

Astrodynamics

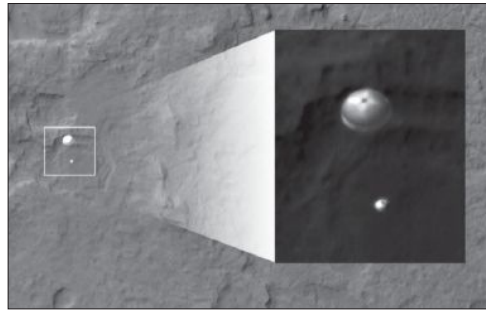
This year began with the arrival of NASA's GRAIL (gravity recovery and interior laboratory) orbiters at the Moon. Launched on a Delta II rocket on September 10, 2011, the twin orbiters Ebb and Flow embarked on a four-month low-energy transfer and performed lunar orbit insertion maneuvers on New Year's Eve and Day. Followed by two months of circularization, the probes were placed in tandem orbits around the Moon and initiated the prime science data collection on March 1, making this the first interplanetary formation-flight mission.

During the three-month prime science phase, the orbiters mapped lunar gravity in unprecedented detail using a technique similar to that of the gravity recovery and climate experiment mission, which on March 17 celebrated the 10th anniversary of mapping Earth's gravity field. The GRAIL orbits were raised in late May to avoid a lunar eclipse and were reconfigured to initiate the extended mission data collection on August 30. GRAIL will be decommissioned this month by impacting the lunar surface.

NASA launched another set of twins, the Radiation Belt Storm Probes, on August 30. They will be studying the Van Allen radiation belt.

On November 6, 2011, the Phobos-Grunt spacecraft was successfully launched aboard a Zenit launcher. However, the spacecraft failed to respond to ground command and was trapped in an undesirable low Earth orbit. The 13-ton spacecraft eventually disintegrated and on January 15 fell back to Earth over the Pacific Ocean. In between its launch and reentry, observers around the world tracked Phobos-Grunt and shared estimates and trending of orbital properties.

On August 6, the Mars Science Laboratory spacecraft, launched in November 2011, successfully landed the 1-ton rover Curiosity on Mars, inside Gale Crater. After successfully navigating to a very tight flight path angle requirement, the interplanetary navigation function performed the first handover to an active guidance system, which adjusted errors during the craft's descent through the atmosphere on its way to the surface. Two other spacecraft, Odyssey and the Mars Reconnaissance Orbiter, were precisely positioned at the time of the landing to receive transmissions and to take descent images of the rover.



NASA's Curiosity rover and its parachute were spotted by NASA's Mars Reconnaissance Orbiter as Curiosity descended to the surface on August 6. The high-resolution imaging science experiment camera captured this picture while the orbiter listened to transmissions from the rover. Courtesy NASA/JPL-Caltech/University of Arizona.

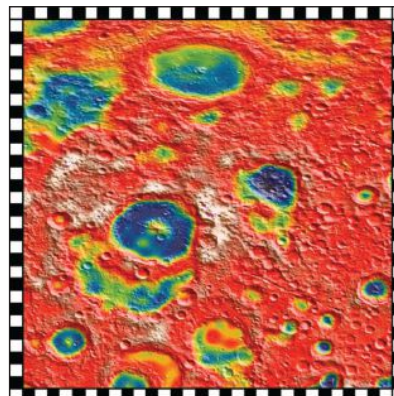
The Dawn spacecraft, which began orbiting the protoplanet Vesta in July 2011, has explored that uncharted world for more than a year. Using its solar electric propulsion system, the probe maneuvered to different orbits to optimize its investigation. The lowest altitude orbit was achieved in December 2011 and mapped Vesta at an average altitude of 210 km for five months. Dawn then gradually spiraled away from Vesta and escaped its gravity well on September 5. The probe is currently enroute to its second target, Ceres, and is expected to arrive in February 2015.

On December 5, 2011, NASA announced that Voyager 1 had entered the stagnation region between interstellar space and our solar system. On March 17, 2012, NASA's MESSENGER (Mercury surface, space environment, geochemistry, and ranging) spacecraft successfully wrapped up a year-long primary campaign for the first complete reconnaissance of the solar system's innermost planet. An extended mission phase started on the following day where the orbit period is reduced from 12 hr to 8 hr.

In April, China's second lunar orbiter, Chang'e 2, departed the Sun-Earth L2 point and headed to the asteroid 4179 Toutatis for a flyby expected in January 2013. On June 18, three astronauts on Shenzhou-9 successfully completed China's first crewed docking with the Tiangong-1 module.

A fifth satellite of Pluto was discovered from a Hubble Space Telescope optical survey. NASA's New Horizon spacecraft is scheduled to conduct the first-ever reconnaissance of the Pluto system in 2015; this new finding adds invaluable information for designing robust flyby sequences. ▲

Free-air gravity from GRAIL depicts a region of the Moon's farside highlands. Red corresponds to mass excesses and blues and purples correspond to mass deficiencies. The crater at center left is about 150 km in diameter. The figure illustrates how GRAIL resolves details of the Moon's highland crust as well as crater structures. Courtesy NASA/JPL Caltech/MIT.



by Ryan S. Park