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

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Synopsis

- Origins and Composition of the Exoplanet Analog Uranus System – a mission concept for an orbiter reaching Uranus in 2041
- Measure both the gravity (J6) and magnetic fields during 13 orbits – a significant improvement over the single Voyager flyby
- Small instrument suite: a radio antenna and a magnetometer
- Not achievable within the New Frontiers budget suggested by the Decadal Survey due to high cost of reaching Uranus and powering the spacecraft while in orbit (Jupiter gravity assist not available until a 2040s launch)

Motivation

- Voyager 2 is the only spacecraft that has visited an ice giant
- The structure and composition of the interiors of ice giants and gas giants differ significantly
- Ice giant sized planets are the most common type of planet according to Kepler data
- Interior models and solar system formation models do not agree on the size of Uranus' rocky core
- The single Voyager flyby did not fully characterize the high-order structure and temporal evolution of Uranus' dynamo

Key trades

Mission Type:

Orbiter	Flyby
2000 kg constrained	500 kg delivered
Single reliable instrument	Low TRL Instrument
$13.5 million instrument cost	$70 million instrument cost

More compelling science at lower cost

Power Source:

Solar Power	Radioisotope Power
$334 thousand cost	$165 million cost
4.03 W/m² at Uranus	290 W at Uranus
361 m² solar arrays	120m² solar arrays (SEP phase)
692 kg	135 kg

Solar power is not feasible due to mass and surface area, cannot deliver spacecraft

Spacecraft:

3-Axis	Spinner
Cheaper orientation sensor	Expensive sensors
Higher mass/power	Lower mass/power

Sacrifice cost for manageable mass and power

Probe Deployment:

Articulating Antenna	Spin-up After Probe Separation
1 ACS method	2 ACS methods
Higher risk	Lower risk

