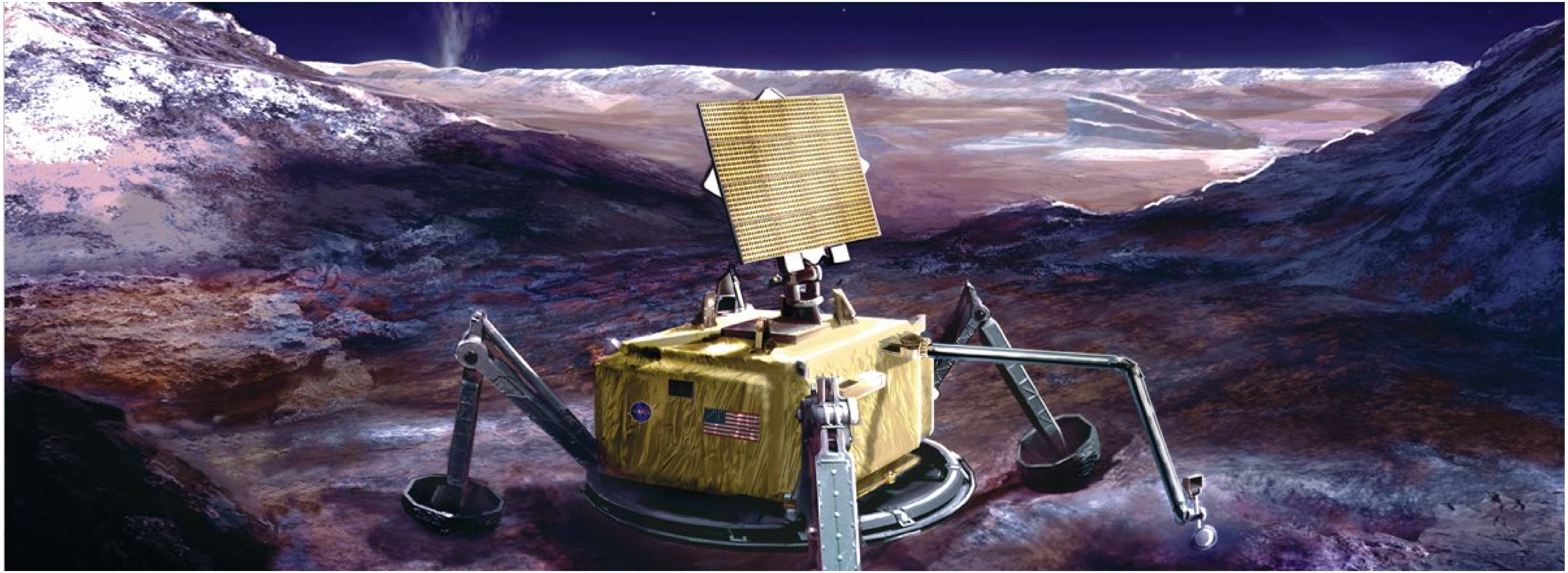

# Europa Lander Mission Concept Overview

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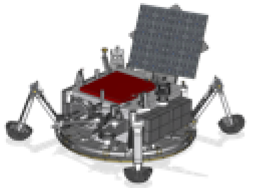
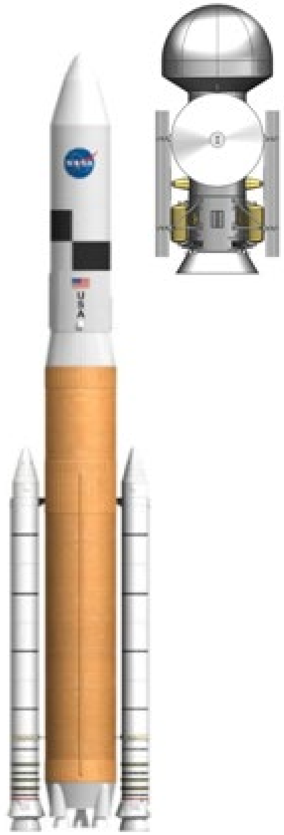
Jet Propulsion Laboratory
California Institute of Technology

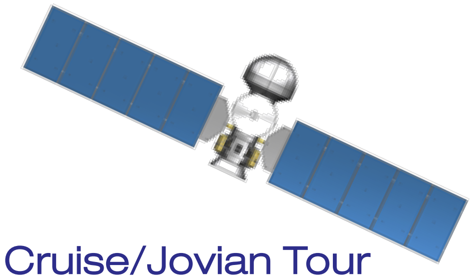
AbSciCon 2019, Bellevue, WA - June 26, 2019

# Europa Lander Mission Concept as of delta-MCR (Nov. 2018)

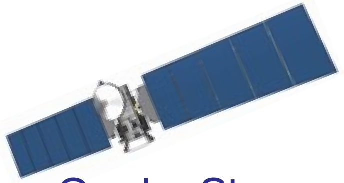




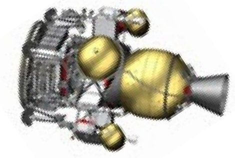
## Launch
- SLS Block 1B



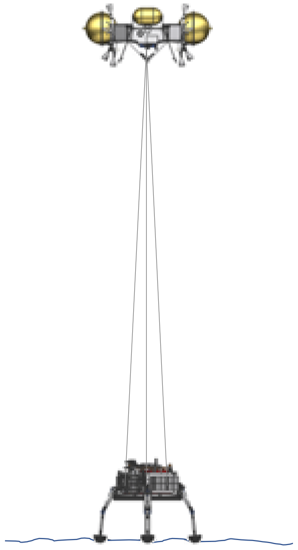
## Cruise/Jovian Tour
- Jupiter Orbit Insertion: L+4.7 hrs
- Europa Landing: JOI+2 yrs

