EJSM/Jupiter Europa Orbiter Design and Status

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3rd EJSM Instrument Workshop

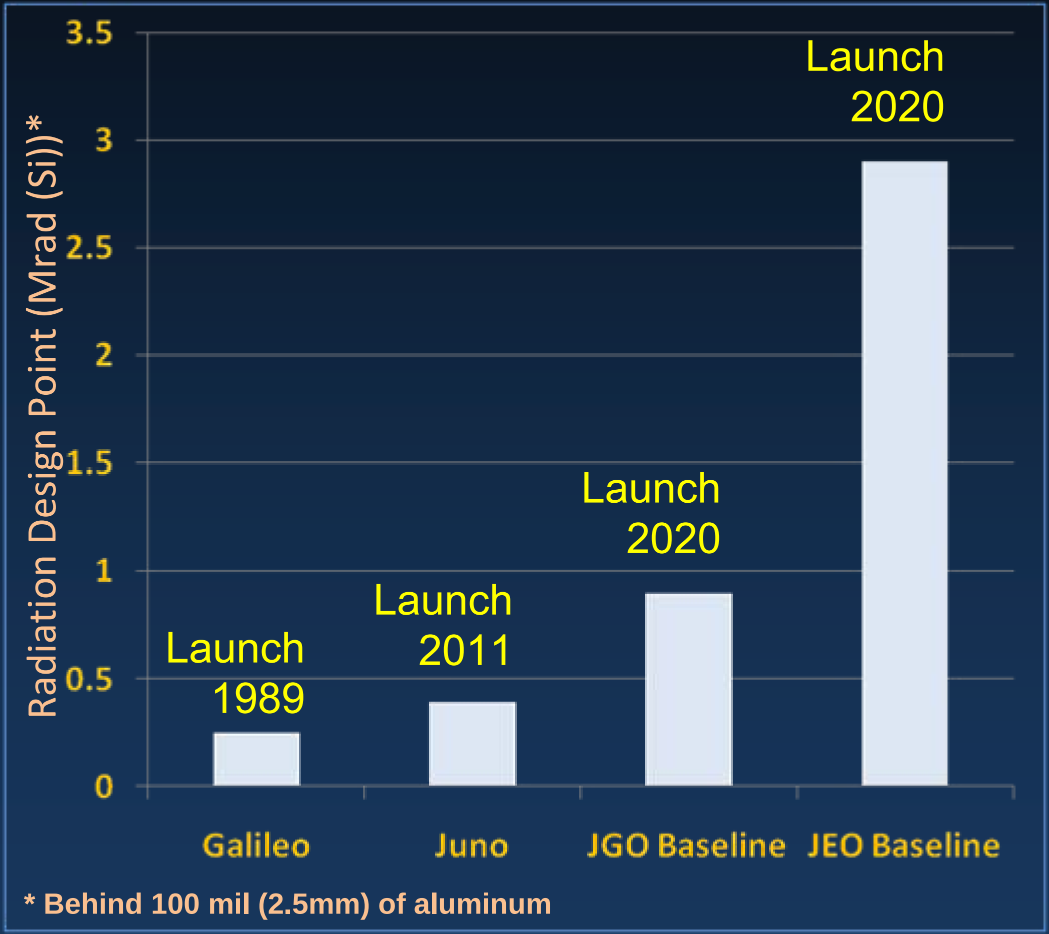
Jupiter Europa Orbiter
The NASA Element of the Europa Jupiter System Mission

For Discussion and Planning Purposes Only

JEO Baseline Mission Overview

- Objectives: Jupiter System, Europa
- Launch vehicle: Atlas V 551
- Power source: 5 MMRTG
- Mission timeline:
  - Launch: 2018 to 2022, nominally 2020
    - Uses 6-year Venus-Earth-Earth gravity assist trajectory
  - Jovian system tour phase: 30 months
    - Multiple satellite flybys: 4 Io, 6 Ganymede, 6 Europa, and 9 Callisto
  - Europa orbital phase: 9 months
  - End of prime mission: 2029
  - Spacecraft final disposition: Europa surface impact
- 11 Instruments, including radio science
- Optimized for science, cost, and risk
- Radiation dose: 2.9 Mrad (behind 100 mils of Al)
  - Handled using a combination of rad-hard parts and tailored component shielding
  - Key rad-hard parts are available, with the required heritage
  - Team is developing and providing design information and approved parts list for prospective suppliers of components, including instruments

