



RANGE COMPLEX

NASA Ames has a long tradition in leadership with the use of ballistic ranges and shock tubes for the purpose of studying the physics and phenomena associated with hypervelocity flight. Cutting-edge areas of research run the gamut from aerodynamics, to impact physics, to flow-field structure and chemistry. This legacy of testing began in the NACA era of the 1940s with the Supersonic Free Flight Tunnel, and evolved dramatically up through the late 1950s with the pioneering work in the Ames Hypersonic Ballistic Range. The tradition continued in the mid-60s with the commissioning of the three newest facilities: the Ames Vertical Gun Range (AVGR) in 1964, the Hypervelocity Free Flight Facility (HFFF) in 1965 and the Electric Arc Shock Tube (EAST) in 1966. Today the Range Complex continues to provide unique and critical testing in support of the Nation's programs for planetary geology and geophysics; exobiology; solar system origins; earth atmospheric entry, planetary entry, and aerobraking vehicles; and various configurations for supersonic and hypersonic aircraft.

SUMMARY DESCRIPTION OF THE TEST COMPLEX

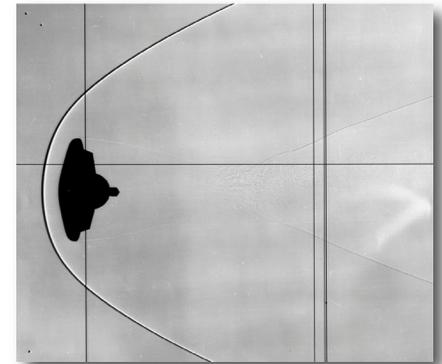
The Test Complex currently consists of three ranges: the Ames Vertical Gun Range (AVGR), the Hypervelocity Free Flight (HFF) Facilities and the Electric Arc Shock Tube (EAST).

The Ames Vertical Gun Range is used to simulate the physics and mechanics of planetary impact cratering and micrometeoroid impacts. The facility utilizes various model-launching guns that can achieve impact velocities approaching 7 km/sec. The angle of elevation of the gun with respect to the horizontal plane can be varied in 15-degree increments from 0 to 90 degrees, thus permitting oblique angles of impact with respect to the gravitational vector. Impact events can be recorded with a variety of high-speed imaging options.

The Hypervelocity Free-Flight (HFF) Facility comprises the Aerodynamic Facility (HFFAF) and the Gun Development Facility (HFFGDF). Both facilities use various guns to launch models at velocities up to 28,000 ft/s (8.5 km/s). Using a shock tunnel counter flow system, relative velocities up to 39,000 ft/s (12 km/s) can be obtained. The HFFAF has a 114 ft (34.7 m) long controlled atmosphere test section with 16 orthogonal shadowgraph stations. Several high-speed imaging cameras are available to measure model surface temperature distributions. The HFFGDF is used for gun performance enhancement, impact studies and aerodynamics testing. It has a 16 ft (4.9 m) long atmospheric pressure aerodynamics range. Using 8 ICCD digital cameras, 50 orthogonal pairs of images of a projectile can be obtained.

The Electric Arc Shock Tube (EAST) Facility is used to investigate the effects of radiation and ionization that occur during very high velocity atmospheric entries. The EAST can also provide air-blast simulations requiring the strongest possible shock generation in air at initial pressure loadings of 1 atm or greater. The facility has three separate driver configurations. Depending on test requirements, the driver can be connected to a diaphragm station of either a 4-in or a 24-in shock tube. The high-pressure 4-in shock tube can also drive a 30-in shock tunnel. Energy for the drivers is supplied by a 1.25-MJ-capacitor storage system. Shock velocities up to 24 km/s (air) and 46 km/s (hydrogen) can be achieved.

The Ames Range Complex provides the Nation with the capability to conduct low-cost "flight tests" in ground-based facilities.



AMES VERTICAL GUN RANGE (AVGR)

The Ames Vertical Gun Range (AVGR) was designed to conduct scientific studies of lunar impact processes in support of the Apollo missions. In 1979, it was established as a National Facility, funded through the Planetary Geology and Geophysics Program. In 1995, increased science needs across various discipline boundaries resulted in joint core funding by three different science programs at NASA Headquarters (Planetary Geology and Geophysics, Exobiology, and Solar System Origins). In addition, the AVGR provides programmatic support for various proposed and ongoing planetary missions through special arrangements with the Facility Manager and Science Coordinator.



