Liftoff

New Zealand's space exploration magazine

NZSA

Issue 263
May-June 2011

Also inside:

- **50th anniversary of Freedom 7, 1st US spaceflight**
- **Rapid prototyping and analog testing for human space exploration**

Liftoff

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NZSA News and Notices

Auckland meetings

The next Auckland meetings are on **4 July** and **1 August** 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
STUDENT	$37.50

New subscriptions paid after 1 February 2011 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 docked space shuttle Endeavour (STS-134), backdropped by a night time view of Earth and a starry sky are featured in this image photographed by an Expedition 28 crew member on the station. (NASA)

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Editor's Corner

It can't have escaped your notice that we've been having a few production problems with *Liftoff* lately, for which we are very sorry indeed. We have been getting the magazine printed privately for the past couple of years, which has (a) saved us considerable money, and (b) allowed us to include colour pages for the first time. Unfortunately, that arrangement has now ended, and we're back to having to get *Liftoff* printed commercially again. Because of the additional cost, the colour pages have had to go.

However, we will soon be bringing the printing of *Liftoff* in-house, as we are buying our own laser printer. While unfortunately this will not have the ability to saddle-stitch (meaning that we'll have to return to the old way of binding), the upside is that we will be able to go colour again! This will hopefully occur within the next few issues.

There have been further committee changes too: Mike Ryan, our long-serving Vice President, has had to step down for personal reasons, and so the Acting Treasurer position, which he recently also assumed, is being shared by yours truly and Matthew Pavletich until we get up to strength again.

(We're not alone in our woes: readers of the British Interplanetary Society's magazine *Spaceflight* will know that they, too, are having a few issues. These are tough times for all.)

We've a full issue for you this month, with Ed Case's report on the last flight for shuttle *Endeavour* (only one more shuttle to go now), a photo feature on the 50th anniversary of Alan Shepard's *Freedom 7* mission, the first US human space flight, and a piece from NASA Earth-based analog testing for future exploration missions to the Moon and Mars.

I hope you can all bear with us while we get over the current rocky patch. It's not the first time we've had problems, and just as in the past, we will triumph over adversity with your support!

-- *David Maclennan*

Conceptual image of OSIRIS-REx. (NASA/Goddard/University of Arizona)

NASA will launch a spacecraft to an asteroid in 2016 and use a robotic arm to pluck samples that could better explain our solar system's formation and how life began. The mission, called Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer, or OSIRIS-REx, will be the first U.S. mission to carry samples from an asteroid back to Earth.

NASA selected OSIRIS-REx after reviewing three concept study reports for new scientific missions, which also included a sample return mission from the far side of the moon and a mission to the surface of Venus.

Asteroids are leftovers formed from the cloud of gas and dust -- the solar nebula -- that collapsed to form our Sun and the planets about 4.5 billion years ago. As such, they contain the original material from the solar nebula, which can tell us about the conditions of our solar system's birth.

After traveling four years, OSIRIS-REx will approach the primitive, near Earth asteroid designated 1999 RQ36 in 2020. Once within three miles of the asteroid, the spacecraft will begin six months of comprehensive surface mapping. The science team then will pick a location from where the spacecraft's arm will take a sample. The spacecraft gradually will move closer to the site, and the arm will extend to collect more than two ounces of material for return to Earth in 2023. The mission, excluding the launch vehicle, is expected to cost approximately US$800 million.

The sample will be stored in a capsule that will land at Utah's Test and Training Range in 2023. The capsule's design will be similar to that used by NASA's Stardust spacecraft, which returned the world's first comet particles from comet Wild 2 in 2006. The OSIRIS-REx sample capsule will be taken to NASA's Johnson Space Center in Houston. The material will be removed and delivered to a dedicated research facility following stringent planetary protection protocol. Precise analysis will be performed that cannot be duplicated by spacecraft-based instruments.

RQ36 is approximately 579 metres in diameter or roughly the size of five US football fields. The asteroid, little altered over time, is likely to represent a snapshot of our solar system's infancy. The asteroid also is likely rich in carbon, a key element in the organic molecules necessary for life. Organic molecules have been found in meteorite and comet samples, indicating some of life's ingredients can be created in space. Scientists want to see if they also are present on RQ36. "This asteroid is a time capsule from the birth of our solar system and ushers in a new era of planetary exploration," said Jim Green, director, NASA's Planetary Science Division in Washington. "The knowledge from the mission also will help us to develop methods to better track the orbits of asteroids."

The mission will accurately measure the "Yarkovsky effect" for the first time. The effect is a small push caused by the Sun on an asteroid, as it absorbs sunlight and re-emits that energy as heat. The small push adds up over time, but it is uneven due to an asteroid's shape, wobble, surface composition and rotation. For scientists to predict an Earth-approaching asteroid's path, they must understand how the effect will change its orbit. OSIRIS-REx will help refine RQ36's orbit to ascertain its trajectory and devise future strategies to mitigate possible Earth impacts from celestial objects.

This is the third mission in NASA's New Frontiers Program. The first, New Horizons, was launched in 2006. It will fly by the Pluto-Charon system in July 2015, then target another Kuiper Belt object for study. The second mission, Juno, will launch in August to become the first spacecraft to orbit Jupiter from pole to pole and study the giant planet's atmosphere and interior. NASA's Marshall Space Flight Center in Huntsville, Ala., manages New Frontiers for the agency's Science Mission Directorate in Washington.

NASA-funded scientists make lunar watershed discovery

A team of NASA-funded researchers has measured for the first time water from the Moon in the form of tiny globules of molten rock, which have turned to glass-like material trapped within crystals. Data from these newly-discovered lunar melt inclusions indicate the water content of lunar magma is 100 times higher than previous studies suggested. The inclusions were found in lunar sample 74220, the famous high-titanium "orange glass soil" of volcanic origin collected during the Apollo 17 mission in 1972. The scientific team used a state-of-the-art ion microprobe instrument to measure the water content of the inclusions, which were formed during explosive eruptions on the Moon approximately 3.7 billion years ago.

The results, published in the 26 May issue of *Science Express,* raise questions about aspects of the "giant impact theory" of how the Moon was created. That theory predicted very low water content of lunar rock due to catastrophic degassing during the collision of Earth with a Mars-sized body very early in its history. The study also provides additional scientific justification for returning similar samples from other planetary bodies in the solar system.

"Water plays a critical role in determining the tectonic behavior of planetary surfaces, the melting point of planetary interiors and the location and eruptive style of planetary volcanoes," said Erik Hauri, a geochemist with the Carnegie Institution of Washington and lead author of the study. "I can conceive of no sample type that would be more important to return to Earth than these volcanic glass samples ejected by explosive volcanism, which have been mapped not only on the Moon but throughout the inner solar system."

In contrast to most volcanic deposits, the lunar melt inclusions are encased in crystals that prevent the escape of water and other volatiles during eruption. "These samples provide the best window we have on the amount of water in the interior of the Moon where the orange glass came from," said science team member James Van Orman of Case Western Reserve University in Cleveland.

In a 2008 study led by Alberto Saal of Brown University in Providence, R.I., the same team reported the first evidence of water in lunar volcanic glasses. They used magma degassing models to estimate how much water was originally in the magmas before eruption. Building on that study, a Brown undergraduate student, Thomas Weinreich, searched for and found the melt inclusions. With that data, the team measured the pre-eruption concentration in the magma and estimated the amount of water in the Moon's interior. "The bottom line is that in 2008, we said the primitive water content in the lunar magmas should be similar to lavas coming from the Earth's depleted upper mantle," Saal said. "Now, we have proven that is indeed the case."

The study also puts a new twist on the origin of water-ice detected in craters at the lunar poles by several recent NASA missions. The ice has been attributed to comet and meteor impacts, but the researchers believe it is possible that some of the ice came from water released by the eruption of lunar magmas eons ago.

Twin craft arrive in Florida for Moon mission

Twin lunar probes have arrived in Florida to begin final preparations for a launch in the late US summer. The two Gravity Recovery And Interior Laboratory spacecraft (Grail) were shipped from Lockheed Martin Space Systems, Denver, to the Astrotech payload processing facility in Titusville, Fla., on 20 May. NASA's dynamic duo will orbit the Moon to determine the structure of the lunar interior from crust to core and to advance understanding of the thermal evolution of the Moon. "NASA's lunar twins have arrived at Cape Canaveral," said Maria Zuber, Grail's principal investigator, based at the Massachusetts Institute of Technology, in Cambridge. "We're only a few full Moons away from a mission that will reveal clues not only into the history of the Moon and Earth, but will provide important data for future lunar exploration."

The Grail twins, known as Grail-A and Grail-B, were removed from their shipping containers on 23 May 23 to begin functional testing to verify their state of health after their ride on an Air Force transport jet from Colorado. Over the next four months at the Astrotech facility, the spacecraft will undergo final testing, fueling and packaging in the shroud that will protect them as the Delta II launch vehicle lifts them into space. The spacecraft will then be transported to the Cape Canaveral Air Force Station for installation atop the rocket that will carry them toward the Moon.

Grail will be carried into space aboard a United Launch Alliance Delta II Heavy rocket lifting off from Launch Complex-19 at the Cape Canaveral Air Force Station in Florida. The launch period opens 8 September 2011, and extends through 19 October.

Grail-A and Grail-B will fly in tandem orbits around the Moon for several months to measure its gravity field in unprecedented detail. The mission will also answer longstanding questions about Earth's Moon, and provide scientists a better understanding of how Earth and other rocky planets in the solar system formed.

More information about Grail is online at: **http://solarsystem.nasa.gov/grail**

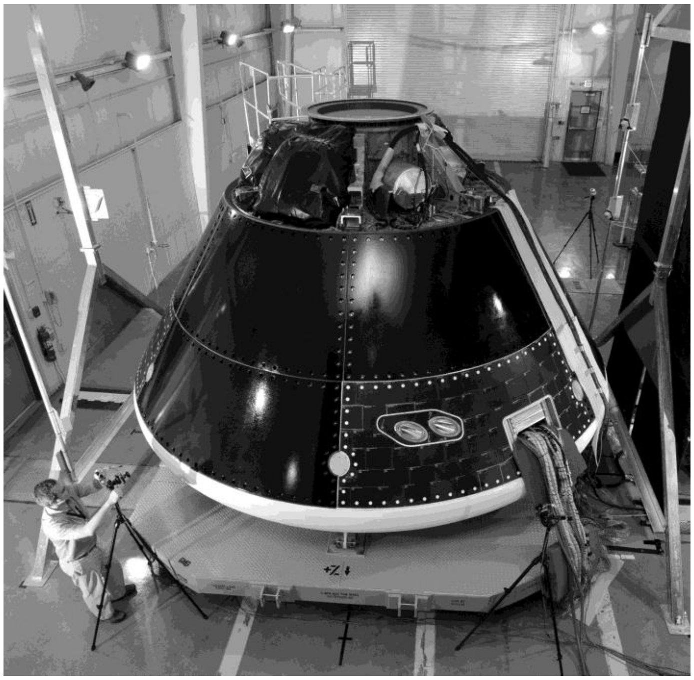
NASA announces key decision for next deep space transportation system

NASA has reached an important milestone for the next U.S. transportation system that will carry humans into deep space. NASA Administrator Charles Bolden announced on 24 May that the system will be based on designs originally planned for the Orion Crew Exploration Vehicle. Those plans now will be used to develop a new spacecraft known as the Multi-Purpose Crew Vehicle (MPCV).

"We are committed to human exploration beyond low-Earth orbit and look forward to developing the next generation of systems to take us there," Bolden said. "The NASA Authorization Act lays out a clear path forward for us by handing off transportation to the International Space Station to our private sector partners, so we can focus on deep space exploration. As we aggressively continue our work on a heavy lift launch vehicle, we are moving forward with an existing contract to keep development of our new crew vehicle on track."

Lockheed Martin Corp. will continue working to develop the MPCV. The spacecraft will carry four astronauts for 21-day missions and be able to land in the Pacific Ocean off the California coast. The spacecraft will have a pressurized volume of 195.2 cubic metres, with 89.4 cubic metres of habitable space. It is designed to be 10 times safer during ascent and entry than its predecessor, the space shuttle.

