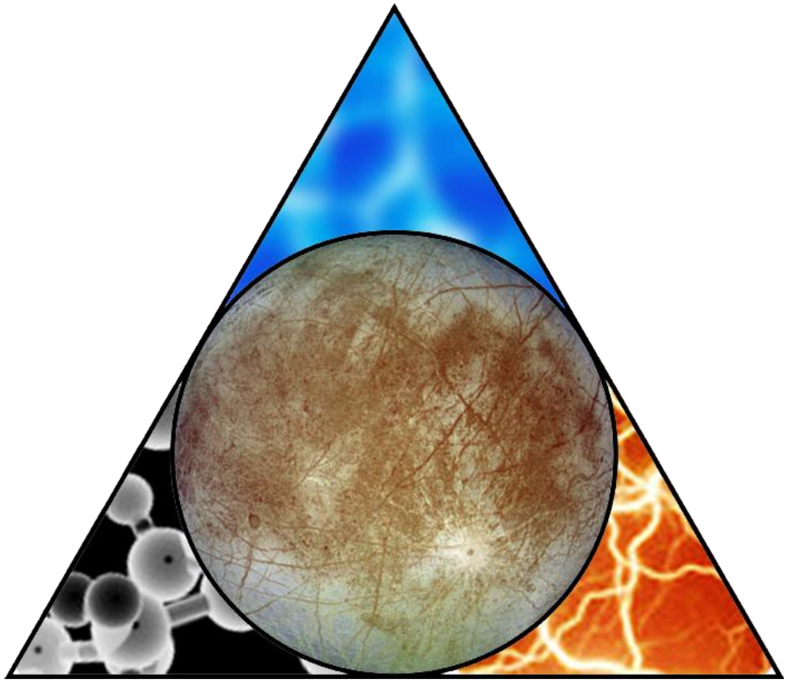

Europa Mission Concept Study Update

9/24/12

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Outline

1. Where we were left you in May…
2. Europa Summer Study
3. The Enhanced Europa Clipper Mission
4. Engineering Investigations

   (solar power, SLS, nanosats)
5. SDT Report and Recommendation
6. Summary & Cost
7. Conclusion

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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.

National Aeronautics and Space Administration

EUROPA STUDY 2012 REPORT

Europa Study Team, 1 May 2012, JPL D-71990
Task Order NMO711062 Outer Planets Flagship Mission

Cover art Michael Carroll

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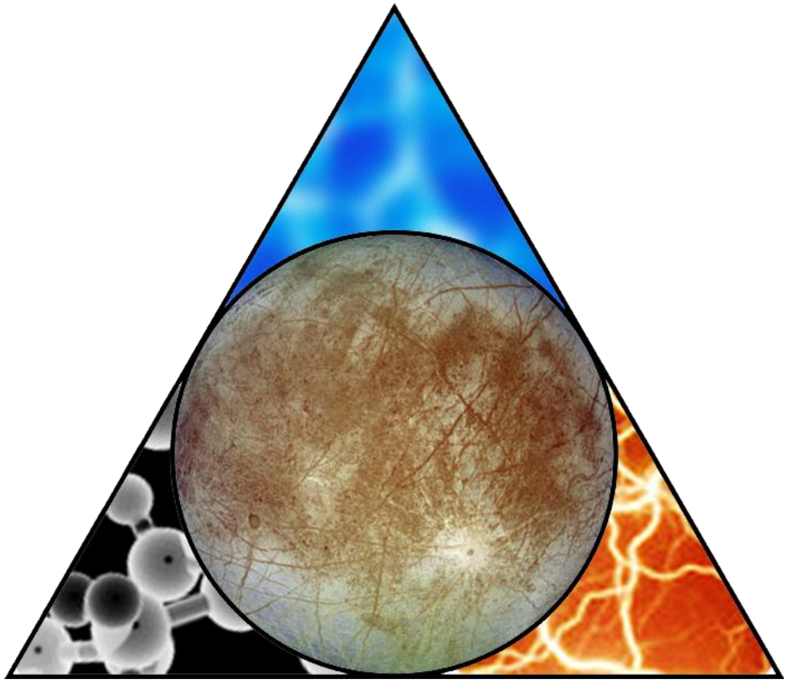

Where we left you in May…

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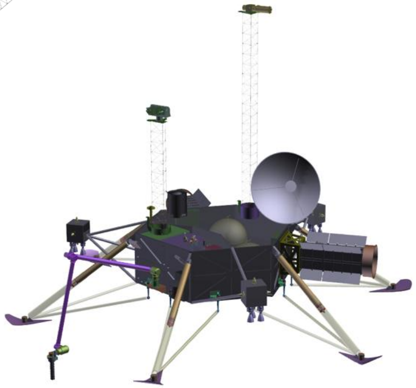
Background

May 2012 Presentation to CAPS

- The Jupiter Europa Orbiter (JEO) mission concept was deemed to be of extremely high science value, but unaffordable, by the NRC Decadal Survey, which requested a descoped option
- A one year study developed mission options (Orbiter, multiple flyby [Clipper], and Lander) that retain high science value at significantly reduced cost
- Independent reviews found that the Clipper concept *"offers the greatest science return per dollar, greatest public engagement, and greatest flow through to future Europa exploration." (Hubbard Review Board)*

Multiple-Flyby in Jupiter Orbit
(The Europa Clipper)

Europa Orbiter



Europa Lander

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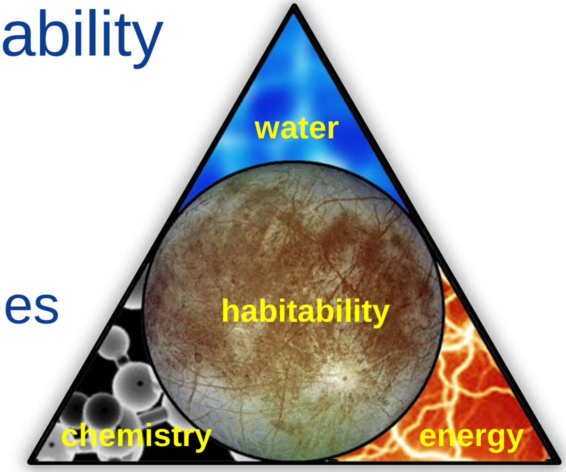
Science Goal, Habitability Themes, and Objectives

- *Goal:* Explore Europa to investigate its habitability
- *Habitability Themes:*
  - **Water:** Solvent to facilitate chemical reactions
  - **Chemistry:** Constituents to build organic molecules
  - **Energy:** Chemical disequilibrium for metabolism



- *Objectives:*
  - **Ocean:** Existence, extent, and salinity
  - **Ice Shell:** Existence and nature of water within or beneath, and nature 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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The Clipper in a Nutshell

May 2012

Science:

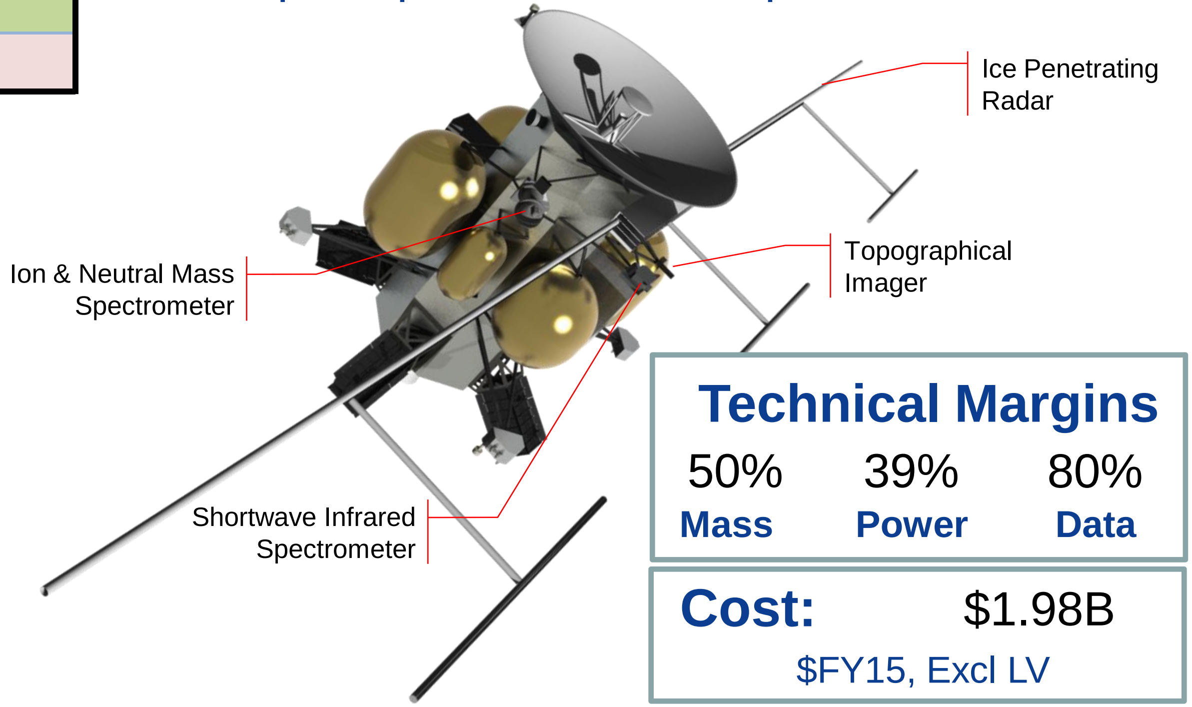
Objective	Clipper Baseline
Ice Shell	√
Ocean	X
Composition	√
Geology	√
Recon	X

Payload:

Instrument	Clipper Baseline
Floor	IPR
	SWIRS
	TI
Baseline	INMS

Operations Concept:

- 32 low altitude flybys of Europa from Jupiter orbit over 2.3 years
- Detailed investigation of globally distributed regions of Europa
- Simple repetitive science operations



