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Past, Present, and Future NASA missions to Jupiter

By Insoo Jun

Jet Propulsion Laboratory, California Institute of Technology

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At the 2016 RADECS, Bremen, Germany

Topics

Pioneer

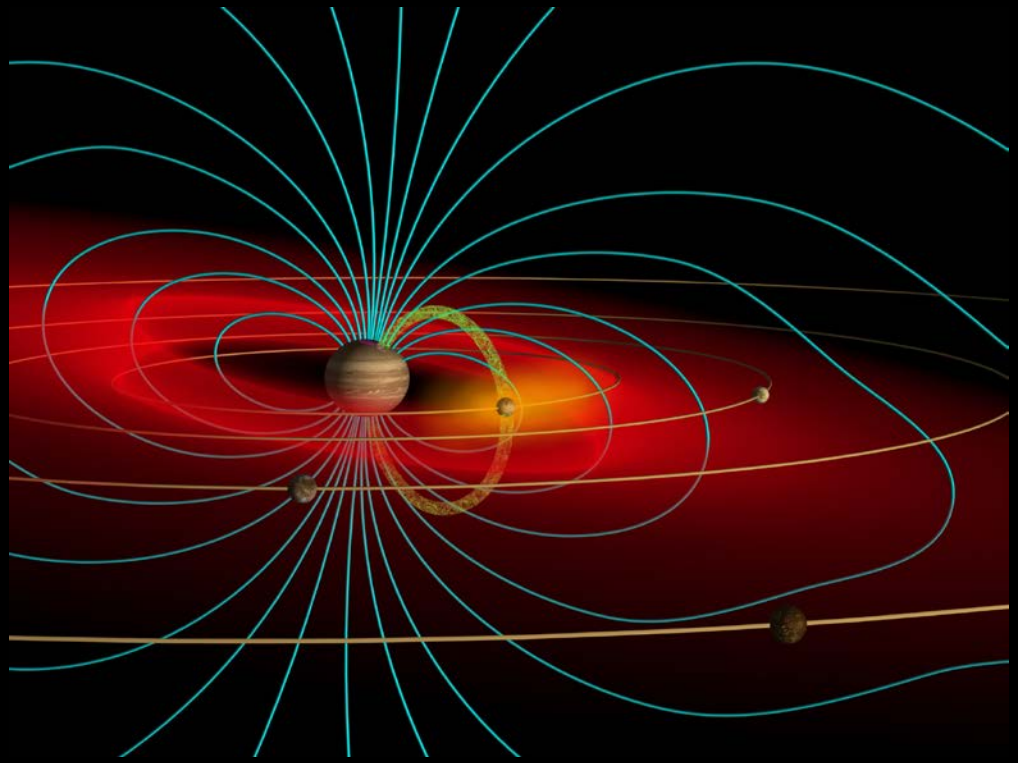
Voyager

Galileo

Juno

Europa Clipper

Jupiter



Why Jupiter?

Mini solar system

The largest planet in the solar system

Influence all other objects in the solar system

How was it formed and how does it influence could provide important clues on the origin of the solar system and the formation of planets (including our own Earth)

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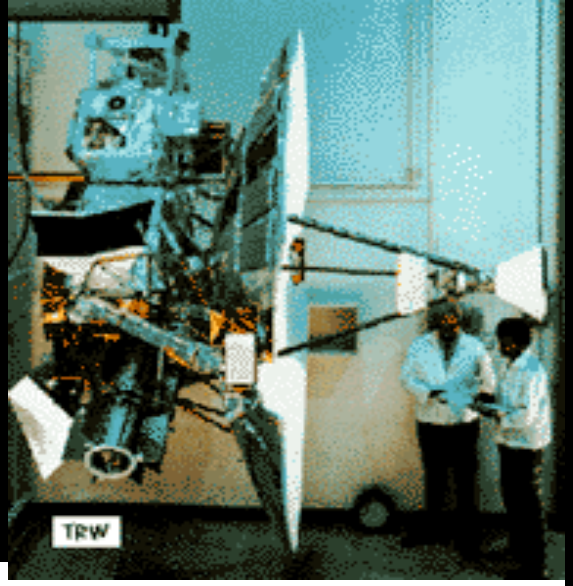
Pioneer



Pioneer 10 and 11 are the first spacecraft to visit Jupiter.

Pioneer 10

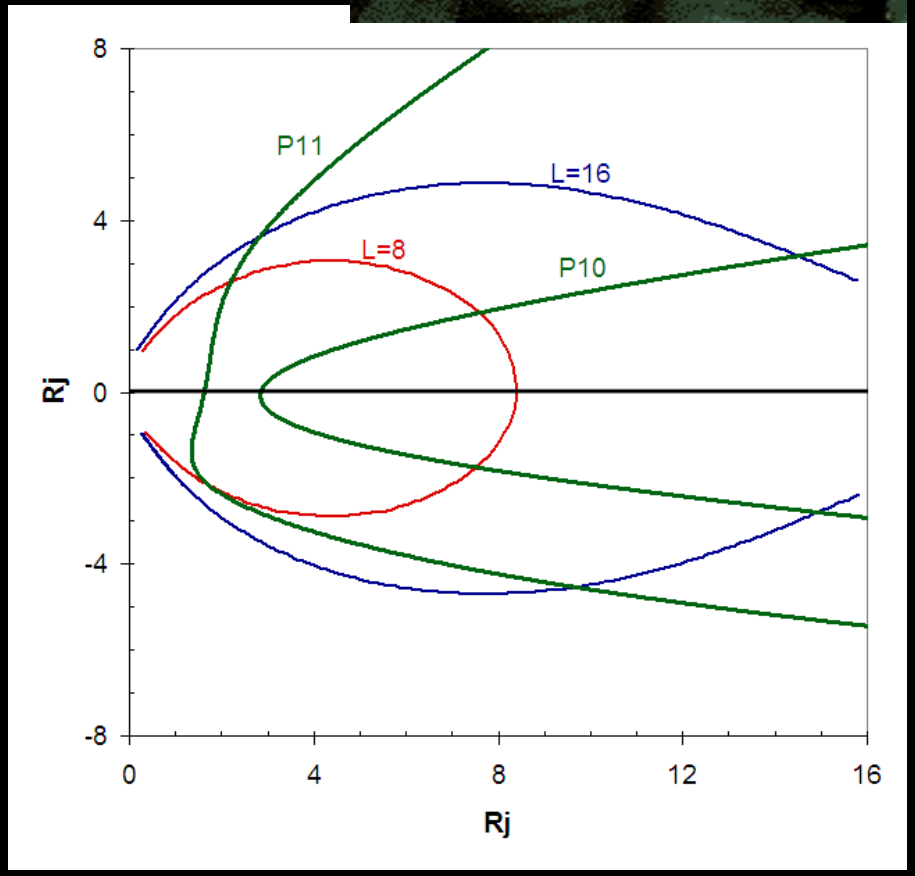
- Launch – March 1972
- Jupiter Flyby – December 1973

Pioneer 11

- Launch – April 1973
- Jupiter Flyby – December 1974

Science Payload (Radiation Related)