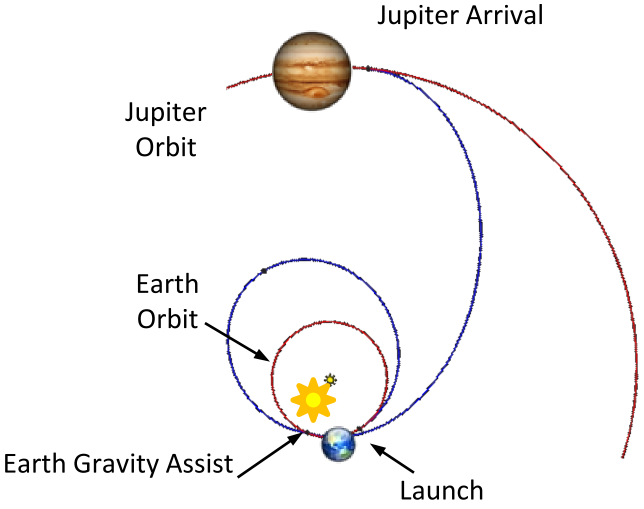


## Carrier Stage
- 1.5 Mrad radiation exposure
- Elliptical disposal orbit

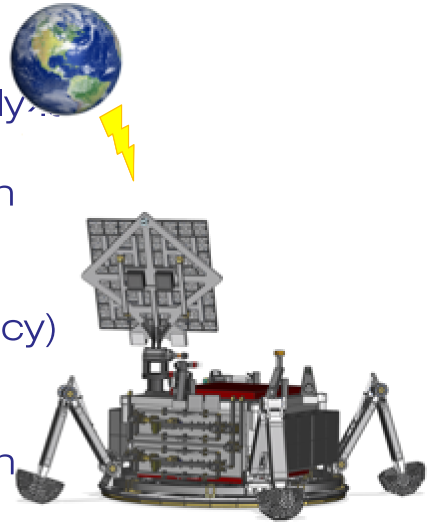


## Deorbit, Descent, Landing
- Guided deorbit burn w/solid rocket motor
- Sky Crane landing system
- 800N throttleable engines
- 100-m accuracy
- 0.1 m/s velocity knowledge
- Terrain-conforming landing system

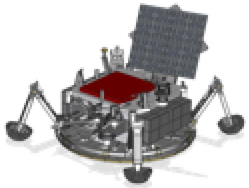


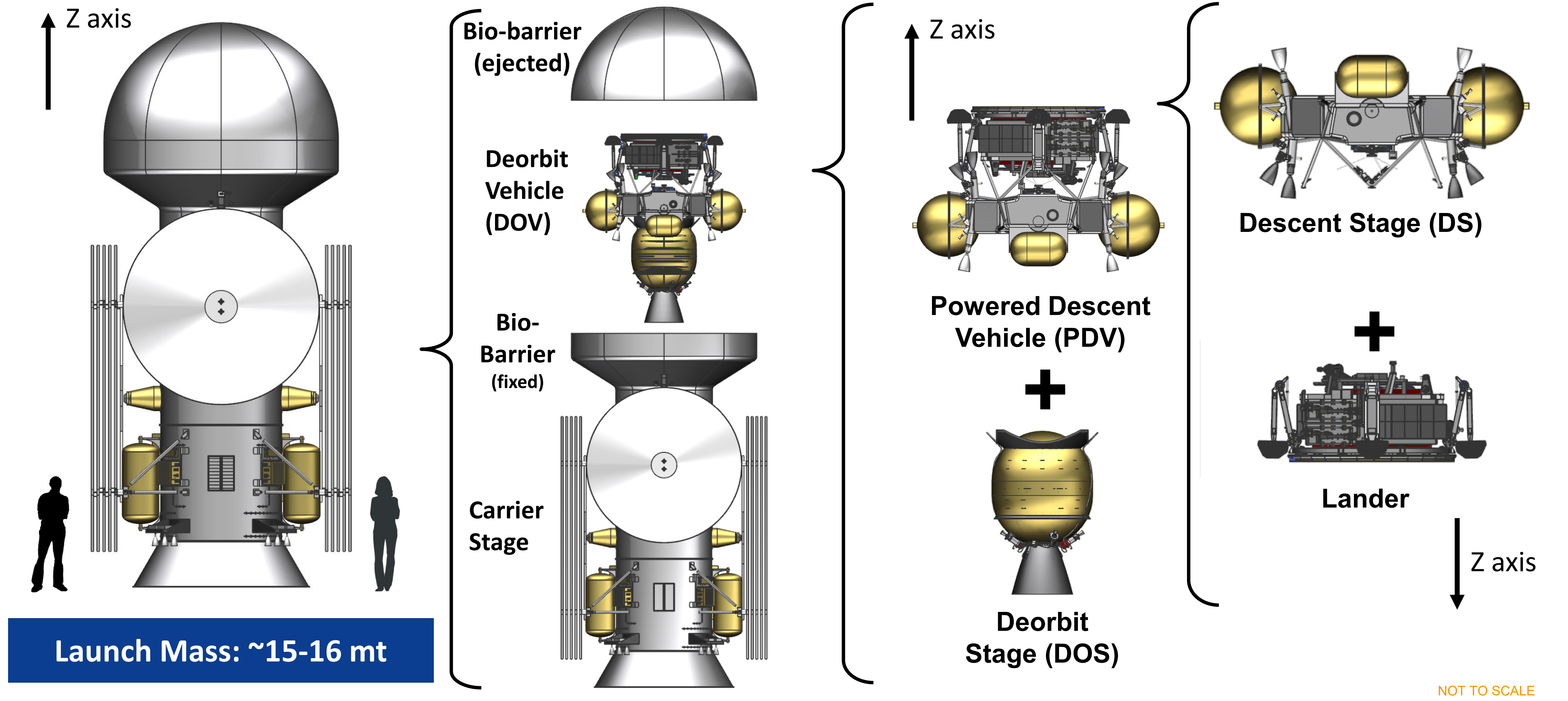



## Surface Mission
- Biosignatures, Geology, & Geophysics
- Excavate to at least 10cm, sample, and analyze cryogenic ice
- Designed for at least 22 day surface mission duration
- High degree of Autonomy
- Direct to Earth Comm or Clipper (contingency)
- 1.5 Gbit data return
- 2.0 Mrad radiation exposure
- Terminal Sterilization for Planetary Protection