"This selection does not indicate a business as usual mentality for NASA programs," said Douglas Cooke, associate administrator for the agency's Exploration Systems Mission Directorate in Washington. "The Orion government and industry team has shown exceptional creativity in finding ways to keep



The Multi-Purpose Crew Vehicle being assembled and tested at Lockheed Martin's Vertical Testing Facility in Colorado. (Lockheed Martin)

costs down through management techniques, technical solutions and innovation."

To learn more about the development of the MPCV, visit: **http://www.nasa.gov/exploration/systems/mpcv**

NASA selects investigations for future key missions

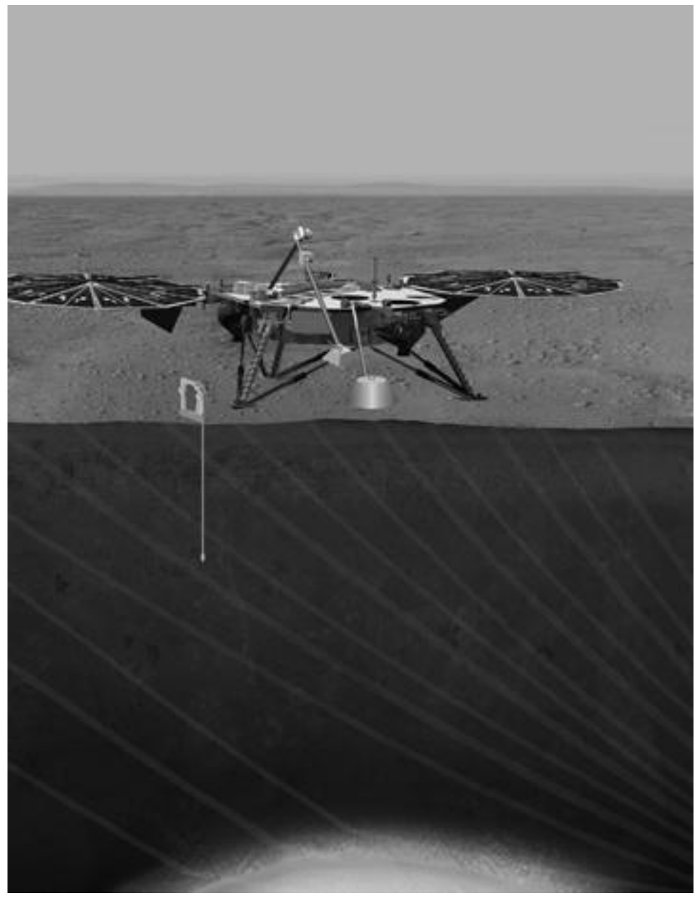
NASA has selected three science investigations from which it will pick one potential 2016 mission to look at Mars' interior for the first time; study an extraterrestrial sea on one of Saturn's moons; or study in unprecedented detail the surface of a comet's nucleus. Each investigation team will receive $3 million to conduct its mission's concept phase or preliminary design studies and analyses. After another detailed review in 2012 of the concept studies, NASA will select one to continue development efforts leading up to launch. The selected mission will be cost-capped at $425 million, not including launch vehicle funding.

NASA's Discovery Program requested proposals for spaceflight investigations in June 2010. A panel of NASA and other scientists and engineers reviewed 28 submissions. The selected investigations could reveal much about the formation of our solar system and its dynamic processes. Three technology developments for possible future planetary missions also were selected.

The planetary missions selected to pursue preliminary design studies are:

Geophysical Monitoring Station (GEMS) would study the structure and composition of the interior of Mars and advance understanding of the formation and evolution of terrestrial planets. Bruce Banerdt of NASA's Jet Propulsion Laboratory in Pasadena, Calif., is principal investigator. JPL would manage the project.

The proposed Mars lander would carry three experiments. A seismometer for measuring Mars quakes would yield knowledge about interior materials from the crust to the core. A thermal probe beneath the surface would monitor heat flow from the planet's interior. Radio capability for Doppler tracking of tiny variations in the planet's wobble would provide information about the size and nature of the core. Understanding more about the deep interior of another planet would enable important new comparisons with what is known about Earth's interior. "We want to know more about how the pieces that formed planets came together in the first place, and about the changes that took place afterwards," Banerdt said. "This would be a mission to understand the formation and evolution of terrestrial planets."



An artist's concept portrays the proposed Geophysical Monitoring Station mission for studying the deep interior of Mars. (NASA/JPL-Caltech)

Titan Mare Explorer (TiME) would provide the first direct exploration of an ocean environment beyond Earth by landing in, and floating on, a large methane-ethane sea on Saturn's moon Titan. Ellen Stofan of Proxemy Research Inc. in Gaithersburg, Md., is principal investigator. Johns Hopkins University's Applied Physics Laboratory in Laurel, Md., would manage the project.

Comet Hopper would study cometary evolution by landing on a comet multiple times and observing its changes as it interacts with the sun. Jessica Sunshine of the University of Maryland in College Park is principal investigator. NASA's Goddard Space Flight Center in Greenbelt, Md., would manage the project.

"This is high science return at a price that's right," said Jim Green, director of NASA's Planetary Science Division in Washington. "The selected studies clearly demonstrate a new era with missions that all touch their targets to perform unique and exciting science."

The three selected technology development proposals will expand the ability to catalog near-Earth objects, or NEOs; enhance the capability to determine the composition of comet ices; and validate a new method to reveal the population of objects in the poorly understood, far-distant part of our solar system. During the next several years, selected teams will receive funding that is determined through contract negotiations to bring their respective technologies to a higher level of readiness. To be considered for flight, teams must demonstrate progress in a future mission proposal competition.

The proposals selected for technology development are:

NEOCam would develop a telescope to study the origin and evolution of near-Earth Objects and study the present risk of Earth-impact. It would generate a catalog of objects and accurate infrared measurements to provide a better understanding of small bodies that cross our planet's orbit. Amy Mainzer of JPL is principal investigator.

A space-based telescope, NEOCam would be positioned in a location about four times the distance between Earth and the moon. From this lofty perch, NEOCam could observe the comings and goings of NEOs every day without the impediments to efficient observing like cloud cover and even daylight. The location in space NEOCam would inhabit is also important, because it allows the monitoring of areas of the sky generally inaccessible to ground-based surveys. "Near-Earth objects are some of the most bountiful, intriguing and least understood of Earth's neighbors," said Amy Mainzer. "With NEOCam, we would get to know these solar system nomads in greater detail."

Primitive Material Explorer (PriME) would develop a mass spectrometer that would provide highly precise measurements of the chemical composition of a comet and explore the objects' role in delivering volatiles to Earth. Anita Cochran of the University of Texas in Austin is principal investigator.

Whipple: Reaching into the Outer Solar System would develop and validate a technique called blind occultation that could lead to the discovery of various celestial objects in the outer solar system and revolutionize our understanding of the area's structure. Charles Alcock of the Smithsonian Astrophysical Observatory in Cambridge, Mass., is principal investigator.

Galileo data reveal magma ocean under Jupiter moon

New data analysis from NASA's Galileo spacecraft reveals a subsurface ocean of molten or partially molten magma beneath the surface of Jupiter's volcanic moon Io. The finding heralds the first direct confirmation of this kind of magma layer at Io and explains why the moon is the most volcanic object known in the solar system. The research was conducted by scientists at the University of California, Los Angeles; the University of California, Santa Cruz;, and the University of Michigan, Ann Arbor. The study has been published in the journal *Science*.

"Scientists are excited we finally understand where Io's magma is coming from and have an explanation for some of the mysterious signatures we saw in some of the Galileo's magnetic field data," said Krishan Khurana, lead author of the study and former co-investigator on Galileo's magnetometer team at UCLA. "It turns out Io was continually giving off a 'sounding signal' in Jupiter's rotating magnetic field that matched what would be expected from molten or partially molten rocks deep beneath the surface."

Io produces about 100 times more lava each year than all the volcanoes on Earth. While Earth's volcanoes occur in localized hotspots like the "Ring of Fire" around the Pacific Ocean, Io's volcanoes are distributed all over its surface. A global magma ocean about 30 to 50 kilometres beneath Io's crust helps explain the moon's activity.

"It has been suggested that both the Earth and its moon may have had similar magma oceans billions of years ago at the time of their formation, but they have long since cooled," said Torrence Johnson, a former Galileo project scientist based at NASA's Jet Propulsion Laboratory in Pasadena, Calif. He was not directly involved in the study. "Io's volcanism informs us how volcanoes work and provides a window in time to styles of volcanic activity that may have occurred on the Earth and moon during their earliest history."

NASA's Voyager spacecraft discovered Io's volcanoes in 1979, making that moon the only body in the solar system other than Earth known to have active magma volcanoes. The energy for the volcanic activity comes from the squeezing and stretching of the moon by Jupiter's gravity as Io orbits the largest planet in the solar system.

Galileo was launched in 1989 and began orbiting Jupiter in 1995. Unexplained signatures appeared in magnetic field data from Galileo flybys of Io in October 1999 and February 2000. After a successful mission, the spacecraft was intentionally sent into Jupiter's atmosphere in 2003.

"During the final phase of the Galileo mission, models of the interaction between Io and Jupiter's immense magnetic field, which bathes the moon in charged particles, were not yet sophisticated enough for us to understand what was going on in Io's interior," said Xianzhe Jia, a co-author of the study at the University of Michigan.

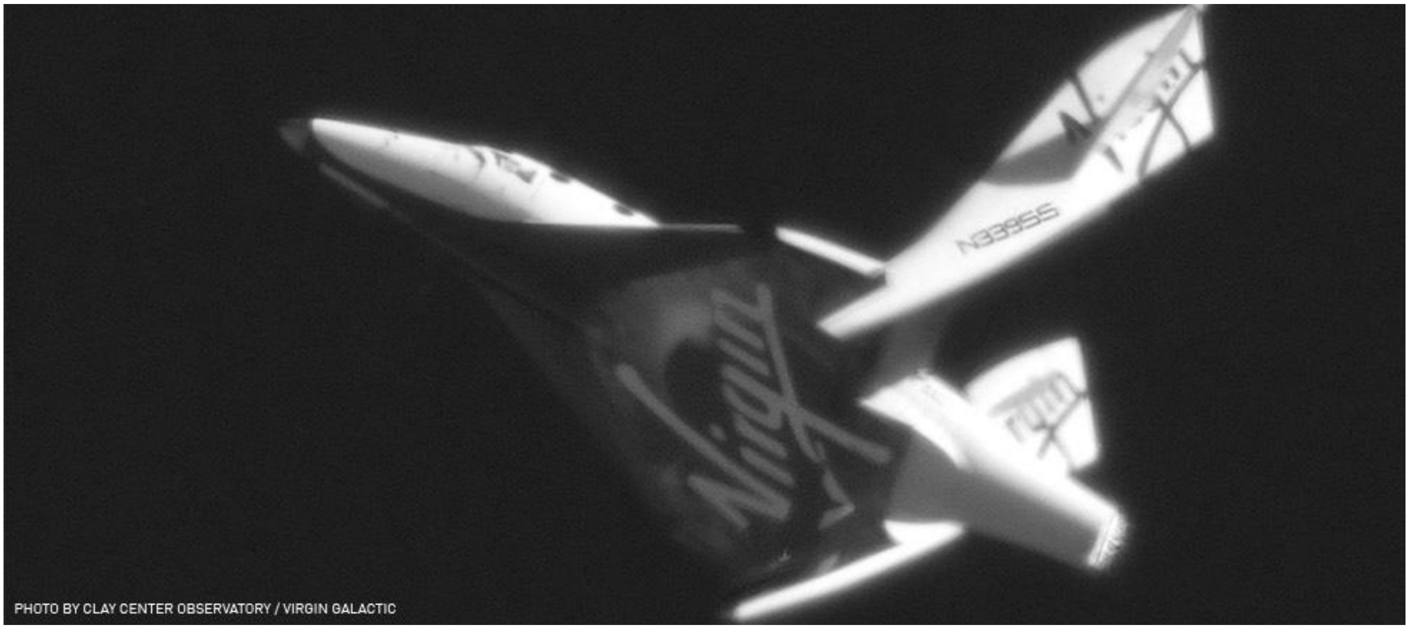
Recent work in mineral physics showed that a group of rocks known as "ultramafic" rocks become capable of carrying substantial electrical current when melted. Ultramafic rocks are igneous in origin, or form through the cooling of magma. On Earth, they are believed to originate from the mantle. The finding led Khurana and colleagues to test the hypothesis that the strange signature was produced by current flowing in a molten or partially molten layer of this kind of rock.