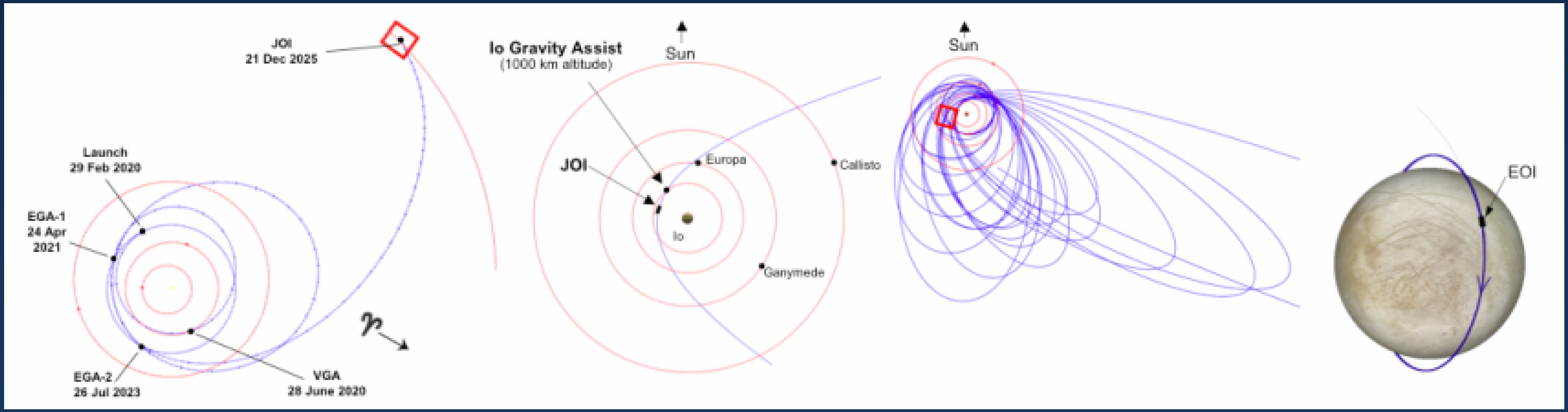
Mission Radiation Challenge



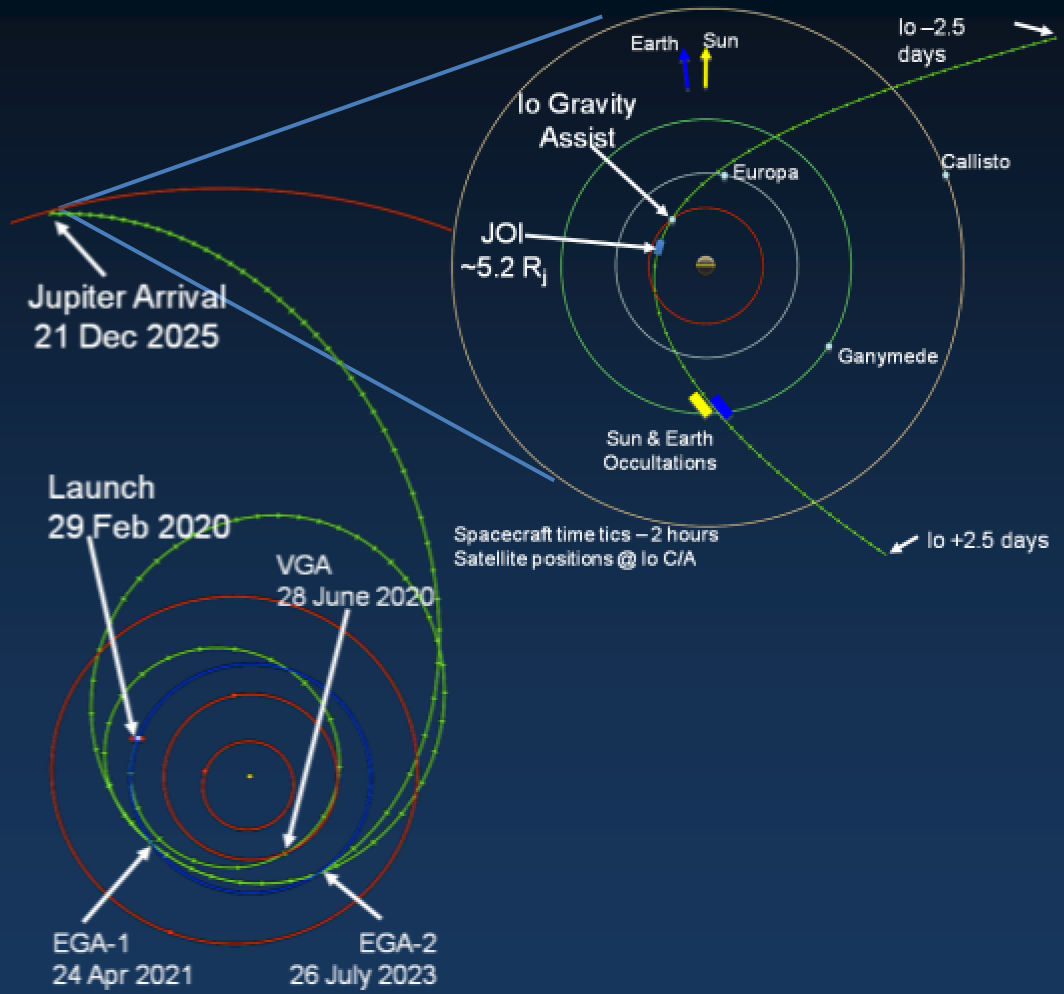
Estimated radiation dose levels unprecedented for NASA/ESA missions

JEO Mission Design Overview

- Interplanetary trajectories feature gravity-assists to greatly reduce the required specific energy of launch
- Jupiter Orbit Insertion occurs low in Jupiter's gravity well, significantly reducing ΔV
- Gravity-assist tour of Jovian satellites greatly reduces size of Europa Orbit Insertion maneuver



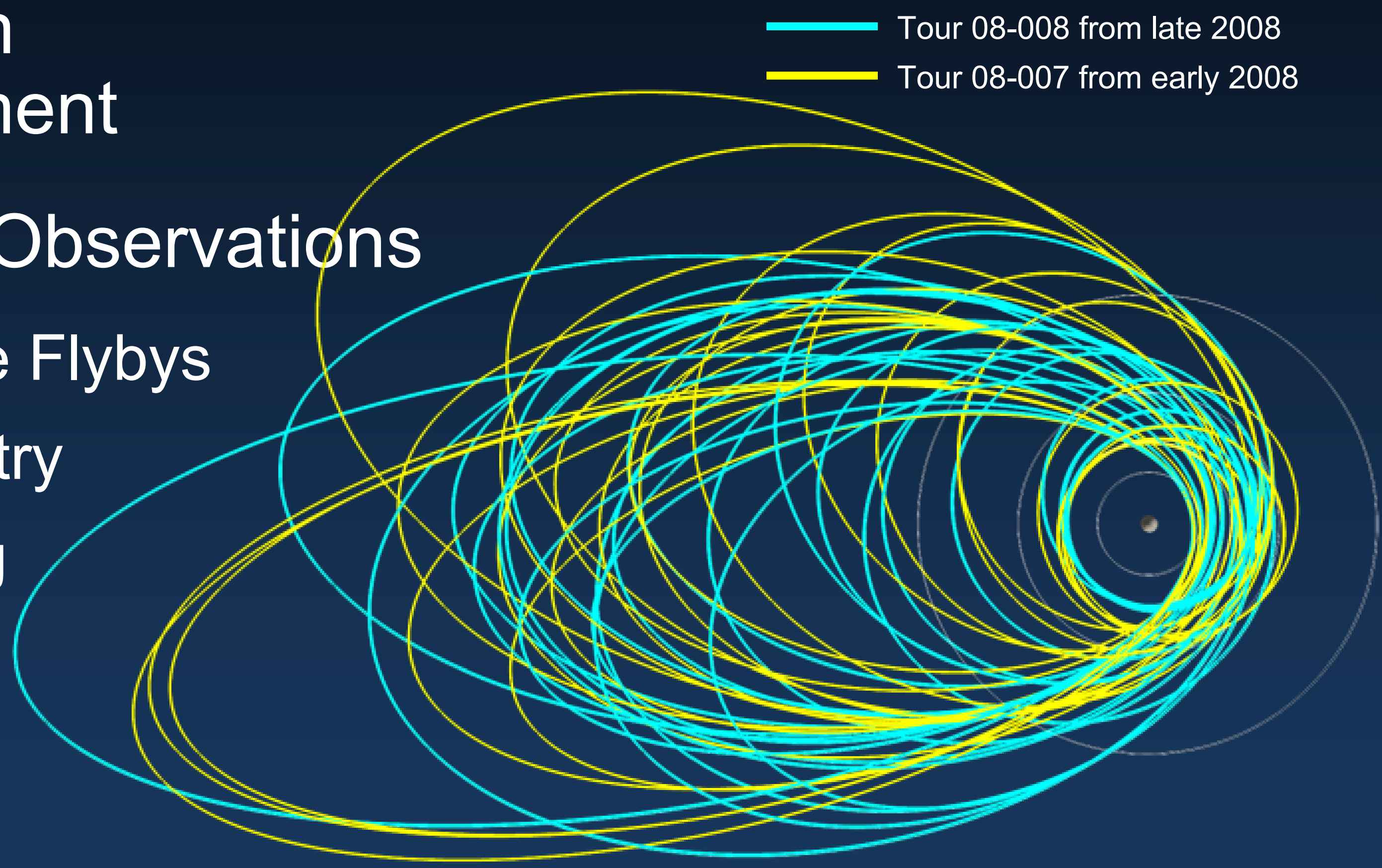
JEO Baseline Trajectory & Orbit Insertion



