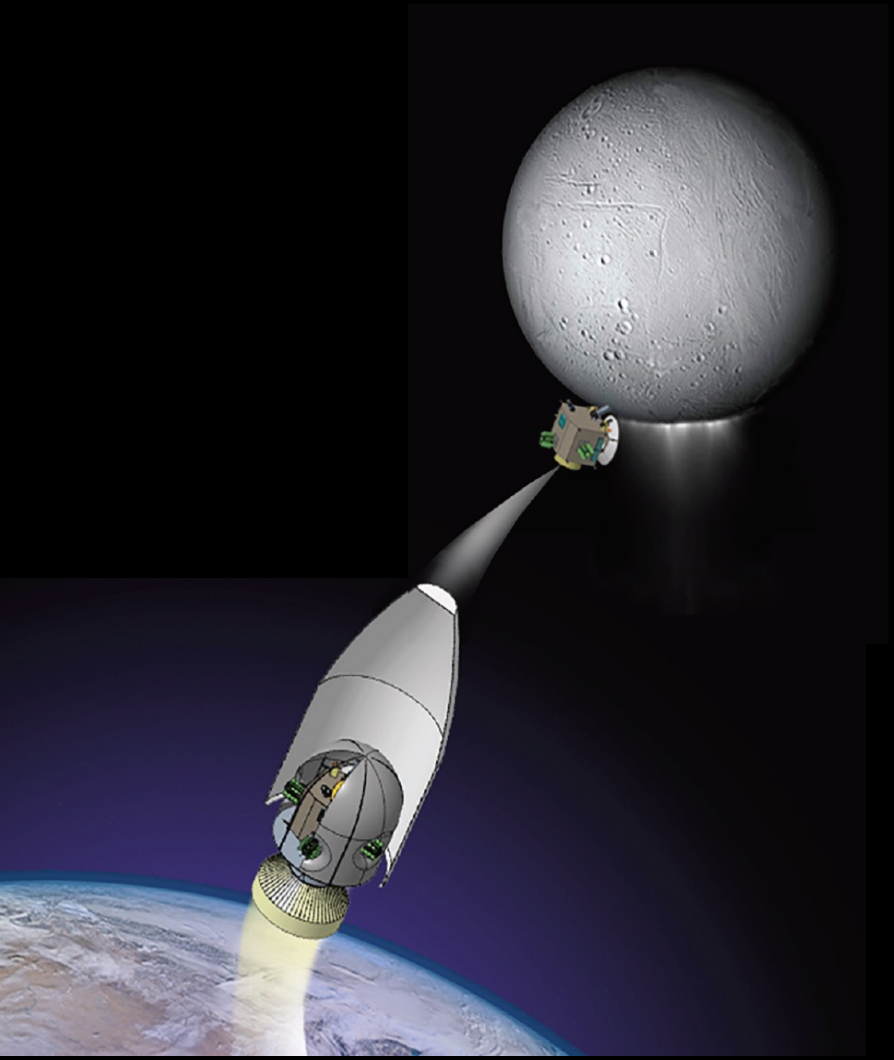

A Bio-Molecular Barrier for Contamination Control

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[2]NASA Goddard Space Flight Center, Planetary Environments Laboratory

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ELSAH Technology Study Team, funded by NASA's New Frontiers Program, 2018-2020

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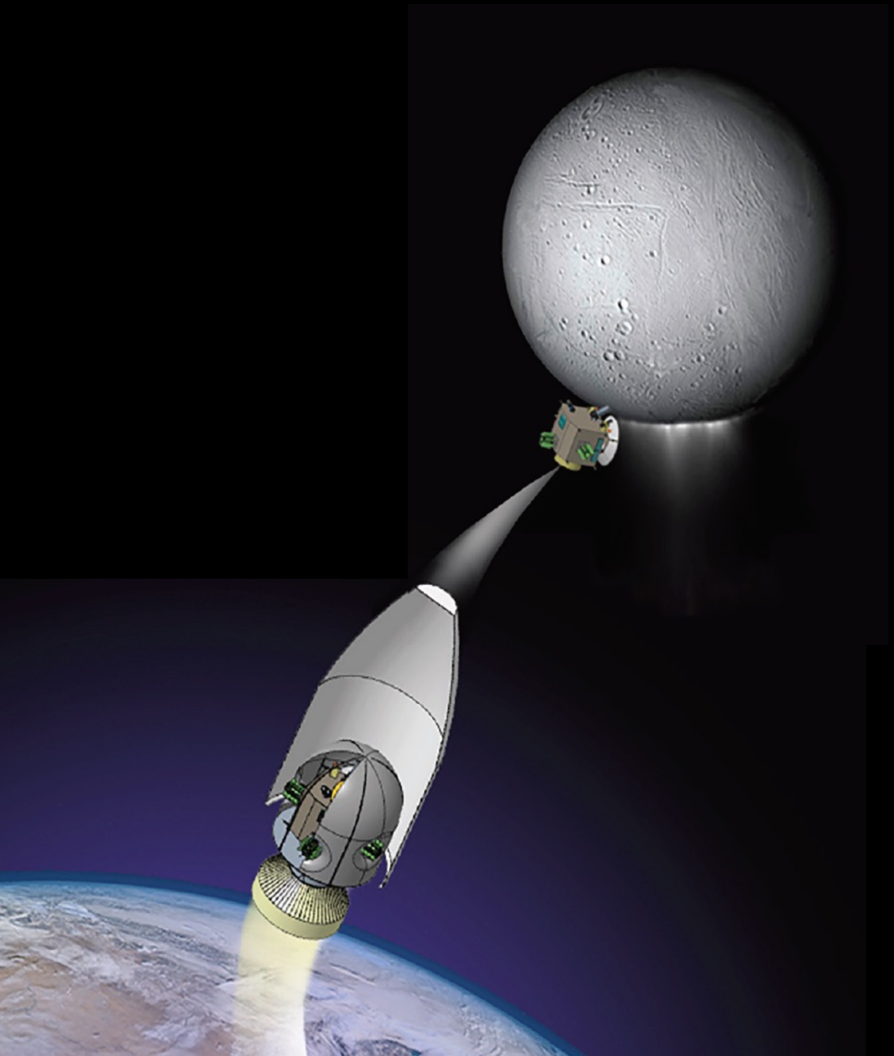

Questions

1. What mitigations reduce the risk of terrestrial contamination compromising our measurements conducted afar?

2. Can we reduce molecular contamination down to femtomole levels?

Traditional Contamination Control Engineering

Launch cleanliness requirements → End of Mission contamination levels

- Determine requirements
- Account for possible contaminant transfer using bulk transfer physics
- Protect the sample path until science operations
- Verify hardware cleanliness at launch

