
The Europa Clipper
Update to CAPS
Sept. 4, 2014
Robert Pappalardo
Barry Goldstein
Jet Propulsion Laboratory,
California Institute of Technology
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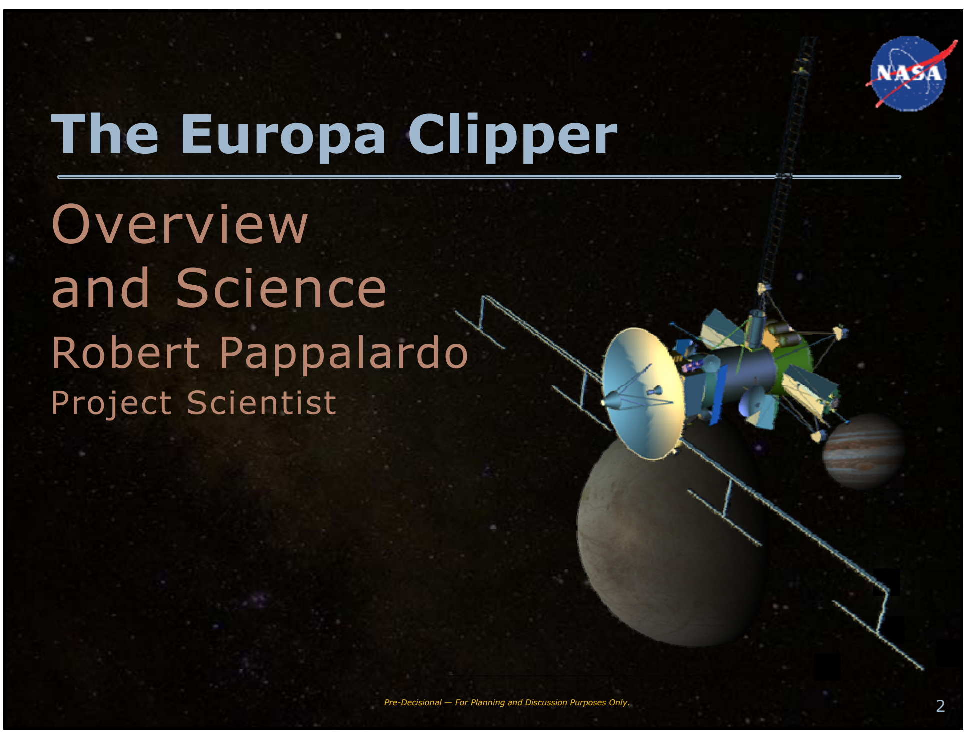
NASA
The Europa Clipper
Overview
and Science
Robert Pappalardo
Project Scientist
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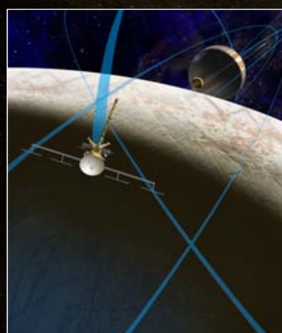
Acknowledgement

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.



JPL
Jet Propulsion Laboratory
California Institute of Technology

APL
JOHNS HOPKINS UNIVERSITY
Applied Physics Laboratory

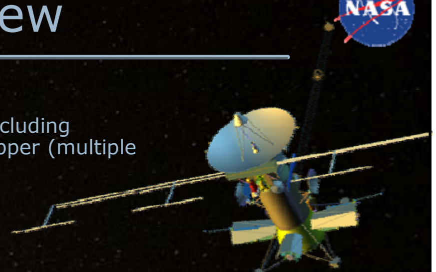
Overview

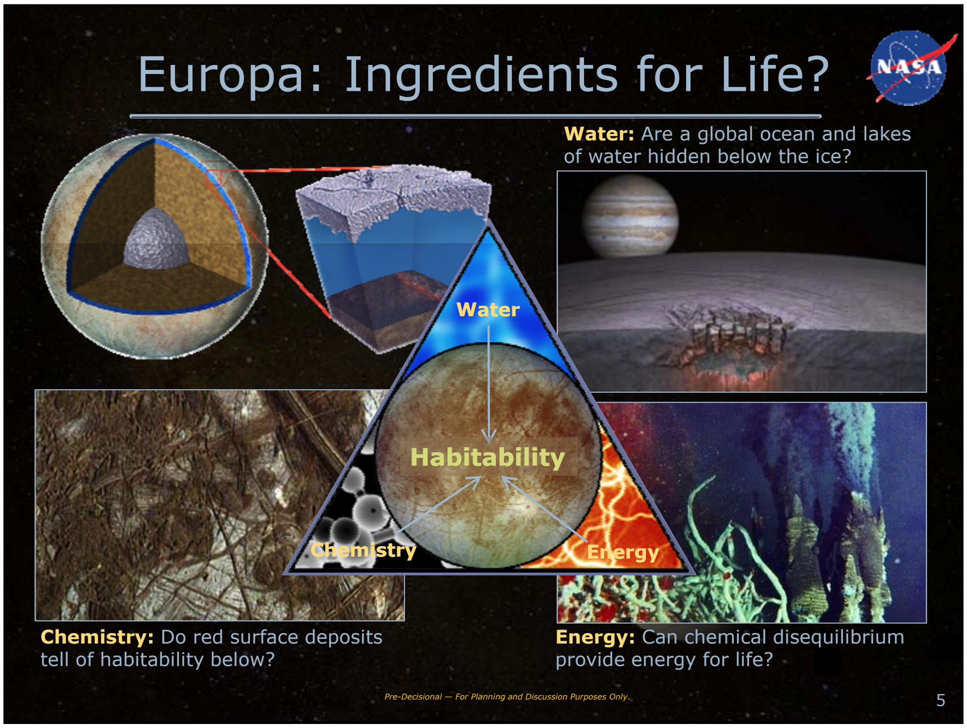
Where we left off

- Briefed CAPS inn Sept. 2012 on "Enhanced" (including reconnaissance) Europa Orbiter and Europa Clipper (multiple flyby) mission concepts
- Submitted report to NASA in December 2012

