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ME - 19-EPSCoR -0001

Multi-scale remote sensing approaches for forest health assessment

Maine Space Grant Consortium

NASA MD: SMD (ES)
Center: GSFC

Director: Dr. Terry Shehata

Science PI: Dr. Parinaz Rahimzadeh Bajgiran, University Of Maine, Orono

Almost one-third of U.S. economic and cultural well-being strongly depends on a healthy forest land-base and its sustainable management. The Northeastern U.S. is the most heavily forested part of the country, with Maine being the most forested state at 89%. The forests of this region provide numerous products and services for rural livelihood, wildlife, and the environment. Sound, scientifically-based management of this resource requires a significant investment in forest inventory and health monitoring. Recent advances in remote sensing (RS) technology are revolutionizing the way in which forests are measured and monitored. The focus of this research is on providing more detailed, finer resolution, accurate, and near-real time data on i) forest tree species identification and ii) forest tree decline detection and damage assessment using optical air- and space-borne hyperspectral and multi-spectral data. The goal is to address immediate information needs for precise pest/pathogen control for current outbreaks in Northeastern forests, as well as for early intervention and host tree protection. This information is also needed for pest risk prediction, estimation of economic impacts of outbreaks, quantifying wood supply losses, identifying changes in wildlife habitat, and as inputs for landscape-scale forest succession and disturbance simulation models.

Since 2000, a large body of RS sensors and platforms has become available to overcome shortcomings related to the unavailability of optical RS imagery and their cost. These sensors can produce enhanced geospatial data products to meet research and decision support needs. Despite these considerable advances, RS methods to adequately apply these data by combining several sensors and platforms are not yet developed in particular for forestry applications. Additionally, high-resolution maps of forest species composition are not yet available, mainly attributed to limited RS data availability in the past, challenges related to the detection of pest induced damages compared to other forest disturbances, and high cost of satellite RS data at a very fine resolution. Consequently, the long-term goal of this project is to develop sound approaches for providing detailed geospatial products on forest tree identification and composition, forest defoliation/damage caused by recent destructive pest/pathogen outbreaks such as spruce budworm (SBW), emerald ash borer (EAB), Caliciopsis canker, and eastern white pine decline and mortality using RS data. The realization of this goal will provide i) better models compared to the traditional aerial survey methods to detect and quantify pest-induced defoliation/damage, ii) potential tools to address shortcomings of current satellite derived forest disturbance products and algorithms, and iii) detailed information on tree species distribution, tree decline indicators and their drivers of change. This proposal addresses this knowledge gap by leveraging various NASA RS technologies including Landsat and in particular, recent NASA Goddard’s Hyperspectral-LiDAR-Thermal system (G-LiHT) data. Rather than a single use technology, the continually updated products offered here will both support a strong and sustainable research program at the University of Maine (UM) as well as provide stakeholders with enhanced forest health information needed for decision making. While the immediate application of these models and products will be for Maine, the developed models can be applicable for

the entire northeastern U.S. and Canada and in other regions with similar problems including western U.S. Finally, research, educational and synergistic activities conducted in this project will foster a collaborative network of junior and senior faculty across various disciplines, as well as post-doctoral researchers, graduate/undergraduate students working with NASA scientists and researchers and other institutes within and outside Maine.

AL - 19-EPSCoR -0002

Development of CO2-Capturing Ionic Liquid Solutions for Spacecraft Air Revitalization Systems

University Of Alabama, Huntsville

Director: Dr. Lawrence Dale Thomas

Science PI: Dr. Kevin Neal West, University of South Alabama

NASA MD: HEOMD
STMD
Center: GSFC

This proposal addresses the development of CO2-capturing ionic liquid solutions for spacecraft air revitalization systems. Air revitalization in closed environments is a mission critical task for NASA, with the chief technical challenge being the removal of CO2 from the recirculating air supply. Specifically, efficient removal of CO2 from closed space craft environments is a NASA research and development priority as stated in the NASA Technology Roadmap Technical Area (TA) 6: Human Health, Life Support, and Habitation Systems document. The practical significance of this requirement was recently illustrated in a NASA study that showed that 7% of the genes changed their expression during spaceflight, which was attributed to metabolic stress on the body due to elevated CO2 exposure in the spacecraft. Additionally, NASA is concerned with cognitive and behavior effects on humans exposed to increased levels of CO2.3. On the international space station, CO2 removal is currently accomplished using a thermally regenerable solid zeolite, Grace 13X. While effective, the solid zeolite has a number of logistical problems including the production of dust from the absorbent bed and sensitivity to ambient humidity. A similar separations challenge exists on submarines, where closed environment CO2 removal is a crucial part of the life support system. On submarines, CO2 is removed via chemical capture with an aqueous ethanolamine solution. This is also an effective process, but with significant disadvantages; chiefly, the volatilization of the amine, which creates a foul odor, can damage electronics and presents long term heath effects. Furthermore, regeneration of the solution (desorption of the CO2) is somewhat energy intensive as the large thermal mass of the solution (often 70 mass % water) must be heated to promote desorption. While the energy requirement is moot on a nuclear submarine, power consumption is a key concern for spacecraft.

OK - 19-EPSCoR -0004

Engineering Thin Film Solar Cells for Radiation Hardness, Lifetime and Efficiency

Oklahoma State University

Director: Dr. Andrew Salvatore Arena

Science PI: Dr. Bayrammurad Saparov, University of Oklahoma, Norman

NASA MD: SMD, STMD, HEOMD

Center: GRC

We propose a combined experimental and theoretical approach for characterization and in-depth study of radiation hard multinary halide and chalcogenide solar cells for space applications. Radiation hardness is among the most desirable characteristics of solar cells for space missions. The two proposed materials technologies in this project are based on Cu(In,Ga)Se2 (CIGS) and emerging lead halide perovskites that demonstrate a combination of remarkable radiation resistance, high efficiency, light weight, thin, and flexible solar cell arrays for NASA's CubeSat and SmallSat applications in which high power, light, low payload systems are highly desirable.

