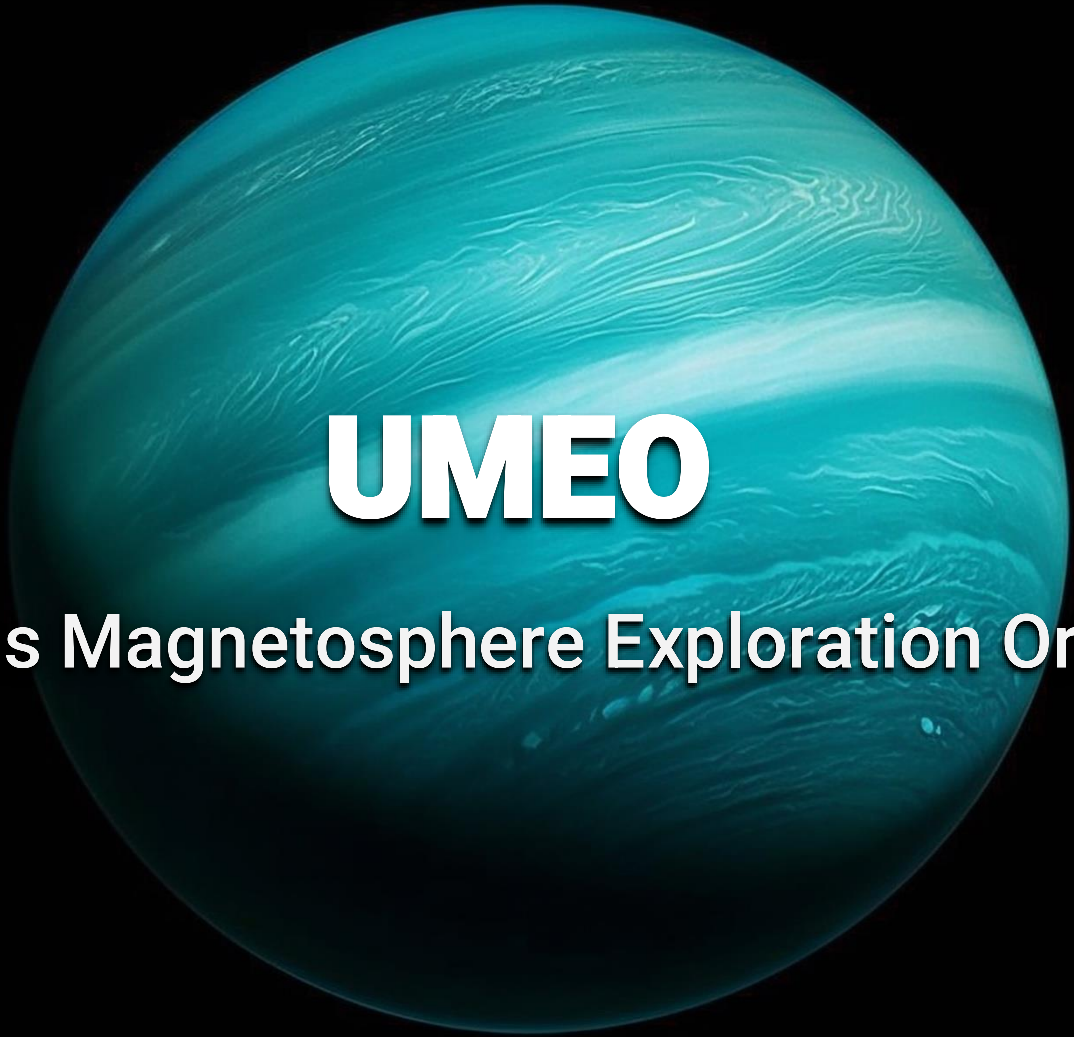
New Exploration of Plasma and Turbulence in the Uranian Near-space Environment

NEPTUNE

UMEO

Uranus Magnetosphere Exploration Orbiter




UMEO
URANUS MAGNETOSPHERE EXPLORATION ORBITER

10,000,000,000€

But what does that buy you?

AGENDA

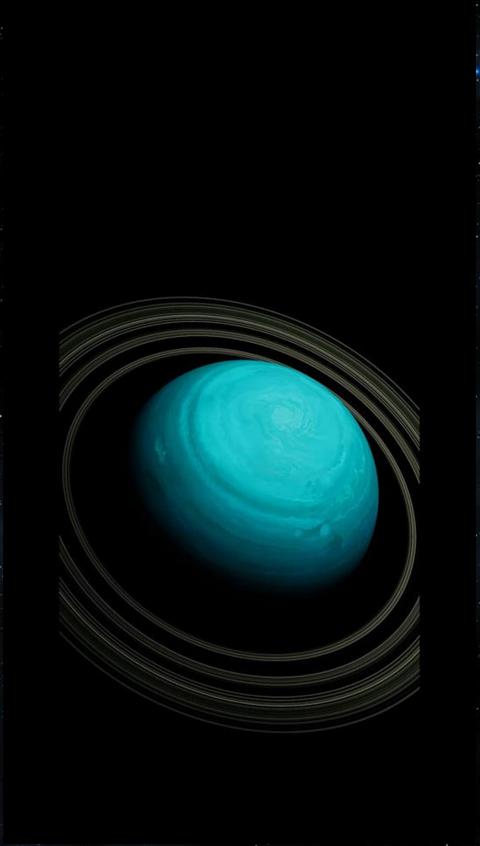
1. Introduction
2. Mission Overview
3. Science & Measurement Requirements
4. Payloads
5. Mission Profile
6. System Architecture
7. Budgets
8. Risks & Costs

INTRODUCTION

A UNIQUE ENVIRONMENT

Uranus offers conditions never previously sampled, providing an essential physical reference for the formation and evolution of **ice giants** and **exoplanets**.

Goal: Orbit Uranus to determine the origin, structure, and dynamics of its magnetosphere and characterise its solar wind interaction.



HIGH-ENERGY PROCESSES

1 Magnetosphere

2 Magnetic reconnection

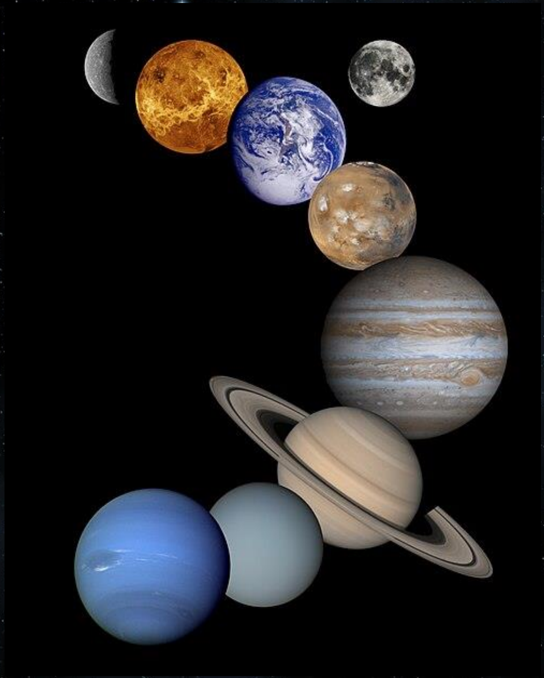
3 Aurora

4 Atmospheric ion loss process

5 Radiation belt mechanisms

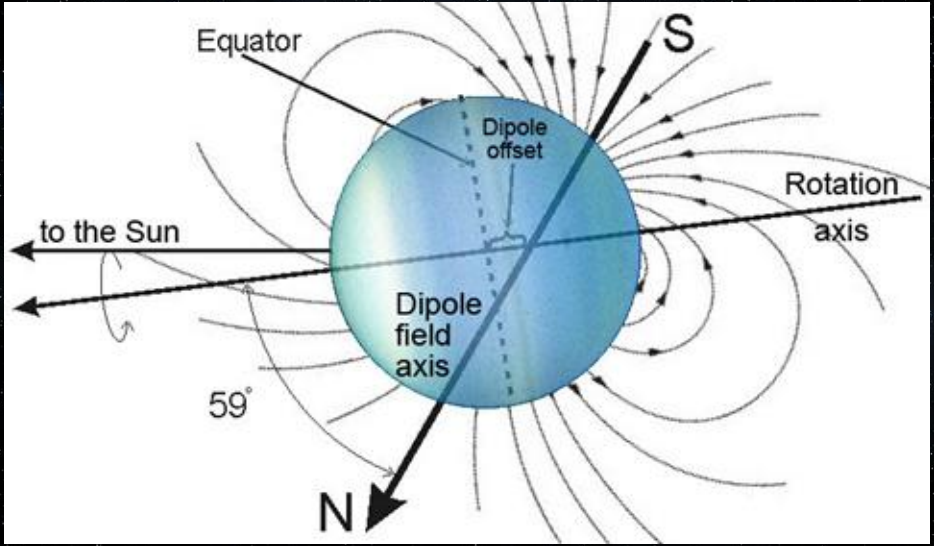
THE PROBLEM WITH CURRENT MODELS

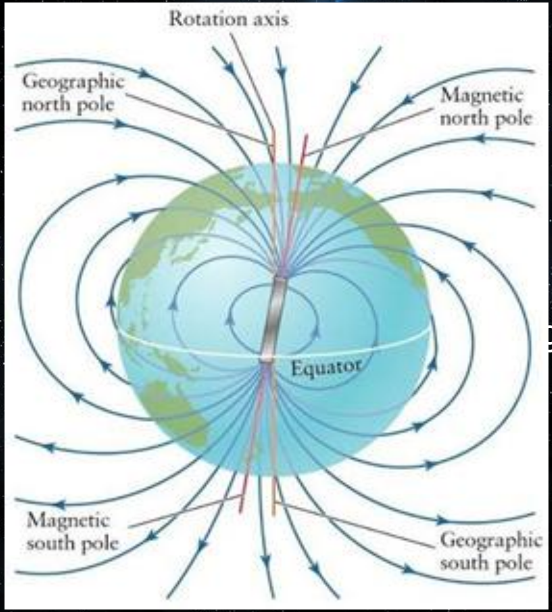
- Earth, Jupiter, and Saturn have relatively stable solar-wind interactions.
- Current geodynamo processes assume highly dipolar magnetic fields.
- Every current model of Uranus' magnetosphere is based on a single, brief flyby from Voyager 2.



URANUS UNIQUE GEOMETRY

- Obliquity: 98° (Earth: 23°)
- Magnetic axis tilted 59° from spin axis
- Magnetic dipole offset ~1/3 planetary radius from center





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SOLSTICE VS EQUINOX

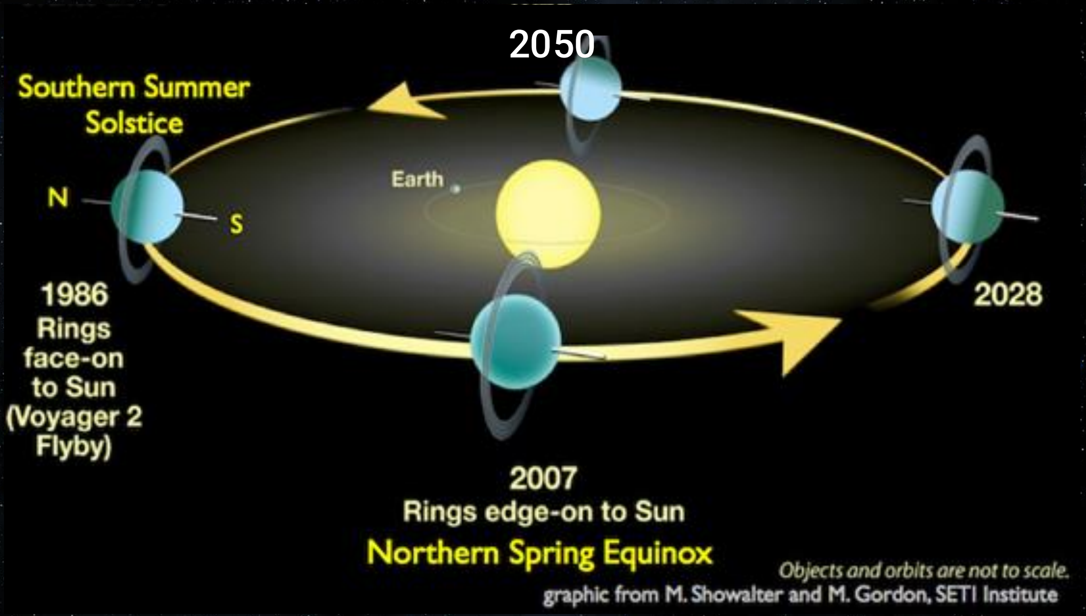
At **solstice:**

- Rotation axis points toward the Sun; solar wind interaction changes dramatically every rotation.

At **equinox:**

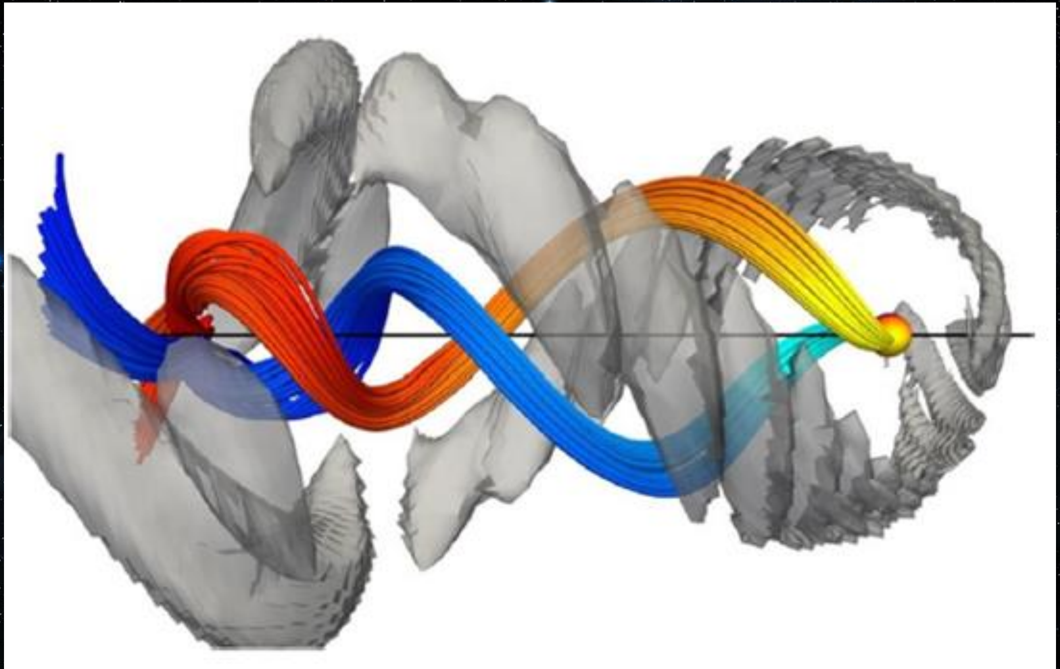
- Rotation axis lies nearly perpendicular to the Sun; interaction resembles a more "classical" magnetosphere

➢ Full cycle: 84 years



MAGNETOSPHERE BENDING

- ➔ Solstice: Highly twisted, helical magnetotail
- ➔ Equinox: Flattened multi-lobed magnetotail

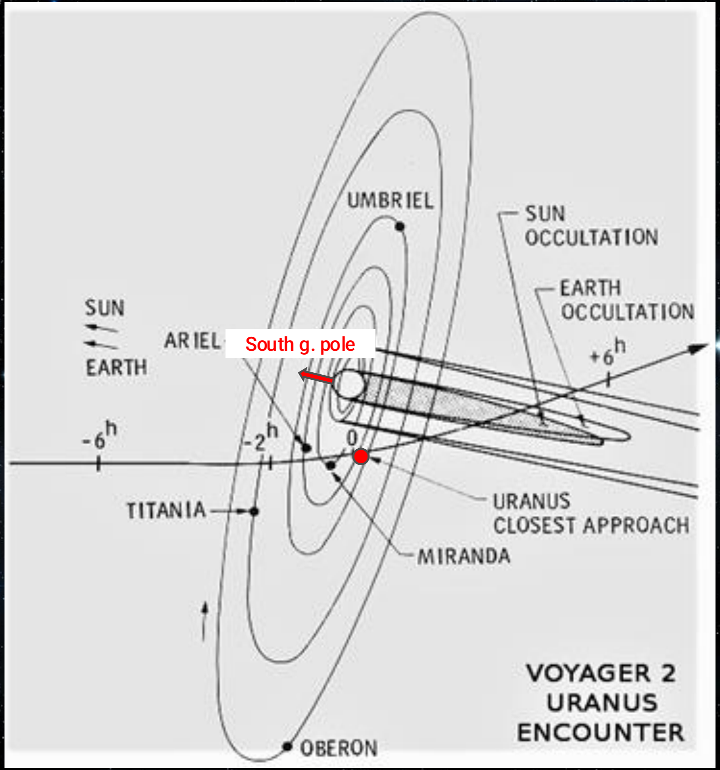


Same planet, same physics different season, different shape entirely.

THE VOYAGER 2 FLYBY - 1986

- Only spacecraft to visit Uranus
- Flyby lasted only a few hours
- Observed southern solstice
- Crossed a solar-wind compression event

Every current model of Uranus' magnetosphere is based on a single flyby.



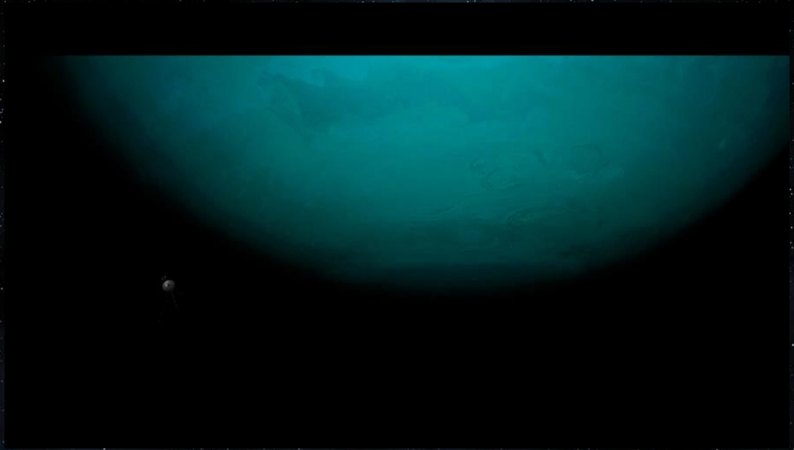
STATE OF KNOWLEDGE

What Voyager measured:

- Magnetic field
- Plasma
- Radiation belts
- Aurora indications

What remains unknown:

- Seasonal variability
- Long-term dynamics
- Typical solar-wind interaction
- Interior dynamo evolution
- Atmospheric escape



UMEO MISSION STATEMENT

WHY:

To establish an essential physical reference for the formation, evolution, and plasma dynamics of ice giants and exoplanets throughout the Galaxy.

WHAT:

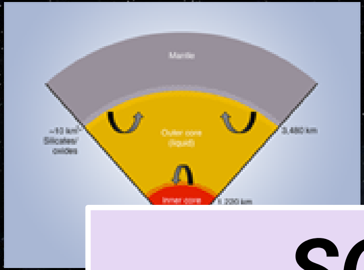
To determine the origin, structure, and dynamics of Uranus's asymmetric magnetosphere and characterise the high-energy processes governing its solar wind interaction.

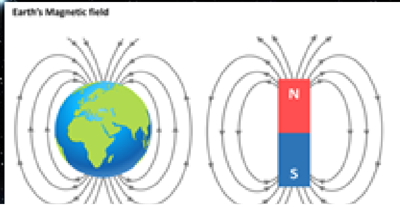
HOW:

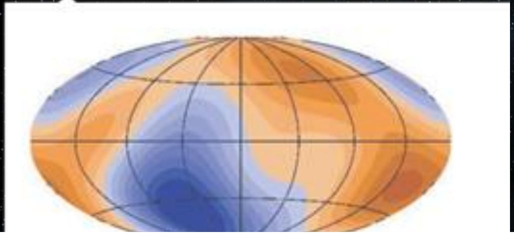
By deploying a dedicated orbiter to the Uranian system to conduct the first-ever in-situ measurements of its near-space environment.

