



## Manufacturing & Prototyping

### Development of a Centrifugal Technique for the Microbial Bioburden Analysis of Freon (CFC-11)

**Commercial applications include pharmaceutical development and quality assurance, and chemical manufacturing.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

NASA Procedural Requirement 8020.12C entitled "Planetary Protection Provisions for Robotic Extraterrestrial Missions" states that the source-specific encapsulated microbial density for encapsulated organisms (div(0)) in non-metallic materials ranges from 1-30 spores/cm<sup>3</sup>. The standard laboratory procedure, NASA Standard Procedures for the Microbial Examination of Space Hardware, NHB 5340.1B, does not provide any direction into the methodologies to understand the bioburden within such a fluid as CFC-11 (Freon). This general specification value for the Freon would be applicable to the Freon charged within the Mars Science Laboratory's (MSL's) Heat Rejection System. Due to the large volume required to fill this system, MSL could not afford to conservatively allocate 55.8% of the total spore budget of the entire laboratory system (rover, descent stage, cruise stage, and aeroshell) of  $5.00 \times 10^5$  spores at launch.

A novel filtration approach was developed to analyze the Freon employing a 50 kDa molecular weight cutoff (MCO) filter, followed by 0.22- $\mu$ m pore-size filter to establish a calculated microbial bioburden.

Filtration of microorganisms from liquid matrices is a standard laboratory approach. Due to the volatility of Freon, a standard vacuum filtration unit would not suffice because of the lack of a cold trap on the vacuum unit. A more economical approach had to be devised. The two-pronged concentration approach is advantageous due to the fact that it initially concentrates the Freon from liters to milliliters where it can then be feasibility filtered and microbes extracted from the filter. This is a technology improvement over prior art as it defines the specific parameters to concentrate microbial organisms from a low-boiling-point fluid such as Freon.

This work relates to the current MSL mission but also has implications for future NASA missions that will utilize the same or similar heat rejection fluids. If the same lot of material is utilized on a future mission, then the experimentally derived value can be directly used based on this study (MSL-heritage). If a new lot or similar material composition is used in a future mission, then this technology can be employed or modified accordingly to accommodate such a fluid. This technology development will allow for a heritage-based starting point for fluids on other missions in which a calculated microbial bioburden is necessary.

*This work was done by James N. Benardini, Robert C. Koukol, Gayane A. Kazarians, and Fabian Morales of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48303*

### Microwave Sinterator Freeform Additive Construction System (MS-FACS)

**This system can create hard surfaces for walkways, roadways, or landing pads.**

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The harmful properties of lunar dust, such as small size, glass composition, abnormal surface area, and coatings of imbedded nanophase iron, lead to a unique coupling of the dust with microwave radiation. This coupling can be exploited for rapid sintering of lunar soil for use as a construction material that can be formed to take on an infinite number of shapes and sizes.

This work describes a system concept for building structures on the lunar surface using lunar regolith (soil). This system uses the ATHLETE (All-Terrain Hex-Limbed Extra-Terrestrial Explorer)

mobility system as a positioning system with a microwave print head (similar to that of a smaller-scale 3D printer). A processing system delivers the lunar regolith to the microwave print head, where the microwave print head/chamber lays down a layer of melted regolith. An arm on the ATHLETE system positions the layer depending on the desired structure.

In support of long-duration human missions to the lunar surface, a variety of *in situ* derived structures have been proposed that would enhance the utility of a permanent outpost, provide safety for the outpost elements, and mitigate the gen-

eration of dust. Using regolith in a variety of ways, it has been proposed that berms, paving, walls, roads, and other structures could be constructed to serve as permanent outpost. However, the means of creating the *in situ* structures with hardened surfaces remains a challenge.

A lunar regolith processing system mounted on the underside of ATHLETE will deliver correctly sized regolith particles to a microwave print head via a material handling system. The microwave print head with tunable microwave chamber then lays down a layer of melted regolith as the ATHLETE arm traces a pre-defined