In recent years, halide perovskites have started a new era of high performance and ultralow-cost-per-watt photovoltaic (PV) materials, whereas CIGS is used in the state-of-the-art commercialized thin film solar cells. Remarkable radiation resistance of CIGS has been documented in many studies, and a few recent studies on the emerging CH3NH3PbI3-based solar cells also report superior radiation resistance compared to the commercialized technologies such as c-Si. Quite unusually, due to the specifics of its chemistry and crystal structure, CH3NH3PbI3-based solar cells also exhibit a self-healing behavior once the irradiation is terminated. Beyond single junction solar cells, a tandem solar cell comprising of CIGS and perovskite absorber layers in which radiation hardness of each layer combine synergistically may provide an avenue for further efficiency improvement. All of these characteristics make CIGS and CH3NH3PbI3-based materials strong candidates for the consideration for space applications, in particular, for the missions to Mars and Beyond, CubeSat and SmallSat applications. Therefore, this project is of strong interest to the Science Mission Directorate (SMD), the Space Technology Mission Directorate (STMD), and the Human Explorations and Operations Directive (HEOD) at NASA.

At the heart of this proposal is the development of CIGS and hybrid halide perovskite thin films with suitable optoelectronic properties including band gaps, carrier concentration, absorption coefficients for their incorporation in solar cells, studies of their performances in working solar cells devices and testing their performance under space conditions (irradiation and AM0). To achieve the goals of this project, a cross-disciplinary team of researchers across Engineering, Physics, Chemistry and Materials Science, involving the largest research universities in Oklahoma (the Univ. of Oklahoma and Tulsa, and Oklahoma State Univ.) has been assembled. The team has been collaborating through the Oklahoma PV Institute, demonstrating the strong working relationship that already exists within this group. Suitable chalcogenides (CIGS and derivatives) and hybrid metal halides will be synthesized (Saparov, Science-I), and their optoelectronic properties, and crystal and electronic structures will be characterized (Borunda, Harikumar and Sellers). Based on the measured properties and band structures, most promising members will be incorporated into thin film solar cell devices (Kim). Performances of solar cells in space conditions (e.g., AM0, under irradiation) will be tested at OU (Sellers) and at NASA Glenn Research Center (GRC) through a collaboration with Dr. Timothy Peshek and Jeremiah McNatt, who are members

of the PV and Electrochemical Systems Branch, where flexible PV and CubeSat technology is currently under development. An important role of the GRC group will be to facilitate high-energy irradiation of devices and materials such that degradation under space conditions can be assessed in the materials proposed. The team assembled will also leverage existing relationships with industry to test commercial grade flexible CIGS from MiaSolÃ© Hi-Tech. Corp. under space conditions, where these materials will be used as reference materials to assess the performance of thin film chalcogenides in outer space.

RI - 19-EPSCoR -0005

Development of a Space-Deployable Dual-Mode LiDAR for Planetary Seismology

Brown University

Director: Prof. Peter H. Schultz

Science PI: Dr. Tao Wei, University of Rhode Island

NASA MD: STMD
SMD
Center: GSFC

LIDAR or Light Detection and Ranging systems have been used in space research for more than 50 years. Besides using LIDARs for altimetry, these devices have been used to study atmospheres and ice. The LIDAR In-space Technology Experiment (LITE) in the 1990's demonstrated a number of capabilities and applications for space applications on board the space shuttle Discovery. One new potential application is the use of LIDARs for planetary seismology. Typically, seismologists exploit measurements of Primary (P), Secondary (S), and Rayleigh waves to infer structure of the underlying planetary body. The P-waves are longitudinal waves which travel at the compressional wave speed in the body. The S-waves or shear waves are transverse waves which travel at the shear wave speed. Rayleigh waves are vertically-polarized propagating waves that are trapped at the interface between an elastic medium and a vacuum (or low density atmosphere such as Earth). These waves can propagate large distance because their amplitudes decay primarily as one over square root of range, as opposed to compressional (P) and shear (S) waves, which decay as one of range. Rayleigh waves are the cause of much damage due seismic activity on Earth but also can be excited by impactors on the moons and rocky planets. Such waves can propagate in ice sheets on Europa. Interface waves at the seabed are called Scholte waves and those waves at the interface of two elastic media are called Stonely waves.

The dispersion of the speed of Rayleigh waves (often referred to as P-SV waves) as a function of frequency is dependent on the underlying vertical profile of elastic medium properties such as the shear modulus/speed. A number of techniques have been devoted to the estimation of the vertical shear speed given measurements of Rayleigh wave dispersion from explosions, impacts and other energetic sources. Measurements of Rayleigh waves have traditionally been taken using geophones at low frequencies and accelerometers at mid- to high frequencies. Recently, we have developed chirp lasers to measure both range and surface motion through a NASA-EPSCoR research seed grant.

Here, we propose to build a low SWaP-C (Size, Weight, Power and Cost) with two operational modes (ranging mode and Doppler mode) for remote surface measurement. Under ranging mode, the LiDAR sends off chirped laser pulse for frequency modulated continuous wave (FMCW) based ranging operation. Under Doppler mode, the laser outputs a high-quality narrow-linewidth single wavelength laser, and receives the beat signal between the incident wave and reflection wave to measure the surface velocity. The dual-mode LiDAR will be built around a digital circuit, the mode can be controlled digitally and remotely, and the switch time is well within 1 ms.

In the first year of the study, the Science PI (T. Wei, URI) and team (G. Potty and J. H. Miller, also URI) propose to (a) investigate the engineering and signal processing; and (b) develop a model to produce synthetic ground motion data and resulting modeled laser pulse returns. In the second year of the project, we propose to demonstrate the chirp laser in a laboratory setting using techniques developed by the P.I.s described above. We also foresee the continued modeling efforts resulting in the development of algorithms for the estimation of ground properties. In the third year of the project, we propose to demonstrate a prototype system in a field experiment. The field experiment would involve measuring both altitude and ground motion using a chirp laser on board a moving aerial platform such as a drone, helicopter or small aircraft. The refinements necessary for this type of system to be launched into space will be investigated through collaboration with researchers at NASA Goddard.

SC - 19-EPSCoR -0006

Peroxide-Producing Microbial Fuel Cells for Space Life Support Systems Applications

College of Charleston

NASA MD: HEOMD
Center: ARC

Director: Dr. Cassandra Jane Runyon

Science PI: Dr. Sudeep Popat, Clemson University

The proposed project seeks to develop microbial fuel cells (MFCs) as an important technology for space life support systems (LSS) applications. NASA has had interest in MFCs for several years, as a potential technology to treat human waste during space missions, while generating energy and allowing water recovery. We propose to develop MFCs for space LSS applications with a major modification that results in production of hydrogen peroxide instead of, or in addition to, electrical power. The key advantage is that peroxide, an important chemical in relation to water and wastewater treartment and/or cleaning is produced.

