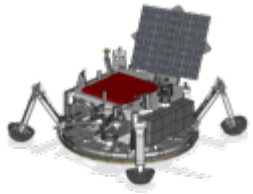
Europa/Ocean Worlds Lander Mission Concept

Europa Lander Pre-Project Science and Engineering teams

May 14th, 2020

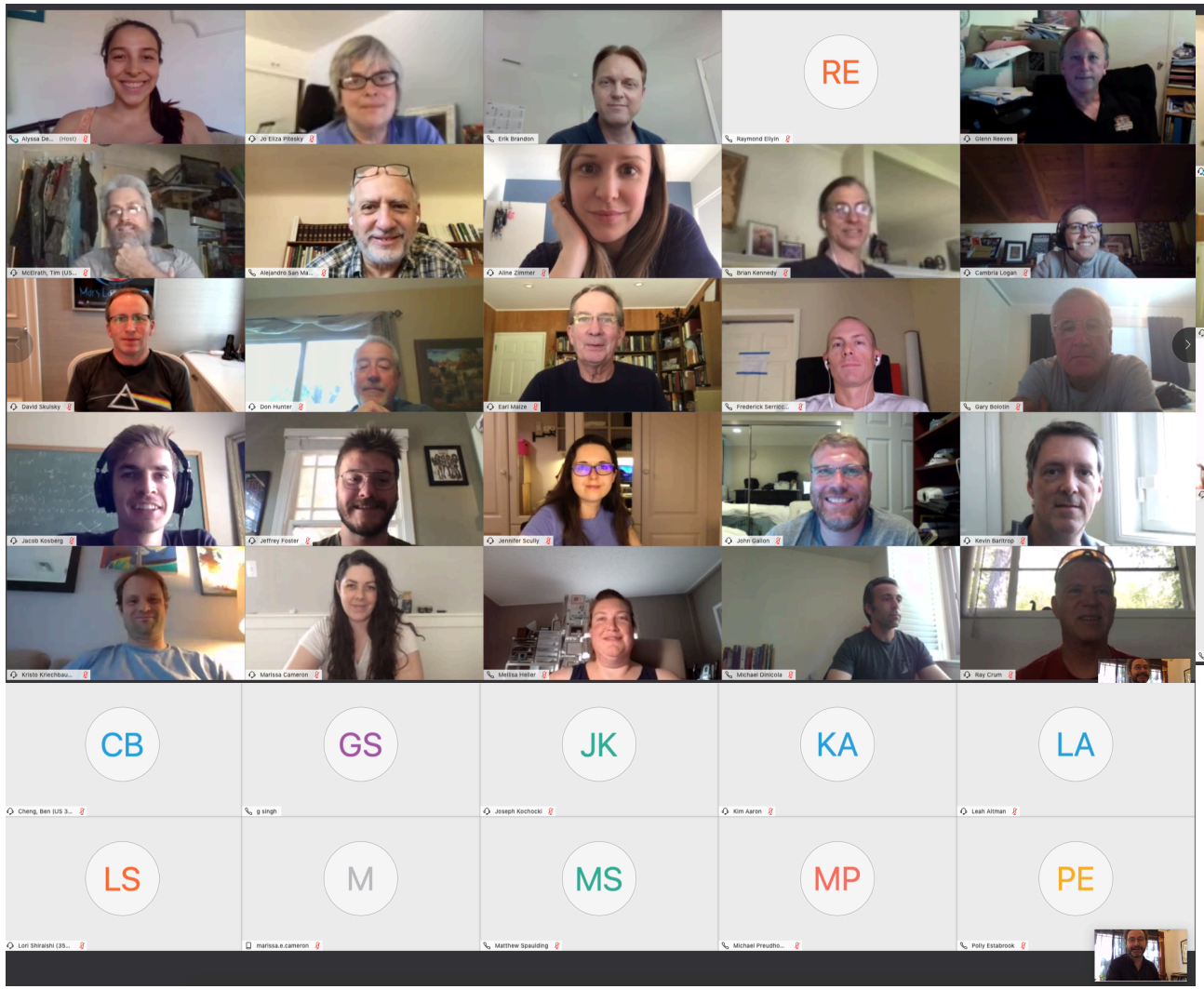
Jet Propulsion Laboratory
California Institute of Technology

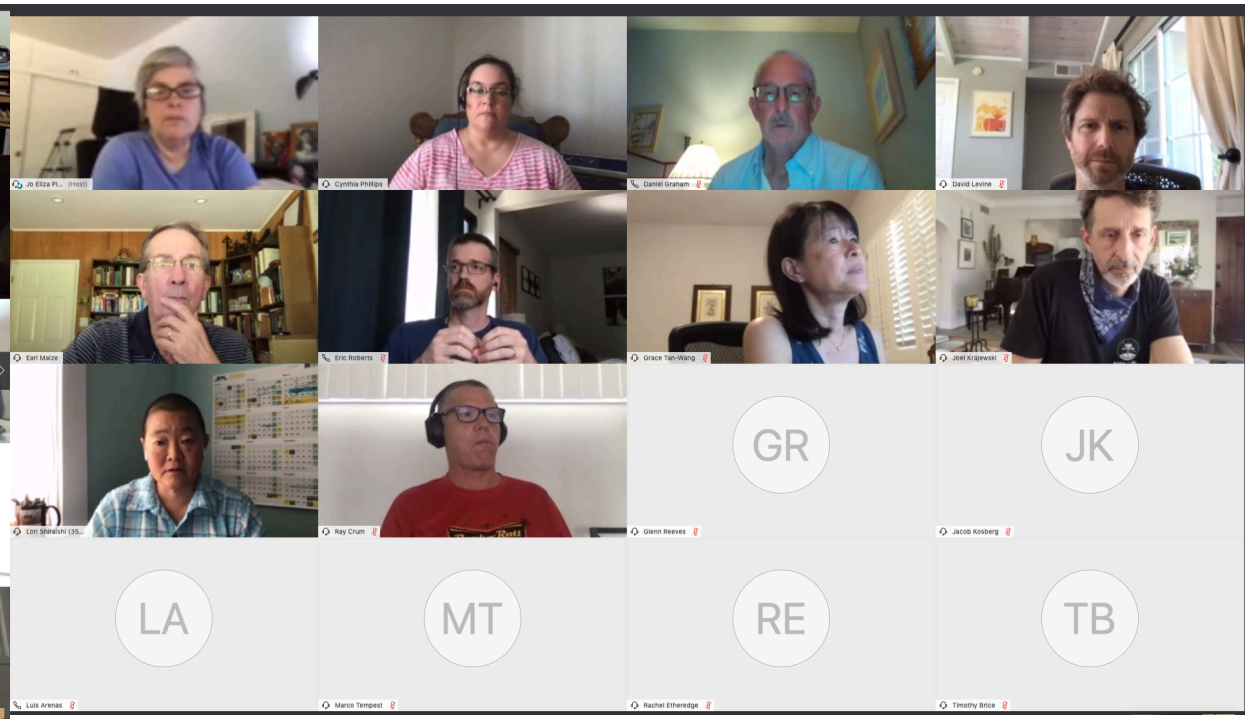
Agenda



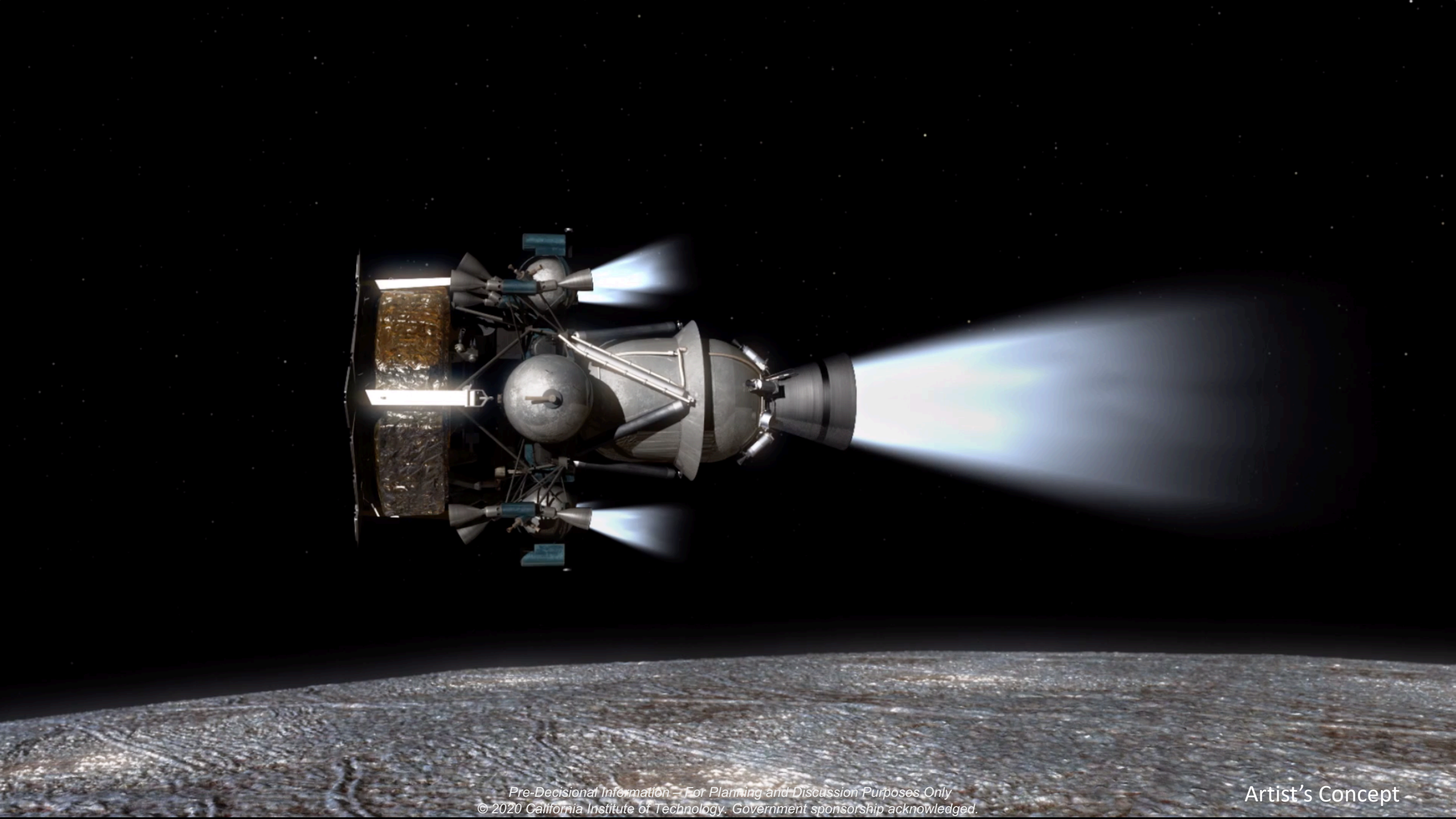
- 10 min: **Welcome to attendees**, Jo Pitesky and Kevin Hand. (JPL)
- 20 min: **Science Goals of the Europa/Ocean Worlds Lander concept**, Kevin Hand and Cynthia Phillips (JPL)
- 10 min: **Mission Concept Overview**, Earl Maize (JPL)
- 15 min: **Flight System Overview**, Ray Crum (JPL)
- 30 min: **Lander Sampling Chain, Surface Phase, and Sampling Concepts**, Joel Krajewski (JPL), Amelia Grossman (Honeybee Robotics), and Charles Malespin (GSFC)
- 15 min: **Surface Excavation and Sample Collection**, Lori Shiraishi (JPL)
- 5 min: **Wrap up before Q&A**, Kevin Hand (JPL)
- 15 min: **Q&A from chat and/or margin**, Jo Pitesky and team (JPL)
- **Questions? Please go to: www.menti.com**

Team



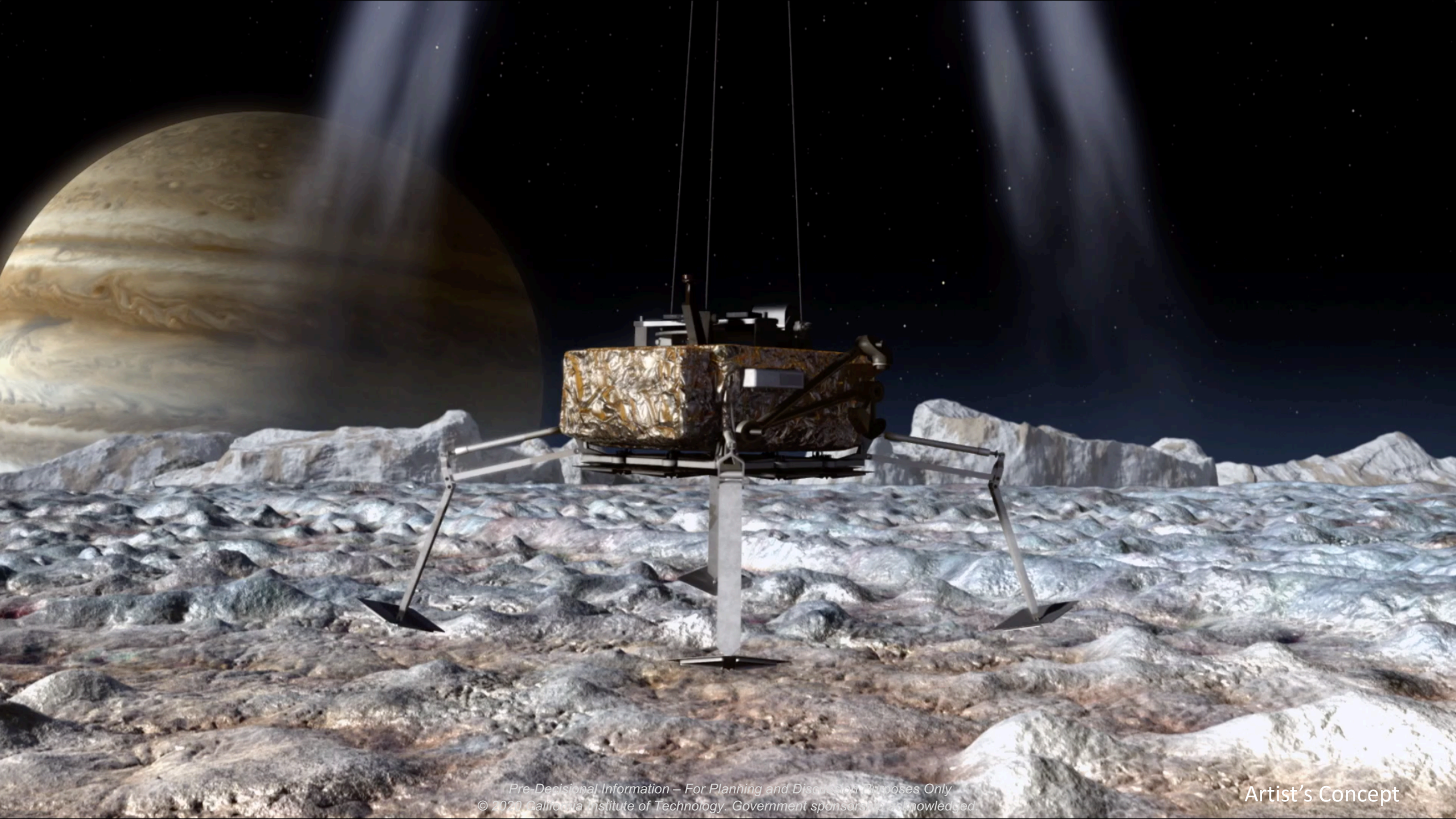


https://www.youtube.com/watch?v=pxin9qJVw48



Artist's Concept

Artist’s Concept



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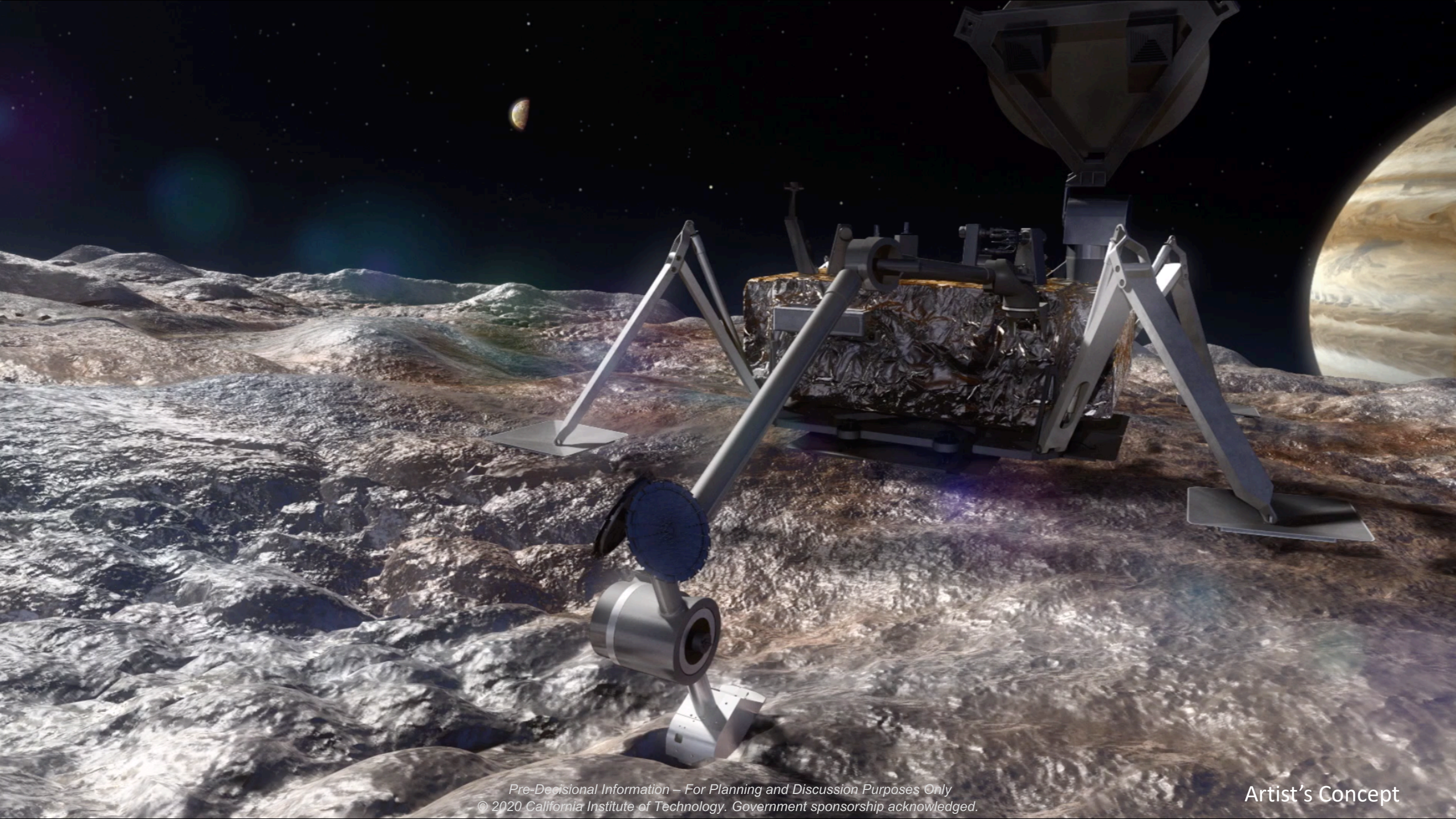

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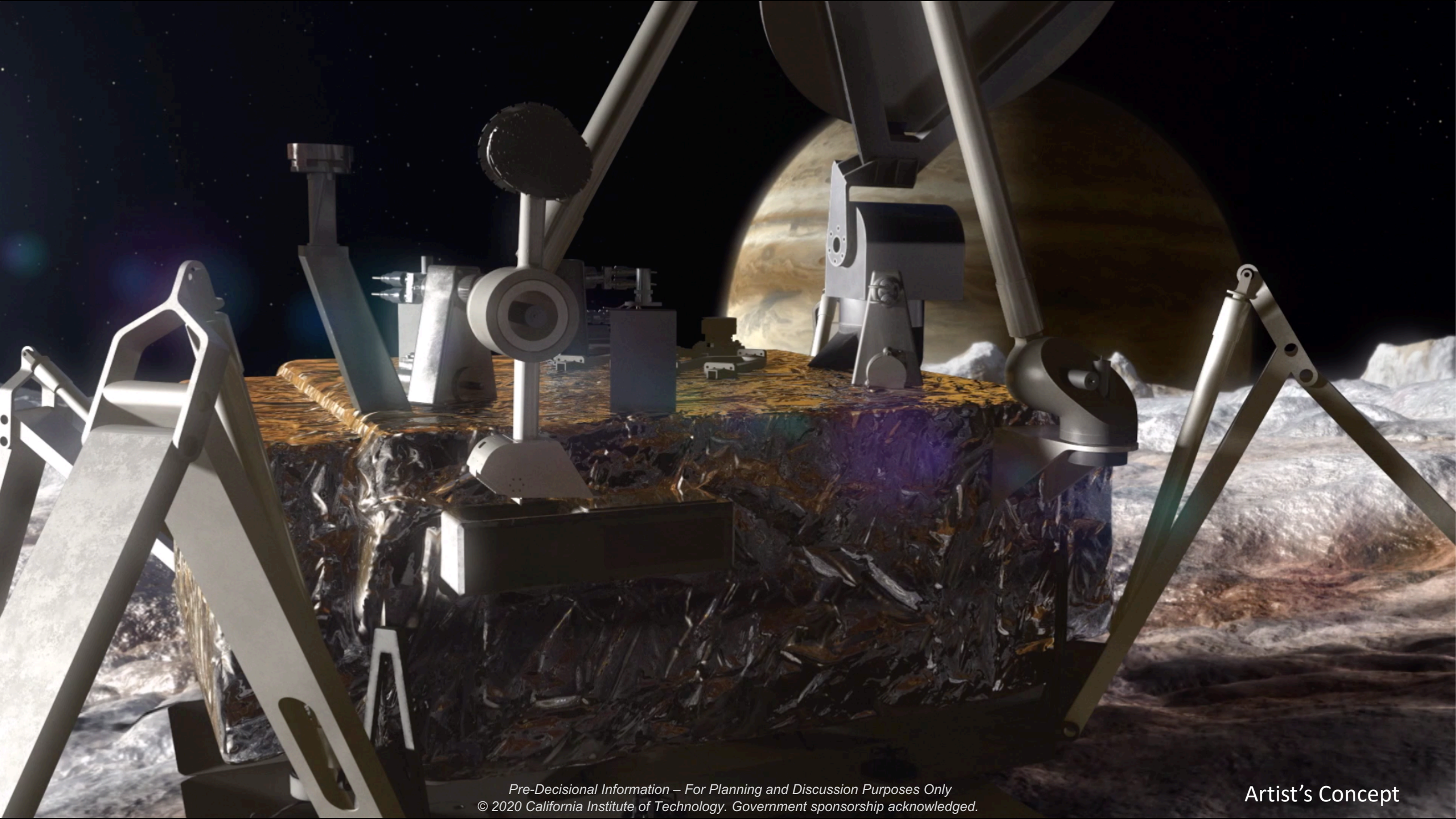
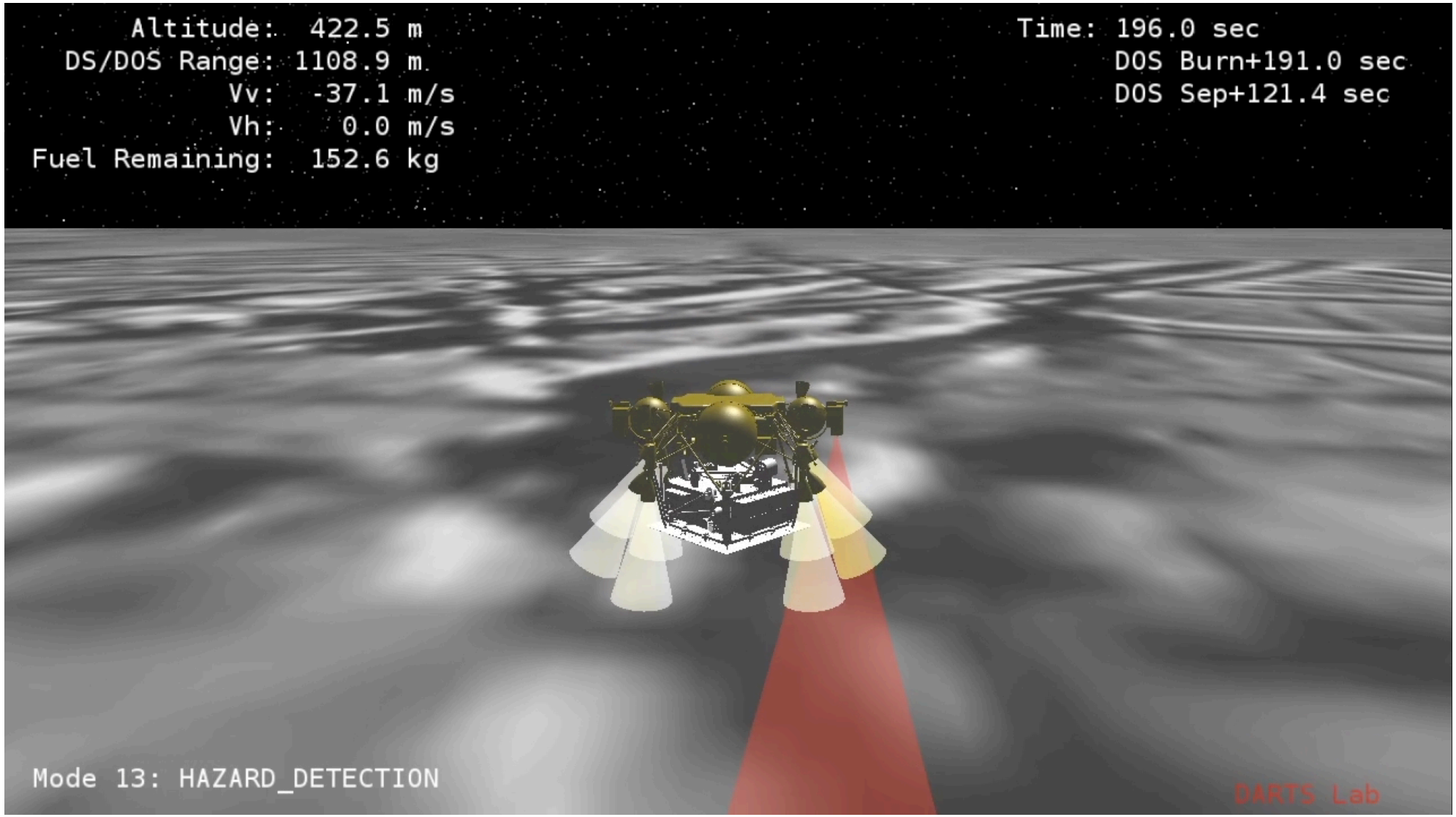


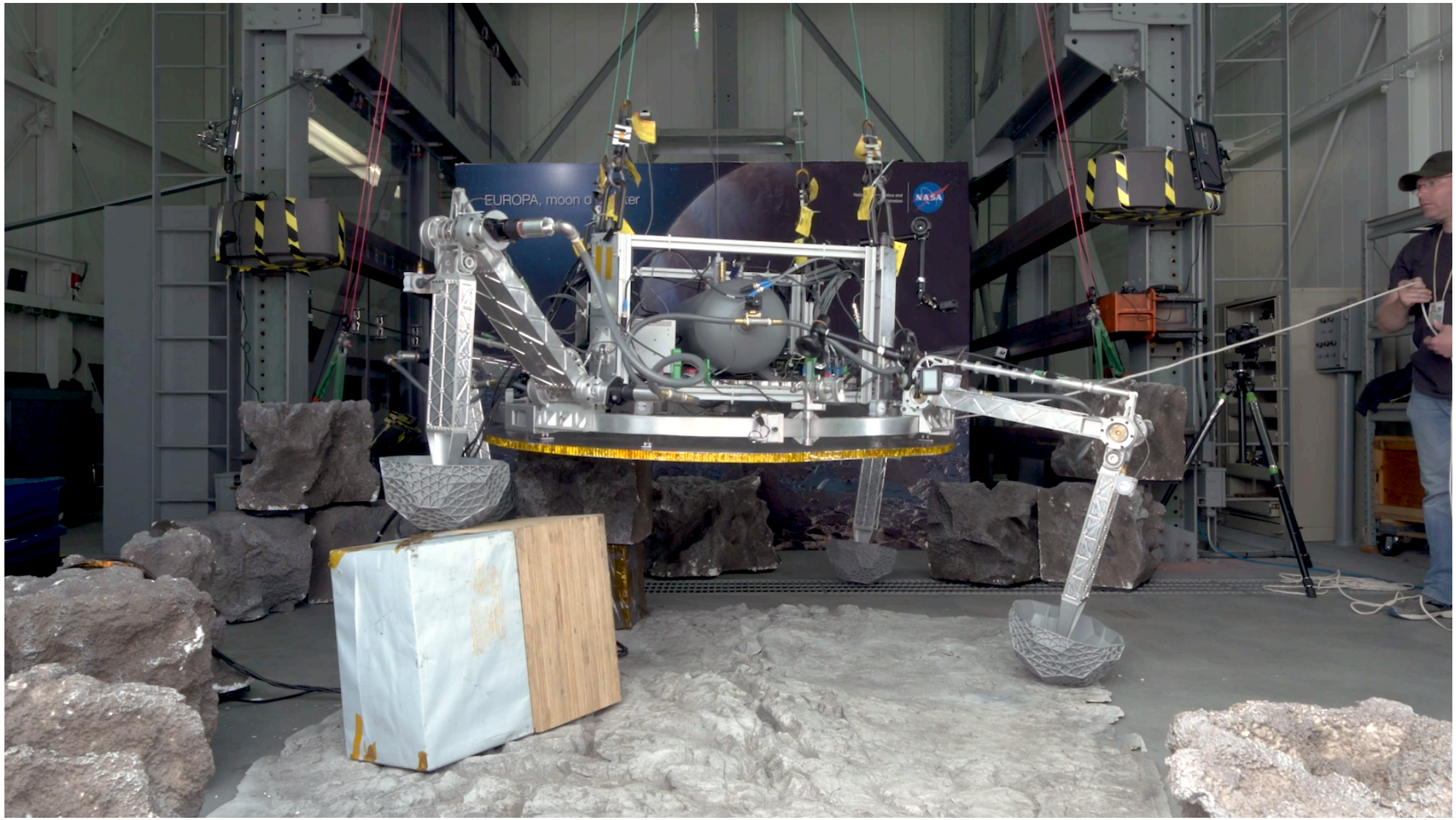
Artist’s Concept

Artist's Concept

Closed-Loop Physics-Based Landing Simulation



Olaf: Lander mechanical testbed



Olaf: Lander mechanical testbed

Science Goals of the Europa/Ocean Worlds Lander

Kevin Hand (JPL)