Major events in 2013

- Europa Science Advisory Group in place, L. 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 Clipper concept only
- NASA released ICEE NRA to aid in retiring instrument risk
- Top-priority mission trades being considered and worked
- Reconnaissance traceability and mission concept being matured
- Notional trajectory updated to simplify operations and fulfill science potential




Europa: Ingredients for Life?
NASA
Water: Are a global ocean and lakes of water hidden below the ice?
Water
Habitability
Chemistry
Energy
Chemistry: Do red surface deposits tell of habitability below?
Energy: Can chemical disequilibrium provide energy for life?
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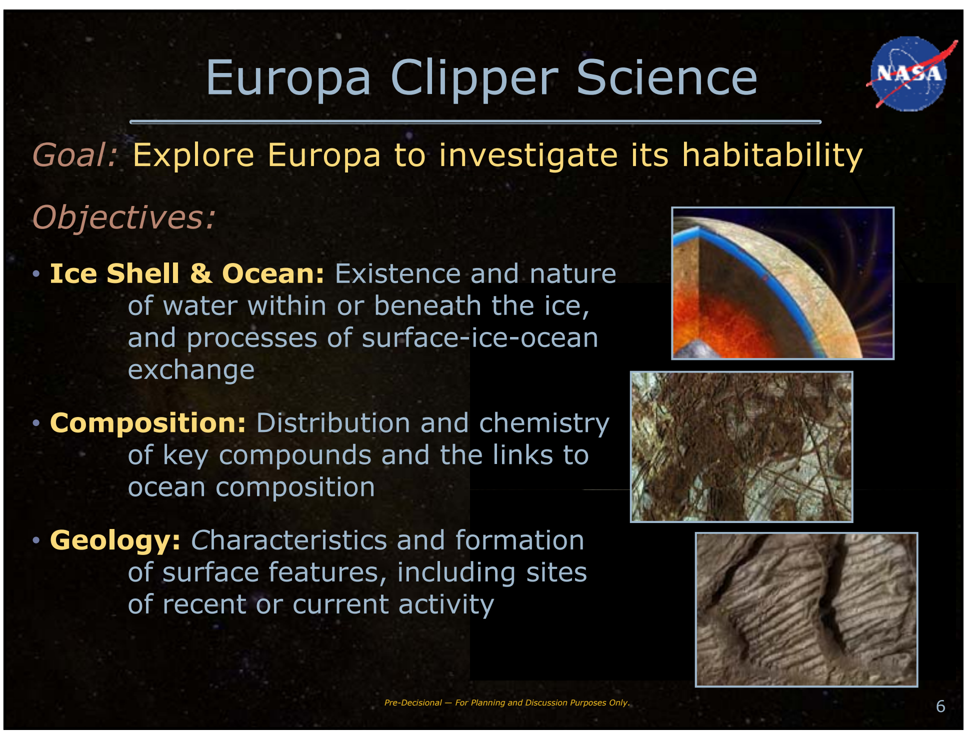
Europa Clipper Science
NASA
Goal: Explore Europa to investigate its habitability
Objectives:
• Ice Shell & Ocean: Existence and nature of water within or beneath the ice, and processes of surface-ice-ocean exchange
• Composition: Distribution and chemistry of key compounds and the links to ocean composition
• Geology: Characteristics and formation of surface features, including sites of recent or current activity
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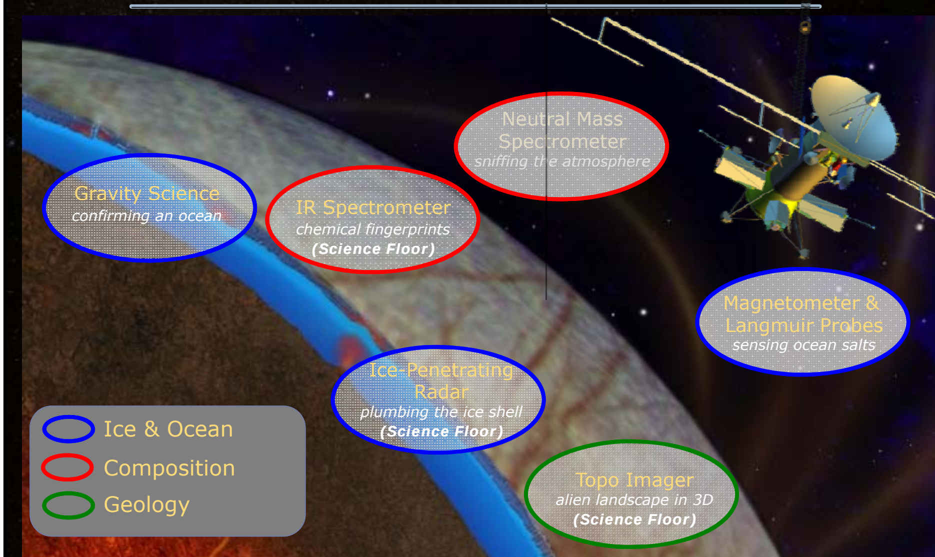
Science Traceability Matrix