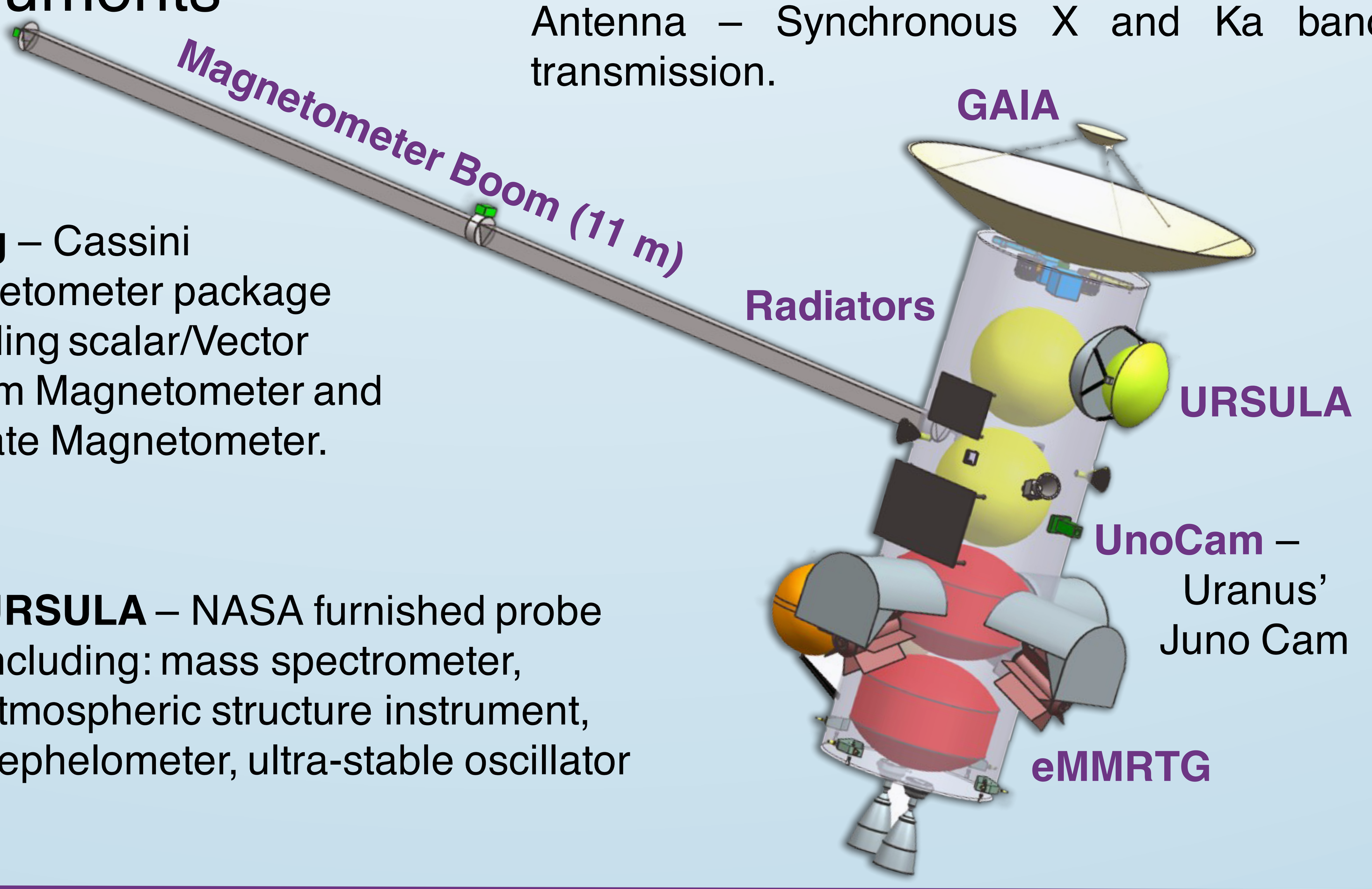
Avoid risk and limit articulation

Science Objectives

- What is the size of Uranus' rocky core? Does it reflect planetary formation models or Uranus interior models?
- To what extent does the unusual tilt of Uranus and the offset between the magnetic field and spin axes affect the structure and dynamics of the magnetosphere?
- Is Uranus' magnetic field generated in a shallow ionic ocean?
- Is Uranus' composition consistent with formation in its current position or planetary migration?
- Is Uranus a super-Earth? Are the atmospheric dynamics on Uranus more similar to those of Earth or the gas giants?

Instruments

GAIA – Gravity and Atmospheric Instrument Antenna – Synchronous X and Ka band transmission.



UMag – Cassini magnetometer package including scalar/Vector Helium Magnetometer and fluxgate Magnetometer.

URSULA – NASA furnished probe including: mass spectrometer, atmospheric structure instrument, nephelometer, ultra-stable oscillator

Cost

- Mission cost cap of $1B, with cost credit of $213.2M for eMMRTGs. Total $1213.2M (FY2015), Our cost: $1180.8 M
- Quasi-grassroots approach using JPL institutional cost model (ICM)
  - ICM based on historical missions
  - Assumes class B mission, in-house development, donated probe, planetary protection category II
- Payload costs calculated using NICM CERs

Mission Schedule

0 month Phase A	2025	2026	2027	2028	2029	2030	2030-40	2041	2042	2043	2044

Phase: B | C | D | E | F

Milestones: PDR/technology cutoff; CDR; Launch; Uranus Orbit Insertion (UOI); Deorbit

Why Oceanus?

Oceanus, son of the Greek god Uranus, was the divine ocean encircling the Earth in which floated the habitable world. The planet Uranus is thought to be enfolded by an ocean that generates a dynamic magnetic field; this puts the significance and complexity of our solar system's ocean worlds in a new and exciting scientific context.