Europa Lander Pre-Project Scientist

Jet Propulsion Laboratory
California Institute of Technology

Europa Lander Concept: Science Goals

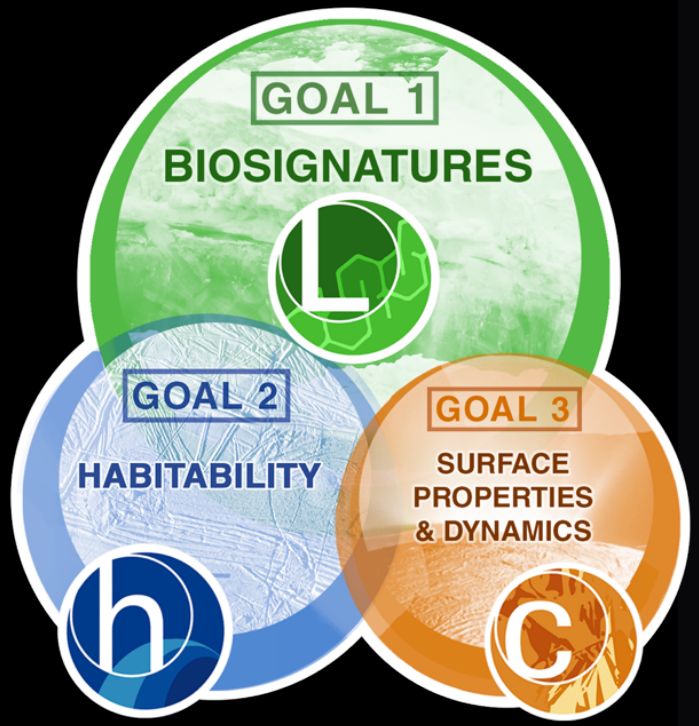
1. **Search for evidence of biosignatures on Europa.**

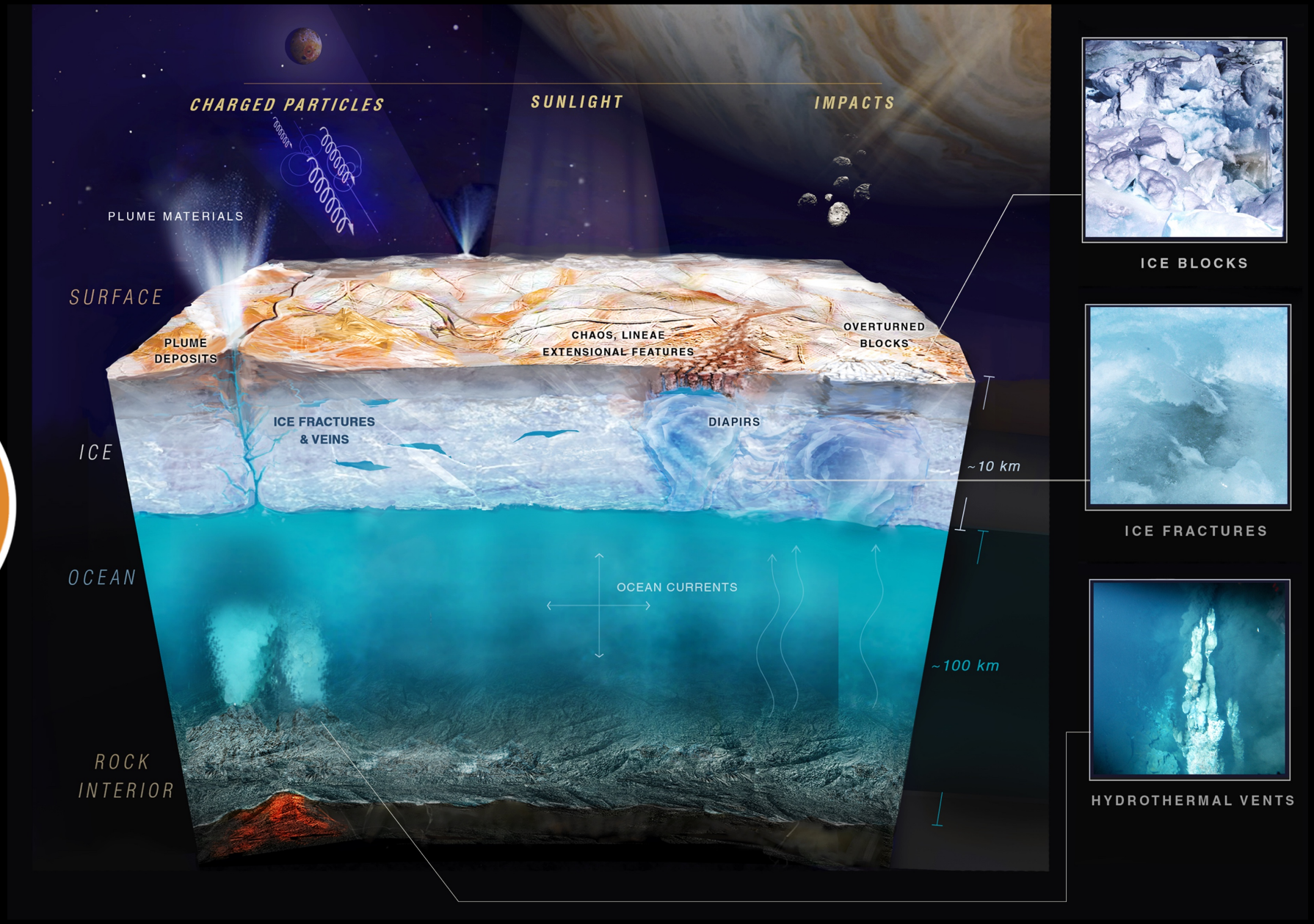
2. **Assess the habitability of Europa via *in situ* techniques.**

3. **Characterize the surface and subsurface of Europa.**

https://europa.nasa.gov/resources/58/europa-lander-study-2016-report/

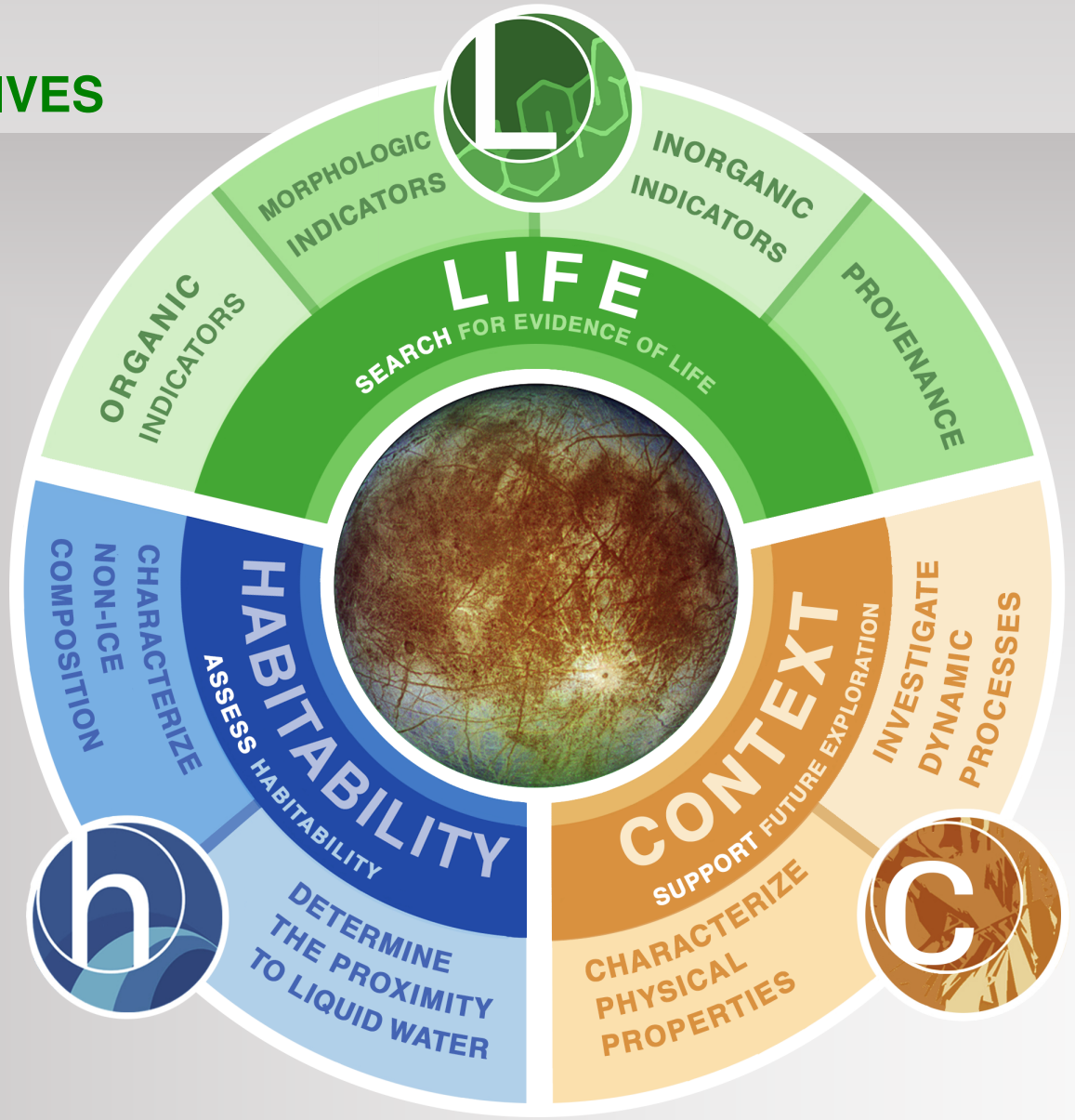
Europa Lander Mission Concept



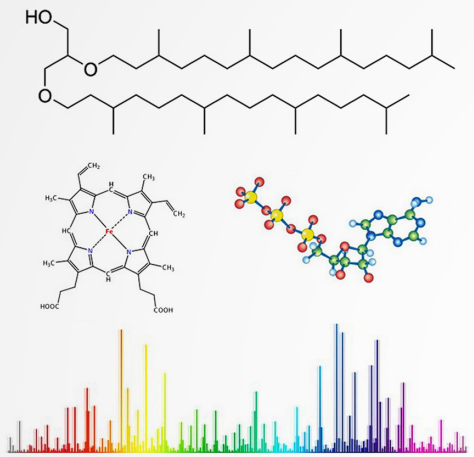


EUROPA LANDER

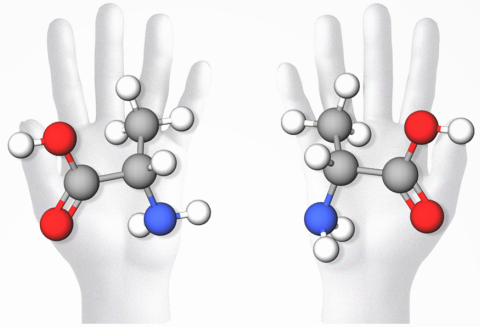
SCIENCE OBJECTIVES



GOAL 1 ORGANIC INDICATORS

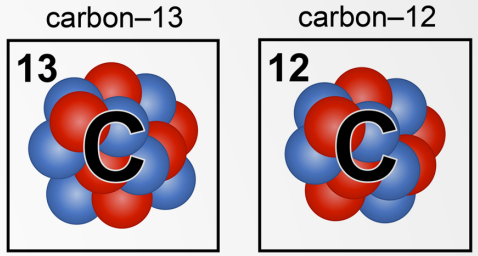


ORGANIC DETECTION, CHARACTERIZATION, COMPOSITION



L-amino acid D-amino acid

ENANTIOMERIC EXCESS

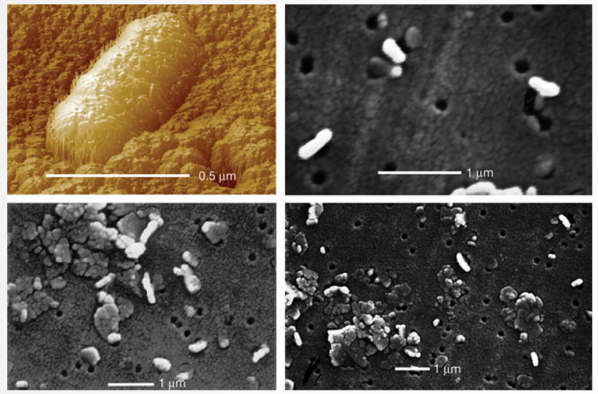


6 protons
7 neutrons
1.07% of all C
HEAVY

6 protons
6 neutrons
98.93% of all C
LIGHT

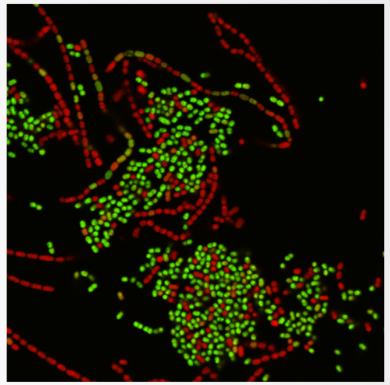
ISOTOPIC INDICATORS

GOAL 1 MORPHOLOGIC INDICATORS



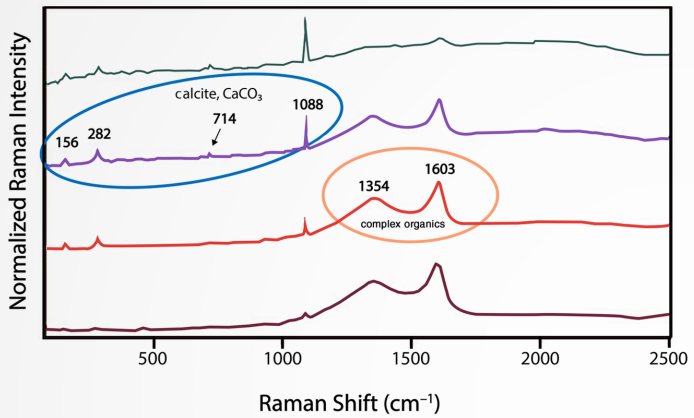
MICROSCALE STRUCTURES

MACROSCALE STRUCTURES

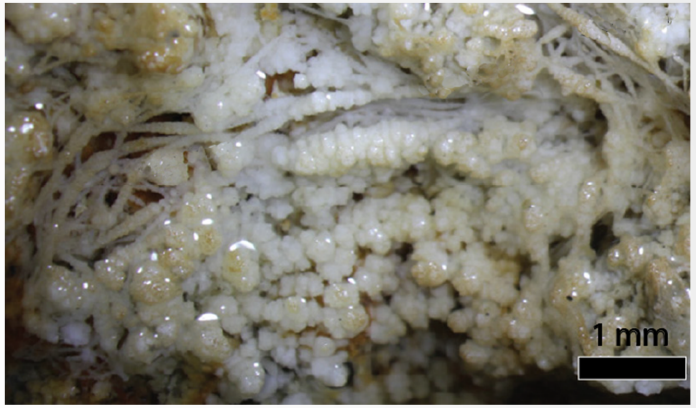


CELLULAR PROPERTIES

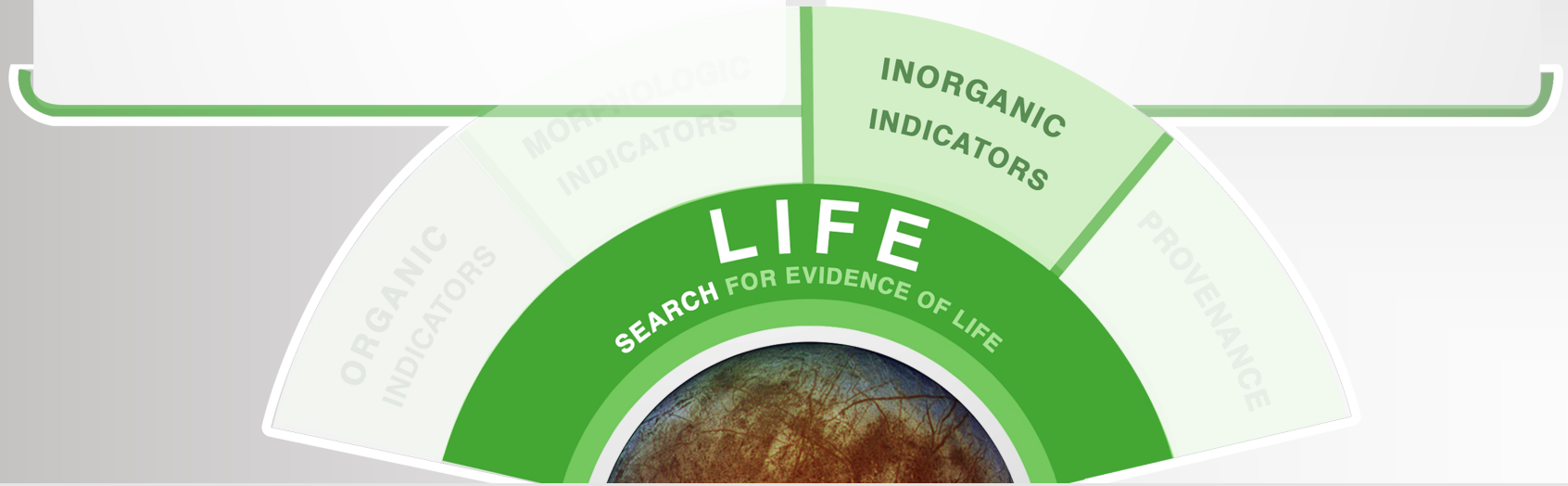
GOAL 1 INORGANIC INDICATORS



INORGANIC COMPOSITION

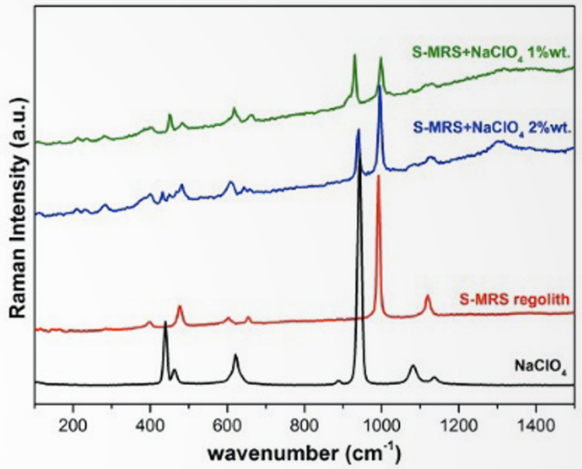


BIOMINERALS



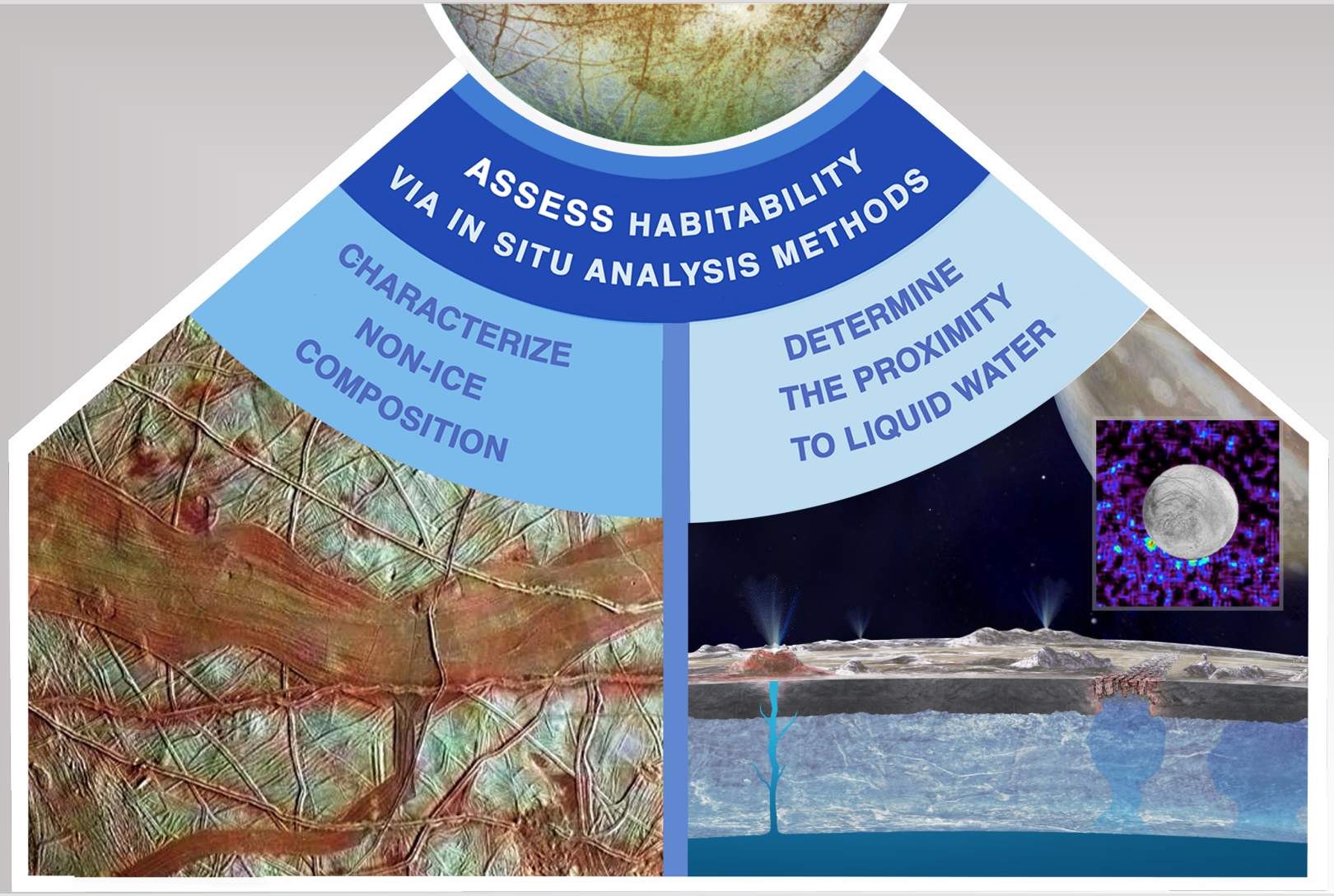
GOAL 1 PROVENANCE

GEOLOGICAL CONTEXT

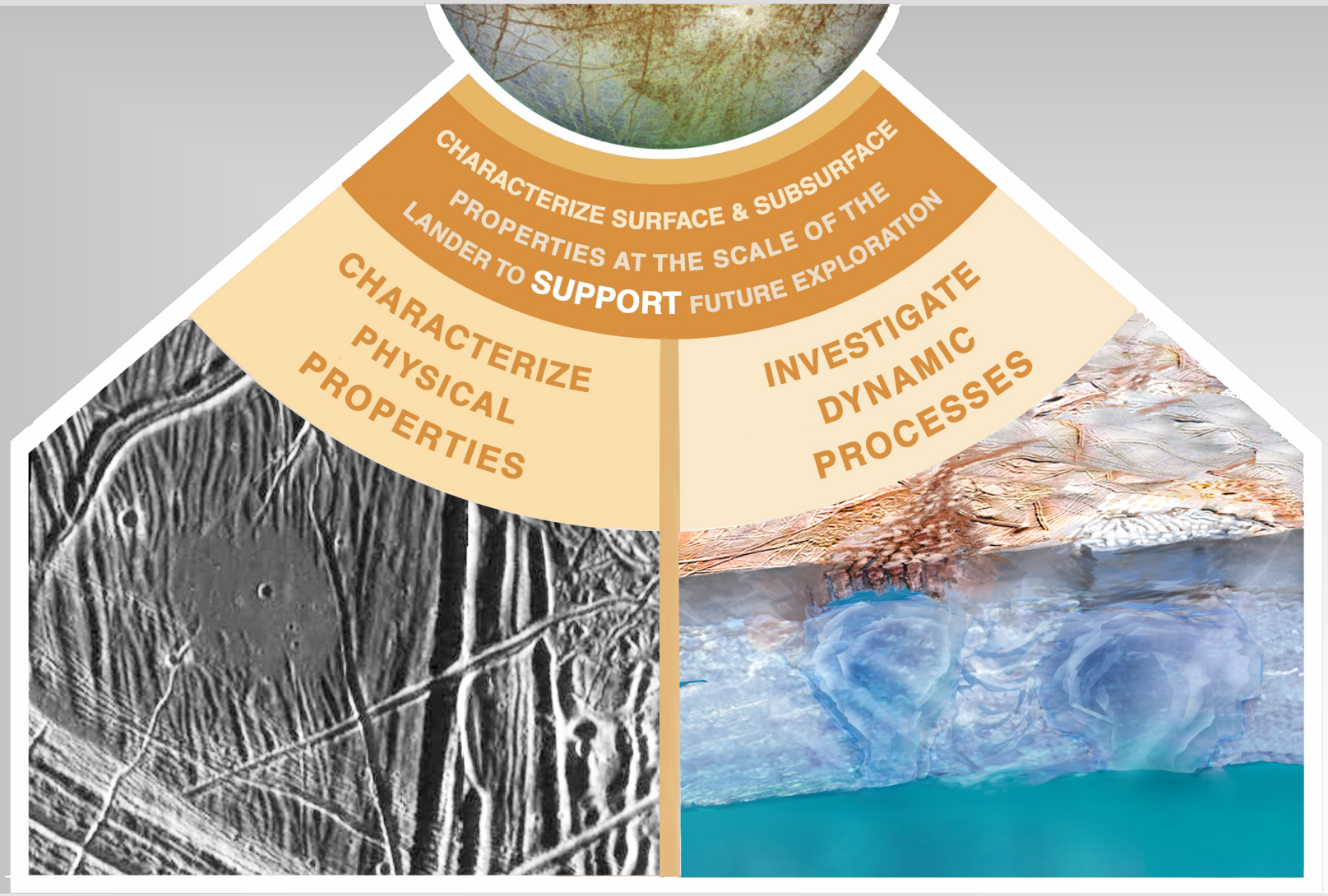


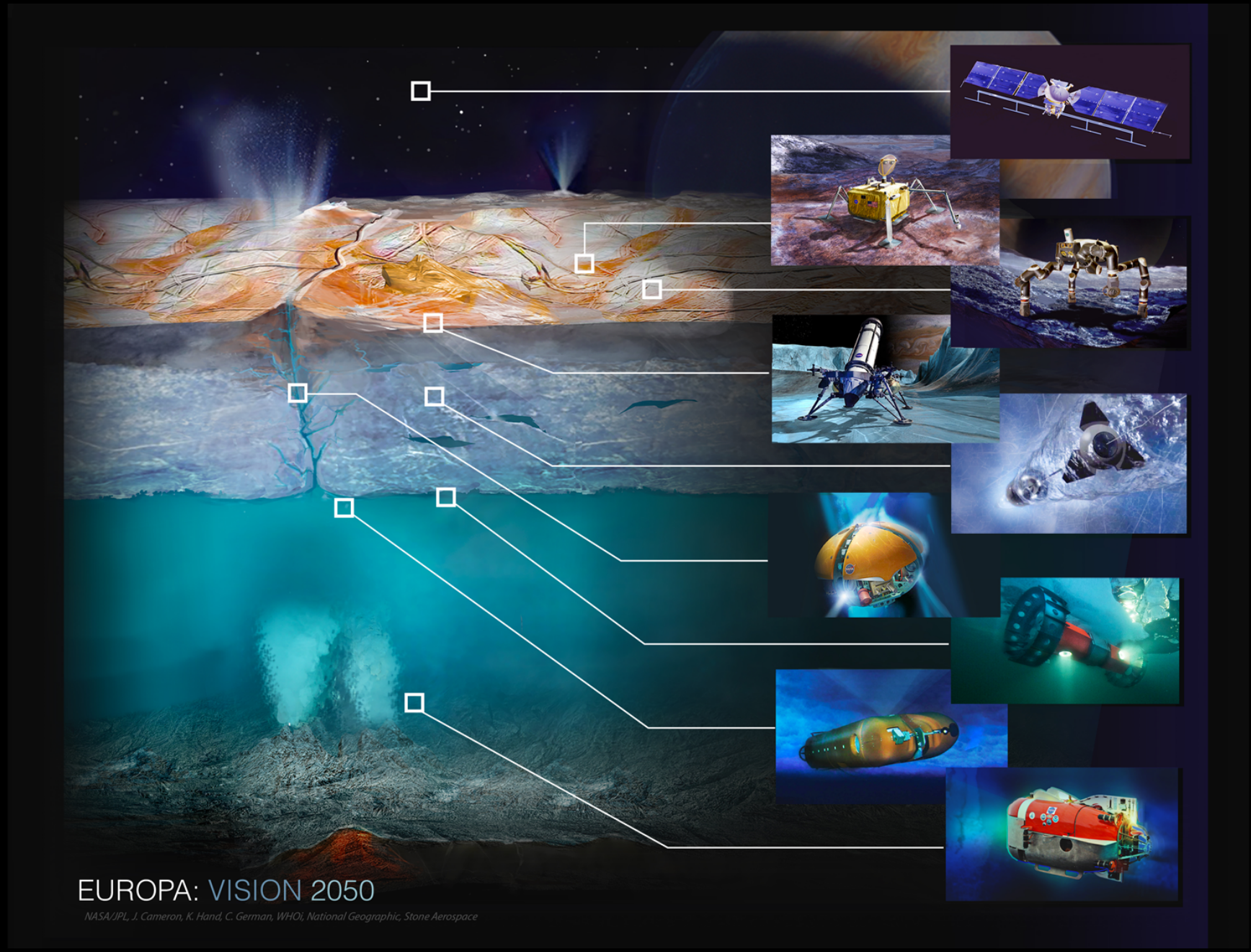
ENDOGENOUS vs. EXOGENOUS ORIGINS AND PROCESSING

GOAL 2 HABITABILITY

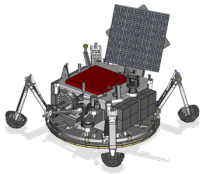


GOAL 3 CONTEXT



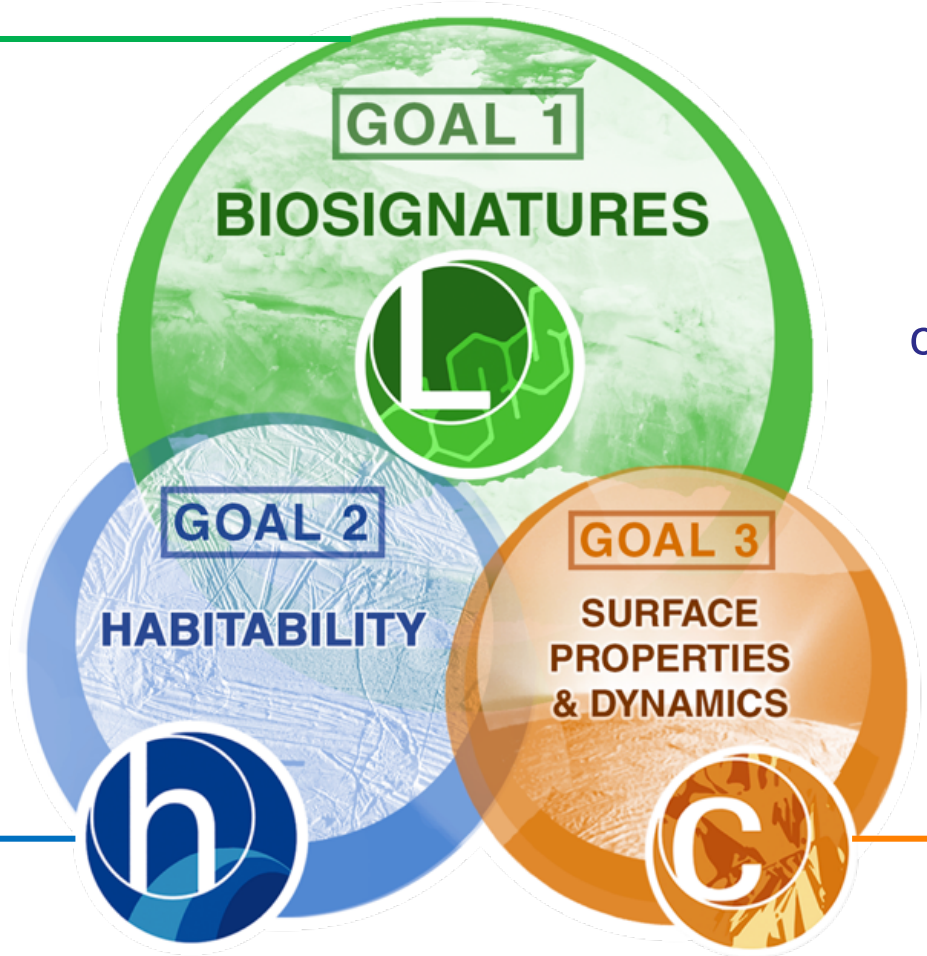


Science Goals, Objectives, Model Payload, & Sampling Threshold



A connected set of goals and objectives addressed with a focused model payload

GC-MS
Microscope
Raman spectrometer
Context cameras



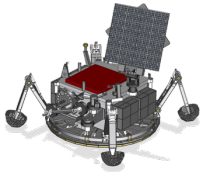
Raman spectrometer
Microscope
GC-MS
Context cameras
Geophone

Raman spectrometer
Microscope
GC-MS
Context cameras
Geophone

42.5 kg allocation for payload.

