Europa Lander Mission Concept

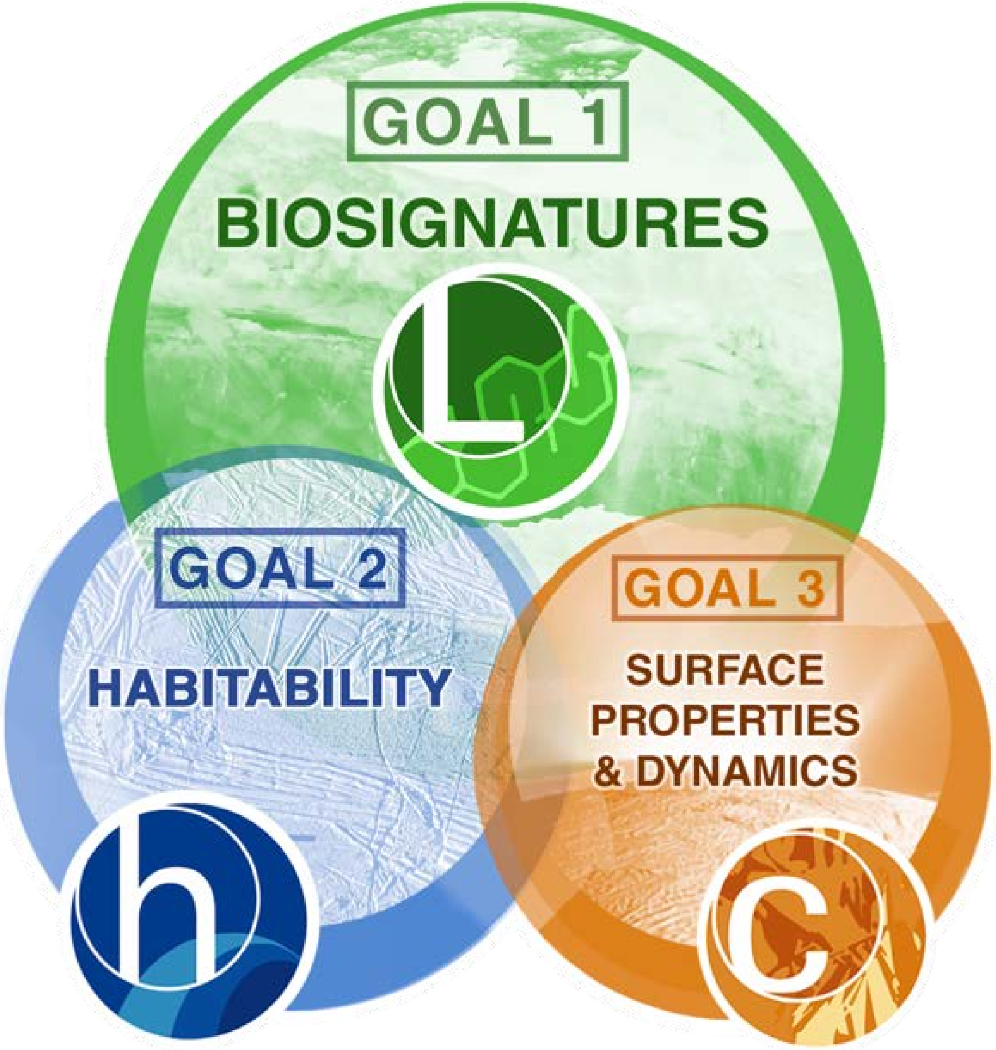
Jet Propulsion Laboratory
California Institute of Technology

Kevin Hand, Cynthia Phillips, Kate Craft, Morgan Cable, Amy Hofmann & Project Science & Engineering Teams

Europa Lander Science Update

New architecture still achieves all three goals from the Science Definition Team Report.

1. Measurements & Model Payload are the same.
2. Mission duration is the same.
3. Reduced cost and complexity.



Presentations to, and Feedback from, the Scientific Community, Review Boards, & HQ

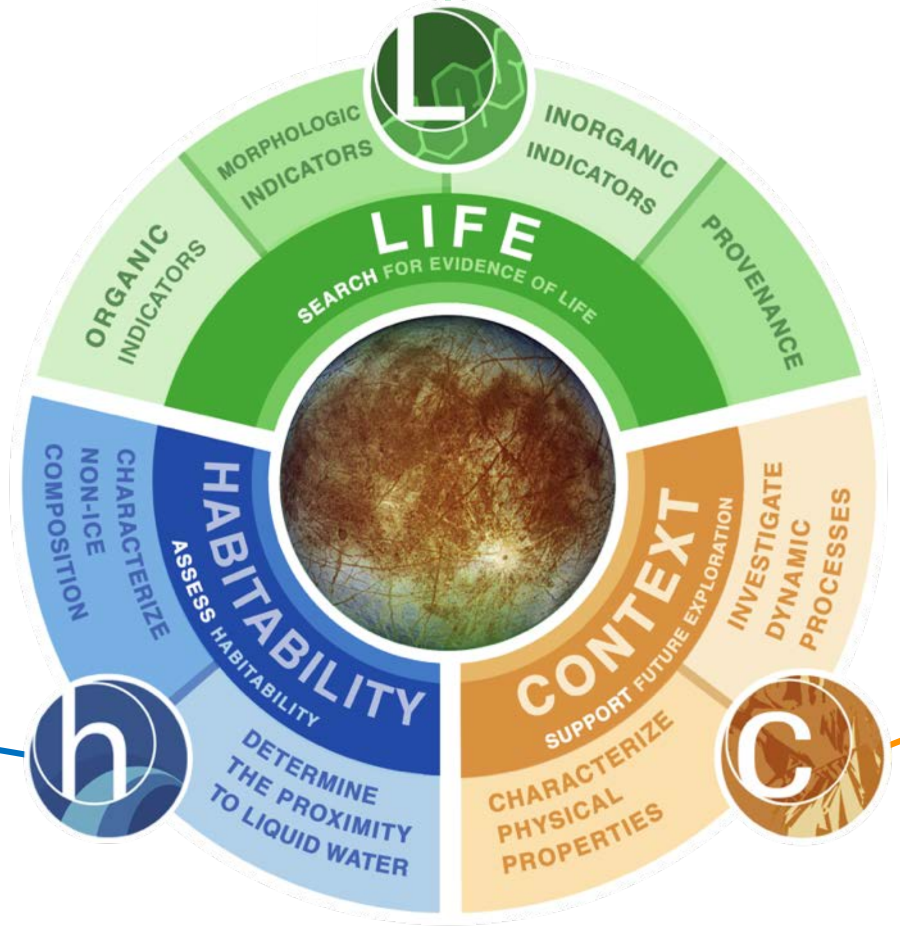
- Town Hall #1: Lunar & Planetary Sciences Conference, February 2017.
    - Approximately 6 hours of presentations and Q&A with HQ assembled committee and LPSC attendees (and open to public).
- Town Hall #2: Astrobiology Science Conference, March 2017.
    - Approximately 6 hours of presentations and Q&A with HQ assembled committee and AbSciCon attendees (and open to public)
    - 15-minute presentation during conference week.
    - Town Hall Executive Committee feedback addressed through response letter to NASA.
- Outer Planets Assessment Group (OPAG)
    - Progress report presentation, Fall 2016.
    - Full report 2-hour out-brief with Q&A, Spring 2017.
    - Update briefing on MCR and next step, Fall 2017
    - Reformulation architecture presentation Feb. 2, 2018.
    - Full Lander and Ocean Worlds Technology session at OPAG in Feb 2018.
- Committee on Astrobiology & Planetary Sciences (NRC CAPS)
    - Progress report presentation, Fall 2016.
    - Full report out-brief March, 2017.
    - Reformulation architecture presentation Feb. 28, 2018.
- Mission Concept Review, June 19-22nd, 2017. Chair: Prof. B. Braun.
    - Post-MCR direction from HQ (7/28/2017) addressed through external board assembled by Braun.
- Report out to HQ by Braun was provided Oct. 2017.
    - Direction Letter from HQ received (12/7/2017): Go with DTE architecture as it preserves science but minimizes cost and complexity.
    - Briefing to HQ on Direction Letter responses (2/16/2018).
- Numerous talks and posters at AGU, DPS, LPSC, AbSciCon, NRC panels, OW3, Deep Dives,…

Europa Lander Science Update

- Science Feedback
  - **OPAG Sept. 2017 Findings**:
    - “While searching for life and understanding Europa’s chemistry are important goals, other science unique to a landed mission is equally important to the OPAG community.”
  - **Mission Concept Review (MCR), June 2017**:
    - “The evidence of life requirement should be cast in terms of achievable measurement objectives (e.g., determine chemical composition, characterize organic compounds, and search for biosignatures)...”
- B. Braun panel for reformulation effort:
  - L. Elkins-Tanton (ASU), J. Lunine (Cornell), K. Craft (JHU-APL), D. McCleese (JPL, retired), Mark Adler (Apple), B.G. Lee (JPL), D. Kusnierkiewicz (JHU-APL), F. Naderi (JPL, retired), D. Adams (JHU-APL), S. Battel (Battel Engineering), B. Sherwood (JPL), B. Buffington (JPL).

A Connected Set of Goals & Objectives Addressed with a Focused Model Payload

GC-MS **Microscope** **Raman spectrometer** **Context cameras**



Raman spectrometer

GC-MS

Context cameras

Geophone

Raman spectrometer

Microscope

GC-MS

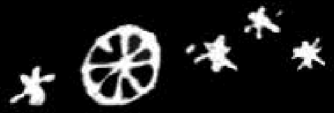
Context cameras

Geophone

Europa Lander

Potential Future Mission Concept

Jet Propulsion Laboratory
California Institute of Technology



Backup Slides

Europa Lander Update

Summary of Feedback from the Community (OPAG, Townhalls [LPSC, AbSciCon], Townhall Board, MCR Board, CAPS, Poster presentations and talks, HQ-TZ):

‘Life detection is hard and it could be a liability; focus on the search for biosignatures.’

Definition of ‘biosignature’: A feature or measurement interpreted as evidence of life.

Life Detection

Concluding that life has been detected requires the **measurement of multiple, complementary, and redundant potential biosignatures**, in at least three independent samples (detection is done in **triplicate**).

Model payload: Europa Lander SDT Report.

Mission architecture: Communications orbiter required for high-bandwidth, ground-in-the-loop decision making to enable triplicate measurement.

Search for Biosignatures

Searching for biosignatures requires the **measurement of multiple, complementary, and redundant potential biosignatures**.

Model payload: Europa Lander SDT Report.

Mission architecture: Without the triplicate requirement, ground-in-the-loop and data rates can be relaxed, which enables direct-to-Earth architecture.

