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4.3 Aerobraking Technology Studies –

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For a Mars Expedition, aerobrakes can play a vital role in several major mission events, including aerocapture to achieve orbit and descent to the planetary surface both at Mars and upon return to Earth. The feasibility of aerobrake designs will depend upon materials and structures technologies because they will serve as a key factor in determining:

- Aerobrake mass and mass fraction
- The extent to which aerobrakes can survive the thermal environment. This is especially important for reusable aerobrakes. With the cancellation of the Aeroassist Flight Experiment, the effort to validate aerobrake designs has focused on laboratory test and analysis.
- The feasibility of assembling and/or deploying large aerobrakes. On-orbit assembly is a critical issue for all spacecraft intended for Mars exploration missions. Current studies are addressing options related to in-space assembly and construction.
- Configuration lift-to-drag (L/D) ratio. High L/D increases convective heating, whereas low L/D emphasizes radiative heating. In general, the lowest L/D design that can satisfy mission requirements is preferred.

Most aerobraking environments are different than those experienced by previous space programs. An aeroassisted Earth entry from the Moon would be similar to the Apollo missions, but significant differences are involved in aerocapture for Earth orbit. The velocities of vehicles returning from Mars could be as high as 15 km/sec. This compares to 8 km/sec for the Space Shuttle and about 11 km/sec for return from the Moon. The use of aerobraking technology in the Martian atmosphere would go far beyond our past experience and require mission planners to accommodate highly variable entry and atmospheric conditions including possible dust storms.

AEROBRAKING
Technology Studies

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to

Space Transportation
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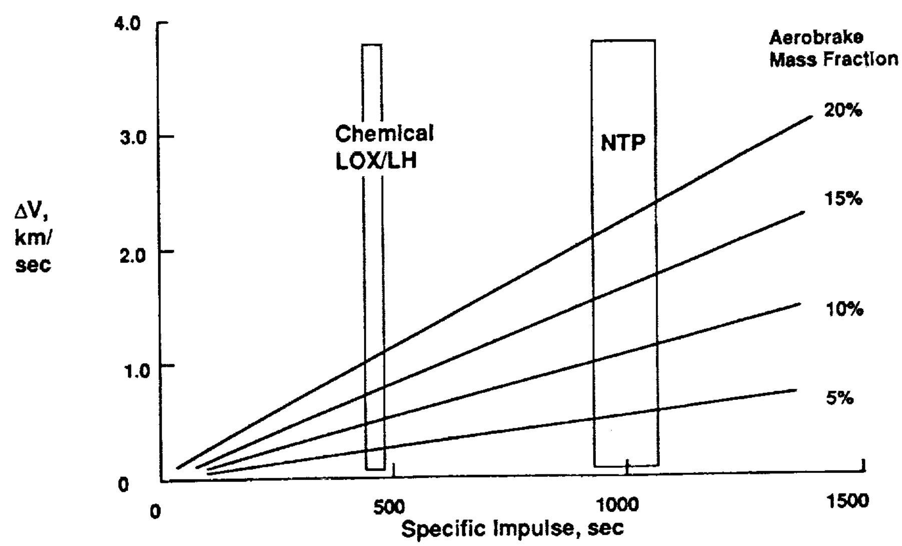
Aerobraking

