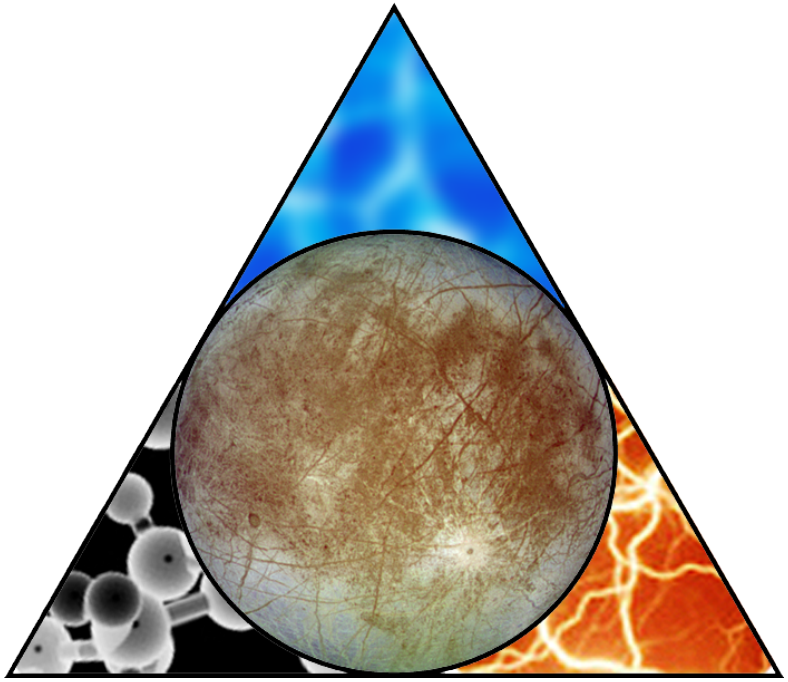

Europa Lander Study

Louise Prockter for Brian Cooke

and the Europa study team

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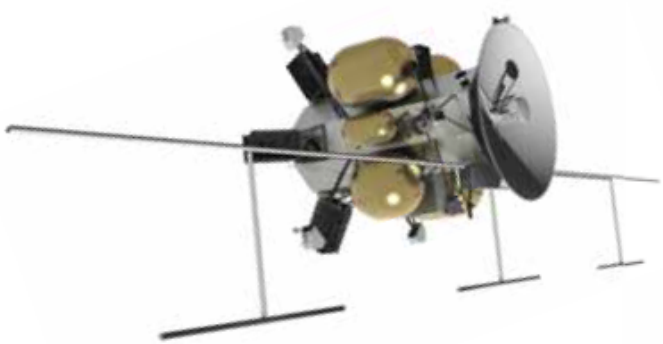
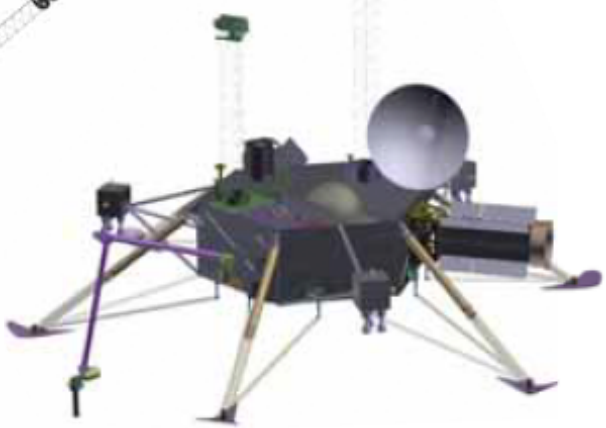
Background to Lander study

- Proposed 2020 Jupiter Europa Orbiter (JEO) mission was deemed extremely high science value, but unaffordable by the NRC Decadal Survey, which requested a descoped option
- NASA directed a 1 year study to develop mission options that retain high science value at significantly reduced cost
- Innovative design options for mission and spacecraft have resulted in 3 mission options
- This presentation summarizes one of these options, the Europa Lander



Multiple-Flyby in Jupiter Orbit
(The Europa Clipper)

Europa Orbiter



Europa Lander

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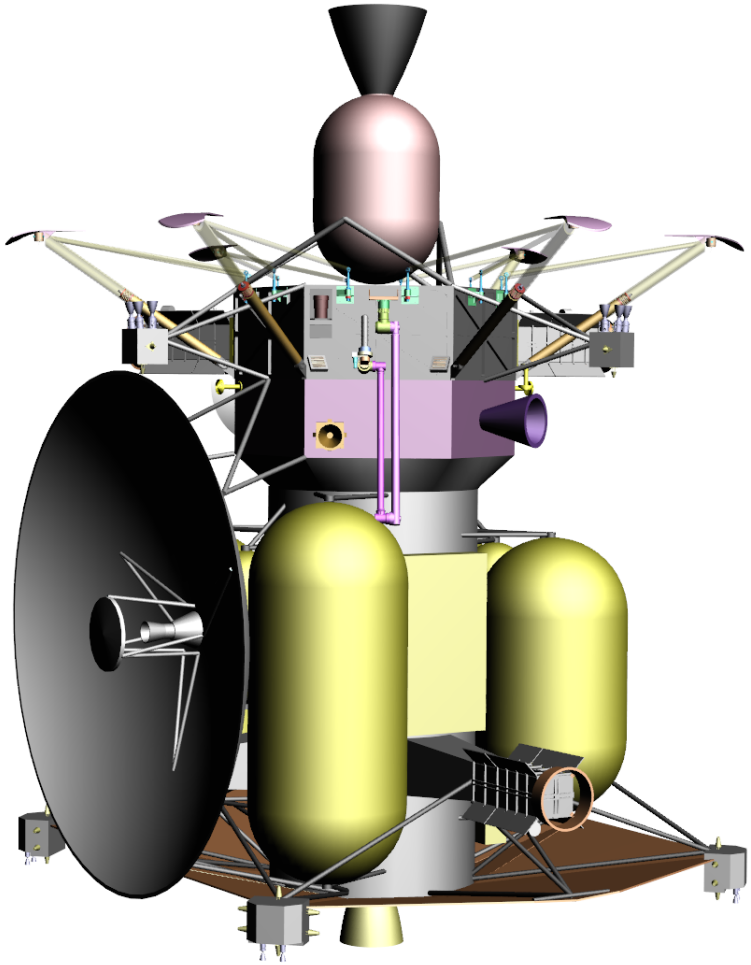
Overview of the Lander

- Comprehensive science from Europa's surface achieving important ocean, ice and composition objectives
- 30 days in Europa orbit to perform landing site certification
- Autonomous precision landing
- Surface operations of 9 eurosols (32 days)
- Drill and sample handling system to deliver material to science instruments
- Data returned via relay with carrier along with direct-to-earth capability



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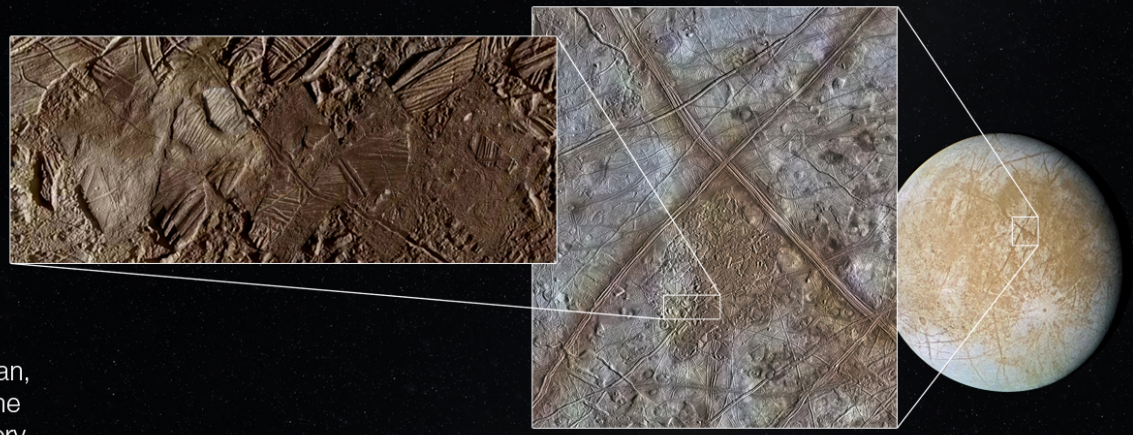
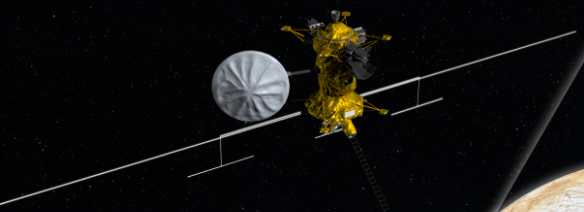
Europa

