

NASA DEVELOPMENT

OF

AEROCAPTURE TECHNOLOGIES

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The work described in this paper was funded in whole or in part by the In-Space Propulsion Technology Program, which is managed by NASA's Science Mission Directorate in Washington, D.C., and implemented by the In-Space Propulsion Technology Office at 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 or travel times.

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Abstract

Aeroassist technology development is a vital part of the NASA In-Space Propulsion Program (ISP), which is managed by the NASA Headquarters Office of Space Science, and implemented by the Marshall Space Flight Center in Huntsville, Alabama. Aeroassist is the general term given to various techniques to maneuver a space vehicle within an atmosphere, using aerodynamic forces in lieu of propulsive fuel. Within the ISP, the current aeroassist technology development focus is aerocapture. The objective of the ISP Aerocapture Technology Project (ATP) is to develop technologies that can enable and/or benefit NASA science missions by significantly reducing cost, mass, and/or travel times. To accomplish this objective, the ATP identifies and prioritizes the most promising technologies using systems analysis, technology advancement and peer review, coupled with NASA Headquarters Office of Space Science target requirements. Plans are focused on developing mid-Technology Readiness Level (TRL) technologies to TRL 6 (ready for technology demonstration in space).

Introduction

The In-Space Propulsion Program is funded by the NASA Headquarters Office of Space Science to develop primary propulsion for space transfer. The principal mission of the ISP is to advance TRL 3-4 technologies to TRL 6 (see Figure 1) for incorporation into mission planning within 3-5 years of initiation. One of the main focus areas of the ISP is aeroassist technologies through the Aerocapture Technology Project.

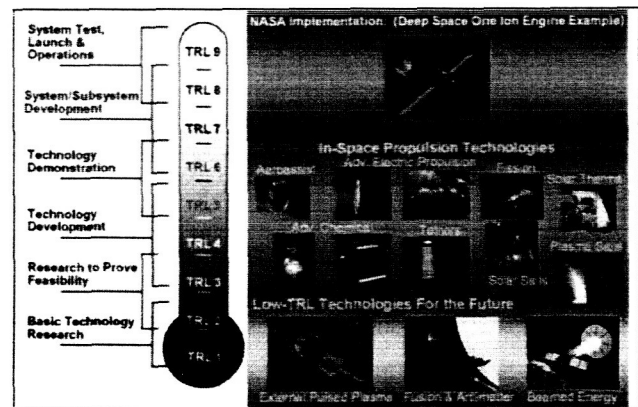


Figure 1. NASA Technology Readiness Levels

Aeroassist is the general term given to techniques that utilize aerodynamic forces with a planetary atmosphere to perform spacecraft orbital maneuvers rather than performing these maneuvers with propulsive fuel. Techniques include aerentry, aerobraking, aerocapture and aerogravity assist. The current focus of the ISP is in aerocapture. Aerocapture relies on the exchange of momentum with an atmosphere to achieve thrust, in this case a decelerating thrust leading to orbit capture. This technique is very attractive since it permits spacecraft to be launched from Earth at higher velocities, thus providing a shorter overall trip time. At the destination, the velocity is reduced by aerodynamic drag within the atmosphere. Without aerocapture, a substantial propulsion system would be needed on the spacecraft to perform the same reduction of velocity. This could cause reductions in the science payload delivered to the destination, increases in the size of the launch vehicle (to carry the additional fuel required for planetary capture) or could simply make the

mission impossible due to additional propulsion requirements.

Integrated In-Space Transportation Planning

In 2001, a NASA-wide team of over 100 engineers and scientists conducted the Integrated In-Space Transportation Planning (IISTP) Phase I activity. This effort was initiated to select and prioritize candidate propulsion technologies for development and resulted in a list of advanced in-space propulsion technologies benefiting multiple NASA Enterprises.

Over a six-month period, the IISTP team evaluated primary propulsion systems intended to transport spacecraft from the launch condition to the destination and back, if required, for twenty eight potential missions. Seventeen propulsion technology architectures were evaluated, and priorities were assigned to the technologies according to their satisfaction of mission requirements, schedule, cost, and other selection criteria.

As a result of the significant reduction in mass fraction and trip times identified during the study, aerocapture emerged from the IISTP Phase I effort as a "high priority" technology (see Figure 2).