Tests showed that the signatures detected by Galileo were consistent with a rock such as lherzolite, an igneous rock rich in silicates of magnesium and iron found in Spitzbergen, Sweden. The magma ocean layer on Io appears to be more than 50 kilometres, making up at least 10 percent of the moon's mantle by volume. The blistering temperature of the magma ocean probably exceeds 1,200 degrees Celsius.

Dawn captures first image of nearing asteroid

NASA's Dawn spacecraft has obtained its first image of the giant asteroid Vesta, which will help fine-tune navigation during its approach. Dawn is expected to achieve orbit around Vesta on 16 July, when the asteroid is about 188 million kilometres from Earth.

The image from Dawn's framing cameras was taken on May 3 when the spacecraft began its approach and was approximately 1.21 million kilometres from Vesta. The asteroid appears as a small, bright pearl against a background of stars. Vesta is also known as a protoplanet, because it is a large body that almost formed into a planet. "After plying the seas of space for more than a billion miles, the Dawn team finally spotted its target," said Carol Raymond, Dawn's deputy principal investigator at NASA's Jet Propulsion Laboratory in Pasadena,



First Feather Flight of SpaceShipTwo. Photo by Clay Center Observatory/Virgin Galactic

Calif. "This first image hints of detailed portraits to come from Dawn's upcoming visit."

Vesta is 530 kilometres in diameter and the second most massive object in the asteroid belt. Ground- and space-based telescopes obtained images of the bright orb for about two centuries, but with little surface detail.

Mission managers expect Vesta's gravity to capture Dawn in orbit on 16 July. To enter orbit, Dawn must match the asteroid's path around the sun, which requires very precise knowledge of the body's location and speed. By analyzing where Vesta appears relative to stars in framing camera images, navigators will pin down its location and enable engineers to refine the spacecraft's trajectory.

Dawn will start collecting science data in early August at an altitude of approximately 2,700 kilometres above the asteroid's surface. As the spacecraft gets closer, it will snap multi-angle images, allowing scientists to produce topographic maps. Dawn will later orbit at approximately 200 kilometres to perform other measurements and obtain closer shots of parts of the surface. Dawn will remain in orbit around Vesta for one year. After another long cruise phase, Dawn will arrive in 2015 at its second destination, Ceres, an even more massive body in the asteroid belt.

Gathering information about these two icons of the asteroid belt will help scientists unlock the secrets of our solar system's early history. The mission will compare and contrast the two giant bodies shaped by different forces. Dawn's science instruments will measure surface composition, topography and texture. Dawn will also measure the tug of gravity from Vesta and Ceres to learn more about their internal structures. The spacecraft's full odyssey will take it on a 5-billion-kilometre journey, which began with its launch in September 2007.

SpaceShipTwo's first "feathered" flight marks latest milestone for Virgin Galactic

Early on Wednesday 4 May 2011, in the skies above Mojave Air and Spaceport CA, SpaceShipTwo, the world's first commercial spaceship, demonstrated its unique reentry 'feather' configuration for the first time. This test flight, the third in less than two weeks, marked another major milestone on the path to powered test flights and commercial operations.

SpaceShipTwo (SS2), named VSS *Enterprise*, has now flown solo seven times since its public roll-out in December 2009 and since the completion of its ground and captive -carry test program.

The 4 May flight saw a 6:43 a.m. (local) runway take off for VSS *Enterprise*, attached to its WhiteKnightTwo (WK2) carrier aircraft, VMS *Eve*. At the controls of the of the spaceship were Scaled Composites' test pilots Pete Siebold and Clint Nichols whilst Mark Stucky, Brian Maisler and Brandon Inks crewed the purpose built, all composite, twin fuselage WK2. After a 45 minute climb to the desired altitude of 15,697 metres, SS2 was released cleanly from VMS *Eve* and established a stable glide profile before deploying, for the first time, its re-entry or "feathered" configuration by rotating the tail section of the vehicle upwards to a 65 degree angle to the fuselage. It remained in this configuration with the vehicle's body at a level pitch for approximately 1 minute and 15 seconds whilst descending, almost vertically, at around 4,724 metres per minute, slowed by the powerful shuttlecock-like drag created by the raised tail section. At around 10,210 metres the pilots reconfigured the spaceship to its normal glide mode and executed a smooth runway touch down, approximately 11 minutes and 5 seconds after its release from VMS *Eve*.

All objectives for the flight were met and detailed flight data is now being analysed by the engineers at Scaled Composites, designers and builders of Virgin Galactic's sub-orbital spacecraft.

Perhaps the most innovative safety feature employed by SpaceshipOne and now SpaceShipTwo is the unique way it returns into the dense atmosphere from the vacuum of space. This part of space flight has always been considered as one of the most technically challenging and dangerous and Burt Rutan was determined to find a failsafe solution which remained true to Scaled Composite's philosophy of safety through simplicity. His inspiration for what is known as the feathered re-entry was the humble shuttlecock, which like SpaceShipTwo relies on aerodynamic design and laws of physics to control speed and attitude.

Once out of the atmosphere the entire tail structure of the spaceship can be rotated upwards to about 65 degrees. The feathered configuration allows an automatic control of attitude with the fuselage parallel to the horizon. This creates very high drag as the spacecraft descends through the upper regions of the atmosphere. The feather configuration is also highly stable, effectively giving the pilot a hands-free re-entry capability, something that has not been possible on spacecraft before, without resorting to computer controlled fly-by-wire systems. The combination of high drag and low weight (due to the very light materials used to construct the vehicle) mean that the skin temperature during re-entry stays very low compared to previous manned spacecraft and thermal protection systems such as heat shields or tiles are not needed. During a full sub-orbital spaceflight, at around 21,336 metres following re-entry, the feather lowers to its original configuration and the spaceship becomes a glider for the flight back to the spaceport runway.

Paolo’s wild ride down

ESA astronaut Paolo Nespoli described his 24 May return to Earth aboard Soyuz TMA-20 at a press conference given two days after landing. A smiling Paolo talked about his ride back to Earth and how he was feeling gravity again after his long stay in space.

“It was really an experience!" said Paolo at the press conference. “After a nice and quiet life in space, the reentry was then rapid, cruel and rough – we were like shaken with a big hammer!”

The return and landing of Soyuz TMA-20 went well, ending in perfect conditions, with the ground crew reaching the capsule soon after touchdown. Paolo was the last of the trio to be helped out and, after a short rest in the warm spring morning air, he was met by the medical team waiting nearby. A check-up by doctors is standard after landing because it is not uncommon that even the strongest astronauts are stressed by the heavy deceleration of reentry and feel weak in the strong pull of Earth’s gravity after a long period of weightlessness on the Space Station.

“I had difficulties in breathing under the strong deceleration. I remembered that I had to extend my head to make breathing easier, but I couldn’t do that because I filled every millimetre of the space in the capsule!”

The three were then flown by helicopters to the nearby city of Karaganda, two hours away. After a traditional welcome ceremony, Paolo and NASA astronaut Cady Coleman took a plane to Houston. The ash cloud from the erupting Icelandic volcano changed the route, adding to the travel time.
Paolo was already feeling good by the time of their stopover in the UK, and after two days’ rest was doing even better. Immediately on reaching NASA’s Johnson Space Center, Paolo began tests for comparison with the results from before and during his flight. “And thanks to all my followers on Twitter and Flickr for all your comments and support. I really appreciate it!”

Soyuz is a rugged and reliable spacecraft, but it does not provide the most comfortable ride back from the orbit. It takes a relatively leisurely two days to reach the Space Station – but the return lasts only a few hours. Paolo’s Soyuz fired its main engine for about four minutes at 01:30 GMT 24 May to begin the descent. The orbital and service modules were then discarded. Commander Kondratyev turned the capsule with its heatshield forwards. At about 02:03 GMT, the crew could feel the friction from the thin gas of the upper atmosphere beginning to brake the craft. As the Soyuz bit into the denser atmosphere, the deceleration built up to about five times Earth gravity. The parachutes opened at 02:11 GMT: the small drogue chute first, and then the big main canopy. This was a violent event: the capsule tumbled and spun, until the main chute was fully open and stabilised the ride.

The Soyuz TMA-20 spacecraft is seen as it touches down in a remote area southeast of the town of Dzhezkazgan, Kazakhstan, on 24 May 2011 (NASA/Bill Ingalls)

During the last 10 kilometres the crew felt the powerful tug of gravity gradually taking over from the reentry forces, as they swung slowly below the parachute. The Soyuz landed, as usual, with pinpoint accuracy right on time at 02:27 GMT on the Kazakh steppe.

Touchdown is not really soft – there is no doubt that terra firma has been reached. In perfect conditions, as on Tuesday, when the wind is still, Soyuz lands nicely upright, firing the retrorockets just before touching down to cushion the landing. In difficult conditions, it can tip over and be dragged along by the parachute before coming to rest.

The Soyuz capsule is small but at least in weightlessness it feels larger. After landing, the crew, weakened by their long stay in space, find it difficult climbing out in their Sokol suits. During a long space mission the human body stretches: an astronaut can ‘grow’ several centimetres. This comes mainly from the spine, which is squeezed and slightly curved on Earth, but extends to its natural length in weightlessness. This can cause back pain during the first days in space, and after landing. The gain in length is taken into account during seat fitting tests (like here) before launch, but the strong re-entry forces can make it feel far from comfortable during descent.

Paolo's last tweet from space said: “Going home from ISS on a wild ride.” And, for him, it was!

STS-134 Mission Report

By Ed Case

Space shuttle Endeavour and its six-member STS-134 crew head toward Earth orbit and rendezvous with the International Space Station. Liftoff was at 8:56 a.m. (EDT) on 16 May 2011, from Launch Pad 39A at NASA's Kennedy Space Center. (NASA)

Endeavour crew:

- Mark E. Kelly (Commander; 4th flight)
- Gregory H. Johnson (Pilot; 2nd flight)
- Gregory Chamitoff (Mission Specialist; 1st flight)
- Michael Fincke (Mission Specialist; 3rd flight)
- Robert Vittori (Mission Specialist, ESA; 3rd flight)
- Andrew J. Feustel (Mission Specialist; 2nd flight)

Notes: 134th shuttle flight, 25th flight for Endeavour and 36th flight to the ISS. The last shuttle flight for Endeavour, and was scheduled for the last shuttle flight in the shuttle program until Congress appropriated money for one more launch. STS-135 (Atlantis) will be the next and last mission. First time a Soyuz spacecraft departed while a space shuttle was docked to the station. This will be the last time a spacewalk by shuttle crewmembers will take place. This was the 25th night landing and the 77th landing at KSC.

On a breezy Monday, 16 May 2011, Soace Shuttle *Endeavour* lifted off at 7:56 a.m. on its last mission carrying the 6,802.5-kilogram, US$2 billion Alpha Magnetic Spectromter-2 (AMS) and a spare-parts carrier. Several hundred thousand people came to the Kennedy area to see Endeavour lift off, and officials estimated the number at a bit over half the crowd at the scheduled April 29 launch, on a Friday afternoon. That launch was scrubbed because of a technical problem.

Aboard the International Space Station waiting to welcome Endeavour and its crew were station Expedition 27 Commander Dmitry Kondratyev and flight engineers, Paolo Nespoli, Cady Coleman, Andrey Borisenko, Alexander Samokutyaev and Ron Garan.

On their first full day in space the astronauts performed an inspection of the orbiter's thermal protection system and checked out the spacesuits and rendezvous tools for the first space walk. The crew took turns monitoring and using the shuttle's robotic arm and its orbiter boom sensor system to look at the reinforced carbon-carbon on the spacecraft's nose and wing leading edges. Vittori and Johnson then latched the shuttle robotic arm onto the Express Logistics Carrier 3 to prepare for its installation shortly after arrival at the station.

Endeavour docked with the ISS at 5:14 a.m. CDT Wednesday 18 May. As the shuttle slowly approached the station, with both spacecraft moving at 27,353 kilometres per hour, it paused about 182 metres below it to do the standard back-flip, beginning at 4:15 a.m. Nespoli, Coleman and Kondratyev used cameras with 400 mm, 800mm and 1,000mm lenses to take numerous pictures of the shuttle's thermal protection system. Following docking, the hatches were opened at 6:38 a.m. After the welcoming ceremony by the Expedition 27 station crew, the shuttle astronauts got the required station safety briefing.