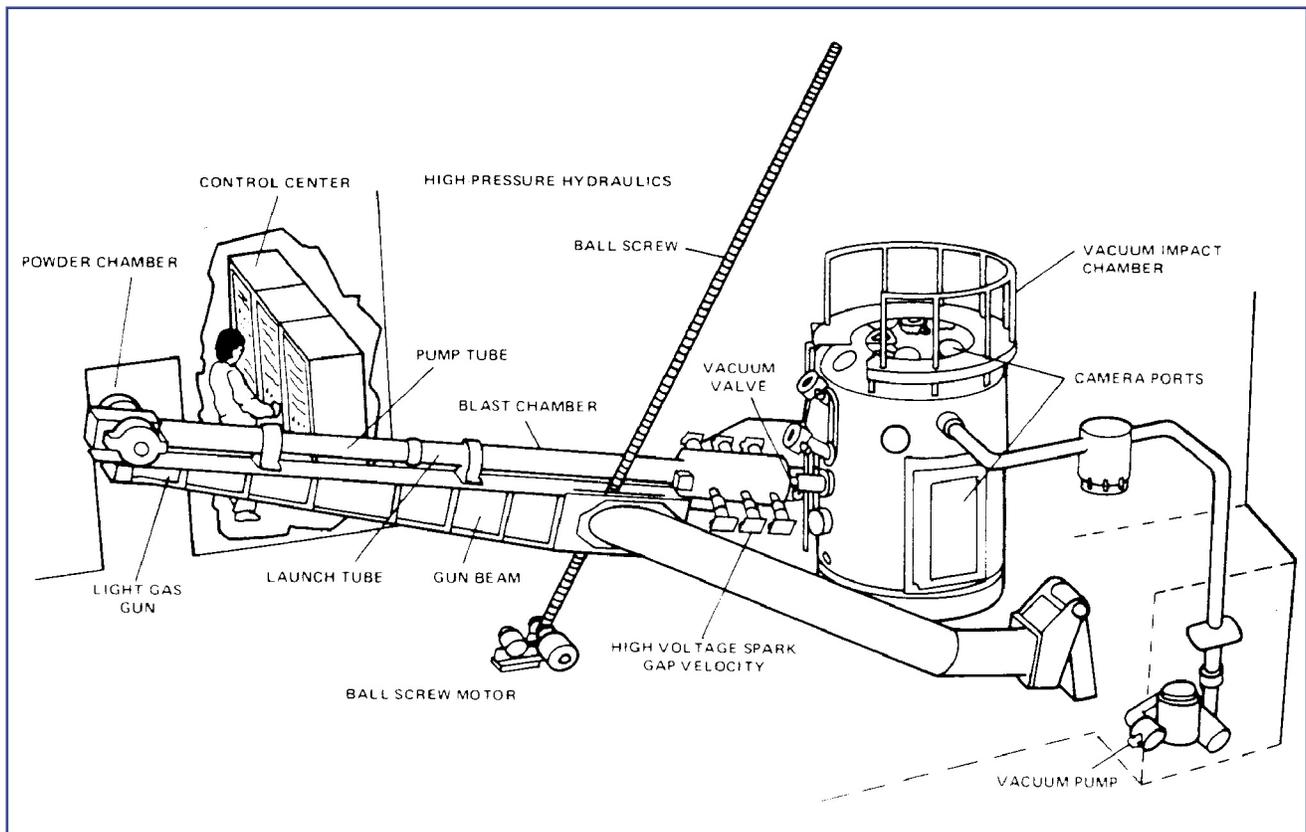
Utilizing its 0.30 cal light-gas gun and powder gun, the AVGR can launch projectiles to velocities ranging from 0.5 to nearly 7 km/sec. By varying the gun's angle of elevation with respect to the target vacuum chamber, impact angles from 0 to 90 degrees with respect to the gravitational vector are possible. This unique feature is extremely important when examining crater formation processes.

The types of projectiles that can be launched include spheres, cylinders, irregular shapes, and clusters of many small particles. The projectiles can be metallic (i.e. aluminum, copper, iron), mineral (i.e. quartz, basalt), or glass (i.e. pyrex, soda-lime). For example, soda-lime spheres can be launched individually for sizes ranging from 1.5 to 6.4 mm (1/16 to 1/4 inch) in diameter; in groups of three for sizes ranging from 0.2 to 1.2 mm (0.008 to 0.05 inch); or as a cluster of many particles for sizes ranging from 2 to 200- μm .

