NASA EPSCoR Rapid Response Research (R3)
Abstracts

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18-EPSCoR R3-0022

Evaluation of Candidate Crop Plants in Biologically Enhanced Martian Regolith

Commercial Space Flight (CSCO)

Dr. James Casler
University Of North Dakota, Grand Forks

Candidate crops for a Mars mission will be evaluated for biocompatibility with Martian regolith that has been amended with biologically degraded organic waste material through the process of vericulture. We propose to compare the growth of a grain (dwarf wheat), leafy green (lettuce) and fruiting (tomato) crop grown in amended regolith with recirculating hydroponic nutrition system in the Inflatable Lunar/Martian Habitat (ILMH)'s Plant Growth Module at University of North Dakota. Yield and quality of the candidate crops grown in Analog Mars Habit under the enriched Regolith will be compared to control plants grown in a recirculating hydroponic system.

The feasibility of adapting techniques for reducing the volume of organic waste, recovering nutrients, and recycling resources in a closed plant growth system for Mars will be evaluated. The viability of incorporating and using vermiculture to reduce organic waste and enrich Martian Regolith will be determined, and the biocompatibility of the resultant biologically enhanced Martian regolith with candidate crop production in a Mars Analog Test will be established.

18-EPSCoR R3-0025

FY18 Alabama NASA EPSCoR Rapid Response: Characterization of Inconel 625 Blown Powder Freeform Deposition Material

Commercial Space Flight (CSCO)

Dr. Lawrence Dale Thomas

University Of Alabama, Huntsville

There is a plethora of commercialized, metal-based AM techniques with the most commonly used being the Powder Bed Fusion (PBF) and Directed Energy Deposition (DED) methods. Laser Engineered Net Shaping (LENS™), one common laser-based DED, or Direct Laser Deposition (DLD), used for fabrication and repair of parts, uses a laser to melt a spot on a metal substrate while blowing metal powder into the molten pool. Under normal operation, the substrate, attached to a Computer Numerical Control (CNC) controlled stage, is moved in a user defined pattern to create a single layer, and upon completion, the deposition head, containing the laser focusing lens and the power nozzles, are moved up to begin another layer, with this process repeating until the part is done. Though AM techniques offer many advantages over traditional manufacturing techniques, many of the process-structure-property-performance relationships are not yet fully understood. Certification and qualification of AM processes, as well as standardization of various post-processing or quality checks, is required for AM technology to further mature and be adopted5. Resultant microstructures of DED Inconel 625 parts have been shown to differ drastically from those of their wrought counterparts6-7-8. The DED process is conducive for epitaxial and elongated grain growth, with strong texture depending on build and major thermal

gradient directions, resulting in anisotropy in the mechanical properties of the resulting part9. Therefore, the production of application-worthy parts becomes problematic, as both process and feedstock-driven defects, as well as inconsistencies in part microstructure, can lead to unpredictable mechanical behavior, especially in its fatigue response.

18-EPSCoR R3-0034

Life on Mars: Algae Cultivation For Long-Term Food and Oxygen Production

Commercial Space Flight (CSCO)

Dr. Lynn F. Fenstermaker

Nevada System of Higher Education

Human exploration of Mars will require significant supplies of both oxygen and food. The ability to grow photosynthetic organisms on Mars would potentially contribute significantly to both of these needs. We here propose to grow algae adapted to extreme terrestrial conditions, as well as edible algae, under a series of conditions relevant to Mars.

Snow algae grow very well in challenging high UV, low temperature, and low nutrient snow environments. We have grown these organisms under low-nutrient conditions, and we propose to expand upon our previous work to grow snow algae under a range of pressures, atmospheric conditions, temperatures, amounts of water and light, and nutrient sources, to determine the suitability of these organisms as potential oxygen sources on Mars. We will similarly grow edible algae species under the same conditions to examine the potential for algae to provide both nutrients and oxygen. In order to complete this work, we will collaborate with NASA Scientist Dr. Doug Ming, who has extensive experience in Life Support, and Dr. James Raymond, who is a snow algae expert. The proposed work has been discussed with Dr. Warren Ruemmele, and will fill important knowledge gaps in the production of oxygen and nutrients on Mars.

