around its sensitive electronics. "Juno is basically an armored tank going to Jupiter," said Scott Bolton, Juno's principal investigator, based at Southwest Research Institute in San Antonio. "Without its protective shield, or radiation vault, Juno's brain would get fried on the very first pass near Jupiter."

An invisible force field filled with high-energy particles coming off from Jupiter and its moons surrounds the largest planet in our solar system. This magnetic force field, similar to a less powerful one around Earth, shields Jupiter from charged particles flying off the Sun. The electrons, protons and ions around Jupiter are energized by the planet's super-fast rotation, sped up to nearly the speed of light. Jupiter's radiation belts are shaped like a huge doughnut around the planet's equatorial region and extend out past the moon Europa, about 650,000 kilometres out from the top of Jupiter's clouds.

"For the 15 months Juno orbits Jupiter, the spacecraft will have to withstand the equivalent of more than 100 million dental X-rays," said Bill McAlpine, Juno's radiation control manager, based at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "In the same way human beings need to protect their organs during an X-ray exam, we have to protect Juno's brain and heart."

The strategy? Give Juno a kind of six-sided lead apron on steroids. With guidance from JPL and the principal investigator, engineers at Lockheed Martin Space Systems designed and built a special radiation vault made of titanium for a centralized electronics hub. While other materials exist that make good radiation blockers, engineers chose titanium because lead is too soft to withstand the vibrations of launch, and some other materials were too difficult to work with.

Each titanium wall measures nearly a square metre in area, about 1 centimetre in thickness, and 18 kilograms in mass. This titanium box -- about the size of an SUV's trunk - encloses Juno's command and data handling box (the spacecraft's brain), power and data distribution unit (its heart) and about 20 other electronic assemblies. The whole vault weighs about 200 kilograms. The vault is not designed to completely prevent every Jovian electron, ion or proton from hitting the system, but it will dramatically slow down the aging effect radiation has on electronics for the duration of the mission. "The centralized radiation vault is the first of its kind," Bolton said. "We basically designed it from the ground up."

Workers place the special radiation vault for NASA's Juno spacecraft onto the propulsion module. Juno's radiation vault has titanium walls to protect the spacecraft's electronic brain and heart from Jupiter's harsh radiation environment. The whole vault, with more than 20 electronic assemblies inside, weighs about 200 kilograms. This image was taken on 19 May 2010, in the high-bay cleanroom at Lockheed Martin Space Systems in Denver, during Juno's assembly process. (NASA/JPL-Caltech/LMSS)

When NASA's Galileo spacecraft visited Jupiter from 1995 to 2003, its electronics were shielded by special components designed to be resistant to radiation. Galileo also didn't need to survive the harshest radiation regions, where Juno will operate.

But Juno isn't relying solely on the radiation vault. Scientists designed a path that takes Juno around Jupiter's poles, spending as little time as possible in the sizzling radiation belts around Jupiter's equator. Engineers also used designs for electronics already approved for the Martian radiation environment, which is harsher than Earth's, though not as harsh as Jupiter's. Parts of the electronics were made from tantalum, or tungsten, another radiation-resistant metal. Some assemblies also have their own mini-vaults for protection. Packing the assemblies next to each other allows them to shield their neighbors. In addition, engineers wrapped copper and stainless steel braids like chain mail around wires connecting the electronics to other parts of the spacecraft.

JPL tested pieces of the vault in a radiation environment similar to Jupiter's to make sure the design will be able to handle the stress of space flight and the Jupiter environment, McAlpine said. In a special lead-lined testing tub there, they battered pieces of the spacecraft with gamma rays from radioactive cobalt pellets and analyzed the results for Juno's expedition.

The vault was lifted onto Juno's propulsion module on 19 May at Lockheed Martin's high-bay cleanroom. It will undergo further testing once the whole spacecraft is put together. The assembly and testing process, which also includes installing solar panels for the first-ever solar-powered mission to Jupiter,

is expected to last through next spring. Juno is expected to launch in August 2011.

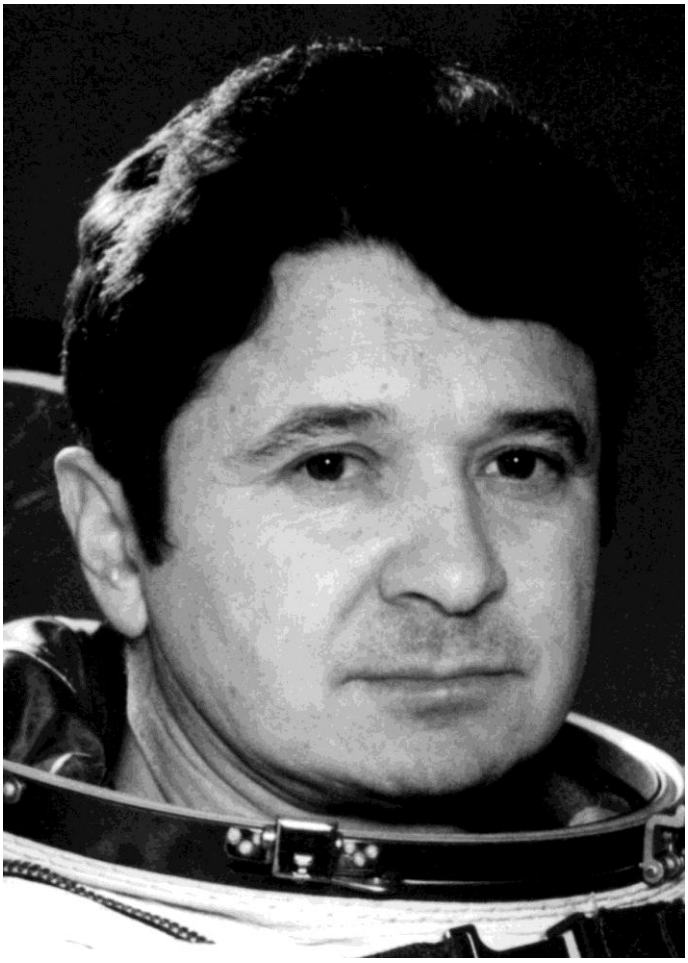
"The Juno assembly is proceeding well," said Tim Gasparrini, Lockheed Martin program manager. "We have a number of the flight and test unit spacecraft avionics components installed into the radiation vault for system testing and we have also just installed the first instrument, the microwave radiometer."

More information about Juno is online at **http://www.nasa.gov/juno** .

Cosmonaut Leonid Kizim dies at 68

Soviet cosmonaut Leonid Kizim, who in 1986 commanded the only mission in history to visit two space stations in one flight, including the first crewed flight to Mir, died on Monday 14 June, according to Russia's federal space agency Roscosmos. He was 68.

Over three space flights, Kizim spent over a year in orbit. Born on 5 August 1941, in Krasnyi Lyman in the Ukraine, Leonid Denisovich Kizim graduated as a pilot in 1963 from the Chernigov Lenin Komsomol Higher Air Force and flew as a test pilot and parachutist before being selected as a cosmonaut in October 1965.



Leonid Kizim

Kizim had to wait until November 1980 to make his first space flight, as a member of the Soyuz T-3 crew together with Oleg Makarov and Gennady Strekalov, flying a 13-day maintenance flight to Salyut 6 as the station's 13th resident crew. This was the Soviet Union's first three-man crew since the ill-fated Soyuz 11 mission in 1971.

Kizim's next mission was Soyuz T-10, launched on 8 February 1984 to the Salyut 7 space station. Kizim, Vladimir Solovyov and Oleg Atkov spent 237 days in space, setting a record for the longest space flight. During the mission Kizim and Solovyov performed a record six spacewalks to repair a fuel line that ruptured the previous year and install a new set of solar arrays on the station.

Kizim's third and final space flight began on 13 March 1986, when he and Solovyov launched on Soyuz T-15, becoming the first crew to visit the newly-launched Mir space station, which then comprised its core module only. Kizim and Solovyov spent 51 days configuring the module and unloading two unmanned Progress cargo vehicles that arrived during their stay.

Departing Mir on 5 May, Kizim and Solovyov piloted Soyuz T-15 to a rendezvous and docking with the ageing Salyut 7, spending a further 50 days aboard the station. Aboard Salyut 7 the two cosmonauts performed a pair of spacewalks, retrieved experiments that were left by the previous crew members and tested the deployment and retraction of a 15.2-metre "girder constructor" device. Kizim and Solovyov also repaired Salyut 7's heat, power and environmental control systems.

On June 26, Kizim and Solovyov flew Soyuz T-15 back to Mir and transferred nearly 408 kg of hardware from the Salyut 7 to the new outpost. After spending a further 20 days aboard Mir making Earth observations, Kizim and Solovyov returned to Earth.

At the time of his passing, Kizim's total time in space was 374 days, 17 hours and 56 minutes, placing him 21st on the list of astronaut and cosmonaut flight durations.

Research suggests water content of Moon interior underestimated

Recent research suggests that the volume of water molecules locked inside minerals in the Moon's interior could exceed the amount of water in the Great Lakes here on Earth. Scientists at the Carnegie Institution's Geophysical Laboratory in Washington, along with other scientists across the US, determined that the water was likely present very early in the Moon's formation history as hot magma started to cool and crystallize. This finding means water is native to the Moon.

"For over 40 years we thought the Moon was dry," said Francis McCubbin of Carnegie and lead author of the report published in the *Proceedings of the National Academy of Sciences*. "In our study we looked at hydroxyl, a compound with an oxygen atom bound with hydrogen, and apatite, a water-bearing mineral in the assemblage of minerals we examined in two Apollo samples and a lunar meteorite."

McCubbin's team utilized tests which detect elements in the parts per billion range. Combining their measurements with models that characterize how the material crystallized as the Moon cooled during formation, they found that the minimum water content ranged from 64 parts per billion to 5 parts per million. The result is at least two orders of magnitude greater than previous results from lunar samples that estimated water content of the Moon to be less than 1 parts per billion.

"In this case, when we talk about water on the Moon, we mean water in the structural form hydroxyl," said Jim Green, director of the Planetary Science Division at NASA Headquarters in Washington. "This is a very minor component of the rocks that make up the lunar interior."

The origin of the Moon is now commonly believed to be the result of a Mars-sized object that impacted the Earth 4.5 billion

years ago. This impact put a large amount of material into Earth's orbit that ultimately compacted to form the Moon. The lunar magma ocean that is thought to have formed at some point during the compacting process, began to cool. During this cooling, water either escaped or was preserved as hydroxyl molecules in the crystallizing minerals.

Previous studies found evidence of water both on the lunar surface and inside the Moon by using respectively, remote sensing data from the Indian spacecraft Chandrayaan-1 and other lunar sample analysis. Carnegie researchers looked within crystalline rocks called KREEP (K for potassium; REE, for rare Earth elements; and P for phosphorus). These rocks are a component of some lunar impact melt and basaltic rocks. "Since water is insoluble in the main silicates that crystallized, we believed that it should have concentrated in those rocks," said Andrew Steele of Carnegie and co-author of the report. "That's why we selected KREEP to analyze."

The identification of water from multiple types of lunar rocks that display a range of incompatible trace element signatures indicates that water may be at low concentrations but ubiquitous within the Moon's interior, potentially as early as the time of lunar formation and magma ocean crystallization.

"It is gratifying to see this proof of the hydroxyl contents in lunar apatite," said lunar scientist Bradley Jolliff of Washington University in St. Louis. "The concentrations are very low and, accordingly, they have been until recently nearly impossible to detect. We can now finally begin to consider the implications – and the origin – of water in the interior of the Moon."

The research was funded by the NASA Astrobiology, Mars Fundamental Research, and the Lunar Advanced Science and Exploration Research programs in NASA's Planetary Division in Washington.

