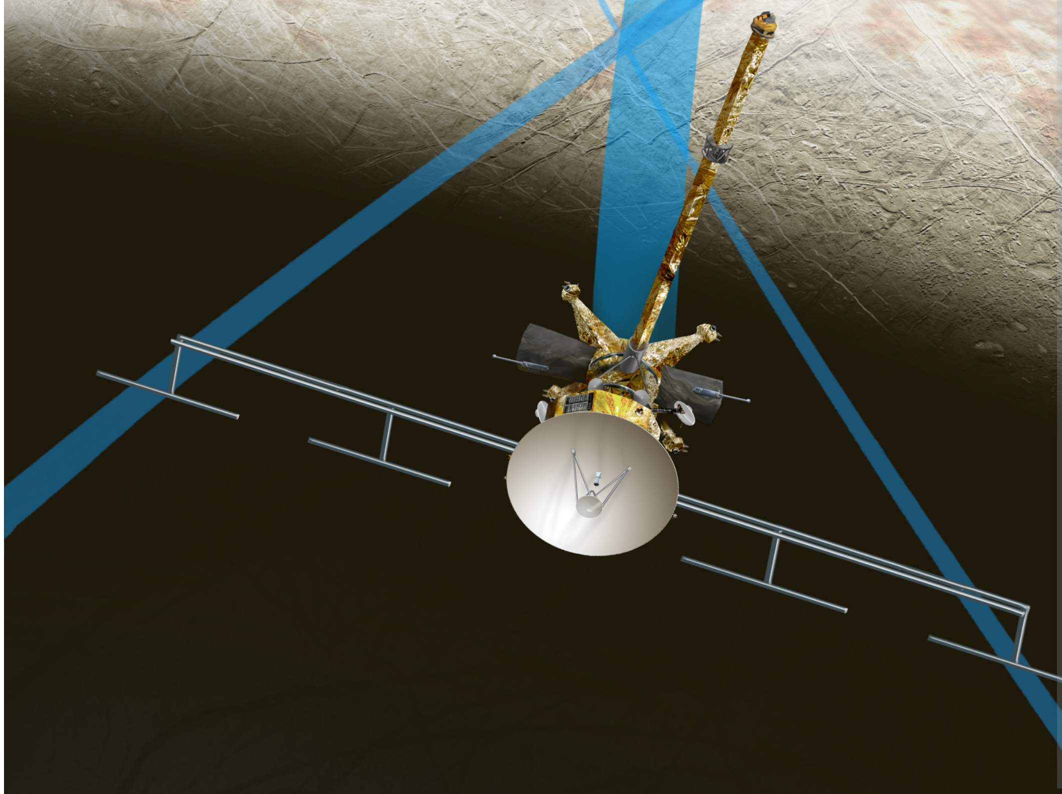
The Europa Clipper

OPAG Update



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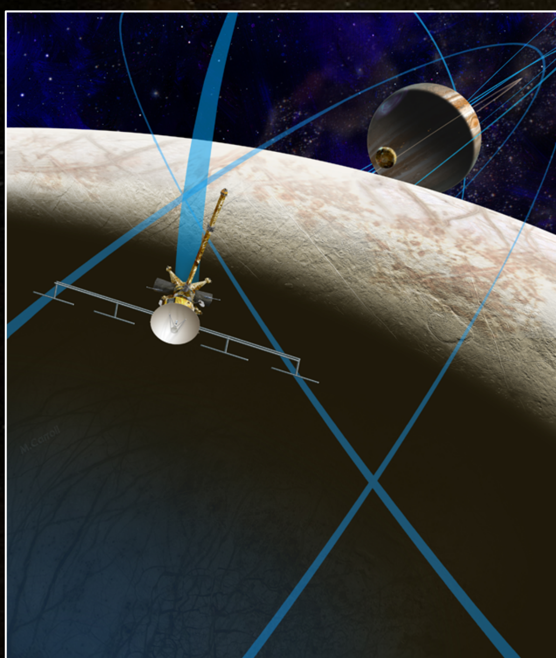
The Europa Clipper

Overview and Science

Robert Pappalardo
Project Scientist

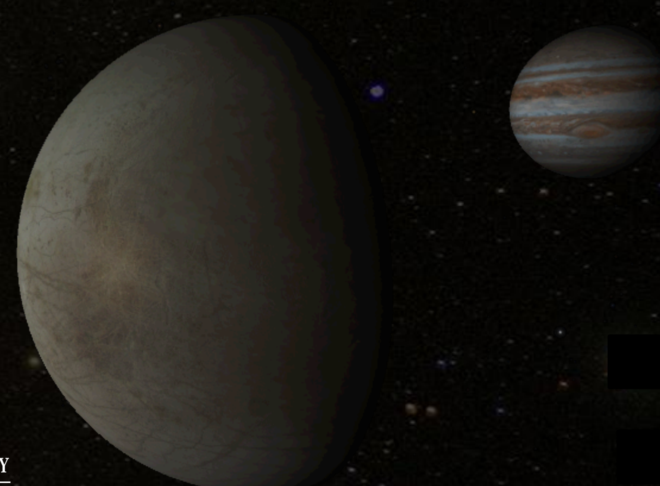
Acknowledgement

This report represents the combined effort since April 2011 of the Europa Science Definition Team and a study team from the Jet Propulsion Laboratory (JPL) and Johns Hopkins University's Applied Physics Laboratory (APL). The team acknowledges and appreciates the support of NASA's Program Scientist and Program Executive.



Jet Propulsion Laboratory
California Institute of Technology

JOHNS HOPKINS UNIVERSITY
Applied Physics Laboratory



Overview

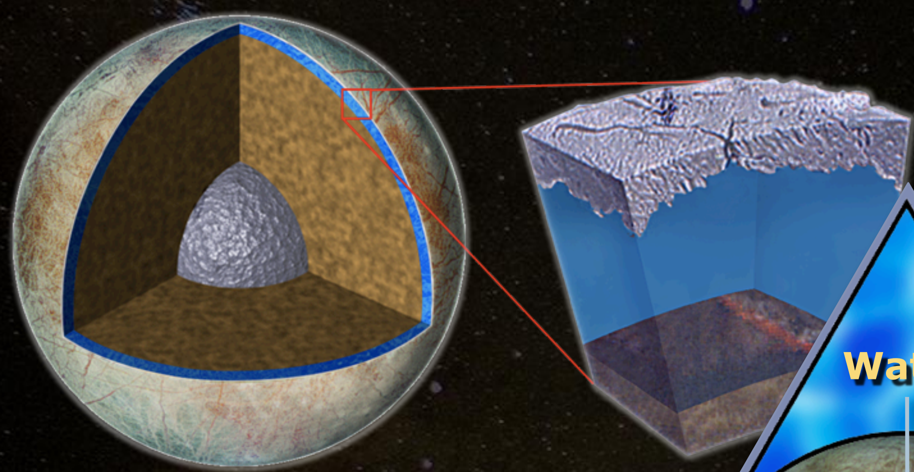
Where we left off

- Submitted report to NASA in December 2012 on "Enhanced" (including reconnaissance) Europa Orbiter and Europa Clipper concepts
- Briefed OPAG in January 2013

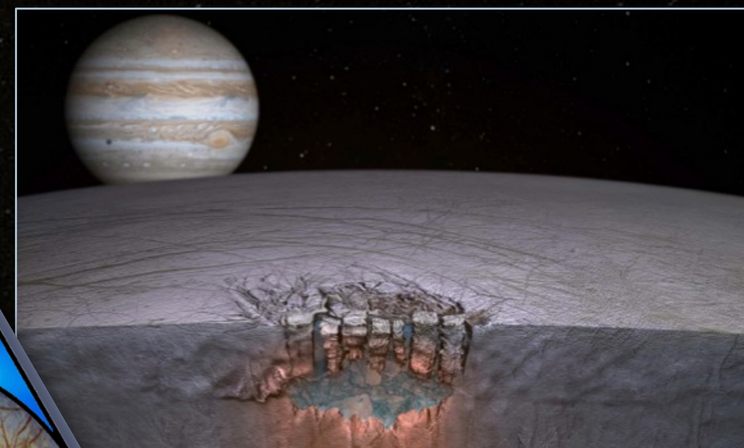
Major events since last OPAG meeting

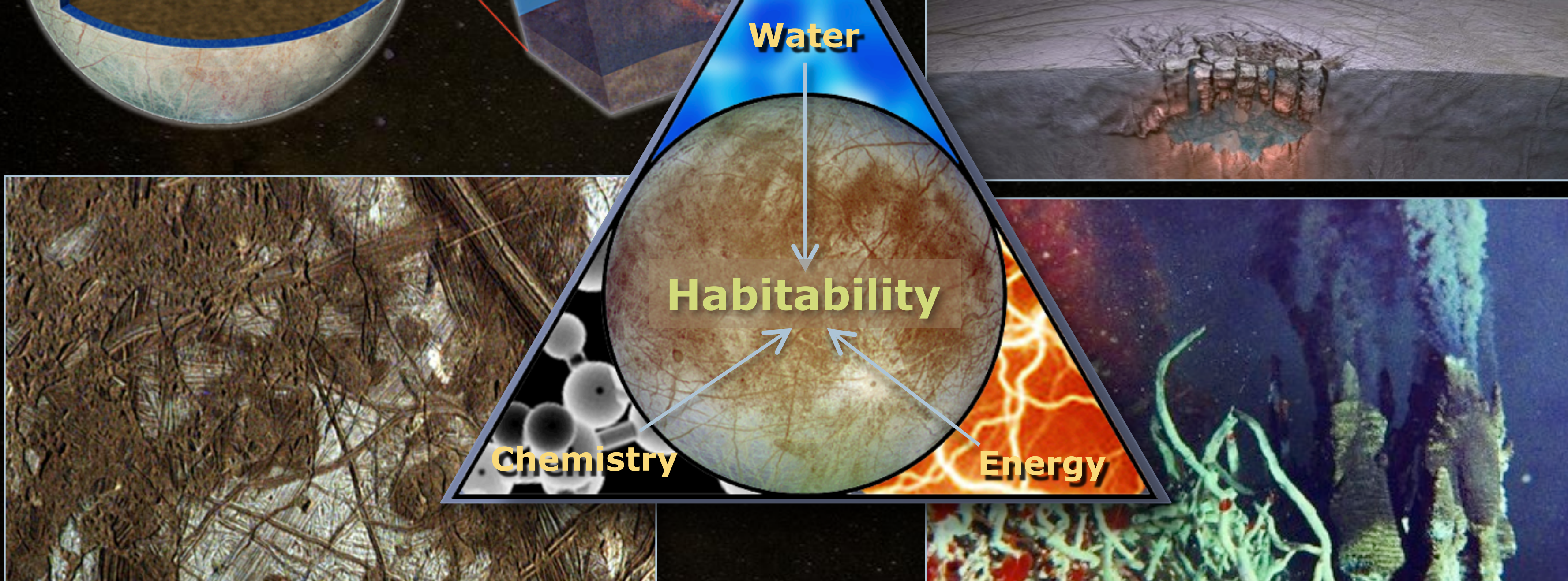
- Europa Science Advisory Group in place, with Prockter as chair:
  - Bills, Blaney, Blankenship, Hoehler, Lorenz, McGrath, Mellon, J. Moore
- Barry Goldstein named Europa Clipper Project Manager
- Congress directed NASA to use FY13 funds to continue Europa mission concept development
- NASA directed continued evaluation of only the Clipper concept
- NASA released ICEE NRA to aid in retiring instrument risk
- Top-priority mission trades are being considered and worked
- Reconnaissance traceability and mission concept are being matured
- Notional trajectory updated to improve the science potential

Europa:Ingredients for Life?



Water: Are a global ocean and lakes of water hidden below the ice?





Chemistry: Do red surface deposits tell of habitability below?

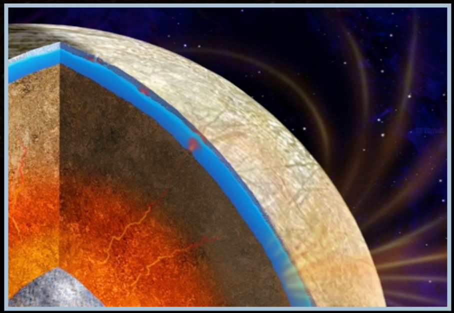
Energy: Can chemical disequilibrium provide energy for life?

