Students: S. Bonetti, B. B. Bolduc, K. Caruana, L. Dall'Osto, G. Blüthner, J. Juul, V. Koßack, C. Maher, A. Ortega, J. Roney, G. L. Robin, J. Siehr, L. Stroud, K. Swoboda, J. B. Trencsenyi.
Tutors: O. Dhuicque, L. Schulz.

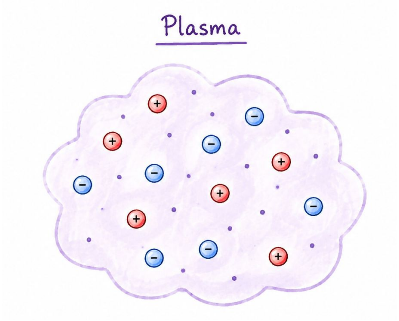
AEGIS

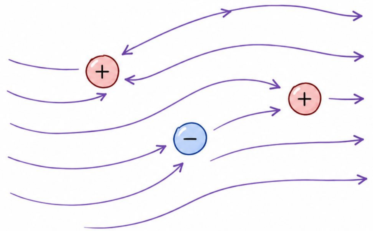
Auroral **E**nergy and **G**lobal **I**nvestigation of the Jovian **S**ystem

Team Red

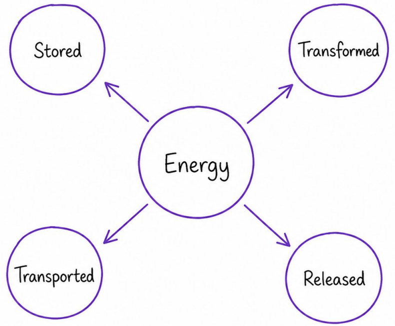
Contents

How Do Planetary Systems Process Energy?





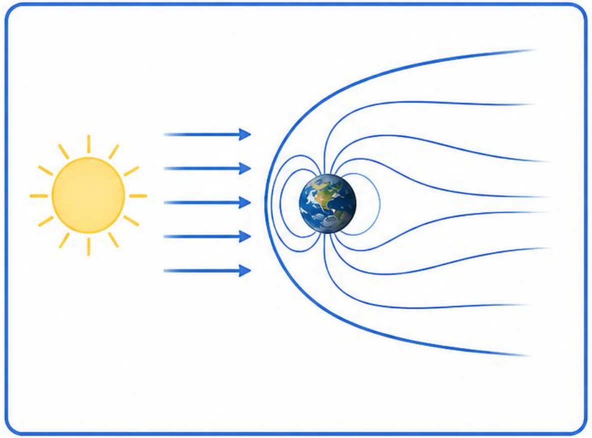
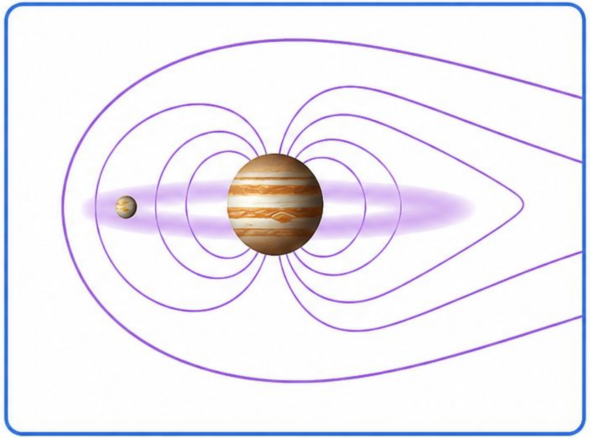
Particles and Fields are in constant interaction



These processes do not occur in isolation → Take magnetized planet and see what happens

AI generated sketches

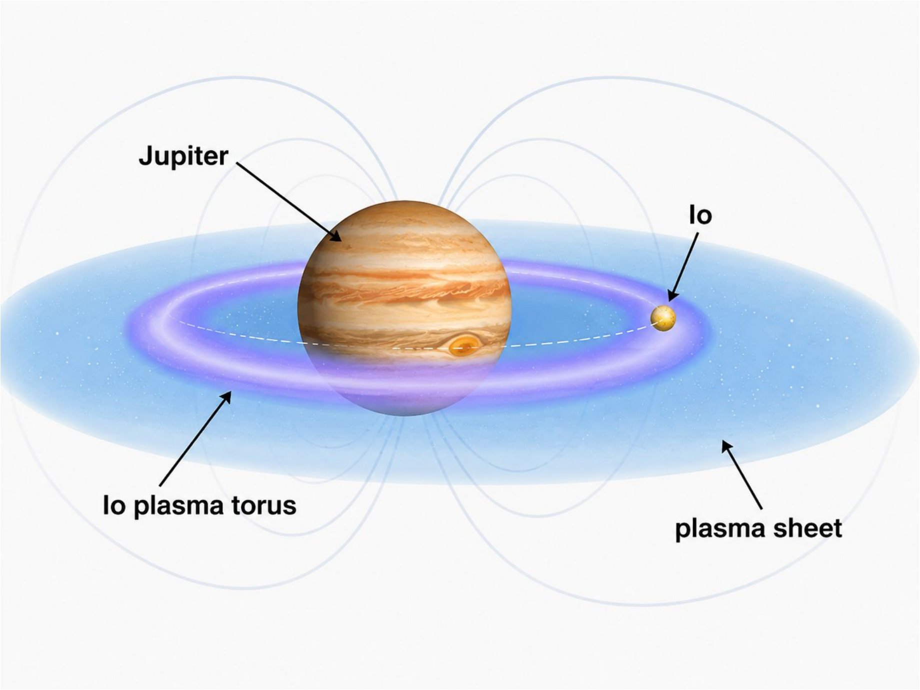
Different Magnetospheres, Different Energy Engines

	Earth - type regime	Jupiter - type regime
		
Powered by	Solar Wind	Rapid Rotation
Main Plasma Source	Solar Wind	Moon mass-loading

AI generated sketches

Key Physics: Mass Loading?

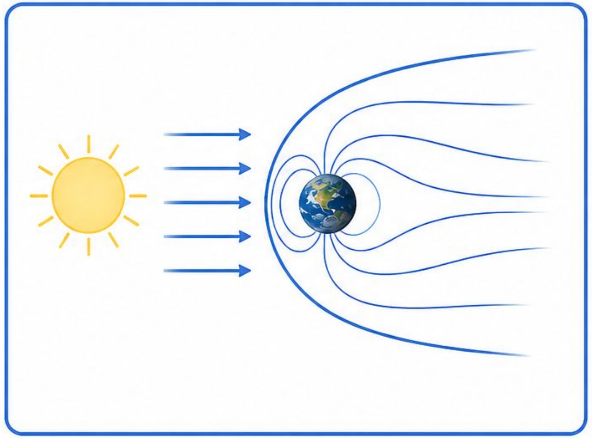
- Io's volcanoes release sulfur-rich **neutral material**
- The neutral material **becomes ionized**
- Jupiter transfers its **rotational energy** and pushes plasma to **corotate**
- This material spreads around Jupiter along Io's orbit
- Plasma forms the Io plasma torus and mass-loads the magnetosphere



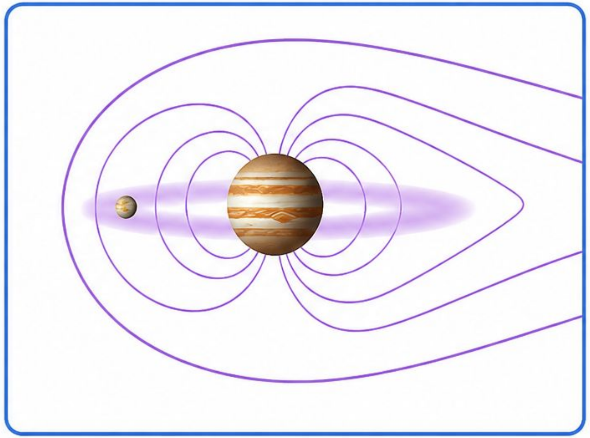
AI generated sketch

Magnetospheres as a Blueprint

Earth - type regime



Jupiter - type regime



AI generated sketches

Why Study This Blueprint?

Extreme plasma environment
- Strong B-field
- Intense Radiation

Unique processes
- Mass loading
- Corotation enforcement currents
- Alfvén wings of moons

How do energy processes evolve?
- Rotational energy transfer
- Corotation breakdown
- Particle acceleration

Context for Habitability

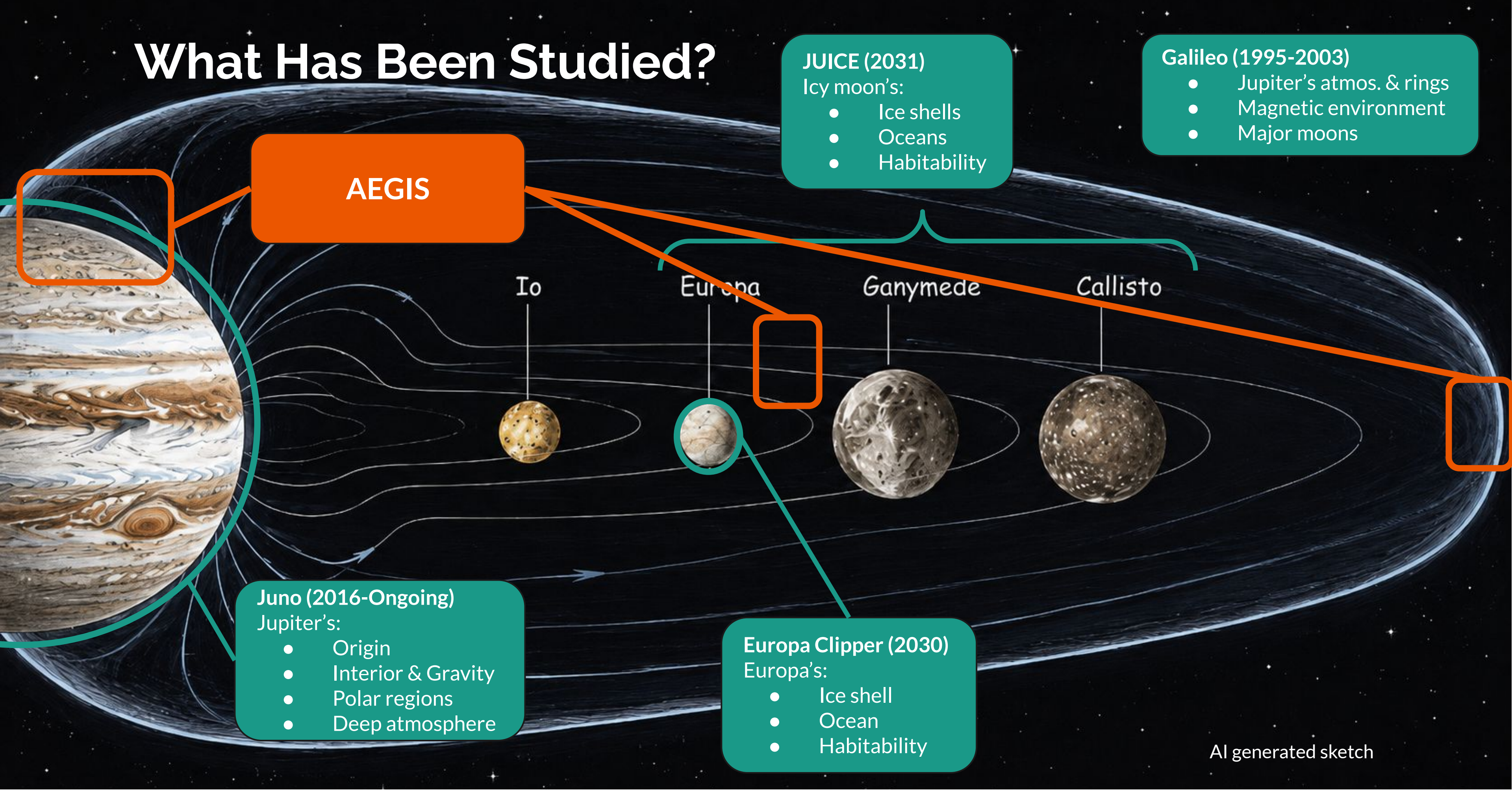
Okay I get it! What now?

Large magnetospheres in our solar system

Interpret exoplanetary environments

stock.adobe.com & wikipedia.com

What Has Been Studied?



JUICE (2031)
Icy moon's:
- Ice shells
- Oceans
- Habitability

Galileo (1995-2003)
- Jupiter's atmos. & rings
- Magnetic environment
- Major moons

Juno (2016-Ongoing)
Jupiter's:
- Origin
- Interior & Gravity
- Polar regions
- Deep atmosphere

Europa Clipper (2030)
Europa's:
- Ice shell
- Ocean
- Habitability

AI generated sketch

Mission Statement

Investigate how moon driven mass-loading impacts high-energy processes inside the magnetosphere of large planetary bodies

Scientific Questions

Q1 - How is Jupiter's rotational energy transported by magnetospheric currents, and deposited in the ionosphere?

Q2 - How do variations in the plasma sheet and solar wind change the energy supplied to the Jovian magnetosphere?

Q3 - How is solar-wind energy transformed across Jupiter's bow shock and transported into the magnetosphere?

Mission Objectives

Mission objectives

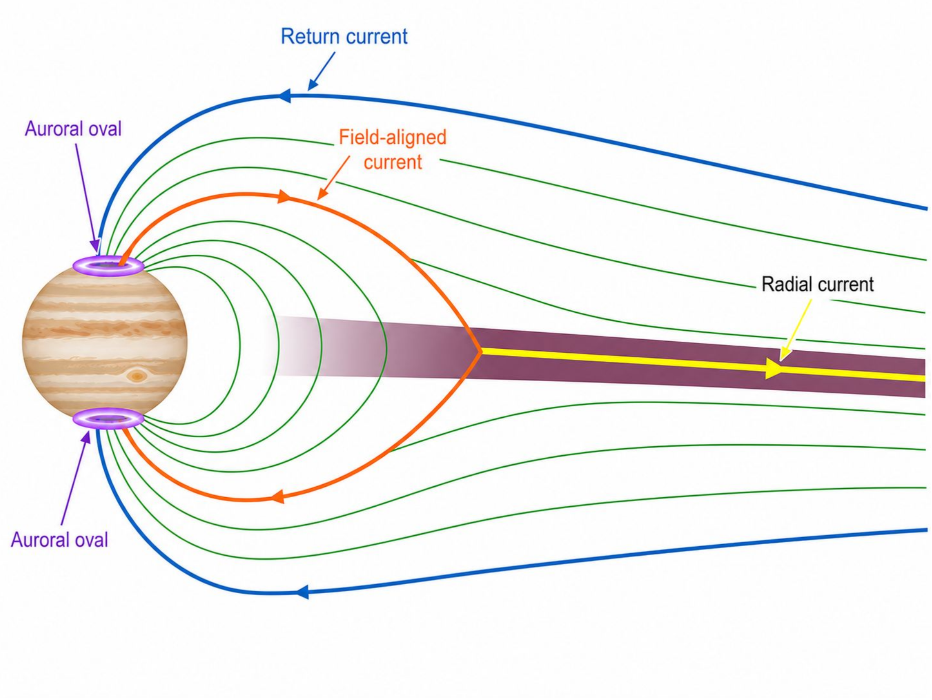
Q1 - How is Jupiter's rotational energy transported by magnetospheric currents, and deposited in the ionosphere?

→

M1 — Determine if and how **corotation breakdown**, couples to the ionosphere via field-aligned currents, and **its role in auroral energy deposition**

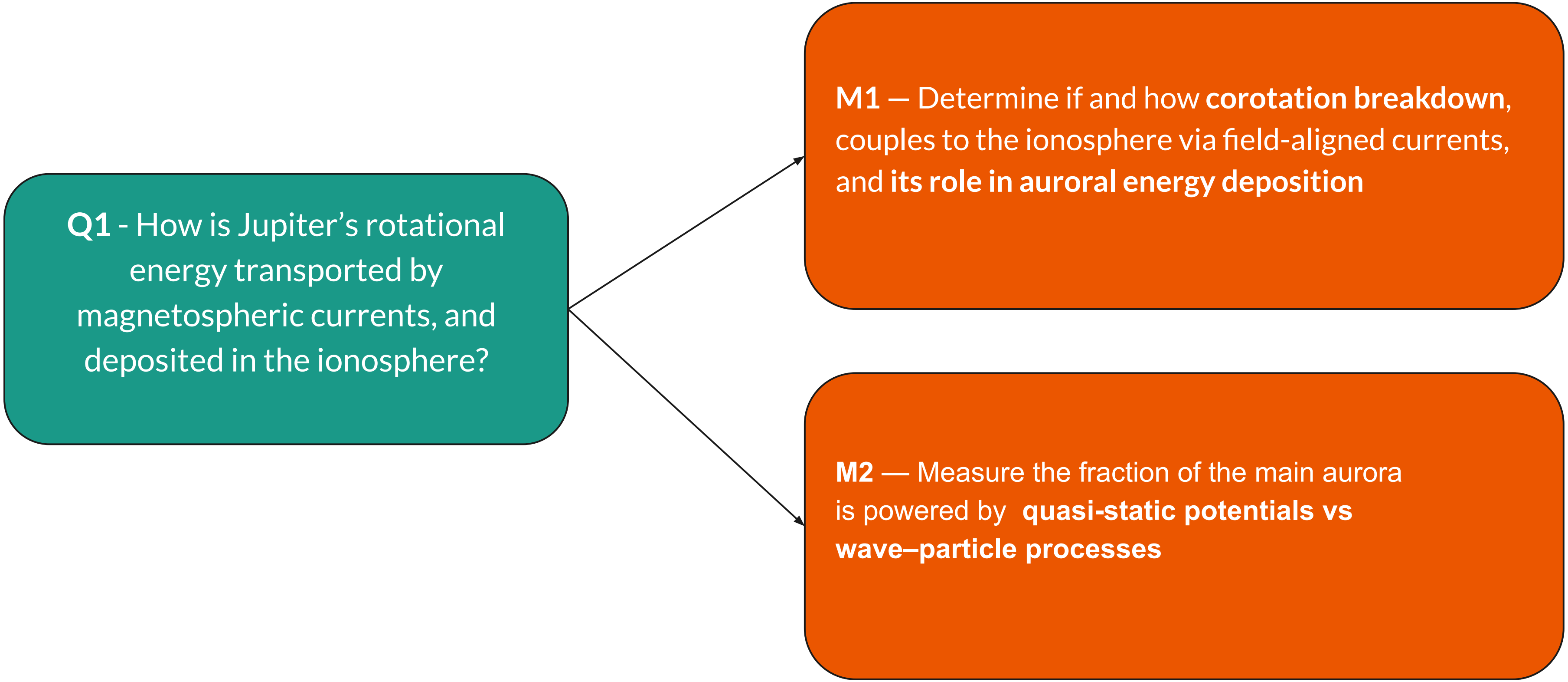
M1 Corotation Enforcement Theory

- The outer **plasma rotates too slowly**
- The ionosphere tries to **pull it forward**
    - Creates an electric field
- **Current circuit**
    - Ionospheric Pedersen current
    - Field-aligned current
    - Radial current
    - Return current
- Where **FAC** is directed **upward**
    - **Electrons** travel **down**
    - Precipitate
    - Producing the **main auroral emission**



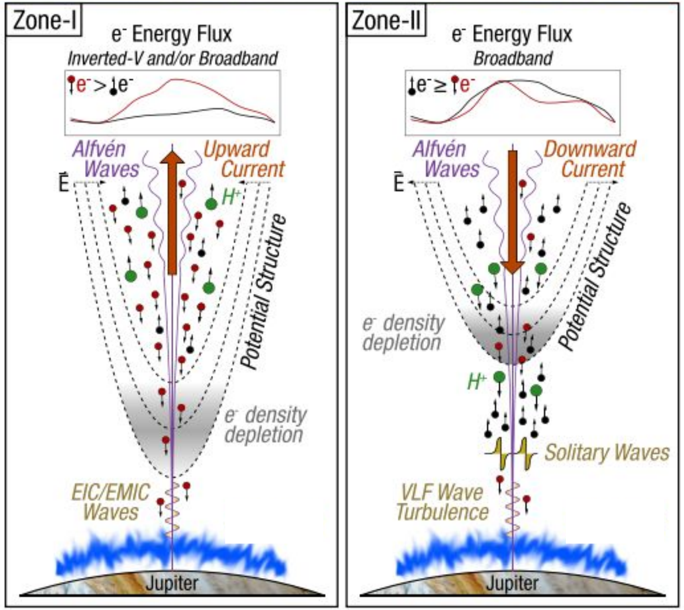
Schematic Ai sketch

Mission objectives



M2 Wave-Particle Interactions = Aurora?

- Juno observed **broadband electron distributions**
- **Monoenergetic electron beams** were uncommon
- This points to **stochastic or wave–particle acceleration**
- Juno lacked **simultaneous measurements of wave energy, propagation, and dissipation**
- Fraction of auroral energy produced by **quasi-static potentials versus wave–particle processes remains unknown**



Sulaiman 2022

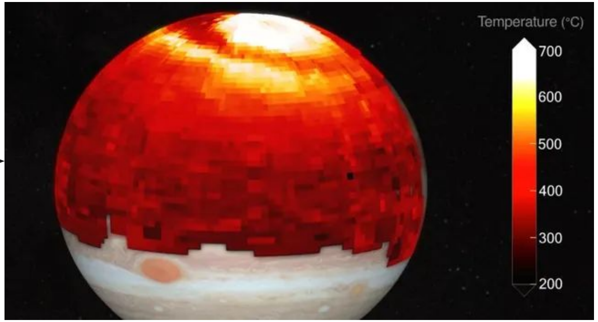
Mission objectives

Q2 - How do variations in the plasma sheet and solar-wind change the energy supplied to the Jovian magnetosphere?

