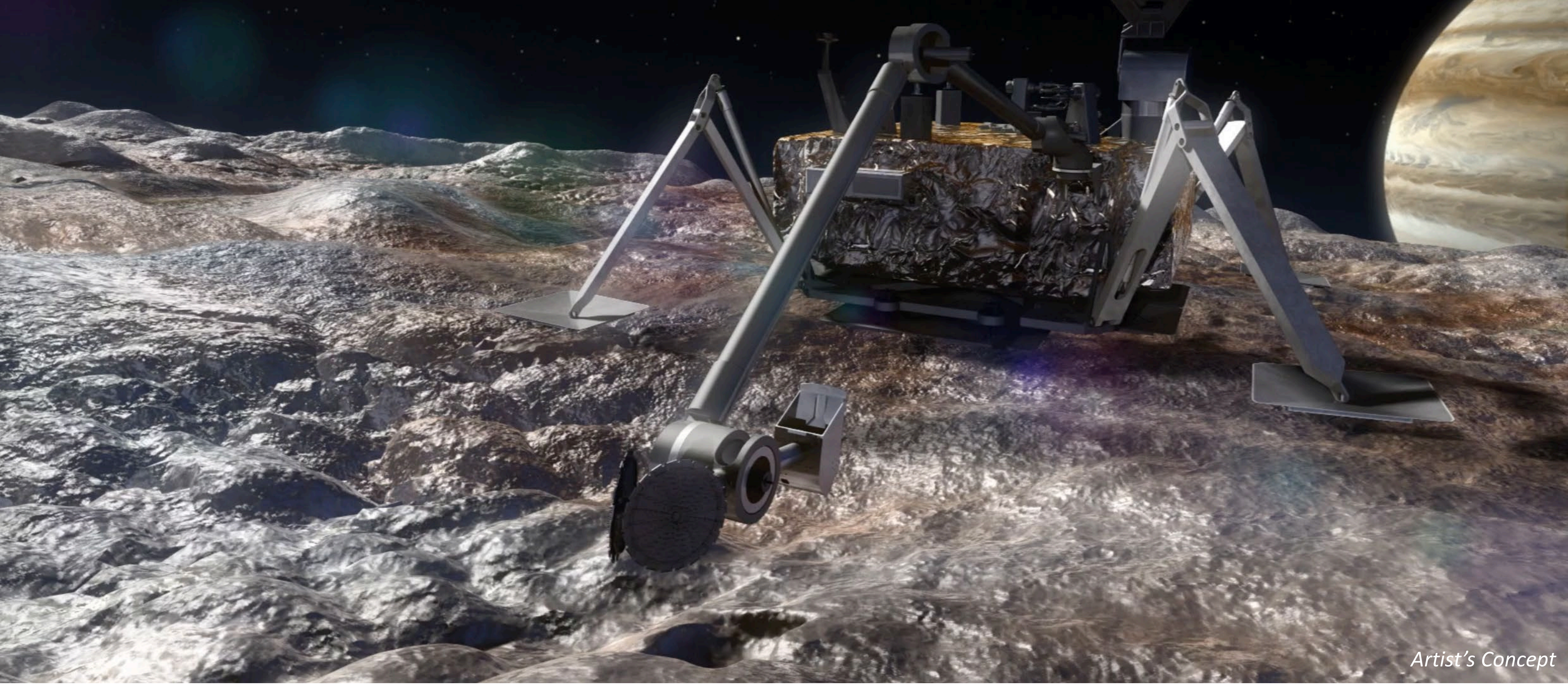

Planetary Protection for Europa Lander Concept

Brian Clement, Lead Planetary Protection Engineer

Jet Propulsion Laboratory
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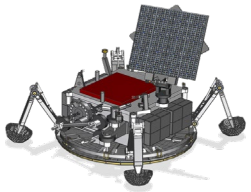
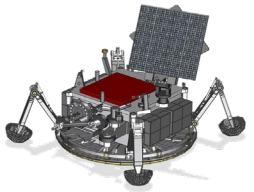
Planetary Protection Context



- Planetary Protection requirements for a landed Europa mission are more stringent than Mars
  - Metric is probability of delivering ≥1 organism to a liquid body
  - Includes *all* organisms not just bacterial spores
  - End point is death of all Earth organisms or 1000 years, whichever comes first
- Increased stringency drives adopting and developing new approaches
  - Technology adoption and development: Terminal Sterilization System, Biobarrier+Vapor Hydrogen Peroxide (VHP)
  - Organism-specific risk analyses: Microbial Genetics/Metagenomics
  - Lethality modeling: Bio-reduction due to spaceflight

	Mars – Cat IVa	Europa – Cat. IV*
Landed Hardware Metric	Microbial Quota	Probability of Contaminating a Liquid Body with ≥1 live organism
Organism Types Considered	Bacterial Spores	All
Value	$<5x10^5$	$<10^{-4}$
Period Considered	n/a	Until all Earth organisms are dead, up to 1000 years

Probability of Contamination Parameters



Per NPR 8020.12D, Probability of Contamination calculations shall include estimates of