As the Sun awakens, NASA keeps a wary eye on space weather

Earth and space are about to come into contact in a way that's new to human history. To make preparations, authorities in Washington DC held a meeting in June: the Space Weather Enterprise Forum. Richard Fisher, head of NASA's Heliophysics Division, explains what it's all about:

"The sun is waking up from a deep slumber, and in the next few years we expect to see much higher levels of solar activity. At the same time, our technological society has developed an unprecedented sensitivity to solar storms. The intersection of these two issues is what we're getting together to discuss."

The National Academy of Sciences framed the problem two years ago in a landmark report entitled *Severe Space Weather Events – Societal and Economic Impacts*. It noted how people of the 21st century rely on high-tech systems for the basics of daily life. Smart power grids, GPS navigation, air travel, financial services and emergency radio communications can all be knocked out by intense solar activity. A century-class solar storm, the Academy warned, could cause twenty times more economic damage than Hurricane Katrina.

Much of the damage can be mitigated if managers know a storm is coming. Putting satellites in 'safe mode' and disconnecting transformers can protect these assets from damaging electrical surges. Preventative action, however, requires accurate forecasting – a job that has been assigned to NOAA (National Oceanic and Atmospheric Administration).

"Space weather forecasting is still in its infancy, but we're making rapid progress," says Thomas Bogdan, director of NOAA's Space Weather Prediction Center in Boulder, Colorado. Bogdan sees the collaboration between NASA and NOAA as key. "NASA's fleet of heliophysics research spacecraft provides us with up-to-the-minute information about what's happening on the sun. They are an important complement to our own GOES and POES satellites, which focus more on the near-Earth environment."

Among dozens of NASA spacecraft, he notes three of special significance: STEREO, SDO and ACE. STEREO (Solar Terrestrial Relations Observatory) is a pair of spacecraft stationed on opposite sides of the sun with a combined view of 90% of the stellar surface. In the past, active sunspots could hide out on the sun's farside, invisible from Earth, and then suddenly emerge over the limb spitting flares and coronal mass ejections (CMEs). STEREO makes such surprise attacks impossible.

SDO (the Solar Dynamics Observatory) is the newest addition to NASA's fleet. Just launched in February 2010, it is able to photograph solar active regions with unprecedented spectral, temporal and spatial resolution. Researchers can now study eruptions in exquisite detail, raising hopes that they will learn how flares work and how to predict them. SDO also monitors the sun's extreme UV output, which controls the response of Earth's atmosphere to solar variability.

Bogdan's favorite NASA satellite, however, is an old one: the Advanced Composition Explorer (ACE) launched in 1997. "Where would we be without it?" he wonders. ACE is a solar wind monitor. It sits upstream between the sun and Earth, detecting solar wind gusts, billion-ton CMEs, and radiation storms as much as 30 minutes before they hit our planet. "ACE is our best early warning system," says Bogdan. "It allows us to notify utility and satellite operators when a storm is about to hit."

NASA spacecraft were not originally intended for operational forecasting – "but it turns out that our data have practical economic and civil uses," notes Fisher. "This is a good example of space science supporting modern society."

2010 marks the 4th year in a row that policymakers, researchers, legislators and reporters have gathered in Washington DC to share ideas about space weather. This year, forum organizers plan to sharpen the focus on critical infrastructure protection. The ultimate goal is to improve the nation's ability to prepare, mitigate, and respond to potentially devastating space weather events.

"I believe we're on the threshold of a new era in which space weather can be as influential in our daily lives as ordinary terrestrial weather." Fisher concludes. "We take this very seriously indeed." *– Dr Tony Phillips, Science @ NASA*

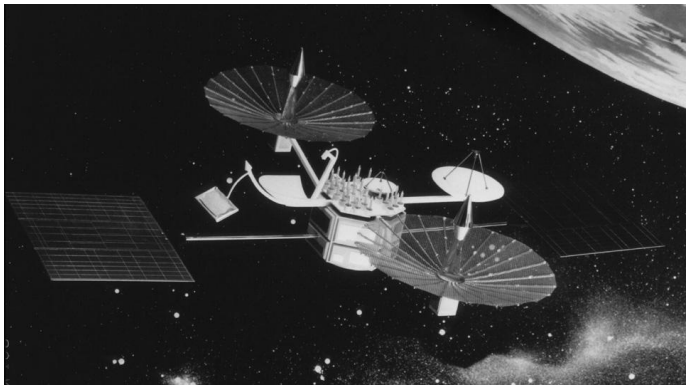
NASA retires first data relay satellite after stellar career

After a long and successful career providing communications support, NASA's groundbreaking Tracking and Data Relay Satellite (TDRS) 1 is retiring. On 27 June, NASA shut down the satellite that launched into orbit during space shuttle Challenger's maiden voyage (STS-6) in April 1983. From 1983 to 1998, TDRS-1 provided NASA with the ability to communicate with other satellites in orbit. NASA reassigned TDRS-1 in 1998 to support the National Science Foundation's (NSF) U.S. Antarctic Program and others on scientific, educational and operational endeavors.

TDRS-1 worked with eight additional satellites to relay data and communications from more than 15 customers, including the NSF, the Hubble Space Telescope, the shuttle and the International Space Station. The TDRS system provides the capability not only to send

commands and receive data, but also to navigate and talk with crews in orbit.

"TDRS-1 paved the way for this incredible space communications system," said Bill Gerstenmaier, associate administrator for NASA's Space Operations Mission Directorate. "The remaining TDRS satellites, and the new satellites that will be online within three years, will carry on these critical capabilities for many NASA missions, including science and human spaceflight."



The Tracking and Data Relay Satellite ((NASA)

TDRS-1 was the first satellite used to support launches from NASA's Kennedy Space Center in Florida in the early 1990s, returning real-time telemetry. It eliminated a dead zone over the Indian Ocean where there previously was no communication, providing full coverage for the space shuttle and low-Earth orbiting satellites.

TDRS-1 proved helpful during a 1999 medical emergency at the NSF's Antarctic Amundsen-Scott South Pole Station. The satellite's high-speed Internet connectivity allowed personnel to conduct telemedicine conferences. Doctors in the United States aided Dr. Jerri Nelson, who had breast cancer, in performing a self-biopsy and administering chemotherapy. Later, in 2002, doctors used TDRS-1 to perform another telemedicine conference with the station to assist in knee surgery for a meteorologist.

Because of its orbit, the satellite was able to link the North and South Poles and relayed the first pole-to-pole phone call. TDRS-1 also transmitted the first internet connection and live webcast from the North Pole and supported the first global television event from the South Pole Station - a worldwide television broadcast to commemorate the beginning of the year 2000.

TDRS-1 was instrumental in supporting innovative astronomy and astrophysics research programs at the South Pole Station, including the one-of-a-kind IceCube Neutrino Observatory and the South Pole Radio Telescope. The satellite transmitted gigabytes of science research data to university researchers worldwide on a daily basis.

The first six TDRS satellites were built by TRW Inc. (now Northrop Grumman Corp.). Boeing Space and Intelligence Systems also built three TDRS satellites. NASA plans to launch two additional satellites into the Tracking and Data Relay Satellite System by 2013. On 13 June 2010, the satellite arrived at its final destination, approximately 36,202.5 kilometres above the Earth. After the orbit is stabilized and the remaining fuel removed, NASA planned to shut down the satellite on 27 June.

Dawn spacecraft fires past record for speed change

Deep in the heart of the asteroid belt, on its way to the first of the belt's two most massive inhabitants, NASA's ion-propelled Dawn spacecraft has eclipsed the record for velocity change produced by a spacecraft's engines. The previous standard-bearer for velocity change, NASA's Deep Space 1, also impelled by ion propulsion, was the first interplanetary spacecraft to use this technology. The Deep Space 1 record fell on 5 June, when the Dawn spacecraft's accumulated acceleration over the mission exceeded 4.3 kilometres per second.

"We are using this amazing ion-engine technology as a stepping-stone to orbit and explore two of the asteroid belt's most mysterious objects, Vesta and Ceres," said Robert Mase, Dawn project manager from NASA's Jet Propulsion Laboratory in Pasadena, Calif.

A spacecraft's change in velocity refers to its ability to change its path through space by using its own rocket engines. This measurement of change begins only after the spacecraft exits the last stage of the launch vehicle that hurled it into space.

To get to where it is in both the record books and the asteroid belt, the Dawn spacecraft had to fire its three engines, one at a time, for a cumulative total of 620 days. In that time, it has used less than 165 kilograms of xenon propellant. Over the course of its eight-plus-year mission, Dawn's three ion engines are expected to accumulate 2,000 days of operation – 5.5 years of thrusting – for a total change in velocity of more than 38,620 kilometres per hour.

"I am delighted that it will be Dawn that surpasses DS1's record," said Marc Rayman, chief engineer for the Dawn mission and a previous project manager for Deep Space 1."It is a tribute to all those involved in the design and operations of this remarkable spacecraft."

At first glance, Dawn's pedal-to-the-metal performance is a not-so-inspiring 0-to-97 kilometres per hour in four days. But due to its incredible efficiency, it expends only 1,048.9 grammes of xenon propellant during that time. Then take into consideration that after those four days of full-throttle thrusting, it will do another four days, and then another four. By the end of 12 days, the spacecraft will have increased its velocity by more than 290 kilometres per hour, with more days and weeks and months of continuous thrusting to come. In one year's time, Dawn's ion propulsion system can increase the spacecraft's speed by 8,850 kilometres per hour, while consuming the equivalent of only 60.6 litres of fuel.

"This is a special moment for the spacecraft team," said Dawn's principal investigator, Chris Russell of the University of California Los Angeles. "In only 407 days, our minds will be on another set of records, the data records that Dawn will transmit when we enter Vesta orbit."

Dawn's 4.8-billion-kilometre odyssey includes exploration of asteroid Vesta in 2011 and 2012, and the dwarf planet Ceres in 2015. These two icons of the asteroid belt have been witness to much of our solar system's history. By using the same set of instruments at two separate destinations, scientists can more accurately formulate comparisons and contrasts. Dawn's science instrument suite will measure shape, surface topography and tectonic history, elemental and mineral composition, as well as seek out water-bearing minerals. In addition, the way the Dawn spacecraft orbits both Vesta and Ceres will be used to measure the celestial bodies' masses and gravity-fields.

STS-132 Mission Report

By Ed Case

Space shuttle Atlantis is featured in this image photographed by an Expedition 23 crew member on the International Space Station soon after the shuttle and station began their post-undocking relative separation. (NASA)

Atlantis crew:

Kenneth T Ham (Commander; 2nd flight)
Dominic A. Antonelli (Pilot; 2nd flight
Michael T. Good (Mission Specialist; 2nd flight)
Garrett E. Reisman (Mission Specialist; 2nd flight)
Piers J. Sellers (Mission Specialist, ESA; 3rd flight)
Stephen G. Bowen (Mission Specialist; 2nd flight)

Notes: 132nd shuttle flight, 32nd for Atlantis, 34th to the ISS. This was the last mission for Atlantis in the shuttle program. However, it will be readied for another mission if needed.

On Friday 14 May, *Atlantis* and its six crewmembers lifted off at 1:20 p.m. at Kennedy Space Center in Florida to begin the STS-132 mission. After reaching orbit, the crew checked out all the systems and opened the payload door. Because of the schedule for this mission, the crew went to bed in the early evening. When they awoke on Saturday 15 May, Good and Bowen spent several hours checking out spacesuits and preparing them for transfer to the station's Quest airlock, where the mission's spacewalks would originate from.