M3 — Quantify the **dynamics of auroral heating** during **changing plasma torus and solar-wind conditions**

M3 — Auroral Heating Under Variable Plasma Conditions

Auroral energy produces atmospheric heating



But what affects the dynamics of the Aurora?

Solar wind impacts Aurora

Plasma waves modulate Aurora

Io's mass loading

Quantify auroral energy deposition under changing solar-wind and plasma-torus conditions.

Mission objectives

Q3 - How is solar-wind energy transformed across Jupiter's bow shock and transported into the magnetosphere?

→

M4 - Determine **energy injection** during **changing solar wind conditions** and relativistic electron accelerations at the planetary bow shock

M4 — Energy Input from the Solar Wind and Bow Shock

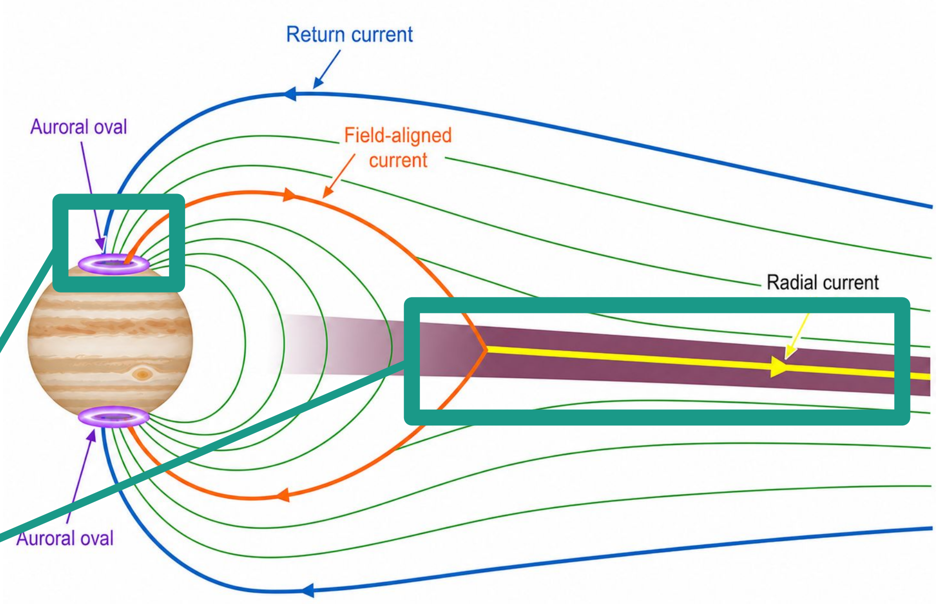
Energy is provided by rapid rotation → Solar wind?

1. A disturbance ahead of Jupiter's bow shock
2. Accelerated electrons to very high energies
3. Boosting them into the magnetosphere
4. Juno directly measured this process at Jupiter for the first time

How is solar-wind energy is transferred through the bow shock and into Jupiter's internally driven magnetosphere?

How and Where do We Measure This? (Measurement Requirements)

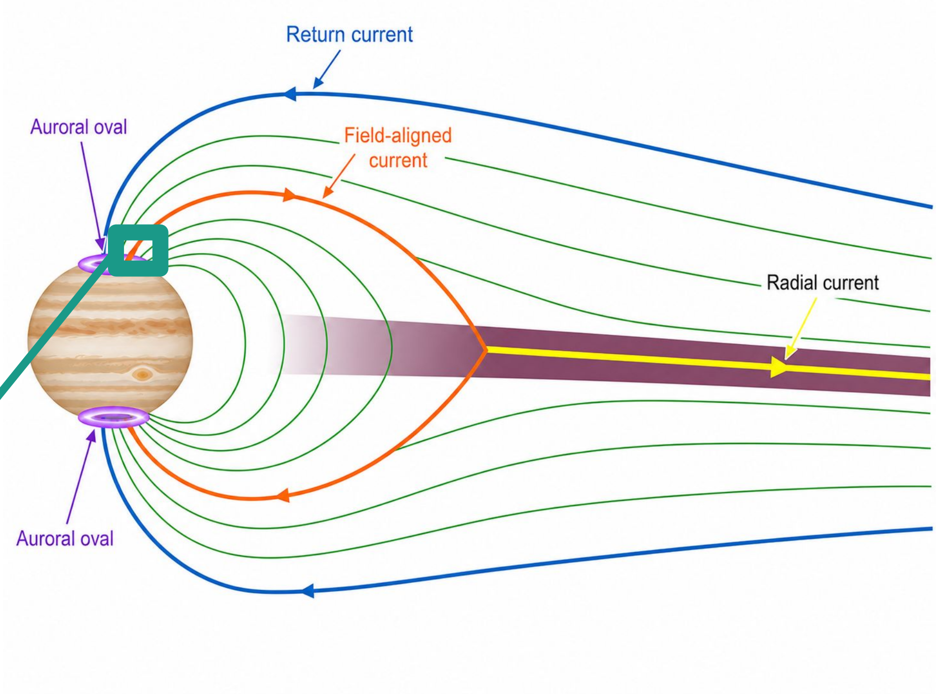
M1 — Determine if and how **corotation breakdown**, couples to the ionosphere via field-aligned currents, and **its role in auroral energy deposition**



Simultaneous UV and current measurements

How and Where do We Measure This? (Measurement Requirements)

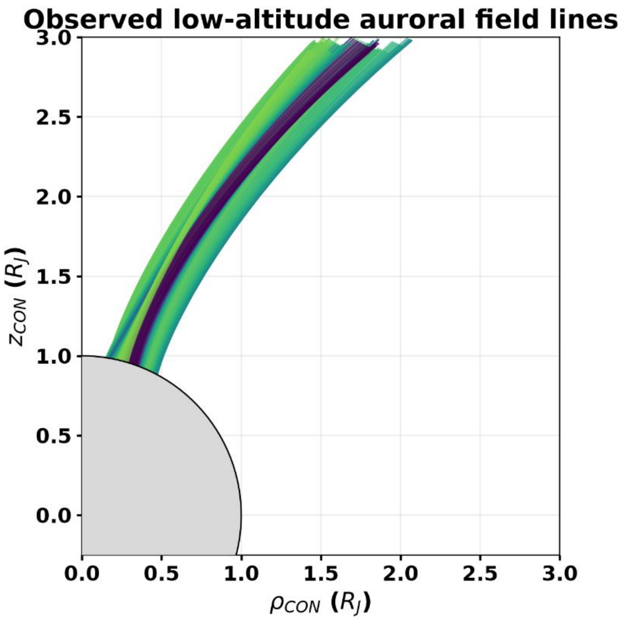
M2 — Measure which fraction of the main aurora is powered by **quasi-static potentials vs wave–particle processes**

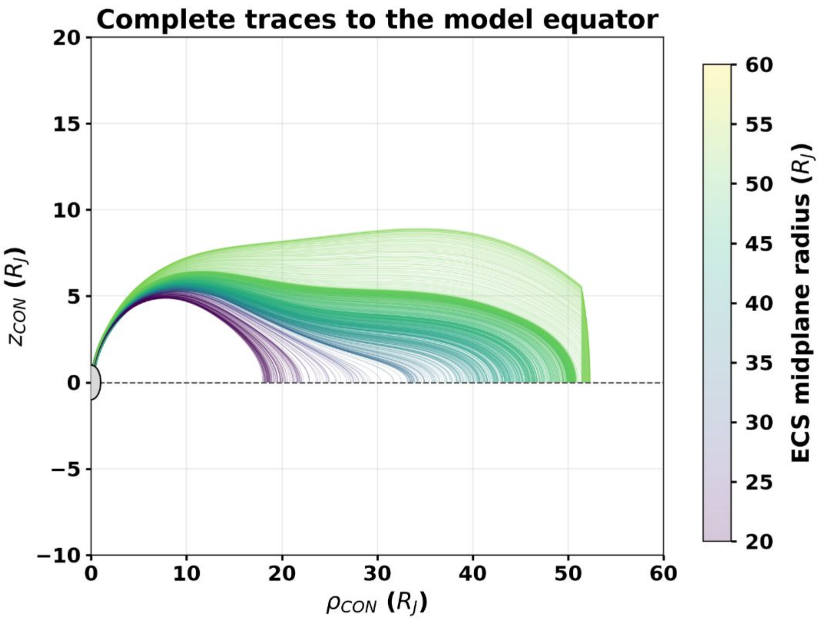


Particle, field and wave measurements in situ, where field aligned currents connect

Where exactly are these regions?

Combined auroral oval study & magnetic field model

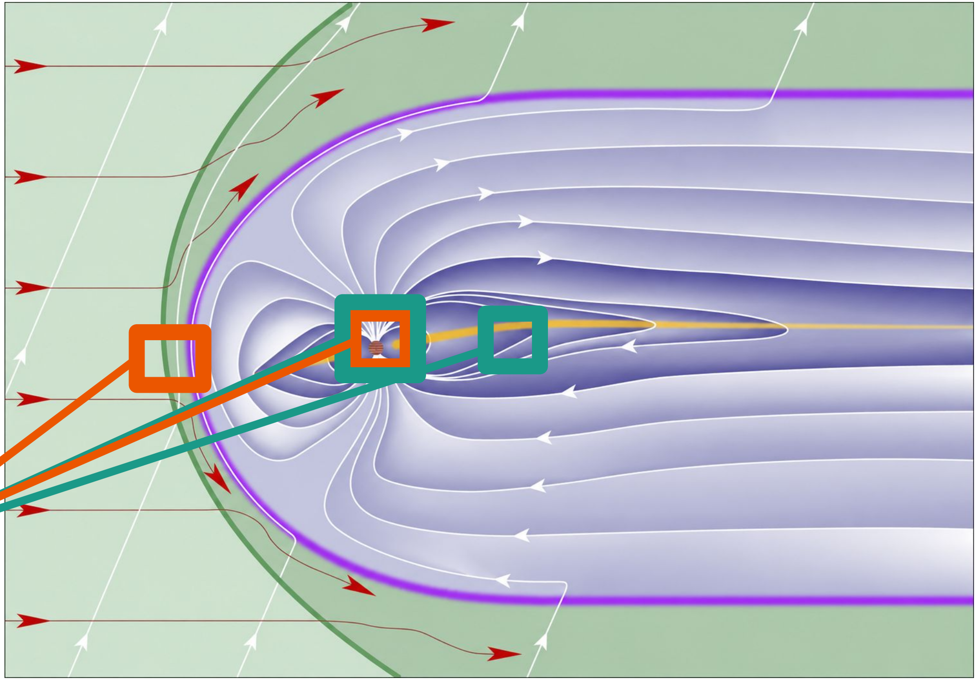




How and Where do We Measure This? (Measurement Requirements)

M3 — Quantify the **dynamics of auroral heating** during **changing plasma sheet and solar-wind conditions**

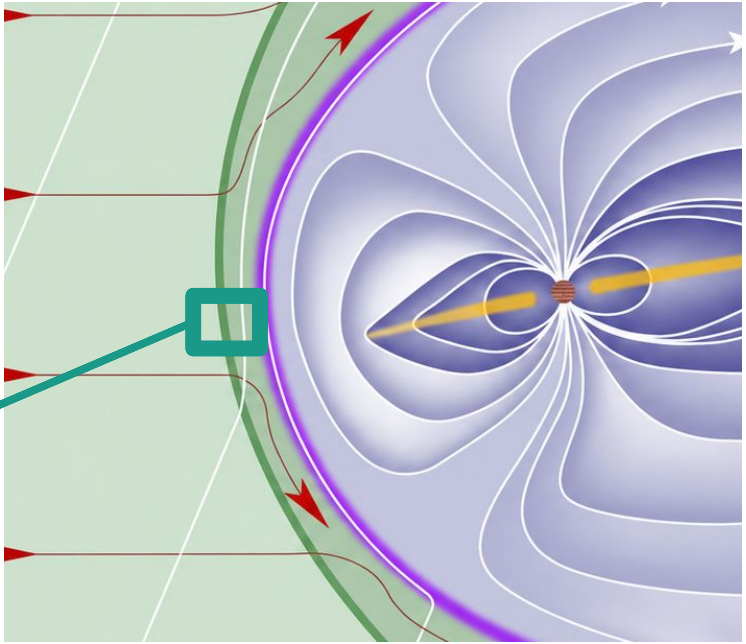
Simultaneous measurements of the solar wind-bow shock boundary / plasma sheet and auroral energy deposition



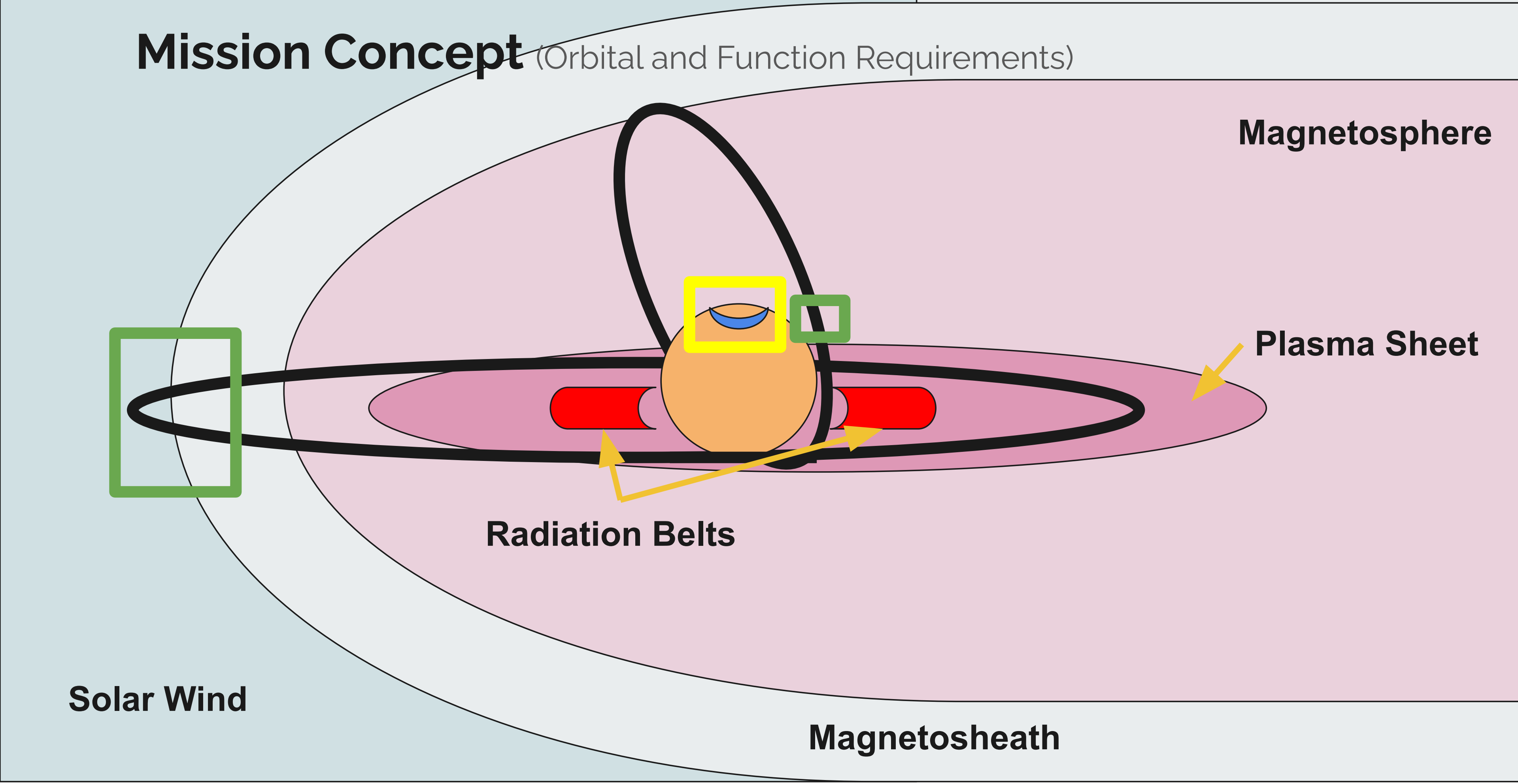
How and Where do We Measure This? (Measurement Requirements)

M4 — Determine **energy injection** during **changing solar wind conditions** and relativistic electron accelerations at the planetary bow shock

High energy particle measurements at the bow shock



Mission Concept (Orbital and Function Requirements)



Payloads
(Derived from Instrument Requirements)

Remote sensing

UVI (imager) - Heritage on Smile (with adaptations)

- Spatial position of emission on planetary disk
- UV auroral emission and emitted power, morphology and variations

IR-1.3.1, IR-2.1.4–2.1.5, IR-3.1.1–3.1.2

UVS (spectrograph) - Heritage on Juno

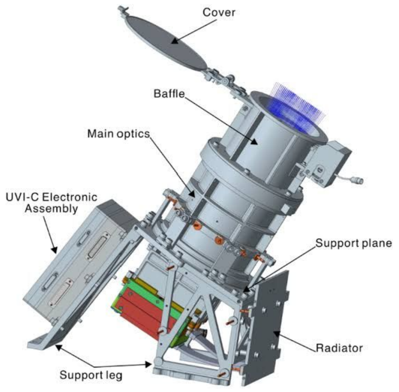
- Spectral fingerprint in the aurora

IR-1.3.1 IR-2.1.4 -2.1.5, IR-3.1.1–3.1.2

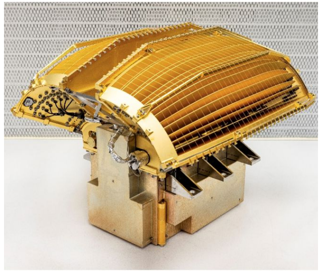
JENI - Heritage on Juice

- Ion transport and remote acceleration mapping

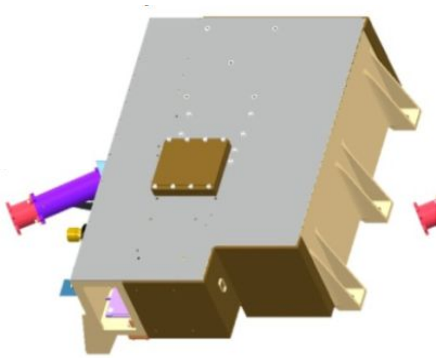
IR-3.3.4, IR-3.3.7, IR-4.2.1



NADIR UVI, Zhang, 2025



JENI, Mitchell, 2022



NADIR UVS, Retherford

Ion and Electron measurements

JDC - Heritage on Juice

- Bulk Ion and Electron moments

IR-1.1.1, IR-3.3.1, IR-3.3.2, IR-3.3.4, IR-3.3.6,
IR-4.1.1–4.1.2, IR-4.1.4, IR-4.2.4

JoEE - Heritage on Juice

- Mid-range electrons

IR-2.1.3, IR-2.2.4–2.2.7, IR-4.2.1–4.2.2

JEI - Heritage on Juice

- Energetic electrons/ions

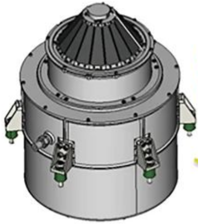
IR-1.2.2–1.2.3, IR-2.1.3, IR-2.2.4–2.2.7, IR-4.2.1–4.2.2

REPT - Heritage on Van Allen Probes (adjustments needed)

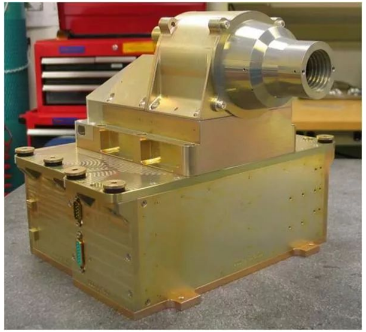
- High-energy/relativistic

IR-4.2.1, IR-4.2.2, IR-4.2.6

JoEE, APL



JDC, Wittmann, 2018



REPT, UNH

JEI, Bambach, 2024

Fields measurements

FGM - Juice Heritage

- Vector Magnetic Fields & Magnitude

IR-1.1.2, IR-1.2.1–1.2.3, IR-2.1.1–2.1.2, IR.2.2.*, IR-3.3.3, IR-4.1.3–4.1.4, IR-4.2.3–4.2.4

SCM - Juice Heritage

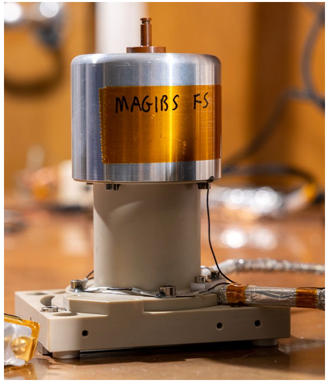
- AC magnetic fields
- δB component

IR-1.2.4, IR-1.2.5 IR-2.1.1, IR-2.1.2, IR-4.2.5

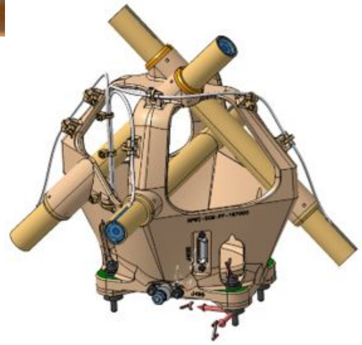
LP-PWI - Heritage

- DC + AC electric fields, plasma density
- δE component

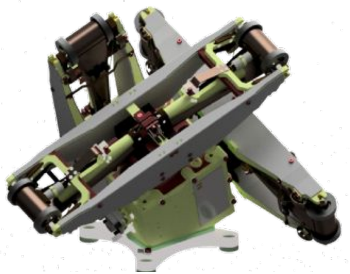
IR-1.2.2–1.2.5, IR-1.2.4, IR-1.2.5, IR-2.1.1, IR-2.1.2, IR-2.1.3, IR-2.2.1-2.2.7, IR-4.2.1, IR-4.2.2, IR-4.2.5



