Europa Mission Concept Study Update

9/24/12

Outline

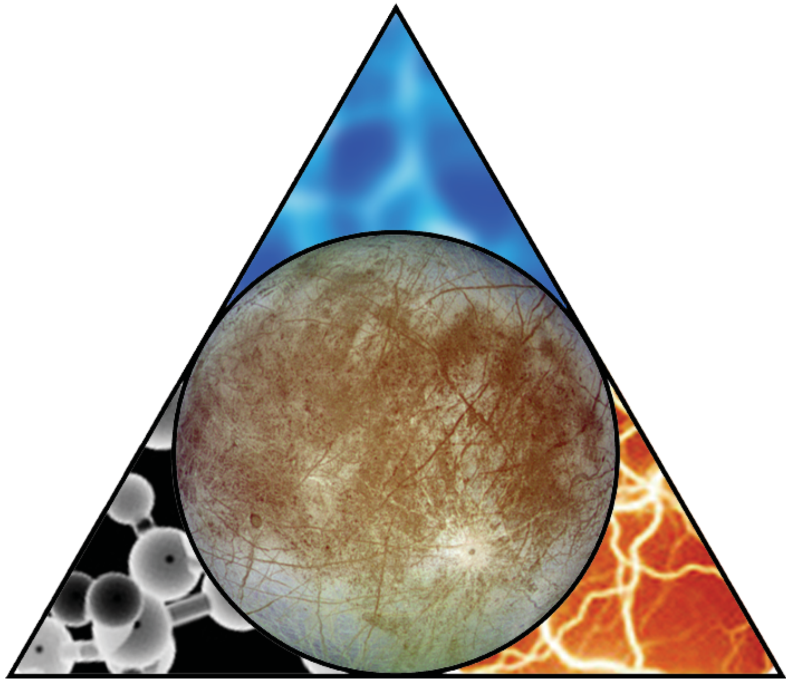
1. Where we were left you in May…
2. Europa Summer Study
3. The Enhanced Europa Clipper Mission
4. Engineering Investigations

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

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.



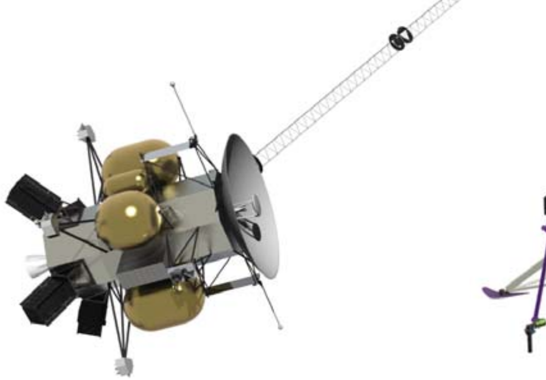
Where we left you in May…

Background

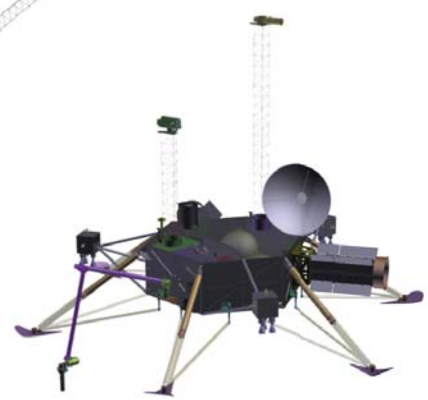
May 2012 Presentation to CAPS

- 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)



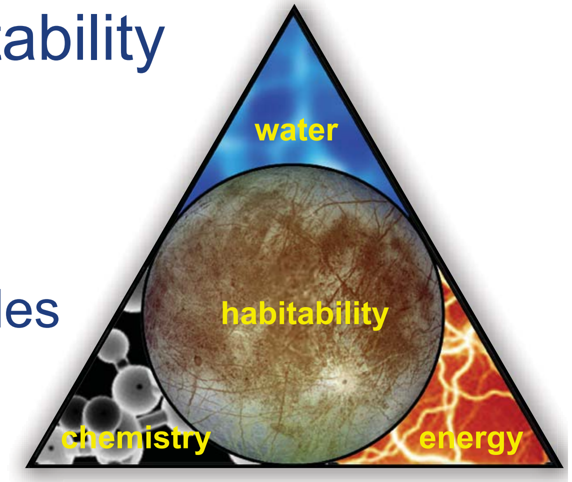
Europa Orbiter



Europa Lander

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

The Clipper in a Nutshell

May 2012

Science:

