Atmospheric Entry Studies for Uranus

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Objectives

- **Establish a range of probe atmospheric entry environments based on the Uranus Flagship mission outlined in the Planetary Science Decadal Survey for two launch windows: Year 2021 and 2034.**
- **Define Uranus entry trade space by performing parametric studies, by varying vehicle mass and size and entry Flight Path Angle (FPA).**
- **Investigate various trajectory options, including direct ballistic entry and aero-capture entry.**
- **Identify entry technologies that could be leveraged to enable a viable mission to Uranus that meets science objectives.**

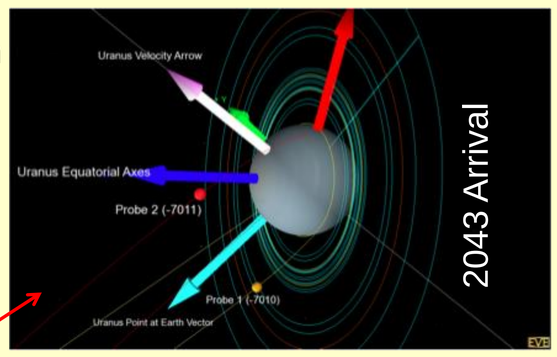
Orbital Mechanics

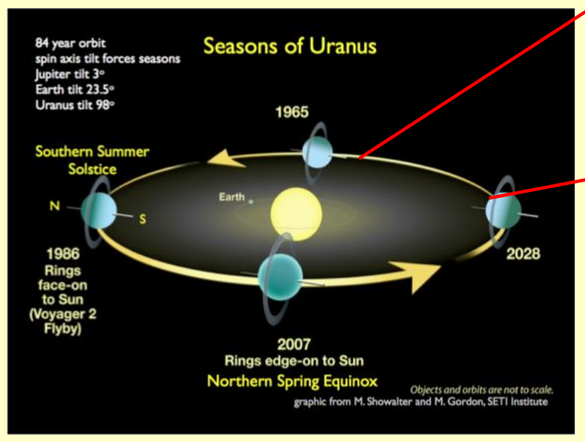
Target Entry Interface Radius: 28,474 km

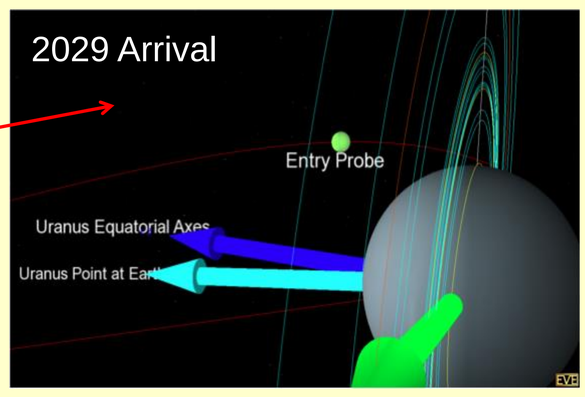
Flight Path Angle (FPA): -19.50^0

Entry velocity (V_E) for 2043: 21.96 km/s

V_E for 2029: 22.53 km/s



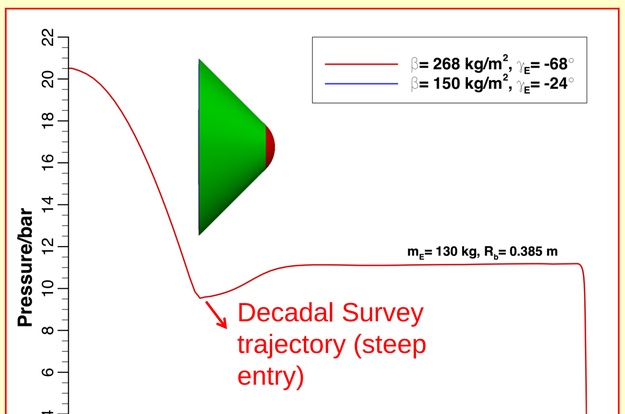




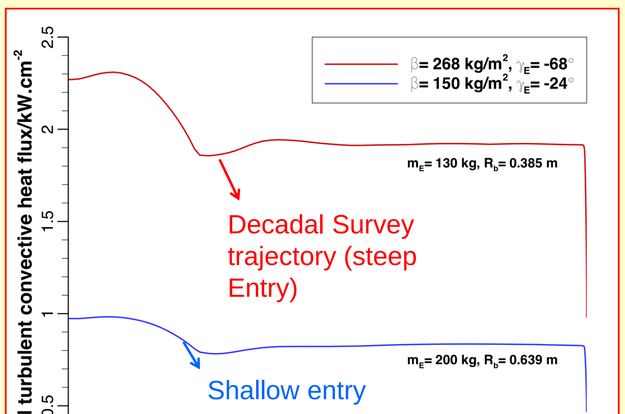
Uranus Orbit and Interplanetary Trajectory

- Earth-Jupiter-Uranus chemical propulsion trajectory was used.
- Various trajectory options were investigated for ring avoidance.
- Two arrival windows were selected for detailed entry trade analysis.

