Liftoff

New Zealand's space exploration magazine

Issue 266
November-December 2011

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- **Asteroid findings from Vesta and Lutetia**

Liftoff

Editor: **David Maclennan**

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

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.

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

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

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

NZSA News and Notices

Auckland meetings

The next Auckland meetings are on **6 February 2012** and **5 March 2012** 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 2011-2012

Subscription rates for 1 September 2011 to 31 August 2012 are as follows:

ORDINARY	$45
SENIOR CITIZEN	$40
STUDENT	$37.50

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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: Artist's impression of the twin GRAIL spacecraft in orbit around the Moon. (NASA)

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Editor's Corner

2011 has been a significant year in space exploration in a number of ways. The major event of this, the year of the 50th anniversary of the first human space flights, was the retirement of the US space shuttle after 30 years and 135 missions. This signals the start of a long gap, until at least 2017 in all probability, before US astronauts once again launch on US-made rockets. Several companies, ranging from old hands like Boeing to newcomers like SpaceX and Sierra Nevada, are developing new vehicles for carrying humans into orbit.

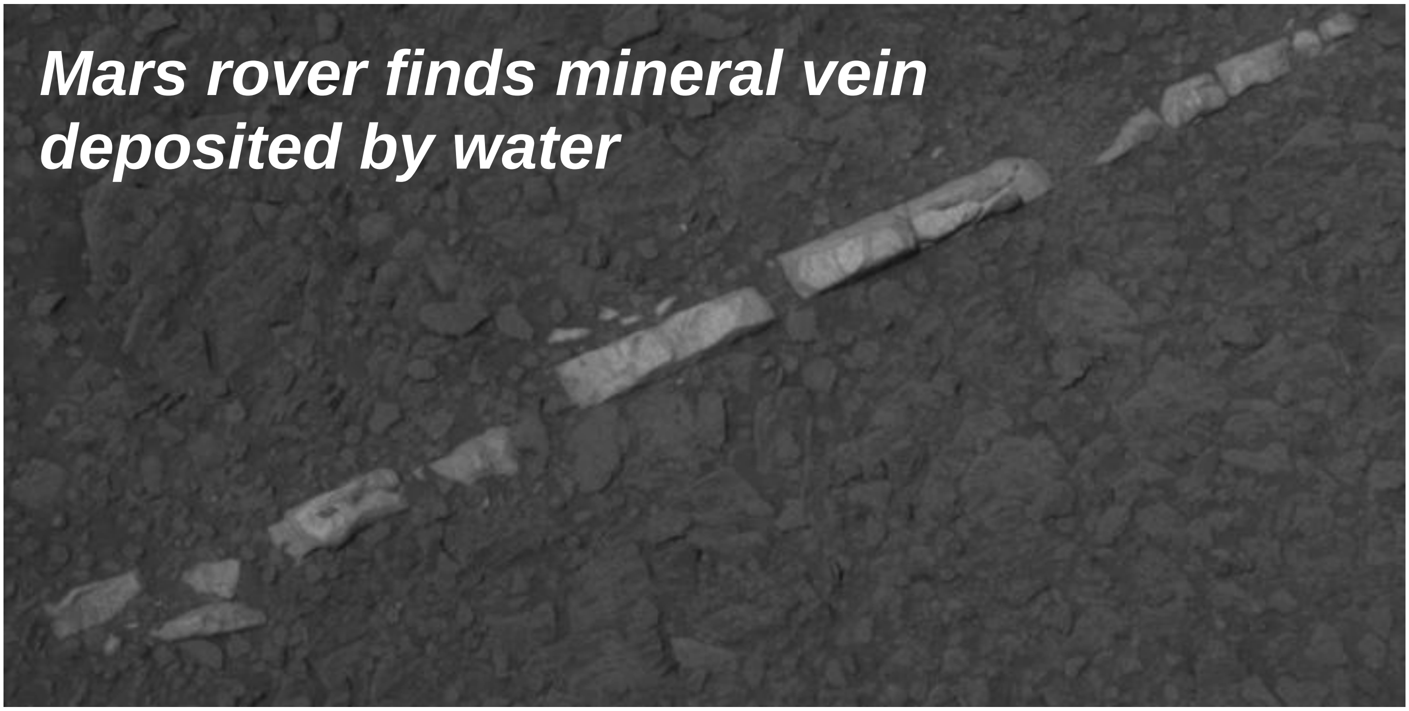
NASA itself has unveiled plans for a huge new Saturn 5-class rocket for use in future exploration missions using the Orion spacecraft (see page 17). However, as there are no firm dates and destinations in mind yet, the chances are that this rocket will not fly until after 2020, if it flies at all. Meanwhile, Russian Soyuz boosters have begun launches from the ESA Kourou space centre in French Guiana, and ESA's smaller Vega rocket will make its debut in the new year.

On the robotic front, NASA's new Curiosity rover is finally on its way to Mars for an August 2012 landing (see page 11), while the hardy little Opportunity rover has now reached the rim of the massive Endeavour crater in Mars' Meridiani Planum region, where it has already made a spectacular discovery (see page 4). Its twin rover, Spirit, is now sadly defunct, however. Russia's Phobos-Grunt mission has unfortunately continued that nation's losing streak when it comes to Mars missions: every mission to the red planet launched by Russia or the former Soviet Union, starting in 1960, has failed.

Meanwhile, NASA's Juno spacecraft is safely en route to giant Jupiter, and the Dawn spacecraft has revealed asteroid Vesta to be a highly unique body since entering orbit earlier this year (see page 23). Dawn will leave Vesta and continue on to the largest asteroid, Ceres, next year.

-- *David Maclennan*

Mars rover finds mineral vein deposited by water



This view of a mineral vein called "Homestake" comes from the panoramic camera (Pancam) on NASA's Mars Exploration Rover Opportunity. The vein is about the width of a thumb and about 45 cm long. Opportunity examined it in November 2011 and found it to be rich in calcium and sulphur, possibly the calcium-sulfate mineral gypsum. The view was taken during the 2,769th Martian day, or sol, of Opportunity's career on Mars (7 November 2011). (NASA/JPL-Caltech/Cornell/ASU)

NASA's Mars Exploration Rover Opportunity has found bright veins of a mineral, apparently gypsum, deposited by water. Analysis of the vein will help improve understanding of the history of wet environments on Mars.

"This tells a slam-dunk story that water flowed through underground fractures in the rock," said Steve Squyres of Cornell University, Ithaca, N.Y., principal investigator for Opportunity. "This stuff is a fairly pure chemical deposit that formed in place right where we see it. That can't be said for other gypsum seen on Mars or for other water-related minerals Opportunity has found. It's not uncommon on Earth, but on Mars, it's the kind of thing that makes geologists jump out of their chairs."

The vein examined most closely by Opportunity is about the width of a human thumb (1 to 2 centimetres), 40 to 50 centimetres long, and protrudes slightly higher than the bedrock on either side of it. Observations by the durable rover reveal this vein and others like it within an apron surrounding a segment of the rim of Endeavour Crater. None like it were seen in the 33 kilometres of crater-pocked plains that Opportunity explored for 90 months before it reached Endeavour, nor in the higher ground of the rim.

During November 2011 researchers used the Microscopic Imager and Alpha Particle X-ray Spectrometer on the rover's arm and multiple filters of the Panoramic Camera on the rover's mast to examine the vein, which is informally named "Homestake." The spectrometer identified plentiful calcium and sulfur, in a ratio pointing to relatively pure calcium sulphate.

Calcium sulphate can exist in many forms, varying by how much water is bound into the minerals' crystalline structure. The multi-filter data from the camera suggest gypsum, a hydrated calcium sulphate. On Earth, gypsum is used for making drywall and plaster of Paris. Observations from orbit had detected gypsum on Mars previously. A dune field of windblown gypsum on far northern Mars resembles the glistening gypsum dunes in White Sands National Monument in New Mexico.

"It is a mystery where the gypsum sand on northern Mars comes from," said Opportunity science-team member Benton Clark of the Space Science Institute in Boulder, Colo. "At Homestake, we see the mineral right where it formed. It will be important to see if there are deposits like this in other areas of Mars."

The Homestake deposit, whether gypsum or another form of calcium sulphate, likely formed from water dissolving calcium out of volcanic rocks. The calcium combined with sulphur that was either leached from the rocks or introduced as volcanic gas, and it was deposited as calcium sulphate into an underground fracture that later became exposed at the surface.

Throughout Opportunity's long traverse across Mars' Meridiani plain, the rover has driven over bedrock composed of magnesium, iron and calcium sulphate minerals that also indicate a wet environment billions of years ago. The highly concentrated calcium sulphate at Homestake could have been produced in conditions more neutral than the harshly acidic conditions indicated by the other sulphate deposits observed by Opportunity. "It could have formed in a different type of water environment, one more hospitable for a larger variety of living organisms," Clark said.

Homestake and similar-looking veins appear in a zone where the sulphate-rich sedimentary bedrock of the plains meets older, volcanic bedrock exposed at the rim of Endeavour. That location may offer a clue about their origin.

Opportunity and its rover twin, Spirit, completed their three-month prime missions on Mars in April 2004. Both rovers continued for years of extended missions and made important discoveries about wet environments on ancient Mars that may

The navigation camera on NASA's Mars Exploration Rover Opportunity recorded this view of the western edge of "Cape York" during the 2,761st Martian day, or sol, of the rover's work on Mars (30 October 2011). Cape York is a segment of the rim of Endeavour Crater. A bright vein, informally named "Homestake," is visible on the right side of the image. The vein is about as wide as a thumb and about 45 centimetres long. Opportunity examined it in November 2011 and found it to be rich in calcium and sulfur, possibly the calcium-sulphate mineral gypsum. (NASA/JPL-Caltech)

have been favorable for supporting microbial life. Spirit stopped communicating in 2010. Opportunity continues exploring, currently heading to a sun-facing slope on the northern end of the Endeavour rim fragment called "Cape York" to keep its solar panels at a favorable angle during the mission's fifth Martian winter.

"We want to understand why these veins are in the apron but not out on the plains," said the mission's deputy principal investigator, Ray Arvidson, of Washington University in St. Louis. "The answer may be that rising groundwater coming from the ancient crust moved through material adjacent to Cape York and deposited gypsum, because this material would be relatively insoluble compared with either magnesium or iron sulphates."

Data show liquid water evidence on Europa

Data from a NASA planetary mission have provided scientists evidence of what appears to be a body of liquid water, equal in volume to the North American Great Lakes, beneath the icy surface of Jupiter's moon, Europa. The data suggest there is significant exchange between Europa's icy shell and the ocean beneath. This information could bolster arguments that Europa's global subsurface ocean represents a potential habitat for life elsewhere in our solar system. The findings are published in the scientific journal *Nature*.

"The data open up some compelling possibilities," said Mary Voytek, director of NASA's Astrobiology Program at agency headquarters in Washington. "However, scientists worldwide will want to take a close look at this analysis and review the data before we can fully appreciate the implication of these results."

NASA's Galileo spacecraft, launched by the space shuttle Atlantis in 1989 to Jupiter, produced numerous discoveries and provided scientists decades of data to analyze. Galileo studied Jupiter, which is the most massive planet in our solar system, and some of its many moons.

One of the most significant discoveries was the inference of a global saltwater ocean below the surface of Europa. This ocean is deep enough to cover the whole surface of Europa and contains more liquid water than all of Earth's oceans combined. However, being far from the sun, the ocean surface is completely frozen. Most scientists think this ice crust is tens of miles thick.

"One opinion in the scientific community has been if the ice shell is thick, that's bad for biology. That might mean the surface isn't communicating with the underlying ocean," said Britney Schmidt, lead author of the paper and postdoctoral fellow at the Institute for Geophysics, University of Texas at Austin. "Now, we see evidence that it's a thick ice shell that can mix vigorously and new evidence for giant shallow lakes. That could make Europa and its ocean more habitable."

Schmidt and her team focused on Galileo images of two roughly circular, bumpy features on Europa's surface called chaos terrains. Based on similar processes seen on Earth -- on ice shelves and under glaciers overlying volcanoes -- they developed a four-step model to explain how the features form. The model resolves several conflicting observations. Some seemed to suggest the ice shell is thick. Others suggest it is thin.

This recent analysis shows the chaos features on Europa's surface may be formed by mechanisms that involve significant exchange between the icy shell and the underlying lake. This provides a mechanism or model for transferring nutrients and energy between the surface and the vast global ocean already inferred to exist below the thick ice shell. This is thought to increase the potential for life there.

The study authors have good reason to believe their model is correct, based on observations of Europa from Galileo and of Earth. Still, because the inferred lakes are several miles below the surface, the only true confirmation of their presence would come from a future spacecraft mission designed to probe the ice shell. Such a mission was rated as the second highest priority flagship mission by the National Research Council's recent Planetary Science Decadal Survey and is being studied by NASA.

"This new understanding of processes on Europa would not have been possible without the foundation of the last 20 years of observations over Earth's ice sheets and floating ice shelves," said Don Blankenship, a co-author and senior research scientist at the Institute for Geophysics, where he leads airborne radar studies of the planet's ice sheets.

Galileo was the first spacecraft to directly measure Jupiter's atmosphere with a probe and conduct long-term observations of the Jovian system. The probe was the first to fly by an asteroid and discover the moon of an asteroid. NASA extended the mission three times to take advantage of Galileo's unique science capabilities, and the spacecraft was put on a collision course into Jupiter's atmosphere in September 2003 to eliminate any chance of impacting Europa.

ESA finds that Venus has an ozone layer too

ESA's Venus Express spacecraft has discovered an ozone layer high in the atmosphere of Venus. Comparing its properties with those of the equivalent layers on Earth and Mars will help astronomers refine their searches for life on other planets.

Venus Express made the discovery while watching stars seen right at the edge of the planet set through its atmosphere. Its SPICAV instrument analysed the starlight, looking for the characteristic fingerprints of gases in the atmosphere as they absorbed light at specific wavelengths. The ozone was detectable because it absorbed some of the ultraviolet from the starlight.

