Europa Focus Group
NASA Ames Research Center
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Europa Exploration: Challenges and Solutions

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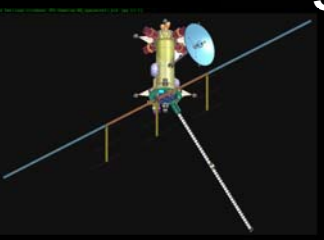


Arctic Ice Sounds: courtesy of Nick Makris, Ocean Engineering, MIT

NO PROBLEM: ARTHUR GAVE HIS OK

Exploring Europa is …. HARD!

- Long trip times, low delivered mass fractions ….. “It’s the rocket equation, stupid”
- RADIATION (BOO!)

But ….. POSSIBLE!

History

- Galileo – we did operate successfully in the Europa environment in flyby mode
- Europa Orbiter (BFC to Europa)
  - Direct trajectory (dry mass ~ 1000 kg)
  - Limited payload - ~ 20 kg
  - Radiation tolerant electronics development needed – computers, avionics, memory
  - Limited time in orbit – 30 days
  - Cancelled 2001

History$^{\text{cont'd}}$

- JIMO (a bridge too far)
  - Nuclear Electric Propulsion
  - Large payload - ~ 1500 kg
  - Science requirements developed by JIMO SDT (R. Greeley, T. Johnson *et al.*)
  - 'Deferred'… indefinitely… in 2005

History$^{\text{cont'd}}$

- Europa Geophysical Explorer – JPL Study for NASA
  - Science: OPAG Europa subgroup – R. Greeley *et al.*
  - Explored indirect trajectories, larger payloads
  - Studied options for radioisotope power in 2012 period
- This study: Europa Explorer Concept
  - JPL funded study
  - Science based on previous SDT and OPAG input organized by an *ad hoc* science team (*i.e.* some of the usual suspects)
  - Goal: Take advantage of previous investments in radiation hardening and mission concepts to develop an exciting Europa mission with ***existing technology*** that could be done in the next decade.

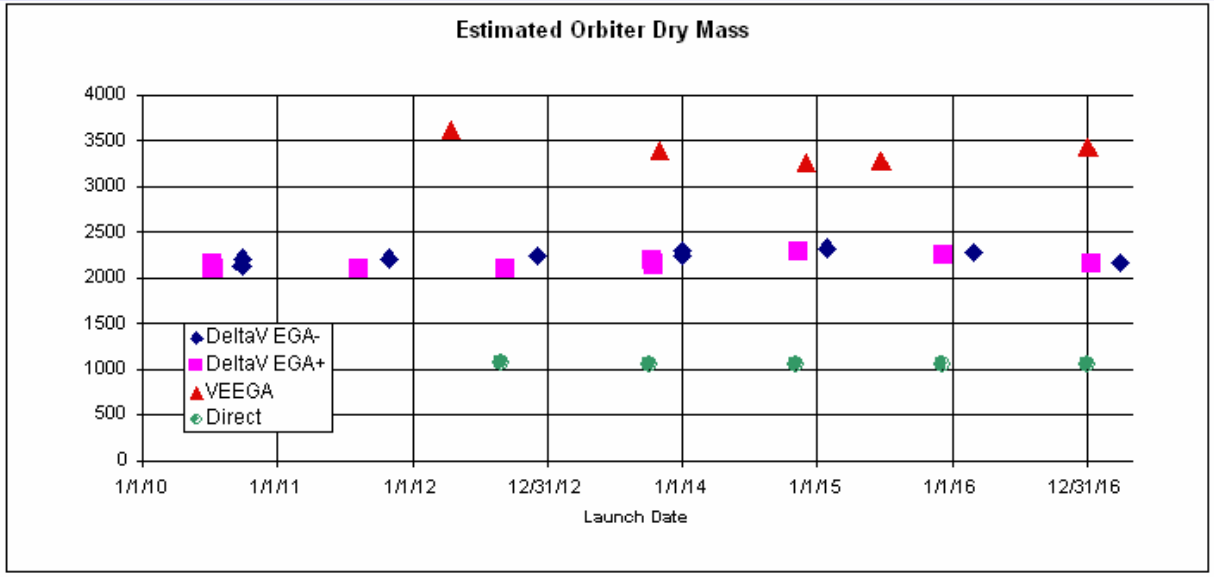
Key Factors

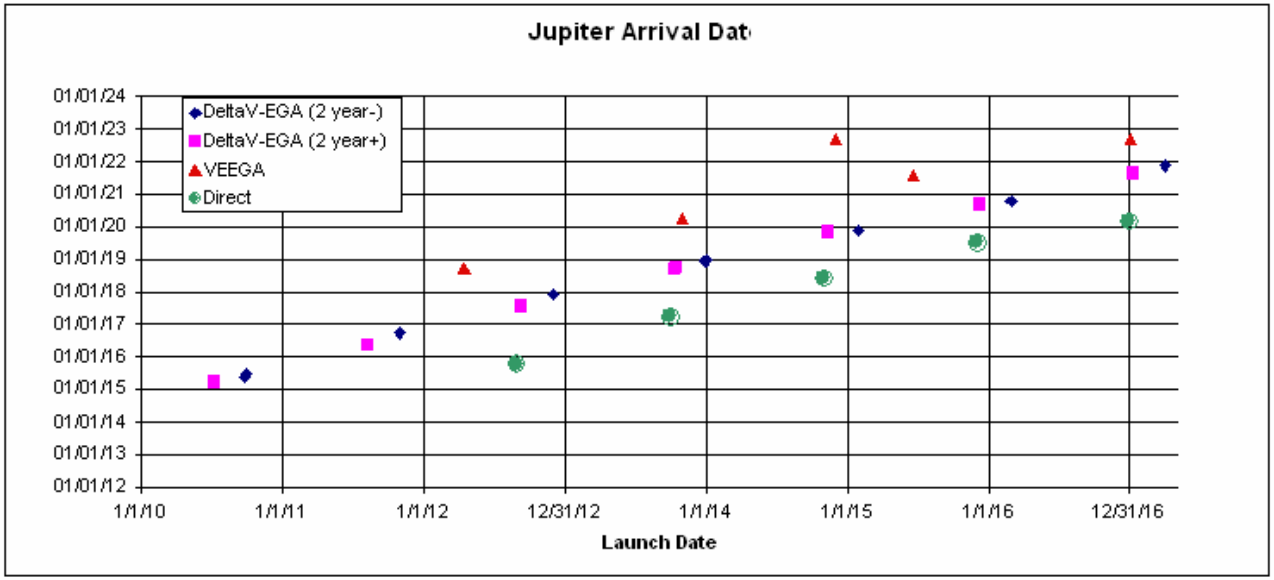
- Indirect trajectories
  - Mass margin available for science payload, shielding, power, possible surface science
- Radiation Tolerant Electronics
  - Current technology is sufficient
  - **2 yr mission at Jupiter – 1.5 yr Jupiter system, 3 months + on orbit at Europa**
- Communications
  - 400 Kbps real-time mission with rad-hard buffer
  - Europa data volume = ~ 3 yrs of Cassini data return
- Planetary Protection: End-of-mission impact
  - Radiation sterilization of surfaces and unshielded components combined with pre-launch sterilization of shielded areas

The Mission

Indirect trajectories – the key to reasonable mass margins

Interplanetary Trajectory Options



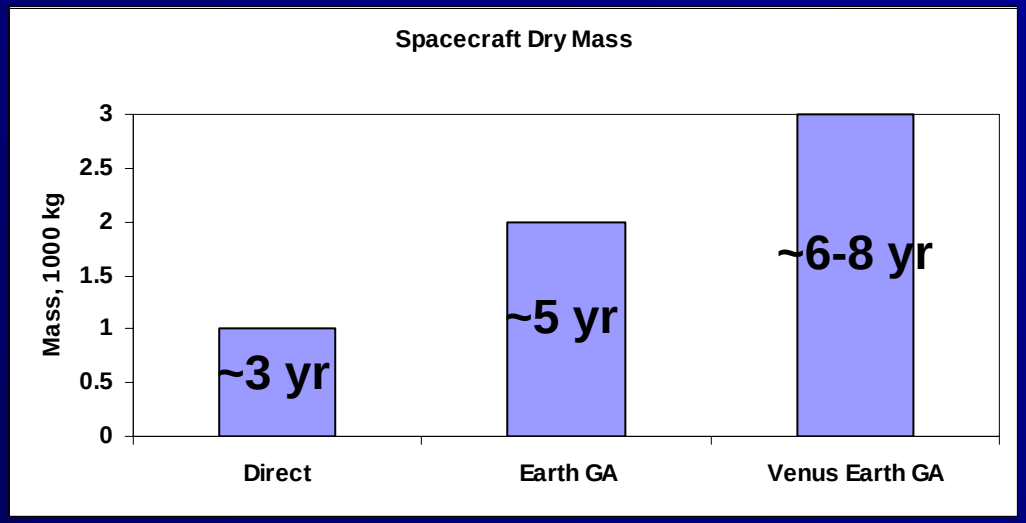


Pre-decisional, for planning purposes only

The rocket equation can be beaten ….

or at least cheated ….

by stealing energy from the planets!