Europa Clipper Science

Goal: Explore Europa to investigate its habitability

Objectives:

- **Ice Shell & Ocean:** Existence and nature of water within or beneath the ice, and processes of surface-ice-ocean exchange
- **Composition:** Distribution and chemistry of key compounds and the links to ocean composition
- **Geology:** Characteristics and formation of surface features, including sites of recent or current activity

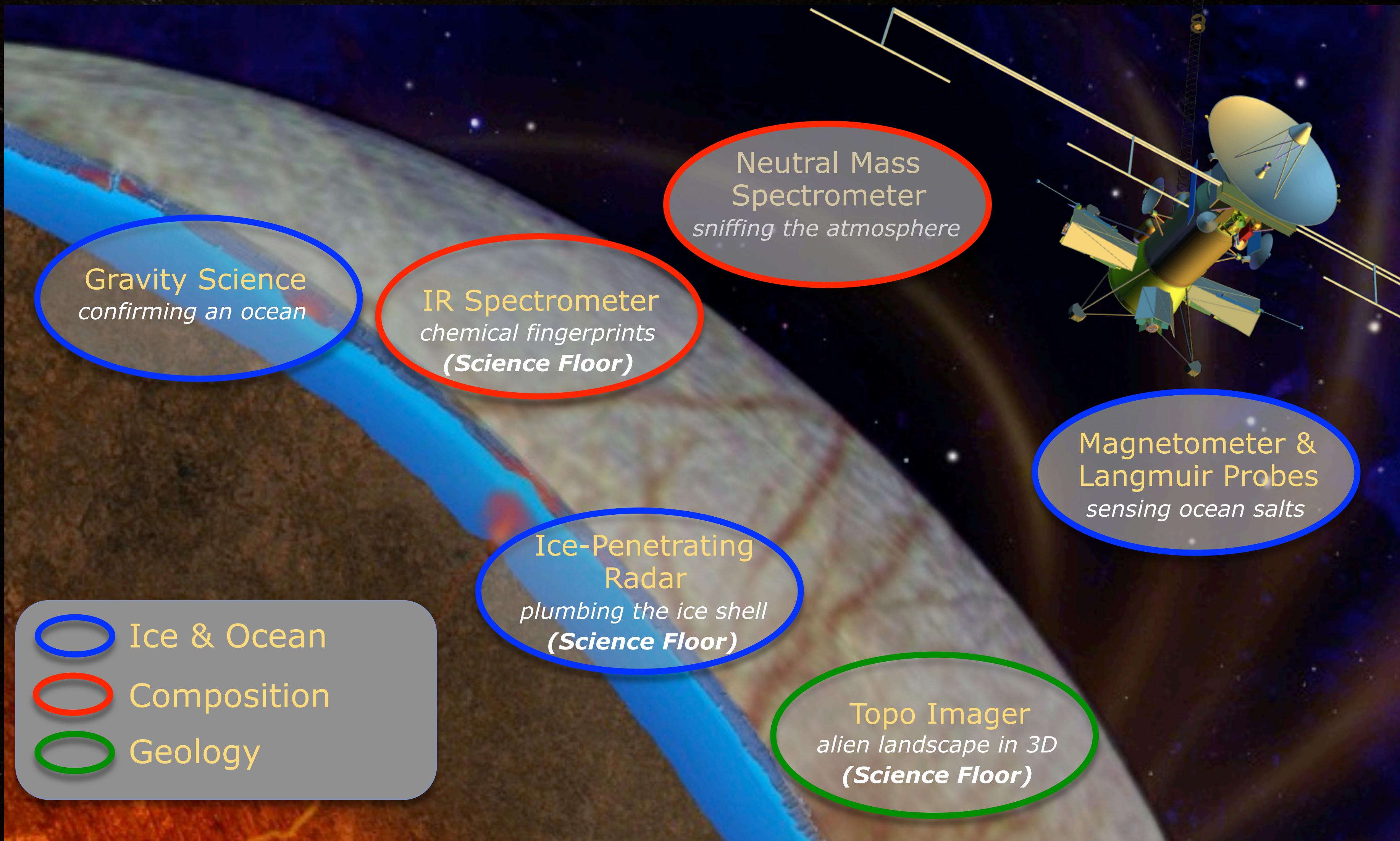


Pre-Decisional — For Planning and Discussion Purposes Only.

Science Traceability Matrix

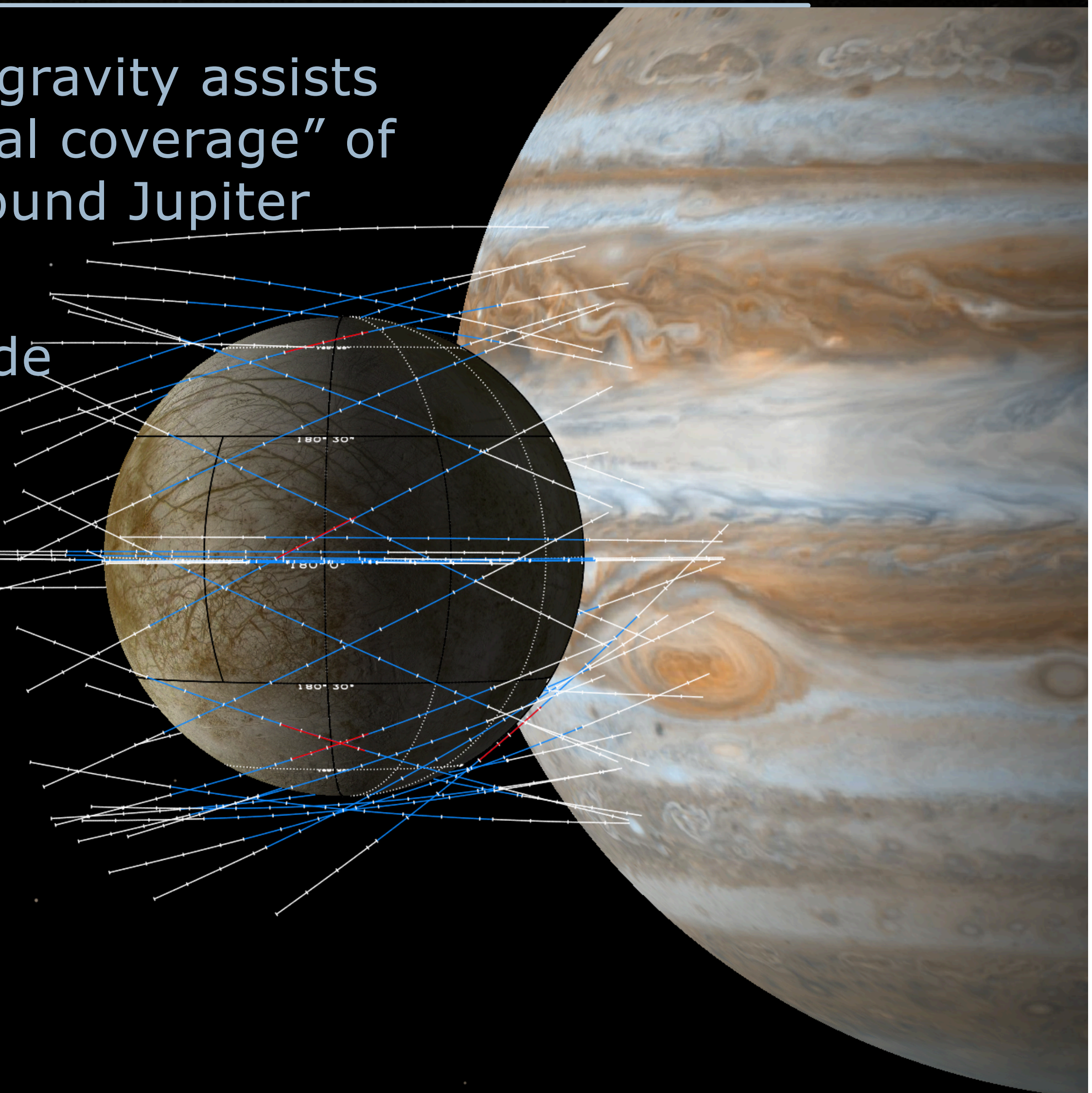
Goal	Objective		Investigation	
Explore Europa to investigate its habitability	Ice Shell and Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange.	IO.1	Characterize the distribution of any shallow subsurface water and the structure of the icy shell.
			IO.2	Determine Europa's magnetic induction response to estimate ocean salinity and thickness.
			IO.3	Search for an ice-ocean interface.
			IO.4	Correlate surface features and subsurface structure to investigate processes governing material exchange among the surface, ice shell, and ocean.
			IO.5	Determine the amplitude and phase of gravitational tides.
			IO.6	Characterize regional and global heat flow variations.
	Composition	Understand the habitability of Europa's ocean through composition and chemistry.	C.1	Characterize the composition and chemistry of the Europa ocean as expressed on the surface and in the atmosphere.
			C.2	Determine the role of Jupiter's radiation environment in processing materials on Europa.
			C.3	Characterize the chemical and compositional pathways in Europa's ocean.
	Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.	G.1	Determine sites of most recent geological activity, and characterize localities of high science interest.
			G.2	Determine the formation and three-dimensional characteristics of magmatic, tectonic, and impact landforms.

Model Payload



Innovative Mission Concept

- Utilize multiple satellite gravity assists to enable “global-regional coverage” of Europa while in orbit around Jupiter
- Current mission design consists of 45 low-altitude flybys of Europa from Jupiter orbit over 3.5 yr
- Minimizes time in high radiation environment (2.1 Mrad TID*)
- Simple repetitive operations

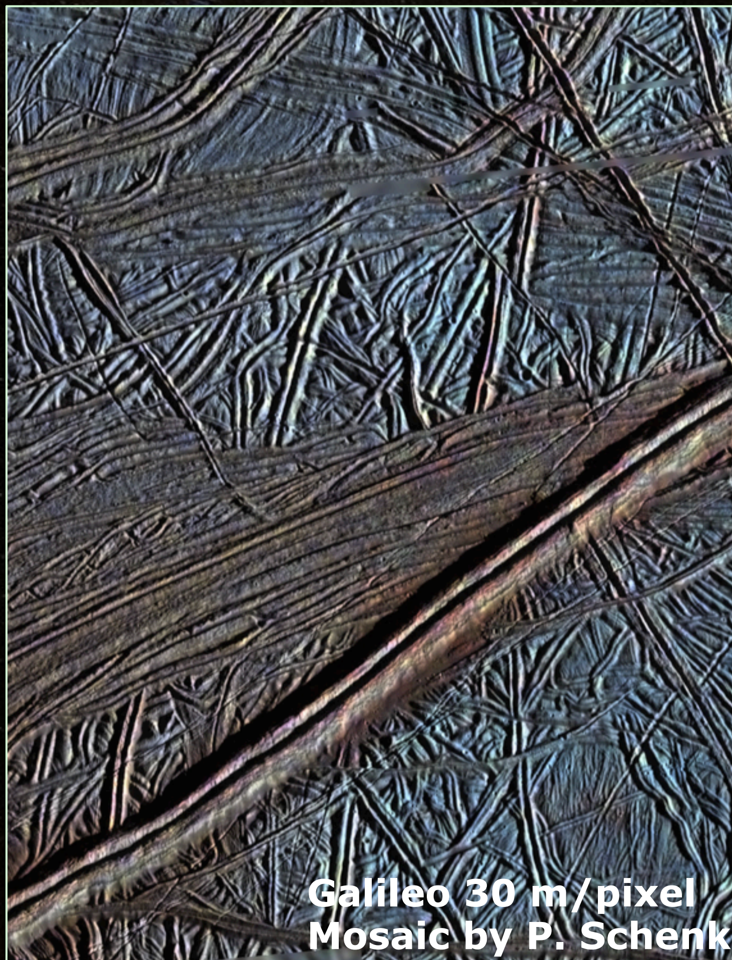


*Si behind 100 mil Al, spherical shell

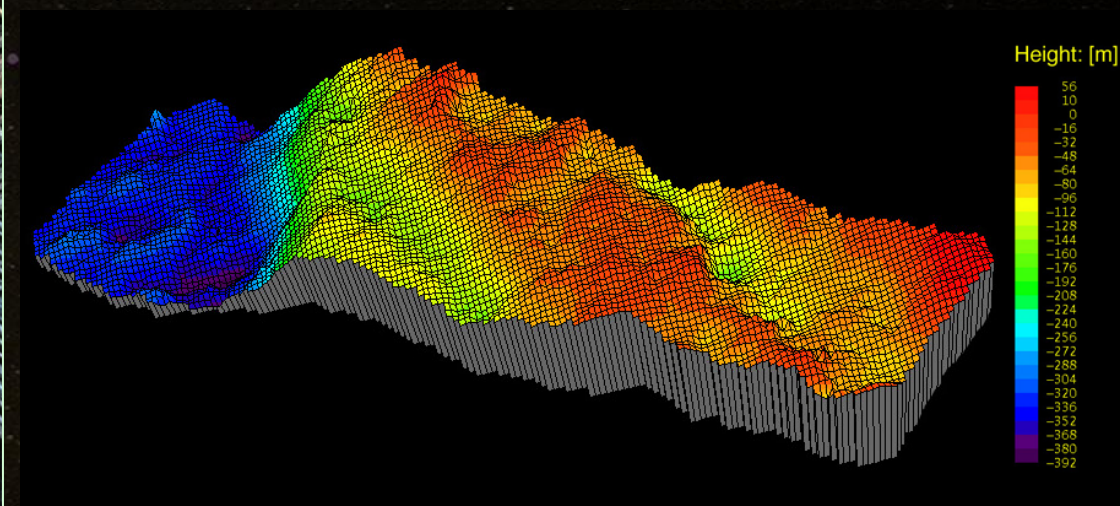
Geology • Composition • Ice Shell & Ocean