- Launch on Atlas V
- 4733 kg wet mass
- Venus-Earth-Earth Gravity Assist (VEEGA)
- Minimum range to Sun ≥ 0.7AU
- JOI date: 21 December 2025
- JOI range: 5.2 Rj
- 200-day initial orbit post-JOI
- Io gravity assist
- Science tour starts post JOI

JEO Tour Design Drivers

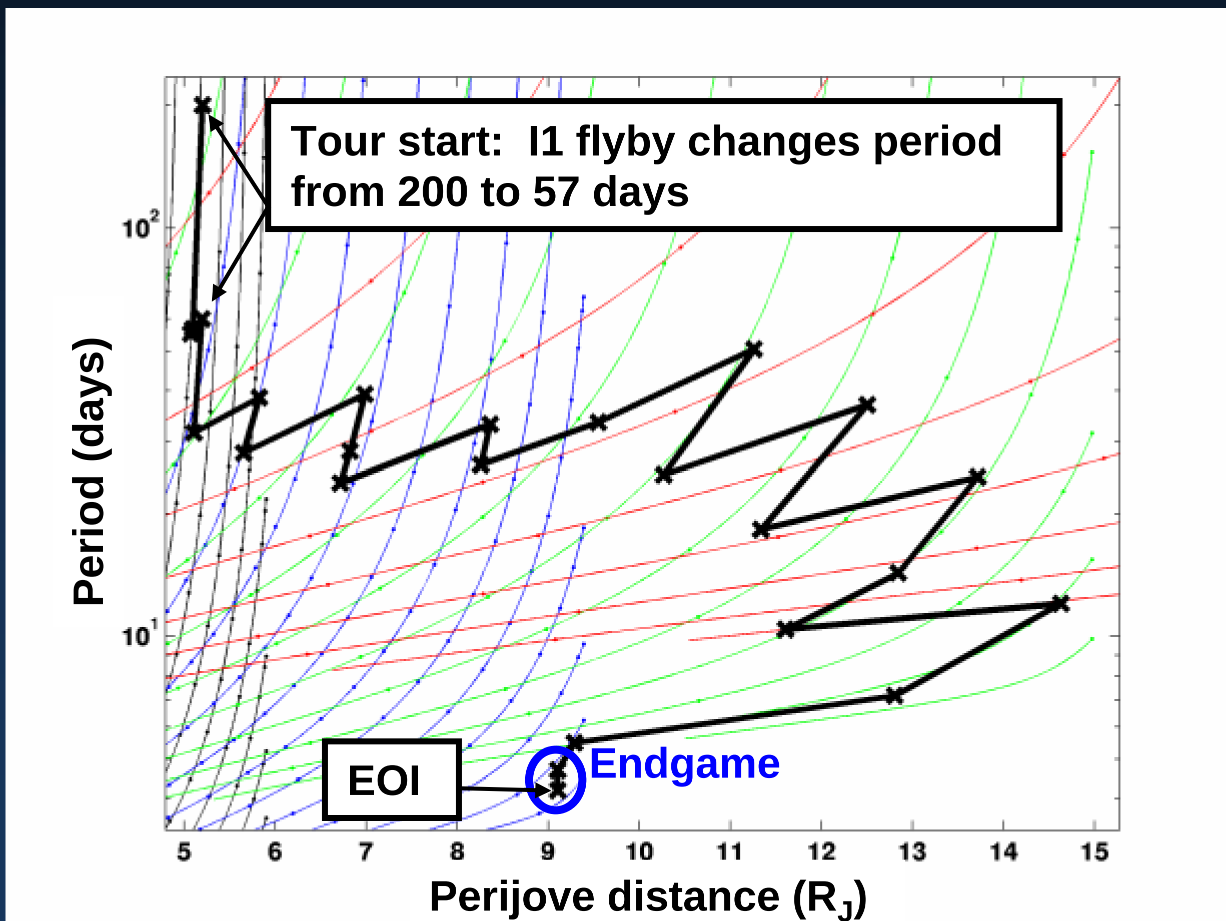
- Radiation Environment
- Science Observations
  - Satellite Flybys
  - Geometry
  - Lighting
- Duration

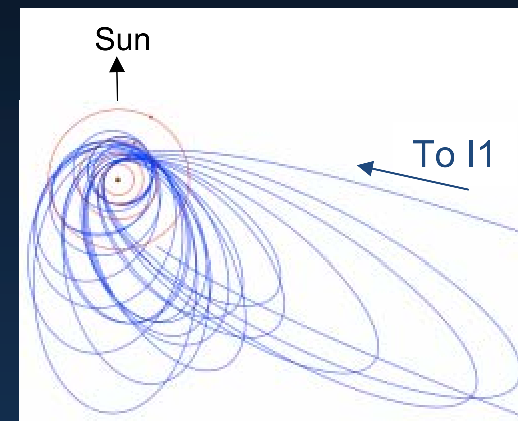


Tour design continues to evolve

JEO Tour Design

- Many tours possible. Baseline tour T08-008 shown here
- No deterministic ΔV between I1 and start of endgame



