An Overview of the Jupiter Icy Moons Orbiter (JIMO)

Mission, Environments, and Materials Challenges

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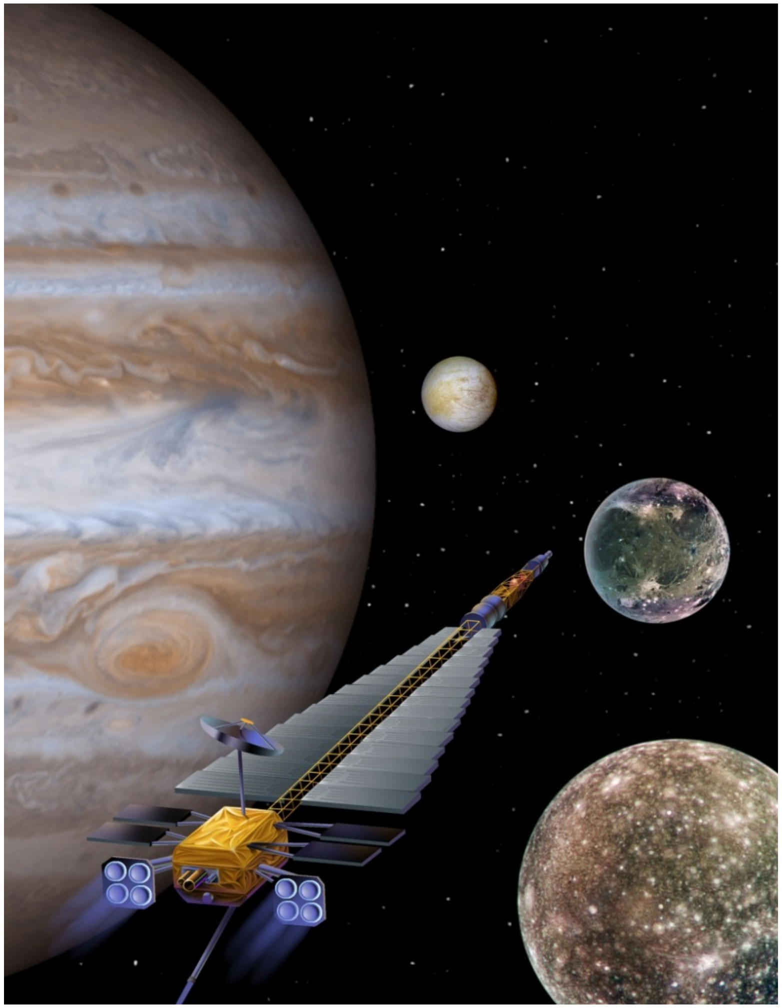
Outline

- Project Overview
- Environments
- Materials Challenges
- Summary

Project Overview

- Congress authorized NASA's Prometheus Project in February 2003, with the first Prometheus mission slated to explore the icy moons of Jupiter with the following main objectives:
  - Develop a nuclear reactor that would provide unprecedented levels of power and show that it could be processed safely and operated reliably in space for long-duration.
  - Explore the three icy moons of Jupiter – Callisto, Ganymede, and Europa – and return science data that would meet the scientific goals as set forth in the Decadal Survey Report of the National Academy of Sciences.



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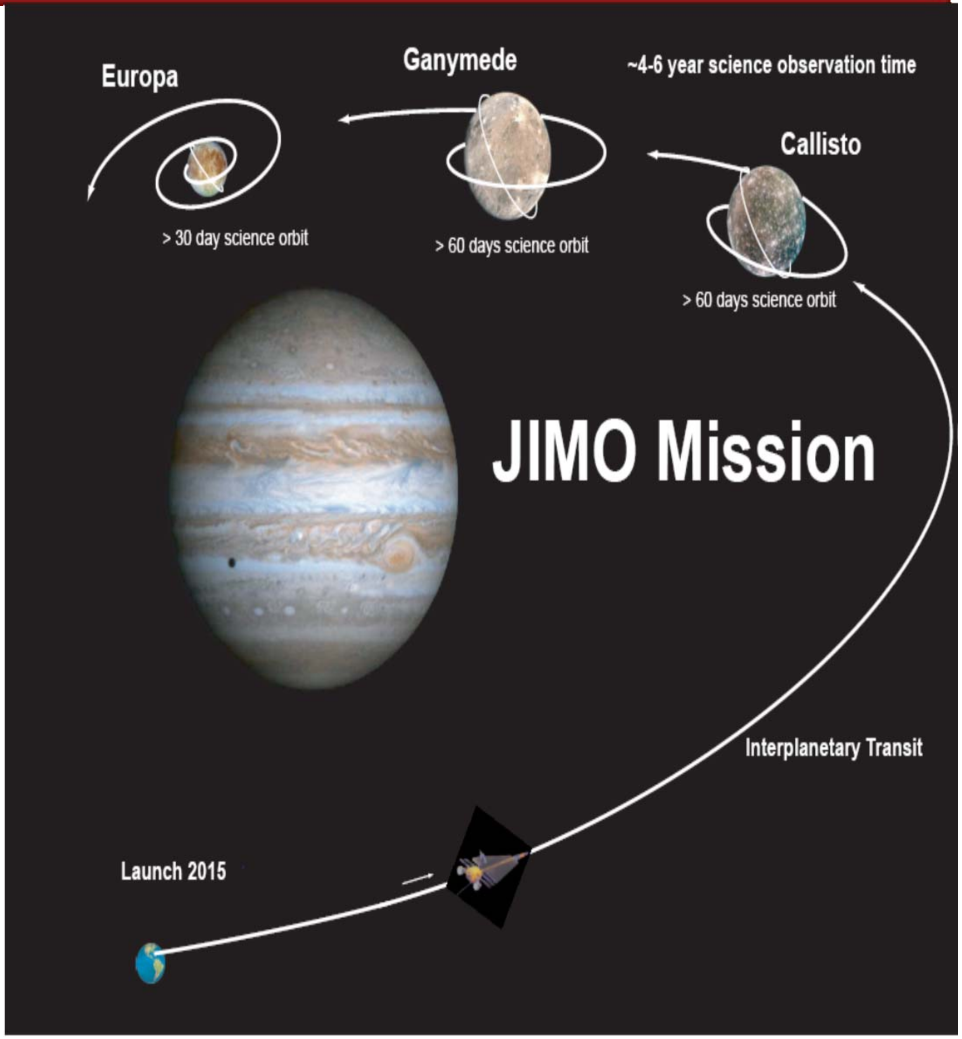
Mission Overview