Juice FGM, TU Braunschweig

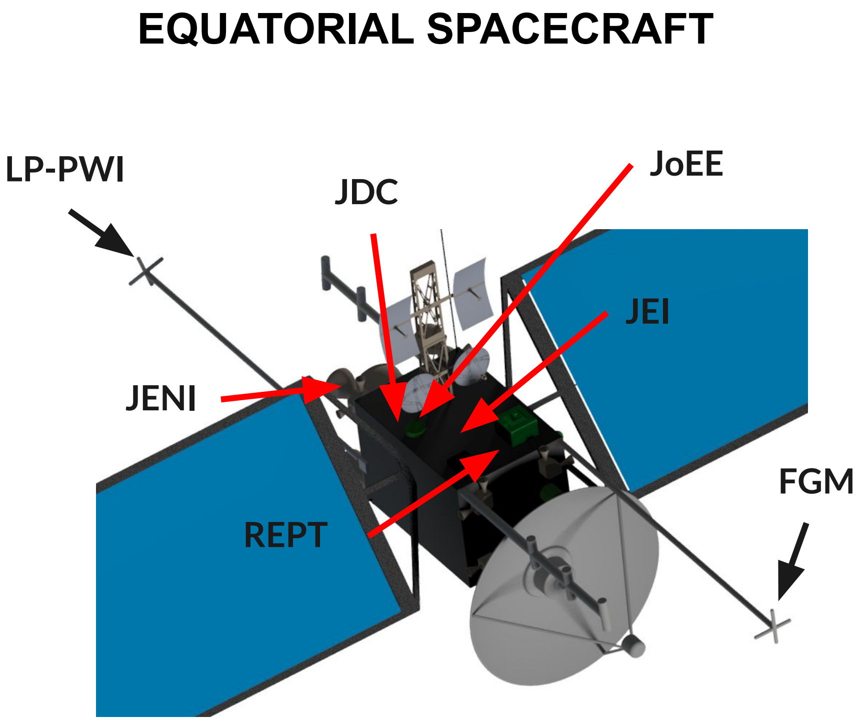


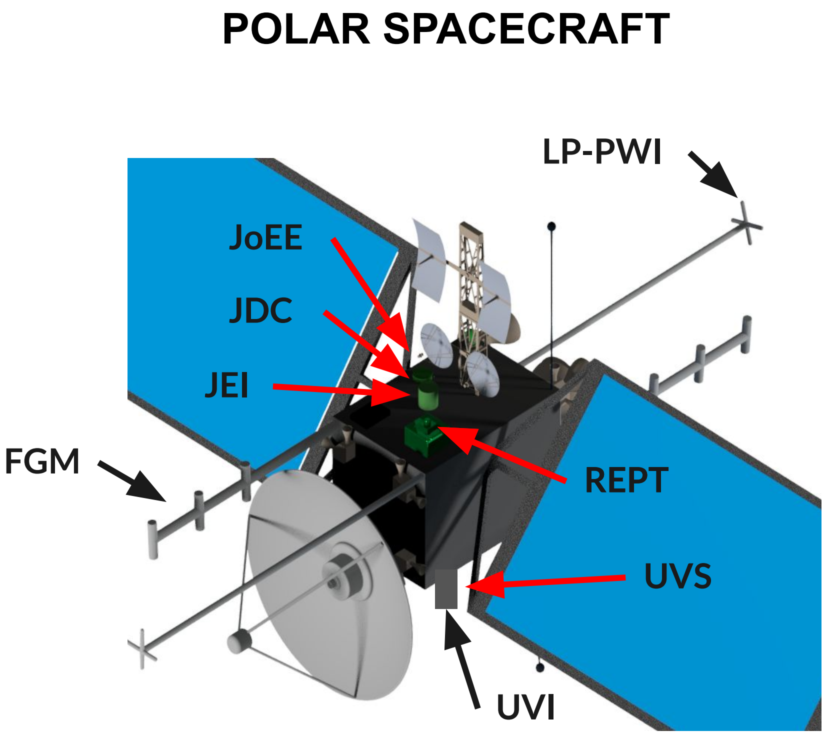
SCM, CNRS



LP-PWI, Wahlund, 2024

Sketch of Spacecrafts





Spacecraft Payload Overview

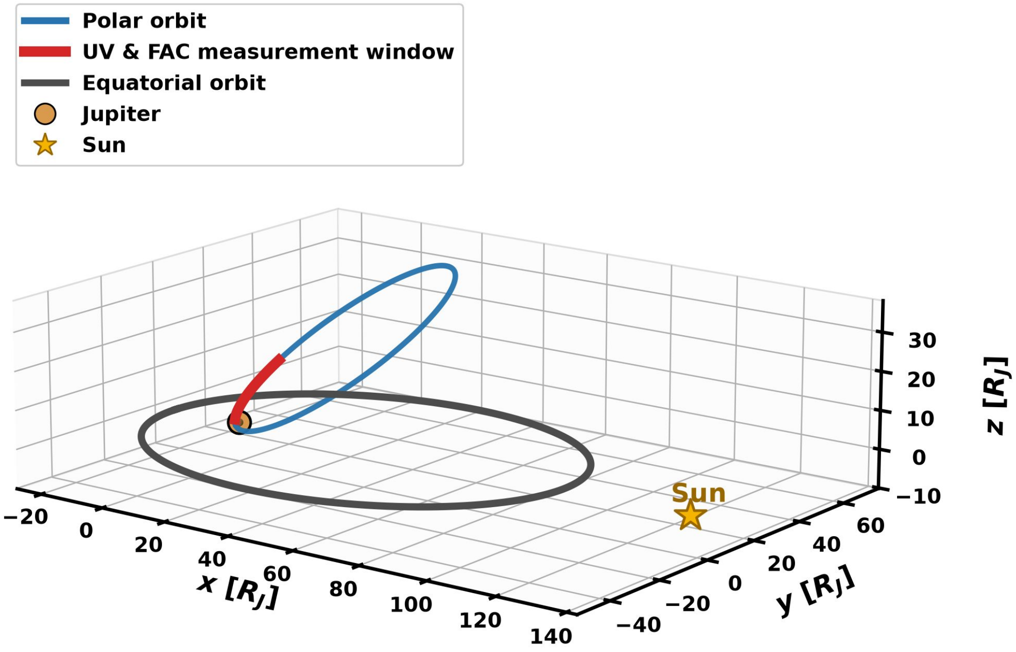
EQUATORIAL SPACECRAFT	TRL	Margin (%)	MASS (kg)	POWER (W)
RPWI	6	15	9	15
FGM	6	15	3	10
JENI	6	15	14	8
JEI	6	15	4	5
JDC	6	15	5	10
JoEE	6	15	3	4
REPT*	5	20	13	6
TOTAL +20%			59	61

POLAR SPACECRAFT	TRL	Margin (%)	MASS (kg)	POWER (W)
UVS	6	15	19	7
RPWI	6	15	9	15
FGM	6	15	3	10
JEI	6	15	4	5
JDC	6	15	5	10
JoEE	6	15	3	4
UVI*	5	20	16	25
REPT*	5	20	13	6
TOTAL +20%			82	87

*margin driver

Concept of Operations

Measurements During Orbit



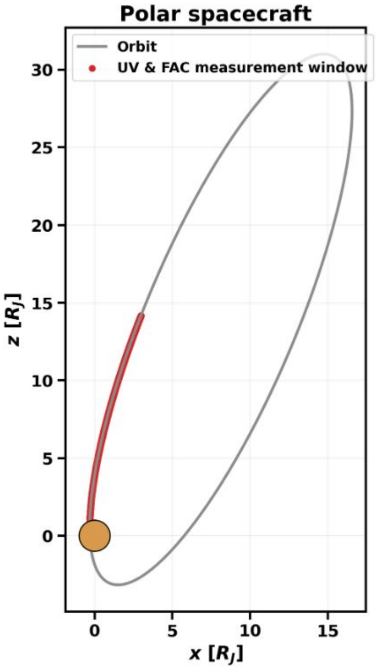
Simultaneous measurements of emission on north pole & drivers

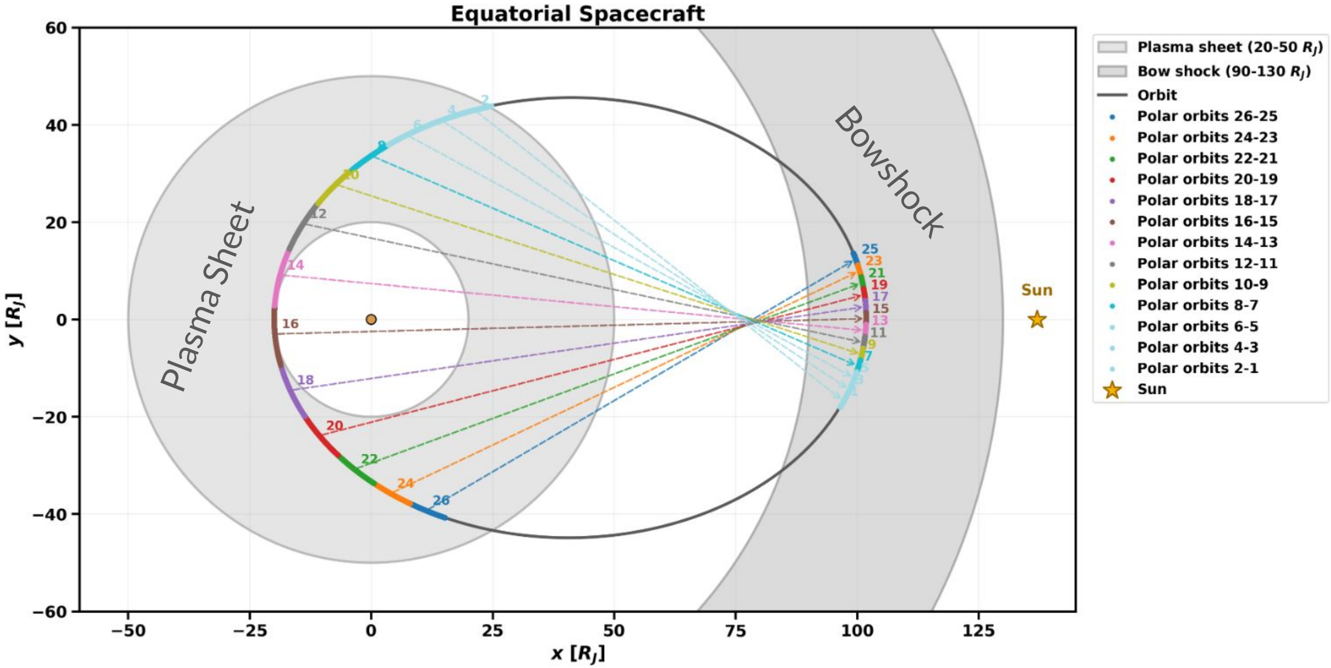
- Dayside magnetospheric boundary
- Plasma sheet

Limited by UV and Field aligned currents (FAC) observational windows

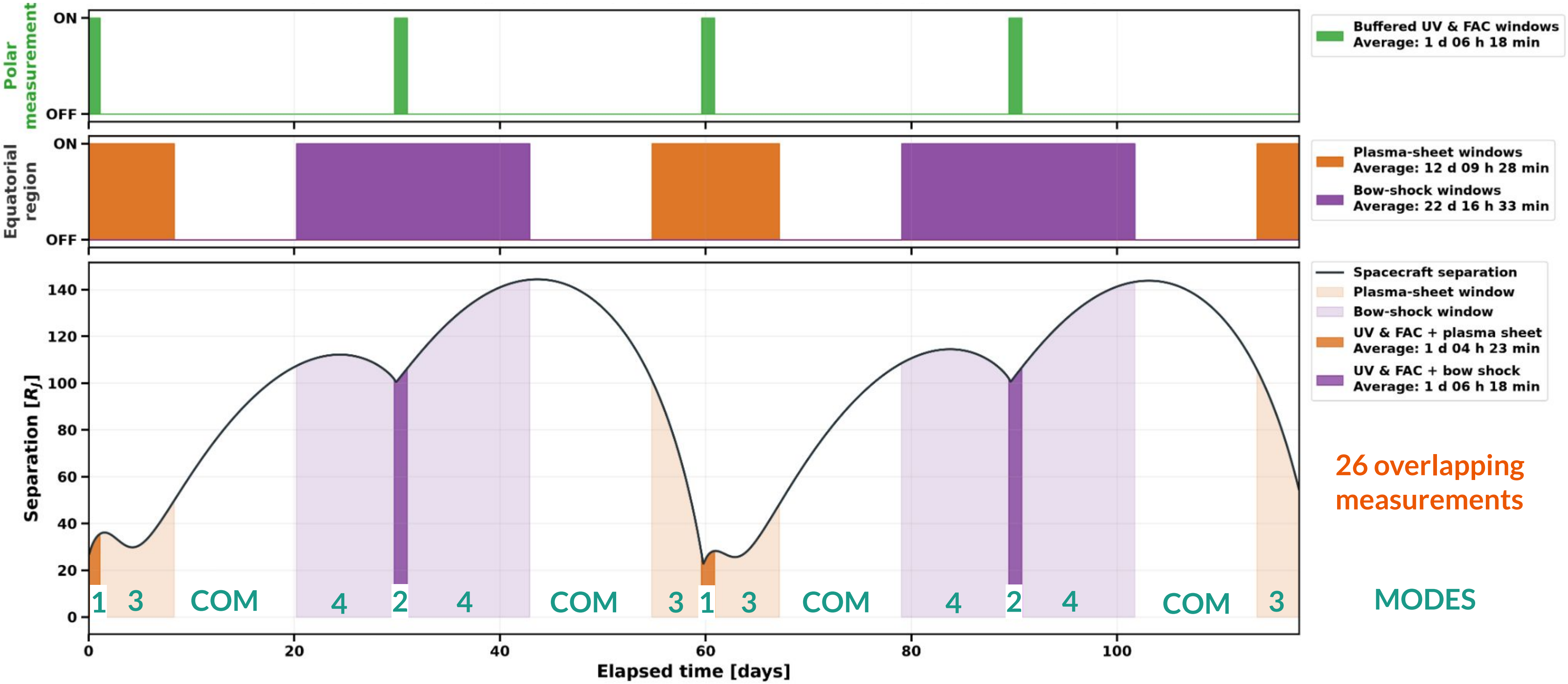
- Avoiding radiation belts
- Near 2:1 resonance
- 26 Polar orbits planned for the nominal mission

Observation Plan





Observation Plan



26 overlapping measurements

Launch, Transfer & Target Orbits

Mission Duration

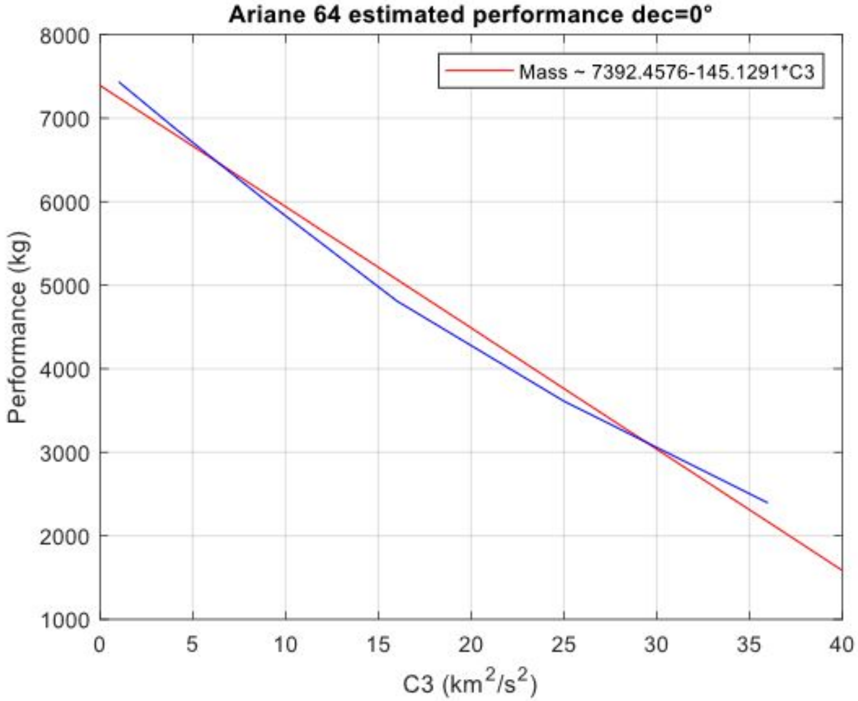
Mar 2044	Jun 2050	Aug 2052
Launch	Arrival @ Jupiter	End of mission

≈ 11,000 hours of measurements

≈ 800 hours of simultaneous measurements

Possible extension of mission through margins

Launcher selection Ariane 64

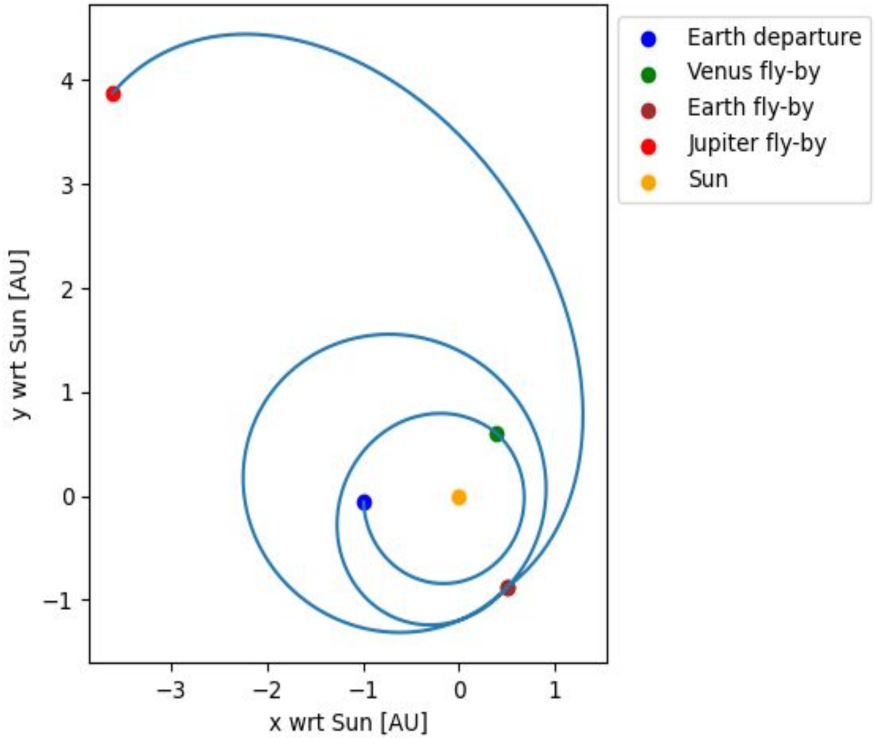


c3: 9.38 km^2/s^2

Payload: 5800 kg

Launch ΔV: 3063 m/s

Interplanetary Transfer to Jupiter (EVEEJ)



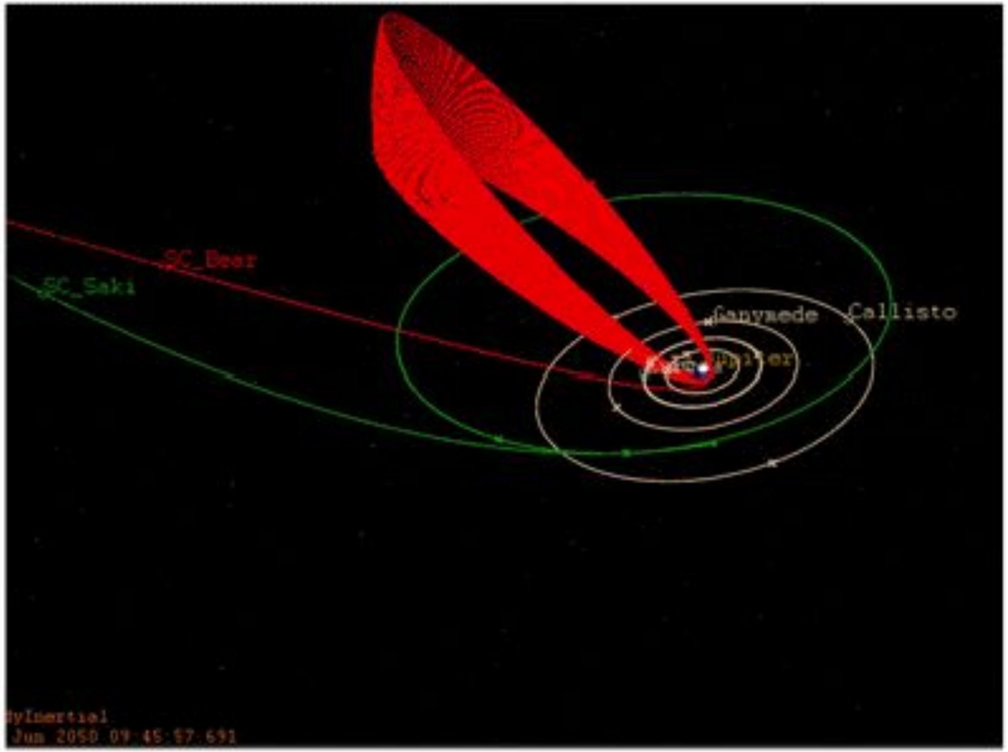
Trajectory Legs

Departure	22 Mar 2044
E → V	172.2 d
V → E	313.3 d
E → E	730.5 d
E → J	1081.2 d
Arrival	06 Jul 2050