Direct trajectory: ~ 1 Ton spacecraft

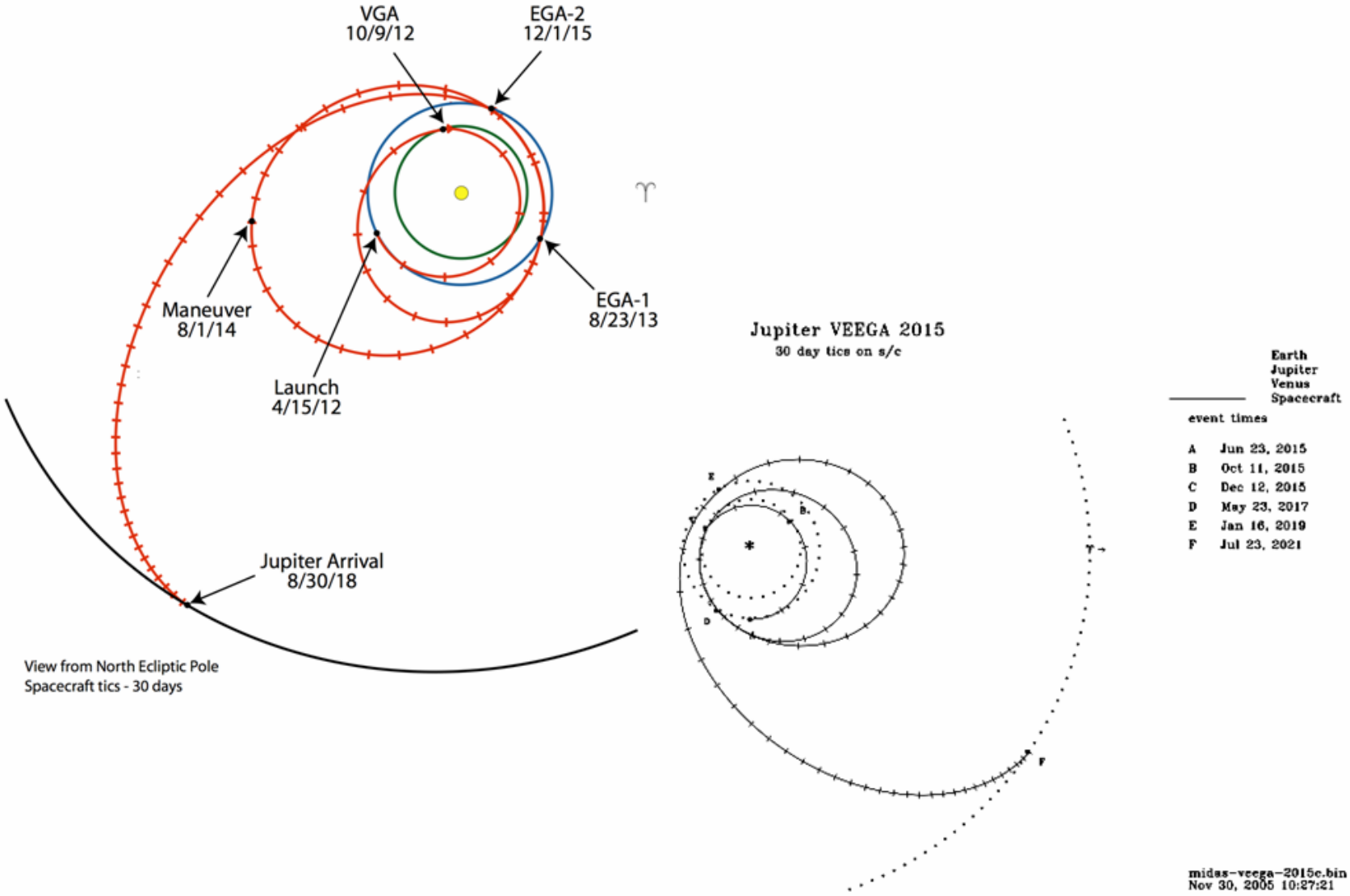
Earth GA trajectory: ~ 2 Ton spacecraft

Venus-Earth GA trajectory: ~ 3 Ton spacecraft

Pre-decisional, for planning purposes only

Cost – trip time to target (*e.g.* Galileo, Cassini)

Representative VEEGA Options



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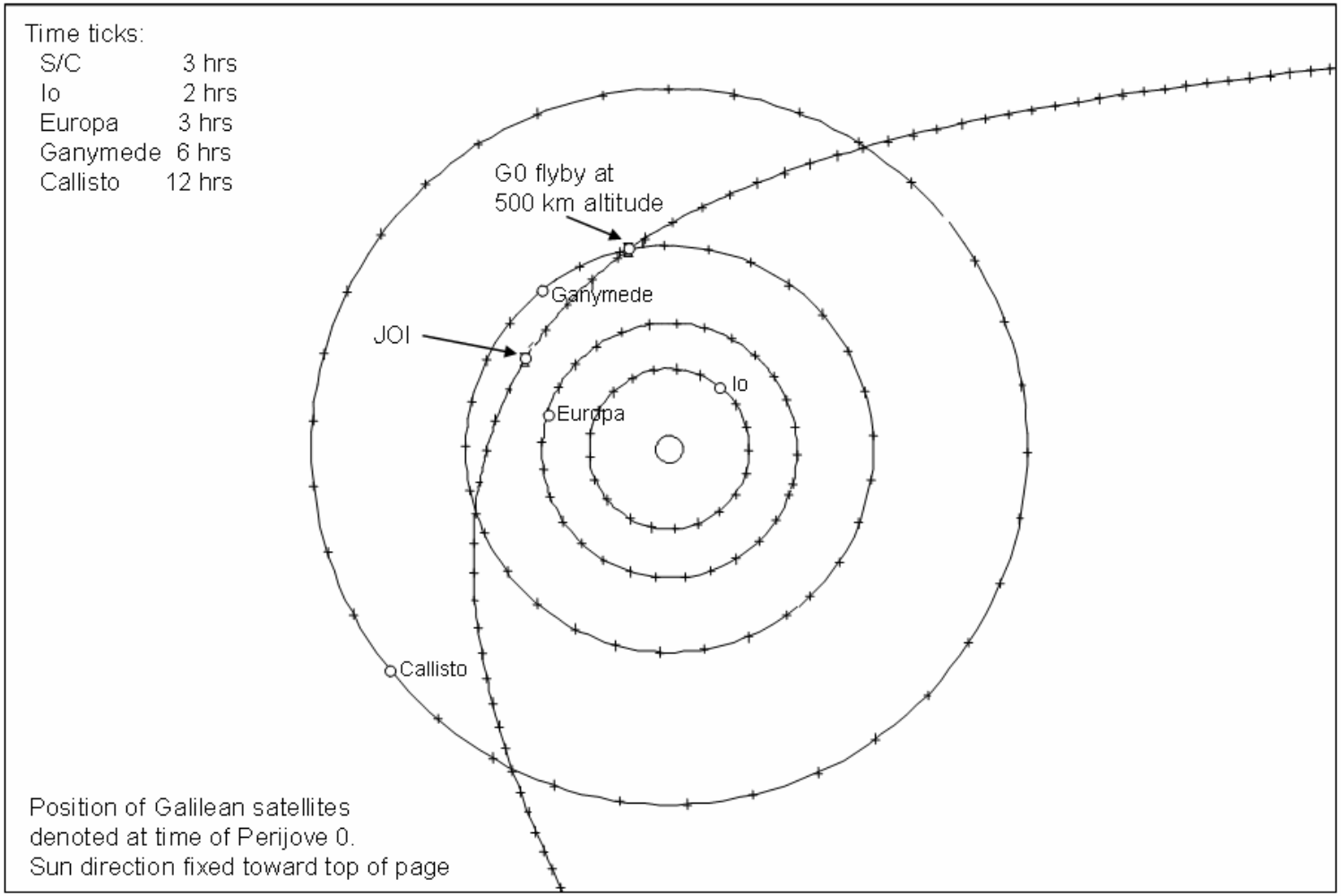
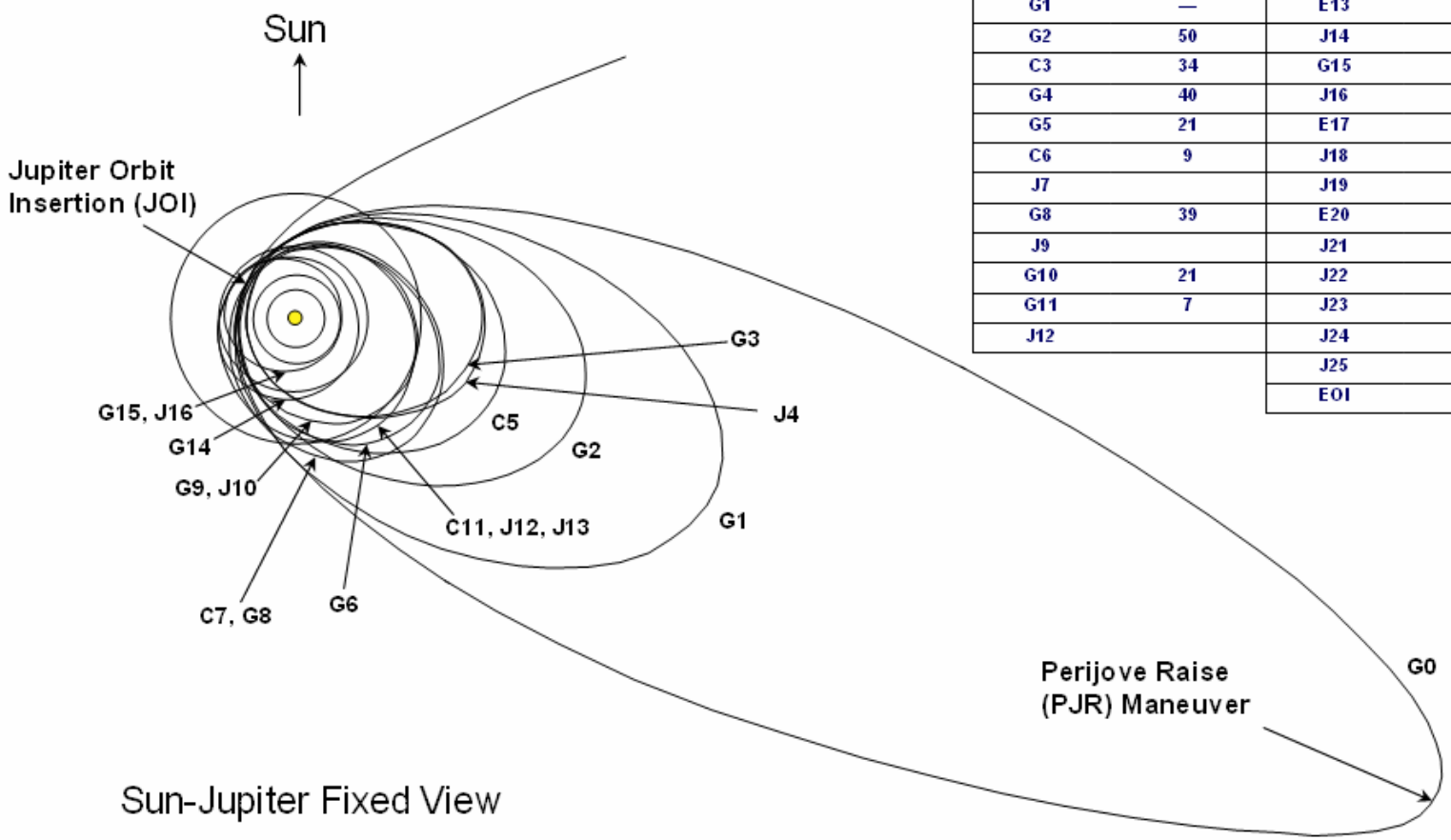
Representative Jupiter Arrival