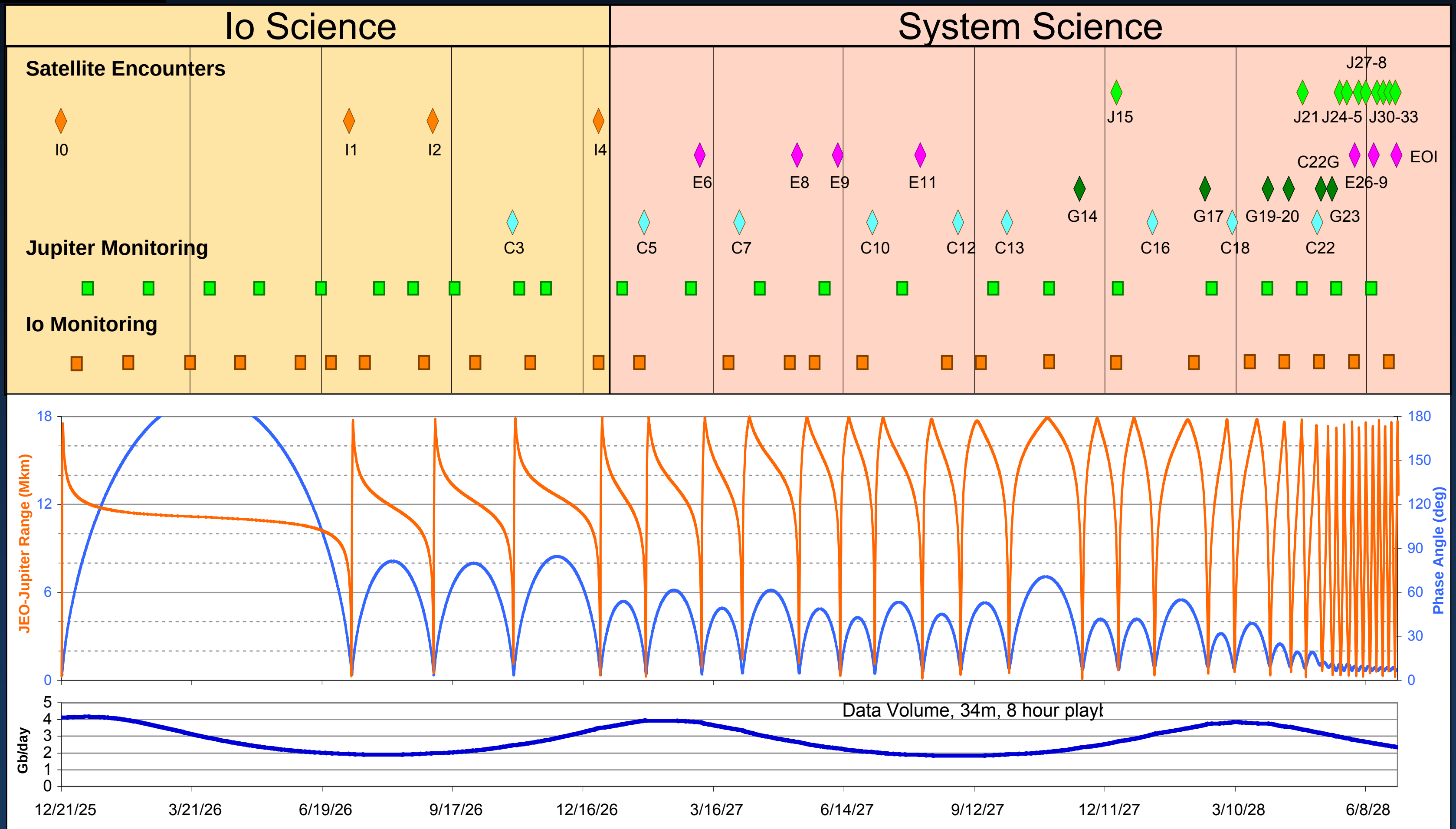


- Periapsis raised early in the tour to minimize radiation exposure (and the attendant shielding)

Baseline JEO Jovian Tour Phase

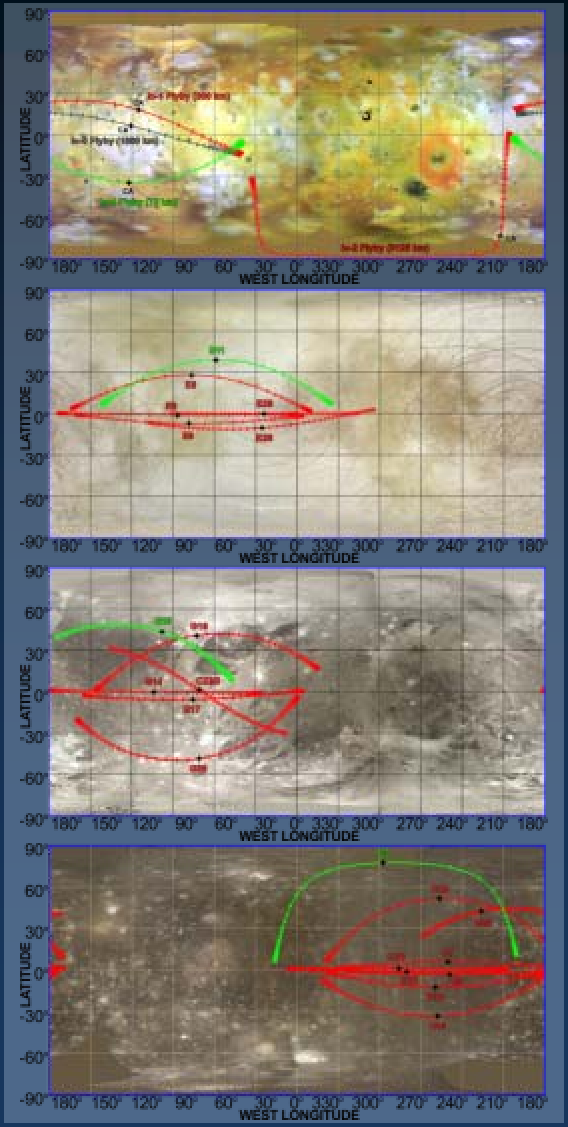
Phase: 100 deg

Phase: 120 deg



Extensive opportunities exist to acquire Jupiter System Science

Baseline JEO Tour Satellite Science



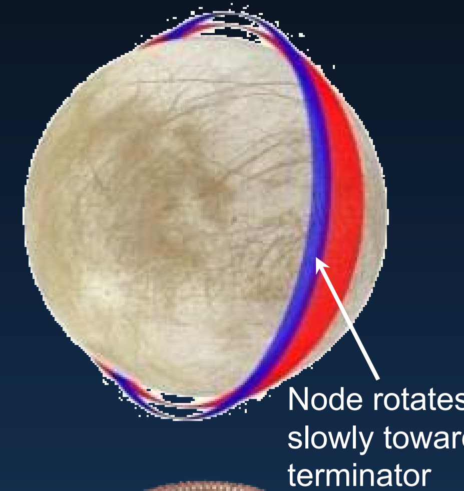
- Io: 3 flybys
  - Opportunities for imaging, IR spectroscopy, and altimetry
  - In situ analysis of extended atmosphere with INMS at 75 km
- Europa: 6 flybys
  - Radar and altimetry characterization and calibration
  - Imaging at up to 10–50 m resolution, NIR 250–1250 m
- Ganymede: 6 flybys
  - Radar sounding of grooved and dark terrains
  - Range of lats, lons for magnetosphere sampling
- Callisto: 9 flybys
  - High-latitude flyby for gravity field determination
  - Ocean characterization with magnetometer
  - Radar for subsurface structure of ancient cratered terrain

