J U P I T E R ' S   M O O N

EUROPA

TEAM TITAN

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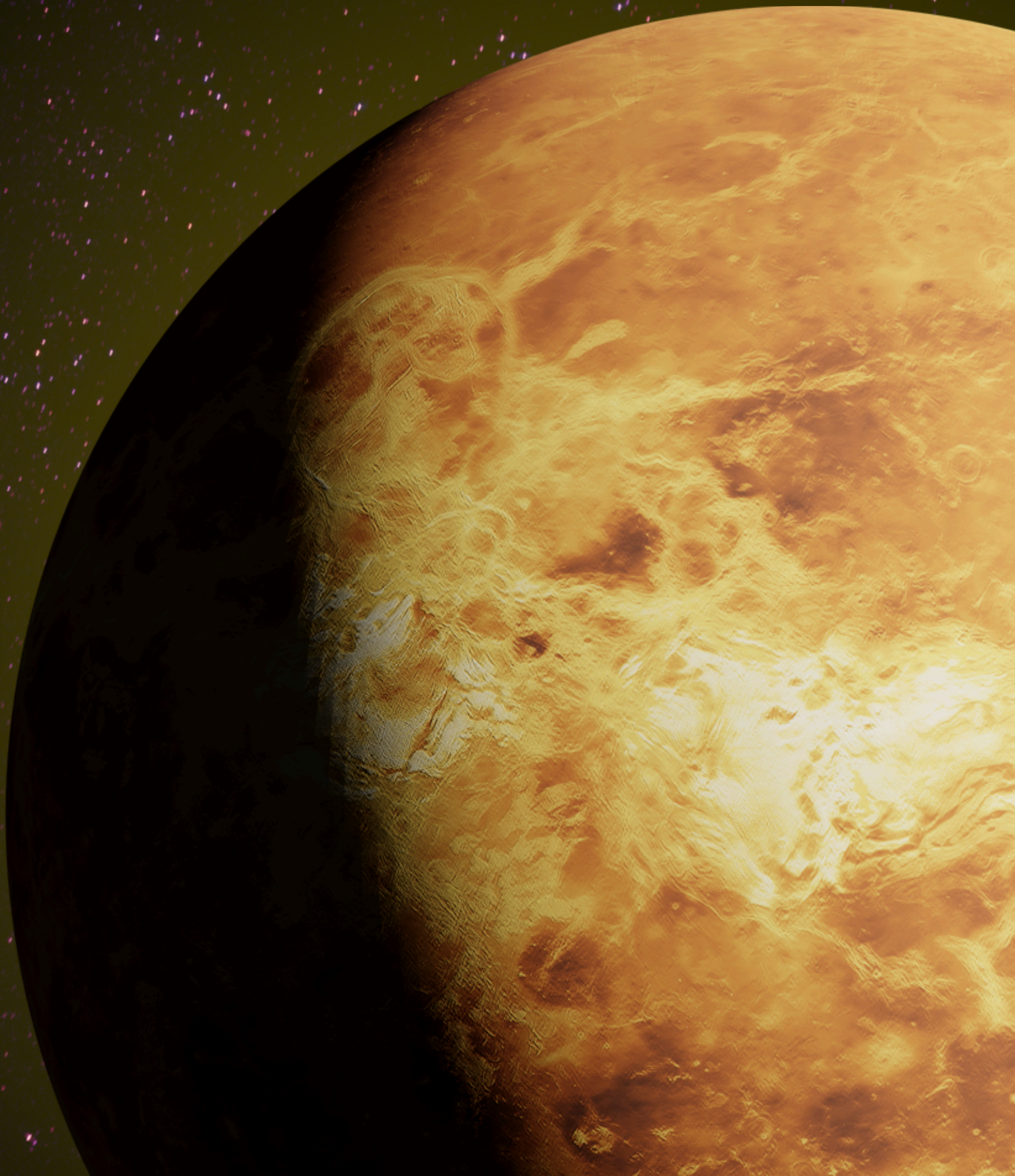
VEHICLE DESIGN

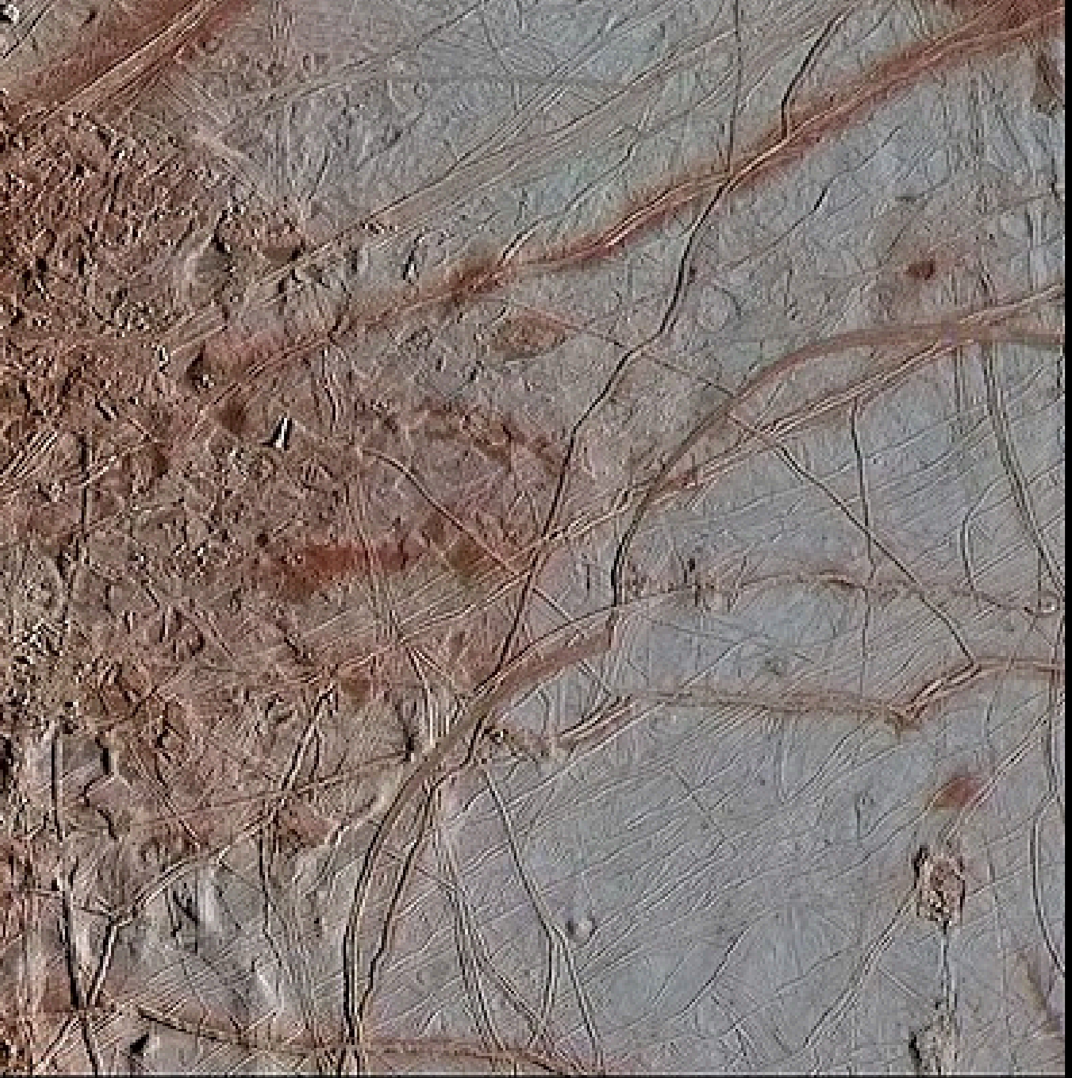
- RELAY ORBITER
- LANDER-DEORBITER
- HEAT-DRILL
- SUBMERSIBLE