The proposed project, by focusing on LSS, addresses one of the key areas of focus of the Human Explorations and Operations Mission Directorate of NASA. One of the main goals of LSS for space missions is the recovery of water from wastewater. Another important goal of LSS is the provision of a safe habitat for crew; here one of the most important challenges is to ensure that surfaces inside space vehicles are clean, and especially devoid of biofilms of potentially infectious microorganisms. Many approaches and technologies are currently being developed, and some are also being tested at the International Space Station to achieve both of these goals, and we propose that MFCs could potentially be an important technology that could address both needs.

The overall objective of the proposed project is to develop and demonstrate peroxide-producing MFCs for space LSS applications. To achieve this objective, several important challenges need to be overcome, and research questions need to be answered. Each of these challenges and questions form the basis for five total work packages for the proposed project. Each work package includes one or two key research tasks that the proposed research seeks to address. These research tasks include determination of the most feasible human waste feed for MFCs in terms of performance and resilience of microbial communities that establish in the anode chamber, development of new cathode architectures and configurations that allow for high peroxide production efficiencies through improved product transport out of the catalyst layer, testing of MFC prototypes at both Clemson University and the NASA Ames Research Center as well as development of engineering designs for possible testing at the ISS, followed by evaluating the best use of peroxide with the context of LSS applications. The project will conclude with a thorough economic and energy assessment of peroxide-producing MFCs against current state-of-the-art technologies for LSS applications include wastewater treatment and cleaning.

The proposed project also addresses several activities highlighted in South Carolina’s Vision 2025 for advancing capacity and expertise in science and technology. Beyond NASA’s needs, the proposed technology addresses important questions at the nexus of food, water and energy, an area that has been getting increasing attention in recent years. The proposed project will include collaborations with two start-up companies based in South Carolina that focus on certain aspects of this nexus; the project allows building research capacity that is of relevance to industry in the state. The proposed project will also be a collaboration between investigators at three institutions of higher education within South Carolina, allowing for the training of four Ph.D. students, and several undergraduate students, thus contributing to the development of technology workforce within the food-energy-water nexus area. The proposed project will also involve high school students and teachers allowing to provide science, technology, engineering and mathematics (STEM) education awareness through hands-on lab experience

VT - 19-EPSCoR -0010

Novel Quantum Materials as Laboratories for Fundamental Physics in Microgravity

University of Vermont, Burlington

NASA MD: HEOMD
Center: JPL

Director: Prof. Darren L. Hitt

Science PI: Dr. Valeri Kotov, University of Vermont, Burlington

Novel two-dimensional (2D), atomically flat materials, such as graphene and transition-metal dichalcogenides, exhibit unconventional Dirac electronic spectra. We propose that their interactions with cold atoms in microgravity can be effectively quantum engineered, leading to a synergy between complex electronic and atomic collective quantum phases and phenomena. This could result in revolutionary technologies in the fields of energy harvesting, quantum information, atomic sensors, custom film coatings, and materials design.

We explore this novel paradigm via three integrated research directions where the microgravity environment of the current and future Cold Atom Laboratory missions on the International Space Station is essential for the elimination of competing interactions and exposing the nature of the emergent quantum behavior. We aim to chart a groundbreaking new direction for the planned BECCAL (Bose-Einstein Condensate Cold Atom Laboratory) mission and well beyond, as envisaged by the NASA Fundamental Physics Program. This proposal is well aligned with the Physical Sciences Program of the Human Exploration and Operations Mission Directorate, and our research spans across the Materials Science (electronic materials), Complex Fluids and Fundamental Physics research areas. The Implementing Center is expected to be the Jet Propulsion Laboratory (JPL).

With the full support of the NASA Fundamental Physics Program leadership, we aim to incubate and explore a new fundamental research direction in microgravity: novel physical phenomena and quantum matter at the interface of atomic and two-dimensional materials research.

In particular, we will: 1) Manipulate the Casimir / van der Waals (vdW) force between atoms and graphene monolayer through the application of strain, electronic doping, etc., thus allowing for selective adsorption and influencing the interactions between individual atoms. This allows us to influence fundamental phenomena such as quantum reflection, and investigate the properties of highly polarizable Rydberg atoms and atomic clusters. 2) Explore exotic quantum many-body phases not yet observed on earth, including anisotropic supersolids and superfluids. 3) Examine 2D materials as substrates for tunable liquid film growth, which can result in exotic quantum wetting phase transitions.

The research will be performed by a tightly integrated team of domain-specific experts in the fields of condensed matter physics, quantum materials, quantum information, ultracold atoms, non-linear phenomena, and experimental design in microgravity with a history of successful collaboration. We aim to incubate a new intellectual center of excellence in Vermont focused on fundamental physics in space.

KY - 19-EPSCoR -0014

Modeling of High-Speed Transitional and Turbulent Flows over Ablative Surfaces

University of Kentucky, Lexington

Director: Dr. Suzanne Weaver Smith

Science PI: Dr. Christoph Brehm, University of Kentucky, Lexington

NASA MD: ARMD
HEOMD
Center: LaRC

Due to its significant impact on heat transfer, skin friction and aerodynamic forces, the laminar-turbulent transition process of high-speed boundary-layers will play an important role in design of NASA's next generation hypersonic vehicles. The transition process is complex, following different paths depending on mean flow properties and the disturbance environment. This complexity is compounded by its dependence on the characteristics of the surface over which the boundary layer forms. This research proposal takes on this challenge by addressing the numerical modeling of transitional and turbulent flows over ablative surfaces in hypersonic flight regimes, an important complement to Kentucky's established research capability for modeling and simulating Thermal Protection Systems (TPS) during high-speed atmospheric entry.

Interactions between transitional/turbulent flows and surface ablation have first-order effects on the aerothermodynamic characteristics of aerospace vehicles. However, no existing simulation capability truly captures the relevant physical mechanisms involved in fully-coupled Fluid-Ablation Interactions (FAI), particularly under realistic flight conditions. Thus, transition prediction remains a significant technical challenge for a wide range of NASA applications, involving both external and internal flows.