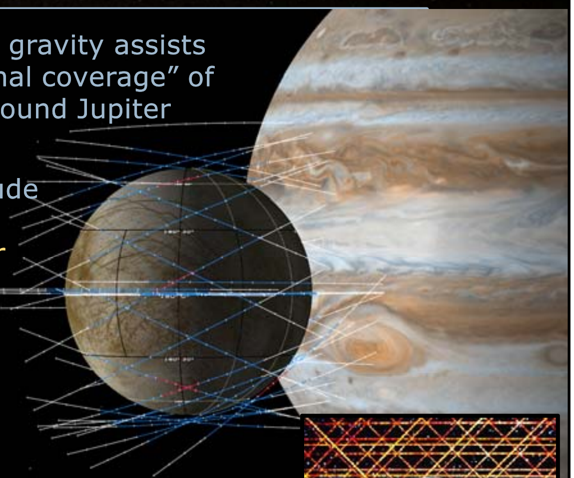
Goal	Objective		Investigation	
Explore Europa to investigate its habitability	Ice Shell and Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange.	IO.1	Characterize the distribution of any shallow subsurface 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.

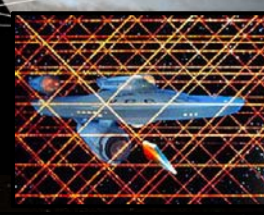
Model Payload



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





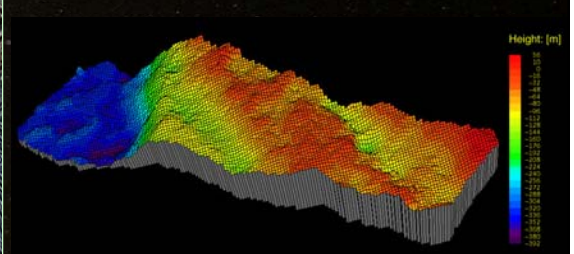
*Si behind 100 mil Al, spherical shell

Geology • Composition • Ice Shell & Ocean

Galileo 30 m/pixel
Mosaic by P. Schenk

Geological activity:

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



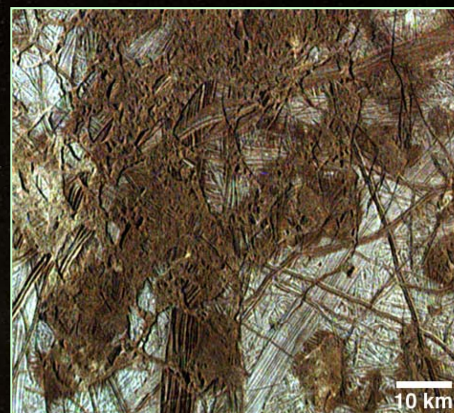
Europa high-resolution topography: 10 m vert.
Elevation model by B. Giese

Stereo imaging can elucidate geology and recent activity

Geology • Composition • Ice Shell & Ocean

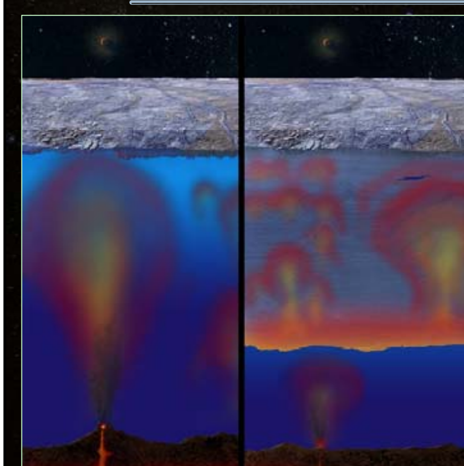
Composition & chemistry:

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



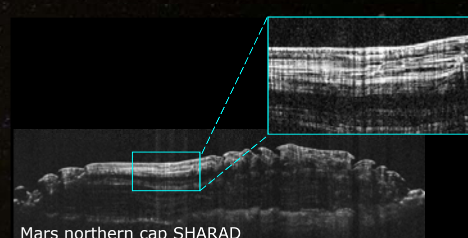
Infrared and neutral mass spectroscopy can derive surface and atmospheric composition to understand habitability

Geology • Composition • Ice Shell & Ocean



Ice shell characteristics:

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

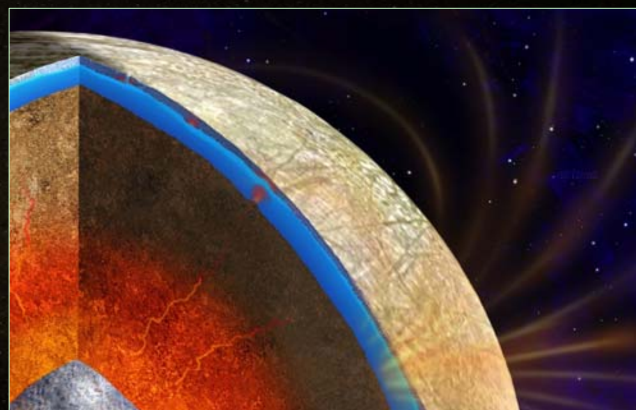


Ice-penetrating radar can find water in and beneath the icy shell

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

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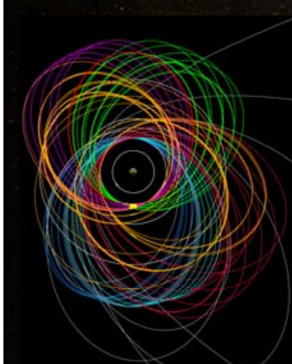
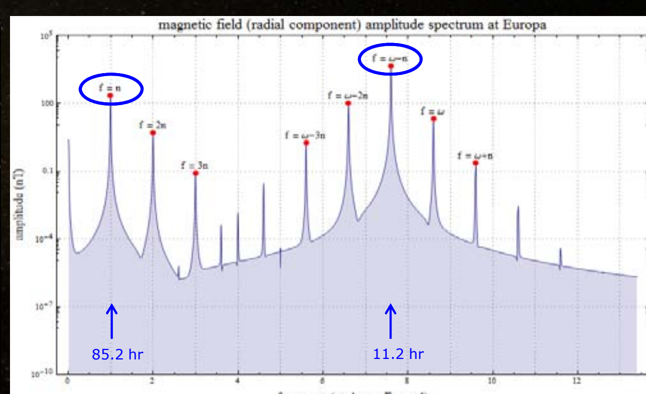
Magnetometry from Flybys