Geological activity:

- Characterize high-interest areas
- Seek signs of recent activity



Galileo 30 m/pixel
Mosaic by P. Schenk



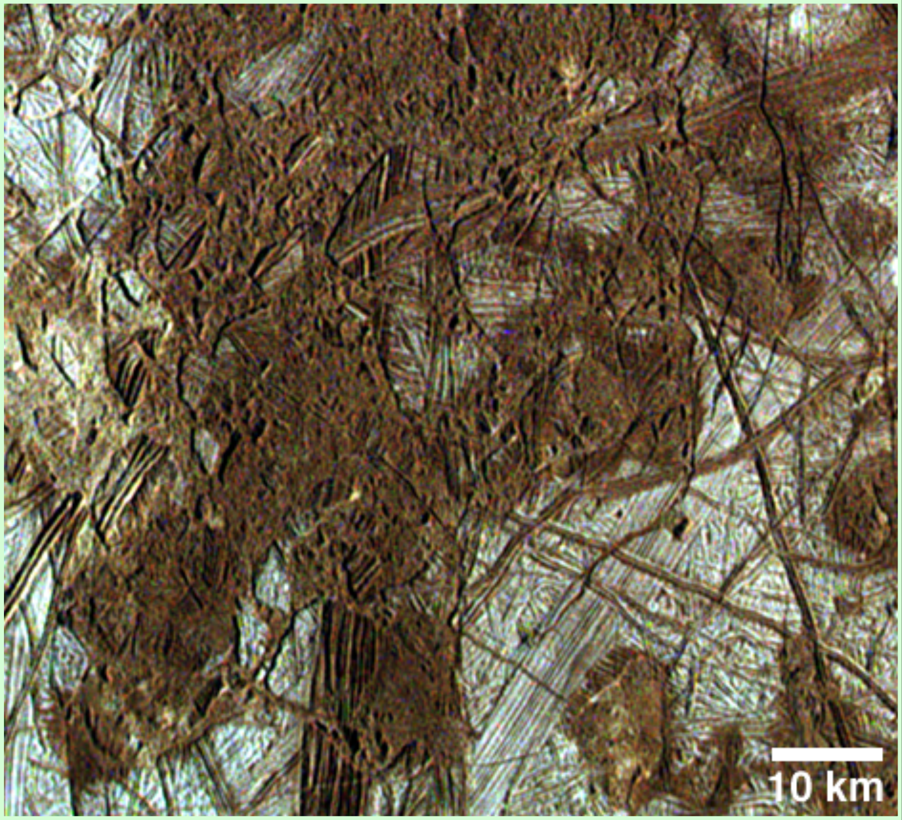
Europa high-resolution topography: 10 m vert.
Elevation model by B. Giese

Stereo imaging can elucidate geology and recent activity

Geology • Composition • Ice Shell & Ocean

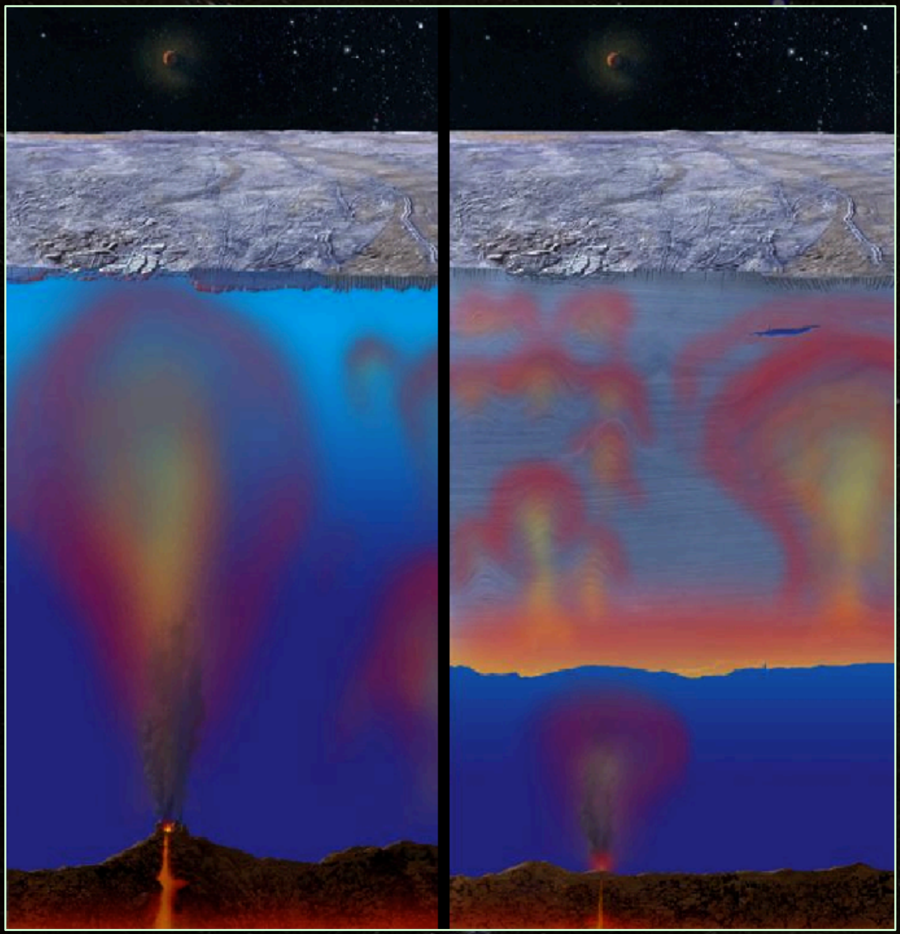
Composition & chemistry:

- Composition and chemistry on surface and in atmosphere
- Radiation effects
- Chemical and compositional pathways from the ocean



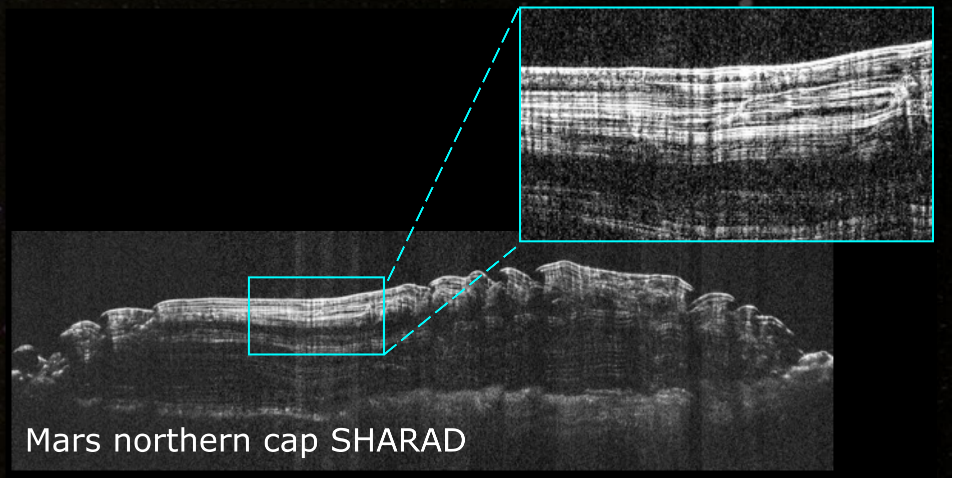
Infrared and neutral mass spectroscopy can derive surface and atmospheric composition to understand habitability

Geology • Composition • Ice Shell & Ocean



Ice shell characteristics:

- Shallow water
- Ice-ocean interface
- Material exchange
- Heat flow variations

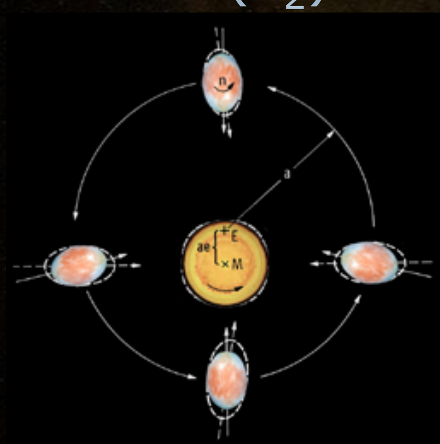


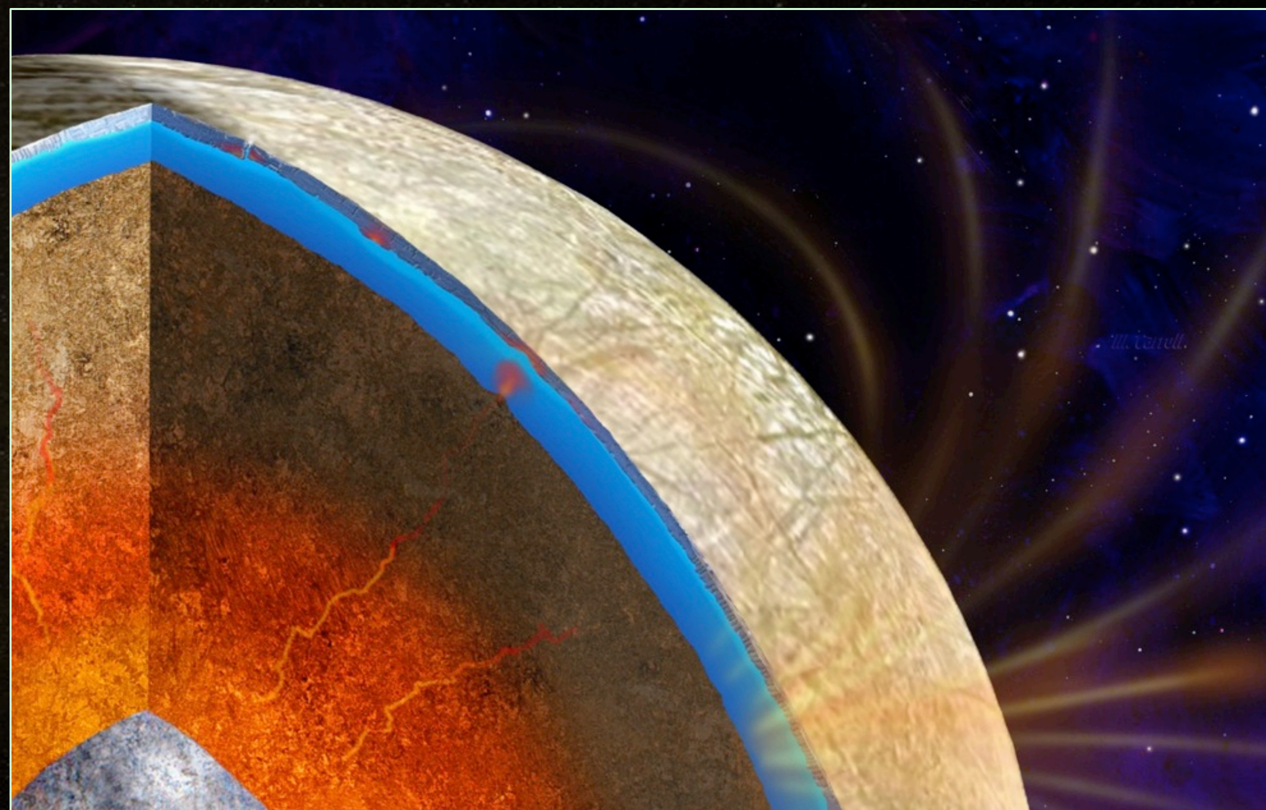
Ice-penetrating radar can find water in and beneath the icy shell

Geology • Composition • Ice Shell & Ocean

Ocean characteristics:

- Magnetic induction (ocean salinity & thickness)
- Gravitational tides (k_2)