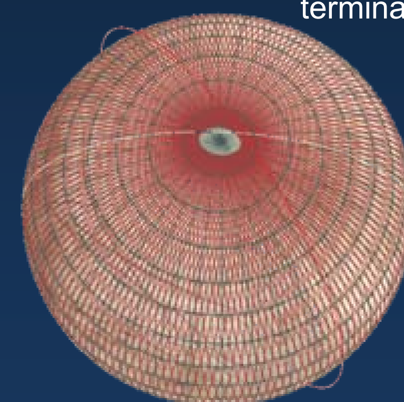
Satellite	≤1000m	≤200m	≤50m	≤10m	Length IPR (km)	Length LA (km)
Io	30%	20%	5%	-	1000	7400
Europa	60%	60%	15%	0.01%	6600	19000
Ganymede	50%	50%	10%	0.02%	17000	28000
Callisto	85%	75%	5%	0.01%	15000	30000

Baseline JEO Europa Science Orbit

- 200 km altitude for early science in the first 28 days, then transition to a 100 km altitude
- Initial orbit at ~2:30 pm LST
- Inclination selected to balance lighting and coverage
  - $85° \leq i \leq 95°$ (selected 95° for slowest orbit rotation)
  - Orbit rotates 0.1 to 0.4 deg/day
- Ground track repeat cycle selected for ground track separation and global imaging coverage
  - Repeat cycle would be set for science needs, would be optimized when payloads are selected
  - 4-eurosol repeat at 200 km gives global coverage in 3 eurosols (~10 days) using every other orbit

Orbit Altitude (km)	Period (min)	Occultation Dur (min)	Orbits Per Day	Ground Speed (km/s)
200	138	46 (33%)	10.4	1.1
100	126	47 (37%)	11.4	1.3





Groundtracks cover 95% of Europa surface

Poles could be imaged off-nadir (some layover)

Notional Europa Science Campaigns

JOI to EOI	Jul 2028	Aug 2028	Sep 2028	Oct 2028

JOI

EOI

Satellite/Jupiter Science

Observing Strategies for Europa Campaigns 1-3

Always on: LA, MAG, PPI, TI, INMS (50%)

2-orbit ops scenario permits power/data rate equalization:

- Even orbits emphasize optical remote sensing:
- Odd orbits emphasize radar sounding to locate water

Targets collected with residual data volume

Eng Assessment (6d)

Europa Science Campaigns

1A | 1B

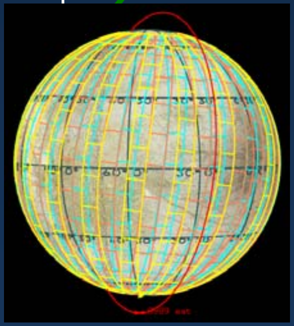
2A | 2B

3

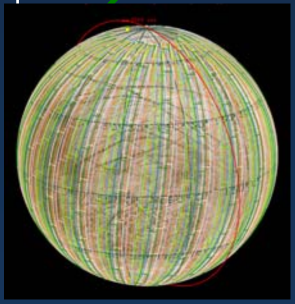
4

Initial Europa Orbit
Altitude: 200 km
Inclination: 95-100 deg
(~85° N lat)
Lighting: 2:30 PM LST
Repeat: 4 Eurosols

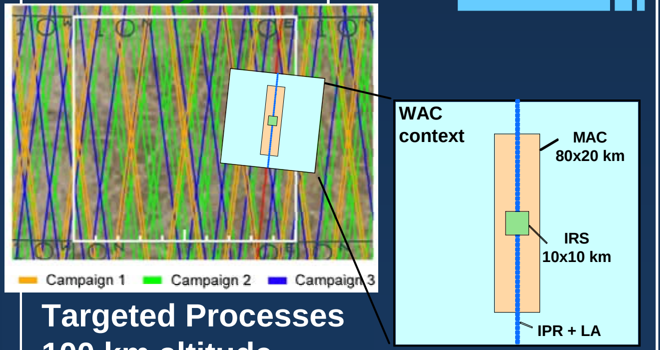
After Campaign 1
Altitude: 100 km
Repeat: 6 Eurosols



Global Framework
200 km altitude
(200 m/pixel WAC)
8 eurosols ≈ 28 days



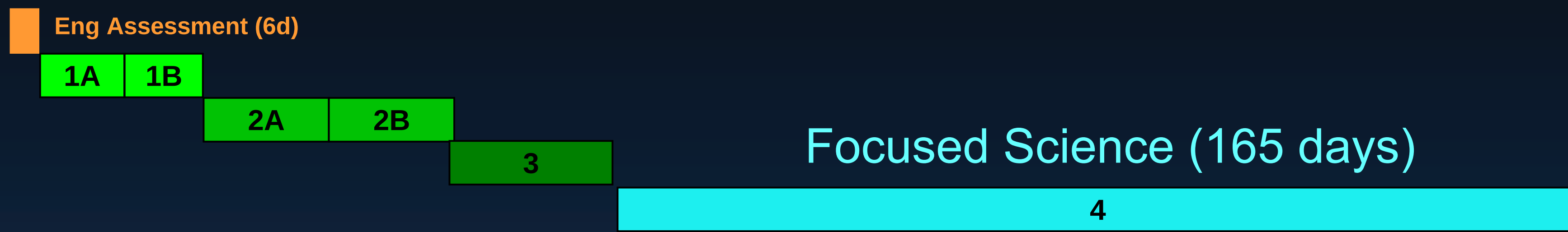
Regional Processes
100 km altitude
(100 m/pixel WAC)
12 eurosols ≈ 43 days



Targeted Processes
100 km altitude
8 eurosols ≈ 28 days

Europa Campaigns 1-3
total 99 days

Notional Europa Science Campaigns



<u>By end of Europa Campaign 3:</u>

99 days orbital science
4 global maps
- 2 @ 200m Color + Stereo
- 2 @ 100m Stereo