- 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)



Europa Clipper petal plot



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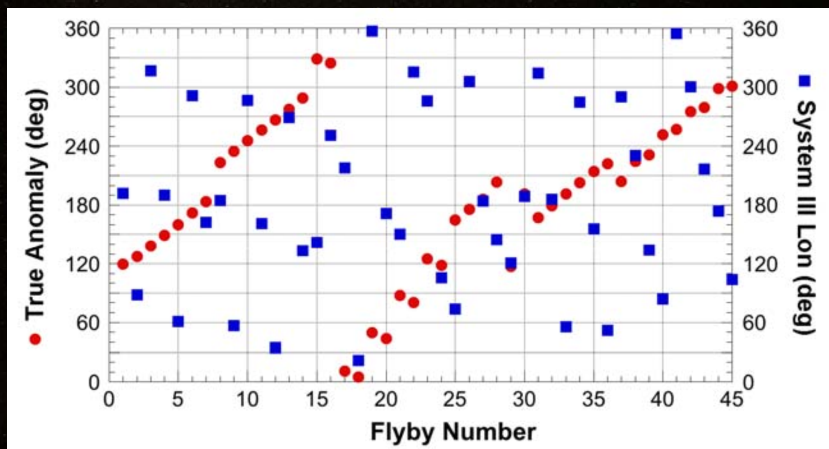
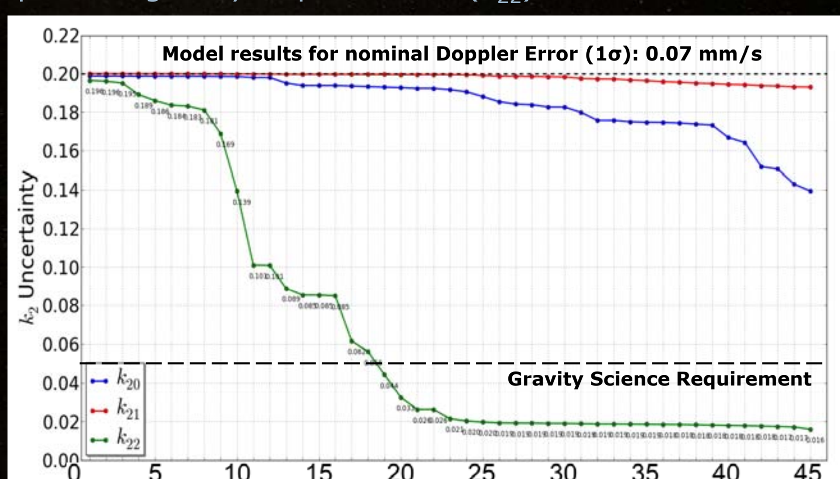
Gravity and Magnetometry from Flybys

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

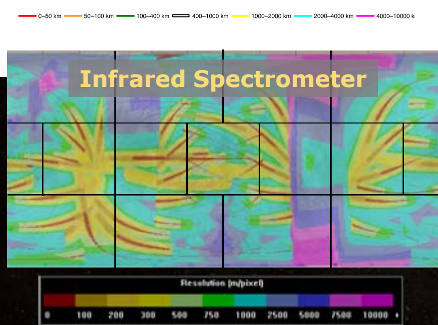


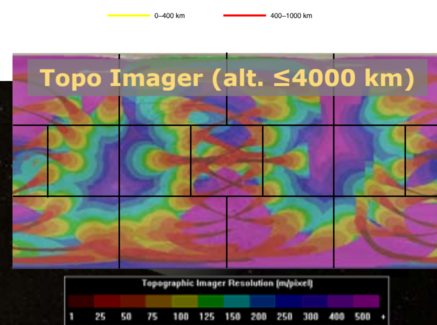
Gravity Science from Flybys

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



Comprehensive S





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Programmatic Need for Feed-Forward Reconnaissance Data Sets

To prepare for a future lander, reconnaissance data is necessary from both science and engineering perspectives:

- Engineering reconnaissance for landing safety
  - Is a safe landing site (within a lander's design margins) accessible to a spacecraft?
  - Assess at least 15 sites to determine conditions and find two that are safe
- Science reconnaissance for landing site selection (enabled by model payload)
  - Is the landing site scientifically compelling in addressing the goal of exploring Europa to investigate its habitability?

