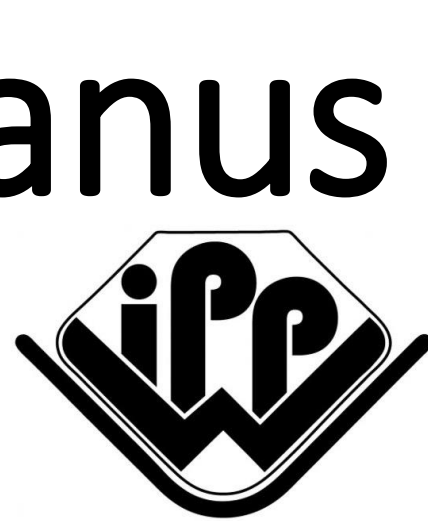
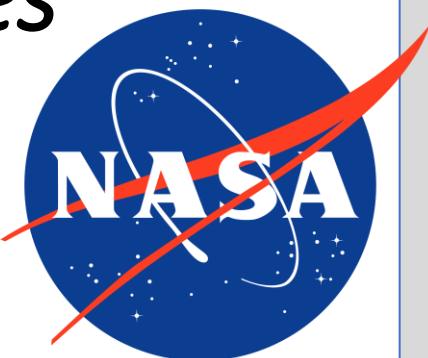


Aerocapture Trajectory Design for Uranus Orbiter

Abstract 14



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NASA Early Career Initiative

Background

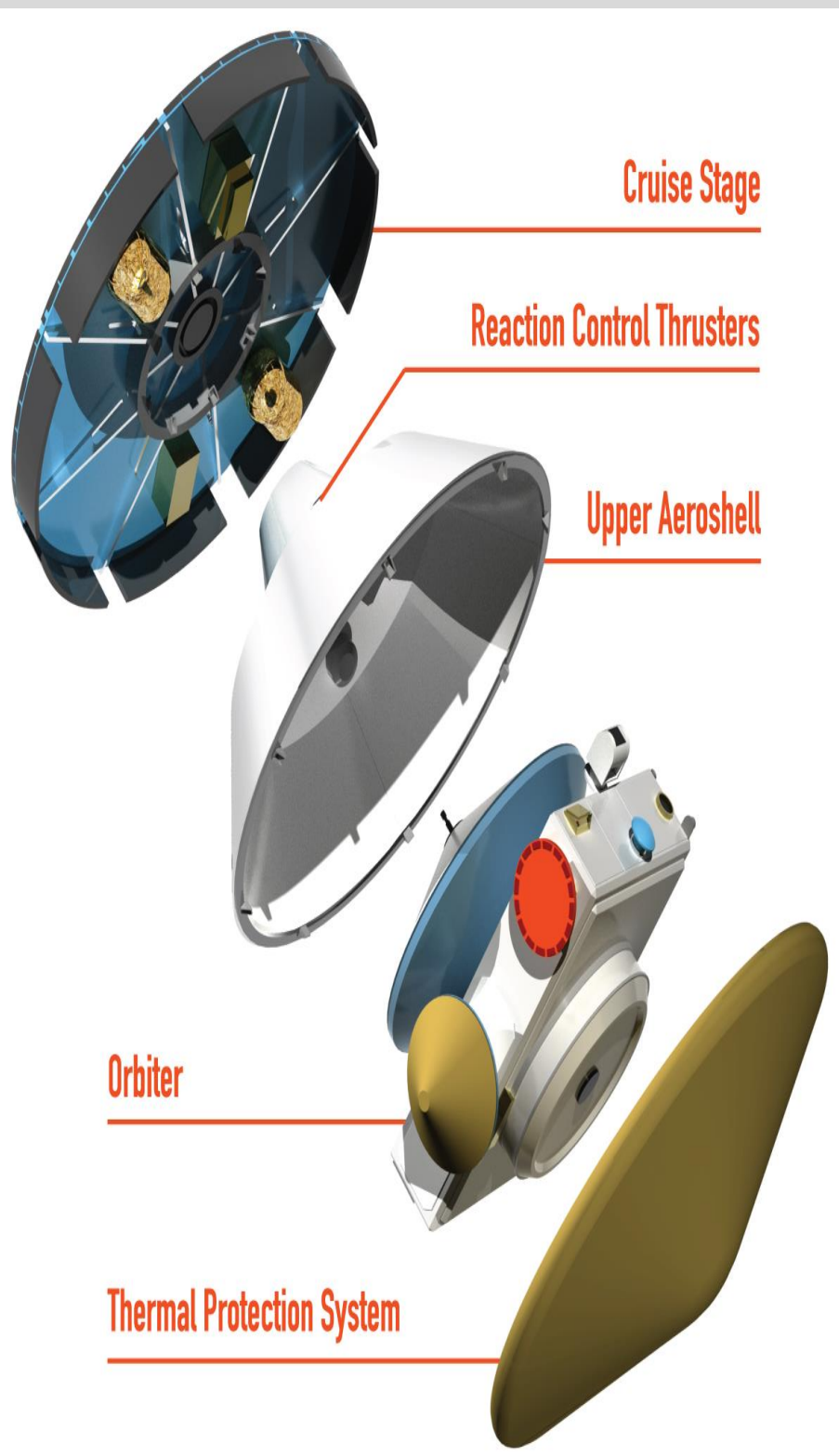
- Traditional fully-propulsive orbit insertion mission has transit time of 13 years and requires 60% of total launch mass allocated for propellant
- NASA Space Technology Mission Directorate is funding a two-year Early Career Initiative investigating Uranus aerocapture
- NASA Science and Space Technology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