The main objective of this work is to develop a robust, efficient, and accurate simulation approach that can be used to improve hypersonic aerothermodynamic prediction capabilities, and simultaneously enhance our fundamental understanding of the coupled interactions between transitional and turbulent flows with surface ablation. To obtain accurate and efficient FAI simulation capabilities on relevant temporal and spatial scales, the proposed numerical scheme consists of five key components: (1) a nonlinear disturbance flow formulation, (2) a dual-mesh overset approach to exchange information between the baseflow and the disturbance flow solutions, (3) dynamic adaptive-mesh refinement, (4) a higher-order accurate immersed boundary method, and (5) a dynamic solid surface response model. These methods will be combined and used to simulate high-speed transitional and turbulent flows interacting with ablative surfaces, particularly the production of macroscopic distributed and discrete roughness patterns formed in the presence of transitional/turbulent flows, and to couple the influence of these surfaces, through roughness patterns and outgassing, back onto the fluid flow behavior. In order to develop an efficient simulation approach the computational performance of the solver framework will be thoroughly analyzed and optimized on modern HPC systems employing vectorization, inter-procedural optimization and multi-threading. The numerical method development will be supported by high-fidelity experiments on transitional and turbulent flow over roughened surfaces employing an advanced spatio-temporal high-resolution wave-packet tracking approach. The proposed research has the potential to be truly transformative and advance the state-of-the-art in predicting high-speed transitional and turbulent flows in the presence of ablative surfaces, as well as increase our understanding of the highly complex physics involved.

If funded, the proposed research builds novel research expertise in high-speed laminar-turbulent transition at the University of Kentucky and combines it with recognized leading research in heat shield modeling. For the design of the next generation of critical TPS, reliable modeling capabilities for FAI are essentialâ€"an enabling technology for NASA's ambitious plans for humans to go and return from the Moon, as well as for future missions to Venus, Mars and beyond.

AR - 19-EPSCoR -0016

Arkansas NASA EPSCoR - High Speed Electronic Devices Using SiGe on Sapphire Technology for Advanced NASA Space Communications

University of Arkansas, Little Rock

Director: Dr. Mitchell Keith Hudson

Science PI: Dr. Zhong Chen, University of Arkansas, Fayetteville

NASA MD: HEOMD
Center: LaRC
GSFC

In order to enable NASA's science, space operations and exploration missions, the space communication techniques with faster and more reliable data transfer rate are always wanted. The very basic function of the spacecraft requires extensive contacts with ground stations for control, command, communication, and data return. A spacecraft command and data handling system processes all the data sent and received by the spacecraft, including operations and science data. The system is connected to radio frequency (RF) transmitter and receiver units that are the sole point of passage for data entering or leaving the spacecraft. The bandwidth of the current transmitter and receiver in the spacecraft limits the maximum data-transfer rate. To provide comprehensive, robust, cost effective, and exponentially higher data rate space communications, the technologies for high-speed reliable electronic devices need to be advanced to maintain a scalable integrated mission support infrastructure. Silicon-on-insulator (SOI) technology has been developed since 1998 and widely used for highspeed RF communication circuits. The parasitic components are eliminated due to the nonconducting substrate. Less heat will be generated during the fast operating of devices. Using the SOI technology, a lower parasitic capacitance of devices enables a faster switching frequency and less power consumption of circuits. The fabrication process is also simplified with less number of masks to define wells and trenches, etc. Another key advantage for SOI technology is the radiation hardness. The soft error rates (SER), which is the percentages of data corruption due to cosmic rays and radioactive signals, can be greatly reduced with the use of the insulating substrate. As one of the first SOI processes, silicon-on-sapphire (SOS) process is commercially available for the fabrications of integrated circuits on synthetic sapphire. Sapphire was chosen as an insulating substrate due to its high dielectric constant, low dielectric loss, good thermal conductivity, and relative availability. The cost of developing SOS circuits is continuously decreasing with the large demand for mobile handsets, broadband consumer, military and space applications. Despite tremendous research efforts in developing high speed electronic devices based on SOS technologies, overall results are still less than satisfactory. For example, the speed of the devices on SOS technology is limited by the Si material. Recent developments of silicon-germanium (SiGe) on sapphire substrate (SGOS) from NASA Langley Research Center (NASA LaRC) demonstrate the much higher device mobility compared with those on the SOS technology. The breakthrough results on the SGOS technology will result in transceiver systems (i.e., transmitter, receiver, frequency synthesizers and amplifiers) with much higher speed and wider bandwidth, which can substantially improve the data rate of space communications, operations and data collection and transfer. Working as a basic building block, devices based on SGOS technology are expected to play a key role in fulfilling the needs of a variety of space exploration missions at NASA.

This project aims to develop Arkansas State research infrastructure so that the team eventually could tackle the grand technical challenge in SOS technology by developing transformative costeffective high speed electronic devices based on the SGOS techniques. The research team includes five researchers from two Arkansas institutions: UAF and UAPB. The team is strongly supported by a senior scientist (Dr. Sang H. Choi) from NASA LaRC.

WV - 19-EPSCoR -0017

From Large to Small Scales and Back: Integrating Observations, Modeling, and Laboratory Experiments of Heliophysics

West Virginia University

NASA MD: SMD, Heliophysics Division
Center: GSFC

Director: Dr. Majid Jaridi

Science PI: Dr. Weichao Tu, West Virginia University

A key aspect of research in NASA's Heliophysics Division is understanding what causes solar activity, including solar flares and coronal mass ejections (CMEs), and how Earth's magnetic environment (the magnetosphere) responds when the energetic radiation and superheated plasma produced during these events impinge upon it. The relevant science questions span the entirety of space plasma physics and are of great importance to the nation and the world through their relation to space weather. Therefore, heliophysics research, including the connection between dynamics on the Sun and its impact on Earth, is of fundamental scientific and practical importance.