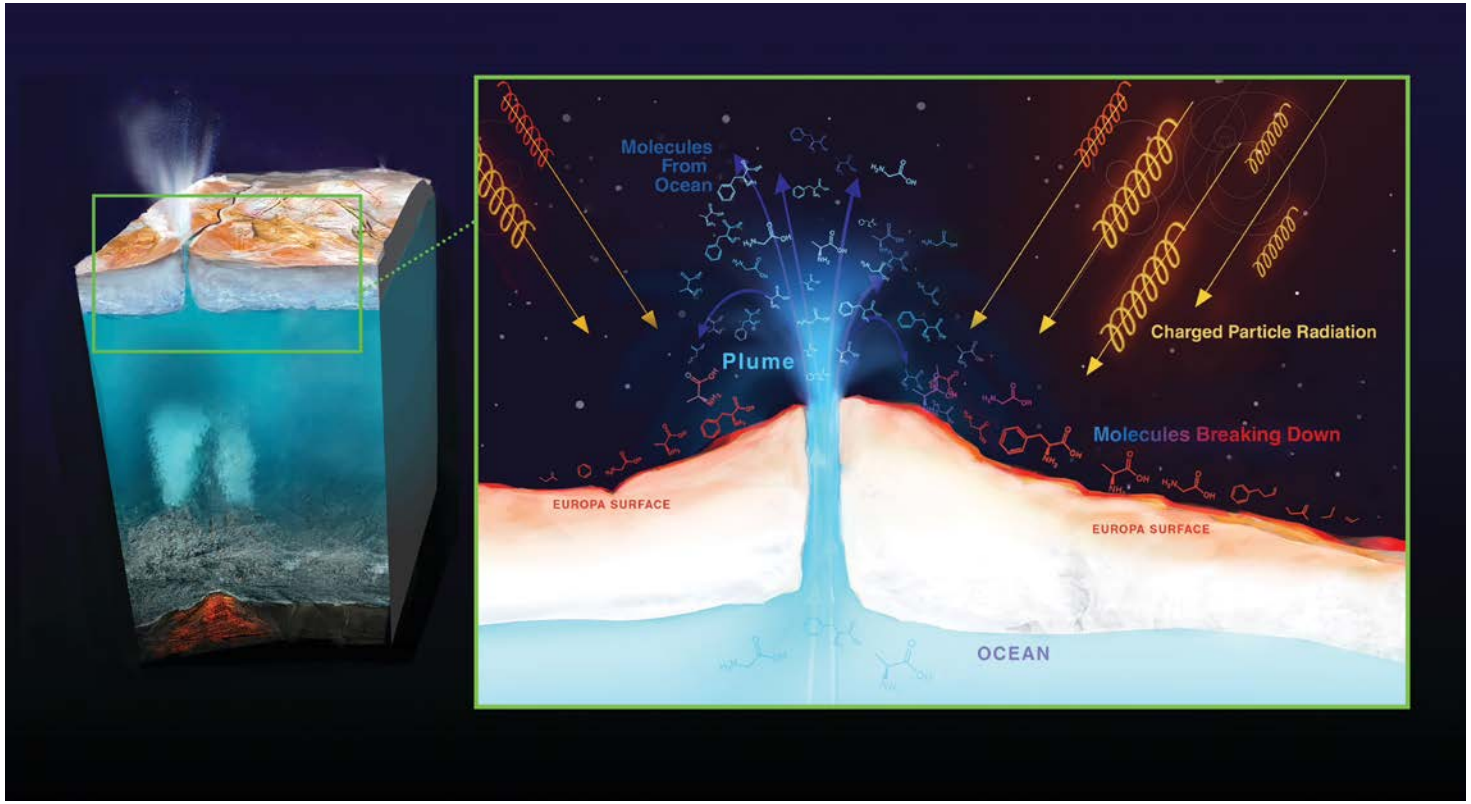
Summary of science & surface phase scenarios

Parameter	Lander w Comm orbiter	Direct-to-Earth Lander
Lander mission duration	20 days	22 days
Stored energy	43 kWh	50 kWh
Required number of samples*	5	3
Required number of trenches*	5	1
Required seismic monitoring	10 days	7.1 days
Required data return (capability)	5 Gbits (24 Gb)	1.5 Gbits (4.6 Gb)
Baseline completion (margin)	12 days (8 days)	7.1 days (13 days)
Number of command cycles	20	12

**All mission architectures can process more samples and excavate more trenches if the energy allocated for margin days is used for science instead of contingency.*

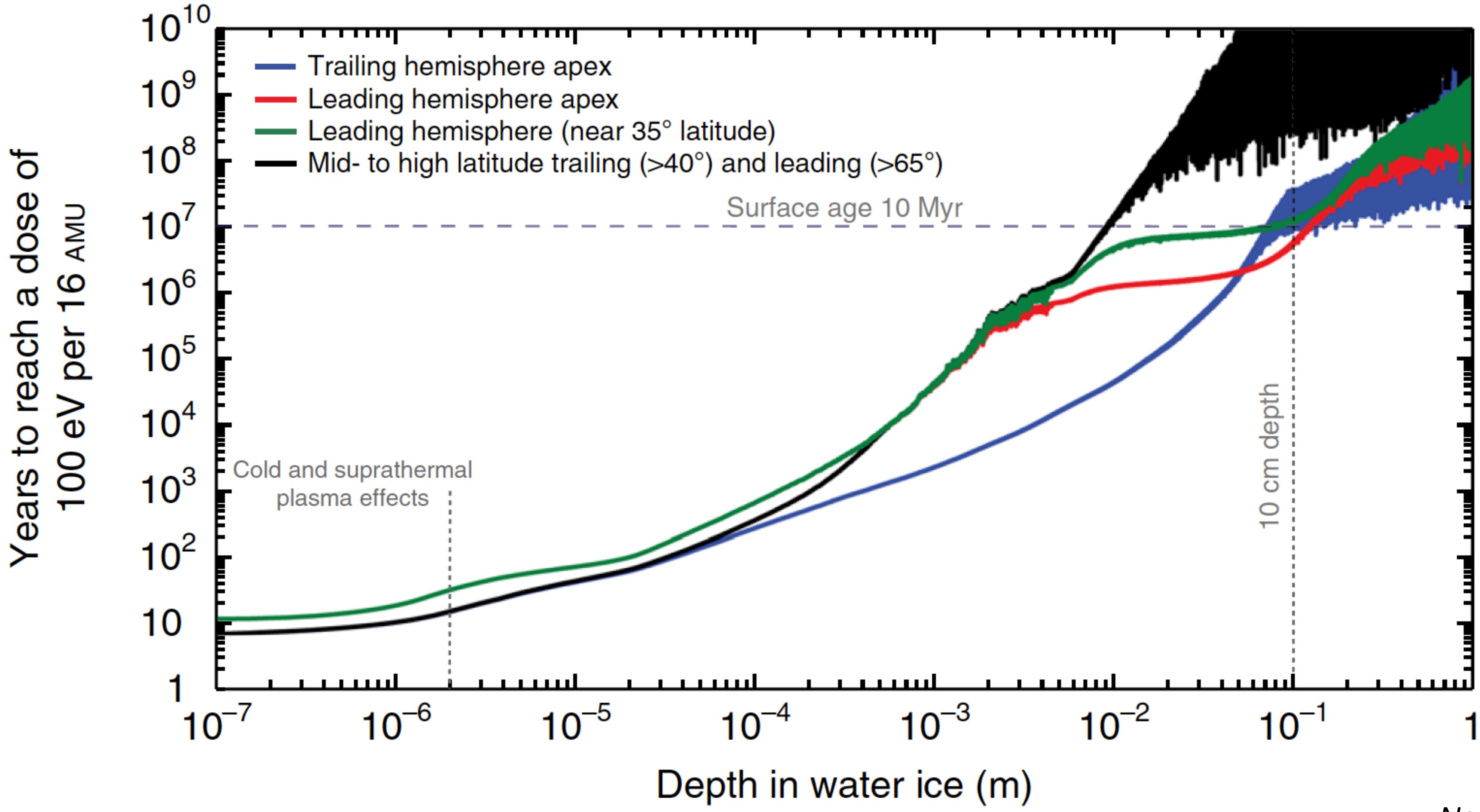
Radiation

Galactic Cosmic Rays



- GCR flux at Mars and Jupiter is comparable.
  - Flux is low and steady. Exposure duration is critical. Mars: ~3.5 Gyr; Europa: ~10-100 Myr.
  - Europa accumulated dose is 1 to 2 orders of magnitude lower than that of Mars.
- Jovian magnetosphere shields Europa from <13 GeV protons, which constitutes >60% of total GCR energy.
- Europa's total accumulated dose from GCRs is ~1/50th to 1/500th that of Mars.

