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20-EPSCoR2020-0014-R3

Dusty Plasmas: Space Life and Physical Sciences and Research Apps.

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NASA MD/Office: NASA Space Life and Physical Sciences and Research Applications

Dusty plasmas are four-component plasma systems consisting of the standard plasma constituents of electrons, ions, and neutral atoms, with the addition of a fourth component:charged, solid, nanometer-to-micrometer-sized particulates (i.e, the dust particles). In both laboratory and space environments, the dust particles become charged through the acquisition of electrons and ions from the background plasma as well as various ionizing processes such as thermionic emission or photoelectron emission. Regardless of the charging processes, the dust particles are coupled to and become part of the plasma through their charge. However, the small charge-to-mass ratio of the dust grains (relative to the electrons or ions) means that the plasma process of the dust component is slowed to time (~10-2 s) and space (~10-3 m) scales that enable simultaneous studies of plasma dynamics in both the kinetic (particle) and fluid (collective) regimes. Moreover, the small charge-to-mass ratio also allows the thermal state of the dust component to be experimentally tuned over a range of Coulomb-coupling parameters (i.e., G, ratio of electrostatic-to-thermal energy) from the weakly-coupled (G << 1) to strongly-coupled (G >>1) regimes. This provides opportunities to explore regimes of plasma behavior that are generally difficult to achieve in standard plasmas.

This proposed project seeks to perform a new investigation of controlled dusty plasma particle transport from weaklycoupled to strongly-coupled regimes. This work leverages the extensive expertise and experimental capabilities of the Auburn Dusty Plasma research group in laboratory and microgravity studies of dusty plasmas. In this work, two main activities are proposed for this one-year activity: (a) demonstration of passively-driven, long-range dust particle transport (i.e., transport distances >> collision mean free path) using biased electrodes to establish cyclical particle motion between several suspended dust clouds and (b) development of a programmable, segmented electrode with the ability to provide steady-state or periodic control of particle transport over long distances in a plasma. The long-term goals of this work are to develop a comprehensive understanding of dust particle transport over a broad range of experimental conditions that can lead to scaled studies of charged dust transport in environments relevant to lunar and Martian conditions. From these studies, it will be possible to provide a scientific basis for the next generation of remote and manned missions on airless and plasmaexposed bodies throughout the solar system.

20-EPSCoR2020-0015-R3

Low-pressure plasma/photocatalytic nanofibrous membrane reactor system for harvesting fuel components from Martian atmosphere: KSC Partnership Office/Conversion of Co2 into Fuel

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NASA MD/Office: KSC Partnerships Office

This project aims at the developing of a light-weight ceramic nanofiber-based, glow discharge enhanced, photocatalytic membrane reactor system operating at reduced pressures to support efficient in-situ resource utilization in future Mars missions. Current processes designed for Mars in situ resource utilization (ISRU) include Sabatier, steam/dry reforming, reverse water/gas shift, electrolysis, Fischer-Tropsch, methanol synthesis and several others. All these and related processes rely on relatively heavy and energy-thirsty equipment and frequently need the temperatures >150 oC and pressures e1bar (up to 50 bar). Several other approaches have been proposed to utilize the Martian atmosphere for fuel components, water and oxygen. Those include solid oxide electrolysis (MOXIE), photocatalysis, and glow-discharge plasma. Photoreduction of CO2 to CO and O2, or to other compounds through the reactions with H2 and H2O is possible due to reasonable solar irradiance (<300 W/m2) on Mars. Plasma technology is also gaining increased interest for the reduction of CO2 to CO and O2. Although some interesting results have been obtained, both plasma and photocatlytic approaches are still in their infancy.

To advance these promising technologies to the next level, the proposed study will explore the potential of plasma/photocatlytic conversion of CO2 into the fuel components by using a light-weight and scalable nanofibrous ceramic (NFC) membrane catalytic reactor system operating under simulated Martian atmospheric conditions. The proposed reactor incorporates the staked flat gas separation membrane, catalytic membrane, and metal mesh electrode system capable of operating at low pressures and down to cryogenic temperatures. The research objectives include the design, fabrication, and tests of NFC membranes for (1) CO2/N2 and CO/O2 separation, (2) CO2 splitting to CO and O2 in glow discharge and under visible light, and (3) CO2 and CO reactions with H2 and CH4 in glow discharge and under visible light at low pressures and temperatures. The feasibility of completion of the proposed tasks is based on the availability of the efficient process to fabricate NFC membranes with different composition and microarchitectures and total porosity up to 99.5%. The process involves a high-yield, free-surface alternating field electro-spinning (AFES) to prepare nanofibrous ceramic precursors, followed by calcination and sintering procedures to fabricate the membranes. This allows the fabrication and screening, in reasonable time, of a variety of prospective membrane compositions and structures. Targeted materials primarily include the nanofibrous transition metal oxides (TiO2, ZrO2, ZrxTi1-xO2) doped with Ni, Mn, Ru, Cu, Fe, and Co, and incorporating, in some cases, carbon nanostructures.

Significant research findings on gas transport and catalytic performance of NFC membranes and entire reactor system under targeted environmental conditions are expected upon completion of these tasks.

20-EPSCoR2020-0017-R3

SiC Zener diode and Voltage References for extended operation (>1000 hr.) at 500 degrees C: SMD Planetary Division, High-Temperature Subsystems and Components for Long-Duration (months) Surface Operations

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NASA MD/Office: New Frontiers Program (SMD Planetary Division)

SiC and GaN are the materials of choice for High temperature electronics because of their wide bandgap and high chemical stability at high temperature and also because these technologies have recently seen a considerable development leading to commercialization on the consumer market. Although they both have acceptable thermal conductivity, SiC is exceptional in that regard, which prevents the occurrence of hot spots in the device when used at high power and high current densities. Several teams have been developing electronics devices for Venus like conditions. Power conditioning for these devices will be needed both for protection and for accuracy. In modern electronics, power conditioning is done using complex integrated circuits. However, GaN or SiC technology are not at the stage where these types of ICs are easily manufactured and tested within a reasonable amount of time. Therefore, discrete Zener diodes, which have been extensively used in earlier Si electronics (and are still used although less commonly) to stabilize voltages, shape signals and protect electronics from overvoltage events have a huge potential for SiC high temperature electronics.

We propose the fabrication and investigation of high temperature (500°C) SiC Zener diodes using ion implantation and evaluate their long term degradation at high temperature. Two main configurations will be pursued: (i) a vertical device, for high power applications and (ii) a lateral device that can be integrated into SiC ICs that are being developed by other groups. The different elements necessary to make the high temperature device will come from expertise developed by the Auburn group in their ongoing and previous studies of devices such as 500°C MOSFET transistors and high temperature integrated circuits. A measurement setup was developed for our ongoing interest in high temperature electronics and will also be used in this case for study of the device behavior over time.
The device will be stressed at high temperature (typically 500°C) for over 1000 hours and the characteristics of the device will be monitored during the test. Of interest are the capacity of the devices to regulate power with minimal drift over time. For such precision devices, contact degradation and the effect of passivation layers will have an important effect on the device performance. The effect of using ion-implanted doped layer as opposed to the conventional way of using epitaxially doped material will also be investigated. Our study therefore will give to other groups involved in the development of devices for NASA missions, the recipes to incorporate Zener diodes into their designs with established properties over time. The difficulties of the project reside in the presence of crystal defects in SiC such as basal plane and threading edge dislocations that are known to grow over time especially at high temperatures. Unfortunately these defects are more prominent in highly doped layers. They are known

to reduce the performance of diodes and may result in faster degradation of the devices at high temperatures. The study proposes both the fabrication and the long-term study of the devices in a set up that allows the parallel biasing of several devices simultaneously at high temperature. Devices will be characterized in situ while at high temperature and be characterized after 1000 hours stress to observe the presence of dislocations and their extent.

