Thermal Protection System Design of Aerocapture Systems for Uranus Orbiters

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The National Academies Planetary Science and Astrobiology Decadal Survey recently identified Uranus and Neptune - called Ice Giants - as the priority destinations for science[1]. The survey assessed both a mission to Uranus through the Uranus Orbiter and Probe (UOP) concept, and Neptune through the Neptune-Triton Odyssey concept and determined that Uranus is the highest priority for a Flagship class mission. The UOP mission will deliver an in situ probe and conduct a multi-year orbital tour of the system to meet the science objectives. While the Uranus mission is currently viable with launch windows starting in 2031 using existing launch vehicles, the mission has a long cruise time to destination (between 12 and 15 years) and would require more than half of its weight in fuel propellant to achieve the change in velocity necessary for orbital insertion.

Aerocapture is a method of orbital control that uses aerodynamic forces generated on a vehicle by the planet's atmosphere to modulate a spacecraft's trajectory, allowing mission designers to target the final orbital state. For the Uranus mission, using aerocapture for orbital insertion can decrease not only the cruise time to the destination by 2 - 3 years, but the propellant required to achieve orbital insertion (by more than 40%) which would, in turn, increase the available science payload and reduce the timeline for retrieving data vital to the mission's science objectives[2]. Achieving orbital insertion via aerocapture requires novel algorithms for Guidance, Navigation and Control[3], and mass-efficient Thermal Protection Systems (TPS) performing in a new atmosphere.

This paper will focus on the selection and tailoring of the Thermal Protection Systems for the forebody and aftbody heatshields of an aerocapture mission to Uranus. While preliminary results indicate that multiple systems in NASA's repertoire are capable of performing in the predicted aerothermal environment there are unique aspects like the inert environment that affect ablation efficiency, and the heatload for aerocapture trajectories to the outer planets are among the highest of any mission to-date[4]. These two factors may impose operational requirements to heatshield separation in order to minimize thermal soak to the payload, and may demand TPS thickness and configurations that have not yet been demonstrated. This paper will discuss the updated maturity, manufacturing, and performance capabilities of candidate thermal protection systems, with specific areas of need highlighted to make thermal protection systems viable for use in the recommended Uranus Orbiter and Probe mission.

References

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