We will address some of the key themes in Heliophysics by studying large-scale dynamics, how it drives small-scale physical processes, and how these small-scale processes conspire to again impact dynamics at the large scale. Our study will be organized by the following questions: (1) How is energy stored, transported, and ultimately released at large spatial scales during solar eruptions? (2) How does large-scale dynamics transfer its energy to small-scale structures and how is that energy ultimately converted at the smallest (kinetic) scales in heliophysical plasmas, i.e., at the scale of a particle's gyration and below? (3) How do kinetic-scale processes feed back on large-scale heliophysical systems? We will address these questions using a broad suite of techniques employed by the WVU space plasma physics program â€" solar and magnetospheric observations and analysis using a variety of missions from the NASA Heliophysics System Observatory, simulations from the solar interior to its atmosphere using global fluid models, global radiation belt diffusion codes with powerful 3D capabilities, state-of-the-art small-scale kinetic particle-in-cell (PIC) and test-particle simulations, and unique heliophysics-relevant laboratory experiments native to WVU with the capability to measure kinetic physics in plasmas.

This project addresses some of the key questions in heliophysics using a novel integrated approach. All three questions listed above are at the cutting edge of heliophysics research, and the tools in use are at the forefront in the field. The projects each address important fundamental physics questions, and also are relevant to space weather. Moreover, a key goal of the NASA EPSCoR Program is building infrastructure to enhance capabilities in EPSCoR states. The WVU solar and space plasma physics program recently expanded with the addition of a tenure-track faculty member and two research scientists. The proposed project builds new connections between new and continuing researchers in complementary areas that will create the infrastructure necessary to be competitive for future funding opportunities (for individual research programs and center-level research programs), will create a strong environment for training students in, and recruiting students to, space plasma physics, and will support the burgeoning space-related capabilities in the state of West Virginia. Research Areas of Interests: Solar Eruptions, Reconnection, Coronal Heating, Radiation Belts, Wave Particle Interactions

PR - 19-EPSCoR -0018

NASA EPSCoR: Personalized Medication System for Deep Space Missions

University of Puerto Rico, San Juan

Director: Dr. Gerardo Morell

Science PI: Dr. Torsten Stelzer, University of Puerto Rico Medical Sciences Campus

NASA MD: HEOMD
STMD
Center: JSC
ARC, GRC

The mismatch between mission duration (>3 yrs.) and drug product shelf life (3 yrs.) represents a major challenge for NASA's Evolvable Mars Campaign. The current practice is to predict and stockpile every drug that might be needed during space missions. One can think of reformulating drugs to increase their shelf life until re-supply is logistically possible, but as mission duration is expected to extend over progressively longer periods, other alternatives need to be explored. Point-of-use drug manufacturing is able to reconcile the need to produce unanticipated drugs and circumvent shelf life issues, with the need to sustain the crew's health and independence from Earth's drug supply during long-term deep space missions. Yet, current practices in pharmaceutical manufacturing (large-scale) are incompatible with the flexible manufacturing needs for small patient populations (mission crews) and the limited resources (time, space, energy, personnel) available in space. The goal of the proposed research program is to deliver a Personalized Medication System for Deep Space Missions that will produce two model drugs, naproxen (dosed â‰¤1.5 g/day) and warfarin (dosed â‰¤10 mg/day). The research will develop several state-of-the-art ÂµL to mL-scale unit operations for flow synthesis, purification, filtration, drying, and formulation using process intensification (Objective 1), which can be integrated in a plug-and-play approach to accommodate the manufacturing needs of the model drugs and future target drugs in space (Objective 2). The solid dosage formulations for both active pharmaceutical ingredients (APIs) demand similar requirements in terms of process analytical technologies and US Pharmacopeia to test for product compliance (yield, purity, solid-form, dose, stability), which will be tested in Objective 3. The model APIs were selected to demonstrate the system's capability to produce a wide range of doses as the required daily dose of the drugs varies (mg to g/day). Particularly, the production of flexible doses for warfarin, the most commonly prescribed oral anticoagulant and poster child of personalized medication will demonstrate the feasibility to reduce risks for drug-related adverse events (Objective 3). Human space flights represent a scenario where therapy failure or adverse side effects need to be prevented at all costs. A recent study indicated that
~30% of the drugs available on the ISS need individual dose adjustments. In the long term, the science advanced by this proof-of-concept system could be employed to manufacture additional drugs of NASA's interest (e.g. amoxicillin, cetirizine, promethazine, zaleplon). The system would also allow the crew to reprocess stockpiled and partially degraded APIs within its purification and formulation capabilities, and thus, will contribute to in situ resource utilization (ISRU) in space. The proposed research brings together past efforts in small-scale (mL-scale) crystallization and pharmacogenetic analysis of warfarin for the formulation of personalized medication at the point-of-use. Ultimately, the realization of the objectives will establish a program that stimulates competitive research and strong partnerships between the jurisdiction and NASA in technology areas that span across multiple NASA Technology Areas (TA 6 & 12). The proposed research is poised to improve current practices in pharmaceutical manufacturing resulting in overall benefits for the general US population (personalized

medication, orphan drugs, cancer, HIV/AIDS, clinical trials, customized fixed-dose combinations), which represents the broader vision of NASA's Technology Roadmaps. The research program, which includes the development of the necessary human capital in STEM, is expected to have an impact on the pharmaceutical industry valued over $1 trillion. This sector represents one of the key economic engines for the US, specifically, Puerto Rico, as a major hub for the bio-pharmaceutical industry.

LA - 19-EPSCoR -0019

Integrated Computational and Experimental Optimization of Materials and Methods for In-Space Manufacturing of Lightweight Metal Alloys (ISM-LMA)

Louisiana Board of Regents

NASA MD: STMD
Center: MSFC

Director: Prof. T. Gregory Guzik

Science PI: Dr. Jonathan R. RaushUniversity of Louisiana, Lafayette

This collaborative research effort, designed to study additive manufacturing processes using lightweight metal alloys for in-space manufacturing applications, is led by Dr. Jonathan R. Raush (Science-I) of the University of Louisiana at Lafayette with collaborators at Louisiana State University and Louisiana Tech University. The project includes strong support from NASA Marshall Space Flight Center, NASA Johnson Space Center, and alignment with critical NASA Space Technology Mission Directorate roadmap objectives (TA 12.1.2, 12.4.1, 12.4.2). The team conducting the research has expertise in additive manufacturing, fused deposition modeling, , material thermal-physical property measurement, computational methods including CALPHAD and Phase Field modeling, and advanced materials characterization including electrostatic levitation and x-ray diffraction techniques .

