NASA Facts

National Aeronautics and
Space Administration

Marshall Space Flight Center
Huntsville, Alabama 35812

Aerocapture Technology

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

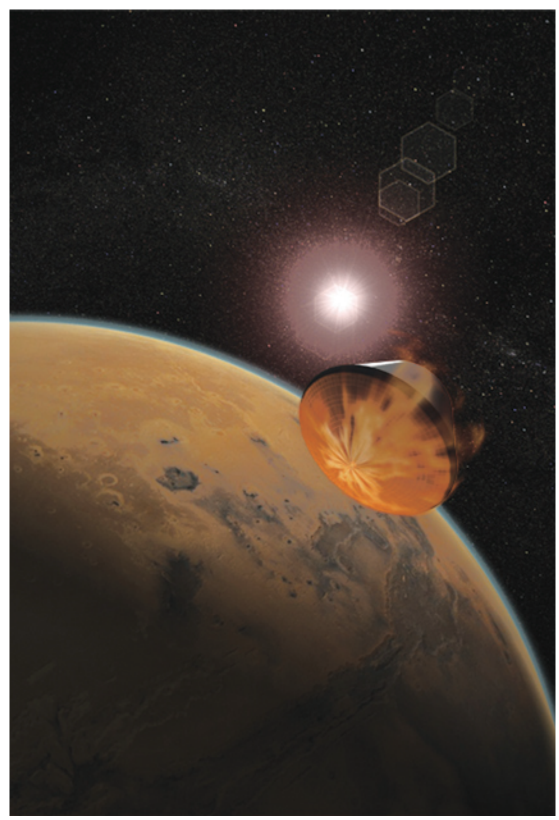
Aerocapture—a flight maneuver that inserts a spacecraft into its proper orbit once it arrives at a planet—is part of a unique family of "aeroassist" technologies under consideration to achieve these goals and enable robust science missions to any planetary body with an appreciable atmosphere. NASA fuels discoveries that make the world smarter, healthier and safer.

Aerocapture technology 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 Marshall Space Flight Center in Huntsville, Ala. 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 proper orbit. The atmosphere is used as a brake to slow down a spacecraft, transferring the energy associated with the vehicle's high speed into thermal energy.

The aerocapture maneuver starts with an approach trajectory into the atmosphere of the target body. The dense atmosphere creates friction, slowing the craft and placing it into an elliptical orbit—an oval shaped orbit.

This nearly fuel-free method of decelerating a space vehicle 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 vehicle.



Aerocapture entering Mars Orbit.

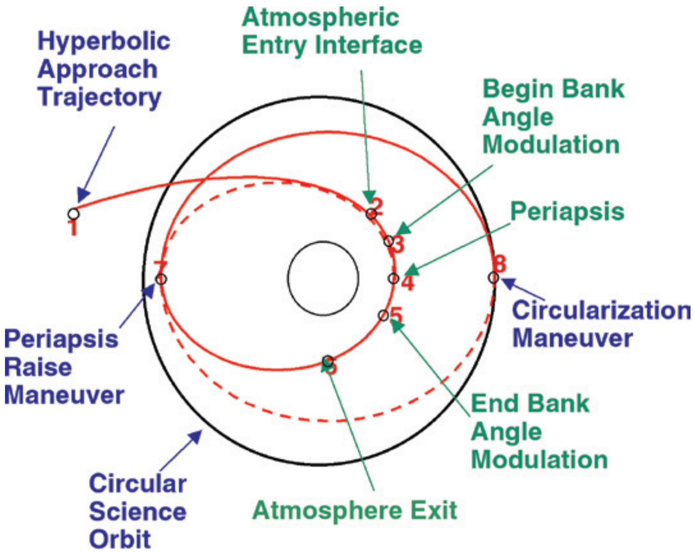


Diagram of Aerocapture maneuver overview.

The requirement to slow down a spacecraft for orbit insertion and to protect it from the heating environment of a planet's atmosphere—the gaseous area surrounding a planet that can vary greatly in temperature—could be achieved in two ways. The craft could be enveloped by a structure with heat shielding applied to the external surfaces. Such rigid "aeroshells" were used during the entry and descent into Mars' atmosphere, and the landing on the planet's surface by the Mars Exploration Rover mission launched in 2003 and the Mars Pathfinder in 1997. Another option could be for the vehicle to deploy an aerocapture device, such as an inflatable heat shield or an inflatable, trailing ballute—a combination parachute and balloon made of thin, durable material and towed behind the vehicle after deployment.

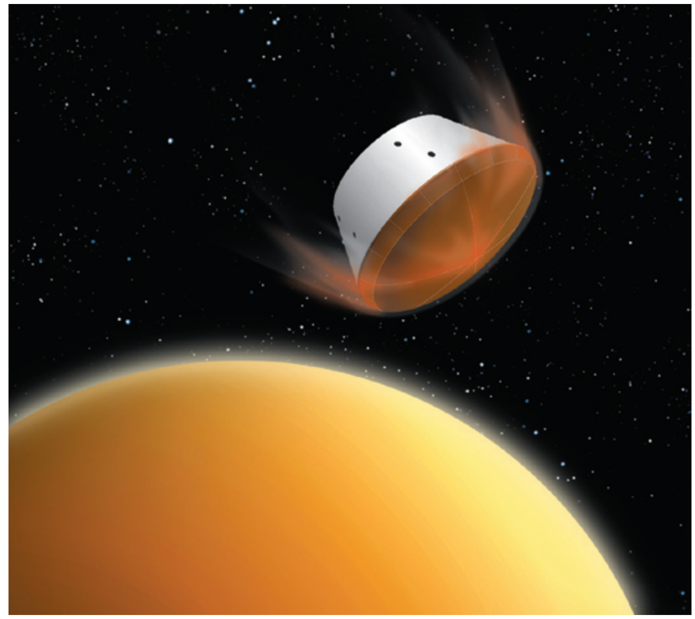
Four different aerocapture concepts under consideration for development are:

- Blunt body, rigid aeroshell design
- Slender body, rigid aeroshell design
- Trailing ballute design
- Attached ballute design

Blunt body, rigid aeroshell design

The blunt body, rigid aeroshell system encases a spacecraft in a protective shell. This shell could provide an aerodynamic surface and protection from the intense heating experienced during high-speed atmospheric flight. Once a space vehicle is captured into a planet's orbit, the aeroshell could then be jettisoned.

The aeroshell would consist of three main parts: the external thermal protection material; adhesives, used to bond the thermal protection system to the aeroshell; and an underlying structure, to which the internal spacecraft and the outside thermal protection material would be attached. The challenges facing researchers are to customize the design and thickness of the thermal protection material to accommodate different heating characteristics endured during aerocapture, develop adhesives capable of withstanding extremely high temperatures, and supporting structures that are lightweight, yet very durable.



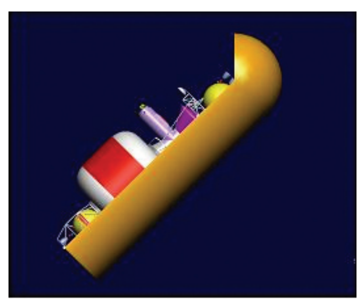
Conceptual design of blunt body, rigid aeroshell.

NASA has used this aeroshell system design 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 continued through the final manned Apollo 17 lunar mission in December 1972.

Slender body, rigid aeroshell design

The slender body configuration looks much like an elongated capsule, with a hard shell surrounding the spacecraft.



Conceptual design of slender, rigid aeroshell.

The enhanced controllability of a slender body shape could provide increased tolerance for navigational and atmospheric uncertainties during the aerocapture maneuver. Preliminary studies indicate the slender body design may be required for robotic missions to Neptune and possibly other outer planetary destinations.

Trailing ballute design

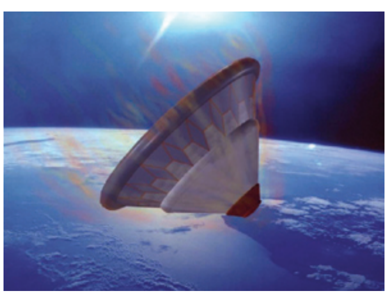
One of NASA's investments in inflatable, deceleration technology is a trailing ballute configuration. The design features a toroidal, or donut-shaped, ballute that is much larger than the spacecraft and is towed behind the craft—much like a parachute—to slow a vehicle down. The "trailing" design also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

Conceptual design of trailing ballute.

The trailing ballute design may have performance advantages over the rigid aeroshell design. In an aeroshell design, the shell takes all the force and heating of re-entry. However, with the trailing ballute design, the ballute would incur most of the aerodynamic forces and heat, possibly allowing any protection around the payload to be very lightweight. The design configuration also could be applied to various size and shape payloads.

Attached ballute design

The attached ballute design looks much like the aeroshell or blunt body design. The attached ballute is often referred to as a hybrid system, with a rigid foreshell and an inflated, attached ballute extending from either the front or back of the spacecraft.



Conceptual design of inflatable re-entry and descent technology at Earth orbit.

The inflatable, attached ballute would extend from a rigid nosecap and work much like a parachute, providing a large surface area to slow the spacecraft down to allow for an aerocapture maneuver to occur. As the spacecraft approaches a planet's atmosphere, the ballute would inflate and then jettison once the craft is captured into orbit.

Made of thin lightweight material, such as Kapton—a material often used in multi-layered insulating (MLI) blankets—the inflatable, attached ballute design could offer many of the same advantages and functionality as trailing ballute designs. The challenge facing researchers is to create a flexible, inflatable thermal protection system that could protect the spacecraft from the high heat conditions experienced during entry into a planet's atmosphere.

Researchers currently are assessing the benefits and application of this concept for potential, future missions.

Potential aerocapture missions

NASA researchers are considering aerocapture technologies for a broad range of future mission objectives.

The aerocapture maneuver has never been flight-tested. Relevant experience, however, exists from ablative entry capsules, so named because the top layer of the craft's heat shield is designed to burn away. Ablative entry technologies have been used throughout the history of the U.S. Space Program—including the Apollo return capsule, used from 1963 until 1972 to return humans from the Moon and Earth orbits; and the Galileo Probe, launched in October 1989 on a 14-year mission to explore the planet Jupiter and its surrounding moons.

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 aeroassist technology development team includes Langley Research Center in Hampton, Va.; Ames Research Center in Moffett Field, Calif.; the Jet Propulsion Laboratory in Pasadena, Calif.; Johnson Space Center in Houston, Texas; and the Marshall Space Flight Center.

Aerocapture technology is being developed by the In-Space Propulsion Technology Program, which is managed by NASA's Science Mission Directorate in Washington and implemented by the In-Space Propulsion Technology Office at the Marshall Space Flight Center in Huntsville, Ala. 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.inspacepropulsion.com

Explore. Discover. Understand.