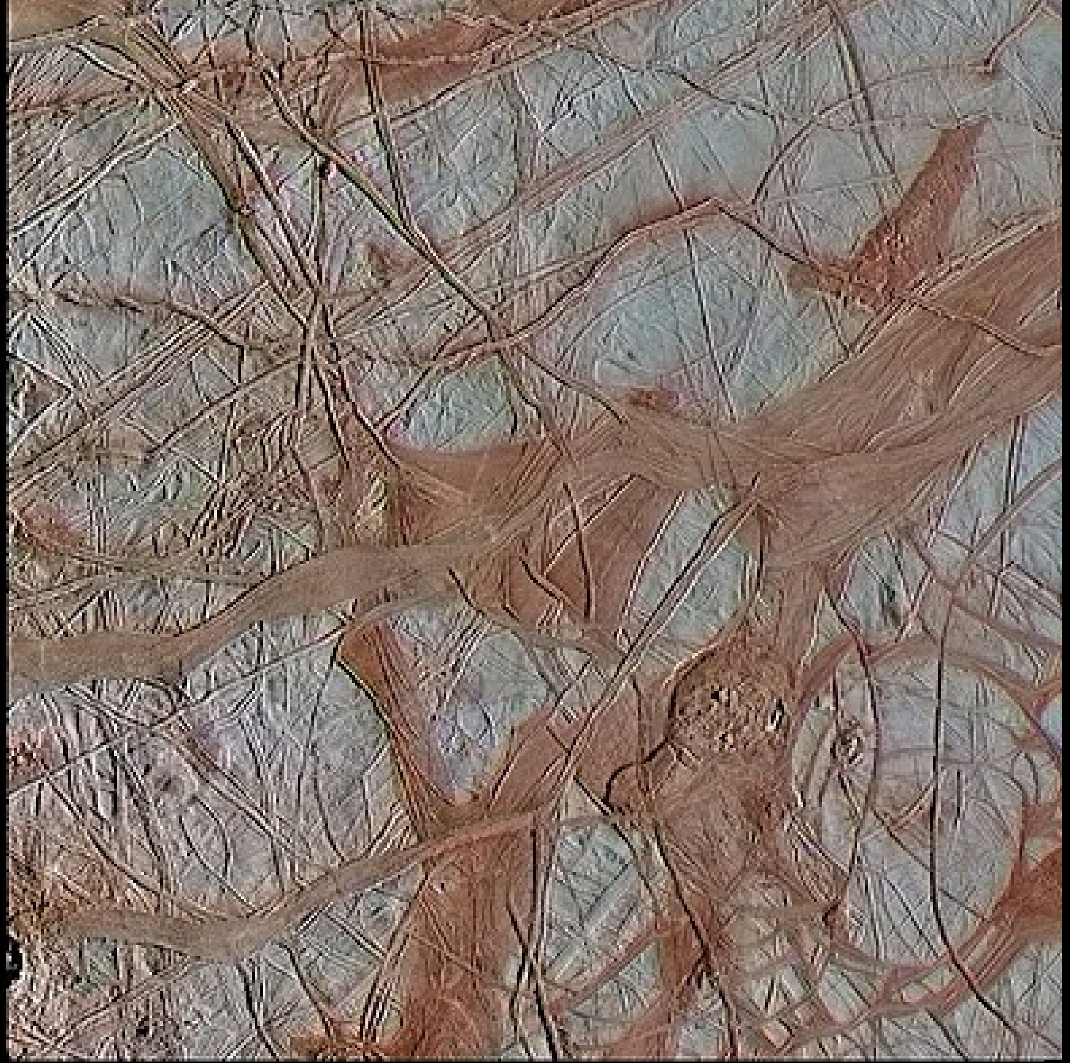


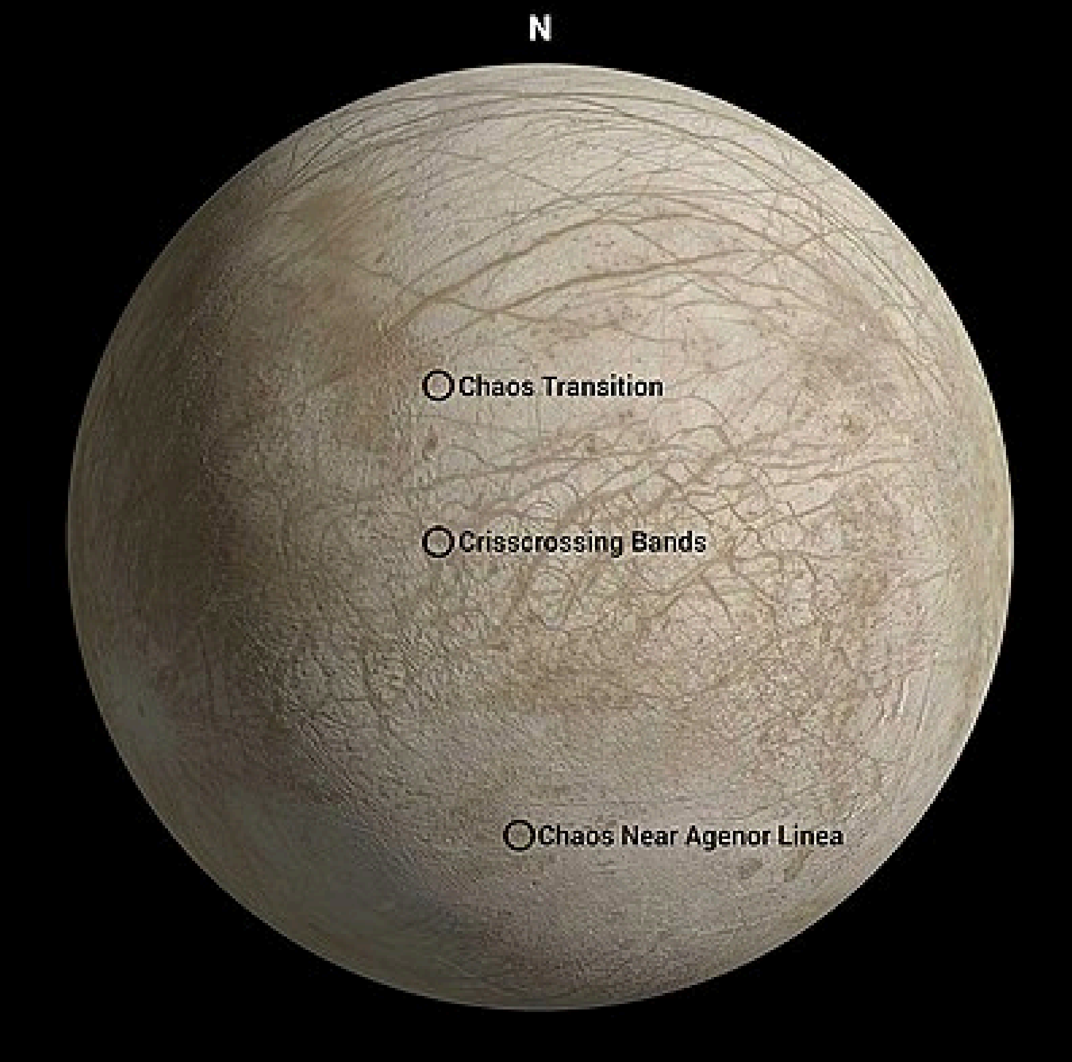
Landing Area

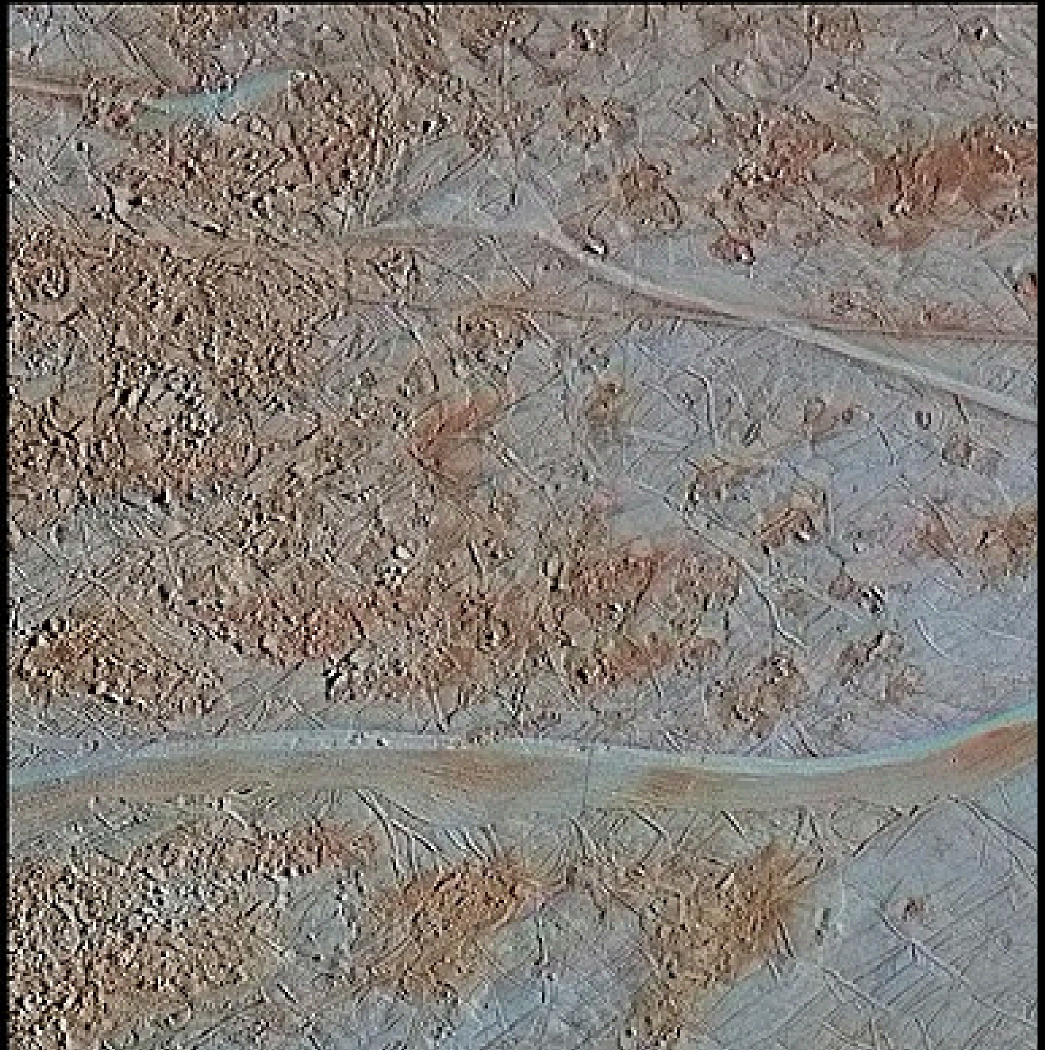
Chaotic Terrain

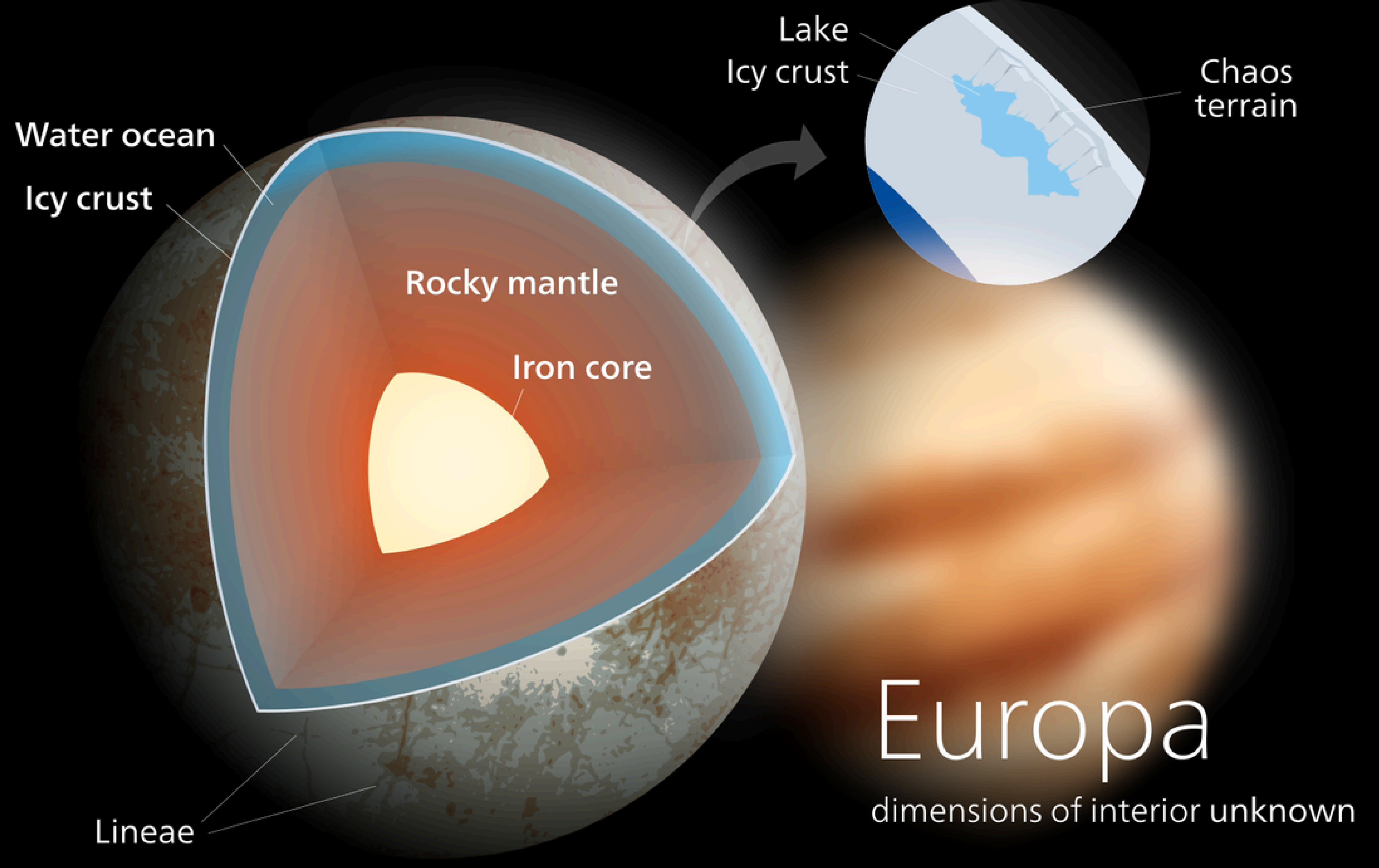
- These regions are made up of icy material that has been broken and moved around, and then frozen back together.
- The red color is due to a non-ice contaminant, such as salts, that may have come from an ocean beneath Europa's surface.







