

Astrodynamics

The year began with the launch of the New Horizons probe, whose Earth-escape velocity of 16.2 km/sec was the largest ever achieved. This spacecraft will arrive at Pluto to begin flyby science observations in 2015, to be followed by encounters with Kuiper Belt objects for several years thereafter.

Another velocity record for a man-made object was set in January with the 12.8-km/sec reentry of the Stardust sample return capsule, following its seven-year mission to comet Wild-2, where it gathered cometary particles and interplanetary dust in an exposed tray of aerogel collectors.

Following two dramatic touchdowns on the asteroid Itokawa and the collection of spectacular imagery in November 2005, Japan's Hayabusa spacecraft suffered a reaction control system leak. The ensuing attitude control difficulties led to complete loss of radio contact with the spacecraft until late January of this year. Since then, vehicle systems have been brought back on line and tested. The ion propulsion engines are in sufficiently healthy condition to begin the return journey to Earth early next year, with arrival scheduled for June 2010.

In March, following a seven-month journey from Earth, the Mars Reconnaissance Orbiter fired a set of six monopropellant rocket engines to allow capture into a 35-hr, highly elliptical orbit around Mars. Over the next five months, this orbit was gradually circularized into its final 2-hr mission orbit by the process of aerobraking, in which the periapsis altitude was adjusted to about 105 km, and aerodynamic drag due to the Martian atmosphere was used to decrease the orbital energy. This process saved about 600 kg of fuel that would be required for equivalent propulsive maneuvers.

The European Venus Express probe entered Venusian orbit in April, terminating a five-month interplanetary trajectory. This spacecraft, which shares many of the instruments

and design features of the still-operational Mars Express vehicle, was ultimately placed into a 24-hr, 250-km \times 66,000-km orbit for conducting a detailed global investigation of the planetary atmosphere.

The Cassini spacecraft continues to provide stunning views of Saturn, its moons, and its ring structure. Numerous targeted flybys of Titan and other moons have been successfully executed. One result was the discovery of water volcanism on the moon Enceladus, which is believed to be a major source of the particles composing Saturn's E-ring. The complicated interaction of small moonlets and ring material have also been observed, including the "shepherding" process by which moons create gaps, waves, and twisted strands in the rings. The enigmatic "spokes," first seen on the Voyager mission, have also been spotted by Cassini.

In Earth orbit, several spacecraft constellations were established or extended this year. NASA's Space Technology-5 mission, comprising three 25-kg microsattellites deployed into the same orbit with only in-track separation, were launched in March to perform magnetospheric studies and to demonstrate efficient constellation control. The Republic of China's ROCSAT-3 mission, consisting of six satellites using the occultation of GPS signals to measure variations in atmospheric properties, was launched in April. Also, the Earth Observing System afternoon constellation acquired two additional members after the Calipso and CloudSat spacecraft were launched in April.

The SPHERES (Synchronized Position Hold, Engage, Reorient Experimental Satellites) began tests in the cabin of the International Space Station this year. The system consists of three self-contained free-flying spheres that serve as a test bed for the development of formation-flying and multispacecraft control algorithms, including reconfiguration, stationkeeping, rendezvous, and docking.

Also noteworthy are two astrodynamics applications that were runners-up in the 2006 NASA Software of the Year competition: Program to Optimize Simulated Trajectories II, or POST2, and the Deep Impact Autonomous Navigation Flight Software, or AutoNav. \mathcal{T}



The New Horizons probe to Pluto was launched in January on an Atlas V-551 booster.



The Japanese Hayabusa spacecraft took this image of the asteroid Itokawa from a distance of 7 km.

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