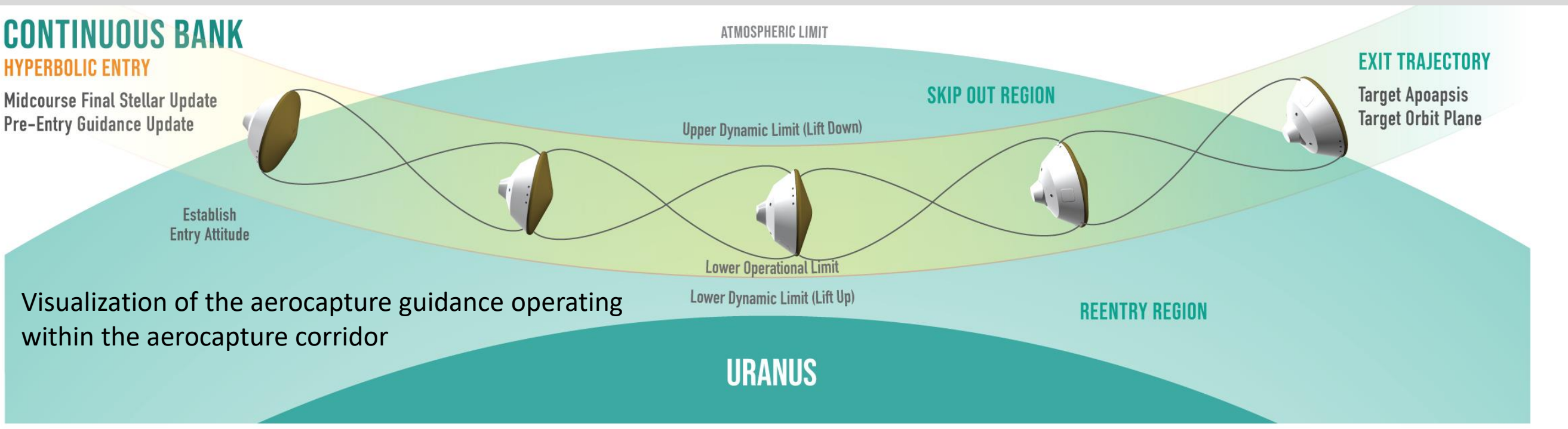
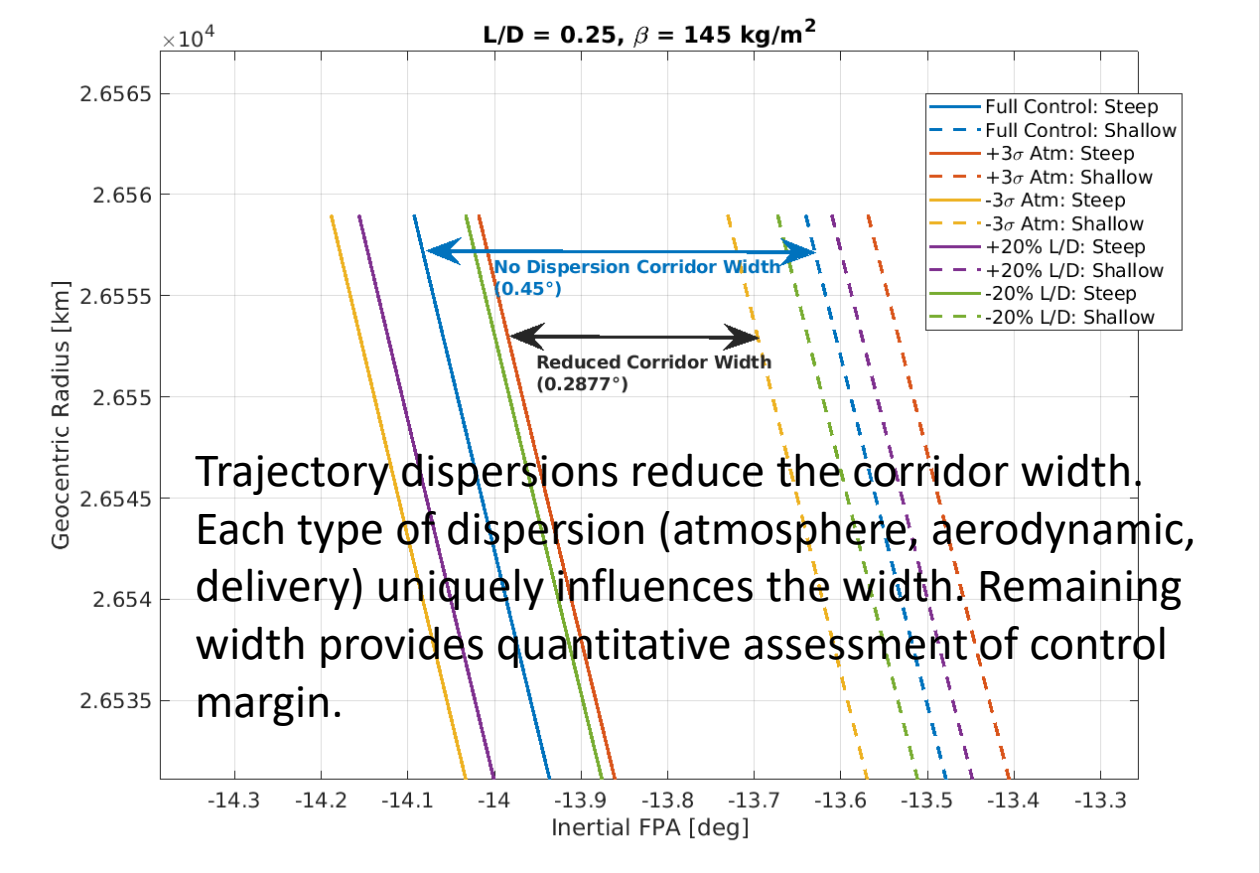