ΔV Breakdown

Man.	ΔV (m/s)
DSM 1	0.3
DSM 2	0.2
DSM 3	44.16

Jupiter Orbit Insertion With Target Orbits



	Polar	Equatorial
Periapsis	1.29 R_J	21.0 R_J
Apoapsis	99.4 R_J	101.0 R_J
Inclination	90°	4.1°
Period	28 d	58 d
Insertion ΔV	1349 m/s	1049 m/s

Separation: 674.23 R_J
(05 Apr 2050)

Total ΔV budget for the mission: 2441.66 m/s
(No launch included)

Equatorial: Insertion at M = 355.5°
(with a Gravity assist by Callisto)

End of Mission

Planetary Protection

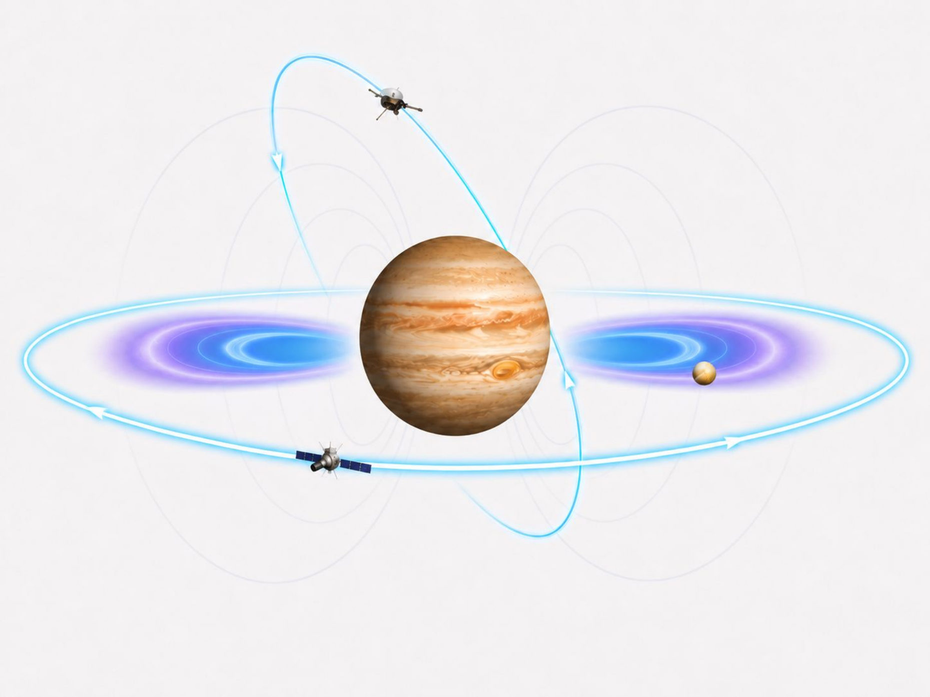
- Jupiter: NASA Planetary Protection Category II
- **Category II:** *A mission poses a rare chance that contamination carried by a spacecraft could jeopardize future missions.*

End-of-Life Disposal

- Perform a controlled atmospheric entry into Jupiter.
- Requires an allocated ΔV (with a 15% margin) for the disposal manoeuvre.

Key System Drivers

Orbit Configuration



Driver: Radiation and Thermal

Limits:

- Measurement time
- Measurement area (Poles)

Driving Subsystems

Electrical Power System

Driver: TCS (Polar) & AOCS (Equatorial)

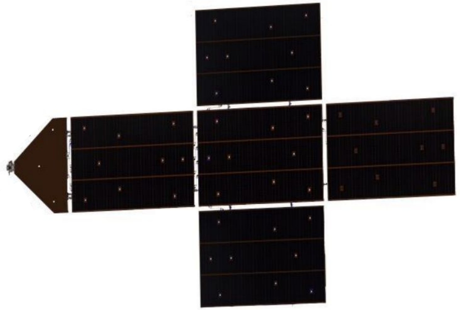
Limits:

- Mass allowance
- Amount of instruments working simultaneously

Uncertainties:

- Radiation damage
- Micrometeorite damage

As used on JUICE



Thermal Control System

Driver: Venus flyby (Hot) & Jupiter Eclipse (Cold)

Limits:

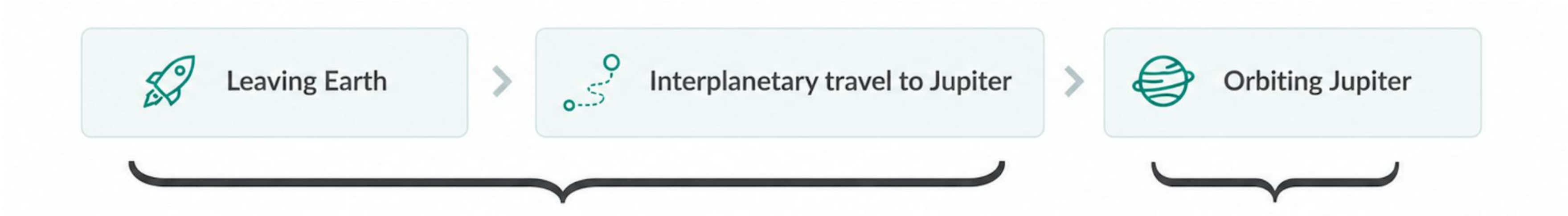
- Electrical Power System

Radiation Environment

Driver: Radiation

Limits:

- Instrument lifetime
- Mass allowance

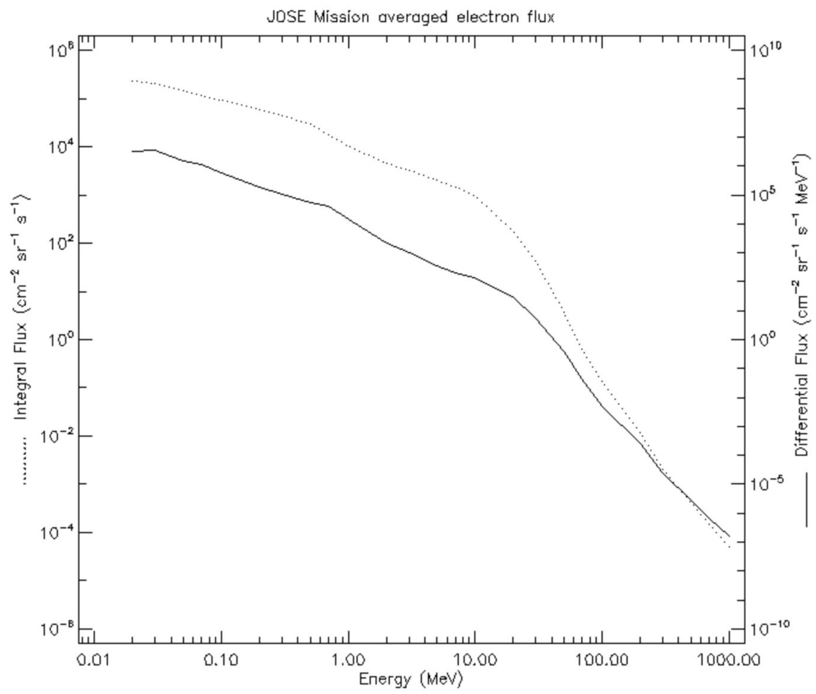


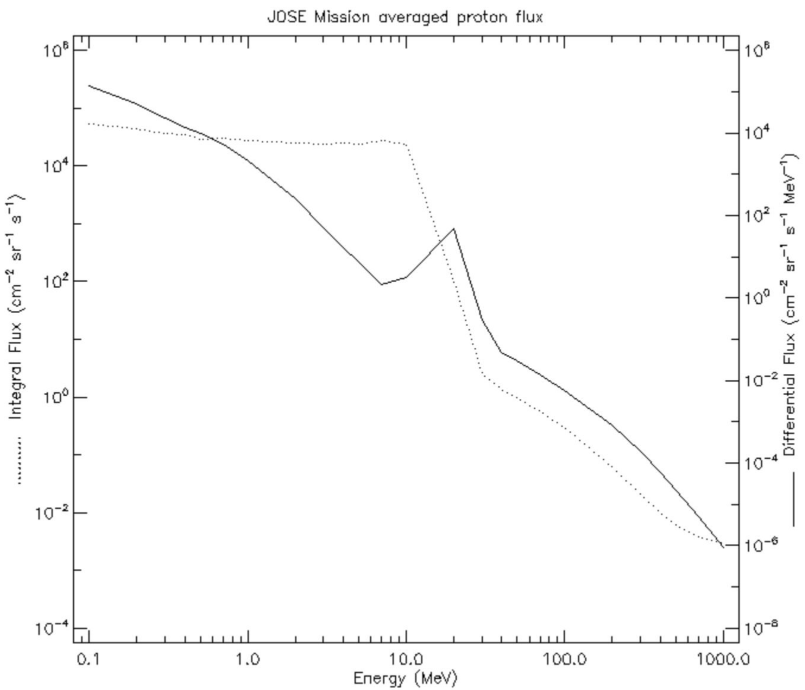
≈20 krad (JGO)
(JGO: Consolidated Report on Mission Analysis [DRAFT], 2010)

SPENVIS

SPENVIS Radiation Simulation - Polar Orbit

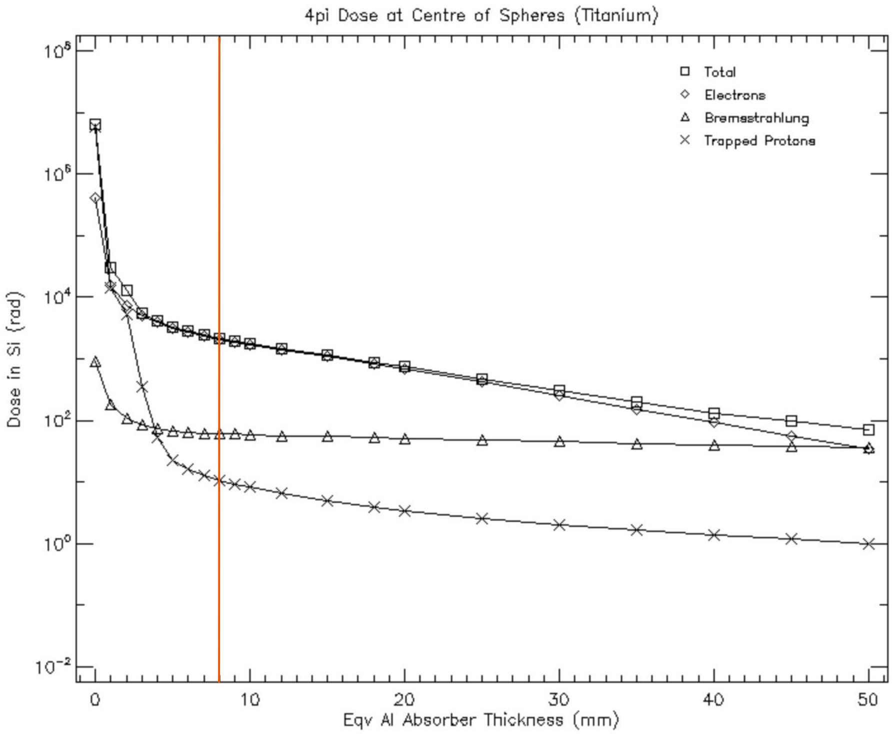
One Orbit





Jupiter Radiation Environment and Effects Models and Mitigation (JOREM), JOSE Trapped Fluxes, 95% confidence

SPENVIS Radiation Simulation - Polar Orbit



8 mm of Al equivalent -> TID ≈ 2 krad per orbit

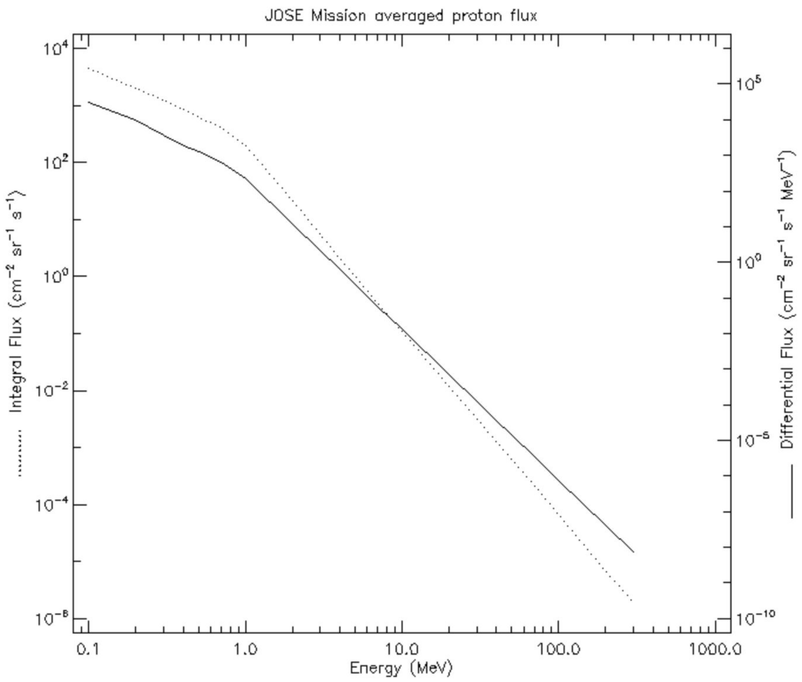
26 orbits in total -> 26 * 2 = 52 krad

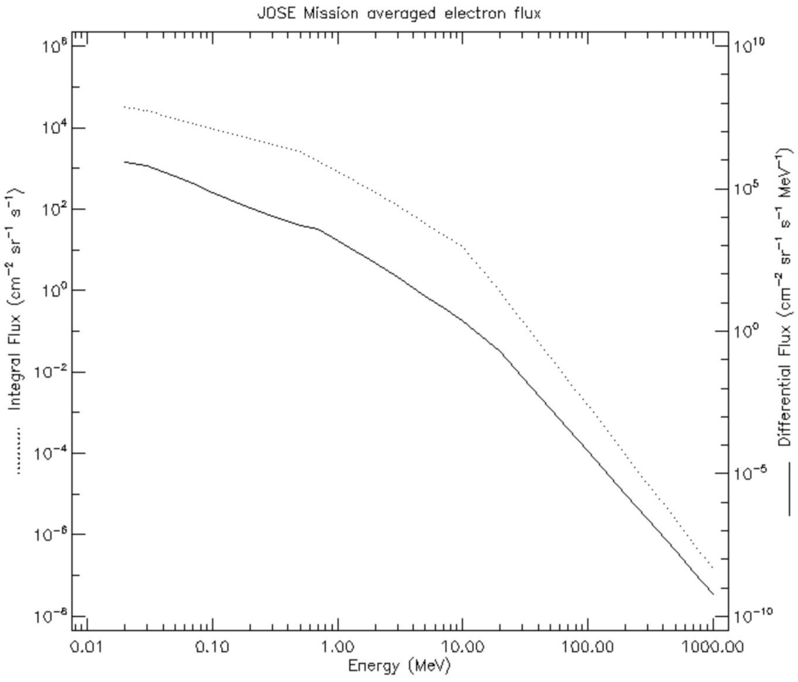
Add the radiation accumulated from Earth to Jupiter -> 52+ 20 = 72 krad

Many uncertainties -> large margin
72 krad + 100% = **144 krad**

SPENVIS Radiation Simulation - Equatorial Orbit

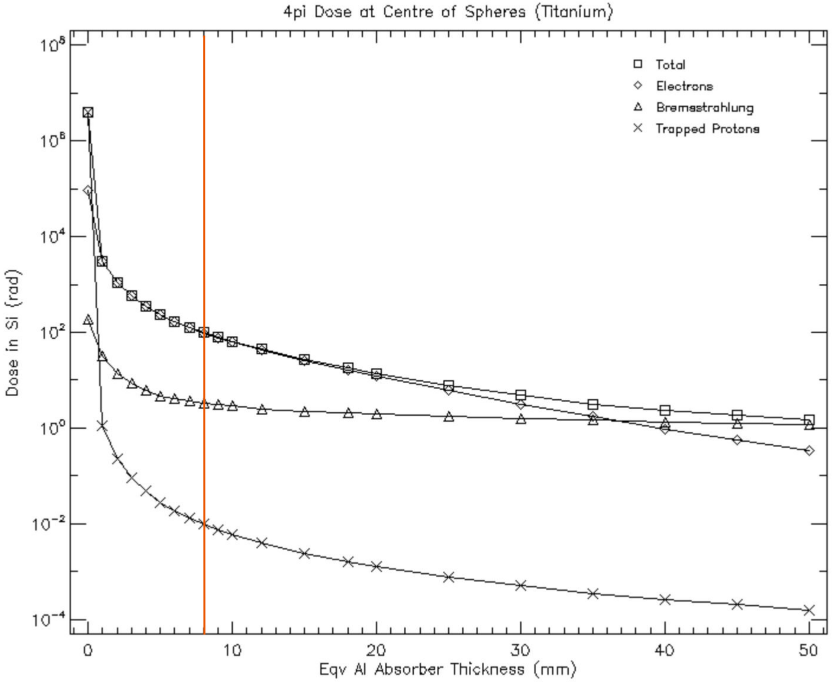
One Orbit





Jupiter Radiation Environment and Effects Models and Mitigation (JOREM), JOSE Trapped Fluxes, 95% confidence

SPENVIS Radiation Simulation - Equatorial Orbit



8 mm of Al equivalent -> TID = 100 rad per orbit

13 orbits in total -> 13 * 100 = 1.3 krad

Add the radiation accumulated from Earth to Jupiter -> 1.3 + 20 ≈ 22 krad

Many uncertainties -> large margin
22 krad + 100% = **44 krad**

Radiation Estimates from Similar Missions

Space Science Reviews (2025) 221:14
https://doi.org/10.1007/s11214-025-01139-9

Check for updates

Europa Clipper Flight System Overview

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2.1 Design Considerations for the Jovian Environment

2.1.1 High Ionizing Radiation

Jupiter's intense radiation belts pose a significant threat to the Europa Clipper spacecraft and its sensitive instruments. More than 2 Mrad of Total Ionizing Dose (TID) is expected to accumulate during the spacecraft lifetime. To safeguard against radiation-induced damage, the spacecraft incorporates shielding and employs radiation-hardened electronic components. Generally shielding limited TID exposure to a maximum of 150 krad and electronic components were chosen with ratings of up to 300 krad, yielding a minimum safety factor of two.

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DOCUMENT

JUICE - Jupiter Icy moons Explorer Consolidated Report on Mission Analysis (CReMA)

A total of 29 fly-bys are used. The total radiation dose during the mission is 235 krad under 10 mm aluminium spheres shielding. As explained in Paragraph 3.7.5, this figure is only an estimation. The Europa phase represents ~10% of the total. Around 40 % of the dose is accumulated during the Ganymede in-orbit phase. In general the perijove radius is always greater than 10 Rj, except during the Europa phase (mandatory because of Europa's orbital radius of 9.4 Rj).

10 mm
Al eq.

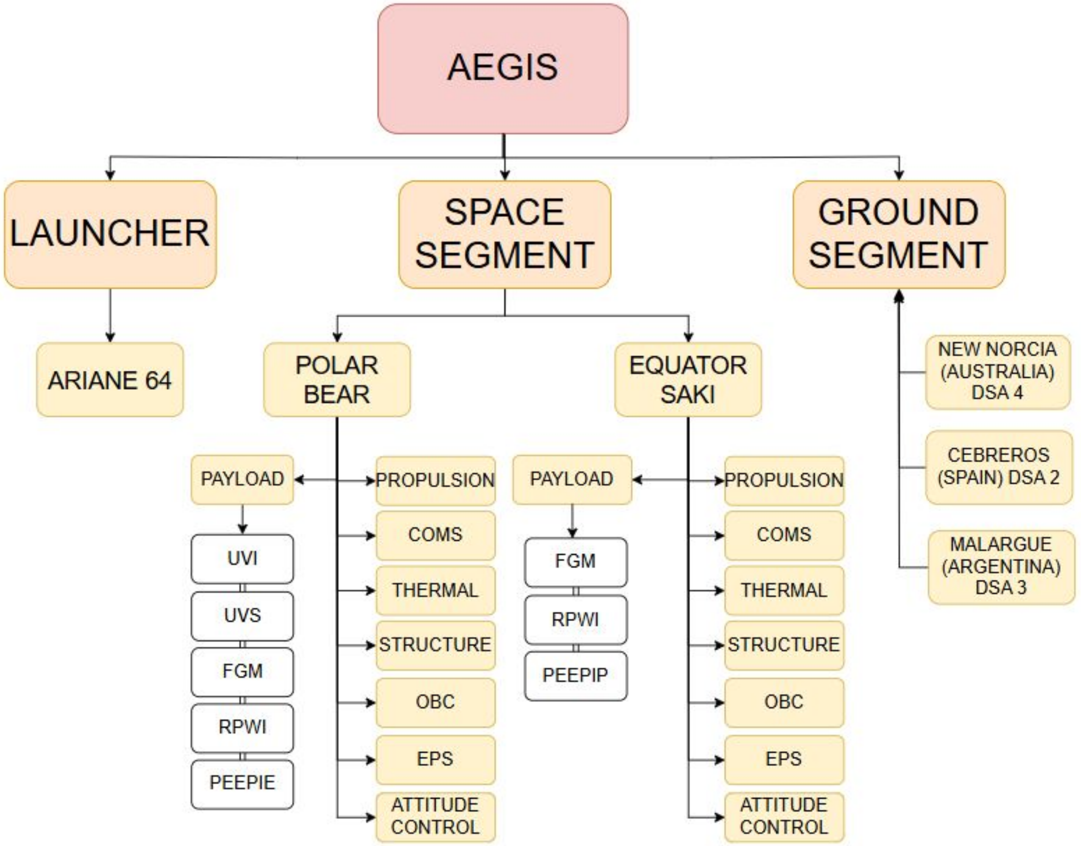
Future Work for the Radiation Estimation

If the trajectory enters Jupiter's radiation belts, what TID is expected? Will the mission survive?