Before the thermal protection system checkout began, the crew encountered a problem with a cable snagging the pan-tilt unit on the end of the 15-metre orbiter boom sensor system. It is the mount for sensor package1, the Laser Dynamic Range Imager and the intensified video camera. As a result, mission control decided to switch to sensor package 2, a laser camera and a digital camera mounted near the end of the boom. That system, which requires daylight or another light source, has a resolution of a few millimeters and can scan at about 6.3 cm per second. Its images of the right wing, the nose cap and much of the left with were sent to the ground for detailed analysis. Additional images would be available after the rendezvous pitch manoevre and from station assets. The change was not expected to affect docking.

Managers in Mission Control decided not to perform a debris avoidance maneuver that would have taken place later in the day. Flight controllers had been carefully monitoring a piece of orbital debris that had threatened to come near the station on Sunday, but updated tracking information showed the object remained at a safe distance.

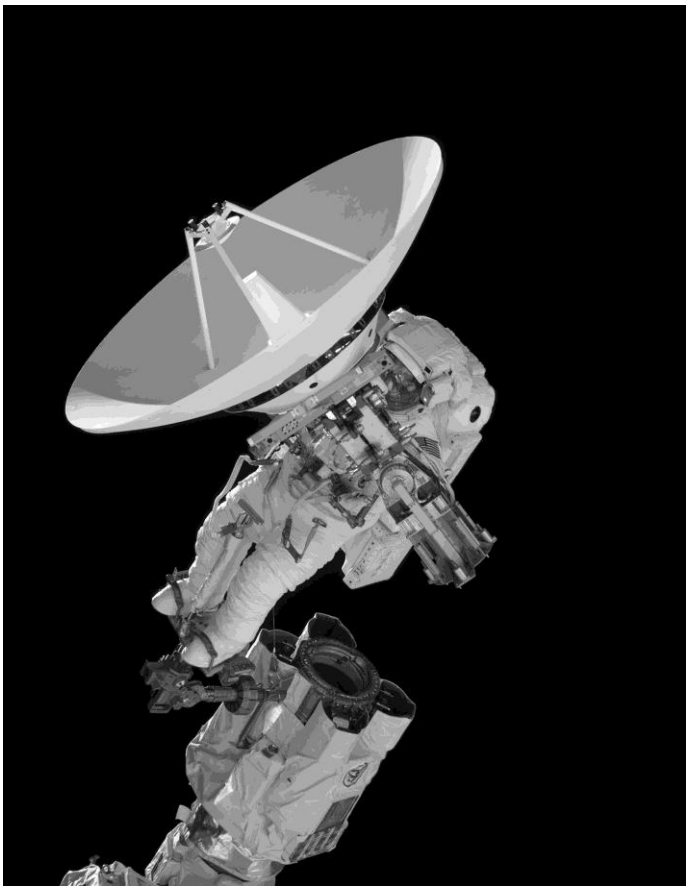
At 9:28 a.m. Sunday 16 May, *Atlantis* docked with the International Space Station, as the crafts were 353.9 kilometres above the far South Pacific Ocean. The shuttle approach and docking went smoothly. Commander Ken Ham flew the shuttle through the rendezvous pitch maneuver, the backflip to enable the three station crewmembers in the Zvezda service module to take photos of *Atlantis*' thermal protection system. Flight Engineers Tracy Caldwell Dyson, T.J. Creamer, both U. S. astronauts, and Russian station Commander Oleg Kotov used cameras with 400 and 800 mm lenses. Hatches between the two crafts were opened at 11:18 a.m. After a brief welcoming ceremony by the station crew, *Atlantis*' astronauts got the standard station safety briefing. Then the shuttle crew promptly went to work with initial transfers of equipment and supplies. Spacesuits were among the first items to go to the station.

The piece of orbital debris that had been followed closely by flight controllers passed the station at a distance of more than 16 kilometres just over an hour after docking.

Later in the day Sellers and Caldwell Dyson used the station's robotic arm to transfer a cargo carrier from *Atlantis* to the arm's mobile base system to prepare for the spacewalks, and Mission Specialists Garrett Reisman and Stephen Bowen spent the night in the Quest Airlock to prepare for Monday's spacewalk.

First spacewalk

On Monday 17 May the mission's first spacewalk began at 6:54 a.m. CDT when Reisman and Bowen switched their suits to battery power. The spacewalk's goals included installing a second antenna for high-speed Ku band transmissions and adding a spare parts platform to Dextre, a two-armed extension for the station's robotic arm. After setup they removed the antenna's nearly 2-7-metre-long boom from the cargo carrier and Reisman, on the end of station's Canadarm2, carried it high above the station and then to the Z1 truss. Intravehicular officer and *Atlantis* pilot Tony Antonelli coached them through their activities. Mission Specialist Piers Sellers and station flight Engineer Tracy Caldwell Dyson operated the arm.



Anchored to a Canadarm2 mobile foot restraint, NASA astronaut Garrett Reisman, STS-132 mission specialist, carries a second antenna for high-speed Ku-band transmissions in the mission's first session of extravehicular activity. (NASA)

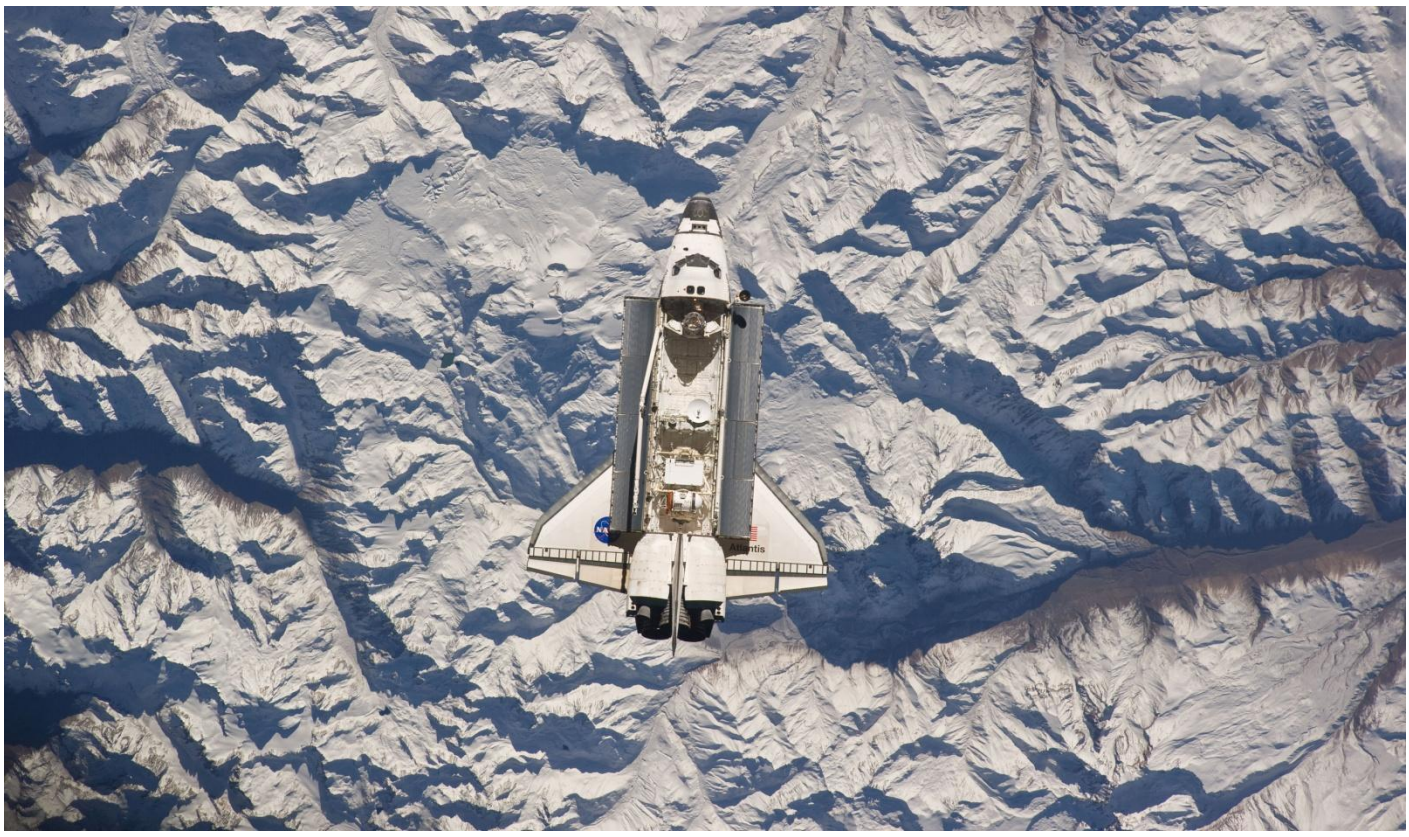
After the two attached and connected the boom, Reisman made a return trip to the cargo carrier on the end of the arm, sometimes fully extended in a windshield-wiper-like manoeuvre. He removed the 1.8-metre-diameter dish antenna, and then held it as the arm took him back to the Z1 truss. There he and Bowen installed it, then refastened bolts and hooked up balky connections. Because of a gap that remained between the dish and the boom, the two did not remove dish launch locks, to keep it from rotating. They used a tether to strap the spare antenna's dish and boom together.

While Bowen recharged his suit's oxygen supply, Reisman removed the spare-parts platform from the cargo carrier, took it to Dextre atop the U.S. laboratory Destiny, and installed it.

More than six hours after the start of the spacewalk, Reisman and Bowen both said they were willing to work beyond the 6.5 hours planned for the activity. Bowen moved on the

(Above) Atlantis docked to the ISS, with the Russian-built Rassvet module visible in its payload bay. (Below) In the grasp of the station's robot arm, Rassvet is attached to the Earth-facing port of the Zarya module of the International Space Station. (NASA)

(Above) Expedition 23 crewmembers Oleg Kotov and Tracy Caldwell Dyson with fresh fruit and vegetables brought to the ISS by the STS-132 crew. (Below) The Andes Mountains provide a backdrop for Atlantis during its approach to the ISS. (NASA)



cargo carrier to loosen bolts on the six 170-kg batteries while Reisman did cleanup work on Canadarm2, removing a foot restraint and retrieving an adapter from the arm's latching end effector. As the spacewalkers were wrapping up their work, Mission Control reported that the shuttle's arm had successfully grappled the Russian Mini-Research Module-1 in Atlantis' cargo bay. The 6-metre module, named Rassvet, would be installed on the next spacewalk. The astronauts spent 7 hours and 25 minutes on this spacewalk.

A new module for ISS

On Tuesday 18 May, the *Atlantis* astronauts used the station's Canadarm2 to connect the new Rassvet module just after sunrise as the combined spacecraft flew over Argentina. Atlantis Commander Ken Ham and Pilot Tony Antonelli used the shuttle's robotic arm to lift Rassvet from the cargo bay to hand it off to the station arm. Then they moved that arm into position for its cameras to monitor the move.

Mission Specialist Garrett Reisman guided the docking probe of Rassvet, at the end of the robotic arm, into the receptacle on the Earth-facing port on the Zarya module. There was about 1 millimeter of clearance on either side of the probe. Capcom Steve Swanson in the station flight control room radioed up that Reisman had made "a hole in one." Mission Specialist Piers Sellers operated a computer linked to the module, also known as Mini-Research Module 1, and the Russian part of the station. The interface between Rassvet, weighing with its cargo a total of 8,054 kilograms, and Zarya was sealed at 7:50 a.m. CDT, about three hours after the module had been lifted from *Atlantis*' cargo bay.