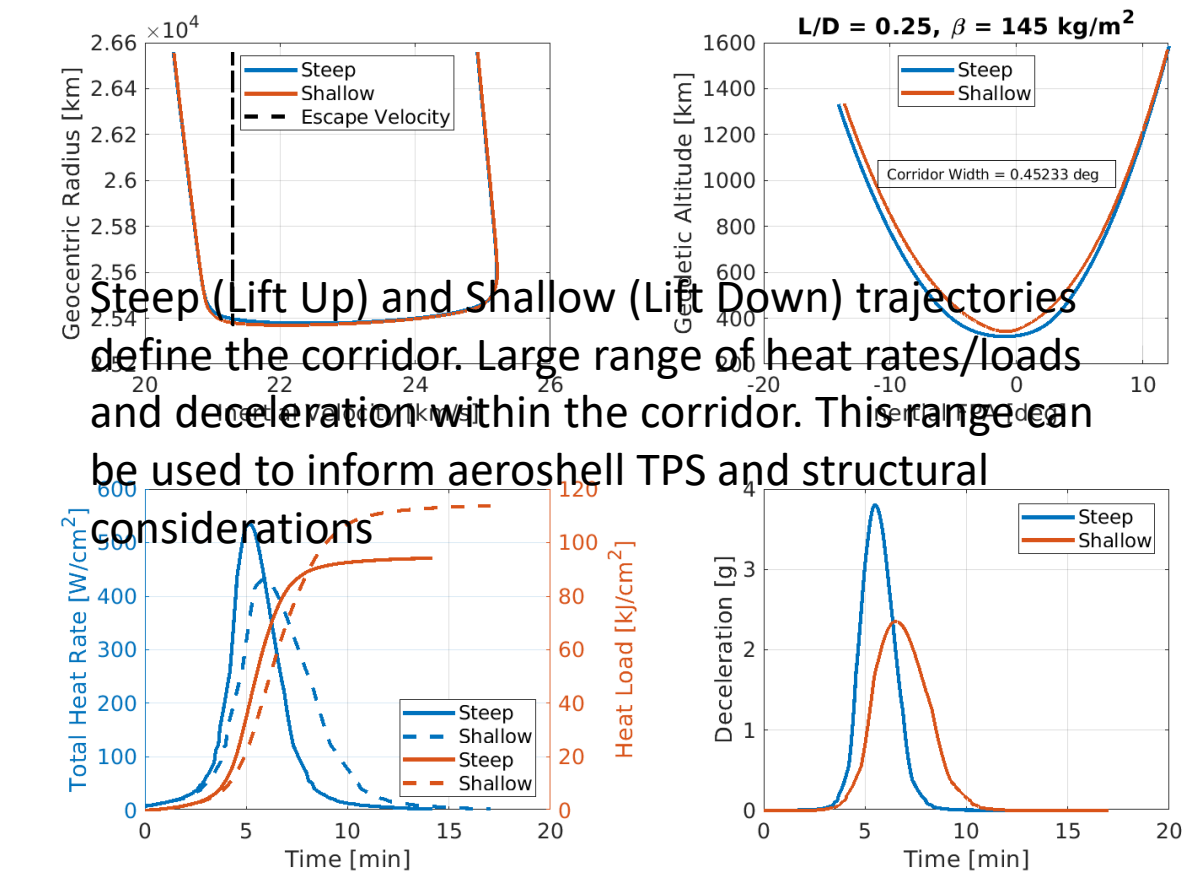
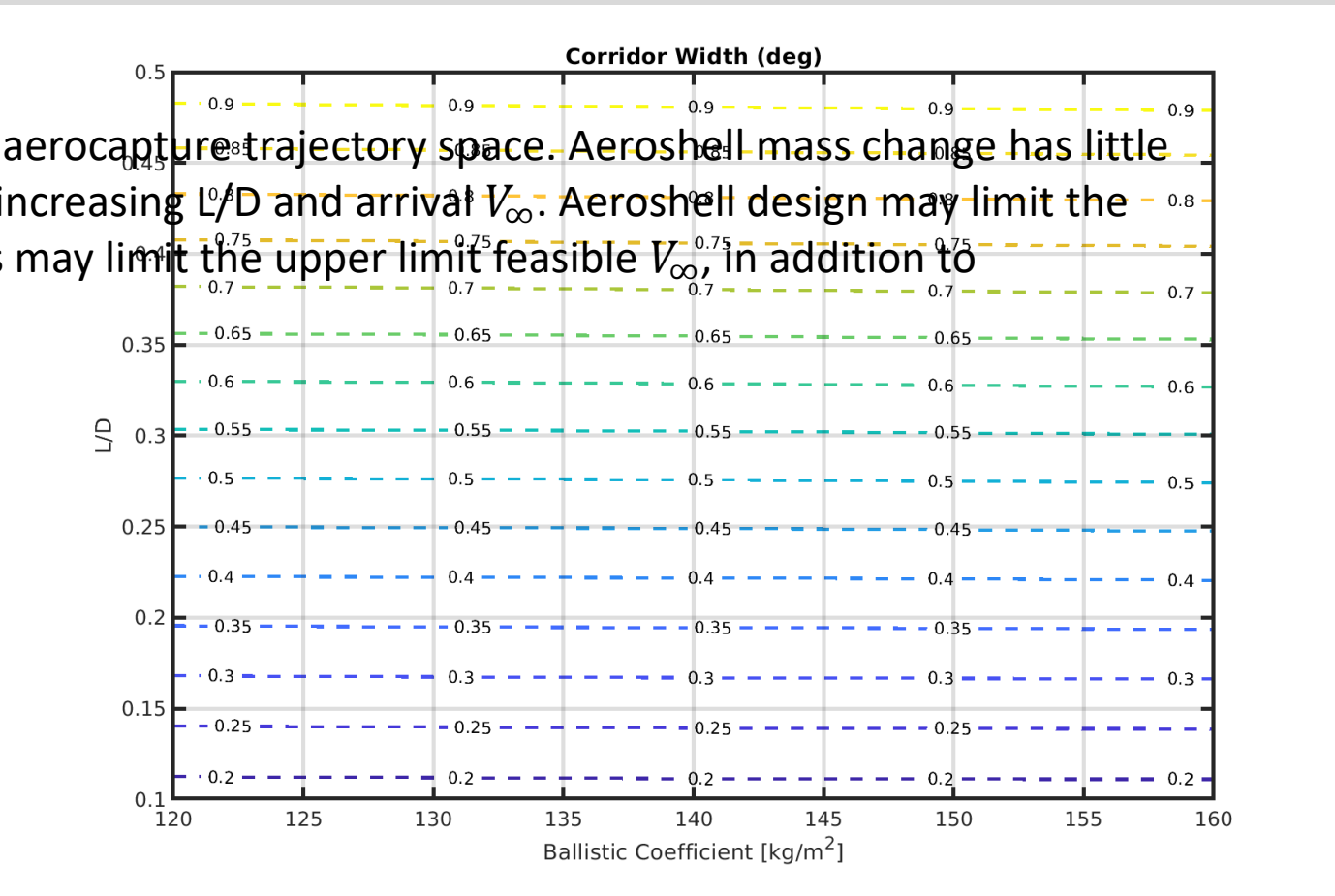