Traditional Contamination Control Engineering

Search for life missions

- Determine requirements → LOD: pico to femtomole, 1-10 cells
- Account for possible contaminant transfer using bulk transfer physics
- Protect the sample path until science operations
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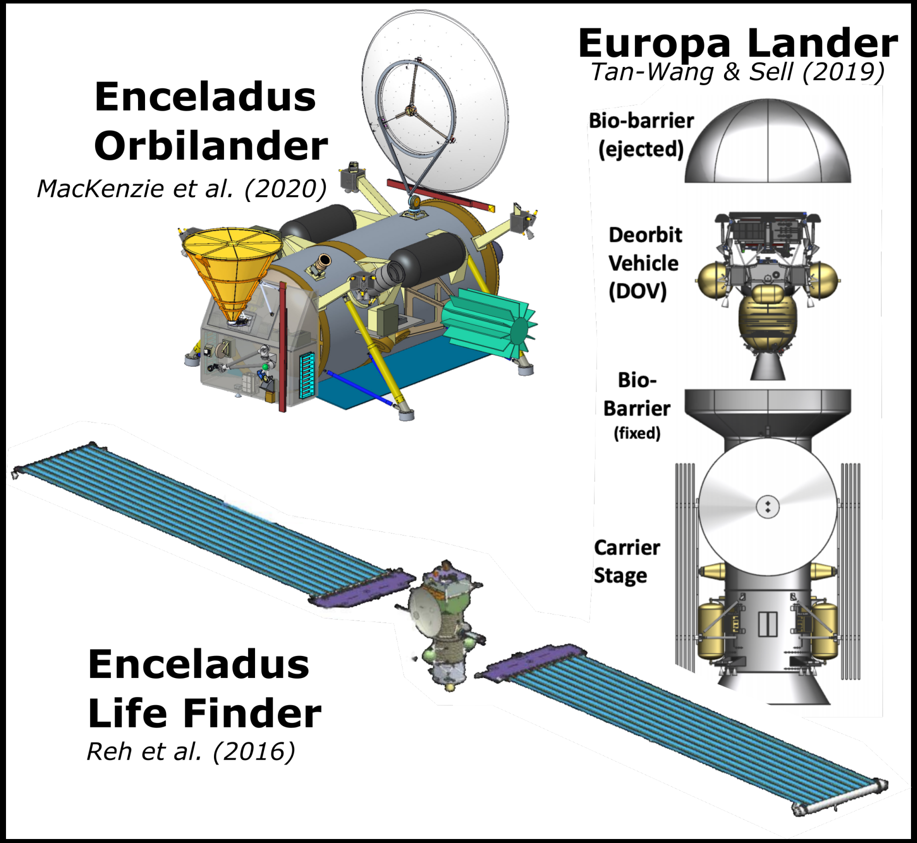

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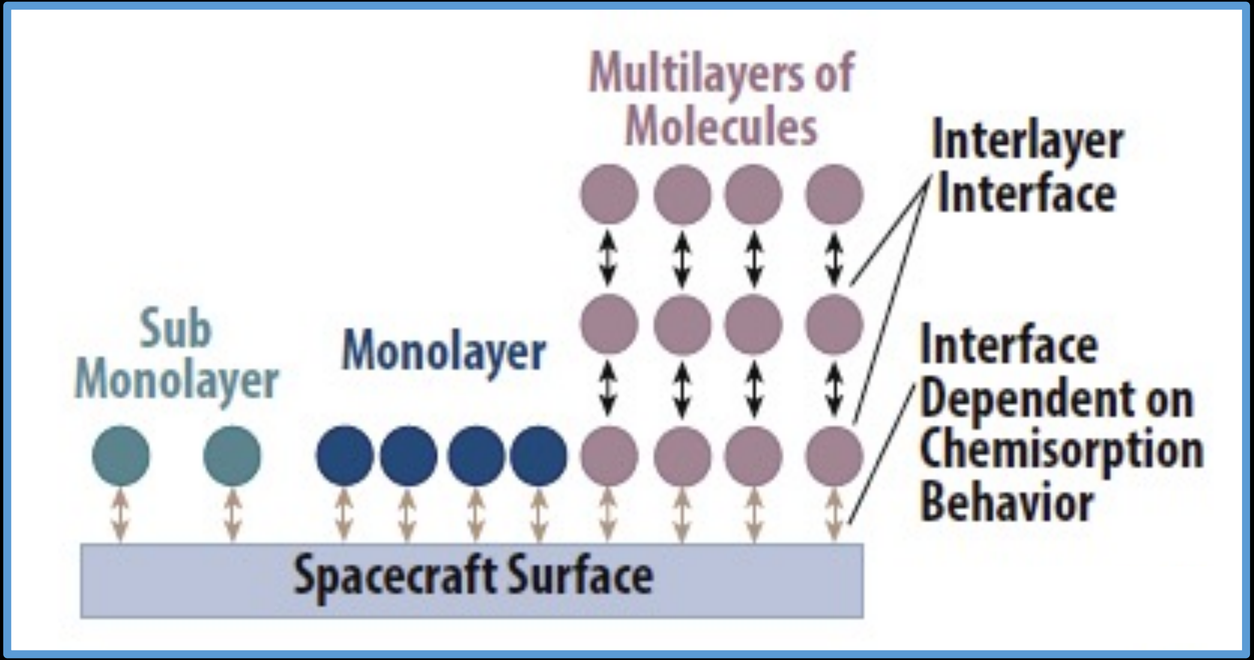

