

NASA's **Asteroid Redirect Mission** concept raised the possibility that small natural bodies can be redirected so that astronauts can visit them more easily. On June 18, NASA announced a request for information seeking system ideas and innovative approaches for the ARM and an increased emphasis on defending Earth against catastrophic asteroid collisions. The agency also announced a Grand Challenge focused on finding all asteroids that threaten human populations and determining what to do about them. NASA released Trajectory Browser, software that calculates requirements for missions to asteroids, comets, planets, and other destinations in the solar system (<http://trajbrowser.arc.nasa.gov/>).

Astrodynamic techniques were used to observe and characterize bodies approaching the Earth-Moon system. On January 17, NASA's **Deep Impact** spacecraft acquired its first images of comet C/2012 S1 (ISON) from a distance of 800 million km and showed that the comet already has a coma and tail. On February 15, an 18-m asteroid entered Earth's atmosphere over **Chelyabinsk, Russia**. This incoming object exploded in an airburst and generated small fragmentary meteorites and a powerful shock wave. About 16 hr later, asteroid **2012 DA14** passed about 28,000 km above Earth's surface with an uncertainty region of only a few kilometers. It was determined later that the two objects were unrelated to each other. This year through August, there have been six additional asteroids that passed Earth to within a half lunar distance.

Asia's space programs continued to grow. On December 13, 2012, **China's Chang'e 2** spacecraft made a 3-km flyby of the asteroid Toutatis with a relative velocity of 10.7 km/sec, making China the fourth nation to conduct a successful asteroid mission. China's fifth manned space mission, Shenzhou 10, was launched on June 11 and performed automatic and manual dockings with the space laboratory module Tiangong-1. On January 30 from the Naro Space Center, Korea Aerospace Research Institute launched STSAT-2C on the Naro-1 carrier rocket with a Russian first stage. This was the first successful orbital launch conducted by South Korea. In November, the Indian Space Research Organization launched its first mission to Mars, using the four-stage Polar Satellite Launch Vehicle. The mission's main objective is to demonstrate technology needed for future interplanetary missions.

The commercial industry also made advances in astrodynamics capabilities. The **Inspiration Mars Foundation** was founded in January and aims to launch a manned mission to fly by Mars and perform a free return to Earth. On March 3, SpaceX's **Dragon** cargo spacecraft was captured by the robotic arm of the ISS and attached to an open docking port. On March 6, the arm removed the grapple bars from Dragon's trunk. This was the first delivery of unpressurized cargo from a commercial spacecraft to the ISS.

New missions, discoveries for astrodynamics

by Ryan S. Park

The Astrodynamics Technical Committee advances the science of trajectory determination, prediction, and adjustment, and also spacecraft navigation and attitude determination.



SpaceX's Grasshopper rocket completed a divert test on Aug. 13, flying to a 250-m altitude with a 100-m lateral maneuver before returning to the center of the launch pad. Credit: SpaceX.

SpaceX also flew its **Grasshopper** experimental reusable rocket five times in 2013 to demonstrate the maneuverability of a reusable launch vehicle. In August, the modified Falcon 9 performed a 100-m lateral maneuver, reached an altitude of 250 m, and safely returned to the center of the launch pad, making it the first test flight to include a lateral component. Grasshopper has reached an altitude of 744 m in the flights from the company's Rocket Development Facility in McGregor, Texas.

On July 1, the 14th moon of Neptune was discovered during postprocessing of images taken by the **Hubble Space Telescope** between 2004 and 2009. The moon, designated S/2004 N 1, is likely to be captured by Neptune. On September 6, NASA's Lunar Atmosphere and Dust Environment Explorer mission was launched on a Minotaur 5 carrier rocket from the Wallops Flight Facility in Virginia and was the first lunar mission to be sent aloft from that site. On October 9, the Juno spacecraft conducted a 550-km Earth flyby, received an energy boost, and then continued on its path toward Jupiter. ♀