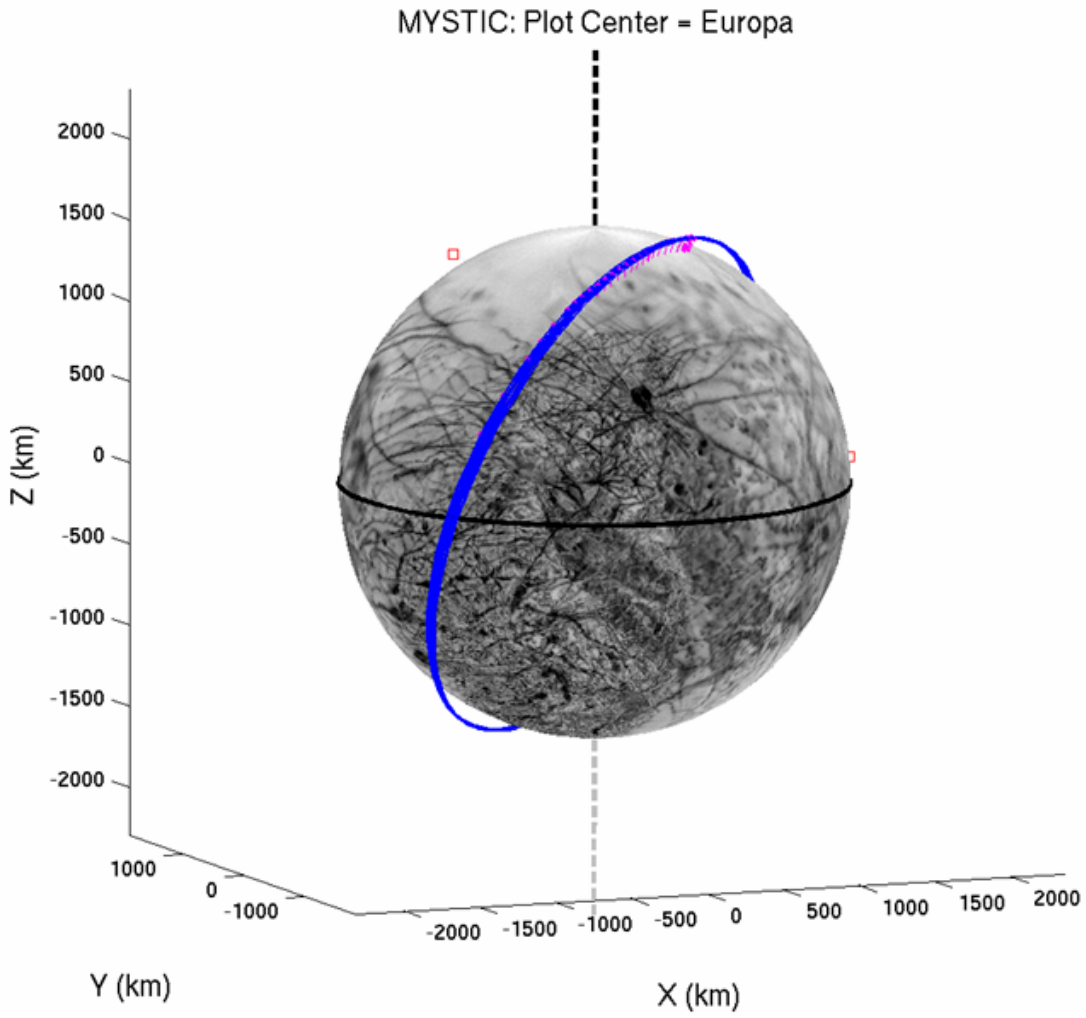


Representative Jovian Tour



Encounter	Days Since Last Encounter	Encounter	Days Since Last Encounter
G1	—	E13	9
G2	50	J14	
C3	34	G15	13
G4	40	J16	
G5	21	E17	8
C6	9	J18	
J7		J19	
G8	39	E20	14
J9		J21	
G10	21	J22	
G11	7	J23	
J12		J24	
		J25	
		EOI	23