Around 5:10 a.m., *Endeavour* Commander Mark Kelly, Johnson, and Mission specialists Feustel, Fincke and station Flight Engineer Ron Garan responded to questions relayed up from moderator Miles O'Brien for Google and the PBS NewsHour. About 9 a.m. Kelly and station Flight Engineer Cady Coleman talked with representatives of National Public Radio, Associated Press, Reuters and Fox News.

Installing the AMS

On Thursday 19 May, the priority task was the attachment of the Alpha Magnetic Spectrometer-2 (AMS) atop the Starboard 3 segment of the ISS truss. Attachment was confirmed at 4:46 a.m. CDT by *Endeavour* Pilot Greg Johnson and Mission Specialist Greg Chamitoff operating the station's Canadarm2. Earlier, Mission Specialists Andrew Feustel and Roberto Vittori had used the shuttle arm to take AMS out of Endeavour's cargo bay to hand it off to the station arm.

The truss is to be the home of the instrument for the life of the station, through at least 2020. The instrument is expected to see 25,000 cosmic particles a second and can downlink six megabits of data per second. The AMS project involves 600 scientists and technicians, 56 institutions and 16 countries. Following initial checkouts, the team members in mission control were quickly able to see a vast amount of data from the detectors already.

Massachusetts Institute of Technology Professor Samuel Ting, AMS principal investigator, congratulated crew members by radio from the station flight control room in the Mission Control Center. He thanked them for the safe delivery to the station. He said their work has "taken us one step closer to realizing the scientific potential of AMS."

First spacewalk

Feustel and Chamitoff "camped out" in the Quest airlock overnight, helping acclimate their bodies to the lower atmospheric pressure of their space suits, reducing the possibility of decompression sickness by purging nitrogen bubbles from their bloodstreams.

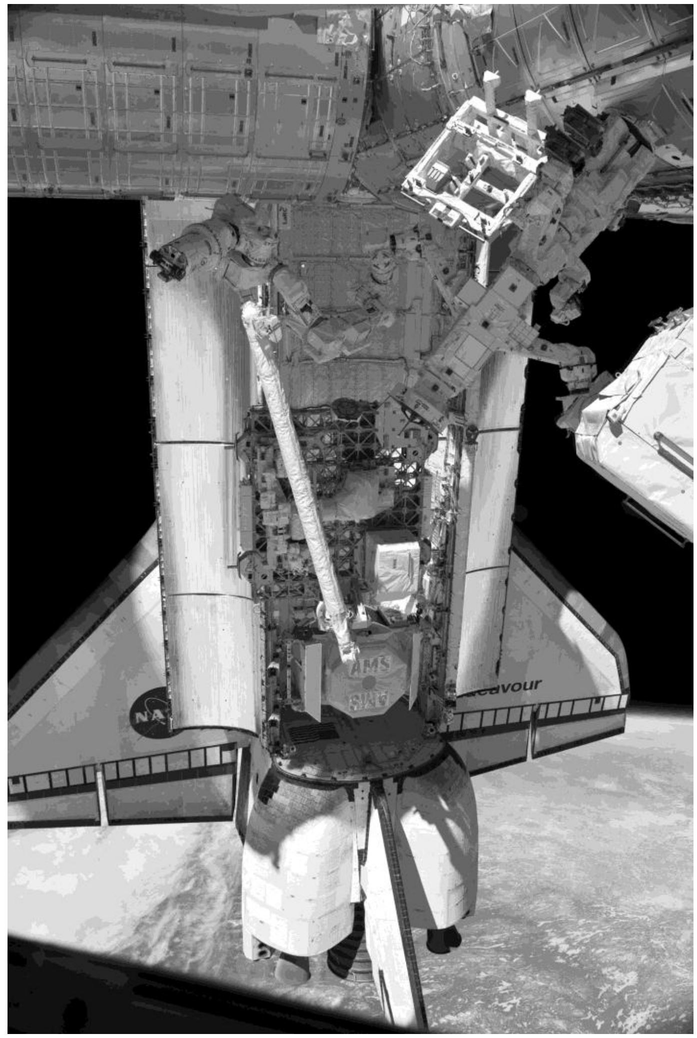
The first spacewalk of the mission started just after 2 a.m. Friday morning, 20 May. Mission specialist Mike Fincke served as intravehicular officer, coaching the spacewalkers through their tasks. Astronaut Steve Swanson, himself a veteran of four spacewalks, was in the station flight control room at the Mission Control Center, serving as spacewalk Capcom. Commander Kelly provided photo and TV coverage.

Feustel and Chamitoff worked first on unhooking power cables and fasteners to retrieve the Materials International Space Station Experiments (MISSE) 7A and 7B from Express Logistics Carrier 2 on the station's starboard truss. The suitcase-like devices, opened to expose small samples of numerous materials to the harsh conditions of space, were installed during STS-129 in November 2009. Feustel installed and connected the new MISSE 8 experiment there, while Chamitoff moved on to the light installation on the Crew Equipment Translation Aid (CETA) cart, on truss rails at the S3 segment. Next the two installed a cover on the starboard solar alpha rotary joint. The joint allows solar arrays to rotate to follow the Sun.

Working together they installed a jumper cable, and vented nitrogen from another loop. That work was in preparation for adding ammonia to the P6 photovoltaic cooling loop during the next spacewalk. The P6 has a slow leak.

For the lengthiest task of the spacewalk, the astronauts moved on to install and connect antennas for the External Wireless Communication system. The antennas are integrated into two replacement handrails. Chamitoff installed them on the U.S. laboratory Destiny while Feustel routed cables. Together the astronauts worked to connect those cables.

An issue with a carbon dioxide level sensor in Chamitoff's suit caused replanning of the later part of the spacewalk. Removal of a micrometeoroid debris shield to access some cable connection points and to hookup some of the cables was put on hold to ensure Chamitoff would be back in the airlock early. There was no indication that his suit's carbon dioxide levels would rise, but without information from the sensor, flight controllers decided on the conservative course of action.



The Alpha Magnetic Spectrometer-2 can be seen at the rear of Endeavour's cargo bay prior to installation on the ISS (NASA)

The spacewalk ended at 8:29 a.m., a little earlier than had been planned. The 6-hour, 19-minute spacewalk was the fourth for Feustel and the first for Chamitoff. It was the 156th for station assembly and maintenance and the 245th by U.S. astronauts.

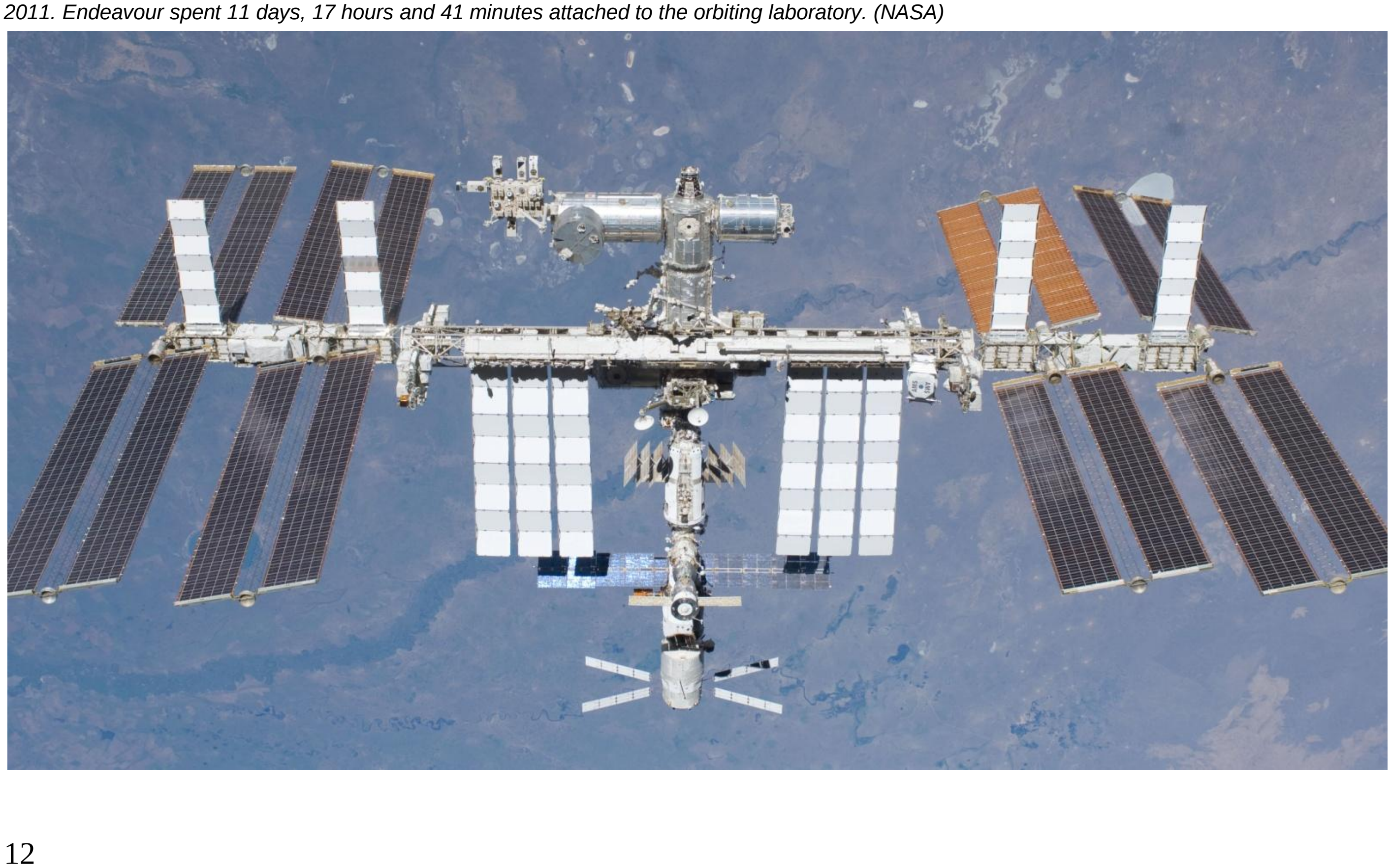
On Saturday 21 May at 6:11 a.m., both crews had a conversation with Pope Benedict XVI. The pope, introduced to the crew by Thomas Reiter, astronaut and director of European Space Agency human spaceflight operations, asked the crews about their views of the thoughts about the Earth. He also asked about what messages they would bring back to Earth from space and what they reflect on in space.