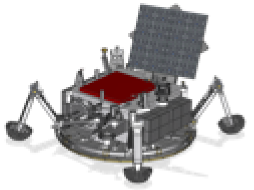


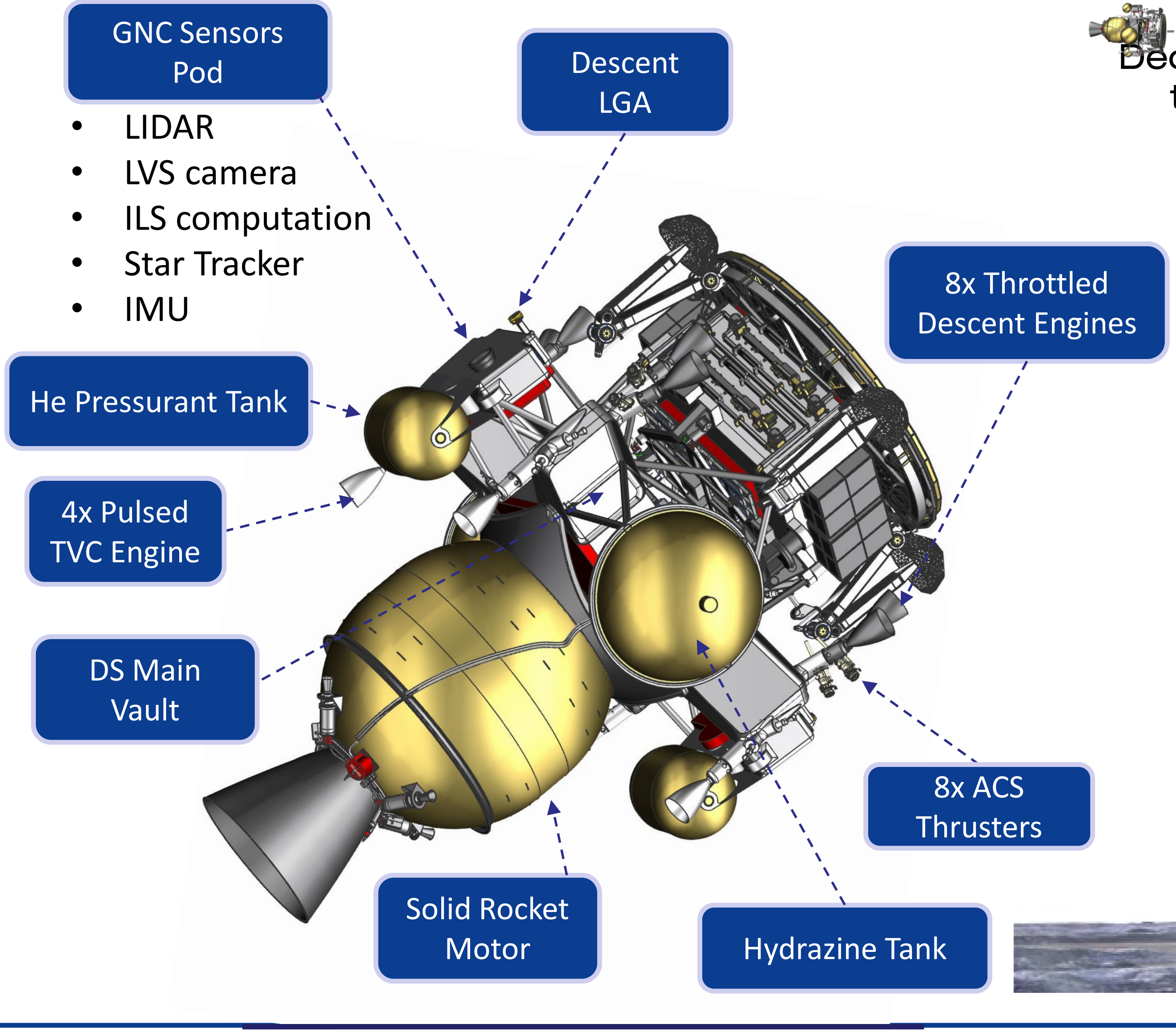
# Baseline Flight System Vehicles

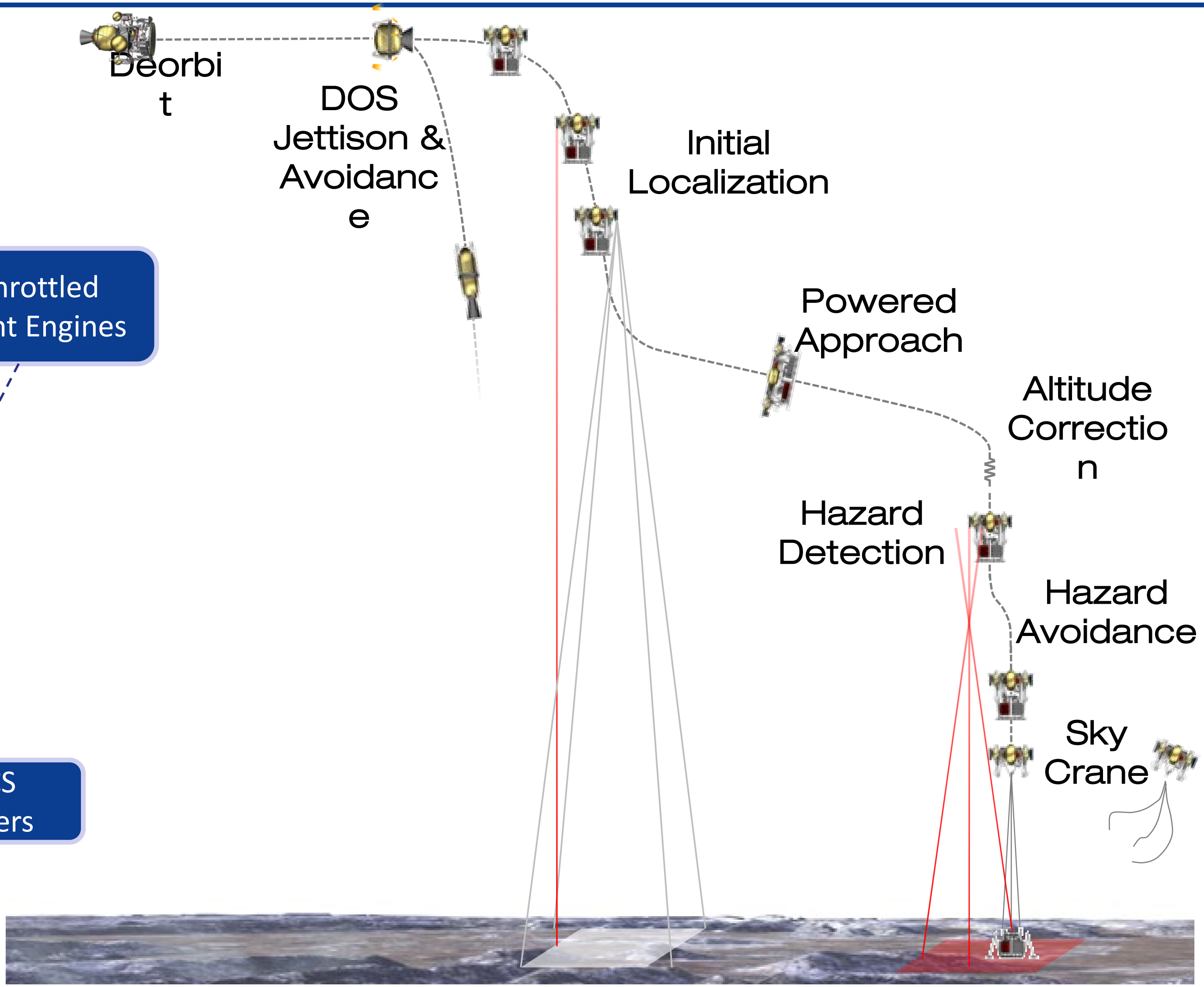




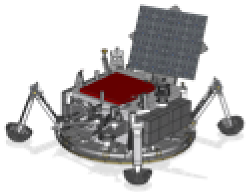
# Baseline Deorbit Vehicle Configuration and Events