20-EPSCoR2020-0022-R3

Quantifying Heat Transfer Rates in Porous Media with Near-Critical Fluids

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NASA MD/Office: New Frontiers Program (SMD Planetary Division)

New engines and power cycles are needed to provide power and cooling for an extended Venus landing, increasing mission times from hours to weeks. State of the art power cycles being developed at NASA to accomplish this goal include systems with a porous media regenerator and fluids at supercritical conditions. For example, researchers at NASA s Glenn Research Center are proposing to utilize supercritical carbon dioxide, available in the Venus atmosphere. However, this working fluid may experience various states, and heat transfer at these conditions has not been studied in detail, particularly in porous media. Conduction, convection, and anomalous heat transfer (e.g. piston effect or reduced heat flux despite enhanced fluid mixing) can occur together, particularly with the fluid near its critical point. The proposed basic research will study these heat transfer and fluid flow processes with nuclear magnetic resonance imaging, focusing on a fluid near its critical point. At the fluid s critical temperature and pressure, the fluid properties are most divergent and the influence of anomalous heat transfer is highest. The resulting data will provide a strong basis for understanding the fundamentals so more advanced systems can be optimized in the future. The work will use supercritical hexafluoroethane (C2F6) as the fluid (T_critical = 293 K and P_critical = 30.4 bar), and a packed bed of encapsulated wax particles will provide the template porous medium. This arrangement allows the NMR experiments to measure heat transfer processes via 1H NMR in the wax and flow via 19F NMR in the fluid. The coupling of these measurements is not available via other experimental techniques. A range of experimental temperatures and pressures are proposed within sub-, near-, and supercritical conditions.

20-EPSCoR2020-0023-R3

Characterization of Low-Pressure Air Plasma Treatment on Polystyrene Coating of Aluminum Alloys 2024 and its Corrosion and Stress Corrosion Cracking Behaviors

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NASA MD/Office: KSC Partnerships Office

An easily o
perated, environmentally friendly passivation/coating protocol is necessary for protecting aerospace components from corrosion. As opposed to the traditional wet chemicals based process, using low-pressure air plasma is a clean, dry technique that doesn t produce hazardous chemical wastes. It can be easily conducted in a plasma chamber under the ambient environment without the need for special handling of pressurized gas. The plasma chamber can also be made portable. All of these features are advantageous to both ground-based and extended duration missions for metal cleaning and coating. Low-pressure air plasma has been well characterized in cleaning polymeric surfaces for bonding with another polymer. Using low-pressure air plasma in treating steel components for passivation is an ongoing study at the NASA KSC. In this project, the researchers aim to explore the low-pressure air plasma technique to treat the aluminum (Al) 2024 alloy for cleaning and coating. The project outcomes will complement NASA s ongoing research by extending the feasibility of low-pressure air plasma treatment from steel to aluminum.

This project will evaluate low-pressure air plasma for its effectiveness and efficiency in the surface treatment and coating of Al 2024 for anti-corrosion. The Al 2024 series is often used for high-strength applications because its major alloying element, copper, provides the needed strength. However, the alloying copper also makes Al 2024 more inclined to corrosion because copper forms a more active galvanic coupling than other elements for promoting local corrosion. Low-pressure air plasma will first be characterized for its effectiveness in modifying the wetting property of treated Al 2024 specimens. Optimal/sub-optimal sets of the plasma treatment parameters -- the plasma power, pressure in which the plasma is produced, and the treatment time -- can be discovered by combinatorial characterization of surface wettability under various plasma treatment conditions to yield the best surface wettability. This project will also look into a new protocol for coating the plasma-treated Al 2024 alloy with polystyrene for its anti-corrosion performance, tested in a no-load and a loaded (at a slow constant strain rate) condition. Polystyrene is a widely used, cheap plastic and can have contact with food. It can be a cheap passivation alternative to traditional anodization or cladding of aluminum. The proposed protocol, the first of its kind, once proved for its feasibility, will be the primary contribution of this project.

20-EPSCoR2020-0029-R3

Thermal and mechanical properties of additively manufactured copper alloys

Louisiana Board Of Regents

Director/PI: Dr. Gregory Guzik

Science PI: Dr. Shengmin Guo

NASA MD/Office: Commercial Space Capabilities Office

This team (Dr. T. Gregory Guzik of LaSPACE, Dr. Shengmin Guo of LSU, and Dr. Michael M Khonsari of LSU) will target NASA Commercial Space Capabilities Office s research call CSCO-2020-01, which allows consideration to award funded extension to the CSCO EPSCOR R3 project Characterization of C-18150 Additively Manufactured Material (18-EPSCoR R3-0001). The objective of 18-EPSCoR R3-0001 is to evaluate the quality of copper-alloy (C-18150) parts made by a powder bed fusion additive manufacturing (AM) process selective laser melting (SLM). This team has established protocols for sample preparation, thermal and mechanical property testing, material characterization, and data analysis. With the demonstrated expertise and equipment capabilities, the proposed renewal will enable the team to study thermal and mechanical properties on additional copper alloy AM parts, such as GRCop-42 (Cu-4 at.% Cr-2 at.% Nb) and GRCop-84 (Cu-8 at.% Cr-4 at.% Nb) alloys.

Thermal property measurements include the testing of bulk thermal diffusivity, specific heat and thermal conductivity on copper AM samples made using different powder sources on different AM machines. Microstructure characterizations include the study of grain size, orientation, porosity, and dispersion phase distribution. The effect of post heat treatment will be examined, assisted by thermodynamics-based phase diagram calculations. For mechanical testing, selected SLM GRCop-42 and GRCop-84 samples will be tested under tensile and low cyclic fatigue conditions. This study will provide NASA/industry with detailed datasets regarding the AM copper parts made using different supplies of feedstock materials on different AM systems.

20-EPSCoR2020-0036 R3

Rover-Mounted Microwave Tool for Direct 3D Mapping of Water Ice on Mars

Iowa State University, Ames

Dr. Tomas Gonzalez-Torres

Successfully locating and extracting water for life-support and energy resources (rocket fuel) from indigenous soils on Mars, directly impacts our ability to establish and sustain habitation. In-Situ Resource Utilization (ISRU) by decomposing H2O and other processes (i.e., the Sabatier) can potentially produce the necessary water, Oxygen and Methane/liquid Oxygen for these purposes. Related to Mars, even in the absence of liquid water on its surface, existence of water in the form of H2O ice beneath the surface, covered by a heterogeneous layer of overburden, is an accepted notion [1-4]. H2O ice serves a number of purposes for habitation life-support and fuel production needs. Consequently, on-site verification (ground-truth data) of the presence of H2O ice, its volumetric distribution, inclusions contained within, host regolith properties, and other desired characteristics, becomes critically important. Furthermore, distinction between H2O ice and clathrates, as additional sources of useful gasses becomes an important aspect of this long-term objective [5-6]. To this end, we aim to devise a direct, real-time and high-resolution microwave imaging methodology, founded on established physics-based and engineering principles, for producing a 3D map of Martian regolith for detecting and quantifying H2O ice, its composition and that of the overburden and the host regolith. The approach uniquely leverages: "the highly sensitive and distinct interaction between microwave signals and H2O molecules and its physical state - liquid, solid (ice) and gas (vapor) [7-8], "the changes in dielectric properties of H2O ice and clathrates as a function of inclusions such as trapped gases (e.g., methane or carbon dioxide), soils, sand, pebbles, and salts (i.e., Chlorates and Perchlorates), temperature, and frequency [8-9], "the adaptation of a successfully-developed portable, real-time, high- resolution microwave imaging technology to a mobile platform (Rover), to rapidly produce 3D map of shallow regolith properties, providing ground-truth information about: heterogeneity, and volumetric extent and content (particularly) of trapped H2O ice, rocks, overburden cover, etc. The envisioned synthetic aperture radar (SAR)-based imaging system, consists of a 2-4 staggered linear arrays of up to 64 individual antennas, with each array having a length of 1.5-2 m. The system is expected to operate in the 0.5-5 GHz frequency range resulting in a spatial resolution in the order of ~10 cm, with a bandwidth of 0.25-1 GHz producing a depth resolution in the same order, with a required operating power of ~25-40 W. These parameters allow for signal penetration to within a few meters from the surface, while providing ample spatial resolution. Unlike ground penetrating radars (GPR) that give much deeper information but with much coarser resolution, using antennae that require intimate contact with the soil surface, the proposed system operates from tens of centimeters away from the surface allowing for unrestricted movement over rough surfaces. Being a real-time and autonomously-operated imaging system, it can be carried on a number of mobile vehicles (i.e., Rovers) and produce rapid 3D images of a substantial area is a matter of minutes, only limited by the speed of the vehicle. The collected imaging data can be readily transmitted any location (on Mars or Earth). The successful implementation of this comprehensive and fully optimizable concept, for 3D-quantification of H2O ice on Mars, will be enabling and transformative in the way we look for water on Mars and other planets. This approach can also be used to monitor shallow water and H2O ice transformation to water vapor in the course of a Martian day during heating and cooling.