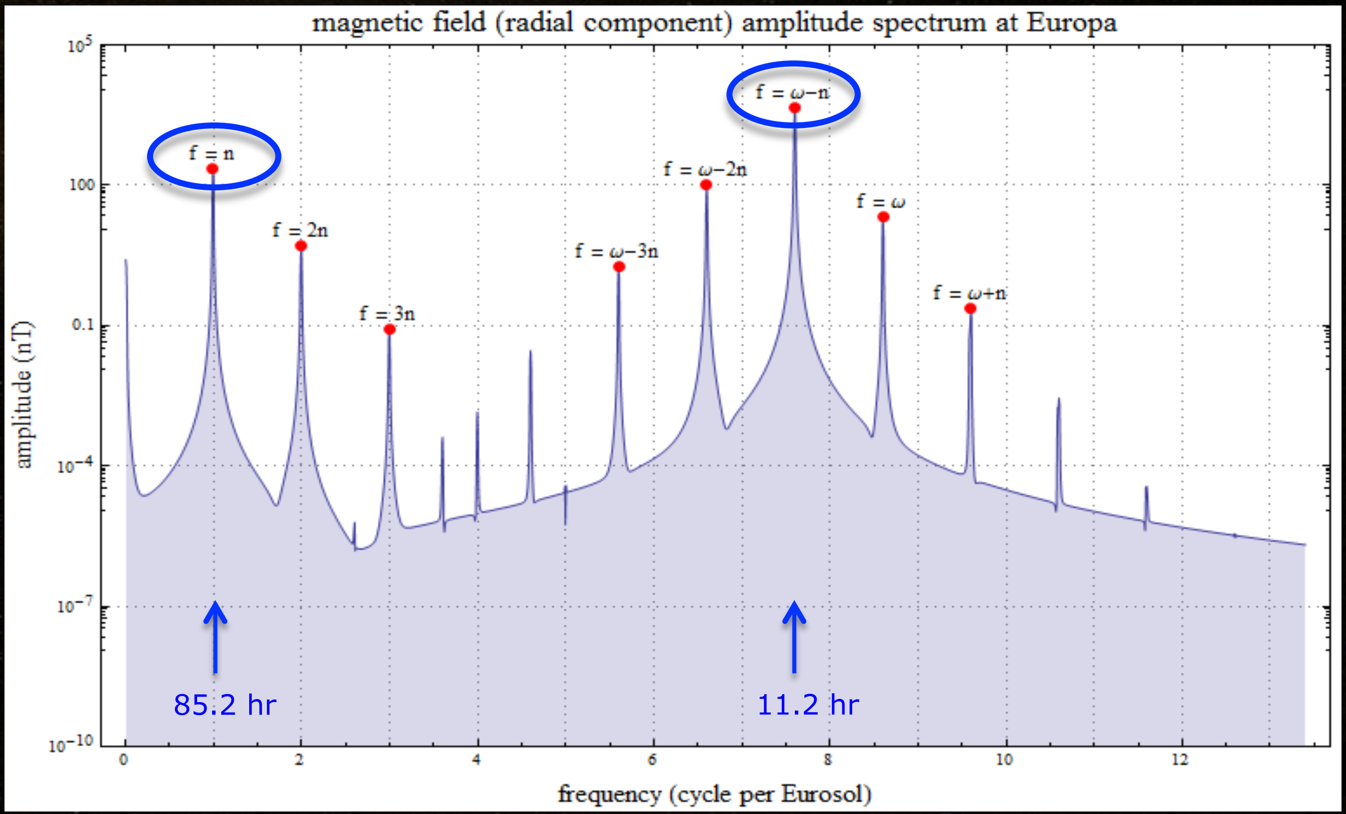




Gravity and magnetometry can confirm and characterize the ocean

Magnetometry from Flybys

- From flybys, Europa Clipper could measure response at the 2 periods with largest input amplitude, necessary to infer ocean salinity and thickness
  - 11.2 hr (Europa synodic period); 85.2 hr (Europa orbital period)



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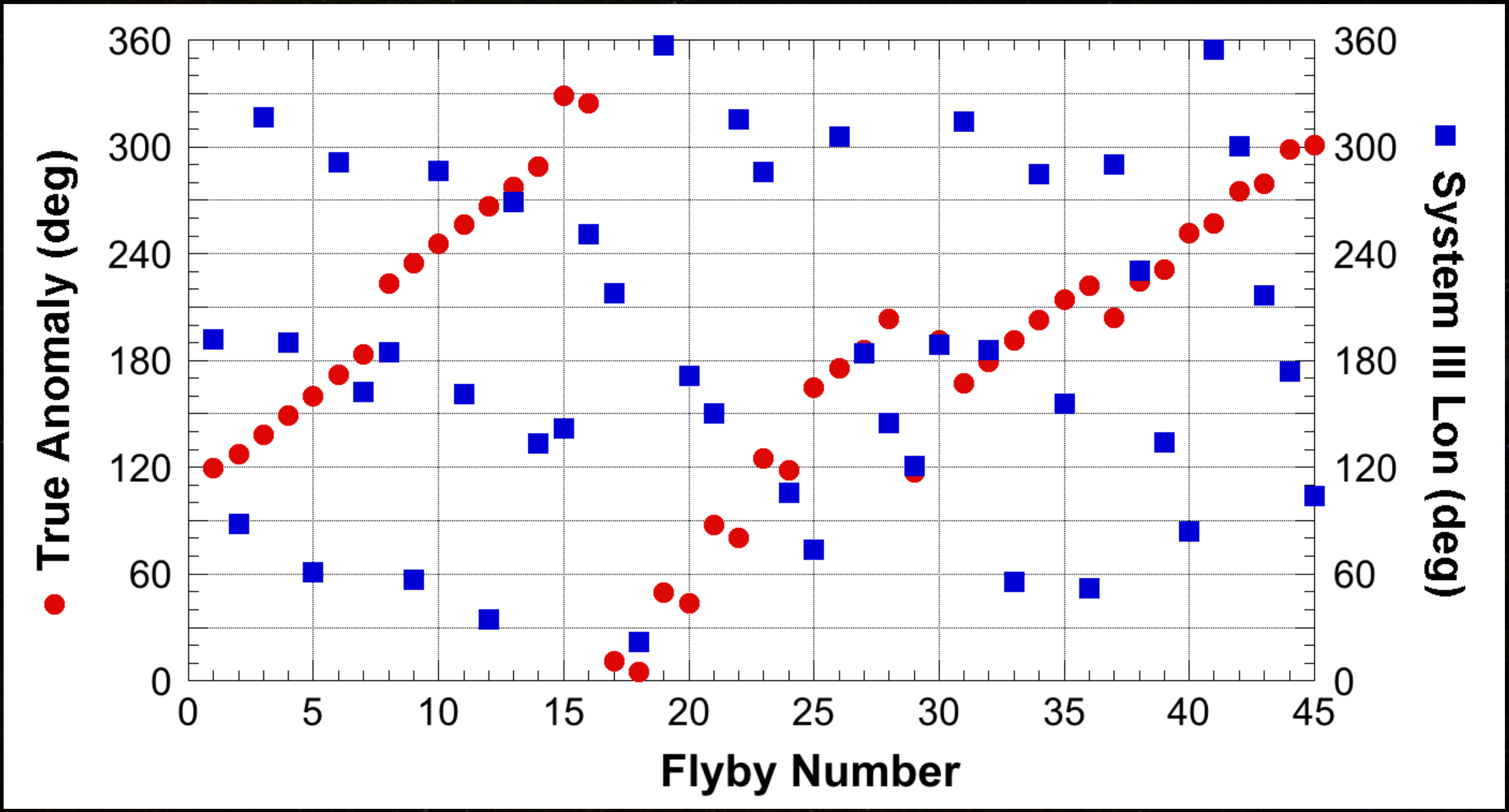
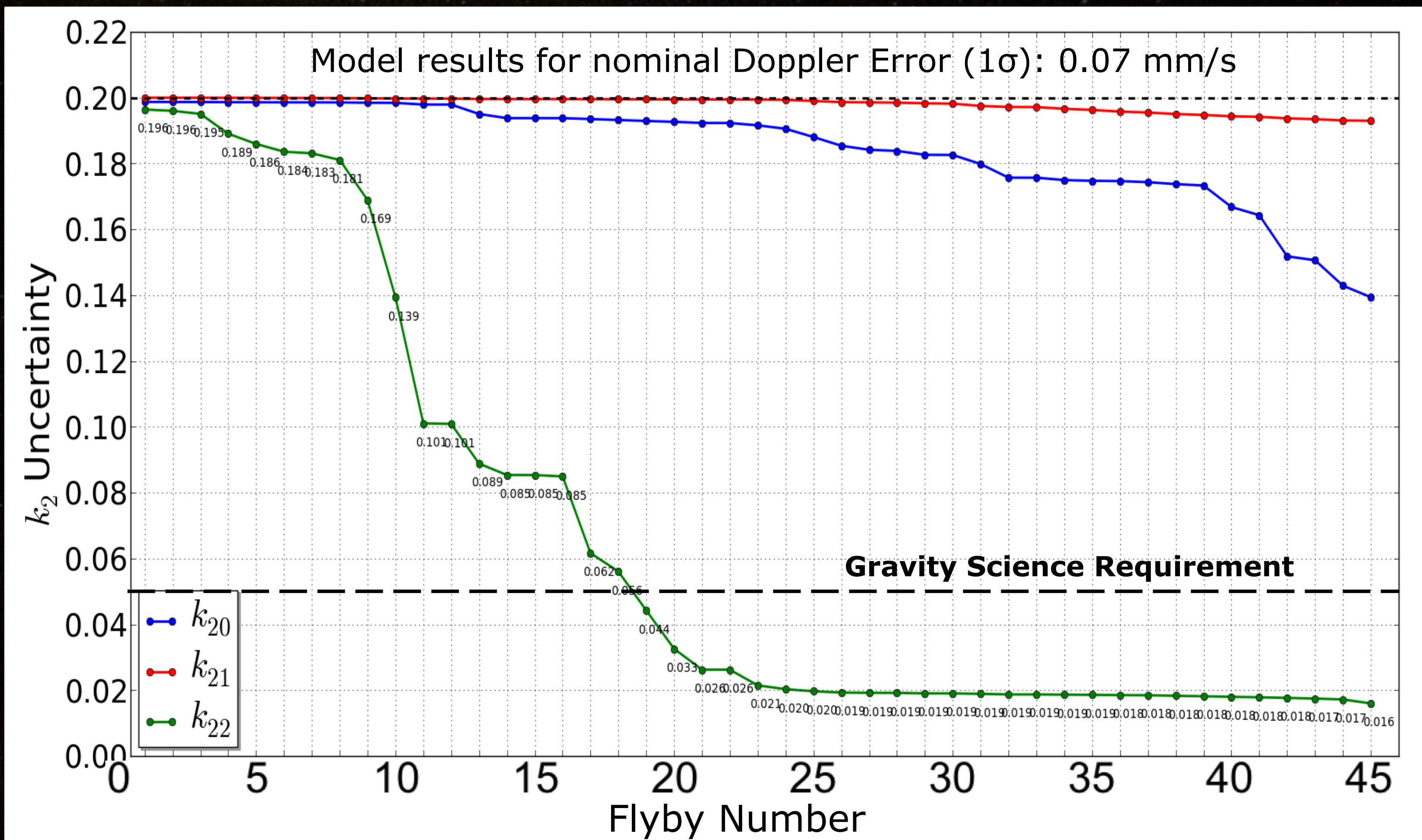
Gravity and Magnetometry from Flybys

- Europa Clipper flybys sample a wide range of true anomalies and Jupiter longitudes to enable gravity (k_2) and magnetic (induced field) measurements



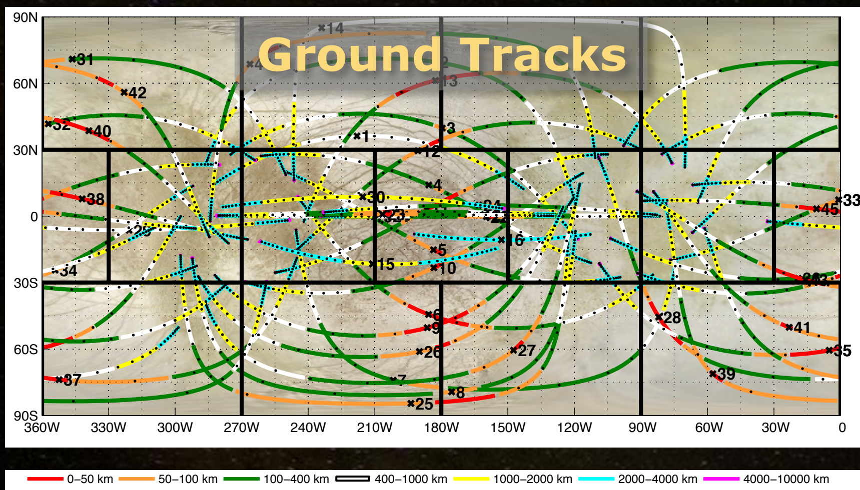
Gravity Science from Flybys

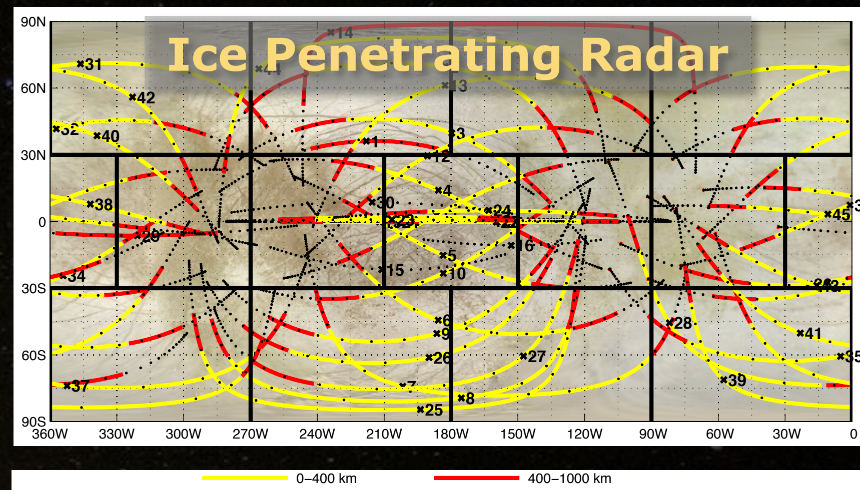
- Assuming nominal Doppler error, parametric evaluation predicts gravity requirement $\sigma(k_{22}) < 0.05$ can be met