Ozone is a molecule containing three oxygen atoms. According to computer models, the ozone on Venus is formed when sunlight breaks up carbon dioxide molecules, releasing oxygen atoms. These atoms are then swept around to the nightside of the planet by winds in the atmosphere: they can then combine to form two-atom oxygen molecules, but also sometimes three-atom ozone molecules. "This detection gives us an important constraint on understanding the chemistry of Venus' atmosphere," says Franck Montmessin, who led the research.

It may also offer a useful comparison for searching for life on other worlds. Ozone has only previously been detected in the atmospheres of Earth and Mars. On Earth, it is of fundamental importance to life because it absorbs much of the Sun's harmful ultraviolet rays. Not only that, it is thought to have been generated by life itself in the first place.

The build-up of oxygen, and consequently ozone, in Earth's atmosphere began 2.4 billion years ago. Although the exact reasons for it are not entirely understood, microbes excreting oxygen as a waste gas must have played an important role. Along with plant life, they continue to do so, constantly replenishing Earth's oxygen and ozone. As a result, some astrobiologists have suggested that the simultaneous presence of carbon dioxide, oxygen and ozone in an atmosphere could be used to tell whether there could be life on the planet. This would allow future telescopes to target planets around other stars and assess their habitability. However, as these new results highlight, the amount of ozone is crucial.

The small amount of ozone in Mars' atmosphere has not been generated by life. There, it is the result of sunlight breaking up carbon dioxide molecules. Venus too, now supports this view of a modest ozone build-up by non-biological means. Its ozone layer sits at an altitude of 100 km, about four times higher in the atmosphere than Earth's and is a hundred to a thousand times less dense.

Theoretical work by astrobiologists suggests that a planet's ozone concentration must be 20% of Earth's value before life should be considered as a cause. These new results support that conclusion because Venus clearly remains below this threshold. "We can use these new observations to test and refine the scenarios for the detection of life on other worlds," says Dr Montmessin.

Yet, even if there is no life on Venus, the detection of ozone there brings Venus a step closer to Earth and Mars. All three planets have an ozone layer. "This ozone detection tells us a lot about the circulation and the chemistry of Venus' atmosphere," says Håkan Svedhem, ESA Project Scientist for the Venus Express mission.

"Beyond that, it is yet more evidence of the fundamental similarity between the rocky planets, and shows the importance of studying Venus to understand them all."

Dark and bright: ESA chooses next two science missions

The powerful influence of the Sun and the nature of the mysterious 'dark energy' motivate ESA's next two science missions. Solar Orbiter and Euclid were selected in early October by ESA's Science Programme Committee for implementation, with launches planned for 2017 and 2019. These two missions are medium-class missions and are the first in ESA's Cosmic Vision 2015-2025 Plan.

Solar Orbiter will venture closer to the Sun than any previous mission. It is designed to make major breakthroughs in our understanding of how the Sun influences its environment, in particular how the Sun generates and propels the flow of particles in which the planets are bathed, known as the solar wind. Solar activity affects the solar wind, making it very turbulent, and solar flares create strong perturbations in this wind, triggering spectacular auroral displays on Earth and other planets.

Solar Orbiter will be close enough to the Sun to sample this solar wind shortly after it has been ejected from the solar surface, while at the same time observing in great detail the process accelerating the wind on the Sun's surface. The mission's launch is planned for 2017 from Cape Canaveral with a NASA-provided Atlas launch vehicle.

Euclid is designed to explore the dark side of the Universe. Essentially a space telescope, the mission will map out the large-scale structure of the Universe with unprecedented accuracy. The observations will stretch across 10 billion light years into the Universe, revealing the history of its expansion and the growth of structure during the last three-quarters of its history.

One of the deepest modern mysteries is why the Universe is expanding at an ever-accelerating rate. This cosmic acceleration must be driven by something that astronomers have named 'dark energy' to signify its unknown nature. By using Euclid to study its effects on the galaxies and clusters of galaxies that trace the large-scale structure of the Universe, astronomers hope to be able to understand the exact nature of dark energy. Euclid's launch, on a Soyuz launch vehicle, is planned for 2019 from Europe's Spaceport at Kourou, French Guiana.

The announcement is the culmination of a process started in 2004 when ESA consulted the wider astronomical community to set Europe's goals for space exploration in the coming decade. That exercise resulted in the Cosmic Vision 2015-2025 Plan, which identified four scientific aims: What are the conditions for life and planetary formation? How does the Solar System work? What are the fundamental laws of the Universe? How did the Universe begin and what is it made of?

In 2007, a 'call for missions' was issued around these aims and resulted in a number of medium-class missions being considered. "It was an arduous dilemma for the Science Programme Committee to choose two from the three excellent candidates. All of them would produce world-class science and would put Europe at the forefront in the respective fields. Their quality goes to show the creativity and resources of the European scientific community," said Fabio Favata, Head of the Science Programme's Planning Office.

NASA developing instruments for Solar Orbiter mission

NASA will begin development and testing of two science instruments, in cooperation with the European Space Agency, to be placed on ESA's newly selected Solar Orbiter mission. The spacecraft will study the Sun from a closer distance than any previous mission. At its closest approach, the European-led project will operate approximately 33 million kilometres from the Sun's surface, near the orbit of Mercury, roughly 25% of the distance from the Sun to the Earth. This unique vantage point will enhance the ability to forecast space weather.

Space weather produces disturbances in electromagnetic fields on Earth that can induce extreme currents in wires, disrupt power lines and cause widespread blackouts. These Sun storms can interfere with communications between ground controllers and satellites and with airplane pilots flying near Earth's poles. Radio noise from the storms also can disrupt cell phone service.

"Solar Orbiter is an exciting mission that will improve our understanding of the Sun and its environment," said Barbara Giles, director for NASA's Heliophysics Division in Washington. "This collaboration will create a new chapter in heliophysics research and continue a strong partnership with the international science community to complement future robotic and human exploration activities."

Solar Orbiter will be close enough to the Sun to sample solar wind shortly after the wind has been ejected from the Sun's surface. Additionally, the spacecraft will observe in great detail the process that accelerates the wind on the Sun's surface. Data will provide views of the Sun's polar regions and far side. The spacecraft's elliptical orbit will allow it to follow the star's rotation, enabling observations of specific areas for much longer than is currently possible.

Launch is planned for 2017 from Cape Canaveral Air Force Station, Fla., aboard a NASA-provided expendable launch vehicle. Among the science investigations, two instruments valued at $80 million are provided by NASA:

- The Solar Orbiter Heliospheric Imager (SoloHI), which will provide revolutionary measurements to pinpoint coronal mass ejections or CMEs. CMEs are space weather events with violent solar eruptions that travel from 96.5 kilometres per second to more than 3,218 kilometres per second with masses greater than a few billion tons. Russell Howard from the Naval Research Laboratory in Washington is principal investigator.
- The Heavy Ion Sensor (HIS), one of a suite of sensors that will measure density, velocity, and temperature of the solar wind. Stefano Livi from the Southwest Research Institute in San Antonio is principal investigator.

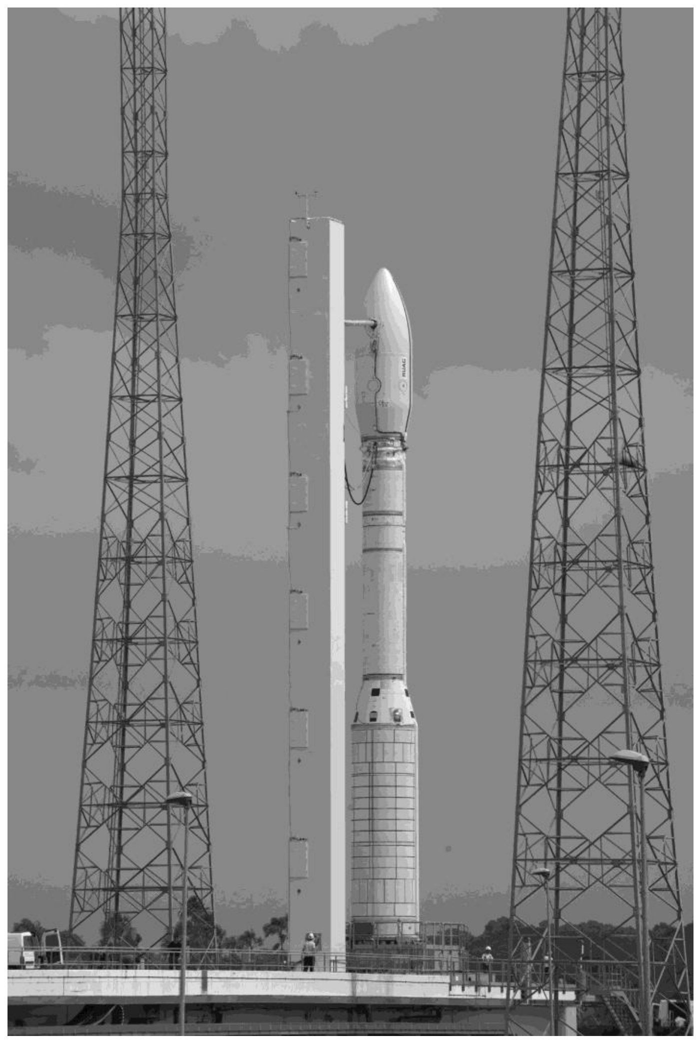
First Vega launch campaign aims for January liftoff

The first Vega launch campaign began on 7 November 2011 at Europe's Spaceport in French Guiana with the installation of the first stage on the pad. Europe's new small launcher is on track for its maiden flight at the end of January.

The hundred-tonne solid-propellant first stage, the P80, was moved from the Booster Integration Building to the pad using the 'Fardier' heavyweight transporter. As with the transfer of Ariane 5's boosters, safety measures minimised the number of operators on site and evacuated nearby buildings. With the P80 installed inside the mobile gantry, all ground installations were configured for the booster's final acceptance, including the Thrust Vector Control system that swivels the large nozzle for steering.

In the weeks following rollout, the two solid-propellant second and third stages, the Zefiro-23 and Zefiro-9, were to be transferred from the Vega Booster Storage and Preparation Building and added to the vehicle. Before the end of the year, after the Flight Readiness Review, the AVUM – Attitude & Vernier Upper Module – fourth stage, will be integrated.

In parallel to the launcher activities, the satellite payloads are being prepared at the spaceport. By the end of the year the LARES laser relativity satellite from Italy's ASI space agency together with at least six small CubeSats and ALMASat-1 from European universities will be ready and enclosed in the fairing. The campaign will continue in January with the integration of the 'upper composite' – the fairing and payload – followed by final check-out of the fully integrated launcher and the countdown rehearsal.



The Vega mockup sits on the launch pad at ESA's Kourou space centre (ESA)

This Vega qualification flight will pave the way for the next five missions that will demonstrate the system's flexibility as part of the VERTA – Vega Research and Technology Accompaniment – programme.

Vega's performance will perfectly complement that of the heavy Ariane 5 and medium-lift Soyuz rockets. It is designed to cope with a wide range of missions and payload configurations in order to respond to different market opportunities. In particular, it offers configurations able to handle payloads ranging from a single satellite up to one main satellite plus six microsatellites.

Vega is designed to cope with a wide range of missions and payload configurations in order to respond to different market opportunities with greater flexibility. In particular, it offers configurations able to handle payloads ranging from a single satellite up to one main satellite plus six microsatellites. Vega is compatible with payload masses ranging from 300 to 2,500 kilograms, depending on the type and altitude of the orbit required by the customers. The benchmark is for 1,500 kilograms into a 700 kilometre-altitude polar orbit.

Altogether, seven ESA Member States (Italy, France, Spain, Belgium, the Netherlands, Switzerland and Sweden) are contributing to the programme. As the future Vega launch service provider, Arianespace is responsible for launch operations.

NASA proposes Orion spacecraft test flight in 2014

NASA plans to add an unmanned flight test of the Orion spacecraft in early 2014 to its contract with Lockheed Martin Space Systems for the multi-purpose crew vehicle's design, development, test and evaluation. This test supports the new Space Launch System (SLS) that will take astronauts farther into space than ever before and provide the cornerstone for America's future human spaceflight efforts.

This Exploration Flight Test, or EFT-1, will fly two orbits to a high-apogee, with a high-energy re-entry through Earth's atmosphere. Orion will make a water landing and be recovered using operations planned for future human exploration missions. The test mission will be launched from Cape Canaveral, Fla., to acquire critical re-entry flight performance data and demonstrate early integration capabilities that benefit the Orion, SLS, and 21st Century Ground Systems programs.

"The entry part of the test will produce data needed to develop a spacecraft capable of surviving speeds greater than 20,000 miles per hour [32,80 km/hr] and safely return astronauts from beyond Earth orbit," Associate Administrator for Human Exploration and Operations William Gerstenmaier said. "This test is very important to the detailed design process in terms of the data we expect to receive."

NASA also intends to release several competitive solicitations to industry in the near future. One solicitation will request proposals for the design, development, test and evaluation of a new advanced liquid or solid booster capability for the SLS. Another future contract NASA intends to compete will be for the development of spacecraft, and payload adaptors and fairings for crew and cargo missions. The competition and award dates for these will be determined as missions are identified.

NASA signs agreement with Space Florida to reuse KSC facilities

In an innovative agreement that will create new jobs, NASA has announced a partnership with Space Florida to exclusively occupy, use and modify Kennedy Space Center's Orbiter Processing Facility-3, the Space Shuttle Main Engine Processing Facility and Processing Control Center.

Space Florida, the aerospace economic development agency of the state of Florida, is leasing the Orbiter Processing Facility-3 to the Boeing Company to manufacture and test the company's Crew Space Transportation (CST-100) spacecraft, creating up to 550 jobs along the Space Coast. The 15-year use permit deal is the latest step Kennedy is making as the center transitions from a historically government-only launch complex to a multi-user spaceport. Boeing is developing the CST-100, a reusable capsule-shaped spacecraft that will consist of a crew module and service module for transporting up to seven people, or a combination of people and cargo to space.