A. Bioburden at launch
B. Cruise survival for contaminating organisms
C. Organism survival in the radiation environment adjacent to the target

→ Control & assess through technology adoption, development

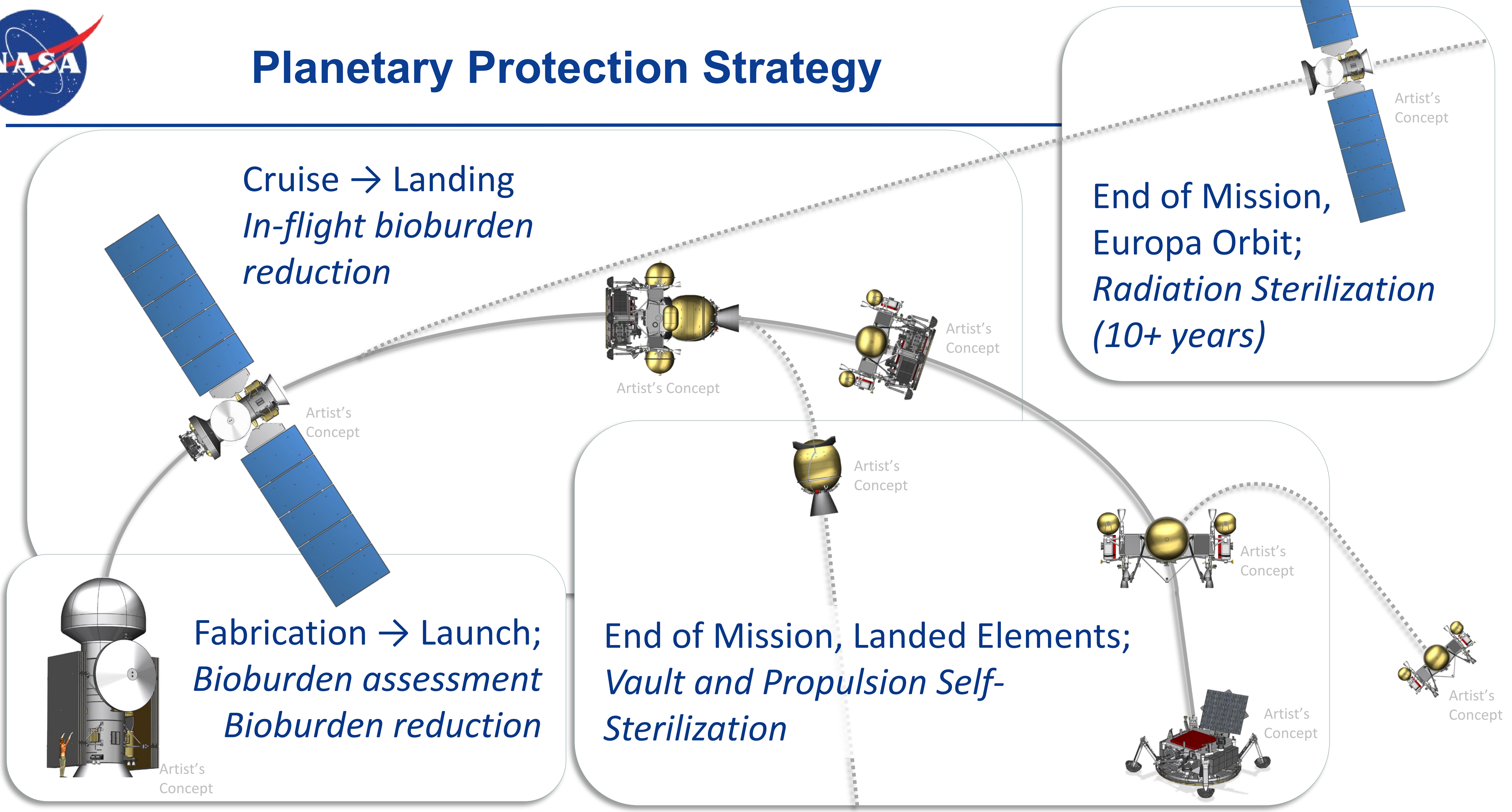
D. Probability of encountering/landing on the target, including spacecraft reliability
E. Probability of surviving landing/impact on the target

→ Probability of ~1 for Landed Missions

F. Mechanisms and timescales of transport to the subsurface
G. Organism survival and proliferation before, during, and after subsurface transfer

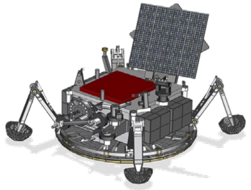
→ Limited data, active scientific debate

Planetary Protection Strategy



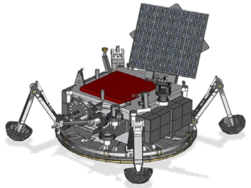
Pre-Decisional Information – For Planning and Discussion Purposes Only

Clipper Planetary Protection Path



- Europa Clipper Project held a Planetary Protection workshop in November 2018
  - Accepted Probabilistic Risk Assessment – met requirement on impact+resurfacing probability alone
  - Bioburden constraints are similar to Mars (numerical limits instead of probabilities)
  - Key parameter shifts
    - 1000 year period of biological exploration (after which PP constraints expire)
    - 2.5 Mrad sterility threshold for radiation exposure