MISSION OVERVIEW

1) THE MAGNETOSPHERE







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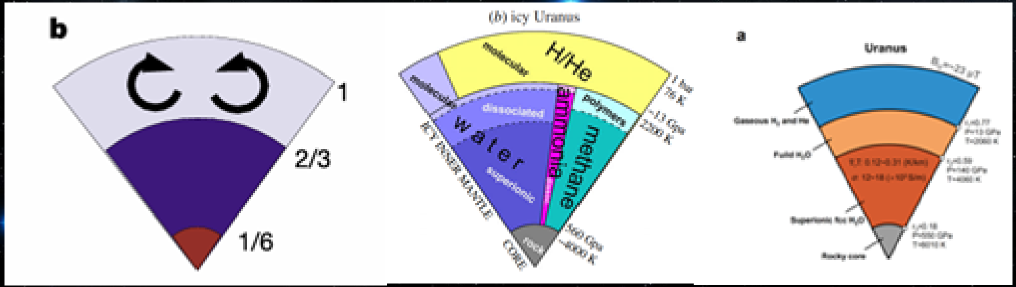
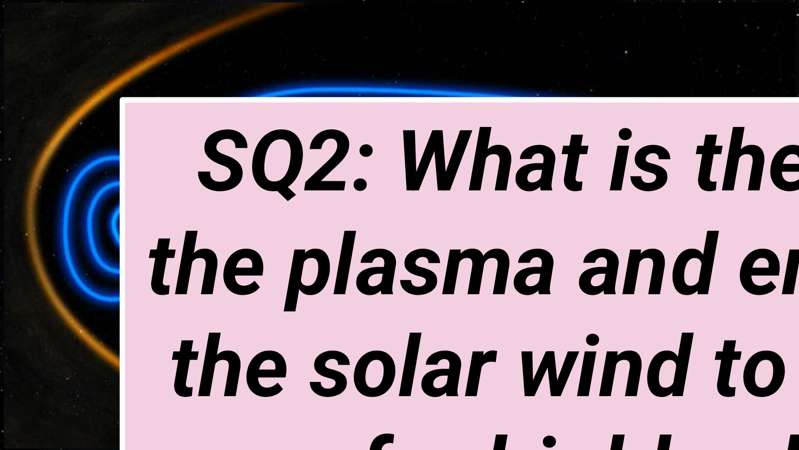
SQ1: How are other icy giant magnetospheres shaped, and what drives their variability?

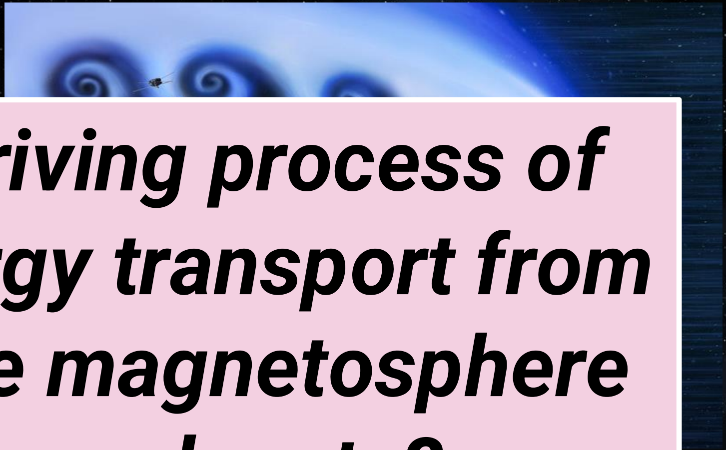
matter that could create this magnetic field



2) MAGNETIC RECONNECTION



Dungey Cycle Reconnection

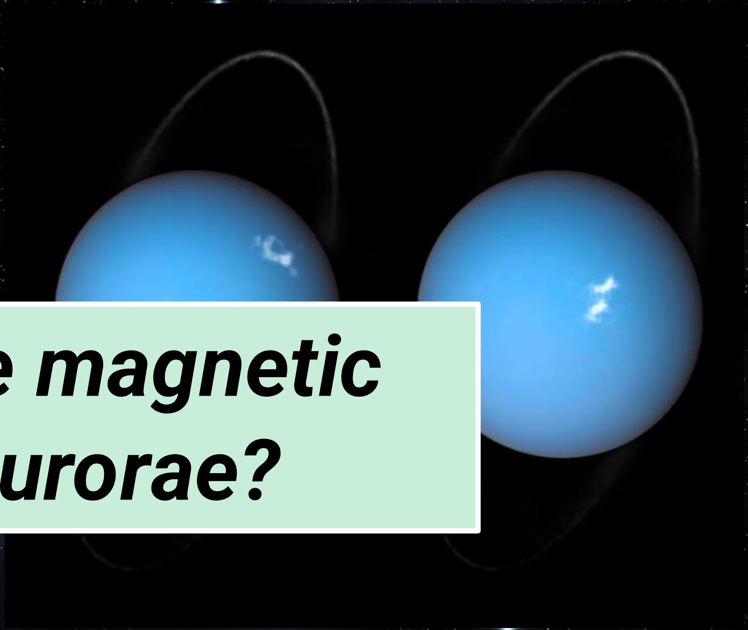


Kelvina-Helmholtz waves

SQ2: What is the driving process of the plasma and energy transport from the solar wind to the magnetosphere for highly oblique planets?

3) THE AURORAE

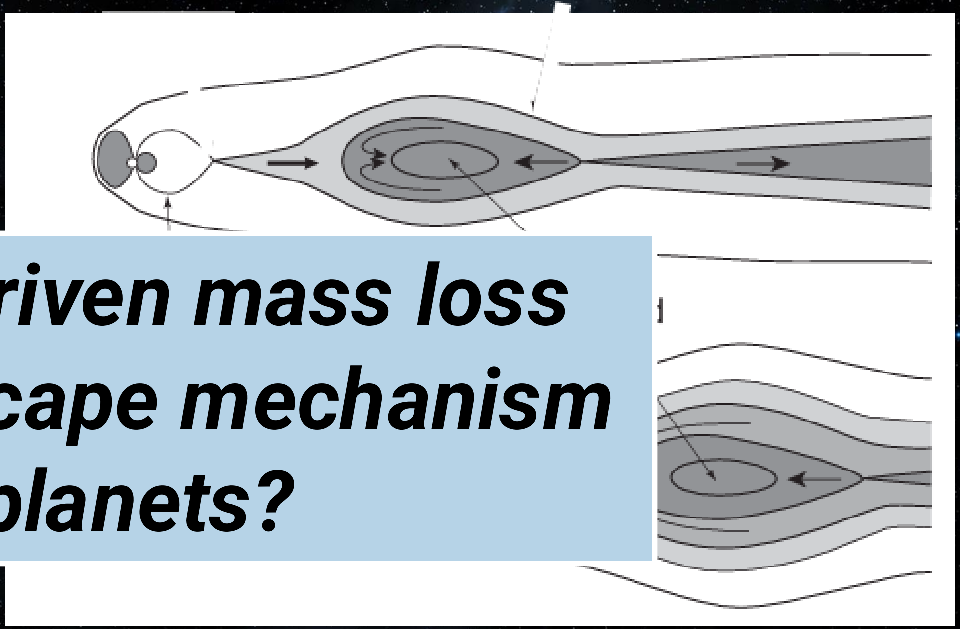
The unusual magnetic geometry causes auroral regions to move continuously



SQ3: How does a unique magnetic geometry influence aurorae?

4) Atmospheric ion loss processes

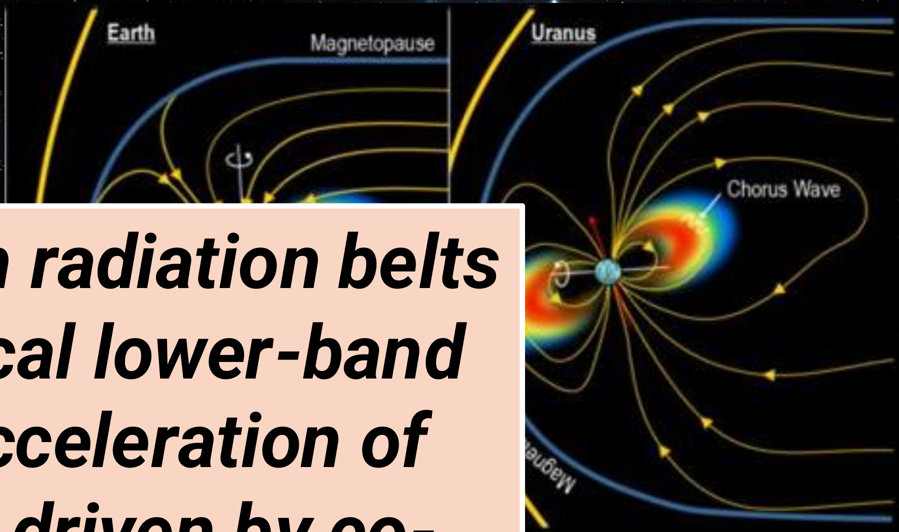
The highly dynamic magnetotail may strongly influence atmospheric escape.



SQ4: Is plasmoid-driven mass loss the dominant ion-escape mechanism for oblique planets?

5) RADIATION BELTS

Uranus has radiation belts almost as intense as Jupiter's, despite a much weaker plasma source

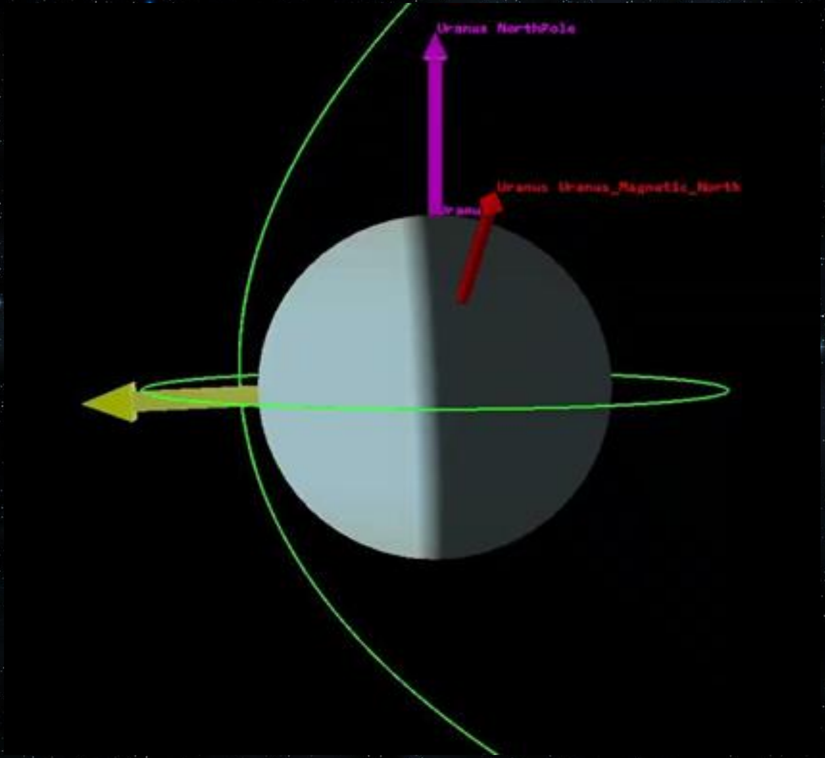


SQ5: Can intense electron radiation belts be generated through local lower-band chorus wave-particle acceleration of seed-particle injections driven by co-rotating interacting regions?

REACHING URANUS BY 2052

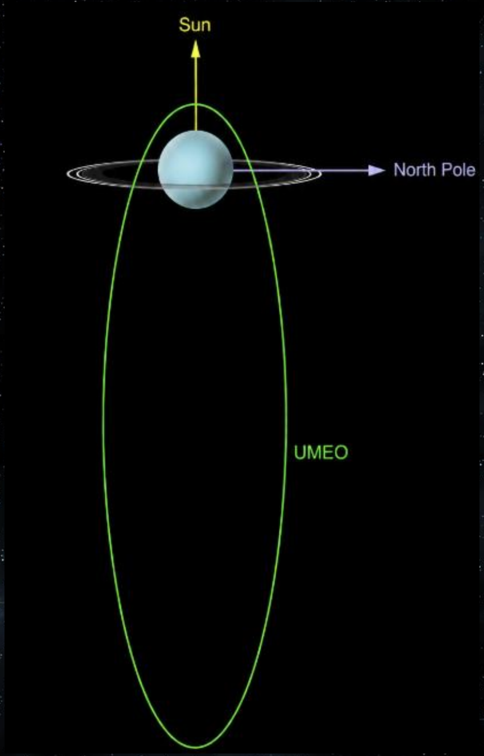
Launch: 2038
Cruise: ~14 years
Arrival: 2052, close to Uranian equinox

Arriving near equinox lets UMEO observe a magnetosphere in a seasonal configuration never explored by Voyager 2, providing the first opportunity to study how Uranus' interaction with the solar wind evolves with season.



MISSION ORBIT DESIGN

- Near-Polar & Highly Eccentric: Designed to sample all magnetic latitudes and regions within a single trajectory.
- Low Periapsis: Close-range passes over the poles to measure the interior dynamo and auroras.
- High Apoapsis: sweeps into the magnetotail and upstream solar wind

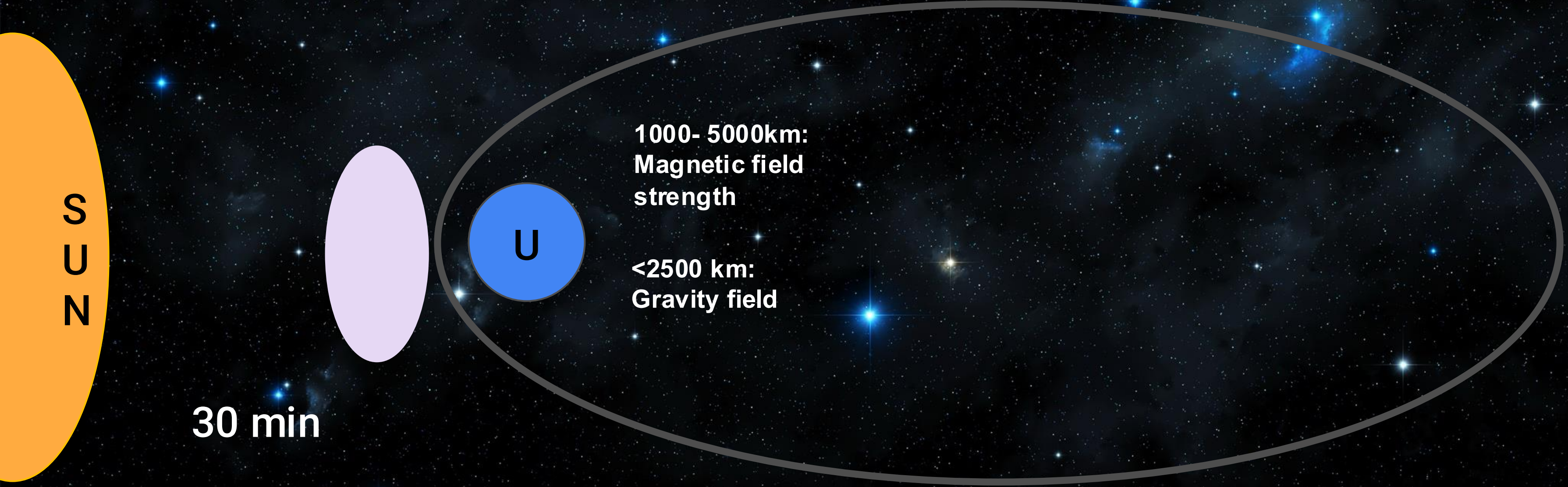


SCIENTIFIC OBJECTIVES OVERVIEW

1) The magnetosphere

SO1: What shapes Uranus's magnetosphere?

Measurements distributed over 4 years



1) THE MAGNETOSPHERE

SO1: What shapes Uranus's magnetosphere?

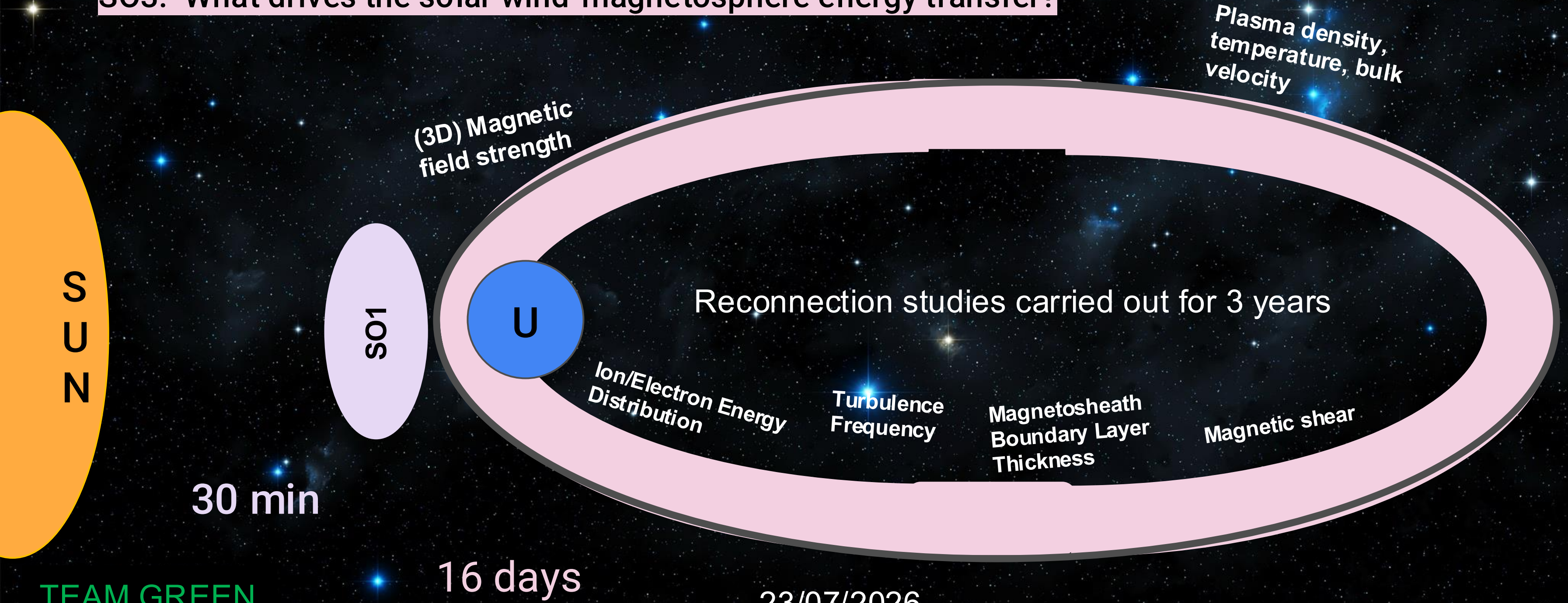
Measurement requirements	Observation requirements
(3D) Magnetic field strength (nT): [0.1 to 20,000] with <1% uncertainty	**Location**: Periapsis **Time**: min. 20 passes at 1000-5000 km measurement length distributed over 4 years (threshold: 2 years)
Gravity field potential (m^2/s2): -1.15×10^{8} to -2.18×10^{8} with an uncertainty of $7x10^{-3}$ (Equivalent a precision of J8)	**Time:** Minimum of 8-10 passes **Location:** Periapsis at <25000 km

SCIENTIFIC OBJECTIVES OVERVIEW

2) Magnetic reconnection

SO2: Does reconnection occur at Uranus's magnetopause?

SO3: What drives the solar wind-magnetosphere energy transfer?



2) MAGNETIC RECONNECTION

SO2: Does reconnection occur at Uranus's magnetopause?

SO3: What drives the solar wind-magnetosphere energy transfer?

