How to Harpoon a Comet
by **Dave Palmer, Design News** 9/12/2014
It's been described as the sexiest space mission of recent years. On Nov. 11, a European space probe will attempt to land on the surface of a comet. The Rosetta probe's journey from Earth to comet 67P/Churyumov-Gerasimenko has taken more than 10 years. Currently, the probe is in orbit about 30 miles from the comet. If Rosetta's lander, named Philae, is successful, it will be the first spacecraft to land on the surface of a comet.

Comets are celestial bodies left over from the formation of the solar system about 5 billion years ago. Known for their magnificent tails that form when they approach the sun, comets are actually "dirty snowballs," in the words of astronomer Fred Whipple. Since comets are the oldest objects in the solar system, their composition may provide clues as to how the solar system formed. Ice from comets may have provided some of the water that now covers about 70% of the Earth's surface. Comets may even hold the secret to the origin of life on Earth.

The first landing on the surface of a comet is an exciting scientific story, but it's also an exciting engineering story. Landing on a comet is no simple task. The comet is moving at about 84,000 mph and rotating with a period of 12.7 hours. It's relatively small -- about 2 miles by 2.5 miles. Also, it's not round. The comet's shape has been compared to a rubber duck. All these factors make just positioning the probe for the landing a challenge.

At a distance of 270 million miles from Earth, it takes about 30 minutes for signals from mission control to reach the spacecraft. This means that the challenge of landing on the comet will need to be handled automatically. This difficult computational task will be carried out by a processor that, according to former NASA software engineer Tim Reyes, is only about as powerful as a mid-1990s hand calculator.

Then there's the fact that the comet's gravity is very weak -- about 1/10,000 that of Earth. This creates the possibility that the lander could bounce off the surface and float into space. To prevent this from happening, the Philae lander is equipped with a pair of harpoons with high-strength beryllium copper tips and stainless-steel barbs. When the lander touches down, tungsten filaments will ignite pyrotechnic charges that will fire the harpoons into the comet at a speed of about 300 feet per second. The harpoons -- attached by cables to the base of the lander -- will embed into the comet's surface. A brushless DC gear motor will pull the cables tight, anchoring the lander to the surface.

At the same time, ice screws in each of the lander's three feet will drill into the surface. A compressed gas thruster at the top of the lander, similar to those typically used to slow spacecraft during their descent but oriented in the opposite direction, will provide additional downward force to hold the lander against the surface.

The Rosetta probe was designed and built to travel to a different comet. However, its mission to comet 47P/Wirtanen was cancelled just a month before its scheduled launch. On Dec. 11, 2002, an Ariane 5 rocket carrying two European communications satellites went off-course and self-destructed three seconds after launch. All European space missions, including Rosetta, were grounded until the cause of this failure could be determined. The Rosetta mission finally launched on March 2, 2004, nearly 14 months after the original planned date.

The delay meant that a new target had to be selected. Instead of comet 47P/Wirtanen, the probe would now travel to comet 67P/Churyumov-Gerasimenko. This created a challenge for the engineering team. Comet 67P/Churyumov-Gerasimenko is larger than comet 47P/Wirtanen. The higher gravity meant that the landing velocity would be increased by a factor of three. Since kinetic energy is proportional to the square of the velocity, the kinetic energy would be increased by a factor of nine. To add to the challenge, the lander had already been built, tested, flight qualified, and attached to the orbiter. This meant that no major hardware changes were possible.

The engineering team used Simpack multi-body simulation software to see how the lander would fare on the new comet. The lander consists of a box-shaped head mounted by a universal joint to three legs. The purpose of the universal joint is to limit the transfer of angular momentum between the lander and the comet. Essentially, it allows the lander's head to swing like a jack in the box. However, the simulation showed that, under certain conditions, the head could crash into one of the lander's legs. Therefore, the engineers designed a mechanical tilt limiter, which restricted the universal joint's rotation to three degrees. The tilt limiter was attached to the lander prior to launch, without having to remove it from the orbiter.

Will this solution work? Hopefully, on Nov. 11, 2014, the world will find out.