- Plasma analyzer
- Charged particle detector
- Ionizing detector



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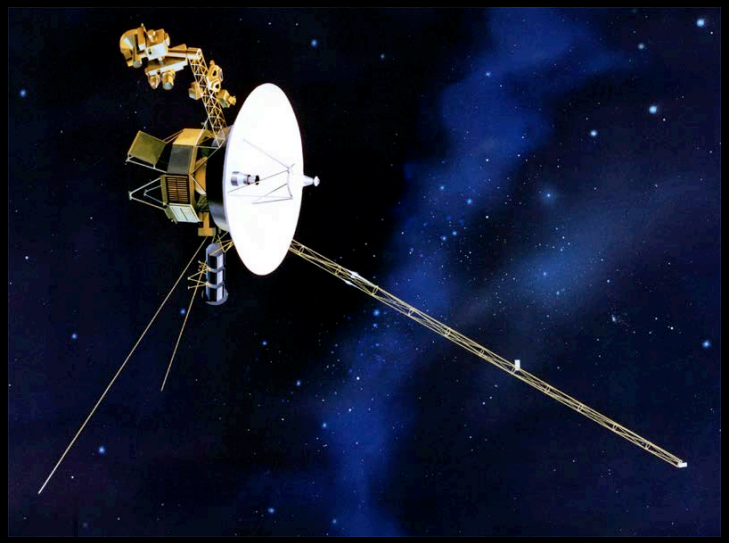
Voyager



Voyager 2

- Launch – Aug 20, 1977
- Closest Approach – July 9, 1979

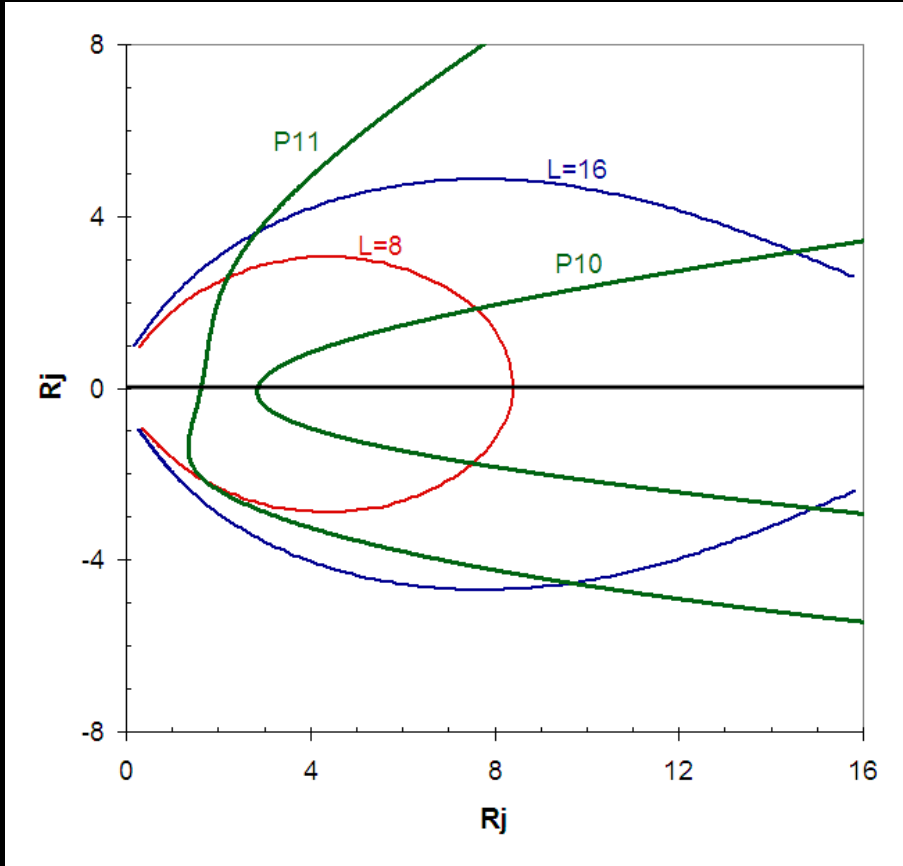
Voyager 1

- Launch – Sep 5, 1977
- Closest Approach – Mar 5, 1979

Science Payload (Radiation related)

- Low energy charged particle investigation (LECP)
- Plasma investigation (PLS)
- Cosmic Ray ray investigation (CRS)

Observed 42 power on reset attributed to internal charging – Wousik Kim's talk



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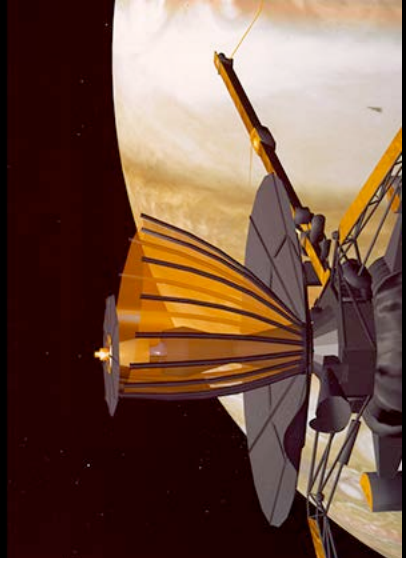
Galileo



Launch – Oct 1989

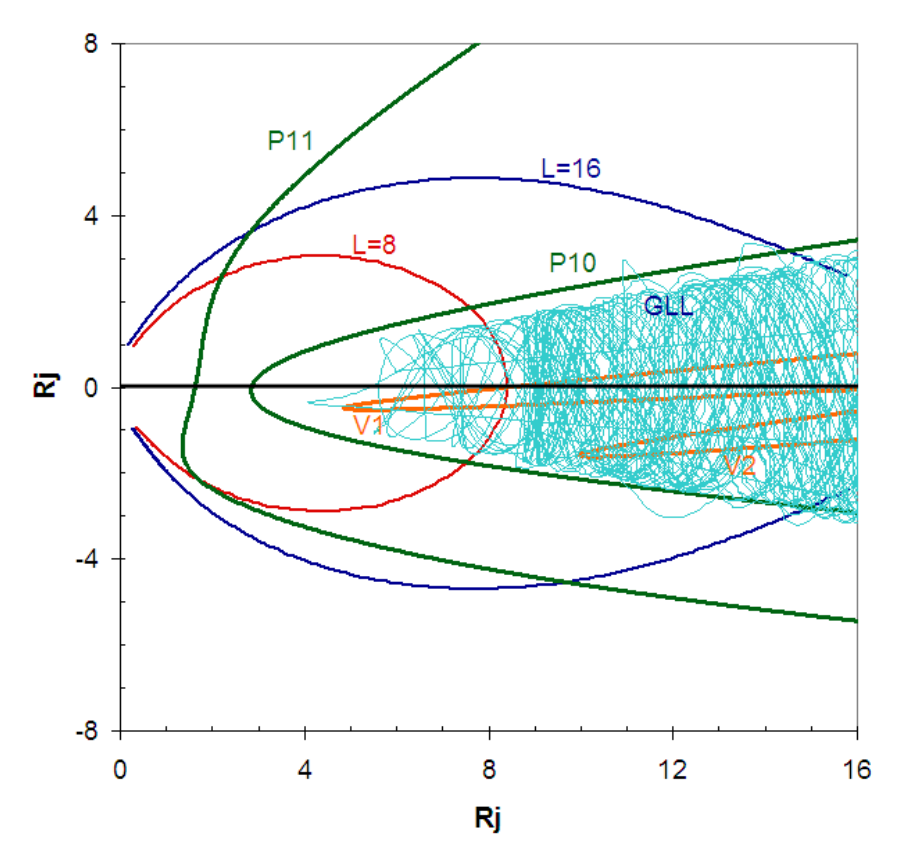
Arrival – Dec 1995

Termination – Sep 2003

35 orbits in 8 years

Science Payload (Radiation related)