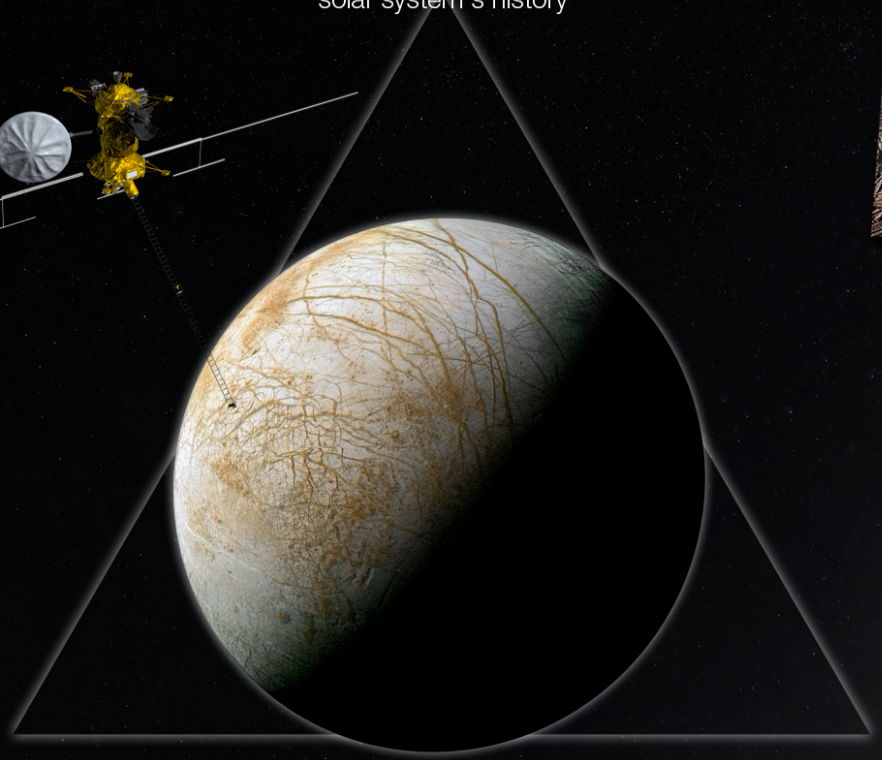
Ingredients for Life?

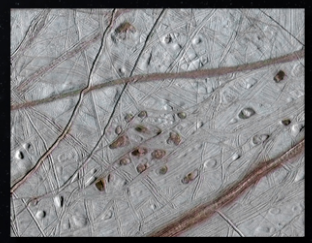


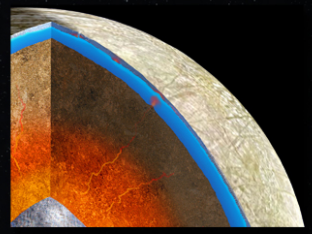
Water

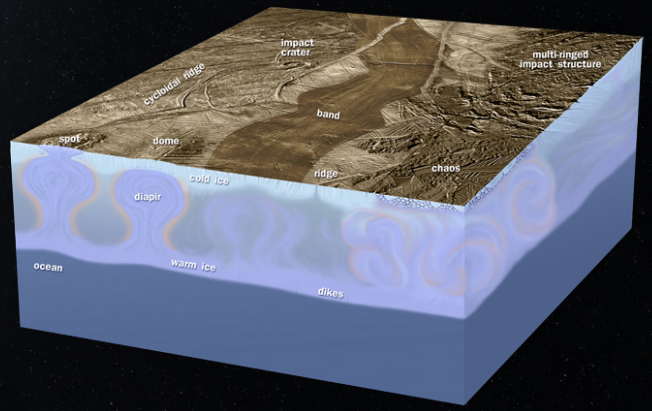
Probable global ocean, stable for most of the solar system's history











Chemistry

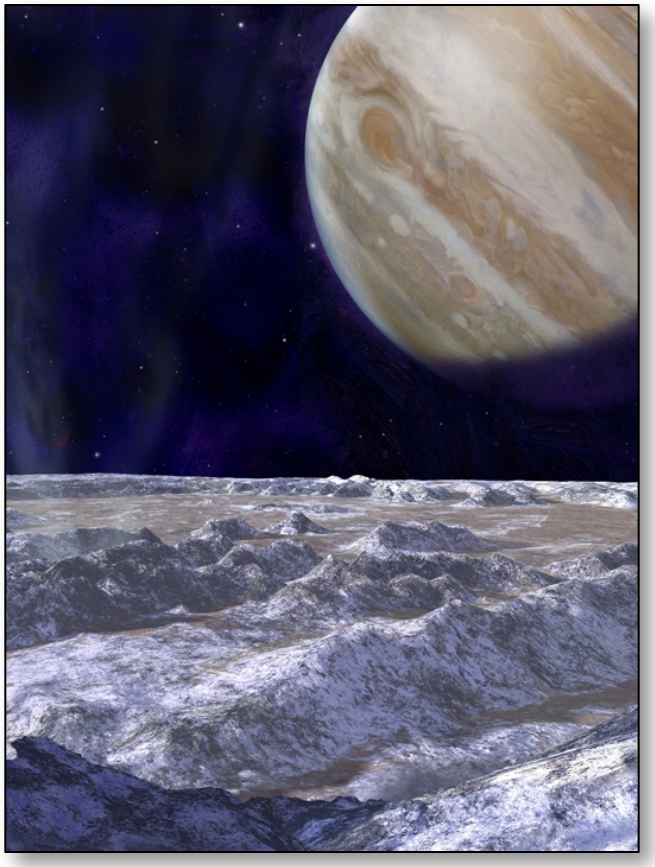
Water in contact with rocky interior leaches elements essential for life: CHNOPS

Energy

Surface radiolytic chemistry and possible ocean floor hydrothermal systems

Lander Science

- **Composition:** Understand the habitability of Europa's ocean through composition and chemistry
- **Ocean & Ice Shell:** Characterize the local thickness, heterogeneity, and dynamics of any ice and water layers
- **Geology:** Characterize a locality of high scientific interest to understand the formation and evolution of the surface at local scales



Provide direct measurement of surface materials along with a geophysical and geological understanding at a local scale

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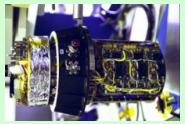
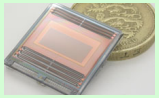
Lander Science Traceability

Goal	Objective		Investigation	Model Planning Payload	Theme		
					W	C	E
Explore Europa to investigate its habitability	Composition	Understand the habitability of Europa's ocean through composition and chemistry	Characterize surface and near-surface chemistry, including complex organic chemistry to constrain ocean composition and understand the endogenic processes from which it evolves	Mass Spectrometer, Raman Spectrometer		✔	✔
			Characterize surface and near-surface chemistry, including complex organic chemistry to constrain the exogenic processes and material fluxes that affect ocean composition	Mass spectrometer, Raman Spectrometer		✔	✔
			Constrain the context of compositional measurements	Site Imager, Reconnaissance Imager, Microscopic Imager	✔	✔	✔
	Ocean & Ice Shell	Characterize the local thickness, heterogeneity, and dynamics of any ice and water layers	Constrain the thickness and salinity of Europa's ocean	Magnetometer, Multi-Band Seismometer Package	✔	✔	
			Constrain the thickness of ice and the thickness of any water layers in the region	Magnetometer, Multi-Band Seismometer Package	✔		
			Search for local heterogeneity of the ice and any subsurface water	Multi-Band Seismometer Package	✔	✔	
			Characterize Europa's seismic activity and its variation over the tidal cycle	Multi-Band Seismometer Package	✔		✔
	Geology	Characterize a locality of high scientific interest to understand the formation and evolution of the surface at local scales	Constrain the processes that exchange material between the surface, near-surface, and subsurface	Site Imager, Reconnaissance Camera, Microscopic Imager	✔	✔	✔
			Constrain the processes and rates by which the surface materials (regolith and bedrock) form and evolve over time	Site Imager, Reconnaissance Imager, Microscopic Imager	✔	✔	✔
			Understand the regional and local context of the landing site	Site Imager, Reconnaissance Camera	✔	✔	✔
			Constrain the physical properties of the surface and near-surface at the landing site to provide context for the sample	Reconnaissance Imager, Microscopic Imager, Engineering data		✔	

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

Lander Model Planning Payload

Science Objective	Key Science Investigations	Model Instrument	Similar Instrument
Composition	Evolved gas analysis, pyrolysis, and gas chromatography, to determine composition of the surface and near surface, through measurement of two obtained samples.	**Mass Spectrometer (MS)**	 Huygens GCMS
	Characterization of surface and near-surface chemistry including complex organics, through measurement of shift in the wavelength of scattered laser light.	**Raman Spectrometer (RS)**	new development
Ocean & Ice Shell	Magnetic induction response, to derive ocean thickness and salinity.	**Magnetometer (MAG)**	Galileo MAG
	Thickness of ice and water layers through seismic analysis, and characterization of seismic activity level, and its variation over the tidal cycle.	**Multi-Band Seismometer Package (MBS)**	 ExoMars SP
Geology	Stereo landform mapping of the landing site from near the lander to the horizon, including the sample acquisition location.	**Site Imaging System (SIS)**	MER Pancam
	High-resolution imaging of collected samples to characterize ice grains and non-ice materials within.	**Microscopic Imager (MI)**	MSL MAHLI
	High-res imaging of candidate landing sites prior to Lander deployment, and imaging of lander on surface to provide context for landed measurements.	**Reconnaissance Imager (RI)**	MRO HiRISE