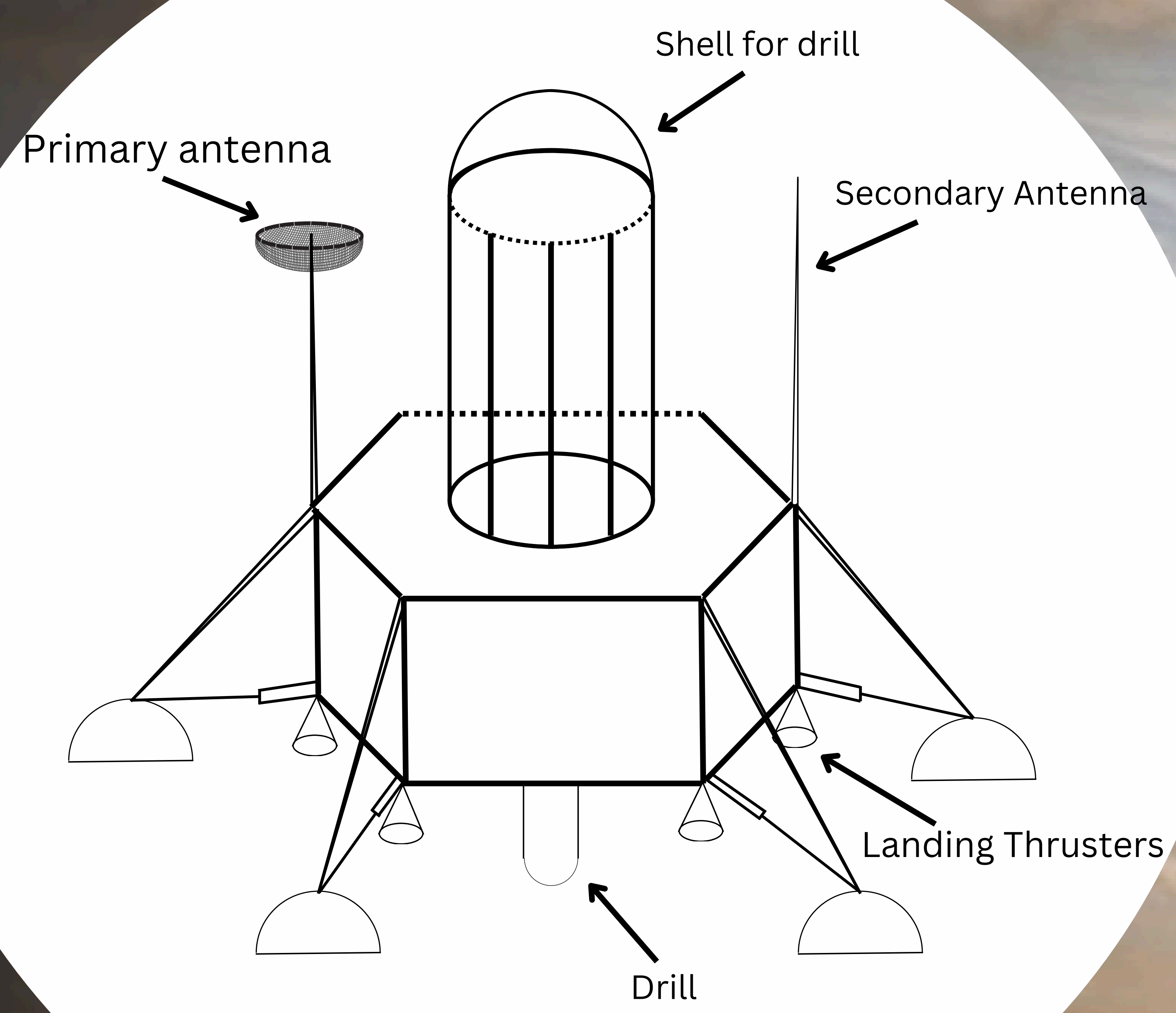




LANDING TECHNIQUES

- **DDL(Deorbit Descent Landing)**
  - Lander would use 4 CE-20 cryogenic engines to land on europa.
  - A lander wouldn't need to get into Jupiter orbit, but just tangent Europa when their velocity difference is the smallest to land on europa

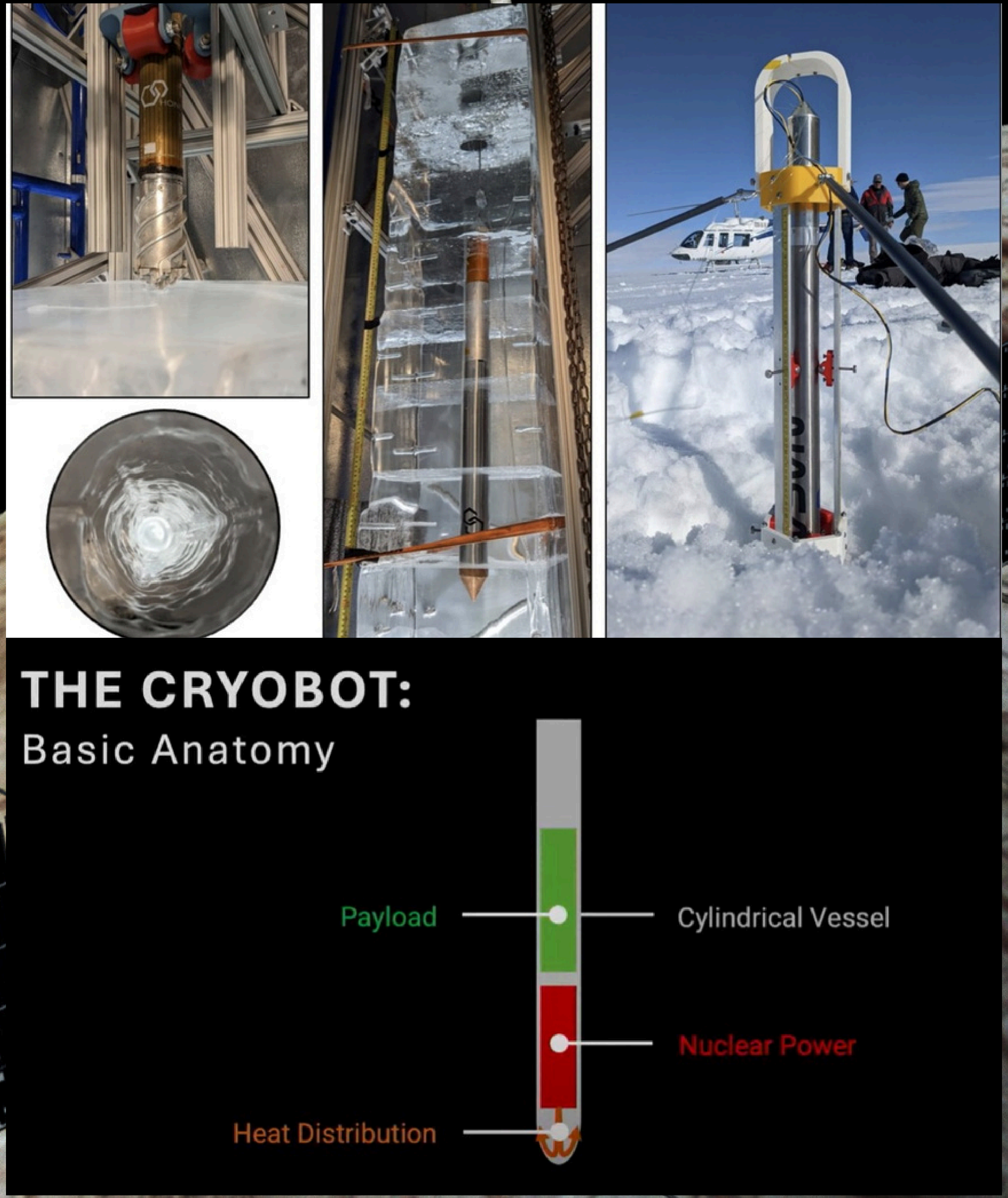
- **Lander Mechanisms:** Lander legs, Drill Deployment, Umbilical connector, Surface Relay Antenna deployment.



Drilling Techniques(Melt-Craft)

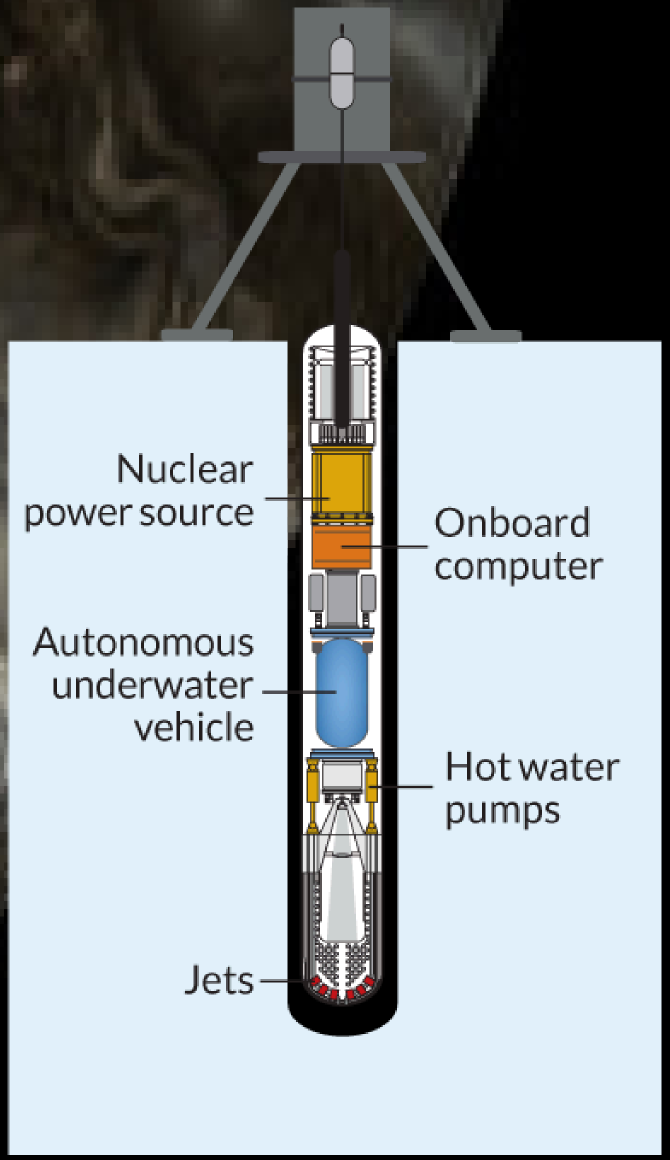
- **Ice Entry, Descent and Ocean Entry(EDO)**

- Plutonium-based RTG to melt ice
- The drill will melt the icy crust of Europa and will sink to the surface due to its weight.
- Sensors will manoeuvre the Driller(Melter) to avoid any obstacles.