20-EPSCoR2020-0042-R3

Impact of extreme cold events on disruption of hydro-energy generation

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Science PI: Dr. Xiaobing Zhou

NASA MD/Office: SMD Earth Science

This proposal is in response to NASA EPSCoR Rapid Response Research (R3) Solicitation (NNH20ZHA001C) that is related to Appendix C: SMD Earth Sciences Division using remote sensing measurements from on-orbit satellites (Terra and Aqua) and a suite of ground based measurements to investigate extreme cold weather on disruption of hydro-energy generation. Hydropower is a key contribution to the U.S. renewable energy portfolio because of its cleanness, high efficiency, and reliability. Research to date indicates it is possible for extreme cold events to increase in frequency or intensity regionally for periods of time (e.g., due to increases in the intensity of cold air advection from polar to lowerlatitude regions), interannual variability can be large enough to allow extreme cold events such as that occurred in North America in 2014. These events can change the water supplies rapidly for hydroelectric power generation. General impacts on hydropower generation by climate variability include earlier snowmelt, change of runoff seasonality, and increasing frequency of extreme events of high and low steam flows. Events of extremely low streamflow will inevitably disrupt the hydropower generation, especially for the run-of-the-river hydroelectric power plants. The objective of this NASA EPSCoR Rapid Response Research project is to investigate how hydroelectric power generation can be disrupted by cold events (temperature < -20 °C for a period of at least a few days) by developing a hydroelectric model driven by remotely sensed snow cover, land surface temperature, and cloud coverage measured by the on-orbit satellites such as Terra and Aqua, along with a diverse set of ground-based weather and hydrological data sets. We proposed to use the on-orbit satellite (Aqua and Terra) MODIS snow, temperature, and cloud data to study the impact of extremely cold weather on the production of hydropower generation, especially the hydropower due to run-of-river hydropower plants or diversion plants where reservoirs have almost no storage capacity and extremely cold weather could reduce streamflow to almost zero.

20-EPSCoR2020-0044-R3

Integrated Geophysical Tools for Prospecting Shallow Ground Ice on Mars

Louisiana Board Of Regents

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NASA MD/Office: Commercial Space Capabilities Office

Much of martian water-ice inventory lies hidden beneath its regolith in the mid-to-low latitudes. Ice that is atmospherically sourced is valuable because it can record climate evolution, the possible existence of past life as well as its value as a key insitu resource. Direct sampling, while precise, is restricted to the vicinity of the sampling sites and most probably will not capture fully the expected lateral changes in composition and geometry of the ice-laden regolith deposits. However, lowrisk and low-cost, high-sensitivity instruments that can characterize ice directly and accurately are scarce.

We propose an autonomous prospecting strategy that uses a single vehicle, featuring a novel wheel-mounted acoustic seismometer system to interrogate the subsurface down to at least 10 m, with especially high fidelity in the upper 2 m. We propose a non-invasive but complete-sensing capability approach, thereby reducing risk by avoiding direct probing of the subsurface. An integrated suite of geophysical tools comprising (1) high-frequency ground seismic, (2) ground-penetrating radar (GPR), as well as (3) a gamma-ray and neutron spectroscopy (GRNS) within a 10 km2 area of interest is most likely to provide exploration information about the spatial distribution, depth, density, nature of overburden, and distinct layering of ice deposits. A range of cross-validated physical property types (electrical, chemical, and mechanical) are more likely to enhance exploration success. Seismic measurements can detect ice indirectly through changes to the sediment rigidity, GPR methods are sensitive to the ice purity and scale readily in resolution from cm to km scale. Both methods will capture mixed materials as well as distinct layers. GRNS will reveal modeled depth variations in hydrogen and will potentially distinguish between frozen CO2, CH4 and water-ice. All three tools are sensitive to clast-size variations as well as regolith stratification in the presence of ice.

Within the scope of the first 12-month performance period, we will focus on the testing and calibration of (1) micro-seismic sensors and sources within a mock-rover wheel and integrate these data with (2) GHz-ground penetrating radar under simulated Mars temperature and ground ice conditions. The proposed work will enable future collaboration with MSFC SPC colleagues to integrate GRNS instrumentation and allow for complete 3D exploration of the shallow subsurface for ice lenses and overburden properties.

We will cross-validate Vp, VSV and VSH attenuation and scattering in seismograms and radargrams against the physical properties of analog soil that include porosity, density, ice content and grain-size heterogeneity. Miniature seismic tools and their cold-hardened electronics will be evaluated over a variety of temperatures between -50o and 50o C and pressures down to ~ 1 kPa. The regolith model of ground ice and soil layers will be informed by Mars Reconnaissance Orbiter and Phoenix lander

observations. A key project outcome will be a prototype array of low-mass (9 g) piezo-ceramic seismic sensors and sources integrated into a mock rover wheel to ensure good mechanical coupling with the soil. We expect the final prototype as the first step towards a higher TRL MATISSE-funded project for automated mapping of shallow ground ice as a key resource to support future commercial missions on Mars.

20-EPSCoR2020-0053-R3

Characterization of bi-metallic joints formed by different processes

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NASA MD/Office: Commercial Space Capabilities Office

Development of the Space Launch System (SLS) vehicle at the NASA- Marshall Space Flight Center (MSFC) supports the Artemis Mission to the moon, Mars and beyond [1]. To sustain these missions, there is a need for fabrication of landers as well as reusable, reliable materials and processes for extraterrestrial fabrication and repair. Thus, the materials and fabrication processes must be suitable for a multitude of components as well as environments. Terrestrially, to support the SLS vehicle fabrication, upgrades are underway to improve the performance and reliability of the RS-25 liquid rocket engine (LRE) [2]. While this provides an opportunity to insert new materials and manufacturing processes, such as additive manufacturing (AM) into the RS-25 production upgrade, it is urgent to develop material property databases to ensure designers have relevant information for designing robust and reliable engine components.