Floor model instrument Baseline model instrument

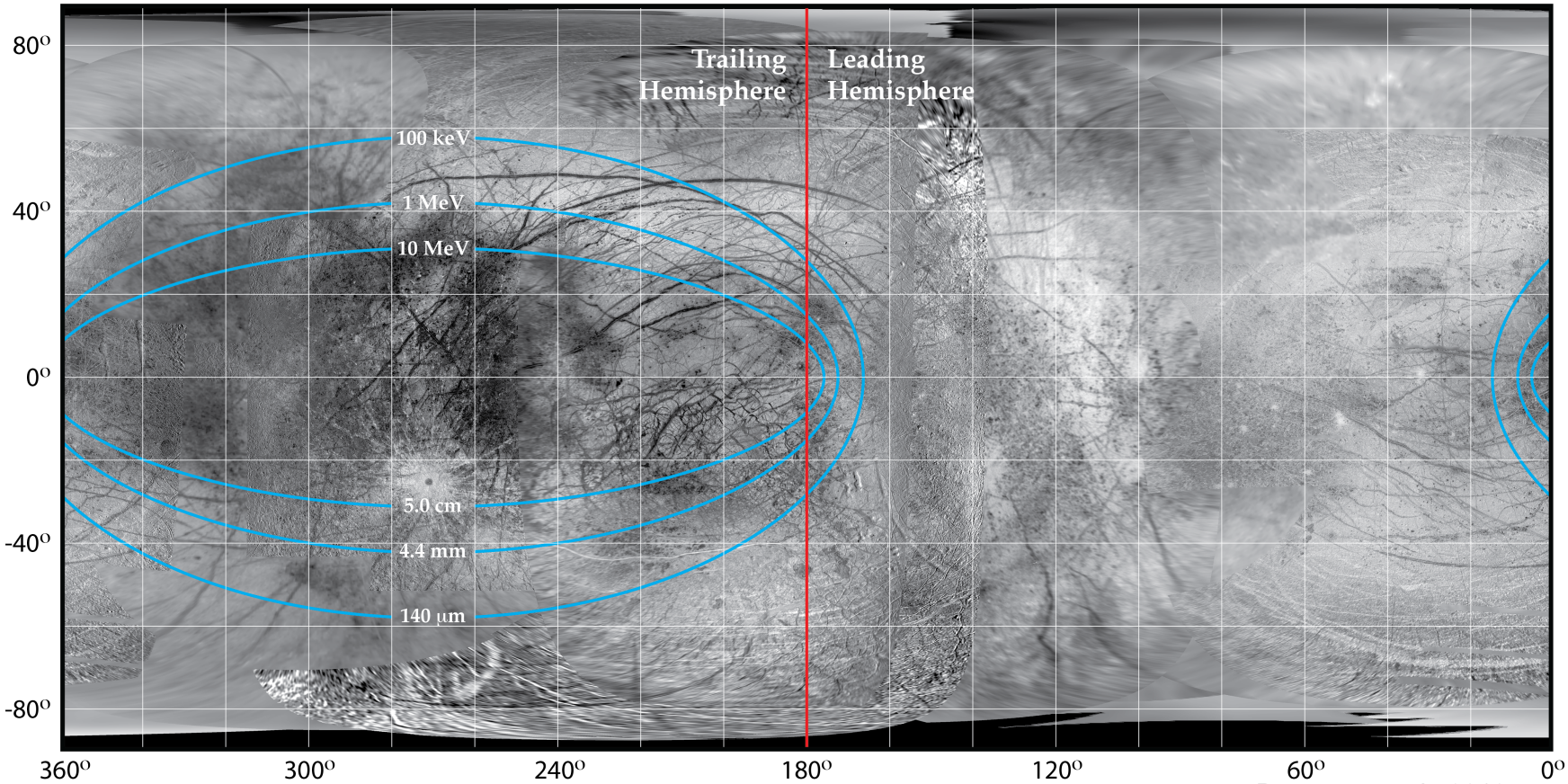
Landing Sites: Science Requirements

Primary landing site characteristics are derived from the science objectives and ideally satisfy the following:

Landing Sites: Science Requirements

Primary landing site characteristics are derived from the science objectives and ideally satisfy the following:

- **Relatively young surface**
  - **Less radiation processing**

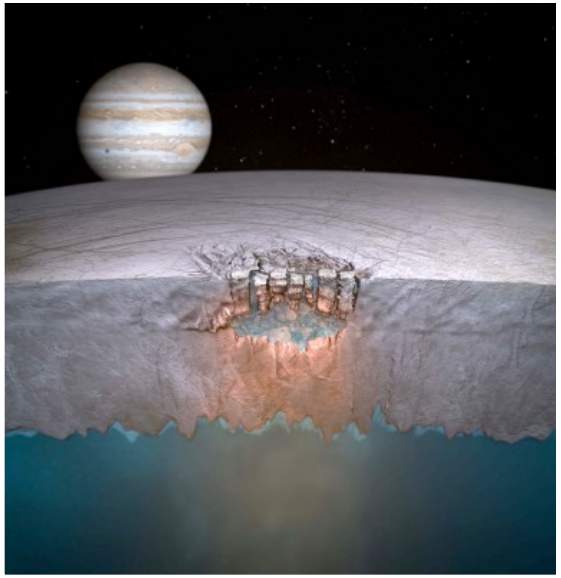


Patterson et al., 2012

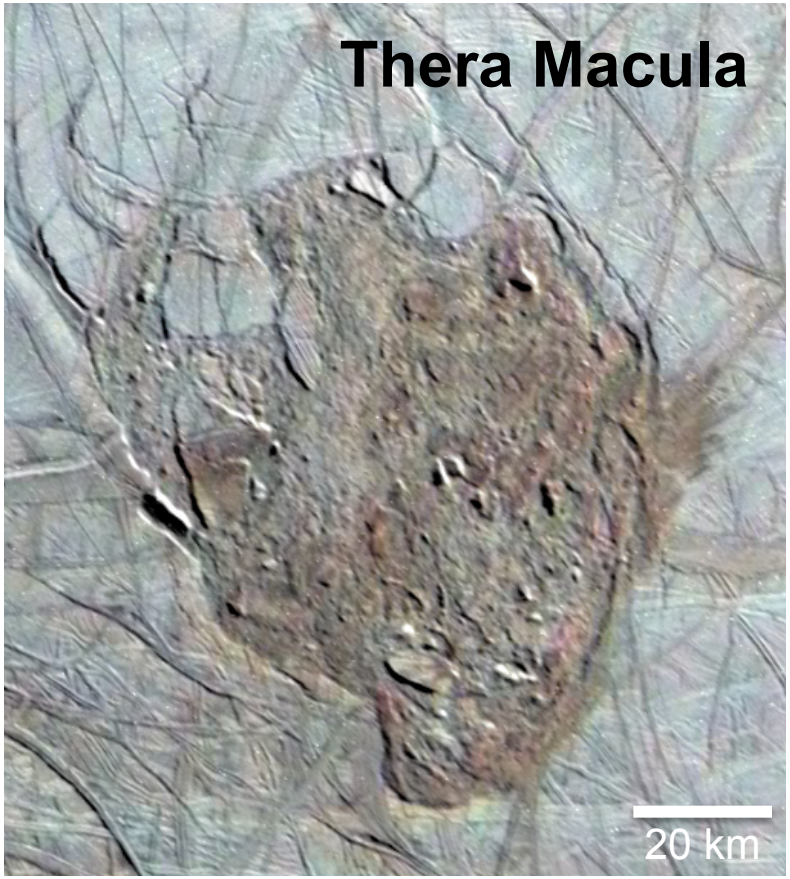
Landing Sites: Science Requirements

Primary landing site characteristics are derived from the science objectives and ideally satisfy the following:

- Relatively young surface
  - Less radiation processing
- **Evidence of recent activity**
  - **May imply recent communication with subsurface ocean**



Schmidt et al., 2011



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- Evidence of recent activity
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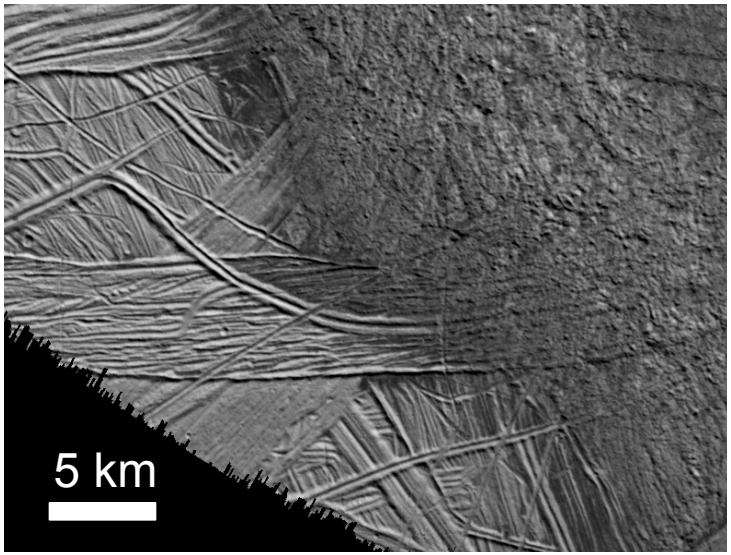
- **Evidence of impurities**
  - **Low albedo regions likely contain impurities which are of higher astrobiological interest**
- **Potential to sample ocean material**
  - **Search for evidence of fluid extrusion on surface**



