**QUEST: A NEW FRONTIERS URANUS ORBITER CONCEPT STUDY.**

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**Introduction:** The ice giants, Uranus and Neptune, represent a distinct class of planet from the gas giants, but compared to Jupiter and Saturn these bodies have been largely unexplored. Uranus, with its exotic magnetic field, strangely hot stratosphere, anomalously low heat flux, and mysterious interior, serves as an extreme environment in which we can test hypotheses for the way our solar system operates [1]. To understand the conditions necessary to produce the observed diversity of planets in our solar system and beyond, it is imperative that we return to this frozen frontier. In the following sections we present the results of a New Frontiers Uranus orbiter concept study carried out during the 30$^{th}$ Annual NASA/JPL Planetary Science Summer Seminar.

**Science Objectives:** This mission concept would directly address two of the highest priority objectives as described for an Ice Giant Flagship class mission in the most recent decadal survey [2]. The major goals of the QUEST mission are to understand dynamos that drive magnetospheres in the solar system and beyond and to determine the relationship between the ionic environment, thermal environment, winds and deeper thermal-compositional structure of Uranus' interior in contrast with the other giant planets. QUEST would achieve these goals through the following science objectives:

1. Resolve between dynamo models for the generation of the magnetic field
2. Establish whether surficial winds and the banded structure of Uranus' upper atmosphere are related to deeper internal dynamics
3. Determine the explanation for Uranus' low thermal emission compared with Neptune and the other giant planets
4. Verify the prediction that Uranus' magnetic field opens and reconnects daily, and determine if this results in heating of the stratosphere

**Instruments:** The QUEST spacecraft will carry a suite of five instruments: a magnetometer, microwave radiometer, plasma wave receiver, radio antenna, and visible light Wide-Angle Camera (WAC) with a methane filter.

*MAGIC:* The magnetometer, Magnetometer Investigations of an Ice Giant, will measure magnetic field and orientation.

*PRESTO*: The plasma wave receiver, Plasma-wave Receiver Exposing Structure of the DynamO, is necessary to remove confounding variables from plasma waves in the Uranus environment to accurately interpret the global 3-D magnetic field map.

*MIRROR*: The MIcRowave RadiOmeteR will probe the deep atmosphere by providing data on spatial cloud structure, gas volume mixing ratios, and patterns in global circulation.

*RadiAnt*: The Radio Science Antenna is used to transmit and receive radio signals in X and Ka bands to and from Earth allowing us to obtain atmospheric temperature, pressure, and density profiles as well as measurements of the gravitational moments of Uranus.

*WAND*: The Wide-Angle methaNe Detector will investigate the upper atmosphere and provide data about methane abundance in the stratosphere.

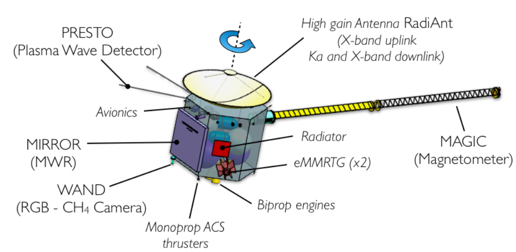


**Figure 1:** QUEST spacecraft potential configuration.

**Mission Design:** In this concept study, QUEST would launch in May 2032 on an Atlas V 551 rocket, undergo an Earth-Deep Space Maneuver-Earth-Jupiter-Uranus trajectory, and arrive at Uranus in May 2045. Figure 2 shows the key events and dates for the selected trajectory.

A selected inclination of ~80 degrees was driven by our science objective requirements as well as additional constraints emanating from ring plane crossing hazard. The orbit periapsis of 1.1 Ru lies within the rings and the inclination was chosen such that the node crossings fell in designated gaps within the ring plane which were deemed safe by the risk and programmatics team. The prime mission of 1 year starting from arrival date at Uranus allows nine 30-day orbits with 1.1 Ru periapsis.

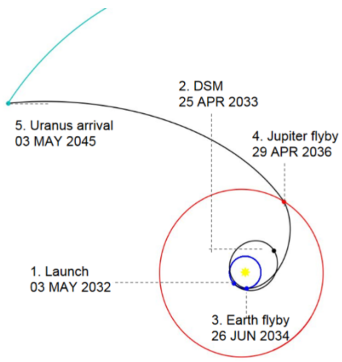


**Figure 2.** Potential 13-year E0EJU trajectory selected for the mission concept (0 indicates DSM).

**Systems:** The QUEST spacecraft concept is designed as a spin-stabilized spacecraft powered by two Enhanced Multi-Mission Radioisotope Thermoelectric Generators (eMMRTGs) providing 220 W after 14 years (EOM). A dual-mode chemical bipropellant system propels the spacecraft and the thermal system is designed to maintain the internal electronics, propulsion module, propulsion lines, and thruster packs within operating temperatures throughout the mission. The bus, containing the propulsion module and electronics, is actively heated from excess heat from the two eMMRTGs totaling 120W and passively cooled via Louver-covered radiators that are sized to dump 320W of heat at UOI.

**Cost, Schedule and Risk:** The guidelines for the 2018 PSSS included a cost cap of $900 M based on the New Frontiers 4 AO [3] inflated to FY18$ with 30% reserves (AO requires 25%). A probability-based estimate from our Team X study placed the total cost for mission development (Phases A-D) at $857M, providing nearly $50M of flexibility for improvements to the instrument suite. Figure 3 shows the preliminary schedule for our mission concept.

Our proposed avionics system is the latest generation of JPL technology, but it is currently TRL 6. The system, Sphinx [4], has been tested for two Class B missions, and our plan to mitigate this risk includes completion of Class A ground-based testing before PDR (03/2029). We also include a TRL 5 beam splitter on MIRROR, and we have allocated $3 M in Phase B to ensure it matures to TRL 6 by PDR, and switches are possible as back-ups.

**Conclusions:** We have described a concept for a flexible, low-cost mission to a nearly unexplored class of planet in our solar system. The implementation would be simple with no moving parts, no articulations, and would consist of standard engineering based on similar successful missions to the outer solar system. We have healthy cost and mass margins allowing for flexibility in future trades including the addition of a donated probe, improvements to the instrument suite, and modifications to our orbital precession to achieve higher quality gravity science measurements. This mission concept is designed to explore one of the most complex magnetospheres in the solar system, the processes of which are critical to understanding how these planetary shields protect the formation and sustainment of life. The mission concept also seeks to unravel the intimate coupling between Uranus' chaotic magnetic field with its deep dynamo generating layer thought to be an ionic ocean composed of supercritical water. Though ice giants are considered the most common class of planet in our galaxy [5], we know so little about them. QUEST's aim is to delve past Uranus' placid exterior to reveal its roiling, dynamic world below.

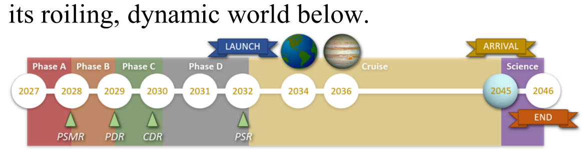


**Figure 3.** Conceptual timeline for QUEST development and mission.

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**Acknowledgments:** This work would not be possible without the NASA-JPL PSSS program; its mentors Charles Budney and Karl Mitchell; administrators Leslie Lowes and Joyce Amijo; and volunteer review panel/TeamX members. This research received JPL funding, under contract with NASA.