- Energetic particle detector
- Heavy ion counter
- Plasma detector



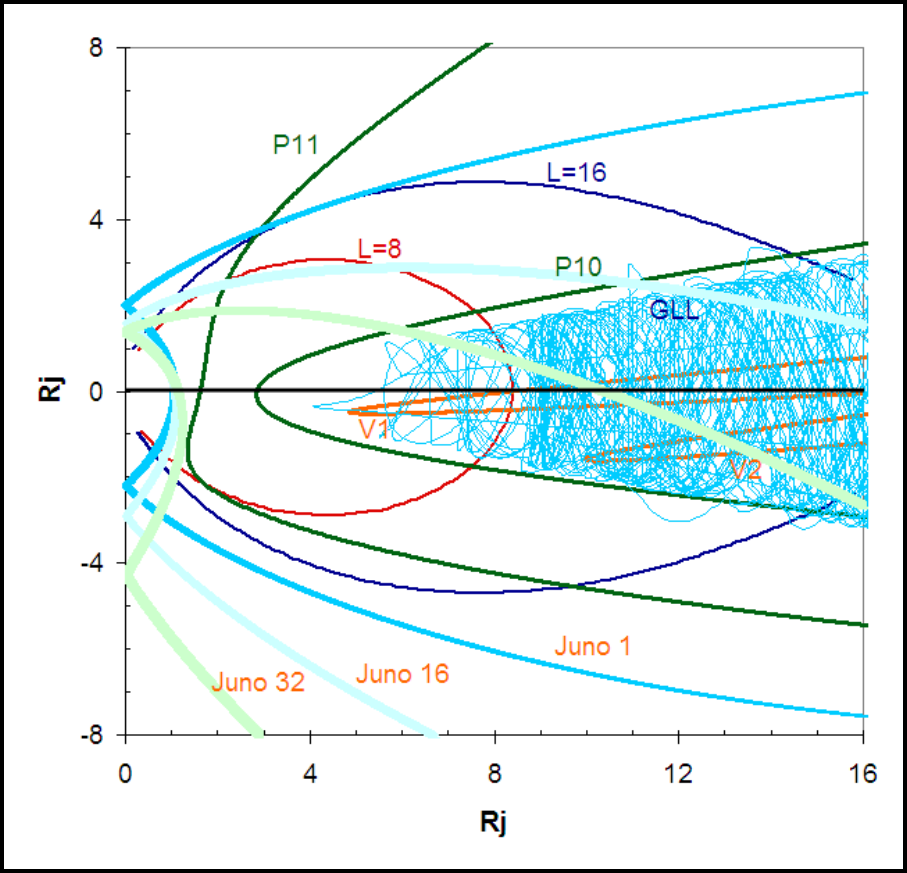
Juno

Jupiter polar orbiter

- 33 polar orbits
- Perijove ~5000 km
- 11 day period
- Spinner
- Solar-powered

Launch August 2011
Arrival (JOI) July 2016

No high energy particle detector



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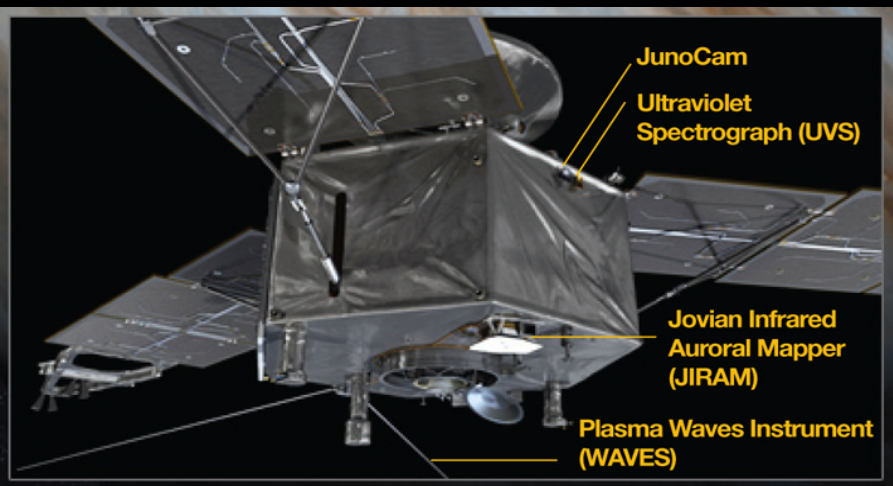
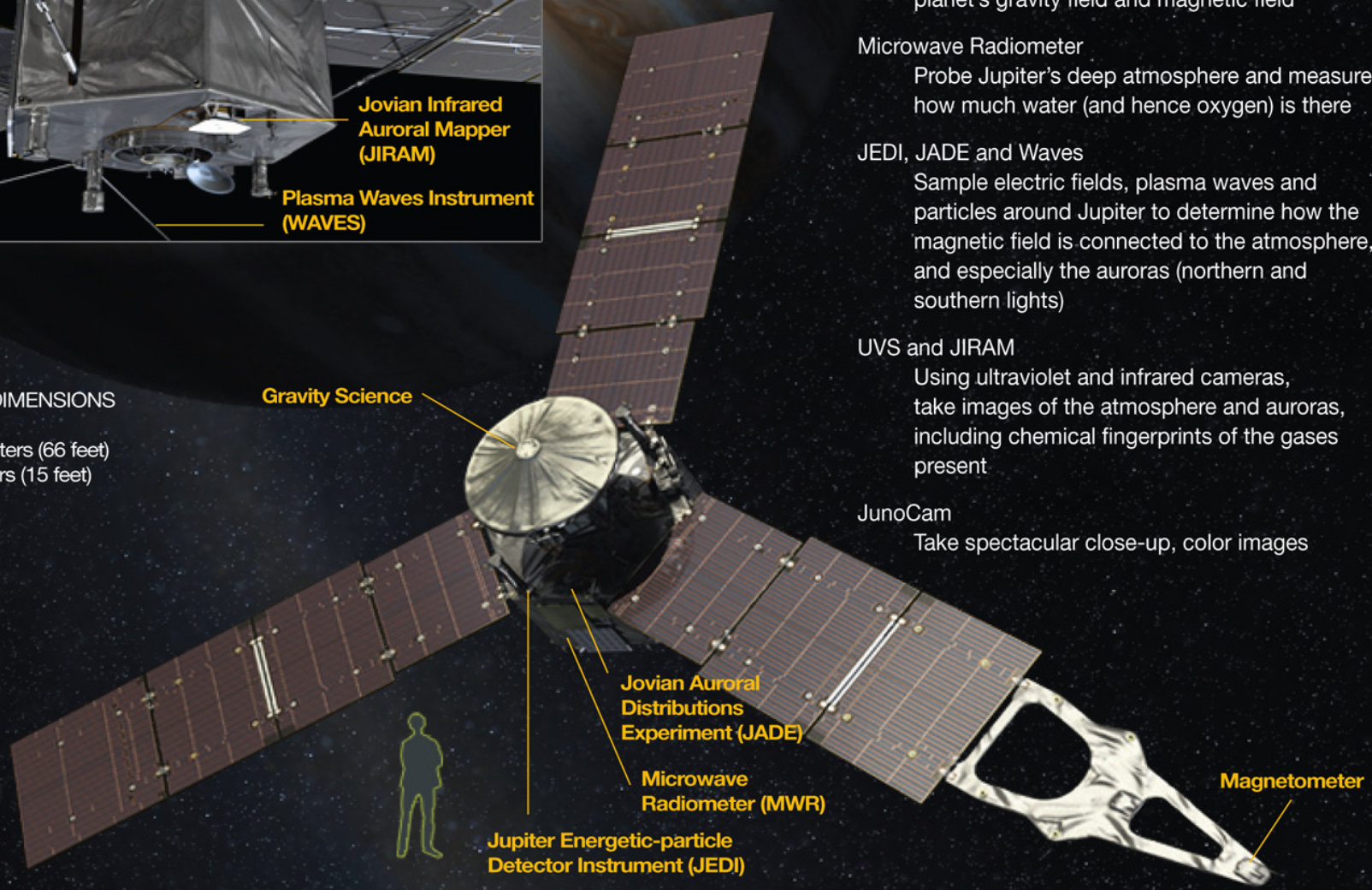
Spacecraft & Payload