18-EPSCoR R3-0040

Stability and Distribution of Methane Clathrate Hydrates on the Surface of Mars

Commercial Space Flight (CSCO)

Dr. Mitchell Keith Hudson

University of Arkansas, Little Rock

Methane has been first identified in the atmosphere of Mars by the Planetary Fourier spectrometer onboard Mars Express (Formisano et al., 2004). It was then confirmed by ground-based observations (Mumma et al., 2009) and later in situ by the Mars Science Laboratory's SAM instrument (Webster et al., 2018). Methane is a potentially significant resource for future exploration of Mars, provided we can identify its sources, locations, and abundances. According to our current knowledge of the surface and subsurface environment of Mars, one of the main sources should be clathrates hydrates, a structure composed of water molecules "cages" entrapping other gas molecules, including methane.

18-EPSCoR R3-0043

Nanotechnological Approach for Improving Plant Stress Tolerance Sustainable Crops for Advanced Life Support in Mars Exploration

Space Biology

Dr. Mitchell Keith Hudson

University of Arkansas, Little Rock

People who will colonize Mars will face several problems including an obvious deficit of oxygen and water. Plants are essential components of human space exploration. They can provide oxygen, remove carbon dioxide, purify water, supply fresh food, pharmaceuticals and are also beneficial for psychological health. All abiotic stresses (cold, drought, salt) reduce plant growth and yield. Abiotic stress is one of the major limiting factors in Space Agriculture, thus preventing crop plants from realizing their full genetic potential. For example, plants established for Mars Agriculture should be able to grow in conditions of significant water deficit. This project will take distinct approaches for addressing this problem and develop tools suitable for Mars Agriculture. The long-term goal of the proposed project is to develop new approaches to increase abiotic stress tolerance in crops. We will achieve this goal by utilizing the unique properties of nanomaterials in planta. First, we will investigate the positive effects of nanomaterials on plant growth, especially under stress conditions, and elucidate underlying mechanisms. Next, we will determine whether DNA-loaded nanoparticles could serve as carriers to deliver genes into plant cells leading to genetic transformation and establishment of stress tolerant plants. These two distinct non-transgenic and transgenic approaches could serve as useful tools for the sustainable growth of plants in stressful conditions of Mars. We will use carbon nanotubes and magnetic nanoparticles as carriers for delivery of DNA encoding genes associated with enhancement of stress tolerance in planta, and carbon-based nanomaterials (multi-walled carbon nanotubes and graphene) forameliorating symptoms of drought stress in two economically important crops: rice and soybeans. In addition, we will test the hypothesis that enhancement of abiotic stress tolerance in plants could occur upon exposure to nanomaterials by studying activation of stress signaling at the molecular level We will also compare the efficiency of non-transgenic and transgenic approaches for the enhancement of plant stress tolerance.

18-EPSCoR R3-0045

High Density Electronic Packaging for Venus Mission

Planetary Science

Dr. Mitchell Keith Hudson

University of Arkansas, Little Rock

Venus presents a significant extreme environment challenge to its exploration. Vehicle, instrument, and system designs in its lander or probe must account for its corrosive, high-pressure (~92bar), and high-temperature (470°C) environment. Despite research efforts in developing extreme environment devices

and integrated circuits (ICs), their packaging and assemblies are still less than satisfactory. This project aims to develop State of Arkansas research infrastructure so that the team eventually can tackle the grand technical challenge in developing transformative cost-effective electronic packaging and assemblies capable of surviving the extreme environment in Venus for at least 60 earth days. The research team has significant research and development experience in harsh environment packaging/assemblies in the High Density Electronic Center at the University of Arkansas. The science principal investigator plans to continue to work closely with Dr. Gary Hunter (NASA Glenn Research Center) and Dr. Quang-Viet Nguyen (Planetary Science Division/Science Mission Directorate, NASA Headquarters) in the current HOTTech program. The goal of this effort is to establish high-temperature electronics packaging systems that go beyond the current single-layer, screenprinted gold traces (~200µm width and spacing) on as-fired alumina. To accomplish this, research will involve reducing line width and spacing using different techniques. The specific goals of the proposed 1-year research efforts are to:

• Evaluate thin film techniques to create multi-level Ti/Au interconnect separated by silicon dioxide via chemical vapor deposition.