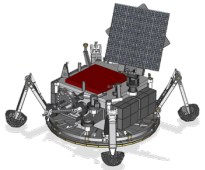
Minimum of **3 samples**,
each of at least **7 cubic centimeters**,
collected from a **minimum depth of 10 cm**.

Science Definition Team Model Payload

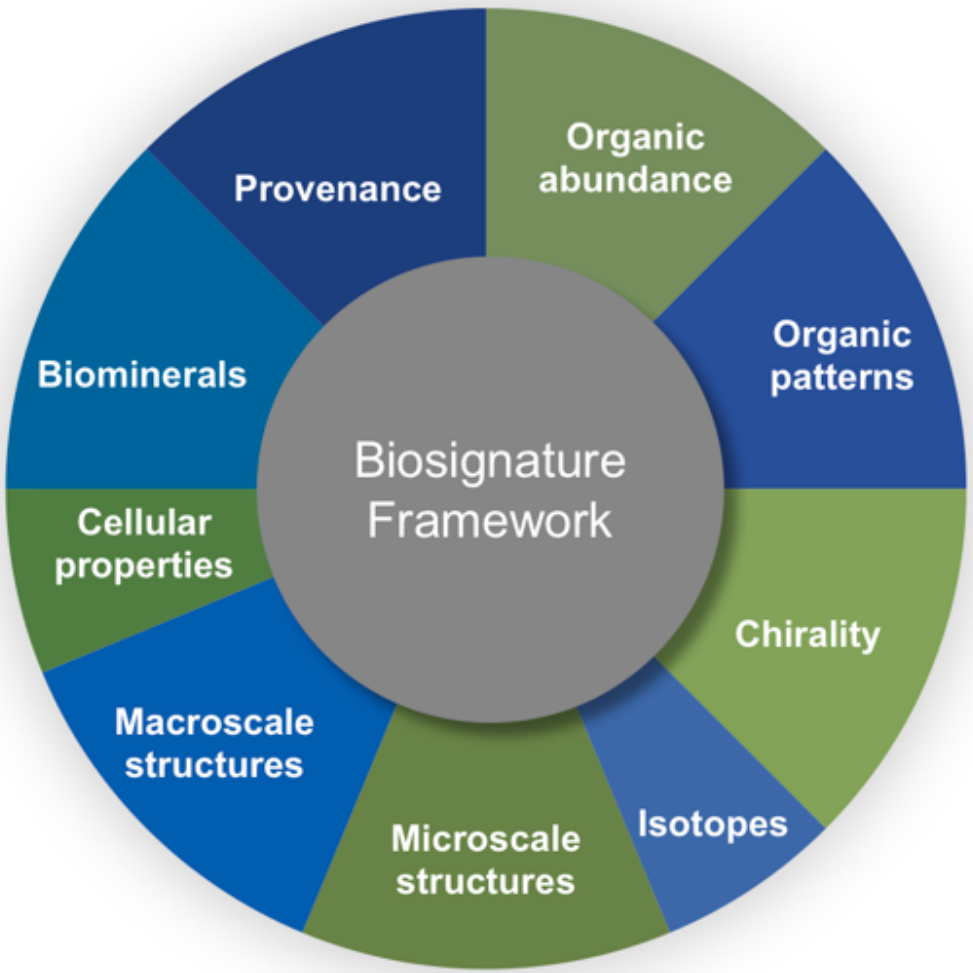


Instrument Class [mass allocation, unmargined], Total = 42.5 kg (with margin)	Model Payload	
	Baseline	Threshold
Context Remote Sensing Instrument (CRSI) [4.3 kg, includes shielding]	2 identical multi-filter, focusable, visible to near-infrared, stereo overlapping cameras with narrowband filters equivalent to those of the Europa Multiple Flyby Mission EIS cameras	2 identical RGB, fixed focus, stereo overlapping cameras
Microscope for Life Detection (MLD) [5.4 kg]	Deep UV resonance Raman and optical microscope with fluorescence spectrometer	Atomic Force Microscope (AFM) with optical context imager
Vibrational Spectrometer (VS) [5.4 kg]		Raman Laser Spectrometer (RLS)
Organic Compositional Analyzer (OCA) [16.4 kg]	Gas Chromatograph Mass Spectrometer (GC-MS) with Chirality Analysis and Stable Isotope Analyzer (SIA)	Gas Chromatograph Mass Spectrometer (GC-MS) with Chirality Analysis
Geophysical Sounding System (GSS) [1.2 kg]	Broad-band seismometer	3-axis geophone

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.**



Surface Operations, Sampling, & Instruments

- From Model Payload to potential instrument providers:
  - 44 proposals submitted to the Instrument Concepts for Europa Exploration (ICEE-2) call (Step 2 due date: Sept. 7, 2018)
  - Many institutions with many instrument concepts. Interest is high.
- 14 ICEE-2 teams selected.
  - MATISSE, PICASSO, COLDTech programs also providing instrument development funds.
- Instrument accommodation and sampling procedures are being developed between the Project and potential instrument providers.

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)
  - 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.
  - Direct-to-Earth architecture presentation Feb. 28, 2018.

OPAG Sept. 2018 finding on the science value of the lander:

"The lander achieves high-value science and would do worthwhile science even in the absence of any signs of life."

- 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.
  - Direction Letter from HQ received (12/7/2017): Go with DTE architecture as it preserves science but minimizes cost and complexity.
- Delta-Mission Concept Review, Nov., 2018. Chair: Prof. B. Braun.
  - Board report: "The review board cannot recall a pre-phase A planetary science concept at this advanced level of fidelity"
- ICEE-2 selections Feb. 8th, 2019. Fourteen teams selected for instrument development.
- Numerous talks and posters at AGU, DPS, LPSC, AbSciCon, NRC panels, OW3, Deep Dives,…

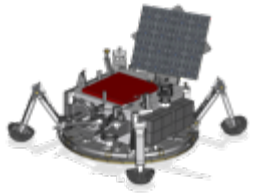
Landing Site Selection

Cynthia Phillips (JPL)

Europa Lander Deputy Pre-Project Scientist

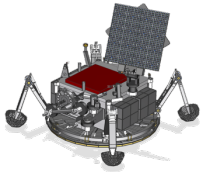
Jet Propulsion Laboratory
California Institute of Technology

Finding a Scientifically Valuable Landing Site



- **Europa Clipper Science Goal: "*Explore Europa to Investigate its Habitability*"**
  - Close approach observations will focus on habitability, compatible with Lander's biosignature goal
- **Science criteria for landing site**
  - Factors include young surface age, composition, radiation exposure, geologic terrain, and proximity to liquid water or recent activity
- **Landing site selection process**
  - Will include both science and engineering assessment
  - Interactions with Europa Clipper
  - Later, community workshops (similar to Mars landing site process)

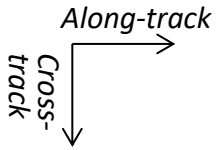
Reconnaissance from Europa Clipper Instruments

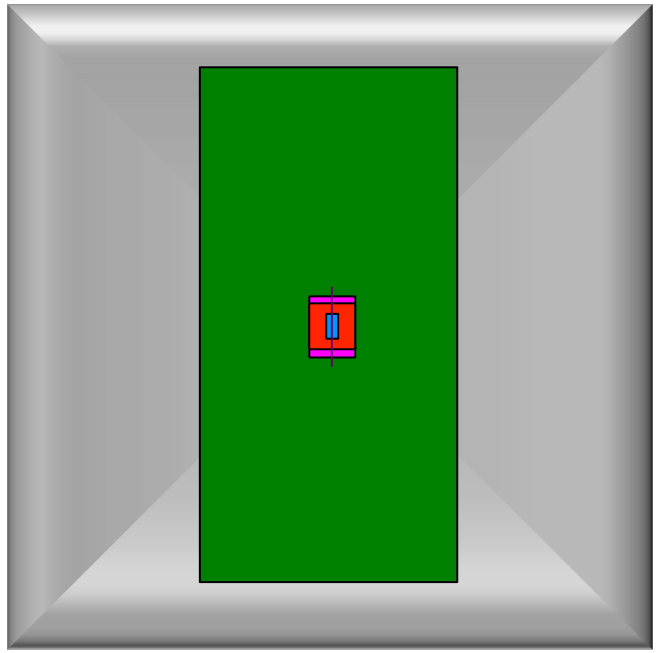


- **EIS (NAC, WAC cameras)**
  - High resolution & stereo imaging of potential landing sites plus regional context
  - Highest resolution 0.5 m/pixel
- **E-THEMIS (Thermal IR)**
  - Up to 250 m/pixel
  - Thermal inertia, block abundance at surface
  - Search for hotspots
- **MISE (Near IR spectrometer)**
  - Surface composition
- **REASON (Radar)**
  - Hardness and roughness of surface and near-surface
- **ECM (Magnetometer)**
  - Average ice shell thickness

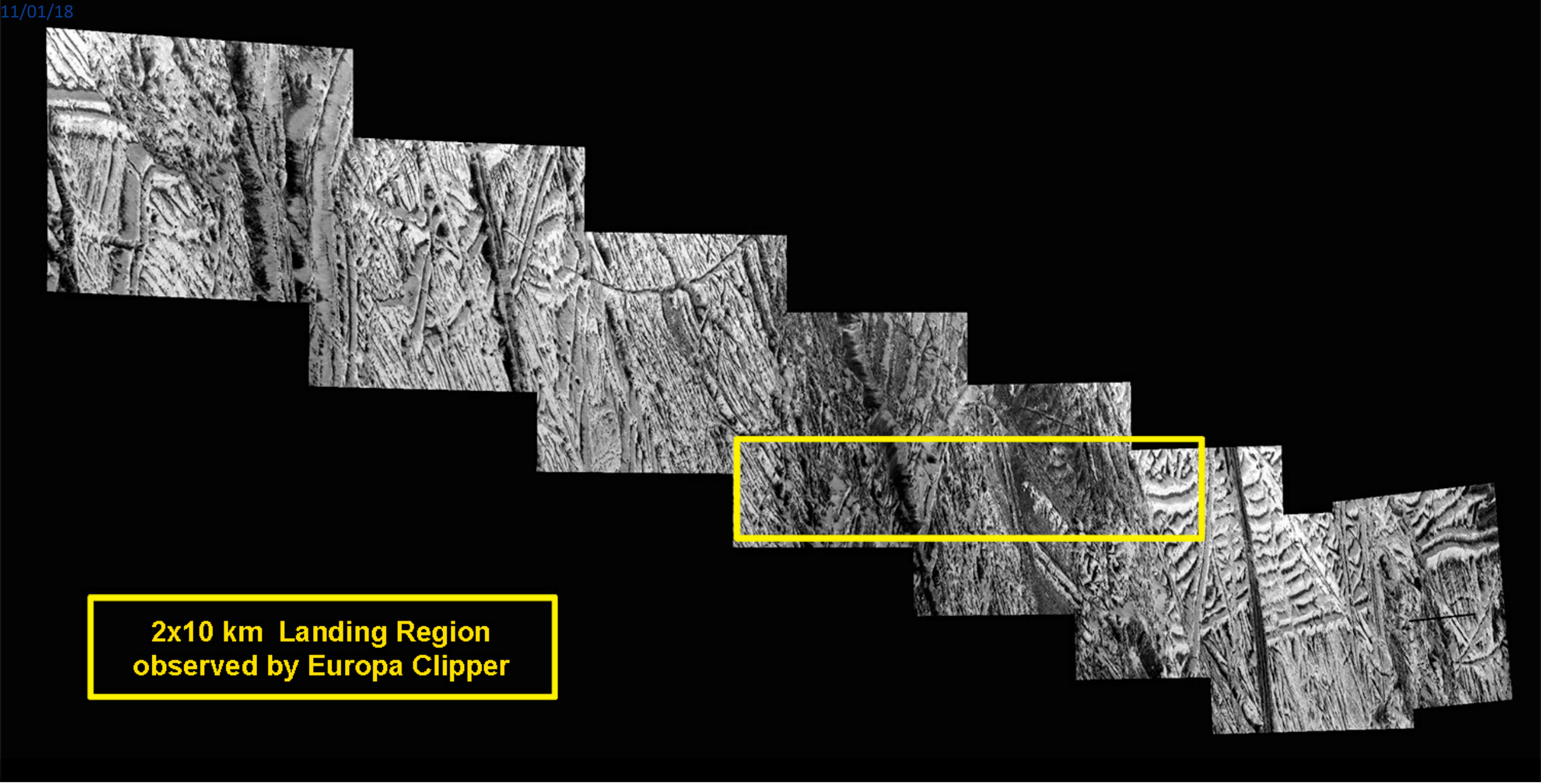
Clipper instrument Pixel scales from 100 km:

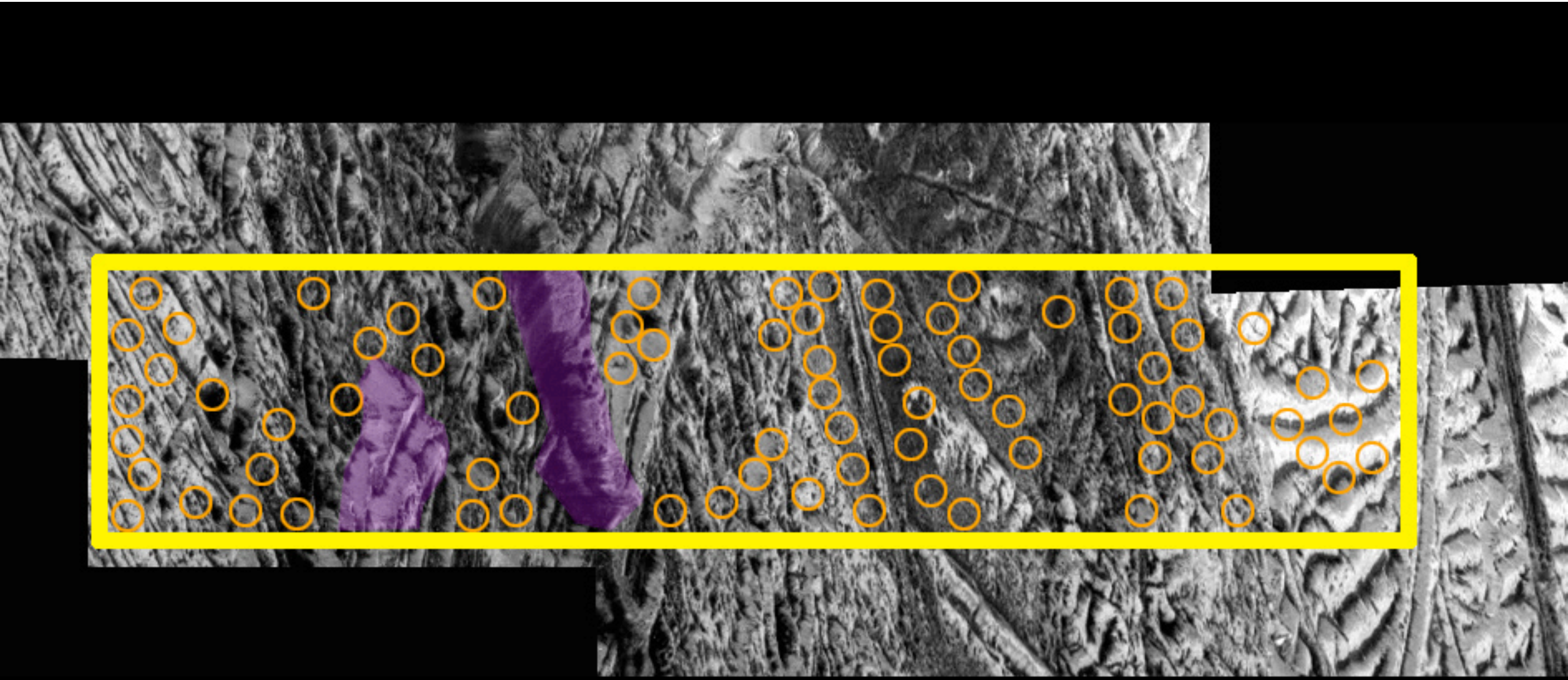
UVS: 35 m
WAC: 22 m
NAC: 1 m
MISE: 25 m
E-THEMIS: 250 m
REASON: N/A





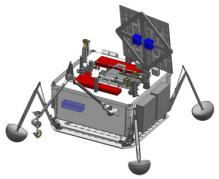
Remote Sensing Fields of View

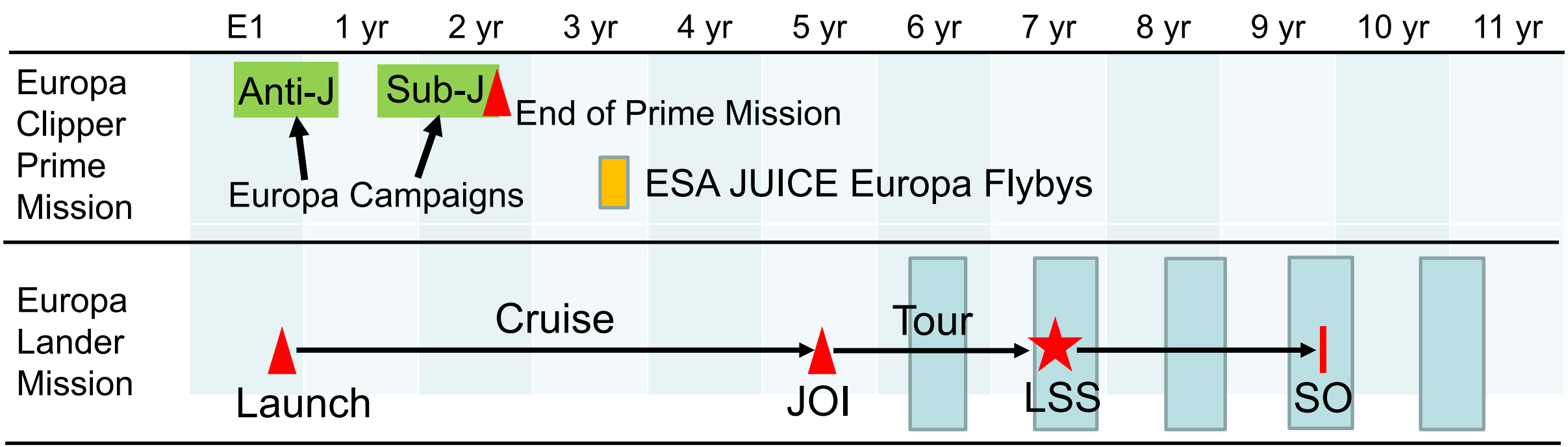




Orange circles: notional 200 m landing sites
Purple: scarps excluded as engineering hazards

Clipper Campaigns vs Lander Notional Timeline





Over 5 years from end of Clipper prime mission to landing site selection date.

Final Landing Site Selection (LSS)

Surface Operations (SO)

Earth-Jupiter Range < 5 AU (aka “landing seasons”)

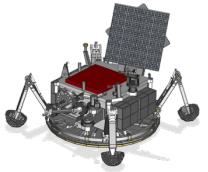
Europa Lander/Ocean Worlds

Earl Maize

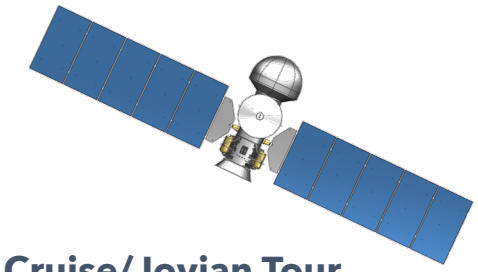
Europa Lander Pre-Project Manager

Jet Propulsion Laboratory
California Institute of Technology

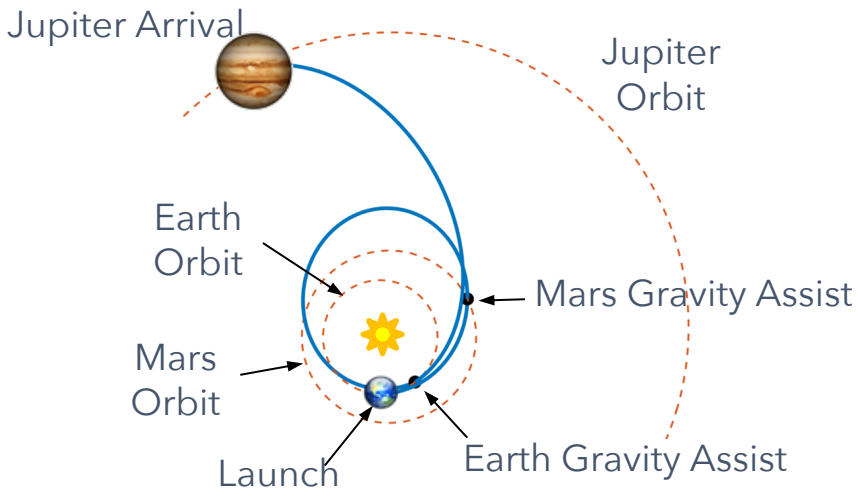
Europa Lander Mission Concept

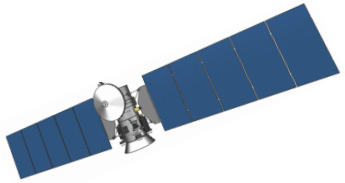


Launch
- SLS Block 1B

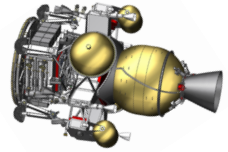


Cruise/Jovian Tour
- Jupiter Orbit Insertion: 5 years after launch
- Europa Landing: 2 years after JOI

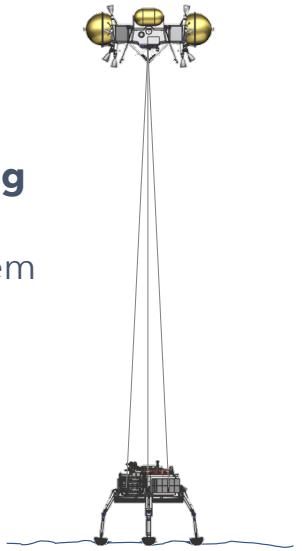




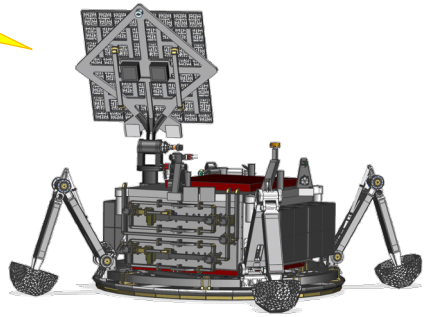
Carrier Stage
- 1.5 Mrad radiation exposure
- Elliptical disposal orbit



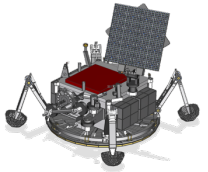
Deorbit, Descent, Landing
- Guided deorbit burn
- Sky Crane landing system
- 100-m accuracy
- DTE tones only

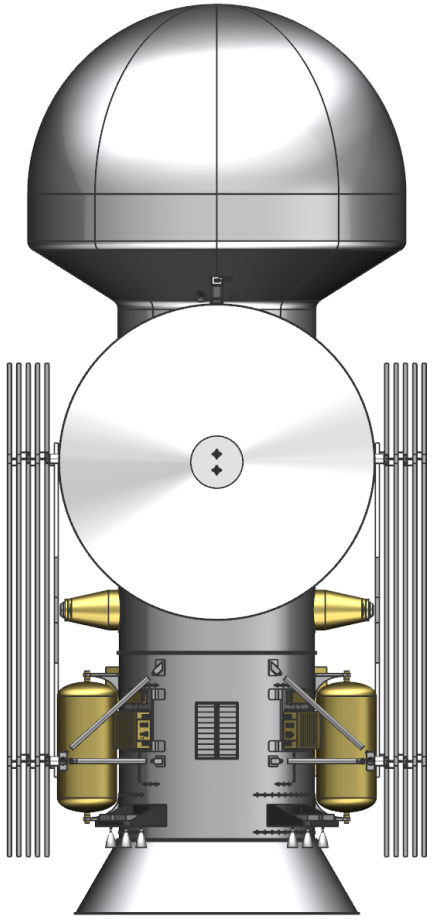


Surface Mission
- Biosignature Science
- ~30 day mission
- Direct to Earth Comm
- 1.5 Gbit data return
- 50 kWh battery
- 2.0 Mrad radiation exposure

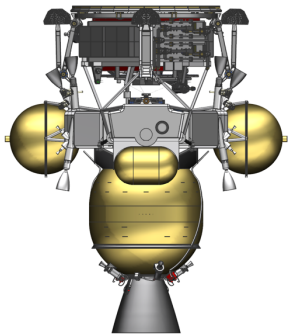


Baseline System Vehicles





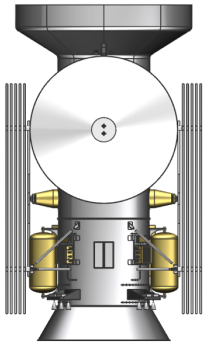
Launch Mass: 15.5 mt



Deorbit Vehicle (DOV)

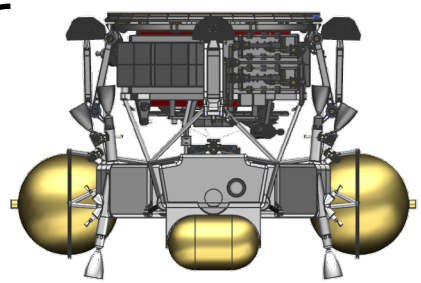
MPV: 3,830 kg

+



Carrier Stage (CS) & Bio Barrier

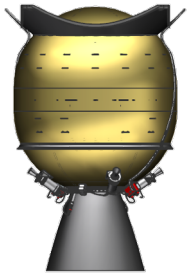
MPV: 11,705 kg



Powered Descent Vehicle (PDV)

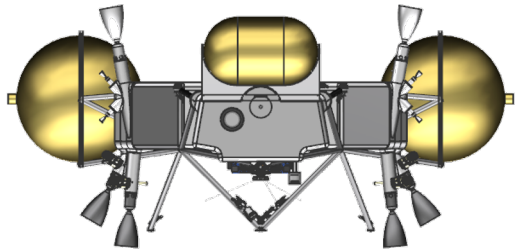
MPV: 1,810 kg

+



Deorbit Stage (DOS)

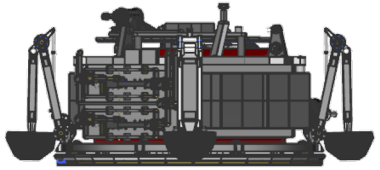
MPV: 2,020 kg



Descent Stage (DS)

