National Aeronautics and
Space Administration

# Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)

Since NASA's inception in 1958, the agency has relied on rigid blunt body aeroshells to decelerate payloads during the critical atmospheric entry phase of its missions.  An aeroshell provides aerodynamic drag to slow down a spacecraft so it can safely perform descent and landing operations, while shielding it from the extreme environments of entry.  For destinations with an atmosphere, it is not the launch vehicle's mass carrying capability, but rather the size (diameter) of the payload's aeroshell, that currently limits the amount of mass deliverable to the surface.

The Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) mission was the culmination of two decades of research and development led by NASA's Langley Research Center for Hypersonic Inflatable Aerodynamic Decelerator (HIAD) technology, demonstrating an inflatable heat shield, or aeroshell, technology that could one day help land humans on Mars.

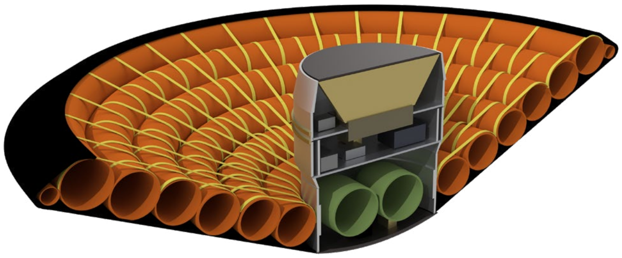
On November 10, 2022, LOFTID launched as a secondary payload on a United Launch Alliance (ULA) Atlas V rocket and successfully achieved orbital reentry and recovery of its Reentry Vehicle (RV).  LOFTID, with its unique inflatable aeroshell, was the first-of-a-kind orbital reentry flight, and the largest blunt body atmospheric entry of any kind.

## A New Kind of Heat Shield

Using atmospheric drag is the most mass-efficient method to slow down a spacecraft.  With a traditionally rigid aeroshell, the spacecraft must fit inside, and the aeroshell size is limited by the payload compartment diameter of its launch vehicle.  This in turn limits the aerodynamic drag during entry, which can ultimately constrain the mass of the spacecraft to ensure safe delivery to its desired destination.

HIAD technology enables much larger aeroshells, which produce more drag and start the deceleration process in the less dense upper reaches of the atmosphere. Thus, an increased diameter allows not only heavier payloads, but also landing at higher altitudes. It could additionally be used to bring an unprecedented amount of mass back from low Earth orbit, including items from the International Space Station. Another significant potential benefit is enabling the recovery of rocket assets for reuse, to reduce the overall cost of access to space.

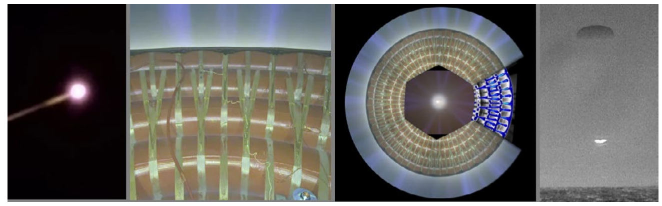
The HIAD design consists of an inflatable structure sufficiently rigid to maintain shape against aerodynamic forces, and a protective flexible thermal protection system (FTPS) that withstands the searing heat and shear of reentry. The inflatable structure is a stack of pressurized concentric rings, or tori, that are strapped together to form an exceptionally strong and lightweight blunt cone shape. The tori are made from high-temperature capable materials, including braided synthetic fibers that are stronger than steel. The FTPS is constructed in three layers: a ceramic fabric outer layer to maintain integrity of the surface, a middle layer of insulators to inhibit heat transmission, and an impermeable inner layer that prevents hot gas from reaching the inflatable structure. The HIAD assembly is foldable, packable, deployable, and tailorable, allowing the design to be customized and scaled to a broad range of mission applications.



# A Triumphant Success

Atop ULA's Atlas V second stage Centaur rocket, the LOFTID RV was stowed within the adapter stack between the Centaur and the primary payload, the National Oceanic and Atmospheric Administration's Joint Polar Satellite System-2 (JPSS-2) satellite, with the HIAD aeroshell packed tightly to a cylindrical shape about 1.3 m (4.3 ft) diameter by 0.5 m (1.5 ft) tall. After the JPSS-2 satellite was delivered to its polar orbit, the Centaur performed two rocket burns to de-orbit the vehicle and put it on a targeted path for reentry. Then the portion of the primary payload adapter covering the stowed LOFTID RV was jettisoned, the HIAD aeroshell inflated to its full 6 m (20 ft) diameter, and the Centaur released the RV on its spin-stabilized (3 rpm) ballistic reentry path.

The 1100 kg (2425 lbm) LOFTID RV entered Earth's atmosphere at 8 km/s (18,000 mph) and exceeded Mach 30. The outer surface of the HIAD aeroshell reached 1500 C (2700 deg F) and the RV experienced 9.5 g's of peak deceleration. The RV was remarkably stable throughout hypersonic, supersonic, transonic, and subsonic descent. After decelerating from 18,000 mph to less than 80 mph, it deployed parachutes and gently descended to splash down on target east of Hawaii, where it remained inflated and buoyant, and was recovered safely from the ocean along with a treasure trove of flight data from the instrumentation onboard. The aeroshell was in excellent condition after the harsh environments of entry, splashdown, and ocean recovery, and the LOFTID RV was brought home to NASA Langley Research Center shortly after the successful mission.



The LOFTID aeroshell was exposed to an aeroheating environment representative of many Mars and low Earth orbit HIAD applications, while successfully demonstrating the ability of the heat-affected inflatable structure to withstand aerodynamic forces that exceeded those expected at Mars. Given this successful demonstration at scale and at relevant entry environments, HIAD could revolutionize the way NASA and industry deliver payloads to planetary destinations with atmospheres. While LOFTID was indeed a first-of-a-kind flight for an inflatable aeroshell, its impressive performance assured that it will not be the last of its kind.

*The LOFTID project was sponsored by the Technology Demonstration Missions program within NASA's Space Technology Mission Directorate in partnership with ULA. LOFTID was led by NASA's Langley Research Center, with contributions from Ames Research Center, Marshall Space Flight Center, Armstrong Flight Research Center, and Kennedy Space Center. LOFTID is dedicated in honor of Bernard Kutter, manager of ULA's Advanced Programs, who passed away in August 2020. He was an advocate for lower cost access to space by using HIAD for launch vehicle asset recovery, and for the broader exploration benefits that its technology demonstration enables.*

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