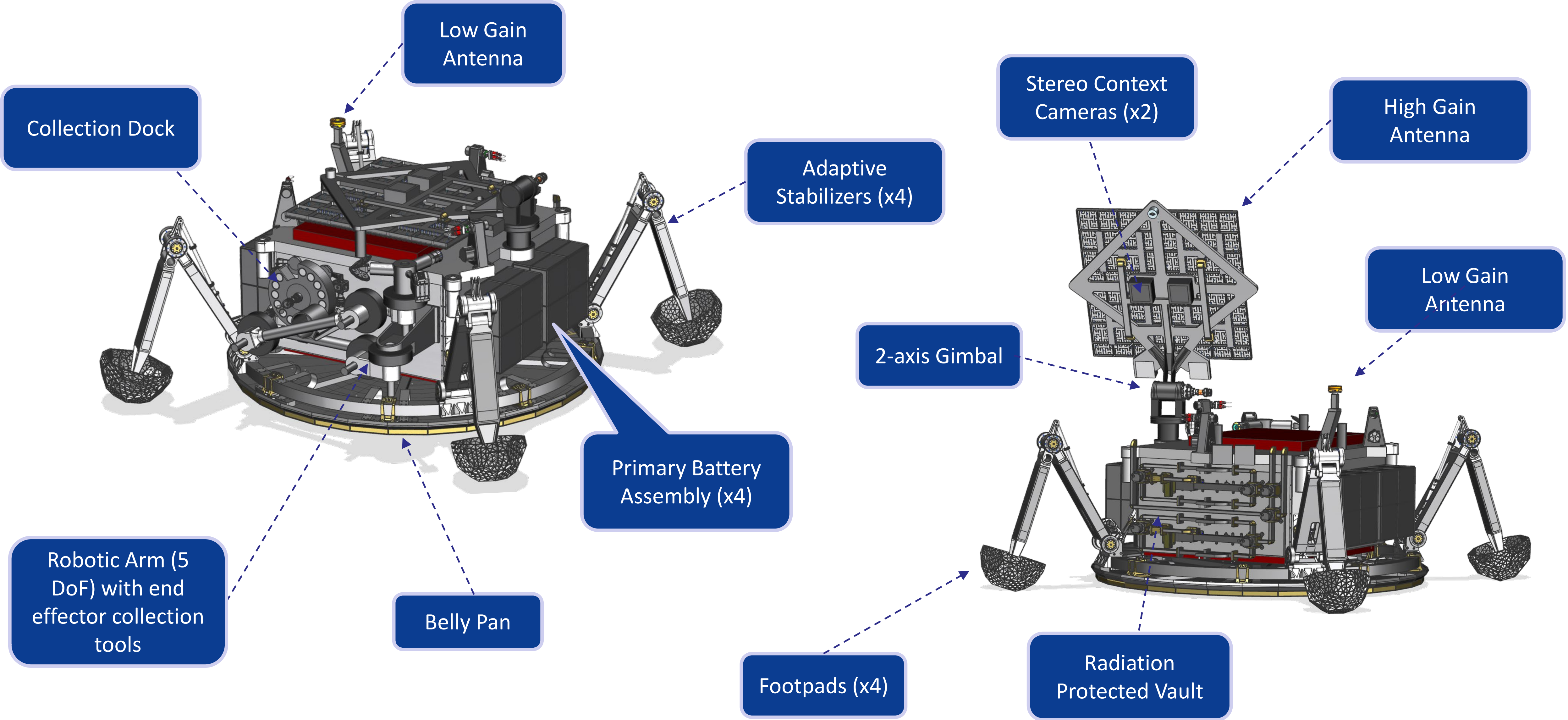


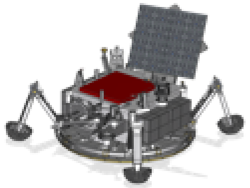


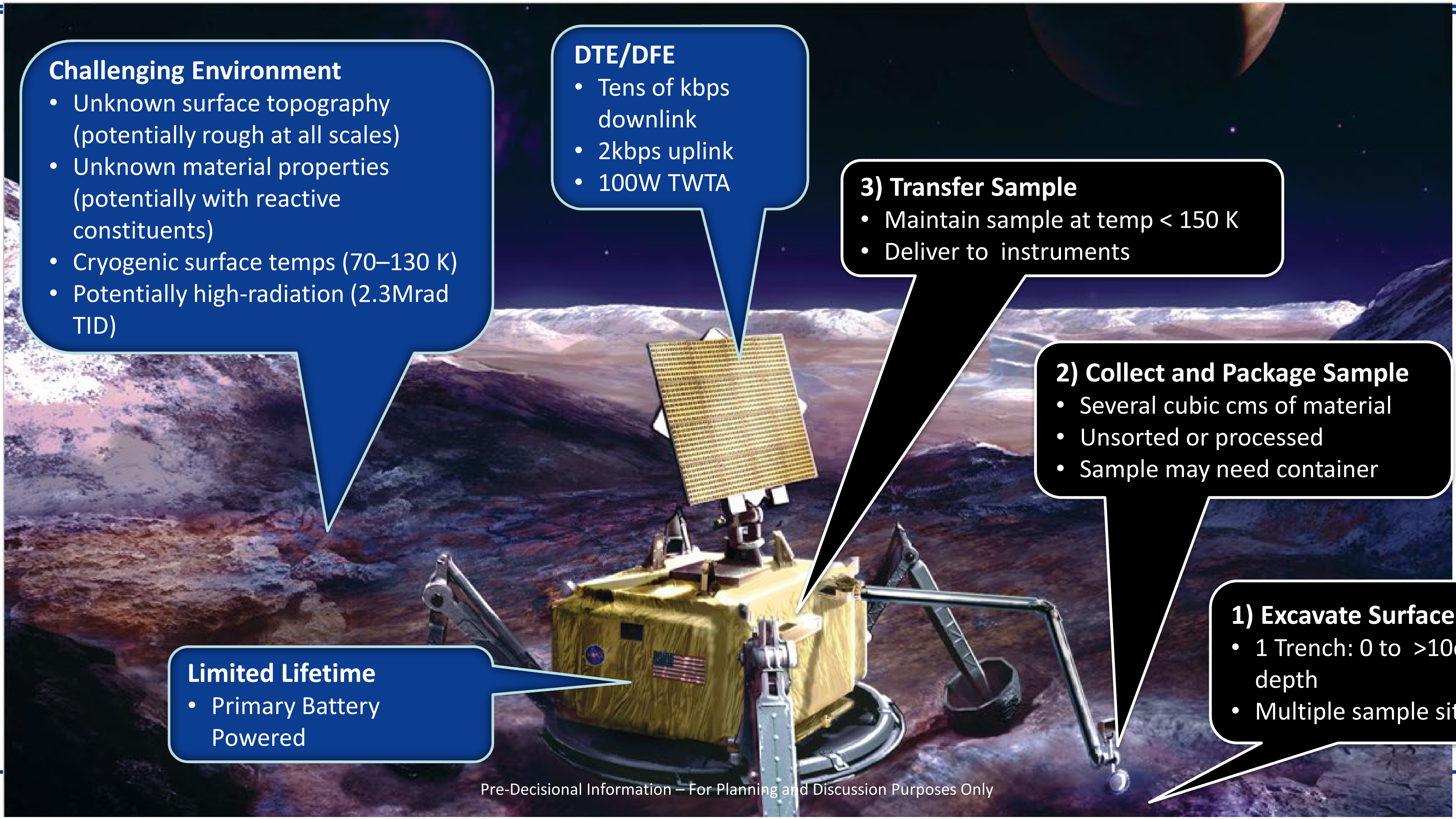
# Baseline Lander Stage Configuration







# Surface Mission Concept Challenges



**Challenging Environment**
- Unknown surface topography (potentially rough at all scales)
- Unknown material properties (potentially with reactive constituents)
- Cryogenic surface temps (70–130 K)
- Potentially high-radiation (2.3Mrad TID)

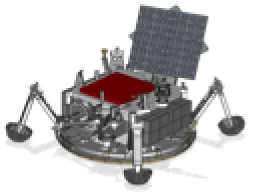
**DTE/DFE**
- Tens of kbps downlink
- 2kbps uplink
- 100W TWTA