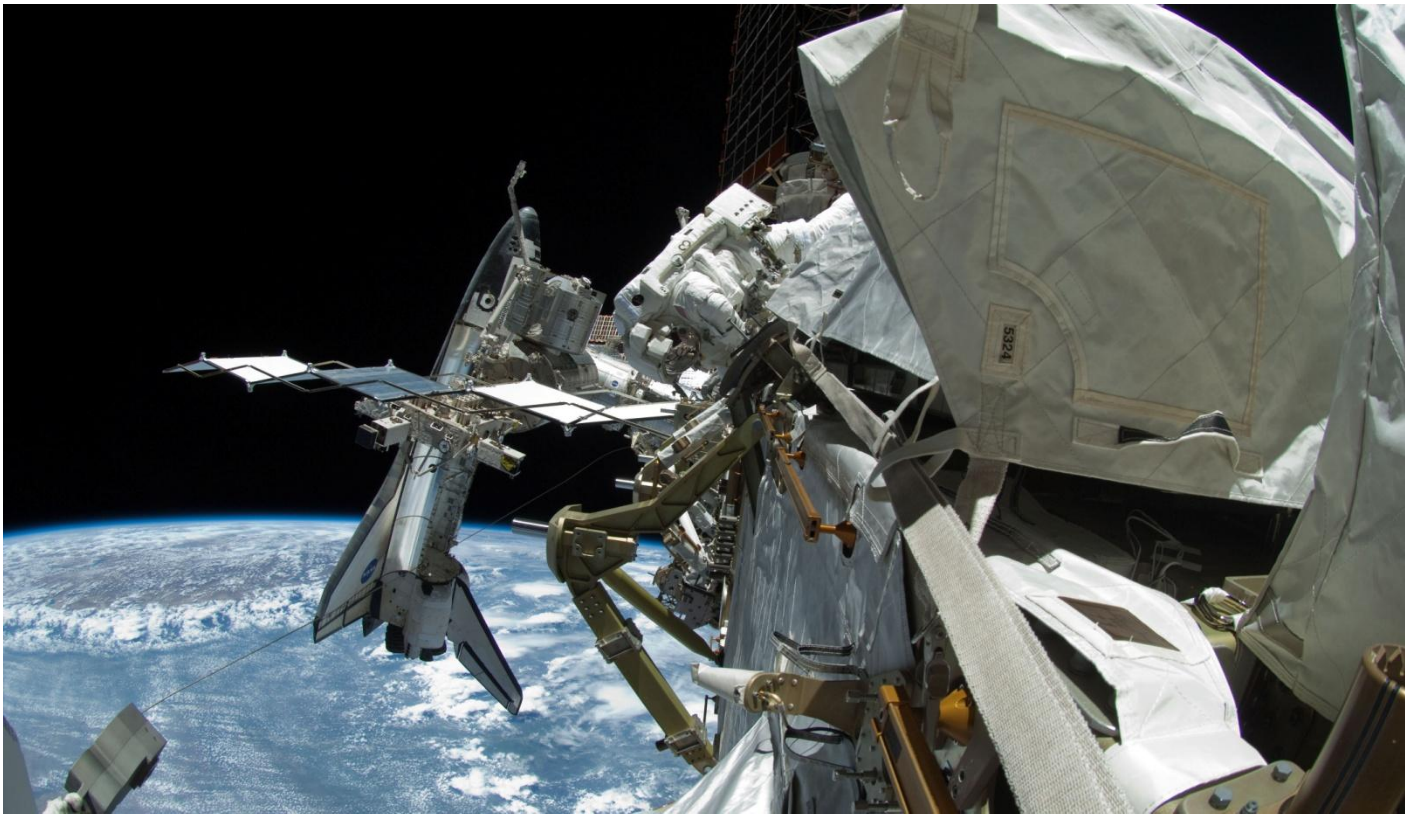
Mission managers also cleared *Endeavour*'s thermal protection system for reentry after analysis of data and images from an early-morning focused robotic inspection of the tiles.

Later in the day, after a rest period, astronaut Vittori worked on transfer and stowage. The Expedition 27 crew joined in the afternoon for a "Change of Command" Ceremony in advance of the Monday departure of outgoing Commander Dmitry Kondratyev and Flight Engineers Paolo Nespoli and Coleman. Andrey Borisenko will serve as commander of Expedition 28, leading Flight Engineers Ron Garan and Alexander Samokutyaev.

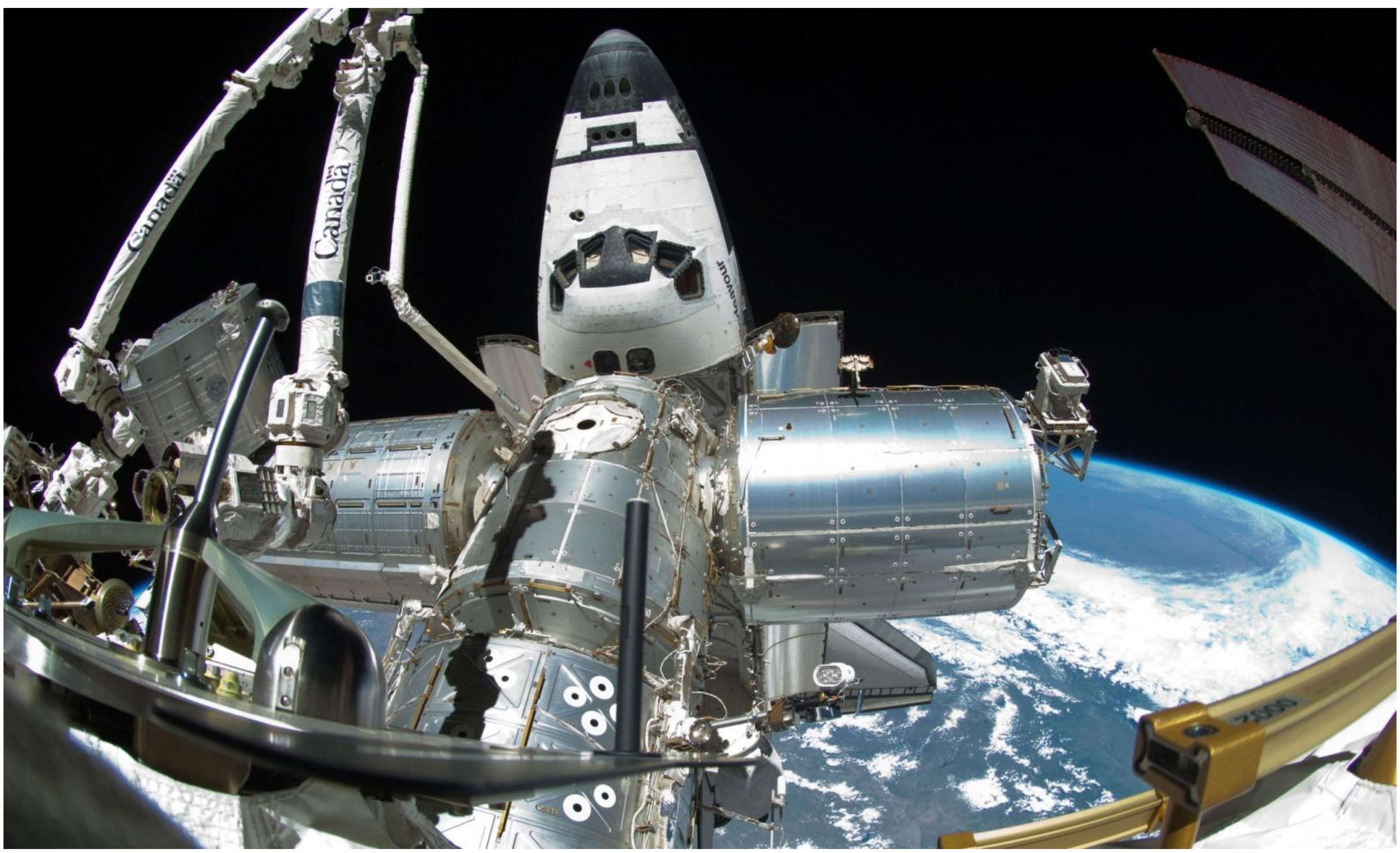
(Top) A portion of the International Space Station is visible in this view of a starry sky and Earth's horizon, photographed by an STS-134 crew member while space shuttle Endeavour remains docked with the station.

(Bottom) The International Space Station is featured in this image photographed by an STS-134 crew member on the space shuttle Endeavour after the station and shuttle began their post-undocking relative separation. Undocking of the two spacecraft occurred at 11:55 p.m. (EDT) on May 29, 2011. Endeavour spent 11 days, 17 hours and 41 minutes attached to the orbiting laboratory. (NASA)





(Top and bottom) A portion of the International Space Station and the docked space shuttle Endeavour are featured in these images photographed by a spacewalker, using a fish-eye lens attached to an electronic still camera, during the STS-134 mission's fourth session of extravehicular activity (EVA). The blackness of space and Earth's horizon provide the backdrop for the scene. (NASA)



Astronauts Mark Kelly (left), STS-134 commander; and Greg H. Johnson, pilot, occupy their respective stations on the forward flight deck of space shuttle Endeavour during rendezvous and docking operations with the International Space Station on flight day three. (NASA)

Second spacewalk

Feustel and Fincke performed the mission's second spacewalk early on the morning of Sunday 22 May, and it turned into a long day as they worked to complete all of their scheduled tasks. The Intravehicular officer, coaching them through this spacewalk, was Greg Chamitoff who participated in the first spacewalk and will go on the fourth and final spacewalk of the mission and last for the shuttle space program. Astronaut Steve Swanson served as spacewalk Capcom in the station flight control room in Houston's Mission Control Center. Commander Mark Kelly readied the spacewalkers and then documented the day though photos and video.

The first task was rerouting an ammonia jumper cable between cooling loops on port-side truss segments, between P3 and P4. With that done, they moved to top off ammonia in a slowly leaking P6 cooling loop, adding about 2.26 kilograms to the loop, which has a capacity of about 25 kilograms.

With that complete, Fincke moved to the port solar alpha rotary joint, which allows the solar arrays to track the Sun, and began to remove covers over the joint so he could lubricate its race ring. After some difficulty – one bolt holding the covers was lost – mission control decided he should remove four of the covers instead of the six originally planned.

After Fincke did the first of two planned lubrications of the race ring, flight controllers began a partial rotation of the port array joint to spread the race-ring lubricant. During that rotation, the two spacewalkers restored the ammonia jumper cables to their original positions.

Feustel's next task was installing a camera cover on Dextre, also known as the Special Purpose Dexterous Manipulator, and lubricating one of the robot's hands. *Endeavour* Pilot Greg Johnson and station flight Engineer Cady Coleman used the Canadarm2 to carry Dextre to Feustel. Coleman was in her last full day aboard the station before her planned return to Earth Monday with fellow Expedition 27 crew members.

Fincke installed two radiator grapple bar stowage beams on the starboard, S1 truss segment. The partial array rotation complete, he and Feustel returned to the joint to give it a second round of lubrication. Next they reinstalled three of the four joint covers. The fourth was returned to the airlock and will be installed later.

The two spacewalkers wrapped up their 8-hour, 7-minute spacewalk at 9:12 a.m. The spacewalk was the fifth for Feustel and the seventh for Fincke: the previous six were in Russian suits. It was the 157th for station assembly and maintenance and the 246 by U.S. astronauts.

On Monday afternoon, 23 May, *Endeavour* astronauts said goodbye to half of their ISS colleagues as the Expedition 27 crew members prepared to return to Earth. Commander Dmitry Kondratyev and flight Engineers Paolo Nespoli and Cady Coleman said their farewells to station crewmates and closed the hatch of their Soyuz TMA-20 spacecraft at 1:45 p.m. that was about two hours after Endeavour astronauts' sleep period had begun. Undocking was around 4:35 p.m.

Endeavour crew members had most of the day off after the demanding and successful activities of their mission to this point. Commander Mark Kelly and Mission specialist Mike Fincke answered questions Sunday night from youngsters among about 400 kindergartens to fifth-grade students at Mesa Verde Elementary School in Tucson, Ariz. Around 8:30 a.m. Mission specialist Roberto Vittori and fellow Italian Nespoli talked with Italian President Giorgio Napolitano in Rome.

On Monday evening, after a rest period, Fincke, with help from Garan, replaced a remote power controller module, essentially a circuit breaker box that allows transfer of files to the ground. Some experiment data was affected, but many of those experiments can store data for later transmission.

Meanwhile Endeavour commander Mark Kelly worked to replace a desiccant bed in a station carbon dioxide removal assembly. Later the work day, Fincke and Chamitoff worked to replace an element of an oxygen generation system. The *Endeavour* astronauts also got a couple of hour of off duty-time.

Just before midnight, Pilot Greg Johnson and Chamitoff talked with media representatives from two San Francisco stations, KPIX-TV and KGO-TV, and Sacramento's KFBK Radio. At about 5:45 a.m. Kelly, Fincke and Chamitoff fielded questions from The Daily, NewsRadio 1020 KDHA in Pittsburgh, Houston's KTRK-TV and the Pittsburgh Tribune-Review.

On Tuesday 24 May, Feustel and Fincke tried a new procedure before their next extravehicular venture the following day. Normally, the spacewalkers spend the night before their spacewalk sleeping in a secluded module at a reduced atmosphere. The new procedure, In-Suit Light Exercise (ISLE), allows for the crew members to sleep in the normal configuration. After wake-up, the participants breathe pure oxygen for one hour as air pressure in the module is lowered to 10.2 pounds per square inch. They then don their spacesuits and perform light exercise, such as small leg motions, for 50 minutes to increase their metabolic rate and purge nitrogen from their bloodstream.

Third spacewalk

The third spacewalk of the mission started around 1 a.m. Wednesday morning, 25 May. Chamitoff was again the intravehicular officer and Kelly did the photos and video.

Feustel and Fincke installed a power and data grapple fixture on the Russian Zarya module that would allow the Canadarm2 to access most of the Russian segments of the ISS. The arm can "inchworm" its way to the new base by grasping it and then releasing the hand holding the old base to become the new and effector. A cable to provide power to that new operating base was on the to-do list for the fourth walk.