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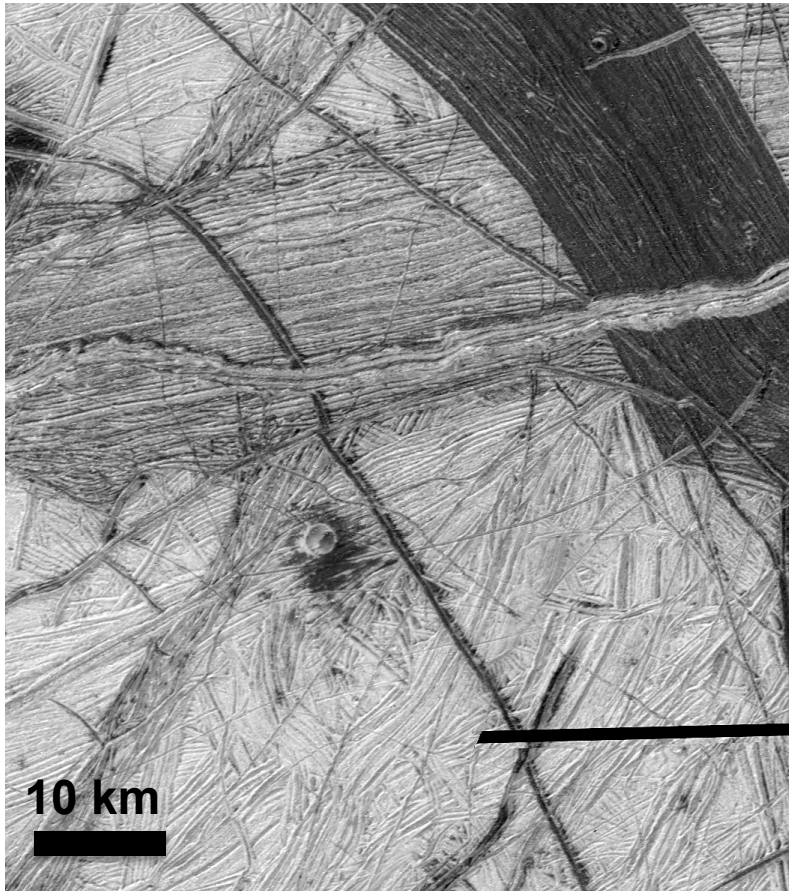
- Potential to sample ocean material
  - Search for evidence of fluid extrusion on surface
- **Potential for tectonic activity**
  - **Characterize seismic sources**



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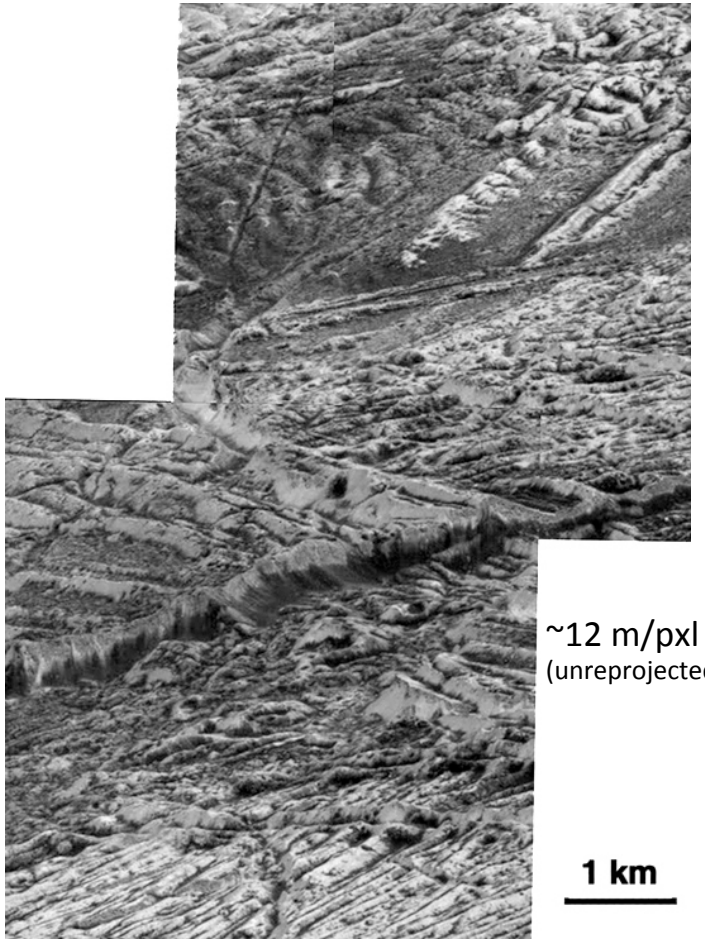
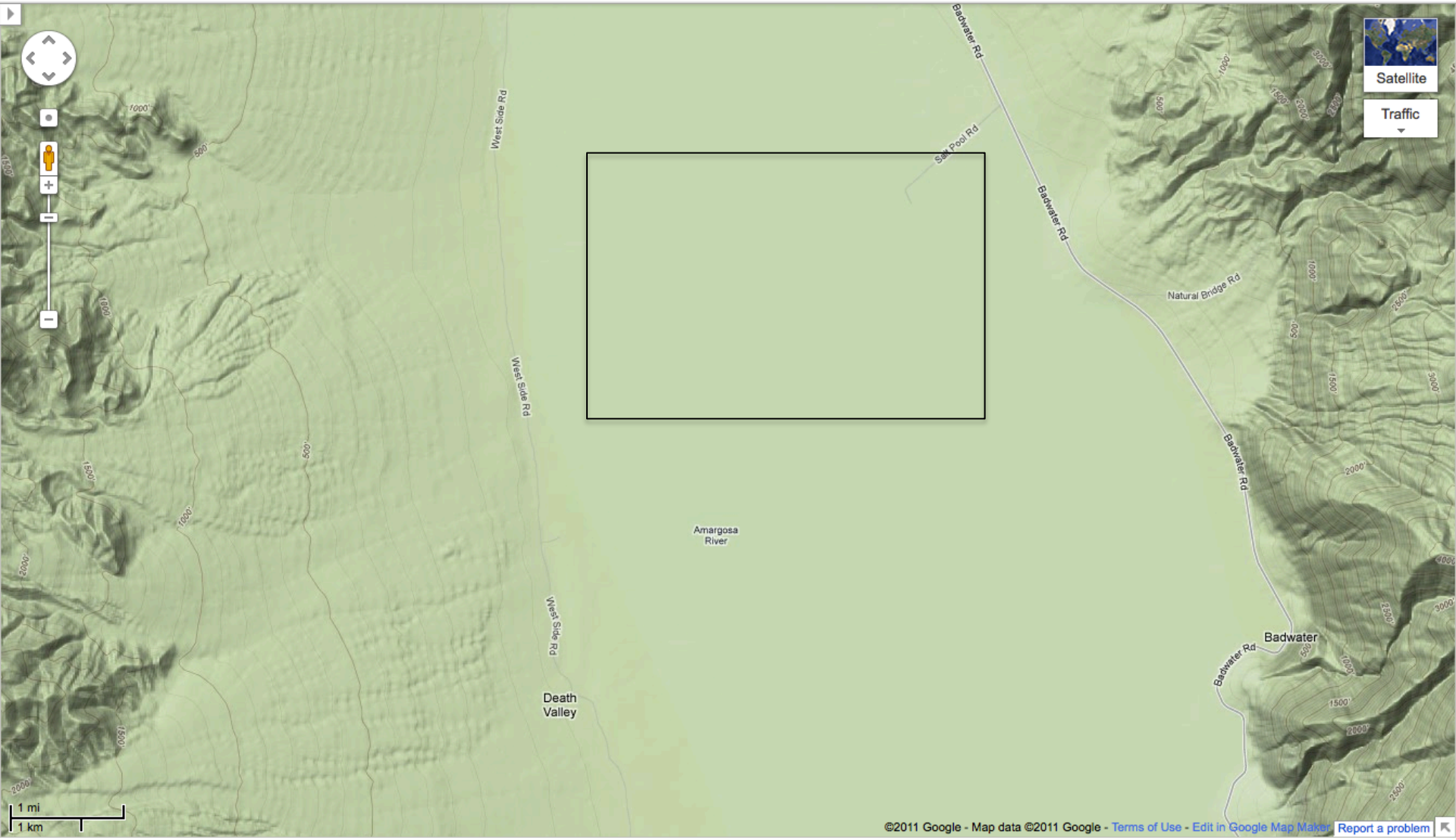
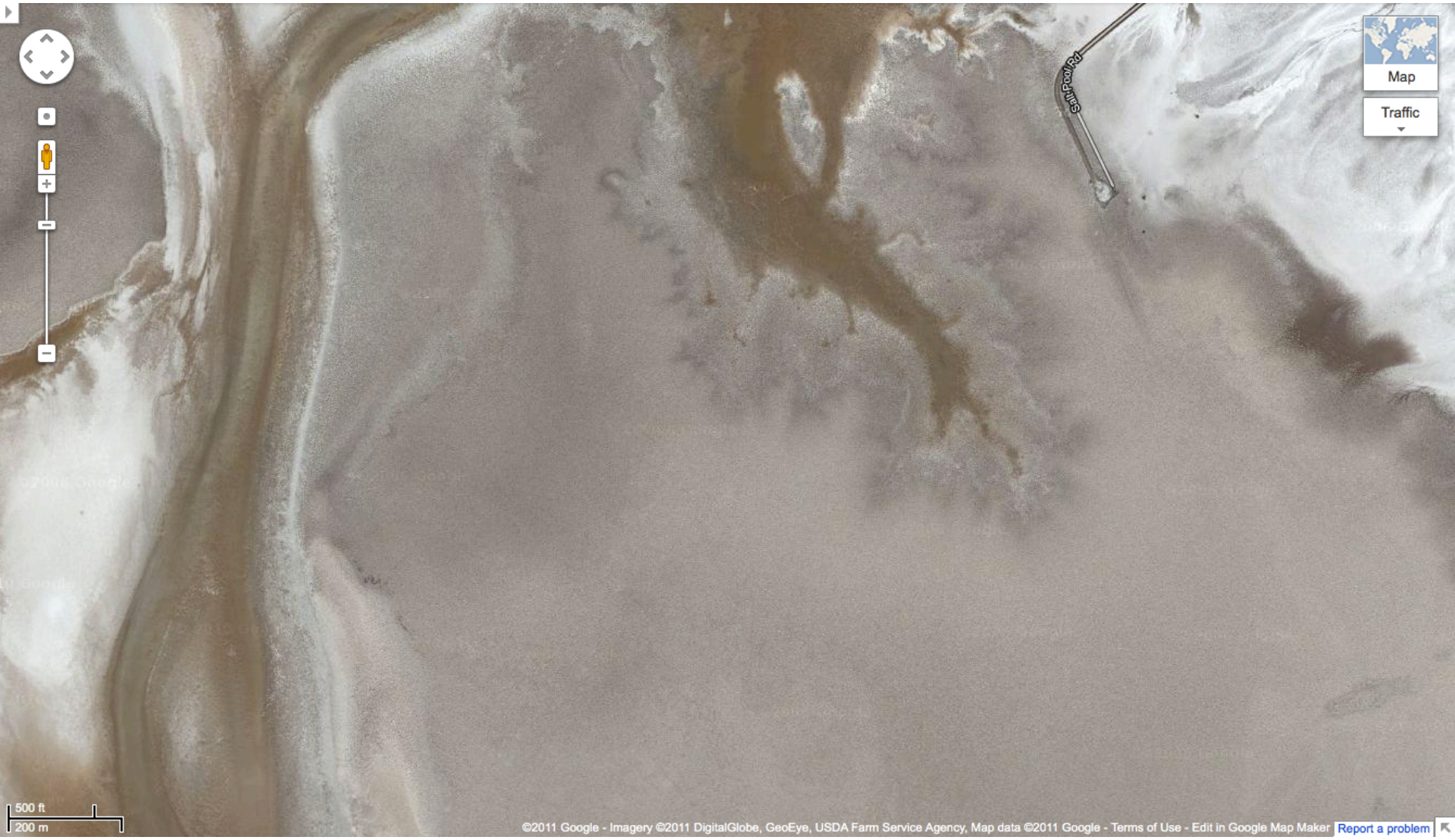
- Potential to sample ocean material
  - Search for evidence of fluid extrusion on surface
- Potential for tectonic activity
  - Characterize seismic sources
- **Relatively safe to land**
  - **Relatively smooth, and lower radiation**