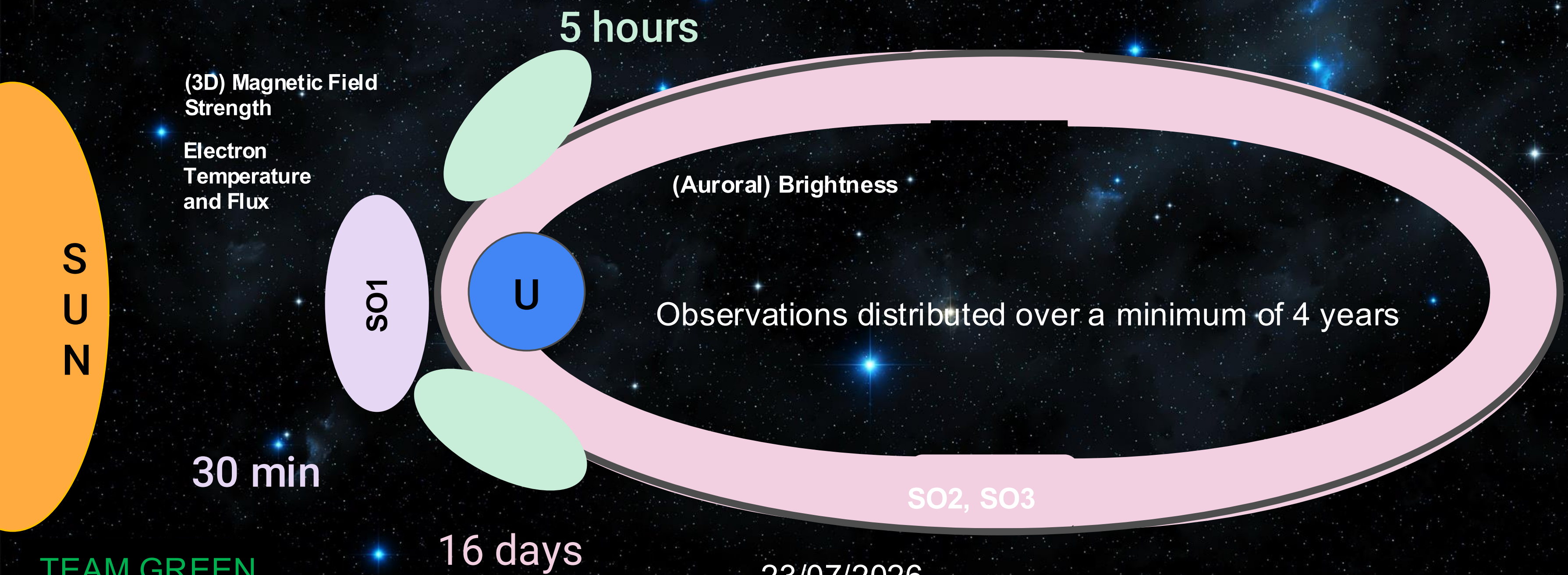
Measurement requirements	Observation requirements
(3D) Magnetic field strength (nT): [1 to 30] with <1% uncertainty	**Location:** Both sides of the magnetopause crossing; Upstream solar wind, outside of bow shock **Time:** 3 years; Continuous whenever spacecraft is upstream of bow shock **Sampling:** >25Hz (for d_i = ~500km, v = 22 km/s); >6/min
Plasma density (cm^{-3}): [0.01 to 0.1] with <20% uncertainty **Plasma Temperature/Energy (eV):** [1 to 10,000] with <25% uncertainty **(3D) Plasma bulk velocity (km/s):** <500 in each direction with <15% uncertainty	**Location:** On both sides of the magnetopause crossing and upstream **Time**: 8*2 min observations over 3 years **Sampling:** >25Hz.
Ion/Electron Energy Distribution/Spectrum (eV^{-1}): <20% uncertainty **Bin Size:** 10 keV for [0 to 30] keV; 100 keV for [0 to 1,000] keV	**Location**: Magnetopause boundary layer, extending to the adjacent exhaust region on both sides. **Time**: 8x2 min observations over 3 years. **Sampling**: >=1 Hz
Turbulence Frequency (Hz): [3 to 400] with <10% uncertainty	**Location**: Downstream of the magnetopause crossing, in the reconnection exhaust **Time**: Burst captures triggered around each of the magnetopause crossings over 3 years, continuous low-rate survey mode elsewhere **Sampling**: survey mode 1 kHz, burst mode >2-4 kHz to capture waveform
Magnetosheath Boundary Layer Thickness (km): [2,500 to 10,000] with <10% uncertainty **Magnetosheath Field Shear (T):** [1 to 30] with <1% uncertainty	**Location**: Whitin the magnetosheath, between bow shock and magnetopause crossings. **Time**: 8x2 min observations over 3 years. **Sampling**: 25 Hz

SCIENTIFIC OBJECTIVES OVERVIEW

3) The Aurorae

SO4: How does auroral morphology track magnetic geometry?

SO5: What particles drive the aurora, and how?



3) THE AURORAE

SO4: How does auroral morphology track magnetic geometry?

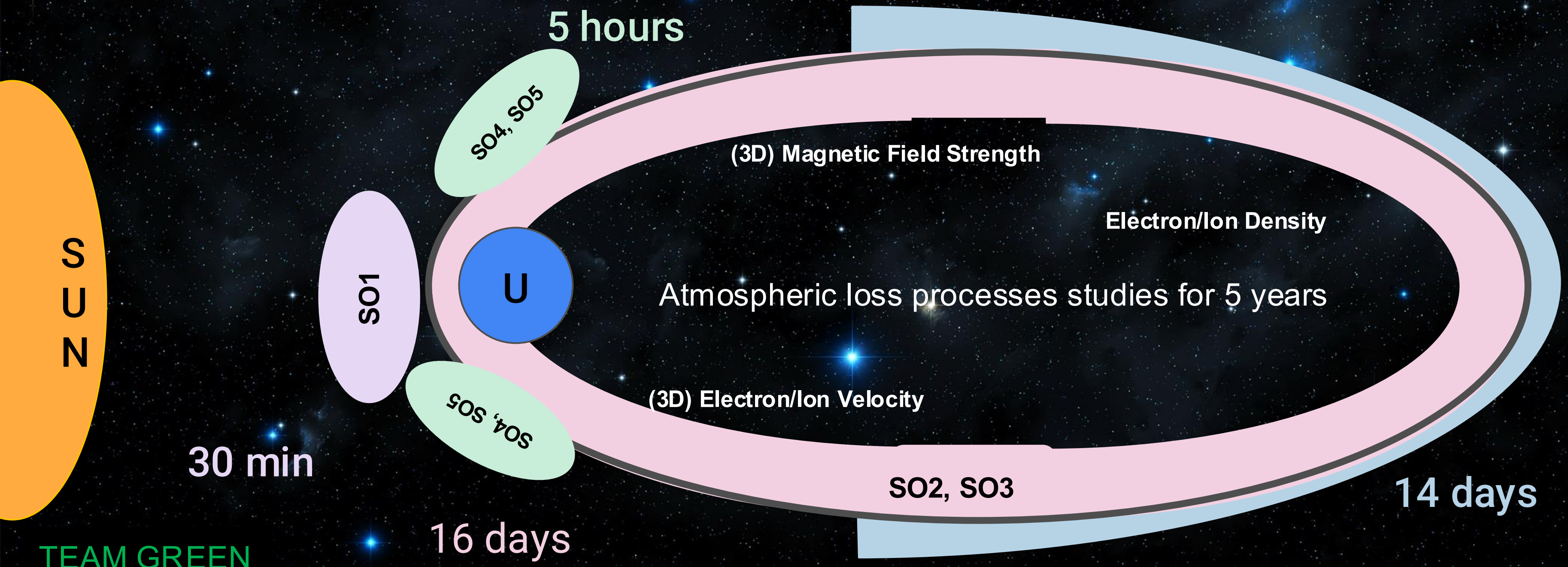
SO5: What particles drive the aurora, and how?

Measurement requirements	Observation requirements
(Auroral) Brightness (kR): (100-120nm): [0.1 to 30 kR] with <20% uncertainty (120.5-122.5nm): [0.1 to 30 kR] with <20% uncertainty (155-165nm): [0.1 to 30 kR] with <20% uncertainty (155-165nm): [0.05 to 5 kR] with <20% uncertainty	**Location**: Polar regions (~30000 km by 30000 km) **Spatial Resolution**: <300km, with a goal of <150 km **Spectral Resolution**: <2nm - not needed now that i am using a camera **Time**: Continuous observations with cadence of <2min when on top of the poles - auroral campaigns once every 5 orbits **Mission Duration:** Observations distributed over a minimum of ~4 years **Sampling**: One complete four-band polar map every <10 min
(3D) Magnetic Field Strength (nT): [0.1 to 20,000] with <1% uncertainty **Electron Temperature (eV):** [30 to 30,000] with <25% uncertainty **(3D) Electron Flux (cm-2 s-1sr-1)**: [10^1 to 5×10^7] with <20% uncertainty	**Location**: Polar regions **Time**: simultaneous observations

SCIENTIFIC OBJECTIVES OVERVIEW

4) Atmospheric loss

SO6: How do magnetotail plasmoids drive mass loss?



TEAM GREEN

4) ATMOSPHERIC ION PROCESSES

SO6: How do magnetotail plasmoids drive mass loss?

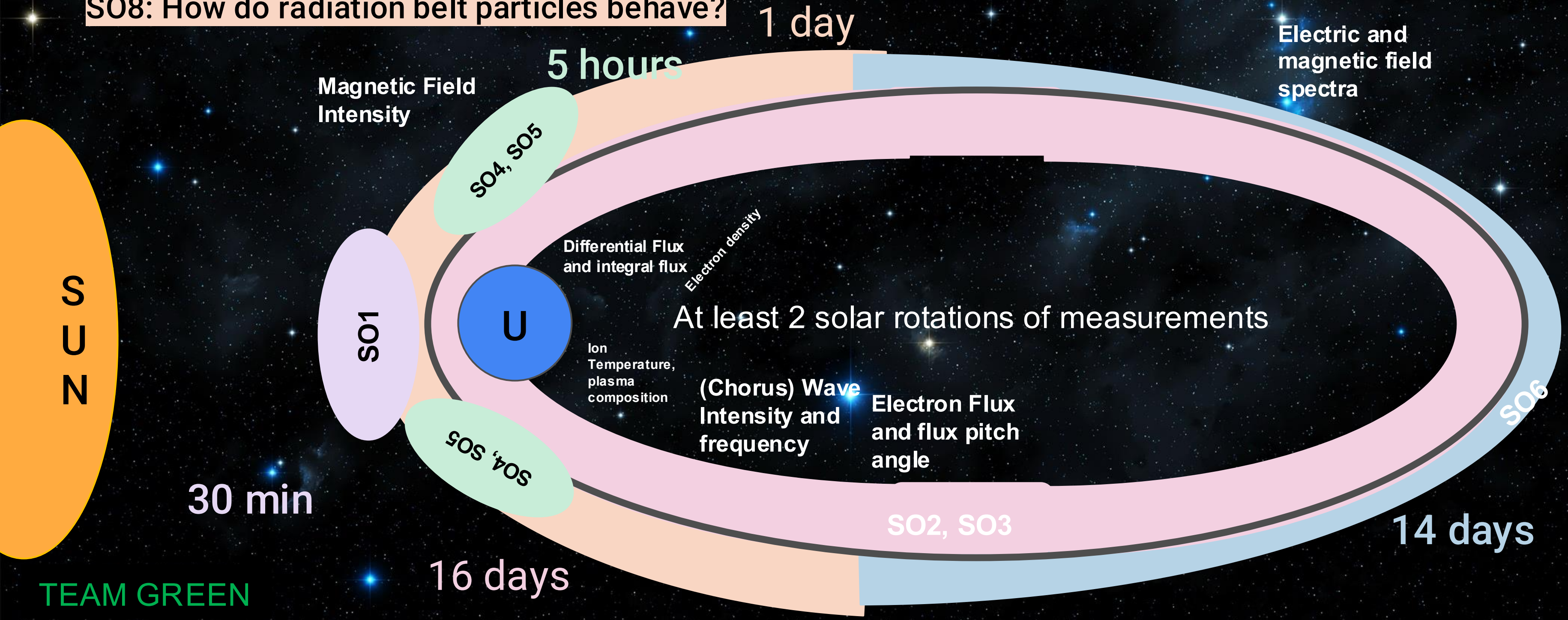
Measurement requirements	Observation requirements
(3D) Magnetic Field Strength (nT): [0.1, 10] with <0.1 nT uncertainty **Electron/Ion Density (cm^{-3}):** [0.001, 1] with <0.0001 cm^{-3} uncertainty **Electron/Ion Energy/Temperature (eV):** [10, 140] & [140, 5950] with 25% uncertainty	**Location**: Near apoapsis, magnetotail (around 50 Uranus' radii) **Time**: Every 0.4 Uranus' radii along the orbit **Samples**: min. 10sec every 2min **Analysis**: Minimum variance
(3D) Electron/Ion Velocity (km/s): [100, 7000] with <10 km/s uncertainty	**Directionality**: along the magnetotail **Location**: near apoapsis, magnetotail (around 50 Uranus' radii) **Time**: every 0.4 R_U, **Samples**: min. 1h every 17h

SCIENTIFIC OBJECTIVES OVERVIEW

5) Radiation belt mechanisms

SO7: What accelerates Uranus's radiation belts?

SO8: How do radiation belt particles behave?



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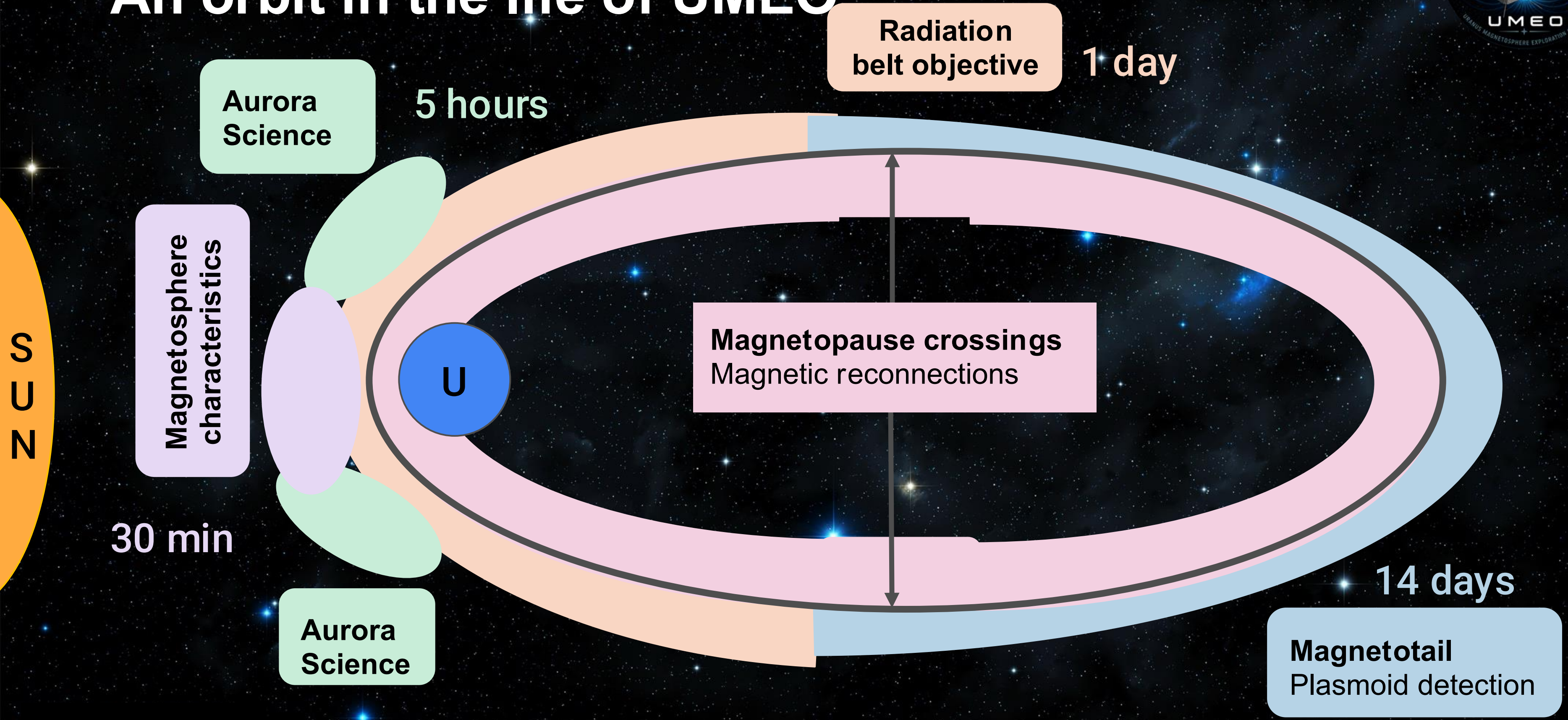
5) RADIATION BELT MECHANISM

SO7: What accelerates Uranus's radiation belts?

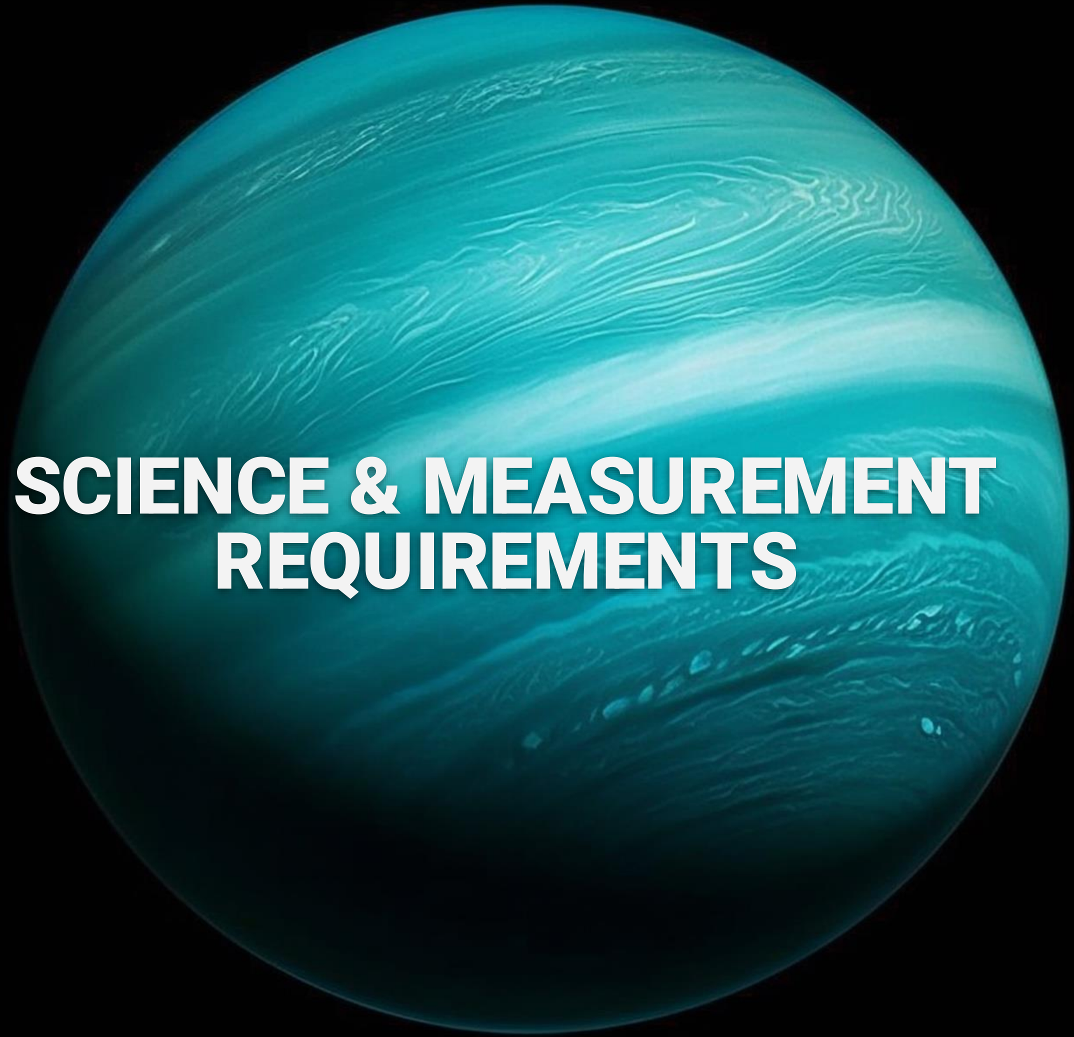
SO8: How do radiation belt particles behave?