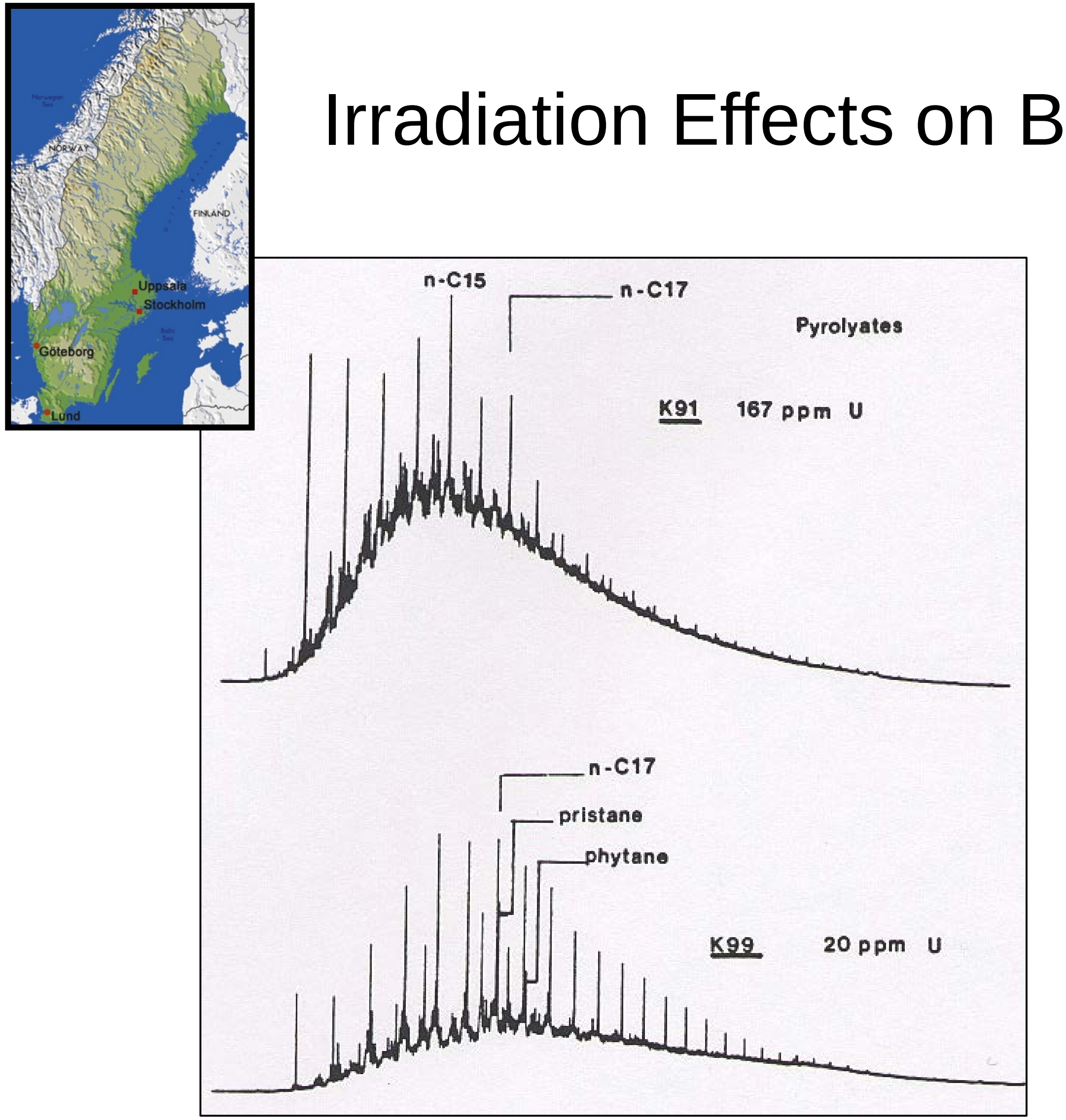
Radiation processing



Nordheim et al., 2018

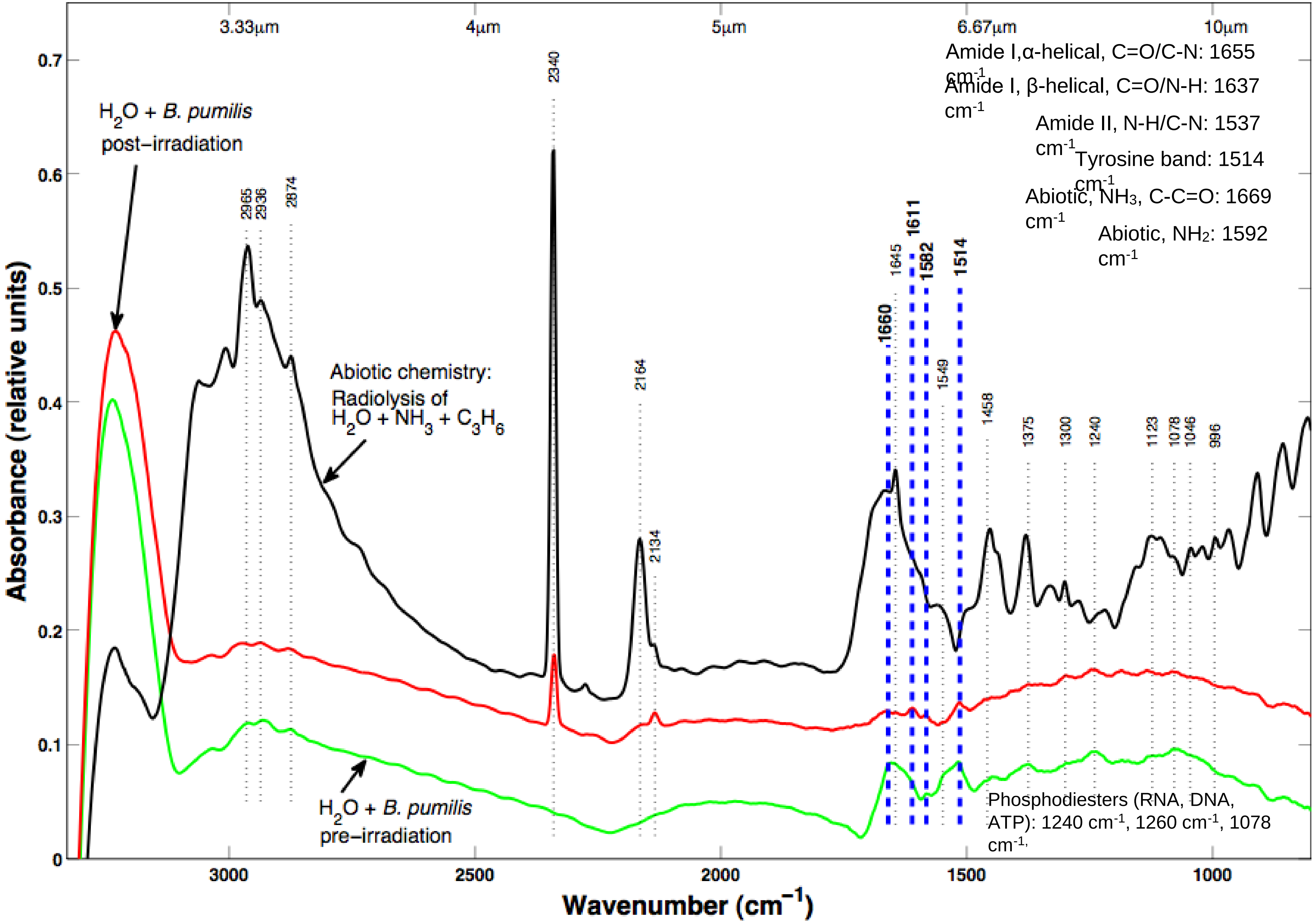
Radiation Processing: Organic Patterns & Complexity

Irradiation Effects on Biosignatures



Sundararaman and Dahl (1993), Hand et al. (2009)

- Uranium-rich rocks on Earth provide a useful guide.
- With $>10^9$ rad ($>10^7$ Gy) the relative pattern changes but the biological ‘Legos’ can still be measured.



Amide I,α-helical, C=O/C-N: 1655 cm^{-1}

Amide I, β-helical, C=O/N-H: 1637 cm^{-1}

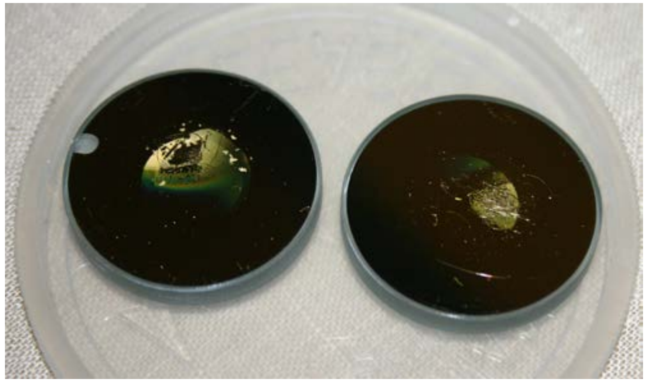
Amide II, N-H/C-N: 1537 cm^{-1}

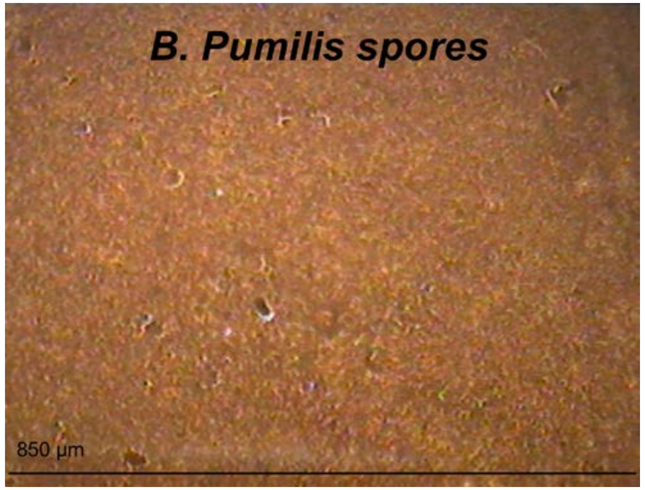
Tyrosine band: 1514 cm^{-1}

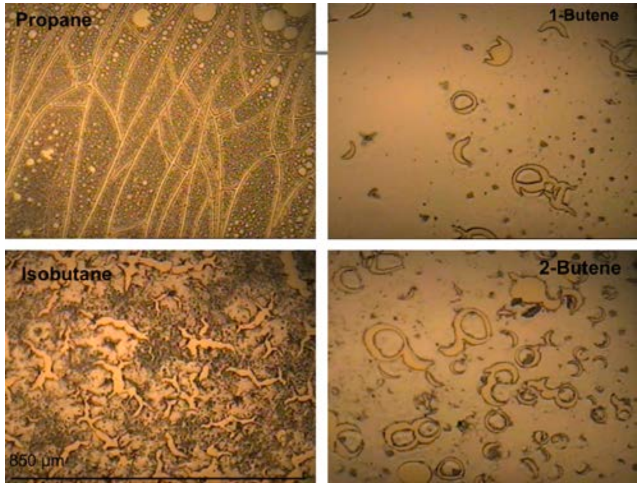
Abiotic, NH_3, C-C=O: 1669 cm^{-1}

Abiotic, NH_2: 1592 cm^{-1}

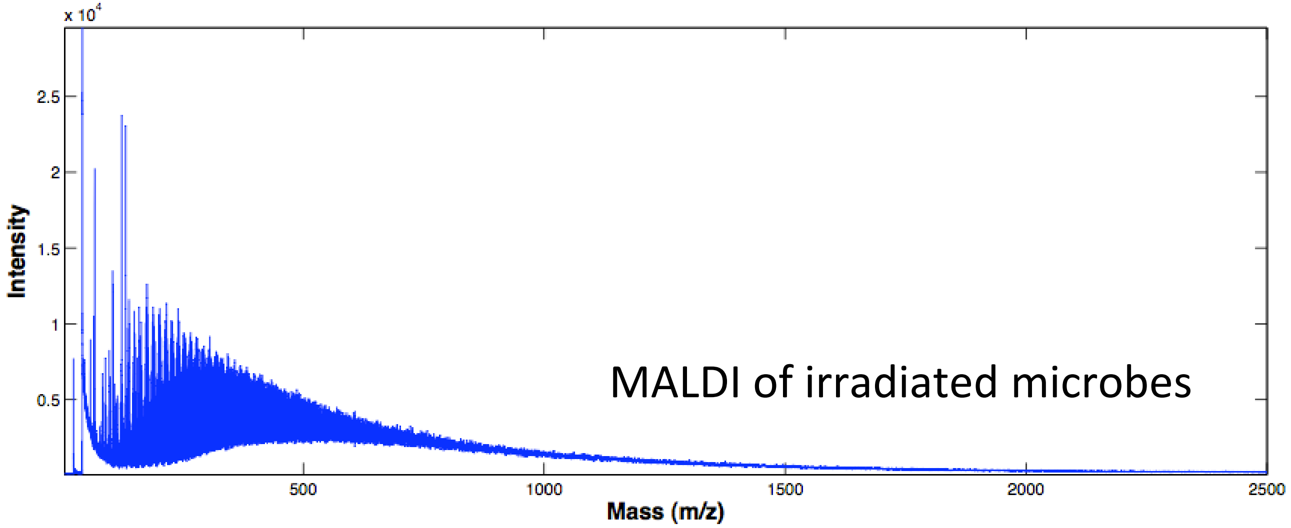
Phosphodiesters (RNA, DNA, ATP): 1240 cm^{-1}, 1260 cm^{-1}, 1078 cm^{-1},

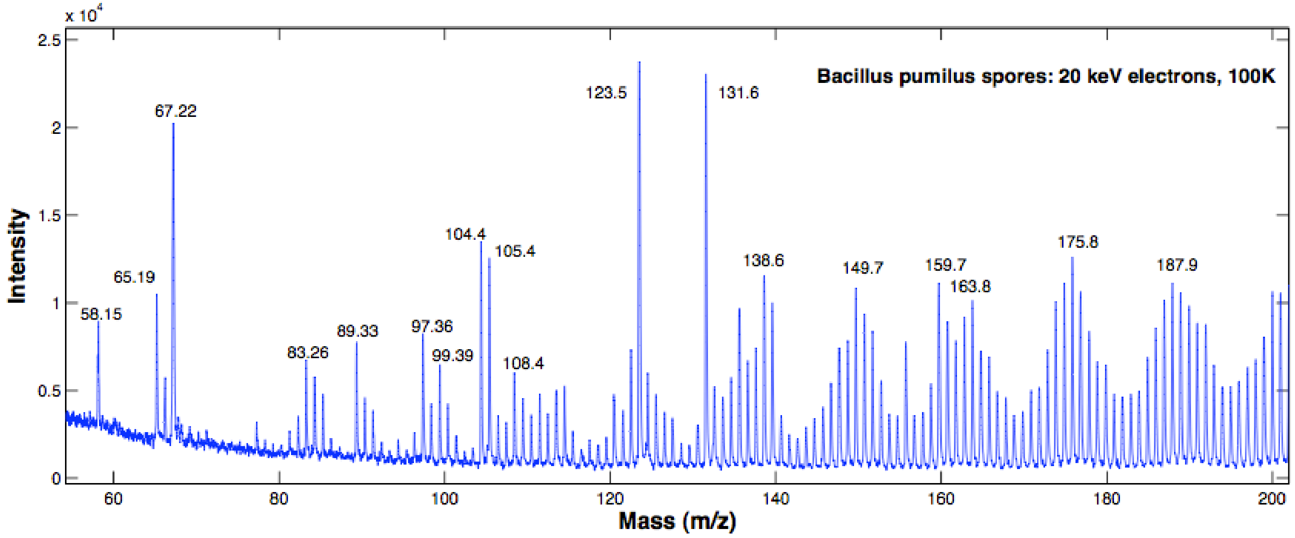






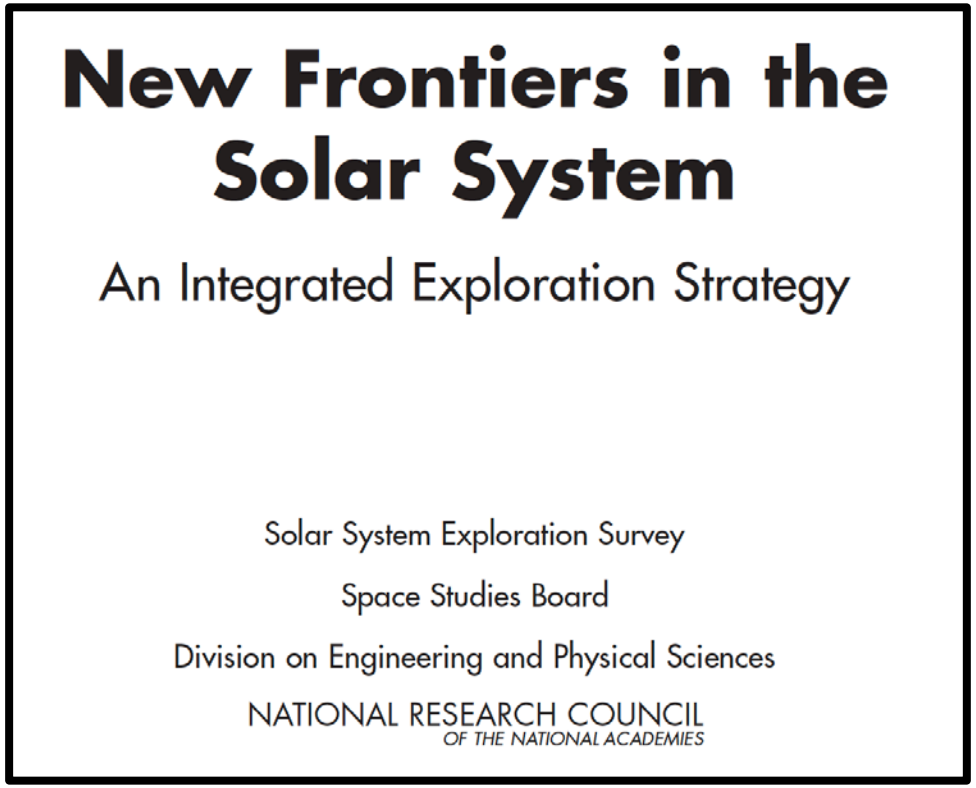
What about bugs in the can?


