Aerocapture Enabling Uranus Orbiter and Probe Mission

Abstract 8011

Uranus Flagship 2023 Workshop
Session: Uranian Systems Posters – Mission Concepts and Considerations

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Background

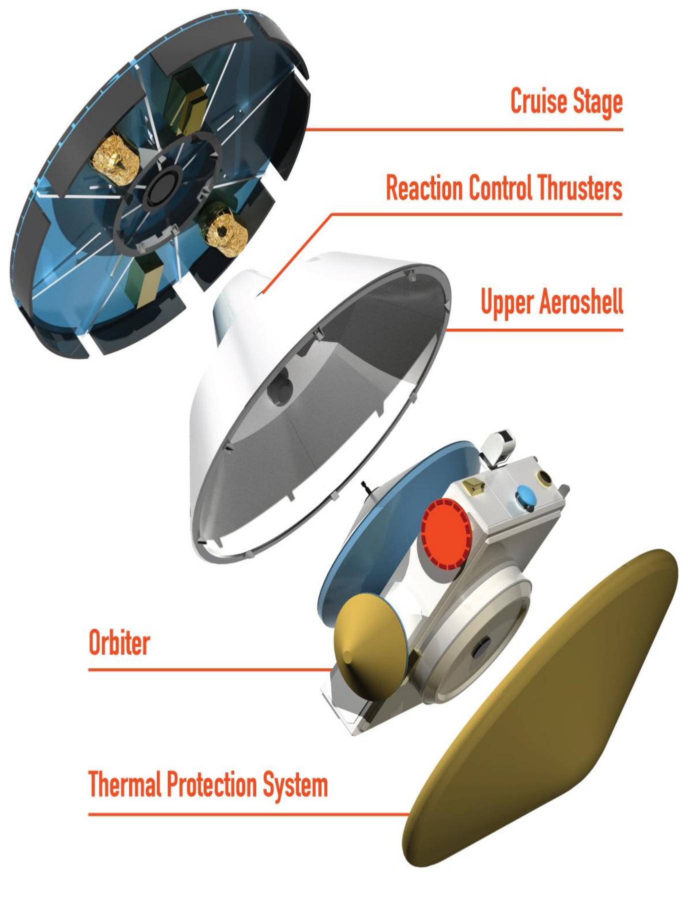
- Traditional fully-propulsive orbit insertion mission has transit time of 13 years and requires 60% of total launch mass allocated for propellant
- NASA Space Technology Mission Directorate is funding a two-year Early Career Initiative investigating Uranus aerocapture
- NASA Science and Space Technology Mission Directorates actively pursing a 2026 aerocapture technology demonstration mission

Merits for Aerocapture

- Uranus atmosphere can be utilized to provide the required change in velocity to capture into orbit (aerocapture)
- Can reduce propulsion needs without significant mass increase associated with an aeroshell. Opens door for more delivered science payload
- Adaptable to changes in interplanetary trajectories and launch delays. Can enable reduced transit time and operations costs (Phase E)

