Applying Aeropropcapture at Titan and the Ice Giants

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Introduction

- Chemical propulsion and aerocapture are two methods to get into orbit around a planet
- Aeropropcapture (APC) is a proposed alternative, using propulsion during the atmospheric pass
- Engine used during pass can be reused in orbit
- APC can have greater control than aerocapture and use less fuel than chemical propulsion
- Increased control leads to lower risk
- Decreased fuel requirements leads to more mass for other systems or lower overall mass

Motivation

- APC uses atmospheric drag to decrease energy, lowering mass dependence on incoming energy
- APC uses propulsion rather than lift, reducing its dependence on atmospheric density or velocity

$$\frac{T}{D} = \frac{\tau(BC)}{q_{inf}}, \quad \tau = \left(\frac{T}{W}\right)_{entry}\sqrt{\frac{\mu}{r^3_{entry}}}, \quad q_{inf} = \frac{\rho V^2/2}{\sqrt{\mu/r_e}}$$

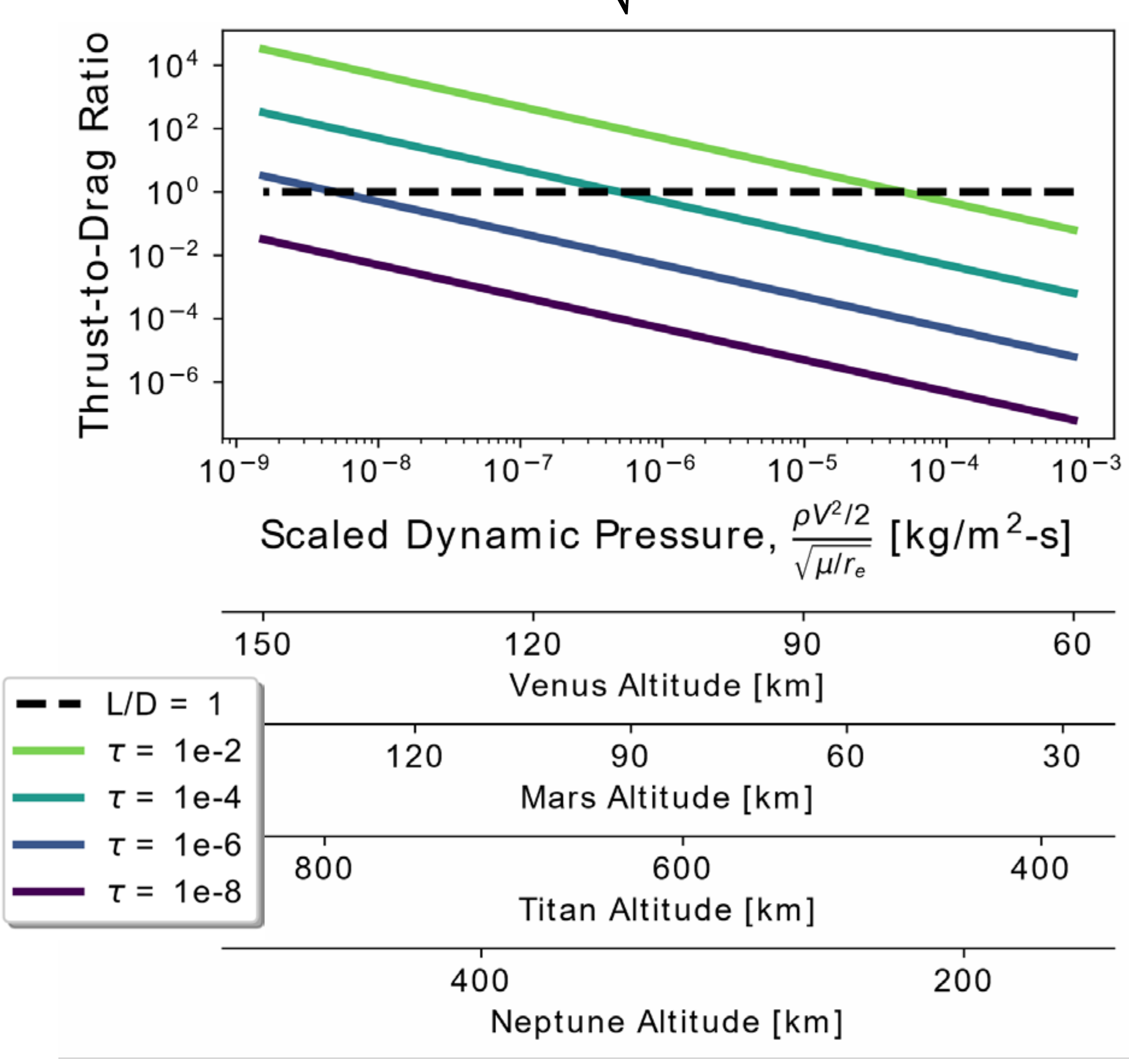

Figure 1: Thrust-to-drag ratios compared to a single lift-to-drag ratio (L/D) for a range of dynamic pressures and select planet-generic thrust-to-weight ratios, τ. Dynamic pressures and thrust-to-weight ratios are scaled to make the values planet-independent. Planet altitudes are lined up using a constant velocity of 9, 6, 7, and 21 km/s for Venus, Mars, Titan, and Neptune, respectively. The ballistic coefficient (BC) considered is 200 kg/m².