"Neither NASA nor the Space Coast can afford to stand still. We must be aggressive in pursuing this next generation of space exploration -- and the jobs and innovation that will accompany it," NASA Administrator Charles Bolden said.

"Kennedy continues working to bring new commercial space activities to the center," said Kennedy Center Director Bob Cabana. "Partnering with Space Florida to enable commercial space operations at Kennedy will help NASA maintain facilities and assets while supporting our nation's space objectives and expanding opportunities for the U.S. economy."

In addition to the agreement Boeing is signing with Space Florida to reuse existing KSC facilities, the aerospace company announced it is locating it Commercial Crew Program headquarters at the center.

"We are extremely pleased that Boeing will locate its commercial crew headquarters here in Florida," said Frank DiBello, president of Space Florida. "This positions our state well for future growth and a leadership role in NASA's next-generation human space exploration initiatives. It is also a key factor in ensuring Florida's space-related economy continues to thrive."

The goal of NASA's Commercial Crew Program is to facilitate the development of a U.S. commercial crew space transportation capability by achieving safe, reliable and cost-effective access to and from the International Space Station and future low Earth orbit destinations.

"We selected Florida for the commercial crew headquarters because of its close proximity to not only our NASA customer at Kennedy Space Center, but also because of outstanding facilities and an experienced space workforce," said John Elbon, vice president and program manager of Boeing's Commercial Crew Programs.

NASA’s new upper stage engine passes major test

NASA conducted a successful 500-second test firing of the J-2X rocket engine on Wednesday 9 November, marking another important step in development of an upper stage for the heavy-lift Space Launch System (SLS).

"The J-2X engine is critical to the development of the Space Launch System," Dan Dumbacher, NASA's deputy associate administrator for exploration systems development, said after the test at NASA's Stennis Space Center in Mississippi. "Today's test means NASA is moving closer to developing the rocket it needs if humans are to explore beyond low-Earth orbit."

Data from the test will be analyzed as operators prepare for additional engine firings. The J-2X and the RS-25D/E engines for the SLS core stage will be tested for flight certification at Stennis. Both engines use liquid hydrogen and liquid oxygen propellants. The core stage engines were developed originally for the space shuttle.

"The J-2X engine team and the SLS program as a whole are extremely happy that we accomplished a good, safe and successful test today," said Mike Kynard, Space Launch System Engines Element Manager at NASA's Marshall Space Flight

Center in Huntsville, Ala. "This engine test firing gives us critical data to move forward in the engine's development."

Stennis has tested engines that carried Americans to space in both the Apollo and Space Shuttle programs. The J-2X engine is being developed for Marshall by Pratt & Whitney Rocketdyne of Canoga Park, Calif. "We look forward to adding to the legacy as we fulfill our responsibility to test engines that will power America's next launch vehicle," said Stennis Director Patrick Scheuermann.

Spinning blood device set to safeguard astronaut health

ESA has begun developing a new blood-testing device for astronauts on the International Space Station. A wide range of ailments from diabetes to heart disease should be diagnosable in moments from a single drop of astronaut blood.

A pinprick of blood is added to a mini-disc embedded with a wide variety of miniaturised test procedures. The disc is then inserted into the 'point-of-care' device and set spinning to spread the blood sample across the surface. Multiple tests are performed simultaneously, with automated results delivered within a matter of minutes. Testing for conditions including diabetes, heart disease, liver and kidney damage, it promises to perform some of the billion or so blood tests ordered by care providers annually to a laboratory level of accuracy in a faster, on-the-spot fashion.

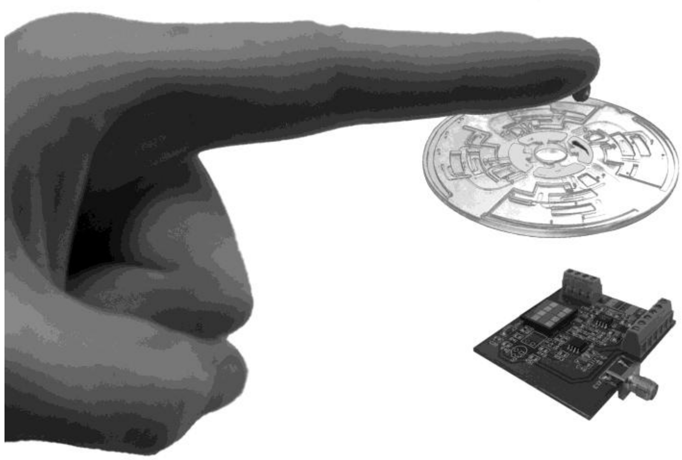


Image: Radisens Diagnostic

ESA is now looking to adapt the device for space, recently signing a contract with Irish company Radisens Diagnostics. Additional tests will be added and the design developed for the space environment, such ensuring its spinning technique works satisfactorily in weightlessness.

"Biochemical analysis aboard the Space Station is becoming a high priority for the human physiology experiments carried out there," explained Nadine Fritz of ESA's Directorate of Human Spaceflight and Operations. "The retirement of the Space Shuttle has significantly reduced the amount of cargo we can download from the Station, so it makes sense to do what analysis we can do in orbit."

Fermi finds youngest millisecond pulsar

An international team of scientists using NASA's Fermi Gamma-ray Space Telescope has discovered a surprisingly powerful millisecond pulsar that challenges existing theories about how these objects form. At the same time, another team has located nine new gamma-ray pulsars in Fermi data, using improved analytical techniques.

A pulsar is a type of neutron star that emits electromagnetic energy at periodic intervals. A neutron star is the closest thing to a black hole that astronomers can observe directly, crushing half a million times more mass than Earth into a sphere no larger than a city. This matter is so compressed that even a teaspoonful weighs as much as Mount Everest.

"With this new batch of pulsars, Fermi now has detected more than 100, which is an exciting milestone when you consider that, before Fermi's launch in 2008, only seven of them were known to emit gamma rays," said Pablo Saz Parkinson, an astrophysicist at the Santa Cruz Institute for Particle Physics at the University of California Santa Cruz, and a co-author on two papers detailing the findings.

One group of pulsars combines incredible density with extreme rotation. The fastest of these so-called millisecond pulsars whirls at 43,000 revolutions per minute. Millisecond pulsars are thought to achieve such speeds because they are gravitationally bound in binary systems with normal stars. During part of their stellar lives, gas flows from the normal star to the pulsar. Over time, the impact of this falling gas gradually spins up the pulsar's rotation.

The strong magnetic fields and rapid rotation of pulsars cause them to emit powerful beams of energy, from radio waves to gamma rays. Because the star is transferring rotational energy to the pulsar, the pulsar's spin eventually slows as the star loses matter. Typically, millisecond pulsars are around a billion years old.

However, in the 3 November 2011 issue of *Science*, the Fermi team revealed a bright, energetic millisecond pulsar only 25 million years old. The object, named PSR J1823−3021A, lies within NGC 6624, a spherical collection of ancient stars called a globular cluster, one of about 160 similar objects that orbit our galaxy. The cluster is about 10 billion years old and lies about 27,000 light-years away toward the constellation Sagittarius.

Fermi's Large Area Telescope (LAT) showed that eleven globular clusters emit gamma rays, the cumulative emission of dozens of millisecond pulsars too faint for even Fermi to detect individually. But that's not the case for NGC 6624.

"It's amazing that all of the gamma rays we see from this cluster are coming from a single object. It must have formed recently based on how rapidly it's emitting energy. It's a bit like finding a screaming baby in a quiet retirement home," said Paulo Freire, the study's lead author, at the Max Planck Institute for Radio Astronomy in Bonn, Germany.

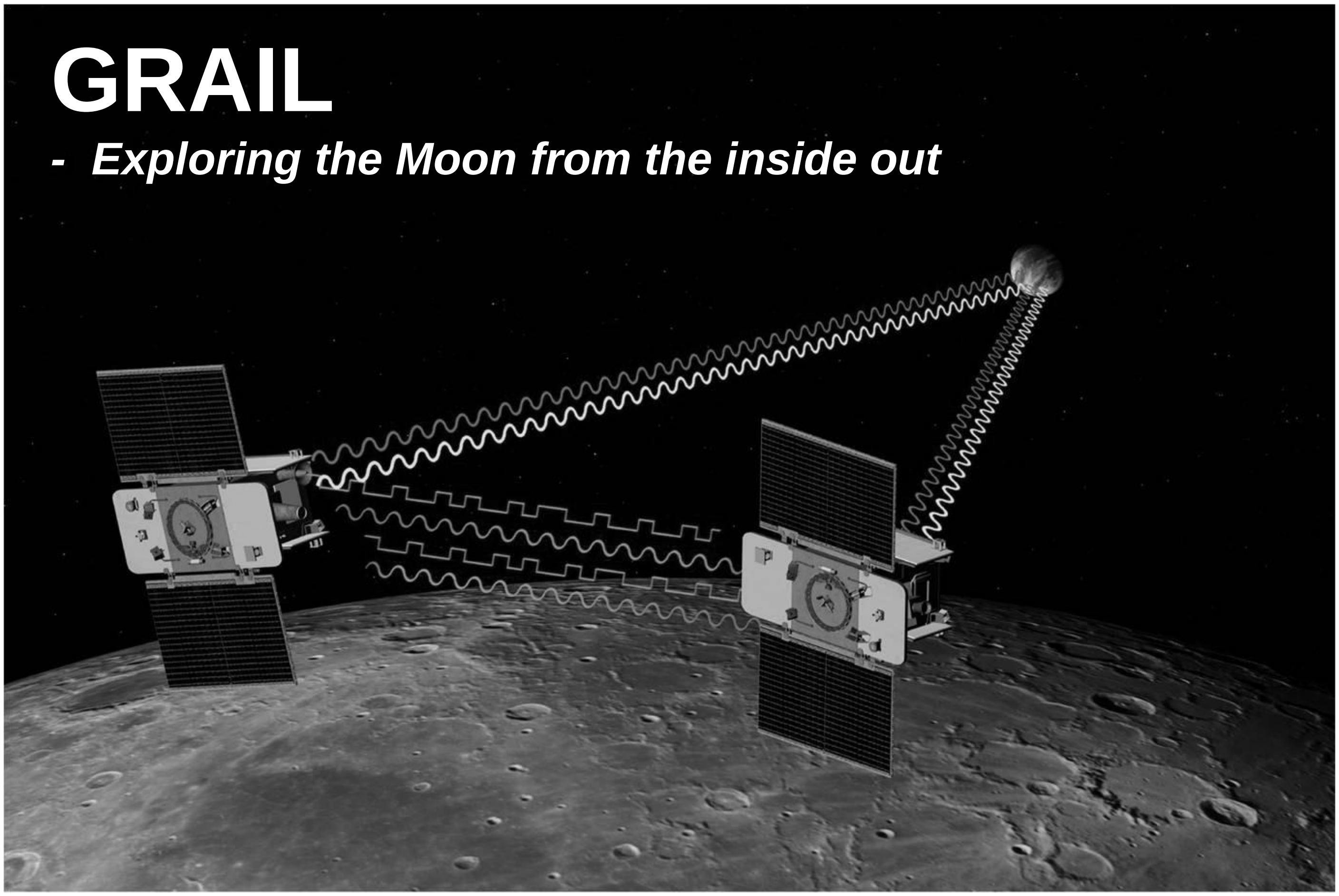
PSR J1823−3021A was previously identified as a pulsar by its radio emission, yet of the nine new pulsars, none are millisecond pulsars, and only one was later found to emit radio waves.

Despite its sensitivity, Fermi's LAT may detect only one gamma ray for every 100,000 rotations of some of these faint pulsars. Yet new analysis techniques applied to the precise position and arrival time of photons collected by the LAT since 2008 were able to identify them.

"We adapted methods originally devised for studying gravitational waves to the problem of finding gamma-ray pulsars, and we were quickly rewarded," said Bruce Allen, director of the Max Planck Institute for Gravitational Physics in Hannover, Germany.

GRAIL

- Exploring the Moon from the inside out



Artist concept of the GRAIL mission. GRAIL will fly twin spacecraft in tandem orbits around the moon to measure its gravity field in unprecedented detail. Image credit: NASA/JPL

On 10 September 2011 a two-stage United Launch Alliance Delta II 7920H-10C rocket soared aloft from Pad 17-B at the Cape Canaveral Air Force Station carrying NASA's twin Gravity Recovery And Interior Laboratory (GRAIL) spacecraft on a mission to map lunar gravity in unprecedented detail, answering longstanding questions about the Moon and giving scientists a better understanding of how Earth and other rocky planets in the solar system formed.

On September 30 GRAIL-A executed a rocket burn to tweak its flight path to the Moon, followe on October 5 by a similar burn by GRAIL-B. The manoevres also increase the separation between the two spacecraft.

The straight-line distance from Earth to the Moon is about 402,336 kilometres. It took NASA's Apollo moon crews about three days to cover that distance. Each of the GRAIL twins is taking about 30 times that long and covering more than 4 million kilometres to get there. This low-energy, high-cruise time trajectory is beneficial for mission planners and controllers, as it allows more time for spacecraft checkout. The path also provides a vital component of the spacecraft's single science instrument, the Ultra Stable Oscillator, to be continuously powered for several months, allowing it to reach a stable operating temperature long before beginning the collection of science measurements in lunar orbit.

GRAIL-A will reach the Moon on New Year's Eve 2011, with GRAIL-B following a day later. The two solar-powered spacecraft will fly in tandem orbits around the Moon. The science collection phase for GRAIL is expected to last 82 days.

When science collection begins, the spacecraft will transmit radio signals precisely defining the distance between them as they orbit the Moon. Regional gravitational differences on the Moon are expected to expand and contract that distance. GRAIL scientists will use these accurate measurements to define the Moon's gravity field. The data will allow mission scientists to understand what goes on below the surface of our natural satellite.