MPV: 1,235 kg

+

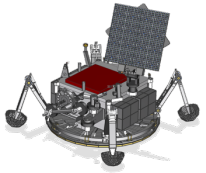


Lander

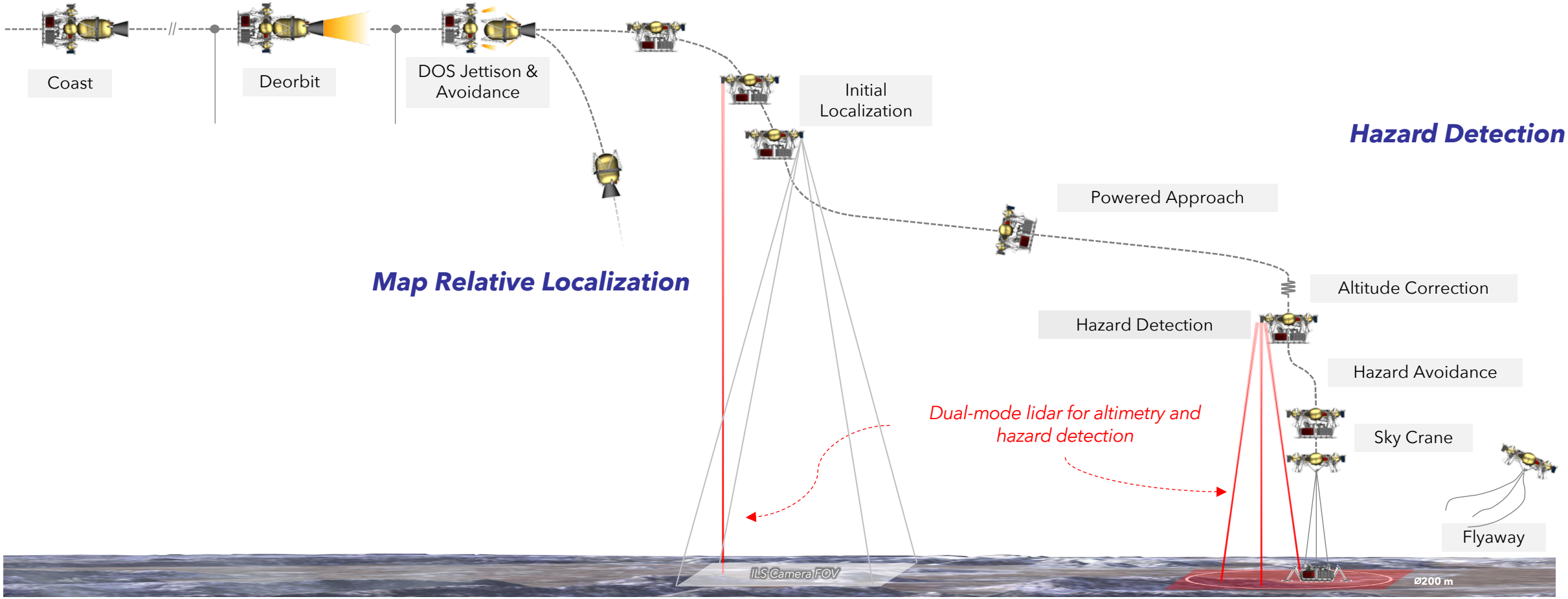
MPV: 575 kg

NOT TO SCALE

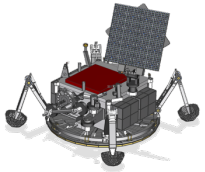
Intelligent Landing System



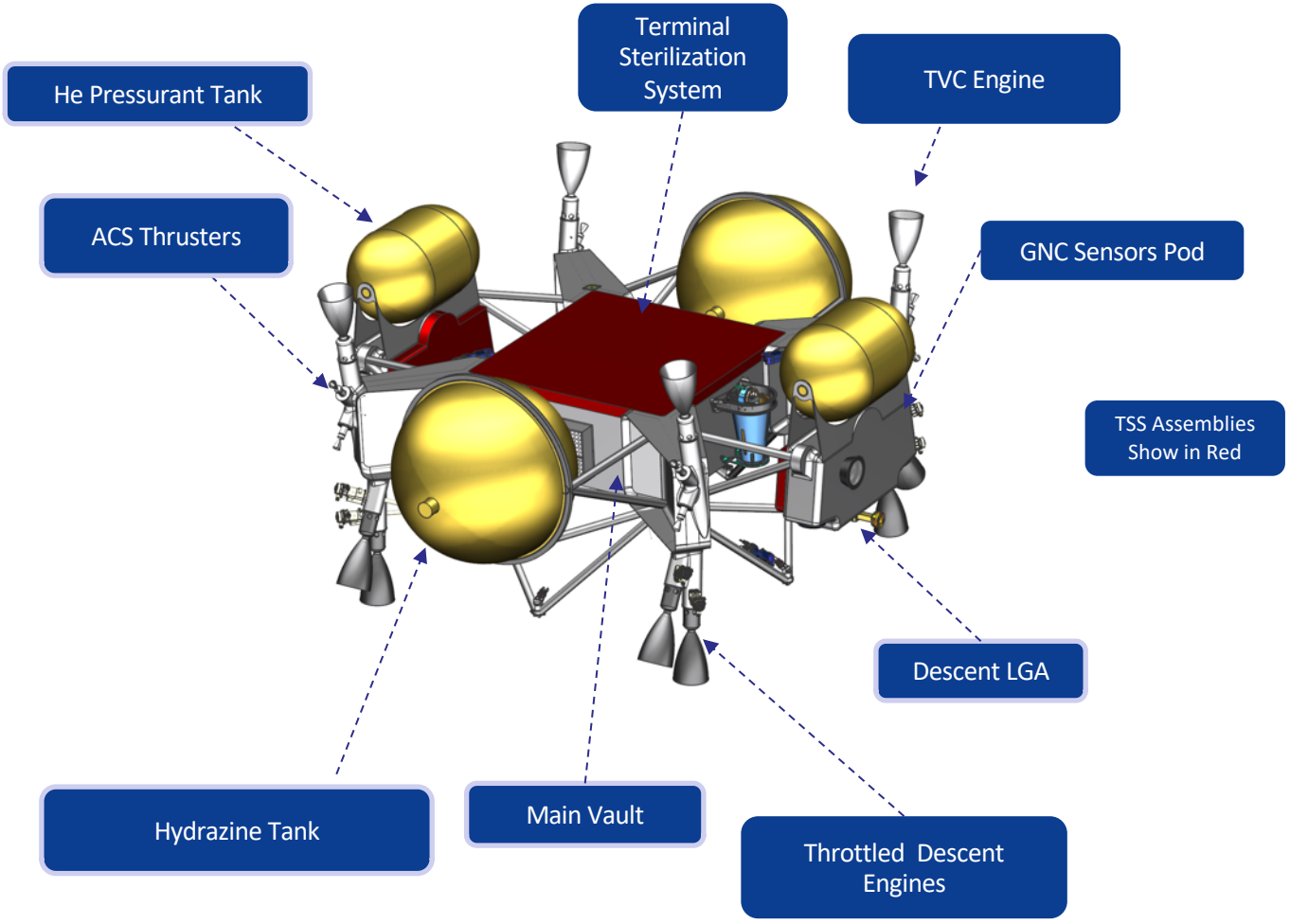
*Measure **Altitude** from 8km down to 10m*



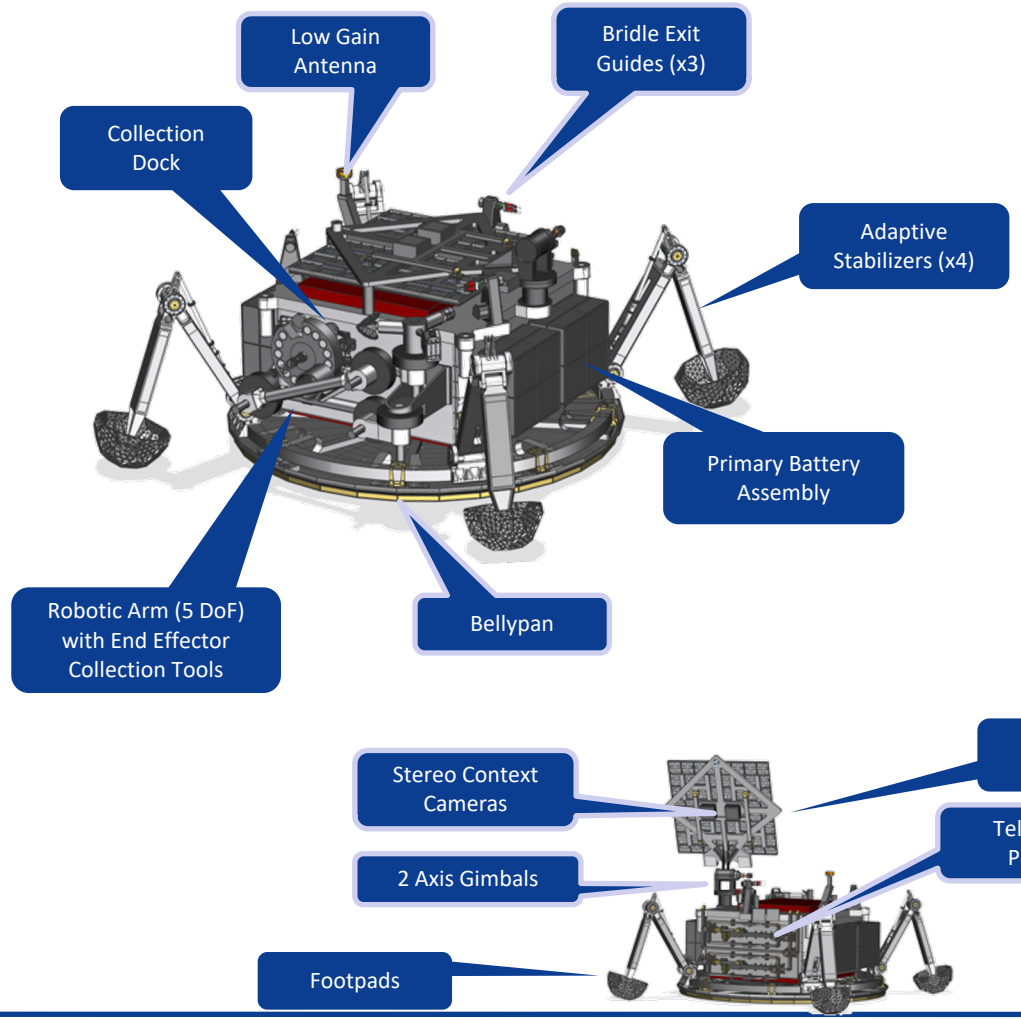
Descent Stage and Lander Concept Configurations



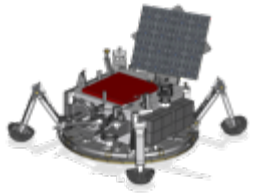
Descent Stage



Lander



Europa Lander pre-Project Current Status



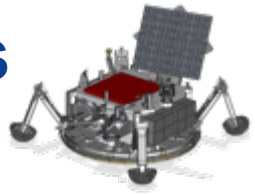
- Mission Concept Review – Jun 2017
  - "The goals of the Europa Lander Mission (ELM) are ambitious and, quite possibly, represent the most exciting science objectives to be adopted by any NASA planetary mission to date. … the team is ready to move into Phase A."
- Δ-Mission Concept Review – Nov 2018
  - "The review board (chaired by Bobby Braun) cannot recall a pre-phase A planetary science concept at this advanced level of fidelity"
- Project is actively pursuing spacecraft/payload advanced development
  - Opportunities to retire development risk and jump-start payload development
  - Funded with FY19 budget allocation, most with three year duration
    - Opportunities for extensions
  - 18 high-priority spacecraft/payload advanced development/maturation tasks
    - Some efforts collaborative with Mars 2020 landing system development
  - NASA selected 14 potential instruments for maturation under ICEE-2
    - Funded out of FY18 budget
  - Many tasks applicable to Ocean Worlds surface missions beyond Europa Lander

Europa Lander Flight System Overview

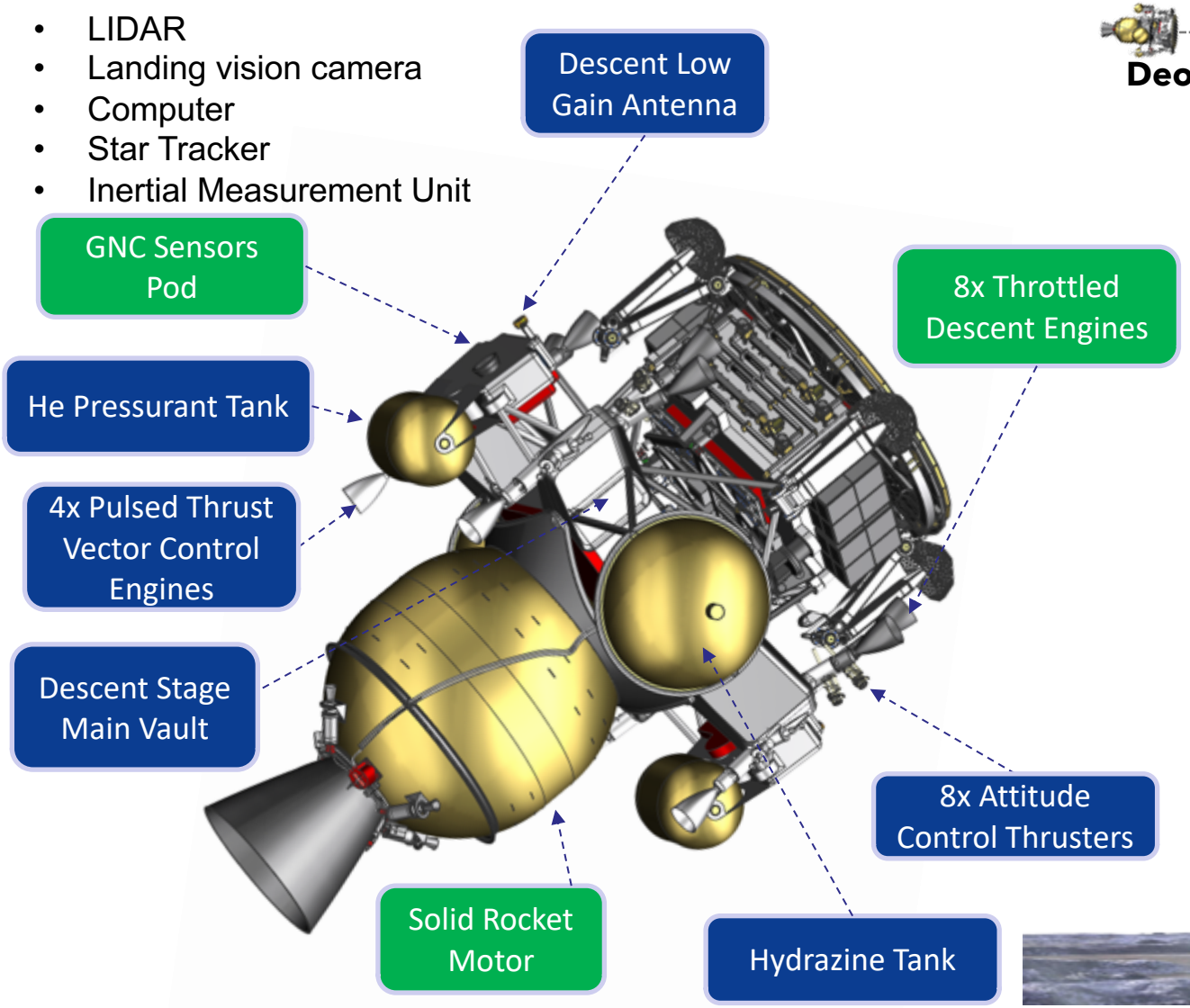
Ray Crum, Flight System Manager

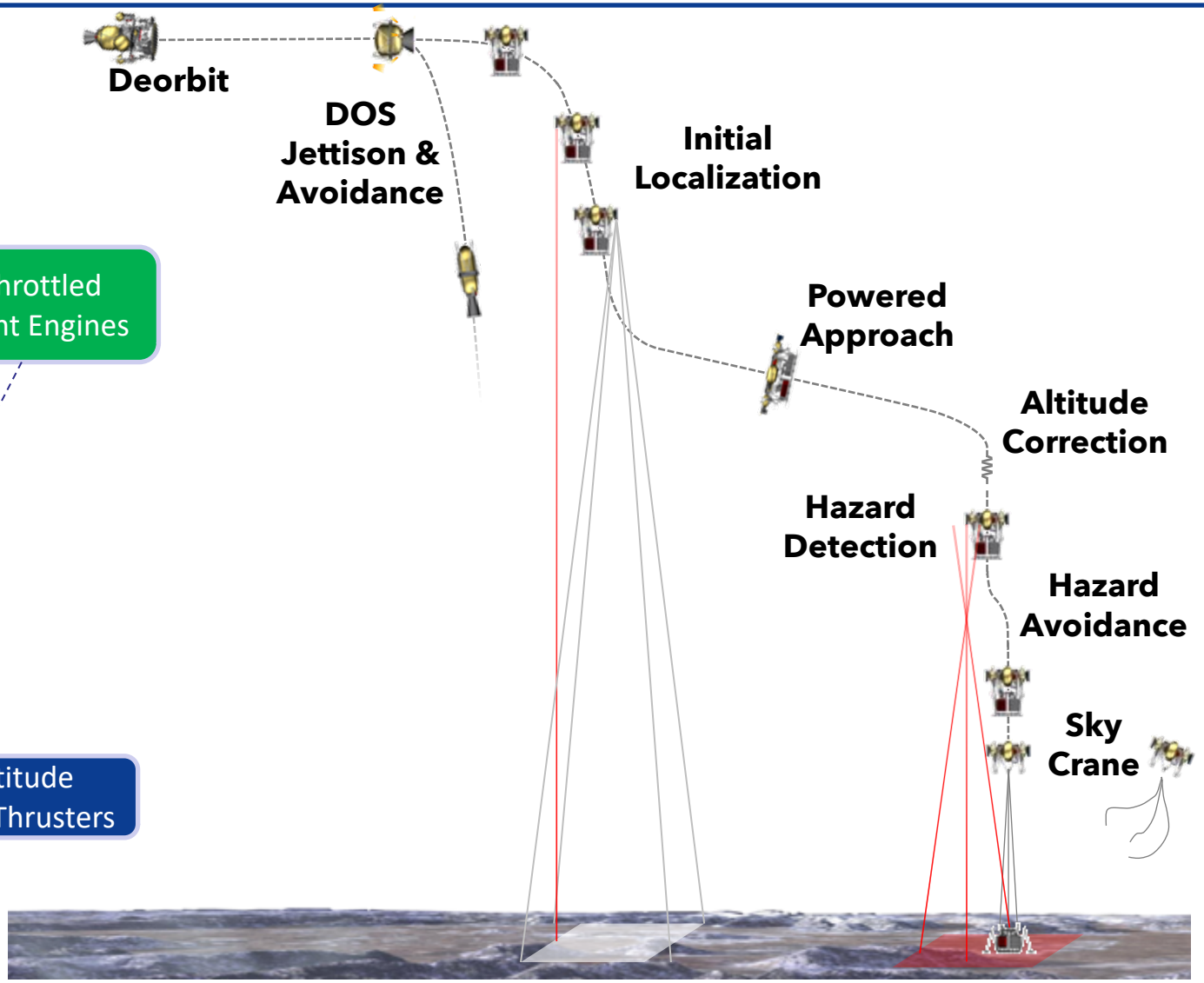
Jet Propulsion Laboratory
California Institute of Technology

Deorbit Vehicle and Deorbit, Descent and Landing Events (Green Items: Advanced Development to Mitigate Risk)

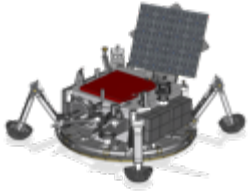


- LIDAR
- Landing vision camera
- Computer
- Star Tracker
- Inertial Measurement Unit

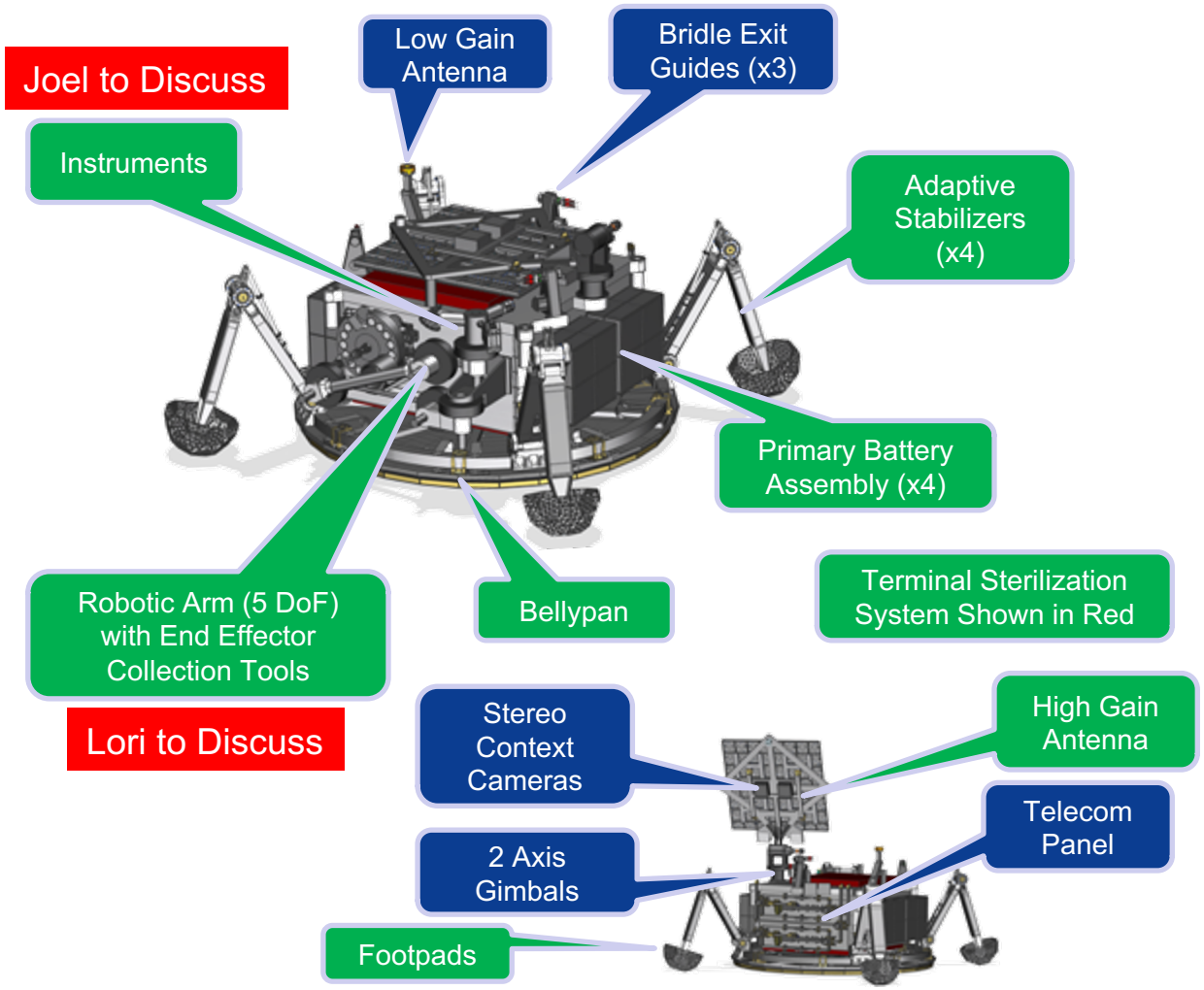




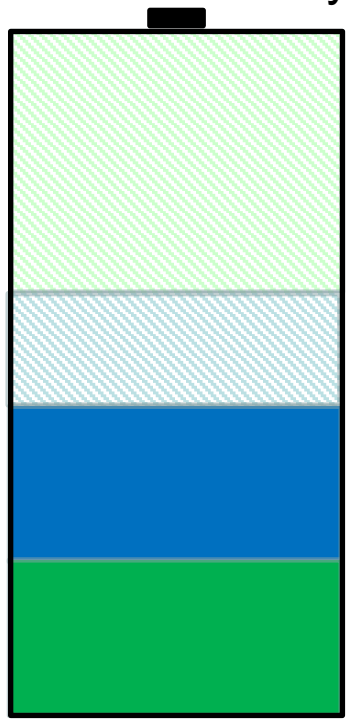
Lander Configuration & Surface Energy (Green Items: Advanced Development to Mitigate Risk)



Lander: 575 kg dry mass; 50 kWh usable energy storage



Lander Battery
(50 kWh = 32 days)



11 days of unallocated margin

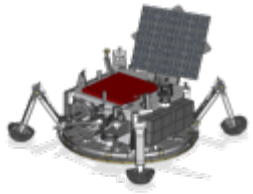
7 days of on-surface margin

7 days of planned contingency

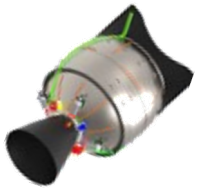
7 days to accomplish full mission success

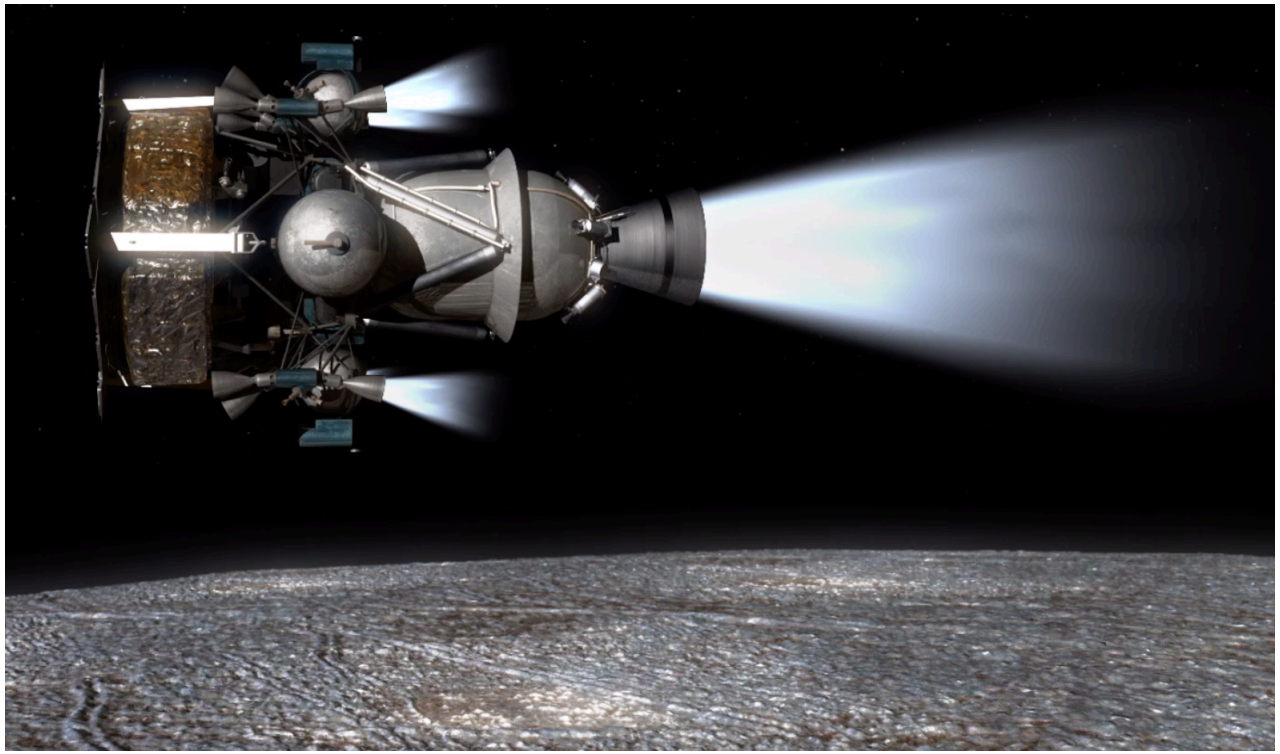
Current Design has Significant Energy Margins
Trade Study to Double Surface Mission Duration
Utilizing Advance Development & Mass Margins

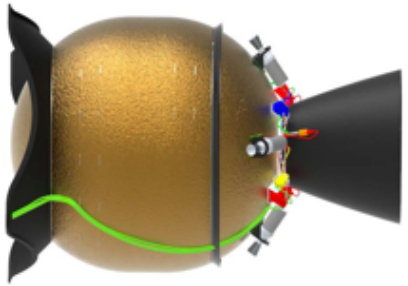
Major Deorbit, Descent & Landing Risk Areas Addressed with Advanced Development



Risk	Advanced Development	Outcome	Current Progress
Unique environment for SRM	Combined environment testing of Solid Rocket Motor (SRM) material	SRM materials selected and demonstrated	Two contractors completed Phase 2; Proposal for Phase 3







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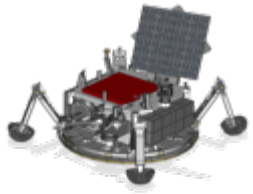

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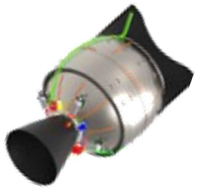

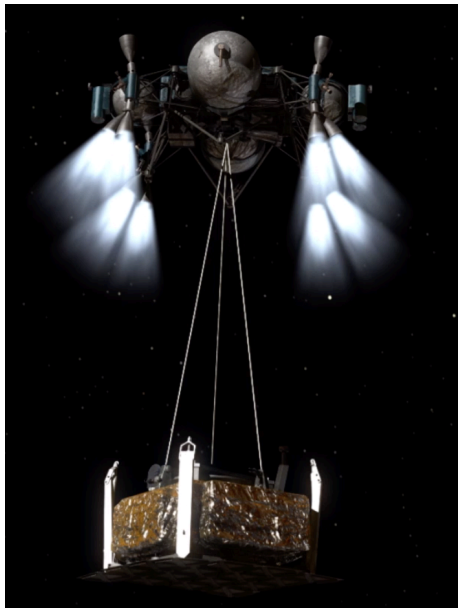

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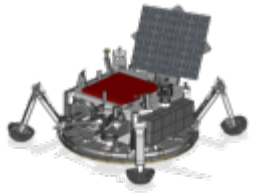

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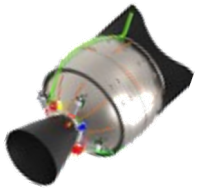

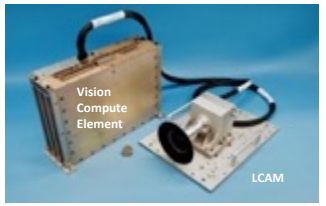

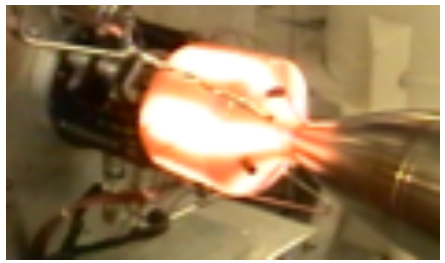

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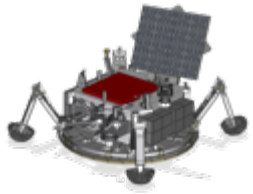

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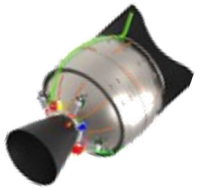
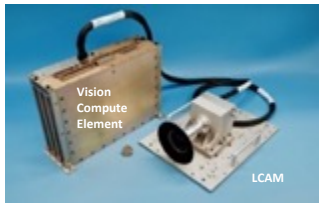
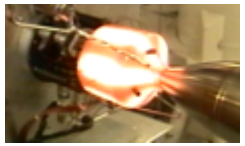
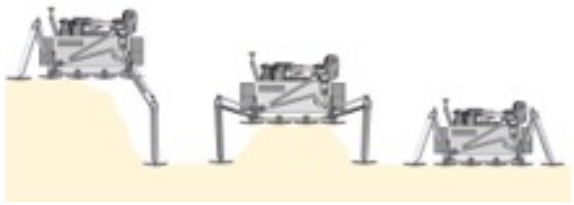
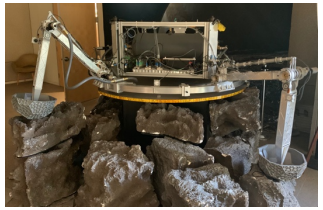


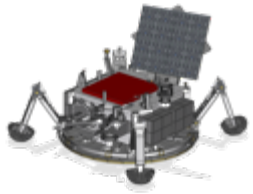








Major Deorbit, Descent & Landing Risk Areas Addressed with Advanced Development



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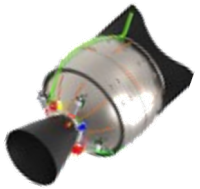
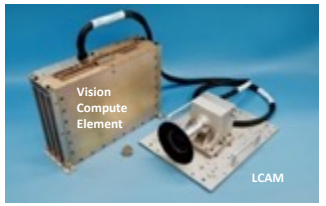
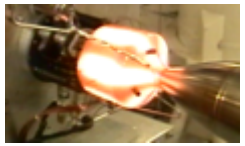
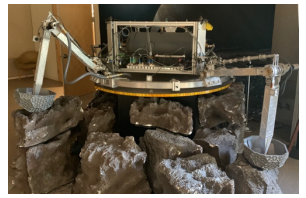
Landing on unknown surface	On-board hazard detection and avoidance for DDL	Flight test of prototype LIDAR	Two LIDAR contracts, Prototypes in design & HW rad test