For more information, please see "Aeropropcapture: Applying Propulsion to Aerocapture Maneuvers," AAS 18-392.

Analysis

- V_{entry}, post-capture apoapsis, and thrust-to-weight ratios (T/W) effects on TCW and PMF are studied
- Theoretical Corridor Width (TCW): width between shallowest and steepest entry flight path angles
- Propellant Mass Fraction (PMF): propellant needed to achieve maneuver as a fraction of entry mass

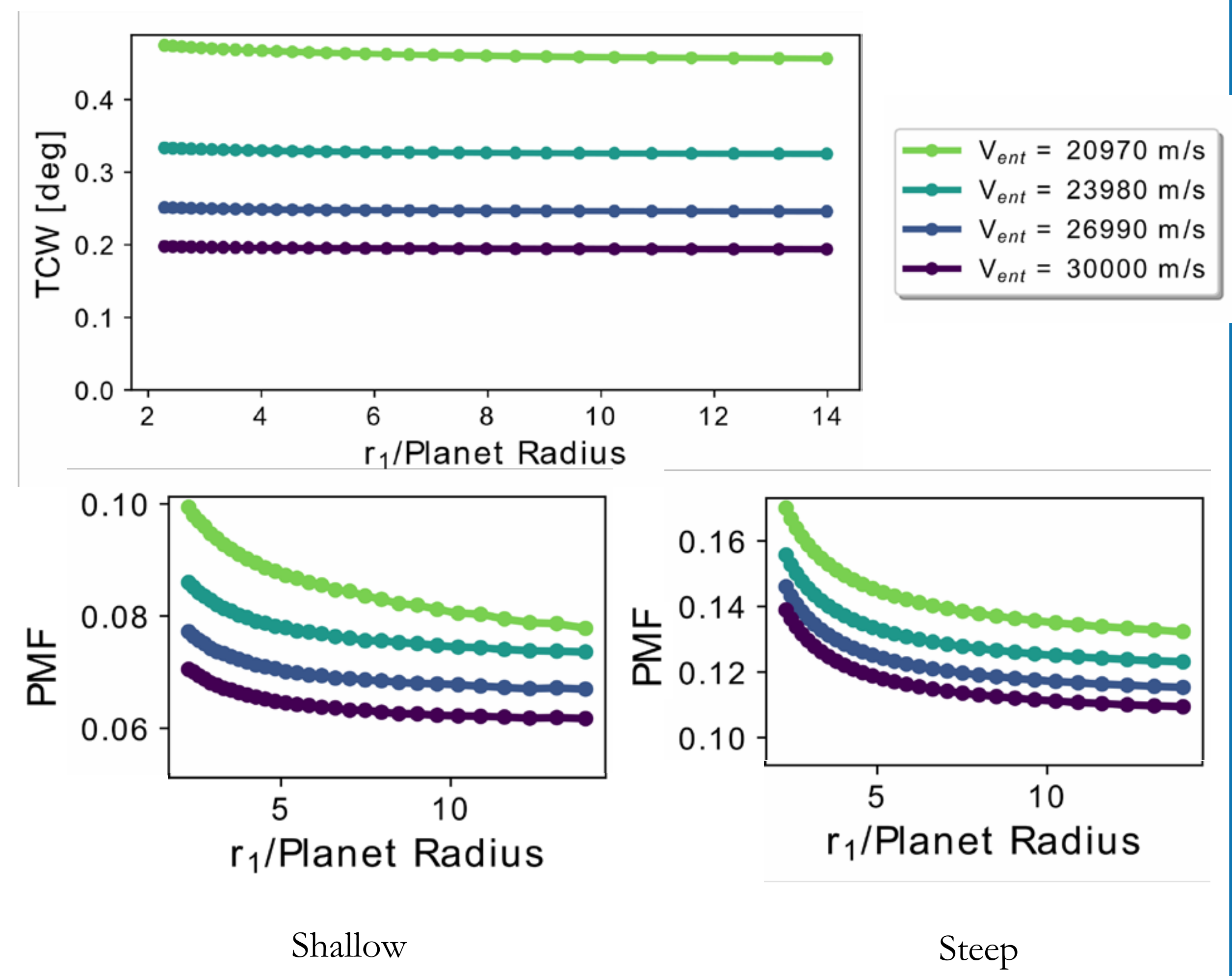

Figure 2: TCW and PMF for shallow and steep trajectories around Uranus for five entry velocities and a range of post-capture apoapsis, r_1. BC is 200 kg/m² and T/W is 0.05.

