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ND-20-EPSCoR-Research-0005

Development of an Advanced Planetary Mobility Spacesuit using Advanced Additive Manufacturing Design and Techniques

United Tribes Technical College

Director/PI: Dr. Caitlin Nolby

Science PI: Dr. Pablo De Leon

NASA MD: HEOMD

This proposal is responding to NASA EPSCoR announcement number NNH20ZHA005C, specifically Appendix G2.2: Commercial Space Capabilities, Research Request Number: CSCO-2020-03, Research Title: Improvement of Space Suit State of Art.
Through our development programs of the NDX-1 and NDX-2 planetary suits, the University of North Dakota team has accrued extensive experience at fabricating complete Extravehicular Activity (EVA) spacesuit prototypes. We propose to meet the above research need through the design, development, and manufacturing of a spacesuit prototype using additive manufacturing (AM). Manufacture of this EVA suit will be equally possible in 1 g on Earth, in µ-g in space, and in fractional-g on the planetary surfaces of the Moon and Mars.
This expertise assures confidence that the following key concerns can be satisfied:

1. That the soft goods and woven materials will exhibit consistent characteristics and will be strong, durable, and reliable for operations in hostile environments
2. That the suits will provide substantial surface mobility to achieve mission success
3. That the ergonomics will ensure safety and comfort, including body contact with the suit and its extremities
4. That the suits will be usable, permitting easy don and doff
5. That the suits will substantially reduce dust contamination
6. That astronaut crews will have the ability to fabricate any suit part in space, and
7. That the suits will be consistently producible through standardized digital manufacturing, materials, and feed stock.

Historically, spacesuit fabrication methodologies have relied extensively on traditional methods of fabric garment assembly and connection through sewing. These manufacturing methods require thousands of hours of artisan-like abilities that include patterning, cutting, sewing, gluing, applying rubber components, etc. Inspection of the work becomes a significant cost because of the normal individual variations.
One of the ongoing challenges in spacesuit engineering is mating hard parts to soft parts. Additive manufacturing can solve a large part of this fabrication challenge by creating parts having both hard, rigid sections and soft, flexible sections while using the same materials.
We expect the utilization of AM techniques to enable manufacturing and repairing pressure garments in-situ, thereby allowing for a sustainable presence on the Moon and Mars. Astronauts at a permanent base on the Moon or Mars will be able to fabricate nearly any EVA spacesuit part they need without waiting for delivery of replacement components from the Earth. The University of North Dakota Human Spaceflight Laboratory will develop AM techniques to produce a fully operational, pressurizable spacesuit. This capability will revolutionize the paradigm of the next generation spacesuit manufacturing. The funding for this proposed research will allow us realistically to advance from the current Technology Readiness Level (TRL) of 3-4 to TRL 6 over the three-year period of performance.

MT-20-EPSCoR-Research-0006

The Origin of Supermassive Black Holes

Montana State University, Bozeman

Director/PI: Dr. Angela Des Jardins

Science PI: Dr. Amy Ellen Reines

NASA MD: SMD

The origin of supermassive black holes with $M_{BH} = 10^6 \; 10^{10}$ Msun remains a major outstanding issue in modern astrophysics. These monster black holes reside in the nuclei of essentially every massive galaxy including our Milky Way and power the most luminous objects at the edge of the observable Universe. However, directly observing the first seed black holes in the earlier Universe - that can eventually grow to upwards of a billion solar masses - is not feasible with current telescopes. Present-day dwarf galaxies, on the other hand, are within observational reach and offer another avenue to learn about black hole seeds since low-mass galaxies can host relatively pristine black holes with $M_{BH} < 10^6$ Msun.