Issue	Possible Solution
Critical components	Spot shielding
Longer mission duration increases TID	Gradient-Z shielding / material selection
Shielding mass penalty	Gradient-Z shielding / material selection

Subsystems

System Overview



Systems Engineering

An example of Traceability Matrix

OBJECTIVES
M1 Determine if and how corotation breakdown, driven by mass loading, couples to the ionosphere via field-aligned currents, and its role in auroral energy deposition.

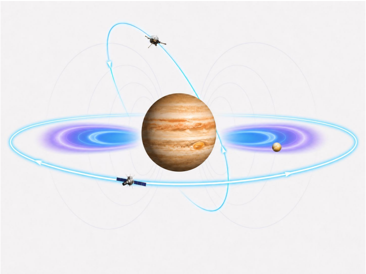
System Engineering

Traceability Matrix

OBJECTIVES	SCIENTIFIC REQUIREMENT	MEASUREMENT REQUIREMENT	INSTRUMENT REQUIREMENT	INSTRUMENT	ORBITAL REQUIREMENT	FUNCTIONAL REQUIREMENT
M1 Determine if and how corotation breakdown, driven by mass loading, couples to the ionosphere via field-aligned currents, and its role in auroral energy deposition.	SR1.1.1. The system shall measure the corotation breakdown and the strength of the corotation-enforcement driver (SC Torus)	SR1.1.1 The system shall measure the plasma angular velocity.	Density range: 20RJ 0.1–100 [cm^{-3}] $\pm$ 0.01 Velocity range: 100–800 [km/s] $\pm$ 10 Angular resolution: 5 [deg] Time resolution: 4 [s]	Particle Instrument (Juice JDC analogue).	The measurement shall be made simultaneously from a spacecraft with a field of view on the planet equator and one with the view on the planet poles.	A dual spacecraft formation around Jupiter (one polar, one equatorial).

+

ConOps



OPERATIONAL MODE

Interplanetary

Subsystem	Safe	Cruise	Comm	Burn
Telecom	on	off	on	on
OBS	on	on	on	on
Propulsion	off	off	off	on

Jupiter orbit

Subsystem	Safe	Science 1	Comm	Burn
Telecom	on	off	on	on
OBC	on	on	on	on
Payload	off	on	off	off
Propulsion	off	off	off	on

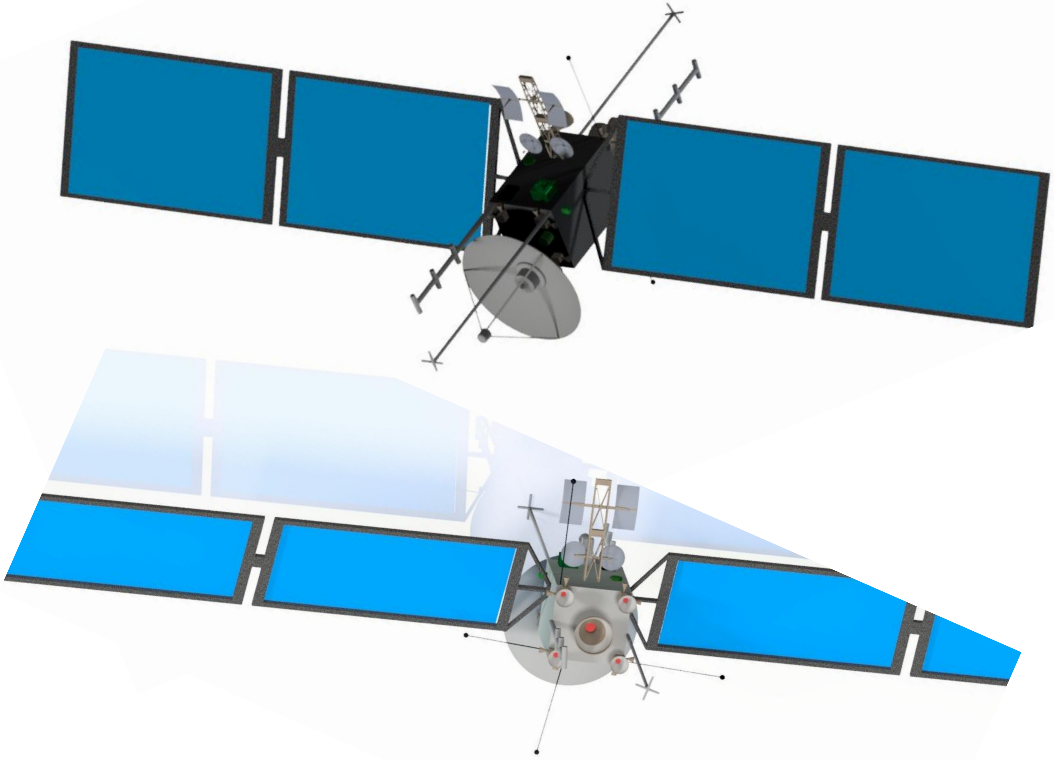
Spacecraft Structure

DESIGN DRIVERS:

- Launch / Maneuvers environment
- Mass of spacecraft

REQUIREMENTS:

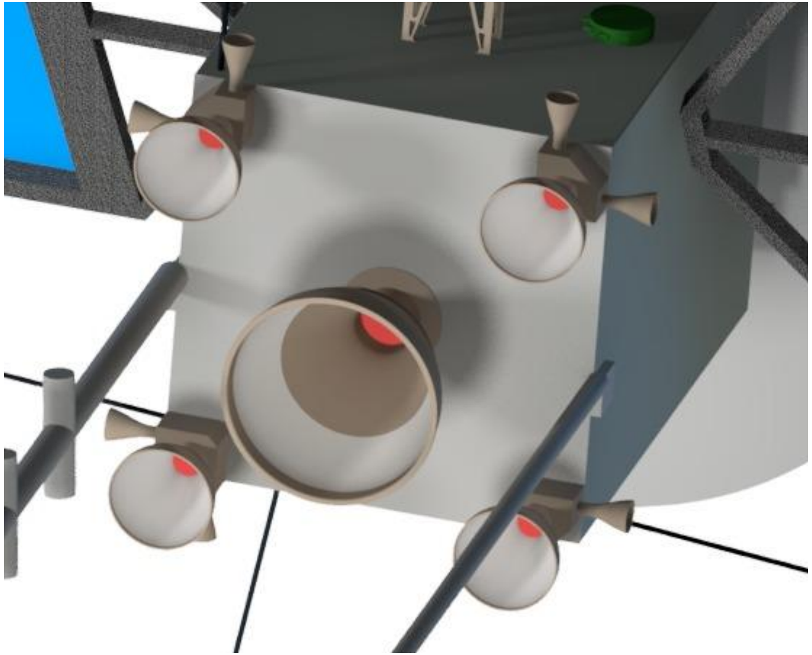
- Load from ARIANE 64
- Max satellite mass give ARIANE 64 the final orbit
- Envelope of the ARIANE 64 fairing



Spacecraft Structure

Components	Mass with 15% Margin Equatorial / Polar [kg]
Primary structure	700
Secondary structure	130
Solar array support / booms	12
Deployment & HDRM mechanisms	20
Radiation vault (titanium)	300

Propulsion System



DESIGN CONSIDERATION:

- ΔV
- High impact on the mission feasibility and mass of the spacecraft

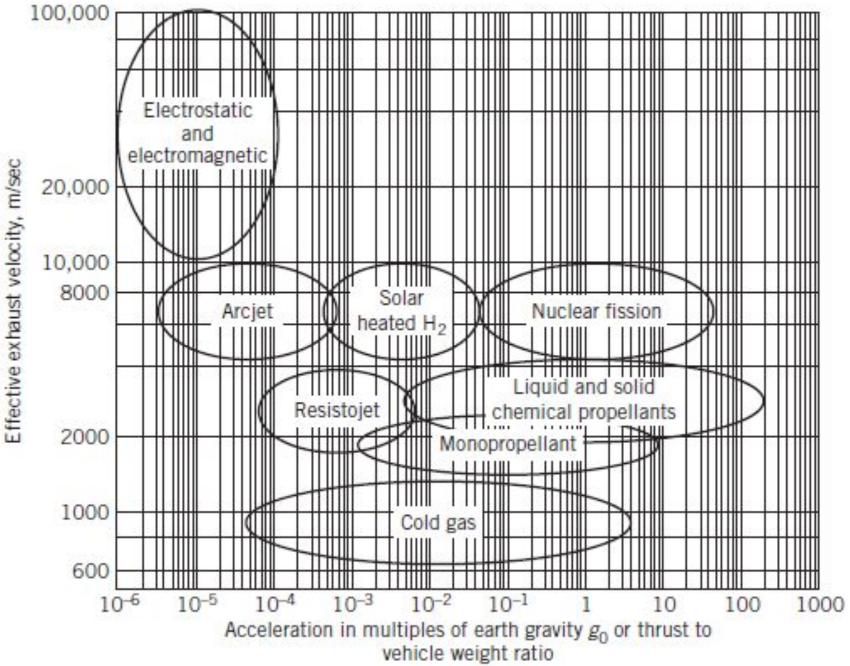
- Storage and propellant decomposition

- Ground handling

REQUIREMENT

- DELTA V (orbit insertions, orbital maneuvers)
  a. Polar: 1349 m/s
  b. Equatorial: 1049 m/s
- DESATURATION REACTION WHEELS

Propulsion System



[Sutton, Rocket propulsion elements]

Why Chemical Bi-Propellant?

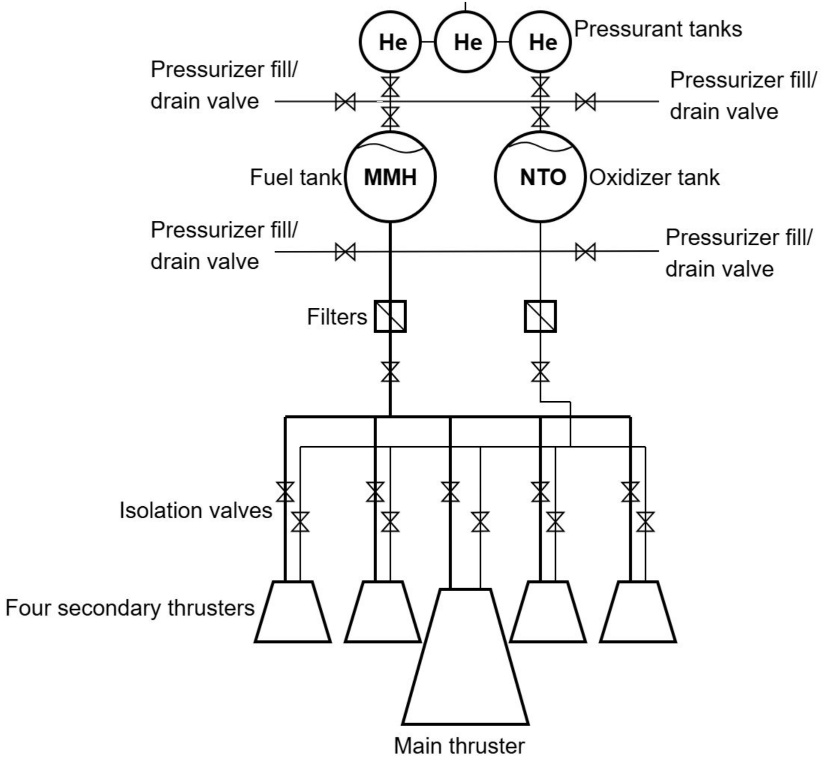
- Acceptable thrust for Jupiter orbit insertion/mission
- Proven and reliable technology with low risk.
- Available in the market/high TRL
- Used for other Jupiter mission

Why Cold gas?

- Simple
- Reliable
- Helium available onboard
- Simplest solution that fulfill requirement with the lowest mass of the system

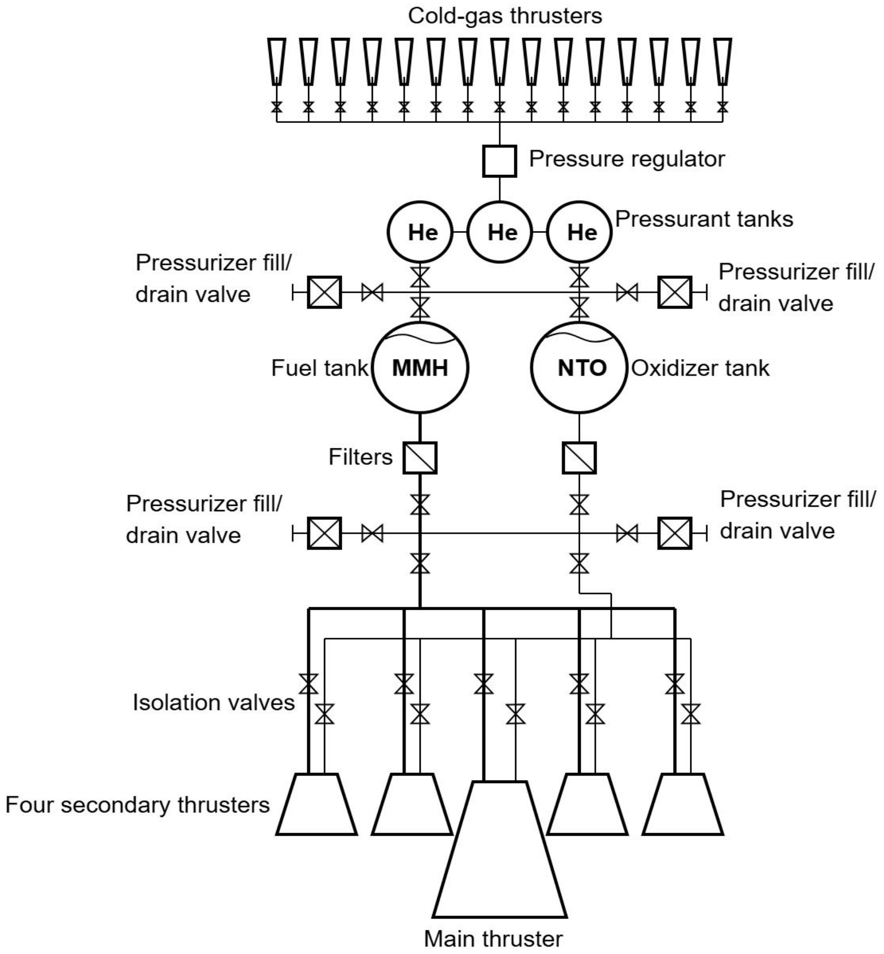
BiProp System

- Propellant: MMH (Monomethylhydrazine) and NTO (Nitrogen Tetroxide)
  - Hypergolic combination
  - Liquid at room temperature
- Pressurant: Helium
  - Non reactive
  - No pump / cavitation problems
- Problem with the tank
  - Tanks might need to be heated -> input for thermal control
  - Need a bladder or liquid trap



Cold Gas System

- He
  - Low molecular mass (better for performance)
  - Heat up during expansion
- Size
  - 0.6mm throat diameter (thin feed line ⅛”)
  - 16 thruster
- Problem: leakage



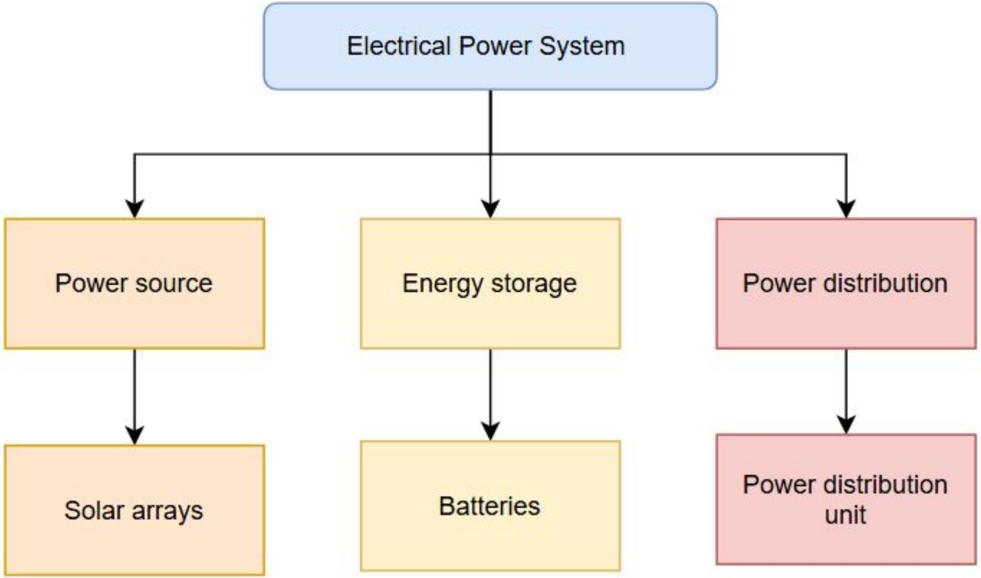
Propulsion System

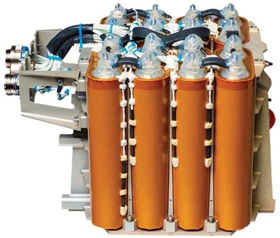
	Polar	Equatorial
MMH mass	275 kg	200 kg
NTO mass	450 kg	350 kg
Tank mass (MMH and NTO tank, Pressurant Helium and tanks)	55 kg	50 kg
Total propulsion system mass (with 20% margins)	850 kg	650 kg

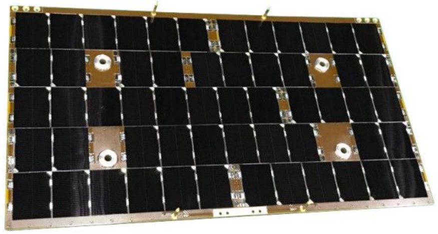
All values with 20% margin

Electrical Power System

Design driver - Reliable power generation, storage, and distribution throughout the mission



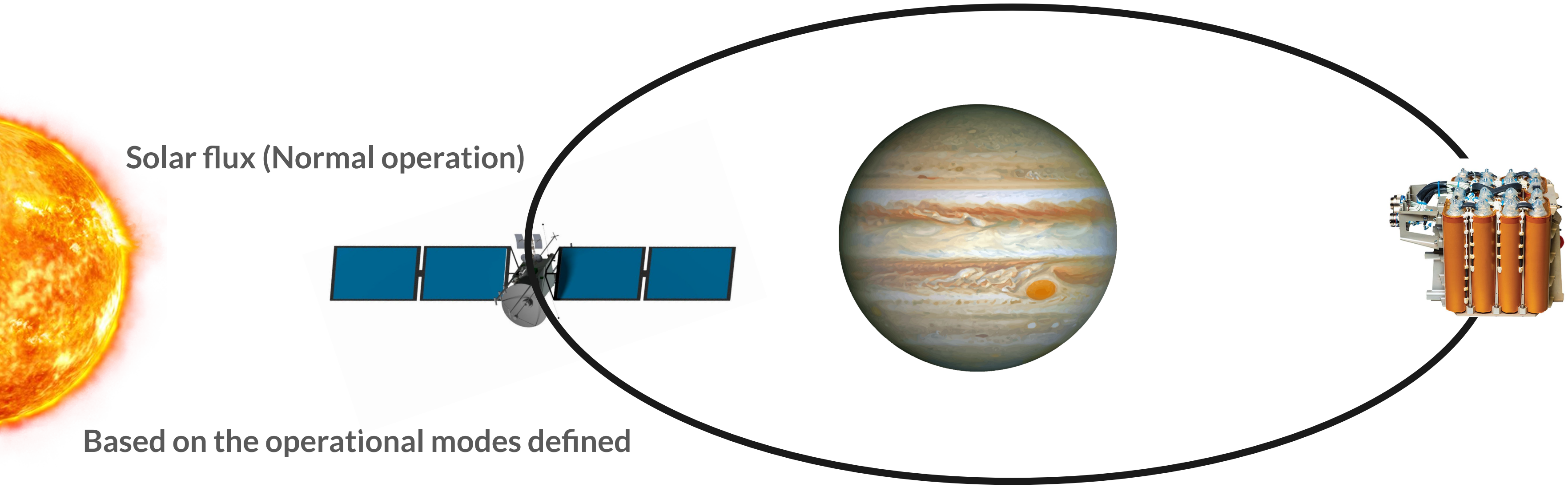




Electrical Power System - Nominal Operation

Design driver - Reliable power generation, storage, and distribution throughout the mission

Solar flux (Normal operation)



