National Aeronautics and Space Administration

Aerocapture Technology

In-Space Propulsion Technology Project

NASAfacts

NASA technologists are developing ways to place robotic space vehicles into long-duration, scientific orbits around distant Solar System destinations without the need for the heavy fuel loads that have historically limited vehicle performance, mission duration, and mass available for science payloads.

Aerocapture, a flight maneuver that inserts a spacecraft into its desired orbit once it arrives at a planet, is just one of many propulsion technologies being developed by NASA technologists and their partners in industry and academia, led by NASA's In-Space Propulsion Technology Office at the Glenn Research Center in Cleveland, Ohio. The Center implements the In-Space Propulsion Technology Program on behalf of NASA's Science Mission Directorate in Washington.

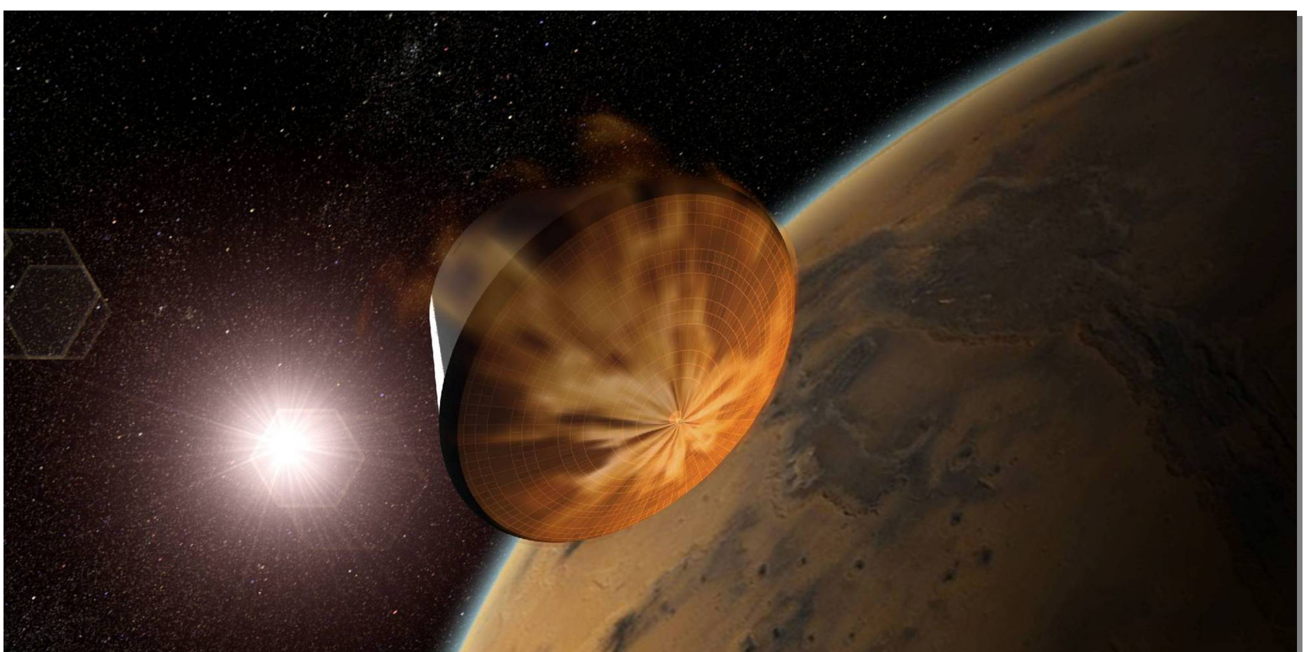
Aerocapture uses a planet's or moon's atmosphere to accomplish a quick, near-propellantless orbit capture to place a space vehicle in its science orbit. The aerocapture maneuver starts as the spacecraft enters the atmosphere of the target body from an approach trajectory. The friction between the vehicle and the dense atmosphere slows the craft. After the spacecraft slows enough to capture into orbit, it exits the atmosphere and executes a small motor firing to circularize the orbit.

This nearly fuel-free method of deceleration could significantly reduce the mass of an interplanetary spacecraft. Less spacecraft mass allows for more science instrumentation to be added to the mission or allows for a smaller and less-expensive spacecraft, and potentially a smaller, less-expensive launch vehicle.