vs. Aerocapture: Equivalent L/D

- Equivalent L/D for selected T/W are found for Titan, Uranus, and Neptune

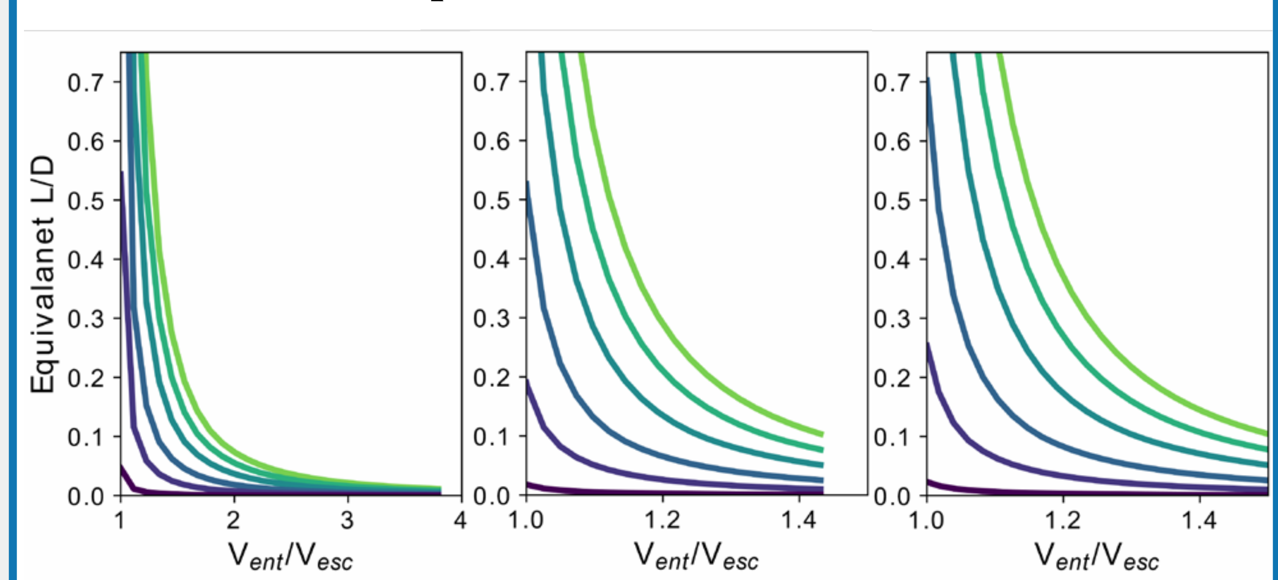

Figure 3: Equivalent L/D for selected T/W on Titan, Uranus, and Neptune over a range of entry velocities, represented as a fraction of escape velocity. BC is 200 kg/m² and post-capture apoapsis is 10 r_{pl}. Equivalent L/D is found by finding a L/D does accomplishes the same TCW for given entry conditions and T/W.

vs. Aerocapture: TCW

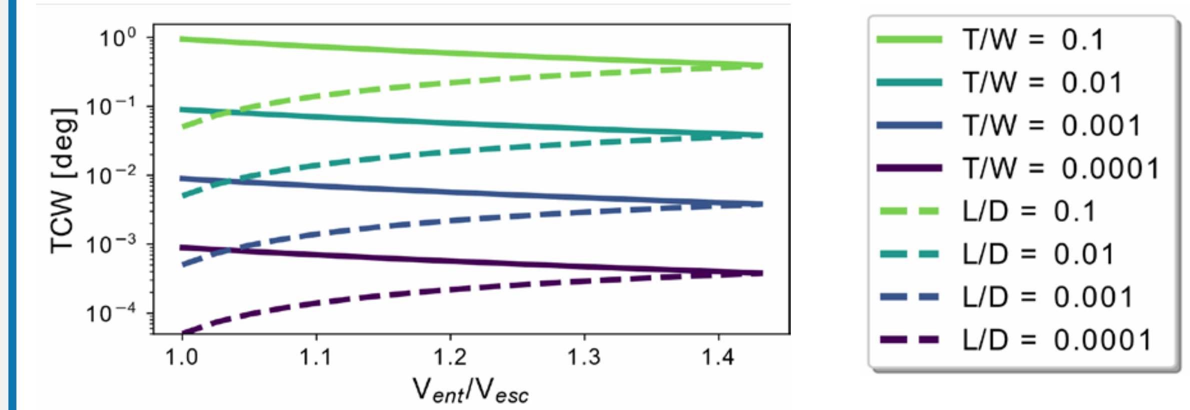

Figure 4: TCW and PMF for trajectories around Uranus for a range of entry velocities and T/W. BC is 200 kg/m² and post-capture apoapsis is 10 r_{pl}.