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

Operations Concept:

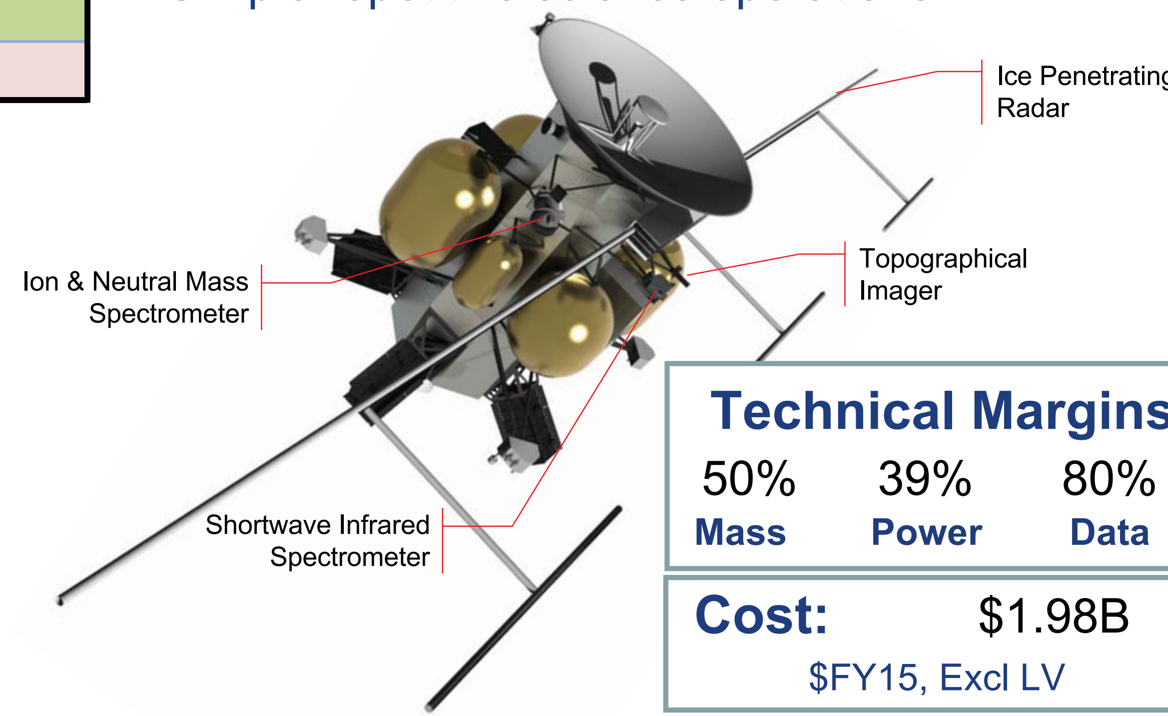
-32 low altitude flybys of Europa from Jupiter orbit over 2.3 years

-Detailed investigation of globally distributed regions of Europa

-Simple repetitive science operations

Payload:

Instrument	Clipper Baseline
Floor	IPR
	SWIRS
	TI
Baseline	INMS



Technical Margins

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

Cost: $1.98B

$FY15, Excl LV

The Orbiter in a Nutshell

May 2012

Operations Concept:

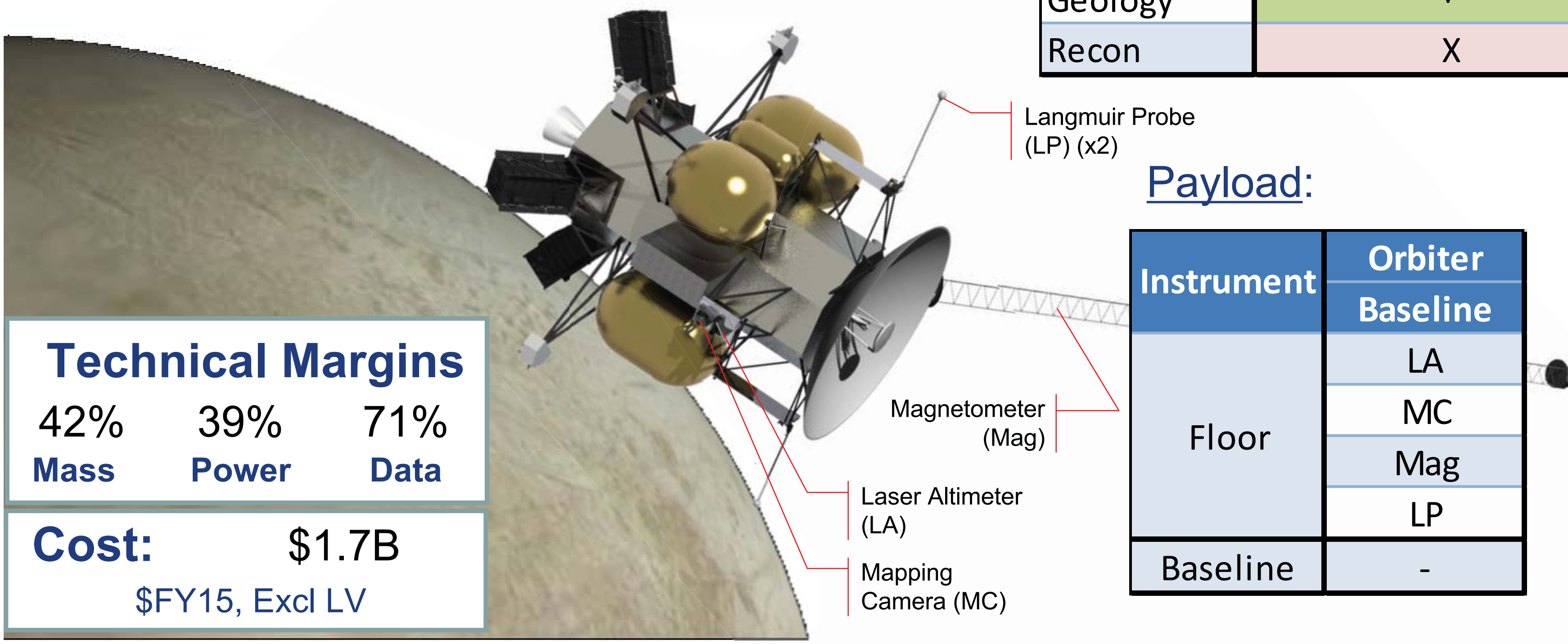
-30 days in 100 km near polar orbit about Europa

-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

The Lander in a Nutshell

May 2012

Operations Concept:

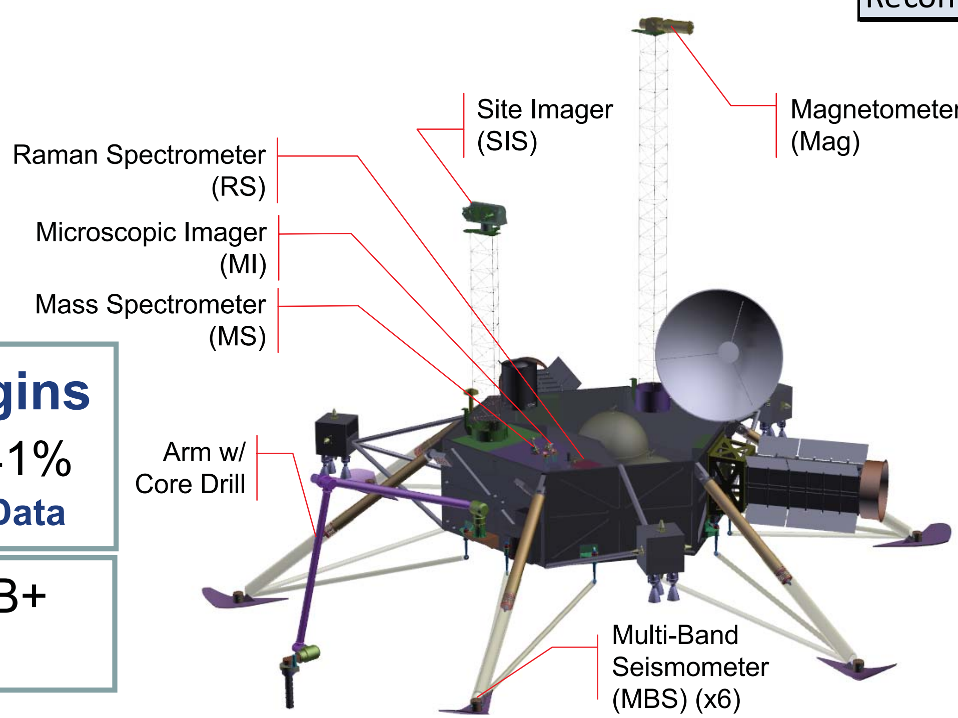
-30 days science investigation on the surface of Europa