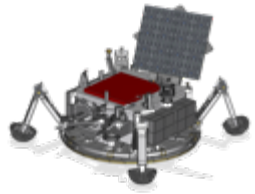




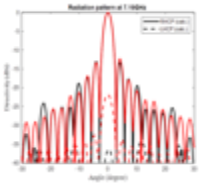


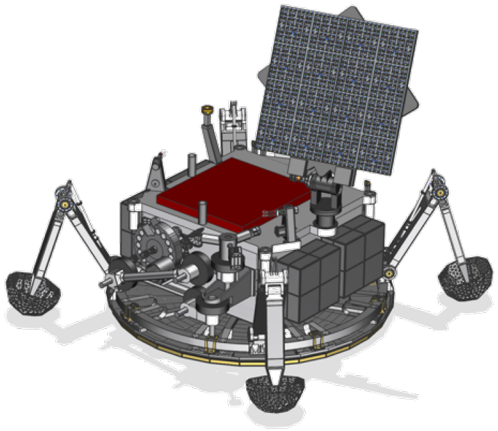


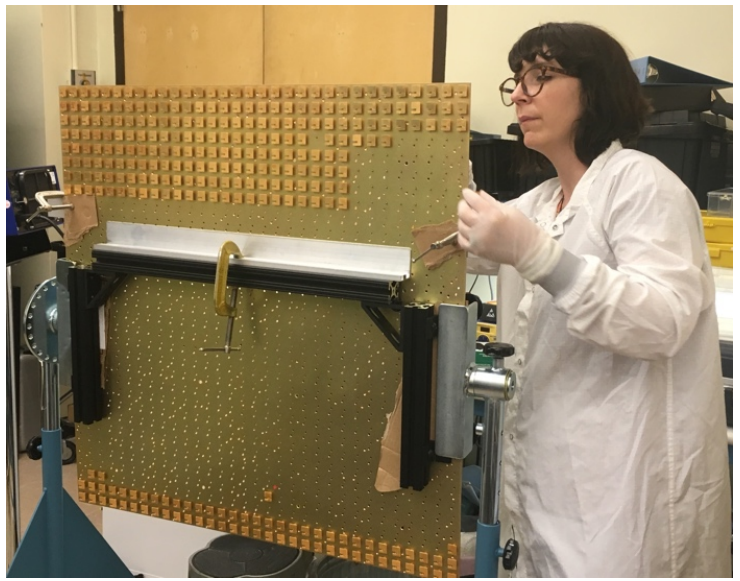
Major Lander Risk Areas Addressed with Advanced Development

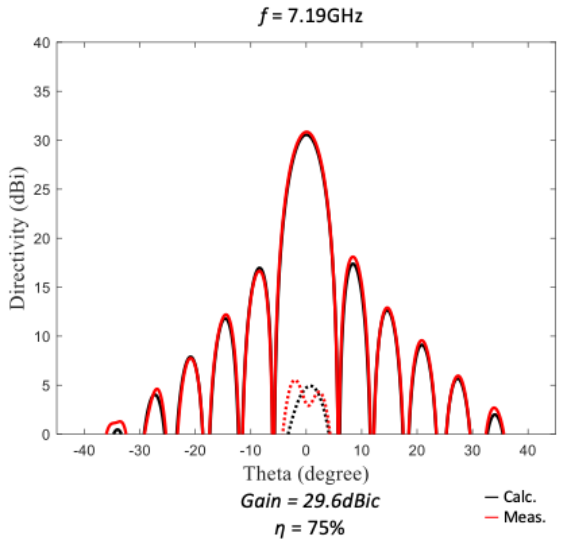


Risk	Advanced Development	Outcome	Current Progress
Data rate to achieve science	Direct to Earth High Gain Antenna	Prototype environmentally tested	32 x 32 meets RF performance; ready for env testing

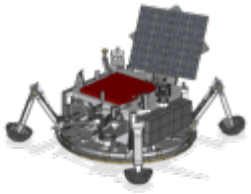




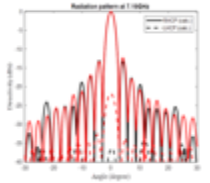


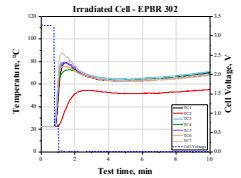


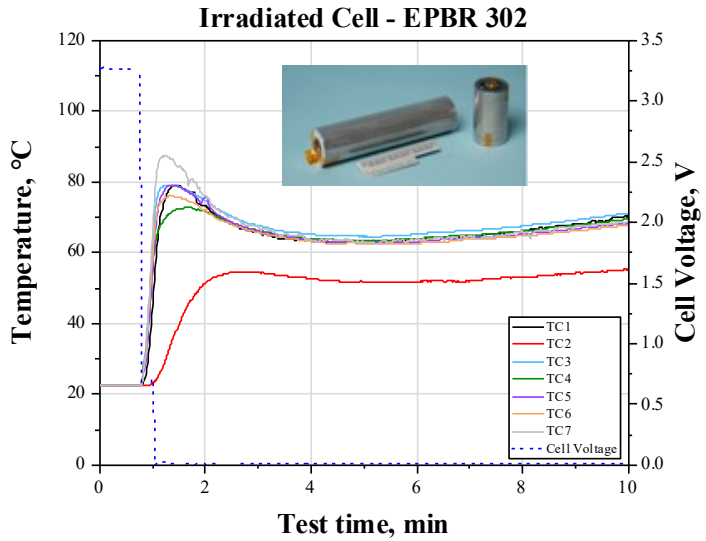
Major Lander Risk Areas Addressed with Advanced Development



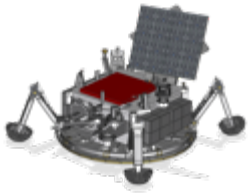
Risk	Advanced Development	Outcome	Current Progress
Data rate to achieve science	Direct to Earth High Gain Antenna	Prototype environmentally tested	32 x 32 meets RF performance; ready for env testing
Energy margin to achieve science	Characterize & improve primary battery for Europa environment	Environment, abuse and life testing on primary battery	Tested Build 1 cells, in test of Build 2 cells, proc improve Build 3







Major Lander Risk Areas Addressed with Advanced Development



Risk	Advanced Development	Outcome	Current Progress
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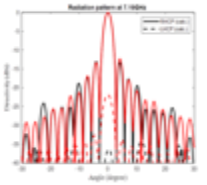
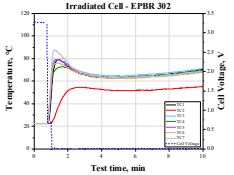
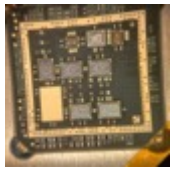
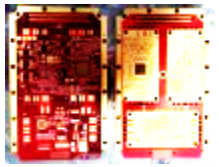
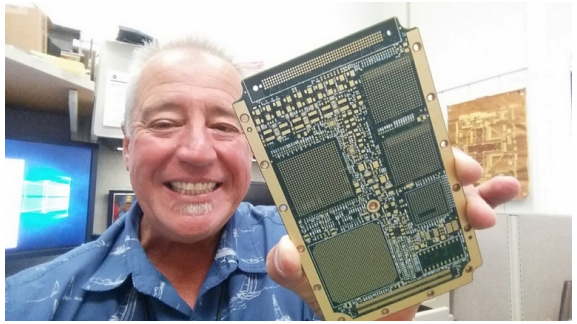


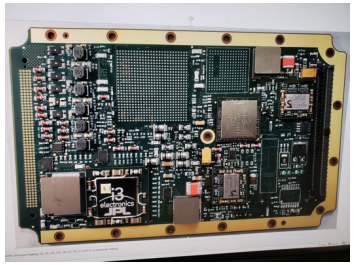




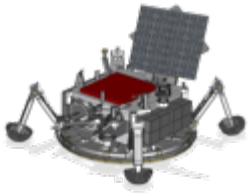




Motor Control Card PWB



Major Lander Risk Areas Addressed with Advanced Development



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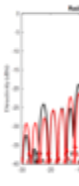
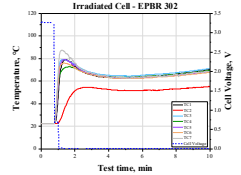
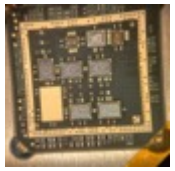
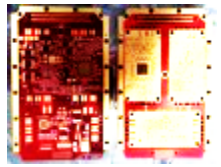
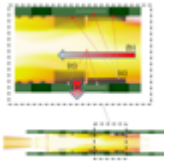




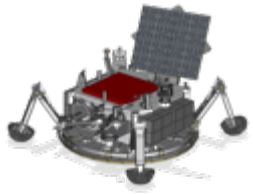






Energetic Material #1 ignition test

Major Lander Risk Areas Addressed with Advanced Development



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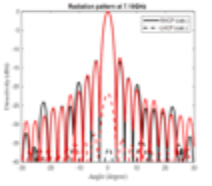
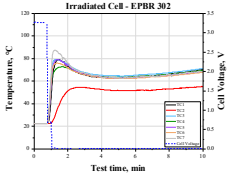
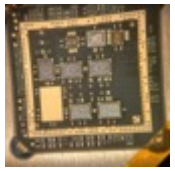
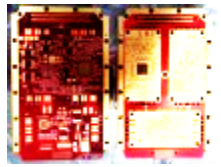
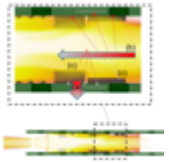
Contamination of samples	Plume contamination test	Validate model of surface contamination	Contract with DLR, test plan complete



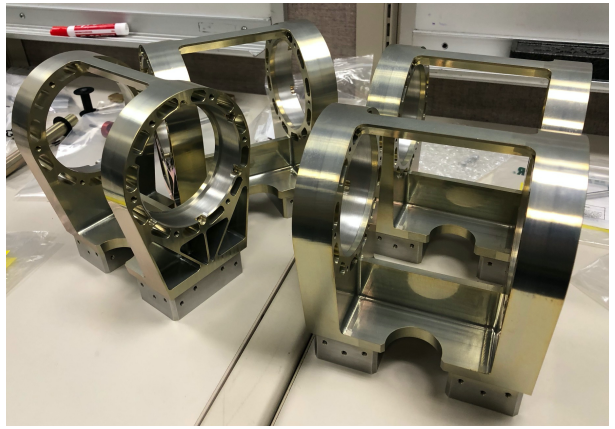






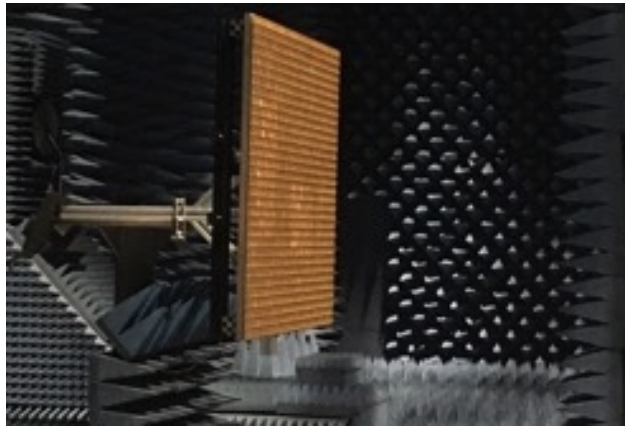


Development Hardware Pictures

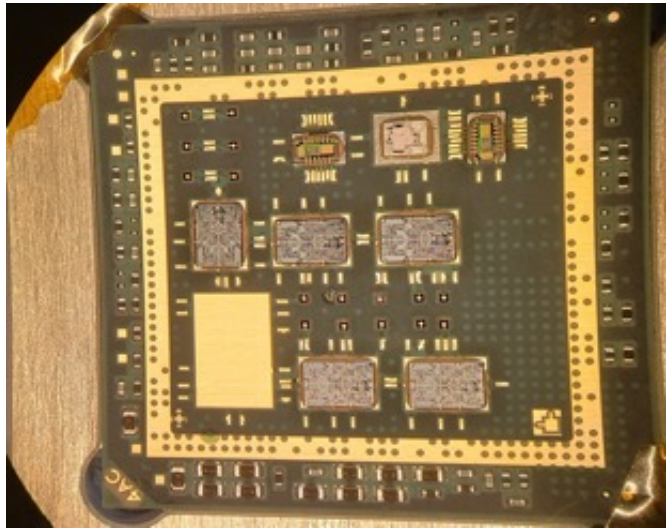


Iteration 2 Landing Legs

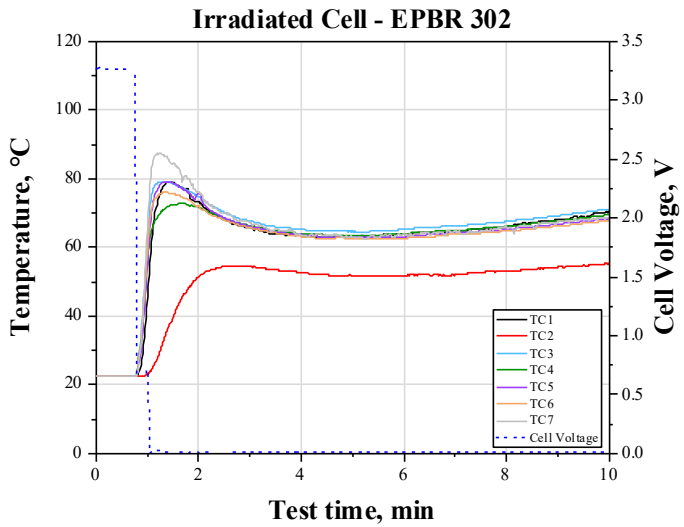
Solid Rocket Motor Material Tests



32 x 32 High Gain Antenna



Motor Control Current Sense



Battery Puncture Test Results

Energetic Material Testing

Overview of the Surface Phase and Sampling Transfer Concepts

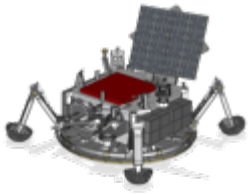
Joel Krajewski, Payload Manager, Europa Lander PreProject

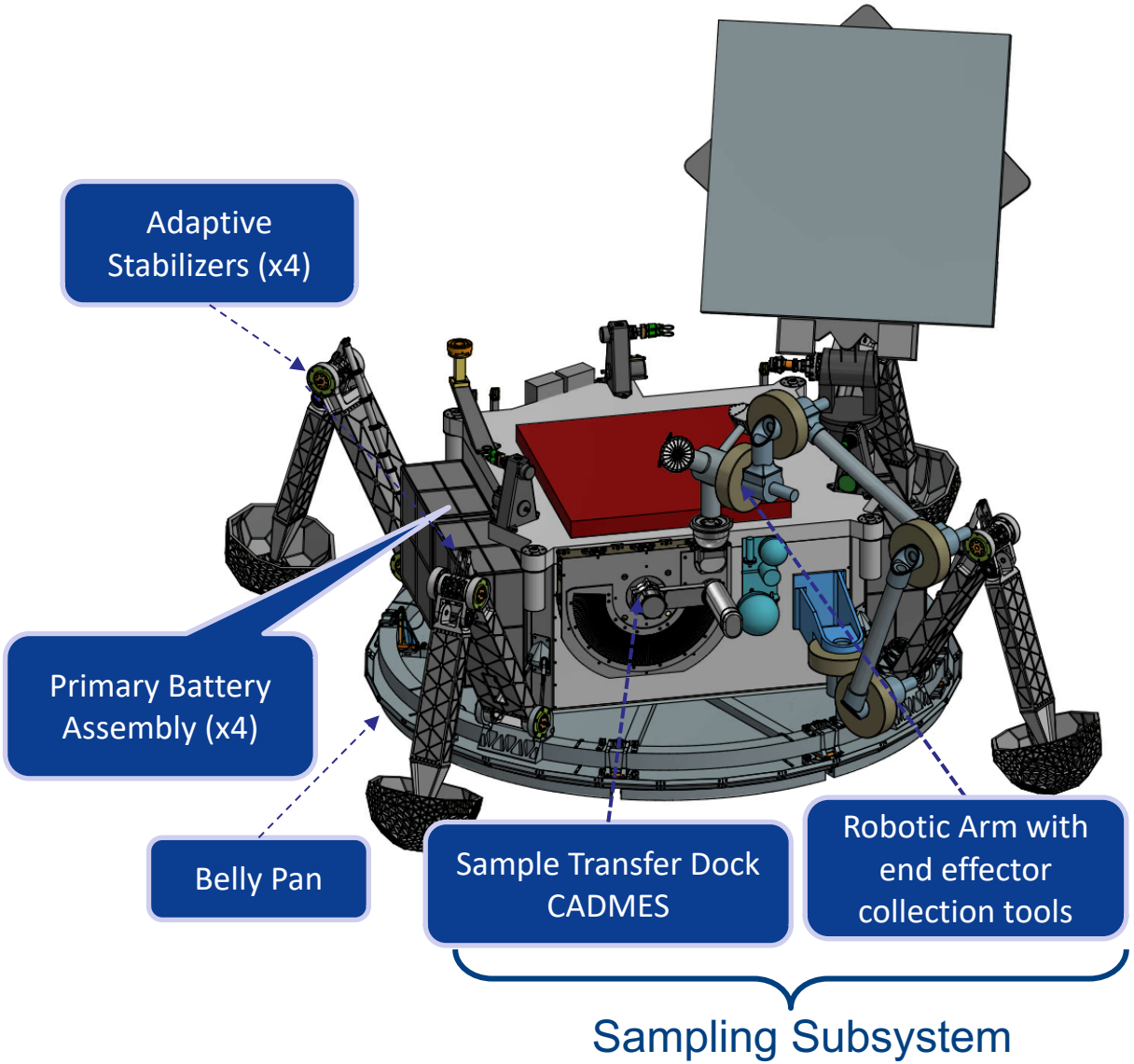
Amelia Grossman, Honeybee Robotics

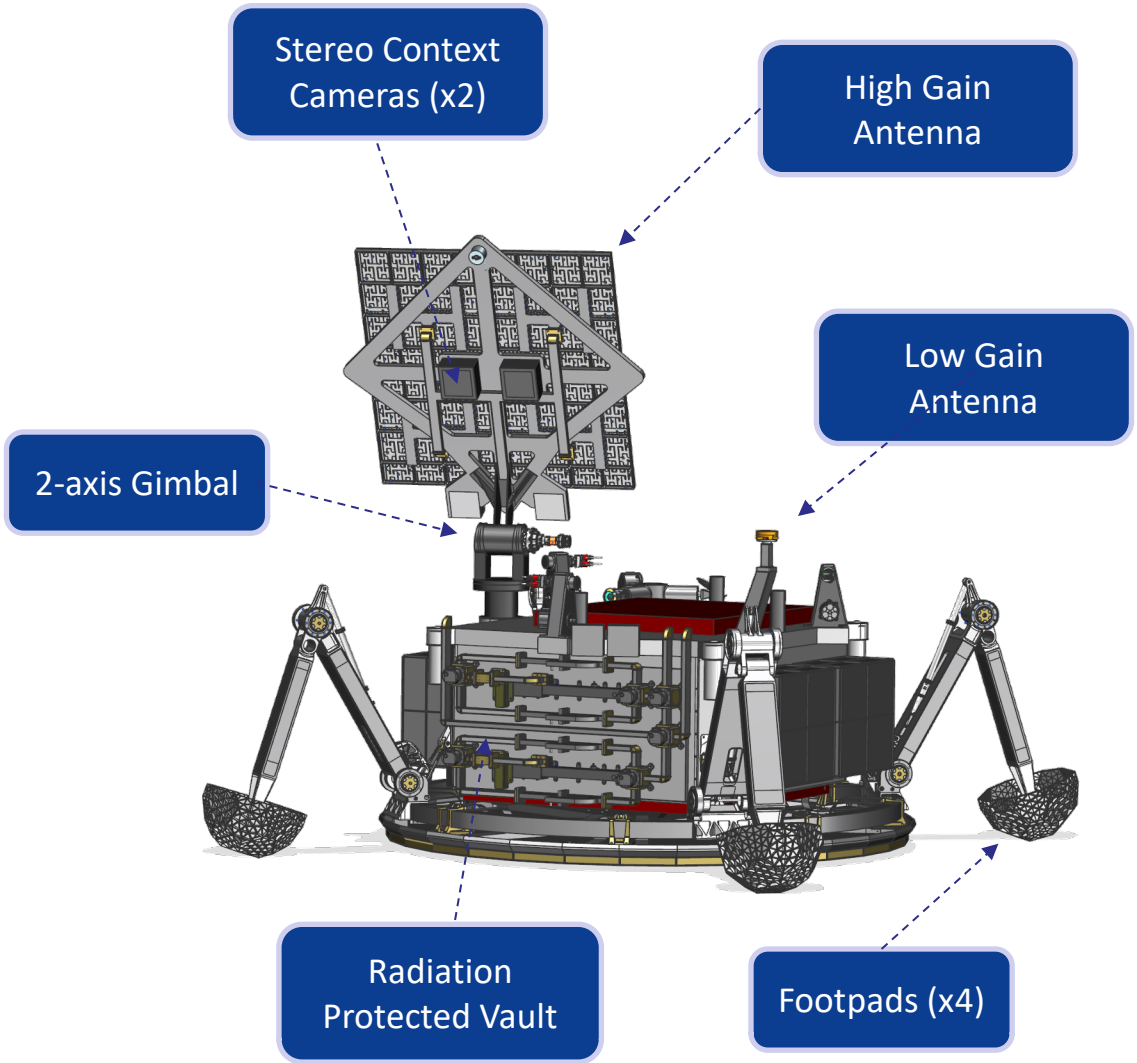
Charles Malespin, CADMES Sample Transfer ICEE-2 PI, GSFC

Jet Propulsion Laboratory
California Institute of Technology

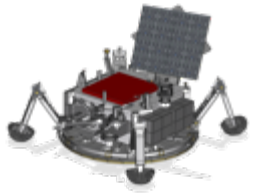
Europa Lander Baseline Surface Configuration

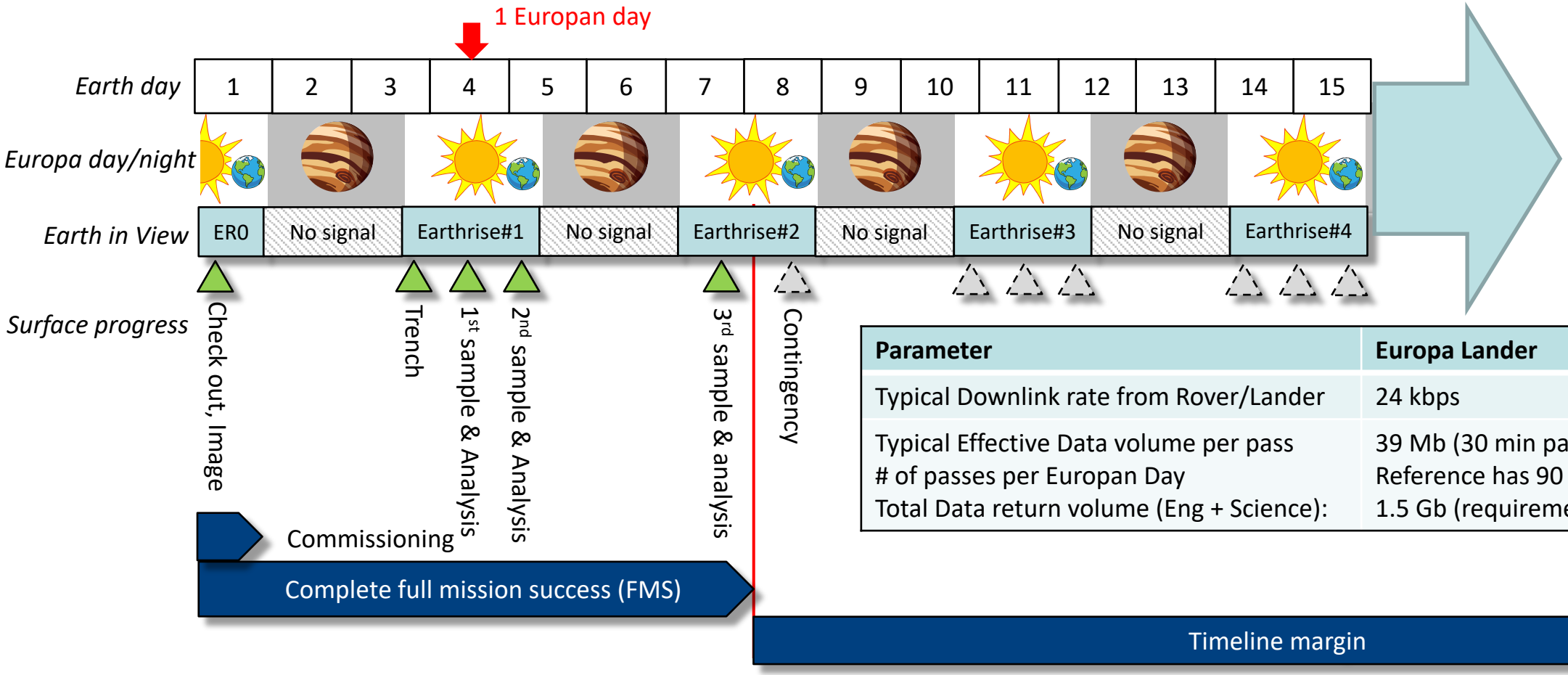






Surface Reference Timeline



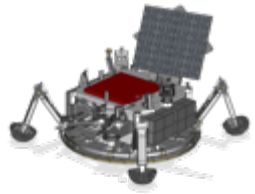


Parameter	Europa Lander
Typical Downlink rate from Rover/Lander	24 kbps
Typical Effective Data volume per pass # of passes per Europan Day Total Data return volume (Eng + Science):	39 Mb (30 min pass) Reference has 90 min/Europan day 1.5 Gb (requirement)

Possibilities for use of energy margin:

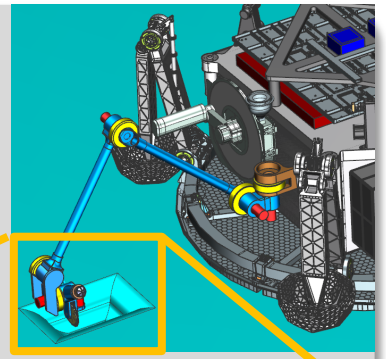
- Additional trench, sample, analysis opportunities
- Increase data return volume (more downlink time)