Measurement requirements	Observation requirements
(Chorus) Wave Intensity ($nT^2\ Hz^{-1}$): [$3\times10^{-11}\ nT^2\ Hz^{-1}$ - $10^1\ nT^2\ Hz^{-1}$] with <20% uncertainty **(Chorus) Wave Frequency (Hz)**: [1,400 to 7,000] with <5% uncertainty **Electric Field Spectrum (V m-1 Hz-1)**: [$3\times10^{-17}\ V^2\ m^{-2}\ Hz^{-1}$ (noise floor) up to ~10^{-8}–$10^{-6}\ V^2\ m^{-2}\ Hz^{-1}$] with <20% uncertainty **Magnetic Field Spectrum (nT Hz-1)**: [$3\times10^{-11}\ nT^2\ Hz^{-1}$ (noise floor, Kletzing et al. 2013) up to ~$10^1\ nT^2\ Hz^{-1}$] with <20% uncertainty	**Location**: L = 3-6 **Spectrum (Hz)**: [1,400–7,000 Hz] with 0.01 Hz bin size **Time**: 30 seconds to several minutes whenever chorus activity is detected **Samples**: 30 s–several min, >12/min
(3D) Electron Flux (cm-2 s-1): [10^1–10^2 to $5\times10^7\ cm^{-2}\ s^{-1}\ sr^{-1}$] with <20% uncertainty **Electron Flux Pitch Angle (°)**: [0 to 180] with ≤15° uncertainty [-20 to 20] relative to local zenith with ≤10° uncertainty **(3D) Magnetic Field Intensity (nT)**: [0.1, 20,000] with <1% uncertainty	**Location**: L = 3-6 **Energy Range**: 30 keV to 10MeV **Time**: ≥2 solar rotations (~54 days minimum) to capture multiple successive CIR passages, ideally spanning the full prime mission **Samples**: ≥1 Hz
Electron Density (cm-3): [0.02 to 1.0] with <20% uncertainty	**Location**: at radial distances between 5-18 Uranus' radii **Samples**: > 6/min
(3D) (e^-, H^+, He^{n+}, C^{n+}, O^{n+}) Differential Flux (cm-2 s-1 MeV-1): [1-10^7] with <20% uncertainty **(3D) (e^-, H^+, He^{n+}, C^{n+}, O^{n+}) Integral Flux (cm-2 s-1)**: [10^1-10^2 to $5\times10^7\ cm^{-2}$] with <20% uncertainty	**Location**: Across radial distances <10 Uranus' radii **Energy Range (keV/nuc)**: [30 to 10,000] **Samples**: >6/min (faster in burst mode)
Ion Temperature/Energy (keV/nuc): [3 to 200] with <25% uncertainty. **Plasma Composition (amu-1)**: [1 to 16] with <10% uncertainty	**Location**: Across radial distances <10 Uranus' radii **Time**: ≥2 solar rotations (~54 days minimum) to capture multiple successive CIR passages, but ideally spanning the full prime mission **Samples**: ≥1 Hz

An orbit in the life of UMEO



SCIENCE & MEASUREMENT REQUIREMENTS



SCIENCE TRACIBILITY MATRIX

Science Question	Science Objective		Science Requirements: Physical Quantity	Science Requirements: Observational Details	Measurement Requirements	Instruments	Instruments capabilities	Mission Requirements
SQ1: How are other icy giant magnetospheres shaped, and what drives their variability?	SO1: Determine the processes controlling the structure and variability of Uranus's magnetosphere.	SR1.1	**(3D) Magnetic field strength (nT)**: [0.1 to 20,000] with <1% uncertainty **Related to**: SR2.1, SR4.2, SR6.1, SR7.3, SR7.5	**Location**: Periapsis **Time**: min. 20 passes at 1000-5000 km measurement length distributed over 4 years (threshold: 2 years) **Samples**:	**(3D) Magnetic Field Strength (nT):** [0.1, 20,000] with <1% uncertainty	Magnetometer	[0.1, 50 000] with 0.002 resolution Error < 2%	1000-5000 km altitude
		SR1.2	**Gravity field potential (m^2/s2)**: −1.15×10^8 to -2.18 ×10^8 with an uncertainty of 7x10^-3. (Equivalent a [illegible]	**Time:** Minimun of 8-10 passes **Location**: Periapsis at <25000 km [illegible]	Doppler shift with radio science with a precision of 0.01 mm/s	Radio science (using the main dish antenna)	0.01 mm/s	< 2500 km altitude Pointing antenna dish toward Earth
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**(3D) Magnetic Field Strength (nT):** [0.1, 20,000] with <1% uncertainty	Magnetometer	[0.1, 50 000] with 0.002 resolution, which gives <2% uncertainty	On both sides of magnetopause crossing
		[illegible]	[illegible]	[illegible]	**Plasma density (cm-3):** [0.001 to 1] with <20% AND <0.0001 cm-3 uncertainty	RPWI		On both sides of magnetopause crossing. Solar wind is measured outside of the magnetospehre upstream
		[illegible]	[illegible]		**Plasma Temperature/Energy (eV):** [1 to 30,000] with <25% uncertainty	JDC	1 eV – 41 keV Error: ΔE/E=12%	On both sides of magnetopause crossing. Solar wind is measured outside of the magnetospehre upstream
		[illegible]	[illegible]		**(3D) Plasma bulk velocity (km/s):** <7,000 in each direction with <15% uncertainty	RPWI	0.1 - 200 km/s	On both sides of magnetopause crossing. Solar wind is measured outside of the magnetospehre upstream
		[illegible]	[illegible]	[illegible]	**Ion/Electron Energy Distribution/Spectrum (eV-1):** <20% uncertainty	JDC	1 eV – 41 keV Error: ΔE/E=12%	During magnetopause crossing (between bow-shock and magnetosheat) extending outside of the regions
		[illegible]	[illegible]	[illegible]	**Turbulence Frequency (Hz):** [3 to 400] with <10% uncertainty	RPWI	[0.1 Hz - 20 kHz]	Downstream of the magnetopause crossing
	[illegible]	[illegible]	[illegible]	[illegible]	**Magnetosheath Boundary Layer Thickness (km):** [2,500 to 10,000] with <10% uncertainty	Magnetometer	[0.1, 50 000] with 0.002 resolution, Error < 2%	Within the magnetosheet
		[illegible]	[illegible]		**Magnetosheath Field Shear (T):** [1 to 30] with <1% uncertainty	Magnetometer	[1, 30] T Error < 1%	Within the magnetosheet
SQ3: How does a unique magnetic geometry influence aurorae?	SO4: Determine how auroral location, brightness and morphology vary with Uranus' rotating magnetic geometry.	SR4.1	**(Auroral) Brightness (kR):** (100-120nm): [0.1 to 30 kR] with <20% uncertainty (120.5-122.5nm): [0.1 to 30 kR] with <20% uncertainty (155-165nm): [0.1 to 30 kR] with <20% uncertainty (155-165nm): [0.05 to 5 kR] with <20% uncertainty	[illegible] **Spectral Resolution**: <2nm - not needed now that i am using a camera **Time**: continuous observations with cadence of <2min when on top of the poles - auroral campaigns once every 5 orbits **Mission Duration:** observations distributed over a minimum of ~4 years **Sampling**: one complete four-band polar map every <10 min	**(Auroral) Brightness (kR):** (100-120nm): [0.1 to 30 kR] with <20% uncertainty (120.5-122.5nm): [0.1 to 30 kR] with <20% uncertainty (155-165nm): [0.1 to 30 kR] with <20% uncertainty (180-195nm): [0.05 to 5 kR] with <20% uncertainty	UV Cam		Pointing at Uranus magnetic pole 5h of continuous measurements (around periapsis except at the 0.5h closest to periapsis)? Depends on the amount of images we need and the time to get them
		SR4.2	**(3D) Magnetic Field Strength (nT):** [0.1 to 20,000] with <1% uncertainty **Relations**: SR1.1, SR2.1, SR6.1, SR12.4	**Location**: same **Time**: simultaneous observations **Sampling**: co-temporal w/ SR4.1	**(3D) Magnetic Field Strength (nT):** [0.1, 20,000] with <1% uncertainty	Magnetometer	[0.1, 50 000] with 0.002 resolution, Error < 2%	5h of continuous measurements (around periapsis except at the 0.5h closest to periapsis)
	SO5: Identify precipitating particles producing Uranu's auroras and determine their effect on the atmosphere	SR5.1	**Electron Temperature (eV):** [30 to 30,000] with <25% uncertainty **Related to:** SR2.3, SR6.3, SR8.3	**Location**: co-temporal w/ SR4.1 **Time**: simultaneous observations **Sampling**: co-temporal w/ SR4.1	**Plasma Temperature/Energy (eV):** [1 to 30,000] with <25% uncertainty	JDC	1 eV – 41 keV Error: ΔE/E=12%	
		SR5.2	**(3D) Electron Flux (cm-2 s-1sr-1):** $[10^1$ to $5\times10^7]$ with <20% uncertainty **Related to**: SR7.4, SR8.1, SR8.2		**(3D) Electron Flux (cm-2 s-1 sr-1):** [TBD to 5E+7] with <TBD% uncertainty	JDC	1 eV – 41 keV, ΔE/E=12% M/ΔM=30	
SQ4: Is plasmoid-driven mass loss the dominant ion-escape mechanism for oblique planets?	SO6: Determine the geometrical structure of plasmoids in the magnetotail and estimate their contribution to atmospheric ion loss.	SR6.1	**(3D) Magnetic Field Strength (nT):** [0.1, 10] with <0.1 nT uncertainty **Related to:** SR1.1, SR2.1, SR4.2, SR7.3, SR7.5	**Location**: near apoapsis, magnetotail (around 50 Uranus' radii) **Time**: every 0.4 Uranus' radii along the orbit **Samples**: min. 10sec every 2min **Analysis**: minimum variance [1]	**(3D) Magnetic Field Strength (nT):** [0.1, 20,000] with <1% uncertainty	Magnetometer	[0.1, 50 000] with 0.002 resolution, Error < 2%	In the magnetotail (~14h around apoapsis) Instrument ON 24/7 but only storing data if measuring sufficient magnetic field Storing 1h of data per 17h of measurements
		SR6.2	**Electron/Ion Density (cm-3):** [0.001, 1] with <0.0001 cm-3 uncertainty **Related to**: SR2.2, SR7.6		**Plasma density (cm-3)**: [0.001 to 1] with <20% AND <0.0001 cm-3 uncertainty	RPWI	10^-5 - 10^4 cm^3 Error: <5% uncertainty	In the magnetotail (~14h around apoapsis) Instrument ON 24/7 but only storing data if measuring sufficient magnetic field Storing 10sec of data per 2min of measurement
		SR6.3	**Electron/Ion Energy/Temperature (eV):** [10, 140] & [140, 5950] with 25% uncertainty **Related to:** SR2.3, SR5.1, SR8.3		**Plasma Temperature/Energy (eV)**: [1 to 30,000] with <25% uncertainty	RPWI	10^-5 - 10^4 cm^3 Error: <5% uncertainty	
		SR6.4	**(3D) Electron/Ion Velocity (km/s):** [100, 7000] with <10 km/s uncertainty **Related to:** SR2.4	**Directionality**: along the magnetotail **Location**: near apoapsis, magnetotail (around 50 Uranus' radii) **Time**: every 0.4 R_U, **Samples**: min. 1h every 17h	**(3D) Plasma bulk velocity (km/s)**: <7,000 in each direction with <15% uncertainty	RPWI	10^-5 - 10^4 cm^3 Error: <5% uncertainty	
SQ5: Can intense electron radiation belts be generated through local lower-band chorus wave-particle acceleration of seed-particle injections driven by co-rotating interacting regions?	SO7: Test chorus-wave acceleration as a driver of Uranus's intense radiation belts and determine whether magnetospheric pre-conditioning enhances CIR-driven acceleration.	SR7.1	**(Chorus) Wave Intensity ($nT^2 Hz^{-1}$)**: $[3\times10^{-11} nT^2 Hz^{-1}$ - $10^1 nT^2 Hz^{-1}]$ with <20% uncertainty **Requires:** SR8.1c, SR8.1d	**Location**: L = 3-6 **Spectrum (Hz):** [1,400–7,000 Hz] with 0.01 Hz bin size **Time:** 30 seconds to several minutes whenever chorus activity is detected **Samples:** 30 s–several min, >12/min	not applicable			Measurements in the radiation belts (altitude 1-10 R_U)
		SR7.2	**(Chorus) Wave Frequency (Hz):** [1,400 to 7,000] with <5% uncertainty **Requires:** SR8.1c, SR8.1d		not applicable			
		SR7.3	**Electric Field Spectrum (V m-1 Hz-1):** $[3\times10^{-17} V^2 m^{-2} Hz^{-1}$ (noise floor) up to $\sim10^{-6}$–$10^{-4} V^2 m^{-2} Hz^{-1}]$ with <20% uncertainty **Required by:** SR8.1a, SR8.1b		**Electric Field Spectrum (V m-1 Hz-1):** $[3\times10^{-17} V^2 m^{-2} Hz^{-1}$ (noise floor) up to $\sim10^{-6}$–$10^{-4} V^2 m^{-2} Hz^{-1}]$ with <20% uncertainty	RPWI	DC – 1.6 MHz Error: 2μV/m/√Hz (>500Hz)	
		SR7.3	**Magnetic Field Spectrum (nT Hz-1):** $[3\times10^{-11} nT^2 Hz^{-1}$ (noise floor, Kletzing et al. 2013) up to $\sim10^{1} nT^2 Hz^{-1}]$ with <20% uncertainty **Required by:** SR8.1a, SR8.1b **Related to:** SR1.1, SR2.1, SR4.2, SR6.1, SR7.5		**Magnetic Field Spectrum (nT Hz-1):** $[3\times10^{-11} nT^2 Hz^{-1}$ (noise floor, Kletzing et al. 2013) up to $\sim10^{1} nT^2 Hz^{-1}]$ with <20% uncertainty	RPWI	0.1 Hz – 20 kHz Error: 8 pT/√Hz (at 1 Hz) 6 fT/√Hz (at 1 kHz & 20 kHz) 4 fT/√Hz (at 4 kHz)	
		SR7.4	**(3D) Electron Flux (cm-2 s-1):** $[10^1$–10^2 to $5\times10^7 cm^{-2} s^{-1} sr^{-1}]$ with <20% uncertainty **Related to:** SR5.2, SR8.1, SR8.2	**Location**: L = 3-6 **Energy Range**: 30 keV to 10MeV **Time:** ≥2 solar rotations (~54 days minimum) to capture multiple successive CIR passages, but ideally spanning the full prime mission **Samples:** ≥1 Hz	**(3D) Electron Flux (cm-2 s-1 sr-1):** $[10^1$–10^2 to $5\times10^7 cm^{-2} s^{-1} sr^{-1}]$ with <20% uncertainty	JoEE	25 keV – 1 MeV, ΔE/E≤20% FoV: 12˚x180˚, ΔΩ=12˚x22˚	
		SR.74	**Electron Flux Pitch Angle (°):** [0 to 180] with ≤15° uncertainty [-20 to 20] relative to local zenith with ≤10° uncertainty		**Electron Flux Pitch Angle (°):** [0 to 180] with ≤15° uncertainty [-20 to 20] relative to local zenith with ≤10° uncertainty	JoEE	25 keV – 1 MeV, ΔE/E≤20% FoV: 12˚x180˚, ΔΩ=12˚x22˚	
		SR7.5	**(3D) Magnetic Field Intensity (nT):** [0.1, 20,000] with <1% uncertainty **Related to:** SR1.1, SR2.1, SR4.2, SR6.1, SR7.3		**(3D) Magnetic Field Strength (nT):** [0.1, 20,000] with <1% uncertainty	Magnetometer	[0.1, 50 000] with 0.002 resolution Error <2%	
		SR7.6	**Electron Density (cm-3):** [0.02 to 1.0] with <20% uncertainty **Related to:** SR2.2, SR6.2	**Location:** at radial distances between 5-18 Uranus' radii **Samples:** > 6/min	**Plasma density (cm-3):** [0.001 to 1] with <20% AND <0.0001 cm-3 uncertainty	RPWI	10^-5 - 10^4 cm^3 Error: <5% uncertainty	
	SO8: Characterise energetic-particle dynamics within the radiation belts	SR8.1	**(3D) (e^-, H^+, He^{2+}, C^{6+}, O^{6+}) Differential Flux (cm-2 s-1 MeV-1):** $[1$-$10^7]$ with <20% uncertainty **Required by:** SR9.1b **Related to:** SR5.2, SR7.4	**Location:** Across radial distances <10 Uranus' radii **Energy Range (keV/nuc):** [30 to 10,000] **Samples:** >6/min (faster in burst mode)	**(3D) (e^-, H^+, He^{2+}, C^{6+}, O^{6+}) Differential Flux (cm-2 s-1 MeV-1):** $[1$-$10^7]$ with <20% uncertainty	JoEE	25 keV – 1 MeV, ΔE/E≤20% FoV: 12˚x180˚, ΔΩ=12˚x22˚	
		SR8.2	**(3D) (e^-, H^+, He^{2+}, C^{6+}, O^{6+}) Integral Flux (cm-2 s-1):** $[10^1$-10^2 to $5\times10^7 cm^{-2}]$ with <20% uncertainty **Requires:** SR9.1a **Related to:** SR5.2, SR7.4		**(3D) Electron Flux (cm-2 s-1 sr-1):** $[10^1$-10^2 to $5\times10^7 cm^{-2}]$ with <20% uncertainty	JoEE	25 keV – 1 MeV, ΔE/E≤20% FoV: 12˚x180˚, ΔΩ=12˚x22˚	
		SR8.3	**Ion Temperature/Energy (keV/nuc):** [3 to 200] with <25% uncertainty. **Related to:** SR2.3, SR5.1, SR6.3	**Location:** Across radial distances <10 Uranus' radii **Time:** ≥2 solar rotations (~54 days minimum) to capture multiple successive CIR passages, but ideally spanning the full prime mission **Samples:** ≥1 Hz	**Plasma Temperature/Energy (eV):** [1 to 30,000] with <25% uncertainty	JDC	1 eV – 41 keV Error: ΔE/E=12%	
		SR8.4	**Plasma Composition (amu-1):** [1 to 16] with <10% uncertainty		**Plasma Composition (amu-1):** [1 to 16] with <10% uncertainty	JDC	1 eV – 41 keV, ΔE/E=12% M/ΔM=30 Hemispheric, ΔΩ=5.5˚x19.5˚	

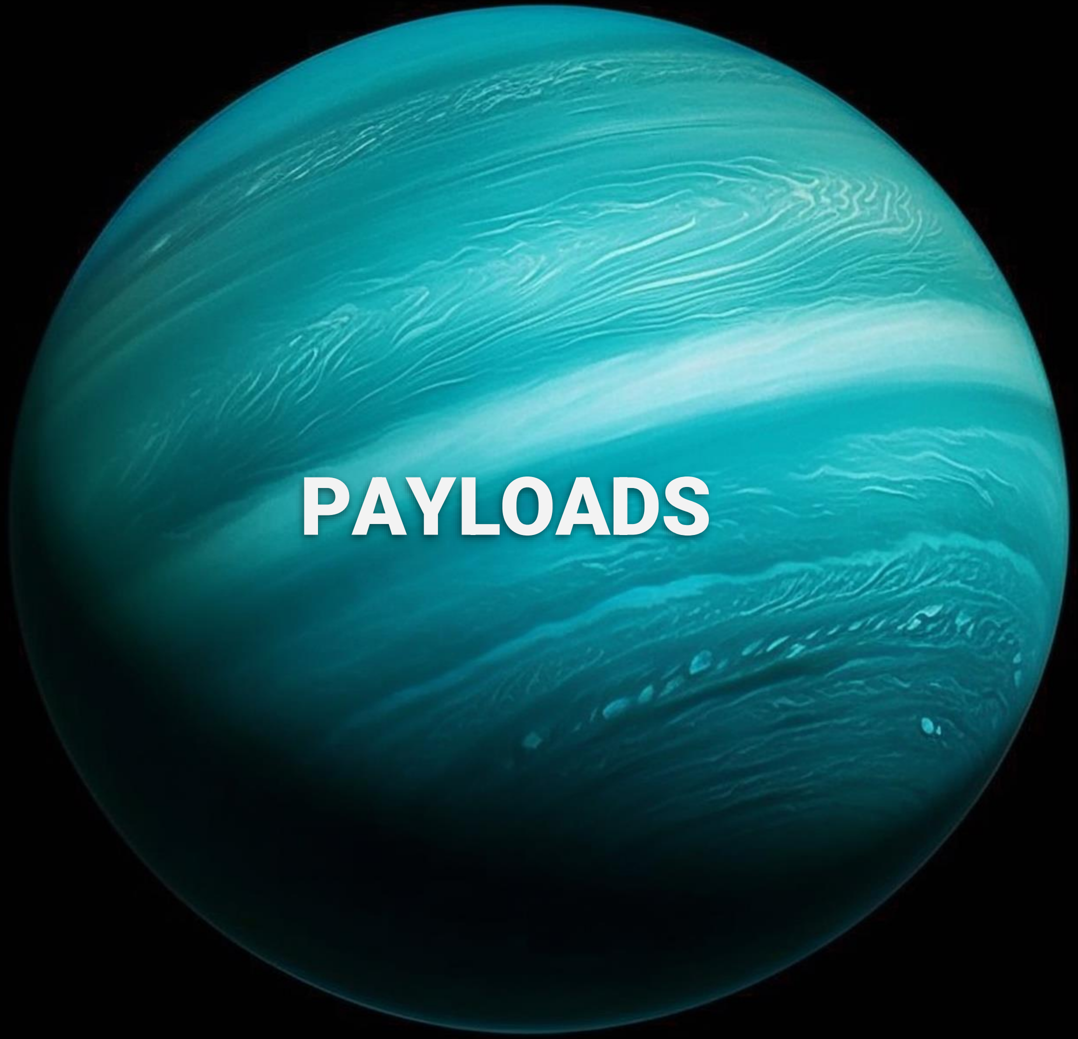
TEAM GREEN

		SR	×10^-8 with an uncertainty of 7x10^-5 (Equivalent a precision of J8)	**Location:** Periapsis at <25000 km **Samples:**
SQ2: What is the driving process of the plasma and energy transport from the solar wind to the magnetosphere for highly oblique planets?	SO2: Determine the occurrence and frequency of magnetic reconnections at Uranus' magnetopause.	SR2.1	**(3D) Magnetic field strength (nT):** [1 to 30] with <1% uncertainty **Related to**: SR1.1, SR4.2, SR6.1, SR7.3, SR7.5	**Location:** both sides of the magnetopause crossing **Time:** 3 years **Sampling:** >25Hz (for d_i = ~500km, v = 22 km/s) AND **Location**: Upstream solar wind, outside bow shock. **Time**: Continous whenever spacecraft is upstream of the bow shock for 3 years reconnection studies. **Sampling**: >6/min
		SR2.2	**Plasma density (cm-3)**: [0.01 to 0.1] with <20% uncertainty **Related to:** SR6.2, SR7.6	**Location:** on both sides of the magnetopause crossing AND upstream to measure undisturbed solar wind and IMF conditions **Time**: 8*2 min observations over 3 years (times two beause we are crossing magnetopause two times) **Sampling:** >25Hz.
		SR2.3	**Plasma Temperature/Energy (eV)**: [1 to 10,000] with <25% uncertainty **Related to:** SR5.1, SR6.3, SR8.3	
		SR2.4	**(3D) Plasma bulk velocity (km/s)**: <500 in each direction with <15% uncertainty **Related to:** SR6.4	
		SR2.5	**Ion/Electron Energy Distribution/Spectrum (eV-1):** <20% uncertainty **Bin Size:** 10 keV for [0 to 30] keV; 100 keV for [0 to 1,000] keV	**Location**: Magnetopause boundary layer, extending to the adjacent exhaust region on both sides, need spatial coverage along the boundary. **Time**: 8x2 min observations over 3 years. **Sampling**: >=1 Hz
		SR.26	**Turbulence Frequency (Hz):** [3 to 400] with <10% uncertainty **Additional Information**: associated with active reconnection sites	**Location**: Downstream of the magnetopause crossing, in the reconnection exhaust **Time**: Burst captures triggered around each of the magnetopause crossings over 3 years, continous low-rate survey mode elsewhere **Sampling**: survey mode 1 kHz, burst mode >2-4 kHz to capture waveform
	SO3: Determine the governing processes responsible for energy transfer between the solar wind and the magnetosphere and quantify their efficiency.	SR3.1	**Magnetosheath Boundary Layer Thickness (km)**: [2,500 to 10,000] with <10% uncertainty	**Location**: Whitin the magnetosheat, between bow shock and magnetopause crossings. **Time**: 8x2 min observations over 3 years. **Sampling**: 25 Hz
		SR3.2	**Magnetosheath Field Shear (T):** [1 to 30] with <1% uncertainty	
				Location: polar regions (~30000 km by 30000 km) **Spatial Resolution**: <300km, with a goal of <150 km

