

**THE AMES VERTICAL GUN RANGE.** J. S. Karcz<sup>1</sup> ([john.s.karcz@nasa.gov](mailto:john.s.karcz@nasa.gov)), D. Bowling<sup>2</sup>, C. Cornelison<sup>1</sup>, A. Parrish<sup>2</sup>, A. Perez<sup>3</sup>, G. Raiche<sup>1</sup>, and J.-P. Wiens<sup>3</sup>, <sup>1</sup>National Aeronautics and Space Administration (NASA) Ames Research Center, Moffett Field, CA 94035, <sup>2</sup>Jacobs Technology Inc., 600 William Northern Boulevard., P.O. Box 884, Tullahoma, TN 37388, <sup>3</sup>Qualis Corporation, 689 Discovery Drive, Suite 400, Huntsville, AL 35806

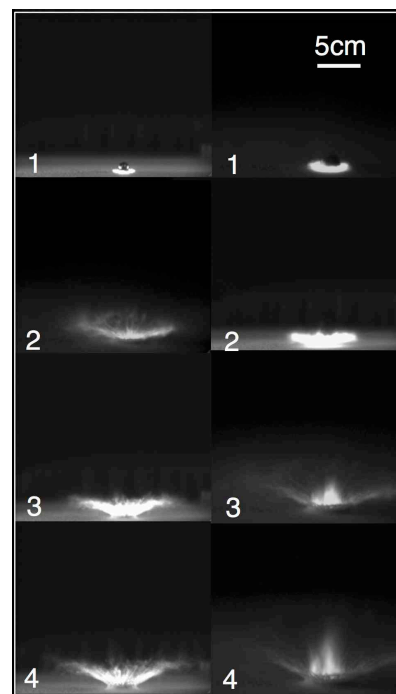
**Introduction:** The Ames Vertical Gun Range (AVGR) is a national facility for conducting laboratory-scale investigations of high-speed impact processes. It provides a set of light-gas, powder, and compressed-gas guns capable of accelerating projectiles to speeds up to 7 km s<sup>-1</sup>. The AVGR has a unique capability to vary the angle between the projectile-launch and gravity vectors between 0 and 90°. The target resides in a large chamber (diameter ~ 2.5 m) that can be held at vacuum or filled with an experiment-specific atmosphere. The chamber provides a number of viewing ports and feed-throughs for data, power, and fluids. Impacts are observed via high-speed digital cameras along with investigation-specific instrumentation, such as spectrometers. Use of the range is available via grant proposals through any Planetary Science Research Program element of the NASA Research Opportunities in Space and Earth Sciences (ROSES) calls. Exploratory experiments (one to two days) are additionally possible in order to develop a new proposal.

**Purpose:** Since the Apollo program, the AVGR has enabled investigations into fundamental impact processes and supported numerous NASA science missions. It was created in 1966 to assess the nature of the lunar regolith and to determine crater-scaling relations that could be used to constrain the age of the lunar surface. After closure in 1977, it was reopened in 1979 as a national facility in response to user interest. Investigations conducted using the AVGR have contributed to understanding of impact physics and the geological processes responsible for features observed throughout the Solar System. They have stimulated the development of new computational approaches and served as benchmarks for computational models. AVGR experiments have contributed input for missions including Deep Impact, LCROSS (Figure 1), Stardust, the Mars Exploration Rovers, and Cassini. In addition, experiments have contributed to the analysis of mission results from Surveyor to Dawn. Examples of recent investigations include examination of the effects of early-stage coupling between the projectile and the target on main-stage crater development [1]; assessment of cratering, disruption, and momentum transfer due to impacts into porous asteroids [2]; high-speed spectroscopic examination of the temporal and spatial evolution of impact-generated vapor [3]; and determination of the temperatures reached during aerogel capture of

hypervelocity particles, as employed by the Stardust sample-return mission [4].

**Facility description:** The range is housed in a 6000 ft<sup>2</sup> space at NASA's Ames Research Center, and it is operated by Ames' Thermophysics Branch. The facility consists of a two-story room (Figure 2) containing the gun, impact chamber, and supporting systems; operations and imaging systems control rooms; target-materials storage and preparations rooms; an explosives magazine; offices for visiting researchers and operations staff; a photo studio for documenting targets before and after tests; and a machine shop.

Several guns are available to launch projectiles. Three light-gas guns, which use smokeless powder to pressurize hydrogen propellant gas, can launch projectiles to speeds between 2.4 and 7 km s<sup>-1</sup>. They can accelerate projectiles with diameters up to 3.175 mm to



**Figure 1:** Comparison of the plume produced by solid (left) and hollow (right) projectiles. The hollow-projectile plume has a central, narrow-angle component. This experiment was conducted as part of a series that examined the behavior of ejecta during the LCROSS lunar impact. The LCROSS impactor, a Centaur upper stage, was a hollow structure. Modified from [5].

speeds up to  $7 \text{ km s}^{-1}$ , diameters up to 6.35 mm to speeds up to  $6.5 \text{ km s}^{-1}$ , and (with an additional large-bore) diameters up to 12.7 mm to  $4 \text{ km s}^{-1}$ . A powder gun can accelerate 6.35 mm diameter projectiles to speeds between 0.5 and  $3 \text{ km s}^{-1}$ , and a pressurized-air gun can conduct tests using projectiles with diameters up to 2.54 cm at speeds up to  $1 \text{ km s}^{-1}$ . Projectiles are typically launched in sabots; shapes including spheres, cylinders, irregular geometries, and clusters can be accommodated. Gun elevation may be varied from vertical to horizontal in  $15^\circ$  increments. Laser-interrupt triggered instruments measure the speed of the projectile and image it to verify its structural integrity during launch.