Technical Margins

50%	39%	80%
Mass	**Power**	**Data**

Cost: $1.98B

$FY15, Excl LV

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The Orbiter in a Nutshell

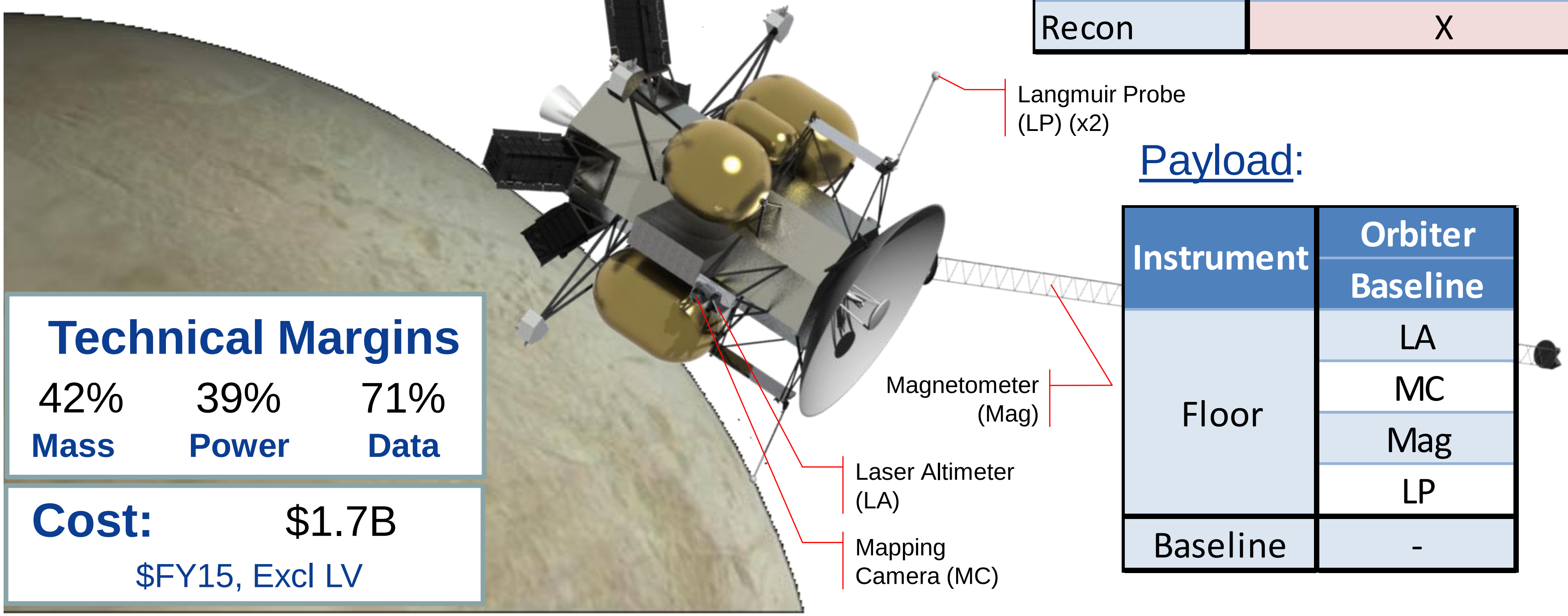
May 2012

Operations Concept:

- 30 days in 100 km near polar orbit about Europa
- Detailed globally mapping and gravity field measurement
- Simple repetitive science operations

Science:

Objective	Orbiter Baseline
Ice Shell	X
Ocean	√
Composition	X
Geology	√
Recon	X



Payload:

Instrument	Orbiter Baseline
Floor	LA
	MC
	Mag
	LP
Baseline	-

Technical Margins

42%	39%	71%
Mass	**Power**	**Data**

Cost: $1.7B

$FY15, Excl LV

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The Lander in a Nutshell

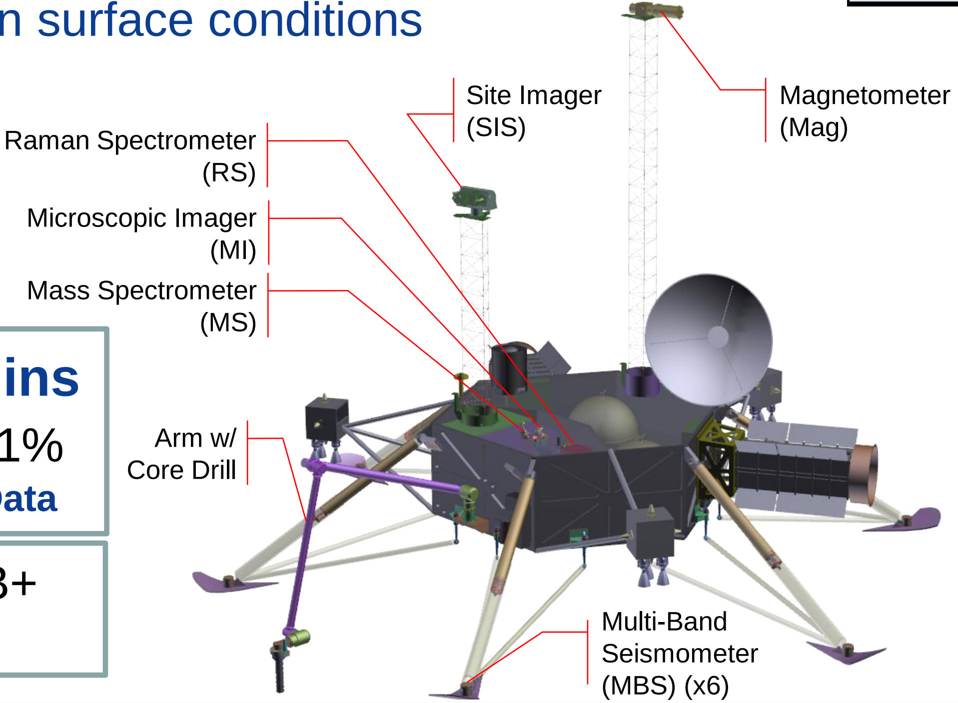
May 2012

Operations Concept:

- 30 days science investigation on the surface of Europa
- Surface and subsurface composition and morphology measurements
- Autonomous precision landing technology required to mitigate unknown surface conditions

Science:

Objective	Lander
Ice Shell	√ (Locally)
Ocean	√
Composition	√ (Locally)
Geology	√ (Locally)
Recon	√



Payload:

Instrument	Lander
Floor	MS
	Mag
	MBS
	SIS
Baseline	RS
	MI

Technical Margins

28%	38%	41%
Mass	**Power**	**Data**

Cost: $2.8B+

$FY15, Excl LV

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Summary from May

- OPAG and an independent review team led by Scott Hubbard found the Europa Clipper mission to provide the greatest science return per dollar as compared to the Orbiter and Lander and the Europa SDT rated its science to be excellent

- The Orbiter was found to provide very good science

- The Lander was deemed to be excellent science, but high risk

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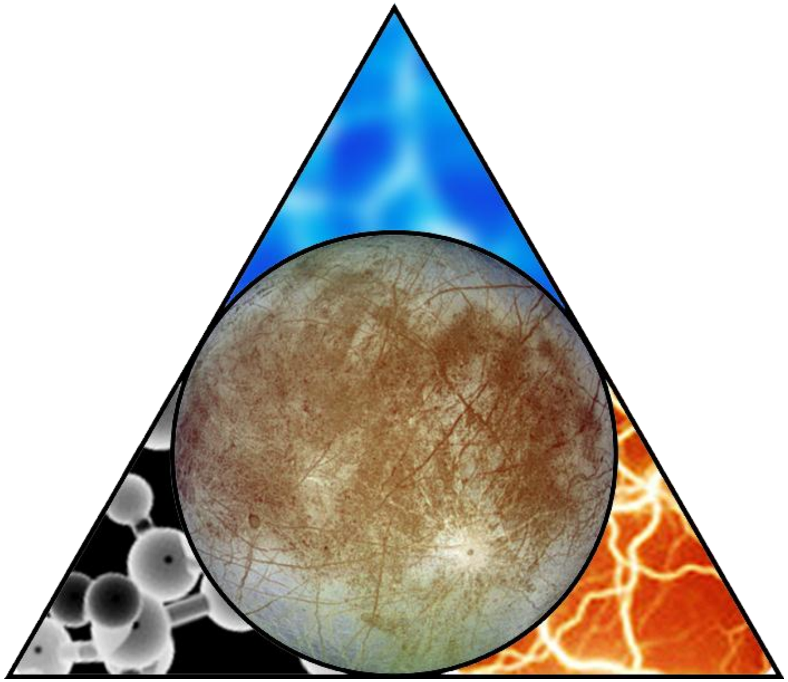

Since May

Summer Study

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Charge from NASA for Summer Study

Enhanced Clipper Science

Examine the ability to address the **Ocean** science objectives with the Clipper mission option and understand implications for the mission design and number of flybys while remaining cost neutral ($2B, FY15$, excl LV)

Landing Site Reconnaissance

Examination of the Landed Mission option in May identified surface condition uncertainty as a risk. Examine capabilities that can be added to the current mission to mitigate concern for a future landed mission.

Enhanced Orbiter Science

Examine the ability to address the **Ice Shell**, **Composition** and/or additional **Geology** science objectives with the Orbiter mission option and understand implications for the mission design and spacecraft architecture. Remaining within the Clipper cost ($2B, $FY15, excl LV)

Engineering Trades

- Investigation of solar power options
- Assess the enabling benefits of the Space Launch System
- Examine the accommodation of potential nanosats and the science they could achieve

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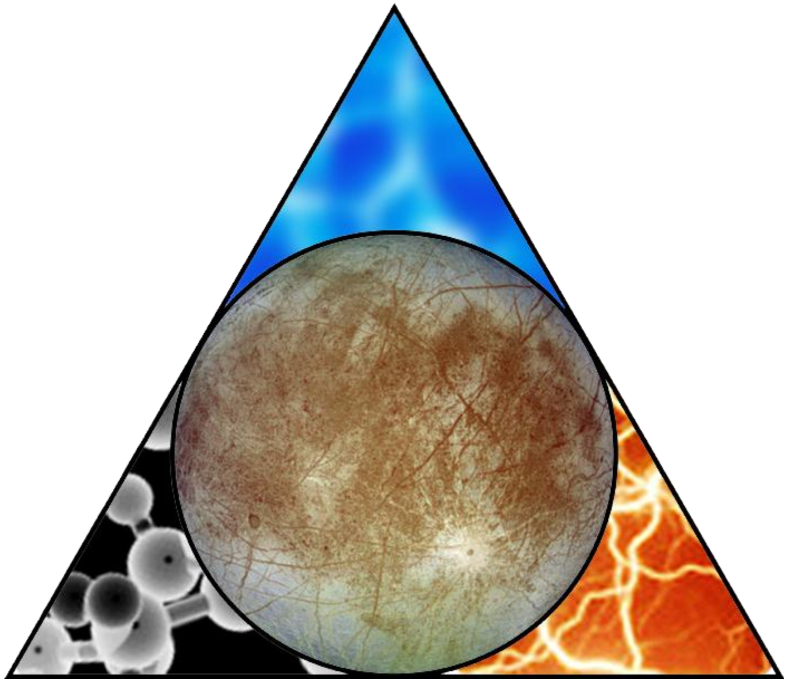