INSTRUMENTS REQUIREMENT MAPPING (ALFRED)

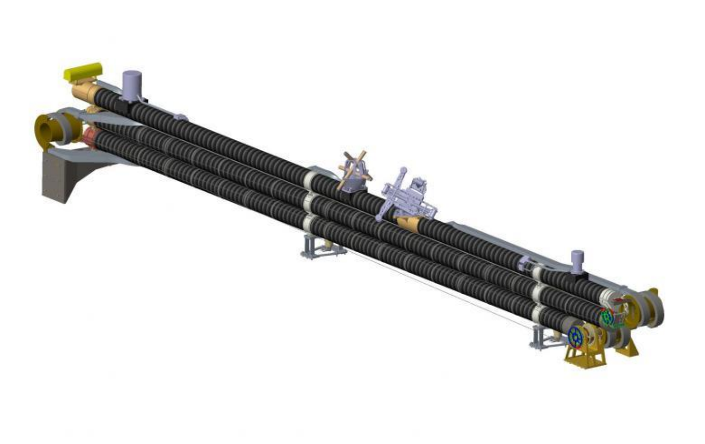
- Used to identify importance of each instrument to the mission
- Identify priority science objectives
- Identify potential descoping options (using priority)

Objective	SO1	SO2	SO3	SO4	SO5	SO6	SO7	SO8	Mass (kg)
Priority	1	2	2	3	3	4	5	5	
JDC		X	X		X			X	6
JoEE							X	X	4
RPWI		X	X			X	X		17
UVCam				X					8
Grav	X								2
MAG	X	X	X	X		X	X	X	27.8


PAYLOADS

MAGNETOMETER (J-MAG)

- Modified JUICE magnetometer
- Boom shortened to 7 meters for mass
- Uses 6 fluxgate magnetometers divided in 2 sensors
- By using this configuration, we can minimise the spacecraft's influence on the measurement



J-MAG instrument

[1] *https://sci.esa.int/web/smile/-/59196-magnetometer-mag*

Particle Package - Jovian plasma Dynamics and Composition analyser (JDC)

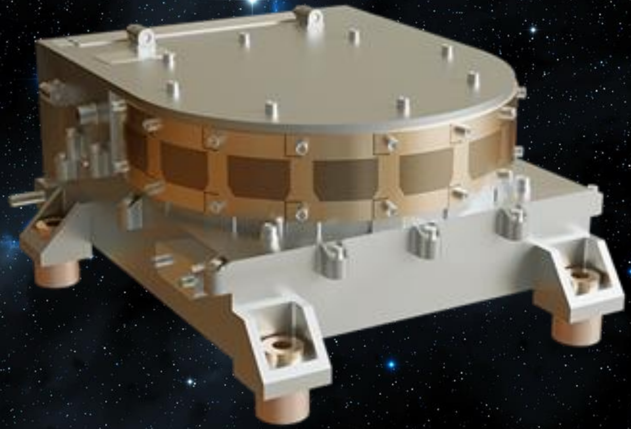
- Low energy (1-41keV) electron and ion spectrometer
- Uses an electric field to filter incoming ions by energy and then measures their exact time of flight between detectors to calculate their mass and composition.
- Allows us to determine the exact composition and dynamics of the surrounding plasma.

JDC instrument

[1] https://cnes.fr/projets/juice/instruments

Particle Package - Jovian Energetic Electrons (JoEE)

- Spectrometer for higher energy (<1MeV) electrons
- Relies on 3D printed collimators that act like directional channels
- Multidirectional, can obtain electron spectra almost simultaneously from nine directions

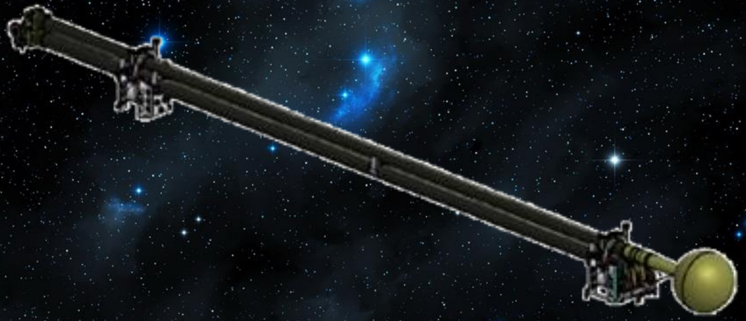


3D rendering of JoEE instrument

[1] https://www.jhuapl.edu/destinations/instruments/joeejeni

Radio & Plasma Wave Investigation

- Measures space plasma, electric fields, and magnetic fields. Detects local electron density and temperature.
- By measuring local electric and magnetic fields allows us to map surrounding plasma properties.

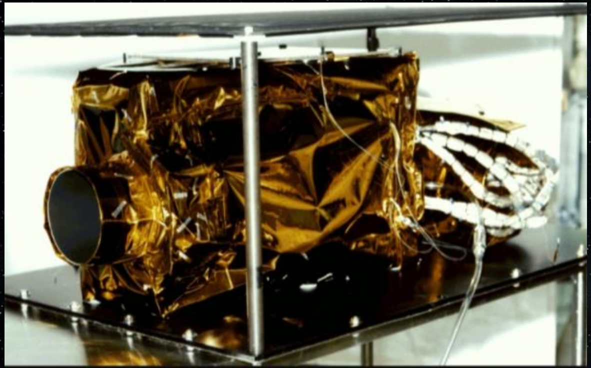


LP-PWI boom instrument

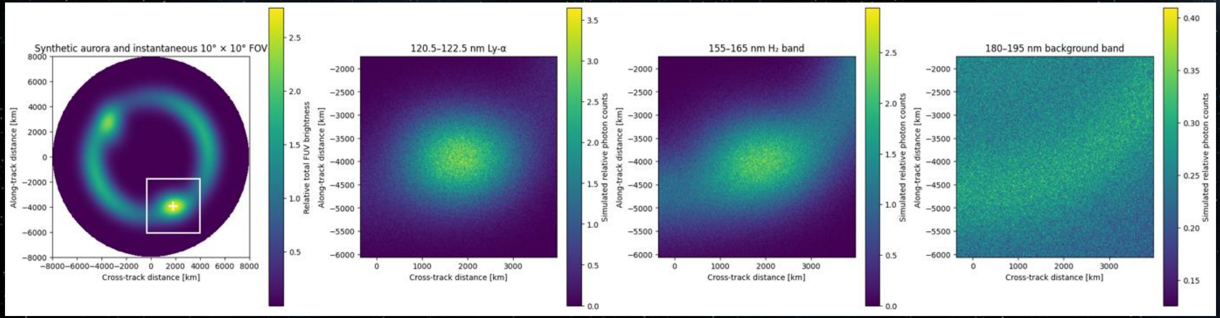
[1] https://link.springer.com/article/10.1007/s11214-024-01110-0/tables/14

UV Camera

- 2D 4-band camera – FOV: 10ºx10º
- 120.5-122.5 nm : Ly-a
- 100-120 nm : H2 band
- 150-165 nm : H2 band
- 180-195 nm : Background



Polar-UVI



[1] https://arxiv.org/pdf/0709.4279

GRAVITY EXPERIMENT

- Maps Uranus' gravity during a flyby.
- Tracks tiny speed changes in the spacecraft via radio Doppler shift
- Measure Uranus's gravity and get an idea of what's inside

Location of the antennas on the JUNO spacecraft

[1] https://www.researchgate.net/publication/320639251_The_Juno_Gravity_Science_Instrument

Visible Light Camera

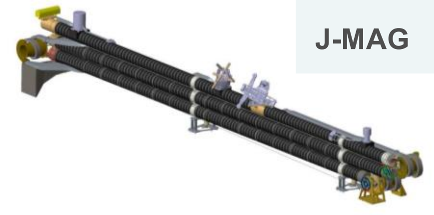
- Based on JunoCam, which was a dedicated outreach camera
- Will take the first images of Uranus since Voyager II (1986)
- Can also take images of Venus during transit as well as Uranus' moons and rings

JunoCam sensor and computer unit

[1] https://www.jpl.nasa.gov/news/press_kits/juno/pdf/juno-hires.pdf

INSTRUMENTS OVERVIEW

	MAG	JDC	JoEE	RPWI	UV Cam	Grav	Vis Cam
Mass (kg) (excluding booms)	5.5	6	4	13	8	2	3.7
Power (W)	12	8	10	12	8	2	6
Data rate (kbps)	1.2	3	3	66	100	0.1	120,000 (per image)
TRL	5	5	5	5	3	5	5

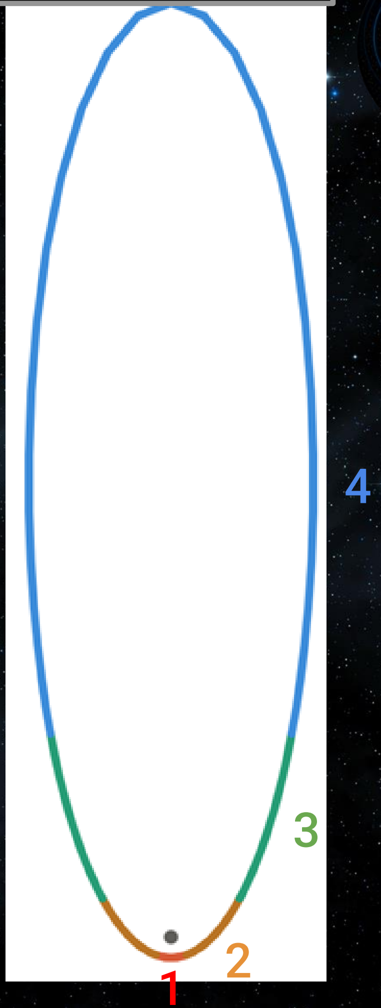


PAYLOAD SYSTEM DRIVERS

- Magnetometer is required in nearly all science cases, this needs to be **durable**
  - Needs to be positioned on a **boom arm to** reduce interference from spacecraft
- Part of the RPWI must also be positioned on a **boom arm to** reduce interference from spacecraft
- UV imaging system must be **pointed** at the poles
- Gravity experiment radio package needs **pointing** at Earth

OBSERVATION STRATEGY

1. < 2500 km altitude (ionosphere): SO1
   - MAG, Radio
2. 5h section around periapsis (aurorae): SO4, SO5
   - RPWI, JDC, MAG, JoEE, UV Cam
3. < 10 Uranus radii altitude: SO2, SO3, SO6, SO7
   - RPWI, JDC, MAG, JoEE
4. > 10 Uranus radii altitude (magnetotail): SO2, SO3, SO6
   - RPWI, JDC, MAG



MISSION PROFILE

DEVELOPMENT TIMELINE

Phase A (2026)
- Iteration of mission design
- Updated feasibility study

Phase B (2028)
- Full system definition, including interfaces
- RTG procurement

Phase C (2031
- Finalised system design
- Engineering Model

Phase D (2033)
- Manufacture of flight hardware
- Qualification campaign

Phase E (2038)
- Next slide

Phase E, Utilisation

Launch (2038)

Earth-Uranus transfer

Insertion (2052)

Science orbit
Primary operations

Possible extension (2057)

Dependant on RTG health, propellant, and funding

Phase F

De-orbit of craft into Uranus atmosphere

Launcher Selection: Ariane 64 baseline option

- Launcher selection drives achievable C3
- Ariane 64: highest available launch mass performance
- Delivers 2.2 tons at C3 = 35 km^2/s^2

Backup launcher option

- Long development time: potential unavailability of Ariane 64
- Future European or super-heavy US launchers are potential backup options
    - Potential increase in mass capability
    - Limited by market availability, maturity, risk

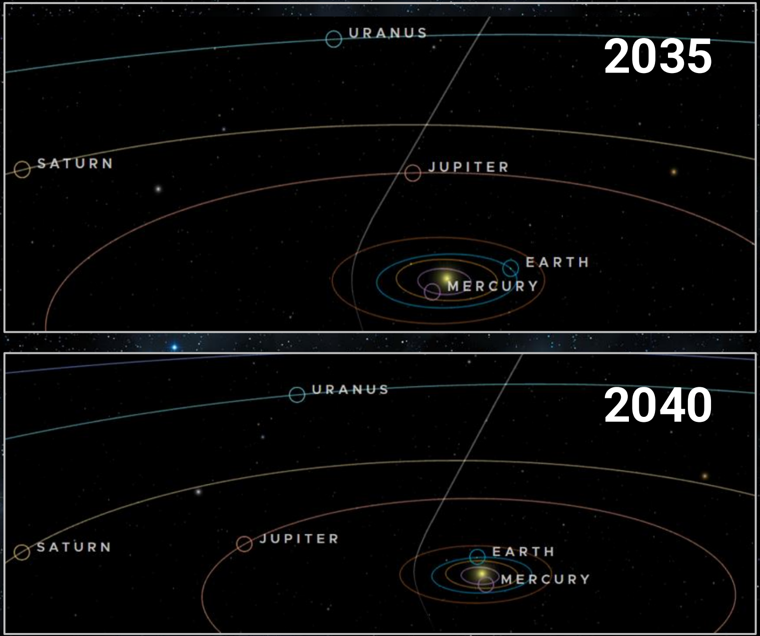
TRANSFER STRATEGY

- Large heliocentric distance (19.2 AU)
  - Drives transfer duration and energy req.
- Multiple Gravity Assist trajectory
- Time of flight: **10-15 years**
- Jupiter GA opportunity
  - Provides required heliocentric energy
  - No favourable geometry during 2035-2045

Launch date	Path	C3 (km^2/s^2)	UOI (km/s)	TOF (yrs)
2029	EVEEJU	14	1.2	14.5
2031	EVEJU	20	1.5	12.0
2032	E(ΔV)EJU	29	1.3	11.8
2038	EVEEU	35	1.3	14.2

Feasible launch opportunities

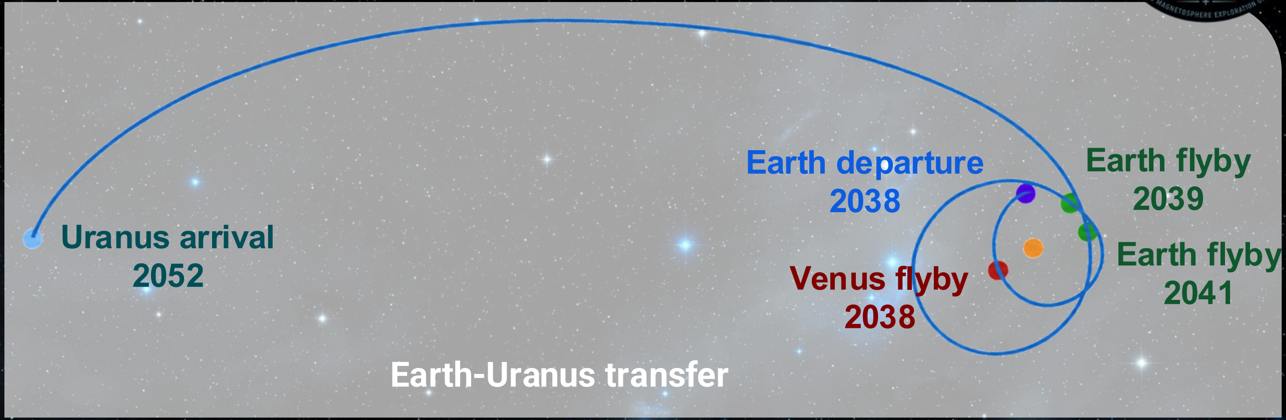
E: Earth, V: Venus, J: Jupiter, ΔV: Manoeuvre



Uranus and Jupiter relative position
NASA Eyes on the Solar System

TRANSFER TRAJECTORY

Launch: **08 Jan 2038**
Trajectory: **EVEEU**
Transfer: **14.2 years**
Arrival V_∞ = **6.74 km/s**
C3 = **35.5 km²/s²**



ΔV BUDGET	
Uranus orbit insertion	1.87 km/s
Station keeping	150 m/s
End of Life	27.5 m/s
Total ΔV	**2.05 km/s**

MASS BUDGET (kg)	
Total wet mass	2130
Propellant mass (incl. 5% margin)	1140
Dry mass	**990**
Spacecraft dry mass	**850**
Dry mass margin	**140**

SCIENCE ORBIT

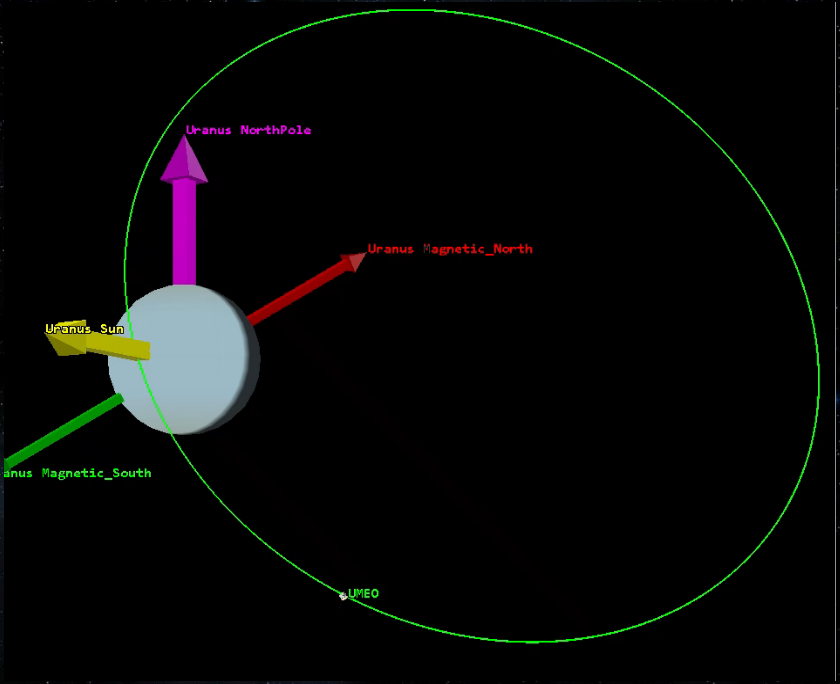
Highly **elliptical** orbit

Semi-major axis	650 000 km (25.6 RU)
Periapsis	25 500 km (1.1 RU)
Apoapsis	1 275 000 km (50 RU)
Eccentricity	0.957
Inclination	81° (near ecliptic)
Orbital period	16 days