The primary goal of the proposed work is to advance our understanding of the birth and growth of supermassive black holes. In particular, the major scientific goals of this project are to (1) systematically search for supermassive black holes in dwarf galaxies using multi-wavelength observations and a variety of techniques, (2) characterize the least-massive galaxies that can form a supermassive black hole, (3) measure the masses of the smallest black holes to constrain seed masses, (4) determine the accretion and radiative properties of low-mass black holes in dwarf galaxies, and (5) probe black hole feedback in dwarf galaxies to inform galaxy formation models at all mass scales. Ultimately, this work will improve our understanding of black holes in dwarf galaxies and the mechanism that seeded the first black holes in the earlier Universe.

The proposed study is closely aligned with the goals of the NASA Astrophysics Division within the Science Mission Directorate (SMD), and contains cutting-edge and innovative research that NASA currently wants performed. The proposed work is of direct relevance to NASA's strategic mission to expand human knowledge through new scientific discoveries, with specific goals of understanding the nature of black holes and the origin and evolution of galaxies. Moreover, this project will exploit the exceptional capabilities of NASA's Great Observatories including the Hubble Space Telescope (HST) and the Chandra X-ray Observatory. The proposed research will also help lay the groundwork for future studies with NASA's next generation of powerful telescopes such as the James Webb Space Telescope.

Science-I Dr. Amy Reines, an Assistant Professor at Montana State University (Bozeman), will direct the proposed study. Dr. Reines is a leading expert in the field of black holes in dwarf galaxies and an experienced user of HST and Chandra. Moreover, our team consists of researchers with a wealth of expertise in astrophysics, mathematics, statistics and big data science, all of which will contribute to the overall success of the proposed work.

This study will also contribute to the research infrastructure, science and technology capabilities, and economic development of Montana. Through our interdisciplinary team and existing ties to NASA researchers, we will build new connections for NASA-related scientific research in Montana. Additionally, a NASA EPSCoR award will increase the number of Montana faculty (and students) working in NASA-related areas, and develop competitiveness for future NASA (and other) funding. Given the big data aspects of this proposal and student/postdoc training, there are also potential connections with Montana's high-tech industry and its need for data scientists. Finally, our proposal is aligned with Montana State University’s commitment to groundbreaking research and the Department of Physics strategic plan to advance our astrophysics focus.

PR-20-EPSCoR-Research-0007

NASA EPSCoR: Center of Sustainable Technologies for Water Reclamation and Reuse (CSTWR2)

University of Puerto Rico, San Juan

Director/PI: Dr. Gerardo Morell

Science PI: Dr. Marco De Jesus

NASA MD: HEOMD

The future of NASAs long-term space missions requires surpassing a major technical and engineering challenge: Provide a highly efficient, self-sustainable and renewable life support system. Such endeavor demands a proper mass balance of water, food and supplies to support the space explorers during these long journeys. Water is heavy and reduces the vectors payload. As a result, a low maintenance, high performance, energy-lean, and durable water recycling and purifying system to reuse water becomes paramount. Accordingly, this proposal aims at developing novel nano-biotechnological approaches for functional water recycling and reuse with stringent monitoring and control systems to produce safe, high-quality drinking water.

Nowadays NASA uses a water recycling system, requiring low-pressure vacuum distillation. The entire process occurs within a rotating distillation assembly that counteracts zero gravity and, therefore, aids in the separation of liquids and gases in space. The system removes free gas and solid materials (hair, lint, etc.) and sends them through a series of multi-filtration beds for further purification. Any remaining organic contaminants and microorganisms are removed by a high-temperature catalytic reactor assembly. Water quality is monitored by electrical conductivity sensors. The drawbacks from this system are centered on its complexity and high energy consumption. NASA has also highlighted the need to enhance the efficiency of its water recovery, along with the microbe monitor and control systems.

An interdisciplinary competitive team has been assembled to work in collaboration with the NASA Marshall Space Flight Center to develop novel, energy-efficient technologies to recover, treat, and purify used water from limited sources in the spacecraft, but mainly, from body fluids (i.e. urine). Three teams are established to address appropriate water impurities removal, while assuring water sanitation, quality and reliability for safe consumption as demanded by future manned missions. The project goals are to address appropriate water impurities removal and remediation, while assuring water sanitation, quality and reliability through biological monitoring and control.