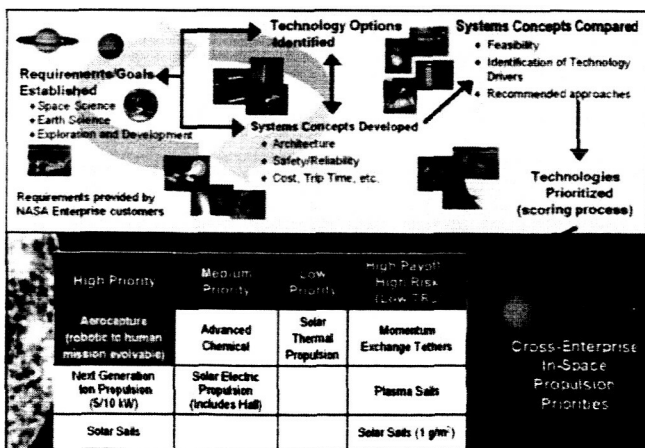


Figure 2. IISTP Process

Aerocapture Technology Project Process Flow

Since aerocapture is a technique that has yet to be performed, the goal is a flight demonstration to validate aerocapture for mission implementation. The ATP has developed the process shown in Figure 3 to work toward flight validation and, ultimately, mission utilization of aerocapture.

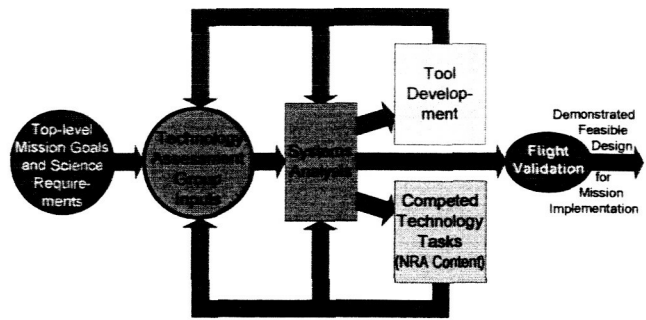


Figure 3. Aerocapture Technology Project Process

Mission goals and science requirements are collected from different NASA Enterprises. These inputs are fed directly into yearly Technology Assessment Groups (TAGs) where experts from all areas relating to aerocapture (Aeroheating, Thermal Protection Systems, Guidance Navigation and Control, Atmosphere Modeling, Inflatables/Ballutes, etc.) participate to identify the areas needing further analysis and/or development to meet these requirements. The results of the first aerocapture TAG in February 2002 are summarized in Figure 4. Figure 5, on page 4, represents a summary of what technology alternatives the TAG participants thought were important for future investments.

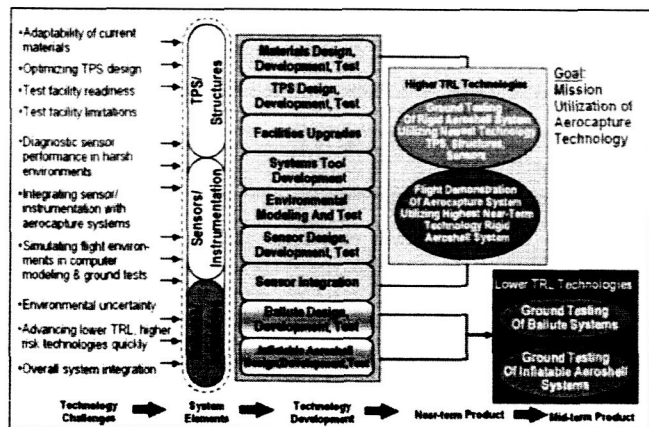


Figure 4. FY02 Aerocapture TAG Results


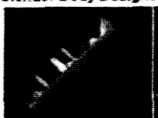


Higher TRL		Lower TRL	
Blunt Body Designs	Slender Body Designs	Trailing Ballutes	Attached Ballutes
			
<ul style="list-style-type: none"> Moderate to high maturity for small bodies, low to moderate maturity for other planets Provides modest tolerance for nav and atmospheric uncertainties 	<ul style="list-style-type: none"> Low to moderate maturity Provides increased tolerance for nav and atmos. uncertainties Design originally for human missions to Mars Preliminary studies indicate that Slender Body Designs may be required for Neptune. Provides increased volume and improved packaging advantages for larger spacecraft. 	<ul style="list-style-type: none"> Low maturity Applicable to all size and shape payloads May have performance advantages over Blunt Body, such as not having the payload enclosed during interplanetary cruise 	<ul style="list-style-type: none"> Low to moderate maturity for Earth & Mars Developed and launched in 1996 by Soviet Union as part of Mars penetrator mission. Launch vehicle failure. Investigating feasibility of using aerodynamic lift for precision trajectory control Has potential volume & packaging advantage for larger spacecraft