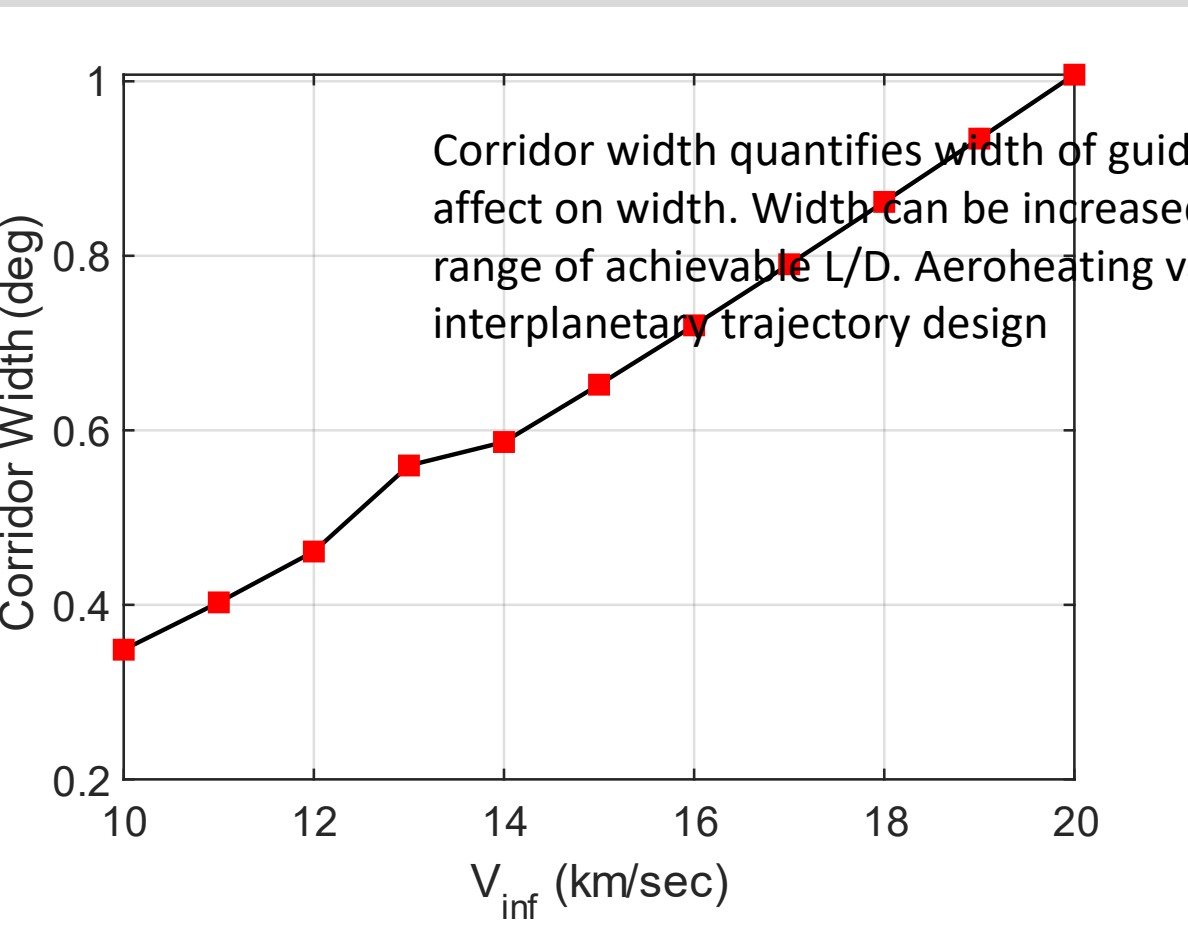
Vehicle Design Consideration