- **114 science orbits** over 5-year nominal mission

15 m/s/year allocated for 10-year orbit maintenance

Disposal via periapsis lower burn



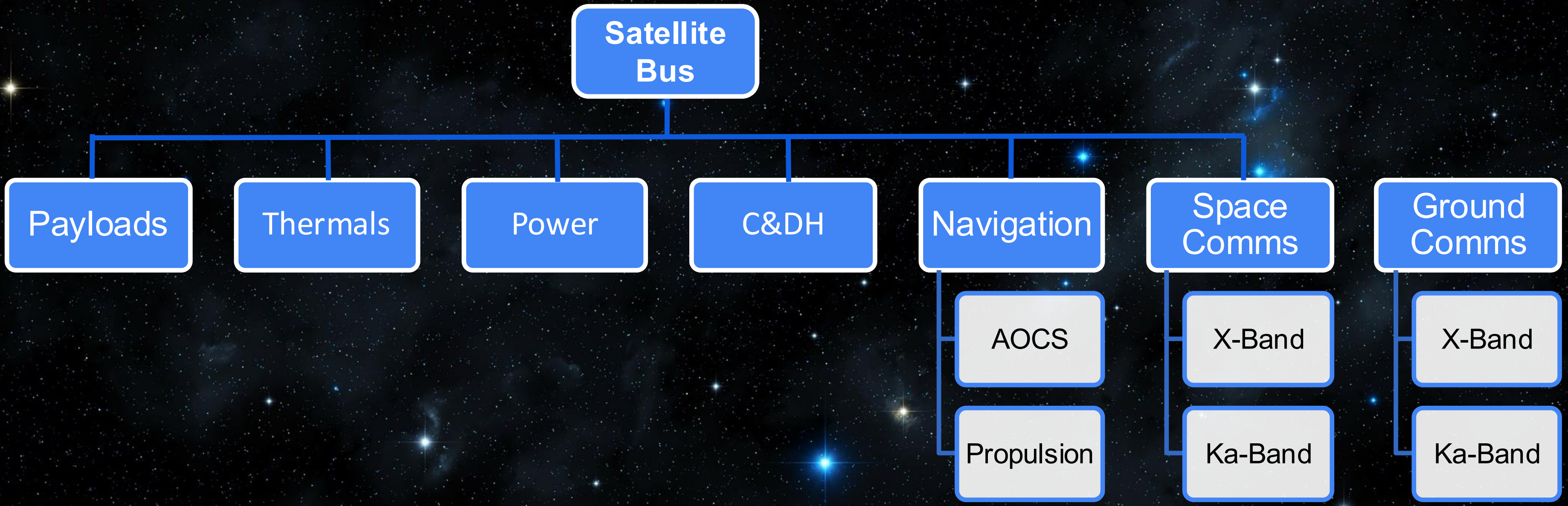
Science orbit animation

North magnetic pole, South magnetic pole
Sun vector, Rotation axis

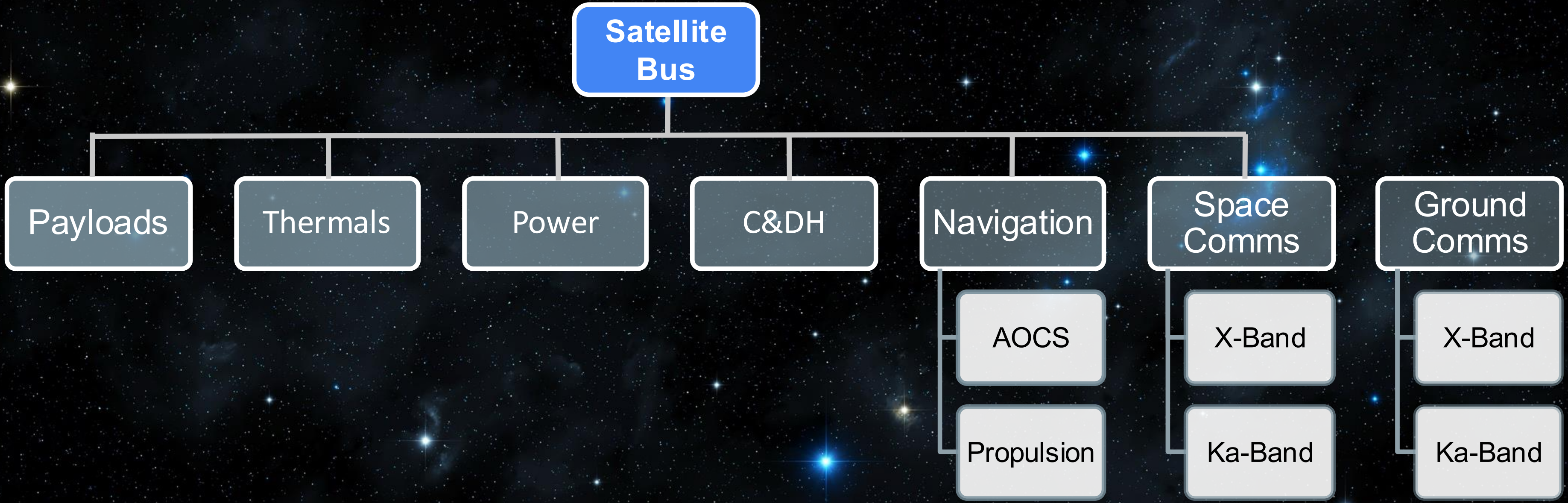
RU: Uranus Radius

SYSTEM ARCHITECTURE

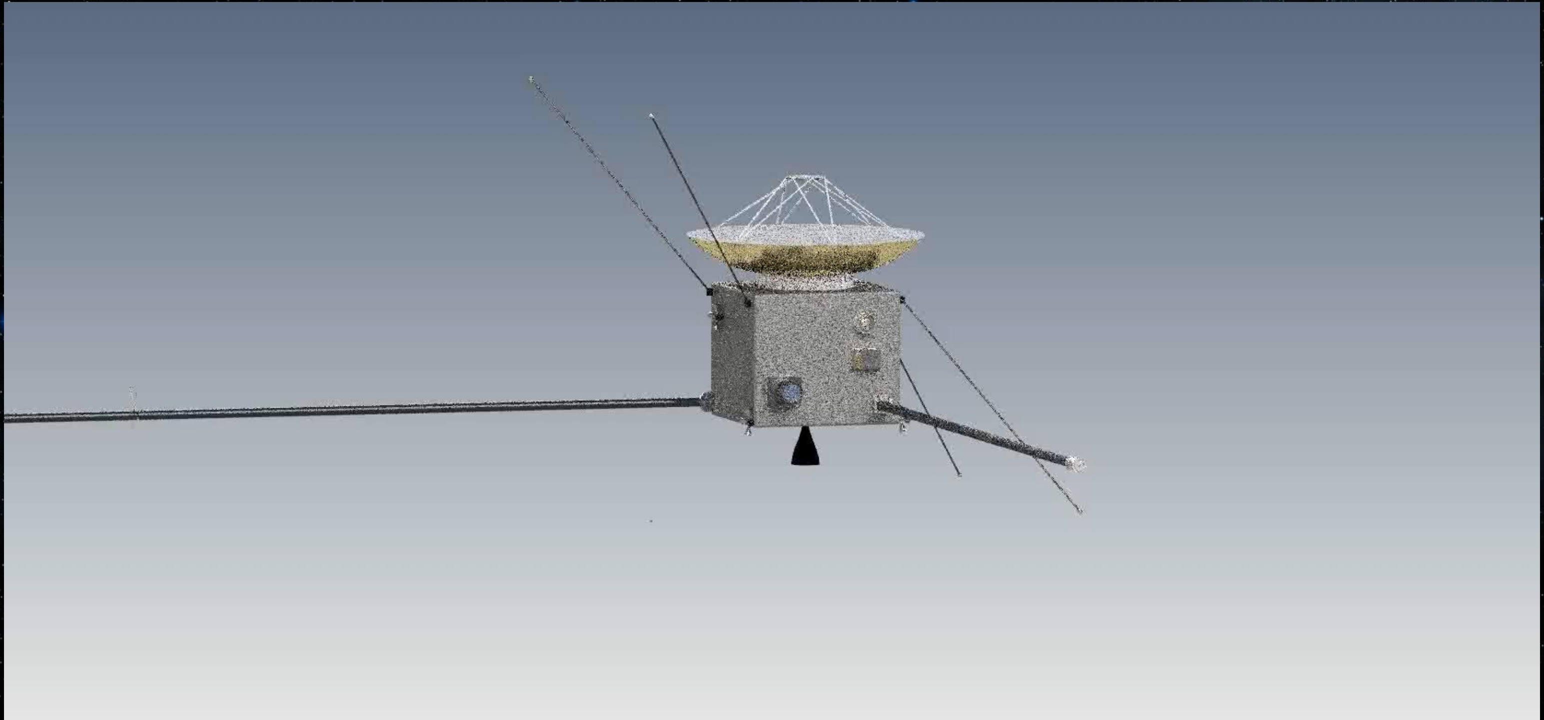
SYSTEM ARCHITECTURE



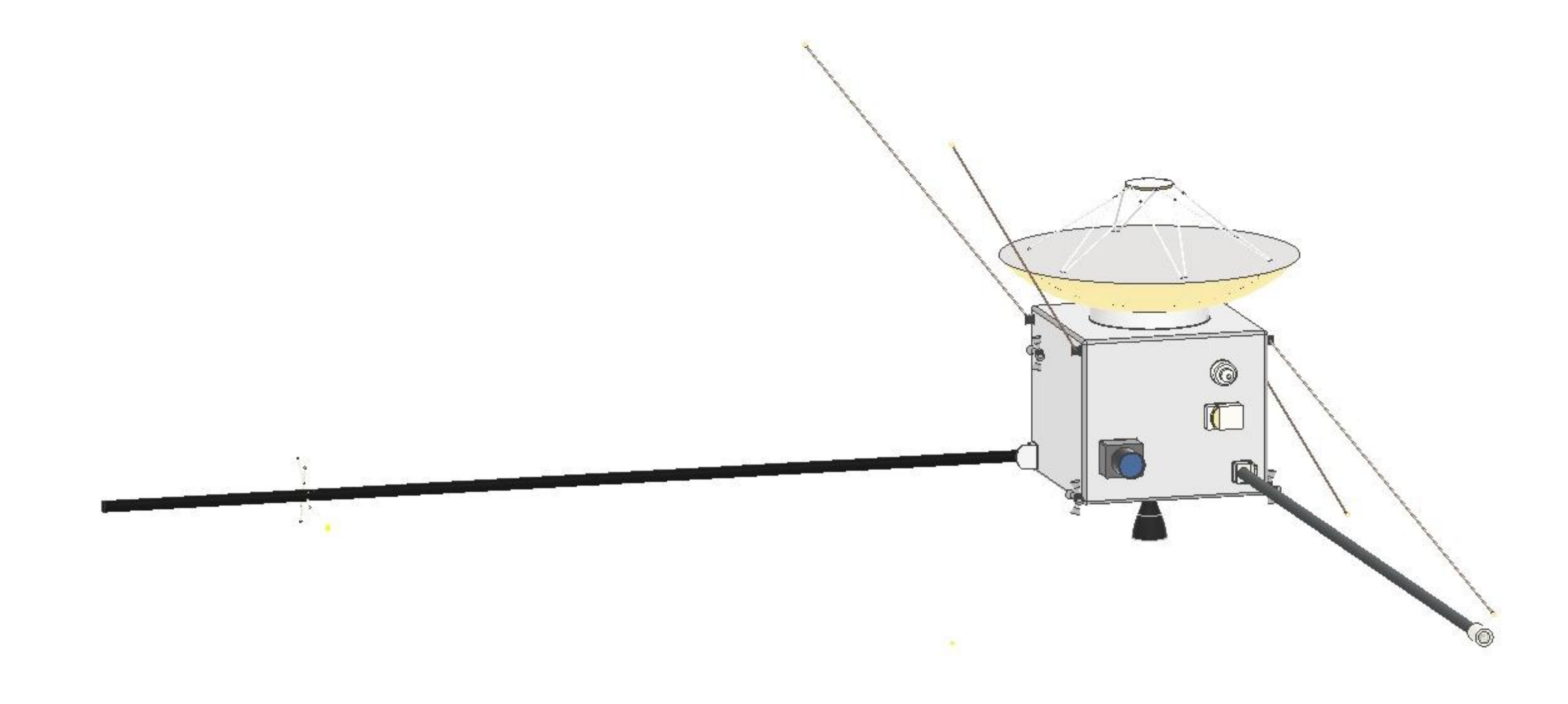
SYSTEM ARCHITECTURE



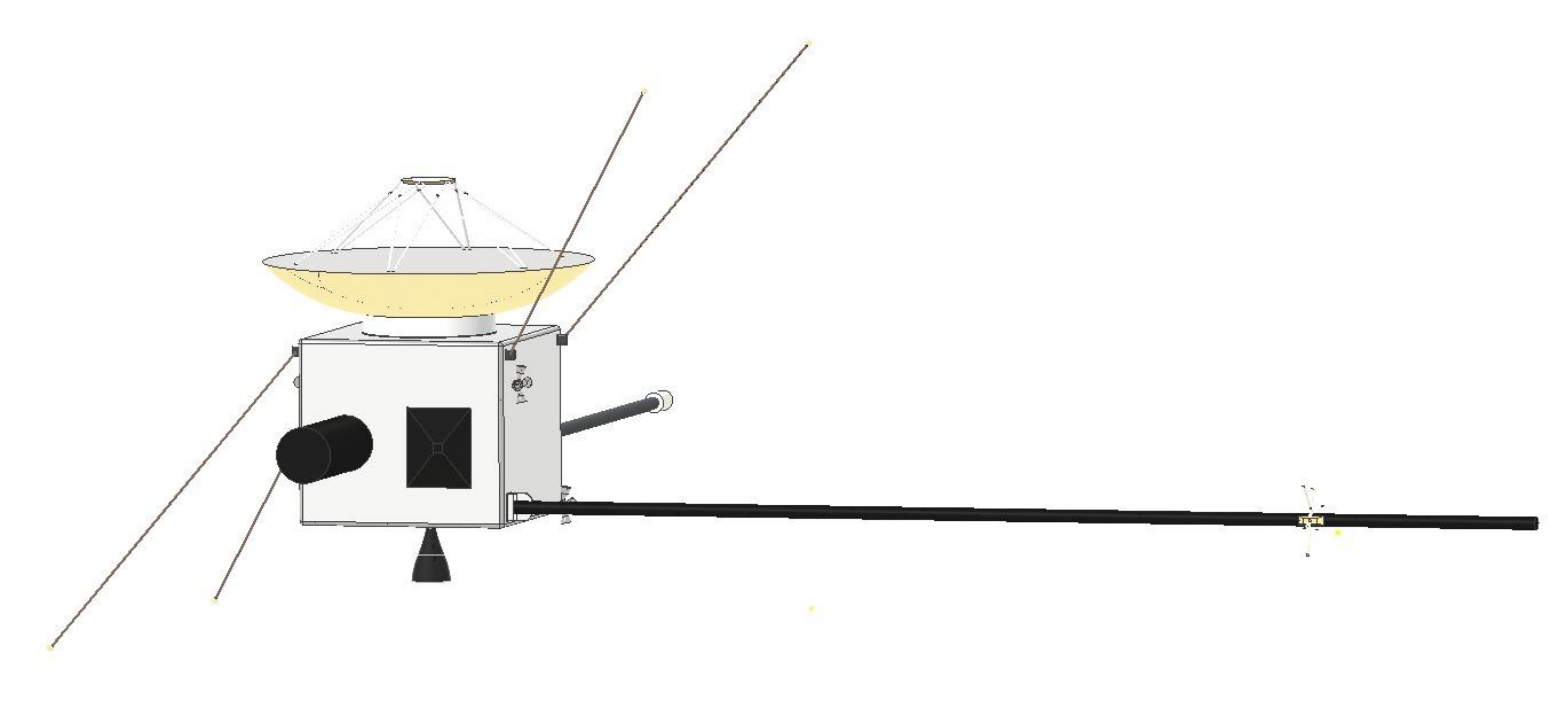
SPACECRAFT CONFIGURATION



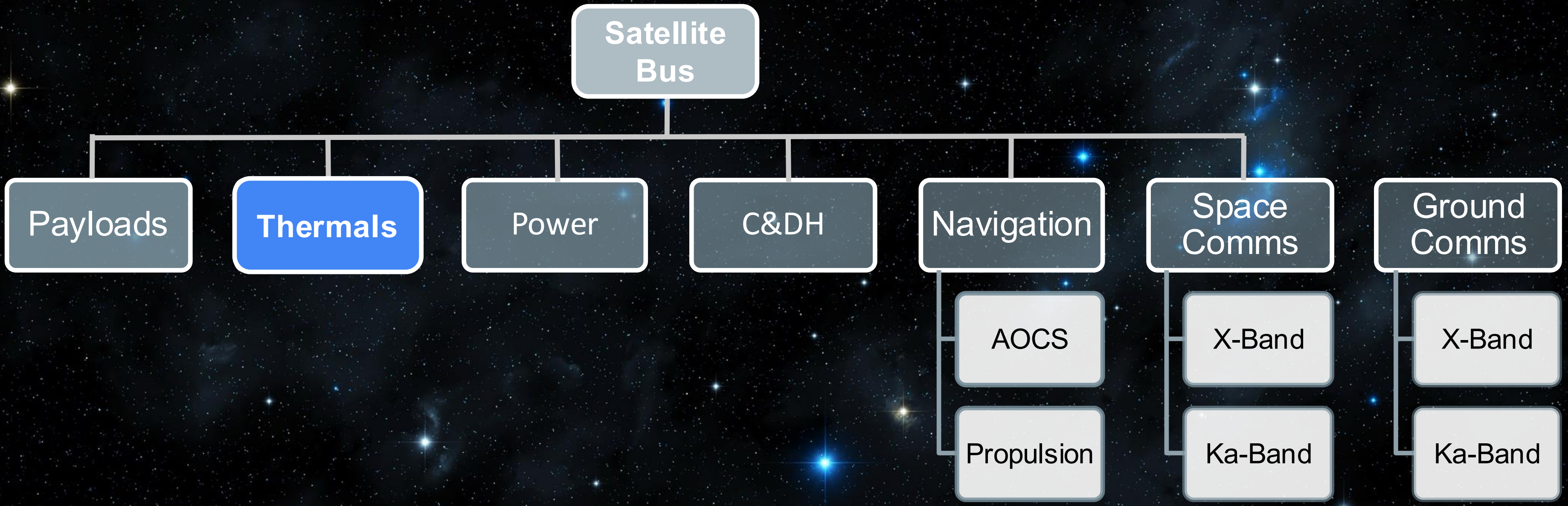
SPACECRAFT CONFIGURATION



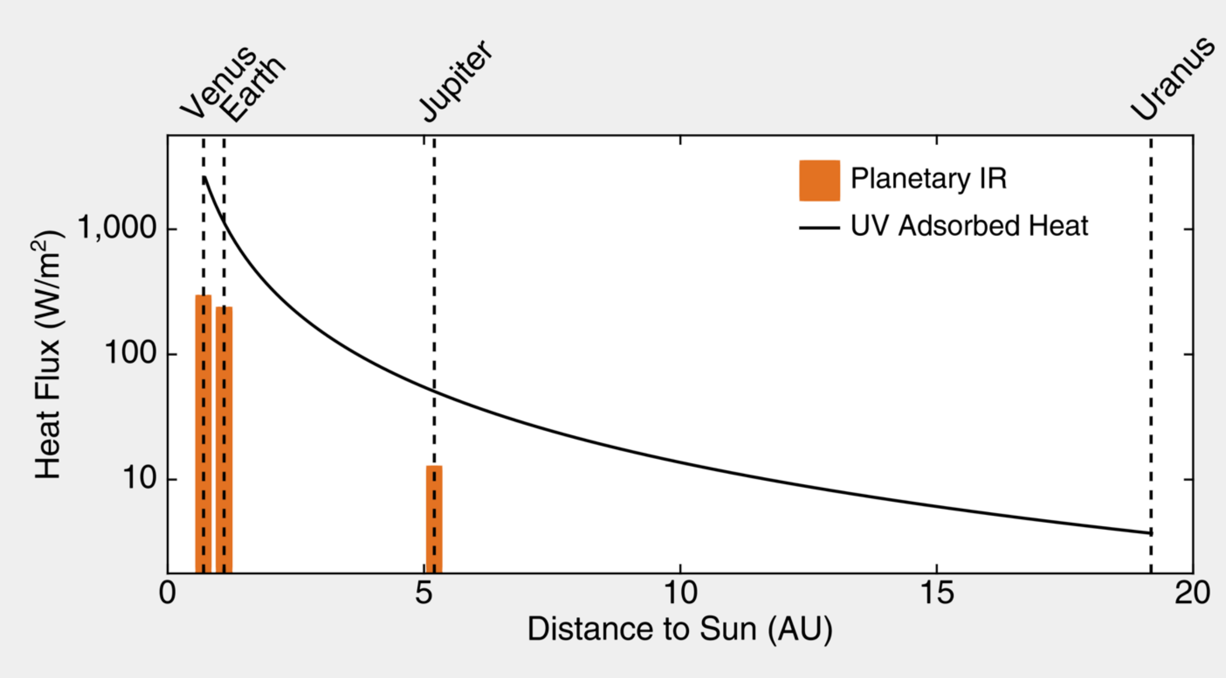
SPACECRAFT CONFIGURATION

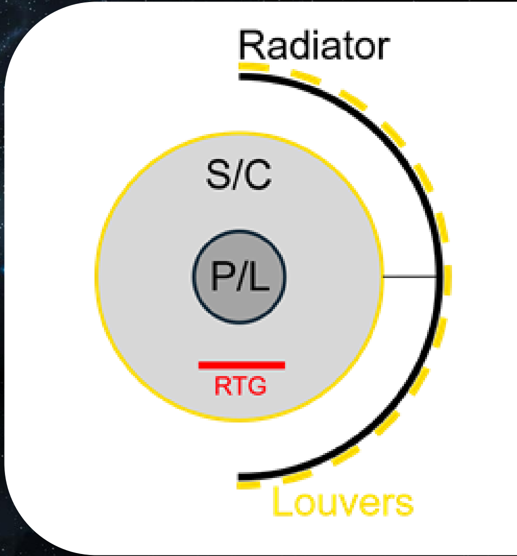


System Architecture



THERMAL CONTROL SUBSYSTEM

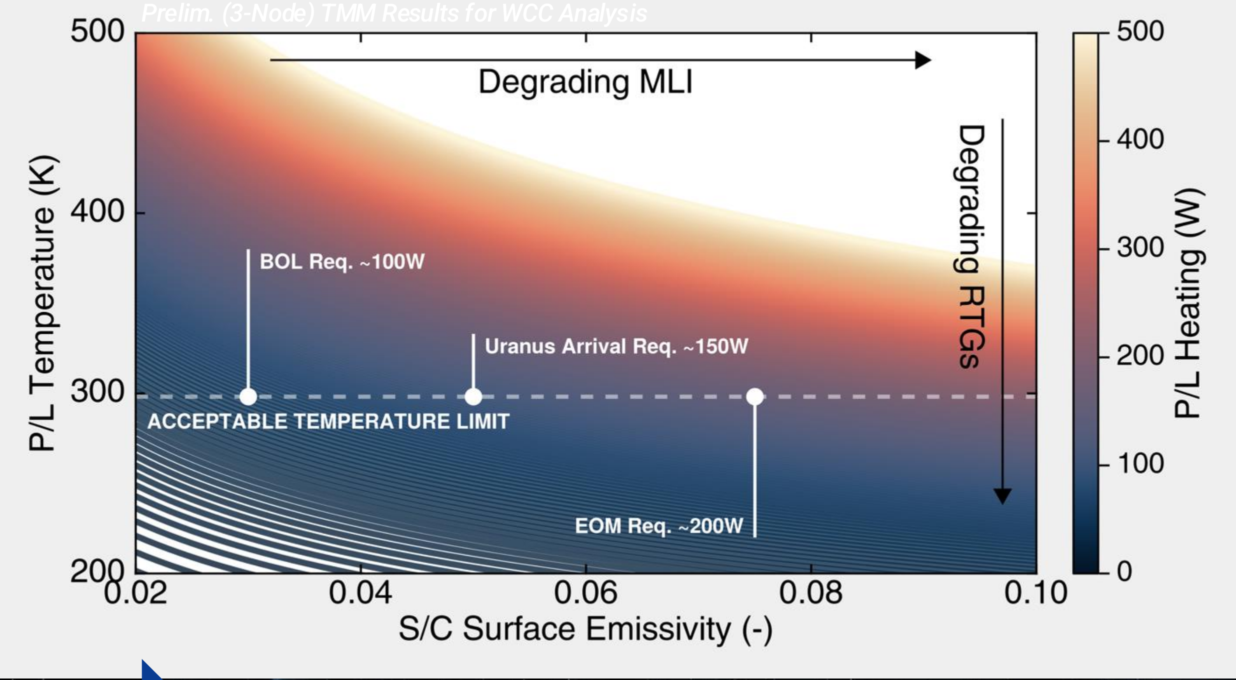


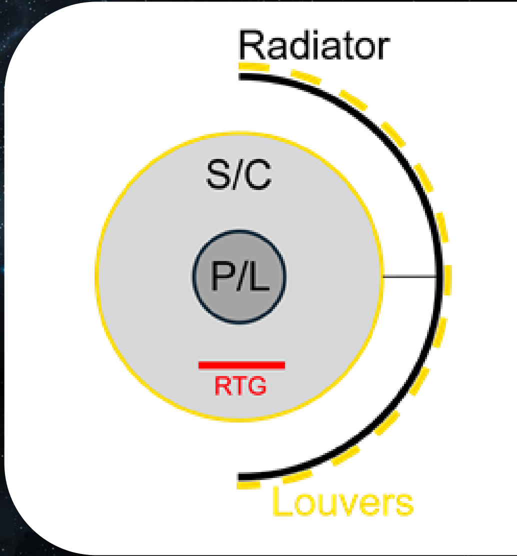


Prelim. (3-Node) GMM

Worst Hot Case (Venus-Flyby)

THERMAL CONTROL SUBSYSTEM





Prelim. (3-Node) GMM

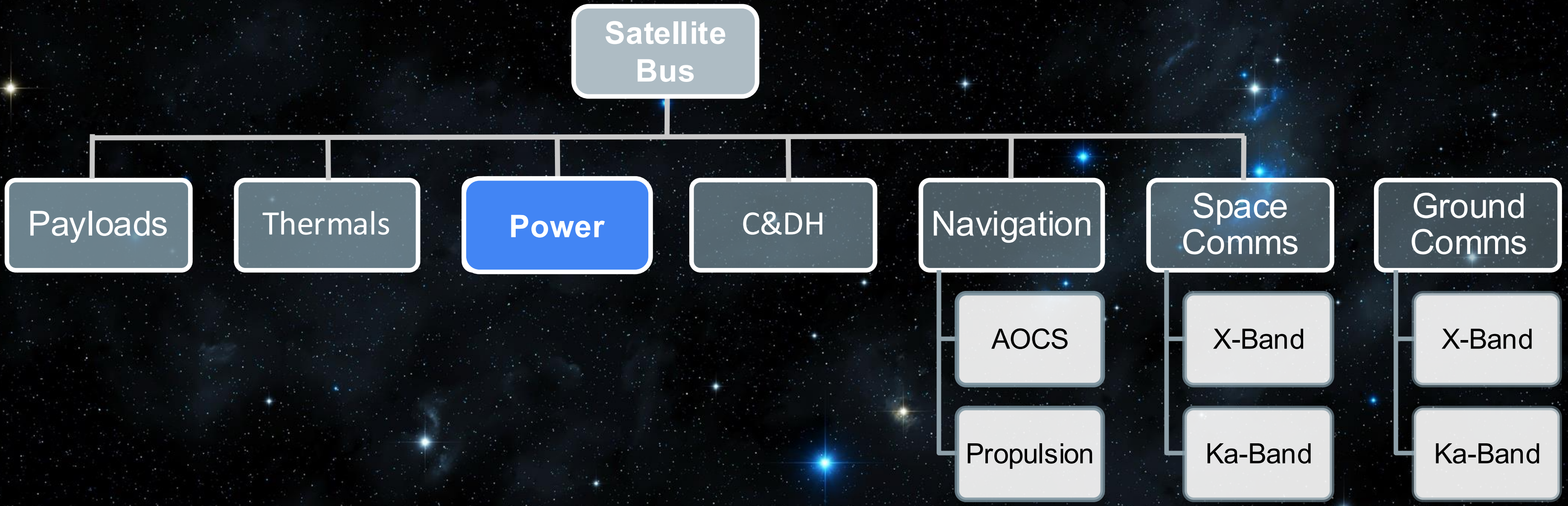
Worst Cold Case (EOM Uranus-Orbit @ Apoapsis)

THERMAL CONTROL SUBSYSTEM

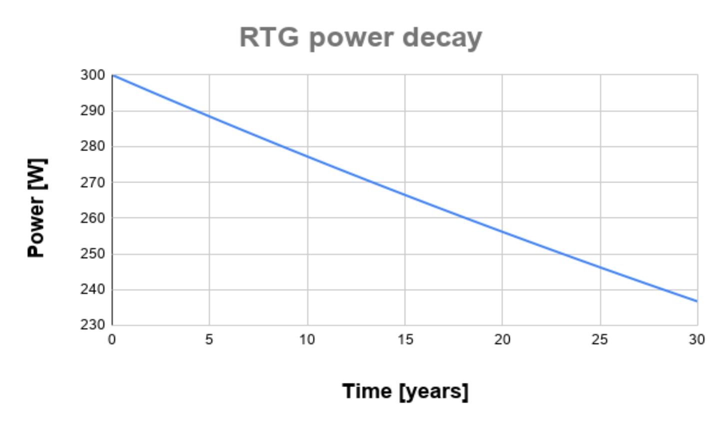
Key drivers:

- **Size matters!**
  Surface area drives absorbed and emitted heat.
- **We need big margins at BOL!**
  Surface properties and RTG will degrade over time.
- **We must use the dissipated heat of RTGs as well as their electrical power.**
  The radiation might be harmful to the sensitive P/L sensors. Placement should be close enough to transfer some heat and but far enough away to protect the equipment.
- **Engineering solutions:**
  MLI, Coatings, Louvers, Heat Pipes, Radiators, Electrical Heaters, Heat Switches + ConOps (S/C orientations)

SYSTEM ARCHITECTURE



POWER SUBSYSTEM



Power source: GPHS-RTG

(Pu-238, α decay, $t_{1/2}$ = 87.7 years, product: U-234)

Mass: 57 kg *(8.1 kg of Pu-238)*

BOL Power: 300 W

EOL Power: 236 W *(30 years)*

Heritage: Ulysses, Galileo, New Horizons

Battery: LiFePO4 (Lithium Iron Phosphate)

(Double RTG output for pole to pole crossing >1500 Wh)

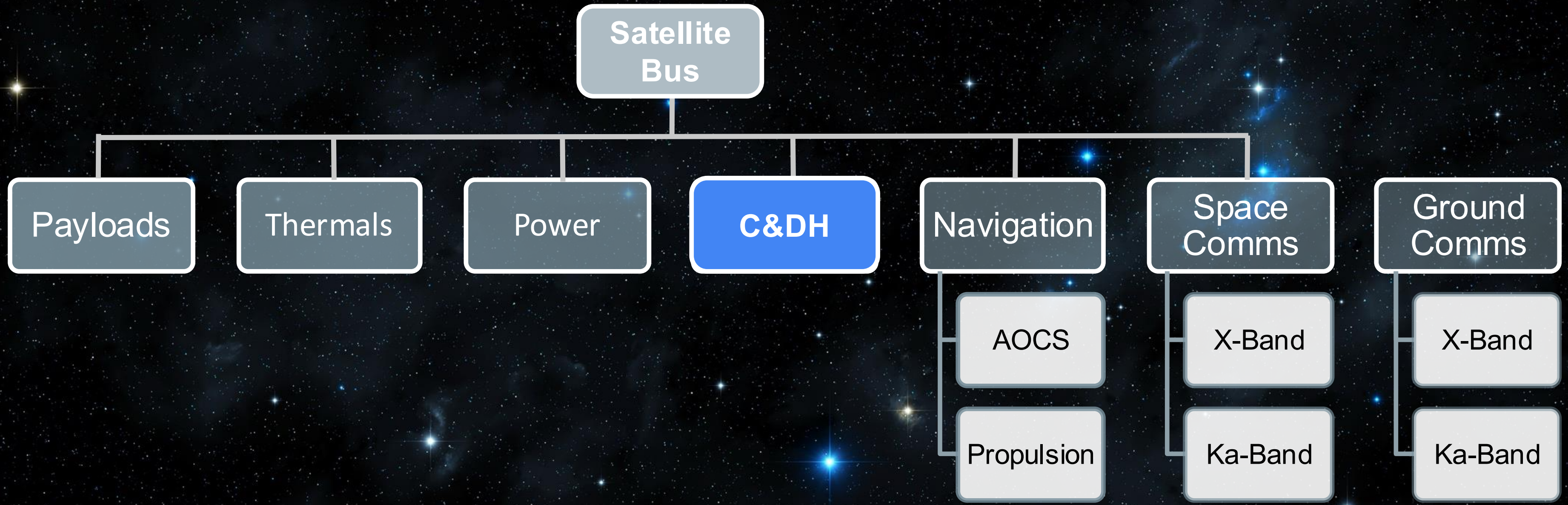
DOD = 15%, DOC = 80%, 160 Wh/Kg, -20 to +60 °C

Mass: 14 kg

BOL Capacity: 2025 Wh

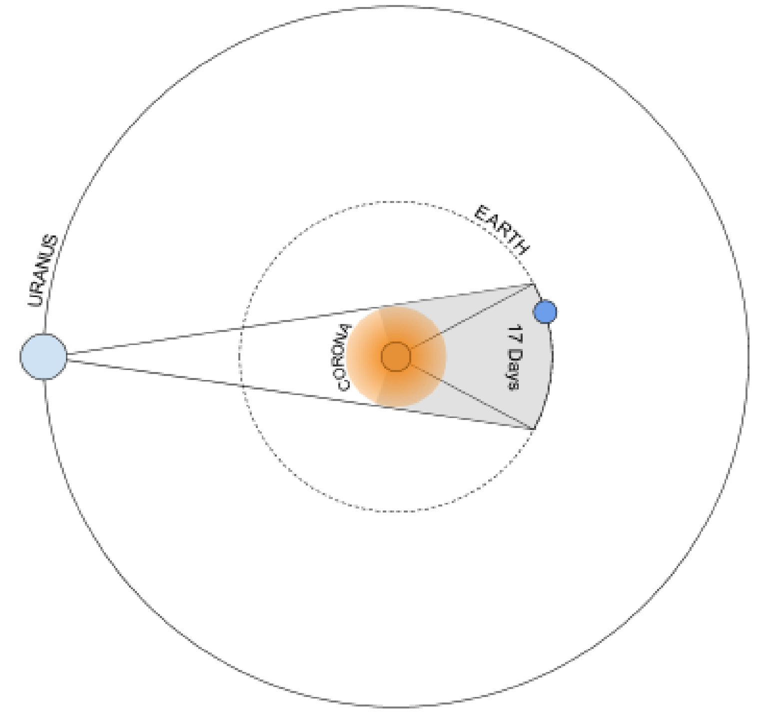