SPACECRAFT DIMENSIONS

Diameter: 20 meters (66 feet)
Height: 4.5 meters (15 feet)



Juno's Science Instruments

Gravity Science and Magnetometers
- Study Jupiter's deep structure by mapping the planet's gravity field and magnetic field

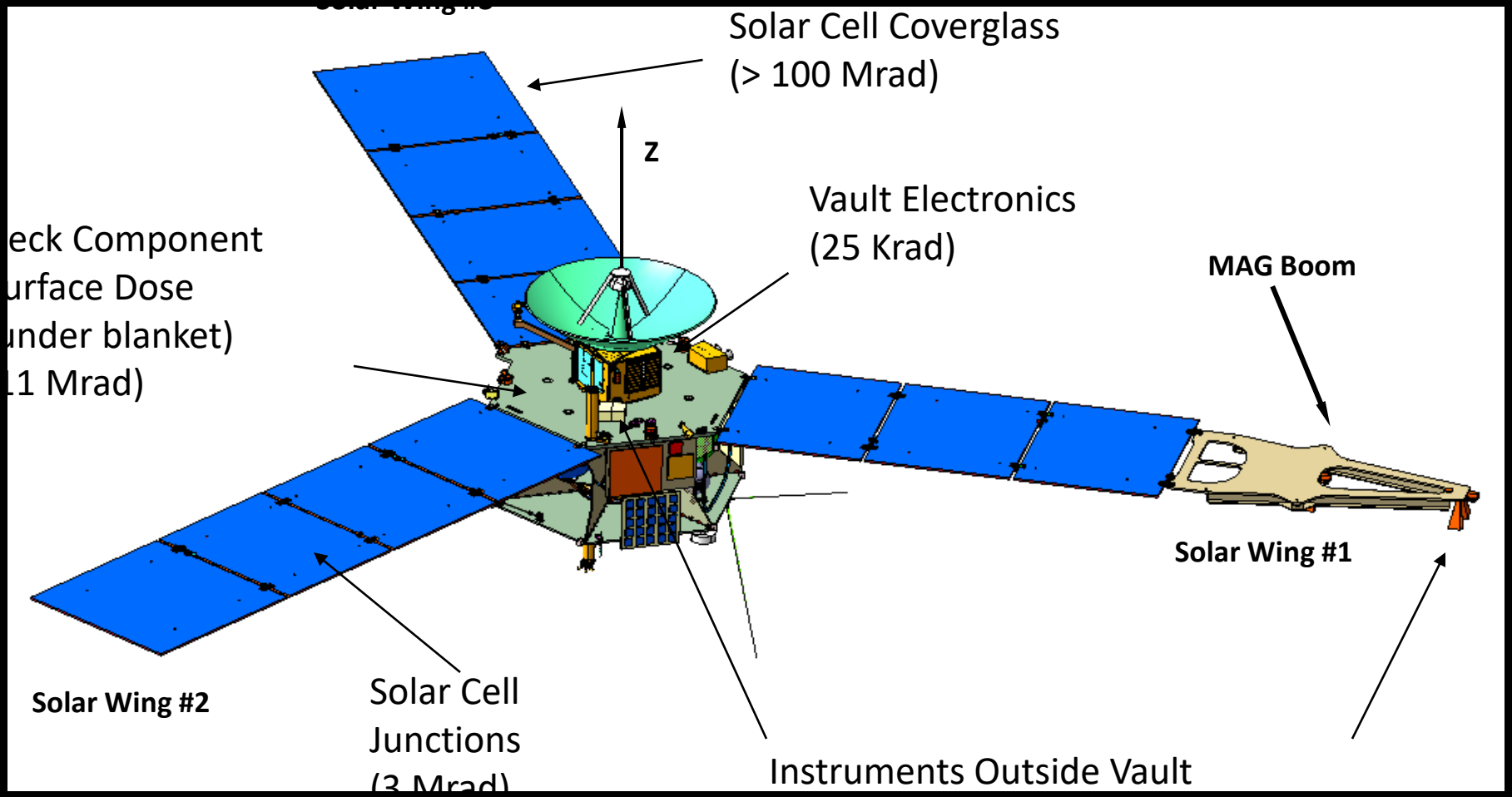
Microwave Radiometer
- Probe Jupiter's deep atmosphere and measure how much water (and hence oxygen) is there

JEDI, JADE and Waves
- Sample electric fields, plasma waves and particles around Jupiter to determine how the magnetic field is connected to the atmosphere, and especially the auroras (northern and southern lights)

UVS and JIRAM
- Using ultraviolet and infrared cameras, take images of the atmosphere and auroras, including chemical fingerprints of the gases present