- The JIMO launch campaign was to open in May 2015 and required 3 separate launches.
- The Earth orbit operations was planned for approximately 5 months and the Interplanetary transfer was planned for approximately 5 years and 4 months.
- The JIMO Mission shall maintain a science orbit around Callisto for at least 60 days, Ganymede for at least 60 days, and Europa for at least 30 days.
- The end of mission was planned with the spaceship in science orbit at Europa.



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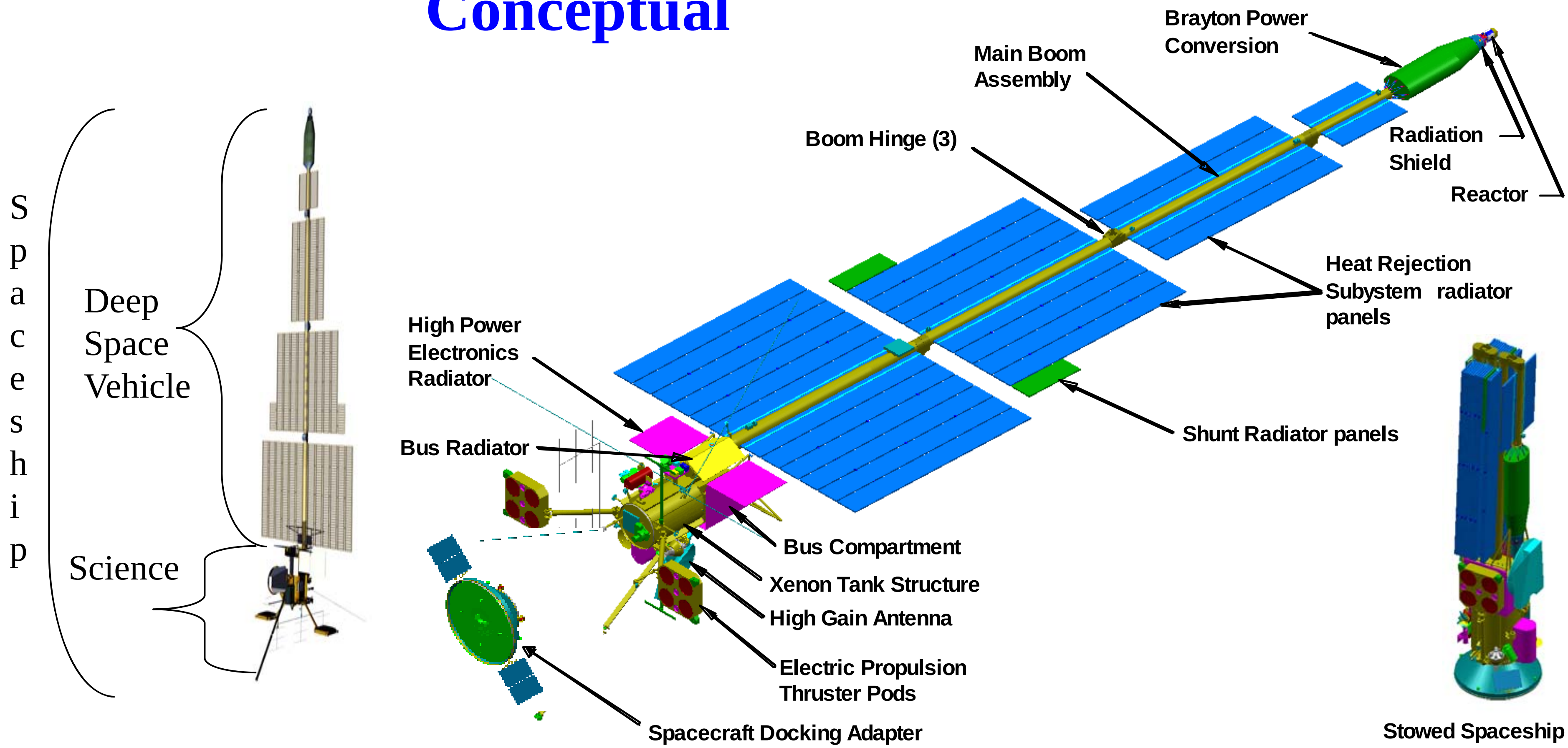
Spaceship Overview