Highest Resolution Europa image currently available

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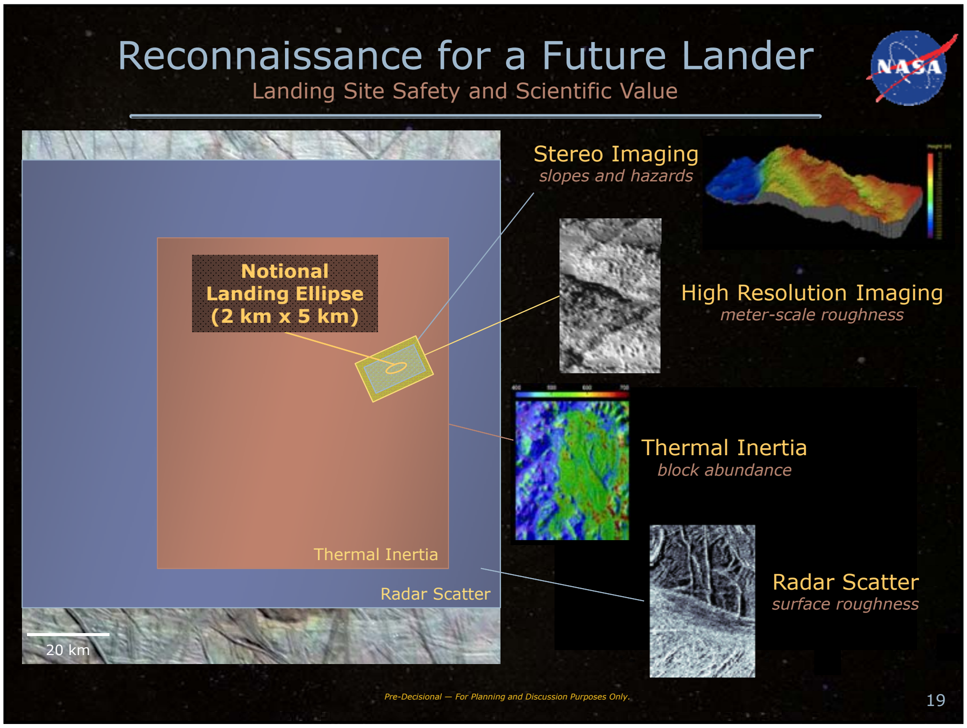

Reconnaissance Traceability Matrix

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 and other roughness elements 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	Characterize the regolith cohesiveness and slope stability within a potential landing site.
			SL.4	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 (that are significantly out of equilibrium with expected nominal diurnal cycles) indicative of current or recent upwelling of ocean material at or near potential landing sites.

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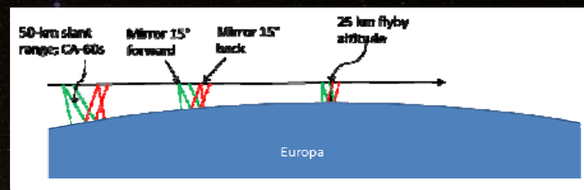
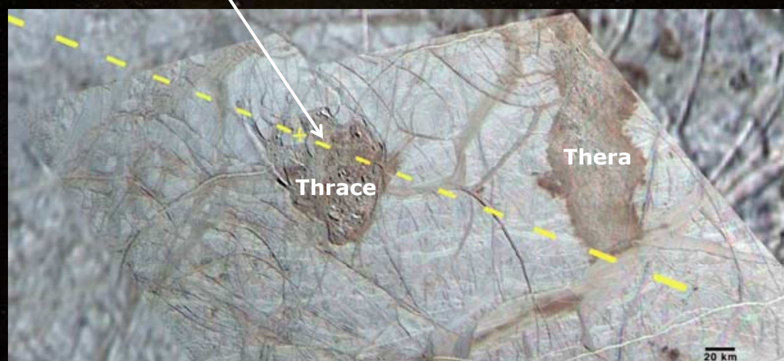
Reconnaissance Imaging Scenario



Stereo imaging at 0.5 m/pixel in 5 x 10 km swaths



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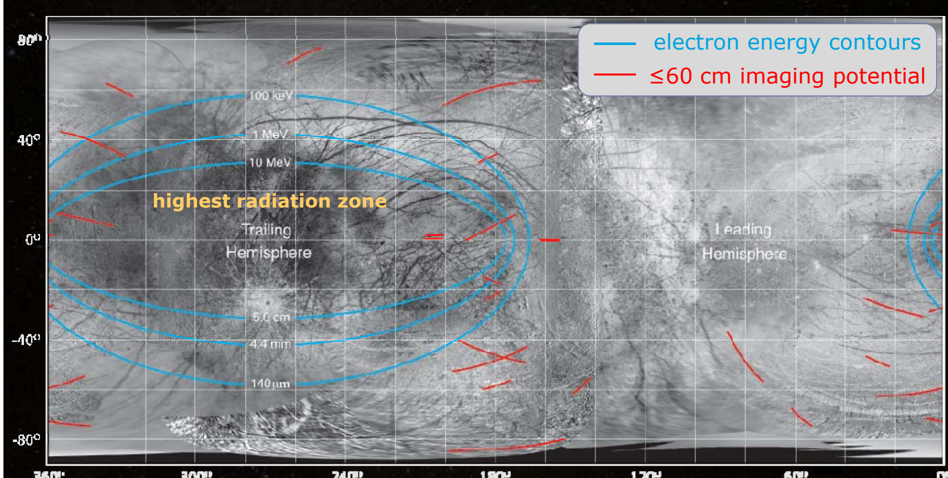
Recon Site Distribution

- Landing site reconnaissance globally, including in lower radiation regions most relevant to a future lander mission



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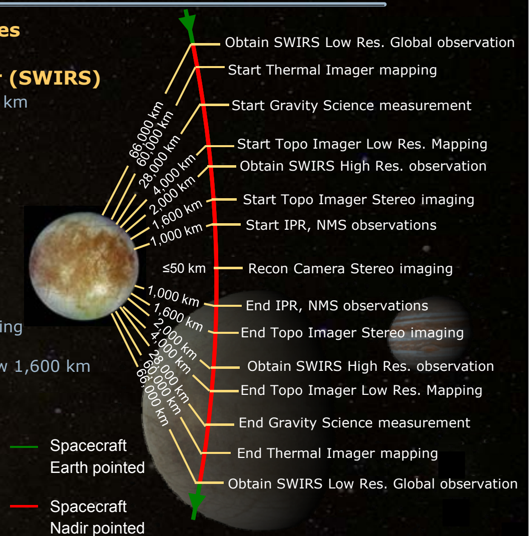
Operations Concept