Titanium is needed as an adhesion layer for gold.

•Leverage existing screen printing tools and screens to reduce line width and spacing beginning with 100µm and attempt an ultimate goal of 20µm.

•Analyze experimental data and make specific recommendations for the most feasible and cost effective approach to miniaturizing an interconnecting base that is 1.5X to 2X the size of the bare die to populate it.

These tasks aid in the realization and maturity of highly functional yet miniaturized packaging for embedded electronic systems and subsystems used in scientific exploration of Venus, Mercury or Gas Giants (e.g., seismic activity sensor).

18-EPSCoR R3-0047

NASA EPSCoR Rapid Response Research: Graph-based Network Analysis of Microgravity Regulated Gene Expression in Arabidopsis Thaliana

Space Biology

Dr. Gerardo Morell

University Of Puerto Rico, San Juan

The goal of this proposal is to identify and characterize molecular pathways and mechanisms that underlie physiological changes in the Arabidopsis Thaliana plant grown in the International Space Station (ISS) using novel graph network analysis methods. As plants provide bioregenerative life support, understanding the gene expression of Arabidopsis in microgravity will enable planning future long term space missions. This plant has been named as one of the important well-established model organism in plant biology. Its genome structure has been well analyzed on ground. Graph based Gene Regulatory Networks (GRNs) will be implemented for the GeneLab datasets obtained from the Arabidopsis experiments conducted in space. Graphs are state-of-the-art biomolecular network analysis tools that can characterize omic datasets obtained by NASA and from other sources. GRNs have been implemented using graphs with no weights. In this project, we will develop GRNs using directed graphs with weighted edges to model connections with different strengths. Network analysis paradigms from electric circuits such as resistance distance, Kirchhoff index, and network criticality will be used to perform genome to phenome analysis. An algebraic approach will be taken to model complex networks that characterize Arabidopsis GRNs, with thousands of nodes and hundreds of thousands of interactions among the nodes. The network analysis will also involve use of bipartite graphs, and graph cuts where network interactions are between two groups of nodes. Analysis of Arabidopsis Thaliana will be done with graph combinatorial algorithms, as classical methods that are currently available would not be sufficient. The objectives for the first year of this NASA Rapid Response Project are:

i) Perform directed and weighted graph based network analysis of the Arabidopsis Thaliana datasets in order to determine which genes are activated by gravity and other stress for regulating plant growth in space.

ii) Develop a bioinformatics tool implementing the novel graph approach in Python for network analysis.

The GeneLab datasets that would be used in this project are low atmospheric pressure stress (GLDS-136), gene expression profile in microgravity and ground based measurement (GLDS-44, 45), geneexpression of the root exposed to high levels of magnesium sulfate (GLDS-22), and transcriptome analysis GLDS-7 from leaves, hypocotyls, and root. The graph based GRN analysis algorithms will be coded as a Python toolbox and provided to NASA.

The data, tables and graphs generated by this project will be made available to the space biology research community. Dr. Jonathan Galazka, Scientist from NASA Space Biosciences Research Branch will be collaborating in this project as advisor. He and his team will enable GeneLab data understanding, connect the PIs with other scientists in this area, provide monthly feedback on research progress, evaluate the outcomes of the GRN analysis, and provide suggestions for improvement. This project will be conducted at the University of Puerto Rico (UPR), Mayaguez Campus and Rio Piedras Campus. The project team is interdisciplinary bringing together the PI, Dr. Manian a faculty in Electrical & Computer Engineering, and Bioengineering, and Co-PI, Dr. Janwa a faculty in Mathematics. This project is conducted in an Hispanic minority serving institution with 99% Hispanic students who will gain knowledge in the fields of space biology, mathematics, bioinformatics, and Python tool development. This project will directly support two graduate students in Space Biology research, and involve many undergraduate students through course work and workshops. They will be exposed to NASA space related research. This project will also enable Hispanic minority students to take up internships with NASA, and add to the workforce development for future NASA missions.