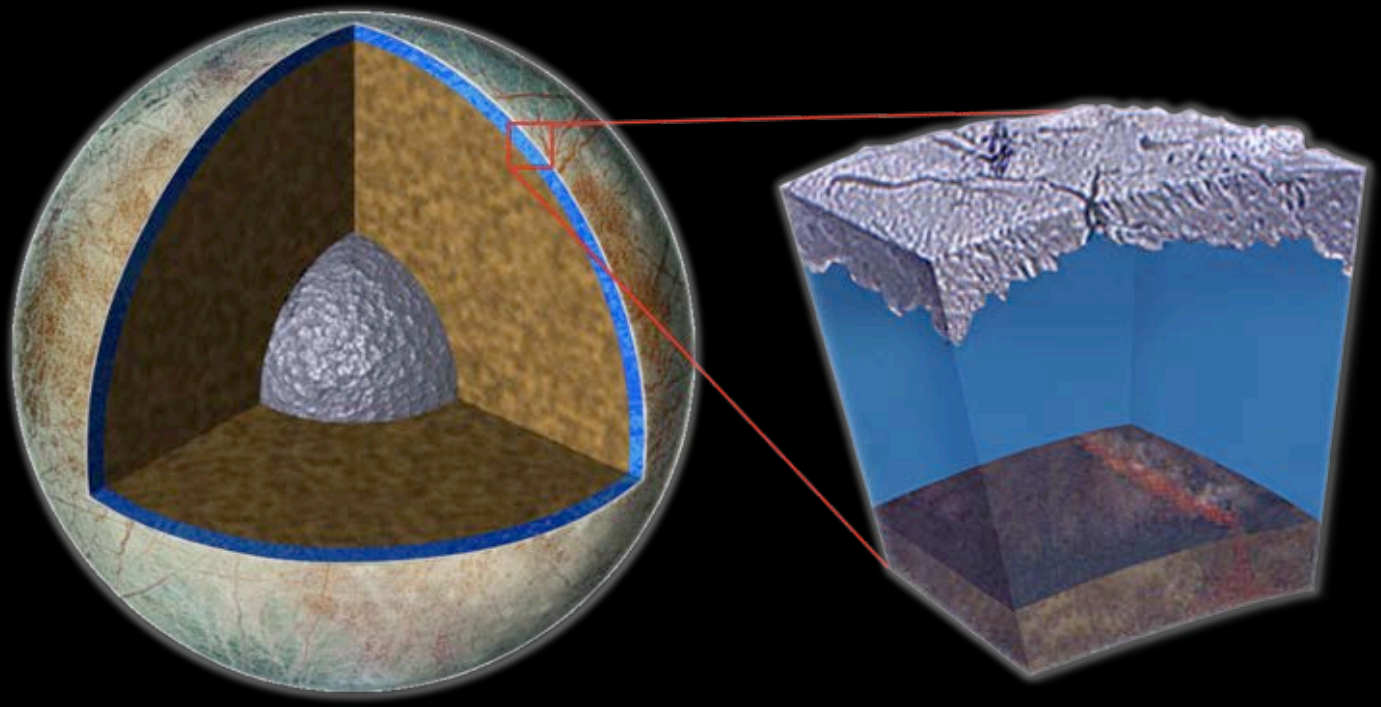
JunoCam
- Take spectacular close-up, color images

End of Mission Radiation TID Levels



Planned Jupiter Europa Mission

The Ocean That Beckons

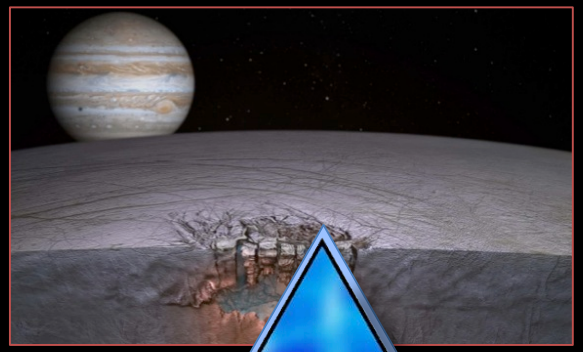


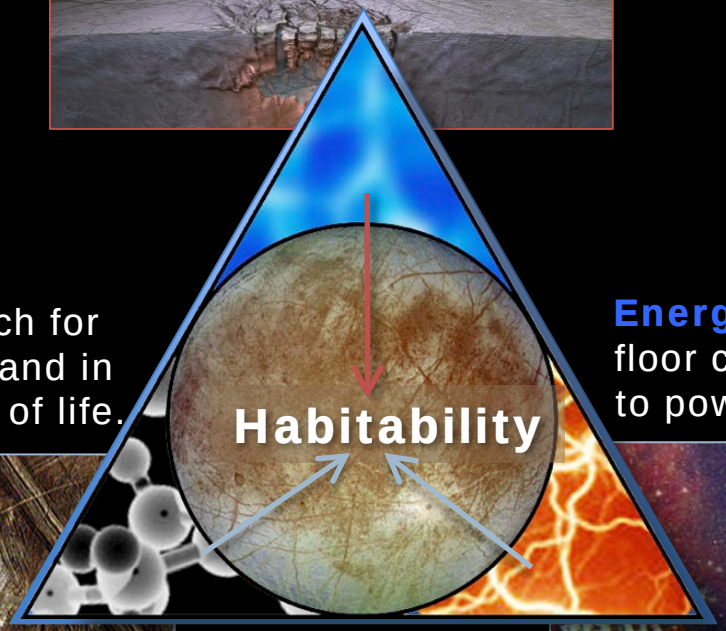
Europa, with its probable vast subsurface ocean sandwiched between a potentially active silicate interior and a highly dynamic surface ice shell, offers one of the most promising extraterrestrial habitable environments, and a plausible model for habitable environments beyond our solar system

The Planetary Decadal Survey, 2011

Europa: Ingredients for Life?

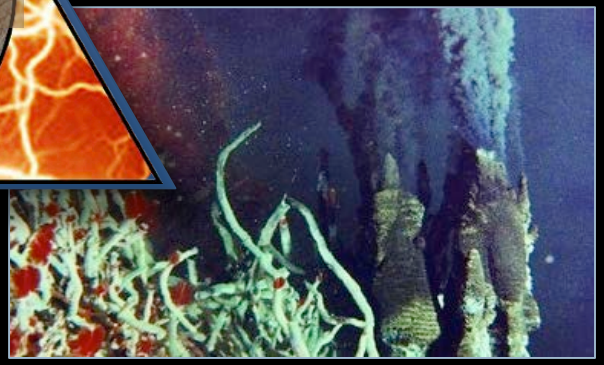
Water: A global ocean and lakes could be hidden by Europa's icy shell





Chemistry: We can search for evidence, on the surface and in plumes, for the elements of life.

Energy: Surface and ocean floor chemicals could combine to power life.