MALDI of irradiated microbes



Relevance to NASA & the Decadal Survey

2003 Decadal Survey: Europa Lander for Astrobiology



New Frontiers in the Solar System

An Integrated Exploration Strategy

Solar System Exploration Survey
Space Studies Board
Division on Engineering and Physical Sciences
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

- Large Initiatives:
  - Europa Geophysical Explorer
  - Titan Explorer
  - **Europa Lander** (Pathfinder or Astrobiology)
  - Neptune Orbiter
- Key Science Question: “Does (or did) life exist beyond Earth?”
  - **Europa Lander**
  - Mars Sample Return

2011 Vision & Voyages Decadal Survey

Planetary Habitats Theme:

> *"Beyond Earth, are there contemporary habitats elsewhere in the solar system with necessary conditions, organic matter, water, energy, and nutrients to sustain life, and do organisms live there now?"*

Relevance to 2011 Decadal Survey

Europa Lander			Decadal Survey	
Goals		Objectives	Themes/Goals	Questions/Objectives
BIOSIGNATURES	**1. Search for evidence of life on Europa.**	**1a.** Detect and characterize any organic indicators of past or present life.	**Crosscutting Theme 2:** Planetary Habitats	**Priority Question 6:** Beyond Earth, are there contemporary habitats elsewhere in the solar system with necessary conditions, organic matter, water, energy, and nutrients to sustain life, and do organisms live there now? … *"a lander will probably be required to fully characterize organics on the surface of Europa "*
			Satellite Science Goal 1: What determines the abundance and composition of satellite volatiles?	**Objective 2:** What determines the abundance and composition of satellite volatiles? **Question 2:** Are volatiles present at the surface or in the ice shell of Europa that are indicative of internal processing or resurfacing? *"Investigations … include determination of the volatile composition of the ices, the stable isotope ratios of carbon, hydrogen, oxygen, and nitrogen"*
		1b. Identify and characterize morphological, textural or other indicators of life.	**Satellite Science Goal 3:** What are the processes that result in habitable environments?	**Objective 4:** Is there evidence for life on the satellites? **Question 1.** Does (or did) life exist below the surface of Europa or Enceladus? *"A key future investigation of the possibility of life on the outer planet satellites is to analyze organics from the interior of Europa. Such analysis requires […] a lander …."* *"Studies of the plume of Enceladus and any organics on the surface of Europa (or in potential Europa plumes) may provide evidence of biological complexity even if the organisms themselves are no longer present or viable."*
		1c. Detect and characterize any inorganic indicators of past or present life.		
		1d. Determine the provenance of sampled material.	**Satellite Science Goal 3:** What are the processes that result in habitable environments?	**Objective 2:** What are the sources, sinks, and evolution of organic material? **Question 3:** Are organics present on the surface of Europa, and if so, what is their provenance?

Relevance to 2011 Decadal Survey

Europa Lander			Decadal Survey	
Goals		Objectives	Themes/Goals	Questions/Objectives
SURFACE HABITABILITY	**2. Assess the habitability of Europa via in situ techniques uniquely available to a lander mission.**	**2a.** Characterize the non-ice composition of Europa's near-surface material to determine whether there are indicators of chemical disequilibria and other environmental factors essential for life.	**Crosscutting Theme 2**: Planetary Habitats	**Priority Question 4:** What were the primordial sources of organic matter, and where does organic synthesis continue today?
			Satellite Science Goal 3: What are the processes that result in habitable environments?	**Objective 3:** What energy sources are available to sustain life? **Question 1:** What is the nature of any biologically relevant energy sources on Europa? *“Important directions for future investigations …include (1) measurement of the oxidant content.”*
		2b. Determine the proximity to liquid water and recently erupted materials at the lander's location.	**Satellite Science Goal 1:** How did the satellites of the outer solar system form and evolve?	**Objective 3:** How are satellite thermal and orbital evolution and internal structure related? **Question 8:** What is the thickness of Europa’s outer ice shell and the depth of its ocean?
				Objective 4: What is the diversity of geologic activity and how has it changed over time? **Question 5:** Has material from a subsurface Europa ocean been transported to the surface, and if so, how? *“…in situ measurements from the surface would provide additional information on the surface composition and environment and the subsurface structure”*
			Satellite Science Goal 3: What are the processes that result in habitable environments?	**Objective 1:** Where are subsurface bodies of liquid water located, and what are their characteristics and histories? **Question 1:** What are the depths below the surface, the thickness, and the conductivities of the subsurface oceans of the Galilean satellites?

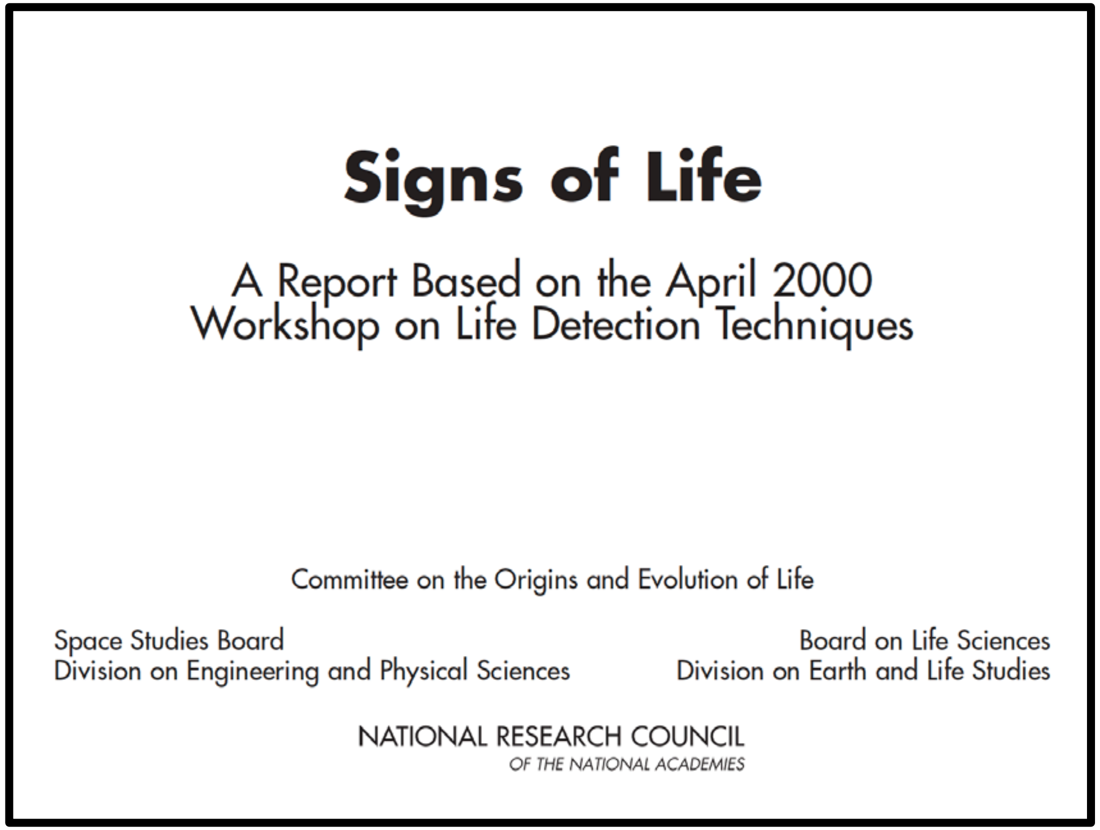
Relevance to 2011 Decadal Survey

Europa Lander			Decadal Survey	
Goals		Objectives	Themes/Goals	Questions/Objectives
SURFACE PROPERTIES AND DYNAMICS	3. Characterize surface and subsurface properties at the scale of the lander to support future exploration.	**3a.** Observe the properties of surface materials and sub-meter-scale landing hazards at the landing site, including the sampled area. Connect local properties with those seen from flyby remote sensing.	**Crosscutting Theme 3:** Workings of Solar Systems	**Priority Question 10:** How have the myriad chemical and physical processes that shape the solar system operated, interacted, and evolved over time?
			Satellite Science Goal 2: What processes control the present-day behavior of these bodies?	**Objective 3:** How do exogenic processes modify these bodies? **Question 4:** How are potential Europa surface biomarkers from the ocean-surface exchange degraded by the radiation environment?
		3b. Characterize dynamic processes of Europa's surface and ice shell over the mission duration to understand exogenous and endogenous effects on the physicochemical properties of surface material.	**Satellite Science Goal 1:** How did the satellites of the outer solar system form and evolve?	**Objective 4:** What is the diversity of geologic activity and how has it changed over time? **Question 5:** Has material from a subsurface Europa ocean been transported to the surface, and if so, how?
			Satellite Science Goal 2: What processes control the present-day behavior of these bodies?	**Objective 1:** How do active endogenic processes shape the satellites' surfaces and influence their interiors? **Objective 3:** How do exogenic processes modify these bodies?

Measurement Approach is Well-Established

Life Detection Strategy
NRC 2000 Signs of Life Report

- Morphology
- Organic Chemistry & Biochemistry
- Inorganic Chemistry
- Isotopic Analyses
- Environmental Measurements



Signs of Life

A Report Based on the April 2000
Workshop on Life Detection Techniques

Committee on the Origins and Evolution of Life

Space Studies Board
Division on Engineering and Physical Sciences

Board on Life Sciences
Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Searching for Signs of Life: Lessons from Viking

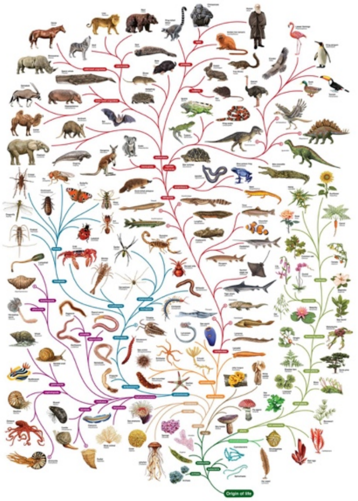
- If the payload permits, conduct experiments that assume contrasting definitions for life.
- **Given limited payload, the biochemical definition of life deserves priority**.
- Establishing the geological and chemical context of the environment is critical.
- **Life-detection experiments should provide valuable information regardless of the biology results**.
- Exploration need not, and often cannot, be hypothesis testing. Planetary missions are often missions of exploration; and therefore, the above guidelines must be put in the context of exploration and discovery driven science.