-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

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

Since May
Summer Study

Charge from NASA for Summer Study

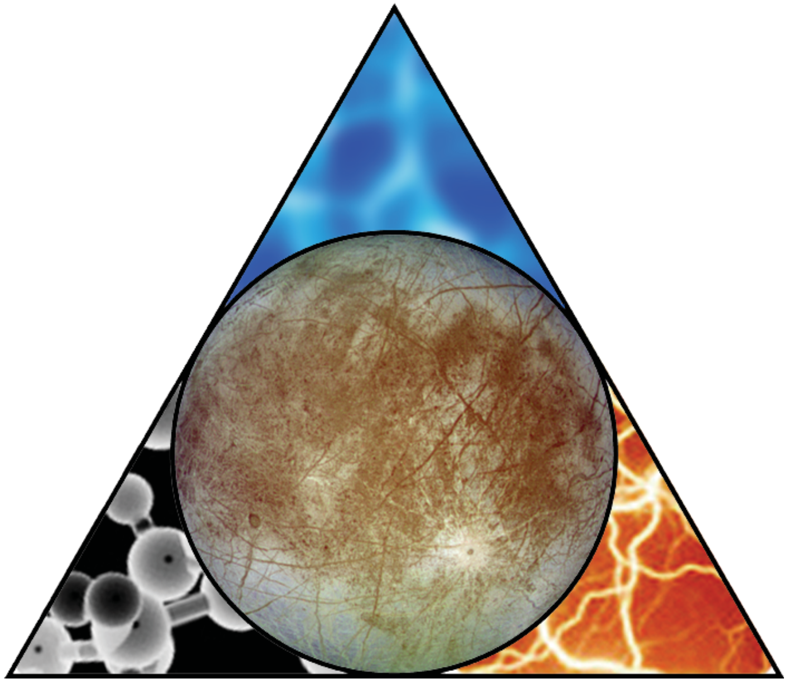
Enhanced Clipper Science
Examine the ability to address the **Ocean** science objectives with the Clipper mission option and understand implications for the mission design and number of flybys while remaining cost neutral ($2B, FY15$, excl LV)

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)

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.

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

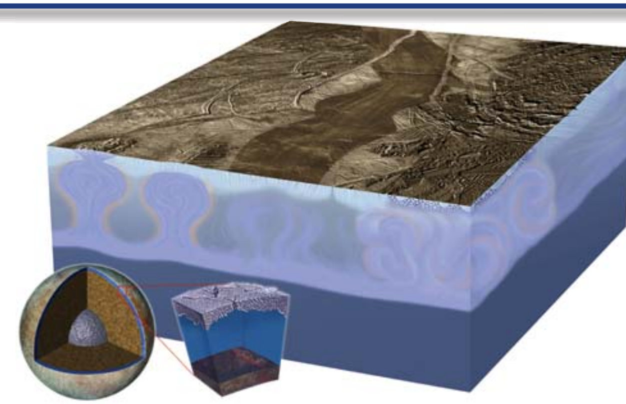


Enhanced Europa Clipper Mission

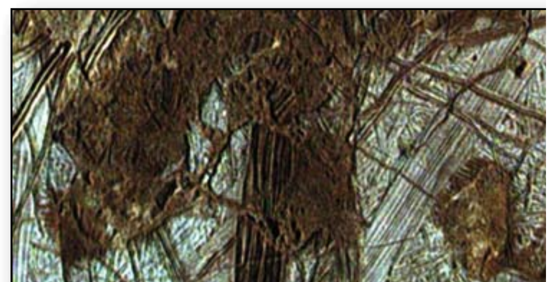
A Multiple-Flyby Europa Mission in Jupiter Orbit