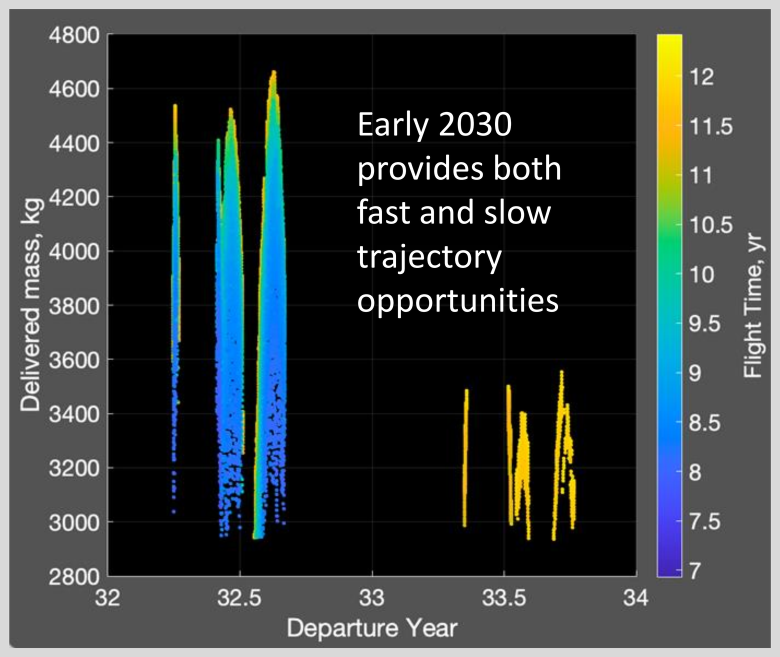
Vehicle Design Consideration

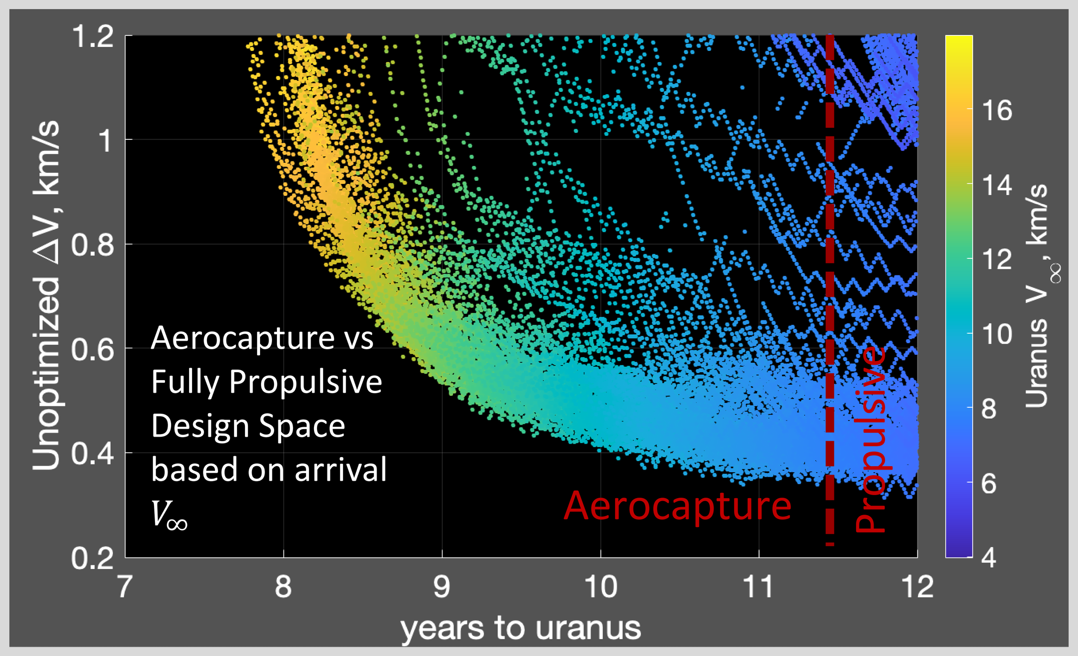
- Aerocapture technology maturity is derived from Entry, Descent, and Landing (EDL)
- Package Uranus Orbiter and Probe subsystem mass in Mars Science Laboratory-derived aeroshell
  - 4.5 m aeroshell with C-PICA TPS
  - Bank Angle Control with Numerical Predictor-Corrector Guidance and Optical Navigation
  - L/D = 0.25, Ballistic Coefficient = 180 kg/m^2