Science phase

The Science Phase activities consist of the collection of gravity science data and the execution of Education and Public Outreach activities using the MoonKAM system.

At the start of the Science Phase, the GRAIL spacecraft will be in a near-polar, near-circular orbit with an altitude of about 55 kilometres. The initial conditions have been designed so that the natural perturbations of the lunar gravity field allow the orbit to evolve without requiring any orbit maintenance manoeuvres.

The science orbit is designed to satisfy the basic science requirements of the GRAIL mission, which are for a low-altitude, near-circular, near-polar orbit that does not require any manoeuvres to maintain the orbit. The primary design parameter from a science perspective is the orbit altitude, since sensitivity to the lunar gravity field is driven by orbit altitude (i.e. the lower the altitude, the more sensitive the science measurements). Limits on the minimum orbit altitude are driven primarily by orbit lifetime considerations.

During the 82-day Science Phase, the Moon will rotate three times underneath the GRAIL orbit. The collection of gravity data over one complete rotation (27.3 days) is referred to as a Mapping Cycle. During Mapping Cycle 1, the mean separation distance between the two spacecraft is designed to increase from approximately 100 kilometres to 225 kilometres. A very small Orbit Trim Manoeuvre executed near the end of Mapping Cycle 1 will then be used to change the separation drift rate. Following this orbital trim manoeuvre, the mean separation distance will decrease from 225 kilometres to approximately 65 kilometres at the end of Mapping Cycle 3 (the end of the Science Phase). The change in separation distance is required to meet the GRAIL science objectives. The data collected when the orbiters are closer together helps to determine the local gravity field, while data collected when the separation distances are larger will be more useful in satisfying the science objectives related to detection and characterization of the lunar core.

Why study gravity?

Gravity is Newton's apple and the stuff of Einstein's theory of relativity, but it is also the law that we all learn to obey from our first breath of life. Gravity is the mutual attraction that pulls two masses together and keeps us firmly planted on Earth.

Sir Isaac Newton first revealed the law of gravity more than 300 years ago. During the 20th century, geophysicists developed techniques to locate mineral deposits and underground formations using spatial changes in Earth's gravity field. Their work laid the modern foundation for the science of geodesy. Today, scientists use measurements from several dozen satellites to develop models of Earth's "geoid" — an imaginary surface upon which the pull of gravity is equal everywhere.

Planetary scientists have taken the study of gravity fields to new heights — and other worlds. The GRAIL mission will forward this scientific endeavor, creating the most accurate gravitational map of the Moon to date.

If the Moon were a smooth sphere of uniform density, there would be no need for a mission like GRAIL — it would measure no changes in the gravity field. However, the Moon isn't smooth and homogeneous — its surface includes mountains that are many miles high, lava flows several hundred kilometres long and enormous lava tubes and craters of every size. Below the surface, things are even more complex and variable. In fact, the Moon has the lumpiest gravitational field known in our solar system. Studying its gravity allows us to better understand the forces that have shaped our natural satellite.

For example, the material that makes up the Moon's highlands has a different density than that making up its "seas," or "maria." Since the highland material is less dense than maria material, the gravity in the maria region is usually subtly stronger. Such uneven distribution of mass on the Moon's surface and in its interior manifests itself as "lumps" in the planet's gravity field.

Previous space missions have mapped the gravity fields of asteroids, Venus, Mars, Jupiter, Saturn and Earth. Even Earth's Moon, the object of GRAIL's attention, has had its gravity field measured on numerous occasions with varying degrees of success. But the accuracy of the GRAIL data will surpass by orders of magnitude that previously obtained, which will allow a new level of understanding about Earth's nearest neighbor.

GRAIL science overview

The primary science objectives are to determine the structure of the lunar interior, from crust to core, and to advance understanding of the thermal evolution of the Moon. The secondary science objective is to extend knowledge gained from the Moon to other terrestrial planets. These objectives will be achieved by obtaining a global, high-accuracy, high-resolution lunar map during a 90-day Science Phase.

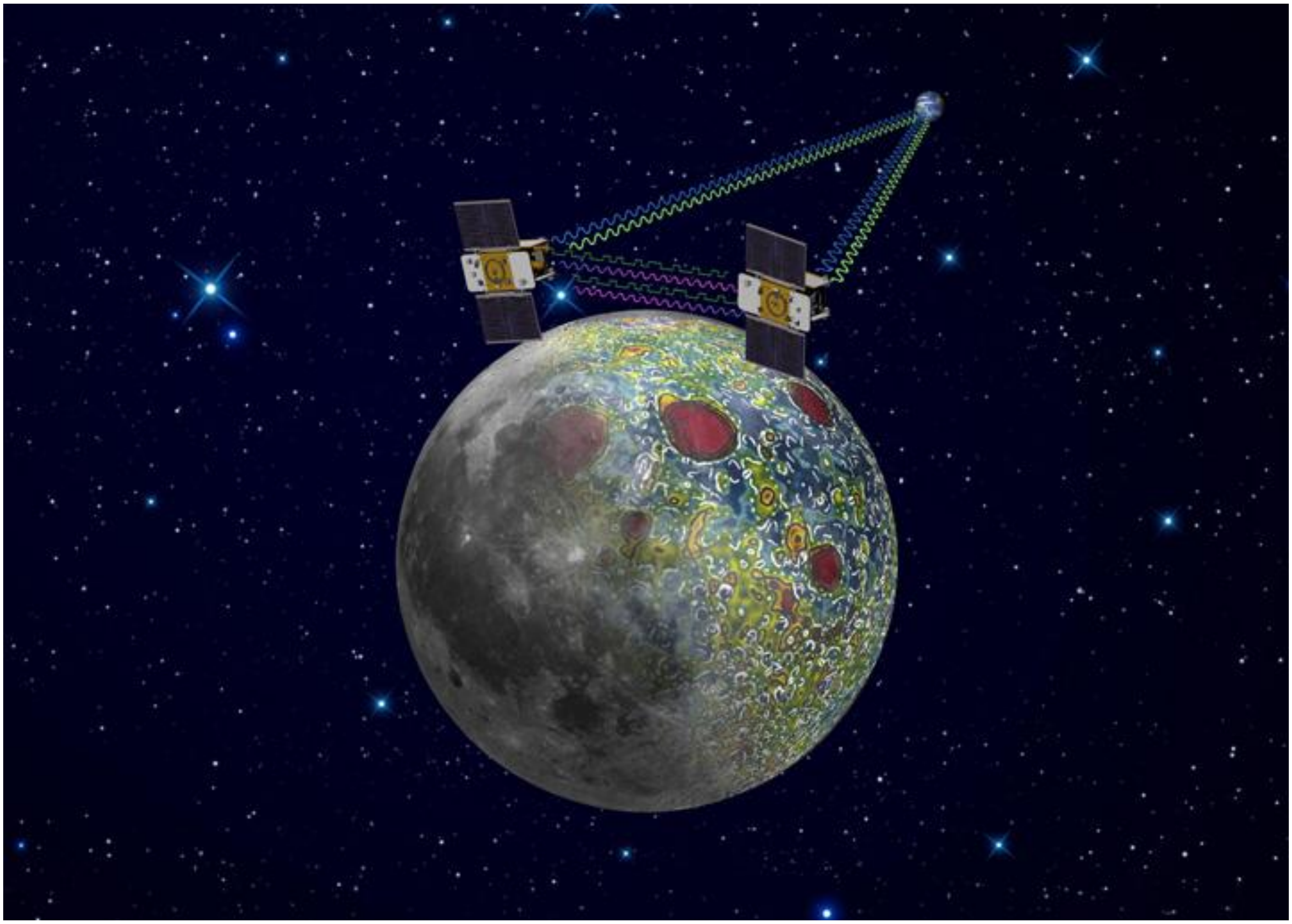
GRAIL launch on 10 September 2011 (NASA/ULA)

The GRAIL mission will create the most accurate gravitational map of the Moon to date, improving our knowledge of gravity on the side facing Earth by 100 times and of gravity on the side not facing Earth by 1,000 times. The high-resolution gravitational field, especially when combined with a comparable resolution topographical field, will enable scientists to deduce the Moon's interior structure and composition, and to gain insights into its thermal evolution — that is, the history of the Moon's heating and cooling, which opens the door to understanding its origin and development. Accurate knowledge of the Moon's gravity will also be an invaluable navigational aid for future lunar spacecraft. Ultimately, the information contributed by the GRAIL mission will increase our knowledge of how Earth and its rocky neighbors in the inner solar system developed into the diverse worlds we see today.

Science objectives

The Moon is the most accessible and best studied of the rocky (aka "terrestrial") bodies beyond Earth. Unlike Earth, however, the Moon's surface geology preserves the record of nearly the entirety of 4.5 billion years of solar system history. In fact, orbital observations combined with samples of surface rocks returned to Earth indicate that no other body preserves the record of geological history as clearly as the Moon.

The need to understand the lunar internal structure in order to reconstruct planetary evolution motivates GRAIL's primary science objectives, which are to determine the structure of the



Using a precision formation-flying technique, the twin GRAIL spacecraft will map the Moon's gravity field, as depicted in this artist's rendering. Radio signals traveling between the two spacecraft provide scientists the exact measurements required as well as flow of information not interrupted when the spacecraft are at the lunar farside, not seen from Earth. The result should be the most accurate gravity map of the Moon ever made. The mission also will answer longstanding questions about Earth's Moon, including the size of a possible inner core, and it should provide scientists with a better understanding of how Earth and other rocky planets in the solar system formed. (NASA/JPL-Caltech)

lunar interior from crust to core and to further the understanding of the thermal evolution of the Moon.

Why thermal evolution? A planetary body such as the Moon, Earth, and the other terrestrial planets,forms by accretion of primordial dust and rock. Eventually, this protoplanet is heated to the melting point by meteoroids smashing into it and by breakdown of radioactive elements within it. Then, over the eons, it cools off by radiating its heat into space. While it's still molten, heavy materials sink down toward the core and lighter materials float on top, ultimately forming a crust. The story of how a particular planetary body processes its heat and how, when and where heat is replenished by meteorite impacts and radioactive elements break down is the story of how its structure came to be. So understanding the Moon's thermal evolution is essential to understanding its origin and development.

The mission's secondary objective is to extend the knowledge it will gain about the Moon to inform our understanding of the development of the other planetary bodies in the inner solar system: Mercury, Venus, Earth and Mars. As the most accessible planetary body besides Earth, and as one that is thought to have changed little since its initial development (unlike Earth, Mars, and Venus), the Moon offers a unique look into the distant past of planetary evolution.

The GRAIL mission's six science investigations are:

1. Map the structure of the lithosphere.

The lithosphere is the portion of the crust and upper mantle with significant strength over a geological time scale. Since the strength of rock is highly dependent on temperature, the thickness of the lithosphere is directly related to thermal evolution. GRAIL will provide evidence of how rigid the lithosphere was — and therefore what the thermal conditions were — at various locations when features were formed.

2. Understand the Moon's asymmetric thermal evolution.

The thickness of the crust suggests the extent to which the surface was melted in its early history. The Moon's crust has a variable structure, thinner on the near side than on the far side, except for the south pole Aitken basin region, and thinned beneath the major impact basins. Scientists would like to know why.

3. Determine the subsurface structure of impact basins and the origin of mascons.

A surprising discovery was made in the 1960s, when it was found that the Moon's gravity was unexpectedly strong over certain impact basins, and that this is what had been pulling lunar spacecraft off course. It was deduced that these impact basins have large mass concentrations (or "mascons" for short) underneath them. GRAIL will provide more information about the nature of these mascons.

4. Ascertain the temporal evolution of crustal brecciation and magmatism.

Analyses of a set of lunar craters indicate that those that formed less than 3.2 billion years ago show less gravity than the surrounding plain, while those formed earlier show about the same gravity as the surrounding plain. GRAIL will help to explain the reasons, including the roles played by brecciation (the formation of new rocks by cementing together fragments of older rocks, often found beneath impact craters on Earth), magmatism (the movement of molten rock inside the moon), and isostatic compensation (a process by which a planetary body evens out the distribution of its mass — for example, by distorting the boundary between the crust and mantle beneath a large impact basin).

5. Constrain deep interior structure from tides.

Earth's gravity creates tides in the solid Moon, just as the Moon creates tides in Earth's ocean. Of course, the Moon's rocky surface doesn't bulge as much as water would — it only deforms about 9 centimetres in response to Earth's gravity from one part of the lunar orbit to another. But what's significant to GRAIL is that the Moon responds to Earth's gravity all the way down to the core, and different internal structures would produce differences in the way the Moon's gravitational field deforms. By analyzing how the field deforms at various parts of the Moon'sorbit around Earth, scientists will be able to deduce information about the core and other deep features.

6. Place limits on the size of a possible solid inner core.

GRAIL scientists will search for evidence of a solid core within the liquid core the Moon is believed to have, and the data they receive will place limits on how big that solid core could be.

Science instruments

The payload on each orbiter consists of a Lunar Gravity Ranging System and an education and public outreach MoonKAM System.

Lunar Gravity Ranging System

The primary payload of the GRAIL spacecraft is the Lunar Gravity Ranging System. The system is responsible for sending and receiving the signals needed to accurately and precisely measure the changes in range between the two orbiters as they fly over lunar terrain of varying density. To accomplish this, the Lunar Gravity Ranging System consists of an ultra-stable oscillator, microwave assembly, a time transfer assembly, and the gravity recovery processor assembly.

The ultra-stable oscillator provides a steady reference signal that is used by all the instrument subsystems. The microwave assembly converts the oscillator's reference signal to the Ka-band frequency, which is transmitted to the other orbiter. The function of the time transfer assembly is to provide a two-way time transfer link between the spacecraft to both synchronize and measure the clock offset between the clocks aboard the two spacecraft.