The new module will host a variety of biotechnology and biological science experiments and fluid physics and educational research. Rassvet contains a pressurized compartment with eight workstations, including a glove box to deep experiments separated from the in-cabin environment; two incubators to accommodate high – low-temperature experiments; and a special platform to protect experiments from onboard vibrations. Attached to its exterior is an experiment airlock that will be used on another Russian laboratory module set for delivery in 2012.

After the midday meal, Reisman and sellers used Canadarm2 to unberth the orbiter boom sensor system from the sill of *Atlantis*' cargo bay. They handed it off to the shuttle arm, again operated by Ham and Antonelli, which itself could not reach the arm extension's grapple fixture while docked. The OBSS would be used to monitor activities during the mission's second spacewalk. Meanwhile, Good and Bowen configured tools and prepared spacesuits for the next spacewalk before spending the night in the Quest airlock.

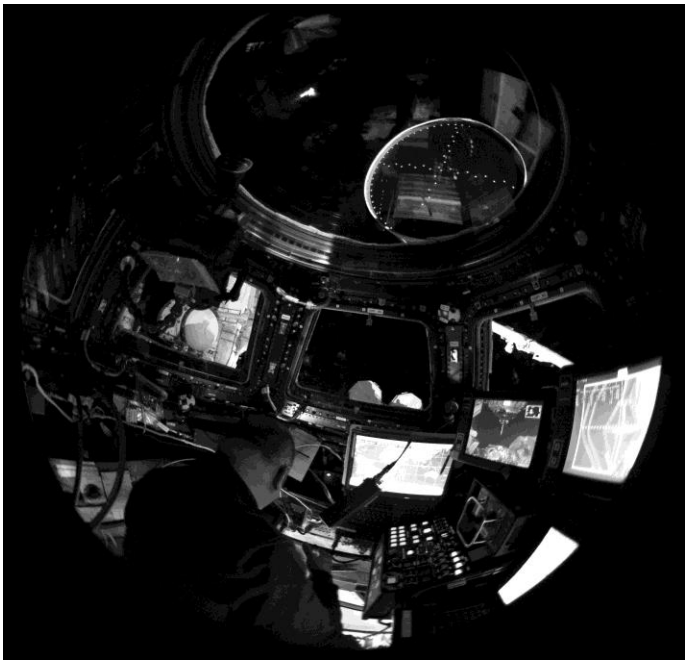
At 1:20 p.m., Ham, Reisman, Sellers, station Commander Oleg Kotov, and Flight engineers Alexander Skvortsov and Tracy Caldwell Dyson took a break to field questions from reporters from MSNBC, Fox News and CNN.

Second spacewalk

On Wednesday 19 May, the second spacewalk – the fifth for Bowen and the third for Good – got under way at 5:38 a.m. CDT, more than 25 minutes ahead of the scheduled start that already had been moved up 30 minutes. One reason for the early scheduled start was the addition of a task to remove a cable snag in the orbiter boom sensor system's pan and tilt mechanism. Bowen accomplished that task in less than 30 minutes, while Good began work with the batteries. After testing, Mission Control declared the heat shield inspection mechanism fully functional.

Atlantis Pilot Tony Antonelli was the intravehicular officer, providing guidance and advice to the spacewalkers. Mission Specialists Reisman and Piers Sellers operated the station's Canadarm2. The spacewalkers took each battery from the cargo carrier held by the station arm, installed it in a space from which they had removed an old battery, then bolted the old battery into the cargo carrier for return to Earth. The fourth old battery was stowed temporarily on the truss. It will be taken to the cargo carrier during the Friday spacewalk.

After the battery work and cleanup of the area, the spacewalkers moved on to the new backup Ku band antenna on the Z1 truss. They tightened bolts holding its dish to its boon, closing a gap left there after Monday's spacewalk. They removed launch latches, leaving the antenna ready to operate. That done, they cleaned up the area and returned to the Quest airlock. The spacewalk officially ended at 12:47 p.m., when the repressurization began. The spacewalk took 7 hours and 9 minutes.



Like a scene from '2001' in this "fish-eye" lens view, NASA astronaut Garrett Reisman, STS-132 mission specialist, is surrounded by windows and computers in the International Space Station's Cupola during his mission's flight day five activities. (NASA)

On Thursday 20 May the hatches between the International Space Station and its new Russian Rassvet module were opened for the first time at 5:52 a.m. CDT. Crewmembers wore eye and breathing protection as a standard precaution when entering a new module. Station Commander Oleg Kotov initially reported that the inside of the module looked clean, but as unpacking activities ramped up reported some metal filings drifting inside the new module. Flight controllers in Houston and Moscow were working with the crew to develop a technique for safely removing the floating debris.

Atlantis Commander Ken Ham, Pilot Tony Antonelli and Sellers transferred equipment, supplies and experiments between the shuttle and station. Mike Good and Garrett Reisman prepared for their Friday spacewalk, configuring tools and preparing suits and the airlock. Intravehicular officer Antonelli, who choreographed the flight's first two spacewalks, and Steve Bowen, who participated in the second spacewalk, helped with preparations.

Ham, Antonelli, Sellers and station Flight Engineer Tracy Caldwell Dyson answered questions from representatives of Associated Press, FOX News Radio and CBS News. Just

before lunch, the crew talked with spacewalk experts on the ground. The crew got about four hours of afternoon free time, until the spacewalk procedure review near the end of their workday.

Third spacewalk

On Friday 21 May, the mission's third spacewalk began with the installation of a backup ammonia coolant jumper between the Port 4 and 5 truss segments. It provides a readily available path for an ammonia recharge should one become necessary. Then the two brought a power and data grapple fixture from *Atlantis*' cargo bay into the station. Those tasks were added to the spacewalk after Good and Mission Specialist Steve Bowen were able to replace four batteries, one more than planned, during their Wednesday spacewalk.

Then the spacewalkers moved farther out the port truss to turn their attention to the batteries. They removed and replaced the fifth and sixth old batteries and returned each to the nearby cargo carrier at the end of the station arm. Finally they took the last battery removed Wednesday from its temporary stowage position on the truss and moved it to the cargo carrier. The station arm moved the cargo carrier with the old batteries to a temporary stowage position, to await its return to *Atlantis*' cargo bay. The batteries, on the Port 6 truss, store power from the station's solar arrays for use during the 16 nights the station experiences each 24 hours.

Good and Reisman moved to the cargo bay where they removed the grapple fixture. Once it was free, both spacewalkers moved with it back to the airlock where it was stowed. It will provide a base for the station's Canadarm2 on the Zarya module, where it is to be installed during a spacewalk scheduled for July. From there the two moved into a get-ahead task, stowing and retrieving tools at Z1 truss tool boxes – basically a cleanup task after previous spacewalks. That was the final job before the moved back to the airlock to end the spacewalk.

The 6 hour, 46 minute spacewalk wrapped up at 12:13 p.m. CDT. This spacewalk was the 146th for station assembly and maintenance. Those spacewalks total 914 hours, 53 minutes.

On Saturday 22 May the astronauts transferred equipment and supplies between the shuttle and the ISS in preparation for their departure Sunday. The cargo carrier that brought six new 170-kg batteries to the station was returned to the shuttle with the old station batteries. They were replaced during the mission's second and third spacewalks on Wednesday and Friday. Cargo bay latches securing the carrier were closed at about 4:50 a.m. CDT. Moments later Mission Specialists Piers Sellers and Garrett Reisman, at the controls of Canadarm2 in the station's new cupola, released the arm's grip on the carrier. They put the robotic arm in a parking position, completing its work for the STS-132 mission of *Atlantis*.

At 6:40 a.m. the *Atlantis* crew and station Flight Engineer Tracy Caldwell Dyson spent about 20 minutes answering videotaped questions from students at 12 NASA Explorer Schools around the US. The schools' three-year partnerships with NASA are aimed at increasing students' interest in science, technology and mathematics.

Departure preparations and transfer activities occupied some of the crew's morning. Much of the transfer work focused on moving items between the station and *Atlantis*' middeck. After the hour-long break for the midday meal and a couple of hours of early afternoon work, the crew was given almost three hours of off-duty time.

Farewells and homecoming

Atlantis undocked from the International Space Station at 10:22 a.m. CDT Sunday 23 May, ending a seven-day stay that saw the addition of a new station module, replacement of batteries and resupply of the orbiting outpost. The joint operations were a good example of friendship and professionalism, station Commander Oleg Kotov said after summarizing the week's accomplishments in the farewell ceremony. *Atlantis* Commander Ken Ham responded: "We are one happy shuttle crew … happy because of all of your efforts too. We were a 12-person crew that operated together."

After undocking, Pilot Tony Antonelli flew *Atlantis* around the station at a distance ranging from about 121 to 182 metres. Crew members took photographs and video of the station with its new module to document its condition. *Atlantis* did the first separation burn, taking the shuttle away from the station, at 11:37 a.m. Later in the day the crew preformed the inspection for landing and had the day off for the remaining day.

Next day the *Atlantis* astronauts stowed spacesuits, wrapped up the standard late inspection of the shuttle's thermal protection system ahead of schedule and enjoyed some time off. Commander Ken Ham, Pilot Tony Antonelli and Mission Specialists Garrett Reisman and Piers Sellers began the inspection well ahead of scheduled start. By 4:50 a.m. they had finished their look at the right wing, by 5:52 a.m. the nose cap survey was complete and the left wing survey was finished at 7:17 a.m., about 2.5 hours ahead of the timeline. The survey was done using he shuttle arm and its 15.2-metre extension, the orbiter boom sensor system. Early in the mission, a pan-tilt assembly at the boom's end supporting a laser dynamic range imager and an intensified video camera had been partly disabled by a snagged cable.

Good and Bowen finished working with the spacesuits and put them away while the survey was being done. After the survey, the boom and the arm were stowed on opposite sides of the cargo bay sill, their work done for the station.

On Tuesday 25 May the crew started standard day-before-landing activities early in their workday. Ham, Antonelli and Good began the flight control system checkout at about 2:40 a.m., operating the rudder and flaps that will control *Atlantis*' flight through the atmosphere to the Florida runway. That completed, Ham and Antonelli fired each of the shuttle's 44 attitude control thrusters that orient *Atlantis* in space as it descends from orbit and through the upper atmosphere. Both those tests were completed successfully.