Direct Ballistic Entry



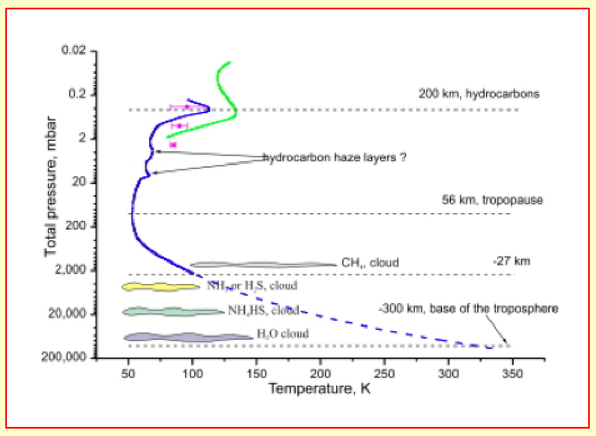
Pressure Distribution



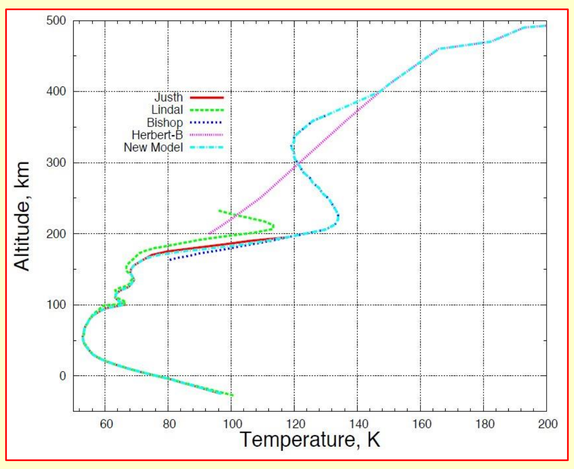
Heat flux Distribution

- For both 2029 and 2043 arrival a range of entry trajectories (several thousands) are generated by varying entry FPA (γ_e) for various ballistic coefficients.
- The entry trade space are generated with these trajectories.
- Suitable ranges for flight path angle for various ballistic coefficients (100kg/m^2- 300kg/m^2) are identified, based on G-load, skip-out and pressure constraints.
- Heat flux, heat load, pressure and shear load are estimated and TPS selection and mass calculations are performed.

Atmosphere



Thermal Profile

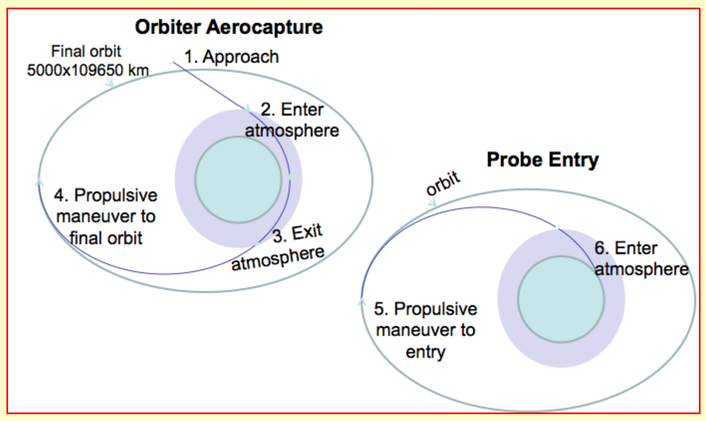


Temperature Variation with Altitude

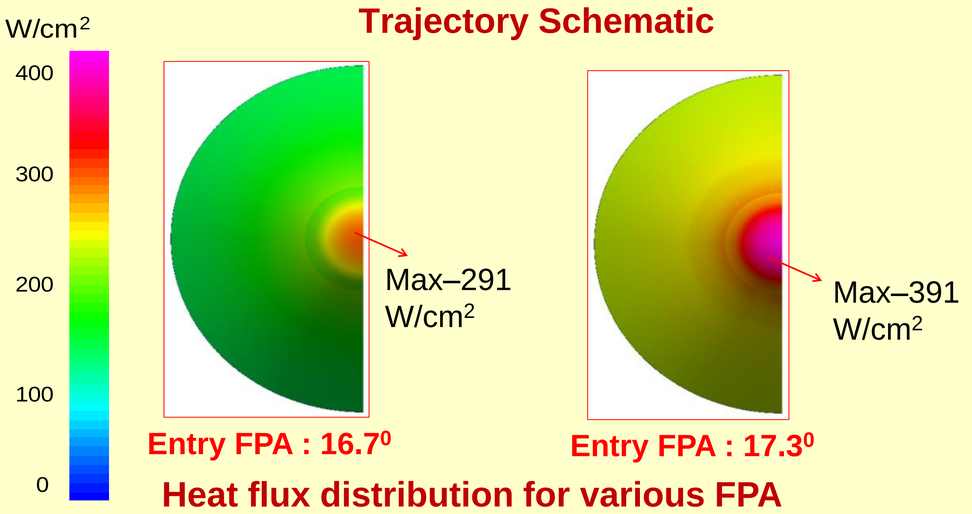
- The different published atmospheric models are stitched together to construct a “new engineering atmosphere model”.
- The ambient temperature at upper altitude is very high (800K); the phenomenon needs investigation.
- The upper atmosphere of Uranus is remarkably dense that influences the entry parameter.

Aerocapture

Aerocapture dissipates ~30% of the total energy



Trajectory Schematic



Heat flux distribution for various FPA

- Entry from orbit would facilitate the use of low density TPS like phenolic impregnated carbon ablator.
- Aerocapture has the potential to save mass as compared to Solar Electric Propulsion (SEP) orbit capture.

Note: Results from this study will be documented in a NASA-TM as well as published in an archival journal in year 2014.