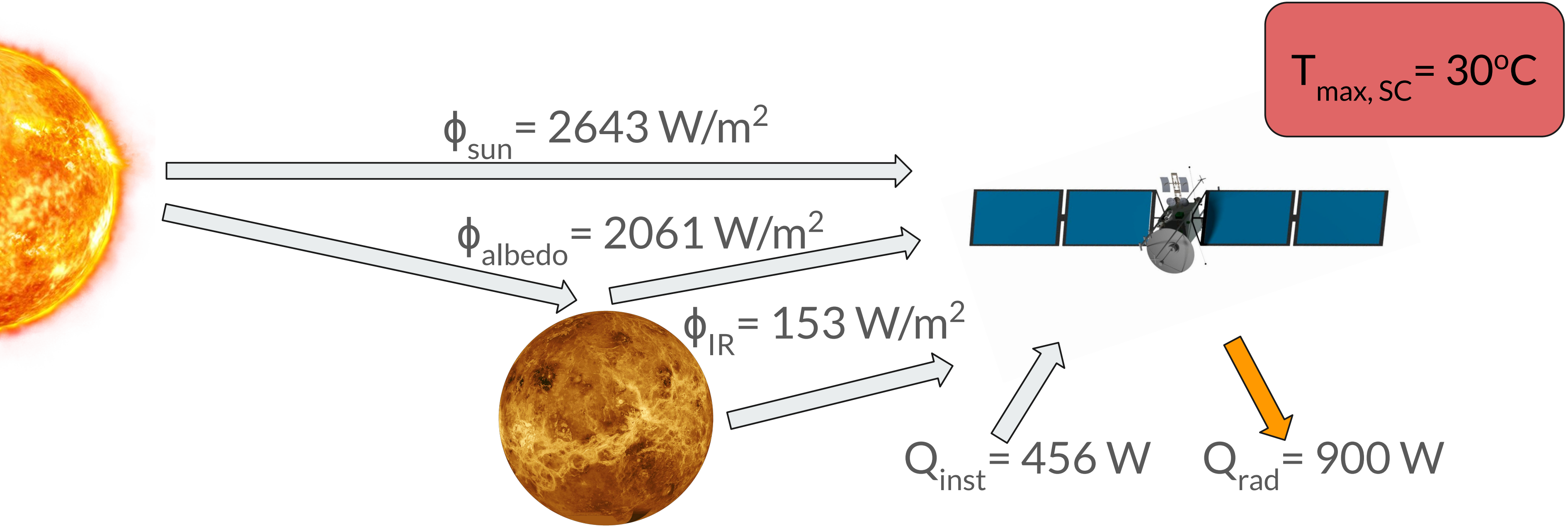
Based on the operational modes defined

Electrical Power System

Parameter	Polar	Equatorial
Average power demand	705 W	411 W
Peak power demand	855 W	658 W
Solar array BOL power (20% margin)	1049 W	615 W
Solar array EOL power (20% margin)	1006 W	590 W
Solar array area	113.2 m^2	66.38 m^2
Solar array mass	97.35 kg	57.1 kg
Battery capacity (20% margin)	14256 Wh	15552 Wh
Battery mass	83.86 kg	91.48 kg

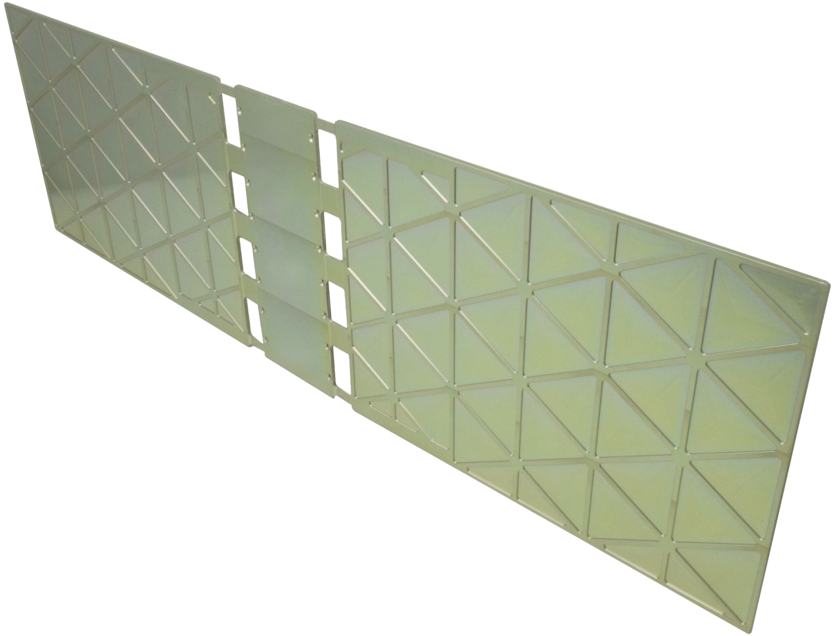
Thermal Control System - Worst Case Hot

Design driver - Maintaining instruments within operational temperature range



Thermal Control System - Cooling

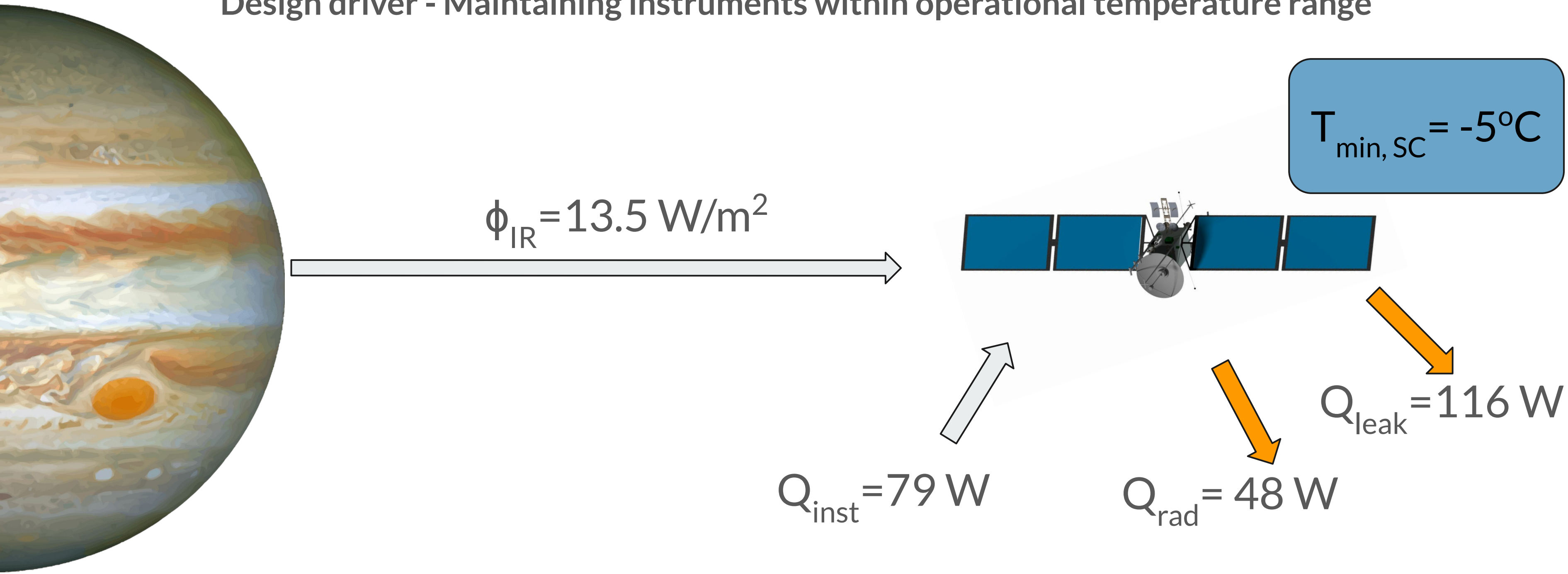
Design driver - Maintaining instruments within operational temperature range



- Radiator sizing
  - Polar: 1.1 m^2
  - Equatorial: 1.1 m^2
- Passive heat rejection
  - Low-absorptivity (α = 0.2) and high emissivity (ε = 0.85)
  - Bimetallic louvers: Fully open to maximise emissivity (ε)

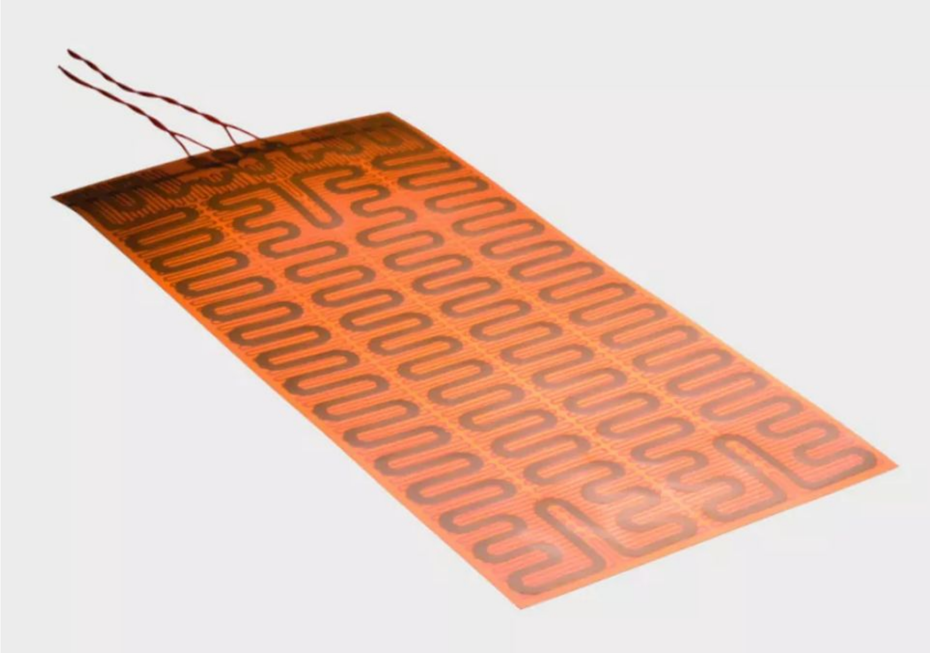
Thermal Control System - Worst Case Cold

Design driver - Maintaining instruments within operational temperature range



Thermal Control System - Heating

Design driver - Maintaining instruments within operational temperature range



- Passive heat preservation
  - Low emissivity (ε = 0.15)
  - Bimetallic louvers: Fully closed to minimise emissivity (ε)
- Active heat generation
  - Polar and Equatorial: 85 W

Thermal Control System - Hardware

Design driver - Maintaining instruments within operational temperature range

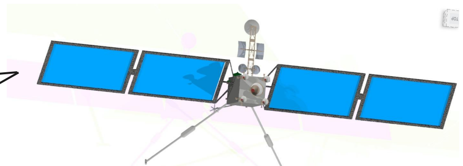
Component	Function
MLI blankets	Mitigates bus leaks
Radiator panels	Radiates internal spacecraft heat
Bimetallic louvres	Varies radiators emissivity passively
Survival heaters	Actively mitigates cool case
Cryogenic cooler	Cools temperature sensitive payload (Flux Gate Magnetometer (FGM))

Attitude and Orbit Control System

Design driver - **Pointing accuracy of <0.1 degrees (Requirement SR 2.1.4)**

Downlink

<0.1°



Data Acquisition

<0.1°

Equatorial

Polar

Disturbance torques generated from:

- Gravity gradient
- Magnetic dipole moment
- Solar wind pressure

Attitude and Orbit Control System

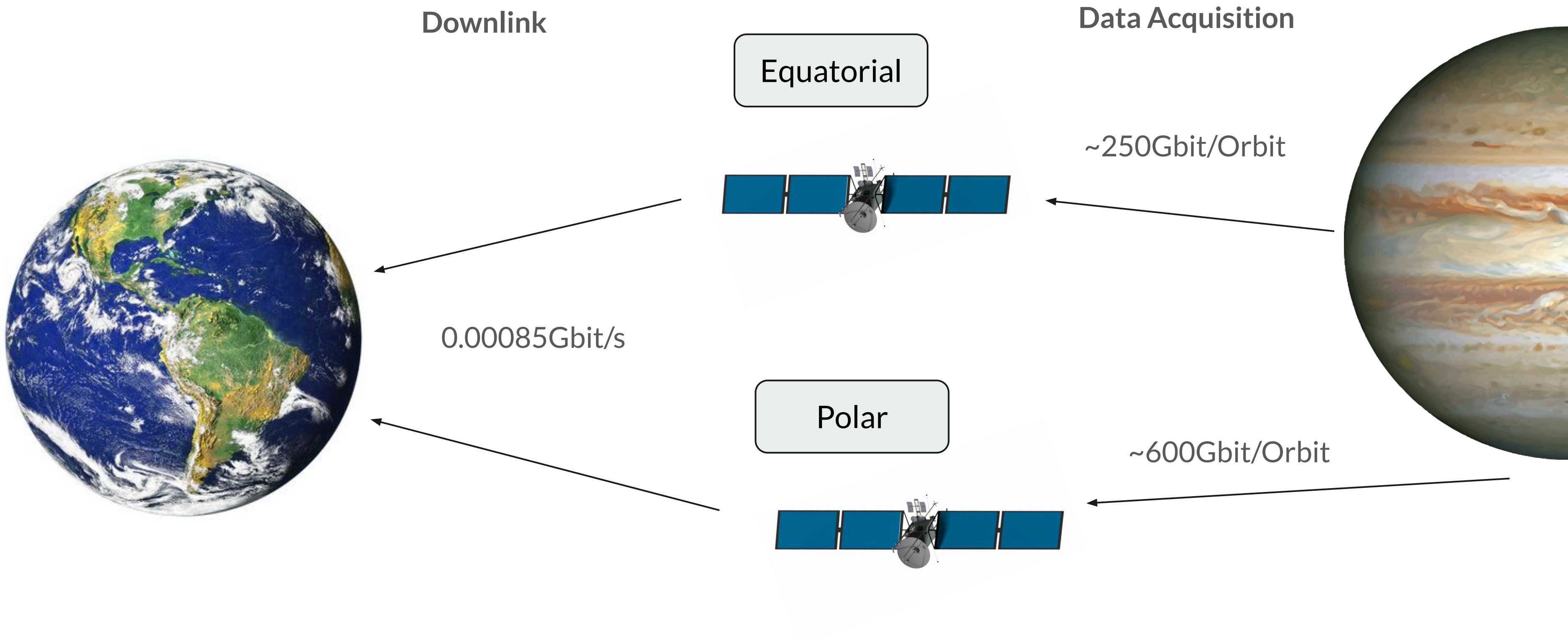
Requirement SR 2.1.4: pointing accuracy of <0.1 degrees

Sensors	Actuators
2 Star Trackers	4 Reaction Wheels
6 Sun Sensors	16 Cold gas thrusters
2 IMUs	

Reaction Wheel Assembly
(adapted from Honeywell Aerospace
Source: https://www.satcatalog.com/component/hr12-12/)

Destauration performed by 16 He cold-gas thrusters, each producing 0.5 N.

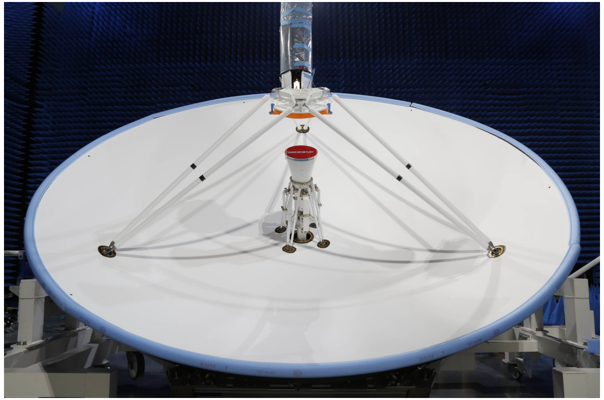
Communication Subsystem



Communication Subsystem

Design Drivers - Downlink ~600 Gbit/Orbit for Polar S/C and ~250 Gbit/Orbit Equatorial S/C

Usage	Equipment
Nominal Operations:	X/Ka-Band HGA, *D*=2.5m
Cruise and Contingency:	X/Ka-Band MGA, *D*=0.5m
Safe Mode:	X/Ka-Band LGA, *D*=0.2m
Signal Management:	X/Ka-band amplifier (54-144W) and transponder
Miscellaneous:	RF electronics (switches, filters, cables)



Thales Alenia Space

Communication Subsystem

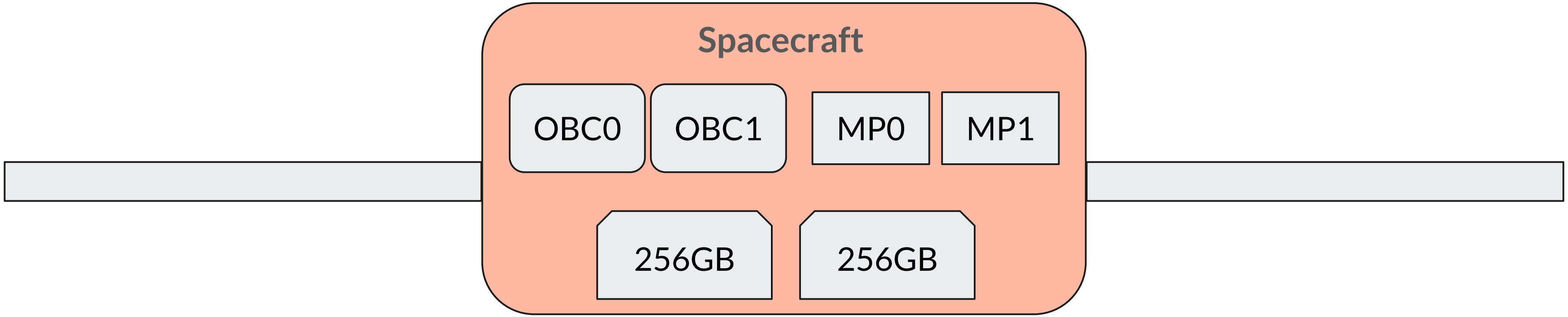
Design Drivers - Downlink ~600 Gbit/Orbit for Polar S/C and ~250 Gbit/Orbit Equatorial S/C

After Compression:

	Compressed Data (Gbit/Orbit)	**Window for Downlinking** (in days)	**Needed days** (12h per day)
Polar	~450	Average: 16 Worst Case: 15	~12
Equatorial	~190	Average: 15 Worst Case: 4	~5

Onboard Control & Payload Data Handling System

Design Driver - Science measurement data storage



- 2x On-board computer
- 2x Microprocessor
- 2x Memory units/ temporary storage: 256 GB

Ground Segment

- Cebreros, Spain (DSA 2)
- Malargüe, Argentina (DSA 3)
- New Norcia, Australia (DSA 4)

- MOC: ESA ESOC, Germany
- SOC: ESA ESAC, Spain

Credits: ESA

Budgets and Risk Assessment

Mass Budget (Allowance of 5,800 kg)

Subsystem	Polar Orbiter [kg]	Polar Orbiter [kg] w/ 20% Margin	Equatorial Orbiter [kg]	Equatorial Orbiter [kg] w/ 20% Margin
Payload	68,3	82	49,2	59
Structure and Mechanisms	1124,2	1,349	1125,0	1,350
Thermal	23,3	28	17,5	21
Power	177,5	213	144,2	173
COM and PDH systems	66,7	80	66,7	80
Attitude and orbit control	35,8	43	35,8	43
Propulsion	750,0	900	541,7	650
Total (individual)	**2245,8**	**2,695**	**1980,0**	**2,375**
Total (combined)		**5,047 w/ 20% Margin**		

Power Budget (Safe mode)

Subsystem	Polar Orbiter [W]	Polar Orbiter w/ 5% Margin [W]	Equatorial Orbiter [W]	Equatorial Orbiter w/ 5% Margin [W]
Payload	0	0	0	0
Thermal	346	363	166	174
Power	36	38	27	28
Communications and PDH systems	333	350	333	349
Attitude and orbit control	41	43	41	43
Propulsion	0	0	0	0
Total	**756**	**794**	**567**	**595**
Total w/ 20% Margin	**—**	**953**	**—**	**714**

Power Budget (Science mode)

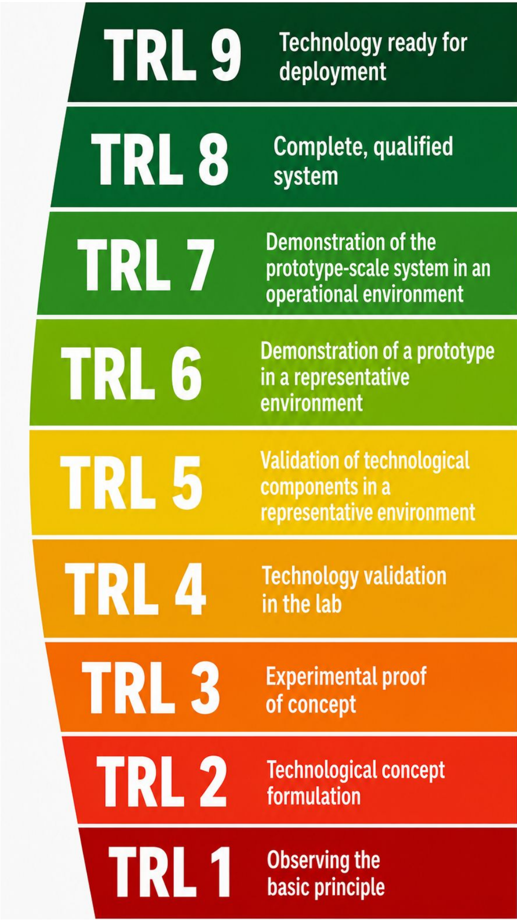
Subsystem	Polar Orbiter [W]	Polar Orbiter w/ 5% Margin [W]	Equatorial Orbiter [W]	Equatorial Orbiter w/ 5% Margin [W]
Payload	83	87	44	46
Thermal	346	363	166	174
Power	27	28	16	16
Communications and PDH systems	61	64	61	64
Attitude and orbit control	41	43	41	43
Propulsion	11	11	11	11
Total	**569**	**597**	**339**	**356**
Total w/ 20% Margin	—	**717**	—	**428**