18-EPSCoR R3-0048

High-temperature subsystems and components for long-duration (months) surface operations: Robust electronic circuits based on layered materials

Planetary Science

Prof. William H. Matthaeus

University Of Delaware

Objectives: The objective is to develop a new material platform for miniaturized, lightweight and low-cost transducers operating in harsh environment, which can be used for probing the surface and interior structures of Venus. The harsh environment on Venus surface limits the lifetime and capability of the electronic instruments on landers. Wide bandgap semiconductor materials, especially Silicon Carbide (SiC), have been successfully developed for integrated electronic circuits in the high temperature environment above 470 degree centigrade. Sensors with ceramic, laminate and nanostructured materials have been developed for measuring temperature, heat flus or mechanical strain in a high temperature and corrosive environment. However, those sensing devices based on existing material libraries are hard to etch/process/integrate, which could limit their implementation in a robust instrument.

Recently, 2D layered materials have emerged as new platform for multi-functional sensing devices. Giving the chemical stability and temperature endurance of a few 2D materials, they can certainly expand their versatile capabilities for high temperature operation. Hybrid integration of those layered materials on the developed SiC electronic platform at NASA can dramatically expand the capability of Venus landers towards months-long operation in the extreme environment. Graphene is densely packed single carbon atom layer in a honeycomb lattice, which can effectively prevent even the smallest molecular of proton to penetrate through. Its high temperature endurance (up to 1000 degree centigrade), flexibility and chemical stability enables robust and high-performance electronic devices on arbitrary substrates. Also, combinations of two dimensional (2D) materials' properties have enabled new transducing mechanism, such as acoustic wave sensor, photodetector, bolometer, pressure sensor etc., potentially suitable for high temperature applications.

Methods/techniques: Recently, we had experimentally verified dramatically improved thermal stability of semiconductor 2D materials with graphene's protection, characterized through a combination of non-invasive optical spectroscopy and atomic structural imaging. We plan to extend current experimental plans to other stacked 2D materials, fabricate transistors and transducers, and characterize those electronic devices through in situ measurement at high temperature. Understanding towards the carrier mobility, material degradation/oxidation, metal migration into the semiconductor 2D materials will be developed through in-situ measurements.

Significance and NASA relevance: The proposed efforts on studying sensing devices based on robust materials align with NAS Glenn Research Center (GRC) Smart Sensors and Electronics Systems Branch's work on SiC semiconductor integrated electronics. The new sensor devices developed through the proposed effort can integrated on those robust electronic processors and thus dramatically expand the capabilities of miniaturized and low cost instruments operating on Venus surface. This proposed work closely aligns with NASA's Venus Technology Plan 'Development of high-temperature electronics, sensors and the thermo-electric power sources designed for operating in the Venus ambient would be enabling for future missions..', and several objectives in NASA's 2018 Strategic Plan, such as GRC's strategic goal '… and use expert knowledge in materials to develop and test electronics for extreme environments such as surface conditions on Venus'.

18-EPSCoR R3-0050

NASA Space Life and Physical Sciences and Research Applications Space Biology Research Request 2 -- Experiments and Simulations of Microbial Growth in Rotating Bioreactor

Space Biology

Dr. Edward F. Duke

South Dakota School Of Mines & Technology

The focus of this proposal is on the creation of a simulation technique to predict the interaction between fluid flow and its affects on bacterial growth, specifically investigating the use of ground-based analogs for bioreactors. Recent investigations have reported increased utilization of ground-based simulators that use rotating reactors to place bacteria in a state of free fall that is similar to conditions on the space station. However, the effects of fluid flow, including convection and sedimentation, on the genomics during bacterial growth are unknown.

Intellectual Merit: In this proposal, the PI will investigate an innovative numerical platform that uses Stokesian dynamics to model bacteria in a rotating wall vessel (RWV). Suspensions of bacteria will be simulated under various operating conditions to identify dominate characteristics the govern suspension mechanics. Successful completion of this project will define the necessary conditions to keep a suspension of bacteria indefinitely suspended. To overcome geometric limitations that are often encountered in previous investigations, assemblies of spheres will be utilized to represent the aspherical nature of the bacteria. These simulations will attempt to match ongoing precision experiments that are being funded through NASA EPSCoR. The investigation will provide detailed insights into the suspension mechanics of the bacteria during their growth in the media, while directing optimal operation of the RWV.