Simple and Repetitive

1. **Magnetometer and Langmuir Probes**
   - Continuous measurements
2. **ShortWave InfraRed Spectrometer (SWIRS)**
   - Low res. global observation below 66,000 km
   - High res. observation below 2,000 km
   - Data not acquired continuously
3. **Thermal Imager**
   - Continuous pushbroom thermal imaging below 60,000 km
4. **Gravity Science**
   - Continuous measurements below 28,000 km
5. **Topographical Imager (TI)**
   - Global and regional res. monoscopic imaging between 4,000 and 1,600 km
   - Pushbroom stereo high-res. imaging below 1,600 km
6. **Ice Penetrating Radar (IPR)**
   - Continuous surface observations below 1,000 km
7. **Mass Spectrometer (NMS)**
   - Continuous In situ observation below 1,000 km
8. **Reconnaisance Camera**
   - Stereo imaging below 50 km



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The Europa Clipper

Mission Update & Path Forward

Barry Goldstein

Project Manager

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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

- Recently competed independent review, and assessment was that the technical issues to be resolved are feasible for Europa Clipper
- Highest mass, lowest cost solution
- Removes dependency on ^{238}Pu availability

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

Removed From Option Space

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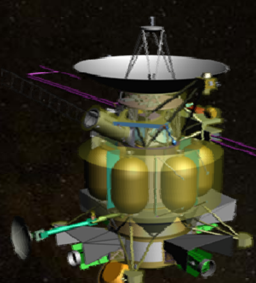
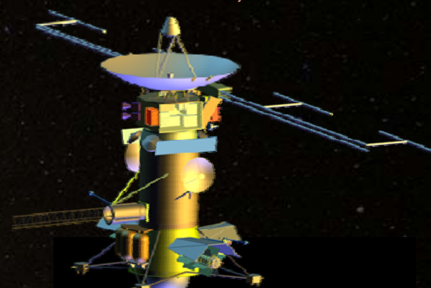
New Spacecraft Tank Configuration