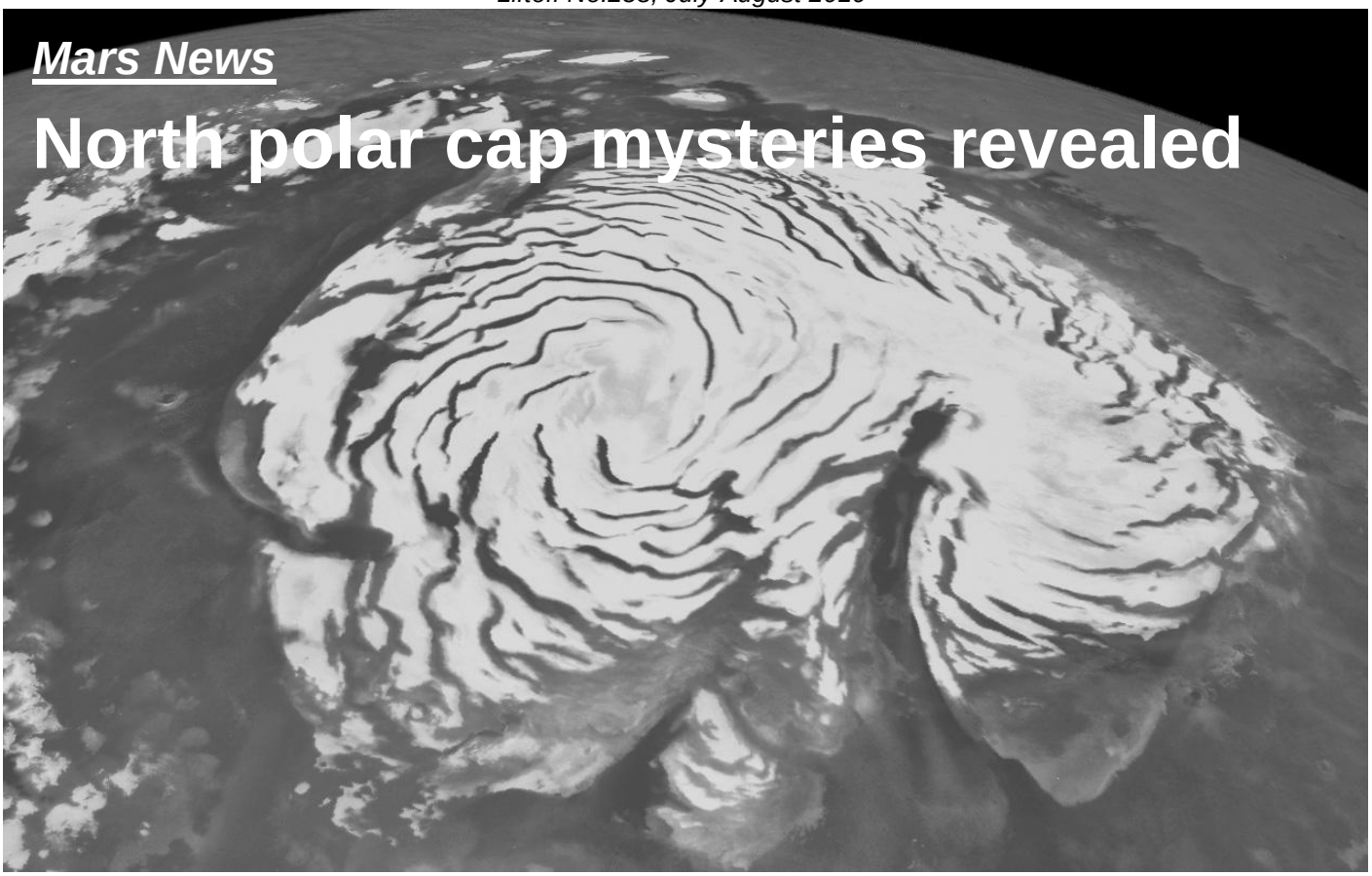
All crewmembers worked at various times throughout the day to stow items in the cabin to prepare for landing. The crew gathered for a 30-minute deorbit briefing at 6:40 a.m. Immediately afterward they talked with representatives of The Colbert Report, ABC Radio Network and WEWS-TV of Cleveland. Late in their day, Reisman and Sellers stowed the Ku –band antenna in *Atlantis*'s cargo bay.

On Wednesday 26 May, after 4,879,978 miles and 11 days, 18 hours, 29 minutes and 9 seconds, *Atlantis* landed on runway 33 at 7:49:18 a.m. EST or 8:49:18 a.m. CDT.

Panama-based NZSA member Ed Case is our regular correspondent on Shuttle and ISS news.

Mars News

North polar cap mysteries revealed



This image, combining data from two instruments aboard NASA's Mars Global Surveyor, depicts an orbital view of the north polar region of Mars. (NASA/JPL-Caltech/MSSS)

Data from NASA's Mars Reconnaissance Orbiter (MRO) have helped scientists solve a pair of mysteries dating back four decades and provided new information about climate change on the Red Planet. Meanwhile, other research is throwing new light on the red planet's watery past,

The Shallow Radar, or SHARAD, instrument aboard MRO revealed subsurface geology allowing scientists to reconstruct the formation of a large chasm and a series of spiral troughs on the northern ice cap of Mars. The findings appear in two papers in the 27 May issue of the journal *Nature*.

"SHARAD is giving us a beautifully detailed view of ice deposits, whether at the poles or buried in mid-latitudes, as they changed on Mars over the last few million years," said Rich Zurek, MRO project scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif.

On Earth, large ice sheets are shaped mainly by ice flow. According to this latest research, other forces have shaped, and continue to shape, polar ice caps on Mars. The northern ice cap is a stack of ice and dust layers up to two miles deep, covering an area slightly larger than Texas. Analyzing radar data on a computer, scientists can peel back the layers like an onion to reveal how the ice cap evolved over time.

One of the most distinctive features of the northern ice cap is Chasma Boreale, a canyon about as long as Earth's Grand Canyon but deeper and wider. Some scientists believe Chasma Boreale was created when volcanic heat melted the bottom of the ice sheet and triggered a catastrophic flood. Others suggest strong polar winds carved the canyon out of a dome of ice.

Other enigmatic features of the ice cap are troughs that spiral outward from the center like a gigantic pinwheel. Since the troughs were discovered in 1972, scientists have proposed several hypotheses about how they formed. Perhaps as Mars spins, ice closer to the poles moves slower than ice farther away, causing the semi-fluid ice to crack. Perhaps, as one mathematical model suggests, increased solar heating in certain areas and lateral heat conduction could cause the troughs to assemble.

Data from Mars now points to both the canyon and spiral troughs being created and shaped primarily by wind. Rather than being cut into existing ice very recently, the features formed over millions of years as the ice sheet grew. By influencing wind patterns, the shape of underlying, older ice controlled where and how the features grew.

"Nobody realized that there would be such complex structures in the layers," said Jack Holt, of the University of Texas at Austin's Institute for Geophysics. Holt is the lead author of the paper focusing on Chasma Boreale. "The layers record a history of ice accumulation, erosion and wind transport. From that, we can recover a history of climate that's much more detailed than anybody expected." The Mars Reconnaissance Orbiter was launched on Aug. 12, 2005. SHARAD and the spacecraft's five other instruments began science operations in November 2006.

"These anomalous features have gone unexplained for 40 years because we have not been able to see what lies beneath the surface," said Roberto Seu, SHARAD team leader at the University of Rome. "It is gratifying to me that with this new instrument we can finally explain them."

Mapping project reinforces belief in huge historic seas on Mars

A geologic mapping project using NASA spacecraft data offers new evidence that expansive lakes existed long ago on Mars. The research points to a series of sedimentary deposits consistent with what would relate to large standing bodies of water in Hellas Planitia located in the southern hemisphere of Mars, said by Dr. Leslie Bleamaster, research scientist at the Planetary Science Institute.

Fine-layered outcrops around the eastern rim of Hellas have been interpreted as a series of sedimentary deposits resulting from erosion and transport of highland rim materials into a basin-wide standing body of water, Bleamaster said. Hellas basin, more than 2,000 km across and 8 km deep, is the largest recognized impact structure on the Martian surface, he said. The mapping project reinforces earlier research that initially proposed Hellas-wide lakes citing different evidence in the west, he said. The new map and accompanying map pamphlet may be found at **http://pubs.usgs.gov/sim/3096/**

"This mapping makes geologic interpretations consistent with previous studies, and constrains the timing of these putative lakes to the early-middle Noachian period on Mars, between 4.5 and 3.5 billion years ago," he said.

A systematic search of high-resolution images revealed that eastern Hellas Planitia, where the fine-layered floor deposits were discovered, is unique in nature representing a confluence between sedimentary sources and sinks. The circum-Hellas highlands represent a significant percentage of the southern hemisphere of Mars and have served as a locus for volcanic and sedimentary activity throughout Martian geologic time. Hellas Planitia preserves the materials shed from these highlands and holds the key to further unraveling some of Mars' long held secrets. "Our mapping and evaluation of landforms and materials of the Hellas region from the basin rim to floor provides further insight into Martian climate regimes and into the abundance, distribution, and flux of volatiles through history," Bleamaster said.

The geologic mapping was published at 1:1,000,000 scale and used Viking Orbiter, Thermal Emission Imaging System (THEMIS) infrared (IR) and visible (VIS) wavelength, and Mars Orbiter Camera (MOC) narrow-angle images, combined with Mars Orbiter Laser Altimeter (MOLA) topographic data, to characterize the geologic materials and processes that have shaped this region and was supported through NASA's Planetary Geology and Geophysics program.

New clues suggest wet era on early Mars was global

Minerals in northern Mars craters seen by two orbiters suggest that a phase in Mars' early history with conditions favorable to life occurred globally, not just in the south. Southern and northern Mars differ in many ways, so the extent to which they shared ancient environments has been open to question.

In recent years, the European Space Agency's Mars Express orbiter and NASA's Mars Reconnaissance Orbiter have found clay minerals that are signatures of a wet environment at thousands of sites in the southern highlands of Mars, where rocks on or near the surface are about four billion years old. Until now, no sites with those minerals had been reported in the northern lowlands, where younger volcanic activity has buried the older surface more deeply.

French and American researchers reported in the journal *Science* in June that some large craters penetrating younger, overlying rocks in the northern lowlands expose similar mineral clues to ancient wet conditions. "We can now say that the planet was altered on a global scale by liquid water about four billion years ago," said John Carter of the University of Paris, the report's lead author. Other types of evidence about liquid water in later epochs on Mars tend to point to shorter durations of wet conditions or water that was more acidic or salty.

The researchers used the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), an instrument on the Mars Reconnaissance Orbiter, to check 91 craters in the northern lowlands. In at least nine, they found clays and clay-like minerals called phyllosilicates, or other hydrated silicates that form in wet environments on the surface or underground. Earlier observations with the OMEGA spectrometer on Mars Express had tentatively detected phyllosilicates in a few craters of the northern plains, but the deposits are small, and CRISM can make focused observations on smaller areas than OMEGA. "We needed the better spatial resolution to confirm the identifications," Carter said. "The two instruments have different strengths, so there is a great advantage to using both."

CRISM Principal Investigator Scott Murchie of Johns Hopkins University Applied Physics Laboratory, Laurel, Md., a co-author of the new report, said that the findings aid interpretation of when the wet environments on ancient Mars existed relative to some other important steps in the planet's early history.

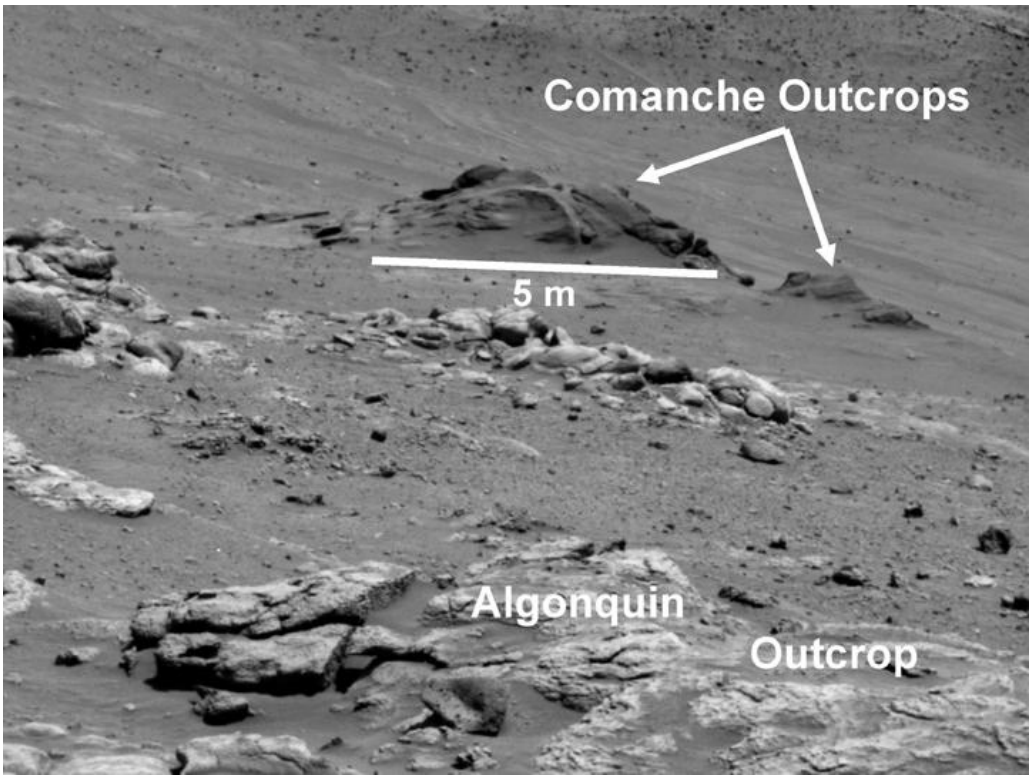
The prevailing theory for how the northern part of the planet came to have a much lower elevation than the southern highlands is that a giant object slammed obliquely into northern Mars, turning nearly half of the planet's surface into the solar system's largest impact crater. The new findings suggest that the formation of water-related minerals, and thus at least part of the wet period that may have been most favorable to life, occurred between that early giant impact and the later time when younger sediments formed an overlying mantle. "That large impact would have eliminated any evidence for the surface environment in the north that preceded the impact," Murchie said. "It must have happened well before the end of the wet period."