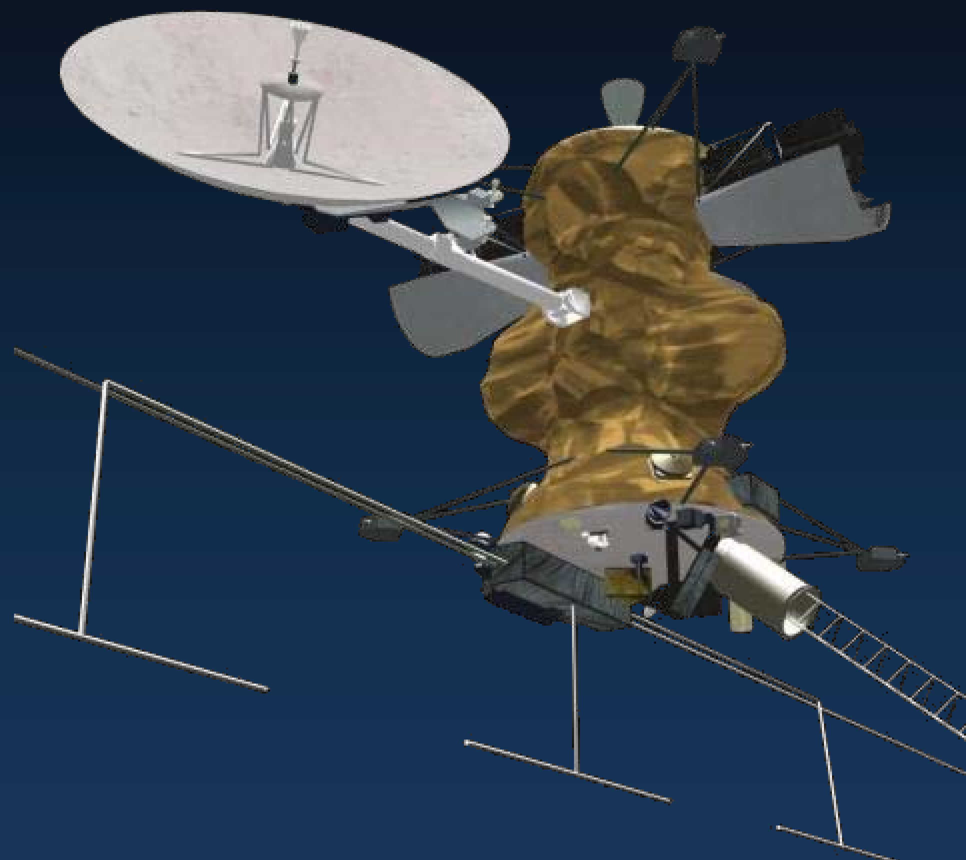
730 imaging and radar targets
18 km profile spacing for LA and TI
35 km spacing for IPR and VIRIS
400 UVS stellar occultations
700 Gb data return

- Follow up on discoveries
- Finer global and regional grid of profiling observations (IPR, VIRIS, TI)
- Continue gravity, laser altimetry, and fields and particles measurements
- Additional coordinated target sets
  - Investigate new discoveries and priorities
  - Characterize candidate future landing sites
- Off-nadir NAC stereo images
- Lower altitude operations
- Monitor Io and Jupiter, 1 to 2 times per week

Extended time in Europa orbit allows additional investigations and exploration

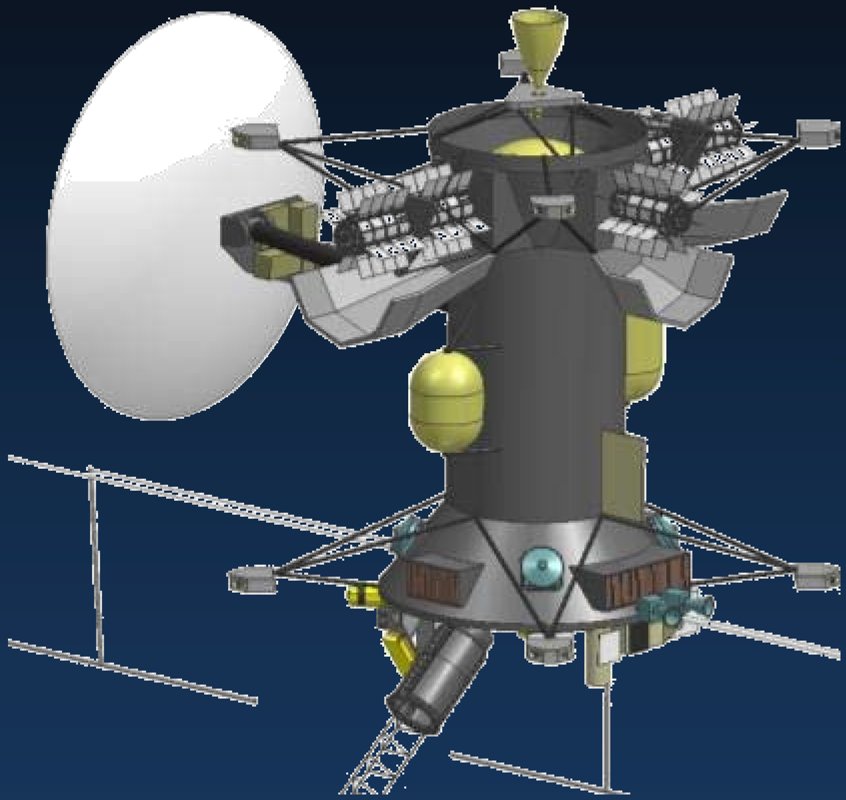
JEO Spacecraft Key Technical Drivers

- Venus fly-by
- Radiation
- Planetary Protection
- Nadir Pointed Instrument Deck
- Real-time Science during Europa orbit
- 17 GB storage for Jovian tour
- 1 GB storage for Europa science