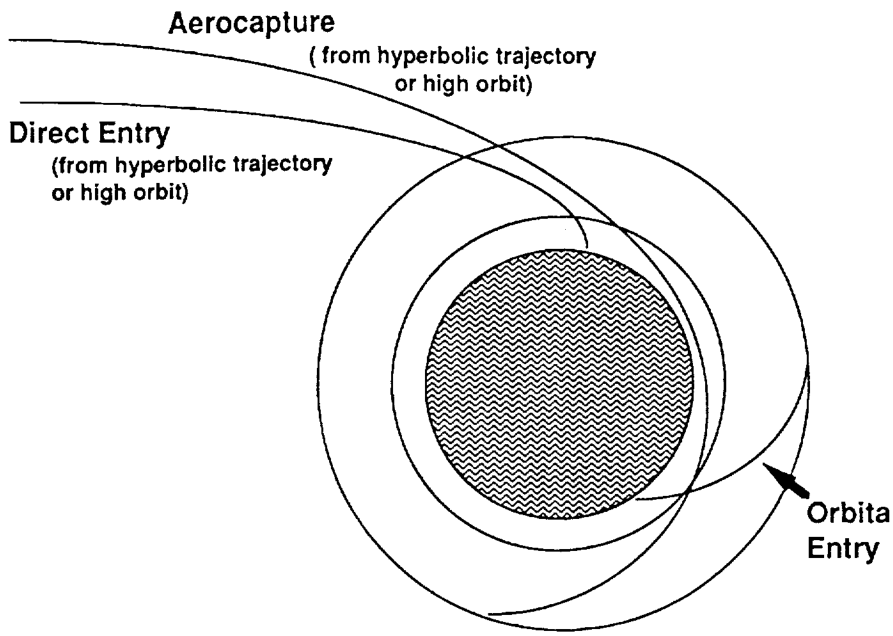
- Aerobraking Benefits
- Aerobraking Modes & Applications
- Structures & Materials Issues
- Aerobrake Status
- Summary

