Aerocapture Enabling Flagship-class Uranus Orbiter and Probe Mission

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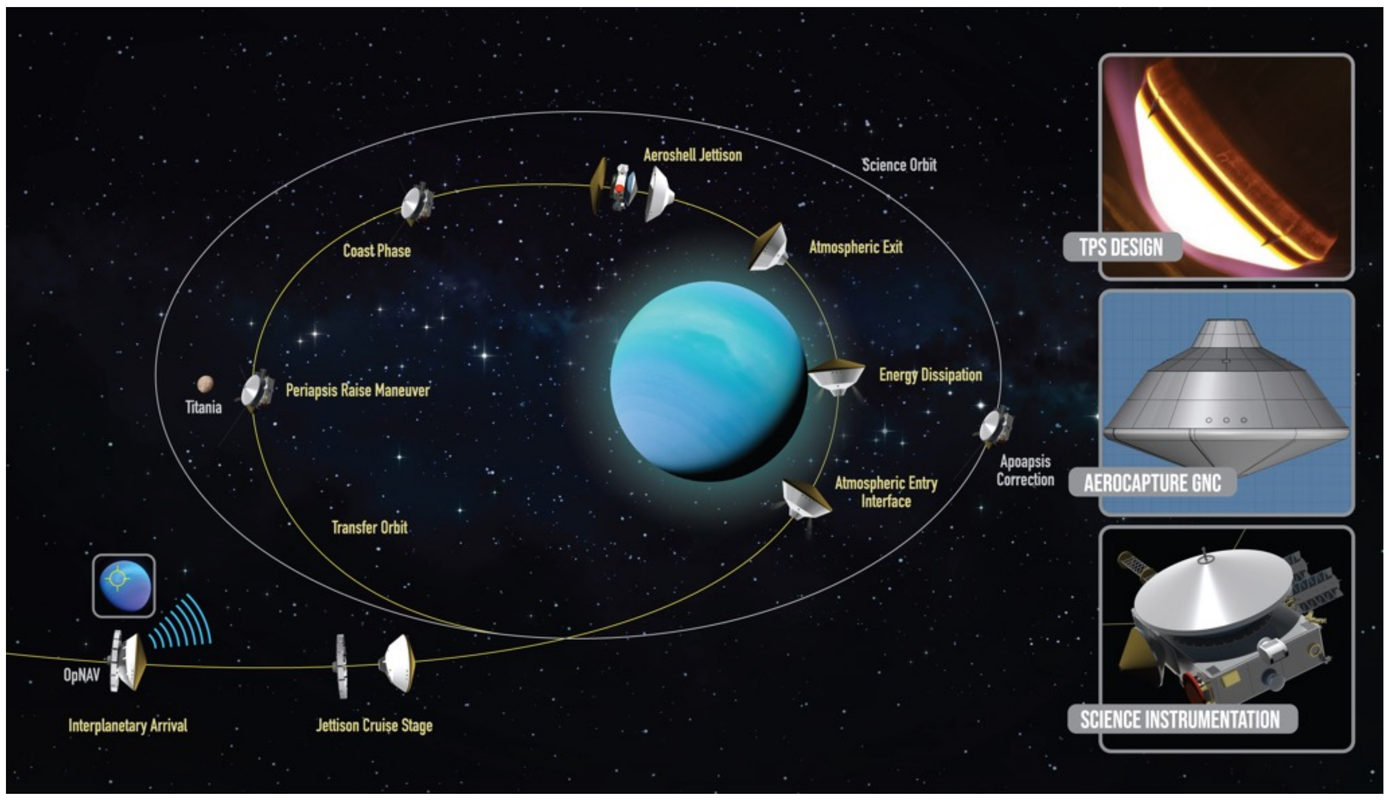
Background

- 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 (STMD) is funding a two-year Early Career Initiative investigating Uranus aerocapture in FY23-24
- STMD is pursuing a 2026 aerocapture technology demonstration mission at the request of NASA Science Mission Directorate

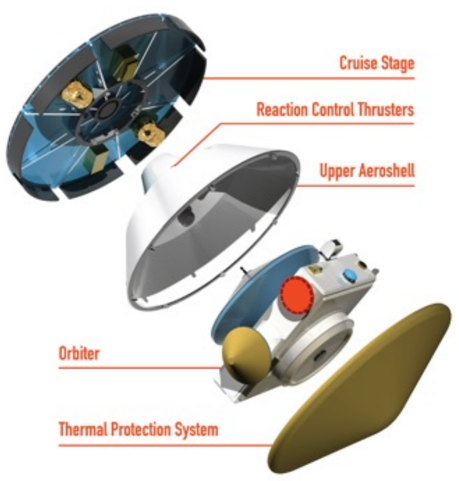
Merits for Aerocapture

- Uranus atmosphere can be utilized to provide the required change in velocity to capture into orbit (aerocapture)
- Reduces propulsion needs without significant mass increase associated with an aeroshell
- More delivered payload – less miniaturized instruments, probes
- Adaptable to changes in interplanetary trajectories and launch delays
- Offers launch opportunities in the late 2030s. New launch vehicles paired with aerocapture can significantly reduce trip times
- Can enable reduced cruise time and Phase E operations costs