The time transfer assembly generates an S-band signal from the ultra-stable oscillator reference frequency and sends a GPS-like ranging code to the other spacecraft. The gravity recovery processor assembly combines all the inputs received to produce the radiometric data that is downlinked to the ground.

The twin GRAIL spacecraft are prepared for launch (NASA)

Outreach Instrument — MoonKAM

MoonKAM is a digital video imaging system that is used as part of the education and public outreach activities for GRAIL. Each MoonKAM system (one per spacecraft) consists of a digital video controller and four camera heads — one pointed slightly forward of the spacecraft, two pointed directly below it, and one pointed slightly backward. The digital video controller serves as the main interface to the spacecraft and provides storage for images acquired by the camera heads. This system can be used to take images or video of the lunar surface with a frame rate up to 30 frames per second.

The MoonKAM system is provided by Ecliptic Enterprises Corporation, Pasadena, Calif., and is operated by undergraduate students at the University of California at San Diego under supervision of faculty and in coordination with Sally Ride Science. Middle school students from around the US will have an opportunity to become involved with MoonKAM imaging. During the Science Phase, operations will be conducted in a non-time-critical, ground-interactive mode.

The spacecraft

The two spacecraft are mirror twins.

Structure

Main structure: 1.09 metres high, 0.95 metres wide, 0.76 metres deep

Power

Total solar array power at 1 Astronomical Unit: 763 watts

Power: Four panels of silicon solar cells mounted on satellite's top and side exterior surfaces

Batteries: 10 nickel-hydrogen cells providing up to 16 amp-hours of 28-volt power

Mass

Launch: 307 kilograms
Dry: 201 kilograms
Fuel (Helium): 106 kilogram

Curiosity launched to Mars

This artist concept features NASA's Mars Science Laboratory Curiosity rover, a mobile robot for investigating Mars' past or present ability to sustain microbial life. In this picture, the rover examines a rock on Mars with a set of tools at the end of the rover's arm, which extends about 2 metres. Two instruments on the arm can study rocks up close. Also, a drill can collect sample material from inside of rocks and a scoop can pick up samples of soil. The arm can sieve the samples and deliver fine powder to instruments inside the rover for thorough analysis. The mast, or rover's "head," rises to about 2.1 metres above ground level, about as tall as a basketball player. This mast supports two remote-sensing instruments: the Mast Camera, or "eyes," for stereo color viewing of surrounding terrain and material collected by the arm; and, the ChemCam instrument, which is a laser that vaporizes material from rocks up to about 9 metres away and determines what elements the rocks are made of. (NASA/JPL-Caltech)

NASA's long-awaited (and over-budget) new Mars rover Curiosity successfully launched from Cape Canaveral Air Force Station aboard an Atlas V rocket occurred at 10:02 a.m. EST (7:02 a.m. PST) on 26 November 2011. The Mars Science Laboratory and its car-sized rover will reach the red planet next August to begin a nearly two-year prime mission to investigate whether the landing site, near the foot of a mountain inside Gale Crater, has ever offered conditions favourable for microbial life, including the chemical ingredients for life.

"We are very excited about sending the world's most advanced scientific laboratory to Mars," NASA Administrator Charles Bolden said. "MSL will tell us critical things we need to know about Mars, and while it advances science, we'll be working on the capabilities for a human mission to the Red Planet and to other destinations where we've never been."

"The launch vehicle has given us a great injection into our trajectory, and we're on our way to Mars," Mars Science Laboratory Project Manager Peter Theisinger of the Jet Propulsion Laboratory in Pasadena, Calif., said after the launch. "The spacecraft is in communication, thermally stable and power positive."

Curiosity's ambitious science goals are among the mission's many differences from earlier Mars rovers. It will use a drill and scoop at the end of its robotic arm to gather soil and powdered samples of rock interiors, then sieve and parcel out these samples into analytical laboratory instruments inside the rover. Curiosity carries ten science instruments with a total mass 15 times as large as the science-instrument payloads on the Mars rovers Spirit and Opportunity. Some of the tools are the first of their kind on Mars, such as a laser-firing instrument for checking the elemental composition of rocks from a distance, and an X-ray diffraction instrument for definitive identification of minerals in powdered samples.

To haul and wield its science payload, Curiosity is twice as long and five times as heavy as Spirit or Opportunity. Because of its one-tonne mass, Curiosity is too heavy to employ airbags to cushion its landing as previous Mars rovers could. Part of the Mars Science Laboratory spacecraft is a rocket-powered descent stage that will lower the rover on tethers as the rocket engines control the speed of descent.

The mission's landing site offers Curiosity access for driving to layers of the mountain inside Gale Crater. Observations from orbit have identified clay and sulfate minerals in the lower layers, indicating a wet history. Precision landing maneuvers as the spacecraft flies through the Martian atmosphere before opening its parachute make Gale a safe target for the first time. This innovation shrinks the target area to less than one-fourth the size of earlier Mars landing targets. Without it, rough terrain at the edges of Curiosity's target would make the site unacceptably hazardous.

The innovations for landing a heavier spacecraft with greater precision are steps in technology development for human Mars missions. In addition, Curiosity carries an instrument for monitoring the natural radiation environment on Mars, important information for designing human Mars missions that protect astronauts' health.

Mars Science Laboratory investigations

NASA's Mars Science Laboratory mission will study whether the Gale Crater area of Mars has evidence of past and present habitable environments. These studies will be part of a broader

examination of past and present processes in the Martian atmosphere and on its surface. The research will use ten instrument-based science investigations. The mission's rover, Curiosity, carries the instruments for these investigations and will support their use by providing overland mobility, sample acquisition capabilities, power and communications.
The primary mission will last one Mars year (98 weeks).

The payload includes mast-mounted instruments to survey the surroundings and assess potential sampling targets from a distance; instruments on Curiosity's robotic arm for close-up inspections; laboratory instruments inside the rover for analysis of samples from rocks, soils and atmosphere; and instruments to monitor the environment around the rover. In addition to the science payload, engineering sensors on the heat shield will gather information about Mars' atmosphere and the spacecraft's performance during its descent through the atmosphere.

To make best use of the rover's science capabilities, a diverse international team of scientists and engineers will make daily decisions about the rover's activities for the following day. Even if the rover's technology all performs flawlessly, some types of evidence the mission will seek about past environments may not have persisted in the rock record. While the possibility that life might have existed on Mars provokes great interest, a finding that conditions did not favor life would also pay off with valuable insight about differences and similarities between early Mars and early Earth.

Habitability

The mission will assess whether the area Curiosity explores has ever been a potential habitat for Martian life. Whether life has existed on Mars is an open question that this mission, by itself, is not designed to answer. Curiosity does not carry experiments to detect active processes that would signify present-day biological metabolism, nor does it have the ability to image microorganisms or their fossil equivalents. However, if this mission finds that the field site in Gale Crater has had conditions favourable for habitability and for preserving evidence about life, those findings can shape future missions that would bring samples back to Earth for life-detection tests or for missions that carry advanced life-detection experiments to Mars. In this sense, the Mars Science Laboratory is the prospecting stage in a step-by-step program of exploration, reconnaissance, prospecting and mining evidence for a definitive answer about whether life has existed on Mars. NASA's Astrobiology Program has aided in development of the Mars Science Laboratory science payload and in studies of extreme habitats on Earth that can help in understanding possible habitats on Mars.

Three conditions considered crucial for habitability are liquid water, other chemical ingredients utilized by life and a source of energy. The Mars Science Laboratory mission advances the "follow the water" strategy of NASA Mars exploration since the mid-1990s to a strategy of determining the best settings for seeking an answer to whether Mars ever supported life.

Every environment on Earth where there is liquid water sustains microbial life. For most of Earth's history, the only life forms on this planet were microorganisms, or microbes. Microbes still make up most of the living matter on Earth. Scientists who specialize in the search for life on other worlds expect that any life on Mars, if it has existed at all, has been microbial.

Curiosity will land in a region where this key item on the checklist of life's requirements has already been determined: It was wet. Observations from Mars orbit during five years of assessing candidate landing sites have made these areas some of the most intensely studied places on Mars. Researchers have used NASA's Mars Reconnaissance Orbiter to map the area's mineralogy, finding exposures of clay minerals. Clays, other

Launch of the Mars Science Laboratory atop an Atlas 5 rocket on 26 November 2011 (NASA)

phyllosilicates and sulphates form under conditions with adequate liquid water in a life-supporting, medium range between very acidic and very alkaline.

Curiosity will inventory other basic ingredients for life, seek additional evidence about water and investigate how conditions in the area have changed over time. The wet environment in which the clay minerals formed is long gone, probably occurring more than 3 billion years ago. Examining the geological context for those minerals, such as the minerals in younger rock layers, could advance understanding of habitat change to drier conditions. The rover can also check for traces of water still bound into the mineral structure of rocks at and near the surface.

Carbon-containing compounds called organic molecules are an important class of ingredients for life that Curiosity can detect and inventory. This capability adds a trailblazing "follow the carbon" aspect to the Mars Science Laboratory, as part of the sequel to the "follow the water" theme.

Organic molecules contain one or more carbon atoms bound to hydrogen and, in many cases, additional elements. They can exist without life, but life as we know it cannot exist without them, so their presence would be an important plus for habitability. If Curiosity detects complex organics that are important to life on Earth, such as amino acids, these might be of biological origin, but also could come from non-biological

Gale crater, the landing site selected for the Curiosity Mars rover (circled above), is 154 km in diameter and holds a layered mountain rising about 5 km above the crater floor. The ellipse superimposed on this image indicates the intended landing area, 20 km by 25 km. The portion of the crater within the landing area has an alluvial fan likely formed by water-carried sediments. The lower layers of the nearby mountain -- within driving distance for Curiosity -- contain minerals indicating a wet history. The intended landing site is at 4.5 degrees south latitude, 137.4 degrees east longitude. (NASA/JPL)

sources, such as carbonaceous meteorites delivered to the surface of the planet.

Curiosity will also check for other chemical elements important for life, such as nitrogen, phosphorus, sulphur and oxygen.

The rover will definitively identify minerals, which provide a lasting record of the temperatures, pressures and chemistry present when the minerals were formed or altered. Researchers will add that information to observations about geological context, such as the patterns and processes of sedimentary rock accumulation, to chart a chronology of how the area's environments have changed over time. Energy for life on Mars could come from sunlight, heat or mixtures of chemicals (food) with an energy gradient that could be exploited by biological metabolism. The information Curiosity collects about minerals and about the area's modern environment will be analyzed for clues about possible past and present energy sources for life.

Curiosity will measure the ratios of different isotopes of several elements. Isotopes are variants of the same element with different atomic weights. Ratios such as the proportion of carbon-13 to carbon-12 can provide insight into planetary processes. For example, Mars once had a much denser atmosphere than it does today, and if the loss occurred at the top of the atmosphere, that process would favor increased concentration of heavier isotopes in the retained, modern atmosphere. Such processes can be relevant to habitability and biology.

Curiosity will assess isotopic ratios in methane if that gas is in the air around the rover. Methane is an organic molecule, and its carbon isotope ratio can be very distinctive. Observations from orbit and from Earth indicate traces of it may be present in Mars' atmosphere. Isotopic ratios could hold clues about whether methane is being produced by microbes or by a non-biological process.

The mission has four primary science objectives to meet NASA's overall habitability assessment goal:

- Assess the biological potential of at least one target environment by determining the nature and inventory of organic carbon compounds, searching for the chemical building blocks of life and identifying features that may record the actions of biologically relevant processes.
- Characterize the geology of the rover's field site at all appropriate spatial scales by investigating the chemical, isotopic and mineralogical composition of surface and near-surface materials and interpreting the processes that have formed rocks and soils.
- Investigate planetary processes of relevance to past habitability (including the role of water) by assessing the long timescale atmospheric evolution and determining the present state, distribution and cycling of water and carbon dioxide.
- Characterize the broad spectrum of surface radiation, including galactic cosmic radiation, solar proton events and secondary neutrons.

Preservation and past environments

Some of the same environmental conditions favourable for life can, paradoxically, be unfavourable for preserving evidence about life. Water, oxidants and heat, all of which can contribute to habitability, can destroy organic molecules and other possible markers left by life, or biosignatures.

Life has thrived on Earth for more than 3 billion years, but only a miniscule fraction of Earth's past life has left evidence of itself in the rock record on this planet. Preserving evidence of life from the distant past has required specific, unusual conditions. On Earth, these windows of preservation have included situations such as insects encased in amber and mastodons immersed in tar pits. Mars won't have fossils of insects or mastodons; if Mars has had any life forms at all, they were likely microbes. Understanding what types of environments may have preserved evidence of microbial life from billions of years ago, even on Earth, is still an emerging field of study.

To determine whether Mars ever supported life, a key step is learning where biosignatures could persist. Curiosity's findings about windows of preservation will serve this mission's prospector role: identifying good hunting grounds for possible future investigations about Martian life's existence and characteristics. They can also guide this mission's own course, informing decisions about where to drive and which rocks to sample in Curiosity's search for organics.

Accumulation of rock-forming sediments writes a record of environmental conditions and processes into those sedimentary rocks. The layers of the mountain inside Gale Crater provide a record of events arranged in the order in which they occurred. Researchers using Curiosity can look at how environments changed over time, possibly including transitions from habitable conditions to non-habitable conditions. Some of the clues are in the textures of the rocks, and Curiosity will be looking for distinctive rock textures. Other clues are in the mineral and chemical compositions.

Some conditions and processes, such as low temperatures and rapid entrapment in the sediments, can favour preservation of organics and evidence about life. As Curiosity looks for organics by analyzing samples drilled from sedimentary rocks, it will be reading the history of past environments whether or not it finds organics.

Some minerals and other geologic materials, such as sulphates, phosphates, carbonates and silica, can help preserve biosignatures. All of these materials, forming under just the right balance of environmental conditions, have the potential to preserve fragments of organic molecules derived from microbes or carbonaceous meteorites. But not just any rock formed of suitable minerals will do. Most on Earth do not. Expectations for Mars are similar, and the chances of a discovery — even if life had been present — are very small. If this sounds sobering, it should be, but this is the only known way to prospect for the vestiges of life on the early Earth.