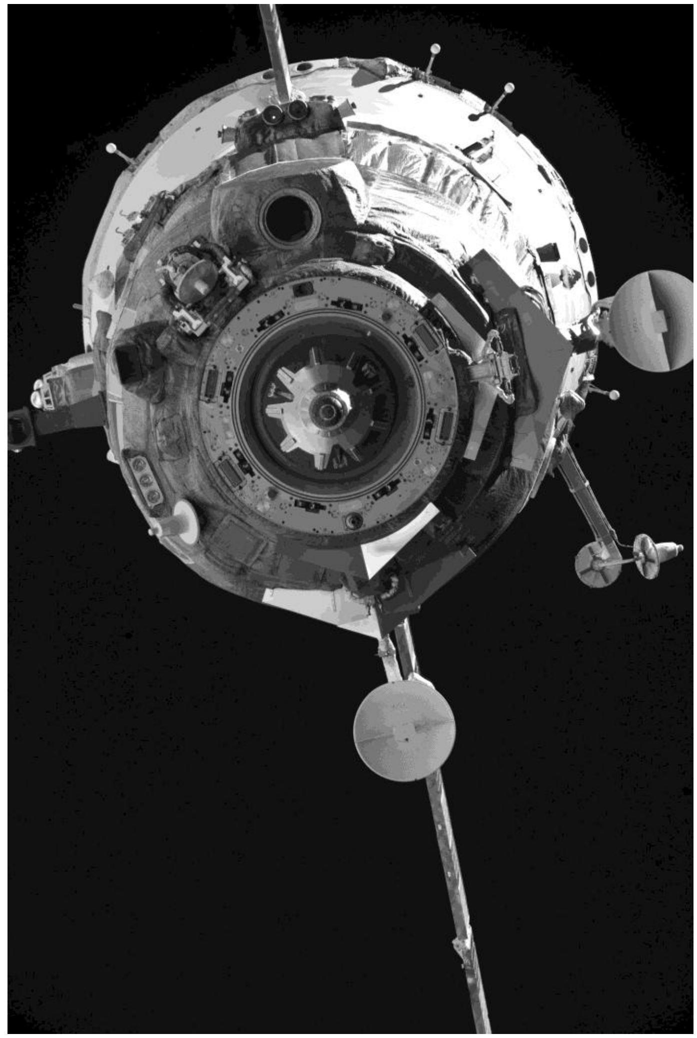
They installed a video signal converter on Zarya and ran power cables from the U.S. segment to Zarya. That provides a backup for transmission of power from the solar arrays tot the Russian segment.

The two completed a job started on the first walk, finishing hookup of an external wireless communications system antenna. The work was postponed because of a malfunction of one suit's carbon dioxide gauge that caused the Friday spacewalk to be cut short. They took photos of some of their handiwork and of Zarya thrusters, and some infrared video of an experiment involving coatings with variable thermal control qualities. The spacewalk ended at 7:37 a.m.. It was the sixth for Feustel and the eighth for Fincke.

The *Endeavour* crew spent much of the next day on late inspection of the shuttle's thermal protection system and preparations for the fourth and final spacewalk of their visit to the ISS. Johnson, Fincke and Feustel used the shuttle arm with the 15.2-metre orbiter boom sensor system to survey the right wing. Vittori, Feustel and Chamitoff looked at the shuttle's nose cap. Johnson, Vittori and Chamitoff would up the survey with inspection of the left wing, completed at 12:16 a.m.

Fourth spacewalk

Fincke and Chamitoff again "camped out" in the Quest airlock prior to the fourth spacewalk. The in-suit light exercise protocol, successfully used for the same purpose before the third spacewalk, was not employed for the fourth, because it requires greater use of carbon-dioxide-removing lithium hydroxide canisters. The carbon dioxide sensor in Chamitoff's suit failed during the first spacewalk. Continuing with the campout was a conservative approach, giving spacewalkers an additional 40 minutes of carbon dioxide scrubbing capability,



Soyuz TMA-20 departs the ISS carrying the Expedition 27 crew back to Earth on 23 May 2011 (NASA)

and was part of the pre-flight plan to prepare for the last spacewalk.

Feustel, who participated in the first three spacewalks, coached Fincke and Chamitoff through their tasks as intravehicular officer. Swanson was spacewalk Capcom from the station flight control room. *Endeavour* commander Mark Kelly again worked with photo and video documentation.

Pilot Greg Johnson and station flight Engineer Ron Garan at the arm's controls in the Cupola took the 15.2-metre boom from the station arm. They moved the boom to the S1 truss and handed it off to the two spacewalkers. Fincke and Chamitoff secured it in attachment fixtures, making it officially a part of the station called the ISS boom assembly.

The two subsequently retrieved a power and data grapple fixture from the left end of the truss assembly and brought it back to the boom. They removed an electrical flight grapple fixture, which the shuttle arm had used, and replaced it with the fixture they had brought back. That fixture enables Canadarm2 to attach to the boom's end, to use it as an extension should the need arise. With the grapple fixture replacement, the boom became the enhanced ISS boom assembly, a name that should stick for a while.

The last major task was working with Dextre, the special purpose dexterous manipulator. At the Express Logistics Carrier 3 on the truss, they removed launch restraints from a spare arm for the robot-like device brought up by *Endeavour*. That

Xenon lights help lead space shuttle Endeavour home to NASA's Kennedy Space Center in Florida. Endeavour landed for the final time on the Shuttle Landing Facility's Runway 15. (NASA)

completed, Fincke and Chamitoff began the standard cleanup tasks, then moved back into the Quest airlock. Repressurization began at 6:39 a.m., marking the end of the 7-hour, 24 -minute spacewalk – the final spacewalk of the shuttle programme.

At 4:02 a.m., the two astronauts completed the 1,000th hour of spacewalk activity for space station assembly and maintenance. It also left Fincke on the threshold of a personal mark. About 7 p.m. Friday evening he became the U.S. astronaut with the most time in space, more than 377 days, including two long-duration station missions. That will surpass the time in space of Peggy Whitson, chief of the Astronaut Office.

The following day Fincke and Chamitoff spent much of their day on the CO2 scrubber, replacing a desiccant/sorbent bed on the device called a carbon dioxide removal assembly. The task was budgeted for about four hours, with additional time for remounting the device, but the work's complexity and difficulty caused it to run longer. Feustel and Vittori worked for about four hours on moving equipment and supplies. The transfer work had been running ahead of schedule and is nearly complete, except for last-minute items like those requiring refrigeration.

Kelly and Johnson spent time in a study of spinal elongation. The importance of the study was illustrated during the Friday spacewalk. Chamitoff had trouble hooking his feet into a foot restraint because, he believes, his spacesuit's legs were slightly too long. He apparently had not grown as much in space as had been predicted.

Early Sunday morning, just after midnight, *Endeavour* used its small vernier jets to reboost the station, raising its altitude by about 963 metres.

Heading for home

Endeavour undocked from the ISS at 10:55 p.m. Sunday night ending a stay of 11 days, 17 hours and 41 minutes at the orbiting laboratory. "*Endeavour* departing," said Expedition 28 Engineer Ron Garan after the traditional ringing of the station's bell. "Fair winds and following seas." Pilot Greg Johnson, at the aft flight deck control, flew *Endeavour* in a circle around the station at distances of about 137 metres to 198 metres. Crew members took still and video images of the station. As Johnson was about to begin the flyaround, Commander Mark Kelly radioed mission control that he could see the Alpha Magnetic Spectrometer particle physics detector *Endeavour* had brought to orbit. "It's a new day for science on the space station," he said to mission control.

After the flyround and a separation burn, Kelly took the controls for a test of an automated rendezvous and docking system called STORRM, for Sensor Test for Orion Relative Navigation Risk Mitigation. Endeavour moved about 6,096 metres above and behind the station, then to a point below and behind it. Kelly subsequently manoeuvred the shuttle on a rendezvous-like course, winding up at a point about 289 metres below the station. There the shuttle did a separation burn, beginning its departure from the area with the STORRM sensors still tracking the station until contact was lost. Initial reports were that the test had produced good data.

This flight, *Endeavour*'s last, was its 25th. Twelve of its missions have taken it to the station, and on one flight it visited the Russian space station Mir. The 12 missions are among 36 visits to the ISS by shuttles. Orbiters have spent a total of almost 268 days docked there.

Monday evening through Tuesday (30-31 May), the crew spent much of their day getting ready for their return to earth. Kelly, Johnson, and Vittori powered up and checked out the flight control system. Fincke, Feustel and Chamitoff stowed items in the cabin for re-entry. Each crewmember got an hour's exercise. After lunch, the astronauts did a 15-minute vision exam, and all gathered for a 30-minute deorbit briefing. Kelly and Johnson spent about 30 minutes with the RAMBO 2 (Ram Burn Observations) experiment, firing an orbital maneuvering system engine. The experiment is aimed at better understanding spacecraft engine plumes.

All the crew talked with representatives of ABC News, CBS News, CNN, NBC News and Fox News Radio. Later they sent a down a tribute to Endeavour, nearing the end of its last flight. The crew began their sleep period at 8:56 a.m.

While *Endeavour*'s crew was preparing to come home, the orbiter that will fly the final space shuttle mission was heading to Launch Pad 39A. Atlantis started its rollout from the Vehicle Assembly Building at 8:00 p.m.

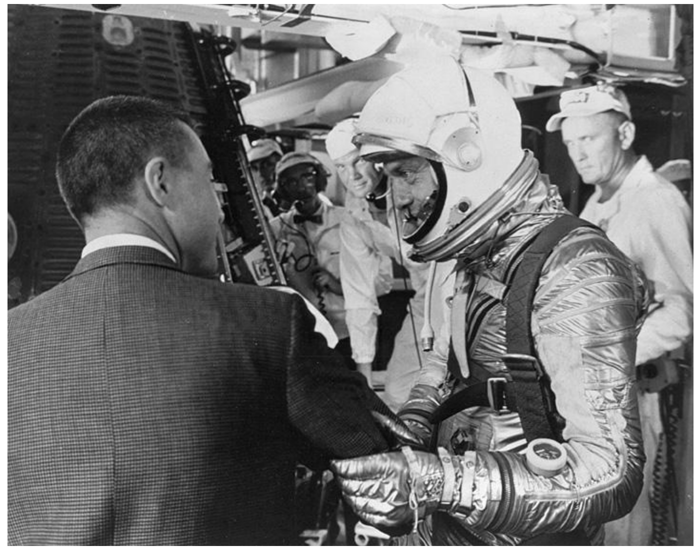
After a six and a half million-mile mission and 248 orbits, *Endeavour* landed on Kennedy Space Center runway 15 with wheels stopped at 1:35:36 a.m. EDT or 2:35:36 a.m. CDT, Wednesday 1 June. Its missions over, the orbiter is now headed for a museum.

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

"Light this candle!"

50th anniversary of Alan Shepard's *Freedom 7* Mercury flight

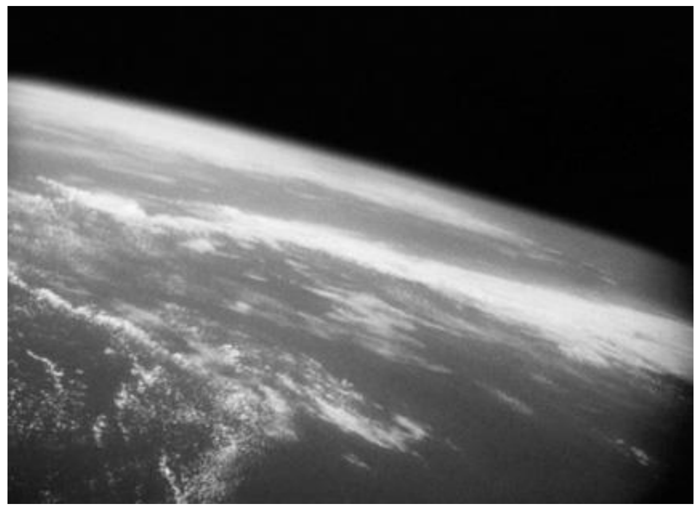
(Above) Alan Shepard suited up prior to his flight. His 5 May 1961, launch from Cape Canaveral, Florida, on a suborbital mission was the first U.S. manned spaceflight.(NASA)



Fellow Mercury astronaut Gus Grissom (in suit) wishes Shepard good luck as he gets set to climb into his Mercury capsule, dubbed Freedom 7, on the morning of May 5, 1961. Glenn looks on in the background. On the way to the launch pad, Shepard had done what he could to "kick the tires" on the Redstone. "I stopped and ... looked back and up at the beautiful rocket, and thought 'Well, OK buster, let's go and get the job done.'" (NASA)

Shepard inside the Freedom 7 capsule before launch (NASA)

In this view, the Mercury-Redstone 3 (MR-3) spacecraft carrying Alan Shepard in Freedom 7 is already headed towards its suborbital maneuver, shortly after lifting off from Cape Canaveral in Florida. (NASA)



(Top) Shepard is seen during the 15-minute flight in a still from a movie camera in the capsule

(Middle) The view of Earth enjoyed by Shepard

(Bottom) A helicopter recovers Shepard and Freedom 7 after splashdown (All NASA)

Rapid prototyping and analog testing for human space exploration

By Douglas Craig, NASA

Space Exploration Vehicle docking with Cabin A for a simulated rescue mission. This simulated mission was part of the 2009 Desert RATS held at Black Point Lava Flow in Arizona. (NASA)

Humanity's dream of exploring the wonders of space—to look for life on other planets and to better understand our place in the universe—has not diminished over the years. But advances in human space exploration beyond low-Earth orbit have been slow to emerge.