Aerobrake Systems vs Propellant Mass



Aerobraking enhances propulsion performance for large ΔV maneuvers

AEROBRAKING MODES

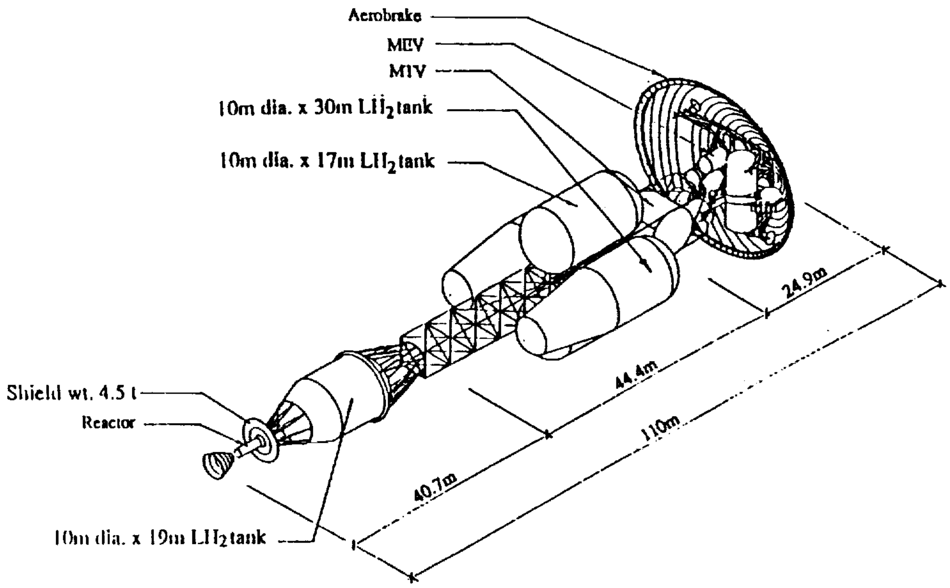


Mars Propulsion Options

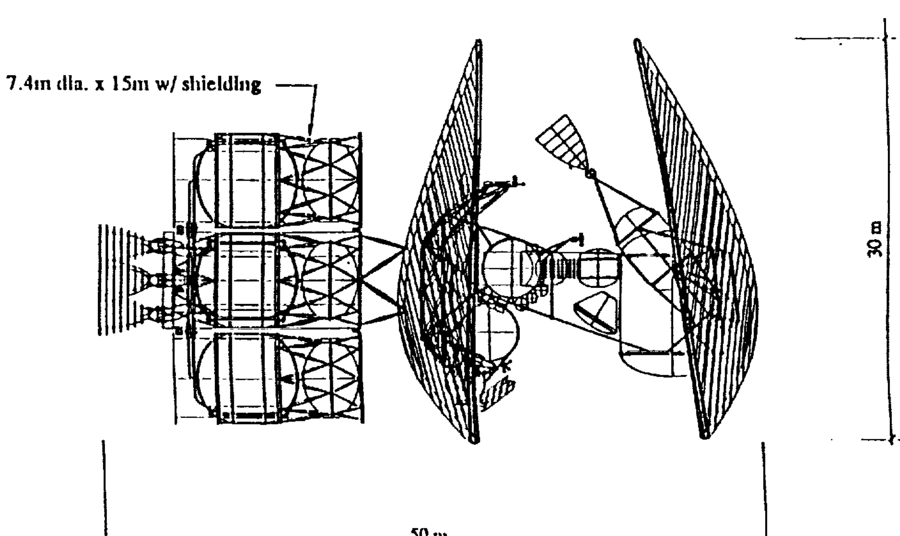
Mission Event Sequence		Propulsion Options: NTP	Chem/AB	NTP/AB Hybrid
TMI	Manned Cargo	NTP	Chem	NTP
MOC		NTP	AB	AB
ME	MEV	AB	AB	AB
MAO		Chem	Chem	Chem
TEI	MTV	NTP	Chem	Chem
EC/EE		AB	AB	AB

Aerobraking is required for 1/3 to 1/2 of all major mission events

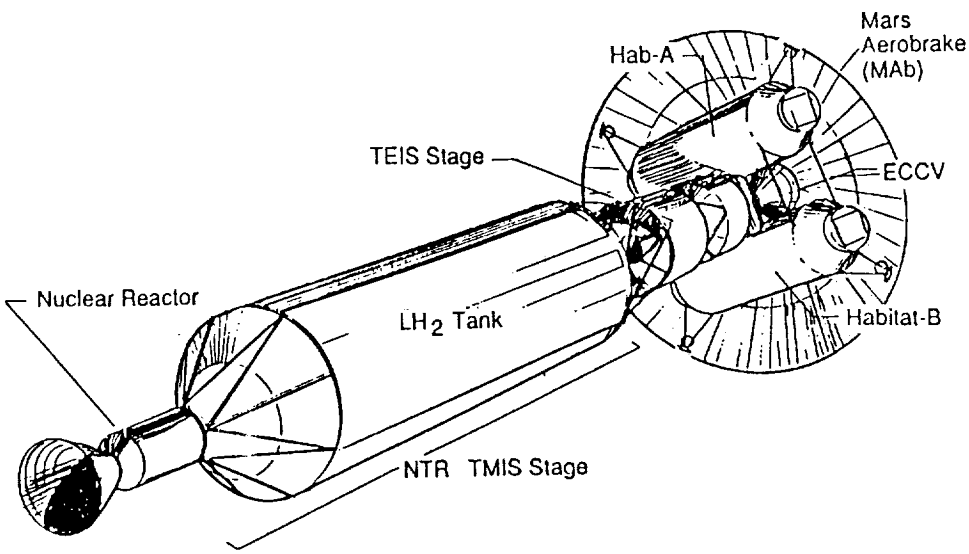
Nuclear Thermal Propulsion Vehicle Concept



Cryogenic Aerobraking Vehicle Concept



Nuclear/Aerobraking Hybrid Vehicle Concept



Structures and Materials Issues

- **Configuration L/D**
- **Mass fraction**
- **Thermal environment**
- **Assembly/deployment**