Broader Impacts: Beyond identifying the necessary operating conditions for the RWV to ensure indefinite suspension and adequate access to nutrition for the bacteria in a RWV, successful completion of this project would provide fundamental insight into the suspension mechanics of bacteria in ground-based microgravity analogs. This information, coupled with models to account for mass transfer, could lead to directed engineering of growth conditions, including suitable nutrient access and consistent mechanical stress conditions. Further, this information will direct new studies to compare ground-based analogs to in-space bioreactors and the differences that these environments have on microbial growth.

18-EPSCoR R3-0053

A Novel Electrochemical Method to Reduce the Surface Roughness of Internal Features in Additive Manufactured Components

Commercial Space Flight (CSCO)

Dr. Lynn F. Fenstermaker

Nevada System of Higher Education

The proposed research is to evaluate and reduce the surface roughness of selective laser melting (SLM) manufactured components. Specifically, this proposal addresses the ""Additive Component Internal Feature Surface Roughness Reduction"" research priority set by the NASA Commercial Space Capabilities Office. The overall goal is to improve component fabrication for propulsion and power conversion applications. To meet this need, we propose a novel ultrasonic assisted electrochemical polishing approach, which is highly scalable, to reduce the surface roughness of internal features of components fabricated by SLM. We will devise an electrochemical setup in which the internal surface of the as-built component will act as an anode while a stainless steel rod will be the cathode. An optimized electrochemical solution will be developed depending on the material of interest. The internal surface will be electrochemically polished under ultrasonic agitation conditions using the setup developed in this research.

During electrochemical polishing, different-sized electrochemical inert abrasive media, such as silicon carbide (SiC) and/or alumina (Al2O3), will be added to the electrochemical solution. Under the influence of ultrasonic agitation and electrochemical polishing conditions, these abrasive media generate a synergistic effect to remove the surface layer and thus efficiently reduce surface roughness. To obtain uniform surface roughness, we will intermittently rotate the setup 180 degrees counter-clockwise and clockwise. Surface roughness parameters will be measured using an optical profilometer after a selected number of cycles to determine the number of cycles required to achieve the desired roughness. The surfaces will be masked with polymeric material at locations where polishing is not required, such as channel inlets and outlets with sharp turns. After the desired roughness is achieved, the internal surface will be polished with fine abrasive media in deionized (DI) water followed by ethanol cleaning with an ultrasonicator to remove any residue. The post-fabrication step proposed here is unique and innovative in its use of tribocorrosion properties to reduce the surface roughness of the internal features of additive manufacturing (AM) metallic components. It is a simple and straightforward method that can easily be scaled up.

18-EPSCoR R3-0054

Metagenome Data Mining to Elucidate Prevalence and Virulence Potentials of Biosafety-level-2 Microorganisms from ISS Environments

Space Biology

Dr. Lynn F. Fenstermaker

Nevada System of Higher Education

In late 2018, our NASA collaborators, Venkateswaran and Singh, reported the proliferation of the dominant BSL-2 pathogen, Klebsiella pneumoniae, on ISS surfaces over a three flight time course (1). Here we propose to utilize the same GeneLab dataset (GLDS-69), supplemented with a ground-based mutigenerational cultivation study of ISS K. pneumoniae isolates, to gain a better understanding of the threat these opportunistic pathogens may pose to astronaut health. This overarching objective will be achieved by mining GLDS-69 to reconstruct metagenome-assembled genomes (MAGs) for K. pneumoniae – using these to assess strain-level diversity and potential changes in pathogenic potential. In parallel, K. pneumoniae isolates from the JPL ISS culture collection will be subjected to multigenerational selection using stressors consistent with extended space travel and tracked for changes in gene expression patterns (e.g. virulence gene complement). Selection in the laboratory (e.g. directed evolution) will be conducted in the presence of disinfectants used on the ISS, followed by a survey of gene expression of evolved and unevolved strains under simulated microgravity. The proposed project will be conducted in collaboration with JPL and GeneLab scientists, to gain a better understanding of strain-level succession of a dominant potential pathogen on the ISS and assess potential stimulation of virulence factors under selective pressure from relevant disinfectants and microgravity.