Example Science Orbit at Europa



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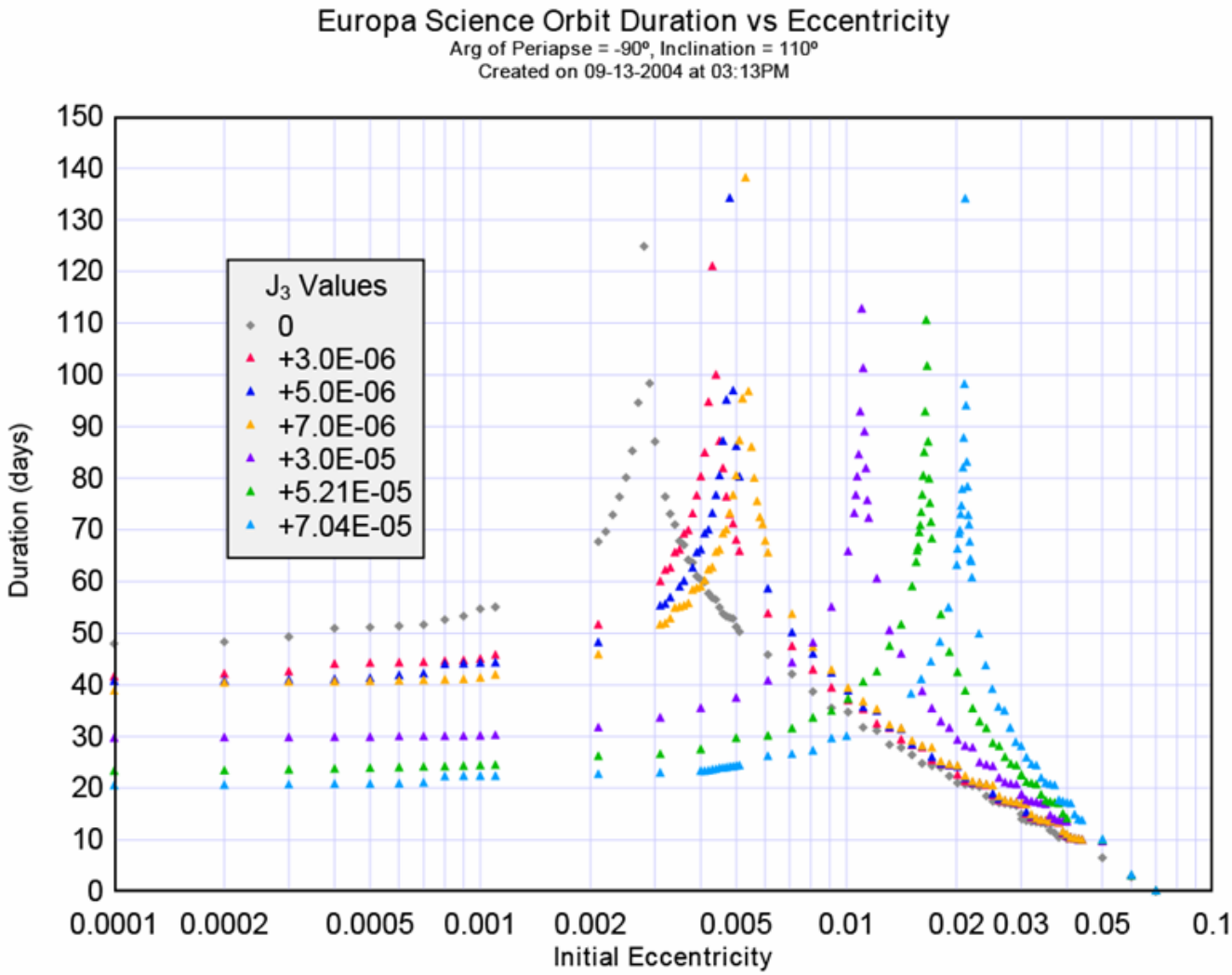
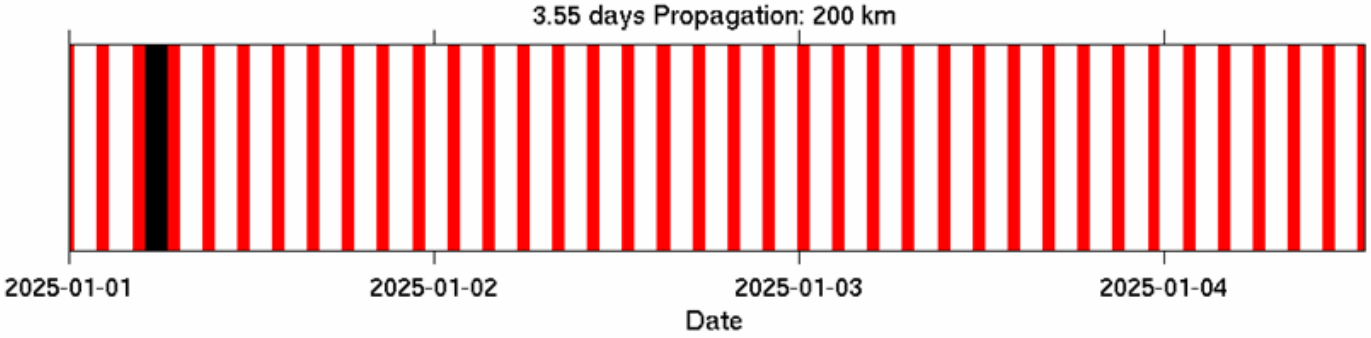
Lifetime of Science Orbit



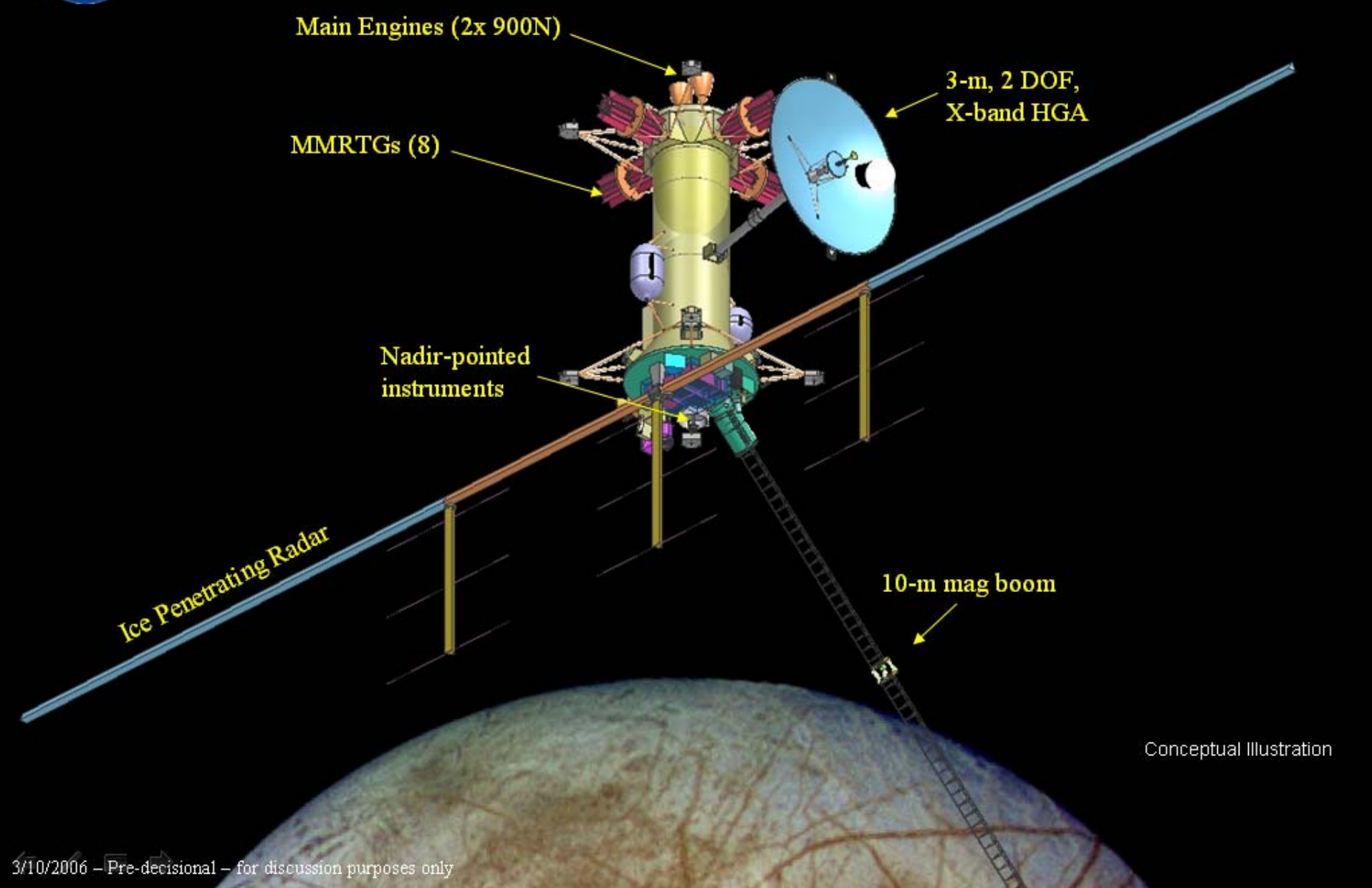
Occultations in Science Orbit

- Earth occulted by Europa
  - Max ~37% of the time for 100 km orbit (2.1 hour period)
  - Max ~33% of the time for 200 km orbit (2.3 hour period)
- Earth occulted by Jupiter ~2.5 hours every Europa rev (3.55 days)
  - ~ 3% of the time
- Solar eclipses have similar duration