Devil’s golf course, Death Valley, CA (Topo map, 5 m interval contours)



Devil’s golf course, Death Valley, CA (1 m/pixel)

Devil’s golf course, Death Valley, CA (Human scale)

Earth

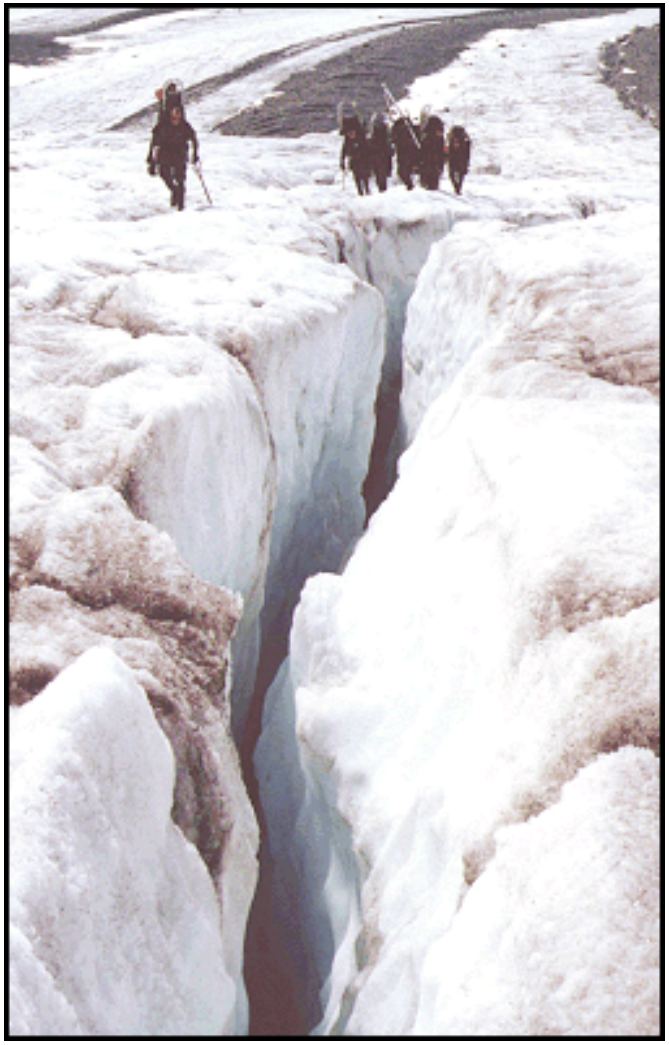
Earth

Where on the surface can we land?

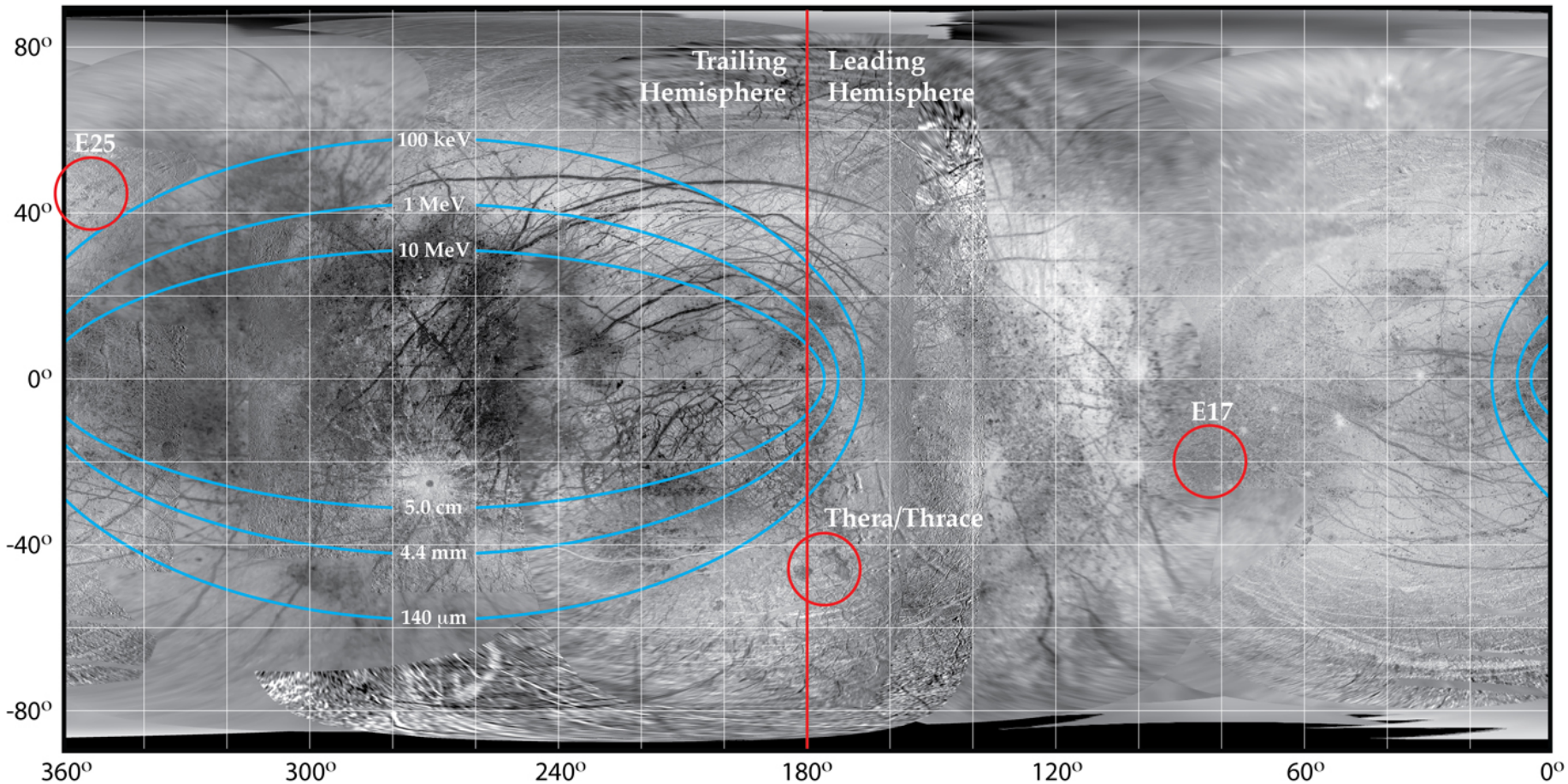
Given that it is highly unlikely that there are any areas on Europa that are smooth at sub-meter scales, we studied two options:

1. Include orbital reconnaissance to characterize blocks at decimeter scales OR
2. Design a lander that can land in extremely rough terrain and still make relevant measurements

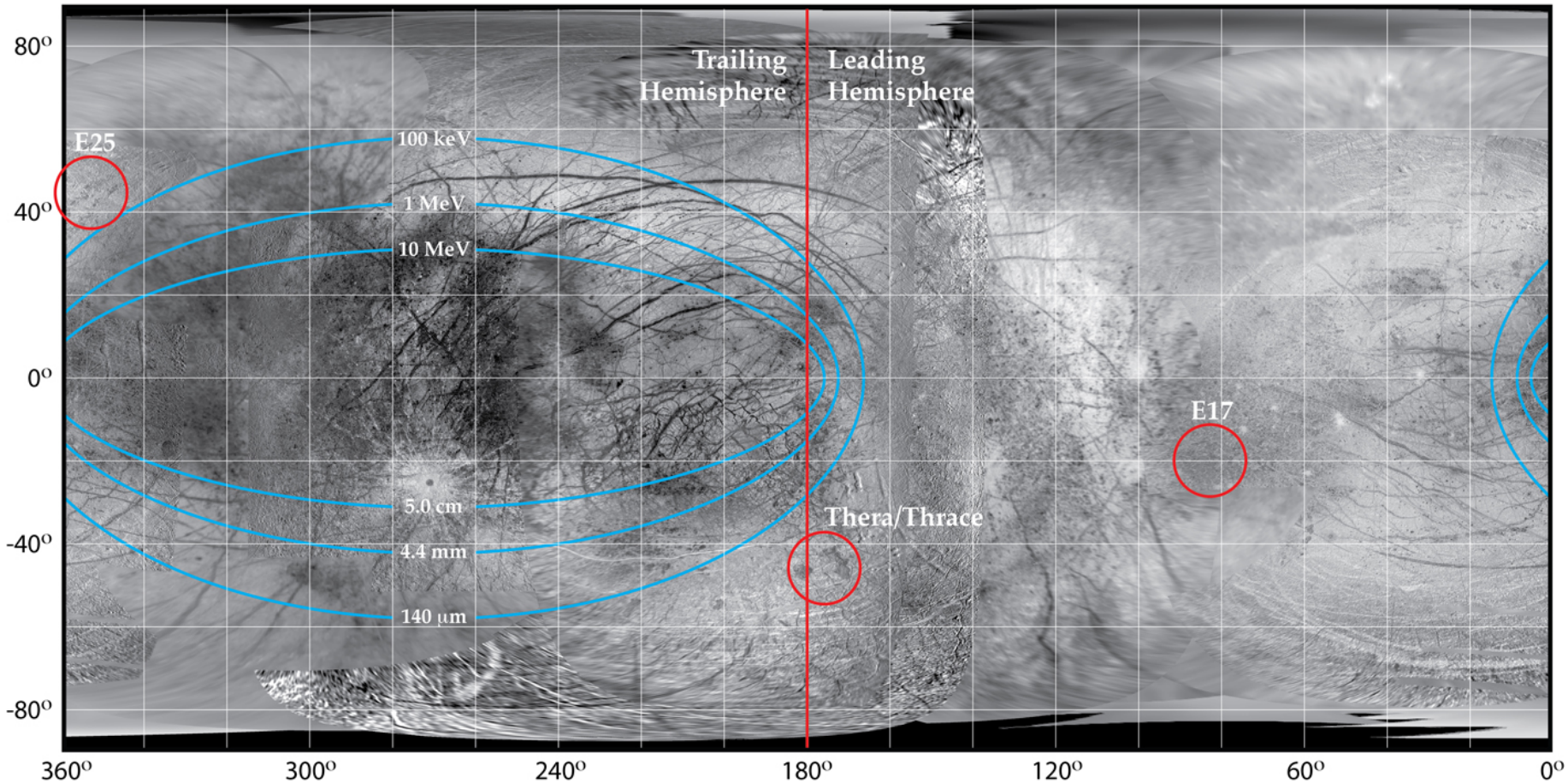
The technical team concluded that including orbital reconnaissance carried lower risk



Landing site candidates



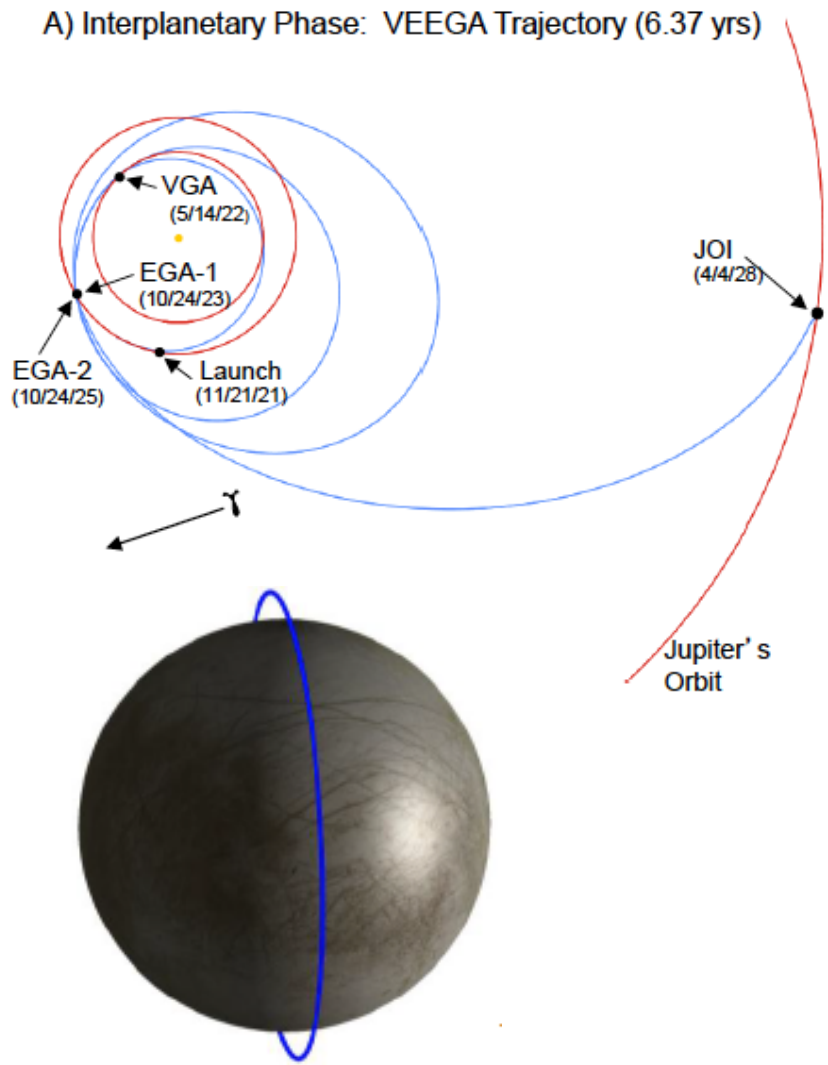
Landing site candidates



Candidate landing sites would be characterized from orbit prior to lander deployment

Mission Overview

- Launch: Nov 2021
- Launch vehicle: Delta IV Heavy
- C3 (max): 15 km^2/s^2
- Earth to Jupiter trajectory: VEEGA
- Interplanetary cruise: 2021-2027
- Jupiter arrival: Apr 2028
- Tour: Apr 2028 – Aug 2029 (1.3 yrs)
- EOI: Aug 29
- Site certification orbit duration: 30 days at 200 km altitude, 95º inclination, 138 min initial period, 07:30 initial node
- Deorbit, descent and landing: Sep 2029
- Prime lander and relay ops: 1 month
- Relay disposal: Europa impact, > Nov 2029