Spirit rover finds clue to Mars' past and environment for life

Rocks examined by NASA's Spirit Mars Rover hold evidence of a wet, non-acidic ancient environment that may have been favorable for life. Confirming this mineral clue took four years of analysis by several scientists. An outcrop that Spirit examined in late 2005 revealed high concentrations of carbonate, which originates in wet, near-neutral conditions, but dissolves in acid. The ancient water indicated by this find was not acidic. NASA's rovers have found other evidence of formerly wet Martian environments. However, the data for those environments indicate conditions that may have been acidic. In other cases, the conditions were definitely acidic, and therefore less favorable as habitats for life.

Laboratory tests helped confirm the carbonate identification. "This is one of the most significant findings by the rovers," said Steve Squyres of Cornell University in Ithaca, N.Y. Squyres is principal investigator for the Mars twin rovers, Spirit and Opportunity, and a co-author of the new report in *Science* magazine. "A substantial carbonate deposit in a Mars outcrop tells us that conditions that could have been quite favorable for life were present at one time in that place."

Spirit inspected rock outcrops, including one scientists called Comanche, along the rover's route from the top of Husband Hill to the vicinity of the Home Plate plateau that Spirit has studied since 2006. Magnesium iron carbonate makes up about one-fourth of the measured volume in Comanche. That is a tenfold higher concentration than any previously identified for carbonate in a Martian rock. "We used detective work combining results from three spectrometers to lock this down," said Dick Morris, lead author of the report and a member of a rover science team at NASA's Johnson Space Center in Houston."The instruments gave us multiple, interlocking ways of confirming the magnesium iron carbonate, with a good handle on how much there is."



Spirit used its panoramic camera to capture this view of the Comanche outcrop during the 689th Martian day, or sol, of the rover's mission on Mars (11 December 2005). (NASA/JPL-Caltech/Cornell University)

Massive carbonate deposits on Mars have been sought for years without much success. Numerous channels apparently carved by flows of liquid water on ancient Mars suggest the planet was formerly warmer, thanks to greenhouse warming from a thicker atmosphere than exists now. The ancient, dense Martian atmosphere was probably rich in carbon dioxide, because that gas makes up nearly all the modern, very thin atmosphere.

It is important to determine where most of the carbon dioxide went. Some theorize it departed to space. Others hypothesize that it left the atmosphere by the mixing of carbon dioxide with water under conditions that led to forming carbonate minerals. That possibility, plus finding small amounts of carbonate in meteorites that originated from Mars, led to expectations in the 1990s that carbonate would be abundant on Mars. However, mineral-mapping spectrometers on orbiters since then have found evidence of localized carbonate deposits in only one area, plus small amounts distributed globally in Martian dust.

Morris suspected iron-bearing carbonate at Comanche years ago from inspection of the rock with Spirit's Moessbauer Spectrometer, which provides information about iron-containing minerals. Confirming evidence from other instruments emerged slowly. The instrument with the best capability for detecting carbonates, the Miniature Thermal Emission Spectrometer, had its mirror contaminated with dust earlier in 2005, during a wind event that also cleaned Spirit's solar panels.

"It was like looking through dirty glasses," said Steve Ruff of Arizona State University in Tempe, Ariz., another co-author of the report. "We could tell there was something very different about Comanche compared with other outcrops we had seen, but we couldn't tell what it was until we developed a correction method to account for the dust on the mirror." Spirit's Alpha Particle X-ray Spectrometer instrument detected a high concentration of light elements, a group including carbon and oxygen, that helped quantify the carbonate content.

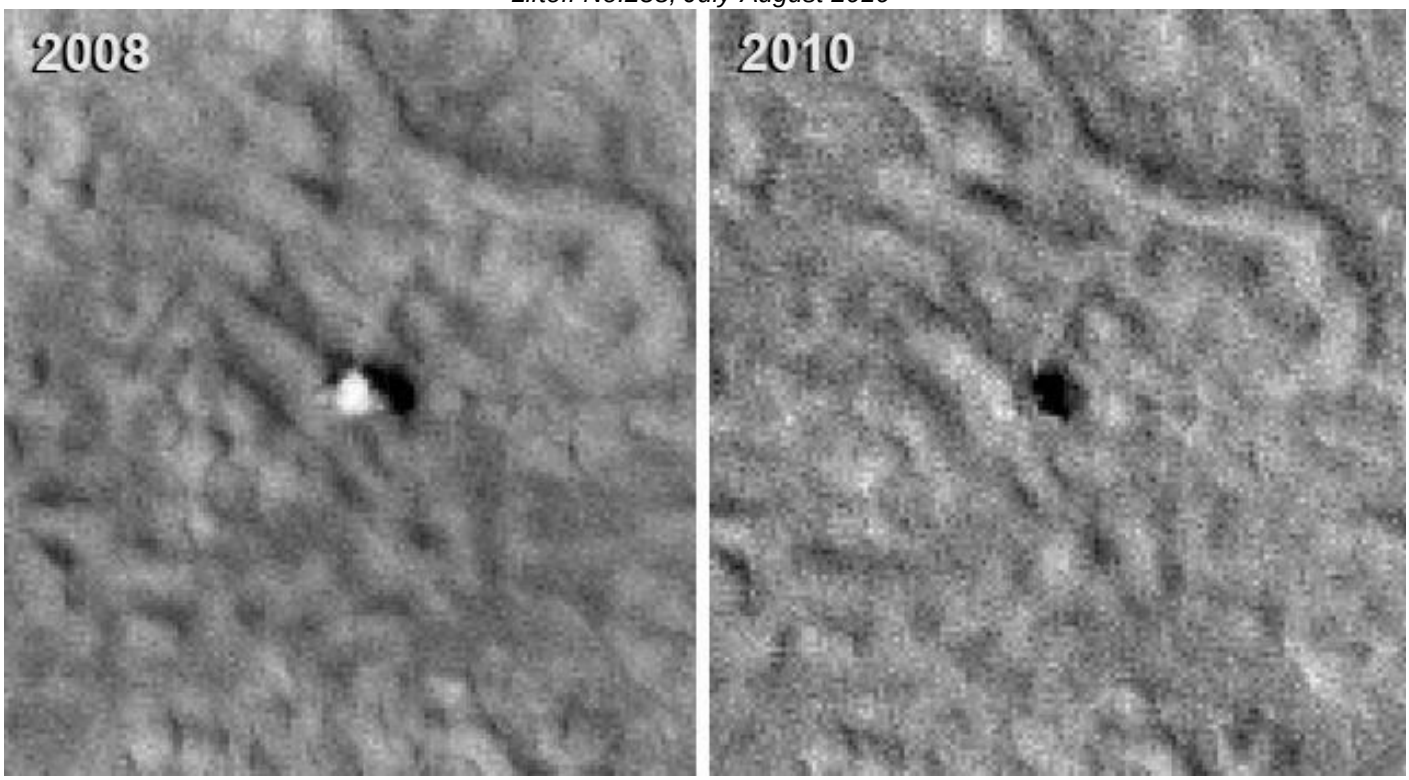
Scientists finds widespread glacial meltwater valleys on Mars

Planetary scientists have uncovered telltale signs of water on Mars — frozen and liquid — in the earliest period of the Red Planet's history. A new claim, made public in June, is that a deep ocean covered some of the northern latitudes.

But the evidence for water grows much more scant after the Noachian era, which ended 3.5 billion years ago. Now planetary geologists from Brown University in the US have documented running water that sprang from glaciers throughout the Martian middle latitudes as recently as the Amazonian epoch, several hundred million years ago. These glaciofluvial valleys were, in essence, tributaries of water created when enough sunlight reached the glaciers to melt a thin layer on the surface. This, the Brown researchers write, led to "limited surface melting" that formed channels that ran for several kilometers and could be more than 45 metres wide.

The finding is "more than 'Yes, we found water,'" said Caleb Fassett, postdoctoral research associate in geological sciences and lead author of the paper published in *Icarus*. "What we see now is there's this complex history of different environments where water is being formed." Fassett, with Brown research analyst James Dickson, professor James Head III, and geologists from Boston University and Portland State University, analyzed 15,000 images snapped by the Context Camera (CTX) aboard the Mars Reconnaissance Orbiter to compile the first survey of glaciofluvial valleys on Mars. The survey was sparked by a glaciofluvial valley that Dickson, Fassett, and Head spotted within the Lyot crater, located in the planet's middle latitudes. The team, in a paper last year in *Geophysical Research Letters*, dated that meltwater-inspired feature to the Amazonian.

In his survey, Fassett found dozens of other Amazonian-era ice deposits that spawned supraglacial and proglacial valleys, most of them located on the interior and exterior of craters in



Two images of the Phoenix Mars lander taken from Martian orbit in 2008 and 2010. The 2008 lander image (left) shows two relatively blue spots on either side corresponding to the spacecraft's clean circular solar panels. In the 2010 (right) image scientists see a dark shadow that could be the lander body and eastern solar panel, but no shadow from the western solar panel. (NASA/JPL-Caltech/University of Arizona)

Mars' midlatitude belt. "The youthfulness (of the features) is surprising," he said. "We think of [post-Noachian] Mars as really, really cold and really, really dry, so the fact that these exist, in those kinds of conditions, is changing how we view the history of water on the planet."

What makes the finding even more intriguing is that the Brown planetary scientists can study what they believe are similar conditions on Earth. Teams from Brown and Boston University have visited the Antarctic Dry Valleys for years, where the surfaces of glaciers melt during the austral summer, sparking enough meltwater to carve a channel. The team will return to the Dry Valleys later this year to continue the study of this microclimate. "It's sort of crazy," said Dickson, a member of the Brown team who stayed in the Dry Valleys for three months last year. "You're freezing cold and there's glacial ice everywhere, and it gets just warm enough that you get a river." Fassett plans to search for more glaciofluvial valleys as more images come from the CTX, which has mapped roughly 40 percent of the planet.

Phoenix does not phone home

NASA's Phoenix Mars Lander has ended operations after repeated attempts to contact the spacecraft were unsuccessful. A new image transmitted by NASA's Mars Reconnaissance Orbiter shows signs of severe ice damage to the lander's solar panels. "The Phoenix spacecraft succeeded in its investigations and exceeded its planned lifetime," said Fuk Li, manager of the Mars Exploration Program at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "Although its work is finished, analysis of information from Phoenix's science activities will continue for some time to come."