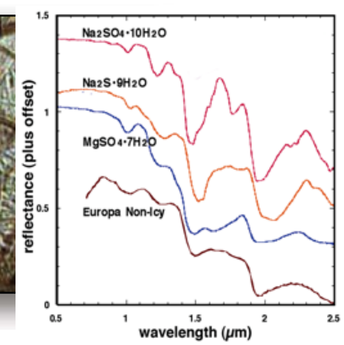
Clipper Science from May Report

- **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

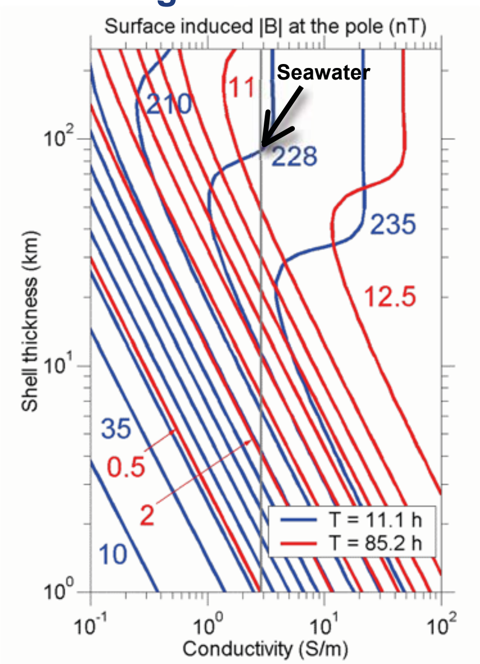
mosaic by "Orion"

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

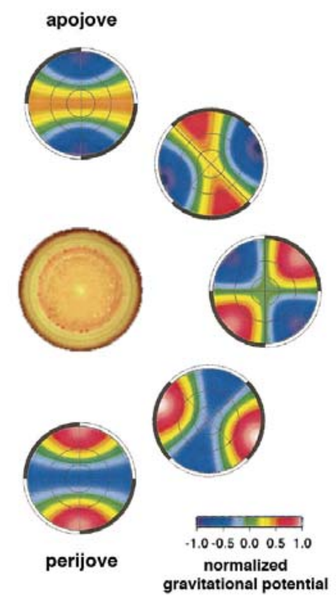
Providing an understanding of the properties of the ocean

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

Clipper Science Traceability

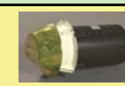
Enhanced with Ocean & Geology Science

Goal	Objective		Investigation	Model Planning Payload	Theme W	Theme C	Theme 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 (shaded rows)