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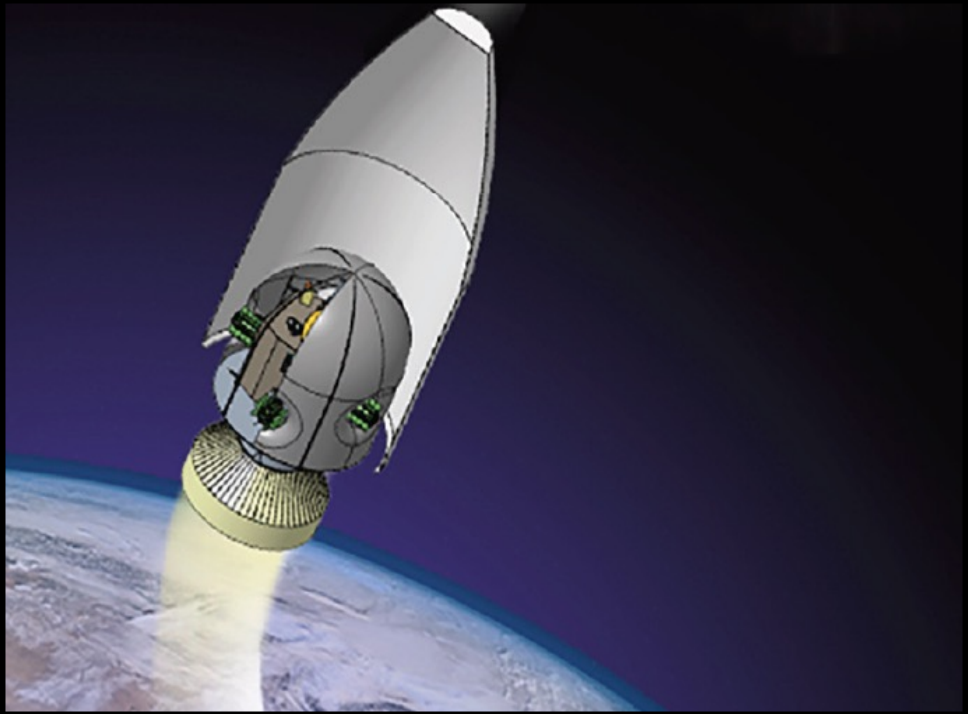

Traditional Contamination Control Engineering

- Determine requirements
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Despite the effectiveness of traditional, well-proven techniques for many planetary missions, **these methods alone are insufficient for meeting the stringent contamination requirements of missions seeking signatures of life.**

Changing the Perspective for Contamination Control Engineering, specifically for Ultra-Sensitive Life-Detection Missions

- Instrument performance requirement
- Molecular/Particulate transfer into detector suite
- Spacecraft outgassing/particulate transfer to collector
- In flight bakeout of collector
- Transfer from launch vehicle/ fairing to spacecraft/collector during launch operations
- Launch hardware cleanliness requirements at launch
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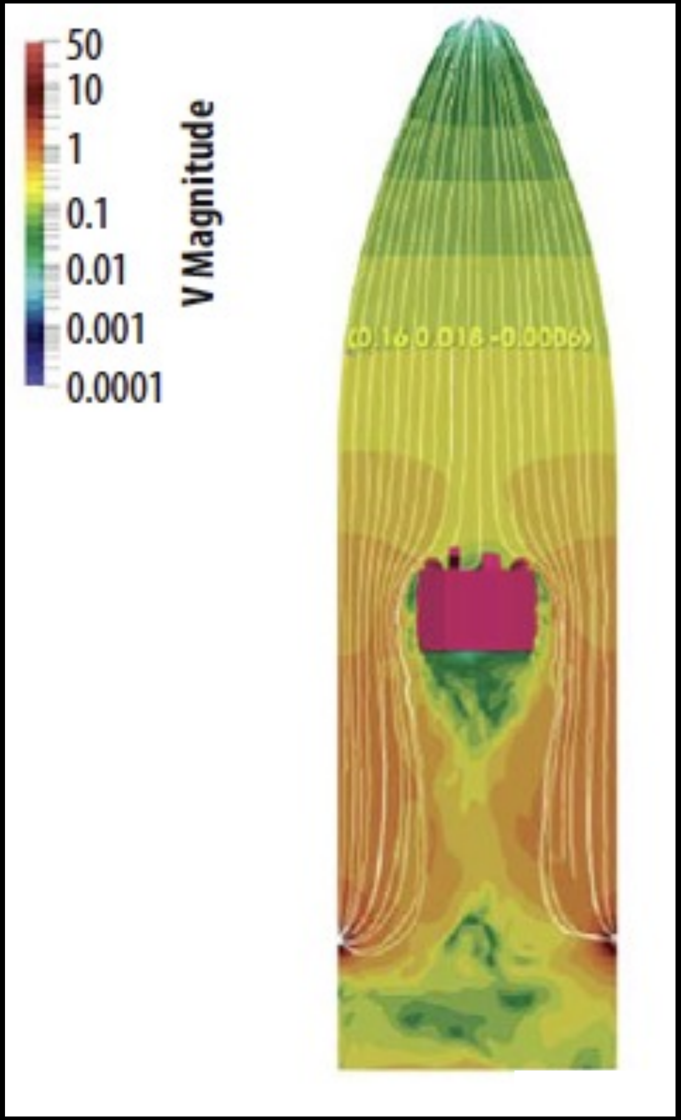
Colors represent the flow velocity magnitude in m/s



A new model for contamination-transport during launch

- High-fidelity model
  - computational fluid dynamics of the launch vehicle environment
  - physics of <=monolayer molecule interaction with ultraclean surfaces
- Enables evaluation of
  - launch redistribution on all spacecraft surfaces
  - decontamination activity (in-cruise bakeout of sample collector)