18-EPSCoR R3-0055

Multi-cohort, Pathway-level Analysis of Spaceflight Disorders

Space Biology

Dr. Lynn F. Fenstermaker

Nevada System of Higher Education

It is known that spaceflight can have negative impacts on astronauts' health and immune systems. As genomics data rapidly populate public repositories, including NIH GEO and GeneLab, we have sufficient data to understand the biological mechanisms in order to provide

immune countermeasures to ensure astronaut health. However, conventional analysis methods that focus on a single cohort are prone to study bias and data heterogeneity, leading to inconsistent conclusions. In addition, most analyses focus on differential analysis at the gene level, exacerbating the inconsistency. Our hypothesis is that a phenomenon can be triggered by a number of different events, through different genes, but still involve common mechanism(s). As signals propagate along a pathway, the genes that are differentially expressed (DE) change over time, while the pathway involved remains the same. Therefore, instead of focusing on DE genes, we propose to characterize spaceflight disorders using pathway signatures. The goal of this project is to develop a multi-cohort technique to identify the pathway signatures of spaceflight disorders using transcription profiling. The long-term goal (beyond this project) is to identify treatments that provide immune countermeasures by repurposing existing drugs. If successful, this project has the potential to significantly improve astronaut health, which is the main objective of NASA Space Medicine.

To achieve our objective, we will develop an R statistical package that can: i) perform multicohort analysis; and ii) identify and visualize pathway signatures (impacted pathways, signaling cascades, and exit interfaces and statistics). This work will be performed by the Science PI Dr. Tin Nguyen, his Ph.D. student Hung Nguyen, and the co-PI Dr. Hung La, in collaboration with NASA scientists Drs. Jonathan Galazka and Sylvain Costes. The project has been discussed with NASA contact Dr. David Tomko.

18-EPSCoR R3-0056

Multilayer Thin Film Coating for Sensor Platform in Extreme Environments

Planetary Science

Dr. James Casler

University Of North Dakota, Grand Forks

Advanced sensor platforms that can be reliably applied under extreme environmental conditions is of critical importance for exploration and long-duration operation on the Venus surface because of its extremely high ambient surface temperature and pressure. To apply sensor platform reliably in such a condition, this project is aimed to develop a protective coating system. Despite recent advances in coating techniques and manufacturing, there are still two major challenges to be overcome: (1) development of a lightweight and durable coating system with excellent mechanical and structural stability under high temperature and pressure conditions and (2) design of the coating systems that could serve as a thermal insulation layer to prevent heat transfer in order to ensure the workability of the sensor platform by maintaining the relatively low temperature state for the sensors. With the recent progress in graphene, to overcome these challenges, it is hypothesized that a multilayer thin film coating based on aero-graphene (i.e., a bulk-like porous material) could serve as a protective coating system to enable long-duration operation for sensor application at Venus surface. It takes the advantages of the low density and thermal conductivity and exceptional mechanical properties of the aero-graphene. Specifically, the proposed multilayer thin film coating consists of mainly three sublayers including a sealing outer-layer made of metal alloy, an insulation middle-layer made of bulk aero-graphene, and a resin inner-layer for attachment of substrate or sensor platform. To achieve the stated goal, multiscale modeling, numerical analysis, and validating experiments will be integrated. The hypothesis will be tested by pursuing three main objectives: (1) computation-assisted design of graphene-based multilayer coating to insulate sensor platform; (2) experimental testing of sensor platform coated by the developed multilayer coating under high temperature and pressure condition; (3) integration of research into STEM education and curriculums. The proposed research will build upon our research team's expertise on multiscale modeling, mechanics of materials, design and testing of smart coating and sensing platforms, and our collaboration with scientist at NASA, creating unique synergies that provide the crucial knowledge and skill set required to achieve the stated goals.

18-EPSCoR R3-0057

Investigate Potential Mars or Lunar Resources

Commercial Space Flight (CSCO)