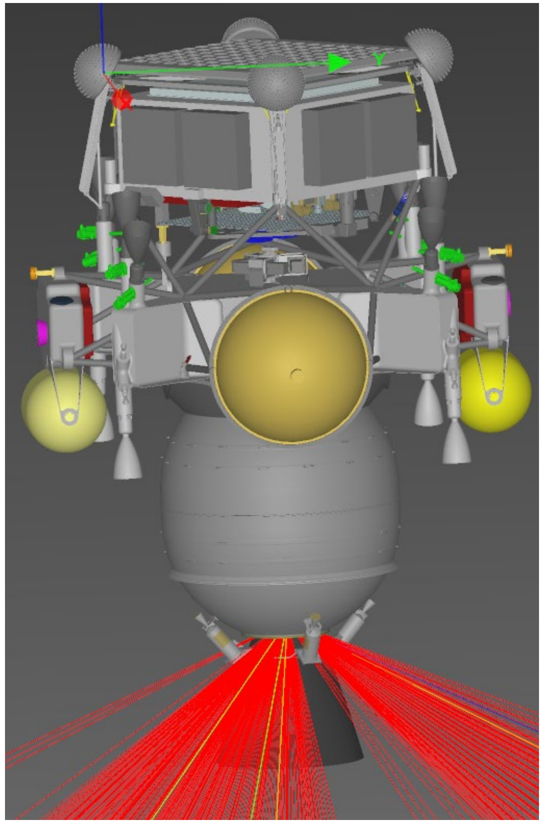
- Implications for Europa Lander
  - Mission as designed *may* meet the P_C requirement without regard to bioburden, *dependent on final trajectory and failure probabilities that are TBD*
  - Bioburden control and characterization approach likely to remain in baseline for both science assurance and planetary contamination risk mitigation



Ongoing Work

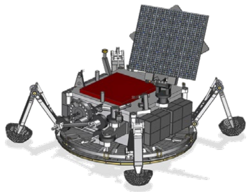
- Predict Post-Launch Microbial Reduction
  - Refine models and develop experimental data informing microbial reduction due to in-flight radiation (Jovian and Solar UV) vacuum and thermal environments
  - Establish a data-driven sterilization threshold for heat; understand heating required for sterility from impacts, terminal sterilization systems

- Develop an informed approach to bioburden risk
  - Use existing DNA-based cleanroom datasets to predict the fraction of organisms with the potential to survive
  - Work with current design iteration to estimate total bioburden at launch
  - Combine the approaches to predict surviving fraction across the mission timeline



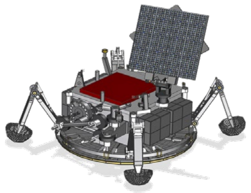
Radiation exposure calculation for De-Orbit Stage aft motor surface indicates 7-17 Mrad at separation from descent vehicle. Note: Preliminary design concept simplified for analysis purposes; not all system elements are shown.

Key Instrument Considerations

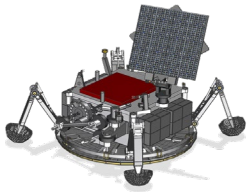


- Current baseline assumptions
  - All instruments behind radiation shielding – likely to receive little to no credit for microbial reduction
  - Initial bioburden control and reduction will be required to facilitate terminal sterilization

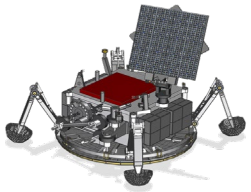
- Sterile and biologically clean are fundamentally different for a biosignature detection mission
  - Even sterilized flight system surfaces and components will be contaminated with “dead bug bodies”
  - Biomolecular contamination constraints could drive bioburden management on disparate parts of the flight system
  - ***Useful to understand early what level of biomolecular contamination compromises each planned measurement***



Thank You



Additional Information



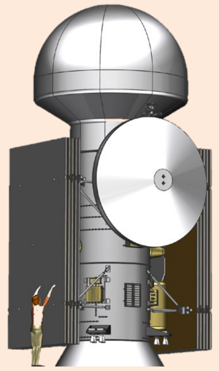
Probability of Contamination Approach

Requirement: ≤10^{-4} probability of 1 viable Earth organism reaching a liquid body

Approach: Assess organism-specific survival capacity via genetics, apply stringent pre-flight microbial reduction, model in-flight lethality and eliminate remaining bioburden at end of mission

Probability of Contamination Model

P_C = Probability a Landing/Impact Site Resurfaces in <1000 years × Probability of Non-Sterile Landed/Impacting Hardware



Artist's Concept

Flight System Bioburden

Contamination Risk Reduction
- *Genetic data*
- *Lethality after launch*

Traditional Microbial Control
- Dry/Ambient Heat
- Manufacturing credit
- Controlled environments

Novel Microbial Control
- *Incineration Device*
- *VHP behind Biobarrier*
- *Gamma radiation*