The aerocapture maneuver can be accomplished with two basic types of systems. The spacecraft can be enclosed by a structure covered with thermal protection material. Another option is for the vehicle to deploy an aerocapture device, such as an inflatable heat shield or an inflatable, trailing ballute—a combination balloon and parachute made of thin, durable material towed behind the vehicle after deployment in the vacuum of space.

Blunt body, rigid aeroshell design

The blunt body, rigid aeroshell system encases a spacecraft in a protective shell. This shell acts as an aerodynamic surface, providing lift and drag, and provides protection from the intense heating experienced during high-speed atmospheric flight. Once the spacecraft is captured into orbit, the aeroshell is jettisoned.



Artist's rendition of the Blunt Body Aeroshell design.

NASA has used blunt aeroshell systems in the past for atmospheric entry missions. The most recent example is the Mars Exploration Rovers, Spirit and Opportunity, which launched in June and July 2003, and landed on the Martian surface in January 2004.

Another example is the Apollo Command Module. The module was used for six unmanned space flights from February 1966 to April 1968 and eleven manned missions from Apollo 7 in October 1968 through the final manned Apollo 17 lunar mission in December 1972.

Because of its extensive heritage, the aeroshell system design is well understood. Adaptation of the aeroshell from atmospheric entry to aerocapture requires mission-specific customization of the thermal protection material to accommodate the different heating environments of aerocapture. Also, higher-temperature adhesives and lightweight, high-temperature structures are desired to minimize the mass of the aerocapture system.

Trailing Ballute design

One of NASA's investments in inflatable deceleration technology is a trailing ballute configuration. The design features a toroidal, or donut-shaped, decelerator, made of a lightweight, thin-film material. The ballute is much larger than the spacecraft and is towed behind the craft, much like a parachute, to slow the vehicle down. The "trailing" design also allows for easy detachment after the aerocapture maneuver is complete.

The trailing ballute design has performance advantages over the rigid aeroshell design, such as not constraining the spacecraft size and shape, and subjecting the vehicle to much lower aerodynamic and thermal loads. Because the trailing ballute is much larger than the spacecraft, aerocapture occurs high in the atmosphere where much less heat is generated. The ballute incurs most of the aerodynamic forces and heat, allowing the use of minimal thermal protection around the spacecraft. One of the primary advantages of the ballute configuration is mass. Where the rigid aeroshell may account for 30-40% of the mass of a spacecraft, the ballute mass fraction could be as little as 8-12%, saving mass for more science payload.

Inflatable Aeroshell design

The inflatable aeroshell design looks much like the aeroshell or blunt body design. The inflatable aeroshell is often referred to as a hybrid system, with a rigid nosepiece and an inflated, attached decelerator to increase the drag area.

Just prior to entering the atmosphere, the inflatable aeroshell extends from a rigid nose-cap and provides a larger surface area to slow the spacecraft down.

Made of thin-film material and reinforced with a ceramic cloth, the inflatable aeroshell design could offer many of the same advantages and functionality as trailing ballute designs. While not as large as the trailing ballute, the inflatable aeroshell is roughly three times larger than the rigid aeroshell system and aerocaptures higher in the atmosphere, reducing heating loads. Because the system is inflatable, the spacecraft is not enclosed during launch and cruise, allowing more flexibility during spacecraft design and operations.

Potential aerocapture missions

NASA researchers are considering aerocapture technologies for a broad range of future mission objectives including orbiters at Titan, a moon of Saturn, Venus, Mars, and Neptune.

Aerocapture is a systems technology in which many of the elements already exist, or are evolved from developments in other aeroentry applications. The aeroshell and thermal protection systems have heritage to those developed for past Earth, Venus, Mars, and Jupiter missions. The ability to guide and control a blunt body through an atmospheric exit maneuver was human-rated for the Apollo Earth-return capsule as a weather-contingency plan, but was never exercised in flight.

NASA's aerocapture technology development team includes Langley Research Center, Ames Research Center, NASA's Jet Propulsion Laboratory, Johnson Space Center, Marshall Space Flight Center, and Glenn Research Center.

Aerocapture technology is being matured by the In-Space Propulsion Technology Program, which is managed by NASA's Science Mission Directorate and implemented by the In-Space Propulsion Technology Office at the Glenn Research Center. The program objective is to develop in-space propulsion technologies that can enable or benefit near and mid-term NASA space science missions by significantly reducing cost, mass and travel times.

For more information about NASA's In-Space Propulsion program and aerocapture research, visit:

http://www.nasa.gov
http://www.grc.nasa.gov/WWW/InSpace/

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