Dr. Lawrence Dale Thomas

University Of Alabama, Huntsville

The objective of this project is to map the thickness of a dust/water ice layer in the Permanently Shaded Regions (PSRs) in the lunar polar regions by considering mixing processes. Water is a key element of future resource in planetary explorations. Signs of water ice have been detected on the Moon by different techniques. Their sources may result from impacts of asteroids and comets, volcanism, or implantation by the solar wind. Classical theories discuss that the accumulation of water ice on the lunar surface is related to heat transfer. Water ice particles in the surface layer can be sublimated (or melted) by various processes such as impact cratering and solar heating. Then, they may be transported at low attitude but trapped by cold spots including the PSRs. However, this explanation is incomplete because lunar surface materials are mixed by impacts and electromagnetic forces. The present project will investigate how material mixing affects the thickness of a dust/water ice layer. The current project will explore the mixing depth of a dust/water ice layer on the floors of three craters, Amundsen, Cabeus B, and Lovelace. The first two craters are located in the south pole region while the third one is in the north pole region. Thus, the investigations of these craters allow us to infer the contrast of the water ice distribution in the PSRs at the north and south poles. We will divide a PSR within each crater into two locations. The first location is a PSR region far from the sunlit-shadow boundary (SSB), or Area 1. The second region is at the SSB, defined as Area 2. We consider that mixing in Area 1 is only controlled by impact bombardment, while that in Area 2 is influenced by both impact cratering and electromagnetic forces. To accomplish this goal, we employ data analysis, statistical modeling, and experiments. Following are the planned tasks. Task A will conduct data analysis by using archived data in NASA/PDS from Lunar Reconnaissance Orbiter (LRO)s the Lyman-Alpha Mapping Project (LAMP) instrument and its camera system (LROC). We will use data from the LROC and LAMP instruments archived in the Planetary Data System. LROC images will be used to develop the crater production function and analyze the crater conditions. LAMP images will be used to analyze the amount of water ice in the SPRs. Task B will quantify the impact-driven mixing depth on the floor of the target craters by using an established statistical model. This model will provide the statistical distribution of the impact-driven mixing depth of a dust/water ice layer in Areas 1 and 2 for each crater, given the CSFD from Task A. In this task, we will assume that the CSFDs of the PSR and the sun-lit region are similar within a crater. Task C will experimentally measure the total amount of dust/water ice transported at the SSB. Experiments will be performed in the Magnetized Plasma Research Laboratory (MPRL) in the Auburn University Physics Department. Task D will integrate all the results in these tasks to give constraints on the effect of material mixing on the thickness of a dust/water ice layer in the PSRs. The present call seeks research of potential for resources including near surface lunar ice with high H2O concentration. Based on the expected results, our project fits the calls goal by providing ideas for water ice sampling technologies.

18-EPSCoR R3-0058

Reduction of Surface Roughness of Interior Surface of 3D-Printed Objects by Additive-Assisted Electroplating of Metals

Commercial Space Flight (CSCO)

Dr. Lawrence Dale Thomas

University of Alabama, Huntsville

The central objective of the proposal is to test if electrochemical deposition of metals can be used to reduce the roughness of the interior surface of three dimensional (3D) printed metal objects by filling up the micrometer-size trenches and voids on the interior surface.

The methods:

We plan to use small amounts of three types of additives, including a leveler, an accelerator, and a suppressor, to modulate the rate of electrochemical deposition of Cu or Ni so that the electrochemical deposition will selectively fill up the voids and trenches on the interior surface of any 3D printed metal objects. We will study how to control the key parameters in the additive-assisted electrochemical deposition, including electro-potential, concentrations of additives, and diffusion rates of electroplating species on the interior surface roughness mechanical properties, and thermo-mechanical properties of 3D printed metal objects,

The impact for NASA:

The proposed additive-assisted electrochemical deposition provides a superior solution than etching and polishing to meet NASA's requirements (in this proposal call), including reduction of the roughness of the interior surface of 3D printed objects to < 1µm, improvement of the mechanical strength, and maintaining the dimensions of the finest features inside of the 3D objects. This method will increase the mechanical strength of the objects because metals will be coated into the open voids and trenches on the surface. The coated metal will not affect the original structures and dimensions of the fine features inside 3D objects because the coating thickness will not exceed 100 µm, which is much smaller than the smallest features (~6,300 µm) inside of the 3D printed objects from NASA. The coated metal will increase the wall thickness of the components inside of the 3D printed objects so that the walls can tolerate pressure difference that is larger than 100 psi. The method will add metal coating of <100 µm on the object’s outlet and inlet, whose function and connectivity will not be affected. Post-deposition cleaning step will remove all organic contaminations inside the object. In addition, this method is can be easily implemented in normal lab environments with low cost and manageable effort for 3D printed metal objects of any geometry and compositions.