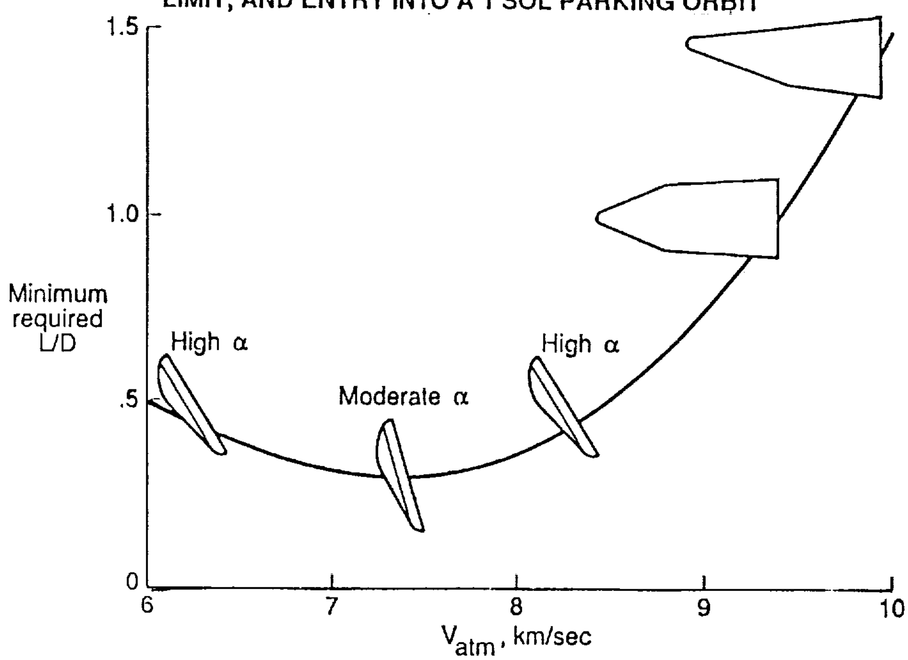
The L/D Issue

Issue	High L/D	Low L/D
Control Authority g loads Nav errors Atmosphere variations	✔	
Payload packaging		✔
Weight		✔
Heating Convective Radiative	 ✔	 ✔
Guidance Control Complexity Adaptive Guidance	 ✔	 ✔

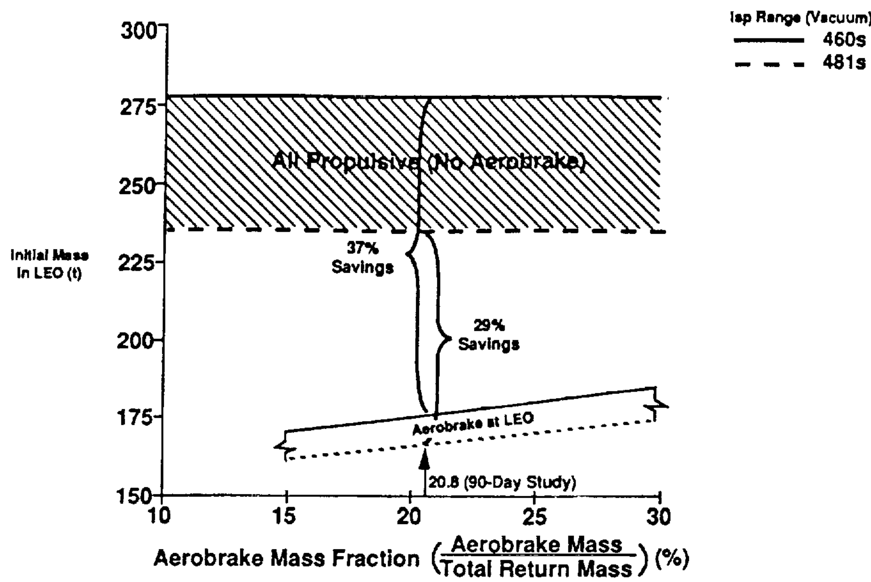
Strategy: Find the lowest L/D which satisfies mission requirements.

MINIMUM AEROBRAKE L/D FOR MARS AEROCAPTURE

1° CORRIDOR WIDTH REQUIREMENT, 5-G DECELERATION LIMIT, AND ENTRY INTO A 1 SOL PARKING ORBIT



Mass Fraction Effects on Benefits of Lunar Aerobraking



Aerobraking Environments

Lunar Missions:

- Extension of Apollo flight experience
  Entry velocity conditions the same
  Repeatable for various opportunities

- Significant differences in flow conditions between:
  Direct entry (like Apollo) and aerocapture