**3) Transfer Sample**
- Maintain sample at temp < 150 K
- Deliver to instruments

**2) Collect and Package Sample**
- Several cubic cms of material
- Unsorted or processed
- Sample may need container

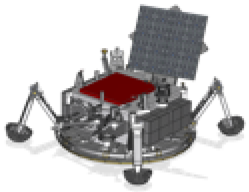
**1) Excavate Surface**
- 1 Trench: 0 to >10cm depth
- Multiple sample sites

**Limited Lifetime**
- Primary Battery Powered



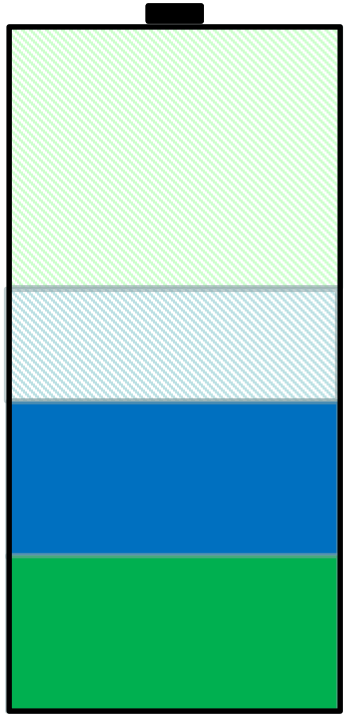
# Robust Lander Design Approach

- Margin
  - Timelines constructed with contingency that results in significant energy margin
- Autonomous and automated functions
  - Self-reliant for all aspects of the surface mission nominal and many off-nominal scenarios
  - Could construct a fully autonomous mission but expect to have GITL for science input
- Robust verification for sampling an uncertain surface
  - Demonstrate over a broad collection of topography and material properties
- Only offering limited flexibility
  - GITL directs high level goals and overall plan but flight system manages execution
  - Anticipate potential for human “want to” with GITL and minimize by design by moving onboard
- Early proof
  - Reference surface mission execution in a prototype testing venue by MDR



# Surface Energy Margins

Lander Battery
(50 kWh Useable)



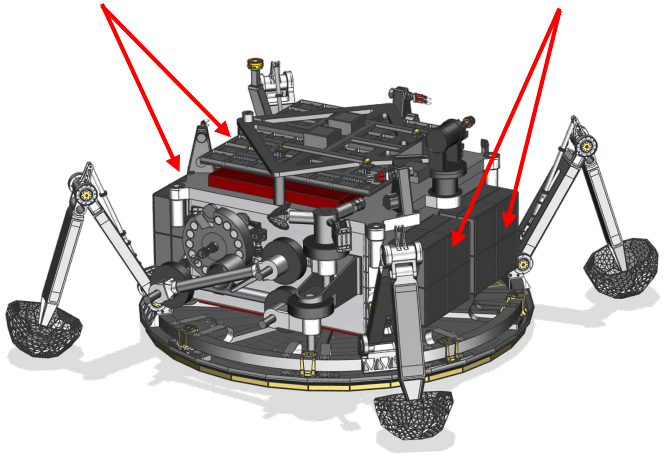
Unallocated margin (35%)