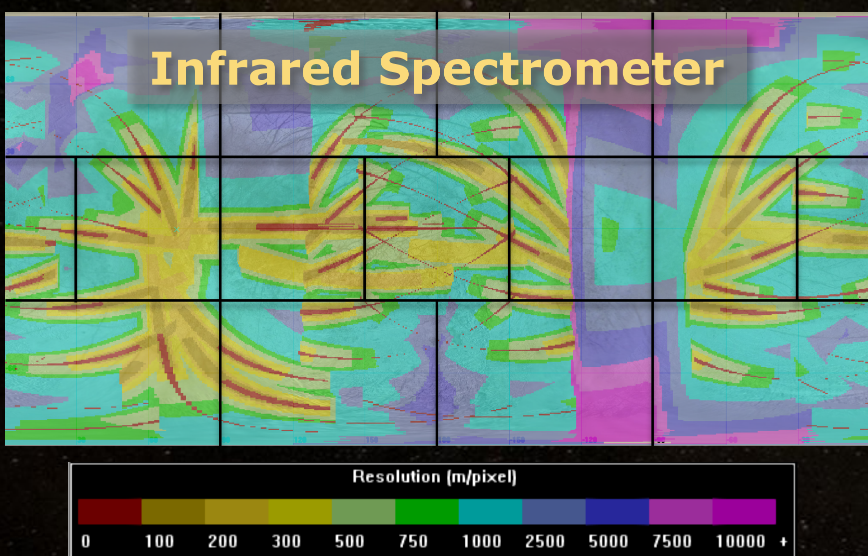


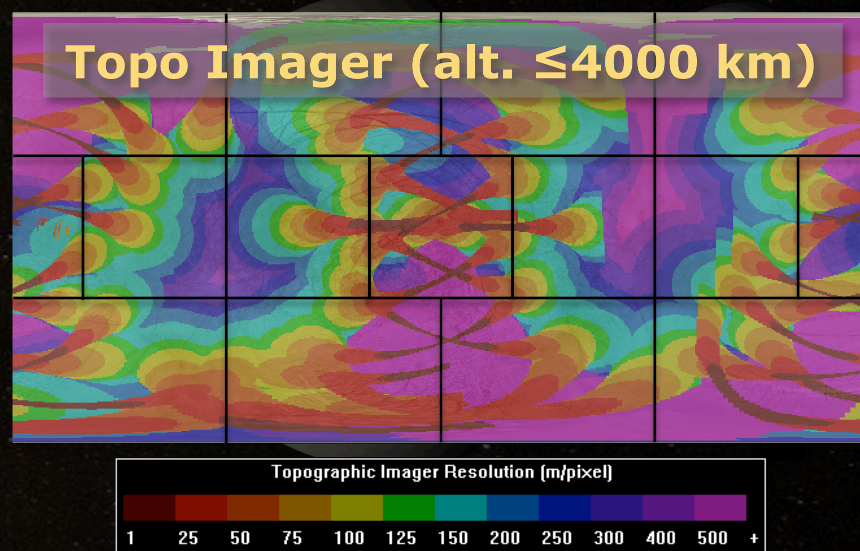
Comprehensive Surface Coverage

Globally Distributed Regional Coverage by Model Instruments





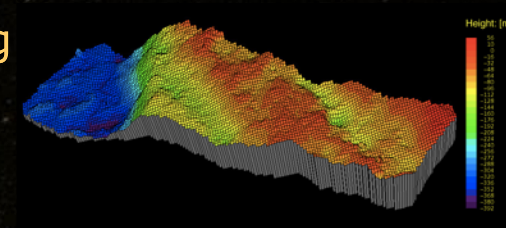


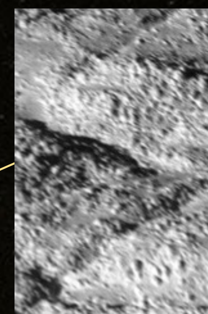


Reconnaissance for a Future Lander

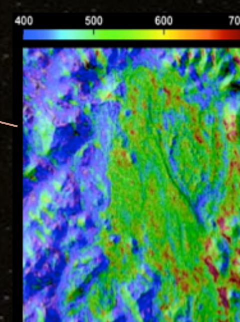
Landing Site Safety and Scientific value

Stereo Imaging
slopes and hazards

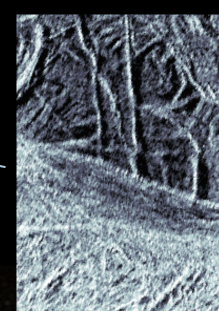




High Resolution Imaging
meter-scale roughness



Thermal Inertia
block abundance



Radar Scatter
surface roughness

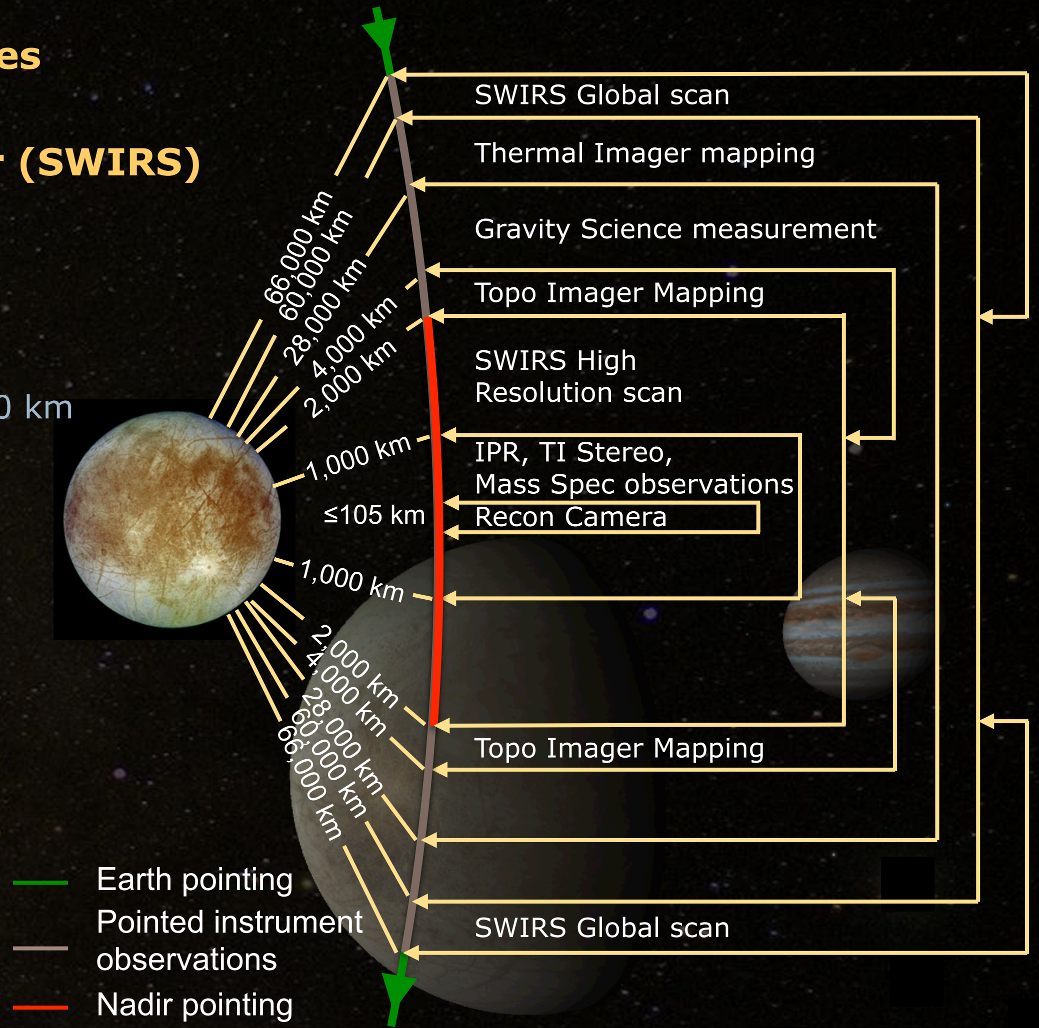
Reconnaissance Traceability Matrix

Goal	Objective		Investigation	
Characterize Safe and Scientifically Compelling Sites for a Future Lander Mission to Europa	Landing Safety	Assess the distribution of surface hazards, the load-bearing capacity of the surface, the structure of the subsurface, and the regolith thickness.	SL.1	Determine the distribution of blocks within a potential landing site at scales that represent a hazard to landing.
			SL.2	Determine the distribution of slopes within a potential landing site over baselines relevant to a lander.
			SL.3	Determine distribution of roughness elements (e.g., scarps, steps, cracks, divots, cusps, spires, etc.) within a potential landing site at scales that represent a hazard to landing.
			SL.4	Characterize the regolith cohesiveness and slope stability within a potential landing site.
			SL.5	Determine the regolith thickness and whether subsurface layering is present within a potential landing site.
	Scientific Value	Assess the composition of surface materials, the geologic context of the surface, the potential for geologic activity, the proximity of near surface water, and the potential for active upwelling of ocean material.	SV.1	Characterize the composition and chemistry of potential landing sites with an emphasis on understanding the spatial distribution and degradation state of endogenically derived compounds.
			SV.2	Characterize the potential for recent exposure of subsurface ice or ocean material vs. degradation of the surface by weathering and erosion processes and provide geologic context for potential landing sites.
			SV.3	Characterize the potential for shallow crustal liquid water beneath or near potential landing sites.
			SV.4	Characterize anomalous temperatures (significantly out of equilibrium with expected nominal diurnal cycles) indicative of current or recent upwelling of ocean material at or near potential landing sites.