Lifecycle Cost Budget ~ €1.8 Billion (L-Class Mission)

Category	Cost (€M)
ESA Payload Contribution	30
Spacecraft 1 Development	600
Spacecraft 2 Development	400
Industrial Costs	200
Mission & Science Operations	150
Contingency Margin	300
Launcher (Ariane 64)	135
Total	**1815**

Technology Readiness Level - Systems

SYSTEM (POLAR and EQUATORIAL)	TRL
Propulsion System	6
Attitude and Orbit Control System	6
Communications and PDH System	5
Thermal Control System	7
Electrical Power System	6
Structures	7

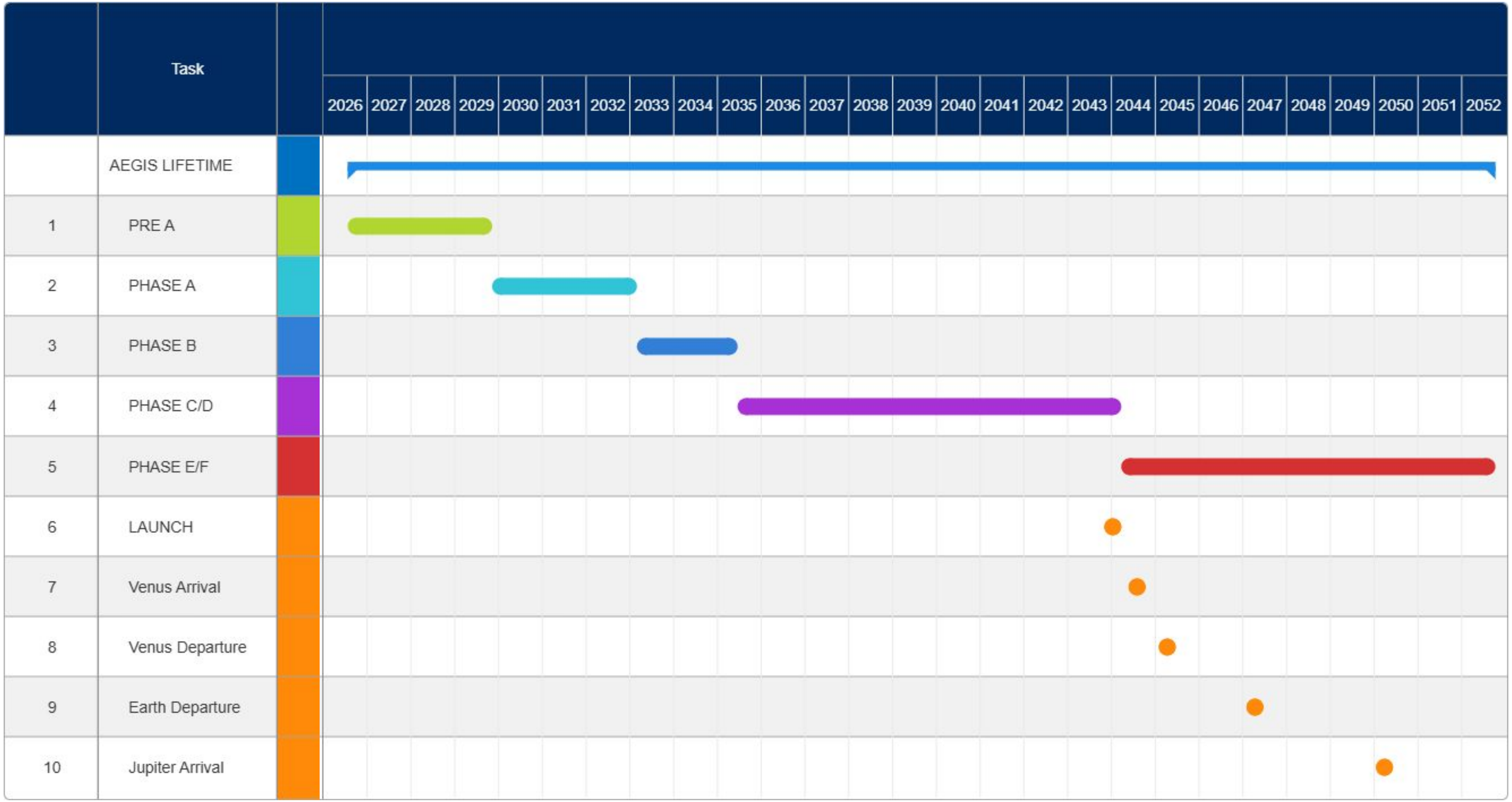


Risk Assessment Matrix

Likelihood

Severity

	Minimum	Low	Medium	High	Maximum
Catastrophic	Radiation damage to avionics	Launcher failure			
Critical		Communications loss	Separation of spacecraft		
Major		Individual instrument failure	RW saturation/failure		
Significant		Failure in deploying a single solar array	Flight software fault		
Negligible					


Task
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2048
2049
2050
2051
2052
AEGIS LIFETIME
1 PRE A
2 PHASE A
3 PHASE B
4 PHASE C/D
5 PHASE E/F
6 LAUNCH
7 Venus Arrival
8 Venus Departure
9 Earth Departure
10 Jupiter Arrival

In Conclusion...

Our mission fulfills all the requirements

-> Allowing the science questions to be answered

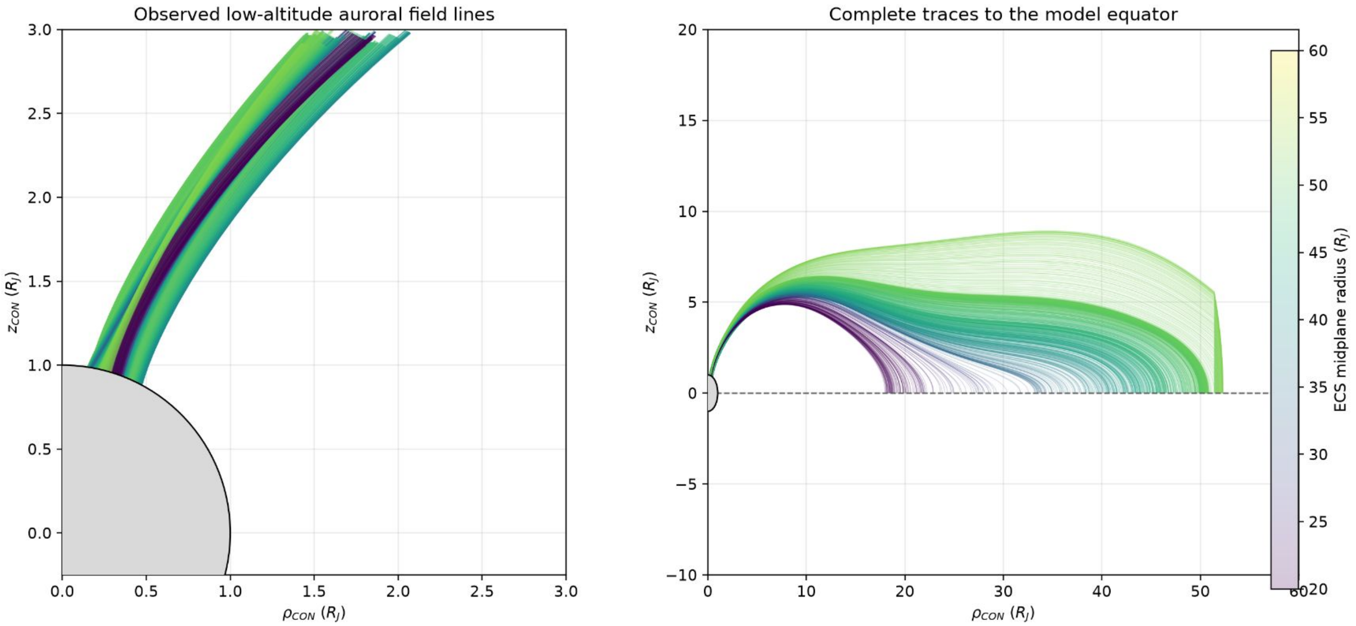
-> And have a successful mission!

Outreach: Merchandise & school events

Thank You for Your Attention <3

Questions?

Backup

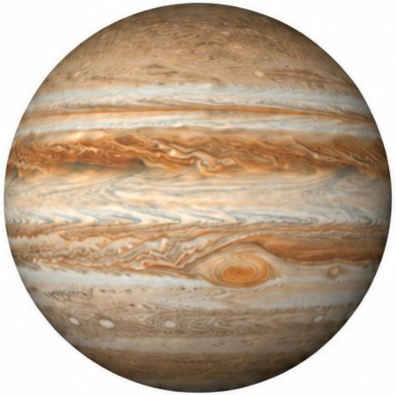


Observed low-altitude auroral field lines
Complete traces to the model equator
z_{CON} (R_J)
ρ_{CON} (R_J)
ECS midplane radius (R_J)

89

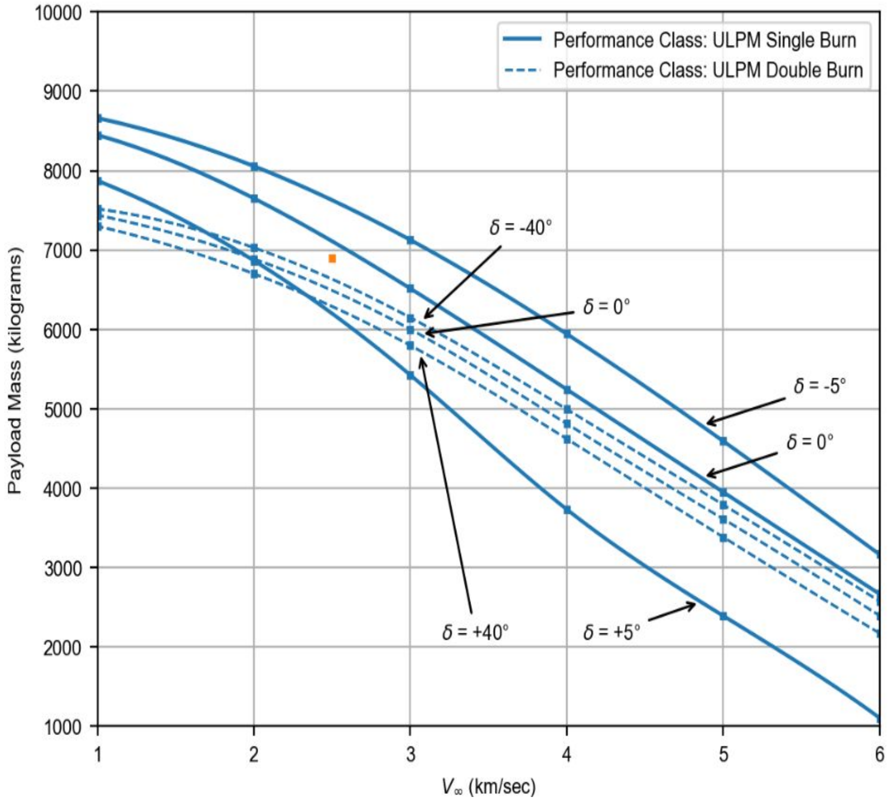
Scientific Questions

Q1 - How is energy **transported and deposited** in the Jovian magnetosphere?



Q2 - How will and has the Jovian system **evolved with respect to energetic input**?

Q3 - How does **energy enter** into the Jovian system?

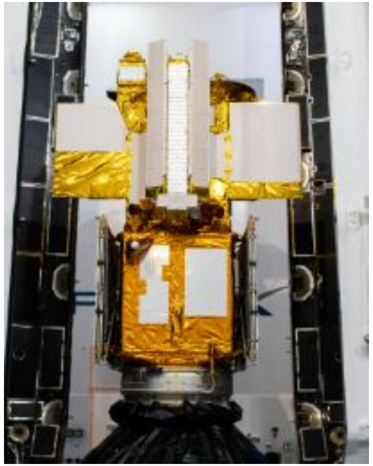


V∞ (km/s)	Payload Mass (kilograms)							
	ULPM Single Burn, DLA (°)			ULPM Double Burn, DLA (°)				
	-5.0	0.0	+5.0	-40.0	-20.0	0.0	+20.0	+40.0
1.0	8661	8447	7872	7518	7485	7438	7367	7300
2.0	8056	7650	6867	7029	6963	6888	6800	6701
3.0	7127	6515	5426	6149	6079	6002	5915	5798
4.0	5943	5245	3734	4995	4911	4812	4711	4622
5.0	4594	3952	2394	3793	3710	3613	3520	3385
6.0	3167	2669	1108	2578	2487	2395	2305	2174

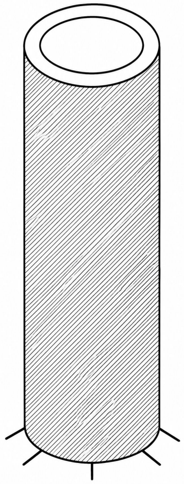
Figure 2: Representative Performance for Earth Escape Missions, Ariane 64

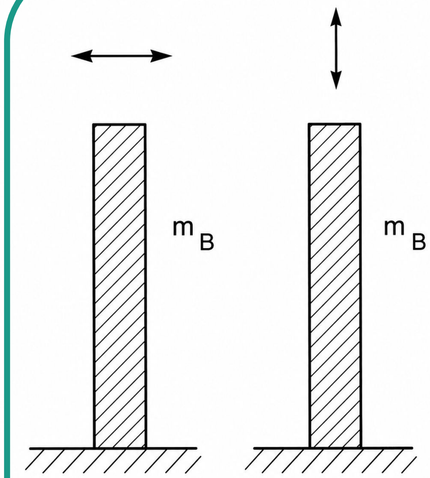
Spacecraft Structure

SIZING FACTOR - LAUNCHER



EQUIVALENT





- Tensile forces
- Compressive forces
- Shear forces

Thickness of the monocoque equivalent

Mass for the structure subsystem

Compare with other missions

Chem Prop.

Bipropellant MMH/N_2O_4, 425N engine + 4x22N/6x10N ACS — JUICE heritage

Sizing tool (MATLAB) verified against a NASA Glenn example — matches

Budget: 382.3 kg / 401.6 kg with margin / 168 W

To do: baseline ΔV (4056 m/s) likely too high, needs revisiting with the trajectory team

Structure

Al 7075-T6 (primary structure), Ti-6Al-4V (tanks/vault), CFRP (solar array booms) — standard choices, strong flight heritage

Safety factors 1.25/1.4 (NASA-STD-5001), upper end of range due to Ariane 64 loads

Radiation vault ~103 kg (titanium), scaled from Juno's — the most Jupiter-specific mass driver

Budget: 269 kg / 311 kg with margin / 15 W

To do: P vs E not yet differentiated, no FEA yet

Feasibility - Risk Assessment

System	Risk	Likelihood	Severity	Mitigation
Structure/avionics	Jupiter radiation damages subsystems	Minimum	Catastrophic	Radiation shielding/rad-hard electronics
EPS	Failure to deploy solar array	Medium	Catastrophic	Qualification of system deployed
Launcher/propulsion	Launch failure	Low	Catastrophic	Flight proven Ariane 64/thrusters
Payload	Individual instrument failure	Low	Major	Redundancy of instruments
Communications	Communications loss	Low	Critical	High-gain antenna
AOCS	RW saturation/failure	Medium	Major	Redundancy/desaturation
Payload	Spacecraft separation	Medium	Critical	Ground testing and qualification

Propulsion System

Dry mass: 3708.7 kg

Wet mass: 4500 kg

Total mass estimate: 401.613 kg w/ margins

Total power estimate: 201.6 W w/ margins

Components
Main bipropellant engine (425N class, S400-15 Juno heritage)
ACS thruster, 22N class (S22/MR-106L heritage)
ACS thruster, 10N class (S10-13 heritage)
Fuel tank, titanium (MMH) → COPV
Oxidizer tank, titanium (NTO/MON-3) → COPV
Pressurant tank, COPV (Helium)

Propulsion

Orbital requirements:

•Δv budget per probe: 1000 m/s (own complete propulsion system, each probe sized independently)

•Architecture: two probes stacked at launch, separate after transfer — no shared propulsion stage

	Polar probe	Equatorial probe
Propellant (w/ margin)	730 kg TBD	640.0 kg TBD
dry mass(w/ margin)	150.0 kg TBD	150.0 kg TBD
total mass	**880.0 kg**	**790.0 kg**

Components

Main engine: LEROS 4 (Nammo, UK) — 1000N bipropellant engine
ACS thruster, 22N class (4x, MR-106L heritage)
ACS thruster, 10N class (6x)
Fuel tank, titanium (MMH) → COPV
Oxidizer tank, titanium (NTO/MON-3) → COPV
Pressurant tank, COPV (Helium)

Propulsion 2

Components

Main engine: LEROS 4 (Nammo, UK) — 1000N bipropellant engine
ACS thruster, 22N class (4x, MR-106L heritage)
ACS thruster, 10N class (6x)
Fuel tank, titanium (MMH) → COPV
Oxidizer tank, titanium (NTO/MON-3) → COPV
Pressurant tank, COPV (Helium)

Summary	
Measurement	**Value**
Mass [kg]	193.56
Mass (w/ margin) [kg]	401.613
Power [W]	168
Power (w/ margin) [W]	201.6

Combined launch mass (both probes, w/ margin): 2054.6 kg — Ariane 64 limit: 4500 kg (54% margin remaining)

Each probe carries its own full propulsion system (own engine, own ACS, own tanks) — no cross-probe sharing. Component types identical between probes; masses sized per probe's own dry mass and instrument load.

POLARBear Instruments

Instrument	Origin	Purpose	Observation Mode
UVS	Juice	Ultraviolet Spectrograph - Looks at the emitted auroral power, morphology, footprint location, and temporal evolution. Relate remote sensing to in-situ particle acceleration and wave energy to energy deposition in poles.	Mode 1, 3
UVI	SMILE	Ultraviolet Aurora Imager - Imaging of auroral emissions; power, morphology, variations.	Mode 1, 3
FGM	Juno	Fluxgate Magnetometer - Determining B field DC measurements, topology, currents along field lines, corotation bend back, shock geometry, and combines with the electric and wave measurements.	Mode 1, 3
REPT	VanAllen	Relativistic Electron-Proton Telescope - Measures the intensity and energy spectra of high-energy electrons.	Mode 1, 3

POLARBear Instruments

Instrument	Origin	Purpose	Observation Mode
JEI	Juice	Jovian Electron and Ion sensor- Measures low-med energy electrons, ions, pitch angle distributions, electron energy spectra, up/down particle flux and acceleration mechanisms.	Mode 1, 3
JDC	Juice	Jovian plasma Dynamics and Composition analyzer- 3D ion distributions, velocity, density, mass composition. Essential to plasma transport, solar wind pressure, bowshock/magnetopause crossings.	Mode 1, 3
JoEE	Juice	Jovian Energetic Electrons - Measures energetic electrons ~ keV - MeV, energetic electron population, auroral precipitation, particle acceleration. Electron energy coverage completed in tangent with JEI.	Mode 1, 3
RPWI -> SCM + LP-PWI	Juice	Langmuir Probe & Plasma Wave Instrument - Measures the cold plasma environment and electric fields of Jupiter Search Coil Magnetometer - 3D magnetic field sensor.	Mode 1, 3

EQUATORIALSaki Instruments

Instrument	Origin	Purpose	Observation Mode
FGM	Juno	Fluxgate Magnetometer - Determining B field DC measurements, topology, currents along field lines, corotation bend back, shock geometry, and combines with the electric and wave measurements.	Mode 1, 2, 3, 4
JEI	Juice	Jovian Electron and Ion sensor- Measures low-medium energy electrons and ions, pitch angle distributions, electron energy spectra, up/down particle flux and acceleration mechanisms.	Mode 1, 2, 3, 4
JDC	Juice	Jovian plasma Dynamics and Composition analyzer- 3D ion distributions, velocity, density, mass composition. Essential to plasma transport, solar wind pressure, bowshock/magnetopause crossings.	Mode 1, 2, 3, 4

EQUATORIALSaki Instruments

Instrument	Origin	Purpose	Observation Mode
JoEE	Juice	Jovian Energetic Electrons - Measures energetic electrons ~ keV - MeV, energetic electron population, auroral precipitation, particle acceleration. Electron energy coverage completed in tangent with JEI.	Mode 1, 2, 3, 4
JENI	Juice	Jovian Energetic Neutrals and Ions - Tracks energetic neutral atoms (ENA) and energetic ions and contains a ion spectrometer.	Mode 1, 2, 3, 4
RPWI -> SCM + LP-PWI	Juice	Langmuir Probe & Plasma Wave Instrument - Measures the cold plasma environment and electric fields of Jupiter Search Coil Magnetometer - 3D magnetic field sensor.	Mode 1, 2, 3, 4
REPT	Juice	Relativistic Electron-Proton Telescope - Measures the intensity and energy spectra of high-energy electrons.	Mode 1, 2, 3, 4

Tentative Lifecycle Cost Budget ~ €1.5 Billion - KC

L-Class Mission

Via consultation with experts, comparison to similar missions (Juice, Juno) and a general top-down view, we estimate a rough cost of **€1.5B**.

Scientific Payload (~€100M) is funded by member states with only a €30M ESA contribution factored in here.

Spacecraft (SC) Development:

SC1: **~€500M**

SC2: **~€300M**

General Industrial costs: **~€200M**

Launcher (Arianne 64): **~€135M**

Mission Operations and Lifecycle Phases:
~**€150M** across MOC and SOC infrastructure.