Enhanced Europa Clipper Mission

A Multiple-Flyby Europa Mission in Jupiter Orbit

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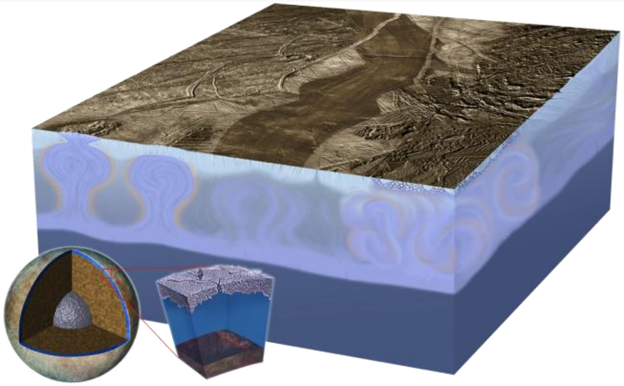
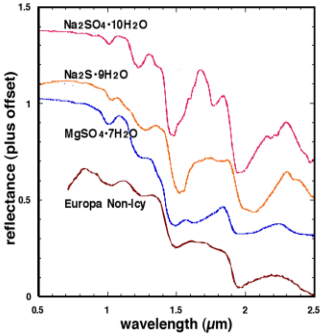
Clipper Science from May Report

- **Ice Shell:** Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange



- **Composition:** Understand the habitability of Europa's ocean through composition and chemistry



- **Geology:** Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities

mosaic by “Orion”

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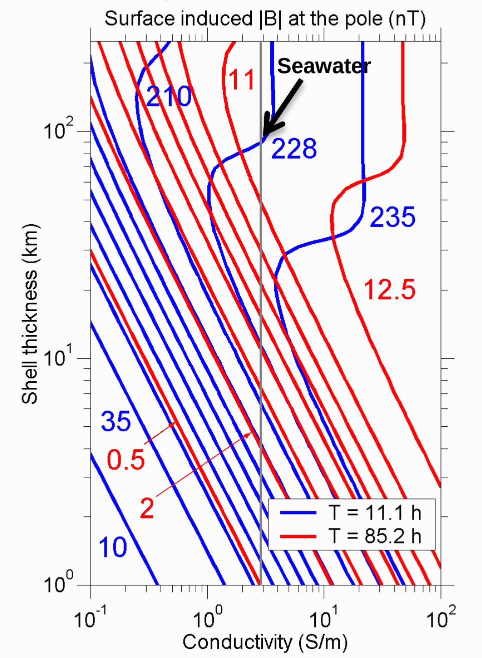
Enhanced Clipper Science

- **Ocean**: Characterize the properties of the ocean
  - Determine Europa's magnetic induction response to estimate ice shell thickness, and ocean salinity and thickness
  - Determine the amplitude and phase of gravitational tides

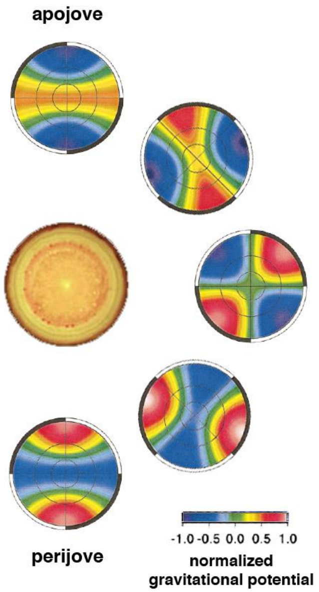
Providing an understanding of the properties of the ocean

Magnetic Induction



From Khurana 2002

Gravitational Tides



From: Moore and Schubert [2000]

- **Geology**: Expand observation strategy to achieve Global & regional along with the local coverage

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Clipper Science Traceability

Enhanced with Ocean & Geology Science

Goal	Objective		Investigation	Model Planning Payload	Theme		
					W	C	E
Explore Europa to investigate its habitability	**Ocean & Ice Shell**	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange and **the properties of the ocean**	Characterize the distribution of any shallow sub-surface water and the structure of the icy shell.	Ice-Penetrating Radar, Topo. Imager	✓		✓
			Determine Europa's magnetic induction response to estimate ocean salinity and thickness	**Mag. & Langmuir Probe**	✓	✓	
			Search for an ice-ocean interface.	Ice-Penetrating Radar, Topo. Imager	✓		✓
			Correlate surface features and subsurface struc-ture to investigate processes governing material exchange among the surface, ice shell, and ocean.	Ice-Penetrating Radar, IR spectrometer, Topo. imager	✓	✓	✓
			Determine the amplitude and phase of gravitational tides.	**Radio Subsystem**	✓		
			Characterize regional and global heat flow variations.	Ice-Penetrating Radar	✓		✓
	Composition	Understand the habitability of Europa's ocean through composition and chemistry.	Characterize the composition and chemistry of the Europa ocean as expressed on the surface and in the atmosphere.	IR spectrometer, NMS	✓	✓	
			Determine the role of Jupiter's radiation environment in processing materials on Europa.	IR spectrometer, NMS		✓	✓
			Characterize the chemical and compositional pathways in Europa's ocean.	IR spectrometer, NMS	✓	✓	
	Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.	Determine sites of most recent geological activity, and characterize high science interest localities.	Topo. Imager	✓		✓
			Determine the formation and three-dimensional characteristics of magmatic, tectonic, and impact landforms.	**Topo. Imager**	✓		✓

Themes: W= Water, C = Chemistry, E = Energy

▨ **Enhancement**

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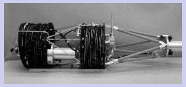
Clipper Enhanced Model Planning Payload

Science Objective	Key Science Investigations	Model Instrument	Similar Instrument
Ocean & Ice Shell	**Time-varying gravity field through Doppler tracking, to detect ocean and determine interior structure.**	**Radio Sub-system (RS); Independent Gimbaled Antenna**	
	Magnetic induction response, to derive ocean thickness and salinity.	**Magnetometer (MAG)**	 **Galileo MAG**
	Local plasma and electric field, to support magnetic induction experiment.	**Langmuir Probe (LP)**	 **Rosetta LAP**
	Sounding of dielectric horizons at two frequencies, to search for shallow water and the ocean.	Ice-Penetrating Radar (IPR)	 MRO SHARAD
Composition	Visible and near-infrared spectroscopy, for global mapping and high-resolution scans, to derive surface composition.	ShortWave IR Spectrometer (SWIRS)	 LRO M3
	Elemental, isotopic, and molecular composition of the atmosphere and ionosphere, during close flybys.	Neutral Mass Spectrometer (NMS)	 Nazomi NMS
Geology	**Medium to** High resolution stereo imagery, to characterize geological landforms, and to remove clutter noise from IPR data.	Topographical Imager (TI)	 New Horizons Ralph/MVIC

🟩 Floor model instrument

🟨 Baseline model instrument

🟪 **Enhancement**

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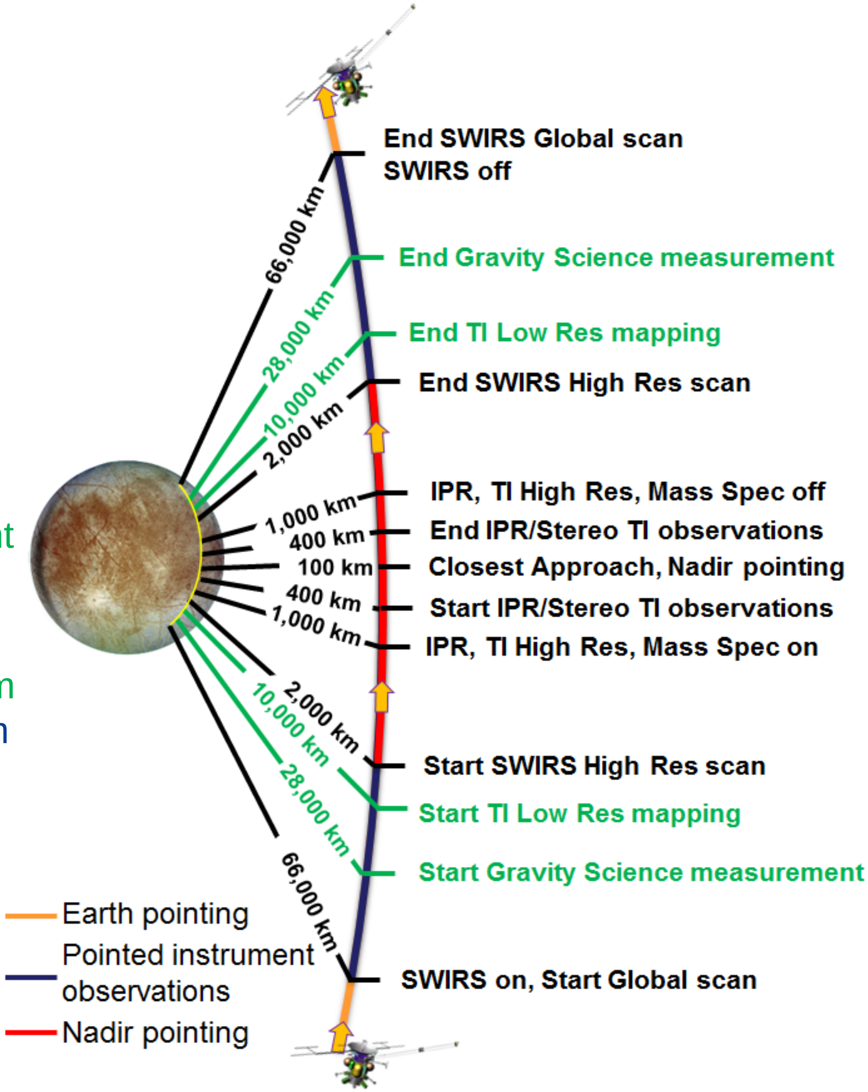
Clipper Science Ops Concept

Simple and Repetitive

1. **ShortWave InfraRed Spectrometer (SWIRS)**
   - Global low resolution scan below 66,000 km altitude
   - Targeted high resolution scan below 2,000 km altitude
   - Passive below 1,000 km altitude
2. **Gravity Science**
   - Two-way coherent carrier only telcom link to Earth via articulated HGA
3. **Magnetometer / Langmuir Probe (MAG/LP)**
   - Plasma corrected magnetic field measurement below 28,000 km
4. **Topographical Imager (TI)**
   - Low resolution area mapping below 10,000 km
   - High resolution stereo images below 1,000 km altitude
5. **Ice Penetrating Radar (IPR)**
   - Power on and calibrate at 1,000 km
   - Surface scans below 400 km altitude
6. **Neutral Mass Spectrometer (NMS)**
   - *In situ* scan below 1,000 km altitude