To achieve those challenging goals, the assembled team encompasses experienced researchers. The teams collective strength and synergy developed over 10 years of collaborative and professional interaction makes this initiative ideally suited to foster innovative applications in an area critical area to NASA interests. The theme is also vital not only for the jurisdiction. In effect, the availability of safe water for human consumption is a global necessity. Therefore, the proposed project reckons with such challenging goal through a system that is affordable, energy-lean, portable, and scalable. CSTWR2 aims at developing novel approaches for functional water recovery and reuse, quality, monitoring and control. Accordingly, this project aims at: 1). Develop novel nano-biotechnological approaches for functional water recycling and reuse with stringent monitoring and control systems to produce safe, high-quality drinking water. 2) Formation of a highly qualified cadre of professionals who would become leaders in NASA-driven STEM fields.

The completion of this project will provide practical and diversified research and education/training experiences to foster the research of 6 graduate and over 6 undergraduates students from underrepresented groups in the applied STEM field of water reuse and reclamation. Project participants will receive a mentored, research training experience in the latest techniques for the detection, characterization prevention and purification of contaminants in water systems. Engineering and use advance tools to purify, characterize, and track emerging contaminants from their point of detection to their point of origin.

SC-20-EPSCoR-Research-0008

Rapid Laser 3D Printing of Reversible Solid Oxide Electrochemical Cell Stacks for Producing Pure O2 from CO2 and Storing Electricity into Carbon

Clemson University

Director/PI: Dr. Cassandra Runyon

Science PI: Dr. Jianhua Tong

NASA MD: HEOMD

This NASA EPSCoR research project will specifically contribute to the mission priorities of NASAs Glenn Research Center (GRC) in space power generation, storage, distribution, and management. Specifically, the purpose of this research project is the development of a highly compacted reversible solid oxide electrochemical cell (R-SOECC) stack manufactured by a rapid laser 3D printing technique for efficient energy storage and oxygen (O2) production through redox cycles of CO2-CO or CO2-C. This technology will use the environmentally available CO2 on Mars to facilitate storage of solar electricity and the creation of pure oxygen, directly benefitting NASAs Moon to Mars campaign.

The success of this project will provide new energy storage concepts and materials, and new advanced manufacturing techniques that will contribute to NASAs mission to drive advances in science, technology and space exploration. The implementation and effort to attain the objectives of this project will contribute to a highly skilled, competent, and diverse workforce in the following areas: 1) Contribution to and promotion of the development of research capabilities in South Carolina (SC) in areas of vital importance to the NASA mission. 2) Improvement in the ability of SC to gain support from sources outside the NASA EPSCoR program. 3) Development of partnerships between and within NASA GRC, Clemson University, the University of South Carolina, and Benedict College (an HBCU). 4) Contributions to the overall research infrastructure, science and technology capabilities of higher education, and economic development of SC.

To fulfill the above objectives, this proposal identifies four tasks. Task 1: Develop Novel Coking Resistive Electrodes for CO2-CO Electrochemical Redox Cycles. Development of new coking resistive electrodes with metal alloy nanoparticles supported double perovskite matrix materials will provide for the steady operation of R-SOECCs. Task 2: Develop Novel Electrodes for CO2-C Electrochemical Redox Cycles. Study of the CO2-C electrochemical redox cycle reaction kinetics and stability will contribute to the development of promising fuel electrode materials. Task 3: Study Laser 3D Printing of R-SOECC Components. This research will develop CAD design and 3D printing processes for R-SOECC components and resolve issues of cracking that occur with the rapid laser processing of ceramics. Task 4: Manufacture, Evaluate, and Characterize R-SOECC Cells and Stacks. This project will fabricate R-SOECC single cells and stacks using the L3DP technique and will test the performance of the single cells and stacks through postmortem analysis of the devices.