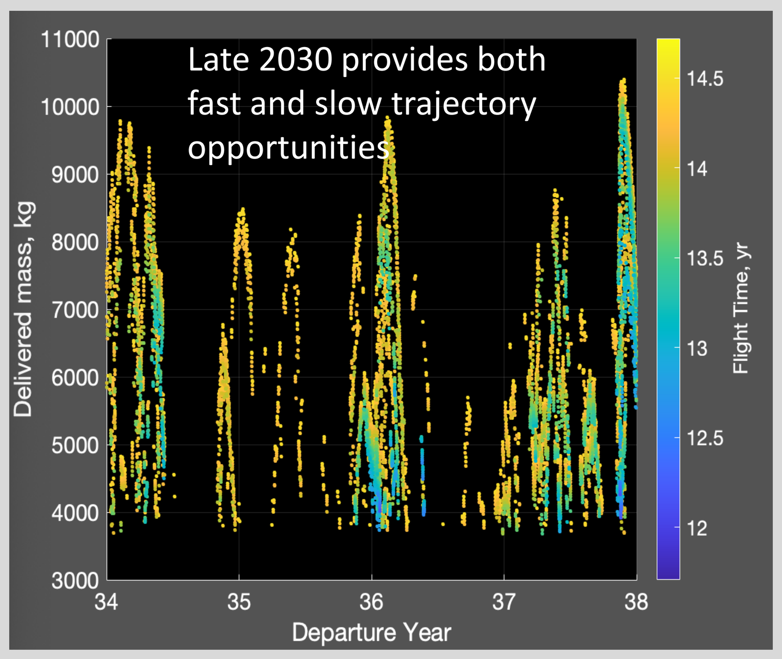


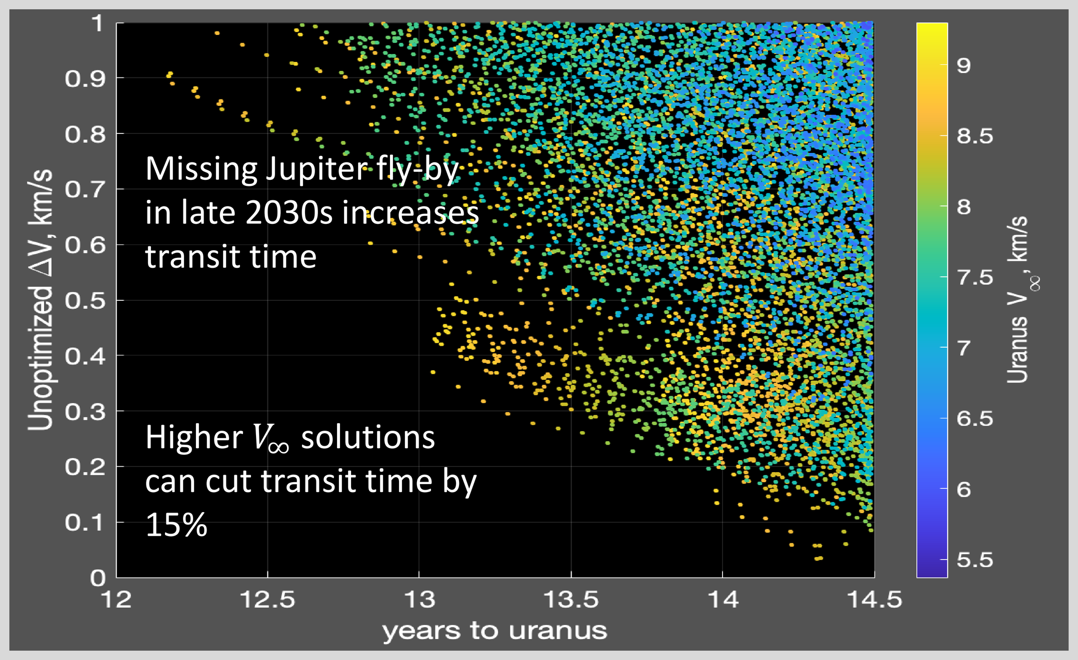
Interplanetary Trajectory Considerations

- Diminishing number of trajectories that utilize Jupiter fly-by near end of 2030s
- Aerocapture opens design-space for orbit insertion from faster arriving trajectories