Artist's Rendering

JEO Flight System

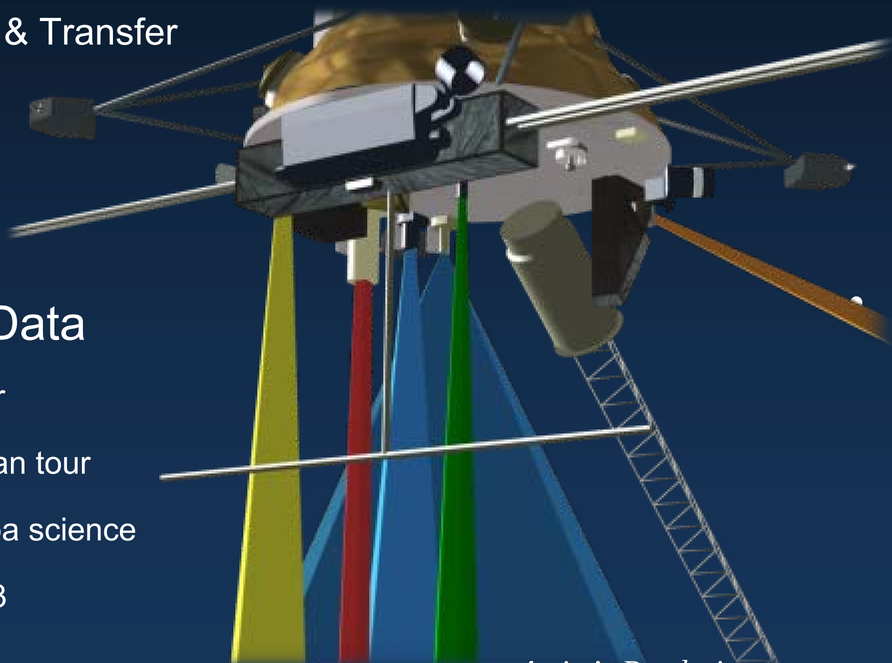


Artist's Rendering

- Three-axis stabilized with instrument deck for nadir pointing
- Articulated HGA for simultaneous downlink during science observations
- Data rate of 150 kbps to DSN 34m antenna on Ka-band
- Performs 2260 m/s ΔV with 2646 kg of propellant
- Five MMRTGs provide 540 W (EOM) with batteries for peak modes
- Rad hardened electronics with shielding to survive 2.9 Mrad (behind 100 mil Al) environment
- 9 year lifetime
- Healthy mass and power margins (43%, >33% respectively)

Payload Design Drivers

- 165 kg total mass
  - Including Contingency
- 71 W average power
  - Data Collection & Transfer
  - Actuators
  - Thermal
  - Stand-by
- Command and Data
  - Rad750 Processor
  - 17 Gb during Jovian tour
  - 1 Gb during Europa science
  - SpaceWire & 1553
- Pointing
  - S/C pointed Nadir during Europa science
  - Instruments must provide own articulation



Artist's Rendering

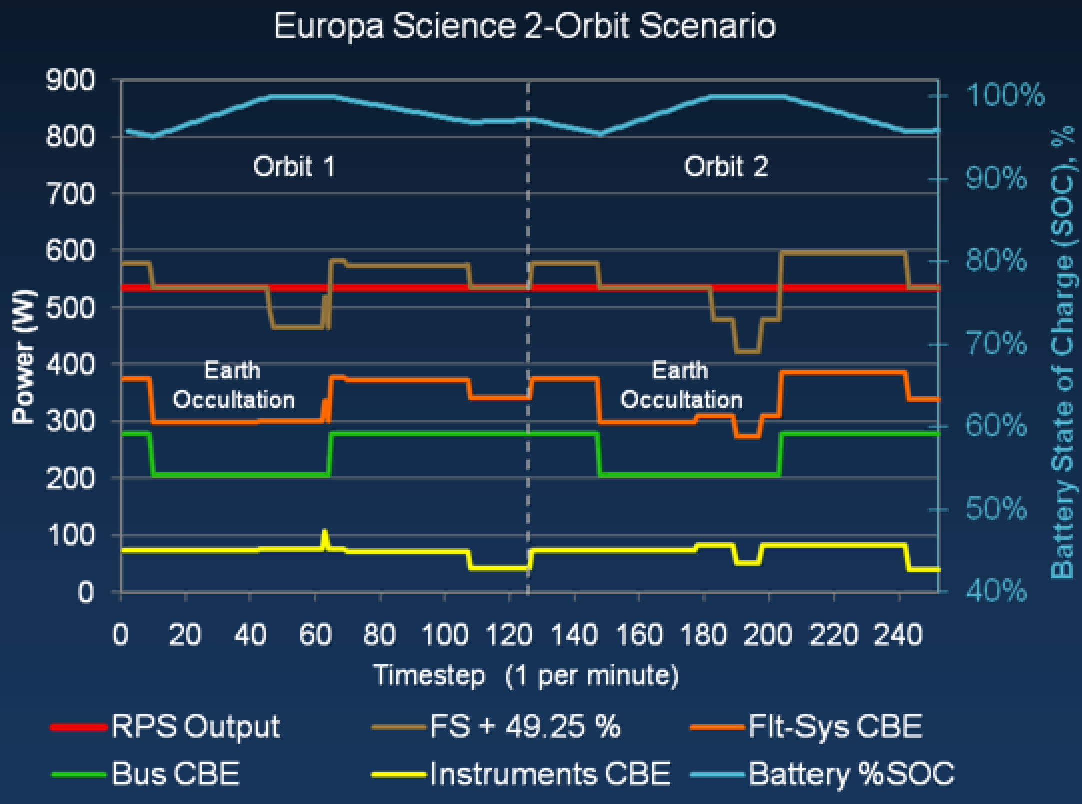
- Thermal
  - Instruments provide own heating/cooling
  - Passive thermal control preferred
  - Power for thermal comes out of 71 W average
- Radiation
  - Shielding mass comes out of 165 kg allocation
  - Most hardware will require more than 2.54 mm (100 mils) of shielding
- Planetary Protection
  - Instruments must be sterilized

JEO Planning Payload

JEO Instrument	Similar Instruments
Radio Science	New Horizons USO, Cassini KaT
Laser Altimeter	MESSENGER MLA, NEAR NLR
Ice Penetrating Radar	MRO SHARAD, Mars Express MARSIS
VIS-IR Spectrometer	MRO CRISM, Chandrayaan MMM
UV Spectrometer	Cassini UVIS, New Horizons Alice
Ion & Neutral Mass Spectrometer	Rosetta ROSINA RTOF
Thermal Instrument	MRO MCS, LRO Diviner
Narrow-Angle Camera	New Horizons LORRI, LRO LROC
Camera Package	MRO MARCI, MESSENGER MDIS
Magnetometer	MESSENGER MAG, Galileo MAG
Particle and Plasma Instrument	New Horizons PEPSSI, Deep Space 1 PEPE