Mission Design

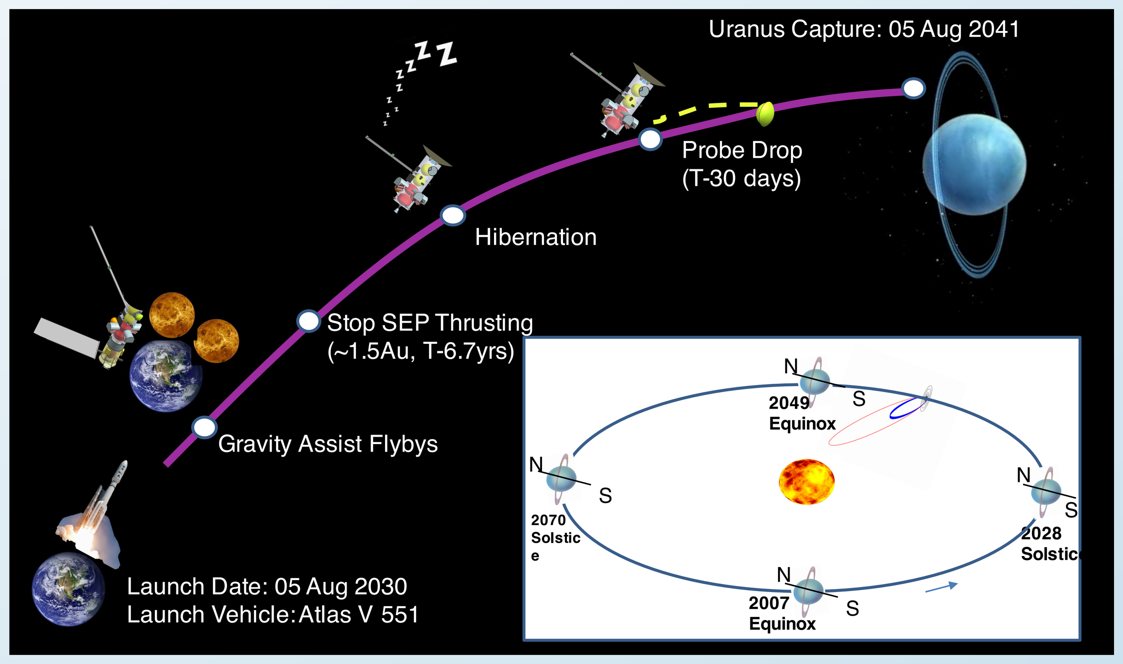


Figure 2. Mission design from launch to orbit insertion including two Venus gravity assists and one Earth gravity assist. Solar Electric Propulsion (SEP) used inside of 1.5 AU.