For both guns, projectiles are typically encased in a sabot (a plastic carrier) to align, support and protect them during their passage through the gun barrel (launch tube). Since the launch tube is rifled, the launch package [sabot and projectile(s)] exits the barrel with both an axial and angular velocity. The resulting centrifugal force separates the sabot from the projectile(s) leaving the projectile(s) in free flight. The projectile(s) pass through a velocity chamber and then into the target vacuum chamber. The velocity chamber uses a set of photomultiplier tubes, light sheets, cameras and counters to detect and record projectile passage (and ultimately determine velocity). At the entrance to the target chamber there is a valve-like device, which deflects the trailing gun gases after projectile passage. The result is a very clean target impact with minimal propellant debris. The target chamber is roughly 2.5 meters in diameter and height and can accommodate a wide variety of targets/mounting fixtures. The chamber can maintain vacuum levels below 0.03 torr, or can be back filled with various gases to simulate different planetary atmospheres. Impact events are typically recorded using high-speed video or film.

AVGR PERFORMANCE SUMMARY

Guns (barrel diameters):	0.30 cal (7.6 mm) Light Gas Gun & Powder Gun 1.76 cal (44.7 mm) Air Gun
Projectile velocity (m/s):	2,500 to 7,000 (LGG) 500 to 3,000 (PG) 10 to 900 (AG)
Projectile size (mm):	0.002 to 6.4 (LGG and PG) 6.4 to 44.7 (AG)
Test chamber pressure (atm):	0.00003 to 1
Test chamber temperature:	270K (ambient)
Test gas:	Air, N ₂ , CO ₂ , Argon, arbitrary
Imaging options (frames/sec):	500 or 1000 (NAC high speed video) 5,000 to 10,000 (NOVA 16 mm film, 400 ft roll) 35,000 (Cordin 35 mm film, 36 exp. strip)
Maximum viewing window:	0.7 x 1 m



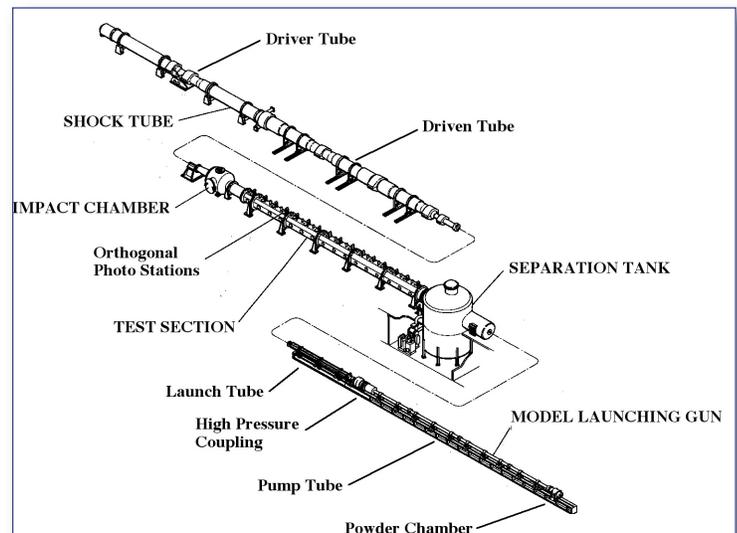
HYPERVELOCITY FREE-FLIGHT FACILITIES

The Hypervelocity Free-Flight (HFF) Range at Ames Research Center (ARC) currently comprises two active facilities: The Aerodynamic Facility (HFFAF) and the Gun Development Facility (HFFGDF). Both facilities were constructed in 1964 and are located in Building N-237.

HYPERVELOCITY FREE-FLIGHT AERODYNAMIC FACILITY

The Hypervelocity Free-Flight Aerodynamic Facility is a combined Ballistic Range and Shock-tube Driven Wind Tunnel. The HFFAF consists of: a model launching gun (light-gas or powder); a sabot separation tank; a test section (with 16 orthogonal shadowgraph imaging stations); an impact/test chamber; a nozzle; and a combustion-driven shock tube (see figure below). The available light gas and powder gun launchers can accelerate particles from 1/8 to 1.2 inch (3.2 to 30.5 cm) diameter up to velocities of 28,000 ft/s (8.5 km/s). The primary purpose of the facility is to examine the aerodynamic characteristics and flow-field structural details of free flying aeroballistic models. For this mode of traditional aeroballistic testing, each of the shadowgraph stations can be used to capture an orthogonal pair of images of a hypervelocity model in flight along with its associated flow-field. These images combined with the recorded flight time history can be used to obtain various aerodynamic coefficients C_D , C_L , C_m , C_{mq} + C_m . In addition, several high-speed thermal-imaging cameras can be used to measure the global surface temperature distribution of a model at different points along its flight path. This information can be used to measure the heat flux rates and determine transition location on models of actual heat-shield materials. For very high velocity testing, models can be launched into a counter flowing gas stream generated by the shock tube. Relative velocities up to 39,000 ft/s (12 km/s) can be achieved. The facility can also be configured for hypervelocity impact testing. In this mode, a light-gas gun is used to launch impact particles (typically spheres or cylinders) at target materials mounted in the impact chamber. A fourth mode of operation is shock tunnel testing. For this type of testing a fixed, instrumented model is mounted in either the impact chamber or at one of the shadowgraph stations in the test section. The combustion driven shock tube is used to generate a short duration reservoir of high-temperature, high-pressure test gas for expansion through the nozzle and over the test article.