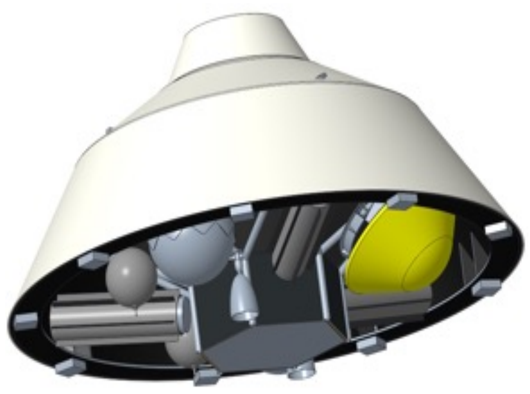
Aerocapture Vehicle

- Leveraging heritage entry technologies from Mars and Earth missions
  - 70 deg. sphere-cone (Mars 2020/Mars Science Lab)
  - 4.57 m aeroshell (within Falcon Heavy fairing diam.)
  - C-PICA Thermal Protection System (Venkatapathy poster)
  - Bank Angle Control with Reaction Control System (Orion/MSL)
  - Numerical Predictor-Corrector Guidance and Optical Navigation
  - L/D = 0.25, Ballistic Coefficient = 180 kg/m^2

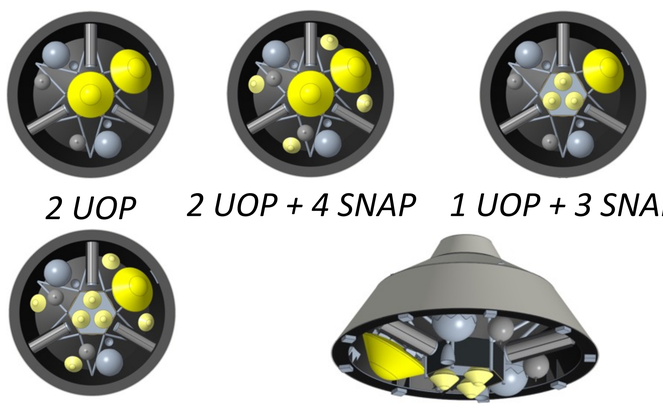


*L/D = Lift-over-drag
*C-PICA = Conformal Phenolic Impregnated Carbon Ablator

Science and Probe Accommodation



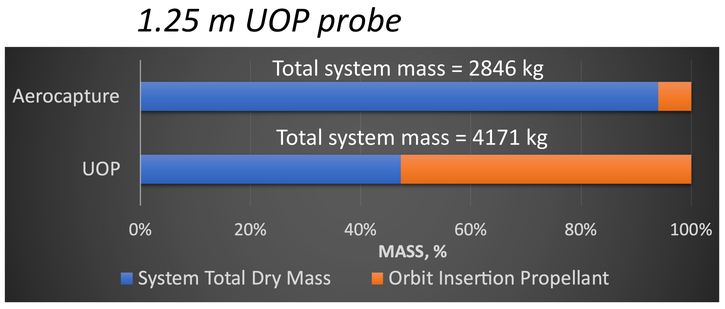
Baseline configuration with single 1.25 m UOP probe



2 UOP | *2 UOP + 4 SNAP* | *1 UOP + 3 SNAP*

1 UOP + 6 SNAP

0.5 m SNAP probe array added

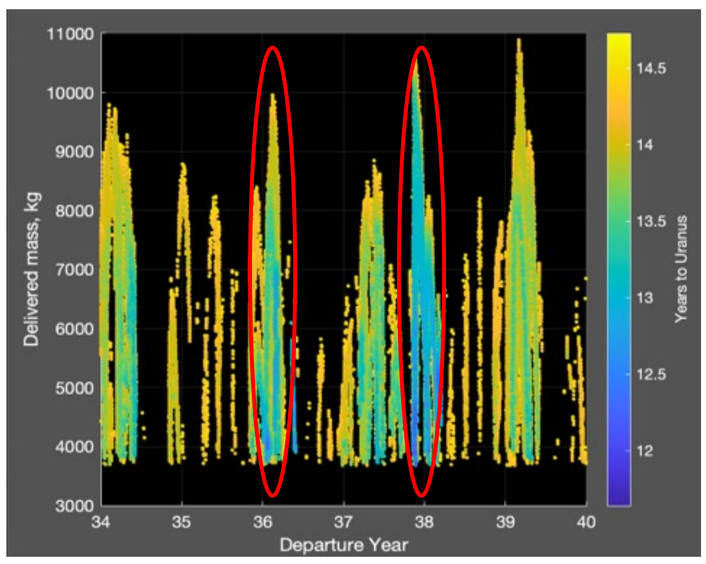


*SNAP = Small Next-generation Atmospheric Probe
*UOP = Uranus Orbiter and Probe

- Aerocapture adds 700 kg to system dry mass but saves 2000 kg in propellant mass
- Delivers same UOP payload mass to orbit
- Saves 1300 kg in total mass; reduces transit time by 40%