The area at Gale Crater accessible to Curiosity as it drives during the mission contains rocks and soils that may have been originally deposited under differing conditions over a range of times. Analyzing samples from different points in that range could identify which, if any, hold organics. The rover might find that the answer is none. While such an answer could shrink prospects for finding evidence of ancient life on Mars, it would strengthen the contrast between early Mars and early Earth. The history of environmental changes on an Earthlike planet without life would be valuable for understanding the history of life's interaction with Earth's environment.

Modern environment

The Mars Science Laboratory will study the current environment in its landing region as well as the records left by past environments. Curiosity carries a weather station, an instrument for monitoring natural high-energy radiation and an instrument that can detect soil moisture and water-containing minerals in the ground beneath the rover. The investigations of organics and other potential ingredients for life can analyze samples of modern-day soil for what nutrients would be available to soil microbes. The ability to check for methane in the atmosphere is a study of modern processes, too. Methane would break down and disappear from the atmosphere within a few centuries if not replenished by an active source, so its presence would be surprising.

Selection of Curiosity's landing site was not based on traits favoring present-day habitability. However, much of the information this mission contributes about the modern environment will enhance our general understanding of Mars. For example, can organic compounds delivered by meteorites persist in the soil close to the surface? How does the modern atmosphere affect the ultraviolet and high-energy radiation that reaches the surface, posing a hazard to life and to preservation of organics? How might we better estimate levels in the past? The rover's monitoring of radiation levels from cosmic rays and the sun also is designed to address astronaut safety on eventual human missions to Mars.

Science payload

On 14 April 2004, NASA announced an opportunity for researchers to propose science investigations for the Mars Science Laboratory mission. The solicitation for proposals said, "The overall science objective of the MSL mission is to explore and quantitatively assess a potential habitat on Mars." Eight months later, the agency announced selection of eight investigations proposed competitively. In addition, Spain and Russia would each provide an investigation through international agreements. The instruments for these 10 investigations make up the science payload on Curiosity.

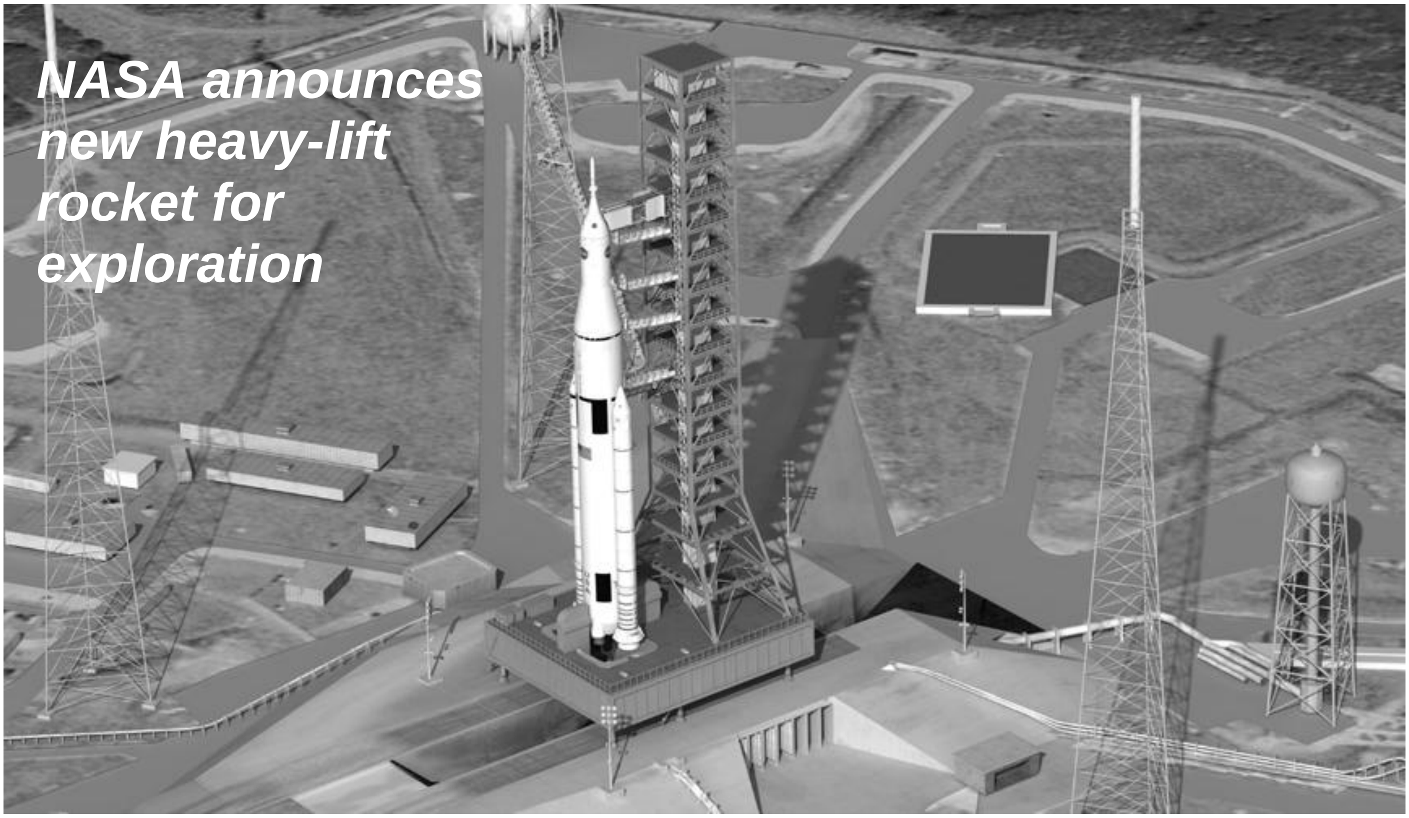
The two instruments on the mast are a versatile, high-definition imaging system, and a laser-equipped, spectrum-reading camera that can hit a rock with a laser and observe the resulting spark for information about what chemical elements are in the rock. The tools on the turret at the end of Curiosity's 2.1-metre-long robotic arm include a radiation-emitting instrument that reads X-ray clues to targets' composition and a magnifying-lens camera. The arm can deliver soil and powdered-rock samples to an instrument that uses X-ray analysis to identify minerals in the sample and to an instrument that uses three laboratory methods for assessing carbon compounds and other chemicals important to life and indicative of past and present processes.

For characterizing the modern environment, the rover also carries instruments to monitor the weather, measure natural radiation and seek evidence of water beneath the surface. To provide context for all the other instruments, a camera will record images of the landing area during descent.

The ten science instruments on the Mars Science Laboratory have a combined mass of 165 75 kilograms, compared with a five-instrument science payload totaling 5 kilograms on each of the twin rovers, Spirit and Opportunity, that landed on Mars in 2004. The mass of just one of Curiosity's ten instruments, 40 kilograms for Sample Analysis at Mars, is nearly four times the 10.6-kilogram total mass of the first Mars rover, 1997's Sojourner on the Mars Pathfinder mission.

Assessing past and present habitability of environments at sites visited by Curiosity will require integrating the results of the various instruments, not any single instrument. Science operations and analysis will be coordinated through the Mars Science Laboratory Project Science Group, whose members are Project Scientist John Grotzinger, of the California Institute of Technology, Pasadena, Calif.; Program Scientist Michael Meyer of NASA Headquarters, Washington; and the principal investigator for each of the investigations.

NASA announces new heavy-lift rocket for exploration



(Top) Artist's impression of the Space Launch System with an Orion spacecraft on Pad 39 at the Kennedy Space Center. (Below) The J-2X engine (NASA)

NASA is moving forward with the development of the Space Launch System -- an advanced heavy-lift launch vehicle that will provide an entirely new capability for human exploration beyond Earth's orbit. The Space Launch System, or SLS, will be designed to carry the Orion Multi-Purpose Crew Vehicle, as well as important cargo, equipment and science experiments to Earth's orbit and destinations beyond. Additionally, the SLS will serve as a back up for commercial and international partner transportation services to the International Space Station. If developed, it will be the most powerful rocket ever built, exceeding both the Space Shuttle and the Saturn 5 that propelled the Apollo missions to the Moon.

The SLS rocket will incorporate technological investments from the Space Shuttle Program and the Constellation Program in order to take advantage of proven hardware and cutting-edge tooling and manufacturing technology that will significantly reduce development and operations costs. It will use a liquid hydrogen and liquid oxygen propulsion system, which will include the RS-25D/E from the Space Shuttle Program for the core stage and the J-2X engine for the upper stage. SLS will also use solid rocket boosters for the initial development flights, while follow-on boosters will be competed based on performance requirements and affordability considerations. The SLS will have an initial lift capacity of 70 metric tons, roughly the weight of 40 sport utility vehicles. The lift capacity will be evolvable to 130 metric tons, enough to lift 75 SUVs. The first developmental flight, or mission, is targeted for the end of 2017 (but will almost certainly be later).

Bill Gerstenmaier, NASA's chief of space operations, said the agency plans one or two unmanned test flights using five-segment solid-fuel strap on boosters built by Alliant Techsystems Inc., builder of the shuttle's four-segment boosters and the bigger five-segment rockets intended for the now-canceled Constellation programme. But NASA intends to issue competitive contracts for follow-on boosters and the first stage

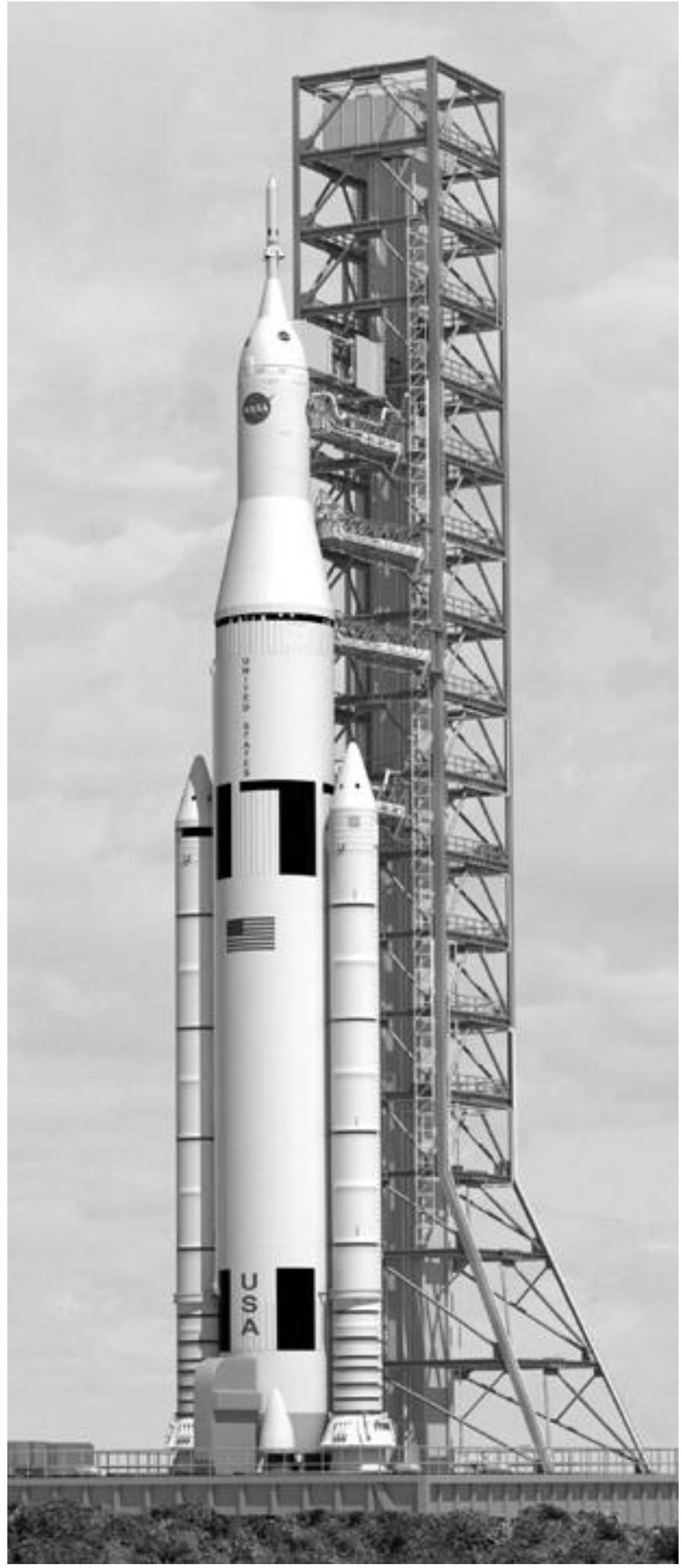
Artist's impression of an SLS launch (NASA)

core will be designed to accommodate either liquid or solid-fuel strap-ons.

NASA believes the Space Launch System will cost about $3 billion per year, or $18 billion through the first test flight in 2017, and can be accommodated within the current out-year budget profile. (This figure includes the cost of the Orion spacecraft and upgrades at the Kennedy Space Center for the new vehicles.

According to NASA, this specific SLS architecture was selected largely because it utilizes an evolvable development approach, which allows the agency to address high-cost development activities early on in the program and take advantage of higher buying power before inflation erodes the available funding of a fixed budget. This architecture also enables NASA to leverage existing capabilities and lower development costs by using liquid hydrogen and liquid oxygen for both the core and upper stages. Additionally, this architecture provides a modular launch vehicle that can be configured for specific mission needs using a variation of common elements. NASA may not need to lift 130 metric tons for each mission and the flexibility of this modular architecture allows the agency to use different core stage, upper stage, and first-stage booster combinations to achieve the most efficient launch vehicle for the desired mission.