7 days of on-surface margin

7 days of planned contingency

DDL+7 days to accomplish full mission success

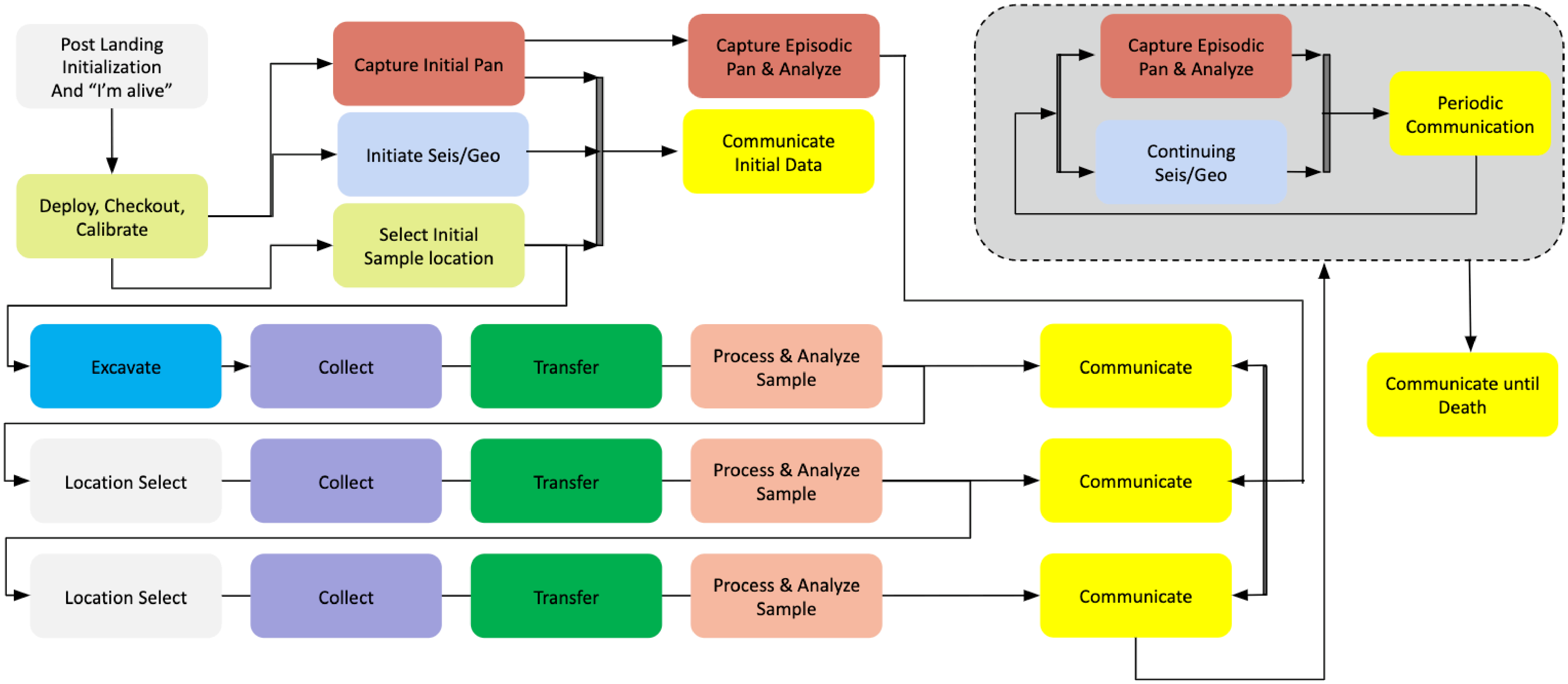
**Four Primary Battery Assemblies**



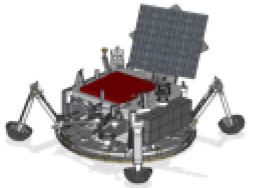
3x energy to accomplish for full mission success

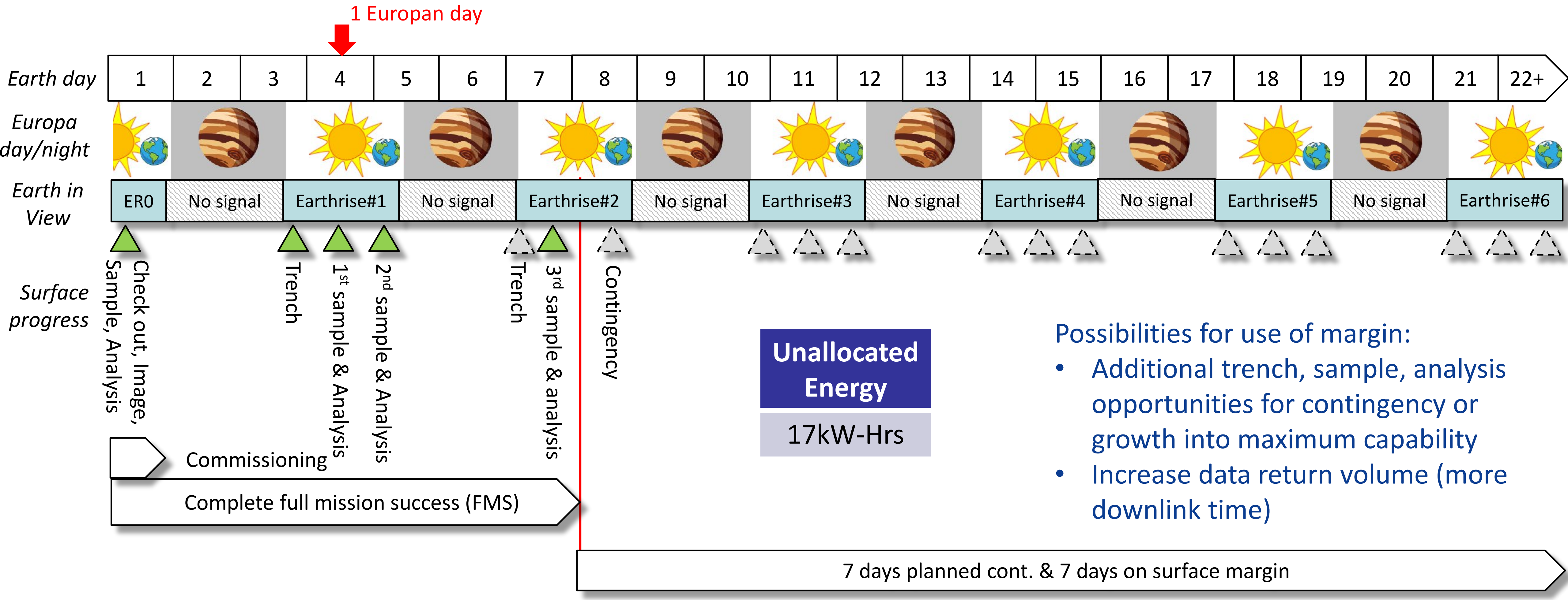