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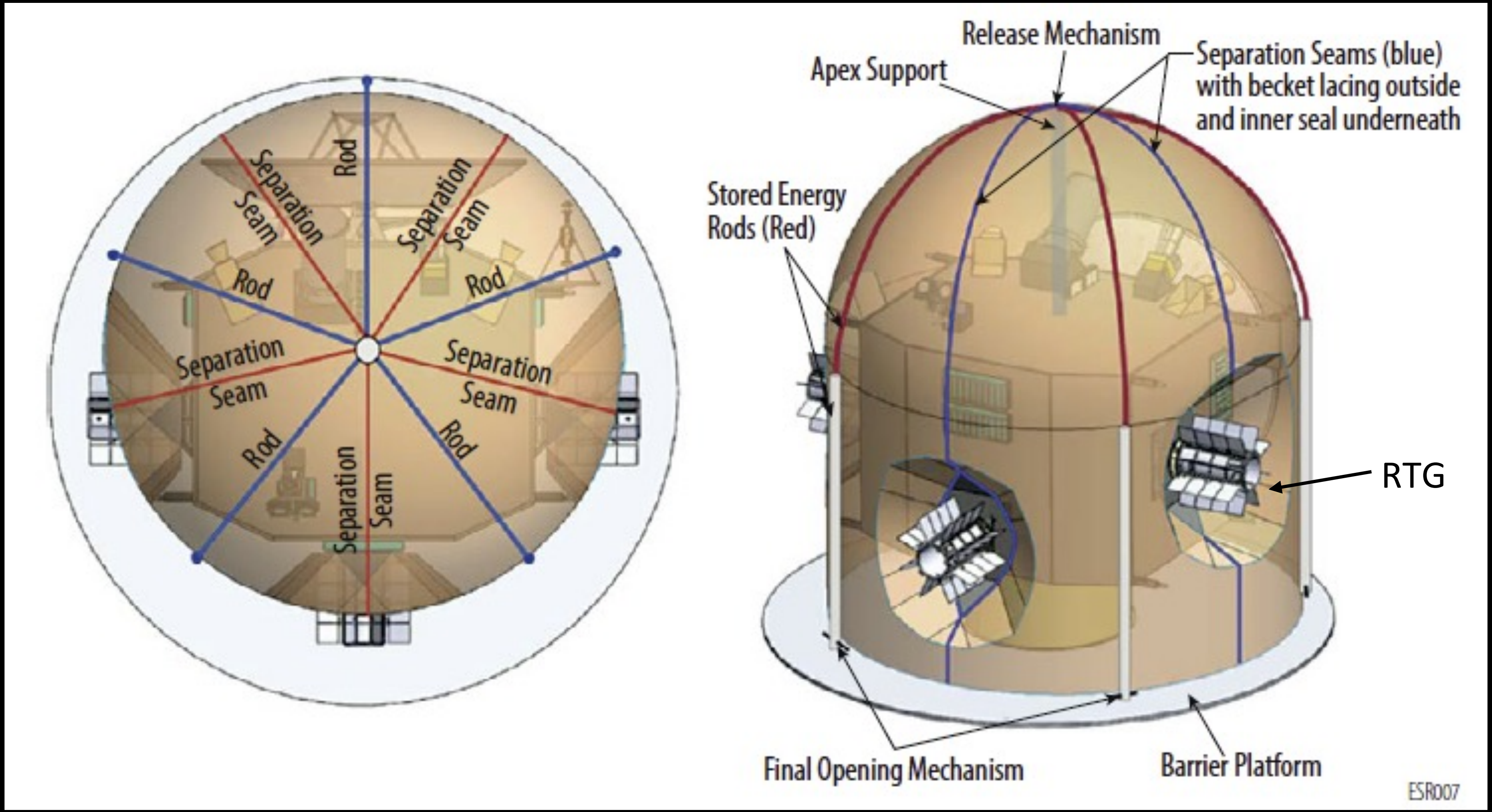
Full-Spacecraft Barrier

- Soft-sided Barrier
- Semi-rigid Skeletal Support



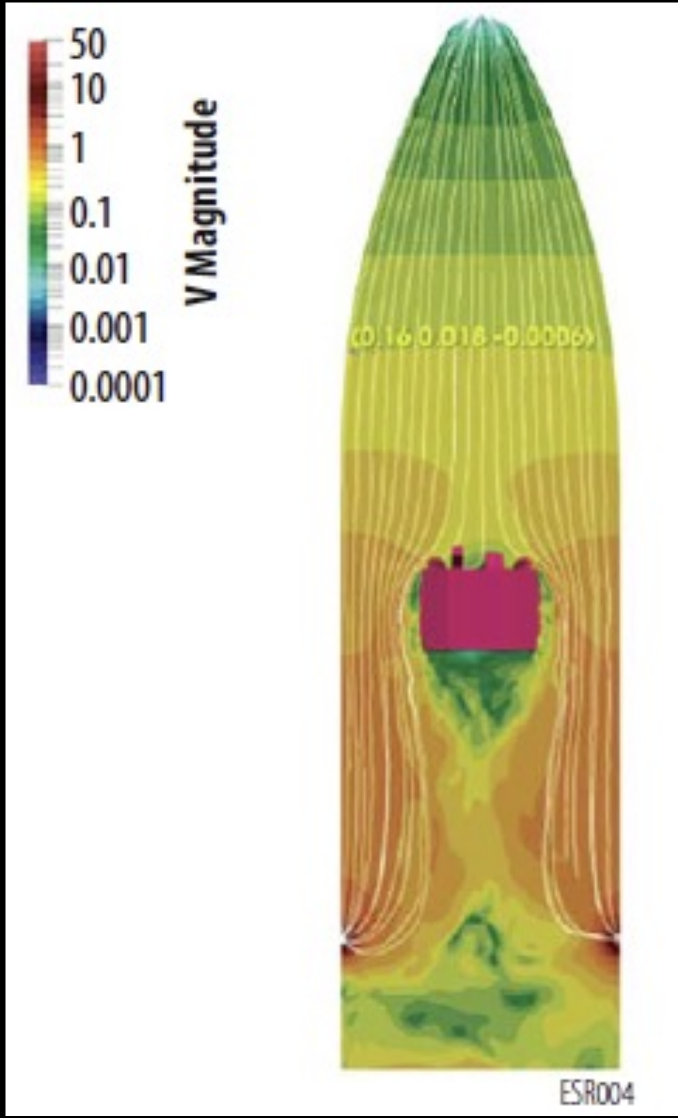
1/3 Scale Demonstration of Full Spacecraft Barrier Deployment

The barrier would open after the fairing is jettisoned at the altitude necessary to avoid new terrestrial contamination.

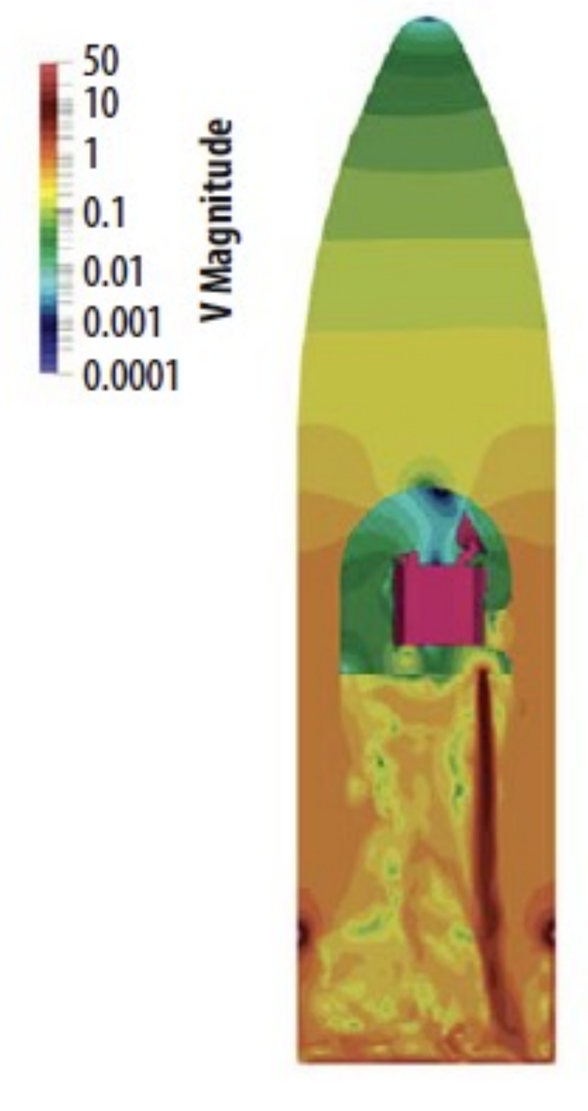
Model comparisons of with and without barrier