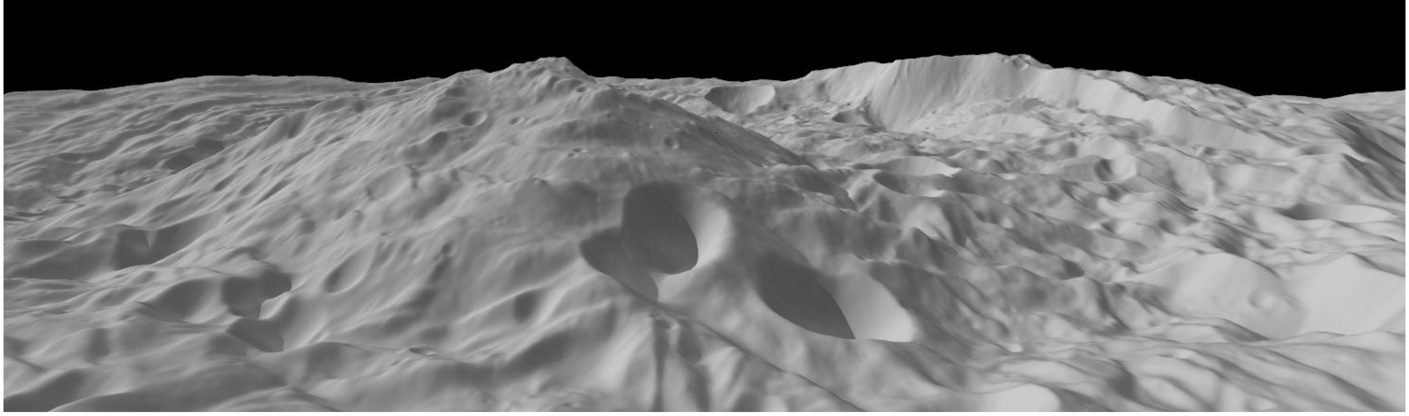
The Space Launch System will be NASA's first exploration-class vehicle since the Saturn 5. Possible missions include flights to nearby asteroids and eventually missions to orbit and



possibly land on Mars. Closer to home, the SLS could be used to send astronauts on satellite service calls to geosynchronous orbit or even to the Lagrangian points.

Is Vesta the "smallest terrestrial planet?"

By Dauna Colter, Science@NASA



This image of the asteroid Vesta, calculated from a shape model, shows a tilted view of the topography of the south polar region. The image has a resolution of about 300 metres per pixel, and the vertical scale is 1.5 times that of the horizontal scale. This perspective shows the topography, but removes the overall curvature of Vesta, as if the giant asteroid were flat and not rounded. An observer on Vesta would not have a view like this, because the distant features would disappear over the curvature of the horizon. (In the same way, if you were standing in North America, you would not be able to see a tall Mt. Everest in the distance, because of Earth's curvature.) (NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI)

NASA's Dawn spacecraft spent the last four years voyaging to asteroid Vesta – and may have found a planet.

Vesta was discovered over two hundred years ago but, until Dawn, has been seen only as an indistinct blur and considered little more than a large, rocky body. Now the spacecraft's instruments are revealing the true complexity of this ancient world.

"We're seeing enormous mountains, valleys, hills, cliffs, troughs, ridges, craters of all sizes, and plains," says Chris Russell, Dawn principal investigator from UCLA. "Vesta is not a simple ball of rock. This is a world with a rich geochemical history. It has quite a story to tell!" In fact, the asteroid is so complex that Russell and members of his team are calling it the "smallest terrestrial planet."

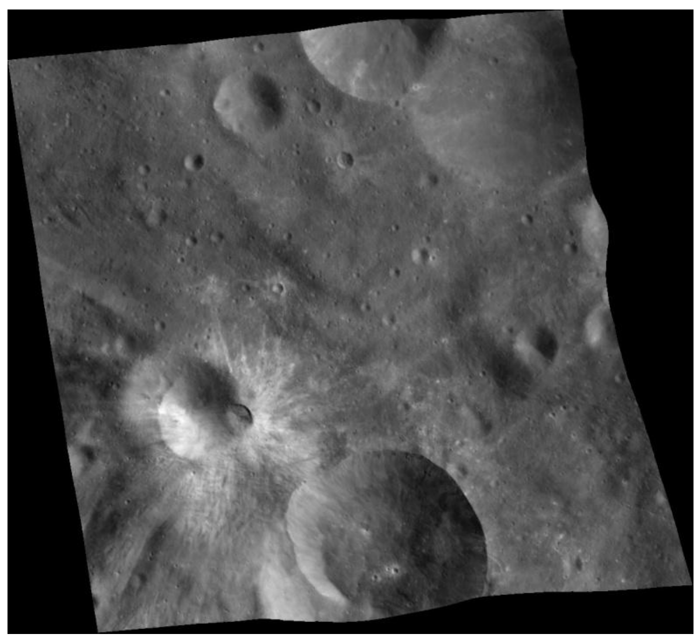
Vesta has an iron core, notes Russell, and its surface features indicate that the asteroid is "differentiated" like the terrestrial planets Earth, Mercury, Mars, and Venus. Differentiation is what happens when the interior of an active planet gets hot enough to melt, separating its materials into layers. The light material floats to the top while the heavy elements, such as iron and nickel, sink to the center of the planet. Researchers believe this process also happened to Vesta.

The story begins about 4.57 billion years ago, when the planets of the Solar System started forming from the primordial solar nebula. As Jupiter gathered itself together, its powerful gravity stirred up the material in the asteroid belt so objects there could no longer coalesce. Vesta was in the process of growing into a full-fledged planet when Jupiter interrupted the process. Although Vesta's growth was stunted, it is still differentiated like a true planet.

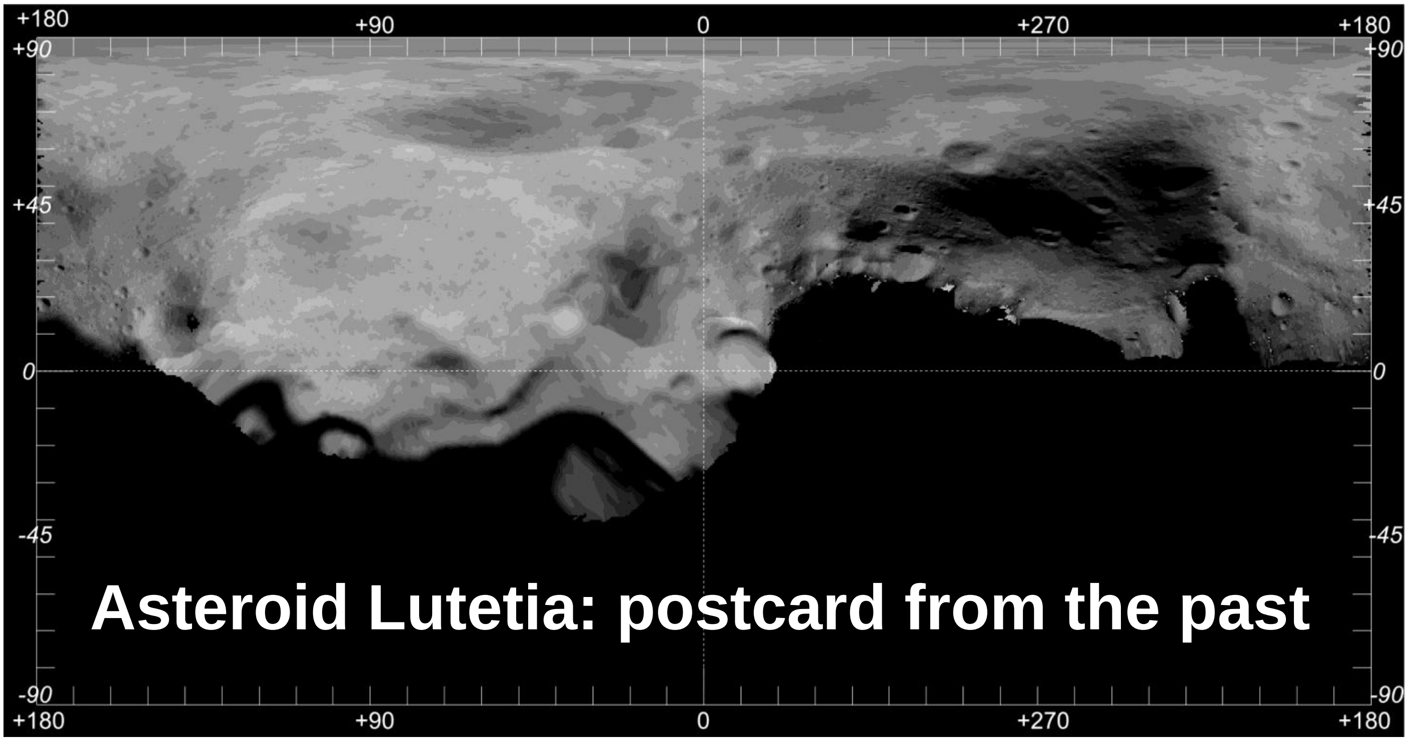
"We believe that the Solar System received an extra slug of radioactive aluminum and iron from a nearby supernova explosion at the time Vesta was forming," explains Russell. "These materials decay and give off heat. As the asteroid was gathering material up into a big ball of rock, it was also trapping the heat inside itself."

As Vesta's core melted, lighter materials rose to the surface, forming volcanoes and mountains and lava flows. "We think Vesta had volcanoes and flowing lava at one time, although we've not yet found any ancient volcanoes there," says Russell. "We're still looking. Vesta's plains seem similar to Hawaii's surface, which is basaltic lava solidified after flowing onto the surface.

Vesta has so much in common with the terrestrial planets, should it be formally reclassified from "asteroid" to "dwarf planet"? "That's up to the International Astronomical Union, but at least on the inside, Vesta is doing all the things a planet does." If anyone asks Russell, he knows how he would vote.



This mosaic of three images was taken by NASA's Dawn framing camera during the high-altitude mapping orbit over the giant asteroid Vesta. The images show an impact crater that is about 28 km wide from north to south and about 33 km from west to east, containing an approximately 22-km mass movement deposit in its interior. The eastern rim is higher than the western rim, and the overall topography is downhill from east to west. (NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI)



Asteroid Lutetia: postcard from the past

Several images have been combined into a map of the asteroid. This image represents the total area viewed by the spacecraft during the flyby, which amounted to more than 50% of Lutetia's surface. (All photos: ESA 2011 MPS for OSIRIS Team MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA)

ESA's Rosetta spacecraft has revealed asteroid Lutetia to be a primitive body, left over as the planets were forming in our Solar System. Results from Rosetta's fleeting flyby also suggest that this mini-world tried to grow a metal heart.

Rosetta flew past Lutetia on 10 July 2010 at a speed of 54,000 km/hr and a closest distance of 3,170 kilometres. At the time, the 130 kilometre-long asteroid was the largest encountered by a spacecraft. Since then, scientists have been analysing the data taken during the brief encounter. All previous flybys went past objects, which were fragments of once-larger bodies. However, during the encounter, scientists speculated that Lutetia might be an older, primitive 'mini-world'.

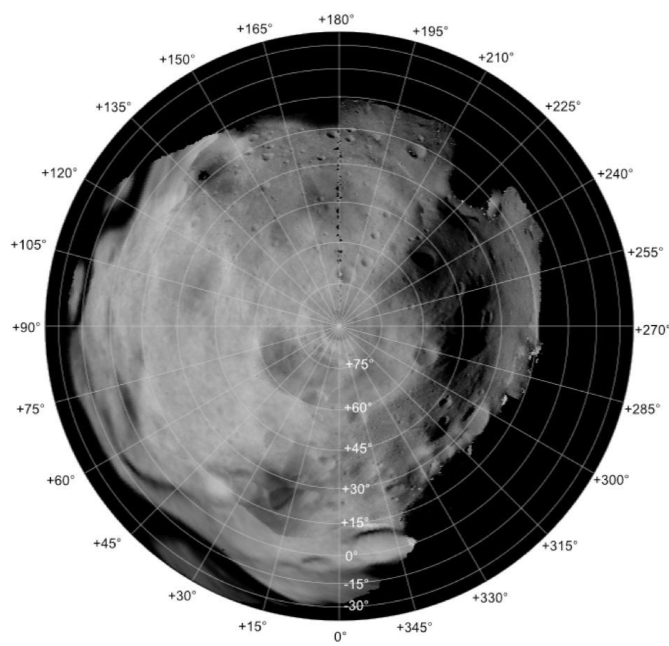
Now they are much more certain. Images from the OSIRIS camera reveal that parts of Lutetia's surface are around 3.6 billion years old. Other parts are young by astronomical standards, at 50 - 80 million years old.

Astronomers estimate the age of airless planets, moons, and asteroids by counting craters. Each bowl-shaped depression on the surface is made by an impact. The older the surface, the more impacts it will have accumulated. Some parts of Lutetia are heavily cratered, implying that it is very old. On the other hand, the youngest areas of Lutetia are landslides, probably triggered by the vibrations from particularly jarring nearby impacts. Debris resulting from these many impacts now lies across the surface as a 1 kilometre-thick layer of pulverised rock.

There are also boulders strewn across the surface: some are 300 - 400 metres across, or about half the size of Ayers Rock, in Australia. Some impacts must have been so large that they broke off whole chunks of Lutetia, gradually sculpting it into the battered wreck we see today.

"We don't think Lutetia was born looking like this," says Holger Sierks, Max-Planck-Institut für Sonnensystemforschung, Lindau, Germany. "It was probably round when it formed."