Drilling Techniques

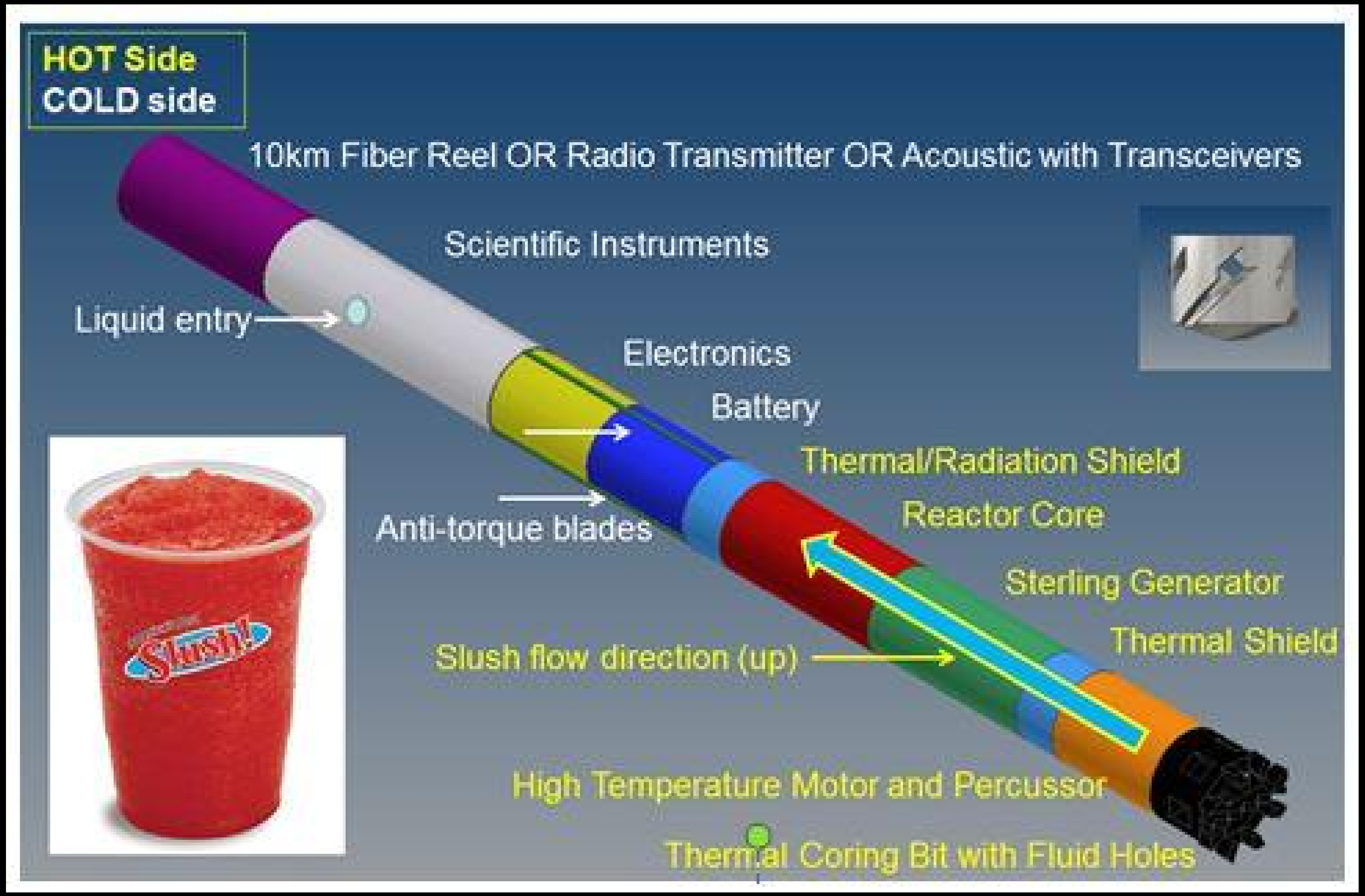
- The drill needs to put anchor points in ice-crust after regular intervals to avoid being pushed up due to outflowing water pressure from subsurface waterbodies.



Alternate Drilling Techniques

SLUSH: Europa Hybrid Deep Drill

- Two design approaches are: a melt probe and an electronical drill.
- Melt probe requires a heat source, required power to melt 50-110K ice is 10s of kW.
- Electro-Mechanical Drill is more energy efficient than a melt probe.
- SLUSH combines both heat and mechanical drilling.
- To break the ice while heating, it uses rotary-percussive action.



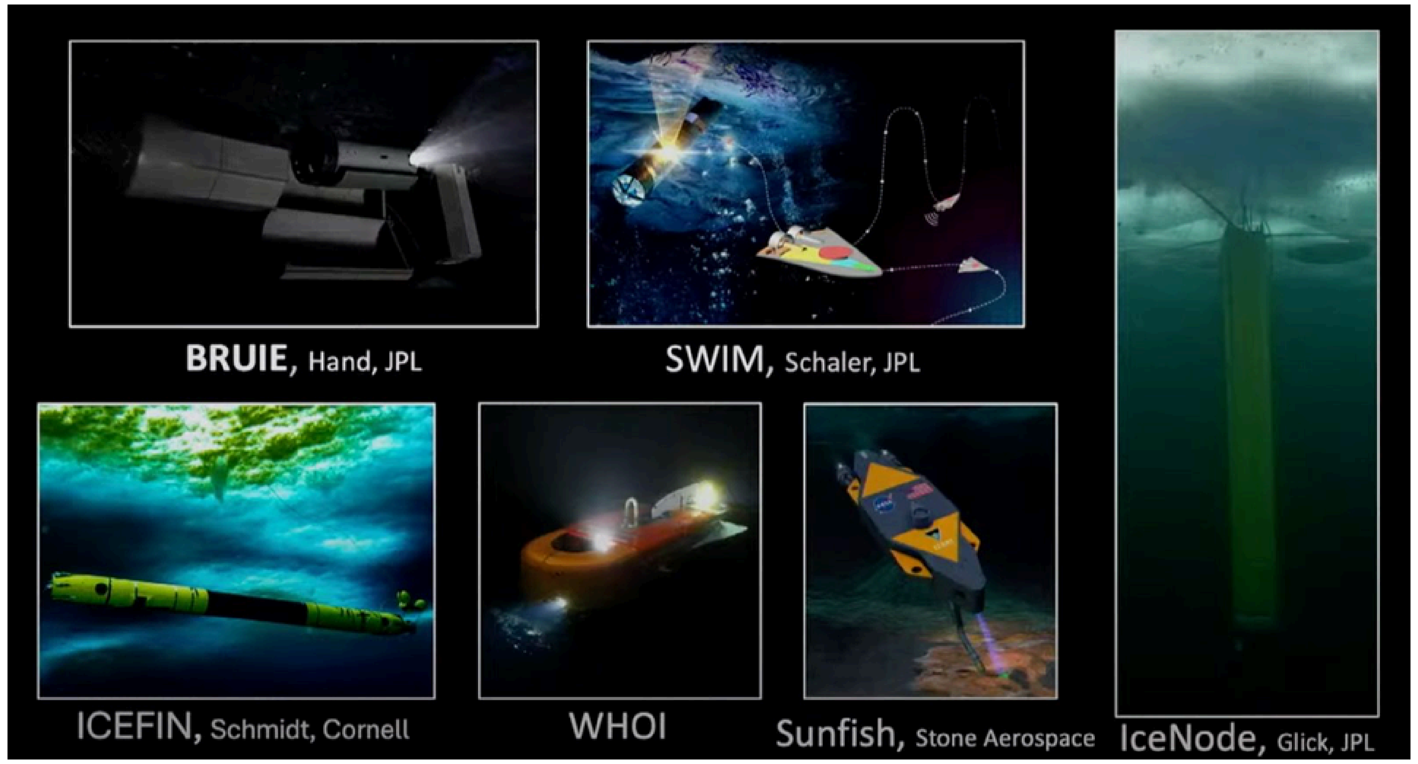
- Ice melting probes have been used in Antarctic since 1950s and have successfully penetrated 3km thick ice using conventional heating techniques.
- Heat drills were widely used in exploration of subsurface lakes and oceans on Antarctica and arctic and is a proven tech.

1968: First “Philberth” probes

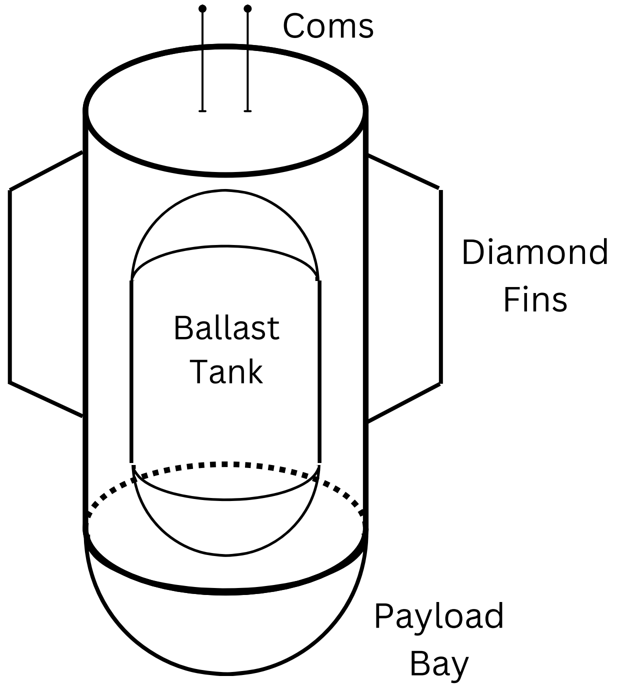
Submersible Technology

Underwater Exploration Vehicles

1. **BRUIE**: Buoyant rover that explores under ice by clinging to its surface.
2. **SWIM**: Small, independent swimmers that map local underwater areas.
3. **ICEFIN**: Instrument-packed vehicle for large-scale, under-ice surveys.
4. **WHOI**: Deep-sea vehicle designed for extreme pressure environments.
5. **SUNFISH**: Autonomous explorer for navigating underwater caves.
6. **ICE NODE**: Hopper with buoyancy control to sink, float, and anchor to ice.



Credits: NASA Jet Propulsion Laboratory



Cryoball Deployment System

1. **Cryoball Deployment**: A lander deploys a cryoball to descend through Europa’s ice shell.
2. **Electronics Module**: Released a few meters below to establish a communication relay with the lander.
3. **Signal Boosting**: Transceivers/repeaters are deployed to enhance wireless communication.
4. **Hazard Detection**: Forward-looking sensors identify and avoid potential obstacles.
5. **Thermal Maneuvering**: A thermal system steers the cryoball around hazards effectively.

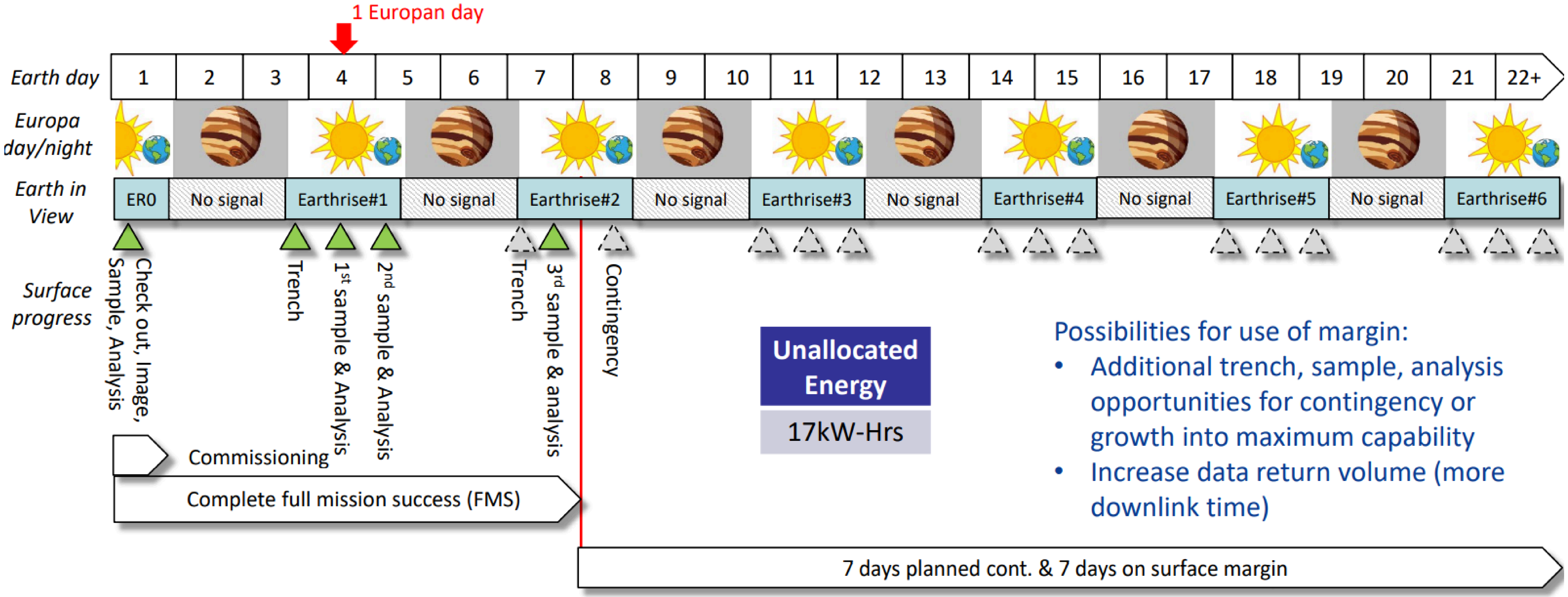
Our Suggestion: Drop Craft

1. Weight Reduction: Eliminate propellers as they are unnecessary for a dropping mechanism.
2. Simplified Design: Focus on a streamlined structure for descent.
3. Layered Data Collection: Gather data from various ocean layers during the descent.
4. Submersibles will use ballast tanks to maintain buoyancy.

