OPAG 2018

Bioburden Reduction Before, During, and After Flight – Planetary Protection for the Europa Lander Mission Concept

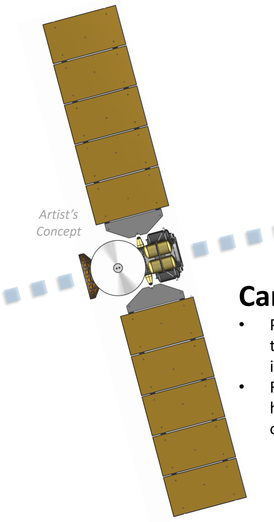
Brian G. Clement[1], Jamie Blockey[1], Raymond Ellyin[1], Mellisa Heller[2], Insoo Jun[1], Wousik Kim[1], Luz Maria Martinez Sierra[1], Shawn Stacy[2] and Tyler Voskuilen[2]
[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [2]Sandia National Laboratories, Albuquerque, NM

Mission Concept

- The Europa Lander mission concept would pursue three basic science goals
  - Search for biosignatures
  - Evaluate overall habitability
  - Investigate geophysical properties and dynamics of Europa

Planetary Protection Requirements and Challenges

- The Europa Lander Mission Concept would pose a novel Planetary Protection challenge by proposing to land on the surface of an Icy Moon above a liquid ocean
- Europa missions must demonstrate that **the probability of contamination (P_C) is less than 10^{-4}, where contamination is defined as the introduction of one or more viable organisms into a liquid water body**
- Key challenges
  - **Scale**: Four-stage flight system concept, nominal mission would result in three stages contacting Europa
  - **Stringency**: microbial reduction and control would be needed for all subsystems to meet the P_C requirement

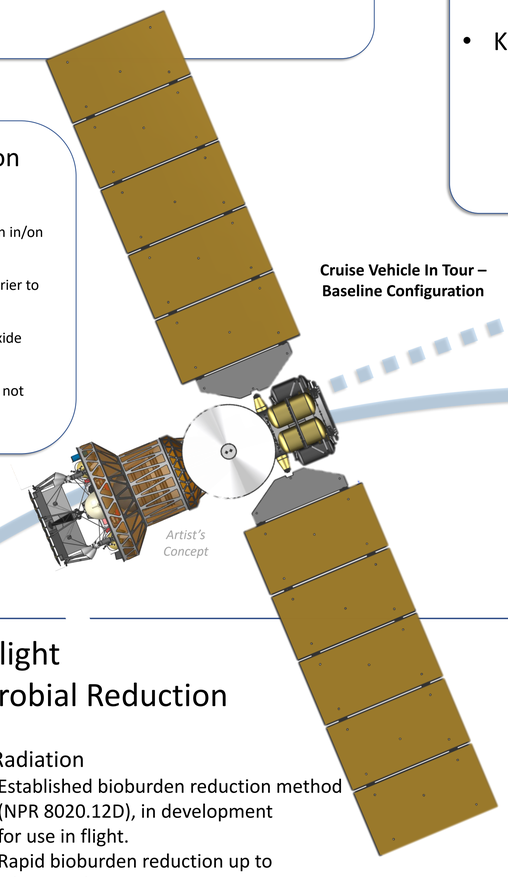


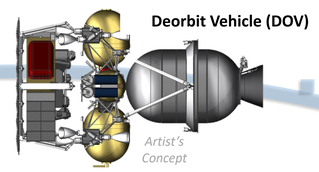
Carrier Stage

- Power and propulsion through Europa orbit insertion
- Final disposition: stable, high-radiation Europa orbit for sterilization

Planetary Protection Implementation Concepts

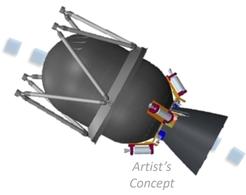
- Apply microbial reduction and clean assembly to limit bioburden in/on primary structures and heat compatible components
- Assemble all three stages planned to contact Europa in a Biobarrier to limit recontamination
- Treat the Biobarrier-enclosed stages with Vapor Hydrogen Peroxide (VHP) after last physical access
- At end of mission, incinerate electronics and other components not previously subjected to microbial reduction





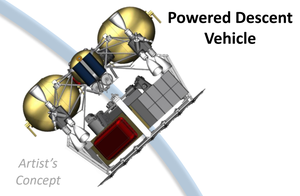
De-Orbit Stage

- Provides propulsion for deorbit maneuver (as DOV)
- Consists of a solid rocket motor with associated structure and separation motors
- Bioburden reduction/control will be a mix of DHMR and self-sterilizing heat (>500 °C) during motor burn
- Final disposition: Europa surface



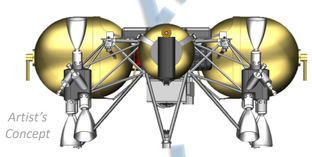
Full Launch Stack

- Four stage flight system to provide propulsion, power, communication, navigation and science capability
- Incorporates 4 stages, plus a biobarrier to permit VHP treatment of all 3 stages planned to contact Europa



