Analysis of Bioreduction Strategies for a Solid Rocket Motor on an Interplanetary Mission to Europa

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The Jovian environment has high levels of ionizing radiation, extreme temperatures and debris [1].

NASA will embark on extensive studies and planning of missions to explore Europa.

Recurrent sightings of active water plumes spewing water to the icy surface has garnered more interest around the moon’s habitability aspect.

The Europa Lander concept will be designed to carry a miniaturized laboratory that will analyze Europan surface samples for its chemical composition and other geological data from the moon [2].

The lander’s search for any biosignature might be endangered by the lander’s own contaminated body, also a contamination threat to any future landers to come from other space agencies with similar astrobiological interest.

Cleaning the systems poses a special challenge to propulsion subsystem planning and manufacturing, since it may introduce harsh bioreduction techniques to the process of a motor that is destined to age.

Figure 1(a) Europa plumes found in 2016 (image) and(b) Europa lander concept illustration [3,4].
• The De-Orbit Stage of robotic exploration of far-away bodies are historically assisted by SRMs due to their high reliability and low-cost functionality.

• The Star 48B propellant for example, survived the Magellan flight 15-month space storage and more than 5 years without material degradation in a long-duration exposure facility (LDEF) [5].

• Aside from the challenges put forth by propulsion subsystem flybys through a high-radiation Jovian environment, raising the probabilities of motor aging, Planetary Protection techniques will amplify any material degradation or malfunction probability [6].
The mission and philosophy of Planetary Protection is to establish a levelled ground.

NASA has a set of requirements specific for all mission types, guided by COSPAR and the OSMA, with the experience brought forth by missions to Mars [8].

At KSC in 2003 two large spacecraft components used in MER underwent dry heat microbial reduction (DHMR) in “tolerable” environment conditions for the materials [9].

**Trade-offs:** At some point in the development of a propulsion subsystem these techniques are applied and modified to fit the requirements for Planetary Protection without affecting system performance.

Building a Planetary Protection Plan and process for the propulsion subsystems of a category IV mission to Europa has never been done before, the biggest complications being attached to the presence of large quantities of solid rocket propellant in some of the larger SRMs.

Figure 3. NPR 8020 by NASA.
Figure 4. SRM make-up [10].
Figure 5. Mindmap of SRM PP.
Planetary Protection Process

Processes

Materials

Environments

Bioburden Assessment
Figure 6. Roadmap of SRM PP procurement requirements [11].
Planetary Protection Process (Non-VHP)

Figure 7. SRM PP process through project stages without including the use of VHP.
Figure 8. Age equivalency to bake-out temperatures at 4th order reduction [12].

3000-degrees
### Planetary Protection Techniques

<table>
<thead>
<tr>
<th>Titanium Case Mated Case</th>
<th>Electronics Box</th>
<th>Pyrotechnic Devices</th>
<th>Insulation, propellant, adhesives, greases, and others</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHMR</td>
<td>Manufacture in clean room/bench to reduce 1 log.</td>
<td>Manufacture in clean room/bench to reduce 1 log</td>
<td>DHMR</td>
</tr>
<tr>
<td>DHMR when compatible</td>
<td>DHMR when compatible</td>
<td>Test for Antimicrobial Properties</td>
<td>Test for Antimicrobial Properties</td>
</tr>
<tr>
<td>Seal off when possible</td>
<td>Seal off when possible</td>
<td>Supplement with thermal models</td>
<td>Supplement with thermal models</td>
</tr>
<tr>
<td>Metallic</td>
<td>Electronic</td>
<td>Pyro</td>
<td>Nonmetallic</td>
</tr>
</tbody>
</table>

Figure 9. SRM PP simple techniques applicable.
Conclusions

• DHMR of the entire motor at once does not appear to be the way to achieve targeted bioreduction for the braking motor’s propellant and liner.

• Scenarios with a sacrificial thermal liner inside the metallic case may benefit from antimicrobial testing and irradiation pre-application.

• Inner-case: bagging procedures scenarios that occur can be used to the advantage of Planetary Protection.

• No-grease design change: eliminating the use of greases and increasing the risk of a rigid mated case unless greases are proven to cause a logarithmic reduction of microbial load.

• Nozzle: sealing mechanisms should be used, and verification of sealant performance and nozzle cap performance should be provided.

• Scenario with no VHP: component integration in a class 8 cleanroom environment and components divided by material compatibility to PP techniques.
Future Work

- Thermal models shall support the Planetary Protection deviation to use motor firing as mode of sterilization in future studies.
- Aside from this, small quantities of propellant, insulation, nozzle and other nonmetallics may be shipped and utilized in cryogrinding procedures to determine initial encapsulated bioburden numbers, different from those assigned by the Planetary Protection Provisions document.
- Future motor burning failure probability studies may corroborate if motor-firing is a viable option for a final probability of contamination for the mission that remains under less than 10-4 with unsterilized propellant.
Acknowledgements

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References