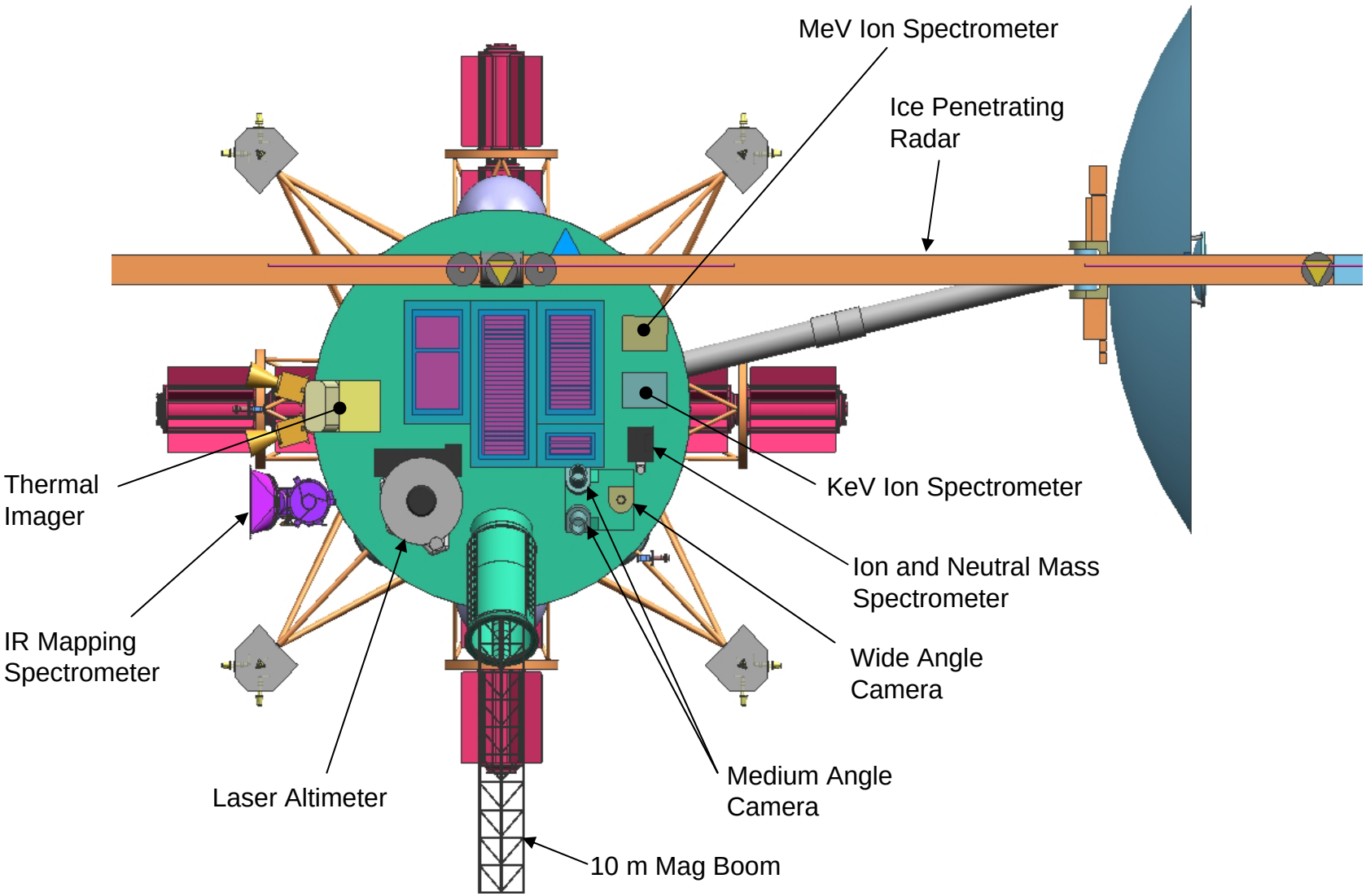
The Spacecraft

EE Spacecraft Configuration



Conceptual Illustration

Science Instrument View



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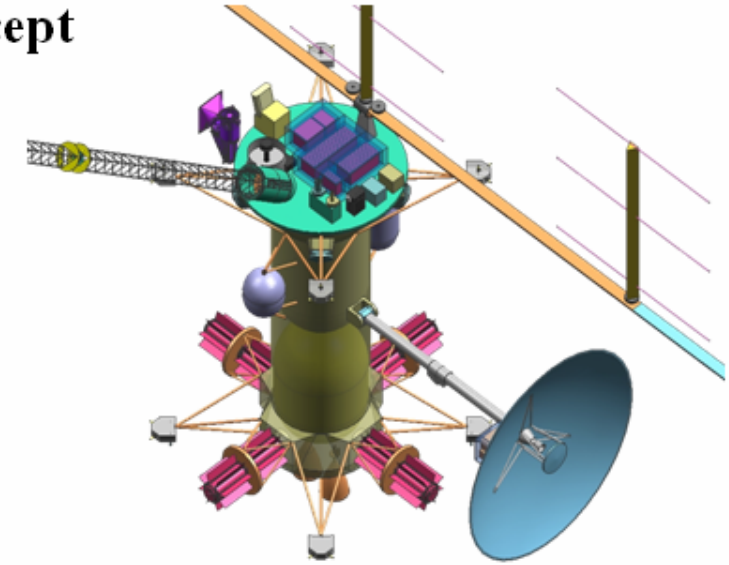
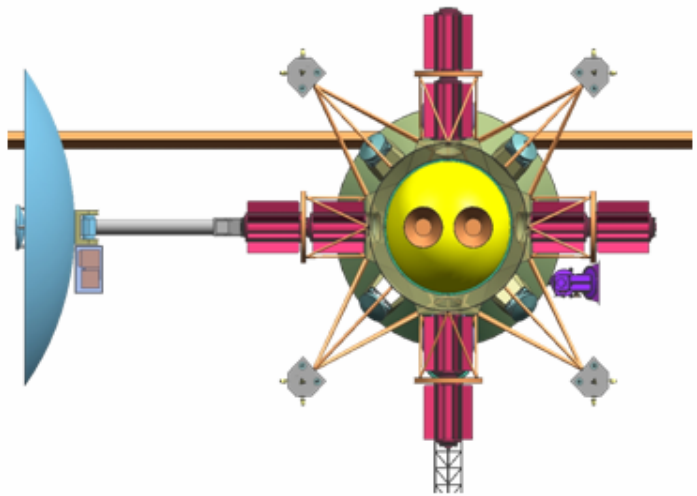
EE Reference Mission Capability

The reference Europa Explorer mission concept has the following capabilities:



- **Launch mass capability: 7230 kg**
- **Spacecraft wet mass: 6888 kg**
- **Spacecraft dry mass: 2608 kg**
- **Power available (EOM): 823 W**
- **Number of MMRTGs: Eight**
- **Data rate (@5.5 AU): 400 kb/s**

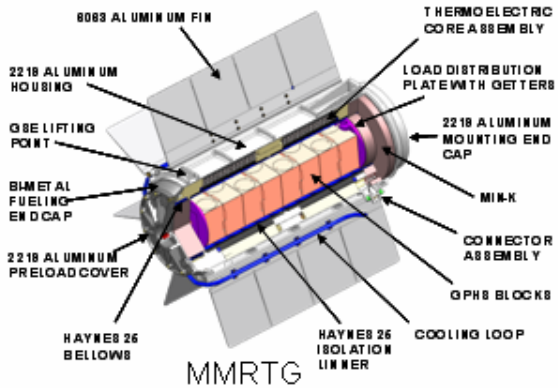
This leaves an **additional 340 kg** of unallocated mass that may be used for greater spacecraft margin and/or mission enhancements.