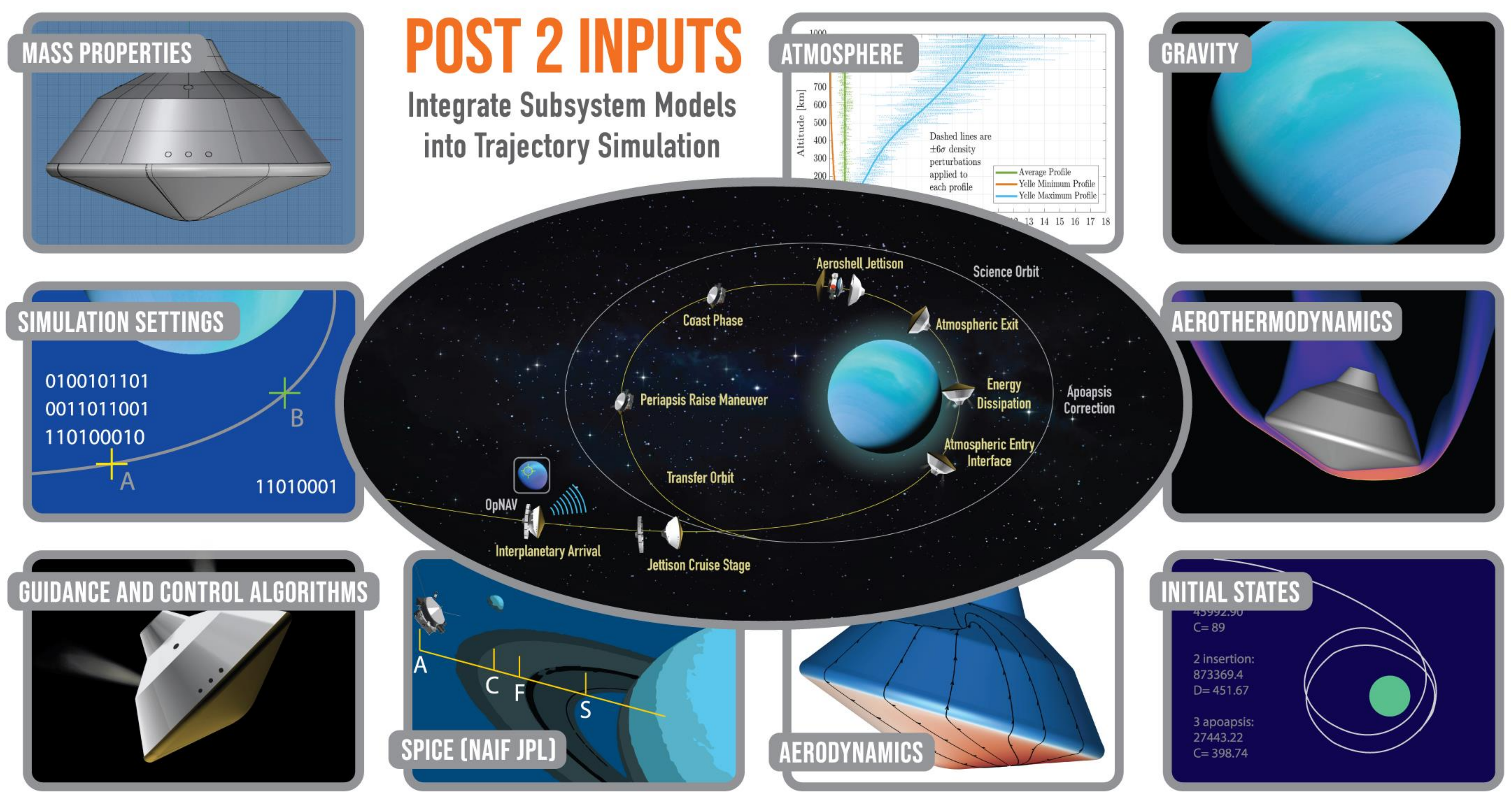








Aerocapture Concept of Operations

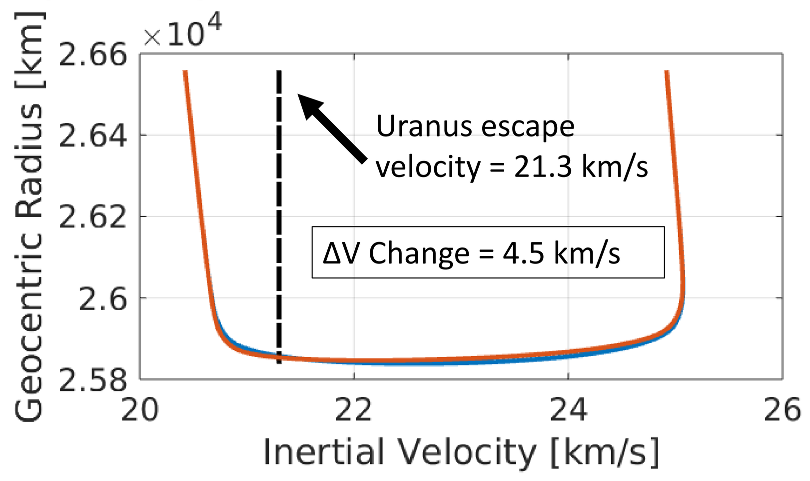


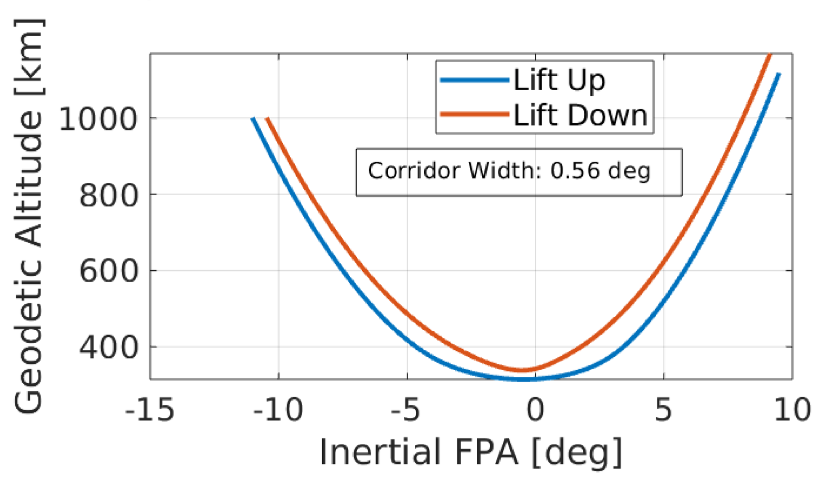
POST2 – Program to Optimize Simulated Trajectories II
Atmosphere – UranusGRAM 2021
Aerothermodynamics – Langley Aerothermodynamic Upwind Relaxation Algorithm
Initial States – Optical Navigation Entry State File

Aerodynamics – Uranus atmosphere developed aerodatabase
SPICE – Relevant Kernels (de430.bsp, ura111.bsp, naif0012.tls, pck00010.tpc)
G&C – Fully Numerical Predictor-Corrector Aerocapture Guidance, Bank Angle Control