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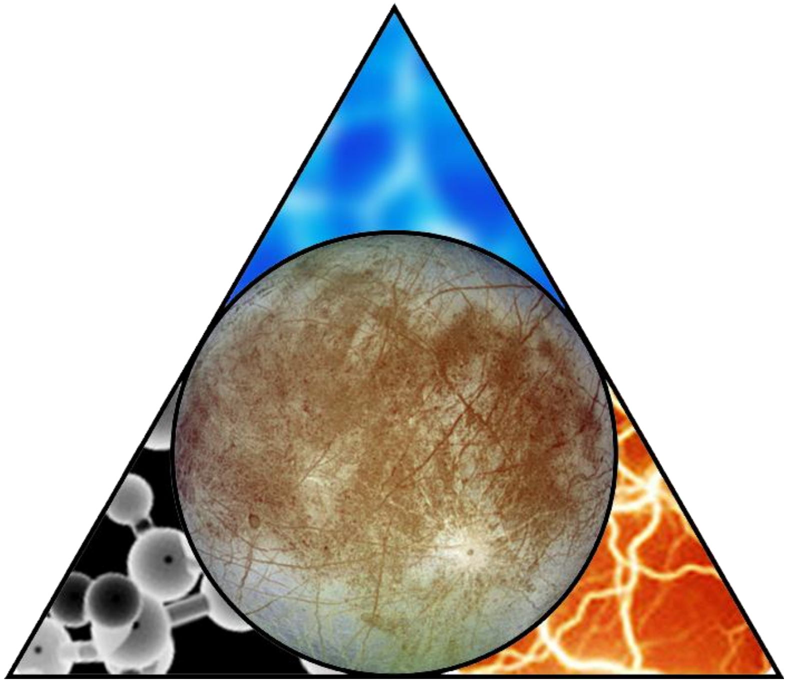

Reconnaissance Data Sets for Future Landers

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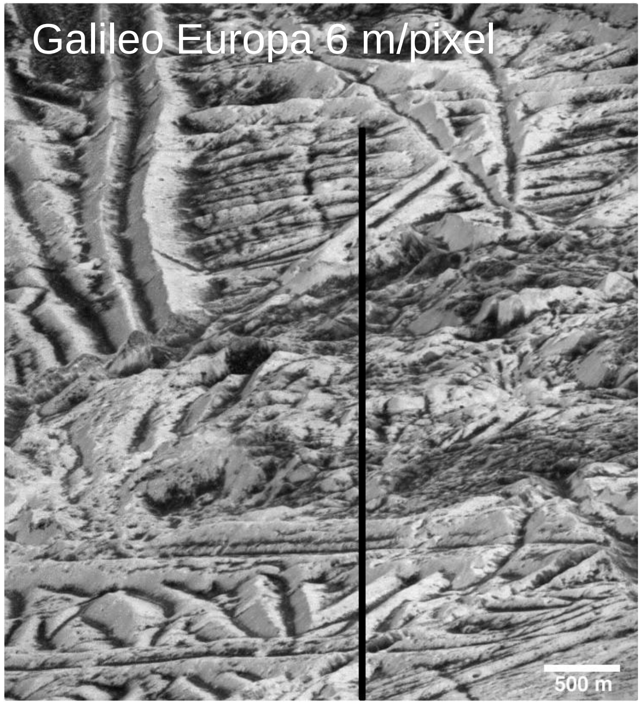
Programmatic need for feed forward Reconnaissance Data sets

- Reconnaissance data is necessary from both science and engineering perspectives:
  - *Science reconnaissance for landing site selection (enabled by the current model payload)*
    - Is the landing site scientifically compelling in addressing the goal of exploring Europa to investigate its habitability
  - *Engineering reconnaissance for landing safety*
    - Is a safe landing site (within the lander's design margins) accessible to a spacecraft?
    - Assess 15 sites to determine conditions and find one that is safe

Highest Resolution Europa image currently available



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Programmatic need for feed forward Reconnaissance Data sets

- The Clipper notional remote sensing payload (SWIRS, TI, IPR) already provides a primary basis for selecting a scientifically compelling landing site
- Enhanced Clipper reconnaissance capability would include key elements to complete the reconnaissance data set needs
  - High resolution imaging at ~0.5 m/pixel
  - Thermal imaging to provide knowledge of the properties of the surface
- Reconnaissance capabilities would also serve to reinforce the landing site scientific rationale

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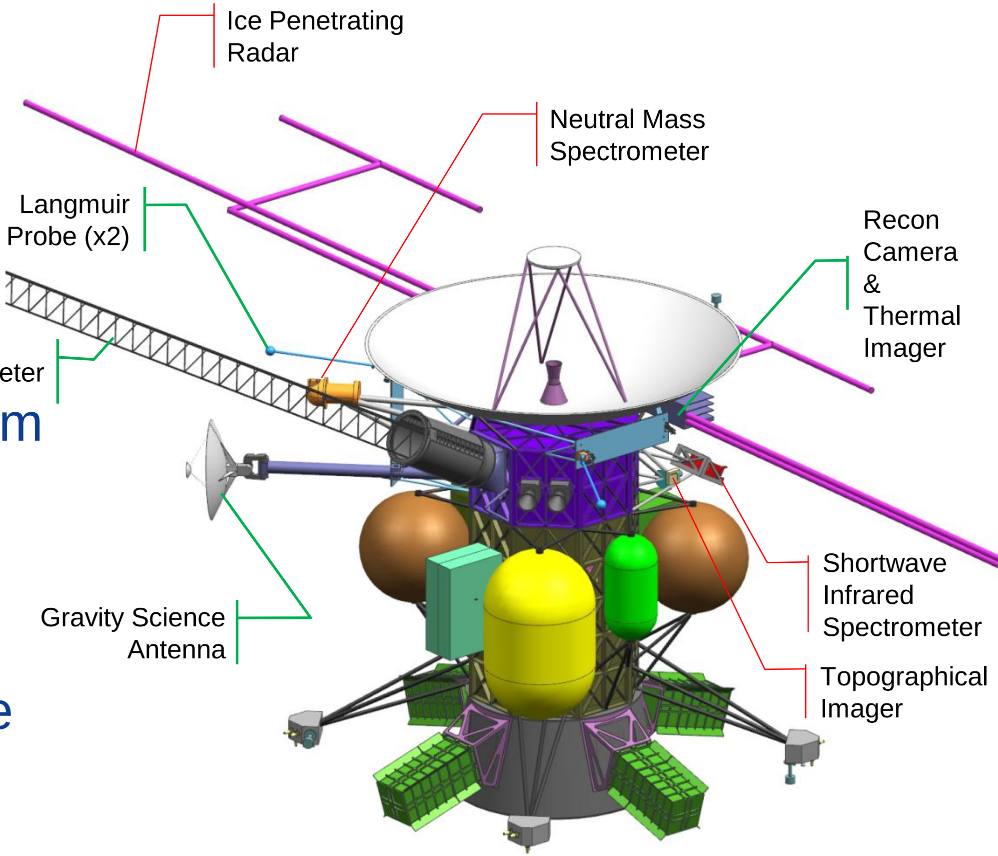
Enhanced Clipper Mission Configuration

Changes made since May 2012:

- Added 3 instruments
  - Magnetometer
  - Langmuir Probe
  - GS Antenna
- Added Recon Camera
  - 0.5m / pxl resolution at 100 km
- Added Thermal Imager
- Added Magnetometer boom
- Resized battery to accommodate higher flyby peak load



Technical Margins

47%	39%	77%
Mass	**Power**	**Data**

Cost: $2.2B

$FY15, Excl LV

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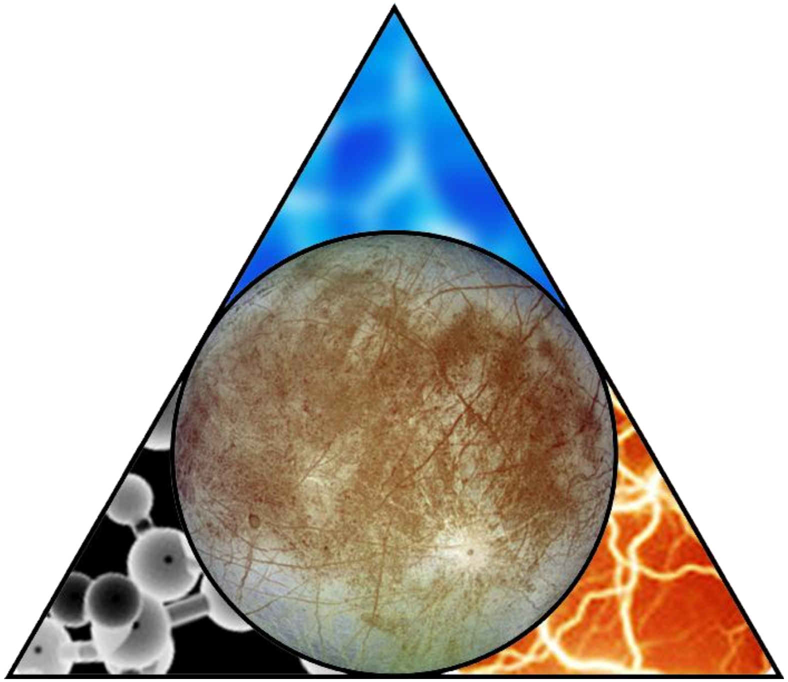

Engineering Investigations

1) Solar Power System
2) Space Launch System
3) Smallsats

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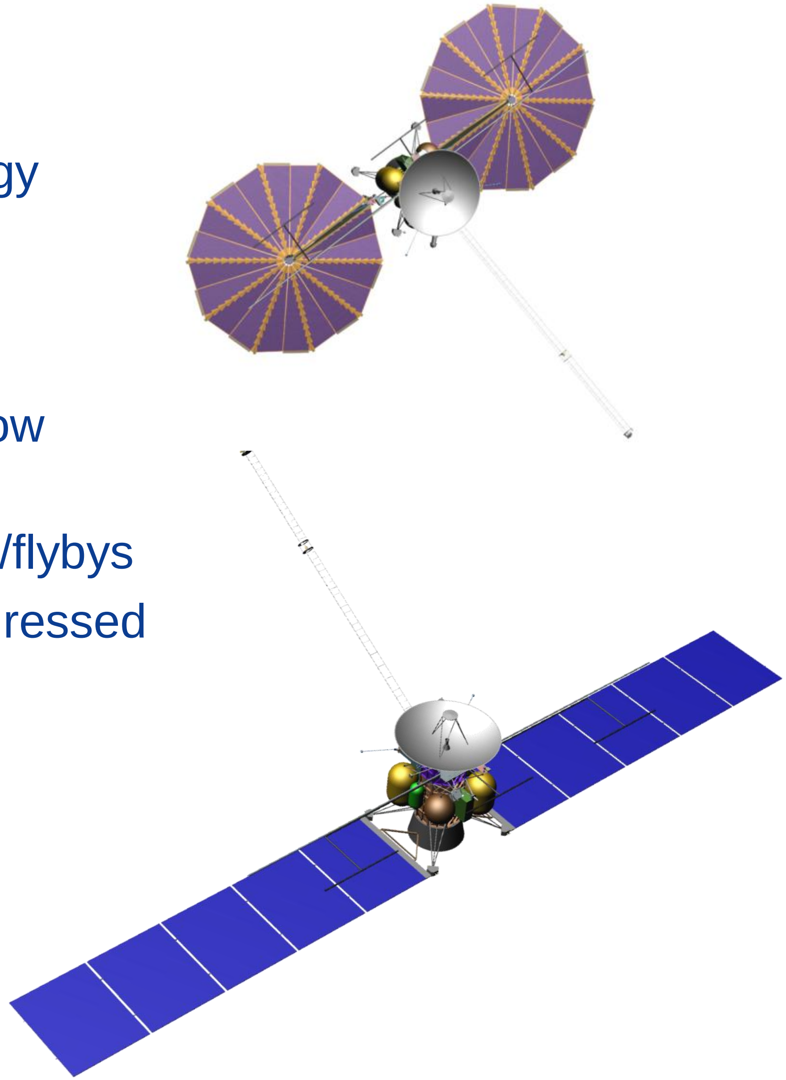
Power Systems