Conceptual Illustrations

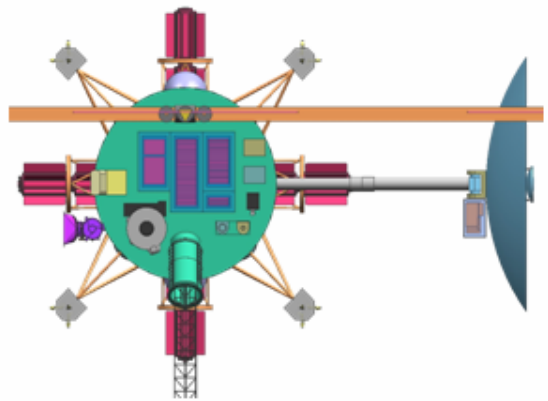
EE Functional Description Summary - 1

- **General**
  - 3-axis stabilized
  - MMRTG powered, with battery
  - 10 body-fixed instruments
  - Deployed appendages: HGA, MAG, IPR antenna array

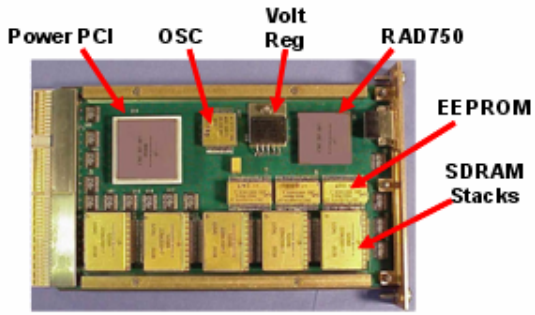


MMRTG

- **Communications**
  - X-band; 50 W(RF); gimbaled 3m HGA
  - Ka up/down for science; 3.5 W transmitter


2-DOF, 3-m HGA

- **Data Handling**
  - RAD750 processors
  - 1553 bus + LVDS interfaces
  - Separate science computer and mass memory
  - Small mass data memories: 300 Mbit



RAD750 Processor

EE Functional Description Summary - 2

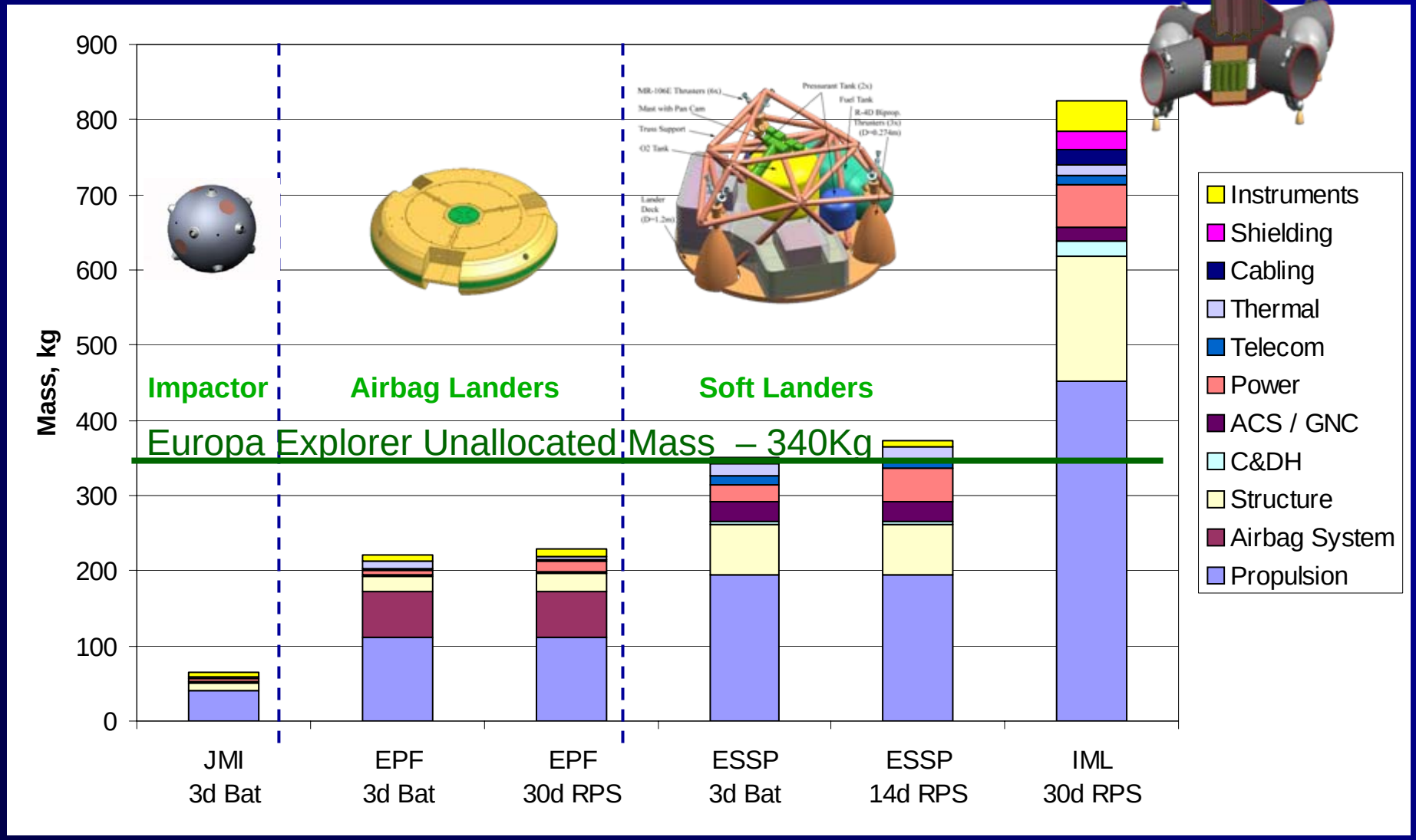
- **Attitude and Propulsion**
  - Reaction wheels
  - Star sensor/IRU/sun sensors
  - 900 N bipropellant main engine
  - 4.5 and 32.5 N monoprop thrusters
  - Translational thrusting in 6 directions

Notional bi-prop thruster

- **Thermal Control, using:**
  - RTG waste heat
  - 140 Radioisotope Heater Units (RHUs)
    - 120 used on Galileo
    - 117 used on Cassini
    - 8 used on each MER rover
  - Electrical heaters, blankets, louvers, etc.

Radioisotope Heater Unit (RHU)

Lander Concepts



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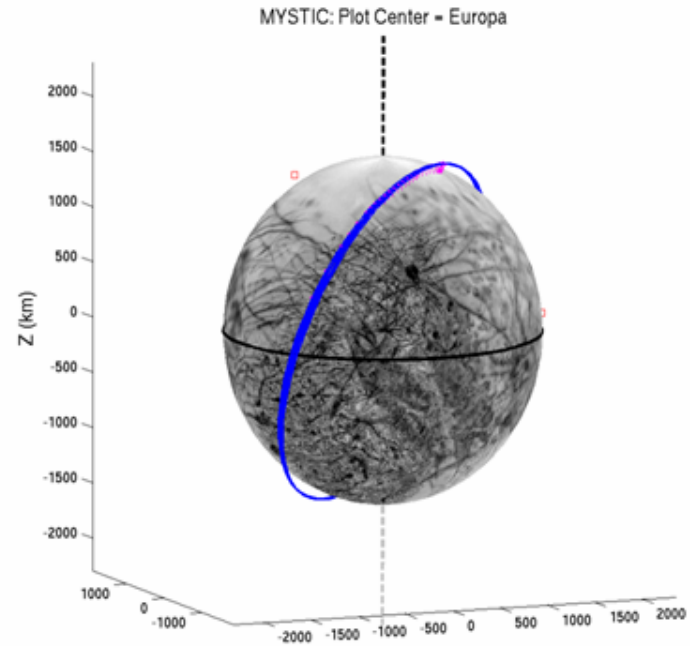
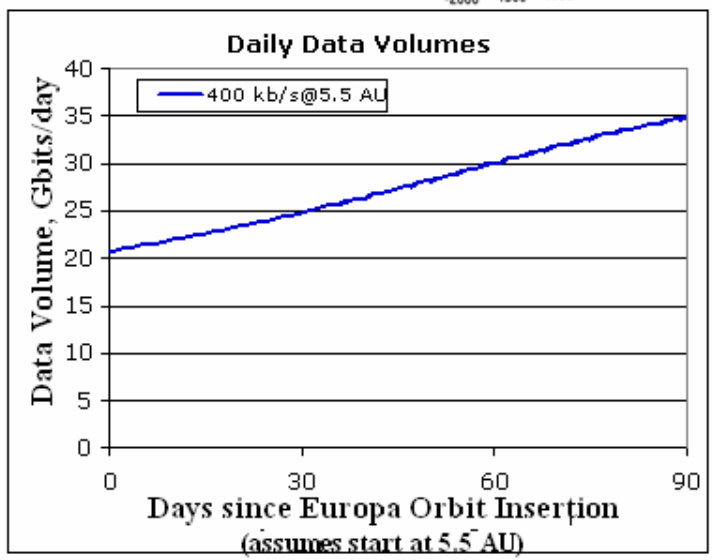
Data

Data Return Solution

- Continuous coverage by the Deep Space Network
- Science memory of only 300 Mb stores data when the spacecraft is behind Europa
- Mission returns 21 Gb/day at the start of the mission increasing to 35 Gb/day after 90 days
- Mission acquires ~3 Tb total data in the 90 day Prime Mission

CHANGES





RADIATION

NOT HEALTHY: FOR CARBON OR SILICON BASED LIFE FORMS

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Radiation Hardening: Progress

- Galileo design standard: 150,000 rad Si
- Current situation: NASA and DOD radiation hardening development in last decade has yielded:
  - Flight computers (Pentium class): 1,000,000 rad Si
  - Many avionics and flight parts: > 300,000 rad Si
- Better characterization of environment by Gaileo
- Bottom Line: With mass for shielding, a Europa mission can now be done with *current technology*