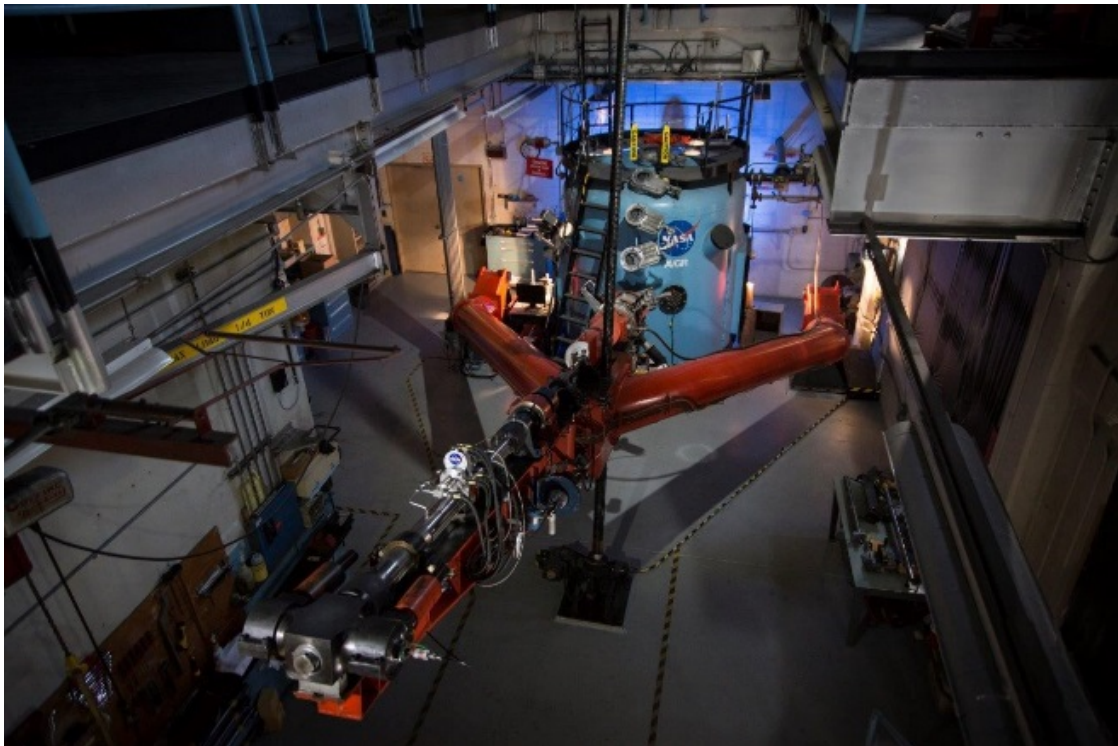
Targets are housed in a large impact chamber (diameter  $\sim 2.5 \text{ m}$ , volume  $\sim 14 \text{ m}^3$ ). They may consist of a variety of compositions (solid, aggregate, liquid, etc.). Cryogenic conduits are available to cool targets with liquid nitrogen or helium. The chamber has numerous viewing and feed-through ports—including a  $1 \times 0.66 \text{ m}$  window—and can accommodate significant experimental apparatus inside. It can maintain pressures as low as about 40 Pa and may be filled with gases other than air. The large chamber size allows long-duration post-impact evolution with limited boundary effects and eases post-impact inspection and analysis of targets and ejecta.

A programmable digital sequencer activates instrumentation and light sources. Apparatus can be triggered off of the gun firing pulse as well as the impact flash. A variety of high-speed cameras are available to record impacts and ensuing phenomena. Multiple viewpoints, stereo imaging, and other instrumentation (for, e.g., spectroscopy or particle velocimetry) can be accommodated.

**Further information:** A complete description of the facility is available in the NASA Ames Thermophysics Facilities Test Planning Guide, which is available at the Thermophysics Branch website (<http://www.nasa.gov/centers/ames/thermophysics-facilities/>). Instructions for investigators interested in incorporating AVGR experiments into their proposals are included in the Planetary Science Research Program section of the ROSES call. Potential users are invited to contact the authors.

**References:** [1] Hermalyn B. et al. (2011) *Icarus*, 216, 269–279. [2] Flynn G. J. et al. (2014) *P&SS*, 107, 64–76. [3] Bruck Syal M. and Schultz P. H. (2014) *LPS 45*, Abstract #2760. [4] Jones S. M. et al. (2013) *Icarus*, 226, 1. [5] Schultz, P. H. et al. (2010) *Science*, 330, 468–472.

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**Figure 2:** The Ames Vertical Gun Range. The gun is mounted on the red beam and is in its horizontal position. It launches projectiles into the blue target chamber, located near the top of the image.