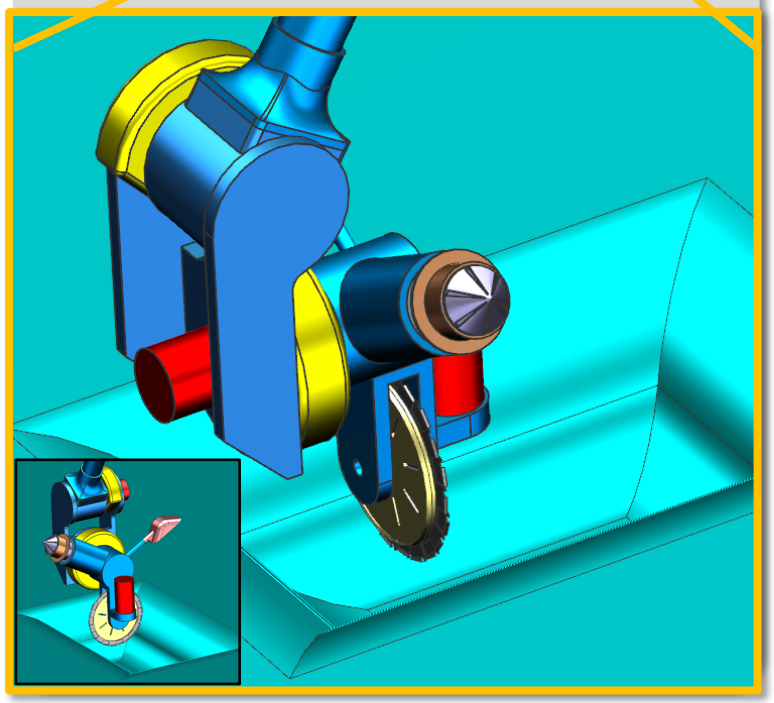
Sampling System Architecture



Excavate

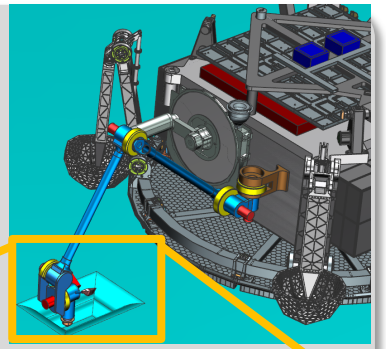
Trench >10cm & remove tailings

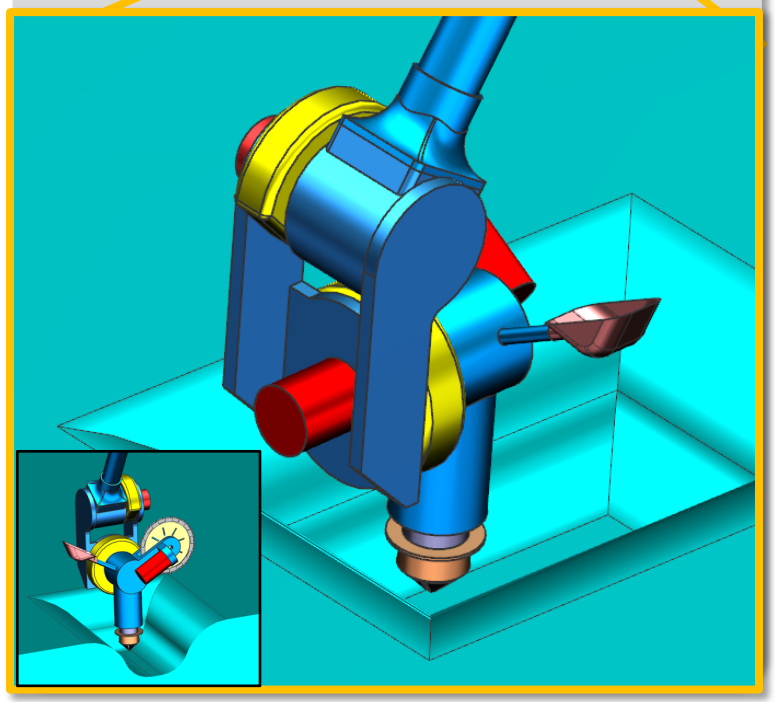




Collect

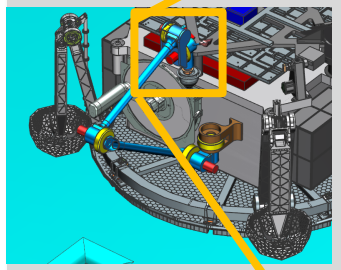
Collect from bottom of trench

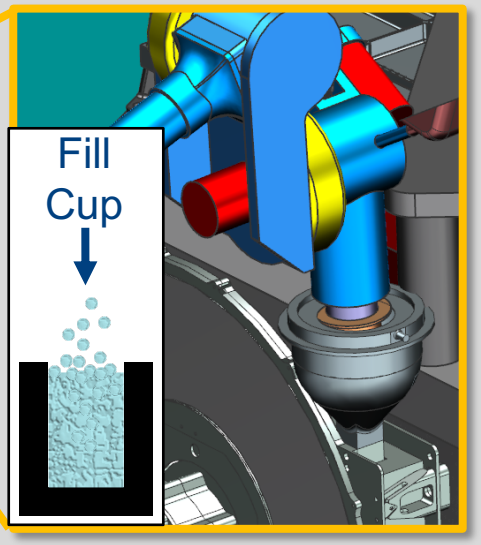




Transfer

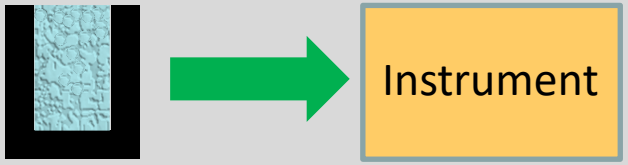
Deposit collected sample to dock



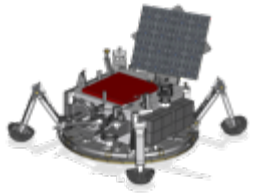


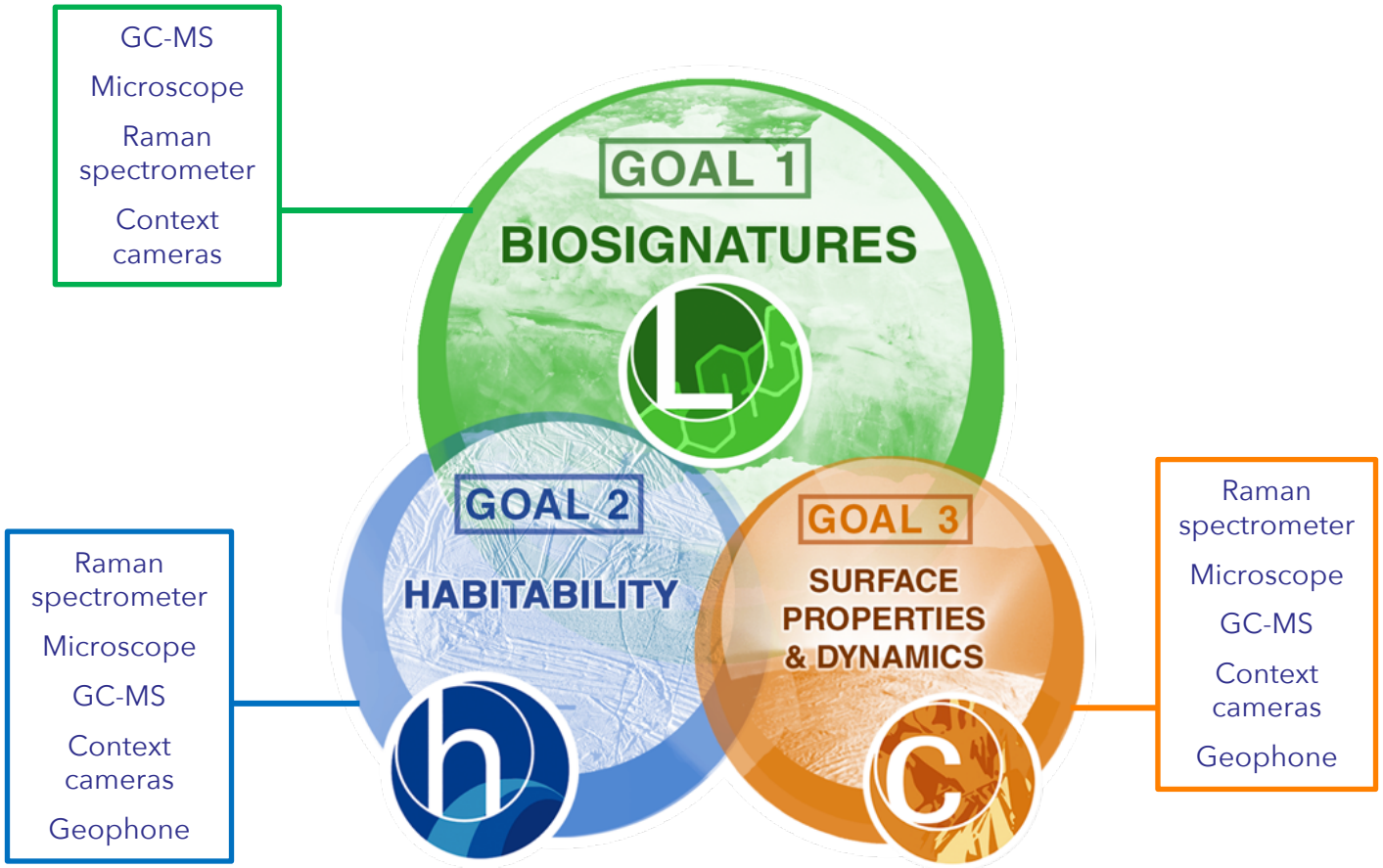
Deliver

Move cup to instrument



Europa Lander SDT Model Payload and Sample Requirements

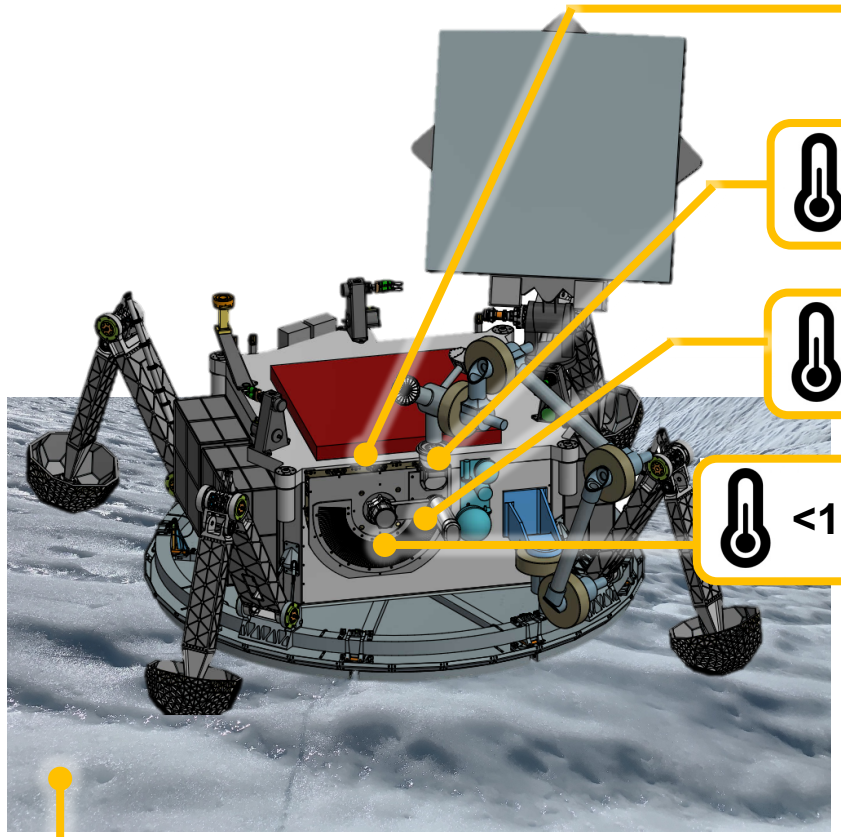




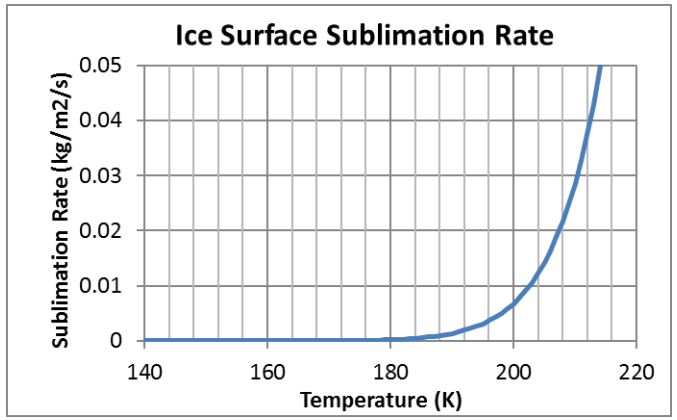
Key Sample Requirements

- Sample >10cm below surface
- Maintain sample temp <=150K
- 3 samples to each of 3 instruments

Sample Handling Thermal Neighborhoods

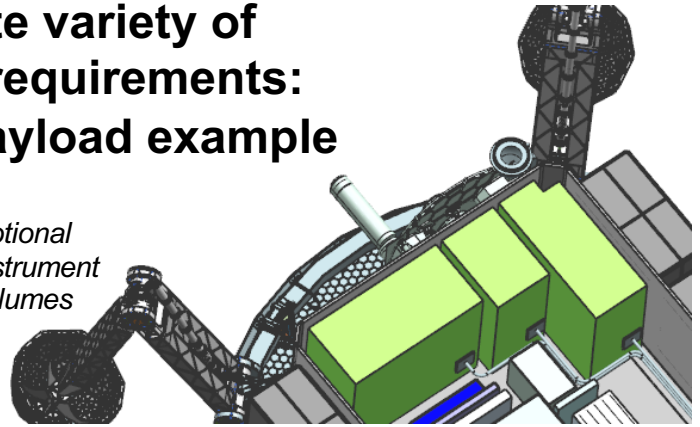


TBD	Rise due to collection/transfer
<150K	CADMES Cups
<150K	Sample requirement at instrument delivery
70-130K	Natural Europan Surface



Anticipate variety of thermal requirements: Model Payload example

Notional instrument volumes

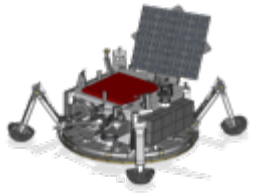


1) OCA, e.g/, MSL SAM-like
- Slow ramp from 150K for volatiles
- Max at ~ 1000K for organics

2) Vibrational Spectrometer, e.g., Raman
- Hold near 150K for ice-phase analysis
- Ramp to ~10C for liquid-phase analysis
- Desiccate for residual solids analysis

3) Fluidic biosignature instrument
- Ramp ASAP to [~ 5C] to melt
- Tightly control delta-T during analysis
- Post-analysis, purge volatiles

ROSES ICEE-2 Program
Instrument Technology Development

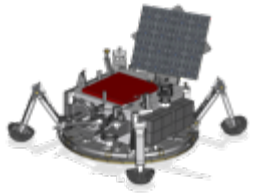


- Award Date: Feb 8th, 2019: 14 awardees selected, 2-year execution
- ROSES Call:
  - "…advance both the technical readiness and spacecraft accommodation of instruments and the sampling system for a potential future Europa lander mission … to TRL 6 in the 2021/2022 timeframe."
  - "…close interaction (including face to face) between the NASA-JPL pre-project lander study team and ICEE 2 selectees…..collaborative discussions of issues and solutions regarding instruments, the sample acquisition and delivery system, and the landed element"
- Deliverables
  - Biannual: Briefings via telecon with NASA program managers
  - End of Year 1: Initial Report on spacecraft accommodation
  - End of ICEE-2 Task: Final Report; Final Briefing at NASA HQ

We are here

ICEE-2 Awardees

PreProject is open to engaging additional instrument teams



Organic Analyzer

CORALS: Characterization of Ocean Residues and Life Signatures
PI: Arevalo, Ricardo D, U. Maryland, College Park

MASPEX-ORCA: MAss Spectrometer for Planetary Exploration -ORganic Composition Analyzer for Europa Lander
PI: Glein, Christopher R, Southwest Research Institute

MOAB: Microfluidic Organic Analyzer for Biosignatures
PI: Mathies, Richard A, UC Berkeley

EMILI: Europan Molecular Indicators of Life Investigation
PI: Brinckerhoff, W. B., Goddard Space Flight Center

Vibrational Spectrometer

CIRS: Compact Integrated Raman Spectrometer
PI: Lambert, James L., Jet Propulsion Laboratory

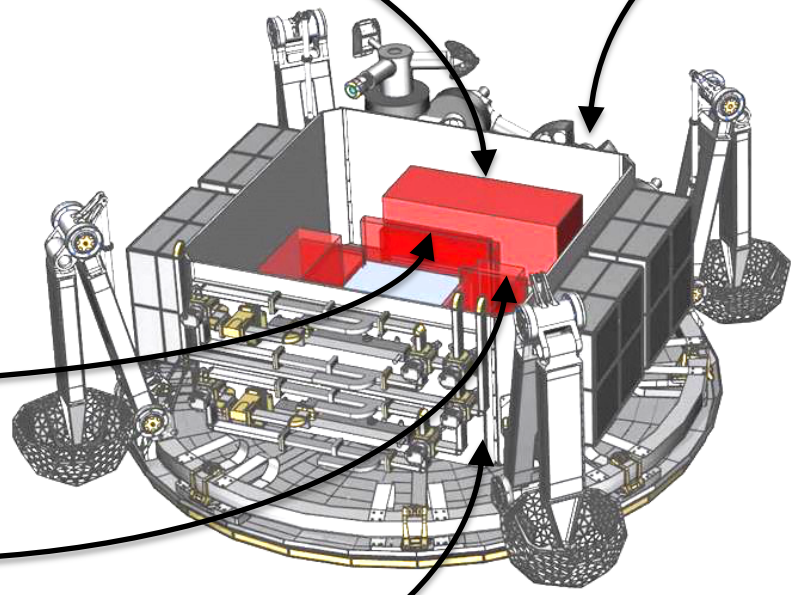
Microscope

ELM: Europa Luminescence Microscope
PI: Quinn, Richard, Ames Research Center

Seismometer

SIIOS: Seismometer to Investigate Ice and Ocean Structure
PI: Bailey, Samuel Hop, University Of Arizona

ESP: Europa Seismic Package
PI: Panning, Mark P, Jet Propulsion Laboratory



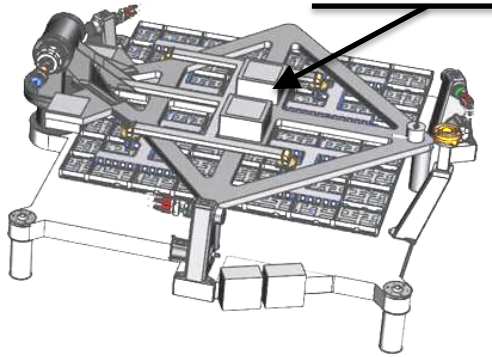
Sample Handling

CADMES: Collaborative Acceptance and Distribution for Measuring Europan Samples System
PI: Malespin, Charles A, Goddard Space Flight Center

Imager

C-LIFE: Cold-Lightweight Imagers for Europa
PI: Byrne, Shane; Univ. Of Arizona

ELSSIE: Europa Lander Stereo Spectral Imaging Experiment
PI: Murchie, Scott L, JHU/APL



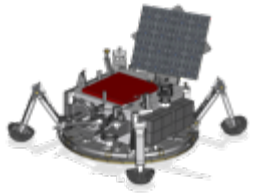
Other Potential Instrument Types

MICA: Microfluidic Icy-World Chemistry Analyzer (Inorganic)
PI: Ricco, Antonio J, Ames Research Center

MAGNET: Radiation Tolerant Magnetometer for Europa Lander
PI: Moldwin, Mark B, U. Michigan, Ann Arbor

EMS: Europa Magnetotelluric Sounder
PI: Grimm, Robert E., Southwest Research Institute

Sample Transfer Interface Approach



Design Objectives

Take 1 Design to Completion

- *Design at least 1 full sample transfer chain approach and analyze mechanical/thermal accommodation implications*

Any 3 Instruments

- *Accommodate any combination of 3 instruments*

Sample Cup Features

- *Handling features common to all instruments*
- *Other features tailored to individual instrument needs*

Sample Transfer Approach is FLEXIBLE to accommodate any future instruments

Development Process

Excellent progress. This work complete

- Select one baseline approach to sample collection and transfer to CADMES
- Survey ICEE-2 PI Sample Interface and processing requirements / desirements
- Develop initial design for instrument unique Sample Cups with common handling features
- Iterate initial design with individual ICEE-2 teams

In process. Prototype hardware being built

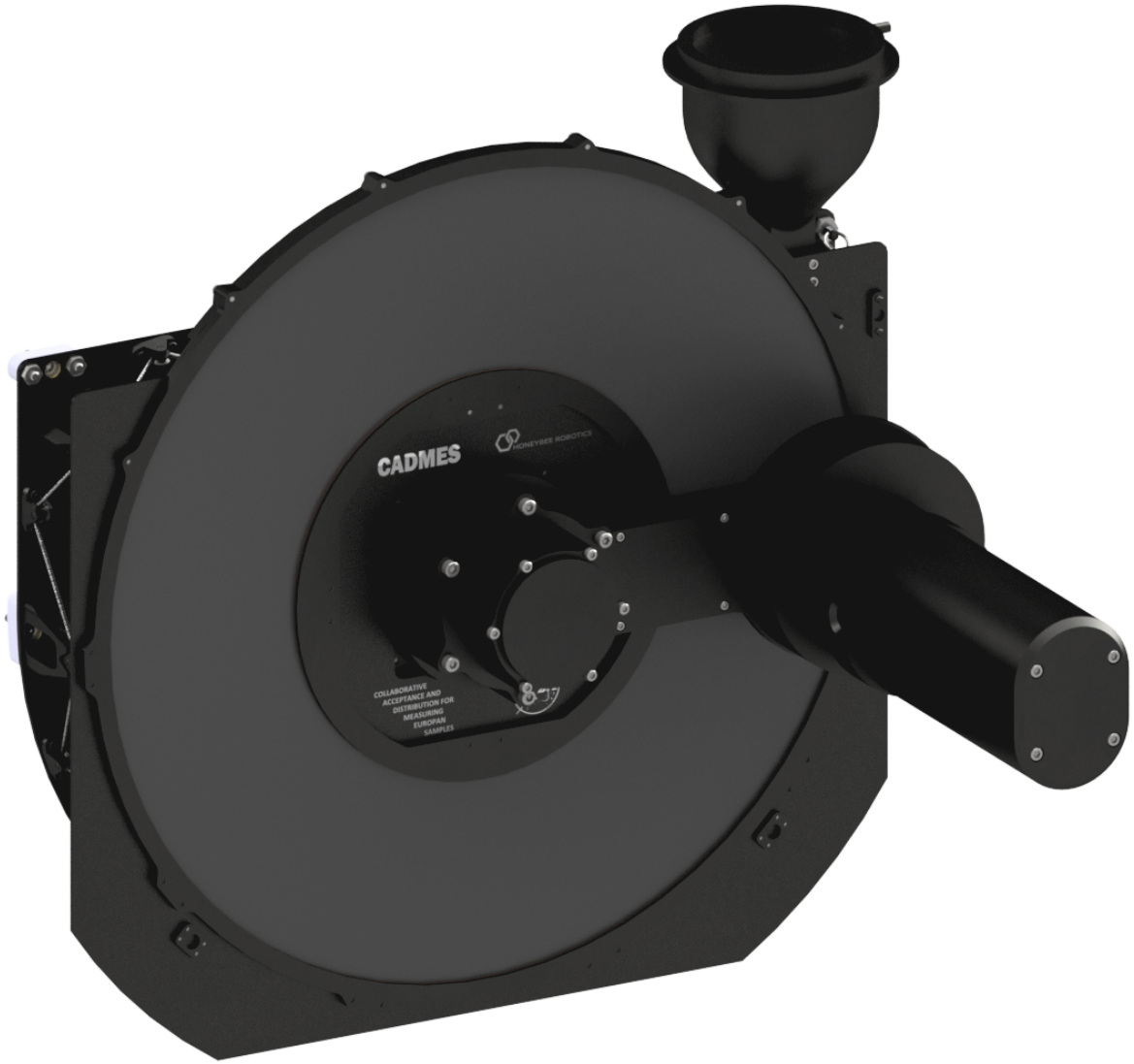
- ICEE-2 teams incorporate instrument-side of approach into their designs
- CADMES team prototypes and tests transfer approach

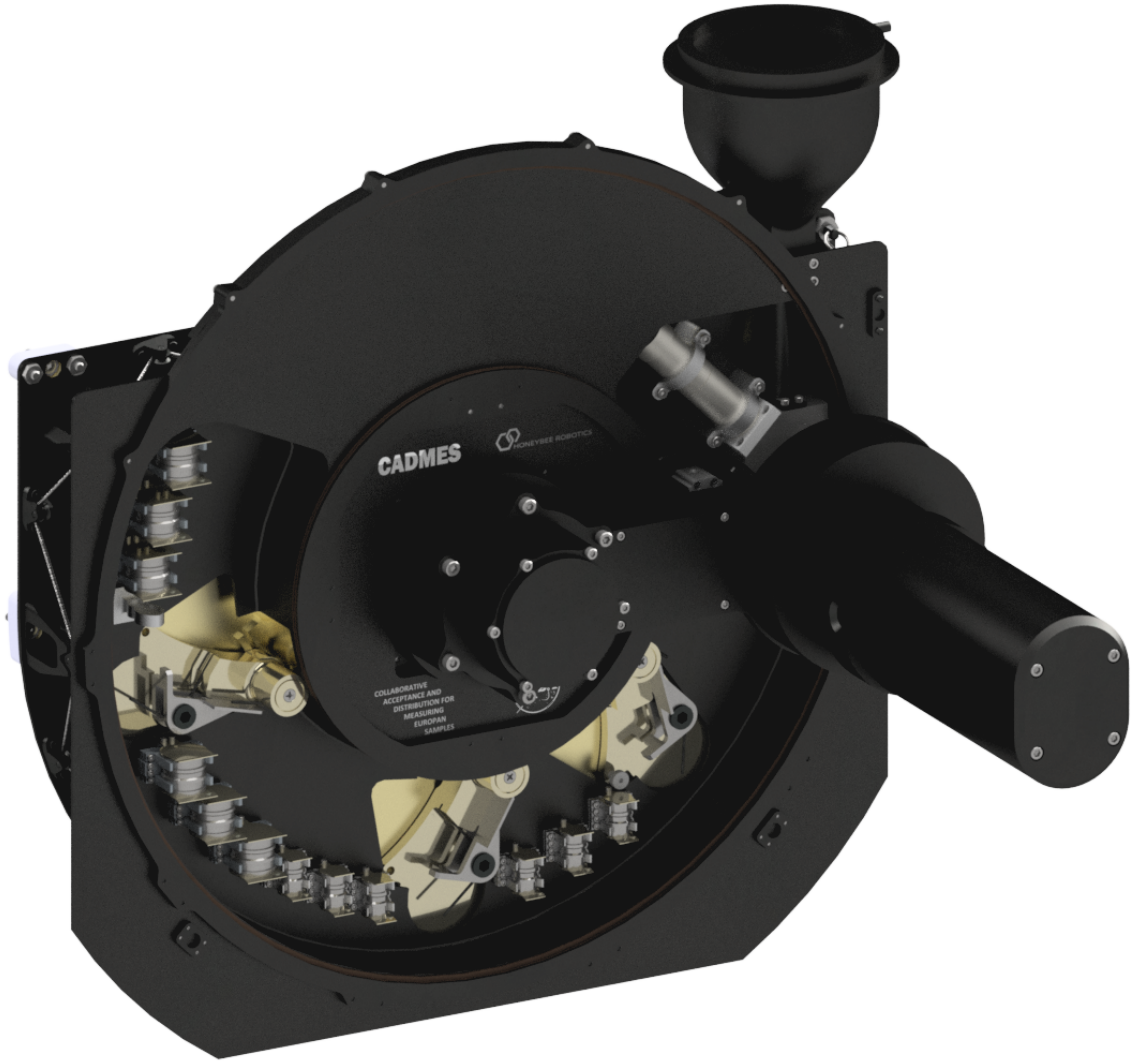
Collaborative Acceptance and Distribution for Measuring Europan Samples (CADMES)

Amelia Grossman, Honeybee Robotics
Charles Malespin, ICEE-2 PI, Goddard Space Flight Center

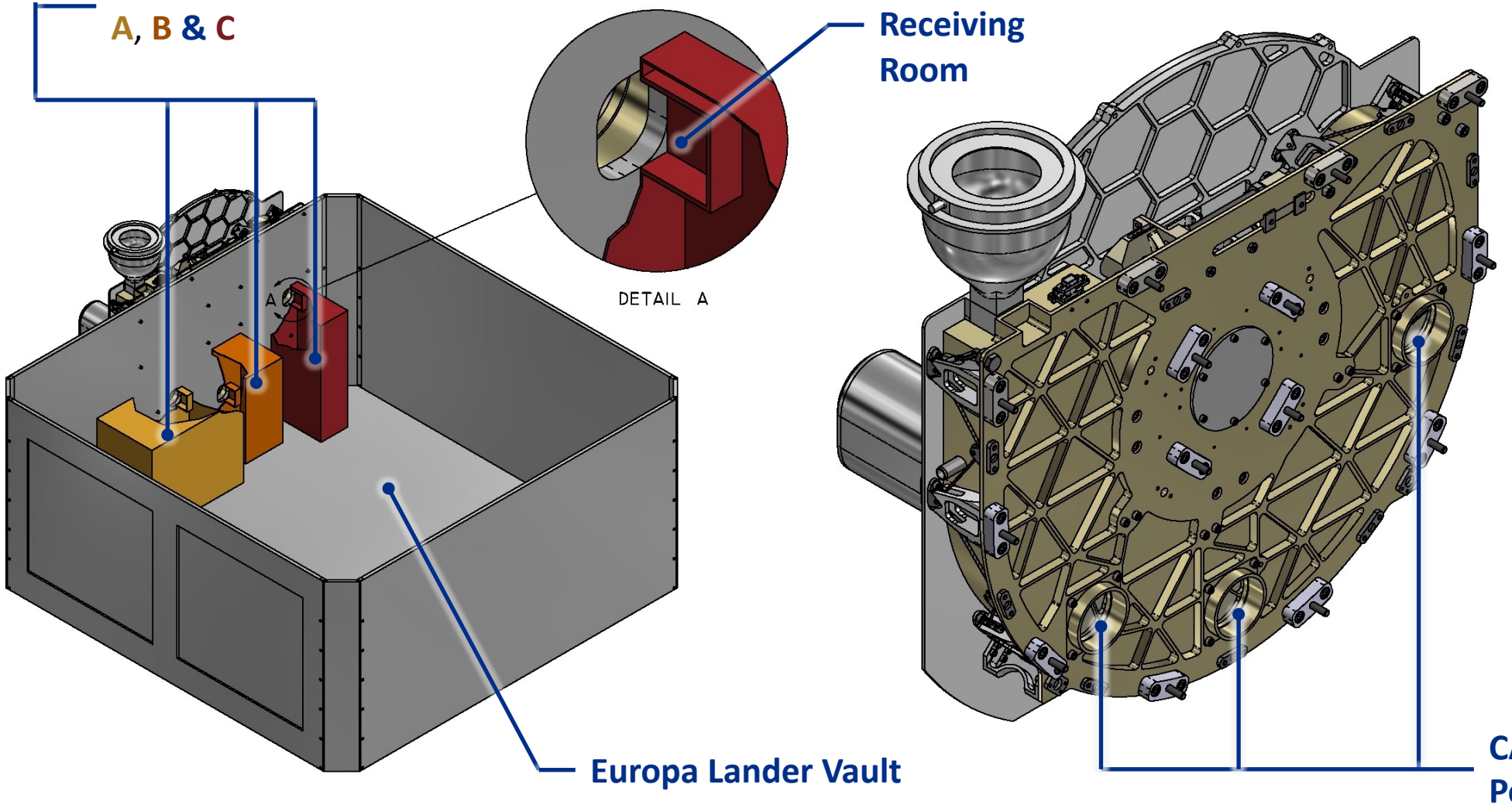
HONEYBEE ROBOTICS

CADMES with and without Dust Shield



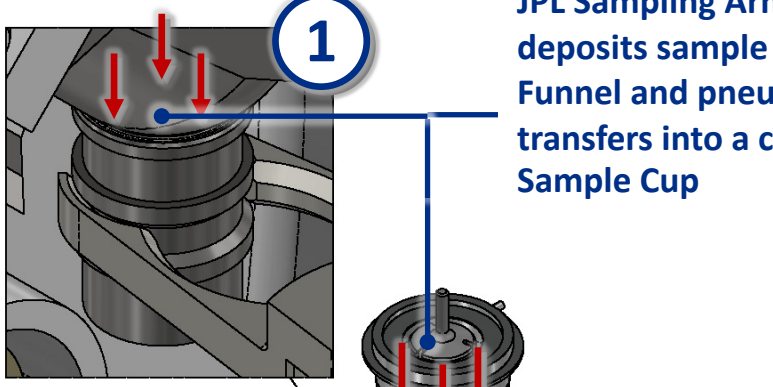


Overview of CADMES Role on Lander



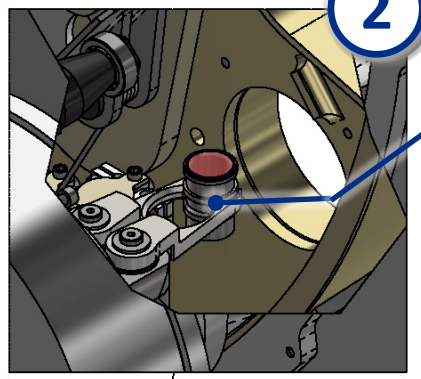
- The Europa Lander Vault will house 3 instruments requiring sample delivery from CADMES
- The instruments are currently represented as generic boxes, which reflect the volume requirements from JPL
- To accommodate the most instruments, the CADMES port locations (for instrument access) were chosen along the path of an arc
- Instruments receive sample from CADMES in their Receiving Room, ultimately designed by the instrument