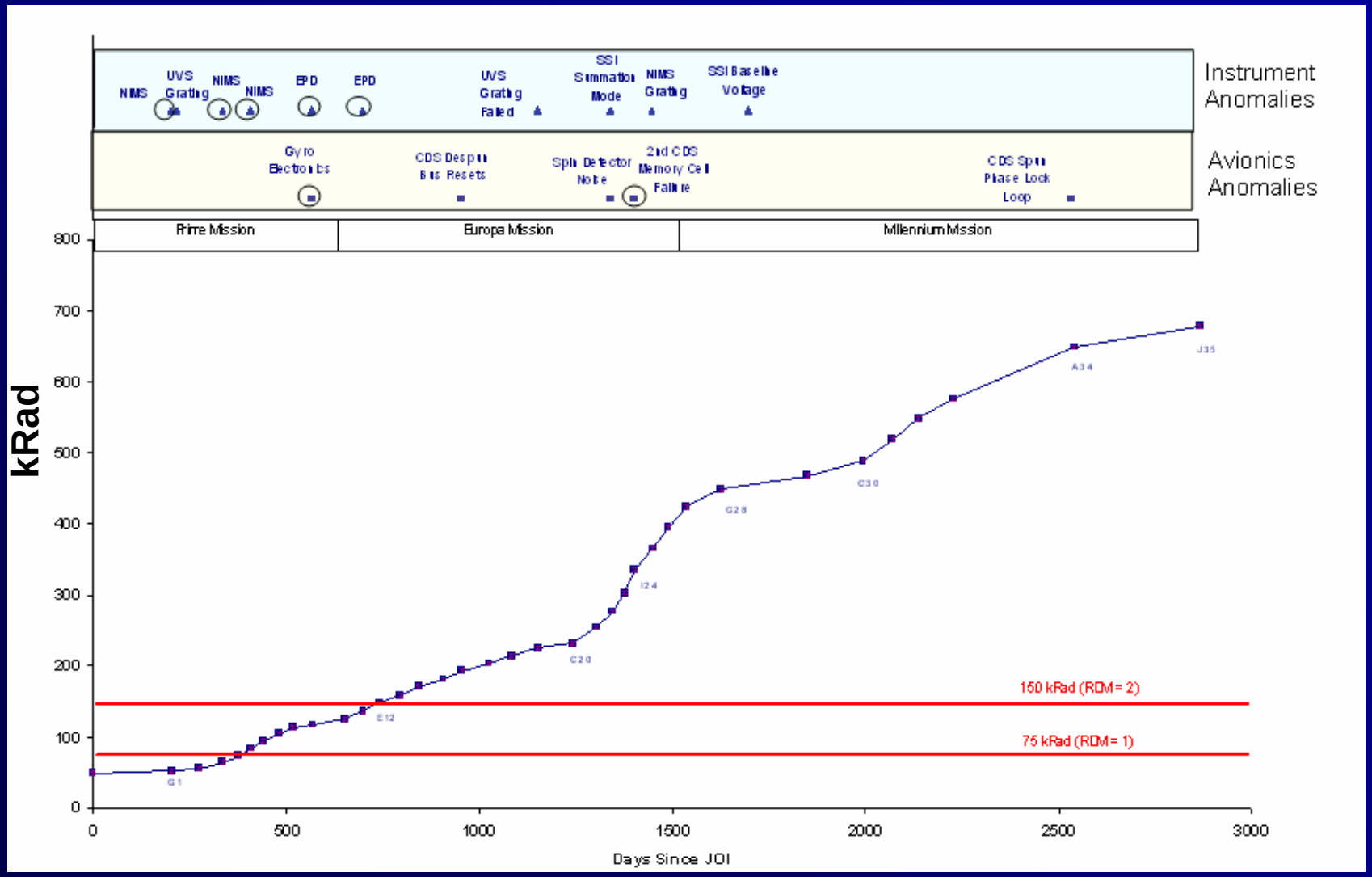
Radiation Design and Mitigations

- **More Rad hard electronics are available**
  - Rad 750 is now in use – it is on MRO
  - Power electronics developed by JIMO before cancellation
  - DOD work has led to more parts being available

- **Galileo experience and knowledge base**
  - Radiation environment model – significantly refined with Galileo data
  - Failure history – what failed, when and why
  - Mitigation methods – annealing, operational work-arounds
  - Fault handling – how quickly can the spacecraft recover

- **A new operational strategy**
  - Real time data transmission from Europa
  - Minimal data storage – feasible with current rad hard technology
  - Minor compromises in data types acquired

Galileo Radiation Failures vs Time in Orbit about Jupiter



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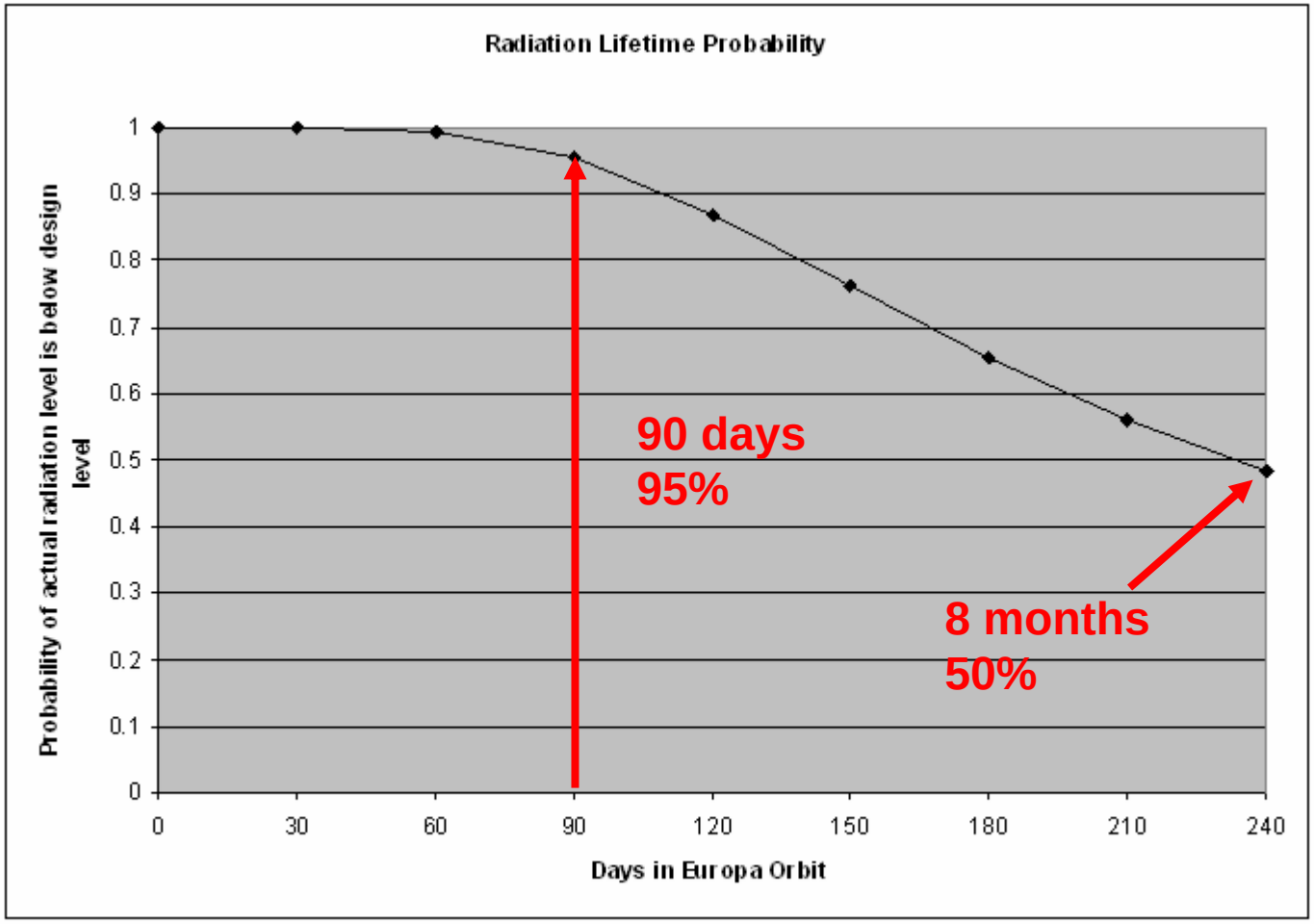
Europa Explorer Concept



Probability that Actual Radiation Environment Seen is Below Selected Design Point