NRC 2000; Chyba and Phillips (2001)

We are ready to resume the direct search for life beyond Earth

1953

DNA discovered



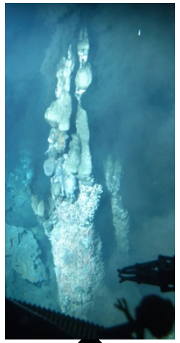
Tree of Life Then…

1976

Viking Landers

1977

Hydrothermal vents discovered



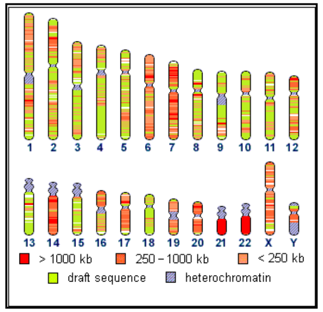
Archaea discovered (3rd domain of life)

Cryptoendoliths in Antarctica discovered

1983

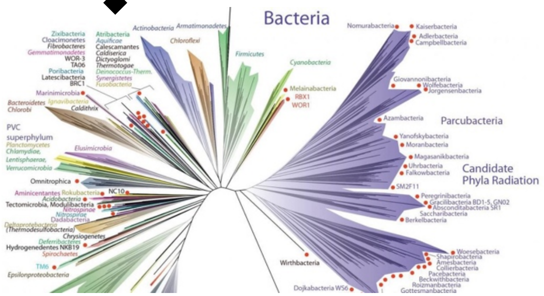
PCR Invented

2003



Human genome sequenced

2016



…Tree of Life Now.

2017

Europa Lander SDT Report

Sub-allocation of 5.0 Gbits (4.1 architecture)

	Data type	DV per use (Mbits)	Number	Total DV (Mbits)	Data Compression	Basis of Estimate
Engineering	Spacecraft	10	20 days	200	-	Phoenix, MSL, and Insight spacecraft telemetry
	Transition	106	1	106	✓	Grassroots analysis of imaging & other transition data
	Excavation	50	5 trenches	250	-	Phoenix decisional data volume for excavation
	Sampling	50	5 samples	250	-	Phoenix, MSL sample documentation
Science	Panorama	various	10+	1662	✓	M2020 Cameras, e.g. 1 lossless pano @ 8bpp, 3 lossy stereo panos @ 2bpp
	Geophone	55.2	10 days	552	-	COTS part, analogous to instruments flown on Ranger
	GCMS	64	5 samples	320	-	SAM based estimate
	Raman	33	5 samples	165	✓	M2020 SHERLOC instrument, imaging Raman
	Microscope	26.2	5 samples	131	✓	Rosetta AFM/SampleCam from M2020
			Margin	1400		Add 39% to cover growth in data volume generation
			Total	**5.0 Gbits**		

Pre-Decisional Information – For Planning and Discussion Purposes Only

Sub-allocation of 1.5 Gbits (4.2 and DTE-only)

	Data type	**DV per use (Mbits)**	**Number**	**Total DV (Mbits)**	**Data Compression**	**Basis of Estimate**
Engineering	Spacecraft	10	20 days	200	-	Phoenix, MSL, and Insight spacecraft telemetry
	Transition	106	1	106	✓	Grassroots analysis of imaging & other transition data
	Excavation	50	**2** trenches	**100**	-	Phoenix decisional data volume for excavation
	Sampling	50	**3** samples	**150**	-	Phoenix, MSL sample documentation
Science	Panorama	various	**4**	**265**	✓	M2020 Camera, e.g. 1/3 lossless pano @ 8bpp, 1 lossy pano @2bpp
	Geophone	**27.6**	**7** days	**193**	✓	Ranger analog, with factor of 2 compression
	GCMS	**9.6**	**3** samples	**29**	✓	SAM based estimate with factor of 6 compression*
	Raman	**3.3**	**3** samples	**10**	✓	M2020 SHERLOC instrument, point Raman*
	Microscope	26.2	**3** samples	**79**	✓	Rosetta AFM/SampleCam from M2020
			Margin	**362**		Add 32% to cover growth in data volume generation
			Total	**1.5 Gbits**		

*Growth of sample science from the 4.2 allocation to the more generous 4.1 allocation would use 252 Mbits of margin (leaving 8% margin)

Estimated data return capabilities

Metric	4.1	4.2	DTE-only
Required data return	5 Gbits	1.5 Gbits	1.5 Gbits
Data return capability	24 Gbits*	9 Gbits*	1.5 Gbits**
Duration to return 200 Mbits	1.9 hrs	4 hrs via CRS 40 hrs via DTE	4 hrs via DTE

*CRS return rate is 40 kbps in 4.1 and 16 kbps for 4.2. Capability assumes 8 hrs per day available for CRS return

**DTE-only data return capability can be increased by shortening mission duration
(1 day shorter mission per 200 Mbits extra data return)

Programmatic Balance

"Planetary science is shorthand for the broad **array of scientific disciplines** that collectively seek answers to basic questions such as **how do planets form, how do they work, and why is at least one planet the abode of life**. These basic motivations explain why planetary science is an important undertaking, worthy of public support."

- 2011 V&V Decadal Survey

	Pioneer 10	Pioneer 11	Voyager 1	Voyager 2	Viking 1	Viking 2	Galileo	....	Cassini	GRAIL	MSL	MESSENGER	Dawn	New Horizons	Juno	Insight	OSIRIS-REx	Lucy	Psyche	Mars 2020	Europa Clipper
Physics	X	X	X	X	X	X	X		X	X		X		X	X	X		X	X		X
Geology			X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X
Chemistry			X	X	X	X	X		X		X	X	X	X	X		X			X	X
Biology					X	X														/	

Programmatic Balance

Discovery Missions

	CONTOUR	Genesis	Lunar Prospector	NEAR	Mars Pathfinder	Moon Mineralogy Mapper	Kepler	Stardust	GRAIL	Deep Impact	MESSENGER	Dawn	Insight	Lucy	Psyche
Physics	X	X	X	X			X	X	X		X		X	X	X
Geology	X		X	X	X	X			X	X	X	X	X	X	X
Chemistry		X				X		X		X	/	X			
Biology															

Programmatic Balance

New Frontiers Missions

	New Horizons	Juno	OSIRIS-REx
Physics	X	X	
Geology	X		X
Chemistry	X	X	X
Biology			

Programmatic Balance

Flagship Missions

	Voyager 1	Voyager 2	Viking 1	Viking 2	Galileo	Cassini	MSL	Mars 2020	Europa Clipper
Physics	X	X	X	X	X	X	X	X	X
Geology	X	X	X	X	X	X	X	X	X
Chemistry	X	X	X	X	X	X	X	X	X
Biology			X	X				/	

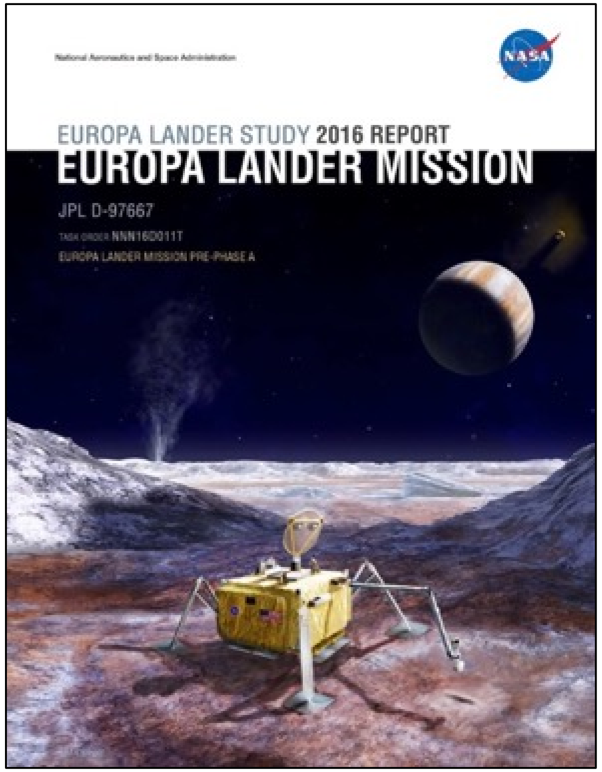
Reformulation Panel

Science Definition Team Report

Co-Chairs: Alison Murray, DRI/Univ. NV Reno, James Garvin, GSFC, Kevin Hand, JPL

- Ken Edgett, MSSS
- Bethany Ehlmann, Caltech
- Jonathan Lunine, Cornell
- Alyssa Rhoden, ASU
- Will Brinkerhoff, GSFC
- Alexis Templeton, CU Boulder
- Michael Russell, JPL
- Tori Hoehler, NASA Ames
- Ken Nealson, USC

- Sarah Horst, JHU
- Peter Willis, JPL
- Alex Hayes, Cornell
- Brent Christner, Univ FL
- Chris German, WHOI
- Aileen Yingst, PSI
- David Smith, MIT
- Chris Paranicas, APL
- Britney Schmidt, GA Tech