Most of the research effort to date has centered on Earth atmosphere entry configurations (Mercury, Gemini, Apollo, and Shuttle), planetary entry designs (Viking, Pioneer Venus, and Galileo), and aerobraking (AFE) configurations. The facility has also been used for scramjet propulsion studies (NASP) and meteoroid/orbital debris studies (Space Station and RLV). At this time, the shock tube is in "stand-by" mode and is not operational.



HYPERVELOCITY FREE-FLIGHT GUN DEVELOPMENT FACILITY

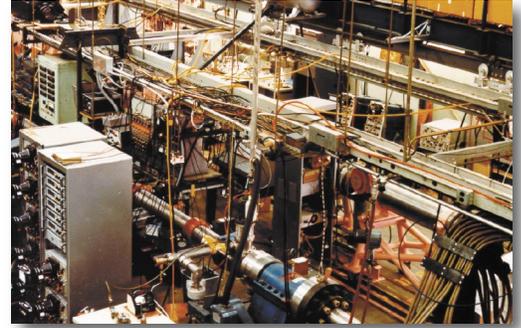
The HFF Gun Development Facility normally consists of: a light-gas gun; a sabot separation tank; a flight tube; and an impact chamber. The flight tube and impact chamber can be replaced by an atmospheric pressure aerodynamics range 16 ft (4.9 m) long. The facility can be used for gun performance enhancement studies, impact studies and studies of the aerodynamics of free flying projectiles. In particular, operational parameters and hardware configurations can be adjusted and/or modified in an effort to increase maximum velocity (and/or launch mass capabilities), while maintaining acceptable levels of gun barrel erosion. The facility operates in a manner similar to the HFFAF with the primary difference being a shorter flight path, 38 ft (11.6 m) as compared to 114 ft (34.7 m). The HFFGDF utilizes the same arsenal of light-gas guns to accelerate particles ranging in size from 1/8 inch (3.2 mm) diameter to 1.2 inch (30.5 mm) diameter to hypervelocity speeds. Particle velocity is measured using several, photomultiplier-tube-based time of arrival stations. Several of the outputs can be used to trigger flash x-ray channels. The atmospheric pressure aerodynamics range is 16 ft (4.9 m) long, 6.5 ft (2 m) high and 6 ft (1.8 m) wide. Using eight ICCD digital cameras, 50 orthogonal pairs of images of a projectile can be obtained. This range is well suited for to determine the aerodynamics of strongly lifting projectiles.

HFF PERFORMANCE SUMMARY

Guns (barrel diameters):	0.28, 0.5, 1.0, and 1.5 cal (7.1, 12.7, 25.4, and 38.1 mm) LGG 0.79, 1.74, and 2.40 cal (20, 44, and 61 mm) PG
Model velocity:	5,000 to 28,000 ft/s (1.5 to 8.5 km/s) LGG [to 39,000 ft/s (12 km/s) relative velocity with counterflow] 1,500 to 6,500 ft/s (0.5 to 2.0 km/s) PG
Model size (mm):	0.125 to 1.5" (3.2 to 38 mm) LGG 0.188 to 2.4" (4.8 to 61 mm) PG
Model mass:	5 to 200 gm (LGG) 10 to 400 gm (PG)
Maximum Reynolds Number:	2×10^6 /ft (6.5×10^6 /m)
Maximum model acceleration:	1.5×10^6 g
Test section pressure	0.03 to 760 torr (4 Pa to 0.1 MPa)
Test section temperature	270 K (ambient)
Test gas	Air, N ₂ , CO ₂ , arbitrary