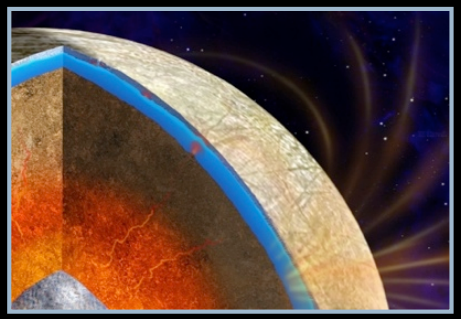
Europa Mission Science Goal & Objectives

Goal: **Explore Europa to investigate its habitability**

Objectives:

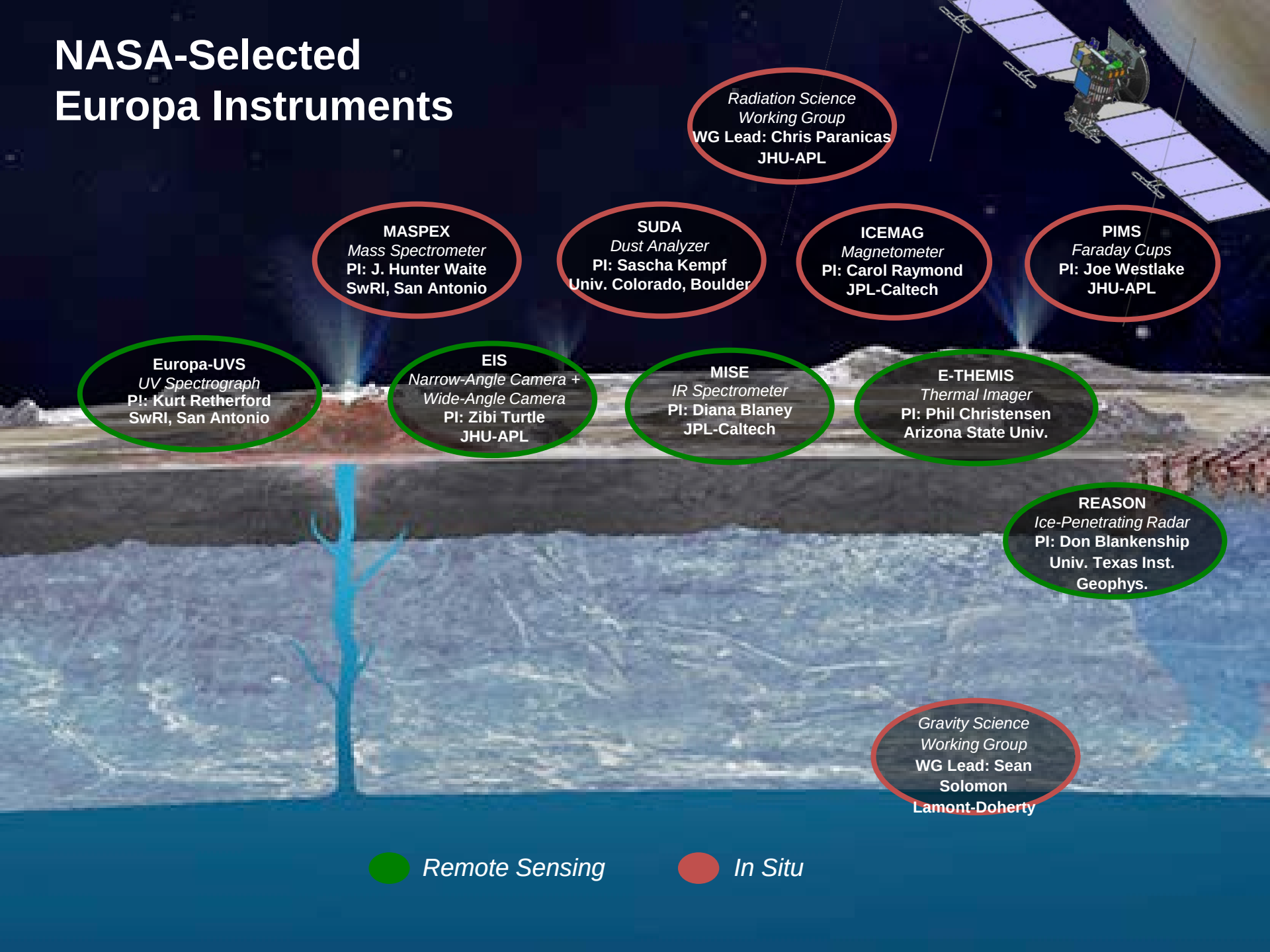
- **Ice Shell & Ocean:** Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange
- **Composition:** Understand the habitability of Europa's ocean through composition and chemistry
- **Geology:** Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities*