Contaminate build-up during launch

No Barrier



With Barrier



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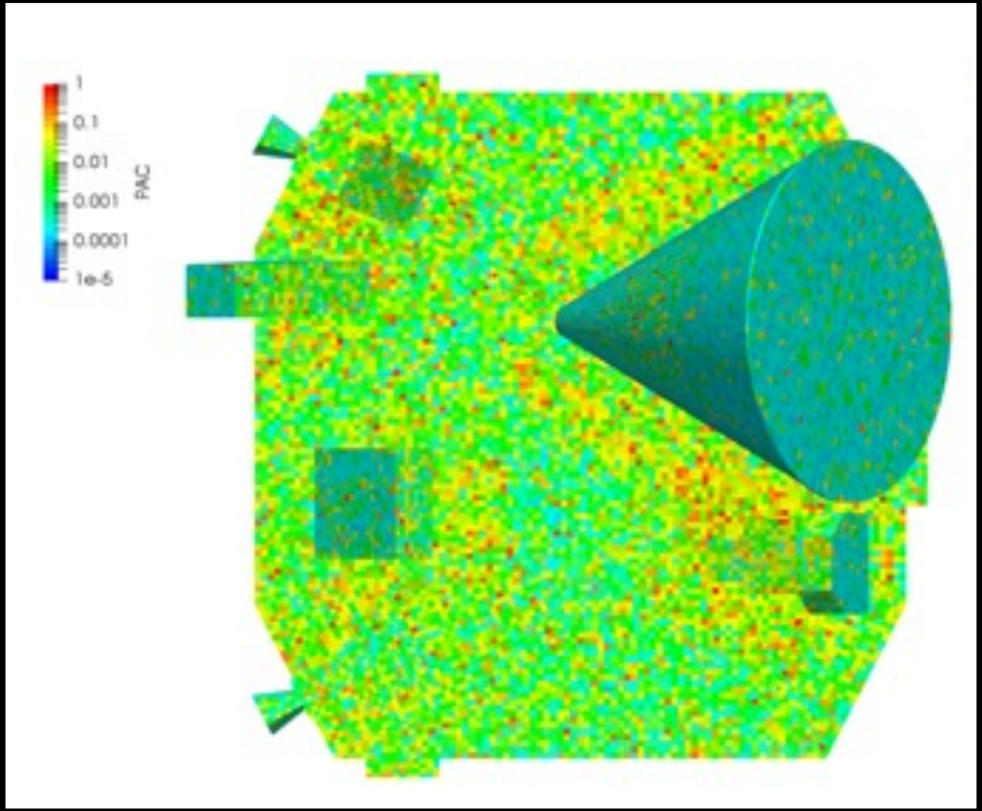

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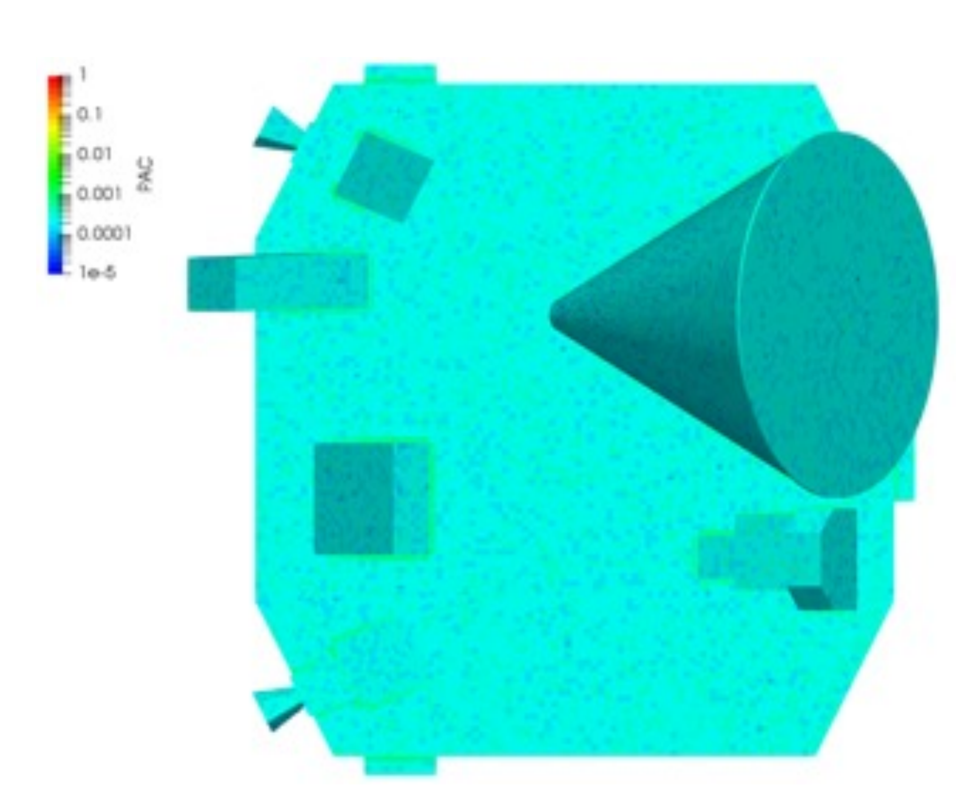

Colors represent the percent area of the surface covered by particles.

