Vision Research Phantom Cameras Aid in Spacecraft and Astronaut Safety for NASA

Here’s an interesting fact: Since the Soviet Union launched Sputnik – the first artificial Earth satellite – in 1957, more than 2,000 satellites have been dispatched into space. As a result, the Earth’s orbit is now littered with defunct man-made objects such as nonfunctional spacecraft, old satellites, mission-related rubble and fragmentation debris. These leftover space mission bits and pieces are referred to as space debris, and the Earth’s orbit is now their permanent home. This debris travels through the Earth’s orbit at hypervelocity speeds, which are speeds so boundless they can make metal behave like a liquid upon impact! You can imagine the threat this causes to NASA’s space missions, especially during launch, orbit, and re-entry operations.

Space debris exists in all sizes. It can measure as small as a speck of paint or a bit of metal that’s fallen off a spacecraft. On the contrary, an entire satellite that is no longer working can account for a piece of large debris. According to NASA, the Earth’s orbit has more than 20,000 pieces of debris that are larger than the size of a softball, and they’re traveling at speeds up to 18,000 miles per hour (MPH). But even the tiniest speck of wreckage can damage a spacecraft, or worse, injure an astronaut whose spacesuit cannot stand up to the impact.
Space debris is so abundant in low Earth orbit (LEO) that it poses a sincere threat to future missions and safety of crew and equipment. In 1978, Donald Kessler, a scientist at NASA, focused his resources on better understanding the impact and threat that this debris posed, the result of which is widely known as The Kessler Syndrome. Kessler’s research looked at the self-sustaining cascading collision of space debris in LEO - a domino effect, that could eventually generate even more debris to the point where LEO could be nearly impassable.

Measuring the Perils of Space Debris

Owing to this, a group of engineers at NASA Johnson Space Center White Sands Test Facility (WSTF) are doing their part to protect both astronauts and spacecraft from the perils of space debris hurling through orbit. Nestled in the foothills of the San Andres Mountains, just east of Las Cruces, New Mexico, WSTF is home to the Remote Hypervelocity Test Laboratory (RHTL), which is a hazardous test area that simulates micrometeoroid and other debris on spacecraft materials and components. The RHTL works in close partnership with the JSC Hypervelocity Impact Technology Facility (HITF) in Houston, TX, to measure and determine the puncture risks posed by space debris.

Run by Donald J. Henderson, RHTL Group Leader, the lab safely handles and tests hazardous targets in a controlled environment; it simulates impacts on shields, spacecraft, satellites and an astronaut’s all-important spacesuit to create better defenses. In doing so, Henderson and his team use four, 2-stage Light Gas Guns (2SLGGs) to fire projectiles that reach speeds exceeding 16,000 MPH. An engineering feat, the guns are 40 yards long and rely on four pounds of exploding gunpowder that drive a piston down a compression chamber, squeezing the hydrogen gas inside to more than 100,000 pounds per square inch. At roughly six times faster than the fastest rifle bullet, the projectiles from the guns mimic the impact of real space debris that travels at even greater speeds in orbit – up to 18,000 miles per hour. If a spacecraft is moving toward the debris, the total collision speed can be even faster.

The projectiles launched at WSTF are primarily made from aluminum, nylon and stainless steel.

“...The safety of our mission and crew is of paramount importance to NASA. The hypervelocity impact testing we’re doing at the RHTL leads to significant modifications and upgrades in spacecraft design, which, in essence save lives. Without the use of high-speed imagery from Vision Research, it would be nearly impossible to gauge exactly what type of improvements need to be made to our spacecraft, shields, components and spacesuits to ensure the safety of our missions moving forward.”
and range in shape from spheres, cylinders, disks, and cubes to multiple projectile "shotgun" shots. They fire at a variety of targets including Kevlar-wrapped oxygen bottles, steel cables, and other makeshift parts of spacecraft. The results? "Most of the time, the oxygen bottles are ripped in half and the steel cables are shredded in two," Henderson said.