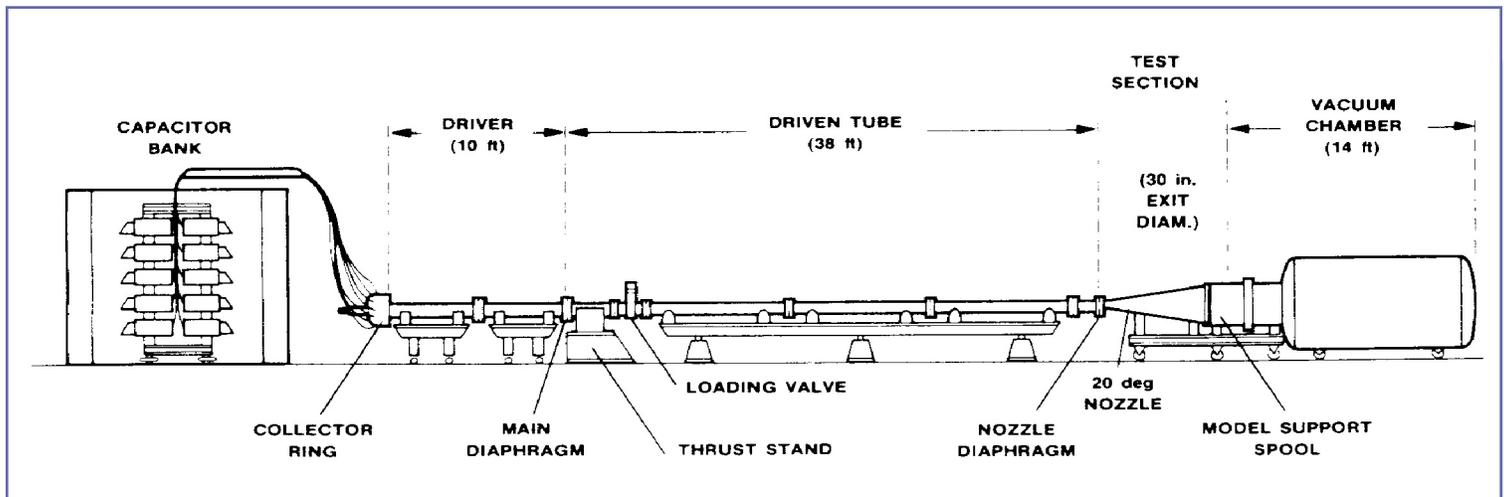
ELECTRIC ARC SHOCK TUBE FACILITY

The Electric Arc Shock Tube Facility is used to investigate the effects of radiation and ionization that occur during very high velocity atmospheric entries. The EAST can also provide air-blast simulations requiring the strongest possible shock generation in air at an initial pressure loading of 1 atmosphere or greater. The facility has three separate driver configurations. Depending on test requirements, the driver can be connected to a diaphragm station of either a 4-in or a 24-in shock tube. The high-pressure 4-in shock tube can also drive a 30-in shock tunnel. Energy for the drivers is supplied by a 1.25-MJ-capacitor storage system. It can be charged to a preset energy at either a 0- to 40-kV mode (1530 μF) or a 0- to 20-kV mode (6120 μF). Voltage, capacitance and arc-driver components are selected to meet, as effectively as possible, the test objectives of a given program. An array of spectrographs, monochromators and photomultiplier tubes are available for optical studies in the UV, visible and IR regions of the spectrum. Pressure transducers are used for pressure and shock velocity measurements. Electron number densities and true conductivities of ionized gases can be measured. An MHD accelerator/generator and a K_2CO_3 seeder are available. A 48-channel data acquisition system with speeds from 1 to 20 MHz is available.



EAST PERFORMANCE SUMMARY

Maximum shock speed: 4-in Shock Tube	1 Torr hydrogen: 46 km/s 1 Torr air: 24 km/s
Maximum shock speed: 24-in Shock Tube	1 Torr air: 5 km/s 0.01 Torr air: 12 km/s



THERMOPHYSICS FACILITIES BRANCH: SAFETY, ACCURACY, PROFESSIONALISM

The Ames Research Center Thermophysics Facilities Branch forges fruitful partnerships with organizations that need to completely, accurately and efficiently test concepts that use innovative materials and/or new design ideas.

We provide a variety of hyperthermal and hypervelocity environments from simulations of the heating of ascent and entry (Earth or other planetary atmospheres) to hypersonic flight regimes. Our goal: seamless integration of your material or flow characterization, model design, pretest planning, testing, and final report.

The Ames Thermophysics Facilities have a remarkable, comprehensive suite of highly adaptable world-class test hardware. When combined with our senior staff's extensive expertise and the wide range of test experiences, we offer a unique set of testing possibilities.

Full details can be found in the Test Planning Guide, available upon request by contacting:

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