



## HIGH ALTITUDE ENGINE START DEMONSTRATION

### CAPABILITIES

Large vacuum test chambers (up to 33,000 cubic ft) can be evacuated using mechanical vacuum pumping equipment to attain altitudes in excess of 200,000 ft. Rocket engines can then be fired into the chamber for short durations to evaluate start transients and/or other parameters, such as pressure gradients between two rocket stages. The maximum engine firing duration depends on the engine flow conditions, the size of the vacuum chamber, and the maximum allowable internal test cell pressure. Additional altitude simulation equipment can be isolated from the chamber during the initial part of the engine firing profile, and then rapidly opened to the chamber at the appropriate time, thus limiting further cell pressure increase. A Mylar diaphragm that was ruptured using explosive cord has been used successfully to connect the large altitude simulation system to the test chamber to maintain adequate test cell pressure conditions after engine start.

### POTENTIAL TEST APPLICATIONS

High-altitude engine start demonstration testing may be required for a number of different system configurations and engine operating conditions. This is particularly applicable to the separation and ignition sequences of multi-stage rocket vehicles. In addition, rocket engine startup pressure overshoot has been shown to be significantly greater at very high-vacuum conditions than at normal atmospheric pressure, which may impose unexpected structural loads. Furthermore, rocket exhaust plume expansion is greater under very high-vacuum conditions, potentially increasing plume impingement effects on adjacent structures.

### WSTF EXPERIENCE

In the late 1960s, the liftoff sequence of the Apollo Lunar Module (LM) ascent stage from the LM descent stage while on the surface of the Moon was simulated by mounting a full-scale LM ascent test article on top of a simulated descent stage, evacuating the large test cell containing the test articles to approximately 240,000 ft equivalent altitude, and then starting the ascent engine. The purpose of the test was to determine the effect of the ascent stage engine exhaust on the structure and external insulation on both the ascent and descent stages during engine start and vehicle liftoff. Insulating blankets and shields on both vehicles could tear and partially obstruct the exhaust gas path between the two stages, and the resultant pressure buildup could damage the extremely fragile structure of the LM, or tip the vehicle during liftoff due to asymmetrical pressure distribution on the base of the LM ascent stage. The configuration of both stages duplicated flight configuration as closely as possible. Extensive pressure and temperature instrumentation was installed on both stages. A Mylar diaphragm was installed over the exhaust diffuser inlet, thereby isolating the vacuum chamber from the large flow capacity altitude simulation system. Explosive cord and detonators were installed on the diaphragm. The vacuum chamber containing the simulated LM ascent and descent stages was evacuated to 240,000 ft with mechanical vacuum pumps, and the high-flow altitude simulation system below the diaphragm was started. The ascent engine was then ignited. When the internal test cell pressure rose to a predetermined level, the diaphragm was explosively ruptured, opening the 33,000 ft<sup>3</sup> cell to the high-flow-capacity altitude simulation system below and limiting further test cell pressure rise. The engine was shut down after approximately 1/2 second, by which time the critical part of the LM staging maneuver had been completed.

### CONTACT

Kevin Farrah, NASA White Sands Test Facility, Altitude Operations Director,  
[kevin.b.farrah@nasa.gov](mailto:kevin.b.farrah@nasa.gov), (575) 524-5160