Operations Concept

Simple and Repetitive

1. **Magnetometer and Langmuir Probes**
   - Continuous measurements
2. **ShortWave InfraRed Spectrometer (SWIRS)**
   - Global low res. scan below 66,000 km
   - Targeted high res. scan below 2,000 km
   - Passive observations below 1,000 km
3. **Thermal Imager**
   - Pushbroom thermal imaging below 60,000 km
4. **Gravity Science**
   - Measurements below 28,000 km
5. **Topographical Imager (TI)**
   - Lower res. pushbroom imaging between 4,000 and 1,000 km
   - Pushbroom stereo imaging below 1,000 km
6. **Ice Penetrating Radar (IPR)**
   - Surface scans below 1,000 km
7. **Mass Spectrometer (NMS)**
   - *In situ* scan below 1,000 km
8. **Reconnaisance Camera**
   - High res. imaging below 105 km

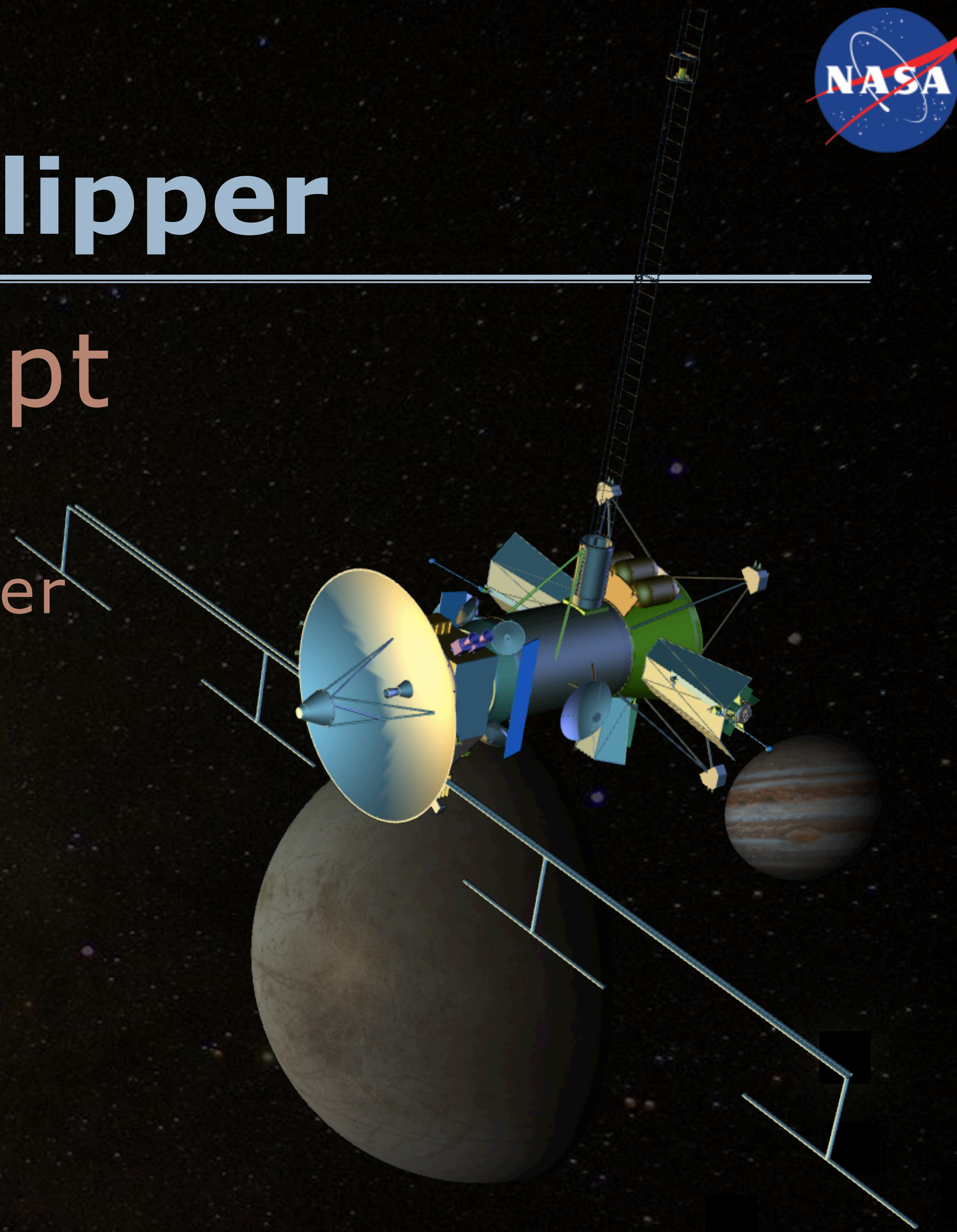


The Europa Clipper

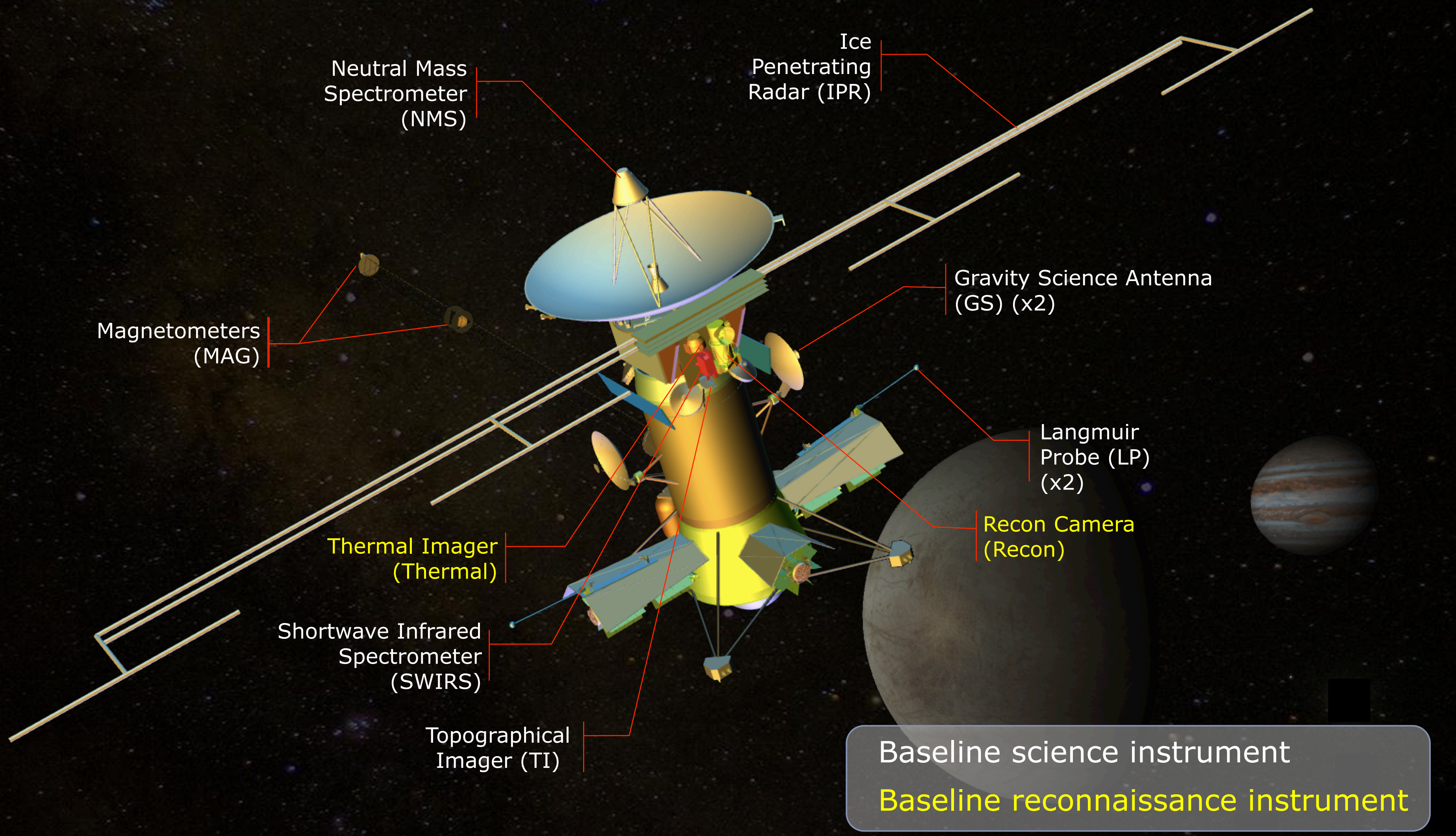
Mission Concept

Brian Cooke

Project System Engineer



Europa Clipper Model Payload



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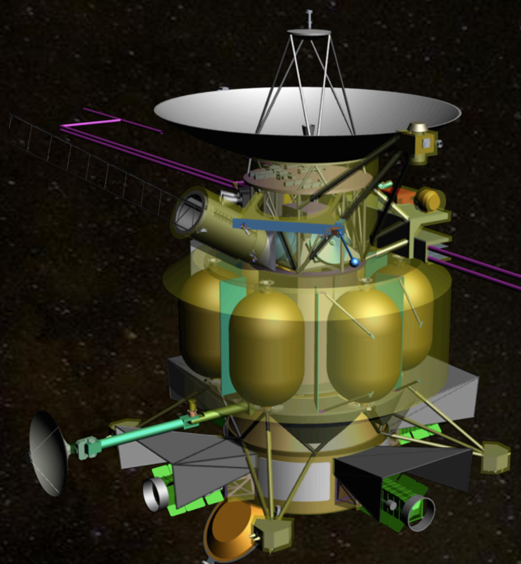
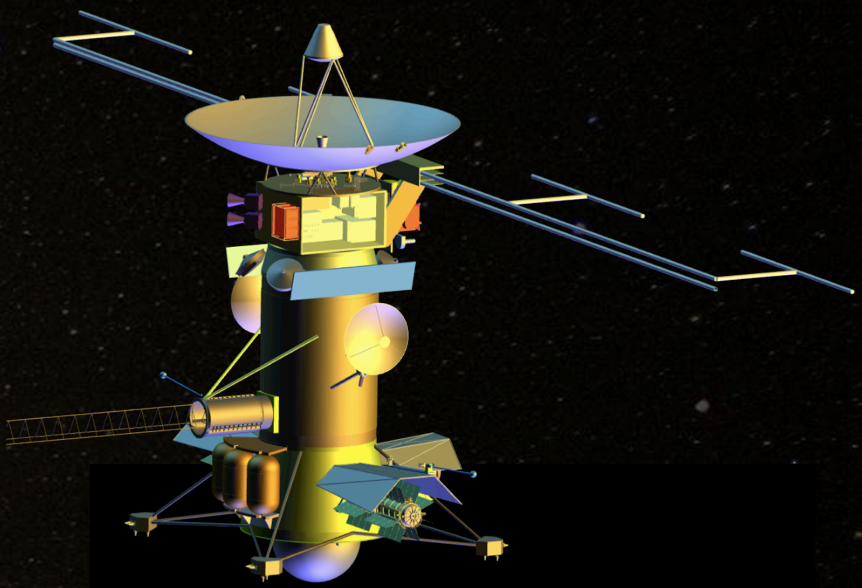
New Spacecraft Tank Configuration

Nested Vault / Distributed Tanks



- Most beneficial to Orbiter Mission Concept where significant fuel remain in tanks during Jovian tour
- Difficult to analyze shielding benefit of residual fuel
- More difficult to manage CG during maneuvers
- More complicated mechanical design

