Supersonic Vehicle Configuration Transitions To Enable SRP During Mars EDL

David J. Blette and Robert D. Braun
Georgia Institute of Technology, Atlanta, Georgia 30332

Background and Motivation

Supersonic retropropulsion (SRP) is an enabling technology for landing high mass payloads on Mars. Recent efforts to develop the state of the art of SRP have primarily focused on SRP system performance during EDL, propulsive-aerodynamic interaction characterization, and CFD modeling capability development.

The vast majority of SRP analyses ignore the challenges and impacts of supersonically transitioning a hypersonic entry vehicle configuration into a vehicle configuration that allows for SRP steady-state operation.

- Configuration transitions impact EDL timeline events and landed mass capabilities.
- Recent analyses have assumed free-fall time penalties before SRP initiation to conservatively account for transition impacts on the EDL timeline.

Challenges

All Mars atmospheric vehicle transitions to-date have occurred subsonic and relied on subsonic free-fall assumptions to mitigate debris recontact risks during solid mass ejections.

- Due to fundamental differences between supersonic and subsonic fluid flows, separation complexity and risk are increased during supersonic transitions.
- Transitions involving mass jettisons pose near-field and far-field recontact risks to the descent vehicle.
- To advance SRP to a flight-ready status, analysis is required to characterize the unique challenges of supersonic transitions.

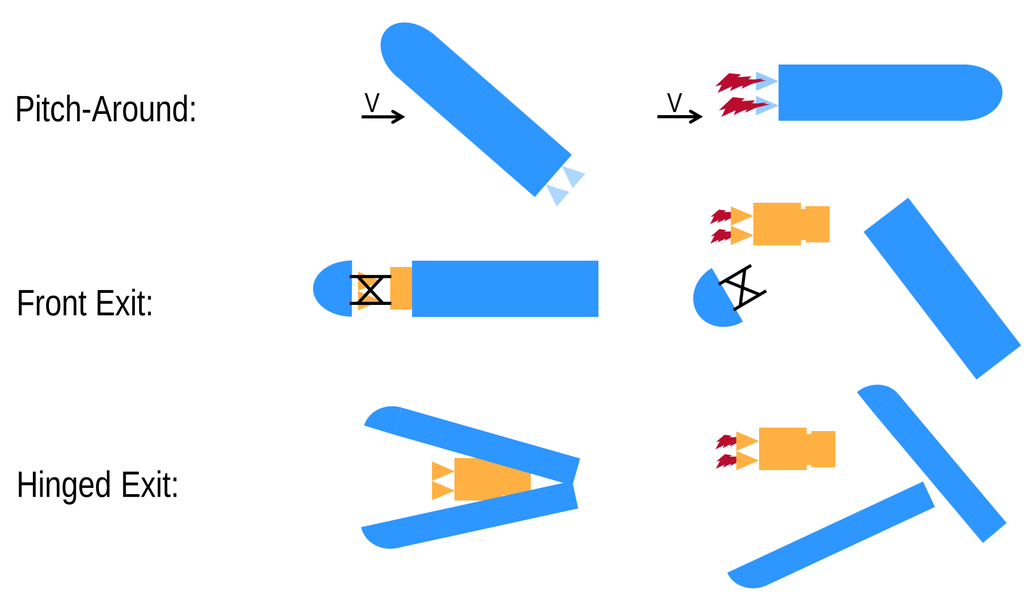
Baseline Mission and Analysis

The entry vehicle design considered in this study closely resembles that of the EDL-Systems Analysis Architecture 1 [Dwyer]:

- 10x30m rigid mid-L/D hypersonic aeroshell
- 110 mT entry mass
- L/D~0.6 at 35º AOA
- Supersonic and subsonic propulsive deceleration

Reference Transition Architectures

Proposed vehicle configuration transitions aim to minimize overall complexity, risk, and required propellant mass during SRP



Proposed Analysis and Expected Outcomes

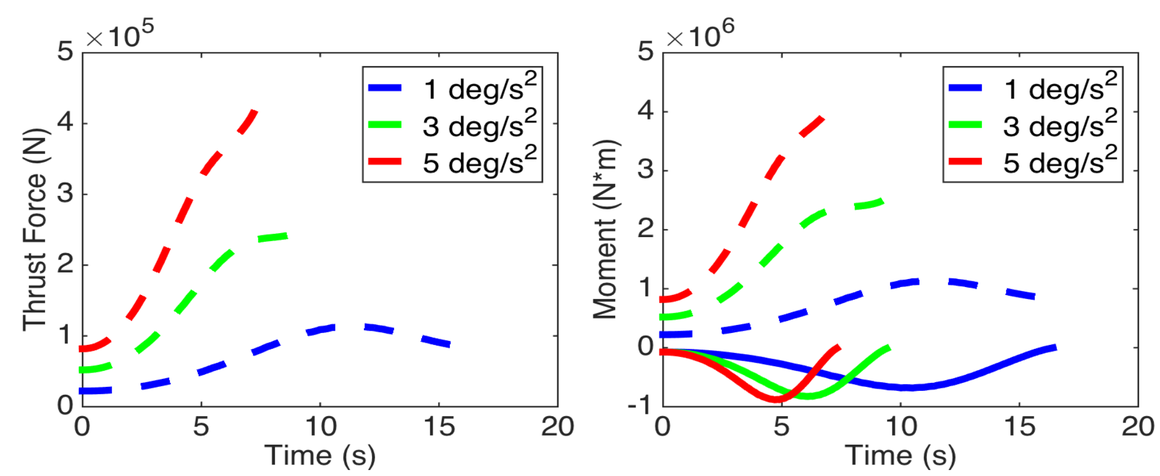
The 3 transition architectures will be compared according to:

- Time to complete transition
- Required subsystem performance
  - RCS and ejection system thrust capability
  - Mass (mechanical and propulsive)
- Altitude-velocity performance

Expected outcomes:

- Provide recommendation for transition architecture
- Bound transition times
- Bound required transition subsystem mass and performance

Preliminary Pitch Maneuver Results



(*Left*) – RCS thrust force required to perform a pitch-around maneuver for varying angular accelerations.
(*Right*) – Aerodynamic moments (solid) and required moments due to thrusters (dashed) to perform a pitch-around maneuver for several angular accelerations.
Initiation Conditions: Mach 3.35, 8.7 km altitude

Conclusions:

- Higher angular accelerations result in faster transition times but require more powerful thrusters to perform the maneuver.
- Commanding an angular acceleration of 5 deg/s^2 requires prohibitively large RCS thrusters (~400 kN). Improvements can be made by limiting angular velocity during the maneuver.
- Accelerations on the order of 1 deg/s^2 result in plausible performance requirements on RCS thrusters (~100 kN).
- 20 seconds is a conservative estimate of supersonic vehicle configuration transitions utilizing a pitch-around maneuver.

Acknowledgments and References

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References:

- Dwyer Cianciolo, A.M., et al., (2010) *Entry, Descent and Landing Systems Analysis Study: Phase 1 Report.*