COMMUNICATION

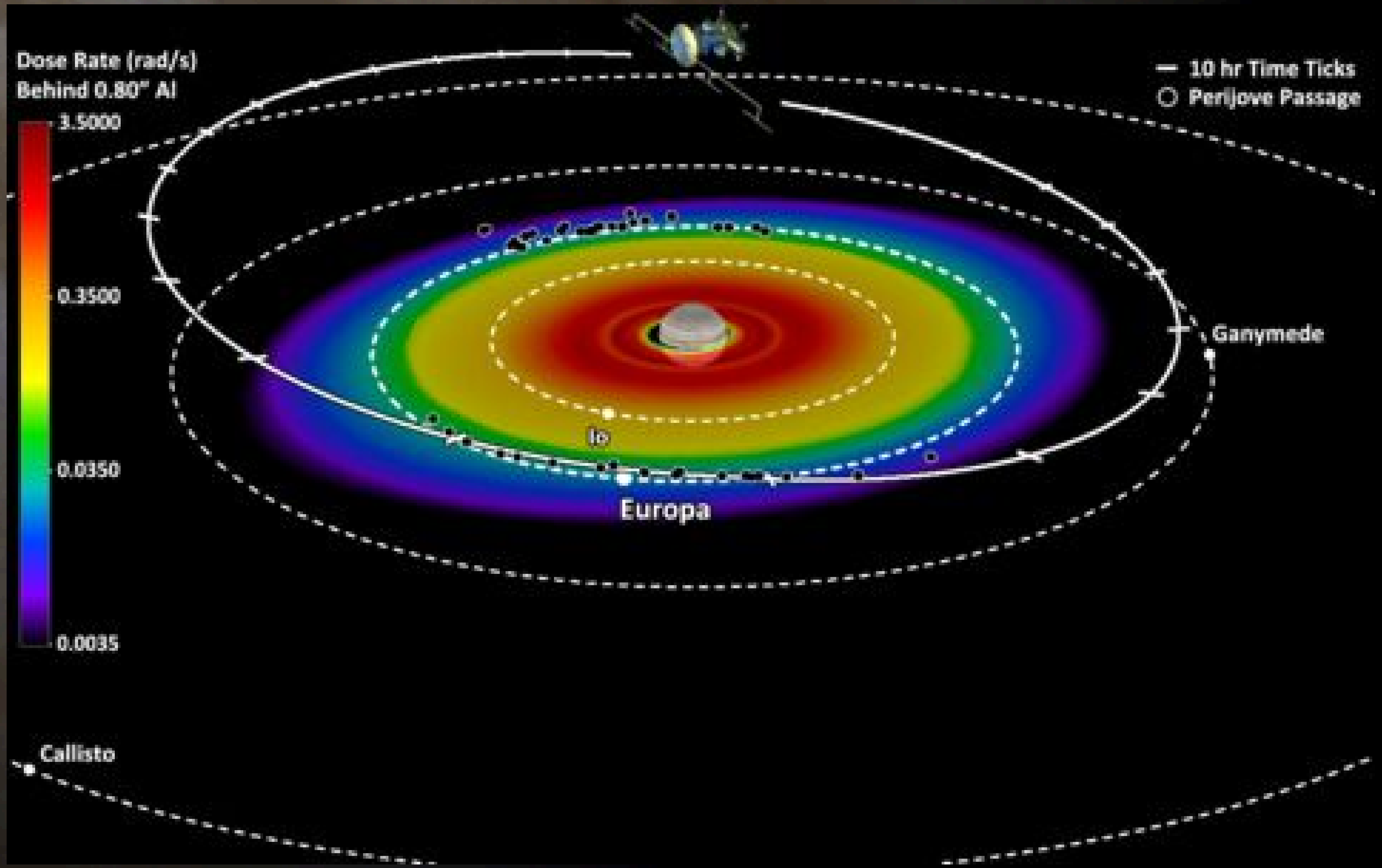
- For communications from surface lander to earth we'll use a Relay satellite in High Jovian Orbit.
- While drilling the probe will deploy small relays while its journey to the ocean.
- These will be wireless relays to boost the signal from the sub-surface to the surface lander.

Why we need a Relay Satellite?

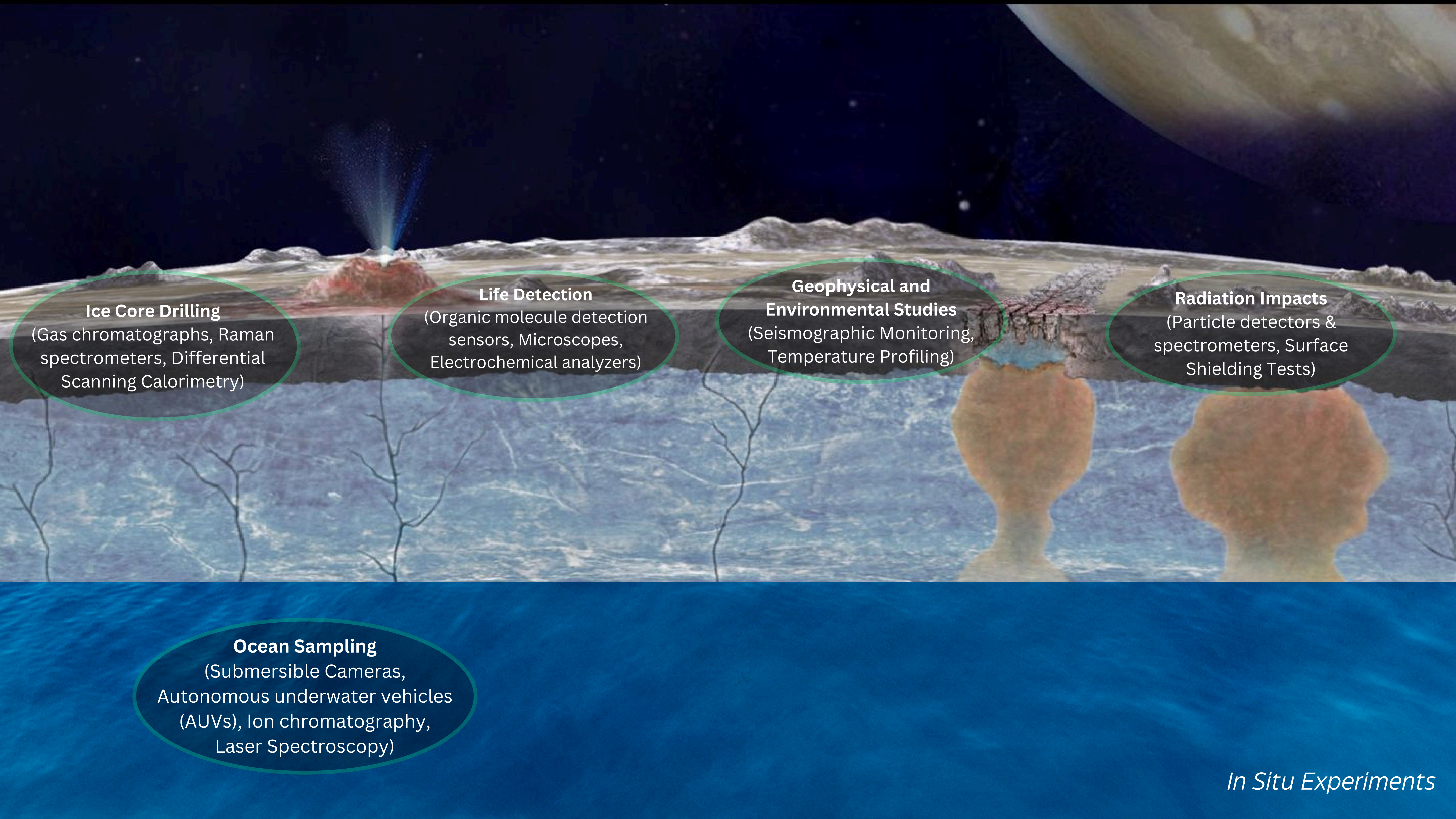


Relay Satellite

- For communications from surface lander to earth we'll use a Relay satellite in High Jovian Orbit(to avoid van-allen belts of Jupiter)
- Relay Satellite will also provide continuous connectivity to Lander on Europa even when Europa is occulted by Jupiter (this happens every 3 days)



Reuters


Ice Core Drilling
(Gas chromatographs, Raman spectrometers, Differential Scanning Calorimetry)
Life Detection
(Organic molecule detection sensors, Microscopes, Electrochemical analyzers)
Geophysical and Environmental Studies
(Seismographic Monitoring, Temperature Profiling)
Radiation Impacts
(Particle detectors & spectrometers, Surface Shielding Tests)
Ocean Sampling
(Submersible Cameras, Autonomous underwater vehicles (AUVs), Ion chromatography, Laser Spectroscopy)
In Situ Experiments

Jupiter and its Moons

Destination	Impulse			Brachistochrone		
	I-1	I-2	I-3	0.01g	0.10g	1.00g
♃ Jupiter	69,990 (5y5m)	72,690 (1y10m)	118,010 (1y)	1,000,000 (3.5m)	3,142,000 (36d)	9,930,000 (12d)
Io	76,220 (5y6m)	70,760 (1y10m)	78,980 (1y)	1,000,000 (3.5m)	3,143,000 (36d)	9,933,000 (12d)
Europa	67,390 (5y6m)	61,850 (1y10m)	71,490 (1y)	1,001,000 (3.5m)	3,144,000 (36d)	9,935,000 (12d)
Ganymede	61,880 (5y5m)	56,250 (1y10m)	67,130 (1y)	1,001,000 (3.5m)	3,145,000 (36d)	9,938,000 (12d)
Callisto	55,400 (5y5m)	49,640 (1y10m)	62,190 (1y)	1,002,000 (3.5m)	3,147,000 (36d)	9,945,000 (12d)

- Impulse trajectory I-1 : (minimum delta_v / maximum time) ; closer to Hohmann orbit
- Impulse trajectory I-2 : In between I-1 and I-3
- Impulse trajectory I-3: delta_v in between high impulse trajectories and low brachistochrone trajectories.
- Brachistochrone : (maximum delta_V / minimum time