- 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/m²

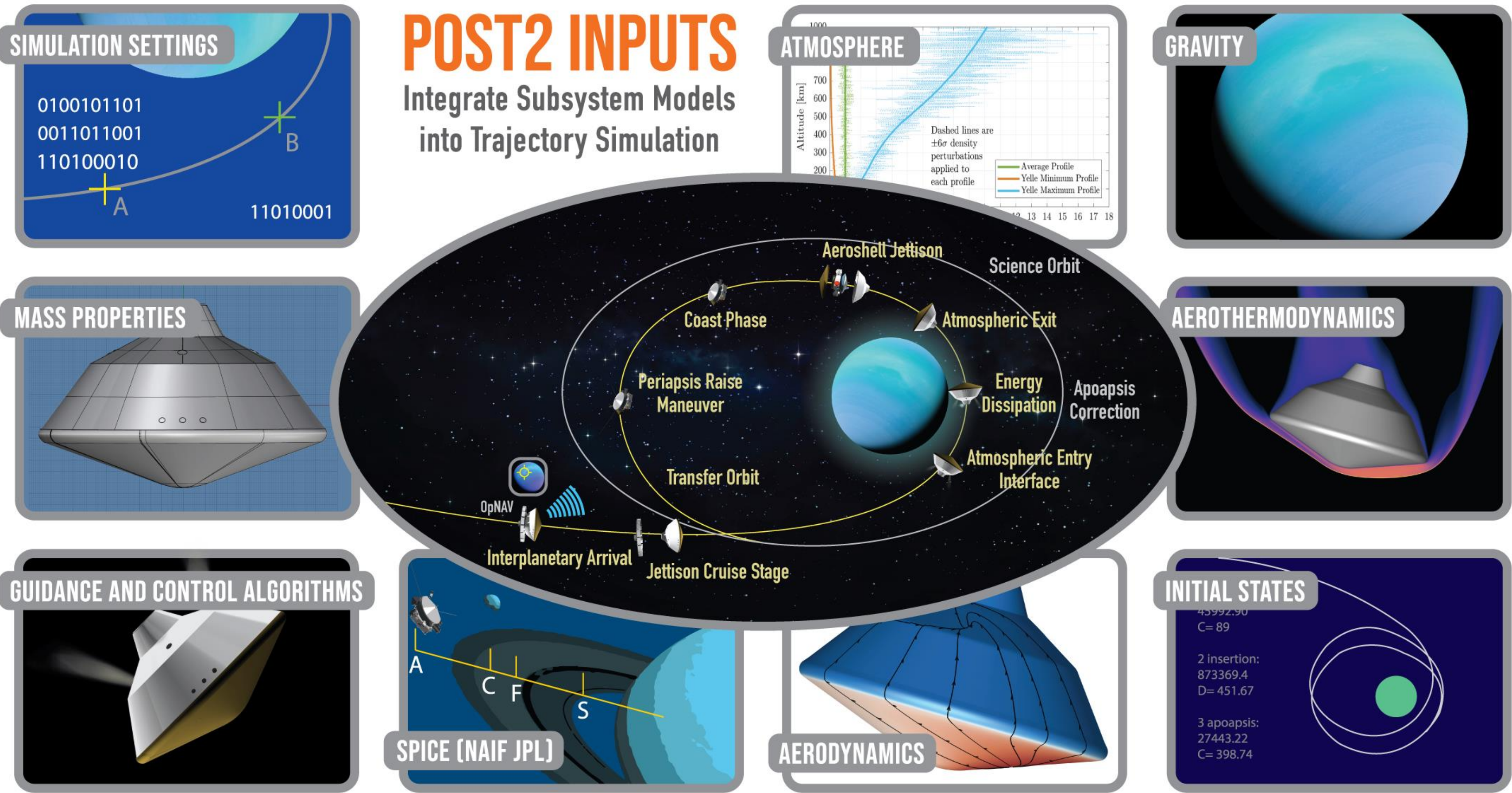


Parametric Aerocapture Trajectory Analysis

- Parametrization done to understand trajectory design space
- Understand how vehicle mass (ballistic coefficient), controllability (L/D), arrival trajectory (V_{∞}), and trajectory dispersions influence Uranus aerocapture
- Identify candidate designs for detailed analysis