NASA's new human space-exploration enterprise requires a strategy that will enable us to explore new worlds, develop innovative technologies, and foster burgeoning industries, all while increasing our understanding of Earth and our solar system. It will allow us to work on objects in Earth's orbit such as the International Space Station (ISS) and satellites while also exploring objects such as near-Earth asteroids, the moon, Mars, and Mars's moons. But traveling to and living on these destinations will require us to develop cutting-edge technologies and new ways to work in space to help us survive and thrive in these forbidding, faraway places.

As a first step, NASA has implemented two separate but integrated activities: rapid prototyping and using analog test environments. Rapid prototyping creates innovative concepts for exploration by rapidly developing low-cost but functional space-system prototypes using small, dedicated teams drawn from NASA's ten centers. These prototypes are incorporated into terrestrial, analog mission tests that enable an inexpensive, integrated validation of mission concepts in a representative environment. These analog missions include going out into the Arizona desert to perform long-distance traverses over lunar- and Mars-like terrain, using the National Oceanic and Atmospheric Administration's (NOAA) underwater Aquarius habitat to conduct simulated extravehicular activities under differing levels of gravity, using the Nuytco Research Deepworker submersibles to study microbialites in a remote freshwater lake in Canada for traverse planning and science data collection, and using the volcanic environment of Mauna Kea in Hawaii to test systems that extract oxygen from volcanic rocks.

Rapid Prototyping

Using lessons learned from the Department of Defense and the sub-sea industry's rapid-prototyping activities, NASA created a management environment for the rapid development of several prototypes at very low costs. The philosophy was to establish a series of iterative design-build-test projects, built on the principle that NASA is at its best working with a clear, simple, and understandable vision and a limited amount of time to achieve that vision. The projects focus on producing functional prototypes of increasing fidelity so systems integration issues can be understood early through rigorous design, build, and human in-the-loop testing.

The project teams are multi-center, multidisciplinary groups of capable and motivated individuals working together virtually from their home NASA centers. Several systems were developed using this philosophy, including the Space Exploration Vehicle (previously the Lunar Electric Rover), a habitat demonstration unit, Robonaut 2, a portable communications tower, and an extravehicular activity suit port.

The Space Exploration Vehicle (SEV)

In the past, many people believed the best way to explore the lunar surface would be similar to the Apollo missions: astronauts in space suits using a rover with no enclosed cabin. Others believed a small rover with an enclosed, pressurized cabin that allowed astronauts to function without being in their space suits—but with the ability to quickly put on or take off a space suit—would be more effective. This debate continued for about a year with experts arguing over presentation charts until, at a workshop break, three people came up with a plan to develop a low-cost, low-fidelity version of the rovers needed to test the competing concepts.

Nine months later, the concept vehicle now known as SEV was sent out into the desert to pit its performance against an unpressurized rover—and prove that pressurized rovers were 67% more effective than unpressurized rovers while providing an environment better suited for long-duration surface exploration missions.

Key to SEV's success was a high-level set of architecture questions to be addressed and a clear vehicle concept. The project manager also had the flexibility to develop a project structure and choose team members. Because of the tight funding and schedule, this team was kept very small, with members having much more responsibility than on larger NASA hardware-development projects. This empowered the task leaders and required them to be creative in their areas of responsibility, instilling a feeling of greater accountability. They also had more agility since the process for making changes involved much less review and paperwork than typical NASA projects.

The SEV project was able to make important design decisions in a thoughtful but cost- and time-efficient manner, due mainly to the small team and the prototype vehicles not being flight vehicles. Quick decisions in the early stages of development—when mistakes are less expensive and less consequential—gave the project team an understanding of how those decisions interact and how they manifest in hardware.

For example, the initial design of the suit port on the SEV consisted of a manual latching mechanism, on the principle of keeping the design as simple as possible. The test at the Desert Research and Technology Studies (Desert RATS) demonstrated that the mechanism design did not perform well in the environment. These results formed the basis for changing the mechanism from the manual mechanical latch to an electrically powered latch. Learning this early on in the design phase allowed the change to be made with minor cost impact.

As missions to other destinations are studied, the SEV concept has been found to be very advantageous for in-space activities such as satellite servicing and exploration of asteroids. As a result, the SEV now has two variants: one for surface exploration and one for in-space exploration.

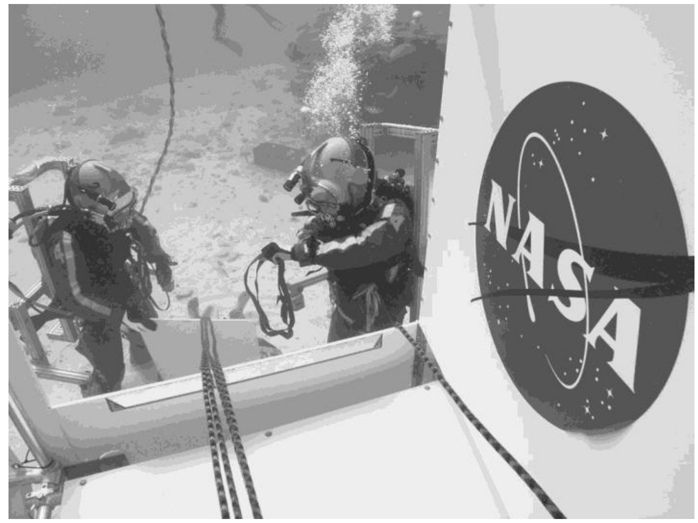
Analog Testing

Driving a rover around a center's rock yard isn't enough to reveal the true operations and limitations of a vehicle designed for long traverses. It is important to test the systems in an integrated, operational field mission to ensure relevant test results. These extreme environments greatly enhance our ability to analyze concepts in simulated conditions and enable experiments with long-range and long-duration expeditions. Additionally, members from the NASA mission and ground operations team as well as international space agencies, industry, academia, and other government agencies take part in these tests. Each test refines our understanding of the systems and human capabilities needed to successfully explore beyond Earth's orbit while developing the teamwork and methodologies to ensure that future space systems are efficiently built to accomplish their tasks.

NASA has developed a process for these tests of system and operational concepts on Earth and on ISS, known as analog missions. These missions are carried out in representative environments that have features similar to the missions' target destinations. These can include locations underwater, in the arctic, on terrestrial impact craters, in the desert, on volcanic lava flows, and on ISS. Two of the larger missions are the NASA Extreme Environment Mission Operations (NEEMO) and Desert RATS, or D-RATS.

NEEMO

NEEMO uses the only underwater research facility in the world: NOAA's Aquarius habitat. Working in partnership with NOAA, NASA uses the habitat because it provides some of the best conditions for practicing space operations in a harsh environment, giving astronauts a broad knowledge and awareness of risks, issues, and objectives associated with human space-exploration missions. There have also been numerous discoveries made during NEEMO missions on human health, engineering, telemedicine, space operations, education, and public outreach that directly relate to spaceflight needs and are being implemented with each mission.



NASA Aquanaut crew performing demonstration of incapacitated crewman recovery on the side hatch of the SEV during the NEEMO 14 mission. (NASA/Bill Todd)

The NEEMO mission tests are developed with the same rigorous timelines as current shuttle and ISS missions. Upon completion of the latest NEEMO mission, the NEEMO mission commander, Astronaut Chris Hadfield, who has flown on two Space Shuttle flights and was the first Canadian to walk in space, stated that this mission was the closest to a real spaceflight mission as you could get on Earth. This rigor allows us to make informed decisions about design changes before project development begins.

For example, the size of side hatches changed significantly between the first and second SEV designs based on testing configurations at the NEEMO and D-RATS analog field tests. The tests were designed to address the human factors group's belief that a larger hatch was needed for mission operations. Results showed that the astronauts had no issues using the smaller hatch size for standard or emergency operations in a low-gravity environment. This enabled the design to be changed to the smaller hatch size, thereby reducing the overall mass of the architecture vehicles that contain a hatch. This, in turn, reduces the cost of the architecture due to less propellant required throughout the architecture phases. The cost of these tests was minor compared with the cost impact if this information was learned during the flight vehicles' development.

D-RATS

D-RATS field tests have become large missions where multiple prototype systems are tested together to evaluate concepts about integrated operations. Using the Black Point Lava Flow and SP Mountain areas in Arizona—because their terrain, geologic features, size, and dusty environment are similar to what would be encountered on surfaces in space—allows NASA to test prototypes under realistic communications and operational scenarios.

The latest D-RATS field test focused on the simultaneous operation of two SEVs, including new ways of performing surface-science operations. Over a fourteen-day period, the astronaut and geologist crew teams performed a science- and

An astronaut and a geologist don spacesuits to test an unpressurized version of a lunar rover concept that enables them to easily disembark and explore. The test was part of the 2008 Desert RATS held at Black Point Lava Flow in Arizona. (NASA)

exploration-driven course of more than 300 km under different communications and operations scenarios, only egressing to perform simulated extravehicular activities: to collect geological samples or to work in the habitat demonstration unit.

One of the major concerns about the SEV was that its size was relatively small. There were people who did not think it was large enough for a fourteen-day mission; they thought it would be too small for two astronauts to work in the confined space for that period of time due to psychological issues. The ability to perform a fourteen-day mission in an SEV would have a major impact on the mission architecture, reducing the number of heavy-lift launch vehicles needed for a lunar campaign. Upon completion of the test, the crew stated that not only was the size adequate for a fourteen-day mission, but they felt as though it would be suitable for a thirty-day mission. A mission spanning thirty days would allow much more exploration of the lunar surface at a greatly reduced cost.

Inexpensive and informed decision making

Validating rapid prototypes of innovative concepts through analog field tests has greatly advanced NASA's understanding of more effective methods for human space exploration. In addition, the process has provided an example of how future human space-exploration systems can be developed at a greatly reduced cost. Rather than sitting through design reviews and trying to understand how systems would be used, these approaches provide realistic insight into system and operational requirements, guiding design changes early in the development phase and saving the time and cost associated with changing designs and contracts later on.

Douglas Craig is currently the manager of strategic analyses for the Exploration Systems Mission Directorate's (ESMD) Directorate Integration Office at NASA Headquarters. His responsibilities include overseeing the human exploration architecture studies; managing rapid-prototype projects, including the Space Exploration Vehicle, Habitat Demonstration Unit, and Robonaut 2; managing the ESMD integrated, analog mission-test activities; and leading the creation and development of associated partnerships.