- In addition to ASRG, study team continues to investigate alternate power sources
  - Currently examining solar power technology options for Clipper and Orbiter
- Clipper preliminary results are encouraging
  - Array size similar to Juno (~60 m2) even accounting for radiation & Low Intensity Low Temperature (LILT) derating
  - Requires large battery capacity for eclipse/flybys
- Engineering issues to be investigated and addressed
  - Cold survival temperature of array
    - Juno qualification difference
  - Radiation 2X Juno test data
    - Radiation testing needs
  - Flexible body effects
    - Pointing implications



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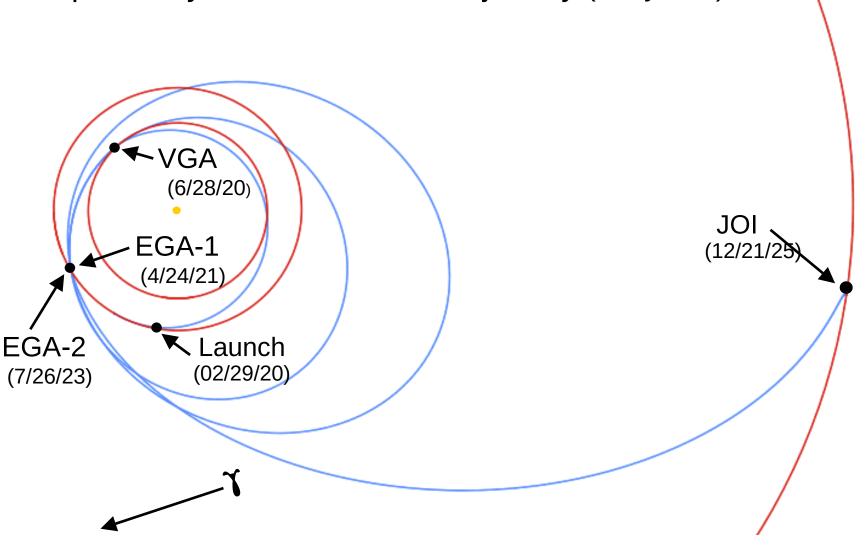
VEEGA Interplanetary Trajectory

Robust with Annual Launch Opportunities

Interplanetary Phase: VEEGA Trajectory (5.8 years)



High performance interplanetary trajectory with annual launch opportunities

Nominal IP Trajectory		
Event	**Date**	**Flyby Alt. (km)**
Launch	**29 Feb 2020**	**-**
Venus	**28 Jun 2020**	**20,266**
Earth-1	**24 Apr 2021**	**3274**
Earth-2	**26 Jul 2023**	**1028**
Ganymede-0	**20 Dec 2025**	**500**
JOI	**21 Dec 2025**	**12.8 R_J**

Nominal

Annual Launch Opportunities				
Launch Date	**Flyby Path**	**TOF to JOI (yrs.)**	**C_3 (km^2/s^2)**	**Atlas V 551 Capability (kg)**
21 Jul 2018	VVEE	6.32	15.0	4585
23 Mar 2019	EVEE	6.91	10.5	5011
29 Feb 2020	**VEE**	**5.8**	**12.8**	**4794**
27 May 2021	VEE	6.87	14.5	4541
21 Nov 2021	VEE	6.37	15.0	4494
15 May 2022	EVEE	7.22	10.2	4935
23 May 2023	VEE	6.18	16.4	4339
03 Sep 2024	VEE	6.71	13.8	4562

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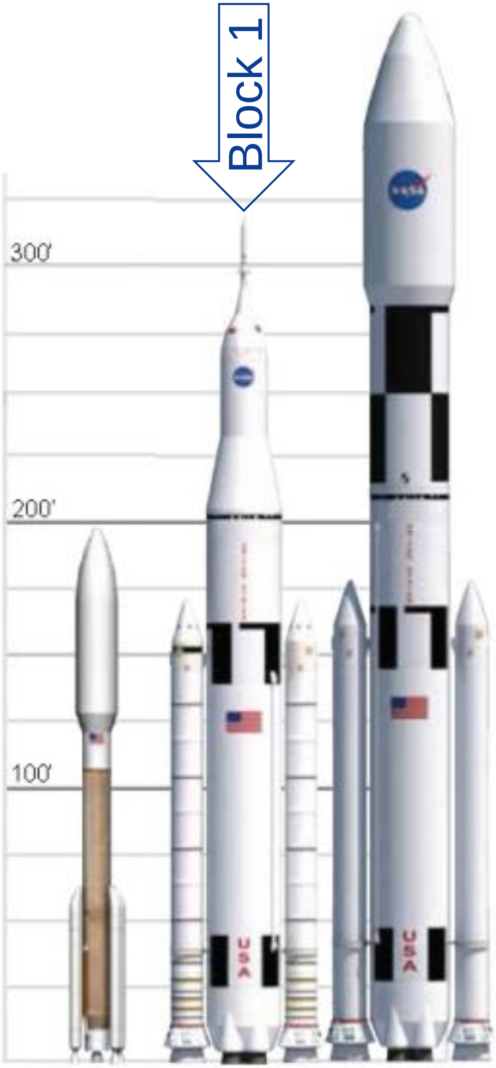
Space Launch System (SLS)

- Examining the benefits of using SLS
  - Greatly increases mass margins
    - >6,000 kg lift mass at a C3 of 73
  - Reduce trip time via more efficient interplanetary trajectory
    - 6 years to 2.8 years
  - Standard Delta IV fairing and payload interface planned in Block 1 design
  - Actively working with MSFC on a cost neutral model



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Nanosats

Potential Nanosat Science

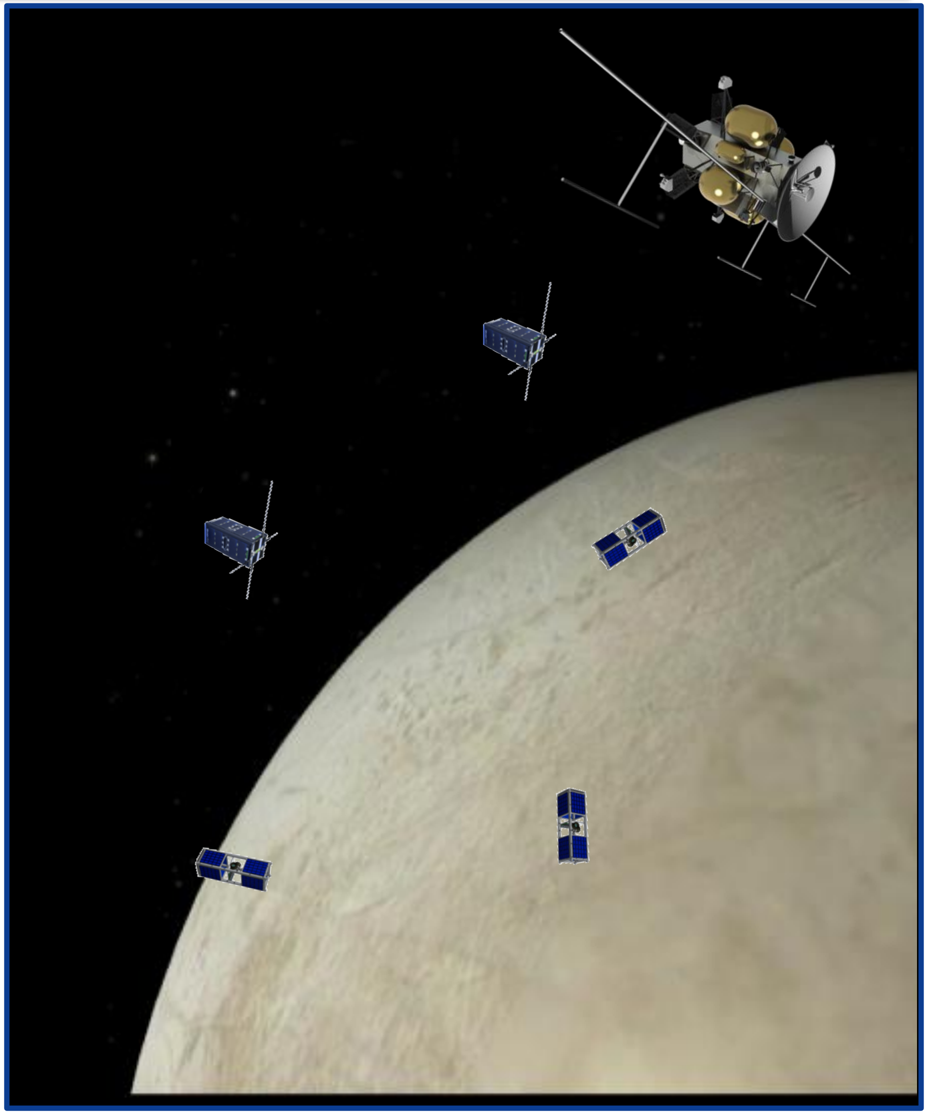
- Ocean conductance measurement
- Radio Science
- High resolution descent imagery
- Magnetometry
- Radiation measurements

Nanosat Development

- University competition, selected on the basis of science, risk, and cost
- 6-12 “Cubesats” at max. 15kg each
- Deployed during flyby
- Project could provide rad-hard parts as required
- Only possible under SLS LV option and outside of current project costs