This research on energy materials and devices and the related advanced manufacturing technology will contribute to the establishment of a collaborative relationship between NASA GRC and SC to accommodate the multiple missions of NASA and the mission of South Carolinas Vision 2025. First, this research will directly address the power storage and oxygen production challenges critical to advancing NASA's On to Mars Mission. This research proposal closely aligns with the mission of NASAs Space Technology Mission Directorate to develop advanced power generation and storage systems for deep space missions and to develop small power components and instruments for small spacecraft. Next, the research will contribute directly to the development of solid oxide fuel cells and electrolysis, CO_2 reduction/utilization, and advanced manufacturing based on 3D printing and laser processing. Finally, the successful implementation of this project will significantly improve the science and technology infrastructure for research and education in related fields in SC.

AK-20-EPSCoR-Research-0011

Development of Test Sites and Atmospheric Corrosion Studies of Metal Alloys and Coatings Exposed to Cold Arctic/Sub-Arctic Climate

University of Alaska, Fairbanks

Director/PI: Dr. Denise Thorsen

Science PI: Dr. Raghu Srinivasan

NASA MD: STMD

It is commonly assumed that there is very little to no corrosion in cold environments. However, previous studies in the Antarctic and Arctic regions have shown significant corrosion damage when exposed to cold conditions. Moreover, very little corrosion data are available for metal alloys exposed to cold arctic and sub-arctic conditions. Atmospheric corrosion occurs when a metal surface is under a thin layer of moisture, but not completely immersed, and the metal surface corrodes while exposed to environmental factors. Three important factors that affect atmospheric corrosion rates are aerosol chlorides, SO2 and time of wetness (TOW) along with other climatic parameters such as rainfall, temperature, humidity, and solar radiation. Aerosol chlorides can be carried to the metal surface both by natural means (wave/surf action or salt-laden snow from the marine environment) and by man-made pollutants (deicing salts on roads). Similarly, SO2 can also be deposited via natural means (volcanic) and man-made pollutants (combustion of fossil fuels). With the recent climate change in the arctic and sub-arctic region, there is a renewed interest to study the atmospheric corrosion mechanisms. The combination of urbanization and proximity to marine/volcanic environments make artic and sub-arctic regions in North America, particularly Alaska, an important natural laboratory to study atmospheric corrosion in cold regions.

Goal and Objectives: The main goal of this proposal is to understand the underlying atmospheric corrosion mechanisms of metal alloys and coatings exposed to cold arctic climate. The main objectives of this proposed research are:

1. To establish atmospheric corrosion test sites across the state of Alaska equipped with weather stations.
2. To study the effect of sample orientation and snow/ice retention on the corrosion rates and study the ingress of air-borne chlorides and oxygen transportation through varying thickness of snow/ice.
3. To evaluate the performance of an already developed anti-corrosion polymer nanocomposite coatings (PNCCs) in natural environments for aerospace applications.

Alignment with NASA: Corrosion continues to be a major problem of NASA since its inception in 1962 and it is included in NASAs Space Technology Roadmap to reduce the cost and improve the sustainability and efficiency of its ground operations in support of future launch activities. According to the NASA Space Technology Roadmap, corrosion prevention, detection and mitigation fall under TA 13 Ground and Launch Systems (TA 13.2.1). One of the grand challenges is to predict the corrosion life of materials systems in actual service conditions. Testing in actual atmospheric condition will also help in devising modified accelerated corrosion testing for better correlation. It is of great importance to study the limits of chemical and electrochemical stability of metal alloys and coatings under extreme conditions, which includes cold artic climate. The proposed project monitors the degradation of metal alloys that are widely used in land, sea and aerospace transportation and the data obtained will enhance the understanding of atmospheric corrosion mechanisms in cold arctic climate.

NASA Mission Directorate Collaboration: This project directly aligns with NASA Kennedy Space Centers Mechanical and Environmental Test Laboratory and complements their facility in Florida. Collaborations with the NASA lab (Dr. Eliza Montgomery) will allow specific corrosion problems to be identified and tested in cold arctic climate conditions. Metal samples will be to deployed at the Beachside Atmospheric test site at KSC to get reference data for the metals exposed to hot tropical marine environment.