A regeneratively cooled, RS-25 combustion chamber consists of a Copper (Cu) liner joined to a structural jacket [3, 4]. Heritage hardware initially used stainless steels (Fe based) whose coefficient of thermal expansion (CTE) closely matched that of the Cu liner [5]. Eventually, the Fe base material was replaced by higher strength nickel (Ni) based superalloys such as Inconel 625. While Inconel 625 provided improved strength, there was a trade off in increased CTE mismatch that affected the fatigue life of the combustion chamber. More recently, the NASA developed an advanced Ni based superalloy called NASA HR-1 that decreased the CTE mismatch [6]. The current evaluation of manufacturing methods, such as AM, provides an opportunity to evaluate improved materials to retain the high strength of the Ni based superalloy while minimizing the CTE mismatch to improve reliability. Of the various AM processes being evaluated for the RS-25 LRE, direct energy deposition (DED) processes offer the best approach toward fabrication of bi-metallic combinations without size restrictions [7]. Improved reliability can be obtained if the resulting bi-metallic interface has adequate strength and microstructural stability at elevated temperatures during hot fire operation. This requires quantification of the properties of the AM materials in parallel with the development of AM processes for LREs. Thus quantifying the material properties from AM processing also must include those of the resulting interface between different families of materials encountered in regeneratively cooled LREs. Prior research has observed significant differences in the interface of samples obtained using different materials, processes and vendors [8-12]. Since there are no current standards or specifications for production of this hardware, the vendors currently apply their best practices, which can widely vary. This means that there is no consistency in the feedstock supplier or equipment settings, factors known to affect the melt pool formation and mixing between materials. Within the liquid metal of the melt pool, Marangoni currents influence the intermixing as influenced by atmospheric contaminations, injection velocity, heat source power density, and elemental composition, resulting in vastly different properties at the interface [13-15]. Since DED is of interest for the bi-metallic structures, characterization of two processes involving blown powder are proposed: blown powder deposition versus cold spray. Thus understanding how variations in DED processing affect the overall properties of the bi-metallic joint will contribute toward increasing the overall technical readiness level (TRL) of an AM RS-25 LRE. This is of relevant interest to both NASA and the commercial space companies [16-19]. Using the unique capabilities at UAH, this proposal will leverage mini-samples from actual hardware [12] in collaboration with NASA and commercial space to characterize and disseminate data.

20-EPSCoR2020-0057-R3

NASA EPSCoR R3: Causal Multivariate Network Analysis of Multi-Omics Datasets for Therapeutic Treatment of Muscle Atrophy in Mice, and Homosapiens in Microgravity

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Science PI: Dr. Heeralal Janwa

NASA MD/Office: NASA Space Life and Physical Sciences and Research Applications

The goal of this proposal is to perform multi-study omics data integration of mice NASA GenLab datasets from the International Space Station (ISS), and predict muscle atrophy in microgravity, beneficial for diagnosis and therapeutic intervention for humans (Homosapiens) in spaceflight. Muscle atrophy is the wastage of muscle tissue that occurs due to aging, genetics, degenerative diseases and injuries. This condition is common among astronauts due to exposure to microgravity. Understanding the effects of novel therapies to treat muscle atrophy in mice is essential to provide similar treatments to human astronauts, as well as patients affected by this condition on Earth. Our study will focus on the analysis of Gene Regulatory Networks (GRNs) of mouse in space flight, and on Earth. Our current study has shown to be successful with the plant Arabidopsis Thaliana gene expression GLDS7, and GLDS120 datasets. Using graph based GRNs we will identify key gene players from these datasets, and identify gene signaling pathways that are associated with muscle and tissue degradation, ultimately leading us to GRN based therapeutics in spaceflight. Muscle atrophy and its treatments and drug-designs have been well studied on Earth, using GRNs, hence we will find correlates between the networks constructed on ground, with those on spaceflight. We will determine causal relations between the effects of therapy on ground, and on spaceflight using multivariate analysis. The objectives for NASA Rapid Response Project are: 1) Analysis from flight and ground: Determine gene regulatory pathways, and common pathways in these networks using Fisher s analysis. 2) Construct causal relational networks for muscle atrophy and its treatment, and implement probabilistic deep learning networks to predict the best therapies for muscle atrophy in spaceflight. The Genelab datasets (GLDS-250, 249 246 245 247 248 243 244) and ground based GEO datasets (https://www.ncbi.nlm.nih.gov/gds) on muscle atrophy, and the effects of therapy, will be used to identify top most common pathways. A causal relational network analysis will be performed to predict the best treatment, and countermeasures for muscle atrophy in microgravity. The causal networks, and the results of analysis generated by this project will be made available to the space biology research community. Dr. Nataniel Szewczyk, Professor of Nottingham Biomedical Research Centre, and Dr. Jonathan Galazka, Scientist from NASA Space Biosciences Research Branch will be collaborating in this project. They will be providing feedback, and insights in to the progress of this research activity. Their backgrounds in medicine, and biology will be indispensable for this project. 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 a Hispanic minority serving institution with 99% Hispanic students who will gain

knowledge in the fields of space biology, mathematics, bioinformatics, and software tool development in Python, R, SageMath, and Cython (with resulting packages freely available for other scientists). 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 Labs, and add to the workforce development for future NASA missions.

20-EPSCoR2020-0061-R3

Constraining wildfire emissions of volatile organic compounds (VOCs) with NASA airborne observations

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NASA MD/Office: SMD Earth Science

Biomass burning is a significant but mostly under-characterized source for atmospheric volatile organic compounds (VOCs), impacting regional air quality and public health. Once emitted, VOCs play an important role in the formation of ozone and fine particulate matter. Many VOCs and their oxidation products from smoke plumes are air toxics. Current air quality models cannot predict ozone or particulate production in the environment influenced by fire smoke, reflecting our knowledge gap in emission, chemistry, and transport of fire-related air pollutants, including VOCs. The western U.S. is of great interest to us due to recent increasing fire occurrence and severity. This project aims to constrain VOC emissions from western U.S. wildfire smoke using recent NASA airborne observations, building upon the Science Investigator (Sc-I) Hu group s ongoing research. The overall goal is to answer the fundamental questions: What are the emissions of VOCs from wildfire smoke, and how do they affect air quality?

An ongoing project by Sc-I Hu is the NSF funded WE-CAN 2018 aircraft campaign (https://www.eol.ucar.edu/field_projects/we-can). The WE-CAN campaign systematically characterized the emissions and the first day of evolution of western U.S. wildfire smoke in August 2018 using NSF/NCAR C-130 aircraft. Hu group led the VOC measurements using a proton transfer reaction mass spectrometer (PTR-MS) during WE-CAN. We are currently analyzing the WE-CAN VOC data and planning on reporting VOC emission factors in the western U.S. The NASA and NOAA co-led FIREX-AQ field campaign took place in July September 2019 (https://www.esrl.noaa.gov/csd/projects/firex-aq/). FIREX-AQ deployed the NASA DC-8 aircraft and sampled a broader region in the U.S. wildfire smoke with a similar instrument payload as WE-CAN. Both field campaigns together covered a mixture of fire sizes, fuel types, and burning conditions for the western U.S. They spanned two fire seasons and significantly increased the number and types of fires being comprehensively characterized, thus better capturing the anticipated large natural variability of wildfire emissions. The project will use a combination of recent airborne observations and a 3D chemical transport model (Task 1) to evaluate widely used biomass burning emission inventories, especially NASA maintained QFED (Quick Fire Emissions Dataset). We will examine VOC emissions from western U.S. wildfires, with combined constraints from WE-CAN and FIREX-AQ to improve statistics. We will focus on hazardous air pollutants measured by PTR-MS. We will examine critical uncertainties in biomass burning emission inventories for fire detection and burned areas (Task 2). We will then focus on diagnosing and improving model errors in VOC emission ratios, emission factors, and vertical distribution (Task 3).