Figure 5. TAG Investment Recommendations

Studies are conducted by the systems analysis group that include planning for specific missions where aerocapture has been identified as an enabling or enhancing technology. To address TAG development requirements, and deficiencies in the data required for systems analysis, ATP uses aerocapture tool development and competed technology development tasks, the products of which feed back into the systems analysis group and the TAGs.

Aerocapture Systems Analysis

Systems analysis plays a key role in the ATP development process. The ISP aerocapture systems analysis team has been tasked with multiple systems definition and concept studies to complement the competed technology development tasks. These studies are detailed in Table 1.

Table 1 Aerocapture Systems Analysis Studies

Year	Study
FY02	Systems Definition Study: Aerocapture at Titan - Rigid Aeroshell
	Systems Definition Study: Aerocapture at Neptune - Rigid Aeroshell
FY03	Concept Study: Aerocapture feasibility study for each possible Code S Destination
	Concept Study: Aerocapture benefits study for each possible Code S Destination
	Concept Study: Analysis of compatibility of aerocapture with other ISP technologies, for each potential planetary destination
	Concept Study: Study of applicability of an Earth flight demonstration to missions at other destinations
FY04	Concept Study: Quick-look of feasibility of a rigid aeroshell vs. a trailing ballute vs. an attached ballute, for various destinations
	Systems Definition Study: "Emerging" Office of Space Science destination
	Concept Studies: Continue

At the request of the NASA Headquarters Office of Space Science, a systems definition study for rigid aeroshell aerocapture at Titan was completed in FY02. The analysis team completed all aspects of system definition for Titan, including: science requirements at each destination, mission analysis for multiple mission profiles, guidance and navigation modeling, atmospheric modeling, aeroheating, thermal protection system selection/applicability, aeroshell structure and design, mass properties analysis and overall spacecraft design. The final report for this study can be obtained by contacting Steve Moon at steve.moon@msfc.nasa.gov.

In FY03 the aerocapture systems analysis team began a systems definition study of rigid aeroshell aerocapture at Neptune. It is planned that in FY04 an additional aerocapture systems definition study will be commissioned for a destination consistent with NASA space science needs.

Aerocapture-specific computational tools required to support aerocapture systems analyses are also an integral part of the ATP. Tools include: engineering reference atmosphere models, guidance and navigation, aerothermodynamic modeling, radiation modeling and flight simulation.

Aerocapture Technology Tasks

In the summer of 2002, the NASA ISP announced the selection of six research organizations to lead key aerocapture technology development tasks, primarily in the area of hardware development: The NASA Langley Research Center in Hampton, Virginia, tasked with development of high-temperature composite structures; Applied Research Associates, Inc. of Englewood, Colorado, tasked with development and testing of lightweight thermal protection system ablators; the NASA Ames Research Center at Moffett Field, California, tasked with characterizing advanced thermal protection systems; the ELORET Corporation of Sunnyvale, California, tasked with development of advanced heatshield instrumentation; Lockheed Martin Astronautics of Denver, Colorado tasked with aeroshell development and integration; and Ball Aerospace Corporation of Boulder, Colorado, tasked with trailing ballute analysis and development.

In Spring 2003, proposals were accepted for inflatable aeroshells in both forebody and afterbody configurations. It is anticipated that these efforts, coupled with development tasks from the previous NRA cycle, will give the ATP several advanced concept options.

Summary

Aerocapture technology development is one of the highest priority technologies of the NASA In-Space Propulsion Program which is managed by the NASA Office of Space Science and implemented by the Marshall Space Flight Center. The objective of the In-Space Propulsion Program Aerocapture Technology Project is to develop aerocapture technologies that can enable and/or benefit NASA missions by significantly reducing cost, mass, and/or trip times.

Exploration target requirements, TAG input, systems analysis results and technology advancements will continue to drive the direction of the ISP Aerocapture Technology Project toward flight demonstration and, ultimately, mission utilization of aerocapture.

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