Forward Plan

- Investigate feasibility and implementation options



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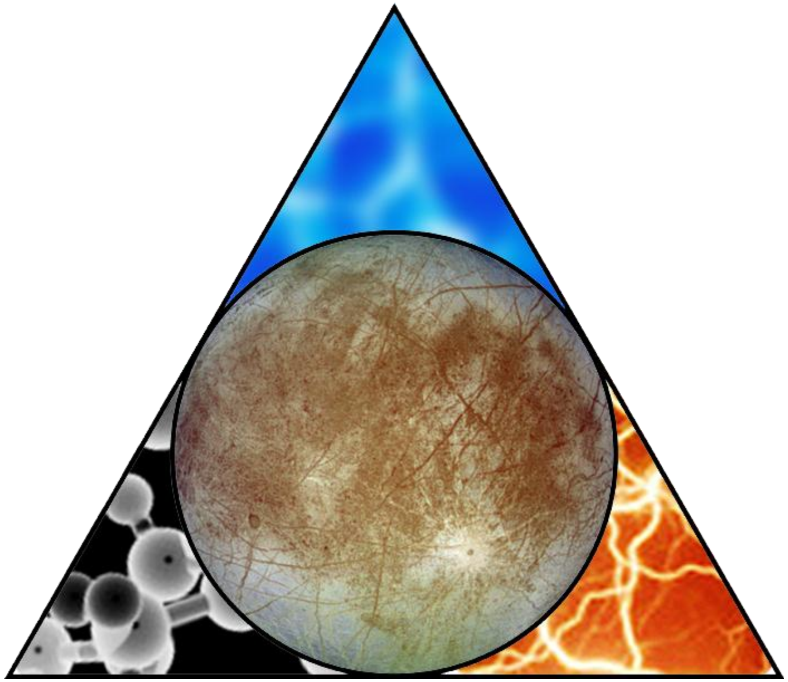

SDT Report

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Enhanced Mission Concepts

- **Clipper**:

  If NASA desires to add some ocean science to the Clipper concept, the SDT recommends:

  - **Ocean, sea floor, and salinity science** (first priority), which can be accomplished by the addition to the payload of a Magnetometer, potentially additional flybys, and a Langmuir probe, and
  - **Ocean confirmation** (second priority), which can be accomplished through gravity science, in the form of a Radio Science experiment

  If cost neutrality is required to do this, then the SDT recommends reducing the existing composition science capability by replacing the notional INMS instrument with an NMS

  If these changes are carried out, then the Clipper concept will address the Europa science objectives of Ice shell, Composition, Geology and Ocean

- **Orbiter**:

  The SDT recommends the addition of ice shell science (in the form of a subsurface sounding instrument)

  If this change is carried out, the Orbiter concept will address the Europa science objectives of Ocean, ice shell, and geology

  The SDT is concerned that composition science cannot be accomplished with this enhanced Orbiter concept under the existing cost cap, thus leaving a noticeable gap in Europa science

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Key Science Questions for Europa

Science Question	Theme	Clipper	Orbiter
1. What are the properties and characteristics of Europa's ocean?	Ocean	▨ ✓	✓
2. How thick is the icy shell?	Ice Shell	✓	✓
3. Is there near-surface water within the ice shell?	Ice Shell	✓	▨ ✓
4. What is the global distribution of geological features?	Geology	✓	✓
5. Is liquid water involved in surface feature formation?	Geology/Ice Shell	✓	▨ ✓
6. Is the icy shell warm and convecting?	Ice Shell	✓	▨ ✓
7. What does the red stuff tell us about ocean composition?	Composition	✓	
8. How active is Europa today?	Geology/Ice Shell	✓	▨ ✓
9. What is the plasma and radiation environment at Europa?	Ocean/Composition		
10. What is the nature of organics and salts at Europa?	Composition	✓	
11. Is chemical material from depth carried to the surface?	Composition	✓	
12. Is irradiation the principal cause of alteration of Europa's surface material through time?	Composition	✓	

▨ ✓ **Enhancements to to each Mission concept**

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Programmatic need for feed forward reconnaissance data sets

- The SDT endorses the inclusion of a programmatic reconnaissance capability on the next Europa-focused orbiter or flyby mission, in preparation for a future Europa surface mission
- The notional Clipper payload as conceived would provided an important basis for selecting a scientifically compelling landing site
- The SDT recognizes that any reconnaissance capability involves a cooperative effort between science and engineering with significant input from the science community to be successful

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SDT Recommendation

August 2012 meeting

- The SDT reaffirms that the mission concepts described in the May 2012 Report continue to provide robust means to accomplish Europa science with the Clipper ranking above the Orbiter in its ability to achieve high priority Europa science

The enhanced Clipper concept is excellent in meeting the goal of exploring Europa to investigate its habitability

- **This concept will provide significant advancement in key ice shell, composition, geology, and ocean science**
- **The Clipper is deemed of higher ranking relative to the refined Orbiter concept**

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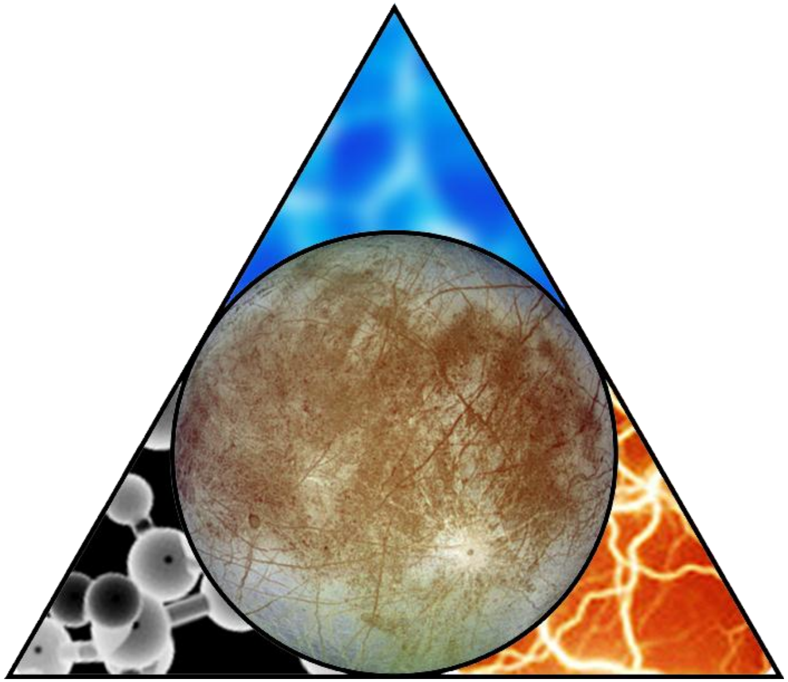

Summary

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Enhanced Clipper w/ Recon

Science:

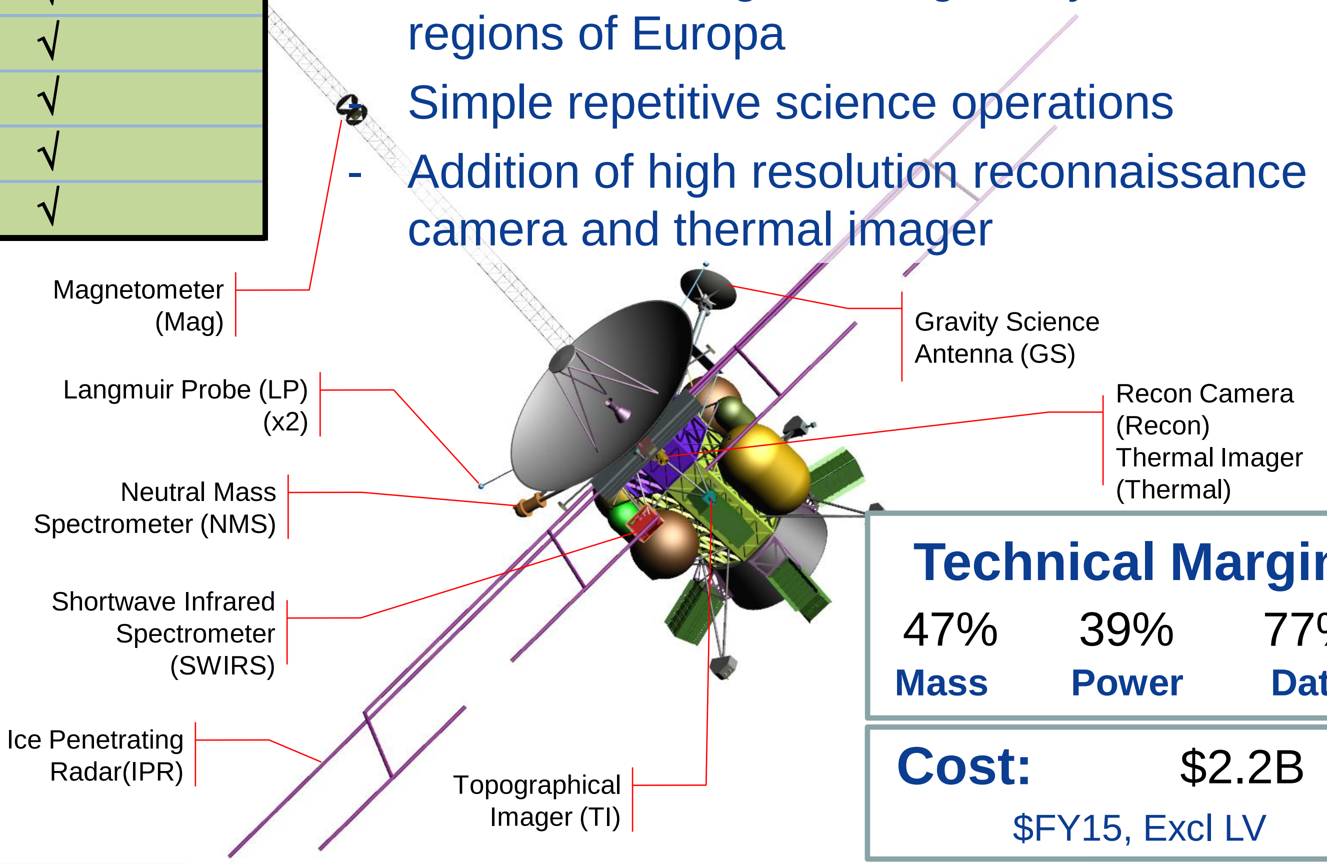
Objective	Clipper Enhanced w Recon
Ice Shell	√
Ocean	√
Composition	√
Geology	√
Recon	√

Payload:

Instrument	Clipper Enh w Recon
Floor	IPR
	SWIRS
	TI
Baseline	NMS
	MAG
	LP
	GS
	Recon
	Thermal

Operations Concept:

- 32 low altitude flybys of Europa from Jupiter orbit over 2.3 years
- Detailed investigation of globally distributed regions of Europa
- Simple repetitive science operations
- Addition of high resolution reconnaissance camera and thermal imager



Technical Margins

47%	39%	77%
Mass	**Power**	**Data**

Cost: $2.2B

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Enhanced Solar Clipper w/ Recon