This project exploit observations from a recent NASA airborne field campaign and improve the quality of a NASA product for biomass burning emission estimates. Collaborations built on here will further enhance the connection between Montana and NASA. It will foster future collaborative work, particularly on validating NASA satellite products such as TROPOMI and the to-be-launched TEMPO satellites, which is part of the Sc-I s research theme.

20-EPSCoR2020-0064-R3

Impacts of Gravity on Dropwise Condensation-Enhanced Heat Pipes

College of Charleston

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Science PI: Dr. Chen Li

NASA MD/Office: NASA Space Life and Physical Sciences and Research Applications

Primarily consisting of evaporation and condensation sections, the heat pipe is a light, highly efficient, and durable twophase device that transports heat over a distance with a small temperature drop and a type of primary devices in thermal control systems of satellites, space shuttles, and manned space stations. Ultrahigh-performance, long, and lightweight heat pipes are critical to future space missions (e.g. manned missions to Mars) and hence, highly desired.

Numerous efforts have been made to improve heat pipe performance by engineering the evaporation section and are nearly approaching the physical limits. However, the heat pipe condensation section that results in an order of magnitude higher thermal resistance than the evaporation one has not been well developed. It is promising if a performance leap of heat pipe technologies can be realized by enhancing the condensation section. Heat transfer rate of dropwise condensation (DWC) is 10 times higher than filmwise condensation adopted in existing heat pipe technologies. Most recently, using super-durable Ni-graphene coatings in a terrestrial environment, the Science PI s team has successfully demonstrated 8 times higher effective thermal conductivity by promoting DWC inside heat pipes. However, the enhancement was highly sensitive to orientations.

In most space environment, due to the reduced gravity, droplets would attach on the wall and DWC could totally fail without quickly removing droplets. The objective of this proposed project is to explore a feasibility in implementing DWC for space missions. Conducting experiments in a drop tower would be the first step to verify the feasibility of wick designs in rapidly removing droplets inside heat pipes. In this proposal, condensation sections of heat pipes will be coated with the demonstrated Ni-graphene coatings. Moreover, various wicking structures will be designed to eventually realize rapid droplet removal in a microgravity environment. The gap between the Ni-graphene coated wall and wicking structures would play a critical role in maximizing DWC and hence, heat pipe performances. Heat pipes with various wicking structure designs and gaps will be evaluated before and in drop tower experiments.

20-EPSCoR2020-0068-R3

A Generic Data-Driven Framework via Physics-Informed Deep Learning

College of Charleston

Director/PI: Dr. Cassandra Runyon

Science PI: Dr. Lang Yuan

NASA MD/Office: Computational and Information Sciences and Technology Office (CISTO)

High-fidelity physics-based computational models become increasingly important to bring predictive, optimized, and focused capabilities to NASA s strategic plan. A complex system, e.g. Earth/Planetary Atmosphere, can consume dramatic computational resources on the current High- Performance Computational facility. Replacing physics-based model components with artificial intelligence evolves as a viable path to enhance performance for HPC applications. In this project, the team at the University of South Carolina proposes to explore and establish a physics-informed deep learning driven computational framework, relying on data from both physics-based numerical models and experimental data, to generate a scalable data-driven model constrained by physical limits to replace computationally intensive high-fidelity models. This work will start to answer whether we can replicate complex interactions in data-driven model and conceptualized them with extensive domain knowledge to reestablish a physically meaningful model that can recognize or react to new circumstances they have not been trained for.

With well-established modeling capabilities in Additive Manufacturing (AM) and availability of experimental data, we propose to start such framework from studying the melt pool dynamics during laser-powder melting process. This system also largely shares the governing equations as in General Circulation Models of a planetary atmosphere, where Navier Stokes equations are solved with thermodynamic terms for various energy sources. In this project, physics-based highfidelity model for melt pool dynamics that solves fluid dynamics, heat transfer, solidification and vaporization will be performed to generate dataset for the learning process of machine learning (ML) algorithms. Informed by ML, multistage virtual and physical experiments will be carried out to reduce the uncertainly of the predictive model and validate the physics-based model. Physicsinformed deep learning, in turn, will be developed by approximating the unknown solution with a
deep neural network. In the meantime, transfer learning will be leveraged to accelerate the datadriven model establishment from both experimental and computational data, and structural causal models will be developed to incorporate physics recovery.

The proposed framework will generate a new paradigm that creates and applies both novel physicsbased and data-driven techniques to dramatically enhance traditional computational, theoretical tools for scientific discovery and application. Interfaces between computational framework, theoretical models with experimental observations through advanced machine learning will be expected to extend to complex problems to generate physically sound mathematical model to evolve applications to exascale.

20-EPSCoR2020-0069-R3

MRI/MRV Brain Scans of Astronaut Brains

College of Charleston

Director/PI: Dr. Cassandra Runyon

Science PI: Dr. Donna R. Roberts

NASA MD/Office: Office of the Chief Medical Officer

We have previously shown that astronauts of long-duration missions aboard the International Space Station (ISS) experience an upward shift of the brain, compression of cortical veins, and crowding of eloquent brain tissue at the vertex along the superior sagittal sinus (SSS). We hypothesize these anatomical changes may impede venous outflow from the cranium resulting in decreased blood flow through the internal jugular veins (IJVs.) Supporting this hypothesis, there have been recent reports of astronauts experiencing abnormal venous outflow from the head and in at least one case, an astronaut was found to have asymptomatic IJV thrombosis.

In addition, increased intracranial pressure (ICP) and papilledema have also been documented in NASA astronauts following long-term missions aboard the ISS months to years after spaceflight which NASA has named the Spaceflight Associated Neuro-ocular Syndrome (SANS). Some researchers have hypothesized that venous outflow obstruction may play a role in the development of SANS.

Here, we aim to characterize the response of the intracranial venous system to spaceflight, evaluate for any evidence of venous congestion or brain edema post-flight, and correlate those findings to intracranial pressure at spinal tap in astronauts with and without SANS. The study will include a total of 12 astronauts: (1.) six astronauts who have been assessed clinically by NASA Medical Operations and have documented signs of SANS, and (2.) 6 astronauts without signs of SANS matched for gender, approximate age, and approximate mission duration will serve as controls.

This proposed study directly addresses a significant health risk that was recently identified in ISS astronauts (abnormal venous blood flow and IJV thrombosis). This study will also provide evidence concerning the role intracranial venous physiology may play in the develop of SANS in susceptible astronauts.

20-EPSCoR2020-0070-R3

Enhanced Spectral Optimization Tools for monitoring the development and dynamics of Harmful Algal Blooms and coral bleaching

