



## **Ice Giant System Architectures: Ramifications for In Situ Science Investigations**

Thomas R. Spilker

Monrovia, CA, United States (planetaryflightarchitect@yahoo.com)

Despite many close similarities between Uranus and Neptune, those planets' systems have some very different architectural elements, such as their positions and orientations in the solar system and the characters of their satellite and ring systems. For instance, Neptune's average heliocentric distance is more than 10 AU larger than Uranus's, and Uranus's  $97^\circ$  obliquity is radically different from Neptune's more Earth-like  $28^\circ$ . These differences have significant ramifications for the architectures of scientific flight missions to those planets, for in-situ investigations and platforms that are parts of those missions, and for technologies key to enabling those investigations.

This paper will include descriptions of the architectures of the Uranus and Neptune systems, emphasizing characteristics that drive science mission architectural options and associated key technologies. The challenge of delivering a flight system of useful mass to the destination ice giant is a significant part of the architectural trade because this limits the mass available for an in situ platform. That delivered mass capability is generally a function of the project's budget (among other influences such as launch date), and the scientific value of the mission typically grows quickly as delivered mass increases. As the tremendously successful Cassini-Huygens mission demonstrated, international collaboration can be a significant avenue for maximizing a mission's scientific value, capitalizing on the combined resources of multiple nations and institutions.

This paper will describe several architectural options (e.g., spacecraft architectures, orbit designs, communications options), with a focus on delivering and supporting in situ platforms and their scientific investigations. This will include brief summaries of results from the NASA-led Ice Giant Missions study of 2016, the NASA-sponsored SNAP study of 2017, and the In Situ Exploration of the Giant Planets Workshop held in Marseille, France in February of this year.