Enabling In-Situ Exploration of the Ice Giants Using Aerocapture. S. Dutta[1], [1]NASA Langley Research Center, 1 N. Dryden St., MS 489, Hampton, VA 23681, soumyo.dutta@nasa.gov.

Introduction: Investigation of the Ice Giants, especially Uranus, via orbiter and atmospheric probes, is required to answer pressing science questions that have been raised in the latest Decadal Survey [1]. As the Ice Giants are the farthest planets from Earth, traditional fully-propulsive orbit insertion missions have transit times to the planetary bodies nearing 13-15 years [2,3] and require a large amount of propellant, leaving less mass for the scientific payload and a planetary probe (dry mass percentages of around 30-40%) [2,3]. Aerocapture uses aerodynamic forces generated by flight within a planetary atmosphere to decelerate and achieve orbit insertion. Although, aerocapture has not been used in the past, recent developments in thermal protection systems (TPS), guidance and control, and interplanetary navigation capabilities enable the use of rigid, heritage entry vehicle configurations already flown at other planetary bodies for Ice Giants aerocapture. Aerocapture can robustly deliver spacecraft to Ice Giant orbits, while substantially increasing on-orbit payload mass (more than 40%) [4,5] that can be used for a robust atmospheric entry probe. Additionally, the aerocapture maneuver would reduce the interplanetary transit time by 2-5 years (15-30%) relative to fully-propulsive orbit insertion [4,5].

Aerocapture Basics: Aerocapture is an atmospheric maneuver where the aerodynamic forces of the vehicle (lift and drag) are used to provide the change in velocity (ΔV) needed to slow down from the approach hyperbolic trajectory to achieve the desired captured orbit around the target planet. The aerodynamic orbit insertion maneuver provides a large savings in propulsion needed to change the velocity of the vehicle, since aerodynamic forces rather than propulsive systems provide majority of the change in velocity. Aerocapture requires an integrated system level design, including TPS, actuator systems for aerodynamic modulation, and autonomous guidance and control systems.

Benefits of Aerocapture: Aerocapture benefits are destination dependent, but large payload mass savings occur for the Ice Giants planets. Due to the large hyperbolic velocities of interplanetary trajectories approaching Uranus and Neptune, large amount of propulsion (approaching 1000 m/s of ΔV) must be used to put a spacecraft in science orbits around these planets with traditional means of orbit-insertion [2,3].

Aerocapture can reduce the propulsion needs by dissipating energy in the sizable atmospheres of Uranus and Neptune without a significant mass increase due to the need of an aeroshell. The 40% mass savings [5] could be used to reduce the launch vehicle requirements, add additional science instrumentation on the orbiter, or create a robust suite of instrumentation on an atmospheric probe.

Additionally, since aerocapture performance is relatively insensitive to increases in hyperbolic excess velocity, the interplanetary trajectory can be designed to arrive at the Ice Giants faster, reducing the interplanetary transit time and operations cost [5, 6]. Aerocapture could potentially help fit a larger class mission within a smaller cap, e.g. a Flagship-class orbiter mission in a New Frontiers class cap.

Enable In-Situ Exploration: Aerocapture orbital-insertion offers some key benefits for in-situ exploration of the Ice Giants. Recent work has shown that co-delivery of an atmospheric probe with the orbiter inserted via aerocapture promises precise delivery of in-situ probes to scientifically interesting points at the Ice Giants with minimal fuel use even under large interplanetary navigation uncertainties [7]. The precise delivery of in-situ probes might not be feasible with fully-propulsive orbit insertion techniques.

Moreover, since during aerocapture the vehicle will dip into the planetary atmosphere and will have a low initial periapsis altitude, orbit insertion using this maneuver naturally allows mission designers to target science orbits with low periapsis altitudes, which are useful for ranging and remote sensing operations. The dip into the atmosphere during aerocapture orbit insertion also provides opportunity for scientific instruments to get novel in-situ measurements.

Summary: This talk will consider the merits of including aerocapture as the orbit-insertion mechanism for an Ice Giants mission. Specifically, the implications of aerocapture orbit insertion for in-situ atmospheric probes will be discussed.

References: [1] "Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032," (2022). [2] "Journey to an Ice Giant System: Uranus Orbiter & Probe", (2021). [3] "Neptune Odyssey: Mission to the Neptune-Triton System," (2020). [4] Dutta, S., et al, (2021) *Bulletin of the AAS*, Vol. 53, No. 4, #046. [5] Lockwood, M.K. et al, (2006), *NASA* TM-2006-214291. [6] Girija, A.P., et al, (2020) *JSR*, Vol. 57, No. 6, 1186-1203. [7] Albert, S.W., et al, (2022), *JSR*, Vol. 59, No. 1, 19-32.