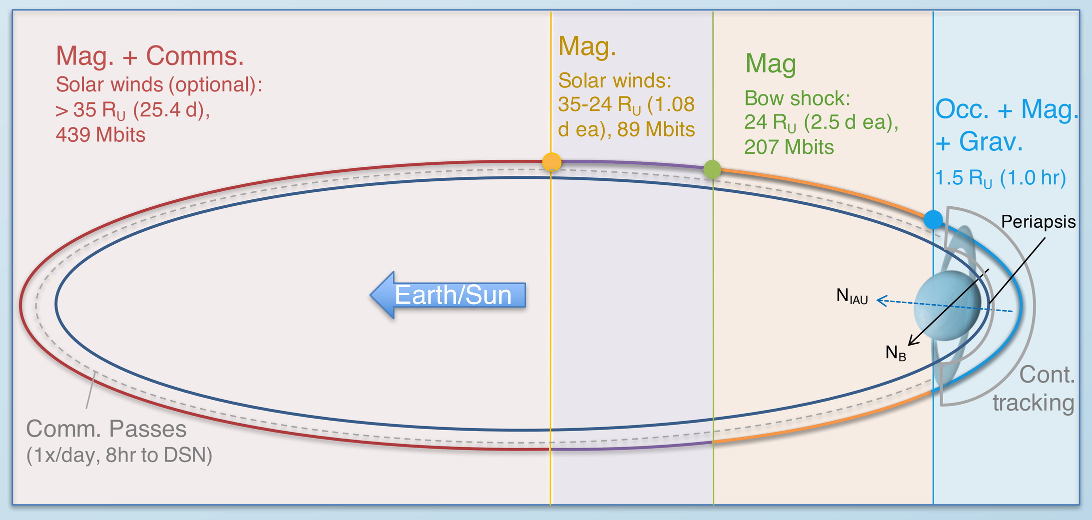


Figure 3. 30 day science orbit with periapsis at 1.1 R_U and apoapsis at 77 R_U. Continuous tracking for gravity measurements when $r < 1.5R_U$. Magnetometer observations at any time including magnetopause and bow shock crossings. Nominal mission 1.5 years, 14 revs.

System Summary

- Atlas 551 launching from KSC
- 3 eMMRTGs producing 290 kW
- Two-phase thermal system technology development
- ACS Systems:
  - SEP phase: 3-axis reaction wheels
  - Cruise phase: RCS thrusters
  - Science phase: Axial spinning
- Mass, Power and Margins:

		Mass Fraction	Mass (kg)	Subsys Cont. %	CBE+ Cont. (kg)	Mode 1 Power (W) Safe	Mode 2 Power (W) Cruise	Mode 3 Power (W) Cruise + Telecom	Mode 4 Power (W) UOI	Mode 5 Power (W) Orbital Science	Mode 6 Power (W) Orbital Science + Comm	Mode 7 Power (W) Approach Science	Mode 8 Power (W) Recharge	Mode 9 Power (W) Gravity Science
Power Mode Duration (hours)						24	24	8	2	16	8	8	1	1
Payload on this Element														
Instruments		1%	12.5	2%	12.8	2	1	1	1	12	13	12	12	14
Additional Elements Carried by this Element														
Probe		11%	127.0	0%	127.0	2	2	2	0	0	0	2	0	0
Spacecraft Bus				do not edit formulas below this line, use the calcualtions and override tables instead -->										
Attitude Control		3%	37.0	8%	40.1	35	43	43	45	45	45	45	45	45
Command & Data		2%	25.8	25%	32.1	37	37	37	37	42	42	42	37	37
Power		16%	180.4	26%	227.8	29	35	37	37	36	37	35	35	38
Propulsion1	FALSE	18%	203.5	5%	214.7	0	1	1	31	0	0	0	0	0
Structures & Mechanisms		33%	369.6	30%	480.5	0	0	0	0	0	0	0	0	0
Cabling		6%	67.1	30%	87.2									
Telecom		5%	56.2	20%	67.5	86	15	86	86	20	91	0	0	141
Thermal		3%	31.3	25%	39.3	5	5	5	5	5	5	5	5	0
Bus Total			971.0	22%	1189.2	192	136	208	242	148	220	127	122	261
Spacecraft Total (Dry): CBE & MEV			**1110.5**	20%	**1329.0**	196	139	211	243	160	233	141	134	275
Subsystem Heritage Contingency	20%		218.5	SEP Con	10%	0	0	0	0	0	0	0	0	0
System Contingency	18%		204.4			83	59	90	104	69	100	60	58	118
Total Contingency	**38%**		422.9											
Spacecraft with Contingency:			**1533**	of total	/o addl p	**279**	**197**	**301**	**347**	**228**	**333**	**201**	**192**	**393**
Propellant & Pressurant with residuals1		61%	2405.4	For S/C mass =		3998.9		Delta-V, Sys 1	2784.3	m/s	siduals =	58.4	kg	
Launch Mass			**3939**	ss for Prop Sizing		1533		EOL Power:	285.2	W				
						Launch C3	0							
Launch Vehicle Margin			**60.1**			on Unique LV Contingency	0%		1640					
						Fairing dia., m	0							
JPL Design Principles Margin			**483.0**	**30%**										
NASA Margin			**264.5**	**20%**							264.5			

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