College of Charleston

Director/PI: Dr. Cassandra Runyon

Science PI: Dr. Wesley J. Moses

NASA MD/Office: SMD Earth Science

This project seeks funding to address the problem of harmful algal blooms (HABs) and coral bleaching through a scientific partnership between the College of Charleston (CofC- SC), the Naval Research Lab (NRL- D.C) and NASA s Ames Research Center (ARC- CA). We propose to assess the uncertainties in existing data and model products that are used to quantify the relationship between observations of optical properties of water by high resolution visible and near-infrared (VNIR) earth observation satellite sensors and optically active constituents (OACs) observed in-situ. This relationship will be tested against long-term records and targeted assessments of HABs and coral health in order to accurately identify potential water quality stressors on ecosystem health. This proposal is in response to NNH20ZHA001C (NASA s Established Program to Stimulate Competitive Research (EPSCoR) Rapid Response Research), focusing on developing a remote sensing tool to not only detect and quantify the presence of various water quality parameters that initiate HABs or coral bleaching but also provide measures of uncertainties in the estimates, which would be valuable for resource managers and decision-makers. This research falls into Appendix C: SMD Earth Sciences Division of the CAN, and research topic 4: Earth System Response to Environmental Disasters, specifically HABs and coral bleaching. Toxic algal blooms in coastal and inland waters are harmful to the environment and human society for a number of reasons, including reduction in biodiversity, disruption of healthy ecosystem functions, infliction of fatal and non-fatal diseases on human and animal life, and disruption of tourism and recreational activities. In coral reef habitats, degraded water quality due to influx from terrestrial pollution is negatively affecting the health of coral reef organisms, resulting in recurring mass bleaching events severely impacting the ecosystem. These effects can be magnified when combined with stressors such as extreme temperature events, which can initiate wide spread development of HABs, and damage coral symbiosis, leading to coral bleaching. Identifying differences in water quality that lead to development of HABs and affect short-term reef organism health and long-term reef development can assist managers in controlling negative impacts on these vital ecosystems. This research is extremely important in regions such as the Great Lakes where HABs result in illness-related public health crises, losses in commercial fisheries as well as recreation and tourism impacts. This research will also have a great impact in the U.S. Virgin Islands (USVI), where coral reef-dependent tourism is the primary driver of the economy and declines in reef related services would have significant economic impacts. In large dynamic marine environments, remote sensing (RS) technology can provide timely and spatially explicit information regarding changes once the data is calibrated using in-situ measurements. Our project will merge two promising classes of model products: a) a radiative transfer based fast spectral optimal estimation (OE) approach, and b) a full waveform spectral decomposition (FWDc) method to develop

the next generation of ocean color remote sensing products best suited for use with multi- and hyper-spectral sensors. For this project, we will use existing in-situ oceanographic and atmospheric data archived at NASA s SeaWiFS Bio-optical Archive and Storage System (SeaBASS) and field data that were collected over several years from our own previous projects in the Great Lakes and in the U.S. Virgin Islands. The specific data that will be used include, but are not limited to, in-situ optical data (radiance, irradiance, backscattering), satellite-derived optical data (Landsat, Sentinel, MODIS) and water quality data (dissolve organic matter, phytoplankton density, turbidity, dissolved oxygen, temperature, etc.)

20-EPSCoR2020-0075-R3

Testing Venus Seismometer Design

University Of Alaska, Fairbanks

Director/PI: Dr. Denise Thorsen

Science PI: Dr. Michael West

NASA MD/Office: New Frontiers Program (SMD Planetary Division)

Developing an understanding of the interior structure of Venus and its current level of geologic activity, particularly the nature and frequency of volcanic and tectonic events, are high priority goals of NASA s planetary exploration program. A network of seismometers could achieve these goals, but the desired observation period of at least weeks far exceeds the ~1-hour lifetimes of previous landers in the harsh Venusian surface conditions. NASA Glenn Research Center (GRC) has an ongoing effort to develop a seismometer capable of surviving for an extended period in the Venus environment, and they are seeking additional partners with relevant scientific expertise. The Geophysical Institute (GI) at the University of
Alaska Fairbanks (UAF) houses the Alaska Earthquake Center (AEC) and a planetary science program with a focus on Venus geoscience. Consistent with the Planetary Science Division s portion of the Rapid Response Research call to address instrument design for extreme environments, especially Venus, we propose a one year program to develop a suitable catalog of Venus analog seismic events and to use the catalog to test elements of likely seismometer design. Over the grant period we will do the following: 1) Estimate the nature and level of seismicity on Venus guided by current understanding of the similarities and differences in Venus and Earth s lithospheric structure and tectonic styles; 2) Using AEC records, create an organized catalog that contains type examples of seismic events from various natural and man-made (e.g., mining explosions) sources that could serve as potential analogs for Venusian seismic sources; 3)
Evaluate the ability to determine various aspects of Venus seismicity under potential seismometer restrictions; and 4) Test and evaluate possible mitigation strategies for current seismometer design limitations. These efforts will be accomplished using AEC software and their data catalog, along with custom software developed during the proposed effort. The results of the proposed RRR work will advance seismometer design and testing efforts at GRC and will initiate a partnership between GRC and GI-UAF. The assessment of Venus seismicity and the events catalog will be useful for those considering other approaches to studying Venus seismicity and geologic activity. The methodologies employed and the mitigation methods developed will have applicability to seismology studies and instrument design efforts for other planetary bodies, including Earth, where power conservation and the ability to withstand extreme environmental conditions are important. Per AO requirements, all funds will be spent in the Alaska EPSCoR jurisdiction. Per NASA EPSCoR goals, the personnel hired, and the relationship built between the GI and GRC, will improve the research infrastructure in the Alaska jurisdiction.

20-EPSCoR2020-0079-R3

Impact of simulated microgravity on potable water bacterial biofilm formation

University Of Vermont, Burlington

Director/PI: Dr. Bernard Cole

Science PI: Dr. Matthew J. Wargo

NASA MD/Office: NASA Space Life and Physical Sciences and Research Applications

All human habitation in space will take place in a non-sterile environment and the multispecies bacterial biofilms in the drinking water are an important source of bacteria to which all astronauts are exposed. This constant exposure to potential bacterial pathogens and the additional roles of biofilms in material corrosion and chemical processes make it is imperative that we improve our understanding of these co-habitants on our space-going vessels.

This proposal addresses the Biology of the Built Environment topic, under the Space Biology Program within the Space Life and Physical Sciences Research and Applications (SLPSRA) directorate. The call notes a particular interest in relation to this topic on determining the impact of simulated microgravity on mixed microbial biofilms and community interactions. Our NASA-related work has focused on studying community interactions driving biofilm formation and physiology by members of the bacterial biofilm present in the Potable Water Reclamation System of the International Space Station. These species are a model of the ISS community and also model drinking water communities in general, including those destined for future space flights, as these species are common globally in municipal water systems.

During the course of our previous NASA EPSCoR-funded research, a six-member bacterial community derived from the ISS potable water reclamation system was characterized and used as a model community to understand biofilm assembly in potable water. This work led to three major findings relevant to this proposal: (i) ISS water system biofilm formation is robust to community composition, (ii) Determination of the species interaction network governing biofilm assembly, (iii) Species interactions suppress pathogen survival.

This proposal will follow up on the initial findings to achieve two goals:

(1) Measure the impact of low-shear simulated microgravity on the community interactions and biofilm formation network in the model ISS biofilm community

(2) Determine if the ability of ISS biofilm members to limit bacterial pathogen growth and invasion of the community continues in low-shear simulated microgravity

20-EPSCoR2020-0090-R3

Renewal of Rock, H2O, and H2: Energy from Water-rock Interactions on Mars

Nevada System of Higher Education

Director/PI: Dr. Lynn Fenstermaker

Science PI: Dr. Elizabeth B. Rampe

NASA MD/Office: Commercial Space Capabilities Office

Here we are proposing a renewal of our current grant entitled Rock, H2O and H2: Energy from water-rock interactions on Mars. Extended human exploration of Mars will likely utilize the martian regolith as plant growth medium, wetting the initially dry regolith with liquid water to form soil that can support plant life. This initial wetting of the martian regolith can release valuable resources. We therefore proposed to react Mars simulants with liquid water, to determine the resources available from these interactions, including hydrogen, perchlorate, Fe and Mg. Our initial results are very promising, showing the production of hydrogen and perchlorate. However, multiple questions remain, particularly including the variability of perchlorate and hydrogen production from different simulants, and how water-rock interactions can best be optimized for the martian surface. We are therefore proposing a renewal to test additional conditions, including varying the water: rock ratio, scaling experiments to better interpret conditions on Mars, the effect of temperature, and time. We propose that our current team will continue working on this project, including Co-I Dr. Christopher Adcock, Science PI Dr. Elisabeth Hausrath, and NASA Scientist Dr. Elizabeth Rampe.