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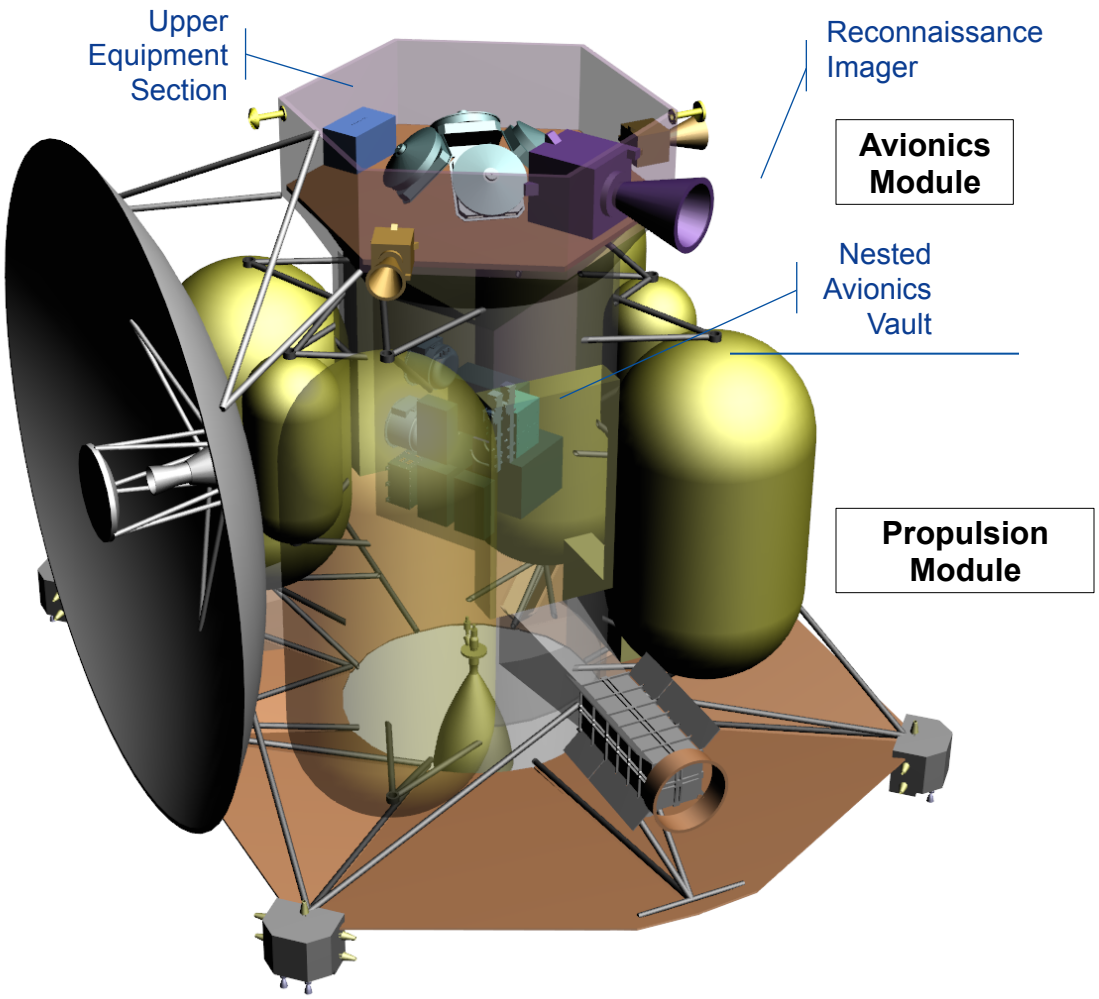
Carrier Element



Carrier-Relay Spacecraft:

- Modular design
- Fixed 3 m HGA, Ka-band, 75 kbps downlink capability
- High-resolution Recon Imager (50 cm/pixel)

Before Lander separation:

- Provides all spacecraft functions
- Performs landing site reconnaissance imaging from Europa orbit
- Executes Lander separation

After Lander separation:

- Imaging for landing site context
- Serves as a high bandwidth telecommunications relay link between the lander and Earth

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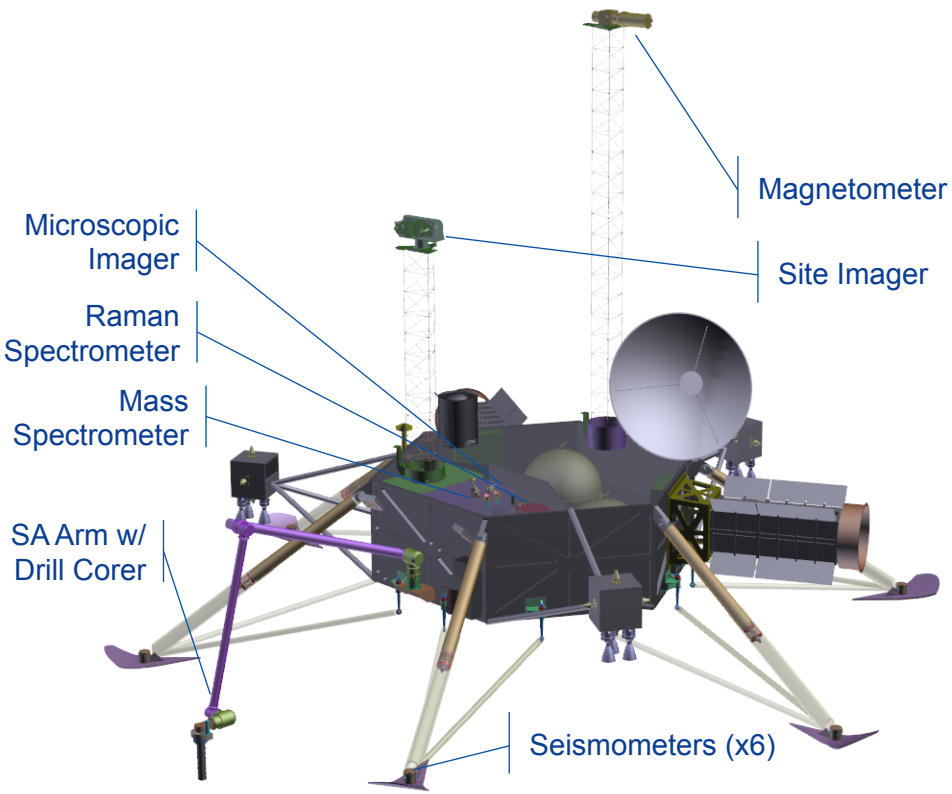
Lander Element



- 3-axis stabilized, thruster-based attitude control. Hazard detection system
- 6 reference science instruments
- 2 ASRGs, 60 Ahr Battery
- DTE backup: X-band, 0.75 m, 2-axis gimbaled HGA, 9 kbit/sec contingency downlink capability

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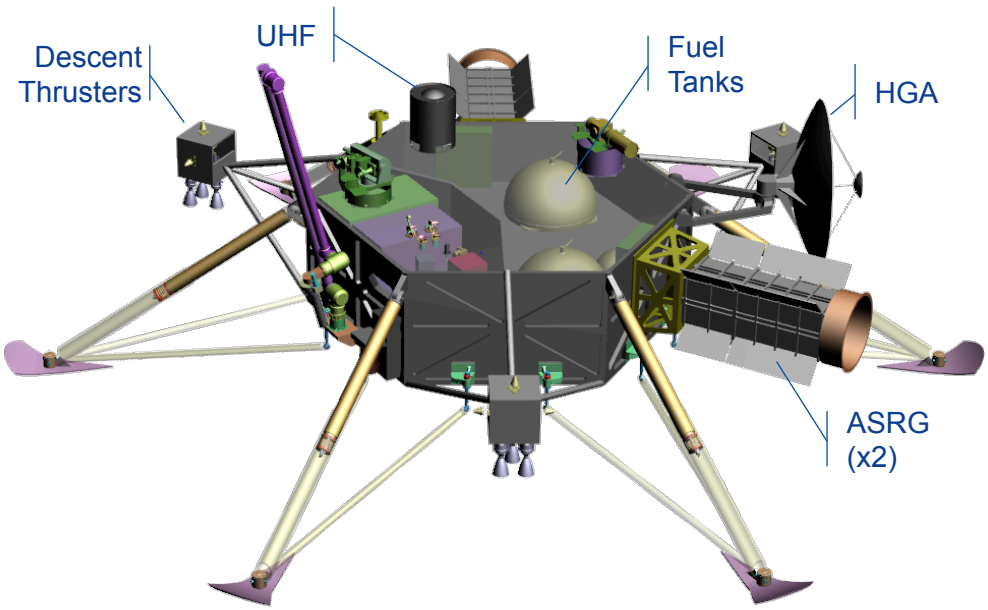
Lander Element



Before Lander Separation:

- Powered off for majority of cruise to Europa
- Passive thermal subsystem maintains thermal control of Lander and Deorbit SRM
- Excess power from Lander's (2) ASRGs available to Carrier

After Lander Separation:

- Performs SRM deorbit burn, descent, terrain relative navigation, hazard avoidance and landing
- Executes science measurements, performs sample collection and transmits results to Carrier spacecraft

