# STRATEGIES FOR STRINGENT CONTAMINATION CONTROL FOR LIFE DETECTION MISSIONS.

J. L. Eigenbrode[1] and R. E. Gold, [1]NASA Goddard Space Flight Center, Solar System Exploration Division, Greenbelt MD, 20771, Jennifer.Eigenbrode@NASA.gov, [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 20723, [3]Contamination Control for Life Detection Team.

**Introduction:** Searching for signs of life in our Solar System is a key science priority for planetary exploration. Life-detection mission concepts proposed thus far seek biomolecular signatures of life, and in some cases, morphological signatures too. Earth-based analogies or simulations are often used to derive Level-1 Science Requirements, such as Limits of Detection (LoD) and minimal signal to noise ratios (SNR). Level 1 requirements must also consider environmental and sampling conditions at the destination, which often result in added margins to minimize science risk (e.g., a false negative). This is achieved by increasing instrument sensitivity and resolution that effectively lower performance LoDs. The trade-off of ultra-sensitivity is the risk of detecting contaminants, potentially preventing detection of target molecules or, alternatively, causing false positive detection.

Notably, planetary protection protocols typically used to reduce bioburden levels (e.g., dry heat microbial reduction), can still leave behind cellular fragments or cellular contents, which become potential sources of chemical and physical contamination for science measurements. Thus, stringent science-derived contamination requirements for achieving performance criteria on life detection missions necessitate mitigation approaches that minimize, protect from, and prevent science-relevant contamination of critical surfaces of the science payload in order to enable successful life-detection determinations.

To this end, we report on technology advances that focus on understanding contamination transfer from pre-launch processing to end of mission and on developing a new full-spacecraft barrier design that restricts contamination of the spacecraft and instruments by the launch vehicle hardware.

**New Full-Spacecraft Barrier Design:** Mechanical and contamination control engineers joined forces to design a new spacecraft barrier design that accommodates late mounting of RTGs and is both cleanable and repairable. For this study, a full-spacecraft, semi-rigid, deployable barrier design was validated by modeling and deemed an effective strategy to isolate the spacecraft from the pre-launch processing and launch environment (e.g., fairing acoustic materials). Deployment of a 1/3 scale model was successfully demonstrated (Figure 1).

**Figure 1.** Barrier deployment.

**New Contamination Transfer Model and Results:** A new, high-fidelity physics, contamination-transport model for particles (including cells and their parts) and science-relevant molecules (e.g., possible biomolecules) was developed to validate the barrier concept. This model takes into account the physics of extremely clean surfaces (i.e., surfaces with monolayers or less molecules) achieved by the best traditional contamination engineering practices. It also introduced computational fluid dynamics of the launch environment. As such, this model is very unique compared to standard contamination modeling approaches that rely on bulk properties and simple arrays.

Model results indicate that the barrier isolation greater than one in ten million for particles (likely biological). For molecular contaminants of concern, no molecular intrusion was predicted under very conservative conditions. In contrast, standard contamination transfer modeling indicated a reduction of $10^{-12}$, demonstrating the impact of inadequate physical considerations of ultra-clean spacecraft surfaces. The model also addressed an on-cruise bake-out of critical surfaces of a collector, which was used to represent a high surface area subsystem in the sample path, and showed the in-flight procedure significantly reduced molecular contamination (by 87%). Subsequently, the probability of a surface contamination particle being transported to an instrument by an ice particle is less than $5.1\text{x}10^{-5}$ (for microbes specifically, $4.39\text{x}10^{-10}$). The modeling results suggest the implementation of a barrier and inflight cleaning steps are highly effective at mitigating forward contamination that could impact science measurements.

**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, then adding the barrier and bake-out step, that the cleanliness levels required to meet the Level 1-Science Requirements down to femtomolar level of molecules is both practical and reasonably cost effective. The mitigation steps studied here are applicable to a wide range of life detection missions and other missions that are ultra-sensitive to contamination. However, in each case, high-fidelity physics modeling will be needed for determining mission design. The techniques developed in this study will enable future life detection missions to provide scientific results with higher confidence in their validity.

**Acknowledgments:** This technology development study was funded by NASA's New Frontiers program "to develop techniques that limit spacecraft contamination and thereby enable life detection measurements on cost-capped missions" (NASA press release, 2017). We acknowledge the hard work of the Contamination Control for Life Detection Team that included contributions from Antonios Seas, John Canham, Erich Schulze, Chris Lorentson, Therese Errigo, David Kusnierkiewicz, Faith Kujawa, Alfonso Davila, Chris McKay, Anthony Dazzo, Michael Swift, Andrew Santo, Charles Sandy, Tony Asti, and John Lin.