20-EPSCoR2020-0095-R3

Characterization of GRCop-42 Additively Manufactured Material -- Extended Investigation

South Dakota School Of Mines & Technology

Director/PI: Dr. Edward Duke

Science PI: Dr. Todd Letcher

NASA MD/Office: Commercial Space Capabilities Office

The overall goal of the second phase of this study is to complete material property testing on a dispersion strengthened copper-alloy, GRCop-42, to determine optimal directed energy deposition (DED) manufacturing parameters. Previously, this material has been extensively studied in non-additive manufacturing methods and by powder bed fusion AM. In the initial phase of this project, our team has learned how to conduct all the testing to match procedures and methods used in previous NASA studies so the test results can be compared. In addition, we have begun testing using other techniques not previously studied (nanoindentaion, LXRD for residual stress, CT scanning, etc.). Currently, a large batch of tensile samples are being tested at room temperature and incrementing up to 800C. Samples were cut in both major direction of the manufacturing process to test anisotropy.

In the second phase of the project, we will continue testing new manufacturing parameters of DED GRCop-42 using the same techniques as learned in the first phase. In addition, we will add low/high cycle fatigue testing as material samples are provided. By the end of phase two, we will have a basic understanding of how DED manufacturing parameters affect overall part quality and how to tailor material properties according to manufacturing parameters.

20-EPSCoR2020-0097-R3

Atomically Dispersed Metal Electrocatalysts Supported on Nitrogen-Doped Carbon Nano-Onions for Efficient and Selective CO2 Conversion into Fuels

University Of Kentucky, Lexington

Director/PI: Dr. Alexandre Martin

Science PI: Dr. Doo Young Kim

NASA MD/Office: KSC Partnerships Office

Kentucky s NASA EPSCoR jurisdiction solicited proposal responses from Kentucky university-led research teams to address NASA research needs listed as tasks for the FY2020 NASA EPSCoR Rapid Response Research (R3) announcement (NNH20ZHA001C). The NASA Kentucky EPSCoR program collaborated with responding faculty researchers to develop and submit relevant proposals that address R3 task objectives.

The proposed work is in response to R3 Appendix E research topic Conversion of CO2 into Fuel. The space mission of NASA for Mars will require sufficient amounts of fuels for the exploration of the planet and the return of samples or humans to Earth. For this, the development of an in-situ, efficient method to synthesize fuels from the resources abundant on Mars is critical. This proposal aims to develop efficient, selective, and durable electrocatalysts for CO2 reduction by developing atomically dispersed metal atoms incorporated in high-surface-area carbon nano-onions (CNOs). If successful, this research will pave a way to efficient and economic conversion of CO2 (the most abundant gas (95 %) in the atmosphere of the Mars) into valuable chemicals and fuels such as such as methane, methanol, ethanol, formate, and syngas. This proposal is based on several innovative concepts:(i) economic and tailorable use of metal atoms atomically dispersed in support for catalyst design, (ii) stablized and abundant immobilization of atomically dispersed catalytic metals by coordination with nitrogen (N), and (iii) enhanced reactivity and abundance of metal-N4 sites by the high curvature of CNO support, that will creae active sites for CO2 reduction reaction (CO2RR). We will establish synthetic methods to modify CNOs by incorporating heteroatoms and subsequent addition of metallic ions (see Figure 1). The active sites formed by this approach will create asymmetric charges on the electrode surface and will facilitate the adsorption of CO2 reactants, thereby will lower the kinetic barrier of CO2 reduction pathway. Through systematic synthesis, structure analyses, electrochemical characterizations, and computational modeling, knowledge will be gained on structure-property-activity relations of catalysts.

20-EPSCoR2020-0101-R3

Probabilistic Approach to Reverse Engineering of Spaceflight Molecular Networks

Wichita State University
Director/PI: Dr. Leonard Miller

Science PI: Dr. Ali Eslami

NASA MD/Office: NASA Space Life and Physical Sciences and Research Applications

Reverse engineering of molecular networks is one of the most challenging tasks in systems biology and bioinformatics. This is mainly due to the complex nature of biological systems which involve many factors and uncertainties. However, with the rapid biotechnological advancements, large-scale high-throughput biological data have become available. These data have enabled researchers to deduce and understand how interactions among the vast array of components in biological systems relate and affect each other. It is a general consensus among system biologists and bioinformaticians that such interactions form networks that aim at capturing the dependencies between the interacting entities.

Therefore, existing literature provides a strong prior biological knowledge to conduct research in this area. However, for Space Biology there is very little research focus on the development of computational and modeling tools that enable the discovery and inference of space environment-specific molecular networks. Although, the ground-based system biology computational tools can be adapted for reverse engineering spaceflight molecular networks, they are largely inadequate to capture biophysical parameters relating to space environment. Thus, the goal of this research is to develop an approach for reconstructing, inferring and analyzing spaceflight molecular networks using data from the NASA GeneLab data system. In addition, we adapt our preliminary probabilistic graphical model tool to validate and quantify how well the inferred networks explain the observed experimental data.

Intellectual merit: The proposed work seeks to grow a research area crossing frontiers in probabilistic methods, graph theory, algorithms, biology and data science. Focusing on the reconstruction, inference and analysis of spaceflight molecular networks for which very little literature exists, the work has the potential to advance knowledge and understanding across several related fields. Furthermore, it provides an opportunity to translate decades of biological data from experiments performed in space environments into information that foster innovation in Space Biology.
Specifically, the significance of the proposed activity is as follows:

- Developing computational tools for the discovery of biological networks influenced by space conditions.
- Establishing mathematical framework for the analysis and validation of spaceflight biological networks.
- Developing algorithmic tools for generating biologically realistic spaceflight expression data.
- Predicting biochemical and kinetic parameters of biological processes in spaceflight.

Broader impacts: The PI believes that the proposed work has far-reaching implications on basic science, education and technology that will benefit society, in general. The broader impacts include:

1. Advances understanding of key biological mechanisms that enable biological organisms to thrive in space environments
2. Training of graduate students in bioinformatic data analysis
3. Integration of research results in the classes taught by the PI and to improve the curriculum at Wichita State University

20-EPSCoR2020-0102 R3

Microgravity Effects On Biofilm Stiffness

University Of Kentucky, Lexington

Dr. Alexandre Martin

Kentucky s NASA EPSCoR jurisdiction solicited proposal responses from Kentucky university-led research teams to address NASA research needs listed as tasks for the FY2020 NASA EPSCoR Rapid Response Research (R3) announcement (NNH20ZHA001C). The NASA Kentucky EPSCoR program collaborated with responding faculty researchers to develop and submit relevant proposals that address R3 task objectives.

The proposed work is in response to R3 Appendix D research topic Biofilms and the Built Environment. Biofilm growth has been observed in Soviet/Russian (Salyuts and Mir), American (Skylab), and International (ISS) Space Stations, sometimes jeopardizing key equipment like spacesuits, water recycling units, air filters, radiators, and navigation windows. Several pathogens pose a risk to the health of astronauts during space missions. For example, Staphylococcus aureus is an opportunistic pathogen prevalent on human skin, is prominent in health-care associated infections, and was found aboard several space missions. Like most infections, staph infections are treated with antibiotics. However, space-grown biofilms exhibit increased antibiotic resistance. Therefore, there is a need to understand S. aureus biofilm characteristics and their relationship to antibiotic resistance to help enable safe, long duration, human space missions. Our project goal is to address TASK D15, Biofilms and the Built Environment, for which we will provide physical insight into S. aureus biofilms grown in simulated microgravity through stiffness, thickness, and antibiotic resistance measurements.