Interplanetary Trajectory Considerations

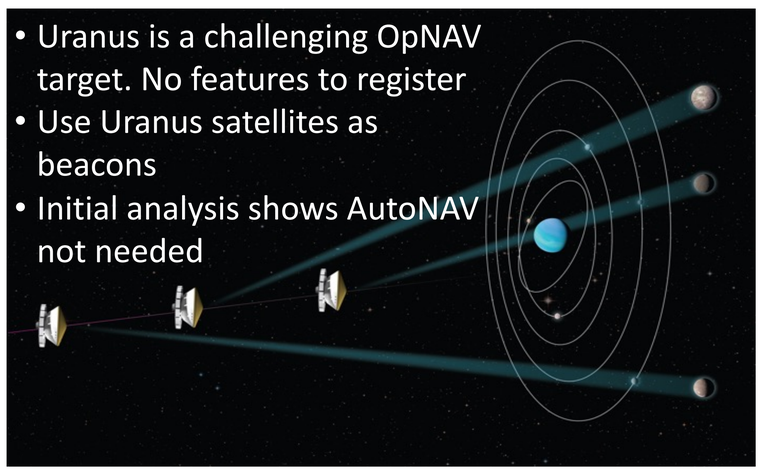
- Few trajectories utilize Jupiter fly-by near end of 2030s
- Aerocapture opens design-space for orbit insertion from faster arriving trajectories



	Launch Year 2036	Launch Year 2038
Delivery mass (kg)	5000	5000
Launch vehicle	Falcon Heavy Expendable	Falcon Heavy Expendable
Time of flight (years)	12.0	11.8
Trajectory	Venus-Earth-Mars-Earth-Uranus	Venus-Earth-Mars-Earth-Uranus
Fully-propulsive alternative time of flight (years)	14.7	14.2
Approach v_∞ (km/s)	9.0	9.0

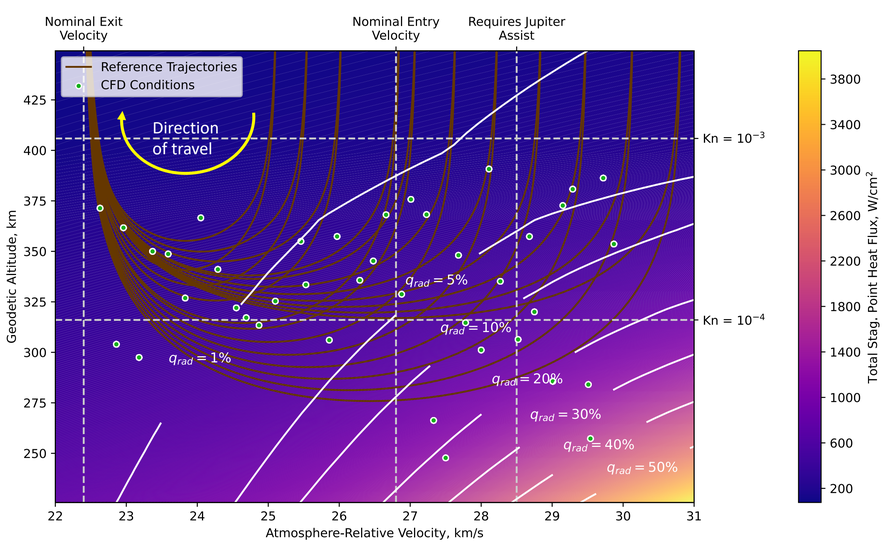
Interplanetary Navigation

- Uranus is a challenging OpNAV target. No features to register
- Use Uranus satellites as beacons
- Initial analysis shows AutoNAV not needed

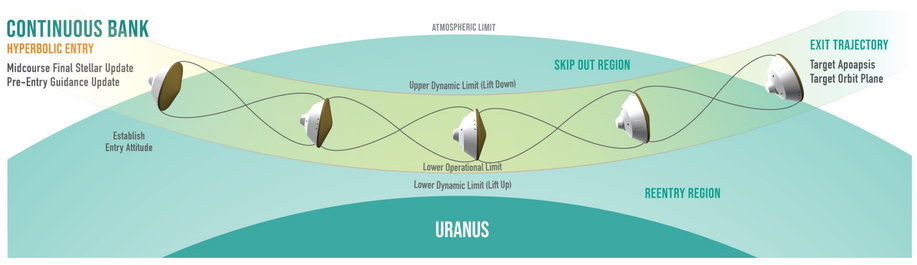


*OpNAV = Optical Navigation
*AutoNAV = Autonomous Navigation

Aerocapture Mission



- Captured into a 30-day orbit
- Aerocapture provides orbit insertion ΔV of 4.5 km/s in 15 minutes of flight time
- 99%+ capture success rate



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. Dutta, S., et. al, "Uranus Flagship-class Orbiter and Probe Using Aerocapture," AIAA 2024-0714, AIAA SciTech 2024, Orlando, FL, doi: 10.2514/6.2024-0714