Area of Expertise: The proposed research requires expertise in the field of corrosion and coatings. Science PI Dr. Raghu Srinivasan has extensive experience investigating corrosion rates and mechanisms associated with atmospheric corrosion.

VT-20-EPSCoR-Research-0012

New Unified Framework for Scalable, Risk-Aware, and Resilient Estimation and Control of Satellite Swarms

University of Vermont, Burlington

Director/PI: Dr. Bernard Cole

Science PI: Dr. Hamid Ossareh

NASA MD: SMD, STMD

Satellite swarm missions have gained significant attention in recent years due to their potential utility in applications such as distributed antennas, synthetic aperture, distributed atmospheric sampling, and in-space assembly of large structures. However, current swarm missions are limited in scope and complexity due to a lack of on-board perception and autonomy, which can be attributed to gaps in the following key areas: (i) uncertainty quantification and robustification; (ii) formation and trajectory planning; (iii) real-time, collision-free navigation and control; and (iv) robust, cooperative estimation and sensor fusion.

The proposed project seeks to fill these gaps by researching and developing a validated and fully-integrated computational and operational framework for formation planning, estimation, and control of a satellite swarm, with application to a synthetic aperture radar (SAR) swarm in close formation. Particular emphasis is on scalability (~100s of satellites), real-time feasibility (~100 MHz CPU, ~1 MB Memory), and quantification and robustness to uncertainties. The framework consists of theories, software tools, and scalable algorithms in the four areas mentioned above, as well as algorithms for fault detection and fault tolerant control of the patented propulsion technology (known as B125) developed by our Vermont-based industry partner, Benchmark Space Systems.

The framework will be validated using software and HiL testing on a large swarm of SAR CubeSats, which must robustly and precisely maintain a desired formation and attitude to image Earth, avoid space debris and collisions, be robust to uncertainties and faults, and optimize the use of fuel. This project will be conducted by the science-I and Co-Is at the University of Vermont (UVM) with collaboration with researchers at Benchmark, as well as NASA scientists and engineers at JPL. Successful completion of this project will offer the burgeoning satellite industry strong evidence that large-scale swarms can be controlled and managed autonomously in an efficient and reliable manner to solve complex problems, and will position UVM and Vermont as leaders in space and CubeSat R&D.

OK-20-EPSCoR-Research-0014

Robust and High-Data-Rate Hybrid RF/Optical Communications for Lunar Missions

Oklahoma State University

Director/PI: Dr. Andrew Arena

Science PI: Dr. Sabit Ekin

NASA MD: HEOMD, STMD, SMD

A space communication network suitable for planned lunar missions requires a new architectural paradigm that is dynamic, scalable, and capable of supporting diverse mission types at unprecedented communication speed with high reliability, continuous coverage, and minimum latency. Considering the low data rate of radio frequency (RF) systems and the outage vulnerability of optical channels, we propose a hybrid approach, incorporating both RF and optical communication elements within a smart networking framework. Our theoretical and experimental effort will integrate RF and optical communication systems for small satellites (SmallSats) and will design an encompassing network architecture that leverages this combination among Earth stations, a LEO SmallSat constellation, the Lunar Gateway, and Moon explorers.

The project will pursue three key research thrusts: (i) Hybrid RF/optical communication system design and integration, (ii) Network design for lunar communication architecture with hybrid RF/optical links, (iii) System-level testing and evaluations. We will investigate the proposed architecture from several perspectives including operational frequency bands, data rates, integration, signal acquisition, quality of service, power requirements, appropriate protocols such as delay/disruption tolerant networking (DTN), access strategies, outage recovery, and communication-aware SmallSat constellation topologies. RF/optical communication modalities and low-cost SmallSats are both growing interests of NASA and bring critical forward progress to important NASA missions, partnering international space agencies, and private industry, such as Iridium, OneWeb, and Starlink (SpaceX).