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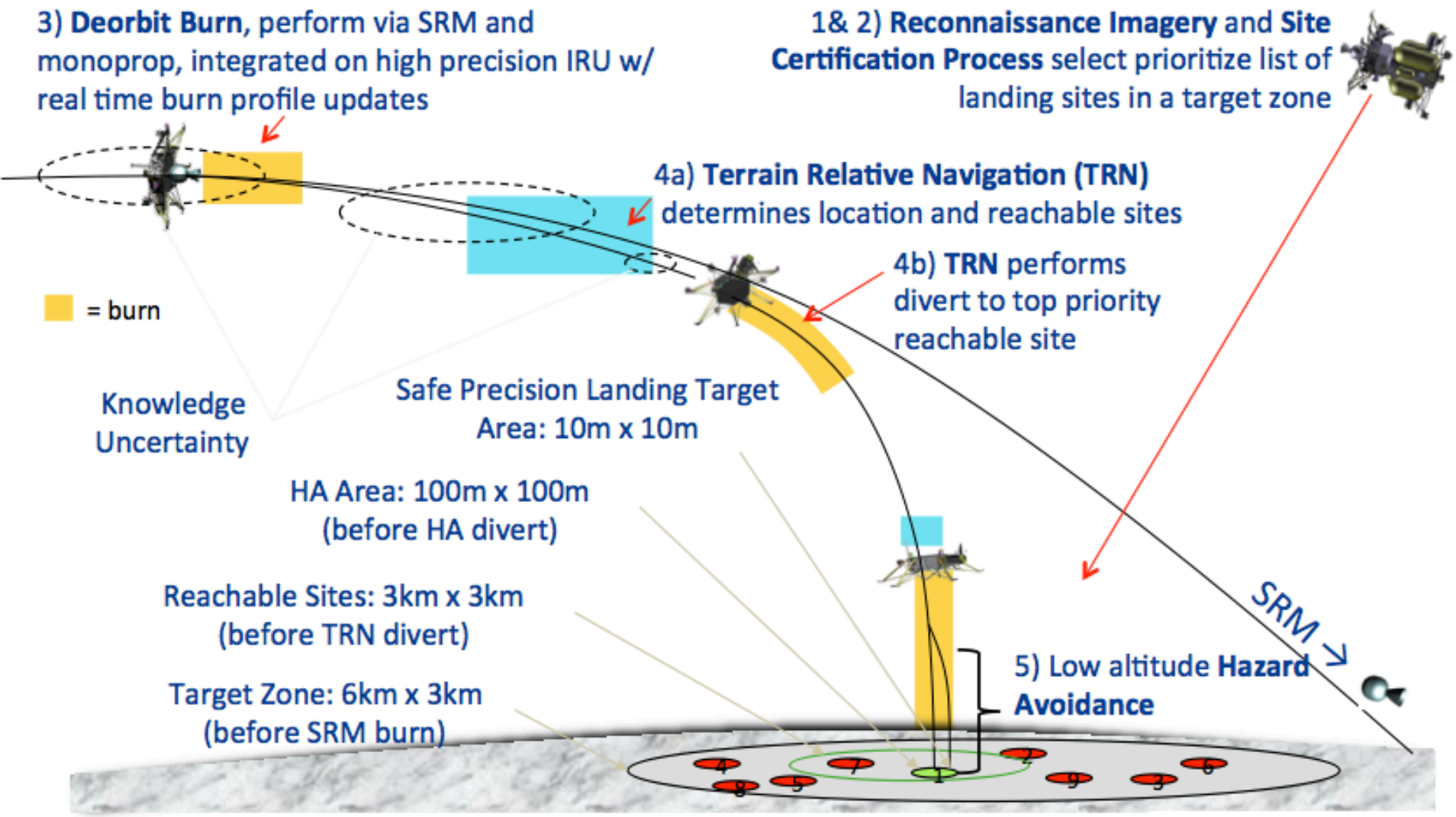
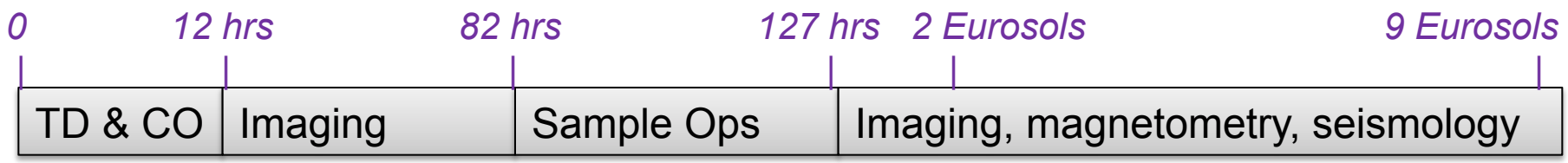
Tiered Landing Site Risk Mitigation



Lander Science Operations

- Surface Operations divided into four phases:
  - Phase 1: Touchdown & Checkout
  - Phase 2: Worksite imaging
  - Phase 3: Sample operations
  - Phase 4: Panoramic imaging, magnetometry, seismometry



Surface Operations timeline

Baseline science objectives achieved in 2 eurosols (7 days); with 7 eurosols (25 days) of contingency

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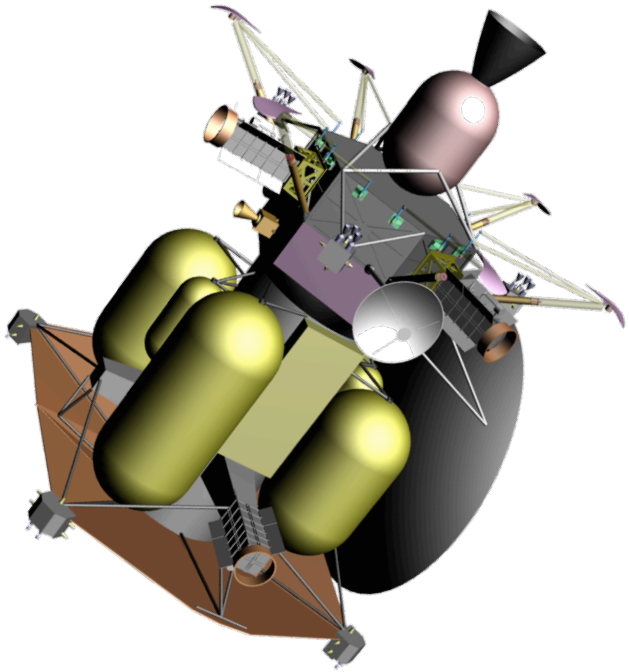
Lander Margins and Cost

Lander Technical Margins

29%	38%	41%
Mass	**Power**	**Data**



Option	Cost (FY15, excl LV)	Risk	Science
Lander	$2.8B	High	Excellent

Comprehensive investigation of Europa at a local scale but significant cost and technical challenges

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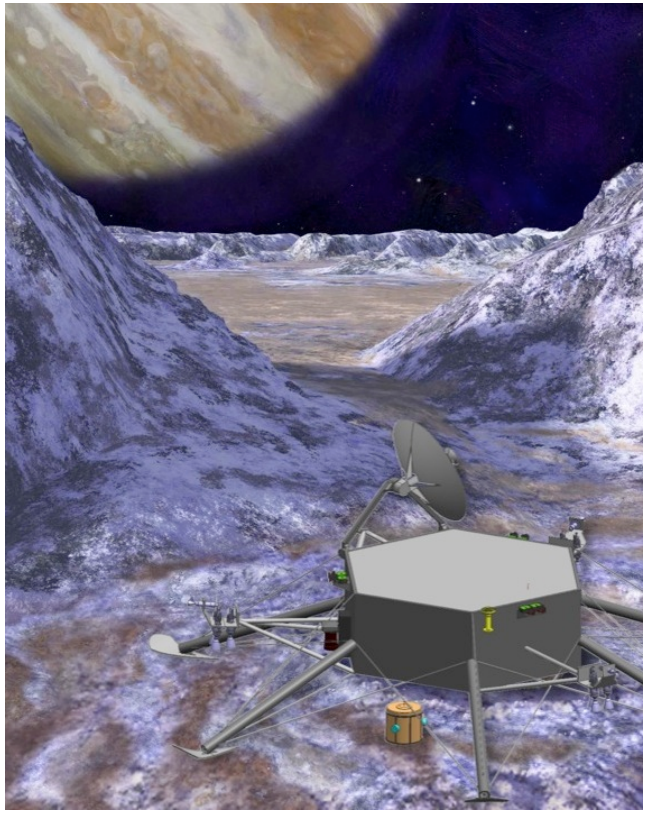
Summary

- A Europa lander enables unique in situ science opportunities
- The most definitive way to probe Europa's composition as relevant to habitability
  - Organics and salt chemistry
  - Exogenic vs. endogenic materials
- Would provide extremely valuable geophysical and geological science
  - Ocean salinity and thickness
  - Seismic activity and ocean-ice structure
  - Geological process at a human scale
- However, significant technology developments are still required, and comprehensive reconnaissance of Europa's surface is needed in order to choose landing sites with the highest astrobiological potential