Science:

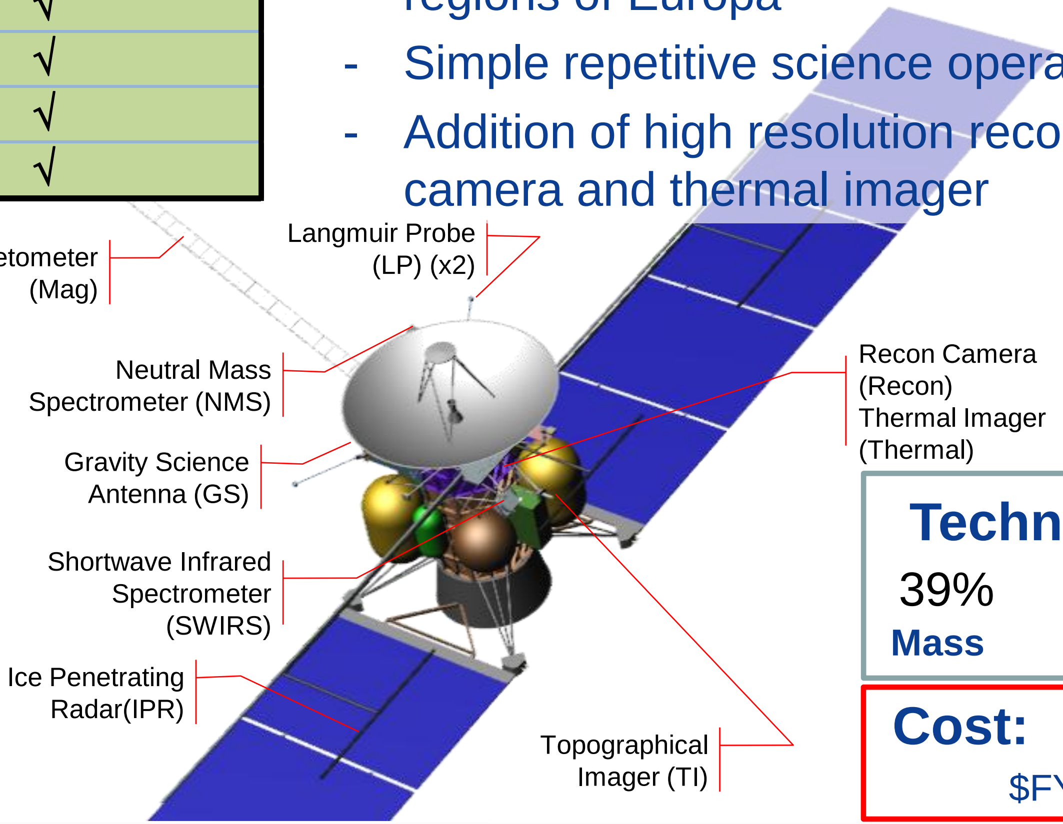
Objective	Clipper
	Enhanced w Recon
Ice Shell	√
Ocean	√
Composition	√
Geology	√
Recon	√

Operations Concept:

- 32 low altitude flybys of Europa from Jupiter orbit over 2.3 years
- Detailed investigation of globally distributed regions of Europa
- Simple repetitive science operations
- Addition of high resolution reconnaissance camera and thermal imager

Payload:

Instrument	Clipper
	Enh w Recon
Floor	IPR
	SWIRS
	TI
Baseline	NMS
	MAG
	LP
	GS
	Recon
	Thermal



Technical Margins

39%	40%	75%
Mass	Power	Data

Cost: $1.98B

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Conclusion

- OPAG finding (May 2012)

  "All 3 Europa mission options are highly scientifically meritorious and responsive to the Planetary Science Decadal Survey. ... The strong majority view of the OPAG community is that the Multiple-Flyby [Clipper] option … offers the greatest science return per dollar, greatest public engagement, and greatest flow through to future Europa exploration

- Europa SDT Meeting (Aug 2012)

  "The SDT is of the opinion that the rebalanced Clipper concept is excellent in meeting the goal of exploring Europa to investigate its habitability"

- Study team has addressed NASA's request to investigate rebalancing the May 2012 mission options
  - Will deliver reports by end of December
- Europa technical concept is mature and implementable within the identified cost target

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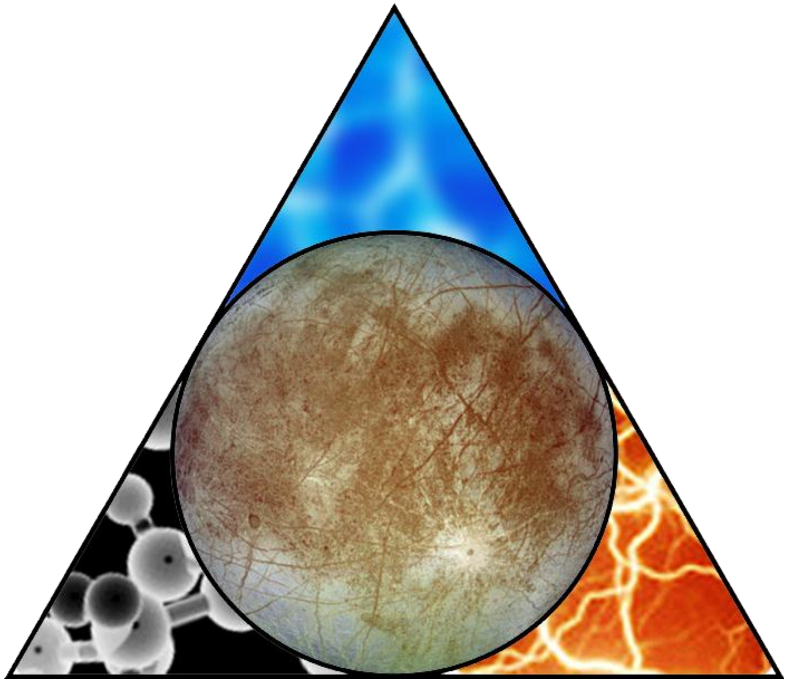

Backup Material

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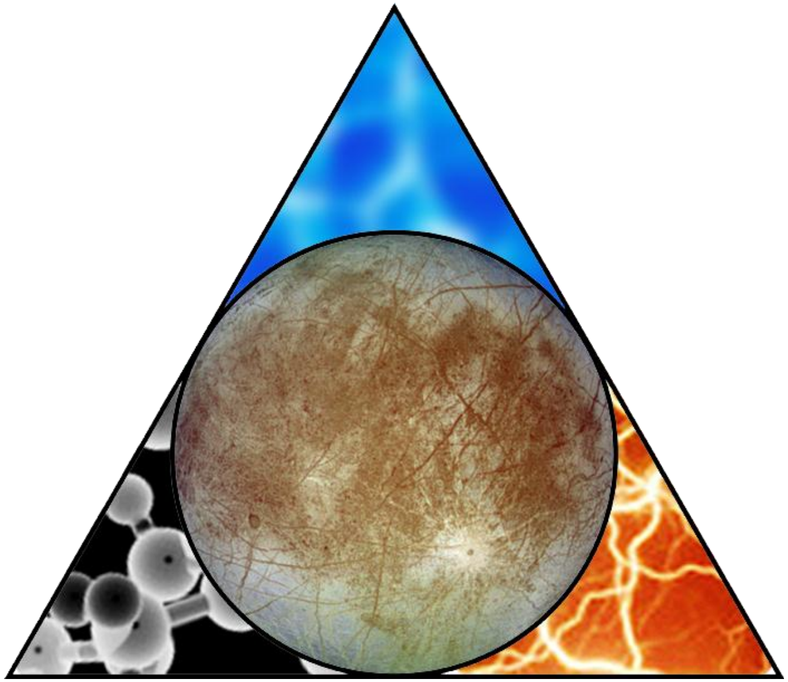

Enhanced Europa Orbiter Science

A 109-day Mission in Europa Orbit

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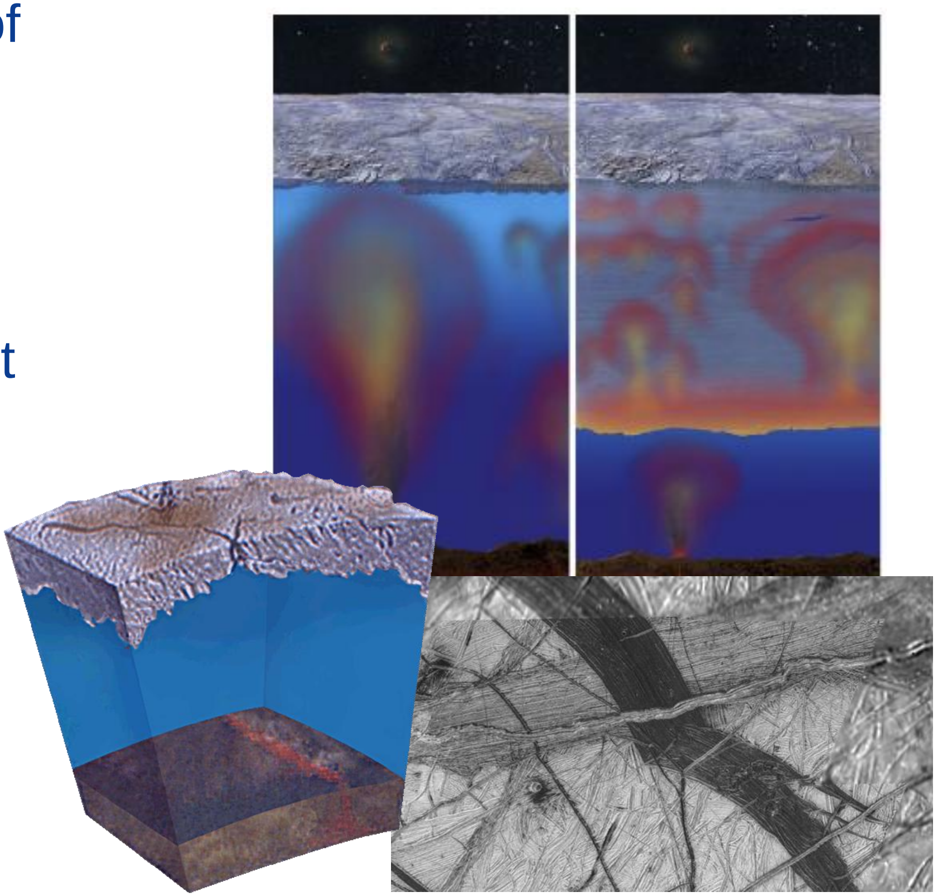
Orbiter Science

- **<u>Ocean</u>:** Characterize the extent of the ocean and its relation to the deeper interior
- **<u>Geology</u>**: Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities

***<u>Science Enhancement</u>*:**

- **Ice Shell:** Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.