The overall project goal is to support NASA's vision of developing in-space manufacturing capabilities, as well as to support Louisiana's top research priorityâ€"Advanced Manufacturing & Materials. Sustainable, long-duration human spaceflight missions require on-demand manufacturing capabilities that provide solutions for fabrication and repair of components, electronics, consumables, tools, and structures. The most promising additive manufacturing method available for in-space manufacturing is the fused deposition modeling process. During this process, green bodies are fabricated with metal powder laden polymer composite feedstock. After a de-binding process, sintering is performed to increase metallic part density. One key technical challenge associated with fused deposition modeling of metallic parts is how to consolidate the loosely packed alloy powders into a dense structure as trapped voids and defects in the sintered parts can significantly degrade the mechanical properties of the manufactured part.

Thus, the primary technical objective of this proposal is to produce robust and high strength fused deposition modeled aluminum parts with minimum porosities. The research will couple theoretical and experimental studies while developing qualified material databases and simulation tools, in order to understand the multiple physics governing the fused deposition modeling sintering process for achieving dense aluminum parts. In this study, we will focus on high strength Al-7xxx series alloys, for which zinc is the major alloying element and, in particular, will plan to accomplish the following tasks: 1) Generate a database of thermo-physical properties for the experimental alloys, including melting range, density, surface tension, and viscosity etc., using advanced experimental techniques such as Electrostatic Levitation and thermodynamics based calculations. 2) Develop a thermodynamic-based model using the data NASA's Physical Sciences Informatics System to simulate the alloy microstructure evolution and predict the properties of printed parts. The model will use the phase-field approach, which will capture the effect of particle size, temperature, pressure, interface energies, composition, surface tension, and their influence on the formation and coalescence of the microstructures. 3) Certify as-built samples through metallurgical, mechanical, and material characterization. As-built samples should achieve comparable levels of relative density and mechanical performance as compared to wrought samples. 4) Conduct in-situ X-Ray diffraction testing to capture the dynamic sintering process to assist process optimization. 5) Design and prepare samples for potential microgravity studies on the International Space Station.

MT - 19-EPSCoR -0020

Tectonic Influences on High Temperature Biosphere Habitability

Montana State University, Bozeman

NASA MD: SMD
Center: GSFC

Director: Dr. Angela Colman Des Jardins

Science PI: Dr. Daniel Colman, Montana State University, Bozeman

Hydrothermal systems integrate geologic processes at a planet's surface with those from the deep subsurface, yielding hot springs with an incredible array of geochemical compositions. Studies of extremophiles inhabiting such environments have framed our understanding of the habitability and origin of life on Earth and the potential for life on other planetary bodies. In particular, hydrothermal systems, such as those in Yellowstone National Park (YNP), Wyoming, USA, have been the focal point of many astrobiological studies. The considerable geochemical variation in YNP hot spring fluids is controlled by several subsurface geological processes including water-rock interactions that occur within predominantly rhyolite-hosted hydrothermal settings. However, rhyolitic volcanic systems were unlikely to be widespread on early Earth when life is hypothesized to have originated. Rather, early Earth was likely dominated by basaltic type volcanism similar to what occurs today in modern-day Iceland. Preliminary evidence described herein suggests that rhyolitic (e.g., YNP) and basaltic (e.g., Iceland) hydrothermal systems host waters that are geochemically distinct, which is likely due to their differing tectonic and geologic settings. Unlike our understanding of YNP high-temperature environments, very little is known of how geochemical variation affects thermophilic communities within Icelandic springs. Moreover, nothing is known regarding the effects of differing geochemistry on the taxonomic and functional composition, activities, and evolution of microorganisms inhabiting basaltic versus rhyolitic hydrothermal systems. These are significant knowledge gaps considering that basaltic environments that can support chemosynthetic life (i.e., removed from photosynthetic processes) are likely to be key analogs informing our understanding of i) processes that supported early life on Earth and ii) the character of subsurface life on other volcanically active planetary bodies (e.g., Europa, Enceladus and Mars).

Here, we propose an integrated suite of studies aimed at determining how variation in the geochemistry of hydrothermal systems in Iceland and YNP: 1) are consequences of tectonic setting and the associated subsurface geological processes; 2) shape microbial diversity and their activity; and 3) promote different evolutionary trajectories of microbial inhabitants. To address these interrelated goals, we will conduct a longitudinal sampling campaign that includes a wide variety of geochemically distinct springs in both Iceland and YNP. We will develop geochemical models to identify the influences of host-rock type (due to differences in tectonics) on the geochemical variation among the springs. We will then use these data to develop new understanding of the controls on the composition of microbial communities, their functions, and their activities, among the two systems. Lastly, we will reconstruct evolutionary histories of microbial populations from metagenomic data to test the hypothesis that Icelandic hydrothermal environments host microbial lineages and functional enzyme homologues that are more early evolving.

Our results will also provide critical new insight on the extent, nature, and evolution of high-temperature, globally distributed, chemosynthetic biospheres. This work will leverage the unique

expertise of four early career scientists in geochemistry, thermodynamic modeling, molecular microbial ecology, bioinformatics, and evolutionary theory. As such, the proposed work will provide training opportunities for two graduate students at the intersection of these exciting disciplines, forge collaborations across Montana institutions (MSU-Bozeman and Montana Tech), and promote the EPSCoR goal of developing NASA research capacity within Montana.

ID - 19-EPSCoR -0021

Plasma-Jet Printing Technology for In-Space Manufacturing and In-Situ Resource Utilization

University of Idaho, Moscow

NASA MD: HEOMD, STMD
Center: KSC, MFSC, ARC

Director: Dr. Joseph D. Law

Science PI: Harish Subbaraman, Ph. D., Department of Electrical and Computer Engineering, Boise State University

C. Technical Summary

Astronauts have access to critical supplies and life-sustaining elements inside the international space station, thanks to the regular cargo shipments from Earth. However, as humans begin to explore space farther away from home on missions lasting several months to a few years, access to essential components and commodities become increasingly difficult, making on-board generation of parts and materials, and utilization of existing resources a critical necessity. The basis of NASA's programs, such as the In-Space Manufacturing (ISM) and the In-Space Resource Utilization (ISRU) revolve around addressing and managing these difficulties, and enabling capabilities and conditions for humans to live and work in space or on planetary surfaces. NASA Ames developed a revolutionary plasma-jet printing technology that can perform in microgravity. This technology, though not as mature as some of the other competing technologies, holds tremendous promise for simultaneously serving a range of cross-cutting areas, including but not limited to: i) in-space manufacturing, ii) sterilization of surfaces, iii) decontamination of organics, and iv) food produce treatment. Such a cross cutting technology is unique and is not feasible with its competing technologies. In this project, we aim to advance this technology through understanding the physical mechanisms of plasma jet operation and demonstrate proof of concept device applications ranging from electrical and optical communication devices surface treatments to decontamination of organics, etc.