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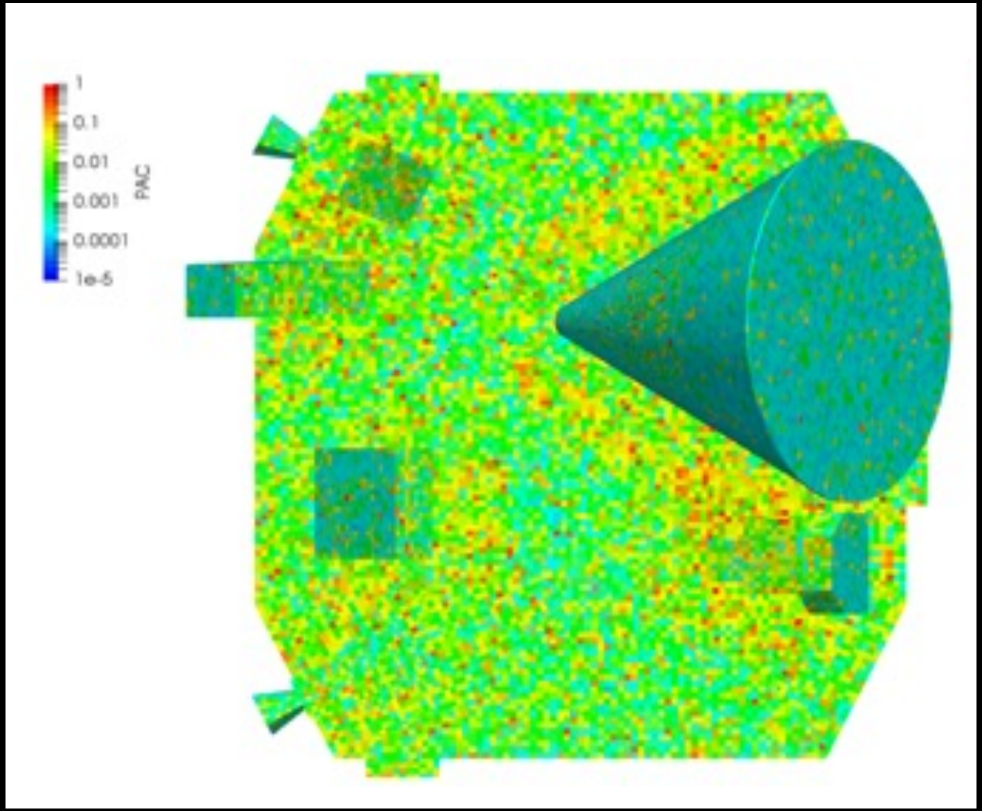

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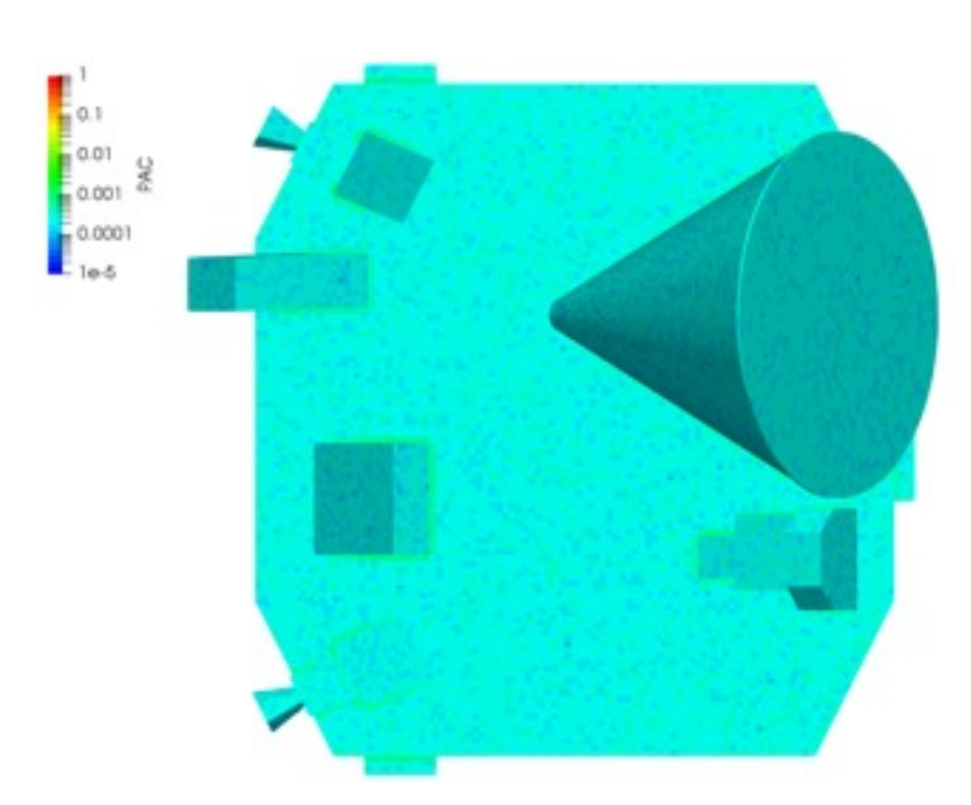


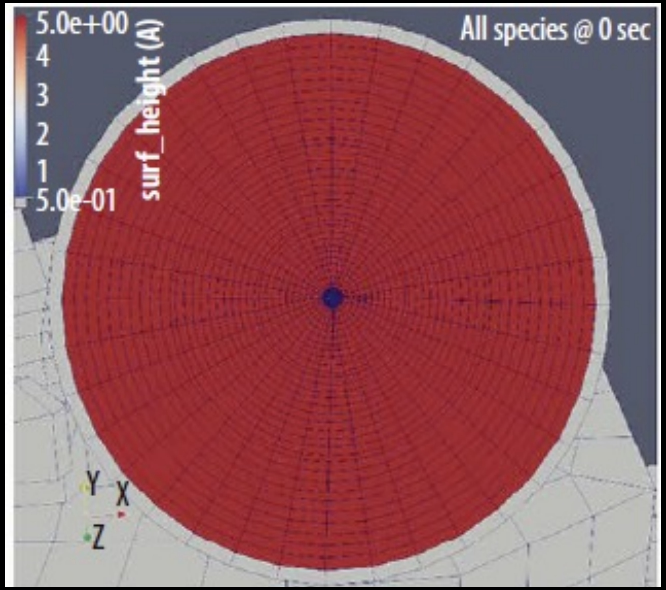
Colors represent the percent area of the surface covered by particles.

The barrier effectively isolates most of the spacecraft from fairing and launch environments.