**Note: Science Definition Team's "Reconnaissance" goal has been folded into the Geology objective*

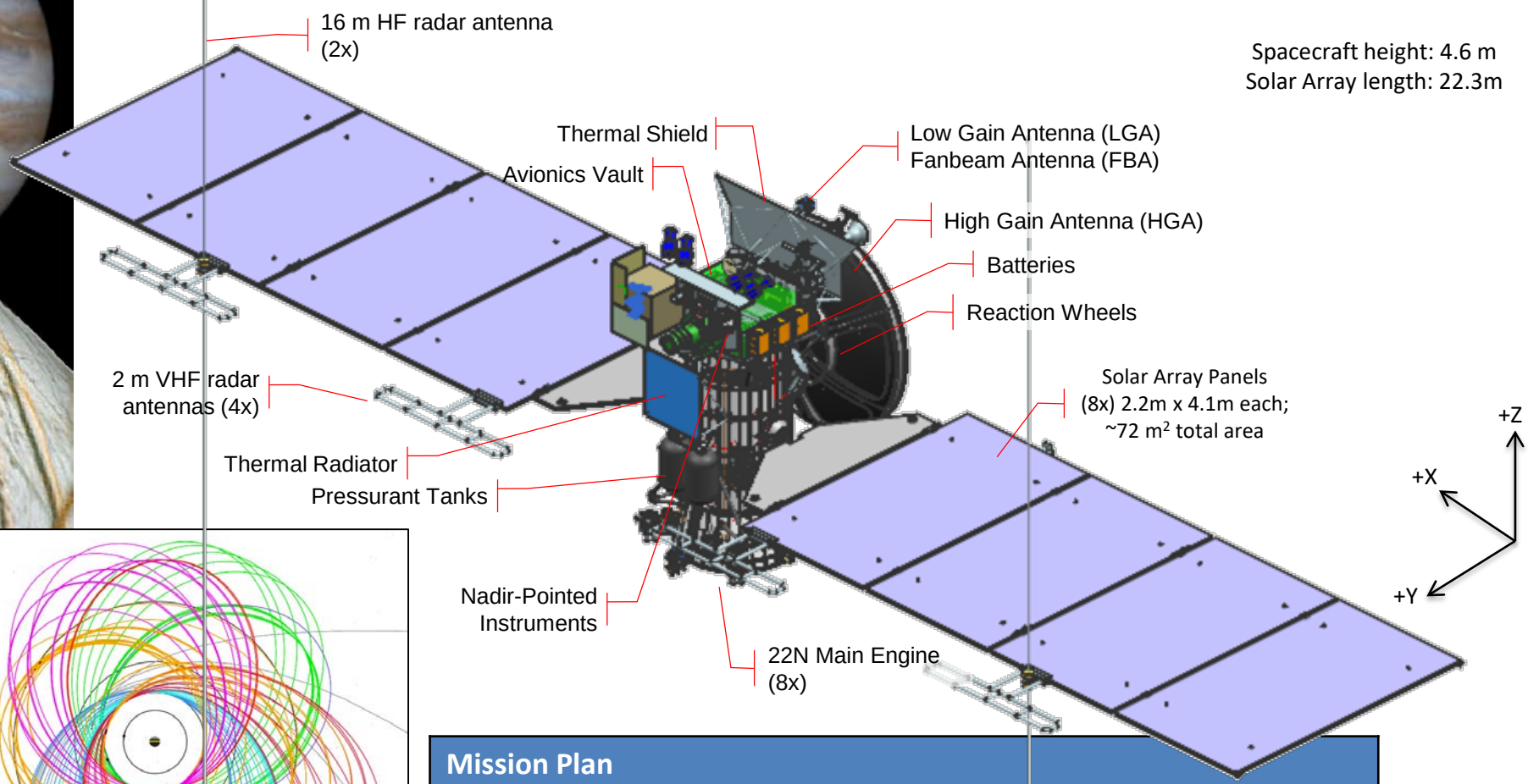


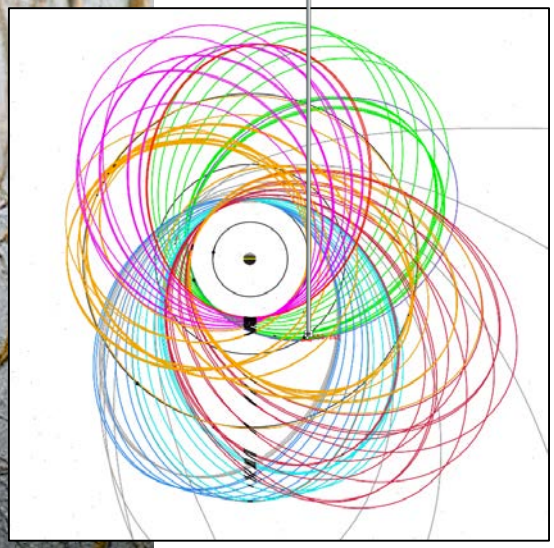
Pre-Decisional Information – For Planning and Discussion Purposed Only

NASA-Selected Europa Instruments



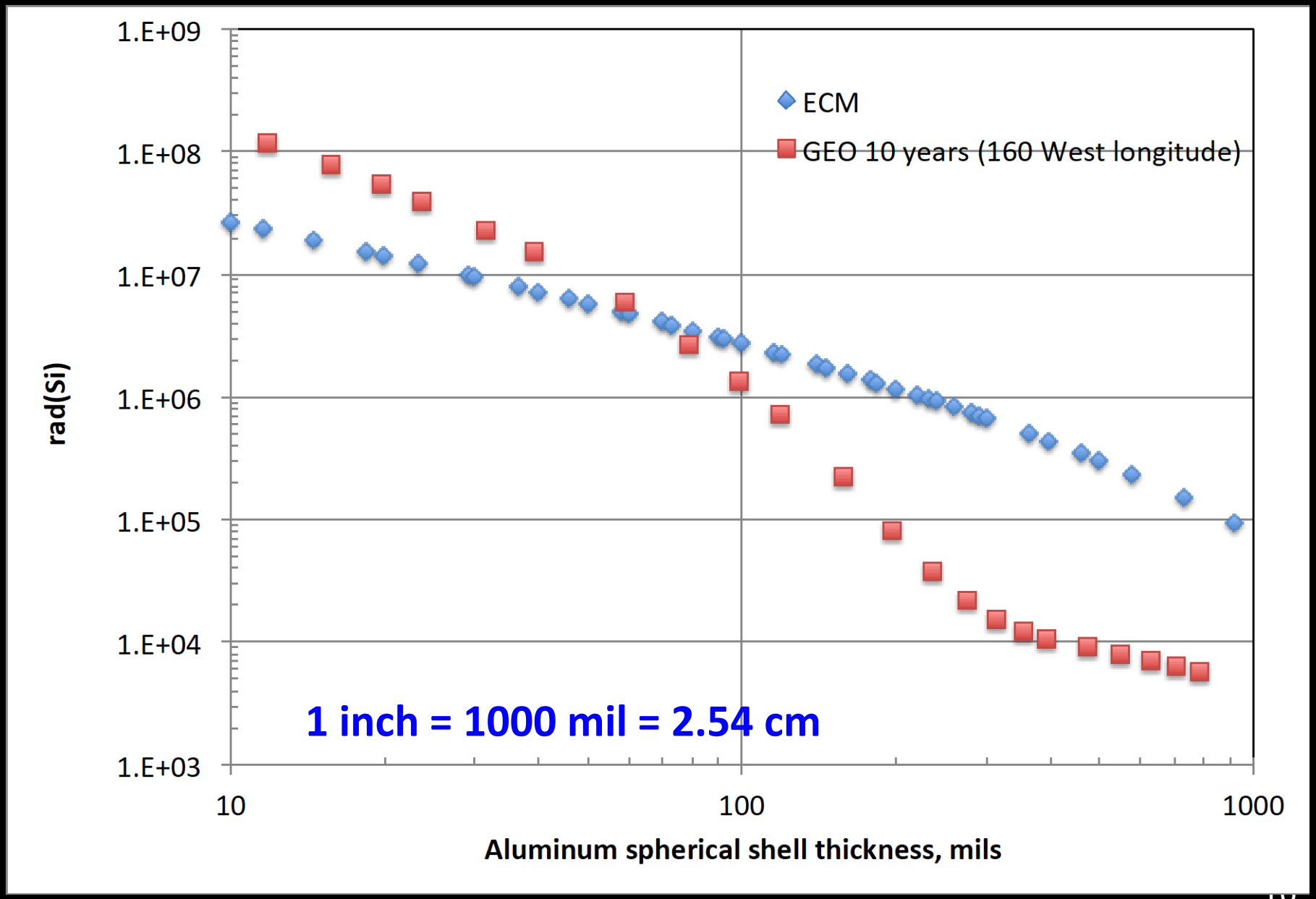
Europa Mission Concept Overview





Mission Plan	
Earliest potential launch date	6 June 2022
Earliest Jupiter Arrival	5 Mar 2025 (if SLS launch)
Science Tour	~42 Europa Flybys in prime mission
Primary Mission End	6 Dec 2028 (Ganymede Impact)

ECM versus GEO



Key Differences between EC and Juno

Because of the nature of the differing science objectives between Europa Clipper and Juno, there are very different environments and concerns

Environment /Concern	Europa Clipper	Juno	Comments
TID (100 mils Si)	2.7 MRad	387 Krad	
Radiation Design Factor	RDF = 2	RDF = 2 RDF = 3 (Spot Shield)	Currently the same for both projects
TID (Vault)	300 KRads	50 KRads	EC requires rad-hard EEE parts
Vault Thickness	380 mils (Al) Estimated	~900 mils Equivalent Al	