**Lander carries ample margins to accomplish surface mission**

# Basic Surface Reference Mission



# Energy & GITL Sizing Timeline

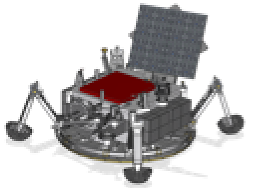


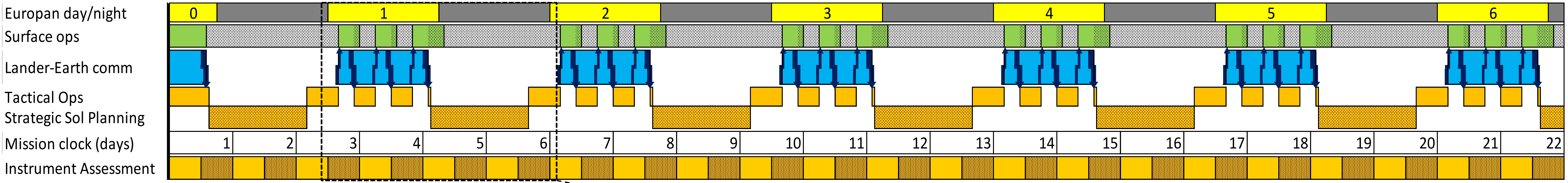



Possibilities for use of margin:

- Additional trench, sample, analysis opportunities for contingency or growth into maximum capability
- Increase data return volume (more downlink time)