Notional Science Scenarios

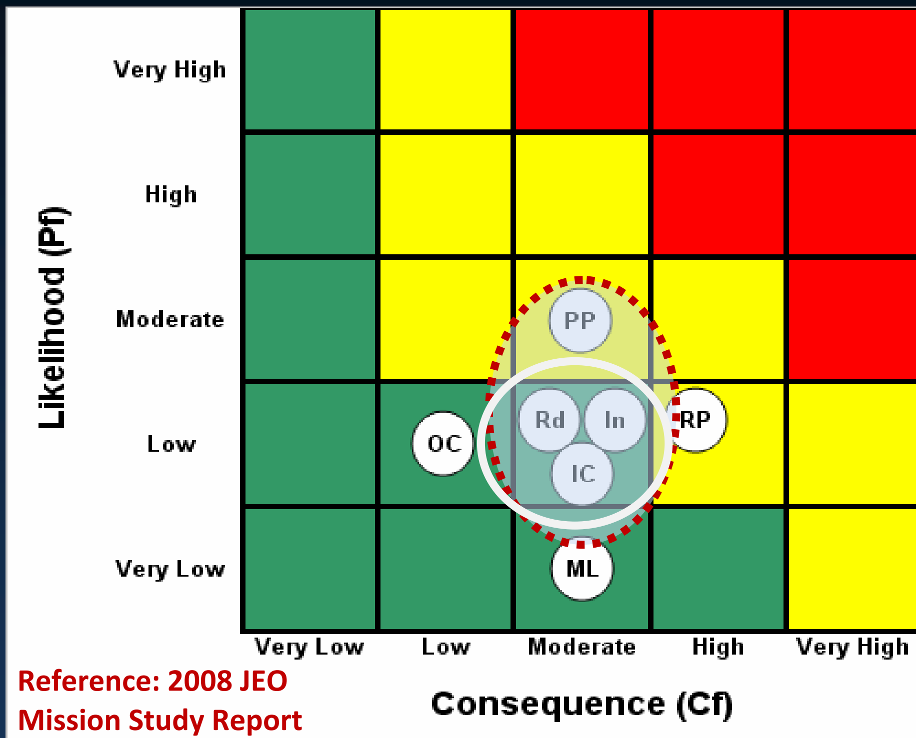
Driving scenario is the baseline Europa Science scenario



- Power is highly constrained
  - Limits instrument modes and downlink data rates
- Science observation scenario is data storage limited
  - Data is transferred real-time to the ground
- 2-orbit operations scenario permits power/data rate balance

Evolving science scenarios will be limited by power and data storage

JEO Mission Concept Risk Assessment



- “Rd”, “IC’ and “In” are radiation related risk categories
- Instrument Development is one of the three radiation risk categories
- PP compliance requires in-flight sterilization via radiation

Risk Categories

Rd Radiation effects in parts, materials, & sensors
IC Internal charging
In Instrument development

PP Planetary protection
OC Operational complexity
RP Radioisotope power source
ML Mission life time

Radiation and PP are major risk categories for the JEO mission concept

Major Components of Approach to Radiation Challenge

- Risk Mitigation Plan (Starting in Pre-Phase A)
  - Early emphasis on reducing risk
  - Periodic peer reviews of plan
- Early emphasis on Instrument development
- Management and System Engineering Teams augmented
- External Advisory Board of Experts
- Extended schedule
- Increased cost for parts, testing, analysis, redesign
  - No heritage
- Design Approach
  - Rad-hard by Process
  - Rad-hard by Design
  - Rad-Hard by Shielding
  - Rad-hard by “System”

Challenge being addressed as a “system”

System Design Process

Analysis

Input Variables

- Science Objectives
- Mission Design—Environment
- Launch Vehicle Capabilities
- Part Capabilities

Dependent Components

- Shielding Design
- Instrument and Circuit Design
- Margin Assessment
- Risk Analysis
- Cost Analysis

Iteration

- System design iterative process continues through Phase B as capabilities evolve and science instrument capabilities solidify
- Acceptable cost and risk posture is a joint discussion between project and NASA Headquarters

Risk Mitigation Plan

Key Elements and Sample Accomplishments

- **Risk Mitigation Plan: Radiation and Planetary Protection**
  - **Focuses on Pre–Phase A activities**
  - **Defining & validating approach**
  - **Obtaining data**

1.0 System Reliability Model

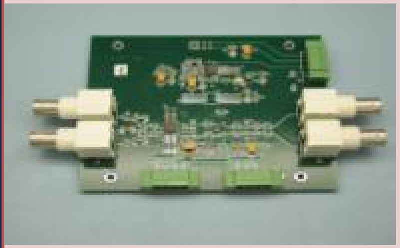
2.0 Environment and Shielding Model

3.0 Radiation Design Methods

4.0 Sensors and Detectors

5.0 Parts Evaluation and Testing

6.0 Approved Parts and Materials List (APML)



Signal Chain Circuit Breadboard

Developed and validated worst-case analysis as part of radiation tolerance design methodology

Image from hardened CMOS test array after 1 Mrad TID provides proof of concept for JEO science imagers

Radiation-tolerant design methodology developed and validated in the laboratory provides design guidelines for subsystem and instrument providers

2009 EJSM Instrument Workshop

- Purpose of the Workshop
  - Prepare the instrument provider community to be ready to propose to the JEO and JGO opportunities
  - Enable an interaction between the radiation capability community and the instrument providers
- Topics covered
  - Background and Context
  - System Engineering, Radiation and Planetary Protection Challenges
  - Designing for Key Challenges
  - Instrument Solicitation and Expectorations
- Attendees
  - Over 275 people attended
  - 38 radiation capable companies/vendors had posters or booths
- All presentations, registrant list can be downloaded from the web

opfm.jpl.nasa.gov

Sample Documents Available for Download

Theme	Title	Download
System	EJSM Risk Mitigation Plan: Radiation and Planetary Protection	
	Return to Europa: Overview of the Jupiter Europa Orbiter Mission	
	Radiation Challenges and Risk Mitigation for the JEO Mission	
Environment	Jupiter Europa Orbiter Radiation Environment	
Radiation Effects	Designing Circuits and Systems for Single Event Effects	
	Test Method for Enhanced Low Dose Rate Sensitivity (ELDRS)	
	Radiation Effects on Detectors and Key Optical Components	
Design Guidelines	Avoiding Problems caused by S/C on-orbit Internal Charging Effects	
	EJSM Radiation Design Guidelines	
	Total Dose and Displacement Damage Design Guideline	soon
	ASIC via FPGA Gu*idelin*e with Addendum on Europa	
	OPFM Long Life Design Guidelines	
Parts	Memory Investigation for JEO Mission	
	JEO Parts Program Requirements	
	Approved Parts and Materials List	Limited access

opfm.jpl.nasa.gov

Near-Term Timeline

- Instrument workshop #4, Summer 2010 timeframe in the Pasadena, CA area
- Increased JEO technical efforts on
  - APML, parts testing and evaluation
  - Core components identification (power converters, microprocessors, FPGAs/ASICs)
  - Shielding approach for sensors/detectors
  - System modeling
- JEO Mission Concept Review, September 2010
- JEO Mission Phase A start, January 2011
- JEO Payload Announcement of Opportunity release, January 2011