vs. Chemical Propulsion

- ΔV required for final orbit placement are compared between APC and chemical propulsion
- ΔV for APC comes from PMF and periapsis-raising maneuver after the atmospheric pass
- ΔV for chemical propulsion assumes single burn

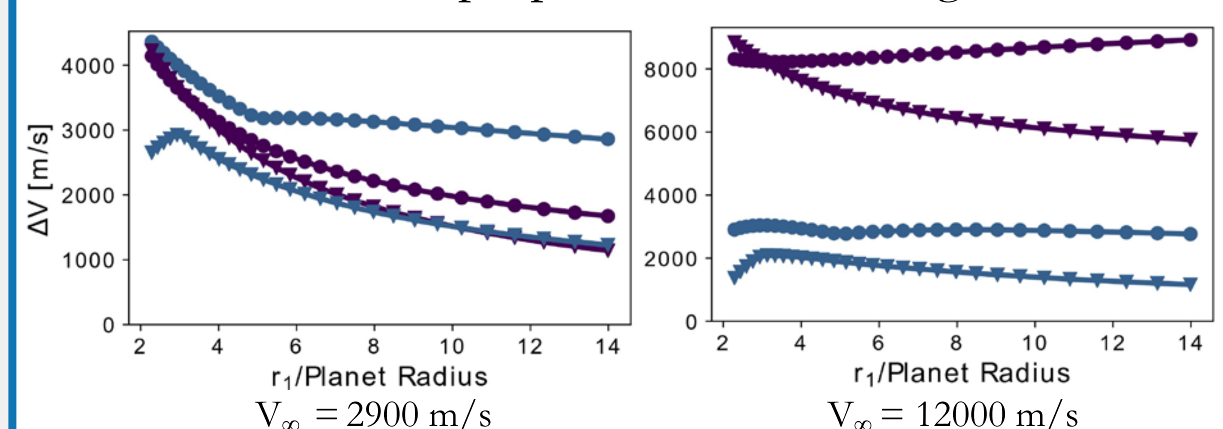

Figure 5: ΔV requirements for both APC and chemical orbit insertion maneuvers on Uranus. BC is 200 kg/m² and T/W is 0.05.

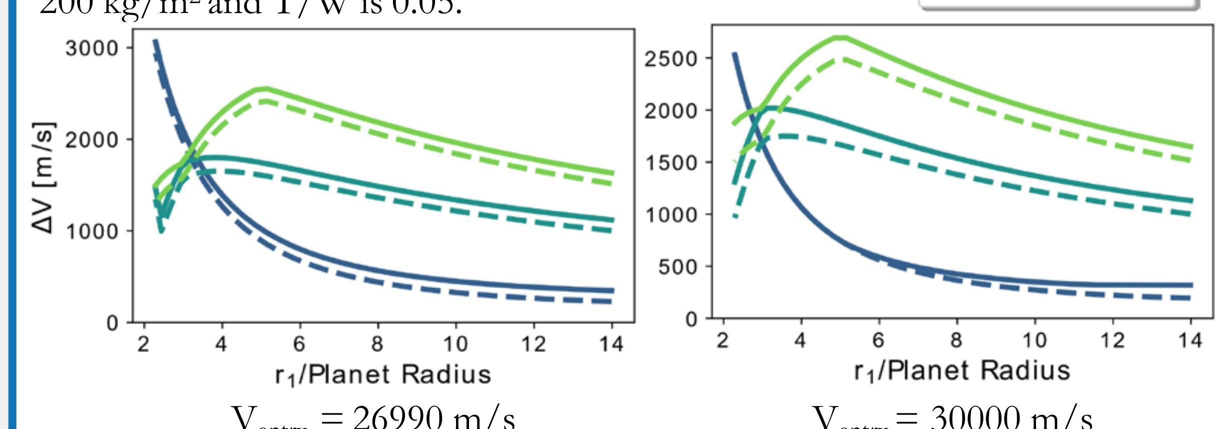

Figure 6: ΔV requirements for steep and shallow maneuvers on Uranus for a variety of final orbit sizes, with post-capture apoapses r_1 and post-capture periapses r_2. BC is 200 kg/m² and T/W is 0.05.

Conclusions

- APC can have larger TCW than aerocapture and lower ΔV requirements than chemical propulsion
- Larger TCW lowers risk; lower ΔV lowers total mass
- Future study is required to better quantify benefits and costs, such as vehicle design and guidance