# Use Case for Ground-in-the-Loop Operations



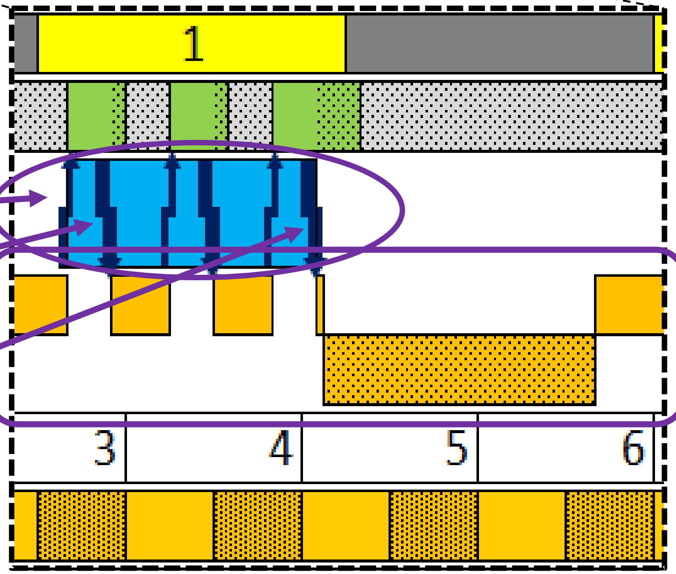



36 hours of communications available only when Earth in view

Opportunities for Ground-in-the-Loop (GITL) supports long periods of strategic planning alternating with short bursts of tactical planning

Example Use Case for design:

- Start each Earth-in-view (EIV) period with an uplink opportunity
- Downlink when critical data is ready for transmission
- Downlink vehicle and plan status before EIV period ends
- Additional opportunities for uplinks to adjust plan within EIV

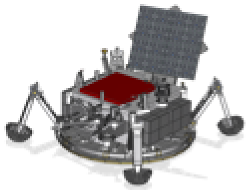



Ground Ops durations envelop variations in surface scenarios

- 8 hours tactical
- 24 hours strategic

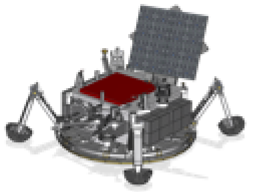
**One Europan Sol Commanding Opportunities**

OWLT = ~45 min



# Back Up

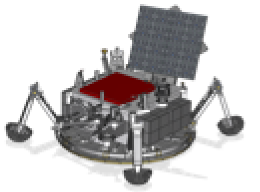
# Not Your Mars Experience



- New Environment
  - Lander scale knowledge of the surface will not be known until we arrive
  - Radiation effects may disrupt electronics
- Lifetime is always slipping away - No power generation, primary batteries only
  - Flexibility isn't as important as lifetime
- Distance to Earth
  - There may be no environmental advantage to day or night
  - Very different downlink rates, contact frequency
    - Mars: UHF relay twice a day for short durations at high data rates (up to 1 Mbps)
    - Europa Lander: 36 hrs DTE while earth in view at very low data rates (~tens of kbps), 36 hours of no communications,
- Cannot afford a ground directed operations strategy that isn't optimized for limited lifetime
  - GITL time to decide, deduce, plan, react, contemplate – all cost lifetime
  - Autonomy, self-reliance and efficiency enable success in the limited lifetime

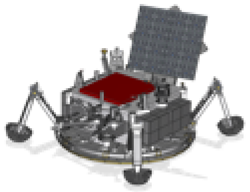
*Successful Europa landed mission in 20+ days will require a different design*

# Europa Lander Status



- Europa Lander pre-Project status
  - Held delta-Mission Concept Review (MCR) in Nov. 2018
    - "The review board (chaired by Bobby Braun) cannot recall a pre-phase A planetary science concept at this advanced level of fidelity"
  - FY19 budget signed, but near-term budgets unlikely to include funding levels required for new start
- NASA selected 14 potential instruments for maturation under Instrument Concepts for Europa Exploration 2 (ICEE-2) @ ~$2M each for 2 years
  - Funded out of FY18 budget
- High-priority Advanced Development maturation tasks have begun
  - Reduces flight development risk
  - Many tasks applicable to projects beyond Europa Lander

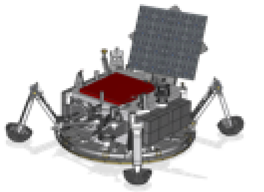
# Advanced Development Activities



- Update launch opportunities and perform flight system impact assessment
  - Launch Period Survey and Interplanetary Trajectories
  - Navigating 3-body arrival with a short period
  - Support to Clipper Reconnaissance Focus Group
  - Assess DDL/Nav trade space

- De-orbit, Descent, and Landing (DDL)
  - DDL sensors
    - Reduce sensor hardware and algorithm development risk
  - Landing
    - Prototype and test landing system (legs, feet, bellypan) concepts for very rugged terrain
  - Propulsion
    - Prototype and test low-thrust throttleable engine
    - Environmentally test solid rocket motor propellant and ignition system

# Advanced Development Activities



- Surface
  - Sampling
    - Prototype and environmentally test excavation, acquisition, and sample transfer techniques
      - Interact with ICEE-2 selectees to conduct rapid-prototype evaluation of interfaces
    - Develop approaches to maintain samples <150K
  - Autonomy: Develop and test concepts for highly autonomous operations
    - Develop software simulation and hardware testbed for development of autonomy designs
    - Mature autonomy sensing, closed-loop control, and computational requirements
  - Resources (size/weight/power/life/computation)
    - Develop and test lightweight, low-power motor controller
    - Continue radiation and life testing of primary batteries
    - Develop and test full-scale High-Gain Antenna
  - Planetary Protection/Contamination Control
    - Conduct planetary protection/bioburden analyses to mature payload and flight system requirements
    - Continue development of Terminal Sterilization System
    - Evaluate outgassing properties of radiation-exposed materials
    - Assess plume product interaction and alteration with cryogenic ices