National Aeronautics and Space Administration

EUROPA LANDER STUDY 2016 REPORT

EUROPA LANDER MISSION

JPL D-97667

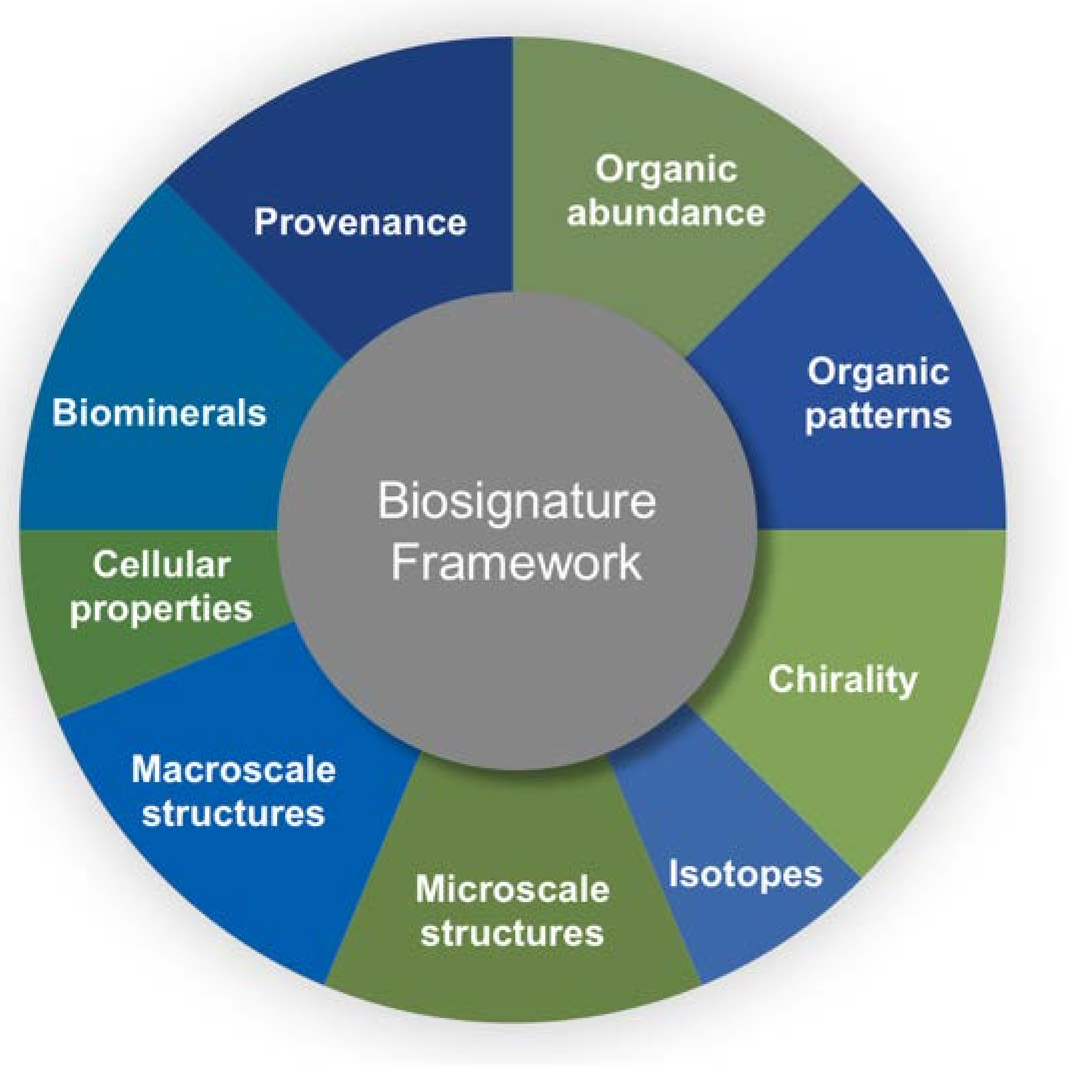
TASK ORDER NNN16D011T

EUROPA LANDER MISSION PRE-PHASE A

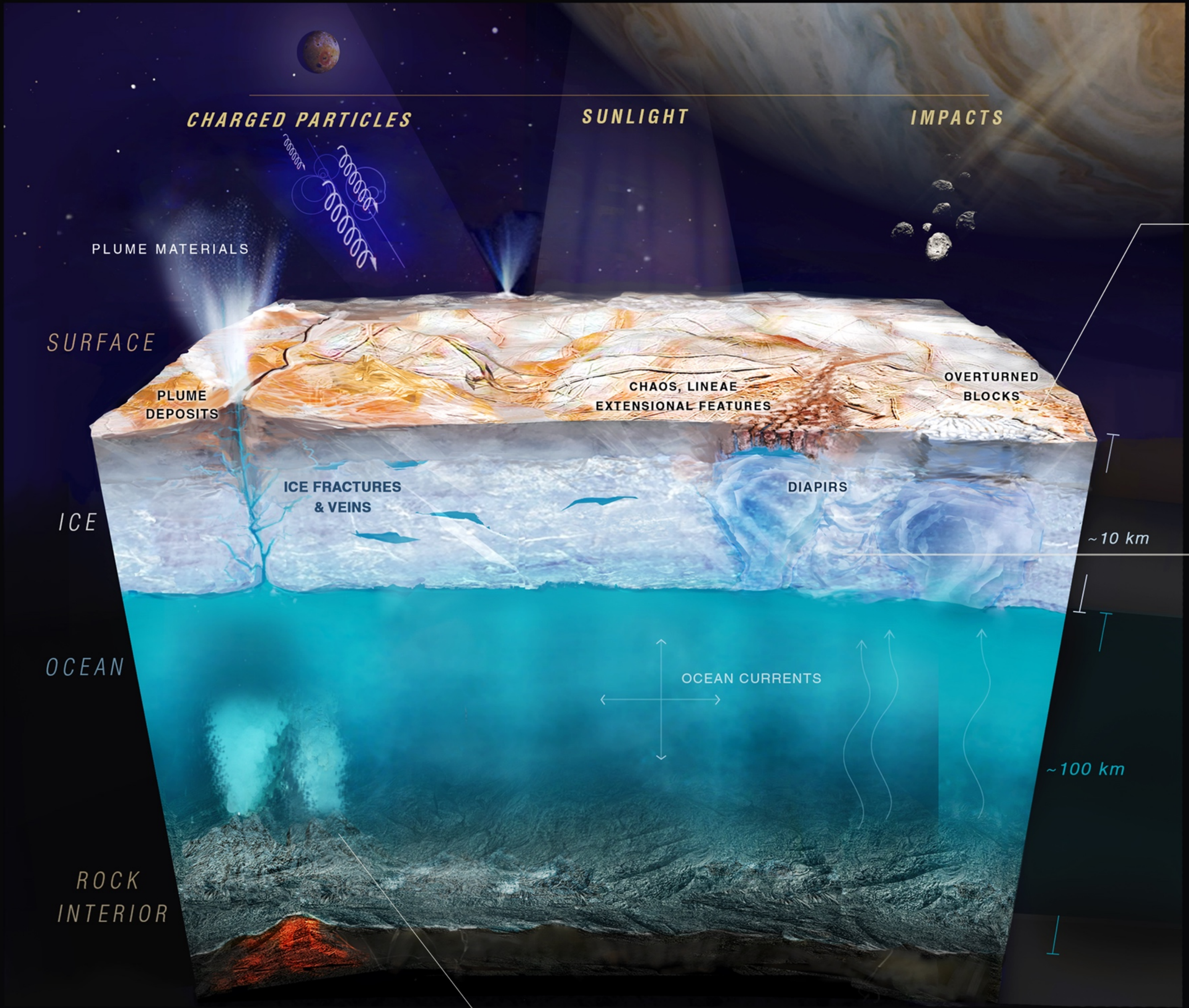
Planetary scientists, Microbiologists, Geochemists

Lander Provides a Robust Suite of Biosignature Measurements

- Model payload provides a minimum of 9 lines of evidence for identifying potential biosignatures
- Biosignature Investigations are highly complementary
- Model payload ensures measurement redundancy
- **Investigations yield high value science even in the absence of any potential biosignatures.**

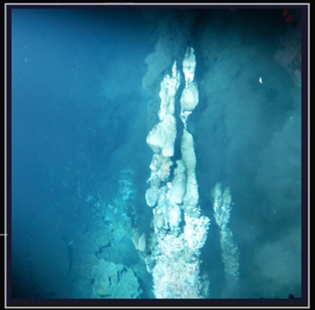


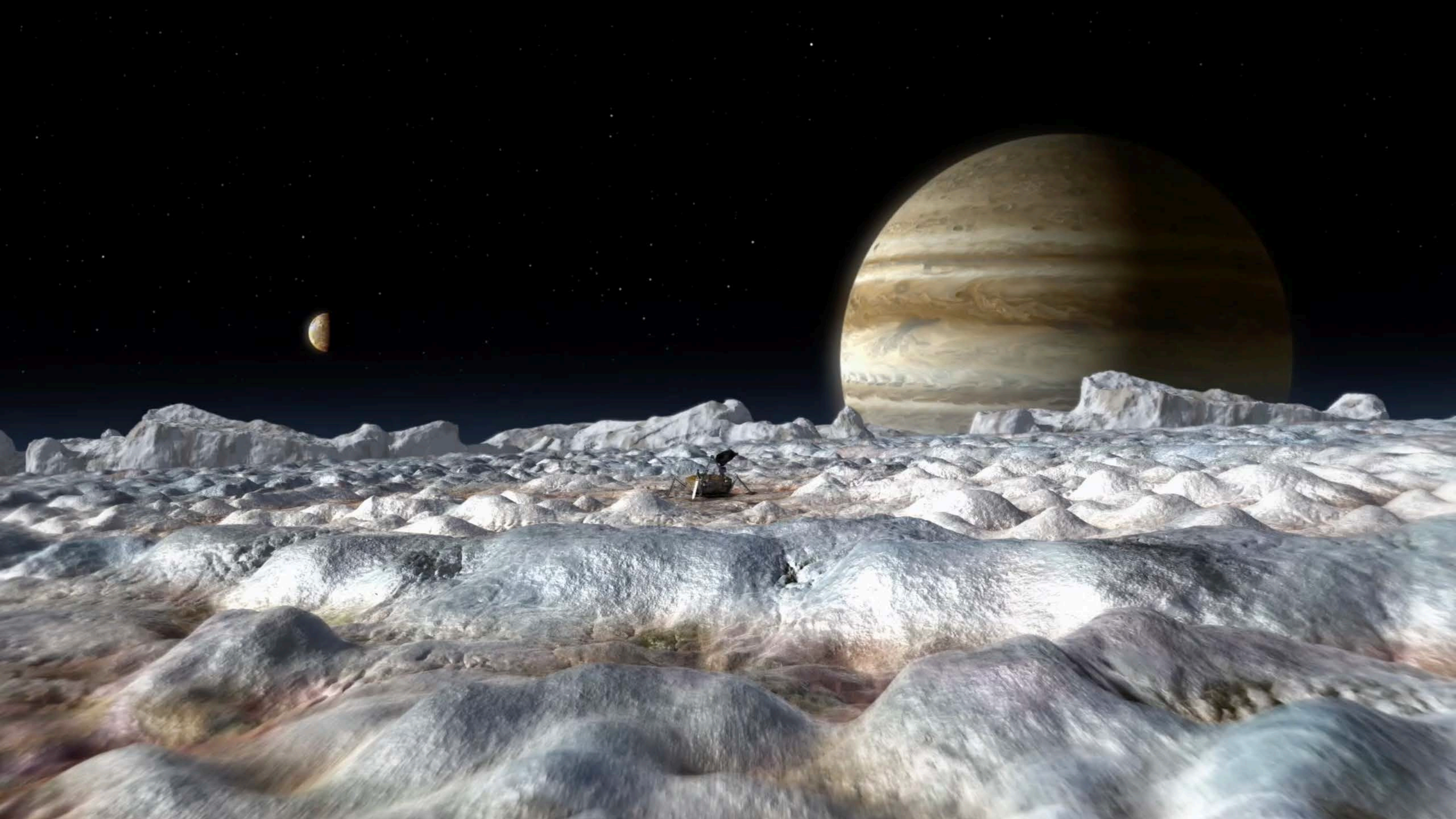
EUROPA


CHARGED PARTICLES
SUNLIGHT
IMPACTS
PLUME MATERIALS
SURFACE
PLUME DEPOSITS
CHAOS, LINEAE EXTENSIONAL FEATURES
OVERTURNED BLOCKS
ICE
ICE FRACTURES & VEINS
DIAPIRS
~10 km
OCEAN
OCEAN CURRENTS
~100 km
ROCK INTERIOR

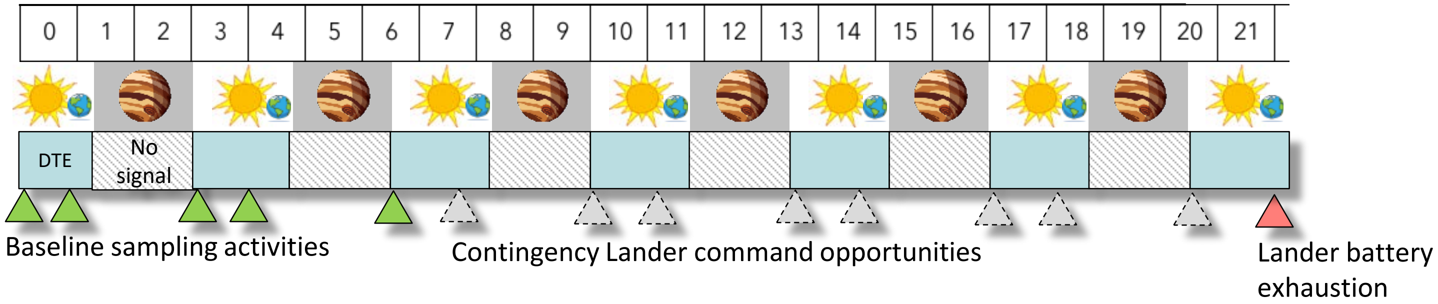

ICE BLOCKS


ICE FRACTURES

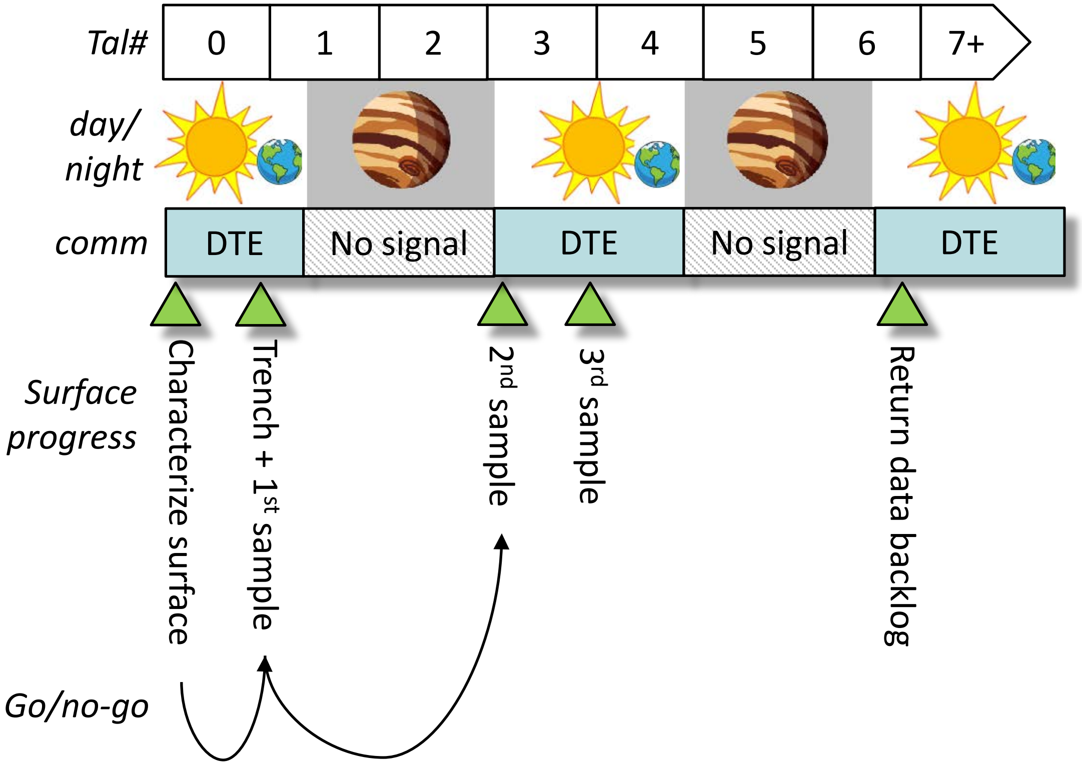

HYDROTHERMAL VENTS



DTE-only Timeline



- DTE-only baseline also completes in 7 days
  - Large data backlog cleared out at end of baseline
  - More reliant on automation, since less information will be available to diagnose problems
- Remaining timeline for contingency and science enhancement above baseline
  - **8 additional command opportunities**