D. Mission Directorates/Centers and Research Areas of Interest

- Ames Research Center (ARC)

  o Nanotechnology-electronics and sensors

- Marshall Space Flight Center (MSFC) o

  In Space Habitation

  o Advanced Manufacturing

  o 3D Printing/Additive Manufacturing/Rapid Prototyping

- Kennedy Space Center (KSC) o

  In-Situ Resource Utilization

  o Life Support Systems and Habitation Systems o Food Production, Processing, and Preservation

o Sustainability and Supportability

- Jet Propulsion Laboratory (JPL) o

Solar System Science

o Human Exploration Destination Systems

o Communication and Navigation

- Johnson Space Center (JSC) o

Wearable Tech

o In-Situ Resource Utilization

- Langley Research Center (LaRC)

o Advanced Materials and Structural System â€“ Advanced Manufacturing

- Glenn Research Center (GRC)

o Communications Technology and Development

- Goddard Space Flight Center (GSFC) o

Advanced Manufacturing

o Advanced Multi-functional Systems and Structures

o Additive Manufacturing Enabled Miniaturized and Optimized System Design

- Human Exploration & Operations Mission Directorate (HEOMD) o

Physical Science Research: Antenna Technology

- The Space Technology Mission Directorate (STMD)

o Advanced manufacturing methods for space and in space

o Efficient in situ resource utilization

E. Areas of expertise required for research o

Plasma Science & Engineering

o Electrical Engineering

o Materials Science and Engineering

o Biochemistry

NV - 19-EPSCoR -0023

High Energy Density Battery Materials at Low Temperatures for Future NASA Missions

Nevada System of Higher Education

Director: Dr. Lynn F. Fenstermaker

Science PI: Dr. Feifei Fan, University of Nevada, Reno

NASA MD: STMD
Centers: GRC, KSC, JSC and JPL

The overarching goal of this project is to enhance the Nevada System of Higher Education (NSHE) research capacity and infrastructure to address NASA's strategic needs on rechargeable batteries for planetary science missions. NASA has a long-term interest in developing robust and lightweight high-energy-density rechargeable batteries that can operate well at low temperatures. One of the major technical challenges specified in the 2015 NASA Technology Roadmaps is developing high-specific-capacity anode nanomaterials with improved low-temperature performance (âˆ’60 Â°C) for lithium-ion (Li-ion) batteries. The research goal of this project is to improve the power density, energy density, and cycle life of anodes for Li-ion batteries at â€“60 Â°C with a fundamental understanding of the controlling mechanisms. Studies have revealed that the poor low-temperature performance of Li-ion anodes mainly relates to slow ionic diffusion and limited Li storage capacity. Therefore, the proposed research will focus on group-IV elements and (transition/binary) metal oxides owing to their high theoretical specific capacity of Li. The central hypothesis is that making use of material doping and simultaneously the high specific capacity can advance lithiation kinetics, ionic diffusion, and capacity retention in anodes at low temperatures.

To test the hypothesis, the proposed research will complete four tightly coupled thrusts by synergistically integrating computational and experimental studies. The four thrusts are (1) identification of high-capacity anode materials and corresponding doping elements that improve power density at â€“60 Â°C; (2) prediction of capacity retention and cycling stability in doped high-capacity anodes with the consideration of chemo-mechanics; (3) electrochemical analysis of the doped anodes and characterization of battery performance at âˆ’60 Â°C; (4) detection and characterization of Li dendrites and potentially hazardous metal clusters in cycled cells for mitigation of short circuits. The research outcomes will address key scientific questions: What are the controlling mechanisms for the charge-transfer kinetics, Li diffusion, and electrochemical degradation in doped high-specific-capacity anode nanomaterials at âˆ’60 Â°C? And how can doping impurities enhance the rate performance and capacity retention of these high-specific-capacity anodes simultaneously? Completion of the proposed research will provide a better understanding of the battery working principle at low temperatures, generate a database containing electrochemical performance of advanced anode materials under a variety of operational conditions at â€“60 Â°C, and thus lead to a rational design guidance of anodes for future Li-ion batteries for space applications.

The project aligns with the current space technology topic of â€œadvanced power generation, storage, and transfer for deep space missionsâ€• in the Space Technology Mission Directorate. The research also aligns with advanced energy and space power generation interests at several NASA Centers including GRC, KSC, JSC and JPL The proposed research will contribute to the strategic goals 1, 2 & 4 in 2018 NASA

Strategic Plan by generating new knowledge and developing low-temperature rechargeable battery technologies that meet the needs of near- and mid-term planetary surface missions. In view of education and training, technology transformation, and public engagement with STEM, the project will contribute to the strategic goal 3 in 2018 NASA Strategic Plan. The project will enhance the research capabilities and competence of NSHE in the area of battery technologies and advance education, training, and workforce development in Nevada. The project will also develop collaboration between NSHE faculty and NASA scientists, and create intellectual advances with commercialization potential.

KS - 19-EPSCoR -0024

Development of Next-Generation Acoustic Liners for Aircraft Engine Noise Reduction

Wichita State University

NASA MD: ARMD
Center: LaRC, AFRC

Director: Dr. Leonard Scott Miller

Science PI: Dr. Bhisham N. Sharma, Wichita State University

Aircraft noise is a significant constraint to increasing U.S. aviation capacity, efficiency, and flexibility. It causes passenger and community annoyance, disrupts sleep, adversely affects the academic performance of children, and increases the risk of cardiovascular disease in people living near airports. Repeated exposure can cause serious psychological and hearing issues in flight crews. Further, strict Federal Aviation Administration (FAA) noise regulations aimed at reducing the general population's exposure to aircraft noise levels directly influence the location of new airports and expansion of current runways at existing airports. The current push towards the development of air taxis and supersonic aircrafts is bound to further exacerbate noise issues. Thus, reducing the noise emitted by modern aircrafts is a critical societal need.

