Shooting Marbles at 16,000 mph

March 14 2007, By Dave Dooling

Death of a shooter. This is a real photo of a pyrex marble exploding on impact at the NASA Ames Vertical Gun Range. Photo credit: Peter Schultz, Brown University, and NASA

NASA scientist Bill Cooke is shooting marbles and he's playing "keepsies." The prize won't be another player's marbles, but knowledge that will help keep astronauts safe when America returns to the Moon in the next decade.

Cooke is firing quarter-inch diameter clear shooters – Pyrex glass, to be exact – at soil rather than at other marbles. And he has to use a new one on each round because every 16,000 mph (7 km/s) shot destroys his shooter.

"We are simulating meteoroid impacts with the lunar surface," he explains. Cooke and others in the Space Environments Group at NASA's

Marshall Space Flight Center have recorded the real thing many times. Their telescopes routinely detect explosions on the Moon when meteoroids slam into the lunar surface.

A typical flash involves "a meteoroid the size of a softball hitting the Moon at 27 km/s and exploding with as much energy as 70 kg of TNT."

"Mind you," says Cooke, "these are estimates based on a flash of light seen 400,000 km away. There's a lot of uncertainty in our calculations of speed, mass and energy. We'd like to firm up these numbers."

That's where the marbles come in....

Cooke is using the Ames Vertical Gun Range at NASA's Ames Research Center in Mountain View, CA, to shoot marbles into simulated lunar soil. The firings allow him to calibrate what he sees on the Moon. His work is funded by NASA's Office of Safety and Mission Assurance.

A 30cm-diameter crater plus spattered dust are all that's left after a test shot in the Ames Vertical Gun. Photo credit: NASA

"We measure the flash so we can figure out how much of the kinetic energy goes into light," he explained. "Once we know this luminous efficiency, as we call it, we can apply it to real meteoroids when they strike the Moon." High-speed cameras and a photometer (light meter) record the results.

The Ames Vertical Gun Range was built in the 1960s to support Project Apollo, America's first human missions to the lunar surface. The Ames gun can fire a variety of shapes and materials, even clusters of particles, at speeds from 0.5 to 7 km/s. The target chamber usually is pumped down to a vacuum, and can be partially refilled to simulate atmospheres on other worlds or comets.

Equally important, the gun's barrel can be tilted to simulate impacts at seven different angles from vertical to horizontal since meteors rarely fly straight into the ground. Black powder propels the marble, and special valves capture the exhaust gases so they don't blow away the impact crater.

Cooke's experiments are being run in two rounds. The first set of 12 shots in October 2006 fired Pyrex glass balls into dust made from pumice, a volcanic rock, at up to 7 km/s. Follow-up experiments will use JSC-1a lunar simulant, one of the "true fakes" developed from terrestrial ingredients to mimic the qualities of moon soil.

Knowing the speed and mass of the projectile will let Cooke to scale the flash and estimate the energies of the softball-size meteoroids that hit the Moon at up to 72 km/s, more than six times the speed of the Ames gun. But luminous efficiency is just part of the question. A lot of the impact energy goes into shattering and melting the projectile -- the main reason for using glass rather than metal -- and then spraying debris everywhere.

"The ejecta kicked out from an impact can travel hundreds of miles," Cooke continued. "We need to know more about that if we are going to live on the lunar surface for months at a time." Because the moon has virtually no atmosphere to slow down flying debris, particles land with the same speed that launched them from the impact site.

So you might dodge a bullet but still get caught by its shrapnel. And the question is, Are you more likely to get cut off at the ankles by debris spattered along the horizon, or hit from above by material on high, ballistic trajectories?

To gauge that danger, Cooke will measure the speed and direction of secondary particles by the sheet-laser technique. Lenses and mirrors spread a laser beam into paper-thin sheets of light so flying particles are briefly illuminated several times. The light traces then tell the size, direction, and speed of debris particles leaving an impact.

The technique requires a lot of image analysis, but it is cleaner and more accurate than the older way of hanging aluminum sheets in the chamber and counting holes.

The answers will help determine the kinds of shielding needed on exploration vehicles protecting humans where every day is for "keepsies."

Source: Science@NASA

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