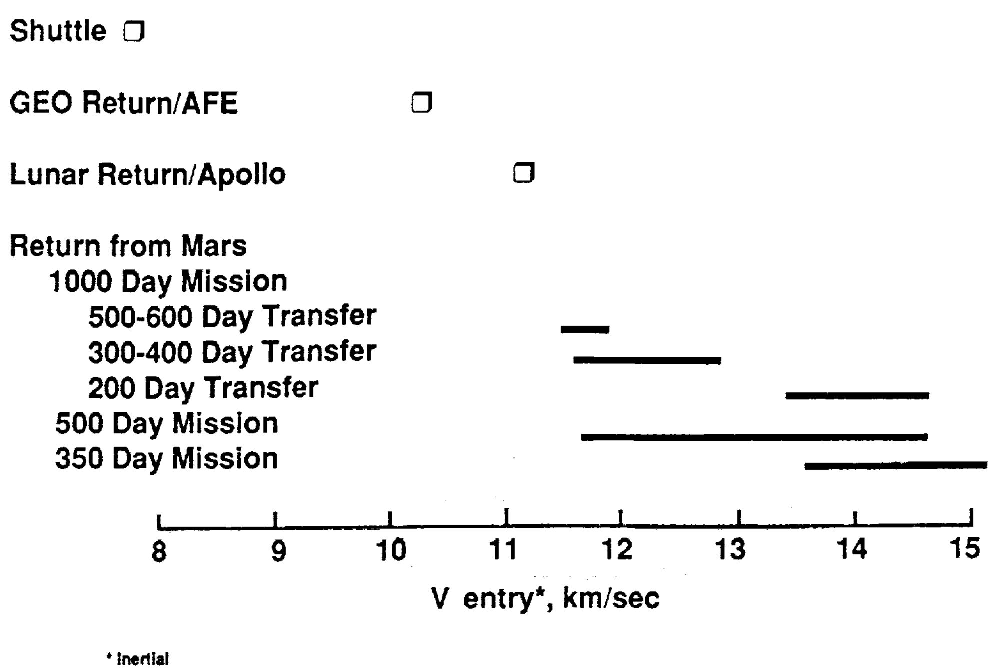
Mars Missions:

- Extend flight environments significantly beyond our past experience for both Mars aerocapture and Earth aerocapture/direct entry

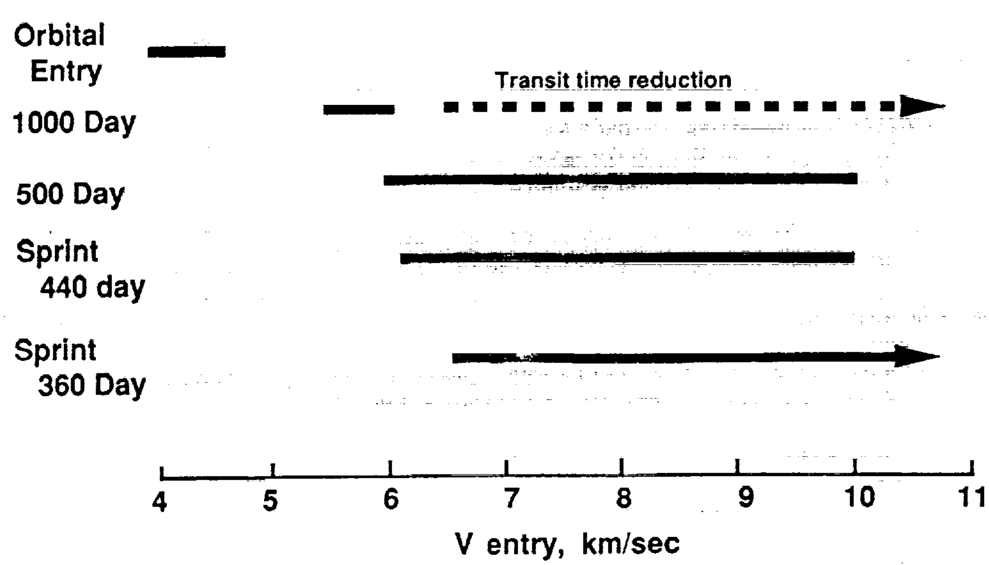
- Highly variable entry velocity conditions with:
  Opportunity year
  Type of mission trajectory