Overview of the CADMES Mechanism Operations



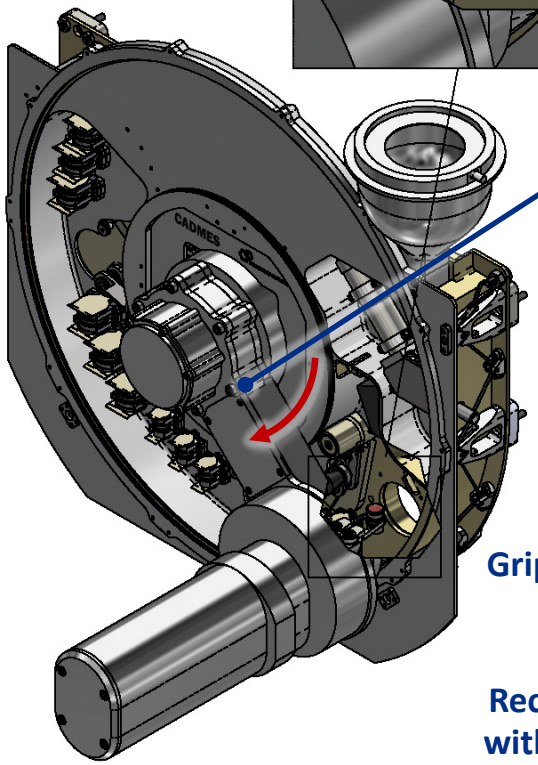
1

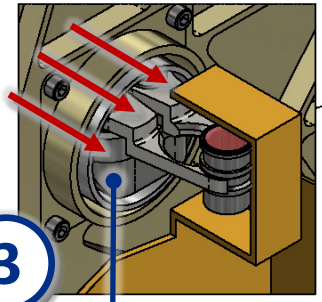
JPL Sampling Arm deposits sample into Inlet Funnel and pneumatically transfers into a clean Sample Cup



2

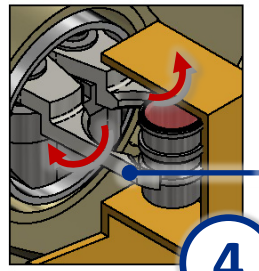
Swing Arm rotates to an Instrument Port with a filled Sample Cup





3

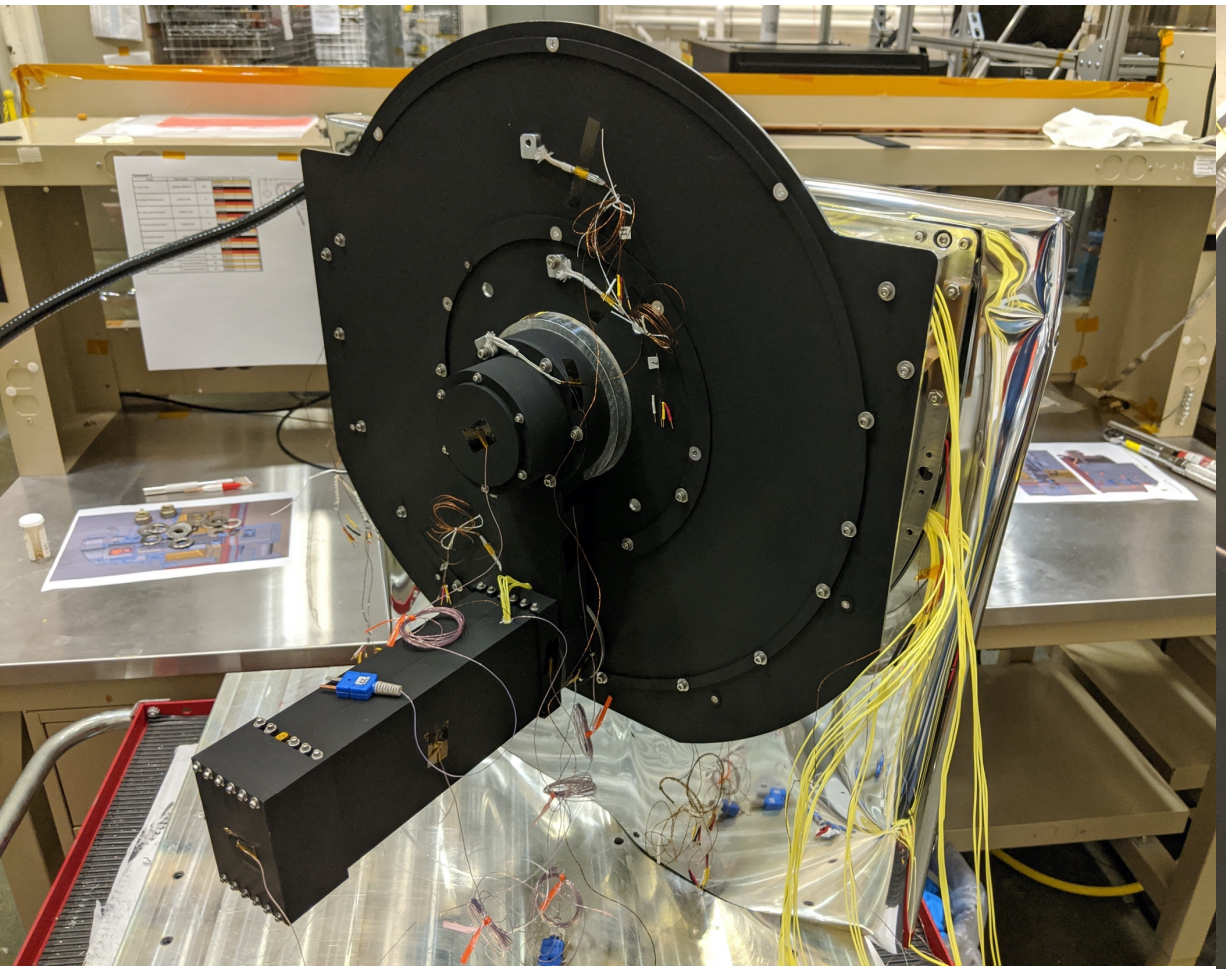
Gripper extends into an instrument's Receiving Room with full Sample Cup

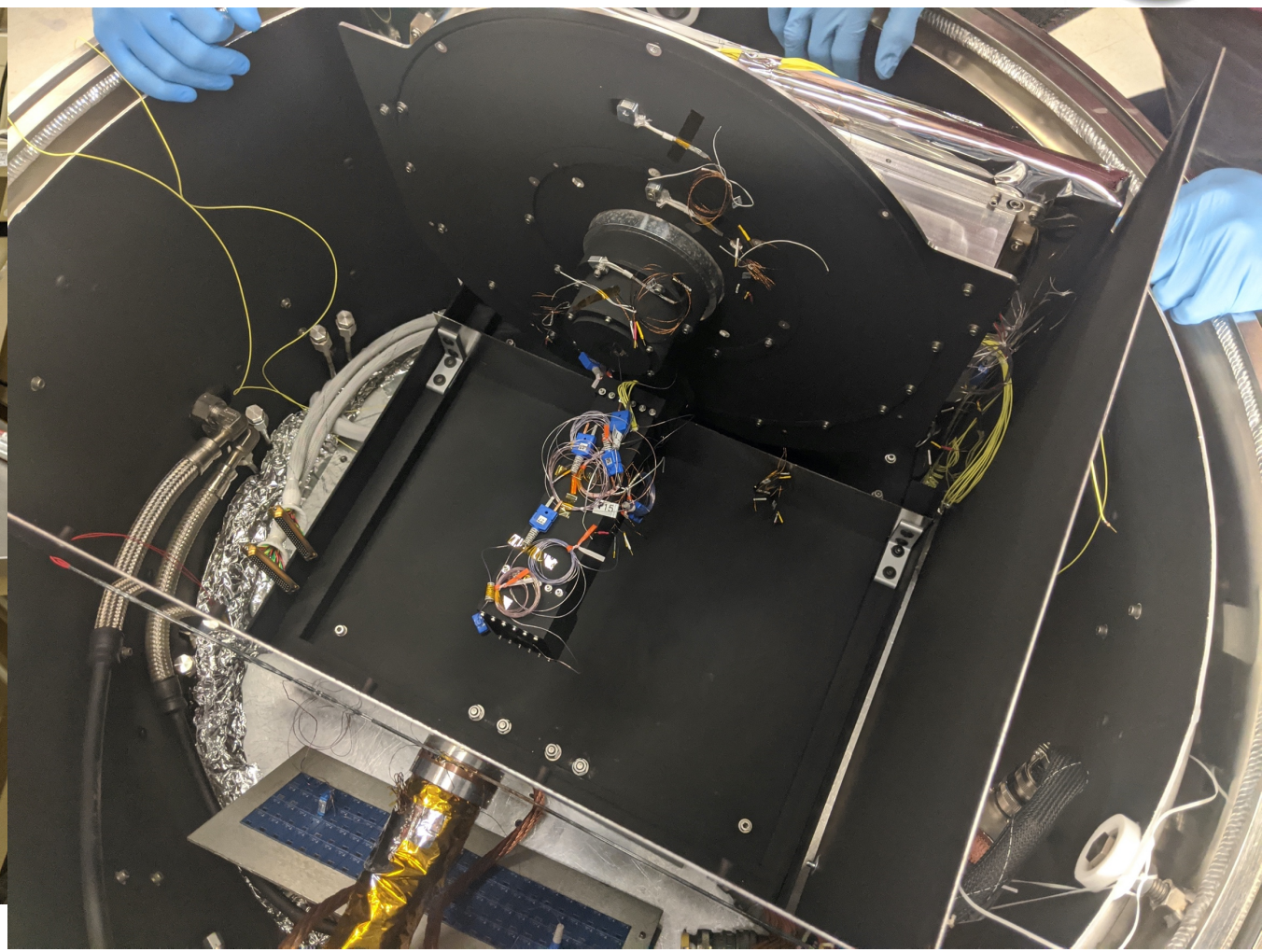


4

Gripper releases cup and retracts out of Receiving Room to repeat the process with next sample

CADMES Thermal Brassboard in Europa TVAC chamber

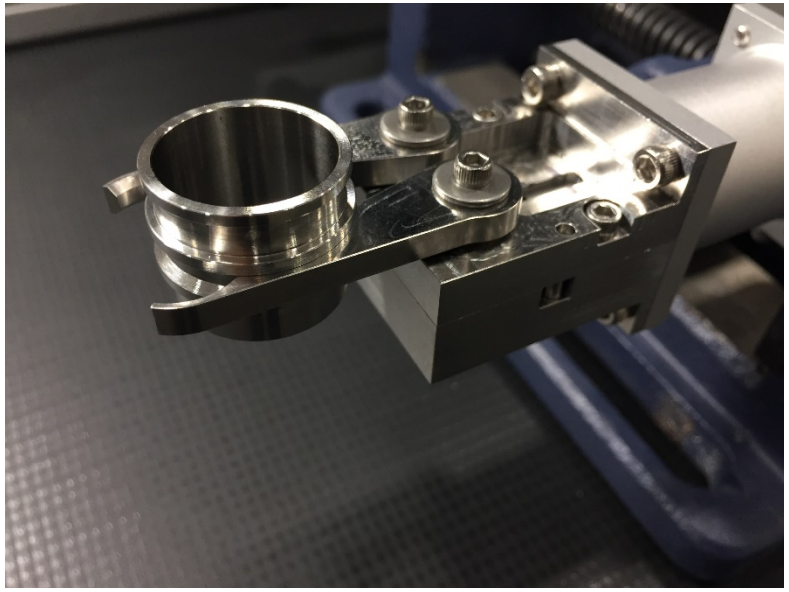


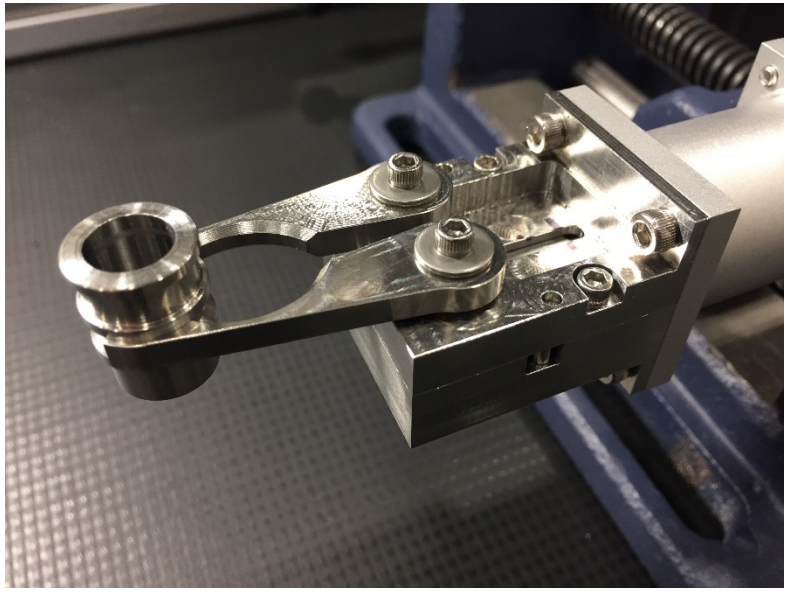


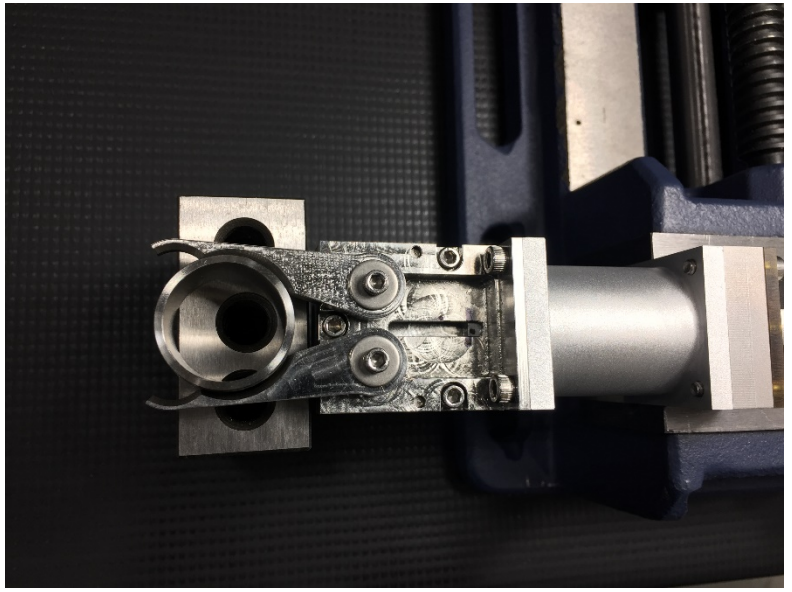
CADMES Thermal Brassboard outside of Europa Chamber

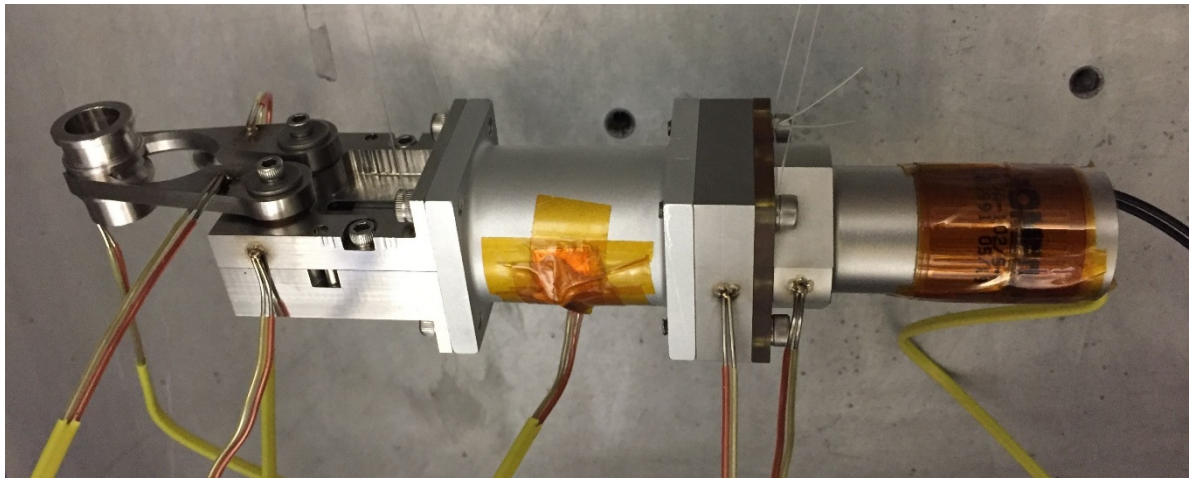
CADMES brassboard inside chamber prior to TVAC testing

CADMES Gripper Brassboard



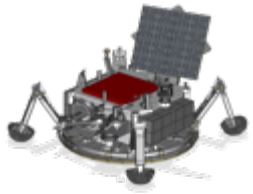






CADMES Gripper design was tested to accommodate a variety of cup sizes, allowing instruments to custom cup for their requirements

Wrap-up



- Sample Handling and Transfer is a key, challenging piece of the Europa Lander design

- Collaboration across multiple teams is making good technical progress:
  - ICEE-2 Sample Analysis Instrument PI-led teams
  - CADMES sample transfer team
  - Europa Lander Flight System
  - Europa Lander Sampling ***<- Next Briefing***

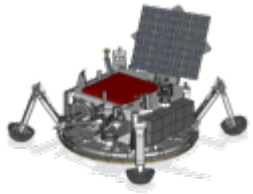
Surface Excavation and Sample Collection

Lori Shiraishi, Europa Lander Sampling Subsystem

Jet Propulsion Laboratory
California Institute of Technology

Surface Excavation and Sample Collection

Summary of Work to Date



Steady effort (over 4+yrs) to buy down risk associated with excavation and collection

dMCR review board report (Nov 2018):

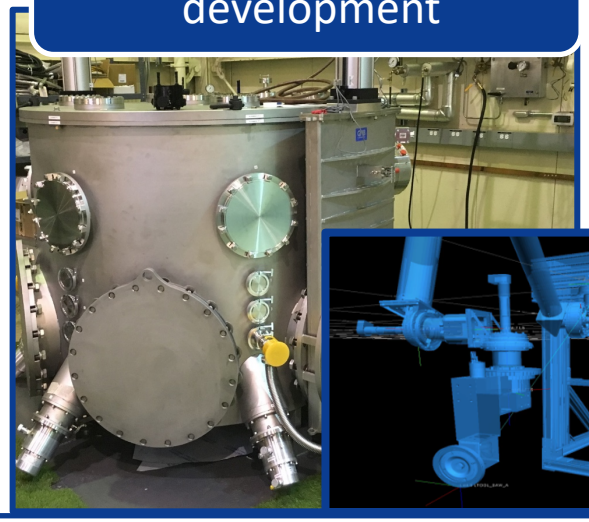
"The sample acquisition chain engineering development is well beyond a pre-Phase A level with hardware prototypes and development testing proceeding at a maturity level one would expect early in Phase B… Developing and downselecting among options for sample preparation and maturing the approach for end-to-end sample integrity must be a significant aspect of Phase A..."

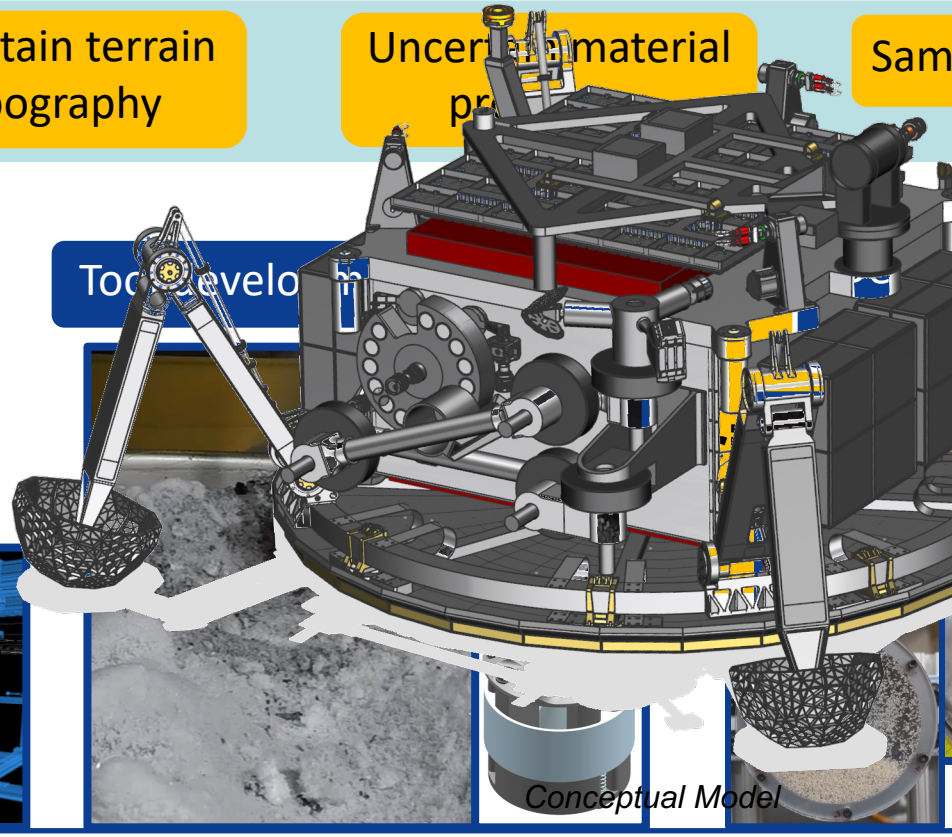
Primary Risks:

- Uncertain terrain topography
- Uncertain material pr…
- Sample Integrity
- Harsh Environment

Retire risks by:

- Testbed and autonomy development
- Tool develo…
- …ing and …esting …f sim…lants
- "Outside the Vault" Working Group

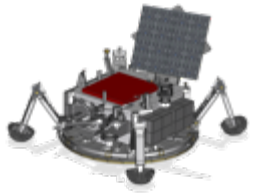




Conceptual Model

Surface Excavation and Sample Collection

CITADEL Testbed (1 of 2)



State-of-the-art cryo vac testbed

CITADEL = Cryogenic Ice Transfer, Acquisition Development, and Excavation Laboratory

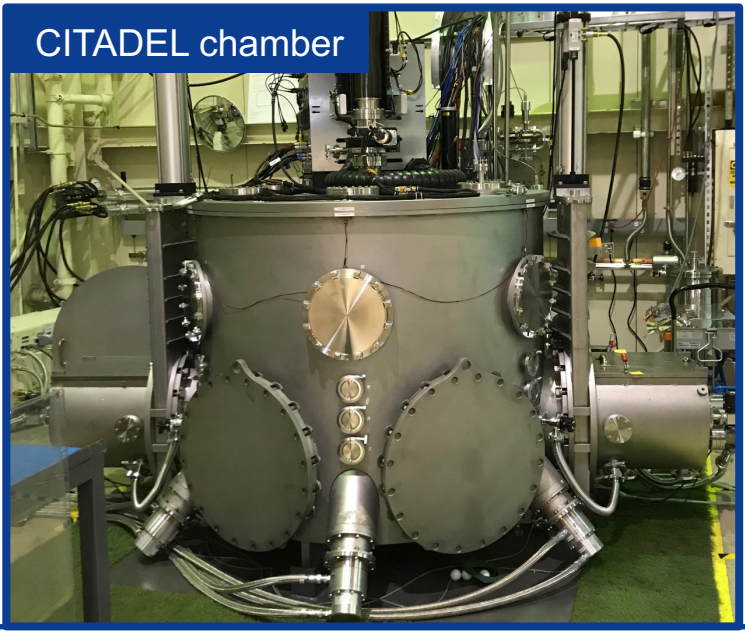
Key Specs

- ~3.5'x2'x3' inside shroud
- Able to cool test material to ~50K
- Environmental pressure < 10E-6 torr
- Load locks enable test-material reconfig while maintaining chamber environment

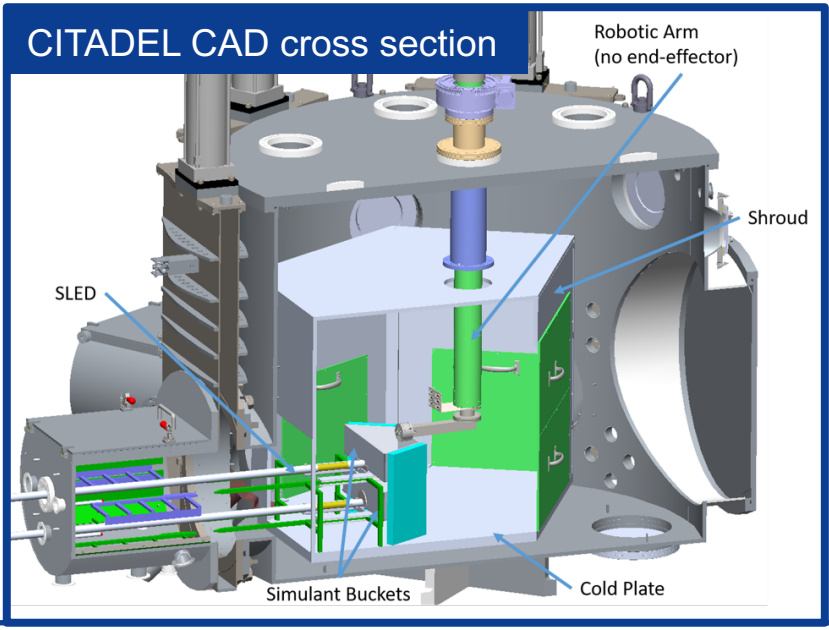
Objectives

- Observe and characterize behavior of cryo cuttings
- Test end-to-end sample integrity, including excavation, collection, sample transfer methods (pneumatic and mechanical)
- Comparison testing to prove adequacy of ambient simulants

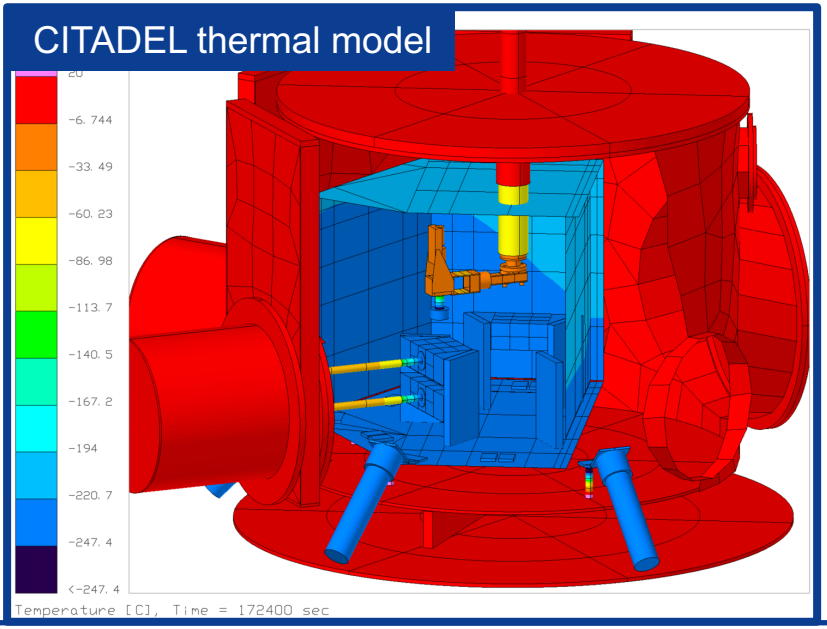
CITADEL chamber



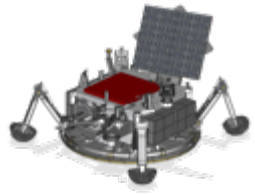
CITADEL CAD cross section



CITADEL thermal model



Surface Excavation and Sample Collection
CITADEL Testbed (2 of 2)

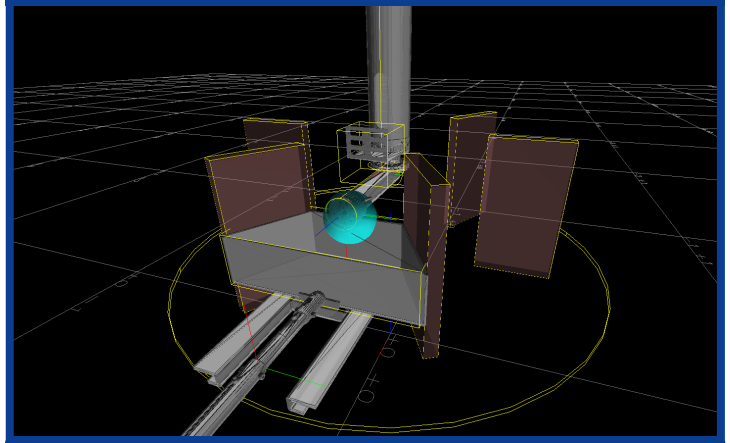


CITADEL Status

- **Testbed is functional, commissioning is complete, cryo ice cutting underway!**
- Embarking on extensive test campaign
- Pneumatics test hardware currently being installed in CITADEL

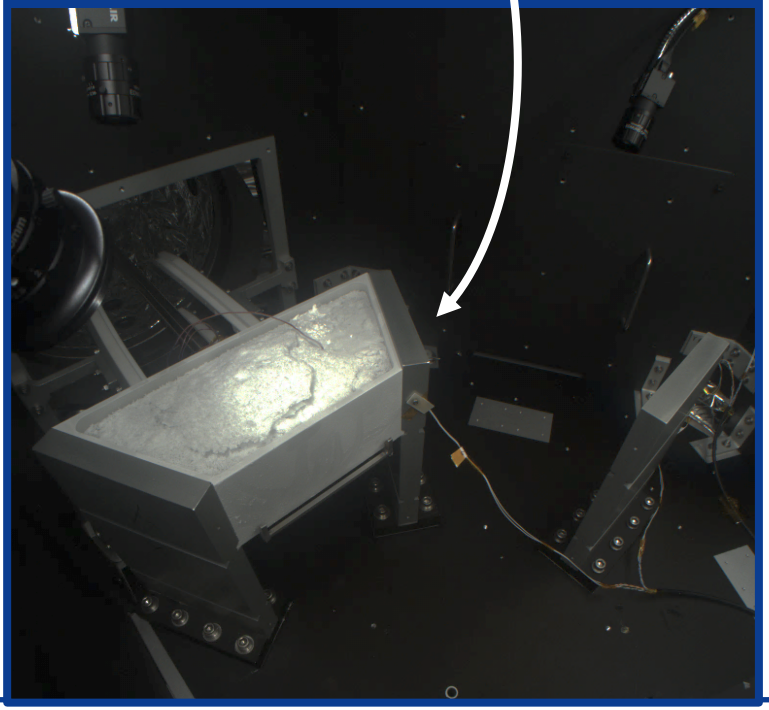
Huge milestone!
There was initial skepticism whether this test venue was even possible.