Conceptual

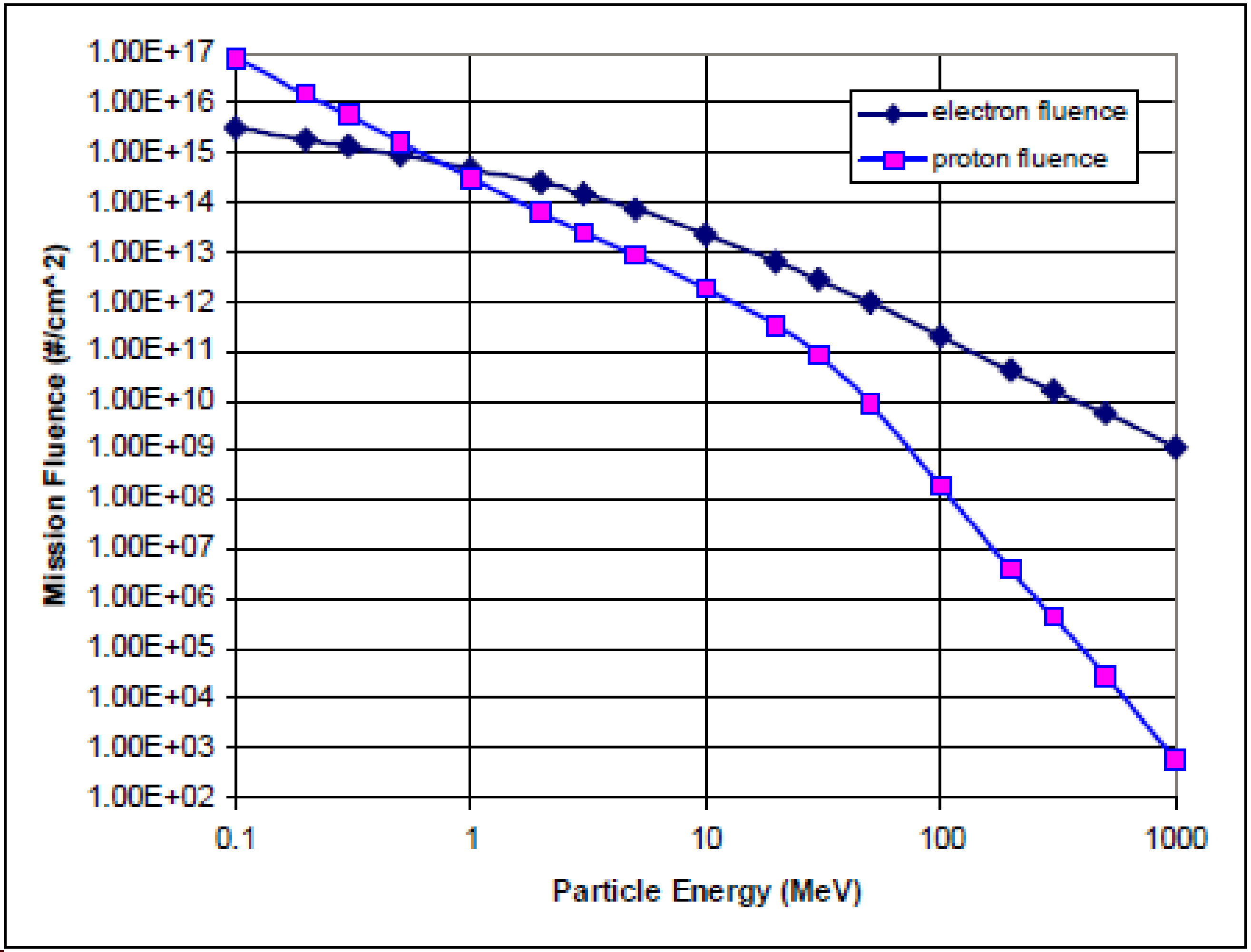


Mission Environments

- Radiation
  - Natural Space
  - Planetary
  - Plasma
  - Onboard radiation
- Meteoroids and Orbital Debris
  - Sporadic Meteoroids
  - Jovian Meteoroids
  - Orbital Debris in Earth Orbit
- Atomic Oxygen
- Contamination
- UV
- Thermal Vacuum
- Thermal Atmosphere
- Thermal Cycle
- Electromagnetic Compatibility (EMC)