Radiation and temperature resistant, long lifespan

SYSTEM ARCHITECTURE



Earth-Sun Eclipse

- Once a year the Sun eclipses the Earth, blocking communication.
- As a simplification, it is assumed that the Suns corona will block all communications.
- The corona could swell to up to 30 solar radii [1].
- This would eclipse the Earth for up to 17 days.
  - This covers 1.1 mission orbital periods.



[1] https://iopscience.iop.org/article/10.3847/2041-8213/ac25fa

COMPUTER & DATA HANDLING

On Board Computer

(Based on CDF-187(C) Ice Giant study report)

Mass: 32 kg

Power: 19.2 W

Specs: RTOS, fault tolerant, redundancy

Data storage

(Driven by Earth-Sun eclipse period)

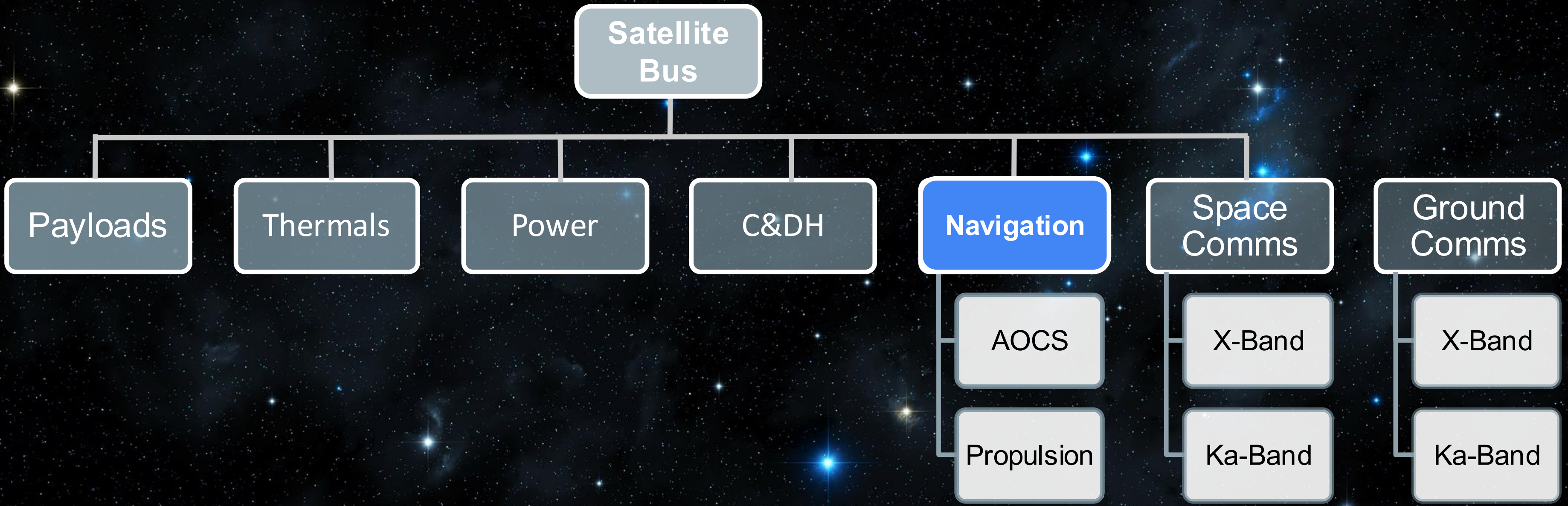
Redundancy: 3x

Capacity: >30Gb

Eclipse period:	1.1 mission orbits
Data per orbit:	8.2 Gbit
20% margin:	1.64 Gbit
Data per eclipse:	9.84Gbit
3x Redundancy:	29.52

Image: https://www.mrcy.com/products/data-management/rad-tolerant-storage-memory/model-rh3480

SYSTEM ARCHITECTURE



PROPULSION SUBSYSTEM

Propulsion System :	Pressure-fed bipropellant (MMH/MON-3)
Main Engine :	Aerojet Rocketdyne R-4D (490 N, Isp = 315.5 s)
Attitude control :	16x 4 N RCS Thrusters
Total Propellant Loaded :	1275.41 kg (including 2% residuals)
Pressurization system:	5.9 kg He at 31 MPa, 100 l COPV

Main Rocket Engine:

R-4D - 490 N

AOCS SUBSYSTEM - SENSORS

- **2x Star Tracker:** Determine absolute spatial orientation by comparing sky images to onboard star catalogs
- **2x Inertial Measurement Unit:** Measure angular velocity and linear acceleration for continuous, fast dynamic tracking
- **2x Sun Sensor:** Detect the Sun's vector. Critical for Safe Mode recovery to point the antenna towards Earth and thermal management
- **1x Coarse Rate Sensor:** Measure high angular velocities. Essential for rate damping to stabilize the spacecraft when fast rotation blinds the Star Trackers

Star Tracker

Sun Sensor

IMU

AOCS SUBSYSTEM - ACTUATORS

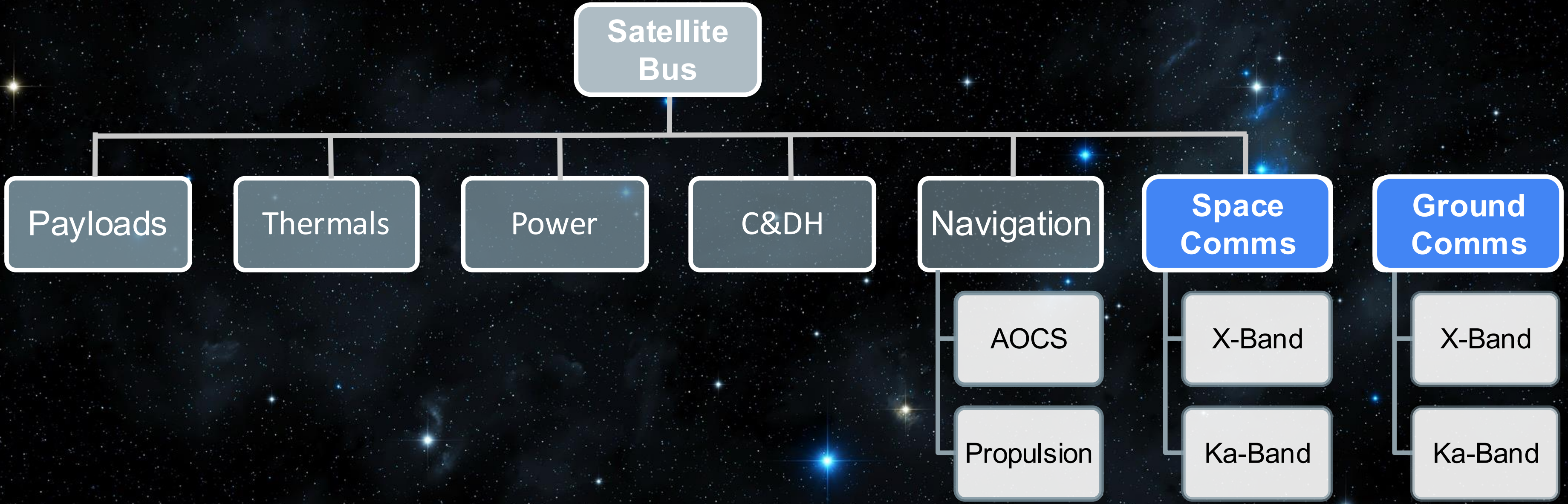
- **4x Reaction Wheel:** Generate torque for highly precise, fuel-free attitude control during science operations
- **Thrusters:** Execute coarse maneuvers, trajectory changes, and momentum dumping (desaturating reaction wheels).