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

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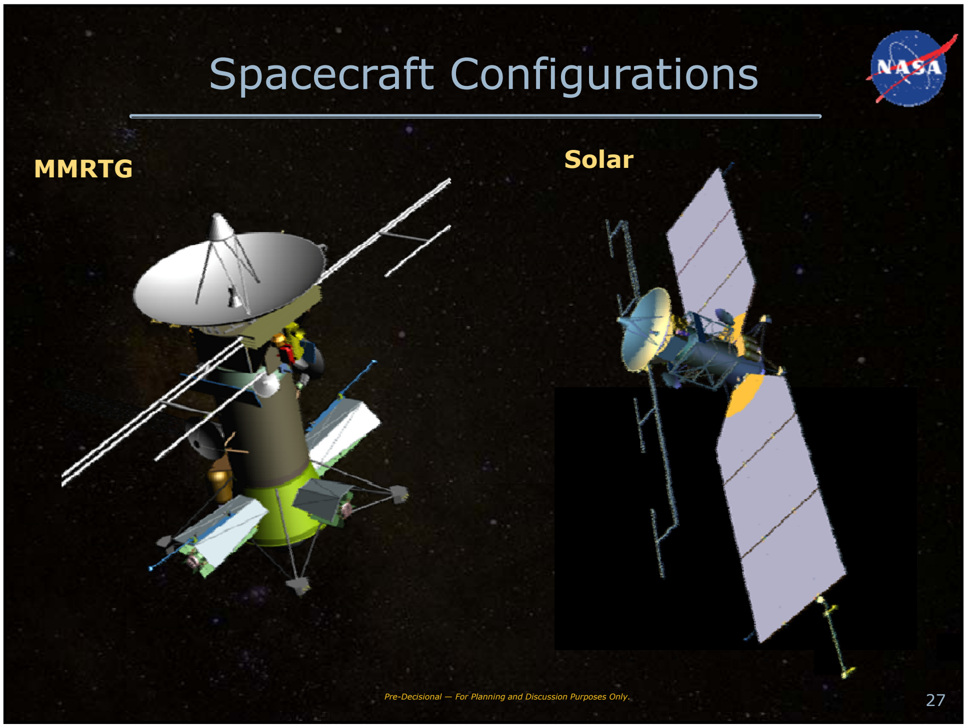
Spacecraft Configurations
MMRTG
Solar
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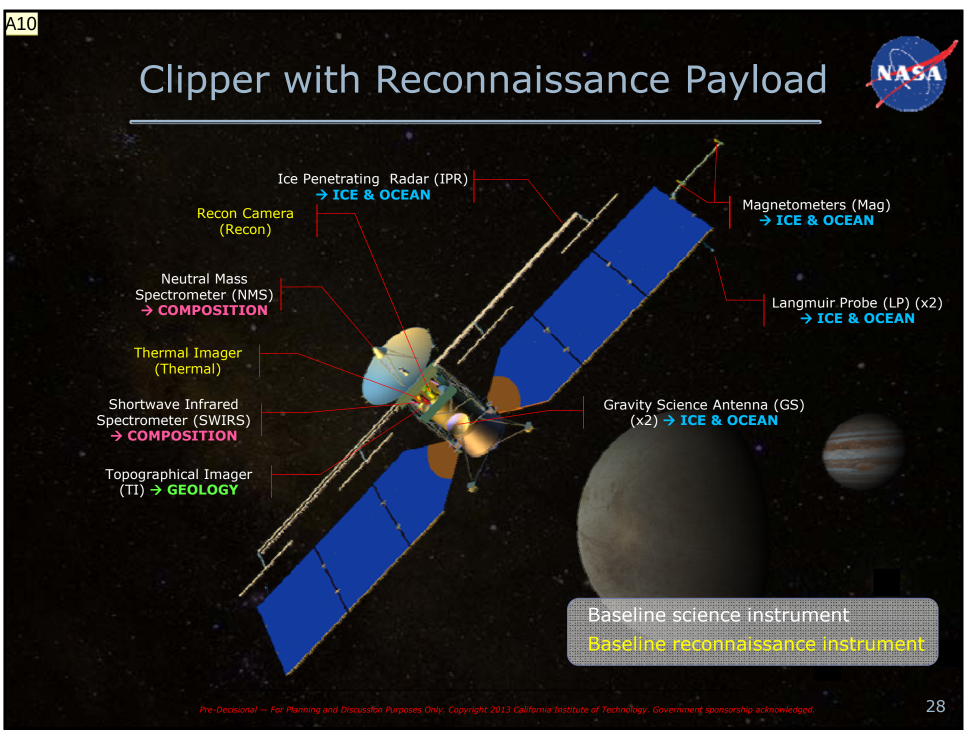
A10
Clipper with Reconnaissance Payload
Ice Penetrating Radar (IPR)
→ ICE & OCEAN
Recon Camera
(Recon)
Magnetometers (Mag)
→ ICE & OCEAN
Neutral Mass
Spectrometer (NMS)
→ COMPOSITION
Langmuir Probe (LP) (x2)
→ ICE & OCEAN
Thermal Imager
(Thermal)
Shortwave Infrared
Spectrometer (SWIRS)
→ COMPOSITION
Gravity Science Antenna (GS)
(x2) → ICE & OCEAN
Topographical Imager
(TI) → GEOLOGY
Baseline science instrument
Baseline reconnaissance instrument
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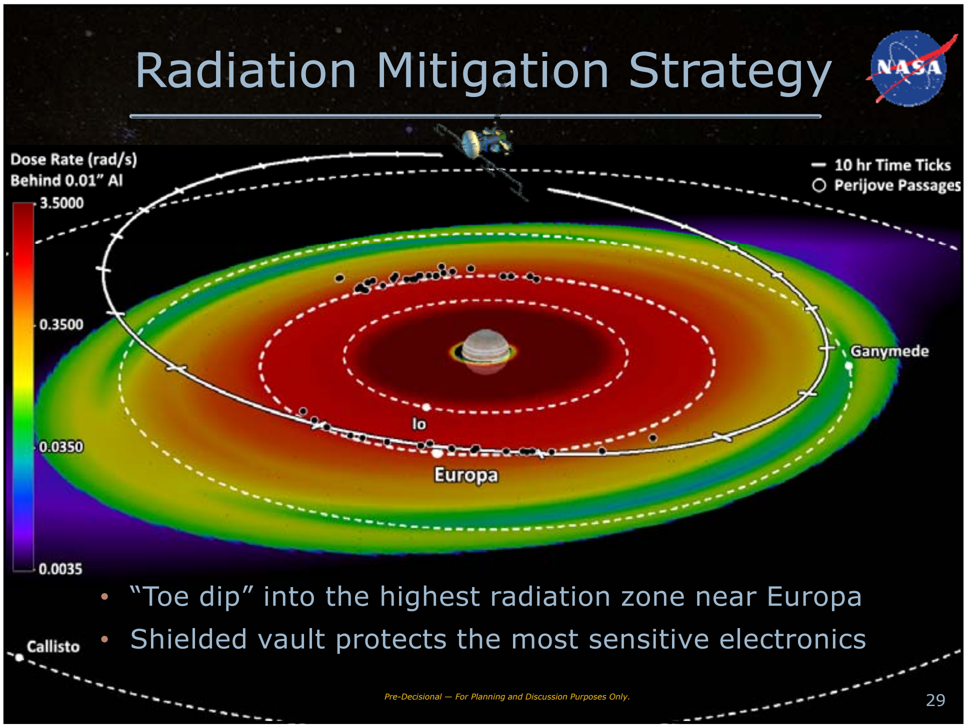
Slide 28

A10 Can we get CAD with transparent background, as to eliminate outline around the s/c?
Author, 4/24/2013