Mission Fluence as of PMSR

- Mission Fluence includes
  - Spiral out from Earth
  - Inter planetary transit
  - Science Orbits at Callisto, Ganymede, and Europa
- Transport codes not verified for these energies
- Testing
  - Accelerated testing
  - Charged particle vs gamma
  - Air vs vacuum



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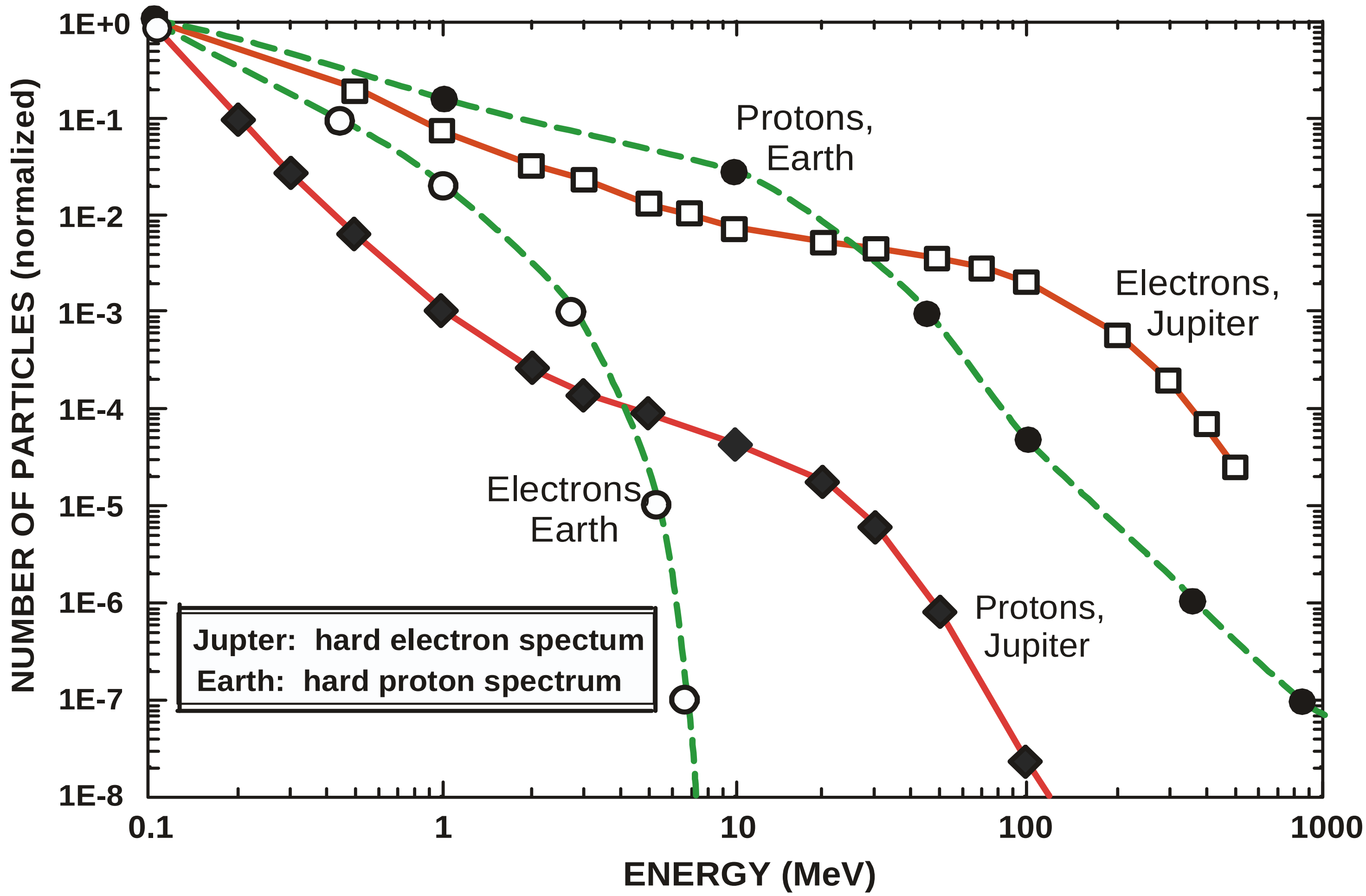
Trapped Belt Energy Distributions