Descent Stage

- Propulsion and navigation for controlled descent and lander delivery via tethers
- Structural elements designed for DHMR
- Propulsion system self-sterilizing by toxicity
- Battery sterilization via gamma irradiation
- Heat-sensitive electronics co-located in vaults containing TSS units for incineration after Lander delivery and divert maneuver (or prior to an off-nominal impact)
- Final disposition: Europa Surface



In-Flight Microbial Reduction

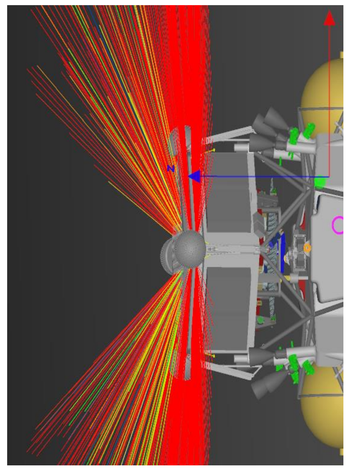
UV Radiation

- Established bioburden reduction method (NPR 8020.12D), in development for use in flight.
- Rapid bioburden reduction up to 4 logs per hour out to 1.5 AU
- View factor is critical to bioburden reduction – dose varies with angle to sun, but long exposures may be sufficient for sterility

A: Full Exposure = 4 log reduction per hour
B: 1° Exposure = 0.07 log reduction per hour

Jovian ionizing radiation

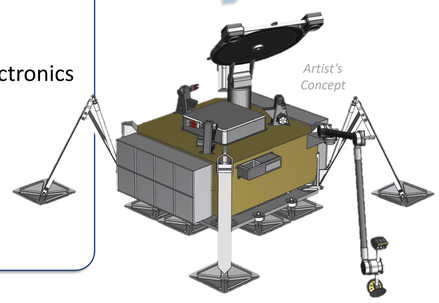
- Established biomedical bioburden reduction method in development for use in flight
- Mission design would expose external surfaces to high total ionizing dose rates prior to Europa landing
- Baseline goal: augment VHP bioburden reduction
- Current work focused on radiation view field of Cruise Vehicle surfaces prior to DOV separation
- Future refinements to include dose behind multi-layer insulation



Example view field analyses of total ionizing dose under preliminary lander thermal shield design. Current estimates are 12.5-30.2 Mrad for the external surfaces; analyses are ongoing for remaining surfaces

Lander

- Thermal management, power, communication, sample acquisition and science payload accommodation
- Primary structure designed for DHMR
- Electronics and science payloads co-located in central vault with TSS unit for incineration at end of mission (including off-nominal events)
- Small, "remote" TSS units used on electronics mounted outside vault
- Batteries treated prior to flight with gamma irradiation
- Final disposition: Europa Surface



Pre-Flight Microbial Reduction

Dry Heat Microbial Reduction (DHMR)

- Established method
- 6-log penetrating microbial reduction for primary structures, compatible subsystems

Vapor Hydrogen Peroxide (VHP)

- Established method
- 6-log microbial reduction for surfaces
- Applied to all three stages that would contact Europa
- Work in progress includes material compatibility and treatment modeling to ensure application efficacy

Biobarrier

- In development
- Would encapsulate Deorbit Vehicle (DOV) after launch stack integration
- Would enable VHP-based 6-log bioburden reduction of DOV surfaces while preventing re-contamination
- Upper section would deploy post-launch while lower section would remain with Carrier Stage

Gamma irradiation

- In development
- Would provide full, pre-launch sterilization of batteries

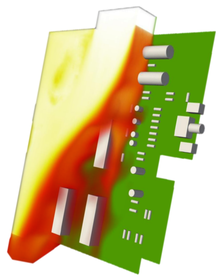
End-of-Mission Microbial Reduction

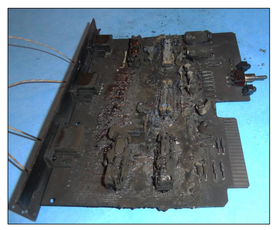
Terminal Sterilization System (TSS) - In development

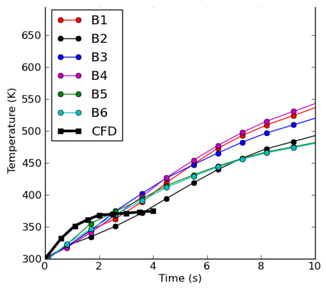
- Rapid incineration devices for vaults and externally mounted electronics on Lander and Descent stages
- Would provide full sterilization of components incompatible with other microbial reduction measures
- Incineration would be initiated at end-of-mission, including off-nominal events

Terminal Sterilization System (TSS) Development

Experimental incineration results showing (l to r) CFD flow model prediction, incinerated electronics board and data comparison between CFD flow model and thermocouples. Model development would be utilized to confirm sterilization at ≥500 °C for ≥0.5 seconds







Note: this poster contains predecisional information, for planning and discussion only