Notional Radiation Environment for ECM

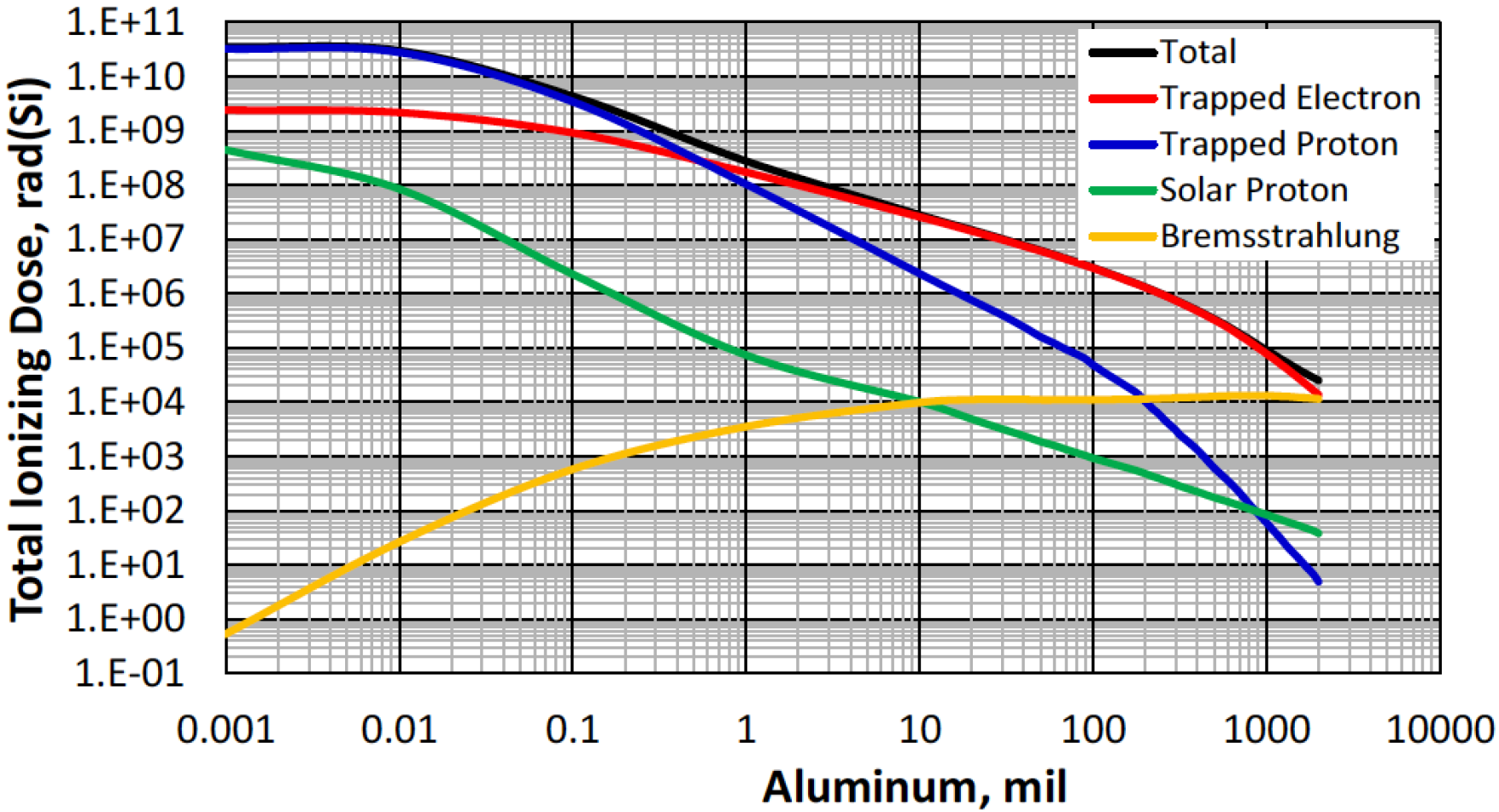


Figure 4.9-3a. Aluminum Spherical Shell TID Dose-Depth Curve for the Design Reference Mission.

1 inch = 1000 mil = 2.54 cm

ECM Radiation Environment

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Environment along the Europa orbit (13-F7)

Magnetic field at spacecraft

>1 MeV electron flux

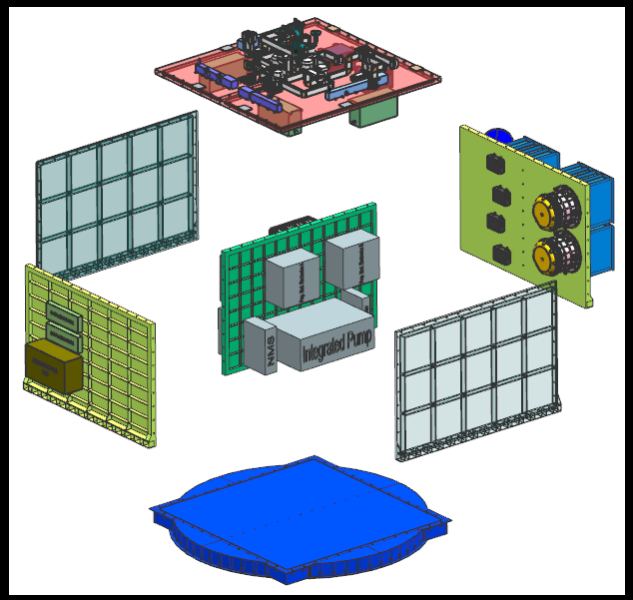
Total dose

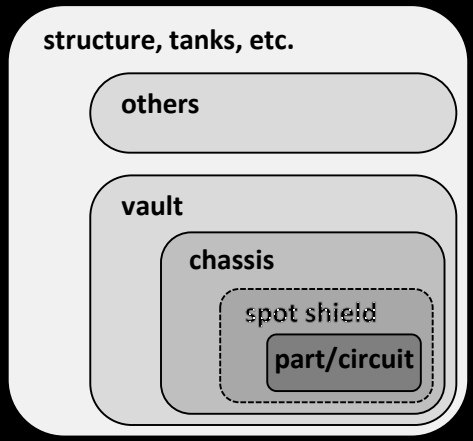
Radiation Effects Concern Level

Effect	Concerns
Total Ionizing Dose (TID)	Very high compared to other NASA missions. Dominated by high energy electrons. Would require special attention for ECM.
Dose rate	Very high, especially during Europa fly-bys. Would require special attention for ECM. May reduce test time for ELDRS. Issue for sensitive instruments
Displacement Damage Dose (DDD)	10 to 100 times higher than other NASA missions. Could be important for optoelectronic devices at Jupiter.
Single Event Effects (SEE)	Typical level as other NASA missions. Trapped heavy ions at Jupiter are not significant issue for most electronics.
Charging	Internal charging is a major issue due to high electron flux. Would require special attention for ECM.
Transient or Secondary radiation	Important design consideration for sensors and detectors. Must include secondary particle due to high energy electron interactions with materials.

Radiation Management

- Bound total dose at 3 Mrad @100 mil Al
- Radiation Design Factor of 2
- Goal: 300 krad electronic parts
- Testing, testing, testing…
- Preferred parts & materials database
- Utilize radiation vault
  - 150 krad environment inside of vault
  - Benefits of packing and self shielding
  - Micro Meteoroid and Orbit Debris protection
  - IESD protection
- Juno IESD approach
  - Protection circuitry
  - Cable overwrap, minimize floating metal
- Accommodation Work
  - In/outside the vault decision
  - IESD approach
  - Vault radiation transport analysis





Radiation Vault: Shielding Sum is Greater than the Parts

Thank You!
Questions?