- Highly variable Mars atmosphere
  Atmospheric density
  Dust storms

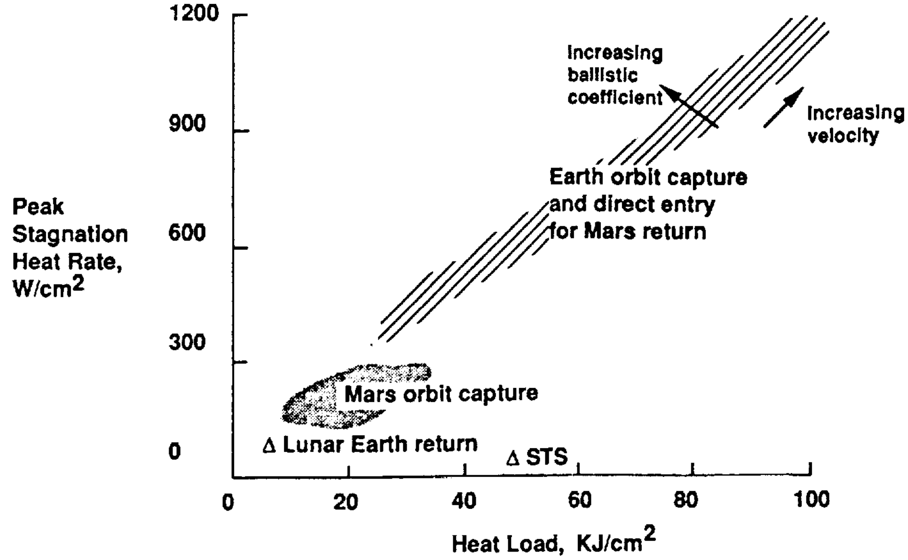
EARTH ENTRY VELOCITY ENVELOPES



MARS ENTRY VELOCITY ENVELOPES



Aerobrake Heating Environments

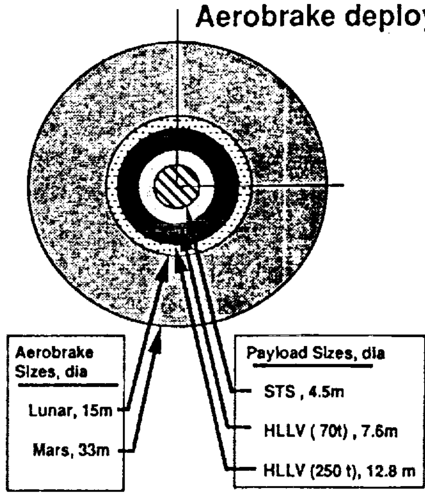


TPS Dust Erosion

- Possible Mars dust storm during aerocapture maneuver
- TPS erosion modeled for worst case dust storm, high aerocapture velocity
- Surface erosion calculated as about 10 mm in stagnation region for ablator TPS
- Assessment: A manageable problem

Aerobrake Deployment/Assembly

Issue: Aerobrakes are too large for conventional intact launch and require precision assembly. What is the impact of Aerobrake deployment/assembly requirements?



Answer:

- Current studies are examining:
  - Designs for simplified assembly
  - Alternatives to assembly
    - Intact launch options
    - Deployable, space rigidized
- Precision assembly is not unique to Aerobrake
  - Propellant feedline connects/disconnects are common to all configurations
- On-orbit deployment/assembly and precision assembly is required regardless of Aerobrake utilization

On-orbit assembly is a critical issue for Aerobrakes as well as all Exploration missions. Current studies are addressing a variety of options.

Aerobraking Status

- Synthesis Report:
  - Nuclear Thermal Propulsion for all missions
  - Aerobrake design issues elevated to showstoppers
- AFE Cancellation Impact
  - Shift validation emphasis to ground test
- Architecture Assessments
  - Baseline NTP but trade alternatives
- Technology Program
  - Multidiscipline, based on flight demonstrated technologies
  - High priority in transportation thrust
  - Continuing at reduced level

Aerobraking Summary

- Aerobraking provides:
  - Essential capabilities for Mars entry and return to Earth
  - Potentially enhancing capabilities for Mars orbit capture
- There are no Aerobraking showstoppers
- There are significant structure and materials challenges in
  - Performance
    - Low weight
    - Thermal protection materials
  - Operations
    - Assembly/deployment