- Cruise Phase: ~6-years to reach Jupiter.
- Science Operations Phase: ~2-years of measurements.

20% Margin: **~€200M**

Spacecraft Structure Components

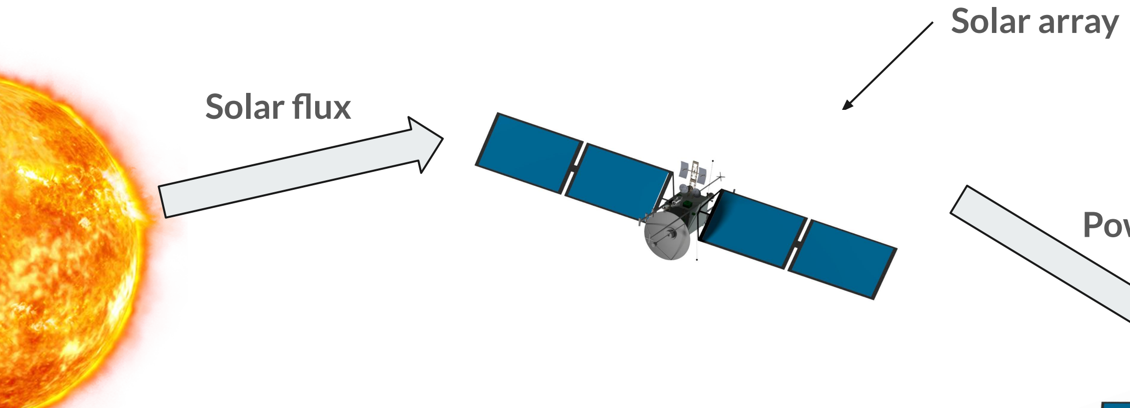
Total mass : 130kg / probe

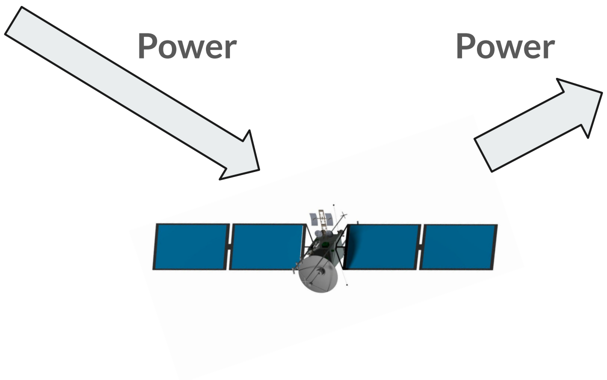
Separation device : 20kg /probe

Element	Purpose	Mass estimate [kg]
Solar array deployment mechanism	Deploy and lock the solar panels	~10–30
High-gain antenna deployment mechanism	Deploy the main communication antenna	~5–15
Instrument mounting brackets / payload panels	Support scientific instruments	~20–50
Propellant tank supports	Hold tanks during launch loads	~20–50
Launch vehicle interface ring	Connect spacecraft to launcher	~20–50

Electrical Power System - Nominal Operation

Design driver - Reliable power generation, storage, and distribution throughout the mission





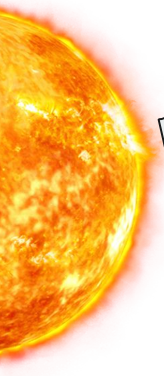
- Payload
- Structure and Mechanisms
- Thermal
- Power
- Data handling
- AOCS
- Propulsion

Based on the operational modes defined

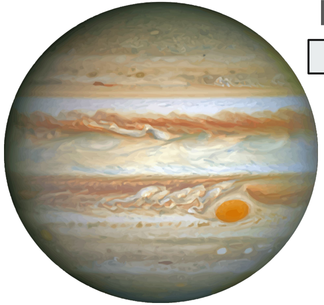
Normal operation

Electrical Power System - Eclipse

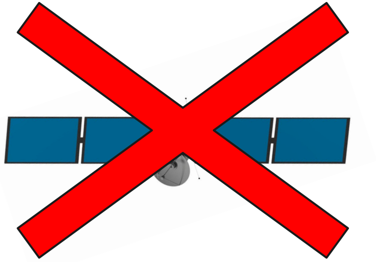
Design driver - Reliable power generation, storage, and distribution throughout the mission



Solar flux



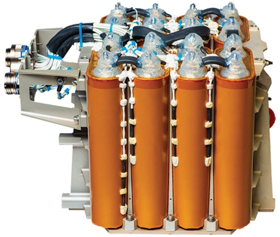
Eclipse



- Payload
- Structure and Mechanisms
- Thermal
- Power
- Data handling
- AOCS
- Propulsion

Based on the operational modes defined

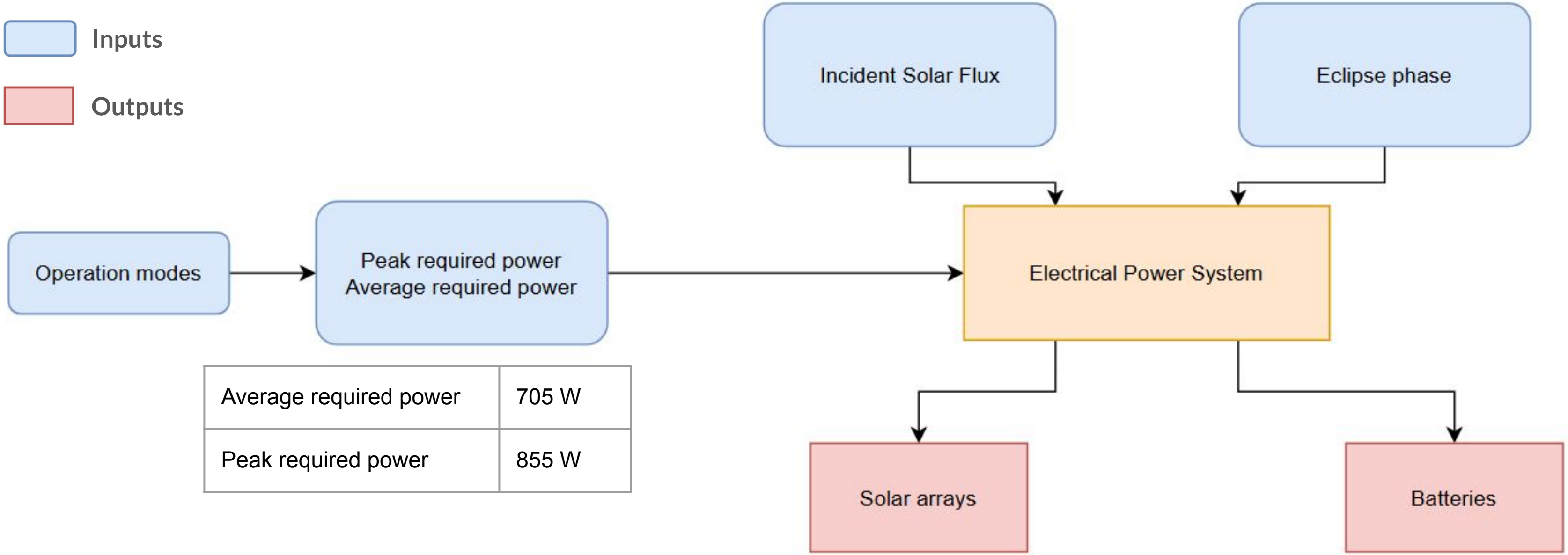
Batteries



Power

Electrical Power System - Polar

Design driver - Reliable power generation, storage, and distribution throughout the mission



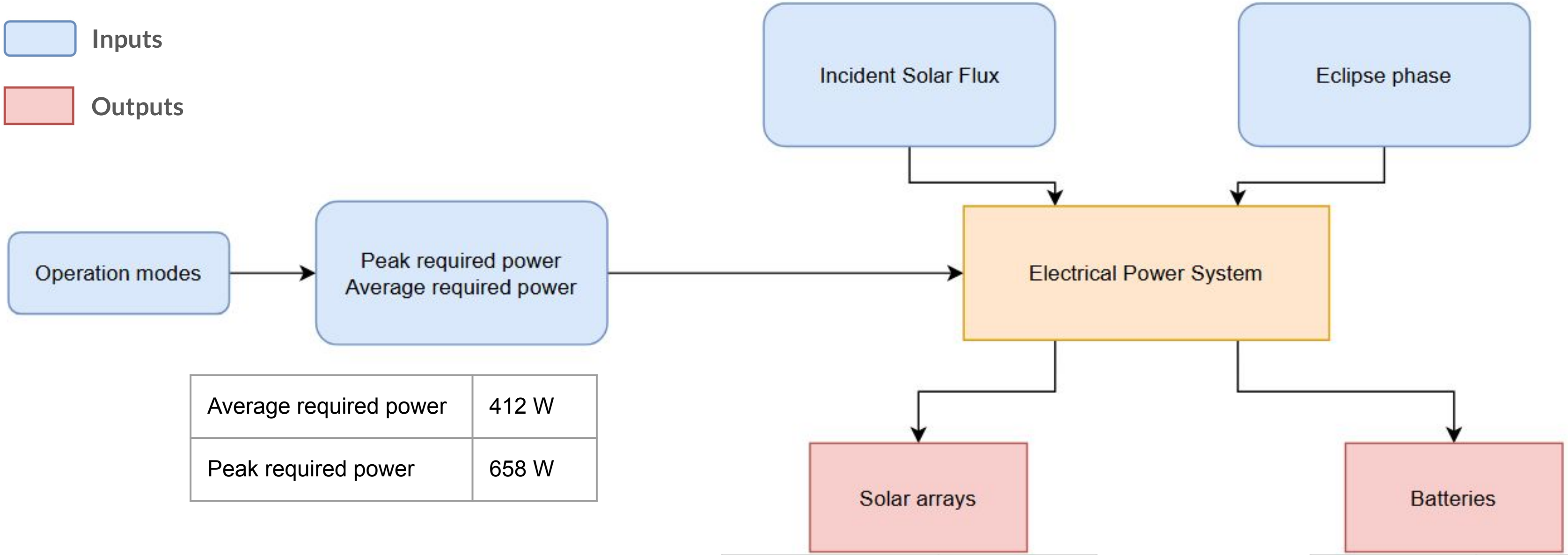
Average required power	705 W
Peak required power	855 W

Solar array area	113.2 m^2
Total mass	97.35 kg

Capacity	14256 Wh
Total mass	83.86 kg

Electrical Power System - Equatorial

Design driver - Reliable power generation, storage, and distribution throughout the mission



Average required power	412 W
Peak required power	658 W

Solar array area	63.4 m^2
Total mass	57.1 kg

Capacity	15552 Wh
Total mass	91.5 kg

Electrical Power System

Design driver - Reliable power generation, storage, and distribution throughout the mission

Power source

Power BOL (20% margin)	1048.735 W
Power EOL (20% margin)	1005.77 W
Average required power	704.99 W
Peak required power	854.81 W
Solar array area	113.197 m²
Total mass	97.35 kg

POLAR ORBIT

- Solar cell selection: AZUR SPACE 3G28, following the precedent set by Juno.

Electrical Power System

Design driver - Reliable power generation, storage, and distribution throughout the mission

Energy storage

Eclipse time	8.5 h
Battery capacity required	13264.2 Wh
Battery type	Saft VES180SA (LiIon)
Cells number	8 series / 11 parallel – 88 cells
Dimensions	46.2 x 36.4 x 55.6 cm
Capacity	14256 Wh
Total mass	83.86 kg

POLAR ORBIT

Electrical Power System

Design driver - Reliable power generation, storage, and distribution throughout the mission

Power source

Power BOL (20% margin)	614.94 W
Power EOL (20% margin)	589.75 W
Average required power	411.51 W
Peak required power	658.19 W
Solar array area	66.38 m²
Total mass	57.08 kg

EQUATORIAL ORBIT

- Solar cell selection: AZUR SPACE 3G28, following the precedent set by Juno.

Electrical Power System

Design driver - Reliable power generation, storage, and distribution throughout the mission

Energy storage

Eclipse time	16 h
Battery capacity required	14778.74 Wh
Battery type	Saft VES180SA (LiIon)
Cells number	8 series / 12 parallel – 96 cells
Dimensions	46.2 x 36.4 x 55.6 cm
Capacity	15552 Wh
Total mass	91.48 kg

EQUATORIAL ORBIT

Thermal Control System - Instrumentation info.

- **Multi-Layer Insulation (MLI):** Aluminized beta cloth MLI
- **Bimetallic Louvres:** SENER Rosetta heritage passive louvres (x3)
- **Survival Heaters:** Kapton polyimide patches delivering up to 98.4 W of active heating during the Jupiter eclipse
- **Radiator Panels:** 1.1 m^2 aluminium honeycomb panels per spacecraft

Thermal Control System - Surface Coating Data

- **Venus Flyby (WCH) - White paint**
  - Absorptivity: 0.1
  - Emissivity: 0.85 (Louvres are fully open -> Maximum heat rejection)
- **Jupiter Eclipse (WCC) - Louvres**
  - Emissivity: 0.15 (Louvres are completely closed -> Minimum heat rejection)
- **Spacecraft bus - MLI Coating**

Thermal Control System - Equilibrium Equation

$$Q_{radiation} + Q_{conduction} + Q_{dissipation} + Q_{external} = M.Cp.dT/dt$$

$$F.A_{rad}.\varepsilon.\sigma.\left(T_{sp}^4 - T^4\right) + C.(T_0 - T) + Qd + A.F_s.\alpha_S.\Phi_{Sun} + A.F_s.\alpha_S.\Phi_{Albedo} + A.F_e.\varepsilon.\Phi_{Earth} = M.Cp.\frac{dT}{dt}$$

F:	radiative view factor between body and space
A_{rad}:	area of radiative surface (m^2)
ε:	IR emissivity of radiative surface
σ:	stefan-boltzmann constant ($W/m^2.K^4$)
T:	temperature of the body(**K**)
T_0:	temperature of conductive interface
C:	conductance between body and boundary (W/K)
Cp:	specific heat of the body (J/K.kg)

Qd:	body internal power dissipation (W)
A:	Radiative surface of your system (m^2)
Fs/Fa/Fe	View factor to sun/albedo/earth (between 0 and 1)
αs:	solar absorbtance
Φ_{sun}:	solar flux (W/m^2)
Φ_{albedo}:	albedo flux (W/m^2)
ε:	IR emissivity (= IR absorbtance!)
Φ_{earth}:	earth flux (W/m^2)

Credit: Bayeux, C., Buti, C., Clément, A., Deschamps, S., & Walker, A. (2025). *Satellite Thermal Control* [Lecture slides]. Master in aeronautical engineering and space technology, ISAE-SUPAERO.

Power Budget (Communication mode)

Subsystem	Polar Orbiter [W]	Polar Orbiter w/ Margin [W]	Equatorial Orbiter [W]	Equatorial Orbiter w/ Margin [W]
Payload	0	0	0	0
Thermal	346	363.3	166	174.3
Power	36.55	38.38	27.55	28.93
Communications and PDH systems	333	349.65	333	349.65
Attitude and orbit control	41	43.05	41	43.05
Propulsion	11	11.55	11	11.55
Total (individual)	**767.55**	**805.93**	**578.55**	**607.48**
Total w/ Margin		**967.11**		**728.97**

Power Budget (Burn in mode)

Subsystem	Polar Orbiter [W]	Polar Orbiter w/ Margin [W]	Equatorial Orbiter [W]	Equatorial Orbiter w/ Margin [W]
Payload	0	0	0	0
Thermal	346	363.3	166	174.3
Power	38.85	40.75	29.85	31.34
Communications and PDH systems	333	349.65	333	349.65
Attitude and orbit control	41	43.05	41	43.05
Propulsion	57	58.1	57	59.85
Total (individual)	**815.85**	**854.81**	**626.85**	**658.19**
Total w/ Margin		**1025.77**		**789.83**

Power Budget (Maneuvers pointing mode)

Subsystem	Polar Orbiter [W]	Polar Orbiter w/ Margin [W]	Equatorial Orbiter [W]	Equatorial Orbiter w/ Margin [W]
Payload	0	0	0	0
Thermal	346	363.3	166	174.3
Power	22.45	23.57	13.45	14.1225
Communications and PDH systems	51	53.55	51	53.55
Attitude and orbit control	41	43.05	41	43.05
Propulsion	11	11.55	11	11.55
Total (individual)	**471.45**	**495.02**	**282.45**	**296.57**
Total w/ Margin		**594.03**		**355.89**

Power Budget (Maneuvers mode)

Subsystem	Polar Orbiter [W]	Polar Orbiter w/ Margin [W]	Equatorial Orbiter [W]	Equatorial Orbiter w/ Margin [W]
Payload	0	0	0	0
Thermal	346	363.3	166	174.3
Power	24.75	25.9	15.75	14.1225
Communications and PDH systems	51	53.55	51	53.55
Attitude and orbit control	41	43.05	41	43.05
Propulsion	57	58.1	57	59.85
Total (individual)	**519.75**	**543.9**	**282.45**	**347.29**
Total w/ Margin		**652.68**		**416.75**

Power Budget (Cruise mode)

Subsystem	Polar Orbiter [W]	Polar Orbiter w/ Margin [W]	Equatorial Orbiter [W]	Equatorial Orbiter w/ Margin [W]
Payload	0	0	0	0
Thermal	346	363.3	166	174.3
Power	19.85	20.84	10.85	11.39
Communications and PDH systems	51	53.55	51	53.55
Attitude and orbit control	0	0	0	0
Propulsion	0	0	0	0
Total (individual)	**416.85**	**437.69**	**227.85**	**239.24**
Total w/ Margin		**525.23**		**287.09**

Power Budget (Operational modes) – POLAR

SUBSYSTEMS		SAFE	SCIENCE 1	COMS	BURN IN	MANOUVERS POINTING	MANOUVERS	CRUISE		W consumption
Payload polar	UVS.1	0	1	0	0	0	0	0		7.5
	MAG.1	0	1	0	0	0	0	0		10
	PART.1	0	1	0	0	0	0	0		5.46
	PART.2	0	1	0	0	0	0	0		10
	PART.3	0	1	0	0	0	0	0		4
	REPT	0	1	0	0	0	0	0		6.2
	UVI.1	0	1	0	0	0	0	0		25
	RPWI.1	0	1	0	0	0	0	0		15
POW	heater	1	1	1	1	1	1	1		346
	PCDU	1	1	1	1	1	1	1		
prop	Prop main	0	0	0	1	0	1	0		35
	prop aux 1	0	0	0	1	0	1	0		11
	prop aux 2	0	1	1	1	1	1	0		11
Telecom	RF components	1	0	1	1	0	0	0		5
	antenna X	1	0	1	1	0	0	0		148
	antenna Ka	1	0	1	1	0	0	0		119
	medium gain antenna	1	1	1	1	0	0	0		10
	low gain antenna	1	1	1	1	0	0	0		0
ADCS	star tracker	1	1	1	1	1	1	0		7
	sun sensor	1	1	1	1	1	1	0		0
	IMUs	1	1	1	1	1	1	0		12
	reaction wheels	1	1	1	1	1	1	0		22
brain	micro pross	1	1	1	1	1	1	1		5
	storage	1	1	1	1	1	1	1		20
	on board computer	1	1	1	1	1	1	1		26
	TOTAL	720	542.16	731	777	449	495	397	0	
	PERCENTAGE OF SYSTEM	1	1	1	1	1	1	0.2		
	TOTAL [W]	720	542.16	731	777	449	495	79.4	0	
	TIME MODE PER ORBIT	100	31	96	2	10	0.5	50	0	

Power Budget (Operational modes) – EQUATORIAL

		SAFE	SCIENCE 1	COMS	BURN IN	MANOUVERS POINTING	MANOUVERS	CRUISE	W consumption
Payload equatorial	PART.1	0	1	0	0	0	0	0	7.6
	~~PART.2~~	0	0	0	0	0	0	0	7
	~~PART.3~~	0	0	0	0	0	0	0	18.5
	PART.4	0	1	0	0	0	0	0	5.46
	PART.5	0	1	0	0	0	0	0	10
	PART.6	0	1	0	0	0	0	0	4
	REPT	0	1	0	0	0	0	0	6.2
	MAG.1	0	1	0	0	0	0	0	10
	MAG.2	0	1	0	0	0	0	0	1
POW	heater	1	1	1	1	1	1	1	166
	PCDU	1	1	1	1	1	1	1	
prop	Prop main	0	0	0	1	0	1	0	35
	prop aux 1	0	0	0	1	0	1	0	11
	prop aux 2	0	1	1	1	1	1	0	11
Telecom	RF components	1	0	1	1	0	0	0	5
	antenna X	1	0	1	1	0	0	0	148
	antenna Ka	1	0	1	1	0	0	0	119
	medium gain antenna	1	1	1	1	0	0	0	10
	low gain antenna	1	1	1	1	0	0	0	0
ADCS	star tracker	1	1	1	1	1	1	0	7
	sun sensor	1	1	1	1	1	1	0	0
	IMUs	1	1	1	1	1	1	0	12
	reaction wheels	1	1	1	1	1	1	0	22
brain	micro pross	1	1	1	1	1	1	1	5
	storage	1	1	1	1	1	1	1	20
	on board computer	1	1	1	1	1	1	1	26
	TOTAL	540	323.26	551	597	269	315	217	0
	PERCENTAGE OF SYSTEM	1	1	1	1	1	1	1	
	TOTAL [W]	540	323.26	551	597	269	315	217	0
	TIME MODE PER ORBIT	100	842	144	1	2	2	0.5	