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

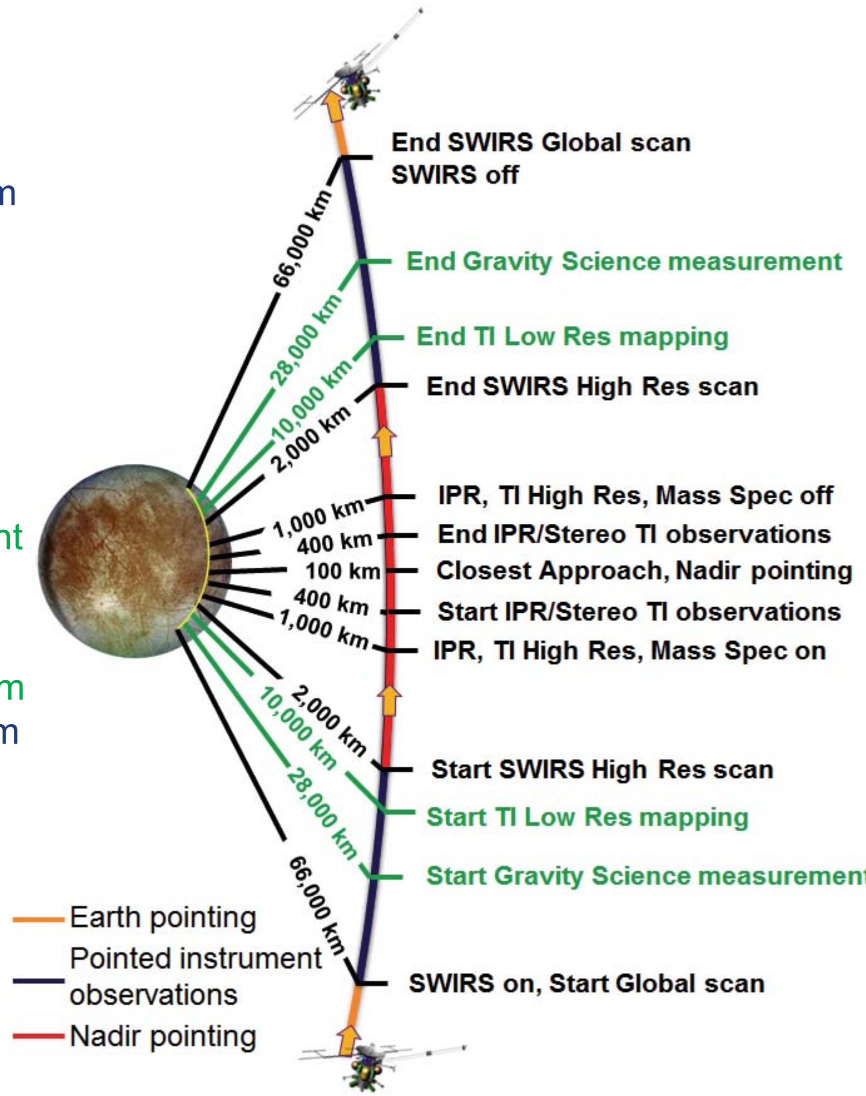
Legend: Floor model instrument (green); Baseline model instrument (yellow); **Enhancement** (purple)

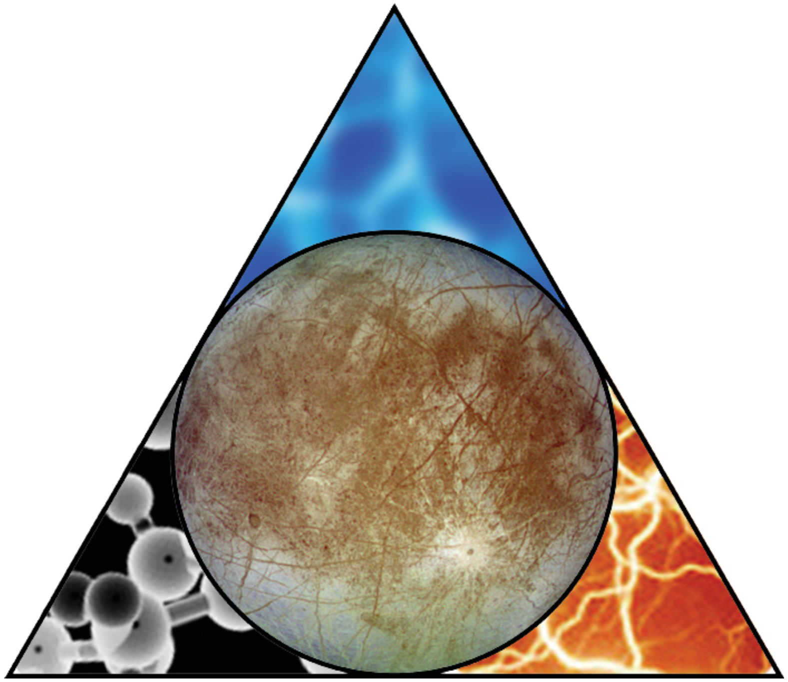
Pre-Decisional — For Planning and Discussion Purposes Only

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





Reconnaissance Data Sets for Future Landers

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