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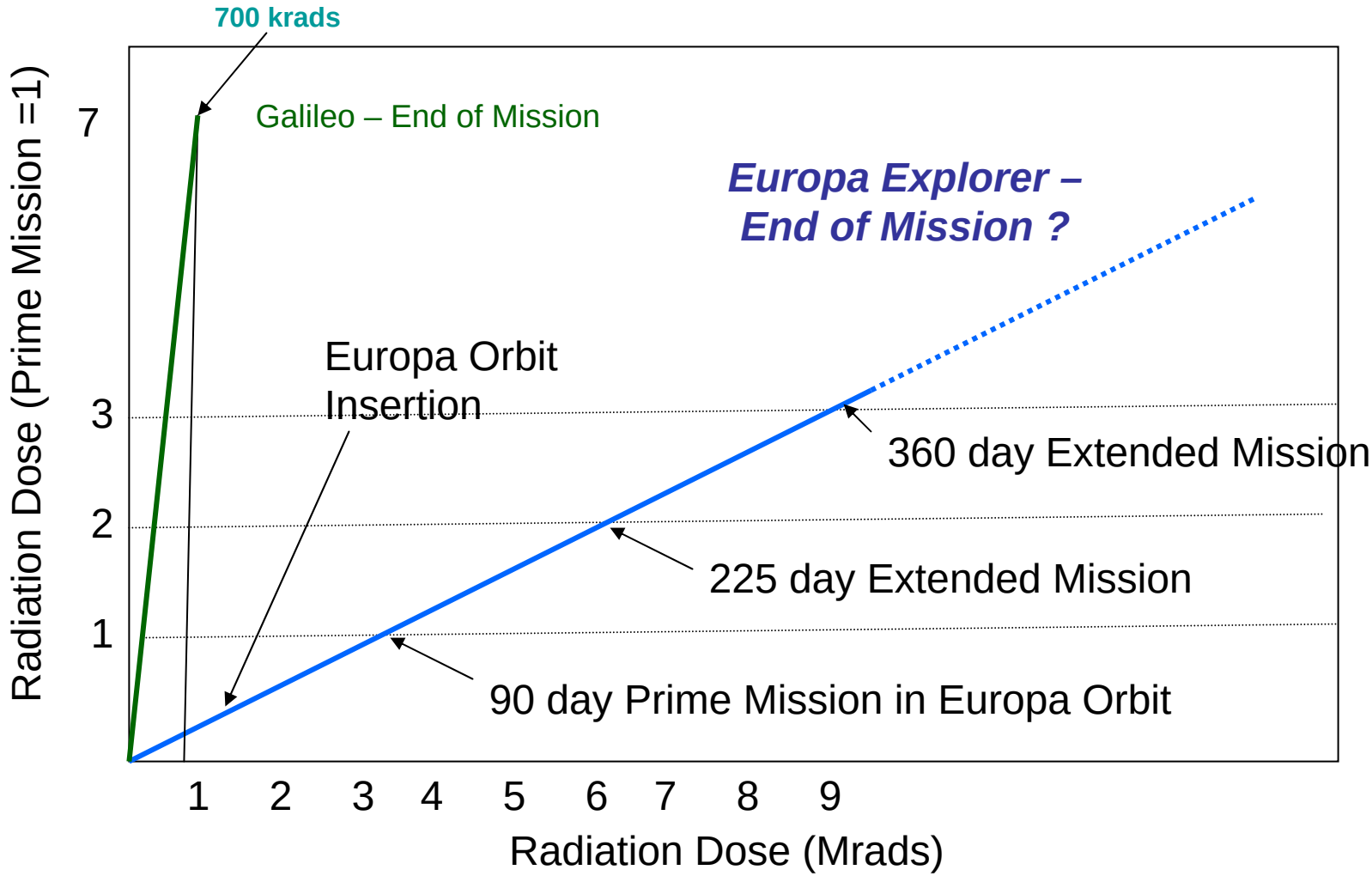
Europa Explorer – Operating Lifetime



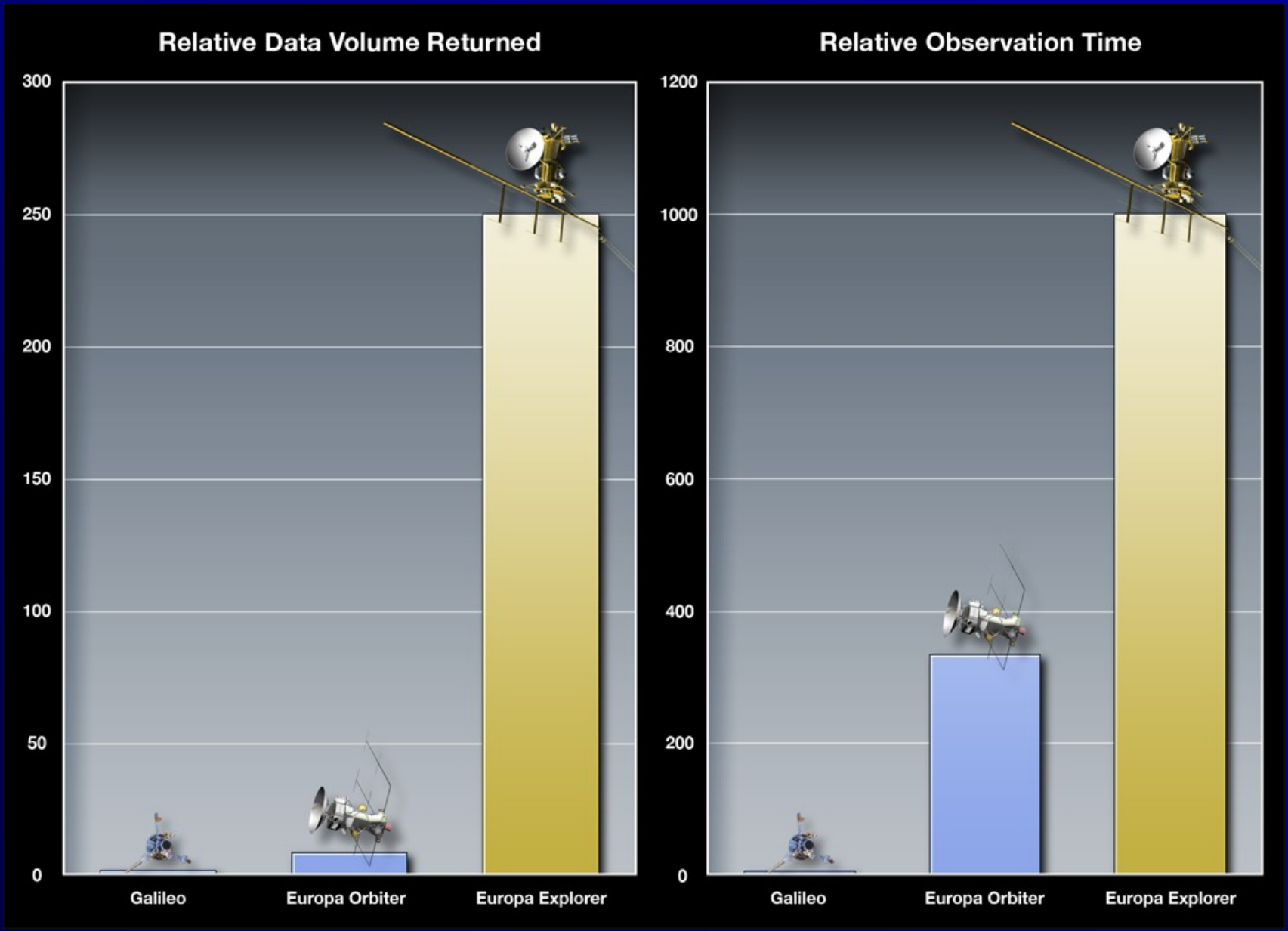
Pre-decisional, for planning purposes only

Concept Comparison

Parameter	*Europa Orbiter*	*Europa Geophysical Explorer*	*Europa Explorer*
Instrument Mass	27 kg	180 kg	180 kg
Instrument Power (Orbital Average)	27 W	154 W	100 W
# Instruments	4	9	10
Lander	Not Possible	850 kg	340 kg
Prime Mission			
Duration	30 Days	30 days	90 Days
Data Return	100 Gbits	1000 Gbits	3000 Gbits
Extended Mission*			
Duration	0 Days	70 Days	135 Days
Data Return (Assumes 24/7 DSN coverage)	N/A	2333 Gbits	4500 Gbits

*** Expect some degradation in performance**

Europa Data Comparison



Summary

Europa Explorer Orbiter would

- be fully operational in Europa orbit for at least 90 days with significant data return expected for up to a year
- produce 1000 times more close-up observations of Europa as the Galileo mission performed in six years of flybys
- carry 180 kg of instruments (including shielding and contingency)
- have ~340 kg of unallocated mass that could be used for additional margin, an enhanced science payload, and/or a Europa lander
- return approximately ~3.0 Tbits of Europa data in first 90 days
- use existing technology

Europa Explorer - A Capable Mission - Now

RETURN TO EUROPA