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Exploring the Ice Giant Systems: Science Objectives and Mission Requirements

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The Ice Giant planets, Uranus and Neptune, are priority targets for future exploration. These poorly understood systems have each been visited only once, in the 1980's, by a flyby spacecraft. They are important because they challenge our understanding of how planets form and evolve (no satisfactory theory exists to explain their composition and release of internal energy), unique physical properties are on display in their rings, satellites, and magnetospheres, and because ice giants are common around other stars. In preparation for the next U.S. Planetary Science Decadal Survey, NASA and ESA undertook a mission study, whose complete report is available at https://www.lpi.usra.edu/icegiants/mission_study/.

This study identifies the two highest-priority science objectives for future missions as
• Constrain the structure and characteristics of the planet's interior, including layering, locations of convective and stable regions, internal dynamics.
• Determine the planet's bulk composition, including abundances and isotopes of heavy elements, He and heavier noble gases.
Ten additional objectives are identified, all considered of equal priority.
• Improve knowledge of the planetary dynamo.
• Determine the planet's atmospheric heat balance.
• Measure planet's tropospheric 3-D flow (zonal, meridional, vertical) including winds, waves, storms and their lifecycles, and deep convective activity.
• Characterize the structures and temporal changes in the rings.
• Obtain a complete inventory of small moons, including embedded source bodies in dusty rings and moons that could sculpt and shepherd dense rings.
• Determine surface composition of rings and moons, including organics; search for variations among moons, past and current modification, and evidence of long-term mass exchange / volatile transport.
• Map the shape and surface geology of major and minor satellites.
• Determine the density, mass distribution, internal structure of major satellites and, where possible, small inner satellites and irregular satellites.
• Determine the composition, density, structure, source, spatial and temporal variability, and dynamics of Triton's atmosphere.
• Investigate solar wind-magnetosphere-ionosphere interactions and constrain plasma transport in the magnetosphere.
The study finds that Uranus and Neptune are equally compelling science targets, and does not rank one as more important than the other. Each planet has things to teach us which the other cannot, however, so ultimately both systems must be explored.

The study investigated many mission architectures and finds that to achieve these objectives requires a well instrumented orbiter making multiple flybys of each major satellite and dropping an atmospheric probe into the planet. The study does not recommend a specific payload, but discusses a range of possible instruments and suggests an orbiter payload of 150 kg is needed. A payload of that size could accommodate cameras, a magnetometer, spectrometers covering various wavelengths, and an in situ particles and fields suite. The spacecraft could also accommodate a new technology instrument (such as a Doppler Imager for detecting planetary oscillations as a

probe of interior structure) should a future science team desire it.