Jupiter and Earth



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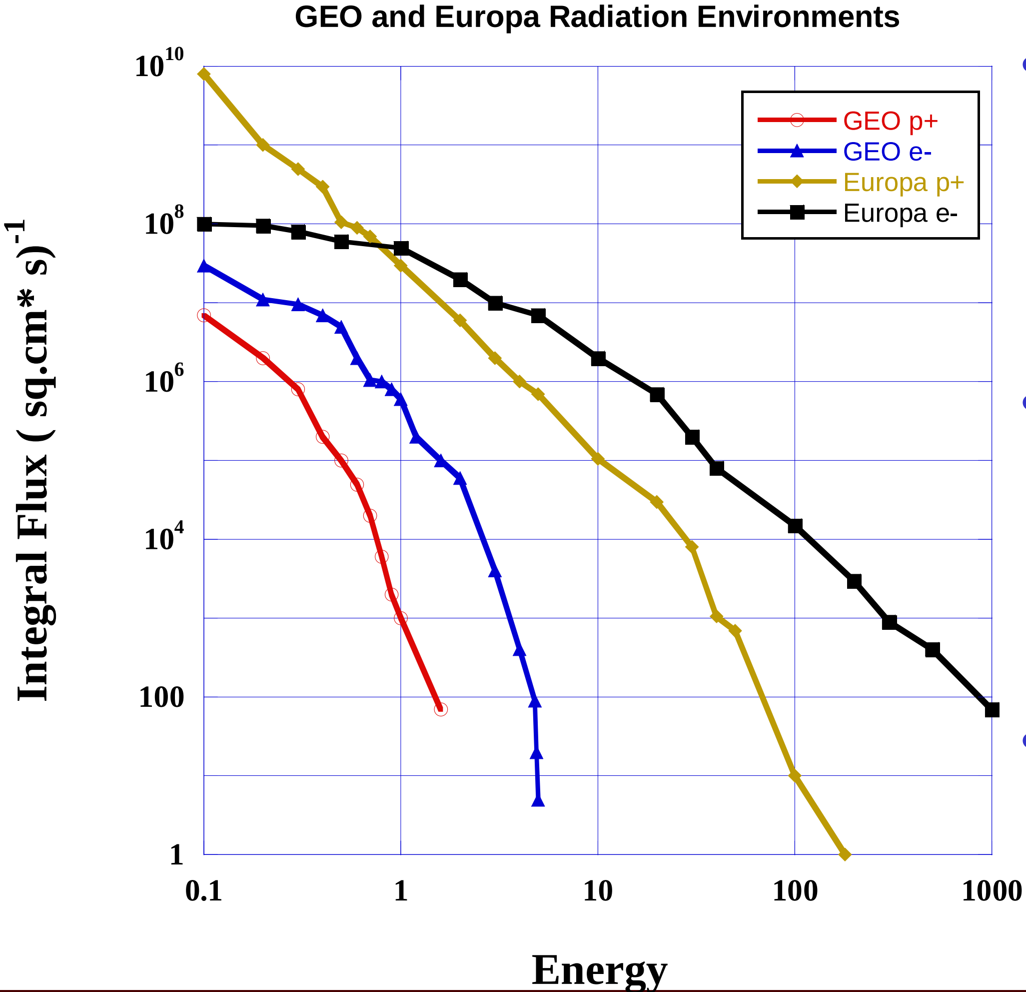
Radiation Environment Comparison



- **Europa energies higher by approx. 2 orders of magnitude.**
- **Electron Integral flux higher by approx. 1 order of magnitude**
- **Proton Integral Flux higher by approx 3 orders of magnitude**

The Jovian Meteoroid Environment Overview

- **Not much known – very few spacecraft measurements.**
- **Need lots of study, especially in identifying sources of meteoroids; possible new ones are Io, Kuiper Belt Objects, and the Jupiter Trojan asteroids.**
- **Electrodynamic forces may be important.**
- **The JPL Divine meteoroid model (METEM) was used to calculate meteoroid fluxes for all phases of the mission.**
- **The following calculations are based on METEM results for 5.2 AU.**
- **"Distance from Jupiter" is the distance from the center of Jupiter, not the cloud tops.**
- **Correction for Jupiter shielding (same expression as for Earth save that r_e is replaced with the Jovian equatorial radius of 71492 km).**

The Jovian Meteoroid Environment Overview con't

- **Grün model was scaled to (distance from Sun)$^{-1.3}$ and used to provide "sanity check".**
- **Meteoroid environment was assumed isotropic (meteoroids come from all directions)**
- **Spacecraft was assumed to be traveling in the ecliptic plane.**
- **Fluxes were provided for a "randomly tumbling" spacecraft *(Note: JIMO will <u>not</u> be "randomly tumbling")* and are for circular orbits from 1.0 to 5.2 AU, in 0.5 AU steps.**
- **Fluences (flux integrated along trajectory) were not provided due to lack of a definitive trajectory.**
- ***<u>These are first order estimates only – refinements will be required, especially in Jovian space, to assure survivable design.</u>***
- **A first-order attempt at gravitational focusing is also performed.**
- **LOTS of work needs to be done in this region.**

Near-Earth Meteoroid Flux

- Meteoroid flux at Earth = Interplanetary Flux at 1 AU X Gravitational Focusing Factor X Earth Shielding Factor.
- Gravitational focusing factor given by

$$G = 1 + \frac{r_e}{r}$$

  - where r_e is radius of the Earth at the top of the atmosphere (6478 km) and r is the distance from the geocenter.

