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

Pre-Decisional Information – For Planning and Discussion Purposes Only
Baseline Flight System Vehicles

Launch Mass: ~15-16 mt

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NOT TO SCALE
Baseline Deorbit Vehicle Configuration and Events

- LIDAR
- LVS camera
- ILS computation
- Star Tracker
- IMU

- He Pressurant Tank
- 4x Pulsed TVC Engine
- DS Main Vault
- Solid Rocket Motor
- Hydrazine Tank

- GNC Sensors Pod
  - LIDAR
  - LVS camera
  - ILS computation
  - Star Tracker
  - IMU

- Descent LGA
- 8x Throttled Descent Engines
- 8x ACS Thrusters

Deorbit

DOS Jettison & Avoidance

Initial Localization

Powered Approach

Altitude Correction

Hazard Detection

Hazard Avoidance

Sky Crane

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Baseline Lander Stage Configuration

Collection Dock

Low Gain Antenna

Adaptive Stabilizers (x4)

Belly Pan

Primary Battery Assembly (x4)

Footpads (x4)

Stereo Context Cameras (x2)

2-axis Gimbal

Robotic Arm (5 DoF) with end effector collection tools

Radiation Protected Vault

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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)

Limited Lifetime
- Primary Battery Powered

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

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

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

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

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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

Lander carries ample margins to accomplish surface mission

Four Primary Battery Assemblies

3x energy to accomplish for full mission success

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Basic Surface Reference Mission

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Energy & GITL Sizing Timeline

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

Unallocated Energy
17kW-Hrs

Complete full mission success (FMS)
7 days planned cont. & 7 days on surface margin
Use Case for Ground-in-the-Loop Operations

- **Europan day/night**
- **Surface ops**
- **Lander-Earth comm**
- **Tactical Ops**
- **Strategic Sol Planning**
- **Mission clock (days)**
- **Instrument Assessment**

**36 hours of communications available only when Earth in view**

**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**

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

**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

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