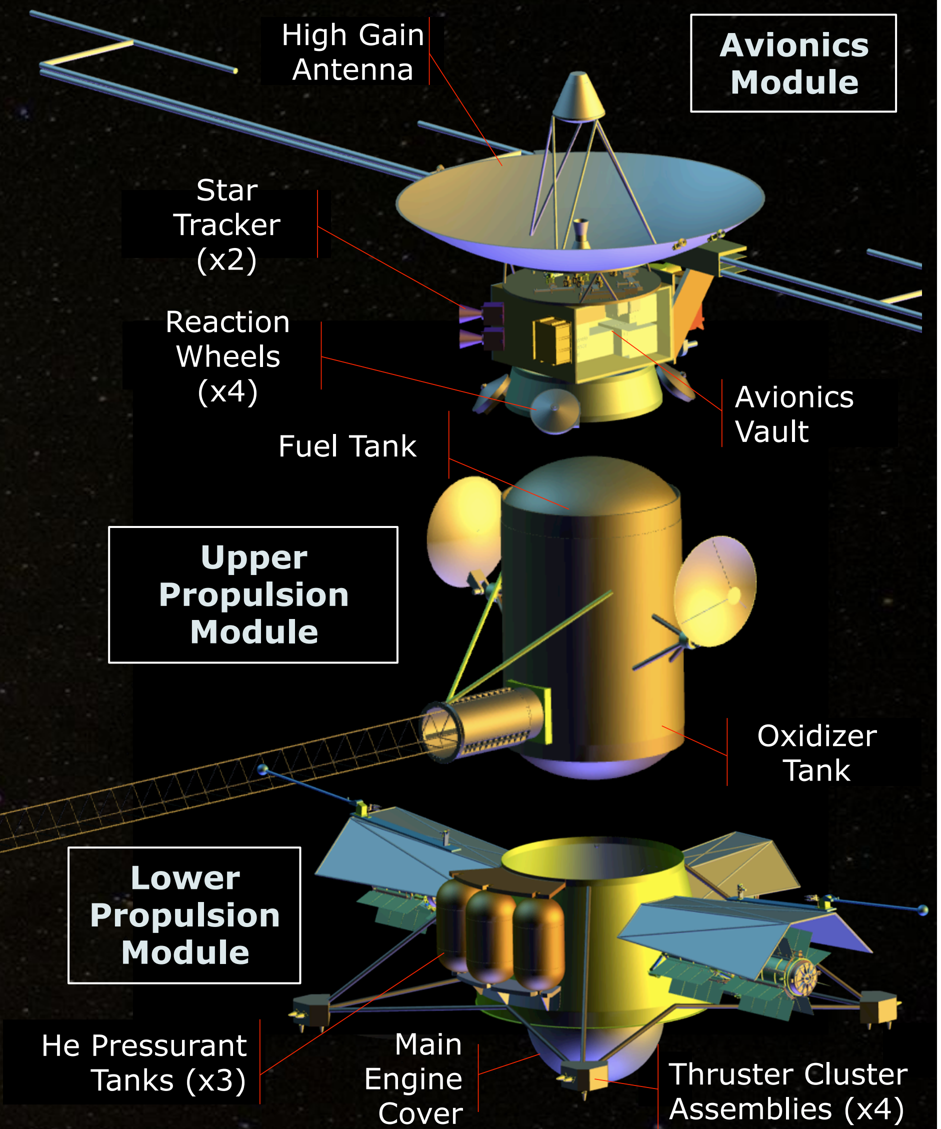
Stacked Tanks / Vault



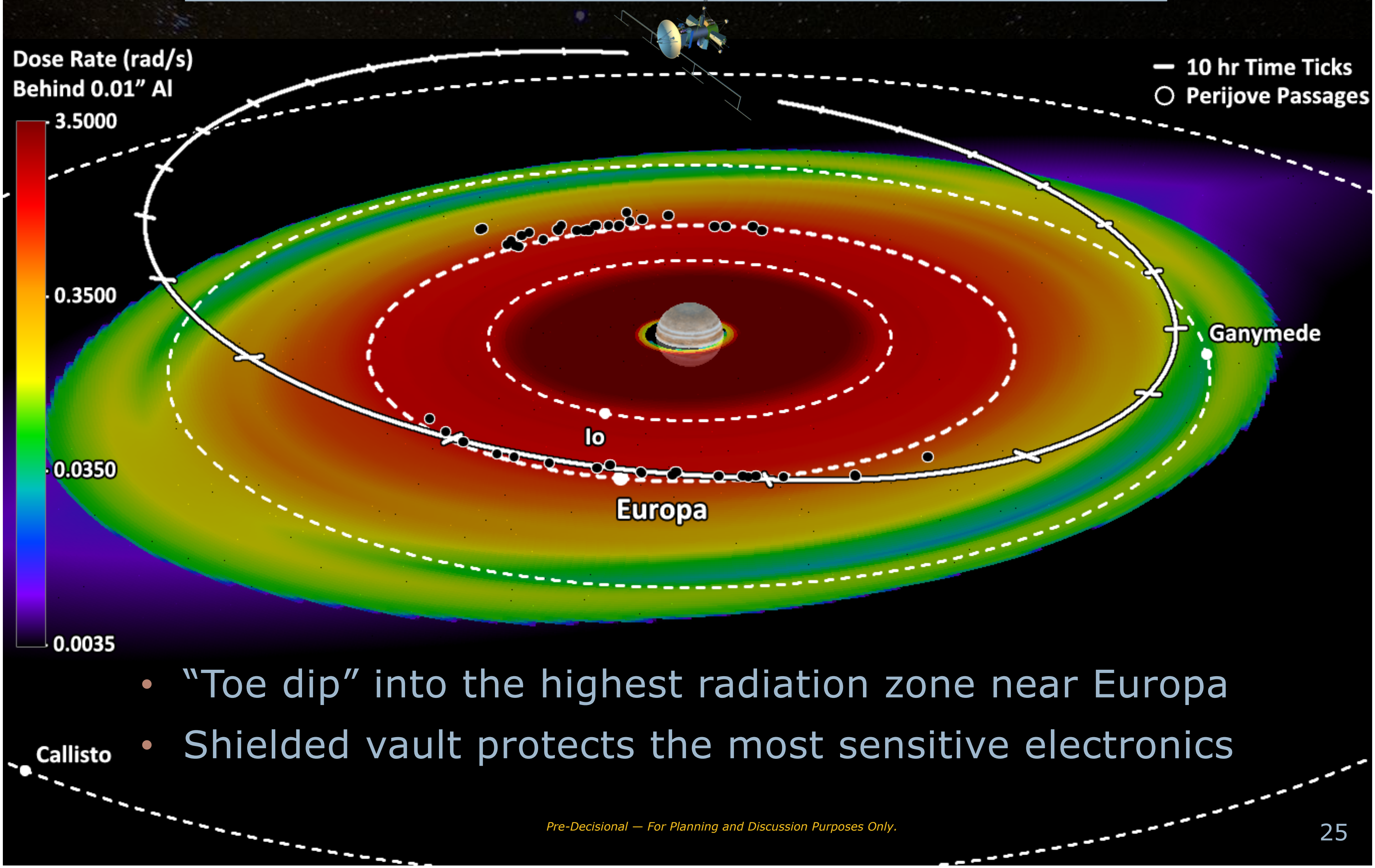
- Much simpler mechanical design; easier to analyze
- Easier to manage CG during maneuvers
- More mass required for vault shielding, but simpler mechanical design results in less net mass

Modular Spacecraft Design

- Implementation flexibility
  - Parallel integration paths
  - Module level integrated testing during Phase C
  - Isolates implementation issues at the module level
- Robust schedule management
  - Decouples qualification testing until late in integration flow
- Smooth funding profile
  - Allows flexible phasing of module implementation schedules
  - This minimizes peaks in project funding profile



Radiation Mitigation Strategy



- “Toe dip” into the highest radiation zone near Europa
- Shielded vault protects the most sensitive electronics

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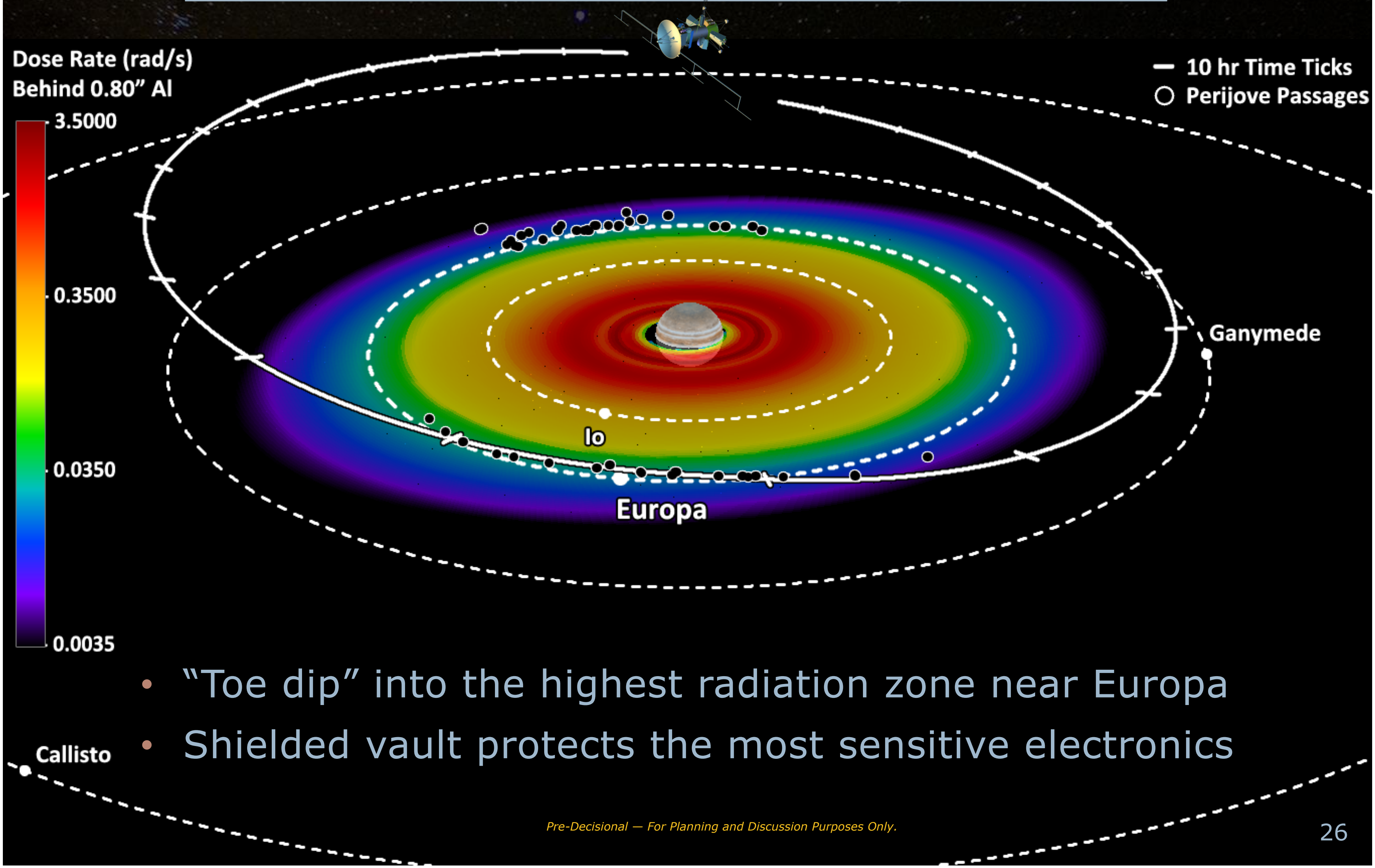
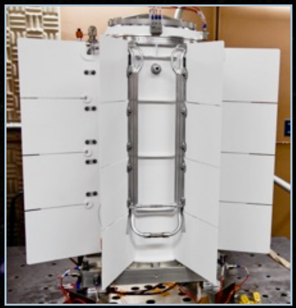
Radiation Mitigation Strategy



- "Toe dip" into the highest radiation zone near Europa
- Shielded vault protects the most sensitive electronics

Power Source Options



MMRTG: Multi-Mission Radioisotope Thermoelectric Generator

- Demonstrated high reliability
- ^{238}Pu available to support 2021 mission is not assured
- Mass and cost impact bounded by Solar and ASRG options

Solar: Foldout Panel Solar Arrays

- Technical issues must be resolved before determining feasibility for Europa Clipper
- Reliability uncertain in high radiation, eclipse cold soak environments
- Highest mass, lowest cost solution

ASRG: Advanced Stirling Radioisotope Generator

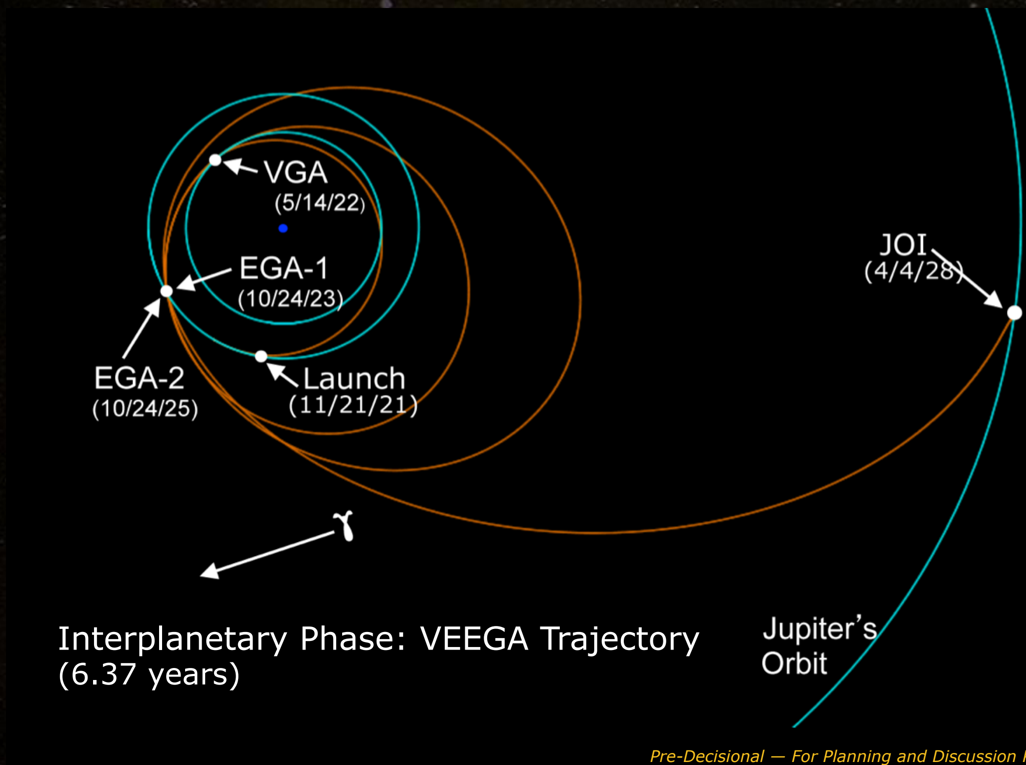
- Recommended by Planetary Decadal Survey
- Technical issues need resolution for compatibility with Europa Clipper
- Reliability not yet demonstrated; high per unit cost

VEEGA Interplanetary Trajectory

Baseline: Atlas V 551

Gravity assist interplanetary trajectory with annual launch opportunities

- 21 Day launch period opens Nov. 21, 2021
- Venus/Earth/Earth Gravity Assist
- Arrive Jovian System April 4, 2028



Interplanetary Phase: VEEGA Trajectory
(6.37 years)