Aerocapture Concept of Operations

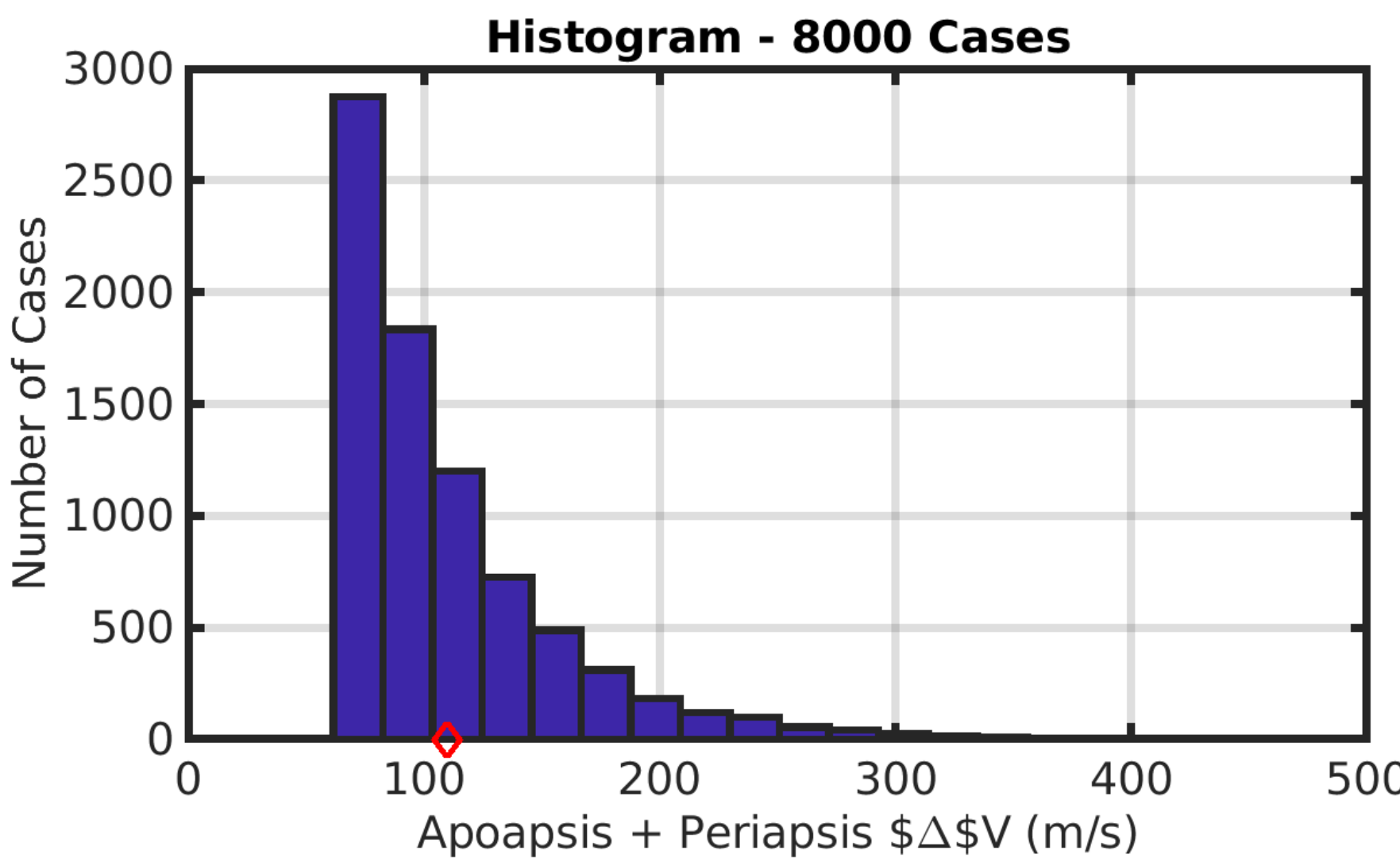