The proposed ideas align strongly with NASA priorities. Recent NASA missions, programs (Artemis), and reports, including The Future Lunar Communications Architecture study by the Interagency Operations Advisory Group (IOAG) on 9/25/19, all identify space communications as a key element of several NASA Strategic Objectives and NASA Technology Taxonomies, particularly the lunar and Mars missions. The project addresses the objectives of Human Exploration and Operations Mission Directorate (HEOMD), Space Technology Mission Directorate (STMD), and Science Mission Directorate (SMD), and complements ongoing research for lunar missions. The work closely aligns with NASA EPSCoR objectives. The project team collaborates with NASA members from Goddard Space Flight Center (GSFC): Dr. Serhat Altunc, Networks Integration Manager, Telecommunication Networks & Technology Branch, Engineering and Technology Directorate, Dr. Obadiah Kegege, Engineering Project Manager, Near Earth Network Project, Flight Projects Directorate, and Mr. Peter M. Hughes, Center Chief Technologist, office of the Center Director. The team has prior partnerships with NASA GSFC through EPSCoR Research Initiation and Travel grants.

The coherent and complementary team provides the expertise needed to complete the project: Science-I Ekin (OSU), industry experience in wireless communication system design, expertise in RF and cognitive radio; Co-I OHara (OSU), expertise in high-frequency RF, optical electromagnetics and atmospheric propagation; Co-I

LoPresti (TU), expertise in optical communication and ad-hoc RF/optical networks; Co-I Imran (OU), expertise in network design, smart networks, and machine learning; Co-Is Song and Choi (OSU), expertise in RF transceiver front-end design; and Co-I Jacob (OSU), expertise in control and mechanical design of unmanned and satellite systems. The team members are from Oklahoma's three largest research universities and have an established relationship and track record of collaboration through NASA EPSCoR, NSF, FAA, and USSOCOM projects. The team is committed to initiating Oklahoma's first CubeSat program, providing an unparalleled opportunity for STEM education, and developing cutting-edge research and technology related to the states aerospace sector.

NM-20-EPSCoR-Research-0015

Next Generation Additive Manufacturing for Space Applications

New Mexico State University

Director/PI: Dr. Paulo Oemig

Science PI: Dr. Igor Sevostianov

NASA MD: STMD

This collaborative research effort focuses on the development of a methodology for quality control and optimization of processing parameters for Additive Manufacturing (AM) technological processes. The main application of the expected outcomes is developing a design-in-manufacturing methodology to produce structural parts in the conditions when processing parameters have to be adjusted during printing. This application is of particular interest to NASA Space Technology Mission Directorate (STMD) for developing materials repurposing technology crucial for 3D-printing in space [2].

The project is strongly supported by NASAs Johnson Space Center, The Ames Research Center and White Sands Test Facility. The research is aligned with the following Technology areas indicated in the NASA 2020 Technology Taxonomy: 12.1.1 (Lightweight Structural Materials), 12.2.2 (Design and Certification Methods), 12.4.1 (Manufacturing Processes), 12.4.2 (Intelligent Integrated manufacturing), and 12.4.5 (Nondestructive Evaluation and Sensors).

The ultimate goal of our project is to propose a novel methodology that integrates measurement techniques (e.g. in-situ sensing modalities) and material characterization (e.g. ex-situ material evaluation) with the optimization of AM processing parameters. Our research will focus on printing specimens from titanium and aluminum alloys and functionally graded materials using the Directed Energy Deposition (DED) method. Initial input parameters will be used for manufacturing the first set of specimens; the manufacturing process will be monitored using in-situ sensors (infrared, optical, and acoustic sensors). The printed specimens will be tested using ex-situ testing (X-ray computed tomography, electrical impedance, and ultrasound testing) and microscopy before being subjected to destructive mechanical tests. Information about a specimens microstructure and material properties will be used to develop and verify/validate the micromechanical model and Auditory Convolutional Neural Network. These two models will be used for optimization of the processing parameters. The flowchart of the proposed research is presented in Fig. 1. The proposed research will be done by an interdisciplinary team representing three universities from the state of New Mexico: New Mexico State University (NMSU), University of New Mexico (UNM) and New Mexico Institute of Mining and Technology (NMT). The team includes specialists in nondestructive testing and in-situ sensing, materials characterization, control and optimization, and micromechanical modeling.