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The Europa Clipper

Path Forward

Barry Goldstein

Project Manager

Potential Advantages of SLS Launch Option

Outer Planet Research: Advantages of SLS

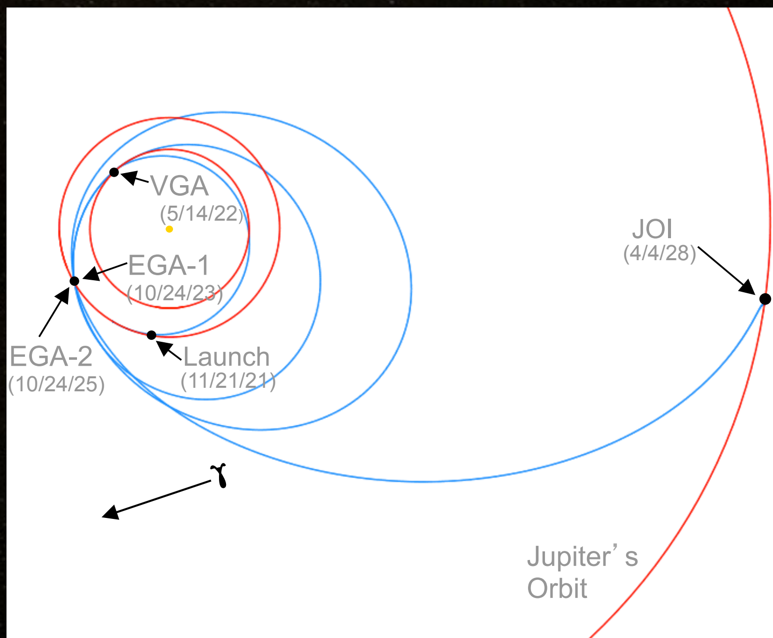
- Science-driven exploration requires 'rapid' response to discovery
- Long cruise time to Jupiter makes rapid response problematic
- Direct trajectory via SLS could cut cruise to Jupiter to <2 years

Europa Clipper: Accrued Advantages of SLS

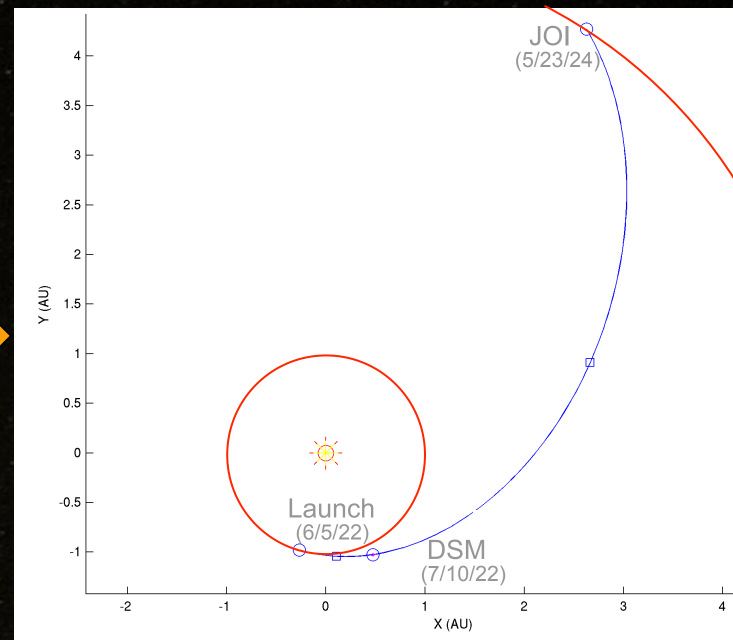
- Clipper Launch in June, 2022 arrives in January 2025
  - Seven month development reserve, and arrives 3 ¼ years earlier
- Enables significant mass margin
- Annual launch opportunities
- Eliminates thermal design challenge of Venus flyby and significant safety precautions for Earth flybys

Atlas V vs SLS Trajectories

Atlas V 551: VEEGA



SLS: Direct



Time of flight:	6.4 years
Earth Flybys:	2
Sun Closest Approach:	0.6 AU
C3:	15 km^2/s^2
Launch Capability:	4494 kg (41% Margin)

SLS Advantages

- Time Of Flight: -57%
- Avoids Venus thermal environment
- Eliminates Earth flyby nuclear safety concern
- 45% mass margin for current concept

Time of flight:	1.9 years
Earth Flybys:	0
Sun Closest Approach:	1.0 AU
C3:	82 km^2/s^2
Launch Capability:	6087 kg (45% Margin)

Europa Clipper Concept Summary

Objectives:

- **Ocean:** Existence, extent, salinity
- **Ice Shell:** Water within or beneath; nature of surface-ice-ocean exchange
- **Composition:** Key compounds; links to ocean composition
- **Geology:** *S*urface feature formation; sites of recent or current activity
- **Reconnaisance:** Surface characteristics at lander scales

Model Payload:

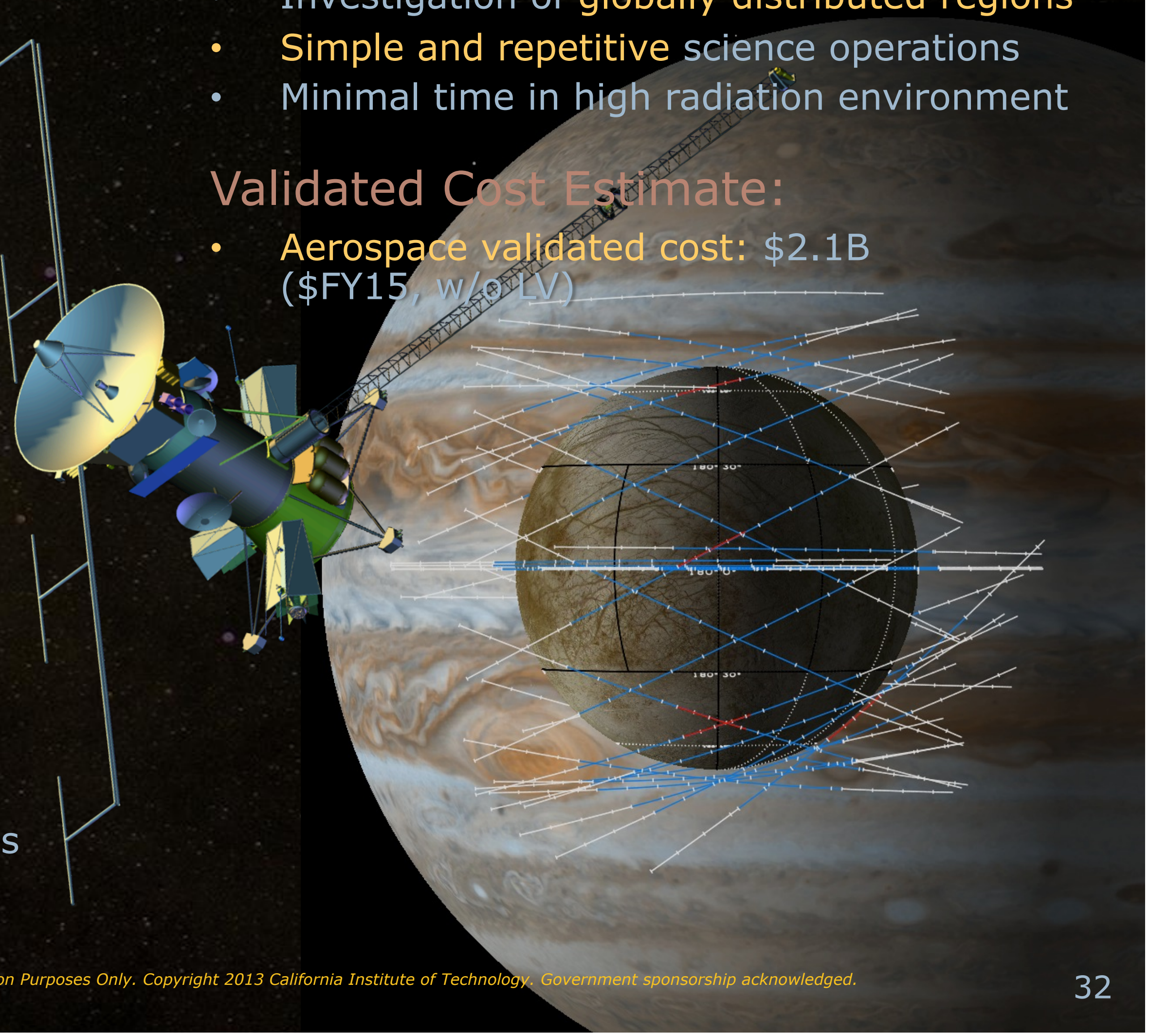
- Ice-Penetrating Radar
- Topographical Imager
- Infrared Spectrometer
- Neutral Mass Spectrometer
- Gravity Science Antenna
- Magnetometer & Langmuir Probes
- Reconnaissance Camera
- Thermal Imager

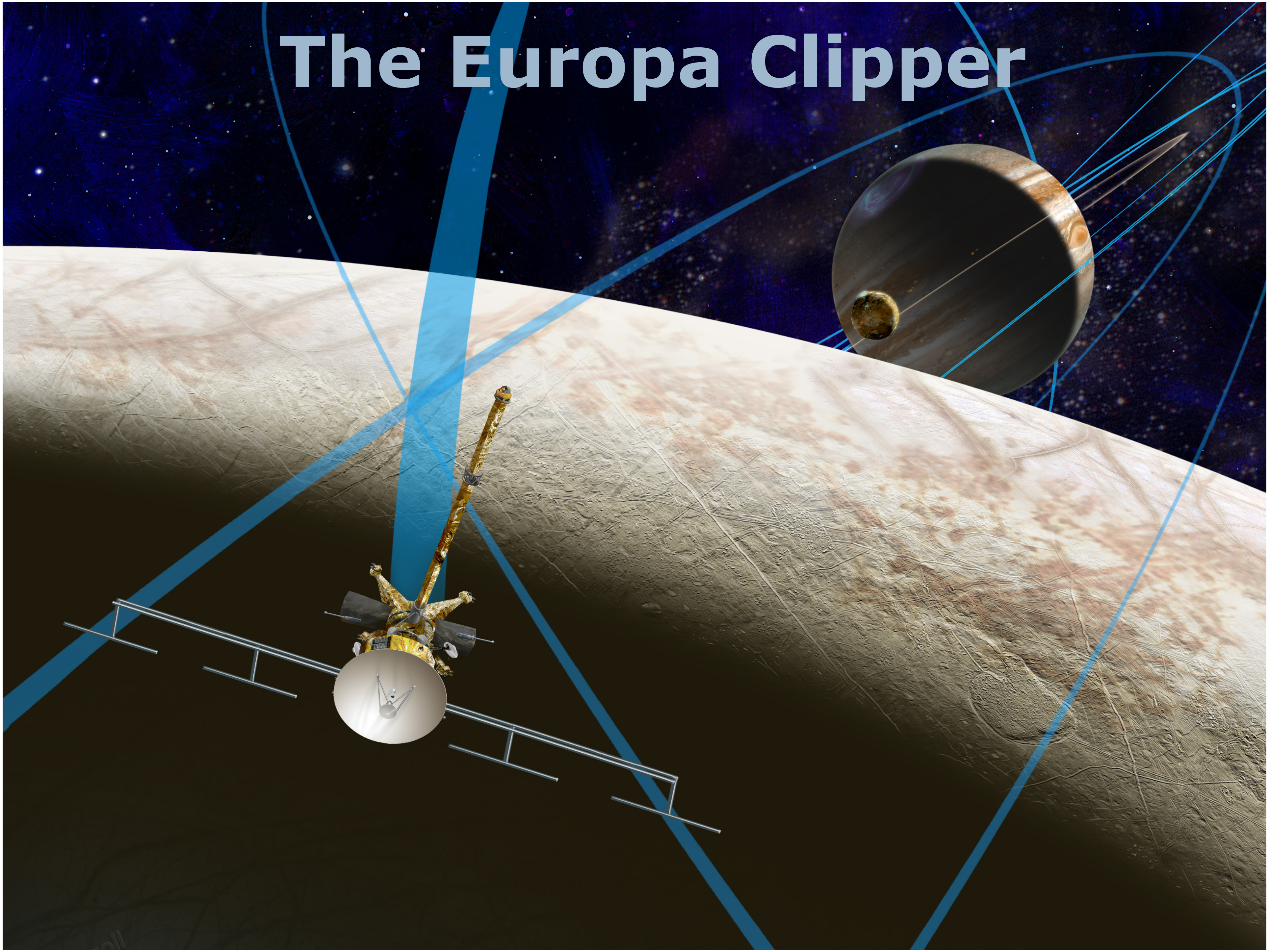
Operations Concept:

- 45 low-altitude flybys from Jupiter orbit
- Investigation of globally distributed regions
- Simple and repetitive science operations
- Minimal time in high radiation environment

Validated Cost Estimate:

- Aerospace validated cost: $2.1B ($FY15, w/o LV)




The Europa Clipper