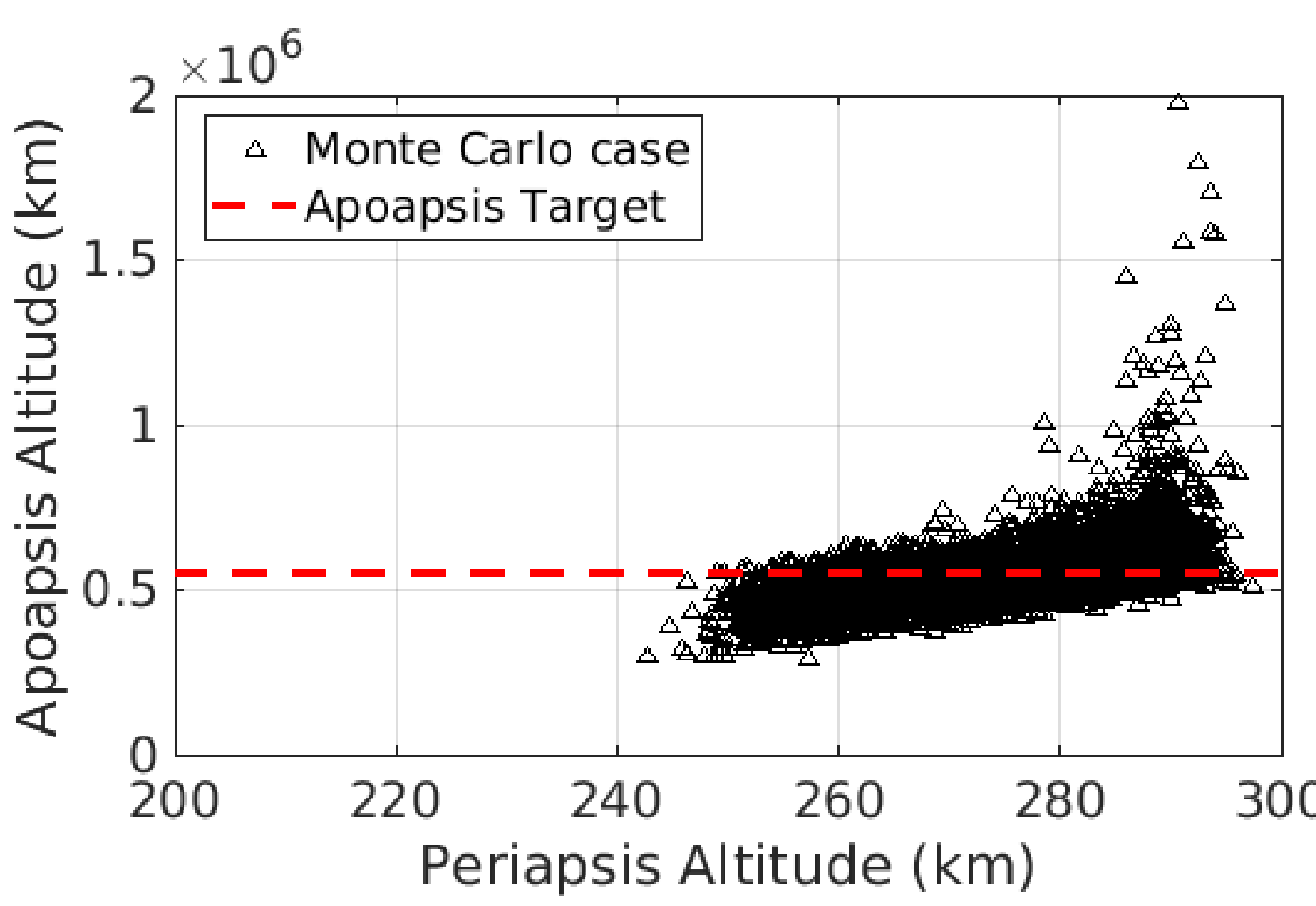
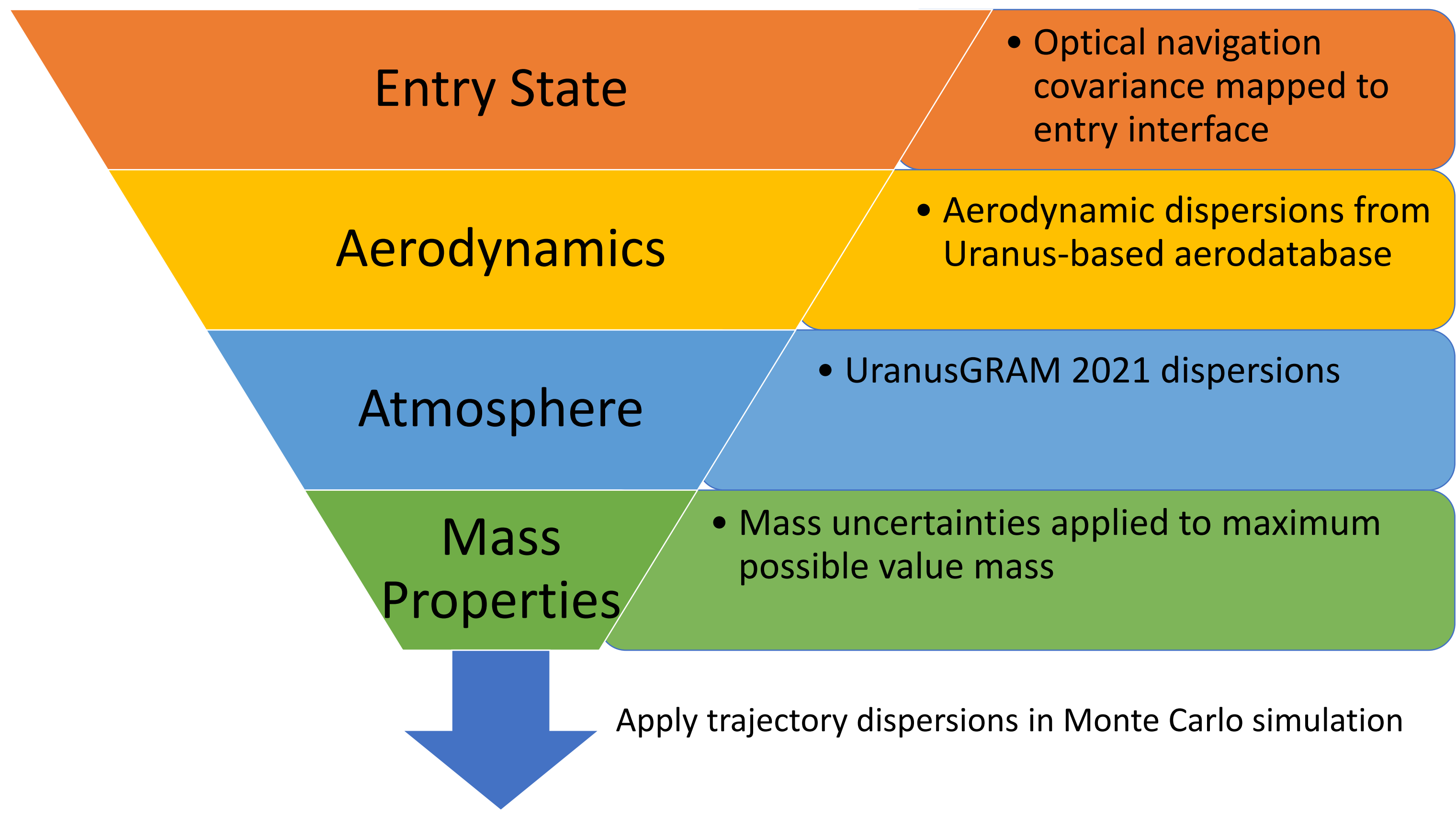