Our hypothesis is that biofilms grown in microgravity produce a densely packed extracellular polymeric substances (EPS) network that results in two measurable outcomes: 1) decreased deformability (increased stiffness) and 2) limited mobility of infiltrants, including antibiotics. Biofilms of Staphylococcus aureus, a potential pathogen that threatens the health of astronauts during space missions, will be grown in simulated microgravity via a high aspect ratio rotating vessel (Synthecon Inc.). Ground control biofilms will also be grown for comparison. We will measure stiffness using atomic force microscopy (AFM) of biofilms grown in simulated microgravity and compare to ground control biofilms. Measures of antibiotic resistance of both types of biofilms will be performed using a BioFilm Ring Test and/or the Biofilm Eradication Surface Test Assay (Innovotech Inc.) in addition to using standard minimum inhibitory concentration (MIC) procedures. This proposal seeks to effectively simulate microgravity to enhance our understanding of fundamental biofilm characteristics. New knowledge gained from this proposal is the relationship between simulated space biofilm stiffness and antibiotic resistance.

20-EPSCoR2020-0104-R3

Classifying Cosmic-Ray Events Detected by Radio Probes

University Of Delaware

Director/PI: Dr. William Matthaeus

Science PI: Dr. Frank Gerhard Schroeder

NASA MD/Office: Computational and Information Sciences and Technology Office (CISTO)

Cosmic-ray research is one of the traditional NASA areas targeting the fundamental understanding of our universe. NASA traditionally operates several space-based and balloon-borne instruments measuring cosmic rays and other particles from the Universe such as photons and neutrinos. These instruments typically create large datasets of millions to billions of detected events per mission. Among those instruments, the balloon-borne ANITA probe is the one targeting the highest energies, otherwise only accessible by ground-based instrumentation. ANITA pioneered a new technique for cosmic-ray detection observing the radio emission of atmospheric particle cascades with antennas mounted on a balloon payload and had four successful flights until now. During the last decade, digital radio detection emerged as a new alternative to traditional optical techniques offering similar precision without being restricted to clear and dark nights. The big advantage of balloon-borne radio detectors over ground arrays is that a single detector can overlook a huge array and thus feature a much higher exposure per antenna than a ground-based array. During these flights massive data sets of time series are acquired by the radio antennas. The challenge is to find the signal events within this huge data set, in particular those events with low signal-to-noise ratio.

This proposal will investigate how the scientific merit of such radio measurements of cosmic particles can be enhanced by machine learning techniques for the classification of the detected events, where the signal templates are created on high-performance computing (HPC) clusters. Machine learning can improve the scientific outcome of future radio probes for cosmic rays and neutrinos, which can be done in at least two ways: First, the classification of signal events against background will increase the purity of the sample, lower the detection threshold, and increase the total statistics of signal events. Second, the detected signal events themselves can be classified according to their mass (with near zero mass for neutrinos and photons). Such a better measurement of the cosmic-ray mass composition is most important to progress in high-energy astroparticle physics. A direct experimental validation is possible by comparing the neuralnetwork classification of radio data to traditional cosmic-ray detectors. As a result, the potential of the machine learning techniques for future flights can be assessed. Based on these findings, subsequent studies can investigate whether such neural networks should be incorporated directly in the data-acquisition running during a flight, or are better used to leverage the subsequent data analysis on the ground. Due to the general applicability of the expected outcomes (lower threshold, higher aperture, improved accuracy) and the increasing use of digital radio detectors for astroparticle physics, the proposed project is expected to create significant impact much beyond just the next NASA flight for radio detection of cosmic rays.

20-EPSCoR2020-0107 R3

Minimizing the food outbreaks in space: Understanding innate plant defense response in leafy greens under zero gravity conditions

University Of Delaware

Dr. William Matthaeus

The production of healthful food crops in space could provide nutritional support for astronauts during long-¬ duration space missions; and successful crop production in a closed ecosystem such as this requires that plants germinate, scavenge for nutrients, and overcome biotic and abiotic challenges of the environment to produce fruit (seed). As part of the Vegetables in Space mission (Vegetable-I-III), NASA in its last three expeditions to space was successful in growing leafy greens (Romaine Lettuce) in the space station. Leafy greens are most susceptible to cross contamination and ingression by multiple human opportunistic pathogens such as Listeria, Salmonella and Escherichia coli. Reducing the risk of foodborne illness associated with fresh produce is a task which the industry and academic researchers have been struggling with for many years. The persistence of human opportunistic pathogens such as Listeria, Salmonella and E. coli in plants, raises the question about food safety measures in crops grown in space stations. The current literature and work done in our labs have shown human opportunistic pathogens such as Salmonella may suppress plant defense for ingression leading to increased chances of foodborne contamination and illness. Our knowledge pertaining to how human opportunistic pathogens survive in plants under an altered gravity condition is sparse. In here, we will test the ingression and persistence of Salmonella and Listeria in lettuce under an altered gravity condition using a prototype designed by the investigators, which will tease the ability of plants to a launch defense response and then stomatal dynamics will be tested under an altered gravity condition. We aim to analyze transcriptional, physiological and biochemical changes in plants and human opportunistic pathogens subjected to an altered gravity condition. If successful, finding conditions that reduce ingression of human pathogens in leafy greens under space-like conditions should lead to efficient and effective food safety measures for space missions. The successful outcome of our proposed research will provide fundamental insight into how the unique plant-microbe associations are modulated under an altered gravity condition.

20-EPSCoR2020-0117-R3

An Active Learning Framework for Increasing Generalizability of Machine Learning Models

Wichita State University

Director/PI: Dr. Leonard Miller

Science PI: Dr. Guanghui Wang

NASA MD/Office: Computational and Information Sciences and Technology Office (CISTO)

Recent years have witnessed a fast development of deep learning and significant success in practical application, such as object detection, recognition, image classification, and natural language processing. Deep learning has also been applied to space exploration, like the recognition of environmental features and classification of planets and supernova. The state-of-the-art deep learning methods require a huge amount of labeled data to train the neural networks, and the training process is computationally expensive and time-consuming. Although many learning models have achieved very impressive performance on benchmark datasets, they all face the issue of generalizability. Most machine learning models, even being well trained on very large datasets, suffer a big loss (4% to 10%) in accuracy for unseen data. Generalizability is still an open problem in machine learning since all learning models, once trained, have to be applied to new environments with new data that have not seen before.

This project aims to solve the generalization challenge of the learned models. We propose an intelligent learning framework by integrating the strategy of active and reinforcement learning to refine the model for unseen datasets. The overall idea is motivated by the observation of children learning to interact with their environment. The proposed framework is composed of three steps mimicking the learning process of children: Observe, practice, and improve, through which the machine can learn the knowledge incrementally from previous tasks and adapt it seamlessly in learning new tasks. Thus, the system can incrementally improve its performance during practical applications. This strategy has a potential impact on current leaning systems.

In addition to its scientific significance, the project has a great impact on NASA and Kansas economy. First, the project fulfills NASA s strategic goal to advance technological innovations for NASA s scientific missions. With large volumes of data collected from various missions of NASA, it is essential to develop new approaches for analysis and discovery by taking advantage of the fast development of artificial intelligence. Second, the study has a significant impact on the economic and scientific development of Kansas. It is reported that about one in five Kansas City jobs is predicted to have high exposure to AI, especially in computers, business, and finance. AI also has a significant impact on the manufacturing and agriculture of Kansas.

The project will also increase the level of education and research of Kansas. Many students want to take AI-related courses, and the project will help the involved students obtain hands-on research experience in AI. Many professors and researchers in Kansas are starting to use machine learning in

their research. The proposed solution will benefit all researchers working in machine learning and enable many other related research topics. Moreover, the project will collaborate with NASA JPL and a local high-tech company. These collaborations will significantly increase Kansas s existing research strength in artificial intelligence, as well as our competitiveness in obtaining external research funding.