Aerocapture as an Enabling Technology for Planetary Missions

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Outline

• What is aerocapture?
• Where can aerocapture help?
• How aerocapture designs have evolved
• Point Design: Uranus aerocapture
• Point Design: Small Satellites aerocapture
What is Aerocapture?

Aerocapture is different than aerobraking. Which skims atmosphere; maneuver takes a long time.

Orbital maneuver where the drag from a single atmospheric pass provides deceleration for orbital insertion.
Where Can Aerocapture Help Missions

**Planetary Science: Uranus and Neptune**

**Typical Fully-Propulsive Mission**
- **Need 50% or more mass** for fully-propulsive orbit insertion (requires ΔV of 1-2 km/s)
- Typical mission **require long cruise phase** (13-17 years)

**Aerocapture Enabled Mission**
- Reduced propellant need
- Savings used for launch vehicle choice, launch opportunities, or increase on-orbit science payload
- Aerocapture can enable faster interplanetary trajectories – **reduce trip time by 3-5 years**
- Fit a larger mission into a smaller funding cap e.g., Flagship class mission in New Frontiers cap

**SmallSat: Planetary SmallSat Missions**
- Typically: Volume and mass constrained; propellant systems are a heavy burden
- Aerocapture systems: Can reduce necessary propellant – **50-80% more useful mass on-orbit** depending on the orbit

**Human Exploration: Human-scale Mars Missions**
- Human-scale missions could **reduce trip time** with a faster interplanetary trajectory and **increase on-orbit mass** compared to traditional orbit insertion

Aerocapture directly infusible to top destinations for the 2023-2032 Decadal Survey
Capabilities that Enable Aerocapture

- **Previously**
  - Aerocapture needed new vehicles
  - Guidance, Navigation, and Control (GNC) and Thermal Protection System (TPS) material development needed

- **Developments in last 10-15 years matured components needed for aerocapture success**

- **Advanced GNC**
  - Entry guidance successful on Mars Entry, Descent, and Landing (EDL) – Mars Science Laboratory and Mars 2020
  - Predictor-corrector guidance flew on Exploration Flight Test-1 and part of Artemis-1
  - Trim tab used on Chinese EDL mission to Mars in 2021

- **TPS for Aerocapture Environments**
  - PICA TPS has flight heritage (Stardust, MSL, Mars 2020) and HEEET (3MDCP) TPS has been chosen for flight projects (Mars Sample Return Earth Entry System)
  - Conformal PICA TPS might be a lightweight solution with performance for aerocapture

- **Optical Navigation (OpNAV) and Autonomous Navigation (AutoNAV)**
  - Improves navigation uncertainty for entry
  - Demonstrated in missions like Deep Space 1
Uranus Aerocapture

- 2021 Uranus Orbiter and Probe mission concept study influenced the 2023-2032 Planetary Decadal Survey choosing Uranus as the top flagship-class destination
  - 2031/2032 launch date; 13 years of transit
  - 1000 m/s ΔV for Uranus Orbit Insertion (1800 kg fuel)
  - 60-70% of launch mass is fuel
  - Nuclear power source lifespan degrades after 17 years

- Recent aerocapture studies have shown UOP payload can fit in heritage aeroshell and have feasible GNC and TPS solutions
  - Transit to Uranus in 7-9 years; save 1000 kg in fuel in orbit insertion
  - Can we enable Flagship class science in New Frontiers budget?
**Small Satellite Aerocapture**

- Planetary exploration using Small Sats will become more common.
- Small Sats are constrained by volume; orbit insertion propellant tanks, fuel may limit abilities for planetary missions.
- Aerocapture can improve volume and mass constraints for Small Sat orbit insertion.
- Options like deployables (inflatable, mechanical) can further allow volume, mass efficient orbit insertion alternatives for Small Sats.

*NASA Small Satellite Fleet*
Summary

• Aerocapture can be mass, volume, and time-saving orbit insertion mechanism that uses atmospheric drag to capture spacecraft into orbit

• Aerocapture has potential usages in planetary science applications, orbit insertion for small satellites, and even for human exploration

• Recent advancements in GNC, TPS, and navigation have extended the capabilities of aerocapture

• Aerocapture is especially enabling for a Uranus flagship mission or small satellites
• Aerocapture has appeared in the literature since the 1960’s
• Three white papers on aerocapture were written for the 2022 Planetary Decadal Survey
  • Aerocapture for Ice Giants (Dutta et al.)
  • Aerogravity Assist to Enable Enceladus Missions (Tackett et al.)
  • Small Satellite Aerocapture (Austin et al.)