

## **FY 2019 Center Innovation Fund Annual Report for FY18 CIF Projects**

### **18-1. Demonstration of Plasma Assisted Waste Conversion to Gas**

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#### **Executive Summary:**

The volume reduction of mission waste is needed to advance waste processing for vent gases on board space vehicles and space habitats for long duration missions. To date, the team has demonstrated early concepts of plasma assisted waste conversion of the following materials cotton (hygiene material), polymers (high density polyethylene (HDPE) and nylon), astronaut food packaging, packaging foam, food, fecal, urine, inedible biomass, maximum absorbency garments, and High Fidelity Waste Simulant. The reactions took place in a quartz cylindrical test cell, where waste was loaded into a quartz crucible and monitored with optical video. The initial reactions included a multi-stage process that was primarily plasma combustion. The reaction product gas was qualitatively and quantitatively analyzed with a gas chromatograph and Fourier transform infrared spectroscopy instrument. The instruments were calibrated with standard gases. Mass conversion was calculated by measuring the starting mass and the remaining mass left over in the system on calibrated laboratory scales.

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### **18-2. Corrosion on Mars: Effect of the Mars Environment on Spacecraft Materials**

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#### **Abstract:**

This report presents the results of a one-year project, funded by NASA's Kennedy Space Center Innovation Fund in FY18, to conduct a theoretical study on the effect of the Mars environment on spacecraft materials. Corrosion resistance is one of the most important properties in selecting materials for landed spacecraft and structures that will support surface operations for the human exploration of Mars. Currently, the selection of materials is done by assuming that the corrosion behavior of a material on Mars will be the same as that on Earth. This is understandable since there is no data on the corrosion resistance of materials in the Mars environment. However, given that corrosion is defined as the degradation of a metal that results from its chemical interaction with the environment, it cannot be assumed that corrosion is going to be the same in both environments since they are significantly different. The goal of this research was to develop a systematic approach to understand corrosion of spacecraft materials on Mars by conducting a literature search of available data, relevant to corrosion in the Mars environment. This project was motivated by the suggestion, by a team of researchers, that some of the structural degradation observed on Curiosity's wheels may have been caused by corrosive interactions with the transient liquid brines, reported to be present on Mars, while the most significant damage was attributed to rock scratching. An extensive literature search, on data relevant to corrosion on Mars, confirmed the need to investigate the interaction between materials, used for spacecraft and structures designed to support long-term surface operations on Mars, and the Mars environment. Previous preliminary experiments, designed to look at the interaction between aerospace aluminum alloy (AA7075-T73) and the gases present

in the Mars atmosphere, at 20oC and a pressure of 700 Pa, showed that there is an interaction between the small amount of oxygen present in the Mars gas and the alloy, when there is a scratch that removes the protective aluminum oxide film. Further studies are needed to consider many other important components of the Mars environment that can affect this interaction such as: the presence of brines, the interaction between these brines and materials, the effect of radiation on these interactions, and the possible catalytic effects of the clays present in the Martian regolith. This theoretical study provides strong justification to conduct experimental work to investigate the interaction between spacecraft materials with simulated Martian environments to reduce Mars exploration costs.

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### 18-3. ECAPS – Eddy Current Approach and Proximity Satellites

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#### Executive Summary:

Some eddy current based magnetic forces are well known and understood. For example, generating a repulsive force can be accomplished by oscillating the current through a loop that is placed near a conductor. Lateral forces can be generated using linear induction motor concepts where the coils are energized at shifted phases to make it appear that there is a traveling magnetic field. This is well known, but the problem will be dealing with the repulsive forces that will also be generated.

This writeup covers the math and experimental data for demonstrating each of the electromagnetically generated forces needed for an Eddy Current Approach and Proximity Satellite (ECAPS) satellite to move around a structure like the International Space Station (ISS). Six degrees of freedom need to be provided by the actuators: translational motion along three orthogonal axes and rotation about each of these axes. Translational motion toward and away from a structure like the ISS can be accomplished with an attractive force actuator to pull you closer and a repulsive force actuator to move you further away. Motion parallel to the structure can be accomplished with a lateral force actuator. The rotational motion can be achieved by using the actuators off of the translational axes running through the center of mass. Applying the forces off-center will cause rotation about that translational axes.

The first force to be explored is attractive force generation, followed by the lateral forces based on a linear induction motor, and finally repulsive magnetic forces. Professor Mason Peck and Katherine Wilson at Cornell University studied the pseudo-forces involved and how to implement a control strategy for the force actuators. Their reports summarizing this work appear as appendices.

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### 18-4. Waste Water Brine Electrodialysis for Water Recovery and Fertilizer Productions

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#### Executive Summary:

Reutilizing resources onboard the International Space Station (ISS) and for future deep space missions are critical for mission longevity and sustainability. Waste water brine produced from water recovery systems contain chemical species that could be processed into a potential fertilizer for future plant systems. Fertilizer production can be achieved through a process called electrodialysis ion exchange. Waste water containing inorganic salt components are fed through a series of ion exchange membranes to produce fertilizer (a phosphate rich stream), electrolysis-grade water, and other useful commodities. Electrodialysis cells consisting of anion and cation exchange membranes, monovalent anion exchange membranes, and bipolar membranes were utilized to achieve selective ion exchange. Ions successfully diffused across their respective membranes into the concentrate, acid, and base streams. This resulted in pure water, a phosphate rich stream, and separate acid and base streams.

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#### 18-5. Microbes Eating Rocket Propellant Hpergols (MERPHs)

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#### Executive Summary:

The objective of this study was to investigate the viability of a unique biological approach in eliminating the hazardous properties of a newly developed storable propellant known as M315E. Also, to further investigate the potential for conversion of the propellant to gaseous nitrogen and water or possibly into a fertilizer product. To accomplish these goals, microbial strains of denitrifying bacteria were first investigated. The denitrifying bacteria *was* employed to transform the nitrogen species present in the propellant formulation, from nitrate and ammonium and then into nitrogen gas. These bacteria exhibit metabolic capability to denitrify/nitrify concomitantly resulting in cyclic conversion of both ammonium and nitrates (Hung). Several different combinations of bacterial strains, carbon sources, oxygen levels, pH conditions, and essential nutrients were tested against varying concentrations of M315E as the nitrogen source. Denitrification rates, over the course of seven days, were observed for M315E. Slight variations in rates were observed resulting from differing oxygen availability, i.e., aerobic vs anaerobic incubation. Testing indicated the microbially-driven conversion of nitrates to ammonium was achieved and has the potential to be utilized as a mitigation strategy to render the propellant free from its explosive properties. Further, denitrification proceeded for solutions of higher M315E concentrations, but eventually plateaued likely due to limited carbon availability. Considering the high concentration of nitrates in the M315E propellant, along with the subsequently high demand for carbon by microorganisms, alternative carbon dense media as bioavailable carbon, should be investigated further.