

Astrodynamics

Spacecraft flybys again enabled, extended, and enhanced a variety of scientific missions throughout the year. The Deep Impact spacecraft, now on its way to the comet Hartley 2 under the EPOXI (Extrasolar Planet Observation and Characterization and the Deep Impact Extended Investigation) mission, essentially began and ended the year with Earth flybys.

In January and October, the MESSENGER (Mercury Surface, Space Environment, Geochemistry and Ranging) spacecraft performed its first flybys of Mercury at closest approach distances of 200 km, imaging previously unseen areas of the surface on the first visits to the innermost planet in over 30 years.

Throughout the year the Cassini spacecraft performed 10 flybys of Titan and four close flybys of Enceladus, coming within 25 km of the surface. Finally, the Mars Express spacecraft made several flybys of Phobos, coming within 93 km and enabling the most detailed images yet of the Martian moon.

Mars Express also joined the Mars Reconnaissance Orbiter (MRO) and Mars Odyssey spacecraft in providing telemetry support to the Phoenix spacecraft, which arrived at Mars in May. To guarantee optimal viewing geometry for Phoenix, these spacecraft made adjustments to their orbit timing through trim maneuvers and judicious use of momentum wheel desaturations. These orbit activities were all successful, to the point where MRO was able to image Phoenix with parachute deployed shortly before landing. The Phoenix spacecraft successfully navigated to a soft landing on Mars—again, the first in over 30 years, and the first at the Martian polar latitudes.

There was yet another flyby of interest at Mars this year. Asteroid 2007 WD5, tracked from Earth, was found to have a small probability of striking Mars in January. Although it ended up missing Mars by a distance of 6.5 Mars radii, witnessing an impact on another terrestrial planet would have been very insightful to scientists. In addition, the European Rosetta spacecraft, continuing its odyssey to comet 67P/Churyumov-Gerasimenko, came to within 800 km of asteroid 2867 Steins in September.

The year was also highlighted by lunar activities. The Japanese SELENE (Selenological and Engineering Explorer) spacecraft released two subsatellites and began science observations in October 2007. The Chinese Chang'e spacecraft achieved its lunar science orbit a month later, and the Indian spacecraft Chan-



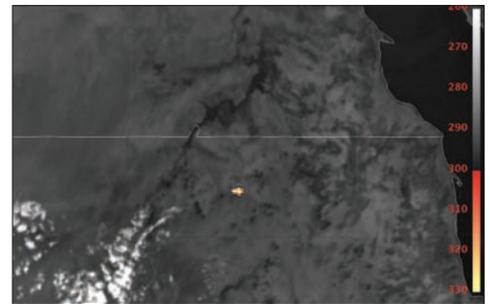
drayaan-1 (carrying a lunar probe) launched this October with a planned lunar orbit insertion on November 8.

Back on Earth, the risk to Earth orbiters from space debris, which was exacerbated by the shoot-down of a Chinese satellite and the explosion of a Russian rocket in 2007, continues to be studied and reassessed by (among others) the U.S. Space Surveillance Network and NASA's Orbital Debris Program Office.

A small (~3 m) asteroid, designated 2008 TC3, was detected on October 6 by the Catalina Sky Survey from its observatory near Tucson, Ariz. Preliminary orbital computations by the Minor Planet Center predicted atmospheric entry of the object the following day. JPL confirmed that an atmospheric impact would occur during early morning twilight over northern Sudan and refined the predicted entry time and place; U.S. satellite observations validated that the prediction was within a second in time and a kilometer in position. Objects of this size enter the Earth's atmosphere every few months, but this is the first time such an event has been predicted ahead of time.

Finally, the Politecnico di Torino in Italy hosted the Third Global Trajectory Optimization Competition. The objective of this international astrodynamics design contest was to optimize the trajectory of a multiple near-Earth asteroid rendezvous spacecraft with return to the Earth. The design challenge was to find the "best" low-thrust trajectory using an objective function that rewarded both low propellant consumption and long stay times at the asteroid (for a fixed total flight time). The winning team for this year, in a very competitive outcome, was from the Centre National d'Etudes Spatiales. A workshop presenting the methods and results from the competitors was held in Turin in June. ▲

MRO's HiRISE camera acquired this dramatic image of Phoenix descending on its parachute. This wide view shows a 10-km-diam crater informally called 'Heimdall,' and an inset of the parachute and lander.



Meteosat 8/EUMETSAT infrared image shows the 2008 TC3 explosion. The scale at the right gives the image intensity. Copyright 2008 EUMETSAT.

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