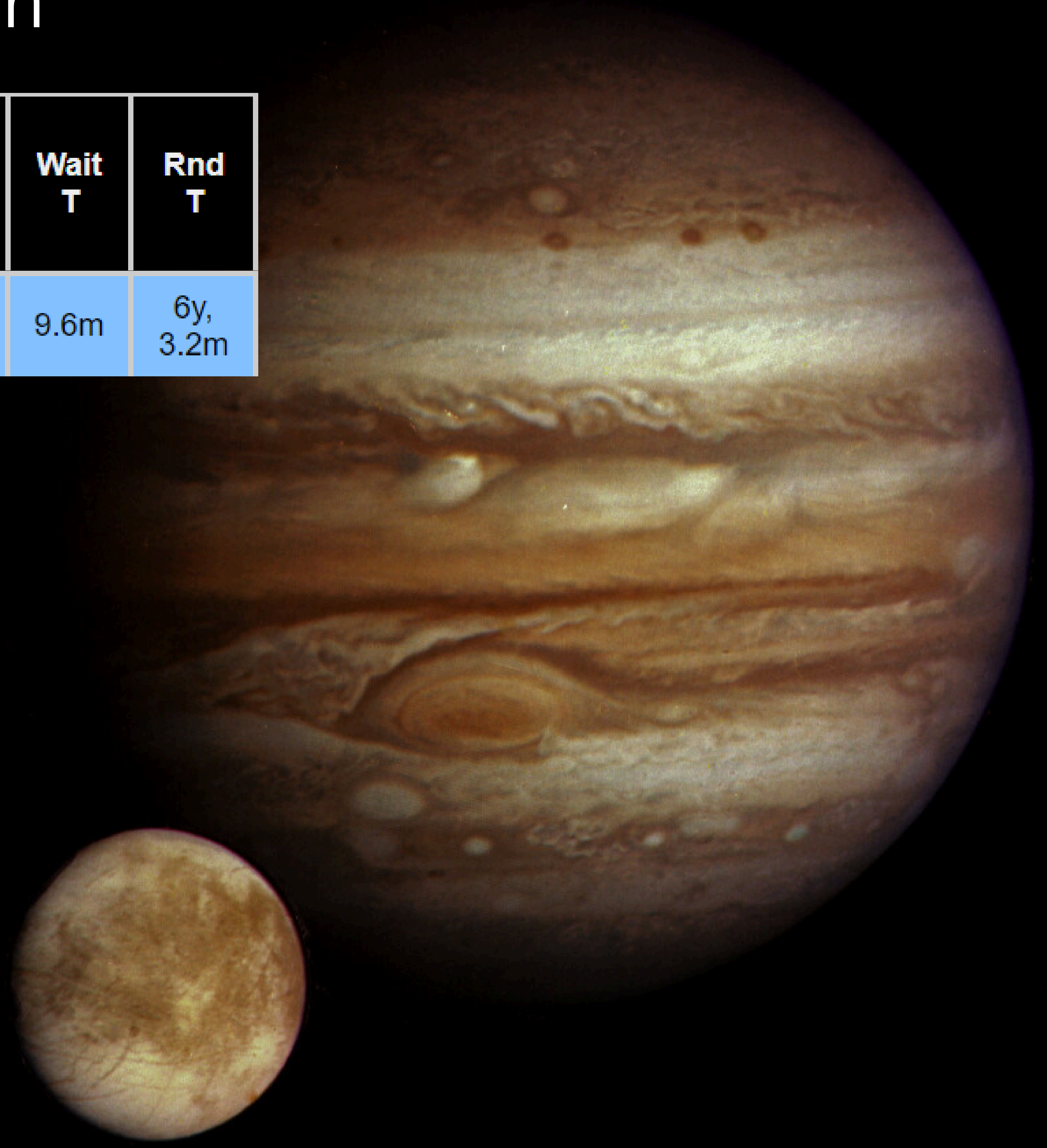
Image: *Europa's Eclipse on Jupiter timelapse captured by **Aaditya Saxena** (us)*

Image: *Io's Eclipse on Jupiter with GRS and newly discovered storm timelapse captured by **Aaditya Saxena** (us)*

Details of Terra - Jupiter related mission

MISSION	Orbit ΔV (km/s)	Orbit T	SYN	ANG	Insert ΔV (km/s)	Arrive ΔV (km/s)	Surf ΔV (km/s)	Rnd Orbit ΔV (km/s)	Rnd Surf ΔV (km/s)	Wait T	Rnd T
Terra-Jupiter	24.2	2y, 8.8m	1y, 1.1m	97.2°	6.3	17.9	31.6	48.4	63.3	9.6m	6y, 3.2m

- Total Orbit delta V (Km/s) of LVM3 (or GSLV Mk III) is approximately 28.8 Km/s.
- The Delta_V (Terra - Jupiter) is 24.2 Km/s.



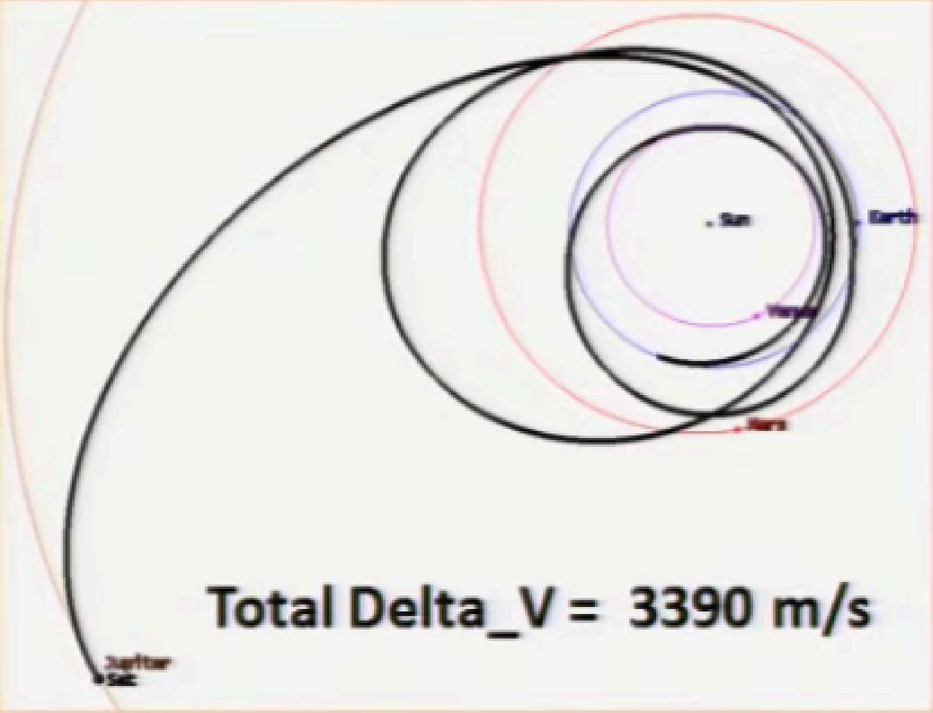
Launch window from Earth

- Using the Hohmann transfer (fuel efficient method), Total Delta_V is approximately 17.8 Km/s.
- This shows significant reduction in fuel requirements compared wtih the direct transfer, that is of delta_V 24.2Km/s.

2023 VEME Gravity Assist Trajectory to Jupiter

Departure Orbit: 170×35975 km, Inclination~ 50 deg. AOP =286.7 deg

Total flight duration: 2325 days (~6.4 years)



Powered Gravity Assist (PGA) Sequence

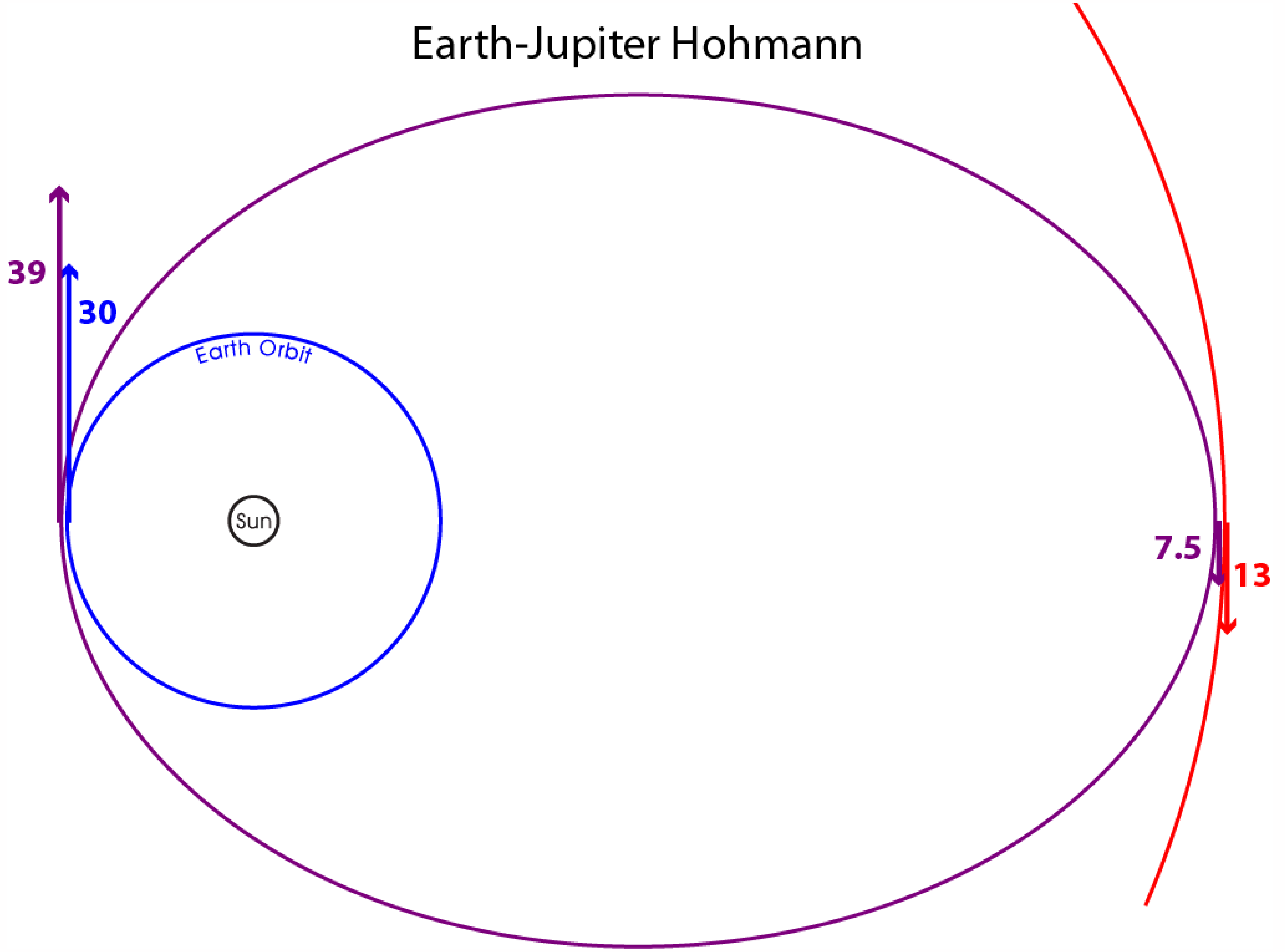
Departure	Epoch (UTC)	Delta-V (m/s)	Flyby Alt. (km)
Departure From Earth	29th May 2023	1211	-
Venus PGA	22nd Oct 2023	175	8715
Earth PGA	02nd Sep 2024	57	1878
Mars PGA	10th Feb 2025	69	1024
Earth PGA	26th Nov 2026	284	3863
Arrival at Jupiter	9th Oct 2029	1595	Capture Orbit (5000km ×20 lakh km)