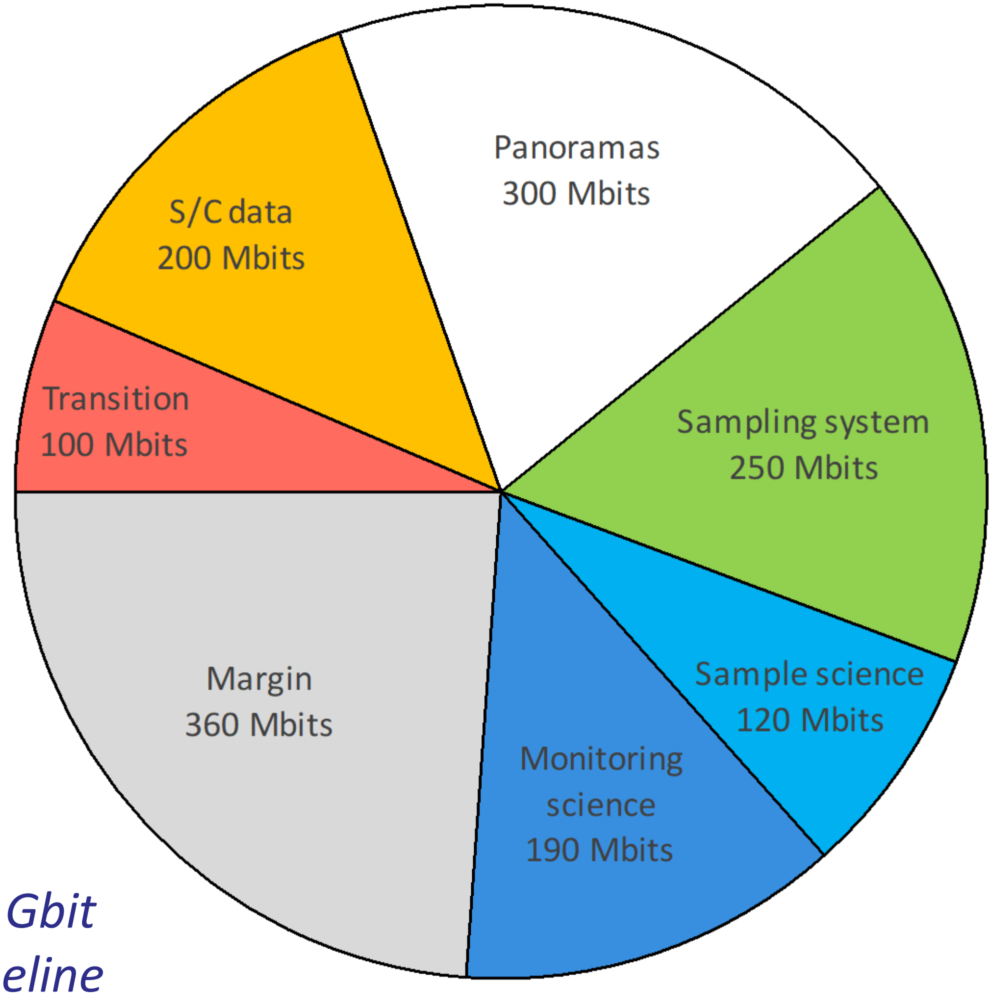
Data volume

- **4.1 (MCR) architecture** => 5 Gbits baseline data return, no DTE capability

- **4.2 architecture** => 1.5 Gbits baseline data return
  - Reduction from 4.1 assumes fewer samples and additional compression
  - Data return has significant margin above 1.5
  - Some minimum success mission will be enabled DTE within 4.2 (currently 0.4 Gbits)

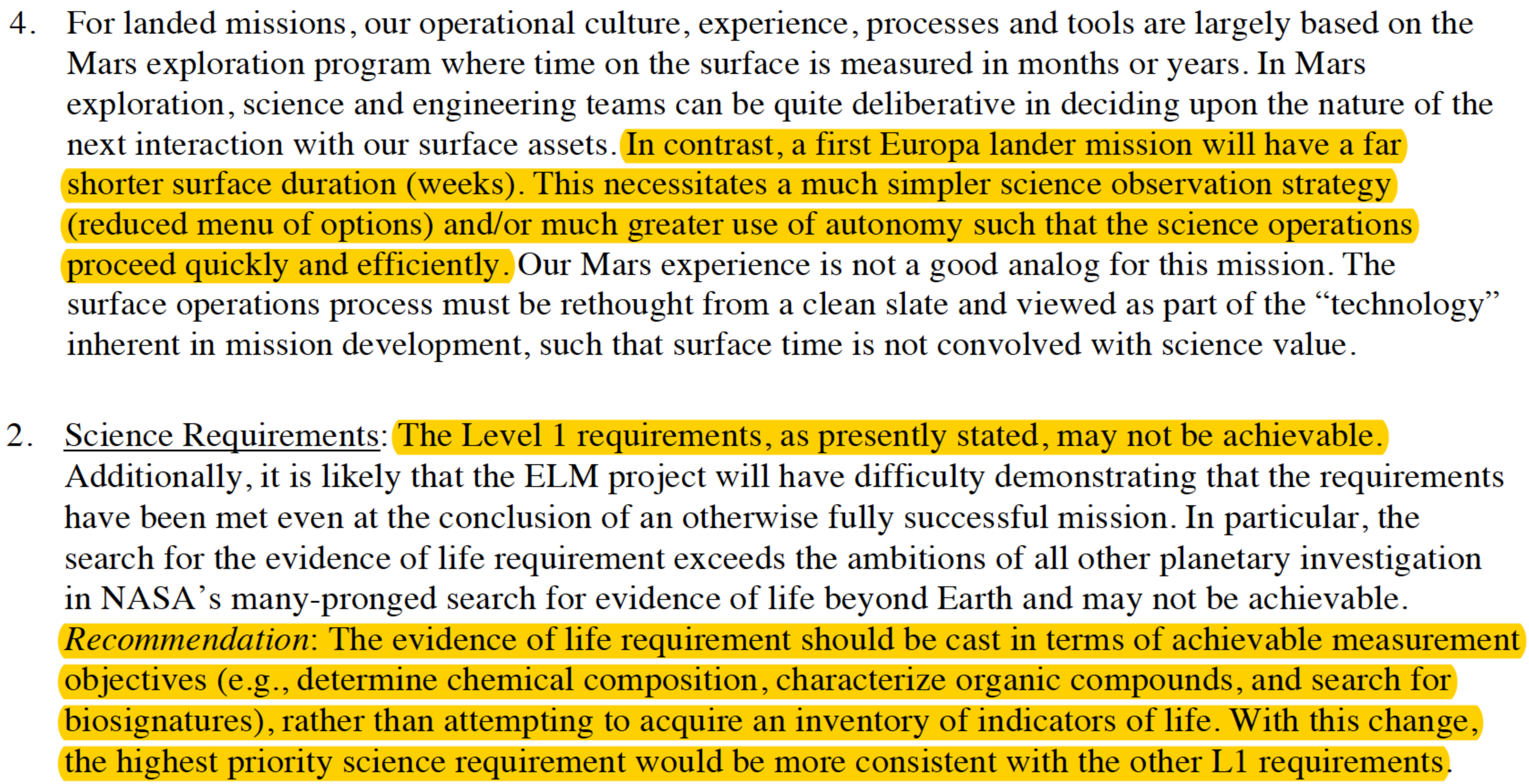
- **DTE architecture** => 1.5 Gbits baseline data return
  - No system-level margin above 1.5 Gbits in design
  - significant impact to battery mass for exceeding allocated data volume (right)

- Grassroots data estimates should replace allocations once payload selected



1.5 Gbit baseline

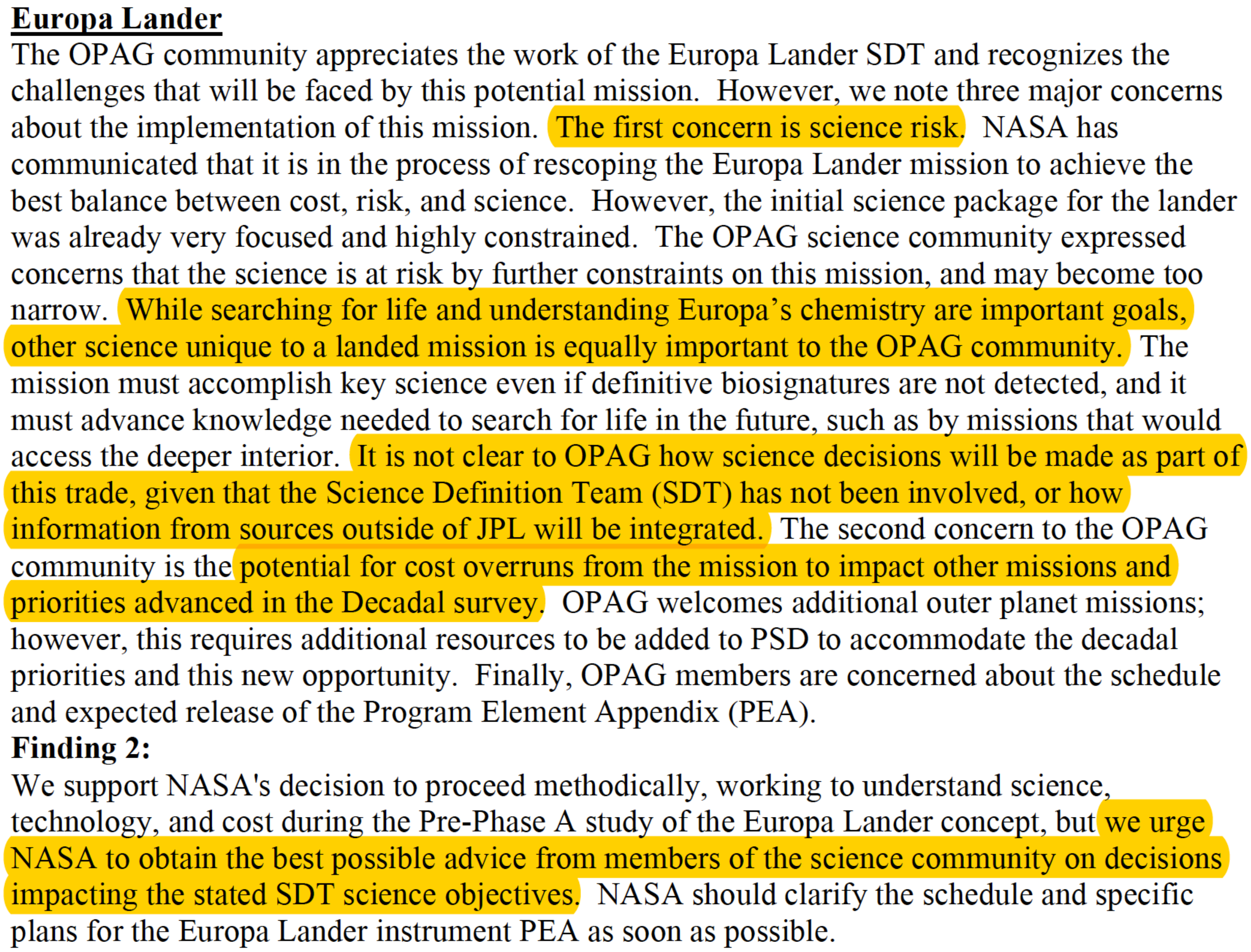
MCR Board Report Findings



4. For landed missions, our operational culture, experience, processes and tools are largely based on the Mars exploration program where time on the surface is measured in months or years. In Mars exploration, science and engineering teams can be quite deliberative in deciding upon the nature of the next interaction with our surface assets. In contrast, a first Europa lander mission will have a far shorter surface duration (weeks). This necessitates a much simpler science observation strategy (reduced menu of options) and/or much greater use of autonomy such that the science operations proceed quickly and efficiently. Our Mars experience is not a good analog for this mission. The surface operations process must be rethought from a clean slate and viewed as part of the "technology" inherent in mission development, such that surface time is not convolved with science value.