Radiation Mitigation Strategy
NASA
Dose Rate (rad/s)
Behind 0.01" Al
3.5000
0.3500
0.0350
0.0035
10 hr Time Ticks
Perijove Passages
Ganymede
Io
Europa
Callisto
• "Toe dip" into the highest radiation zone near Europa
• Shielded vault protects the most sensitive electronics
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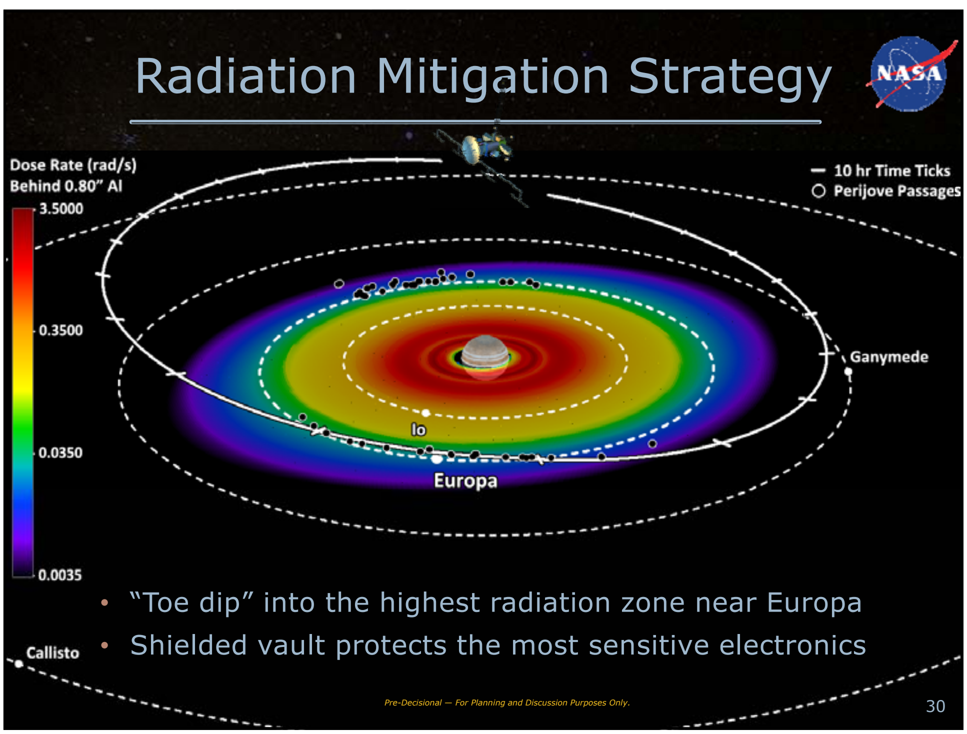
Radiation Mitigation Strategy
NASA
Dose Rate (rad/s)
Behind 0.80" Al
3.5000
0.3500
0.0350
0.0035
10 hr Time Ticks
Perijove Passages
Ganymede
Io
Europa
Callisto
• "Toe dip" into the highest radiation zone near Europa
• Shielded vault protects the most sensitive electronics
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Launch Vehicle Trade

Atlas V-551 Current Baseline

- Venus, Earth, Earth Gravity Assist (VEEGA) time of flight 6.4 years
- Estimated Cost ~$350M
- Earliest Launch : November 2021
- Earliest Arrival : April 2028

Atlas V 551

Working With MSFC on SLS Option

- Direct to Jupiter trajectory time of flight 1.9 years
- Estimated Recurring SLS Cost ~$500M
- Earliest Launch : June 2022
- Earliest Arrival : May 2024

NASA SLS

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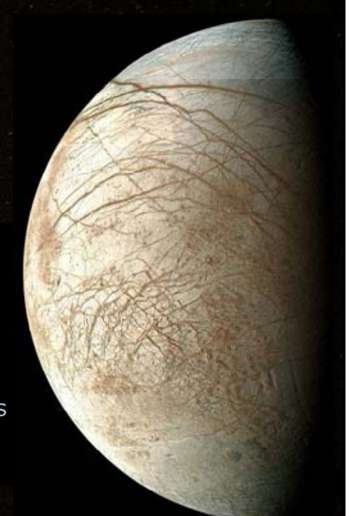
On-Going and Future Work

Prep Work for Preliminary Mission Concept Review, 3/4-5/14

- Using model payload, iteration on mission design
  - Figures of merit → instrument performance, radiation total dose, eclipse time, etc.
- Multiple S/C and mission trades
  - Recent stacked vs. nested prop-tank
  - Gravity Science implementation
  - Power source options
  - Launch Vehicle options
- Mission requirements generation
  - Based on best understanding of Level 1 requirements

Risk Reduction Tasks

- Active thermal control component tests
- Planetary Protection methods
- Electronics and materials radiation sensitivity tests
- Thermal and Radiation testing of solar cells
- Enhanced Li-Ion battery capacity for deep space
- Science risk reduction tasks



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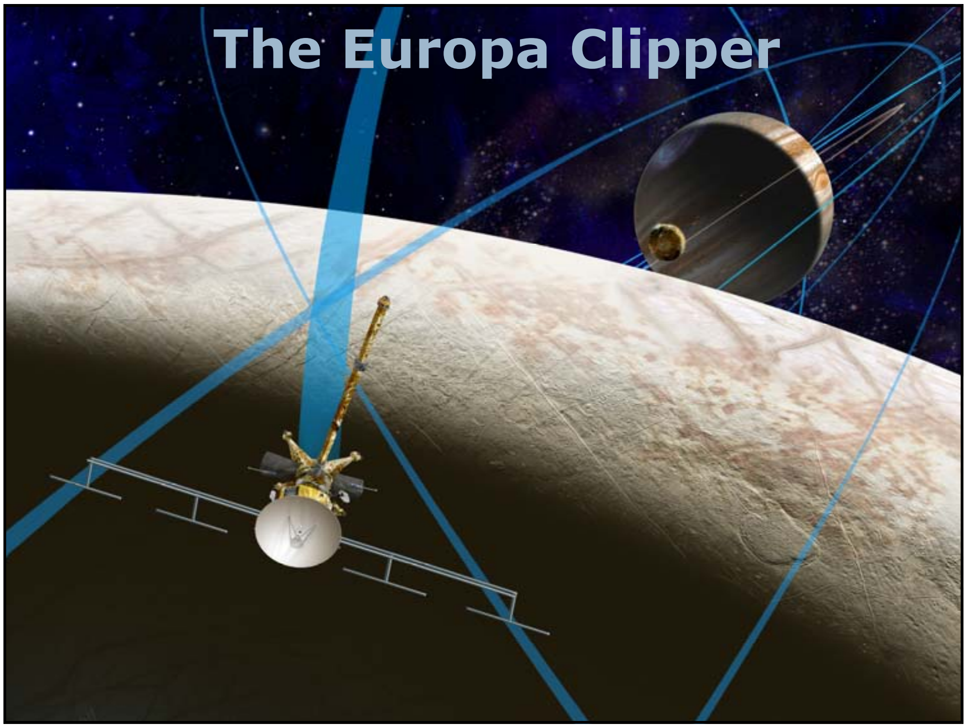
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