Orbital Mass

With GSLV (CUS restart): 757 kg

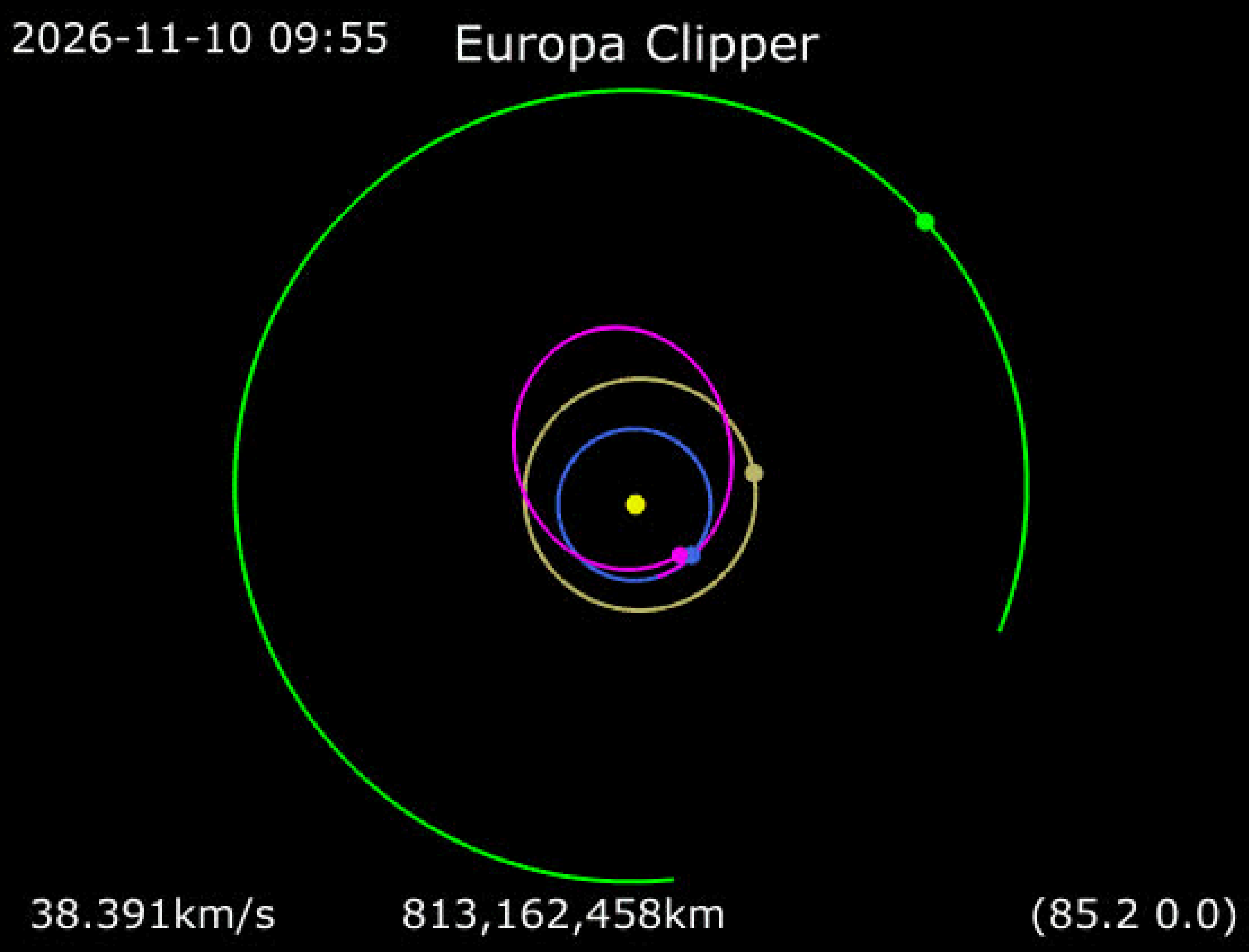
HLV: 1865 kg

Europa Landing



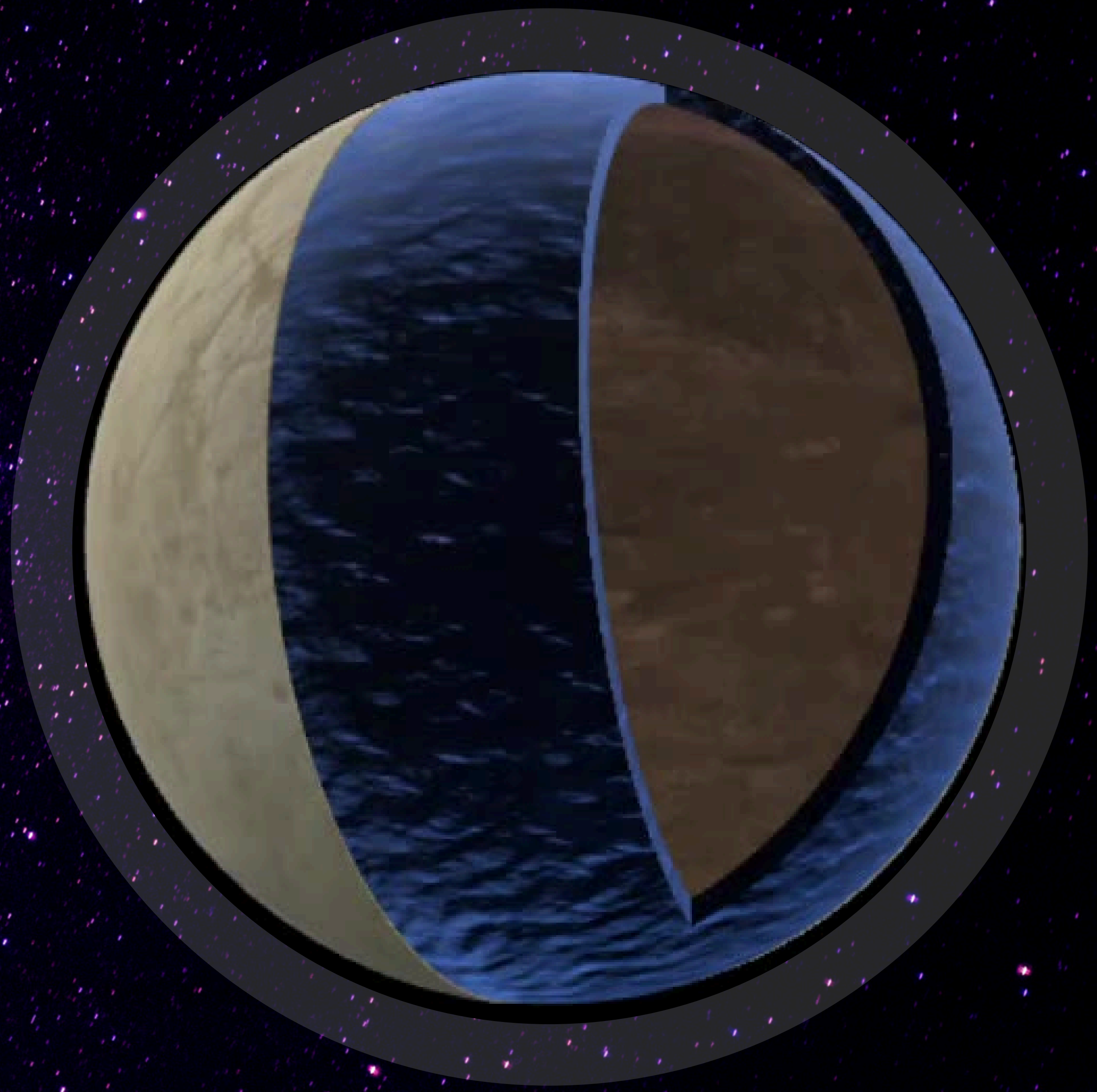
- Jupiter arrival Vinf is ~5.5 km/s. At Europa's altitude Jupiter escape velocity is about 19.5 km/s. Sqrt(5.5^2 + 19.5^2) is about 20 km/s. But Europa's velocity is about 14 km/s, so you get to subtract that 14 from 20 for a 6 km/s delta V.
- LEO Trans Jupiter Insertion (TJI) is about 6.3 km/s
- Europa's orbital speed 13.7 km/h
- A lander wouldn't need to get into Jupiter orbit, but just tangent Europa when their velocity difference is the smallest to land on europa

- Our path will be as:
- Earth - Venus - Earth - Mars - Earth - Jupiter
- As Delta_V of GSLV Mk III is low, so for extra Delta_V, we took a path of Earth - Venus - Earth. By this, we get extra velocity.
- And the remaining part of the path is exactly similar to the Europa Clipper's path. This is because, after taking the above path, we got the similar delta_V as Europa Clipper.



Scientific Instruments & Experiments - Lander

- **Ice Core Drilling:**
  - Gas chromatographs (analyse trapped gases)
  - Raman spectrometers (identify complex organic molecules)
  - Differential Scanning Calorimetry (thermal properties of ice to understand melting & freezing processes)
- **Life Detection:**
  - Organic molecule detection sensors (Metabolic Activity Tests)
  - Microscopes (visually inspect water or ice for microbial structures)
  - Electrochemical analyzers (redox processes, pH & salinity measurements critical for microbial metabolism)
- **Geophysical and Environmental Studies**
  - Seismographic Monitoring (detect ice cracking or subsurface movements)
  - Temperature Profiling (High-resolution thermal sensors)
- **Radiation Impacts:**
  - Particle detectors & spectrometers (study how surface radiation alters organic molecules and ice)
  - Surface Shielding Tests (Simulate the impact of radiation on potential life and protective mechanisms in ice)



Scientific Instruments & Experiments - Submersible

- **Ocean Sampling:**
  - Submersible Cameras (High-resolution imaging of ocean floor); equipped with LED lights (visibility in dark)
  - Autonomous underwater vehicles (Filtered water collection for chemical and microbial analysis)
  - Ion chromatography (studying dissolved salts and ions)
  - Laser Spectroscopy (isotopic ratios of hydrogen and oxygen (e.g., H_2O, HDO) to infer the ocean's history)

- **Ice Sampling (Driller)**
  - Inertial Measurement Unit (Tracks drill's orientation for accurate directional drilling)
  - Gas chromatographs (analyse trapped gases)
  - Raman spectrometers (identify complex organic molecules)
  - Differential Scanning Calorimetry (thermal properties of ice to understand melting & freezing processes)
  - Ground Penetrating Radar (Map subsurface ice layers by reflecting radar waves)
  - Magnetometer (Measures magnetic field variations caused by mineral inclusions)
  - AI-powered Drill Head & Ice Stress Measurement (adapts speed & pressure based on real-time sensor feedback)
  - Acoustic Monitoring (listen for natural ice movements or water flow)

Credits: NASA Jet Propulsion Laboratory

Radiation from Jupiter

High Radiation from Jupiter can handled by :