16x thrusters in a redundant configuration

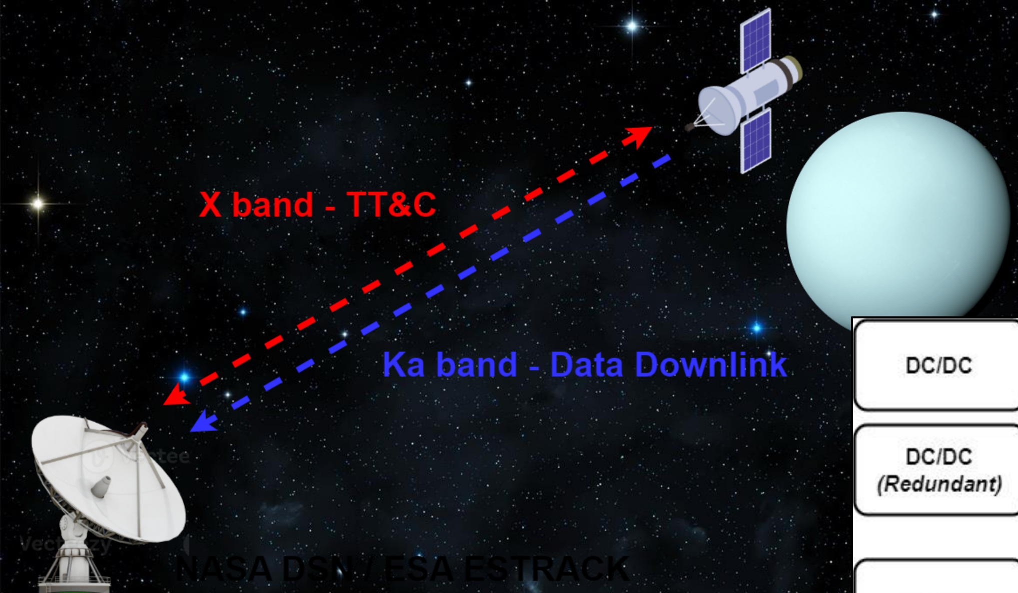
Reaction Wheels

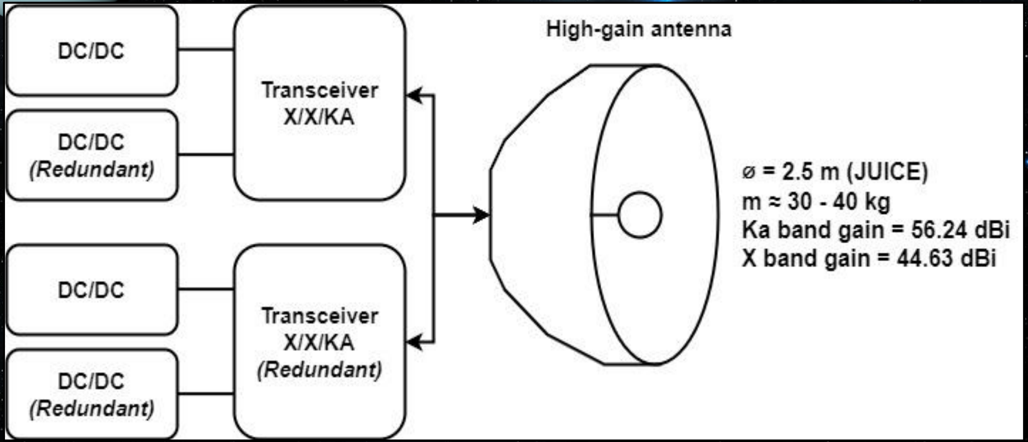
Spacecraft Bipropellant Thruster

SYSTEM ACRHITECTURE



COMMS SYSTEM - ARCHITECTURE

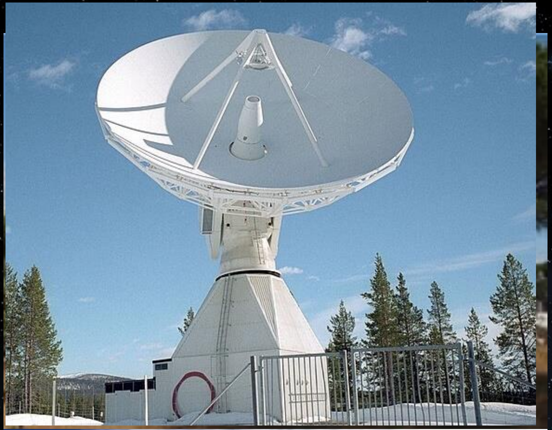




Total mass ≈ 50 Kg

Transceivers of BepiColombo (Thales-Italy) - TRL 9

GROUND SEGMENT



ESA ESTRACK (⌀ = 35 m)

- X band Downlink data rate - up to 2.29 kbps
- X band Uplink data rate - up to 234.03 kbps
- Ka band Downlink data rate - up to 30.31 kbps

NASA DSN (⌀ = 70 m)

- X band Downlink data rate - up to 8.15 kbps
- X band Uplink data rate - up to 782.60 kbps
- Ka band Downlink data rate - up to 79.72 kbps

[1] https://it.wikipedia.org/wiki/ESTRACK#/media/File:Sede_ESA_Kiruna.jpg
[2] https://www.futura-sciences.com/en/nasas-70-meter-giant-antenna-fails-at-the-worst-possible-time-what-it-means-for-upcoming-space-missions_26278/

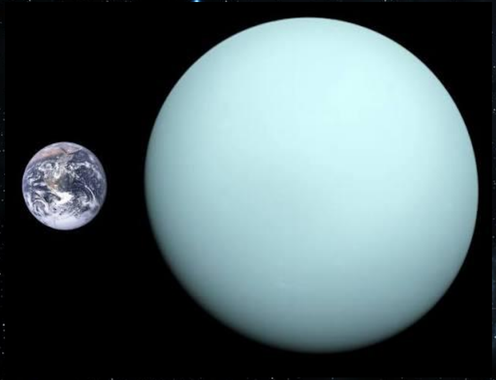
LINK BUDGET

Free space loss ≈ 312.09, 300.47 dB

One way signal travel time ≈ 2.5 - 2.8 h

Walking travel time ≈ 67 903 years

Snail travel time ≈ 7 300 000 years



Rain loss for - Ka, X band:

- **fog/0.25 mm/h ≈ 0.1, 0 dB/km**
- **25 mm/h ≈ 8, 0.1 dB/km**
- **150 mm/h ≈ 25, 1dB/km**

Troposphere loss (Zenith) ≈ 1.2, 0.12 dB

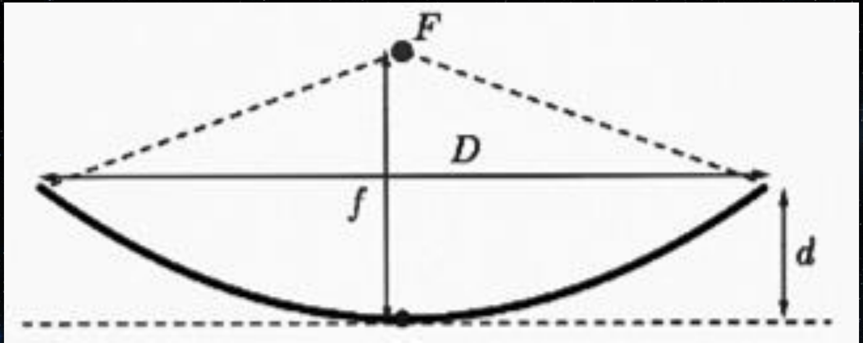
Troposphere loss (Horizon) ≈ 12.4, 1.24 dB

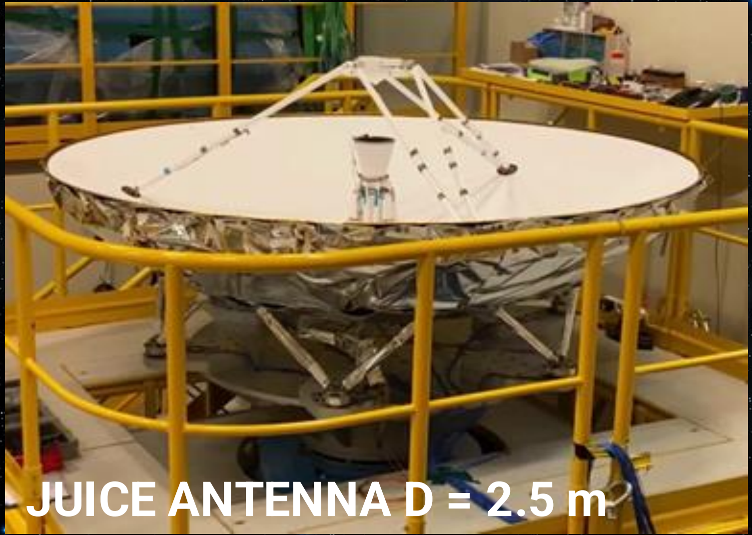
[1] https://commons.wikimedia.org/wiki/File:Uranus,_Earth_size_comparison_2.jpg

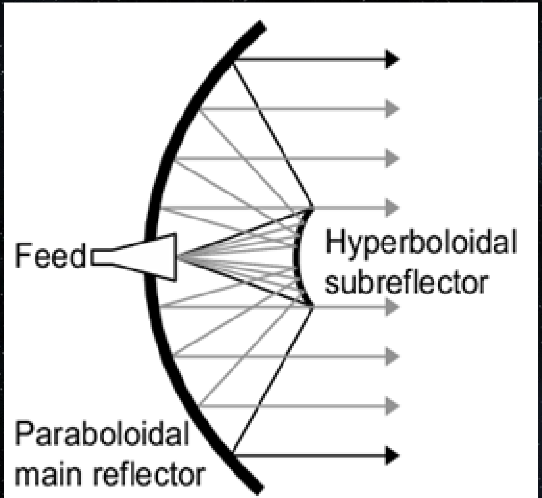
[2] https://haitiantimes.com/2025/10/22/tropical-storm-melissa-haiti-flood-risk/

SPACECRAFT ANT

2 Feeds for one antenna - Ka, X band
Ka band gain = 56.24 dBi
X band gain = 44.63 dBi





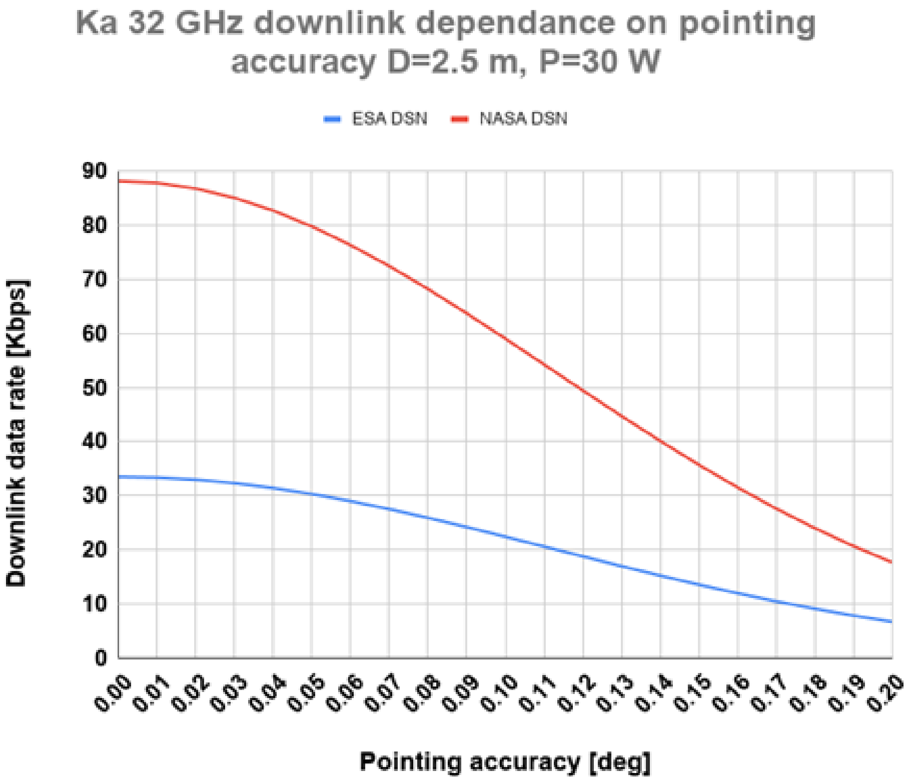


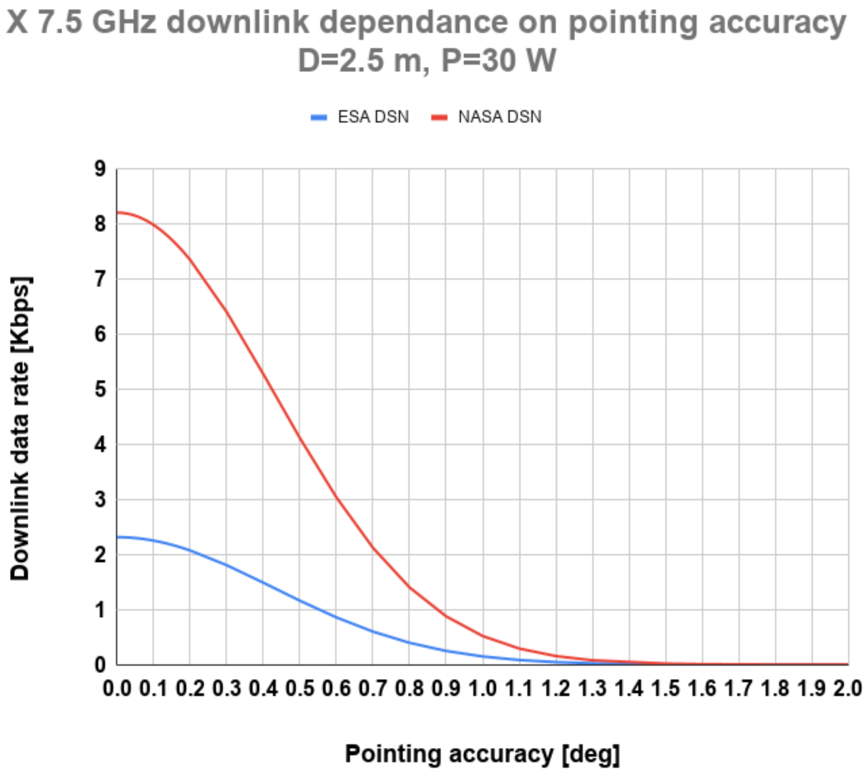
D - Diameter = 2.5 m
f - Focal length = 1 m
d - Dish dept = 0.39 m
Mass ≈ 30-40 kg

[1] https://www.esa.int/ESA_Multimedia/Videos/2021/04/Juice_antenna_vibration_testing
[2] https://www.analyzemath.com/parabola/focus-of-parabola-calculator.html
[2] https://www.semanticscholar.org/paper/1.-Antenna-Basics-Boccia-Breinbjerg/87827763b4b6823eb57cb43c4b69db80df95015a

POINTING SENSITIVITY OF THE LINK

ESA DSN NASA DSN





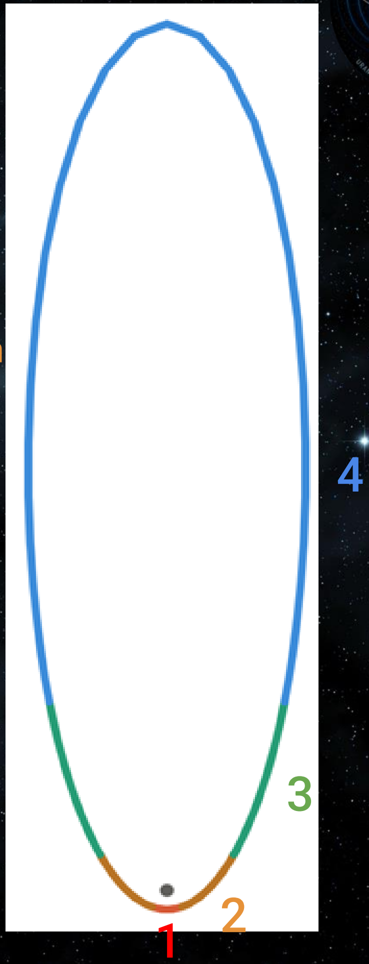
TRL & BUDGETS

Dry Mass Budget

Sub system	Mass (kg)	Notes
Payload	79.93	
Structure	173.15	(Structure is 22%, Harnessing is 5%)
Thermal	36.2	
Power	91.86	RTG, Battery, PSU
C&DH	38.48	
Comms	71.28	Antenna, Transponder, cabling
AOCS	44.92	Sensors, Actuators
Propulsion	171.72	Nozzles, tanks, harnessing
Total	**849.05**	(Of 990kg)

Power Consumption (Science Orbit)

1. < 2500km altitude (ionosphere study)
   - 38W (RPWI, JDC, MAG, Radio) + 24W C&DH+ 15W Comms
2. 5h section around periapsis (aurorae study)
   - 50W (RPWI, JDC, MAG, JoEE, UV Cam) + 24W C&DH+ 15W Com
3. < 10 Uranus radii altitude
   - 46W (RPWI, JDC, MAG, JoEE) + 24W C&DH + 15W Comms
4. > 10 Uranus radii altitude
   - 36W (RPWI, JDC, MAG) + 24W C&DH + <120W Comms



Data budgets

**Assuming factor 2 compression*

Payload	Data rate in use (kbps)	Time per orbit (h)	Total data per orbit* (Mb)	Percent of total budget*
Magnetometer	1.2	51.06	110.29	1.3 %
RPWI	65.7	41.96	4,962.63	60.8 %
JDC	3	23.56	127.22	1.7 %
JoEE	3	22.15	119.62	1.6 %
UV Camera	1520	1.01	2,757.9	33.9 %
Gravity Sensor	0.1	0.50	0.02	0 %
Optical Camera	50	0.6	120	0.7 %
		Total	8,197.66	3.2 days

Data Downlink

Data generated per orbit:	8,197.66 Mbit
Data link:	30.21 kbps
Time for downlink:	**3.14 days**

Table 1: Downlink time estimation

Payload power:	36W
C&DH power:	24W
Downlink power:	60W
Uplink power:	60W
Total Power	**180W**
(RTG EOL Power)	**(236W)**

Table 2: Downlink power consumption

RISKS & COST

RISK MATRIX

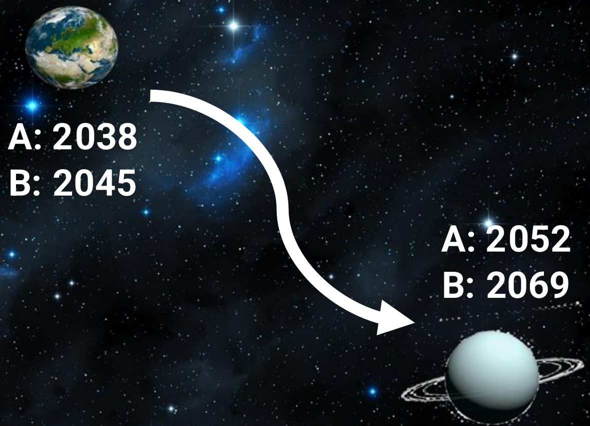
Derived from the RBD & FMECA

	Criticality		
Occurence	High	Major	Catastrophic
High	Limited launch window	Atmospheric drag	
	Limited instrument field of view and configuration		
Low	Cannot establish an earth link or to provide minimum pointing accuracy		
	Minimum acceptable mission duration of 6 years		
	Comms to earth blocked by the sun		
	Sufficient performance launcher unavailable		
	Uranus orbit cold case		
	Inactive instrumentation during transfer		

MAIN RISK DRIVERS & MITIGATIONS

Derived from the RBD & FMECA

- **Atmospheric drag:** Option to lower orbit altitude late in the mission before planned de-orbit
- **Limited launch window:** Backup launch plan considered
- **Limited payload configuration and field of view:** Considered payload measurements in multiple orientations and with additional instruments
- **Minimum acceptable mission duration:** 5 years minimum mission duration considered mission success with fuel-enabled 15 year extension
- **Comms to earth blocked by sun:** estimated 12 days maximum blockage means safe mode spacecraft operations



COST

Item	Cost (€ million)	Notes
Spacecraft:	650	
Extra payload engineering:	20	
RTG:	200	
ESA management cost:	168	(25% of industrial cost)
Mission operations (MOC):	90	
Science operations (SOC):	80	
Total Spacecraft:	1,208	
Laucher:	135	(Ariane 64)
Nuclear regulations:	20	(on-site security, de-risking, etc)
Total:	1,363	

SUMMARY

- Mission to Uranus to study magnetic fields, to give insight on exoplanetary processes.
- 7 Payloads, including magnetometers, particle detectors, and cameras
- €1.36 billion mission, with 850 kg payload.
  - Earth-Venus-Earth-Earth-Uranus trajectory
- Aiming to launch in 2038, for 2052 arrival


THANK YOU
FOR YOUR ATTENTION!

Thank you from the Green (Dream) Team

- Josephine Balan 🤌
- Michael Doležel 🍺
- Liliana Francalanza 🏗️
- Alba González del Castillo 🥇🚩
- Jan Grabowski 🚀
- Tanja Grundnig ⛰️
- Alexandre Hamieh 🥐
- Sam Holdcroft 🫖
- Miłosz Jurczak 🍅
- Panagiotis Kourkoutas 🙄
- Alexander Peschel 🥨
- Robin Savonet 🍟
- Julia Servin 🥔
- Christos Thomopoulos 🫒
- Urszula Wasilewska 💤

- Florine Enengl 🏃
- Willem Jellema 🔭