2. Science Requirements: The Level 1 requirements, as presently stated, may not be achievable. Additionally, it is likely that the ELM project will have difficulty demonstrating that the requirements have been met even at the conclusion of an otherwise fully successful mission. In particular, the search for the evidence of life requirement exceeds the ambitions of all other planetary investigation in NASA's many-pronged search for evidence of life beyond Earth and may not be achievable. *Recommendation*: The evidence of life requirement should be cast in terms of achievable measurement objectives (e.g., determine chemical composition, characterize organic compounds, and search for biosignatures), rather than attempting to acquire an inventory of indicators of life. With this change, the highest priority science requirement would be more consistent with the other L1 requirements.

OPAG Findings Sept., 2017



Europa Lander

The OPAG community appreciates the work of the Europa Lander SDT and recognizes the challenges that will be faced by this potential mission. However, we note three major concerns about the implementation of this mission. The first concern is science risk. NASA has communicated that it is in the process of rescoping the Europa Lander mission to achieve the best balance between cost, risk, and science. However, the initial science package for the lander was already very focused and highly constrained. The OPAG science community expressed concerns that the science is at risk by further constraints on this mission, and may become too narrow. While searching for life and understanding Europa's chemistry are important goals, other science unique to a landed mission is equally important to the OPAG community. The mission must accomplish key science even if definitive biosignatures are not detected, and it must advance knowledge needed to search for life in the future, such as by missions that would access the deeper interior. It is not clear to OPAG how science decisions will be made as part of this trade, given that the Science Definition Team (SDT) has not been involved, or how information from sources outside of JPL will be integrated. The second concern to the OPAG community is the potential for cost overruns from the mission to impact other missions and priorities advanced in the Decadal survey. OPAG welcomes additional outer planet missions; however, this requires additional resources to be added to PSD to accommodate the decadal priorities and this new opportunity. Finally, OPAG members are concerned about the schedule and expected release of the Program Element Appendix (PEA).

Finding 2:

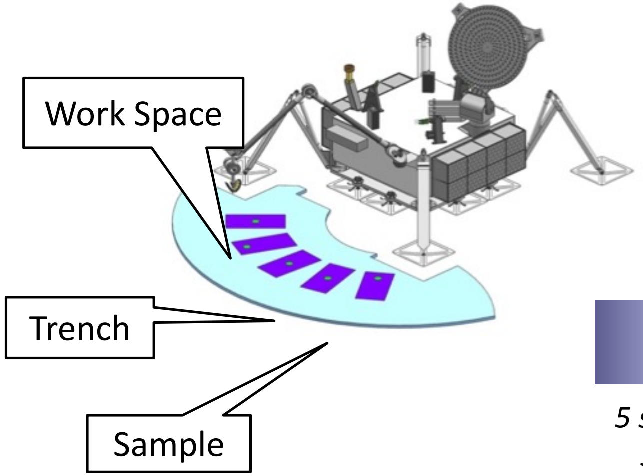
We support NASA's decision to proceed methodically, working to understand science, technology, and cost during the Pre-Phase A study of the Europa Lander concept, but we urge NASA to obtain the best possible advice from members of the science community on decisions impacting the stated SDT science objectives. NASA should clarify the schedule and specific plans for the Europa Lander instrument PEA as soon as possible.

Science: Priority order of rescope options

Finding the 'knees in the curve' of minimizing complexity and maximizing science:

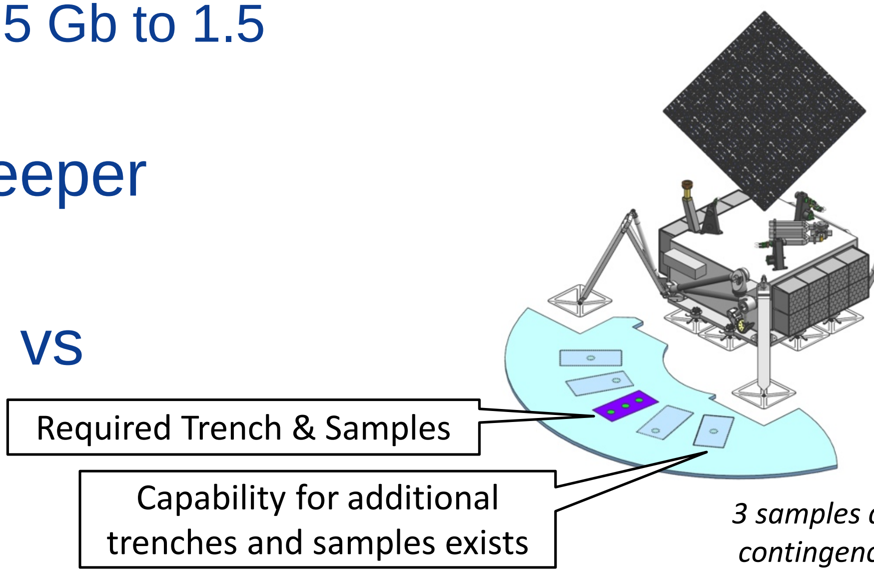
Data volume reduction is enabling for DTE.

1. Reduce number of samples, images, and monitoring time to Threshold values.
   - Example impact: Reduction of data volume from 5 Gb to 1.5 Gb.
2. Reduce number of trenches, but enable deeper trenching.
3. Reduce instrument capabilities (Threshold vs Baseline in some cases).
4. Remove instruments. *[not needed]*



4.1

5 samples and 5 trenches required.



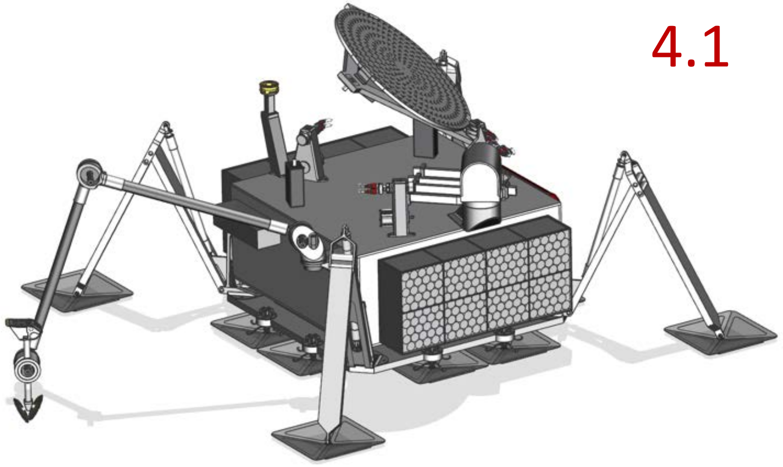
4.2/DTE

3 samples and 1 trench, plus a contingency trench, required.

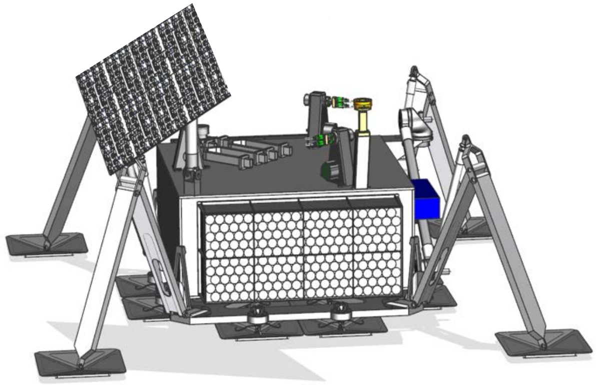
Post-MCR work on mission architecture

- **Chair**: B. Braun, CU Boulder
  - **Members**: L. Elkins-Tanton (ASU), J. Lunine (Cornell), Mark Adler (Apple), K. Craft (JHU-APL), B.G. Lee (JPL), D. Kusnierkiewicz (JHU-APL), F. Naderi (JPL, retired), D. Adams (JHU-APL), S. Battel (Battel Engineering), D. McCleese (JPL, retired), B. Sherwood (JPL), B. Buffington (JPL).
- **Objective**: Create a handful of viable Europa lander mission architectures in an effort to reduce complexity and cost (Phases A-D).
- Outbrief to HQ by Braun on Nov. 16, 2017.
- Direction Letter received by Project from HQ on Dec. 7, 2017
- Outbrief to HQ by Project on Feb. 16, 2018.

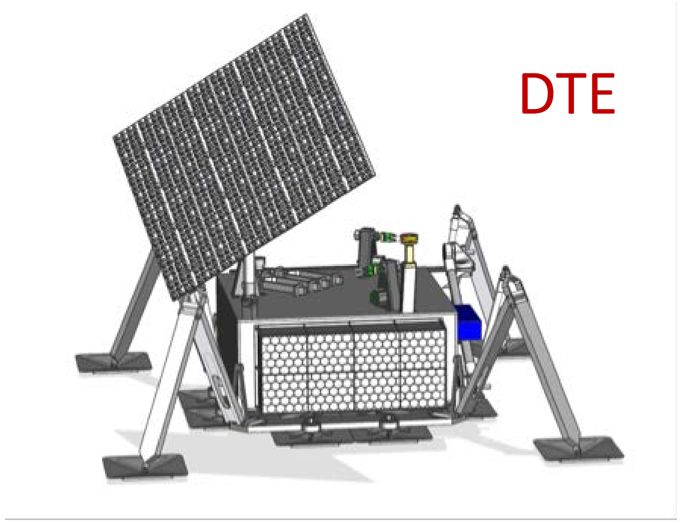
Lander Mission Architectural Options



4.1



4.2



DTE

- **30 cm** Heritage Gimballed HGA
- Carrier Relay: Prime (High data rate)
- Clipper Relay: Contingency
- 5 Mbit Data volume
- Clipper Avionics
- Carrier Tank Staging

- ***40 cm*** *New Tech. Gimballed HGA*
- *Carrier Relay: Prime (High data rate)*
- *DTE/DFE: Backup*
- *1.5 Mbit Data volume*
- *Low Mass/Power Avionics*
- *No Tank Staging*

- ***80 cm*** *New Technology Gimballed HGA*
- *DTE/DFE: Prime*
- *Clipper Backup Relay: DDL Comm*
- *1.5 Mbit Data volume*
- *Low Mass/Power Avionics*
- *No Tank Staging*
- *Clipper Solar Arrays*

Europa Lander Science Update

A few comments on the range from Life Detection to Habitability

1. **Life Detection.**
2. **Search for Biosignatures.**

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3. **Characterization of the Environment for Biosignatures.**
4. **Assess Habitability.** ***[Clipper]***