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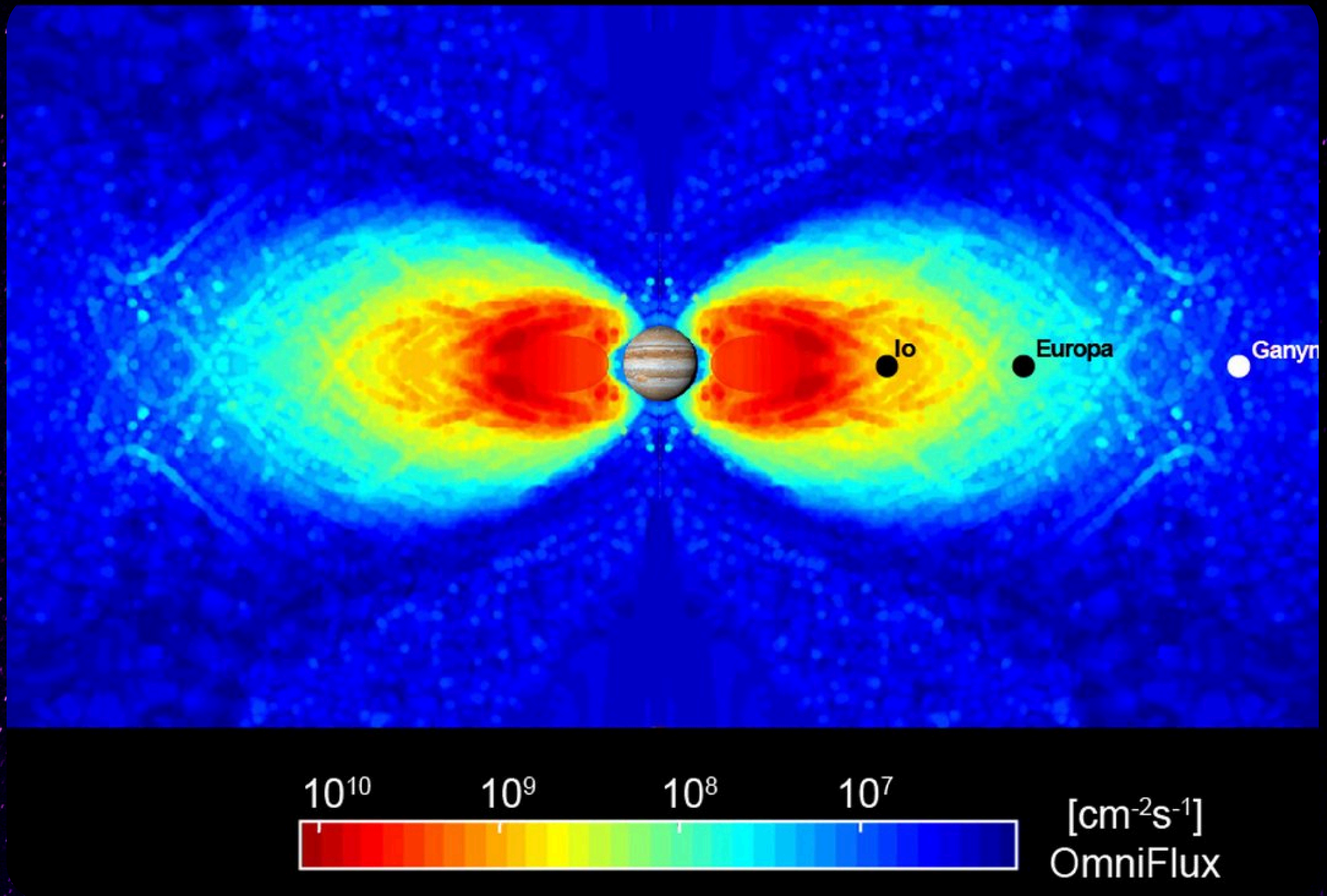
- **Radiation-Hardened Materials**
- **Protective Vaults**
- **Active Monitoring**
- **Radiation-Tolerant Electronics**



Juno makes a radiation map of Jupiter

Radiation from Jupiter

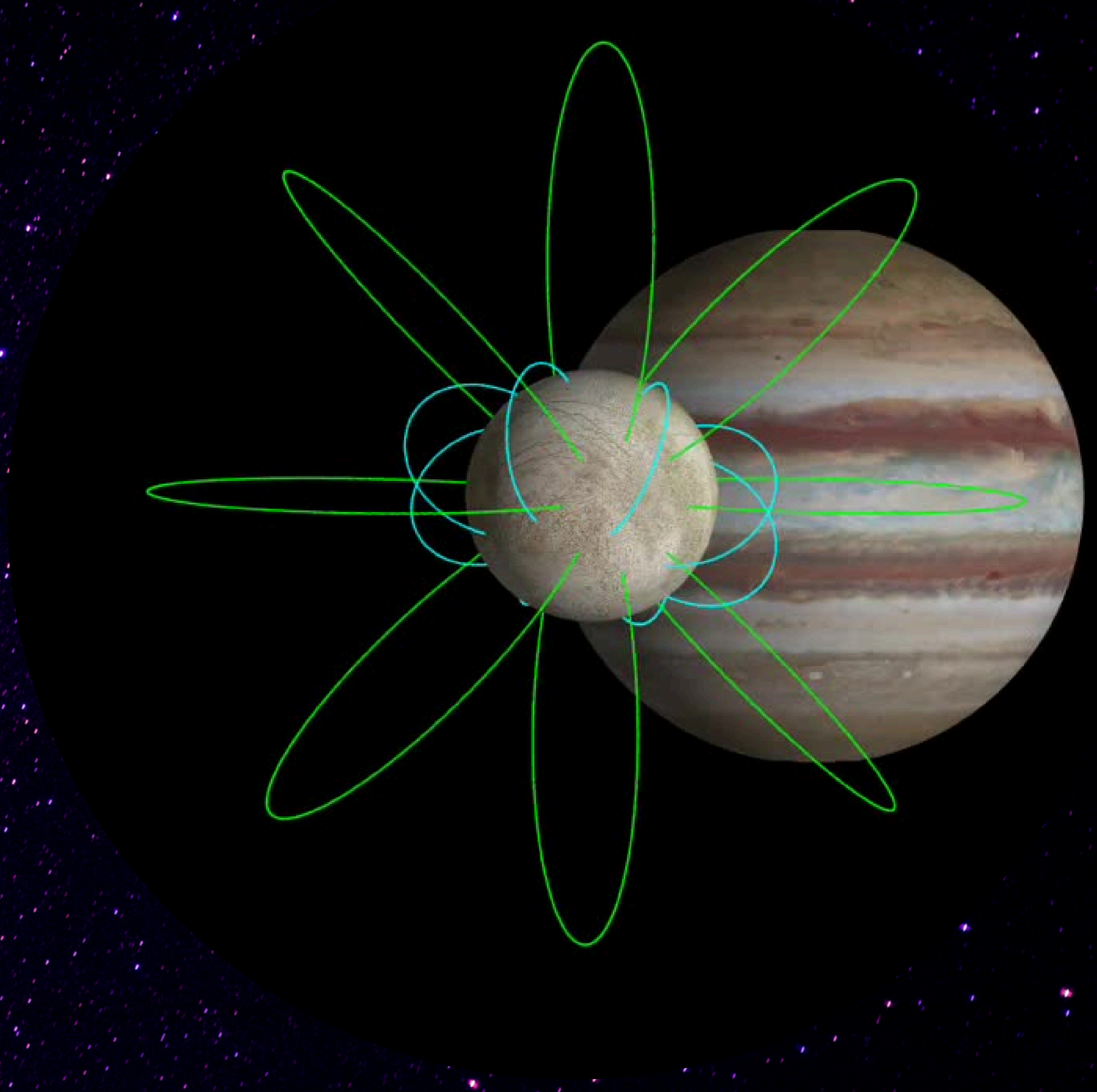
Lander-Deorbiter

- **Radiation-Hardened Materials:** Use tungsten or tantalum shielding around avionics, communication systems, and propulsion units to minimize radiation exposure during orbit and landing.

- **Protective Vaults:** Enclose critical electronics (e.g., navigation and communication systems) in a centralized, shielded vault to reduce mass while maximizing protection.

- **Active Monitoring:** Install radiation detectors to assess exposure during deorbiting and surface operations, enabling adaptive protective measures or operational pauses.

- **Radiation-Tolerant Electronics:** Equip the lander with processors and memory components resistant to single-event upsets caused by radiation.



Radiation from Jupiter

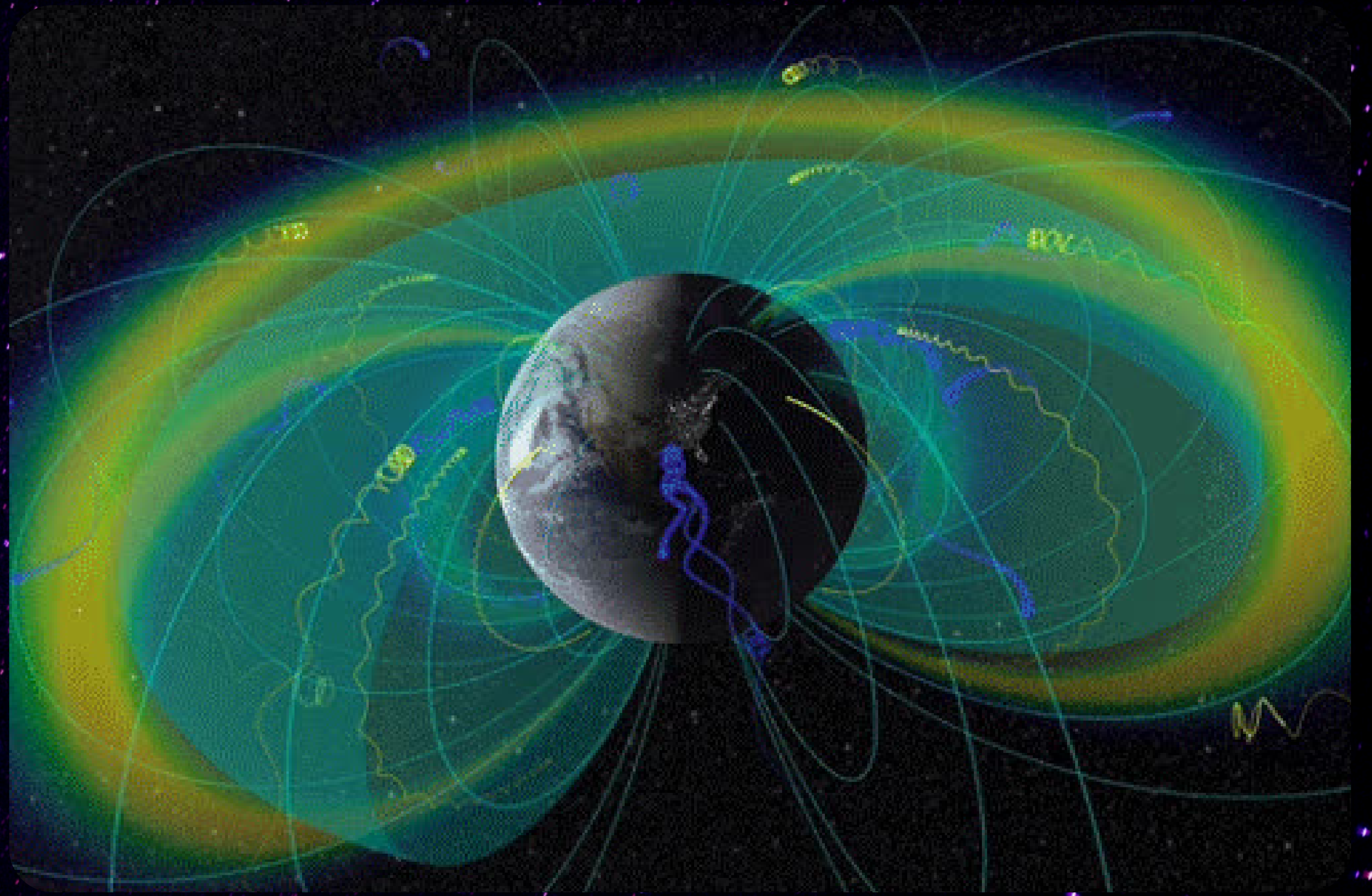
Heat-DRILL

- **Radiation-Hardened Materials:** Use thin layers of tantalum shielding around motor controllers and sensors to maintain durability without hindering the drill's functionality.

- **Protective Vaults:** Position sensitive control electronics in a compact, radiation-shielded housing near the surface, reducing exposure while maintaining efficient operations.

- **Active Monitoring:** Embed radiation sensors to ensure real-time assessment of the drill’s exposure and allow recalibration or pauses in operation if thresholds are exceeded.

- **Radiation-Tolerant Electronics:** Incorporate radiation-resistant microcontrollers to maintain precise drilling performance under high-radiation conditions.



Radiation from Jupiter

Submersible

- **Radiation-Hardened Materials:** Utilize tungsten shielding around sensitive scientific instruments and data processors to protect against residual radiation after penetrating the ice.

- **Protective Vaults:** Seal critical electronics (e.g., navigation, communication, and sampling systems) in watertight, radiation-shielded modules to ensure continued functionality in extreme environments.

- **Active Monitoring:** Deploy radiation sensors to track exposure levels during subsurface navigation and adjust operational parameters as needed.

- **Radiation-Tolerant Electronics:** Use robust electronics to process and store data in real-time without corruption from radiation.