POST2 – Program to Optimize Simulated Trajectories II
Atmosphere – UranusGRAM 2021
Aerothermodynamics – Langley Aerothermodynamic Upwind Relaxation Algorithm
Initial States – Optical Navigation Entry State File

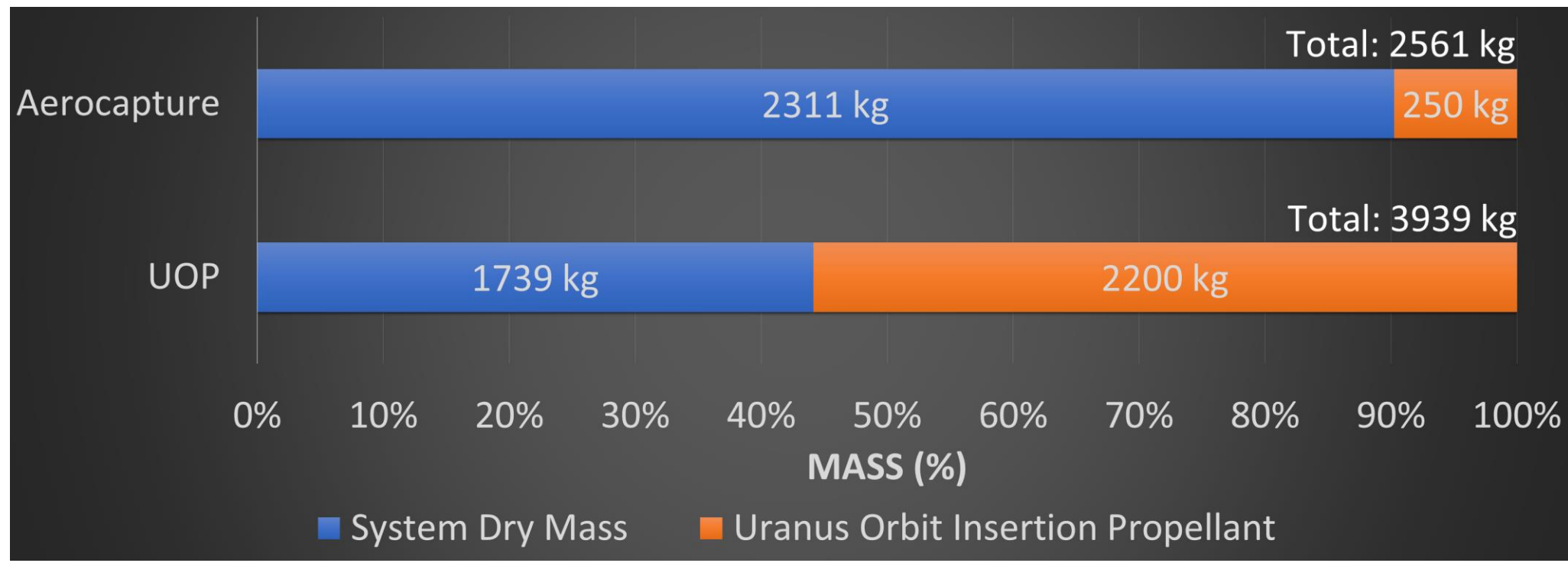
Aerodynamics – Uranus atmosphere developed aerodatabase
SPICE – Relevant Kernels (de430.bsp, ura111.bsp, naif0012.tls, pck00010.tpc)
G&C – Fully Numerical Predictor-Corrector Aerocapture Guidance, Bank Angle Control

Aerocapture Analysis

- Interplanetary Trajectory with arrival $V_{\infty} = 13.6$ km/s and transit time of 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
- Monte Carlo simulations run to assess aerocapture robustness to uncertainty



- MSL-derived aeroshell provides sufficient controllability over trajectory dispersions
- 100% capture success rate with post-Aerocapture $\Delta V = 290$ 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

- National Aeronautics and Space Administration, "FY23 Early Career Initiative (ECI) Awards," <https://www.nasa.gov/centers/ames/cct/eci-2023>
- 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>.
- Program to Optimize Simulated Trajectories II (POST2): <https://www.nasa.gov/post2>