In this project, our central objective is to develop next-generation acoustic liners to help quieten aircraft engines. To this end, we will develop lightweight, minimal thickness liners using advanced cellular porous materials engineered to provide high sound absorption over a wide frequency range and capable of withstanding extreme engine environments. Cellular materials offer a distinct advantage over traditional liner materials: their structural and functional properties are directly controlled by their local microstructural architecture. Thus, by engineering their microstructure, they can be tailored to provide significantly enhanced properties without parasitic mass addition. Here, our focus will be on three cellular material systems: (a) open-celled metal foams; (b) 3D printed polymeric bulk absorbers; and (c) aerogel-based structures. The key research objectives are: (1) design, fabricate, and test open-celled foam-metal liners with variable through-thickness properties; (2) leverage 3D printing techniques to design new bulk absorbers with novel local topological surfaces; and (3) design and fabricate ultra-lightweight aerogel-based bulk absorbers for aircraft liner applications. These objectives will be achieved by combining experimental and quantitative techniques to understand the role played by the absorber's cellular topology on its acoustic properties. The insights gained will be used to design minimal thickness acoustic liners with exceptional noise attenuation capabilities.

The project goals will be achieved via close collaboration between three Kansas universities (Science-I Dr. Bhisham Sharma at Wichita State University, Co-I Dr. Zhongquan Charlie Zheng at University of Kansas, and Co-I Dr. Dong Lin at Kansas State University), two NASA Research Centers (Langley Research Center and Glenn Research Center), and three industry partners (ERG Materials and Aerospace Corporation, Honeywell Aerospace, and Spirit AeroSystems). The work proposed here is responsive to the NASA Aeronautics Research Mission Directorate's 2018 Strategic Plan and is aligned with Strategic Goal 3: Address national challenges and catalyze economic growth; Objective 3.2: Transform aviation through revolutionary technology research, development, and transfer. Specifically, the proposed work supports the research objectives of NASA's Advanced Air Transport Technology (AATT) Project whose central goal is to explore and develop novel acoustic liner configurations for use in commercial aircraft liners. The discovery and innovation stimulated through this collaborative project will help build the foundation in Kansas for sustained research and development growth in the areas of structural acoustics and advanced materials research. Results from this project will translate into new devices and methodologies relying on metal foams, 3D printed bulk absorbers, and aerogels â€“ materials of high importance to meet future challenges in aviation and beyond.

AK - 19-EPSCoR -0025

Remote sensing of formaldehyde at northern high latitudes: Probing the chemical impacts of Arctic greening

University of Alaska, Fairbanks

NASA MD: SMD
Center: GSFC

Director: Dr. Denise Thorsen

Science PI: Dr. Jingqiu Mao, University of Alaska, Fairbanks

The Arctic (north of 65N) and boreal regions (between 45N and 65N) have undergone dramatic temperature and ecological changes over the past century and the rate of this change has accelerated in recent decades. Satellite observations of leaf area index (LAI) and normalized difference vegetation index (NDVI) suggest that northern high latitudes shows a significant trend of greening in the past three decades as a result of vegetation growth. A major unknown is how these changes will impact biosphere-atmosphere exchange and subsequently feedback on Arctic climate and air quality.

Formaldehyde (HCHO) serves as an important indicator of biogenic volatile organic compound (VOC) emissions on regional and global scales. HCHO column abundance can now be observed from space by several satellite-based sensors including OMI on Aura (2004-), GOME-2 on MetOp-A (2006-) and MetOp-B (2012-), OMPS on SUOMI-NPP (2011-) and JPSS-1 (2017-), and TROPOMI on Sentinel-5P (2017-). But there are large uncertainties and inconsistencies among these satellite sensors, due to instrument sensitivities, retrieval algorithms, timing of observation with respect to the diurnal cycle, and other factors. In this work, we use two ground-based instruments (Pandora and MAXDOAS for total column and vertical profiling, respectively), to provide validation of HCHO columns for these satellite sensors at northern high latitudes, with a major focus on boreal forest region. In collaboration with scientists from Harvard-Smithsonian Center for Astrophysics, we will establish a long-term record of HCHO column densities in Arctic and boreal region over the past twenty years. This will improve our understanding of biosphere-atmosphere exchange at high latitudes in past and future decades. Our main scientific questions include:

1. Do ground-based measurements of HCHO agree with satellite-based observations? If not, how can we use ground-based measurements of HCHO column densities to improve satellite-based retrievals?

2. Can we use ground-based and satellite-based measurements, together with chemical transport models, to estimate regional emissions of biogenic VOC in boreal and Arctic regions?

3. Is there a long-term trend of HCHO column density in boreal region as a result of Arctic greening and warming? What is the impact of Arctic greening on air quality and atmospheric composition in Arctic?

By improving our understanding on biosphere-atmosphere exchange at northern high latitudes and their impact on climate and air quality, this work aims to make significant contributions to three key science questions in the Earth science program of Science Mission Directorate (SMD). They are: (1) How is the global Earth system changing? (2) What causes these changes in the Earth system? (3) How will the Earth system change in the future?

This work aligns well with NASA Pandora project and related satellite remote sensing research at NASA Goddard Space Flight Center. The Pandora project and associated networks are priorities of the NASA Tropospheric Composition Program within the Earth Science Division (ESD) of the Science Mission Directorate (SMD). With NASA Pandora instrument, we will join NASA’s emerging Pandora Global Network (PGN) and expand PGN’s ability to integrate air quality data across a larger, more global scale for future satellite validation. This works aligns well with Alaska NASA EPSCoR’s research priority: â€œMonitoring of environmental change, mapping and remote sensing, and hazard prediction and mitigation.â€• Given the lack of long-term observations in Arctic, we also hope to develop a long-term ground-based remote sensing site at UAF and surrounding areas in Alaska. Our ultimate goal is to make UAF a primary high-latitude gas and aerosol satellite validation site for NASA, ESA, and other space agencies.