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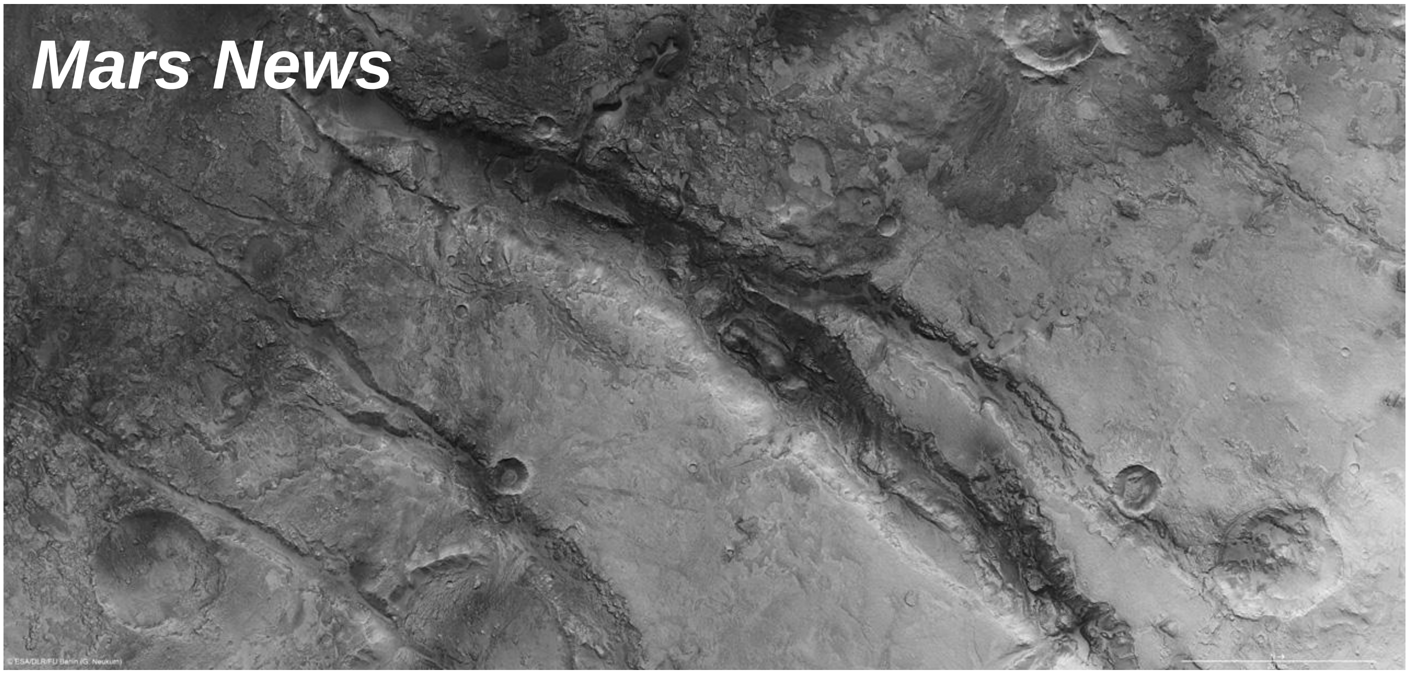
Mars News



Nili Fossae is a graben system on Mars. It is found at 22°N / 77°E, northeast of the Syrtis Major volcanic province, on the northwestern edge of the giant Isidis impact basin. This image shows an area covering approximately 10 300 sq km. It was taken during orbit 5270, on 8 February 2008, using Mars Express's High-Resolution Stereo Camera with a ground resolution of approximately 22 m per pixel. It was derived from the nadir channel, which provides the highest detail of all the channels. (ESA/DLR/FU Berlin, G. Neukum)

Mars Express sees deep fractures on Mars

Newly released images from ESA's Mars Express show Nili Fossae, a system of deep fractures around the giant Isidis impact basin. Some of these incisions into the martian crust are up to 500 m deep and probably formed at the same time as the basin.

Nili Fossae is a 'graben' system on Mars, northeast of the Syrtis Major volcanic province, on the northwestern edge of the giant Isidis impact basin. Graben refers to the lowered terrain between two parallel faults or fractures in the rocks that collapses when tectonic forces pull the area apart. The Nili Fossae system contains numerous graben concentrically oriented around the edges of the basin. It is thought that flooding of the basin with basaltic lava after the impact that created it resulted in subsidence of the basin floor, adding stress to the planet's crust, which was released by the formation of the fractures.

A strongly eroded impact crater is visible to the bottom right of the image. It measures about 12 kilometres across and exhibits an ejecta blanket, usually formed by material thrown out during the impact. Two landslides have taken place to the west of the crater. Whether they were a direct result of the impact or occurred later is unknown. A smaller crater, measuring only 3.5 kilometres across, can be seen to the left of centre in the image and this one does not exhibit any ejecta blanket material. It has either been eroded or may have been buried.

The surface material to the top left of the image is much darker than the rest of the area. It is most likely formed of basaltic rock or volcanic ash originating from the Syrtis Major region. Such lava blankets form when large amounts of low-viscosity basaltic magma flow across long distances before cooling and solidifying. On Earth, the same phenomenon can be seen in the Deccan Traps in India.

Nili Fossae interests planetary scientists because observations taken with telescopes on the Earth and published in 2009 have shown that there is a significant enhancement in Mars' atmospheric methane over this area, suggesting that methane may be being produced there. Its origin remains mysterious, however, and could be geological or perhaps even biological.

As a result, understanding the origin of methane on Mars is high on the priority list and in 2016, ESA and NASA plan to launch the ExoMars Trace Gas Orbiter to investigate further. Nili Fossae will be observed with great interest.

Spirit rover completes mission on Mars

NASA has ended operational planning activities for the Mars rover Spirit and transitioned the Mars Exploration Rover Project to a single-rover operation focused on Spirit's still-active twin, Opportunity. This marks the completion of one of the most successful missions of interplanetary exploration ever launched.

Spirit last communicated on 22 March 2010, as Martian winter approached and the rover's solar-energy supply declined. The rover operated for more than six years after landing in January 2004 for what was planned as a three-month mission. NASA checked frequently in recent months for possible reawakening of Spirit as solar energy available to the rover increased during Martian spring. A series of additional re-contact attempts ended today, designed for various possible combinations of recoverable conditions.

"Our job was to wear these rovers out exploring, to leave no unutilized capability on the surface of Mars, and for Spirit, we have done that," said Mars Exploration Rover Project Manager John Callas of NASA's Jet Propulsion Laboratory, Pasadena, Calif.

Spirit drove 7.73 kilometres, more than 12 times the goal set for the mission. The drives crossed a plain to reach a distant range of hills that appeared as mere bumps on the horizon from the landing site; climbed slopes up to 30 degrees as Spirit became the first robot to summit a hill on another planet; and covered more nearly a kilometre after Spirit's right-front wheel became immobile in 2006. The rover returned more than 124,000 images. It ground the surfaces off 15 rock targets and scoured 92 targets with a brush to prepare the targets for inspection with spectrometers and a microscopic imager. "What's really important is not only how long Spirit worked or how far Spirit drove, but also how much exploration and scientific discovery Spirit accomplished," Callas said.

One major finding came, ironically, from dragging the inoperable right-front wheel as the rover was driving backwards in 2007. That wheel plowed up bright white soil. Spirit's Alpha Particle X-ray Spectrometer and Miniature Thermal Emission Spectrometer revealed that the bright material was nearly pure silica. "Spirit's unexpected discovery of concentrated silica deposits was one of the most important findings by either rover," said Steve Squyres of Cornell University, Ithaca, N.Y., principal investigator for Spirit and Opportunity. "It showed that there were once hot springs or steam vents at the Spirit site, which could have provided favorable conditions for microbial life."

The silica-rich soil neighbors a low plateau called Home Plate, which was Spirit's main destination after the historic climb up Husband Hill. "What Spirit showed us at Home Plate was that early Mars could be a violent place, with water and hot rock interacting to make what must have been spectacular volcanic explosions. It was a dramatically different world than the cold, dry Mars of today," said Squyres.

The trove of data from Spirit could still yield future science revelations. Years of analysis of some 2005 observations by the rover's Alpha Particle X-ray Spectrometer, Miniature Thermal Emission Spectrometer and Moessbauer Spectrometer produced a report last year that an outcrop on Husband Hill bears a high concentration of carbonate. This is evidence of a wet, non-acidic ancient environment that may have been favorable for microbial life.

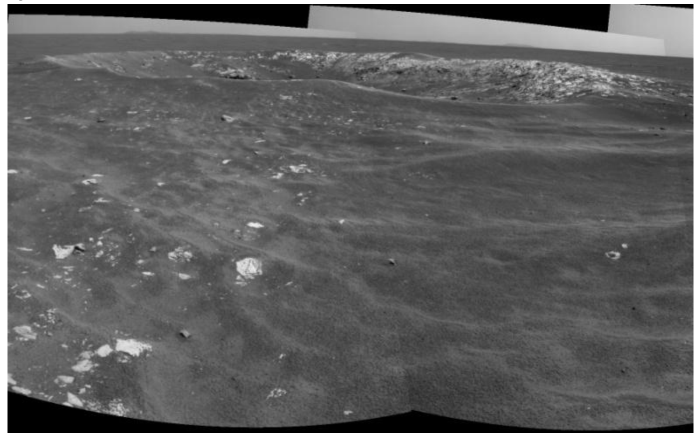
"What's most remarkable to me about Spirit's mission is just how extensive her accomplishments became," said Squyres. "What we initially conceived as a fairly simple geologic experiment on Mars ultimately turned into humanity's first real overland expedition across another planet. Spirit explored just as we would have, seeing a distant hill, climbing it, and showing us the vista from the summit. And she did it in a way that allowed everyone on Earth to be part of the adventure."

Mars tribute marks memories of Shepard's flight

The team exploring Mars via NASA's Opportunity rover for the past seven years has informally named a Martian crater for the Mercury spacecraft that astronaut Alan Shepard christened Freedom 7. On 5 May1961, Shepard piloted Freedom 7 in America's first human spaceflight.

The team used Opportunity in early May to acquire images covering a cluster of small, relatively young craters along the rover's route toward a long-term destination. The cluster's largest crater, spanning about 25 metres, is the one called "Freedom 7." The diameter of Freedom 7 crater, about 25 metres, happens to be equivalent to the height of the Redstone rocket that launched Shepard's flight.

"Many of the people currently involved with the robotic investigations of Mars were first inspired by the astronauts of the Mercury Project who paved the way for the exploration of our solar system," said Scott McLennan of the State University of New York at Stony Brook, who is this week's long-term planning leader for the rover science team. Shepard's flight was the first of six Project Mercury missions piloted by solo astronauts.



NASA's Mars Exploration Rover Opportunity recorded this view of a crater informally named "Freedom 7" shortly before the 50th anniversary of the first American in space: astronaut Alan Shepard's flight in the Freedom 7 spacecraft. The image combines two frames that Opportunity took with its navigation camera during the 2,585th Martian day, or sol, of the rover's work on Mars (2 May 2011). Shepard's suborbital flight lasted 15 minutes on May 5, 1961. The crater is about 25 metres in diameter. It is the largest of a cluster of about eight craters all formed just after an impactor broke apart in the Martian atmosphere. (NASA/JPL-Caltech)

Rover team member James Rice of NASA Goddard Space Flight Center, Greenbelt, Md., said, "The first 50 years of American manned spaceflight have been built upon immeasurable courage, dedication, sacrifice, vision, patriotism, teamwork and good old-fashioned hard work, all terms that embody and define the United States and her people. Alan Shepard's brave and historic 15-minute flight in Freedom 7 put America in space, and then a scant eight years later, Americans were standing upon the surface of the moon." Shepard himself would later walk on the moon when he commanded the Apollo 14 mission in early 1971, less than 10 years after his Freedom 7 flight. He died on 21 July 1998.

By taking advantage of seeing many craters of diverse ages during drives toward major destinations, the Opportunity mission is documenting how impact craters change with time. The cluster that includes Freedom 7 crater formed after sand ripples in the area last migrated, which is estimated to be about 200,000 years ago. "This cluster has about eight craters, and they're all the same age," said Matt Golombek, rover team member at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "They're from an impactor that broke up in the atmosphere, which is quite common."

Opportunity and its twin, Spirit, completed their three-month prime missions on Mars in April 2004. Both rovers continued for years of bonus, extended missions. Both have made important discoveries about wet environments on ancient Mars that may have been favorable for supporting microbial life. Spirit has not communicated with Earth since March 2010. Opportunity remains active. It has driven 28.6 kilometres total on Mars, including 1.9 kilometres since leaving "Santa Maria" crater on 24 March 2011, after studying that crater for three months.

Space Shuttle Endeavour seems to be heading straight for the Sun as it bursts through cloud cover during the STS-134 launch on 16 May 2011. It was the 25th and final flight for Endeavour, the newest of NASA's shuttles. (NASA)