- Earth shielding factor given by

$$\eta = \sin^{-1}\left(\frac{r_e}{r}\right)$$

$$S = \frac{1 + \cos\eta}{2}$$

- Average meteoroid speed ~ 20 km s^{-1}.
- Average meteoroid density ~ 1 g cm^{-3} (ice).

Gravitational Focusing at Jupiter

- **Based on expression derived by Don Kessler:**

$$G = 1 + \left(\frac{R v_{esc}^2 r_p}{v_{earth}^2 r} \right)$$

- **where R is the heliocentric distance of the planet, v_{esc} is the planet's escape velocity at the surface, r_p is the planet's radius, v_{earth} is the escape velocity from the surface of the Earth, and r is the distance from the center of the planet.**
- **In the case of Jupiter, this results in**

$$G = 1 + 147.2 \left(\frac{r_j}{r} \right)$$

- **A more complicated numerical procedure is needed to handle focusing by Jupiter and its satellites.**

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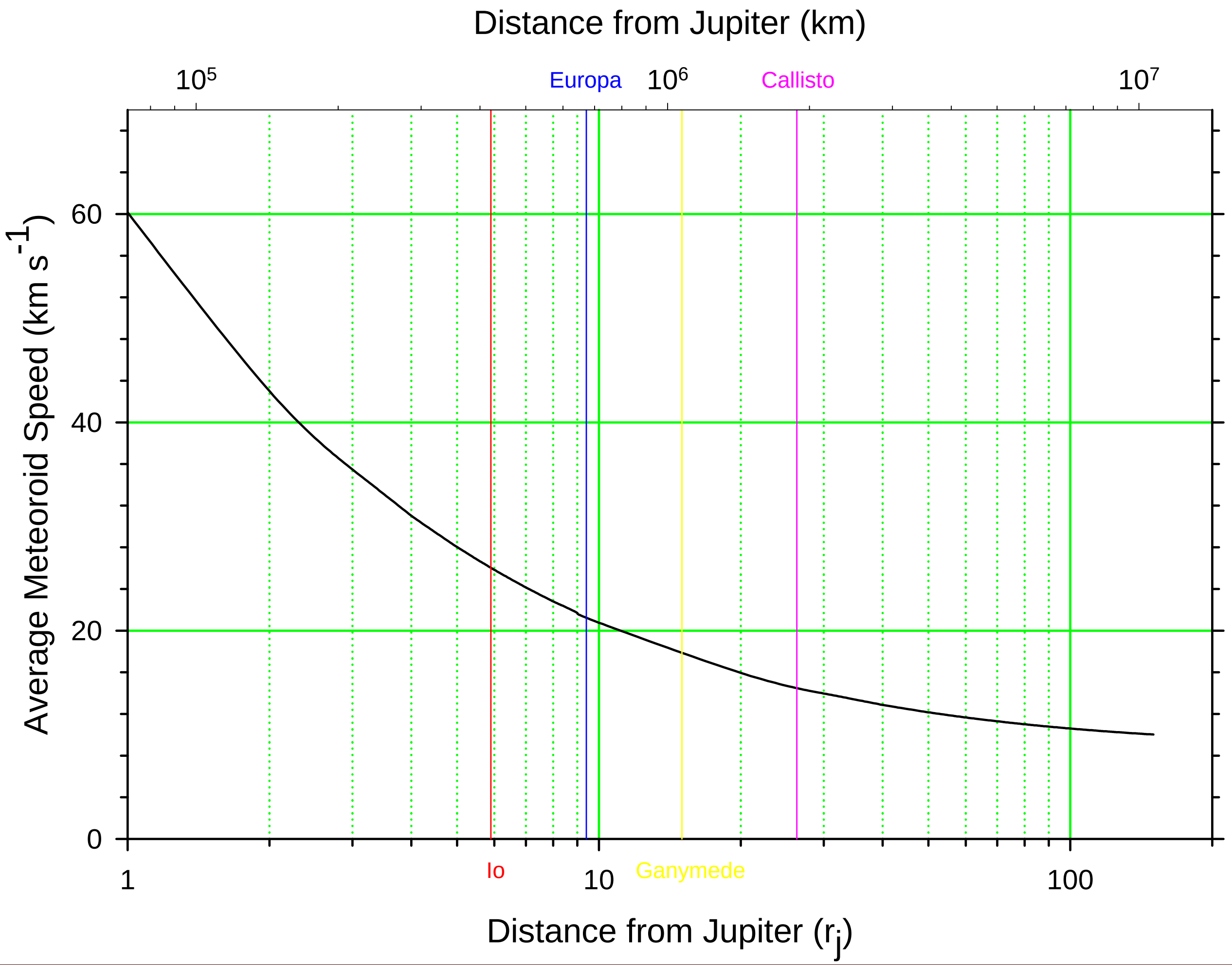
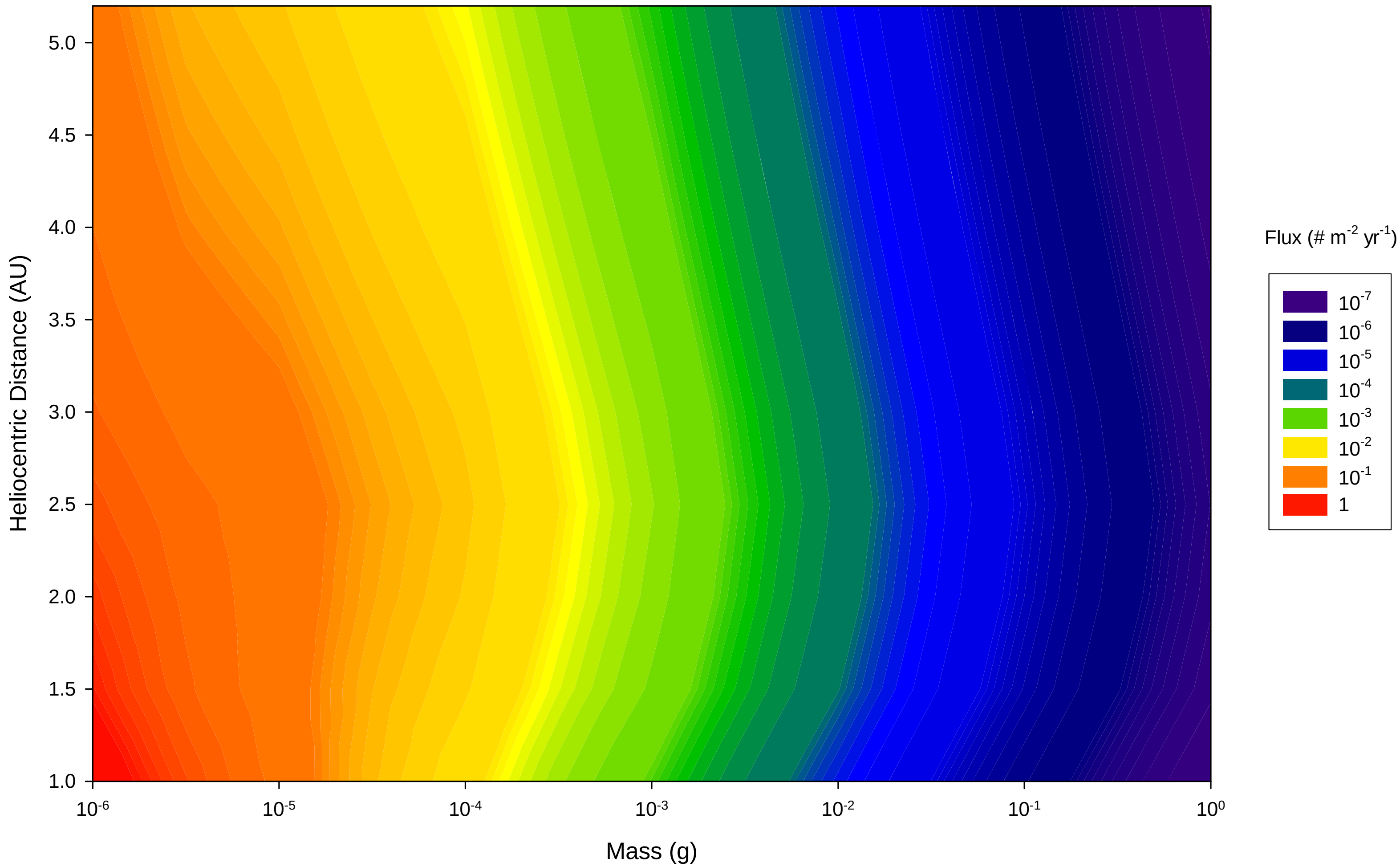
Gravitational Enhancement of Meteoroid Speed

- **Jupiter's gravity greatly enhances speed of meteoroids (by a factor of 5 at the cloud tops) as they "infall" to the planet.**

- **A mission to Io will encounter meteoroid speeds at least 1.5x that of those in LEO.**