It’s not just large debris that poses a threat, he continued. "There are millions of fragments in orbit that are too small to track, but incredibly harmful. Even something like a tiny fleck of paint can damage a spacecraft when traveling at these velocities. We want to test everything as close to a real-world-scenario as possible, so most of the projectiles we use are smaller than the size of a pea."

**Assessing Hypervelocity Projectiles with Ultra-High-Speed Imagery**

The team at RHTL performs more than 400 shots per year with the Light Gas Guns to evaluate puncture risks posed by space debris. With such an important and ongoing project happening, the team needed a way to record the velocity testing at very high speeds since they’re traveling at a pace that they can’t actually see with their own eyes. To accomplish this feat, they turned to Vision Research and selected two Phantom v711 ultra-high-speed digital cameras and one Phantom v2512 – which is part of Vision Research’s new ultrahigh-speed 12 Series of cameras.

With the ability to capture events undetectable to the human eye, the Phantom ultrahigh-speed cameras provide large amounts of critical data for Henderson and his crew to examine and analyze. They help the team understand the impact dynamics of hypervelocity testing, such as shockwaves and pressure waves as they travel through their shields from the impact point to the frame. "Since we’re unable to actually see the projectiles with our own eyes because they’re moving too fast, the frame rates in the Phantom cameras are instrumental when recording this type of data; the faster the better. With the v711, for example, we’re able to leverage the camera’s high throughput to get higher resolution at the speeds we need."

Due to the low-light conditions inside the RHTL, Henderson acquired a v2512 after receiving advice from Vision Research because it handles low-light conditions like no other camera. It includes a high sensitivity sensor which lessens the lighting challenge at the RHTL and gives the team the option of a faster shutter speed, thus reducing motion blur and generating clearer and more crisp imagery.

As an example, Henderson discussed the cameras’ key role in helping the team at RHTL solve the issue with framing target materials, particularly cloth materials. "The shock and pressure waves were causing edge effects that made the apparent damage from the projectiles appear worse. But with the cines from the Phantom cameras, it was easy to discern the difference. The data we acquired from the cines also helped explain edge effects in window materials where the shockwaves traveled to the edge and back to

**Sequence of images from a hypervelocity impact**
coalesce and cause artificial rupturing. Through a process of trial and error, we learned to impact off-center and place dampening materials at the frame edges to get optimal results.”

Without the ability to see and analyze the speed and damage caused by each projectile, the RHTL would have little understanding of the level of destruction a piece of space wreckage causes to a spacecraft or astronaut. “The safety of our mission and crew is of paramount importance to NASA. The hypervelocity impact testing we’re doing at the RHTL leads to significant modifications and upgrades in spacecraft design, which, in essence save lives. Without the use of high-speed imagery from Vision Research, it would be nearly impossible to gauge exactly what type of improvements need to be made to our spacecraft and spacesuits to ensure the safety of our missions moving forward.”

**About the RHTL:**

NASA’s White Sands Test Facility (WSTF) Remote Hypervelocity Test Laboratory (RHTL) is a unique, access-controlled hazardous test area capable of simulating micrometeoroid and orbital debris on spacecraft materials and components. Located in New Mexico, it safely handles and tests hazardous targets, and simulates impacts on shields, spacecraft, satellites, and spacesuits. Four, 2-stage Light Gas Guns (2SLGGs) propel single 0.05 mm to 22.2 mm diameter projectiles to velocities in excess of 7.5 km/s. Due to the WSTF’s remote location and attention to safety, the RHTL is capable of implementing test programs that propel projectiles at toxic or explosive materials and components such as batteries, aerospace fluids, and pressurized containers in a controlled laboratory environment.

For more information on the RHTL and the important work it does, please visit NASA WSTF:

http://www.nasa.gov/centers/wstf/laboratories/hypervelocity/

See some sample impact movies in our Web Gallery. Look in the Case Studies category.