**OCEANUS: A Uranus Orbiter Concept Study from the 2016 NASA/JPL Planetary Science Summer School**


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**Why an Ice Giant Mission?**
- The need to explore the ice giants is imperative - they are the least-explored class of planet. The structure and composition of these planets differ significantly from the gas giants. Current interior models disagree with models of solar system formation on the expected size of the core. The unique magnetic field orientations and dynamo generation have not been well characterized.
- Voyager 2 in the 1980s is the only spacecraft to have visited the ice giants. It visited Uranus close to southern summer solstice, which will occur again in 2070. To obtain new seasonal data (especially important due to Uranus’ high obliquity), the next mission should arrive well before 2070.
- Ice giant-sized planets are the most numerous type of exoplanet discovered, making Uranus and Neptune the exoplanet analogs in our own solar system.

**OCEANUS (Origins and Composition of the Exoplanet Analog Uranus System) was designed to explore the origins and evolution of planetary systems by studying Uranus’ interior structure, magnetosphere, and atmosphere.**

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**Science Objectives**
- 1. What is the size of Uranus’ rocky core, and is it consistent with core accretion formation models (core ~3-6 ME) [e.g. Pollack et al. 1996; Rice & Armitage 2003] or gravitational instability models (core <1 ME) [e.g. Boss 1997, 2000]?
- 2. How and where is the magnetic field at Uranus generated, and to what extent does the offset between the unusual tilt of the spin axis and magnetic field affect the structure and dynamics of the magnetosphere?
- 3. Is Uranus’ composition consistent with formation in its current position or does it suggest planetary migration? And is its atmospheric profile more similar to that of Earth or the gas giants?

**Baseline Mission Design**
A 2030 launch to orbit insertion in 2041 would involve two Venus gravity assists and one Earth gravity assist. Solar Electric Propulsion (SEP) would be required within 1.5 AU if a Jupiter gravity assist is unavailable. OCEANUS would be at Uranus close to equinox in 2049, providing important new data relating to Uranus’ seasonal variability.

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**Projected Cost**
- Total budget: $1213.2M (FY2015)
- Our cost: $1180.8M
  - Mission cost cap of $1B, with cost credit of $213.2M for eMMRTG.
  - SEP stage cost: $142.8M (over 10% of OCEANUS’ budget)
  - OCEANUS features a low-cost instrument suite: $14.1M for the magnetometer and $8.0M for the engineering and navigation camera.

**Key Trades**
- Mission Type: Flyby
  - Orbits: 2000 kg constrained
  - Single reliable instrument: 500 kg delivered
  - Solar power: Low TRL Instrument
    - Power Source (modules): $334 thousand cost
      - $165 million cost
      - 403 W/m² at Uranus
      - 361 m² solar arrays
    - 692 kg
      - 135 kg
  - Spacecraft:
    - 3-Axis: Cheaper orientation sensor
    - Spin-up After Probe Separation
      - 1 ACS method
        - 2 ACS methods
        - Higher risk
          - Lower risk

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**Conclusions/Lessons Learned**
- An ice giant mission is of high priority.
- In the event a flagship-class mission to an ice giant in the next decade is unavoidable, we considered a medium-class Uranus orbiter concept focused scientific scope that would accomplish 3 of the 9 objectives outlined by NASA’s Decadal Survey on a total budget of $1.2B (FY2015).
- Mission design, power, mass and cost constraints make such a mission to Uranus with a New Frontiers budget difficult.
- To accomplish an ice giant orbiter launch before 2040 (for arrival within the lifetime of current planetary scientists, and to obtain new seasonal data for Uranus), cost allowances for radioisotope power systems and/or powerful launch vehicles may be necessary for a mission of limited budget.

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**Baseline System Summary**
- 3 eMMRTGs producing 290 kW
- Two-phase thermal system technology development to utilize eMMRTG waste heat while only requiring 5 W (vs. 25 W for a traditional single-phase pump system)
- Propulsion controlled by two biprop engines for orbital insertion
- ACS Systems:
  - SEP phase: 3-axis reaction wheels
  - Cruise phase: RCS thrusters
  - Science phase: Axial spinning, pointing accuracy of 1 mrad

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**Baselined Instruments**

- **GAIA (Gravity and Atmospheric Instrument Antenna)** – Synchronous X and Ka band transmission.
- **GAIA**
- **URSULA** (Understanding Real Structure of the Uranian Laboratory of Atmosphere) – Probe including mass spectrometer, atmospheric structure instrument, nephelometer, ultra-stable oscillator
- **Unocam (Uranus’ Juno Cam)** – Visible light, color camera

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**Notional Mission Schedule**

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**Mass, Power and Margins**

- Mass: 290 W at Uranus
- Power: 361 m² solar arrays
- Spacecraft: 692 kg

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