Interplanetary Meteoroid Flux



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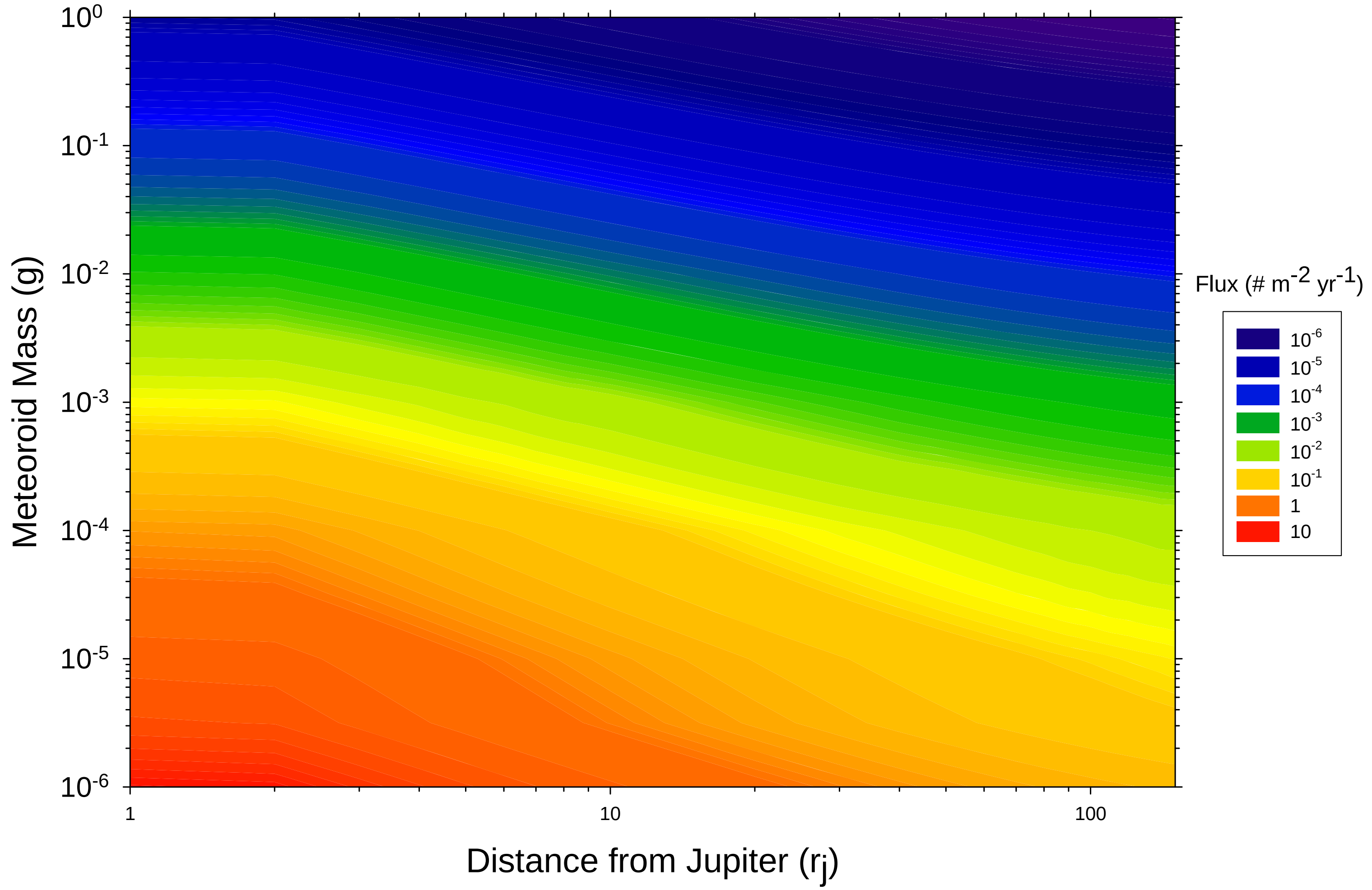
Jovian Meteoroid Flux



Materials Challenges

- In general the material radiation tolerance in a high energy electron environment is not well known.
- Cables – specifically the polymers in the cables
  - Dielectric constant change
  - Gas generation from breakdown mechanical breakdown
  - Internal charging
- Long Mission Life (approx. 20 years)
- Verification in relevant environment
- Radiation testing and characterization
  - Locating facilities
  - Test design
- Component life test requirements
- Design Margins
- System design and shielding for meteoroids
- ElectroStatic Discharge (ESD) is a Concern
  - Jovian Energetic plasma environment
  - Emphasize design to mitigate ESD
- 2 of the top risk items identify concerns of radiation effects on electronic parts and material performance

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Summary

- The Prometheus Project / JIMO Mission successfully completed phase A and was indefinitely postponed after successfully completion of the Project Mission and Systems Review (PMSR)
- Much work was accomplished during phase A pertaining to Environment definitions and identification of materials and systems susceptible to degradation by the space environment
- Work initiated during JIMO was leveraged to help design and develop JUNO and follow-on missions
- Additional information may be obtain by contacting NASA Headquarters or the JPL Librarian. Library@hq.nasa.gov
- The Project Prometheus Project Final Report is available on-line at:

  http://en.wikipedia.org/wiki/Jupiter_Icy_Moons_Orbiter