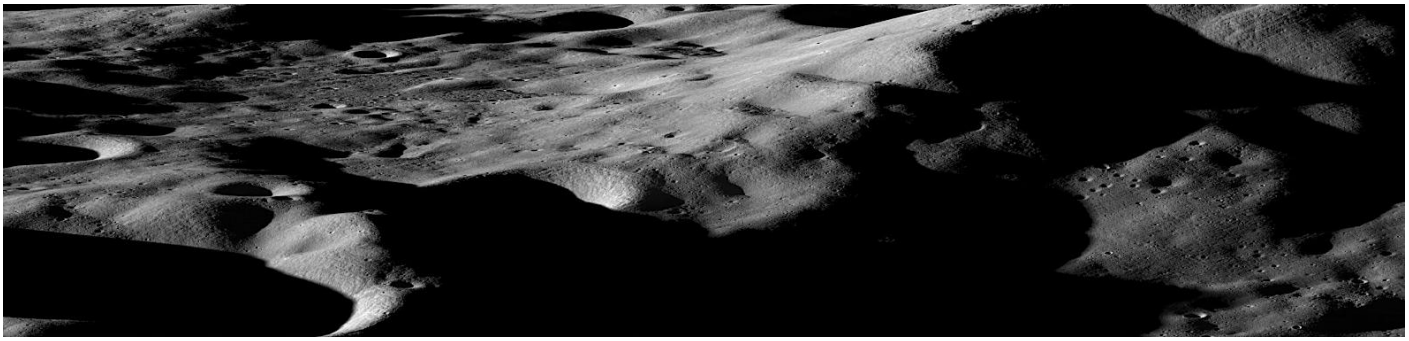
In mid-May, NASA's Mars Odyssey orbiter flew over the Phoenix landing site 61 times during a final attempt to communicate with the lander. No transmission from the lander was detected. Phoenix also did not communicate during 150 flights in three earlier listening campaigns this year.

Earth-based research continues on discoveries Phoenix made during summer conditions at the far-northern site where it landed on 25 May 2008. The solar-powered lander completed its three-month mission and kept working until sunlight waned two months later. Phoenix was not designed to survive the dark, cold, icy winter. However, the slim possibility Phoenix survived could not be eliminated without listening for the lander after abundant sunshine returned.

An image of Phoenix taken this month by the High Resolution Imaging Science Experiment, or HiRISE, camera on board the Mars Reconnaissance Orbiter suggests the lander no longer casts shadows the way it did during its working lifetime. "Before and after images are dramatically different," said Michael Mellon of the University of Colorado in Boulder, a science team member for both Phoenix and HiRISE. "The lander looks smaller, and only a portion of the difference can be explained by accumulation of dust on the lander, which makes its surfaces less distinguishable from surrounding ground."

Apparent changes in the shadows cast by the lander are consistent with predictions of how Phoenix could be damaged by harsh winter conditions. It was anticipated that the weight of a carbon-dioxide ice buildup could bend or break the lander's solar panels. Mellon calculated hundreds of pounds of ice probably coated the lander in mid-winter.

During its mission, Phoenix confirmed and examined patches of the widespread deposits of underground water ice detected by Odyssey and identified a mineral called calcium carbonate that suggested occasional presence of thawed water.



An oblique image of Cabeus crater shows a dramatic view of the Moon's mountainous terrain. (NASA/Goddard/Arizona State University)

Ten cool things seen in the first year of LRO

Having officially reached lunar orbit on 23 June 2009, the Lunar Reconnaissance Orbiter (LRO) has now marked one full year on its mission to scout the moon. Maps and datasets collected by LRO's state-of-the-art instruments will form the foundation for all future lunar exploration plans, as well as be critical to scientists working to better understand the moon and its environment. In only the first year of the mission, LRO has gathered more digital information than any previous planetary mission in history. To celebrate one year in orbit, here are ten cool things already observed by LRO. Note that the stories here are just a small sample of what the LRO team has released and barely touch on the major scientific accomplishments of the mission. If you like these, visit the official LRO web site at **www.nasa.gov/LRO** to find out even more!

The coldest place in the solar system

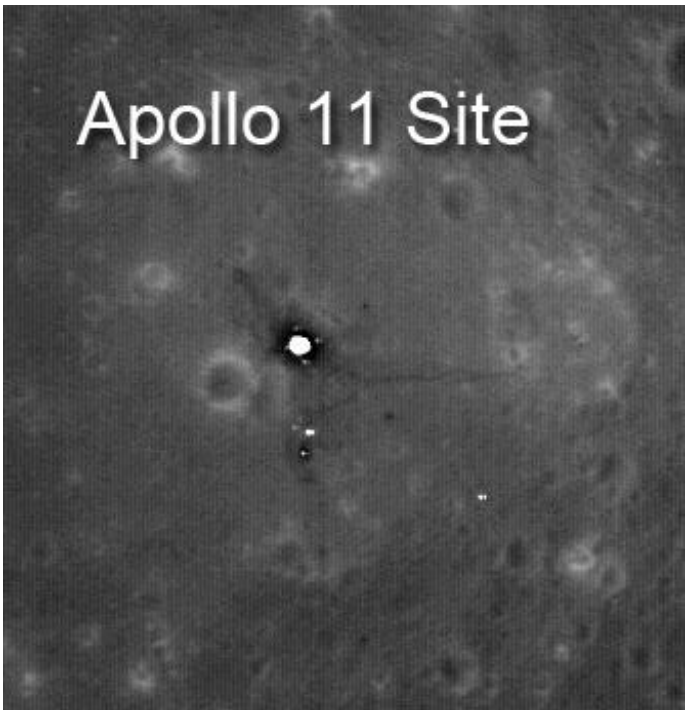
One of LRO''s observations from the past year goes beyond cool to absolutely frigid. Diviner, LRO's temperature instrument, found a place in the floor of the moon's Hermite Crater that was detected to be -248 Celsius, making it the coldest temperature measured anywhere in the solar system. For comparison, scientists believe that Pluto's surface only gets down to about -184 Celsius. Extremely cold regions similar to the one in Hermite Crater were found at the bottoms of several permanently shaded craters at the lunar south pole and were measured in the depths of winter night.

Astronauts' first steps on the Moon

On 20 July 1969, NASA added a page to the history books when Apollo 11 astronauts Neil Armstrong and Buzz Aldrin were the first humans to set foot on the moon. Though their stay was only brief, Armstrong and Aldrin had about two and a half hours to track around outside the module, taking pictures and deploying a few science experiments before returning to orbit and ultimately, the safety of Earth. Images of the Apollo 11 landing site from LRO clearly show where the descent stage (about 3.6 metres in diameter) was left behind as well as the astronauts' tracks and the various equipment they deployed. This LRO data has important scientific value, as it provides context for the returned Apollo samples. Beyond their use for science, the images of all six manned landing sites observed by LRO provide a reminder of NASA's proud legacy of exploration and a note of inspiration about what humans are capable of in the future.

The Apollo 14 near miss of Cone Crater

While all of the Apollo missions are fascinating, the Apollo 14 activities provided a particularly interesting story to see in the

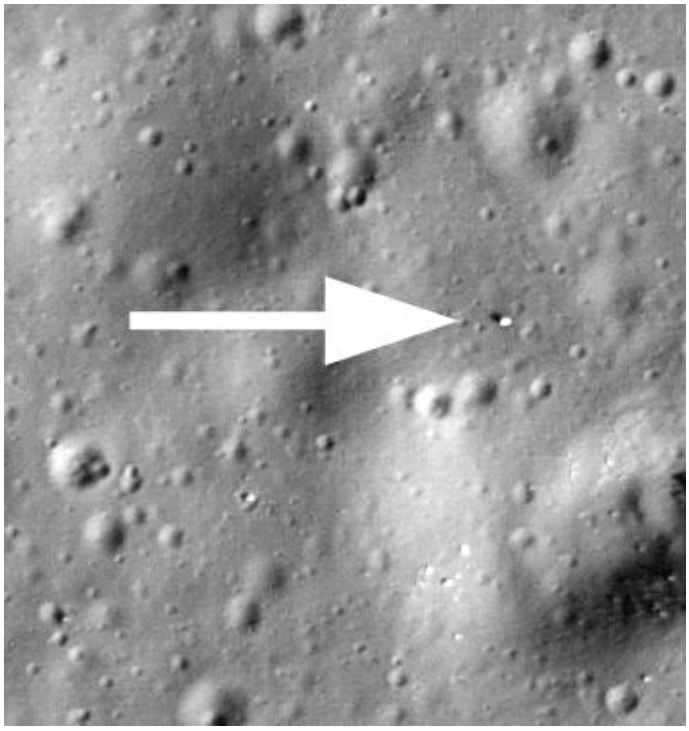


(NASA/Goddard/Arizona State University)

images from LRO. The mission called for Alan Shepard and Edgar Mitchell to go to Fra Mauro where they would attempt to gather samples from the rim of Cone Crater. Without having the aid of the lunar rover and having to drag a cart full of scientific equipment along with them, the trek from the descent module to Cone Crater proved to be a physically intense one. After traversing nearly 1,400 metres, the steep incline of the crater rim, the high heart rates of the astronauts and the tight schedule of the activity resulted in mission control ordering them to gather whatever samples they could and return to the landing module. They never reached the edge of the crater. Though geologists say it did not greatly affect the success of the scientific goal, the astronauts were personally disappointed in failing to make it to the top. Images from LRO now show precisely just how far the astronauts traveled and how close they came to reaching the crater, their tracks ending only about 30 metres from the rim!

A lost Russian rover is found

Lunokhod 1 was the name of a Russian robotic rover that landed on the moon in 1970 and navigated about 10 kilometres of the lunar surface over 10 months before it lost contact in



The Lunokhod 1 rover on the Moon (NASA/Goddard/Arizona State University)

September 1971. Scientists were unsure of the rover's whereabouts, though at least one team of researchers were searching for it, hoping to bounce a laser off of its retroreflector mirrors. In March 2010 however, the LROC team announced they had spotted it, miles from the location the laser team had been searching. Using the info provided by LRO, a laser pulse was sent to Lunokhod 1 and contact was made with the rover for the first time in nearly four decades. Not only did Lunokhod 1's retroreflector return a signal, but it returned one that was about five times better than those that have routinely been returned by Lunokhod 2's mirrors over the years.

The lunar far side: the side never seen from Earth

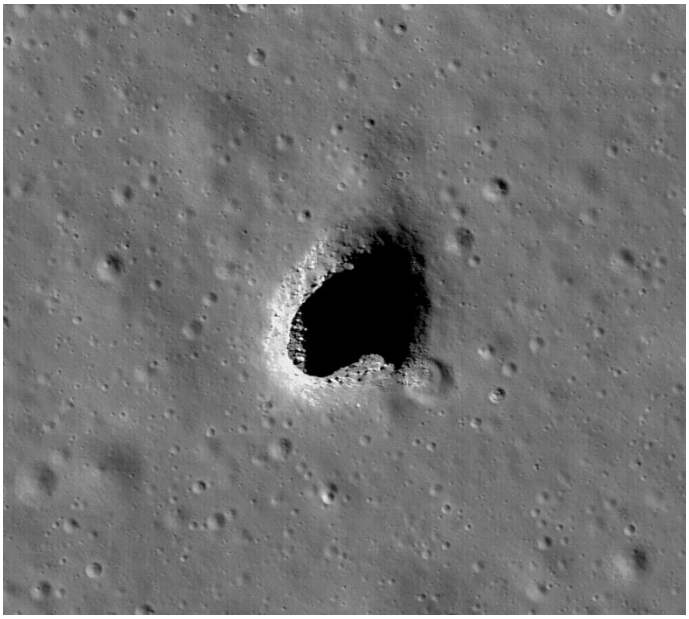
Tidal forces between the moon and the Earth have slowed the moon' rotation so that one side of the moon always faces toward our planet. Though sometimes improperly referred to as the "dark side of the moon," it should correctly be referred to as the "far side of the moon" since it receives just as much sunlight as the side that faces us. The dark side of the moon should refer to whatever hemisphere isn't lit at a given time. Though several spacecraft have imaged the far side of the moon since then, LRO is providing new details about the entire half of the moon that is obscured from Earth. The lunar far side is rougher and has many more craters than the near side, so quite a few of the most fascinating lunar features are located there, including one of the largest known impact craters in the solar system, the South Pole-Aitken Basin. (See cover image.)