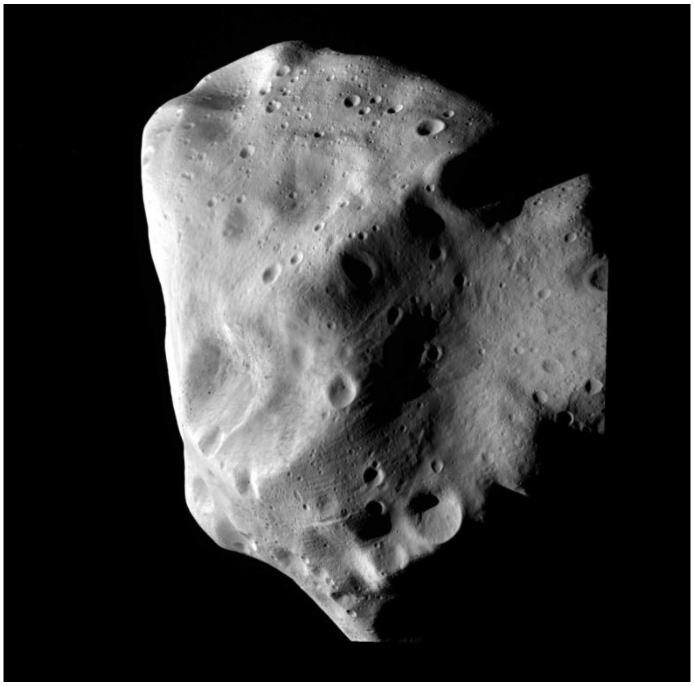
Rosetta's VIRTIS spectrometer found that Lutetia's composition is remarkably uniform across all the observed



This map of Lutetia is centred on the north pole. The number of craters in the asteroid's various regions have been used to date the surface. Some parts of the surface are 3.6 billion years old, while others are just 50–80 million years old.

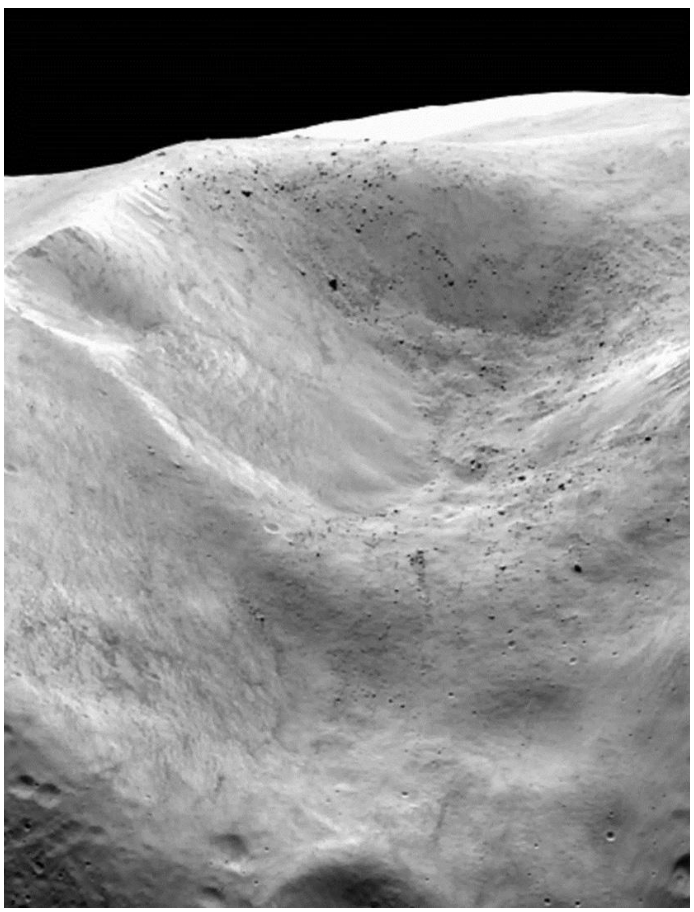
regions. "It is striking that an object of this size can bear scars of events so different in age across its surface while not showing any sign of surface compositional variation," says Fabrizio Capaccioni, INAF, Rome, Italy.

This is just the start of the mystery. Rosetta also let scientists investigate beneath the asteroid's surface. It appears



(Above) An image of Lutetia taken at Rosetta's closest approach to the asteroid.

(Below) Landslides on Lutetia are thought to have been caused by the vibrations created by impacts elsewhere on the asteroid dislodging pulverised rocks.



that Lutetia tried to grow an iron core like a bona-fide planet when it formed. During the encounter, Lutetia's weak gravity tugged on Rosetta. The slight change in Rosetta's path was reflected in radio signals received back at Earth, indicating a mass of 1.7 million billion tonnes.

This was a surprise. "The mass was lower than expected. Ground-based observations had suggested much higher values," says Martin Pätzold, Universität zu Köln, Germany, leader of the radio science team. Nevertheless, when combined with its volume, Lutetia still turns out to have one of the highest densities of any known asteroid: 3,400 kilograms per cubic metre. The density implies that Lutetia contains significant quantities of iron, but not necessarily in a fully formed core.

To form an iron core, Lutetia would have had to melt as a result of heat released by radioactive isotopes in its rocks. The dense iron would then sink to the centre and the rocky material would float to the top. However, VIRTIS indicates that Lutetia's surface composition remains entirely primordial, displaying none of the rocky material expected to form during such a molten phase.

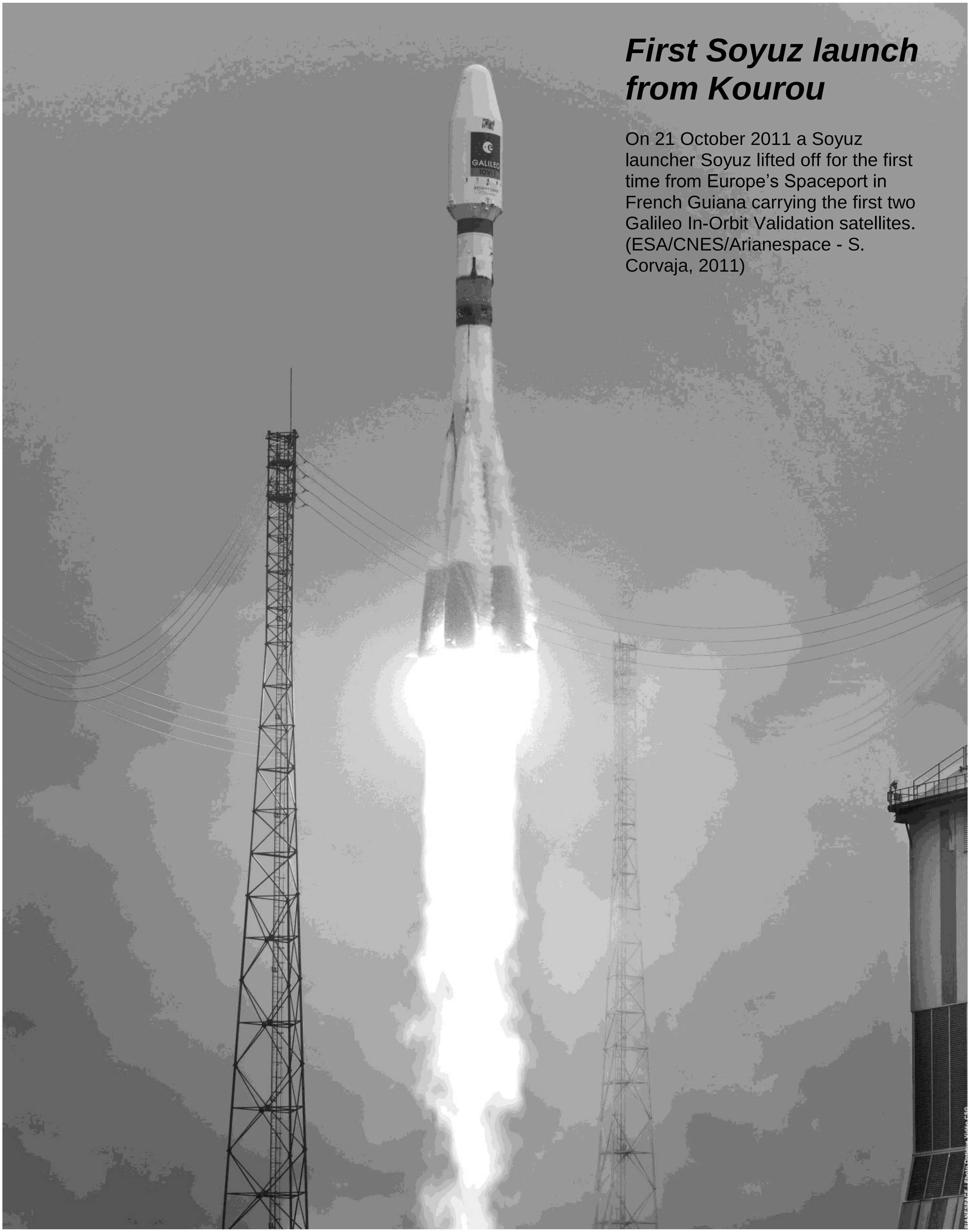
The only explanation appears to be that Lutetia was subjected to some internal heating early in its history but did not melt completely and so did not end up with a well-defined iron core. These results, all gathered during just a short flyby, make Lutetia a unique asteroid and an invaluable postcard from the past, at a time when Earth was forming.

"We picked a most important member of the asteroid belt," said Rita Schulz, ESA's Rosetta Project Scientist. "All the asteroids encountered so far were different from each other, but Lutetia is the only one in which both primordial and differentiation features have been found.

"These unexpected results clearly show that there is still much more to investigate before we understand the belt fully."

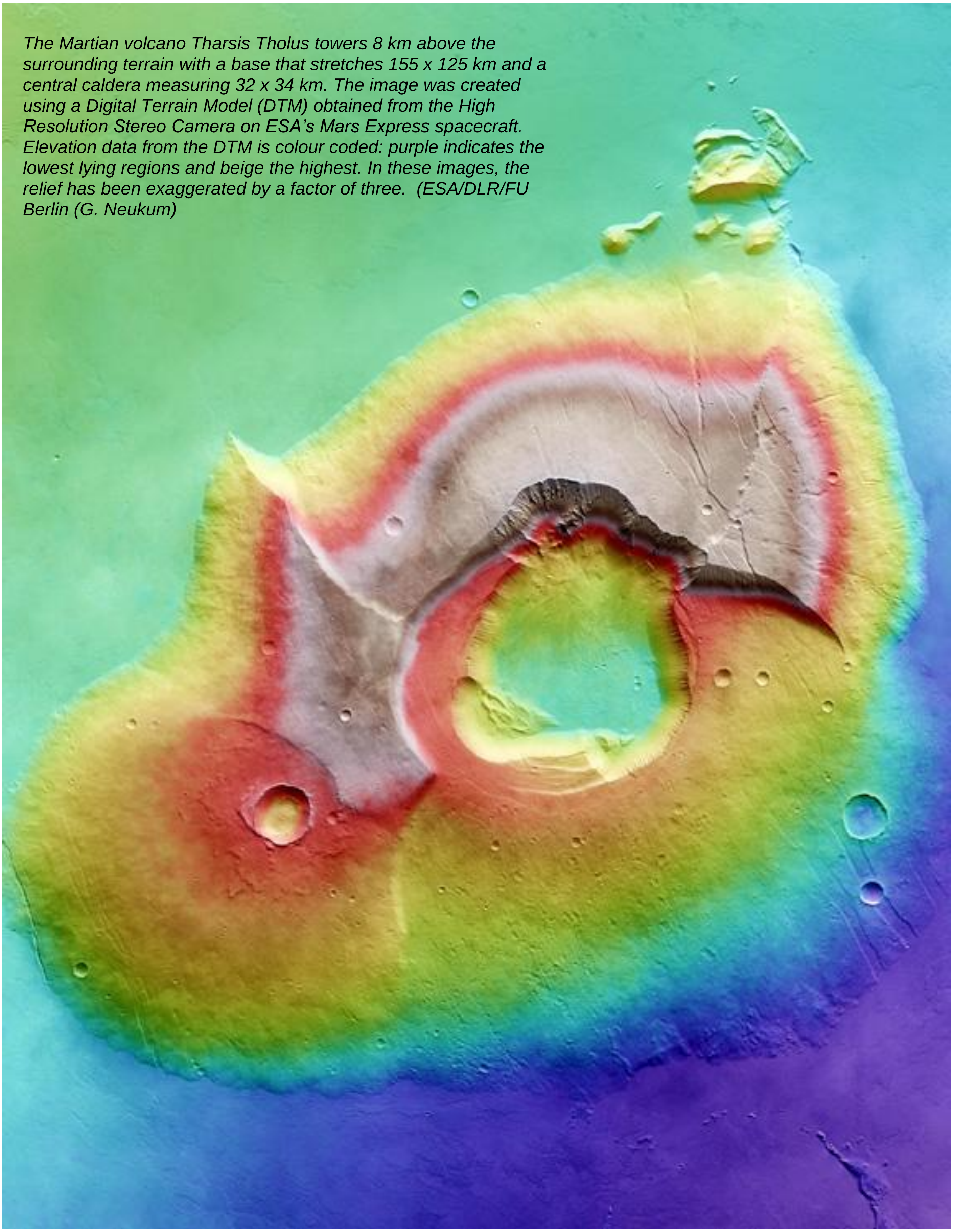
Having now left Lutetia far behind, Rosetta is in hibernation and en route to its 2014 rendezvous with comet Churyumov–Gerasimenko.

The Rosetta spacecraft (ESA)



First Soyuz launch from Kourou

On 21 October 2011 a Soyuz launcher Soyuz lifted off for the first time from Europe's Spaceport in French Guiana carrying the first two Galileo In-Orbit Validation satellites. (ESA/CNES/Arianespace - S. Corvaja, 2011)



The Martian volcano Tharsis Tholus towers 8 km above the surrounding terrain with a base that stretches 155 x 125 km and a central caldera measuring 32 x 34 km. The image was created using a Digital Terrain Model (DTM) obtained from the High Resolution Stereo Camera on ESA's Mars Express spacecraft. Elevation data from the DTM is colour coded: purple indicates the lowest lying regions and beige the highest. In these images, the relief has been exaggerated by a factor of three. (ESA/DLR/FU Berlin (G. Neukum)