Remote operation software visualization

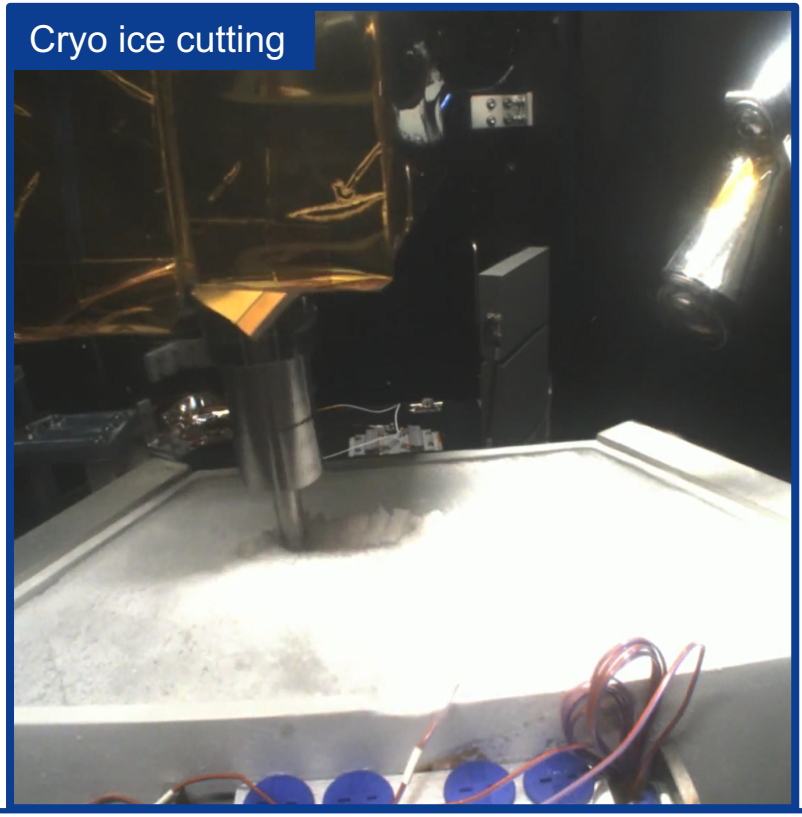


Test data products include:
- Video
- Force/torque measurements
- Motor current
- Chamber pressure
- Temperature measurements

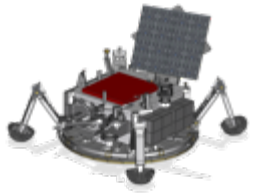
Accommodate up to 6 test material blocks
~30cm x 10cm x 8cm



Cryo ice cutting



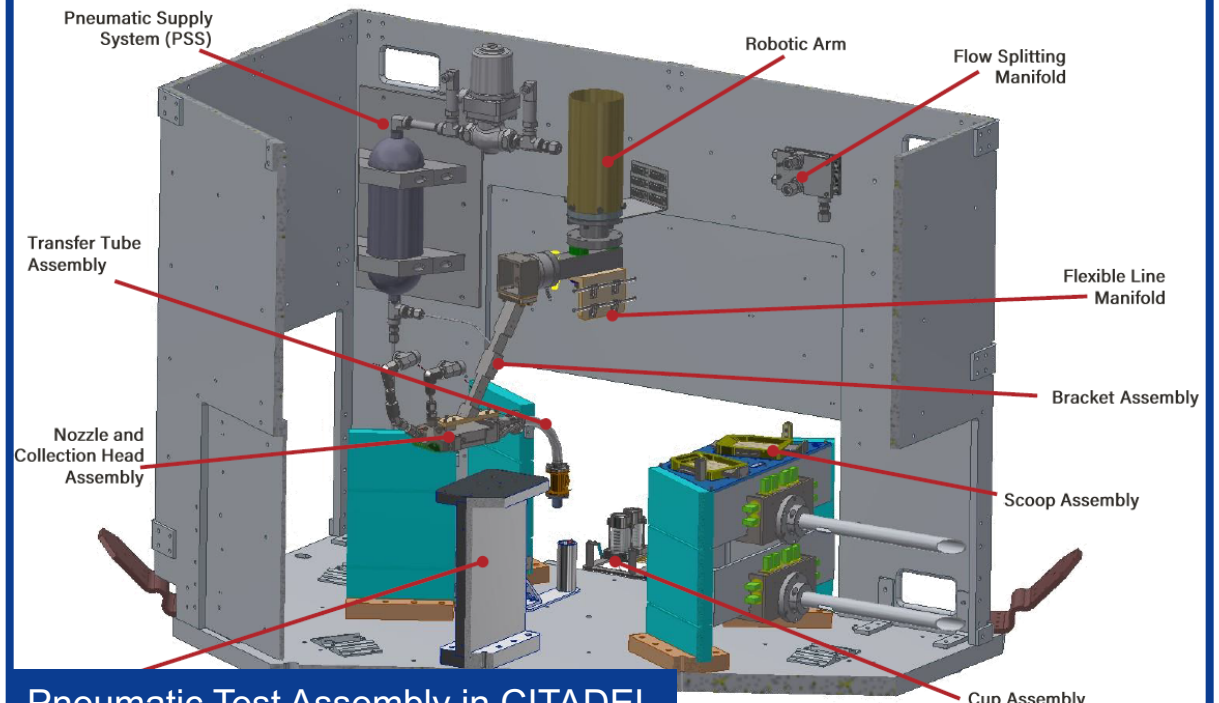
Surface Excavation and Sample Collection
Pneumatic Development



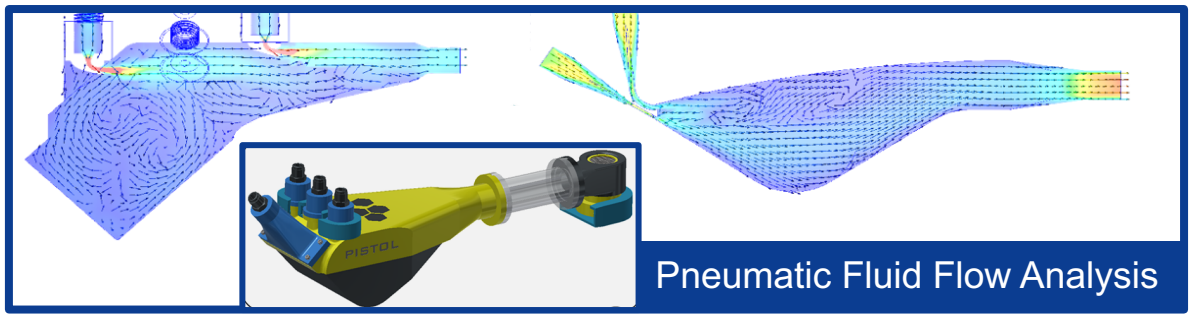
Pneumatic Sample Handling

Development work being done at both Honeybee and JPL

- **Exploring both mechanical and pneumatic methods for transporting sample during end-to-end processing**
- Significant exploration into pneumatic sample flow analysis, hardware development, and testing (ambient and vacuum)
- Developing particle fluidization testbed to verify particle dynamics and relevant material properties
- Pneumatic transfer will soon be tested at cryo vac in CITADEL

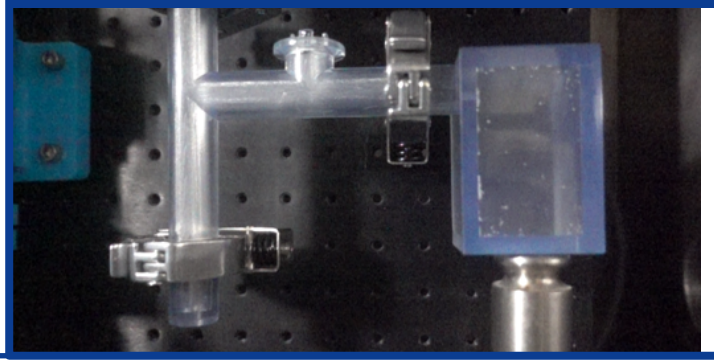


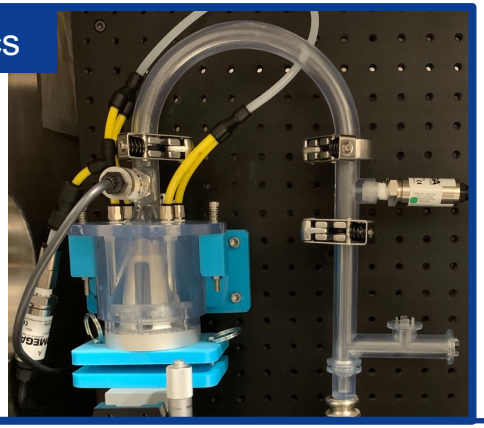
Pneumatic Test Assembly in CITADEL



Pneumatic Fluid Flow Analysis

Pneumatic Testbeds at Honeybee Robotics





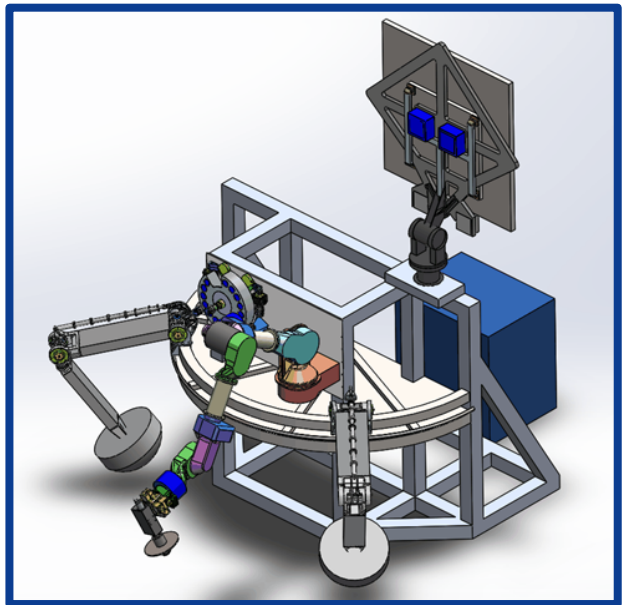
Surface Excavation and Sample Collection
Ambient Testbeds

Ambient Testbeds

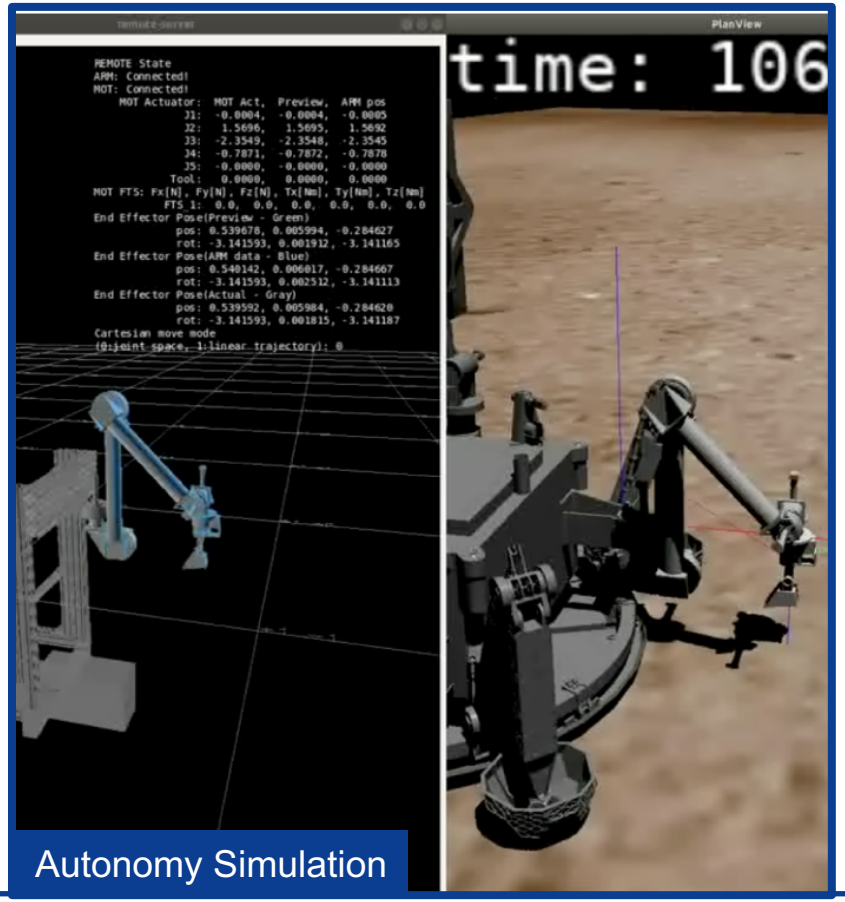
- **Variety of ambient testbeds** to investigate: autonomy algorithms, effects of system compliance, initial tool investigations
- **300+ ambient tests to date.** Most significant testbeds shown below. Variety of low DOF testbeds as well.

- StORM
- Tool testing
- 6 DOF

- SAEL v1
- Autonomy/ End-to-End Testing
- 5 DOF



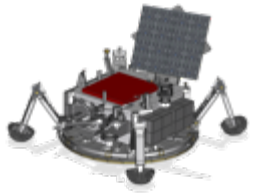
- SAEL v2
- Autonomy/End-to-End Testing
- 4-7 DOF (configurable)
- Supports range of tools/terrain
- Reconfigurable link lengths
- Reconfigurable compliance



Autonomy Simulation

Surface Excavation and Sample Collection

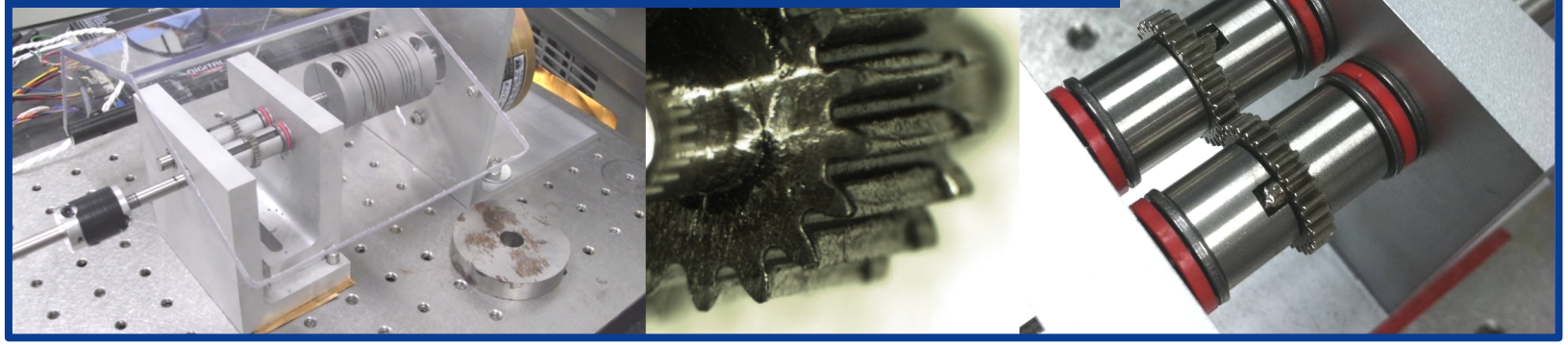
Outside the Vault Working Group



OTV Charter: *Select materials and components compatible with Europa's harsh surface environment*

- Building on relevant Clipper research, testing, data, and processes.
- Regular working group discussions with Radiation, Cabling, Materials, and Contamination Control subject matter experts
- Building on NASA Game Changing Development (2016-present) for low temperature actuators

Cold actuator material testing and component level development



Cold Actuator demonstration at 100K, vacuum
(current state of the art for Mars missions heats actuators to ~220K before use)

Cable material investigations

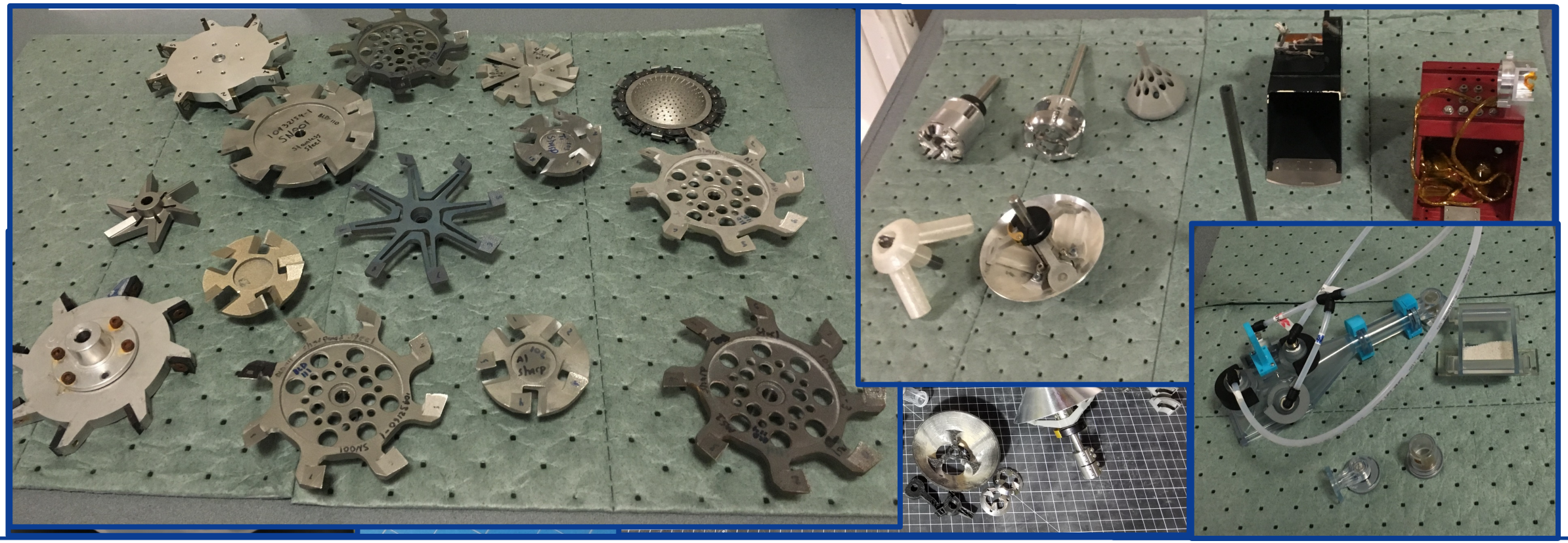
Surface Excavation and Sample Collection

Tool Development

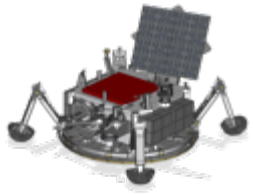
Tool Development Status

Confident we can develop an arsenal of tools which are robust to range of possible terrain and material properties.

- Have considered >200 tool concepts
- Still evaluating saws, drum cutters, rotary drills/cutting, reciprocating axial tools, augers, scoops/scrapers
- Building on *hard-earned* experience building and operating sampling systems for Mars. Pulling the right lessons learned.



Surface Excavation and Sample Collection
Simulant Development



Simulant Methodology

- Uncertain topography and material composition – need to be capabilities based for a wide range of challenges
- Developing simulants for cryo and ambient testing to identify key material properties driving device design/performance
- Mechanical properties, terrains, and boundaries defined with science team and codified in Terrain Specification Document

Develop

esting

TOPOGRAPHY

MATERIAL COMPOSITION

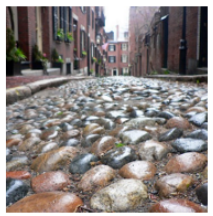
Considering range of challenges to really stress capabilities of sampling system

Topographical roughness presents different challenges at different scales

Salt Flats

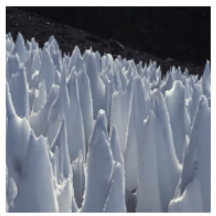
Beach

Gravel Bed



Cobblestone Street

Devil's Golf Course



Chilean Penitentes

"Hard to cut" is relative – each material has its own challenges associated with it

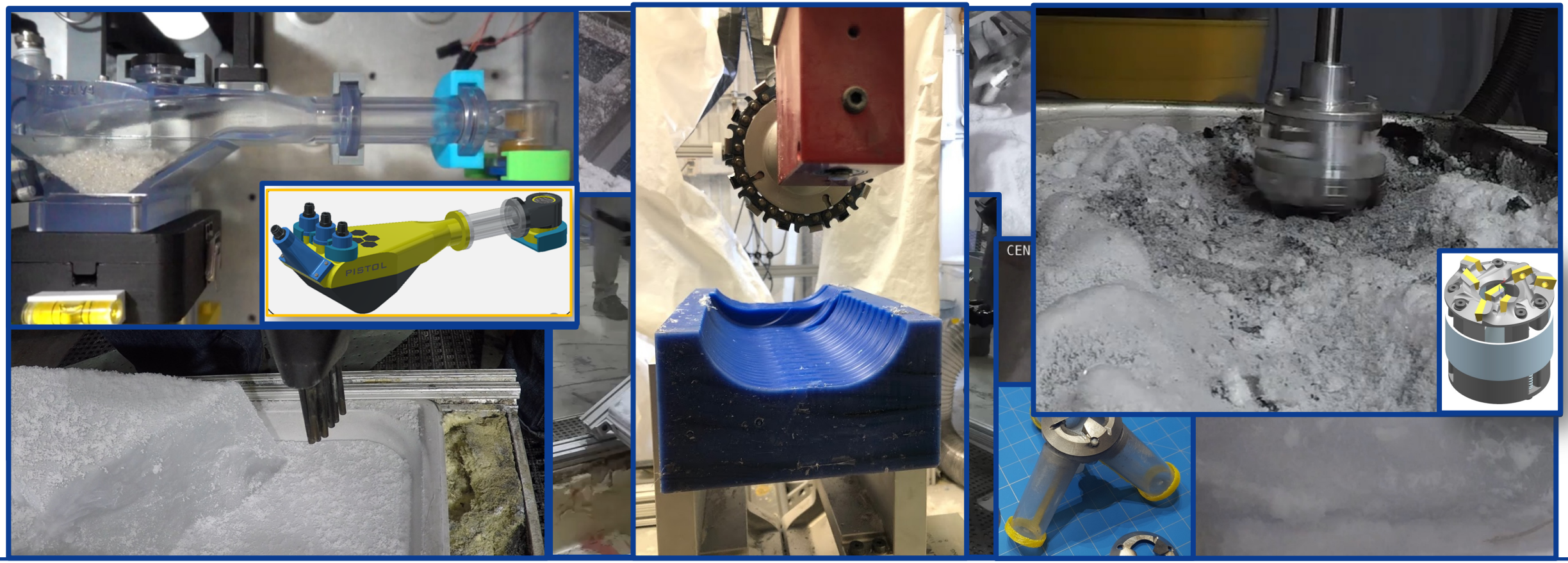
MMS Dust	Minus 30 Sand	Loose Ice	Comet Simulant	Grill Brick	Lake Koehn Evaporite	250 K	190 K	123 K	Saltwater Ice	Composite Cryogenic Ice	Kramer Massive Mudstone
						Water Ice					
• Granular and loose materials			• Low compressive strength, porous			• Ices, fractured, salty				• Heterogenous, tough	

Surface Excavation and Sample Collection

Surface Interaction

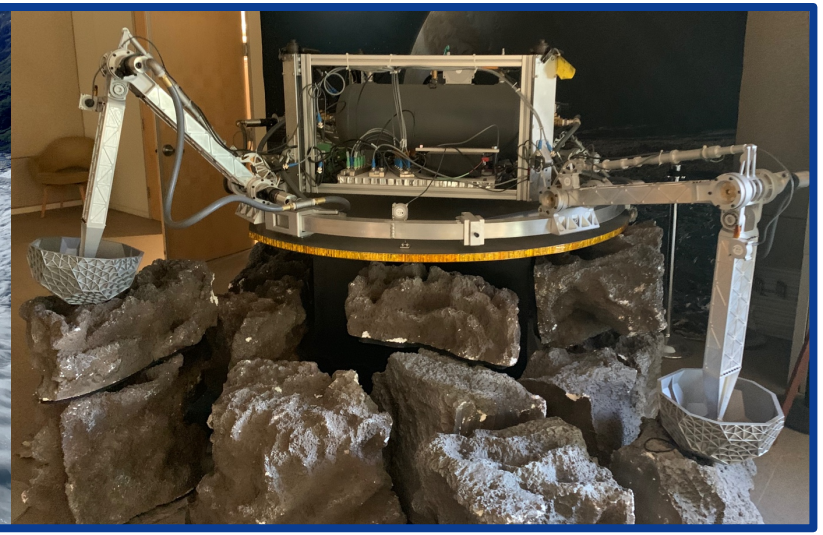
Testing Approach

- Testing range of tool prototypes in variety of terrains/simulants.
- Significant tool test campaign in development

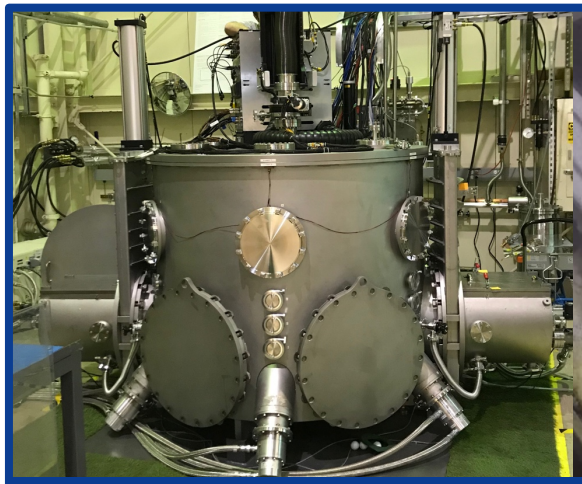


Surface Excavation and Sample Collection

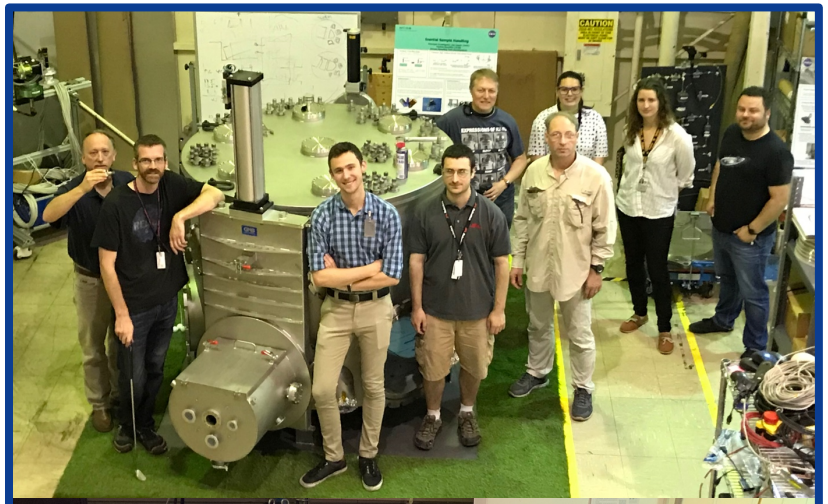
Future Plans



Autonomous Field Testing

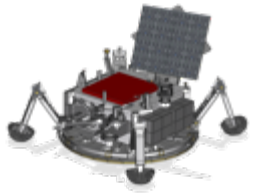


Continue risk reduction though testing and development



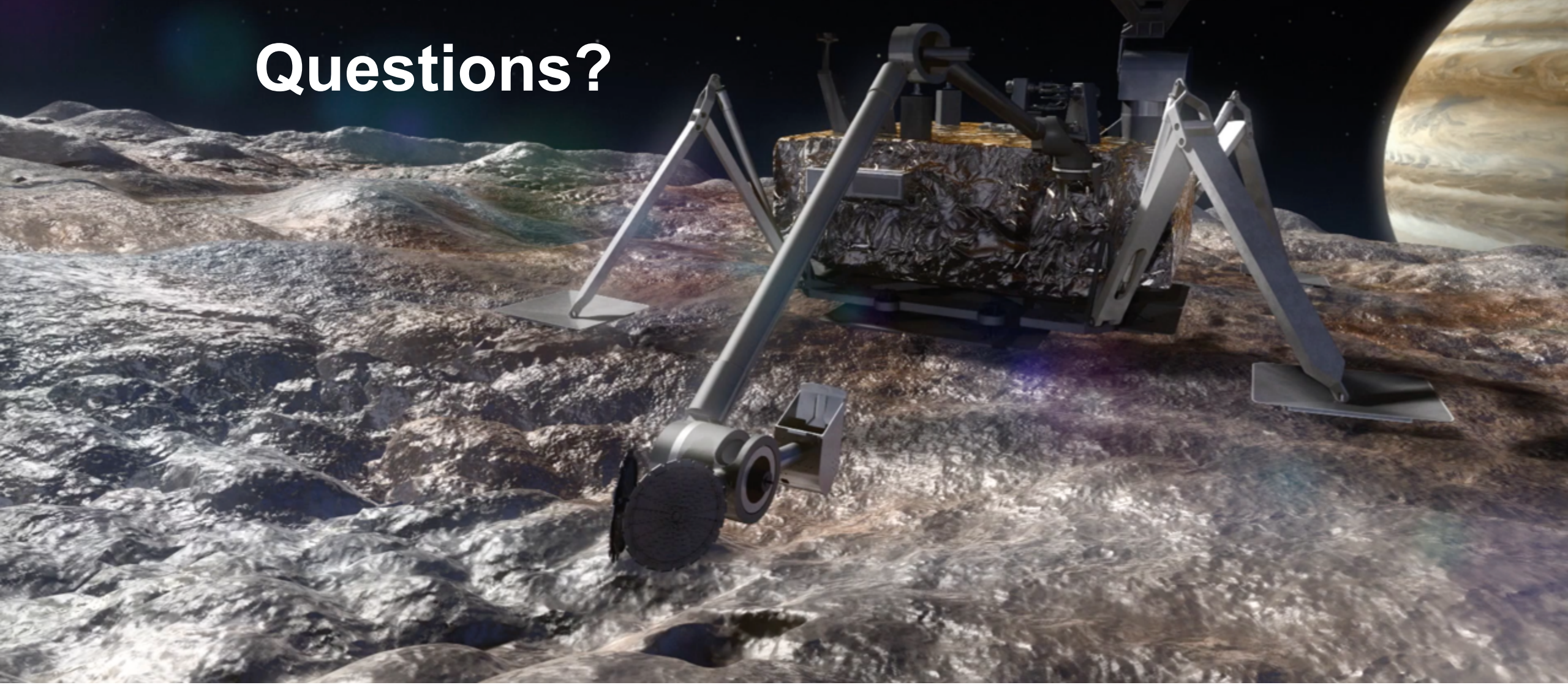
Subset of the sampling team

Wrap Up for today



- Where to find information:
  - https://www.jpl.nasa.gov/missions/europa-lander/
- Future talks: Is there interest?
  - Deorbit, Descent, and Landing
  - Autonomy
  - Planetary Protection
- Europa/Ocean Worlds Lander Decadal Survey White Paper
  - How to help, support, and potentially sign.
- Q & A from Mentimeter

Questions?



Europa/Ocean Worlds Lander Mission Concept

Europa Lander Pre-Project Science and Engineering teams

Jet Propulsion Laboratory
California Institute of Technology

Thank you!

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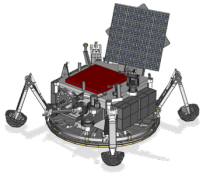
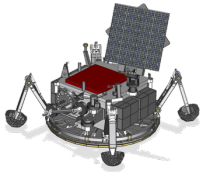


Extra/Backup Slides

Europa Lander Mission Concept



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.

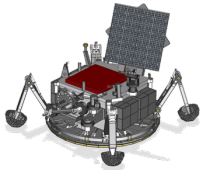
Search for Biosignatures

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.

Europa Lander Science



- Clipper provides robust dataset for landing site selection
  - Surface composition (MISE, MASPEX, SUDA),
  - Surface morphology (EIS, REASON, E-THEMIS),
  - Radiation processing (MISE, PIMS),
  - Geologic activity, indicators of surface age, and global/regional context (EIS, E-THEMIS, UVIS).
- Clipper completes Prime Mission ~5.5 years before Lander site selection date.