Focus on providing a comprehensive understanding of the ocean and its tidal interaction with the icy crust

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Orbiter Science Traceability

Enhanced with Ice Shell Science

Goal	Objective		Investigation	Model Planning Payload	Theme		
					W	C	E
Explore Europa to investigate its habitability	Ocean	Characterize the extent of the ocean and its relation to the deeper interior.	Determine the amplitude and phase of gravitational tides.	Radio subsystem, Laser altimeter	✓		
			Determine Europa's magnetic induction response.	Magnetometer, Langmuir probe	✓	✓	
			Determine the amplitude and phase of topographic tides.	Laser altimeter, Radio subsystem	✓		
			Determine Europa's rotation state.	Laser altimeter, Mapping camera	✓		
			Investigate the deeper interior.	Radio subsystem, Laser altimeter, Magnetometer, Langmuir probe	✓	✓	✓
	Ice Shell	**Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.**	**Characterize the distribution of any shallow subsurface water and the structure of the icy shell**	**Ice Penetrating Radar Mapping camera, Laser altimeter**	✓		✓
			Search for an ice-ocean interface.	**Ice Penetrating Radar Mapping camera, Laser altimeter**	✓		✓
			Correlate surface features and subsurface structure to investigate processes governing material exchange among the surface, ice shell, and ocean.	**Ice Penetrating Radar Mapping camera, Laser altimeter**	✓	✓	✓
			Characterize regional and global heat flow variations.	**Ice Penetrating Radar**	✓		✓
	Geology	Understand the formation of surface features, including sites of recent or current activity to understand regional and global evolution.	Determine the distribution, formation, and three-dimensional characteristics of magmatic, tectonic, and impact landforms.	Mapping camera, Laser altimeter	✓		✓

Themes: W= Water, C = Chemistry, E = Energy

▨ **Enhancement**

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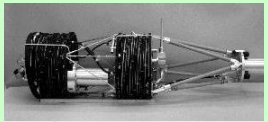
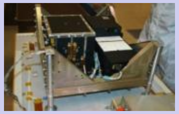
Orbiter Augmented Model Planning Payload

Science Objective	Key Science Investigations	Model Instrument	Similar Instrument
Ocean	Time-varying gravity field through Doppler tracking, to detect ocean and determine interior structure.	**Radio Sub-system (RS)**	
	Time-varying tidal amplitude, to detect ocean and determine interior structure.	**Laser Altimeter (LA)**	 NEAR NLR
	Magnetic induction response, to derive ocean thickness and salinity.	**Magnetometer (MAG)**	 Galileo MAG
	Local plasma and electric field, to support magnetic induction experiment.	**Langmuir Probe (LP)**	 Rosetta LAP
Ice Shell	**Sounding of dielectric horizons at two frequencies, to search for shallow water and the ocean.**	**Ice-Penetrating Radar (IPR)**	 **MRO SHARAD**
Geology	Uniform global mapping, for landform global distribution and stratigraphy.	**Mapping Camera (MC)**	 MPL/MSL MARDI

Note: Model instrument baseline and floor are equivalent

🟪 **Enhancement**

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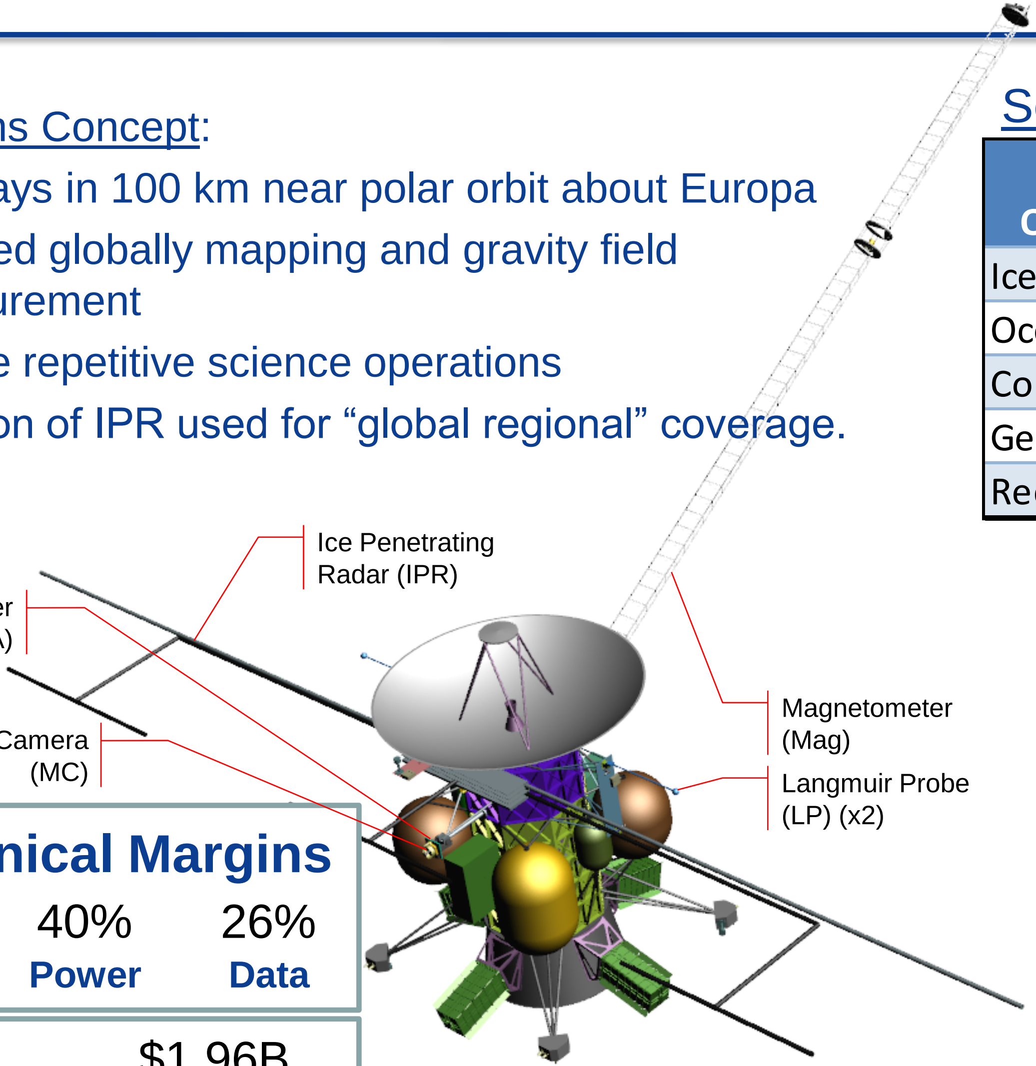
Enhanced Orbiter

Operations Concept:

- 109 days in 100 km near polar orbit about Europa
- Detailed globally mapping and gravity field measurement
- Simple repetitive science operations
- Addition of IPR used for “global regional” coverage.



Science:

Objective	Orbiter
	Enhanced
Ice Shell	√
Ocean	√
Composition	X
Geology	√
Recon	X

Payload:

Instrument	Orbiter
	Enhanced
Floor	LA
	MC
	Mag
	LP
Baseline	IPR

Technical Margins

41%	40%	26%
Mass	**Power**	**Data**

Cost: $1.96B

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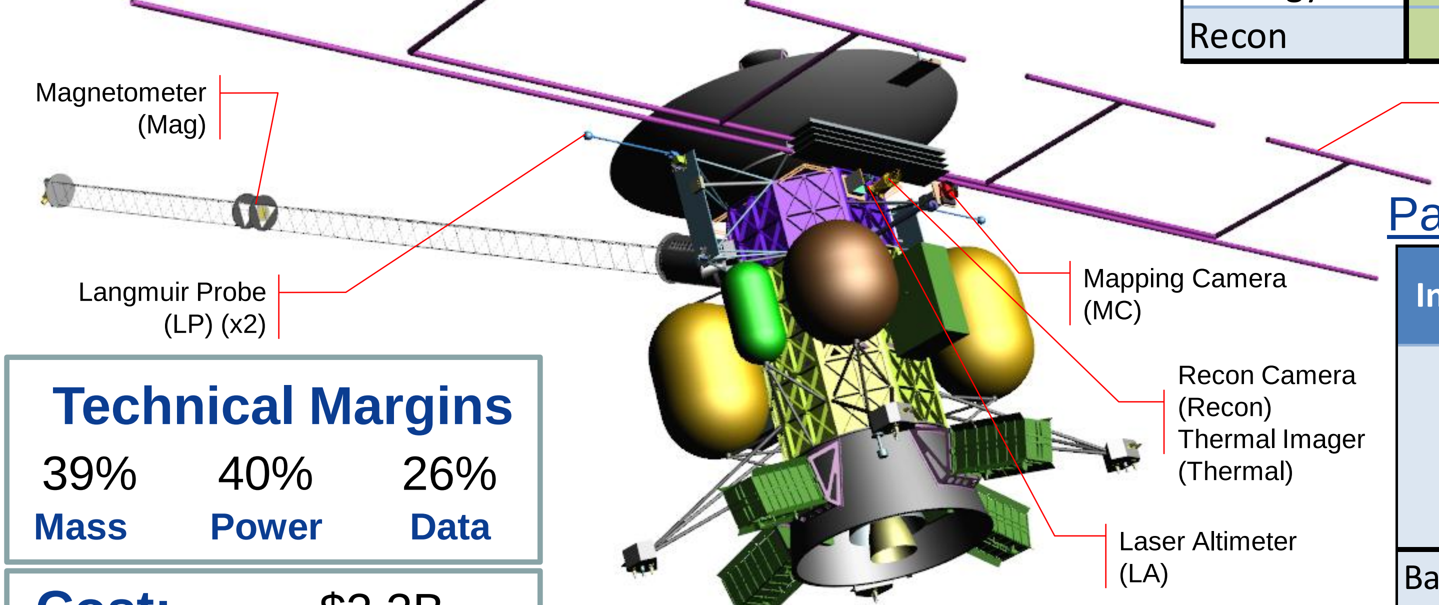
Enhanced Orbiter w/ Recon

Operations Concept:

- 109 days in 100 km near polar orbit about Europa
- Detailed globally mapping and gravity field measurement
- Simple repetitive science operations
- Addition of IPR used for “global regional” coverage.

Science:

	Orbiter
Objective	Enhanced w Recon
Ice Shell	√
Ocean	√
Composition	X
Geology	√
Recon	√



Payload:

Instrument	Orbiter
	Enh w Recon
Floor	LA
	MC
	Mag
	LP
Baseline	IPR
	Recon
	Thermal

Technical Margins

39%	40%	26%
Mass	**Power**	**Data**

Cost: $2.2B

$FY15, Excl LV

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