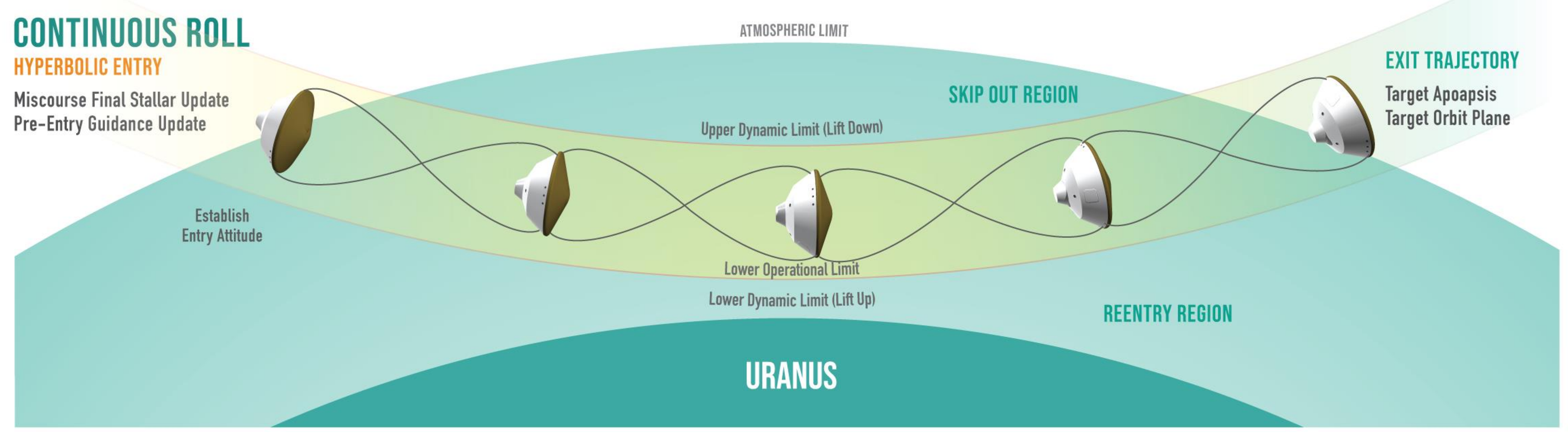
Aerocapture Analysis

- Interplanetary Trajectory with arrival V_∞ = 13.6 km/s and transit time ~ 8 years
- Targeting 4,000 x 550,000 orbit to enable Uranus moon tour campaign
- Aerocapture provides orbit insertion ΔV capability of 4.5 km/s within 15 minute flight time

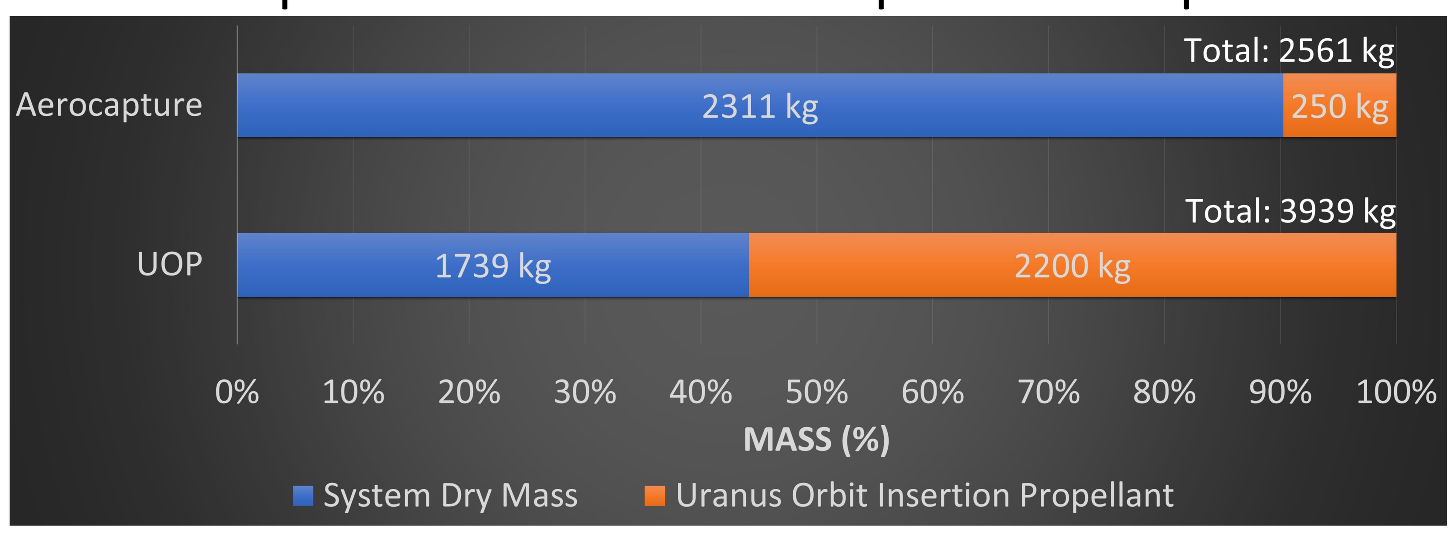




- MSL-derived aeroshell provides sufficient controllability over trajectory dispersions



- Monte Carlo simulations run to assess aerocapture performance and robustness
- Aeroheating environment within C-PICA capability (See J. Williams talk, Abstract 8123)
- 100% capture success rate with post-Aerocapture ΔV = 290 m/s



✓ Aerocapture adds 570 kg to system dry mass but saves 1950 kg in propellant mass

✓ **Aerocapture delivers same UOP payload mass to orbit while saving 1380 kg in total mass and reducing transit time by 40%**

References

1. National Aeronautics and Space Administration, "FY23 Early Career Initiative (ECI) Awards," https://www.nasa.gov/centers/ames/cct/eci-2023
2. National Academies of Sciences, Engineering, and Medicine. 2022. *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26522.
3. Program to Optimize Simulated Trajectories II (POST2): https://www.nasa.gov/post2