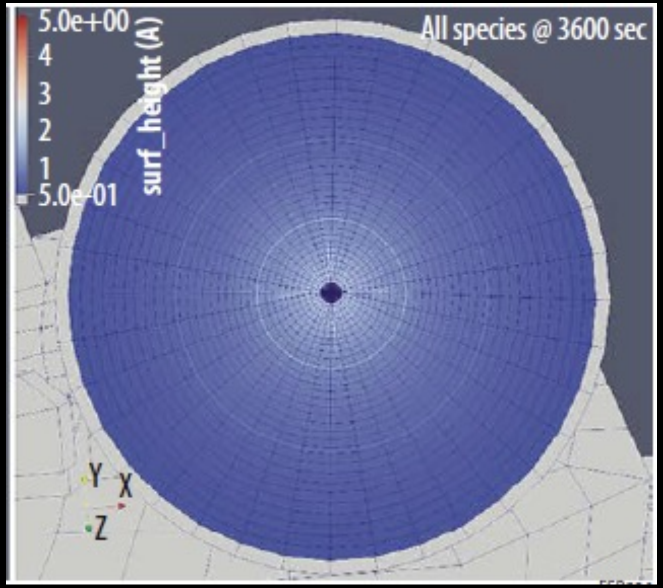
Model comparisons of with and without barrier

In-cruise bake out of sample collector

Time 0 = one monolayer



After 1 hr heating (mostly n-pentacosane remains)



Colors represent the linear scale of 0.5 to 5 Angstroms

Molecules used in model:
- n-dioctyl phthalate
- n-hexadecane
- n-eicosane
- n-pentacosane

- New model indicates 87.1% reduction of molecules.
- The traditional "bulk" transport model (unrealistic assumptions) indicated a 10^{-12} reduction.

Model comparisons of with and without barrier

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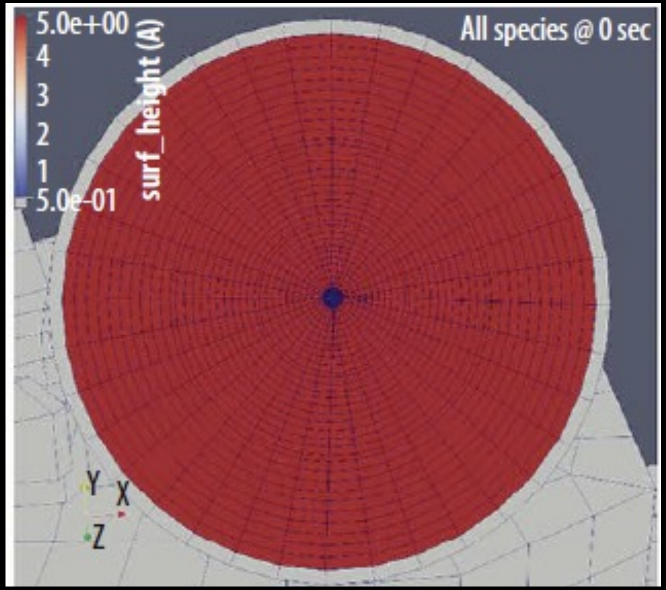

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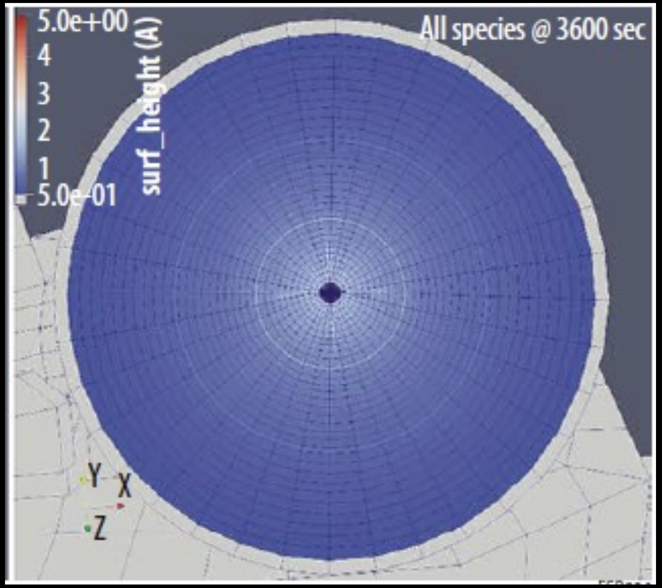

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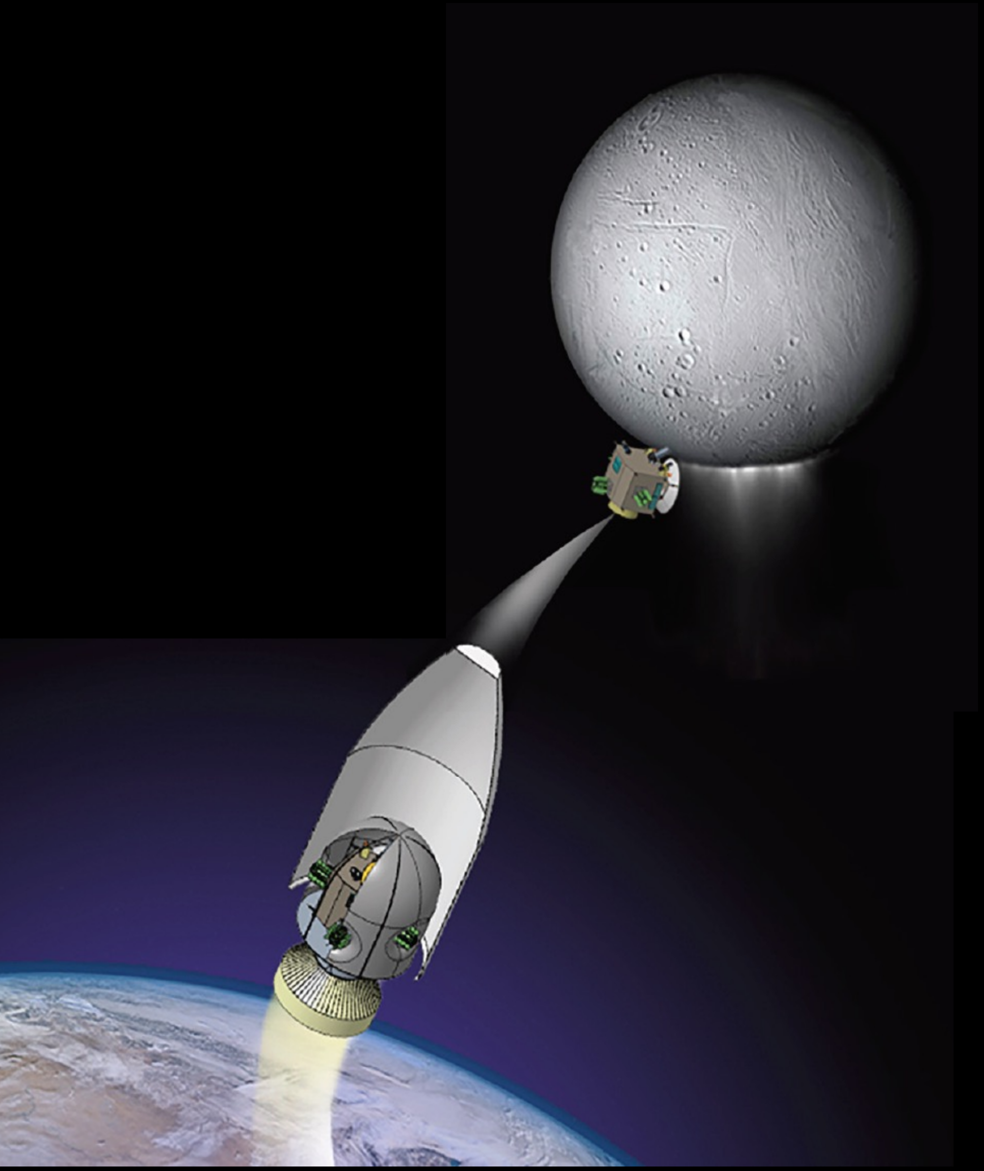
Bake out was remarkably effective at accomplishing further reduction in molecular levels on the sample collector surfaces.
Comparable in-flight decontamination steps should be considered for other mission scenarios.