Counting craters and boulders

The LRO Camera (LROC) has a resolution about ten times better than any previous lunar orbiter missions. That means for every pixel imaged by other spacecraft, LROC gathers 100 pixels in that same area, enough to distinguish details never before possible. One of the most striking ways this manifests itself is in the ability to make out detailed craters and individual boulders, some no larger than a few feet on the lunar surface. In order to understand the history of the lunar surface and its features and mechanisms, scientists look at the abundance, size, shape, and distribution of both craters and boulders. By comparing and analyzing these feature counts across different regions as well as other places like the Earth and Mars, we can gain a better understanding of our solar system's natural history. With the increased resolution of the LRO Camera as well as the new information gathered by LRO's other instruments, scientists can characterize the moon's surface in ways never before possible. This information will be critical for both science and future exploration plans. Not only that, but now thanks to the "Moon Zoo" (http://www.moonzoo.org) the public can get involved doing their own crater and boulder counts to aid in the research. With hundreds of gigabytes of new data returning daily, the contribution of "citizen scientists" can play a crucial part in lunar science.

Mountains on the Moon

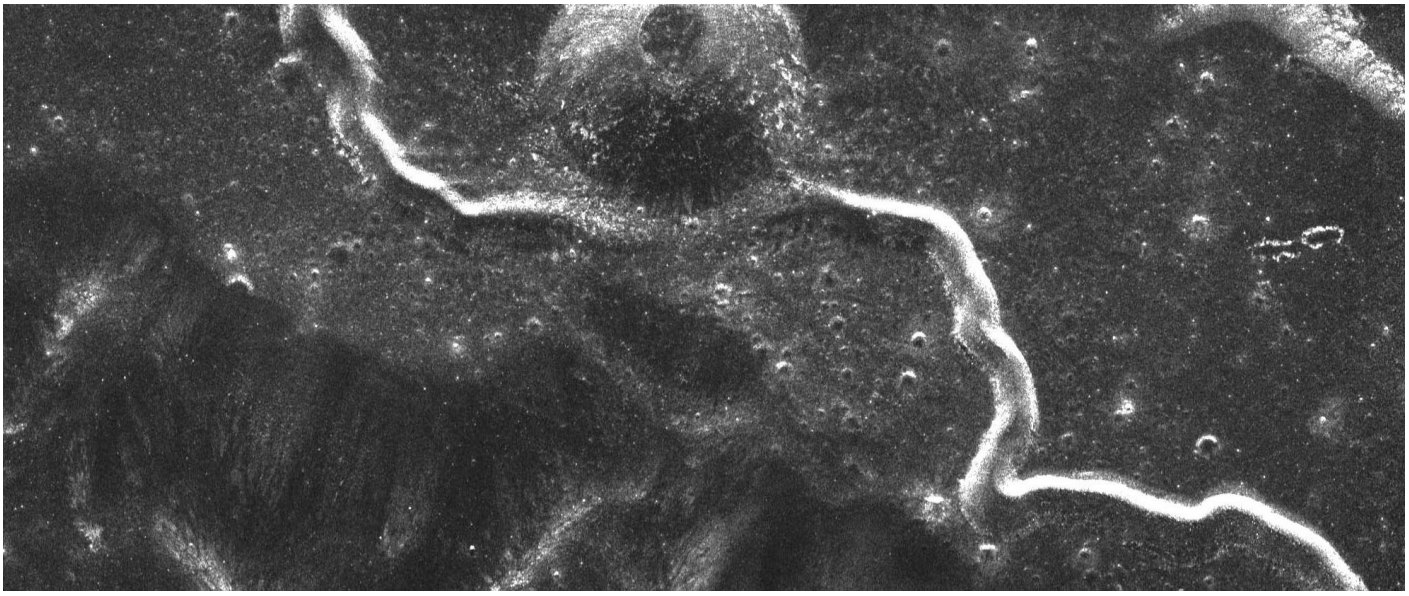
On the Earth, we are taught that mountains form over millions of years, the result of gradual shifting and colliding plates. On the moon however, the situation is quite different. Even the largest lunar mountains were formed in minutes or less as asteroids and comets slammed into the surface at tremendous velocities, displacing and uplifting enough crust to create peaks that easily rival those found on Earth. On a few occasions in the past year, NASA has tilted the angle of LRO to do calibrations and other tests. In such cases the camera has the opportunity to gather oblique images of the lunar surface like the one featured here (previous page) of Cabeus Crater providing a dramatic view of the moon's mountainous terrain. Cabeus Crater is located near the lunar south pole and contains the site of the LCROSS mission's impact. Early measurements by several instruments on LRO were used to guide the decision to send LCROSS to Cabeus. During the LCROSS impact LRO was carefully positioned to observe both the gas cloud generated in the impact, as well as the heating at the impact site.



(NASA/Goddard/Arizona State University)

Lunar pits

LRO has now collected the most detailed images yet of at least two lunar pits, quite literally giant holes in the moon (above). Scientists believe these holes are actually skylights that form when the ceiling of a subterranean lava tube collapses, possibly due to a meteorite impact punching its way



A lunar rille seen by LRO's Mini-RF instrument (NASA/JHUAPL/LSI)

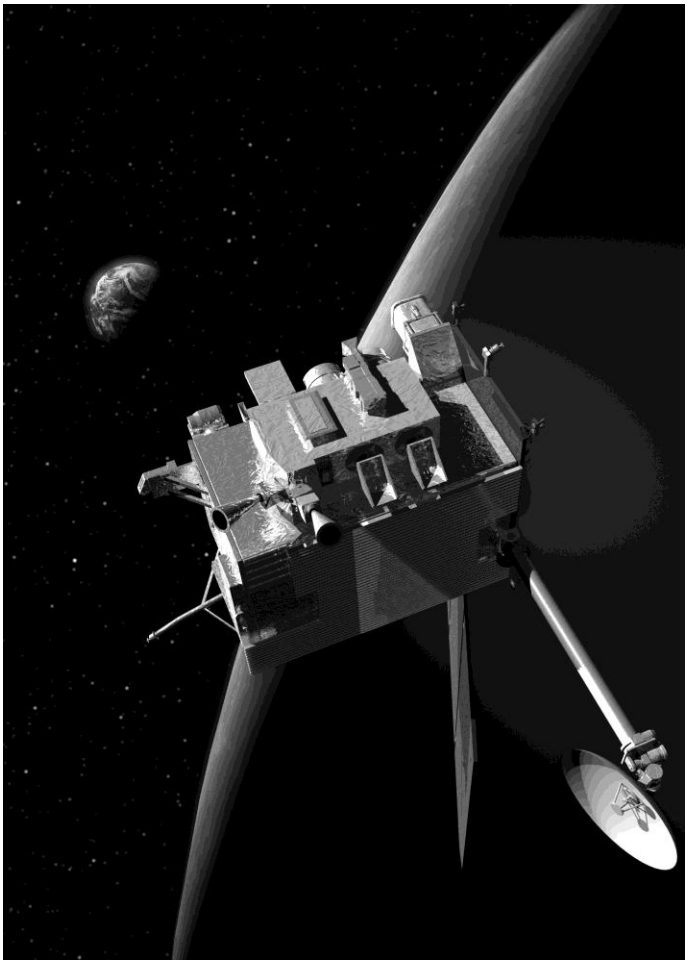
through. One of these skylights, the Marius Hills pit, was observed multiple times by the Japanese SELENE/Kaguya research team. With a diameter of about 65 metres and an estimated depth of 80 to 88 metres it's a pit big enough to fit the White House completely inside. The image featured here is the Mare Ingenii pit. This hole is almost twice the size of the one in the Marius Hills and most surprisingly is found in an area with relatively few volcanic features.

Lunar rilles: mysterious channels on the Moon

Rilles are long, narrow depressions on the lunar surface that look like river channels. Some are straight, some curve, and others, like the ones highlighted here, are called "sinuous" rilles and have strong meanders that twist and turn across the moon. Rilles are especially visible in radar imagery, like that gathered by LRO's Mini-RF instrument. The formation of lunar rilles is not well understood. It is believed there may be many different formation mechanisms including ancient magma flows and the collapse of subterranean lava tubes. Imagery from LRO will help researchers to better understand these mysterious "river-like" lunar features.

Areas of near constant sunlight at the south pole

One of the most vital resources LRO is searching for on the moon is solar illumination. Light from the sun provides both warmth and a source of energy, two critical constraints to exploration efforts. The moon's axis is only slightly tilted so there are areas in high elevations at its poles that remain almost constantly exposed to the sun. Using LRO's precise measurements of topography scientists have been able to map illumination in detail, finding some areas with up to 96% solar visibility. Such sites would have continuous sun for approximately 243 days a year and never have a period of total darkness for more than 24 hours.



The Lunar Reconnaissance Orbiter (NASA)

Source: NASA Goddard Space Flight Center

(Above) At right, Matthew Pavletich (foreground), Maree Pavletich and Jeff Green answer questions from visitors to Model-X. (Below) Part of the NZSA stand at Model-X this year.

NZSA at Model-X, Auckland

By Matthew Pavletich, Publicity officer, NZSA

2010 marks the 15th Anniversary of our involvement with the annual Model-X exhibition at the West Wave Recreation Centre, Henderson, Auckland, held over Queen's Birthday weekend. I enjoy the interactions we have with the general public but I admit, the conspiracy theory rubbish does get on my nerves at times. Fortunately, there have been no repeats of the "Moon hoax" documentary lately, so we were not plagued as much as we could have been.

But you simply cannot help the likes of one very eccentric gentleman who marched up to our display and in a couple of sentences declared: *"Good afternoon, I don't believe America landed on the Moon – I don't wish to discuss the matter nor read any of your leaflets on the subject – but I think your display is very good. Thank you and Good Day!"* And with that, he was off!! You can't reason with people like that, can you? All you can do is cope. And usually we do, very well.

Our display is normally limited to three or four tables, which we pack with models, pictures, artifacts and a video display. We decided this year to downplay the historical aspect of space, except for an inevitable Apollo presence. But it is difficult to show the prospects of a future in space when there are so few models available. And with the cancellation of most of Constellation, so much is now up in the air, so to speak.

At each Model-X we hand out at least 100 NZSA flyers and traditionally we would get at least one new member for our efforts. But to me, Model-X has never exclusively been about increasing our membership – doing so is the icing on the cake. I look upon it as an opportunity to inform the N.Z. public about the past, present and future of manned and unmanned spaceflight.

And as far as spaceflight goes, there are a few good anniversaries to go yet: 2011 marks the 50th commemoration of Yuri Gagarin's Vostok 1 mission and the 40th Anniversaries of Soyuz 11/Salyut 1 and Apollos 14 and 15.

But here's hoping we have more to look forward to in the years to come than merely reliving the past.

Atlantis's last launch? The STS-132 mission lifts off at 2:20 p.m. (EDT) on 14 May 2010, from launch pad 39A at NASA's Kennedy Space Center. If an additional Shuttle mission is approved, *Atlantis* will launch one more time in mid-2011. (NASA)