Conclusions

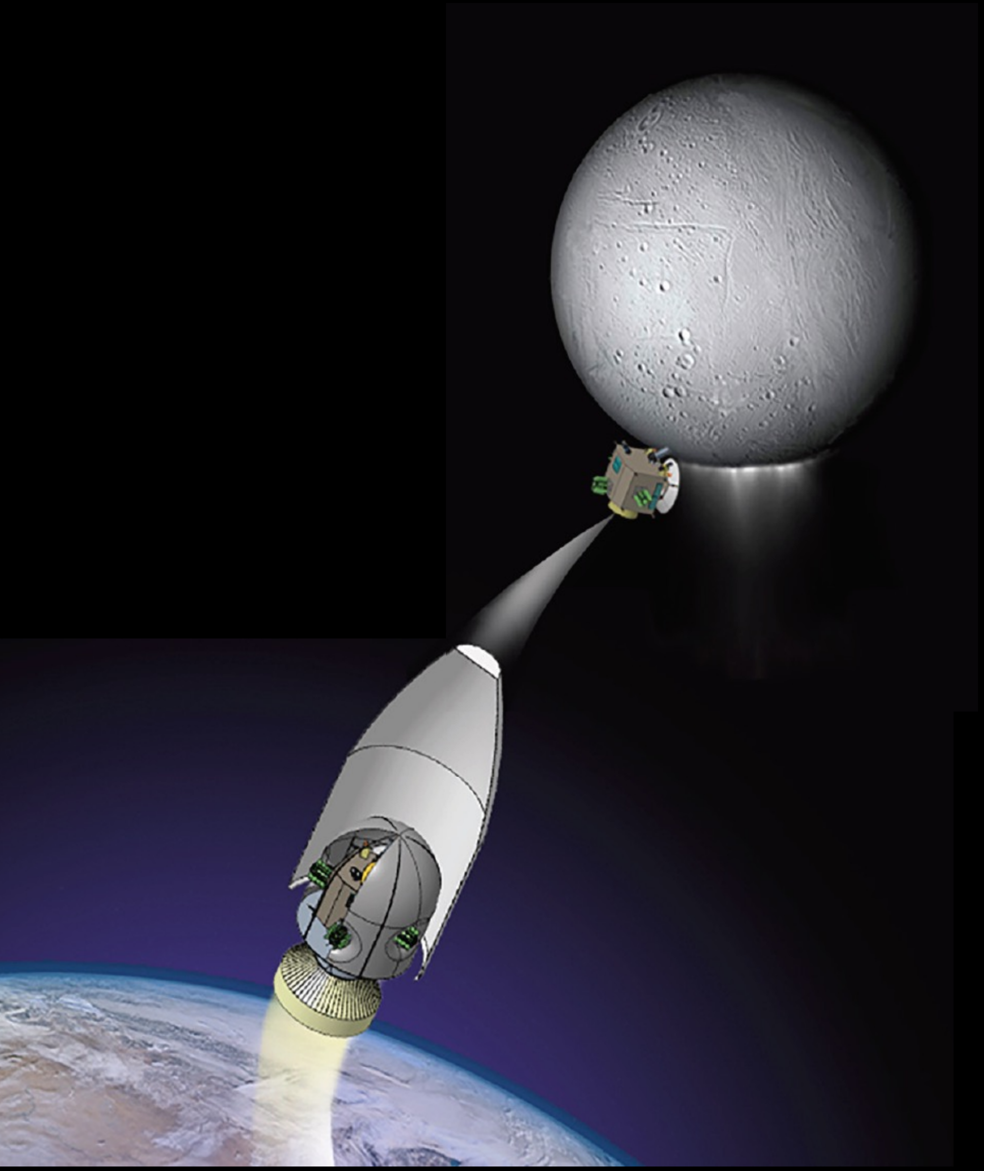
- Both the full-spacecraft barrier that protects an ultra-clean spacecraft from the launch environment and fairing AND secondary cleaning steps (collector bake out) are effective contamination control techniques consistent with traditional engineering approaches.

- With the new, high-fidelity physics model we now know that
  - when starting with an attainable cleanliness levels for the spacecraft,
  - adding the barrier and bake-out step,

  the cleanliness levels required to meet the Level 1-Science Requirements are both practical and reasonably cost effective.

- The mitigation steps studied here are applicable to other life detection missions. However, in each case, high-fidelity physics modeling will be needed for determining mission design.

Conclusions



- For more details, see Eigenbrode, J. L., et al. "Contamination Control for Ultra-Sensitive Life-Detection Missions." *Frontiers in Space Technologies*: 6. (2021) https://doi.org/10.3389/frspt.2021.734423

TECHNOLOGY AND CODE article
Front. Space Technol., 08 October 2021 | https://doi.org/10.3389/frspt.2021.734423

Check for updates

Contamination Control for Ultra-Sensitive Life-Detection Missions

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[1]NASA Goddard Space Flight Center, Greenbelt, MD, United States
[2]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, United States
[3]Peraton, Inc., Beltsville, MD, United States
[4]NASA Ames Research Center, Mountain View, CA, United States

- *Future work:* Barrier engineering tests and verification of the model to understand errors.