The proposed research has four technical and three non-technical objectives:
Technical objectives
1. Develop and use in-situ sensing modalities for real-time process monitoring.
2. Determine the statistical correlations between microstructural defects, such as pores and microcracks, and processing parameters.

3. Develop a micromechanical model linking processing parameters with the overall properties of 3D-printed specimens.
4. Develop a real-time control system to modify and optimize the process parameters to minimize the concentration of microstructural defects.

Non-technical objectives
1. Contribute to New Mexico aerospace engineering education and research programs; use these aerospace programs to engage New Mexico K-12 students in STEM disciplines.
2. Develop a statewide Research Center in Advanced Manufacturing and related areas such as verification and validation (V&V), modeling and simulation, damage prognosis and prevention. The Advanced Manufacturing research area and the aforementioned Research Center will be a primary focus for Workforce Development Programs.
3. Develop collaborations with aerospace industry and relevant NASA Centers, enhancing prospects for future nationally competitive research (see supporting letters).

LA-20-EPSCoR-Research-0016

Satellite-Assisted Forecasting Environment for Improving Oyster Safety (SAFE Oyster)

Louisiana State University

Director/PI: Dr. T. Gregory Guzik

Science PI: Dr. Zhiqiang Deng

NASA MD: SMD

The purpose of this project is to develop and demonstrate innovative technologies to automatically transfer, sustainably use, and interactively visualize NASA satellite remote sensing products for intelligently forecasting oyster safety risks, protecting public health, and promoting economic (particularly oyster industry) development in Louisiana and beyond.

Remote sensing is the only technology that can be used today to monitor large remote areas like oyster harvesting waters. A key barrier to the adoption and sustained use of remote sensing products in oyster safety monitoring and decision-making is the lack of experienced users and/or integrated systems that could work automatically. To overcome this barrier, the overall goal of this project is to investigate and develop products, which will advance the utility of NASA satellite remote sensing assets in improving oyster safety and protecting public health to achieve a paradigm shift in oyster safety management from the current post-outbreak response to a satellite-assisted forecasting model. This effort is directly related to the NASA Science Mission Directorate Earth System Division to understand the response of the Earth system to disasters as well as to further the use of Earth system science research to inform decisions and provide benefits to society. Further, this project will make a significant contribution to the economic development of Louisiana by reducing costly oyster ground closures and oyster recalls and thereby increasing oyster production.

To achieve the project goal, the following research objectives will be addressed: (1) Convert NASA satellite remote sensing images to parameters indicating the environmental health of oyster harvesting waters; (2) Create models incorporating the remote sensing parameters to forecast the oyster safety risk level; and (3) Develop tools for automating the conversion, transfer, and sustained use of NASA satellite remote sensing data for assessing oyster safety and public health risk. These objectives motivate the development of a Satellite-Assisted Forecasting Environment, called SAFE Oyster (an automated decision support system), for monitoring environmental indicators of potential oyster safety threats, informing decisions on oyster safety and public health, and enabling the automated transfer and sustained use of NASAs archive of Earth observations.

Development and validation of individual components of the SAFE Oyster system constitutes the specific tasks of this project: Task 1: Satellite-Assisted Monitoring of Environmental Predictors for Oyster Safety; Task 2: Forecasting of Oyster Norovirus Outbreak Risk; Task 3: Forecasting of Vibrio Prevalence Risk; Task 4: Field Sampling and Laboratory Analysis for Validation of Model Forecasts; Task 5: Quantitative Risk Assessment of Norovirus and Vibrio Threshold Infectivity Limits; Task 6: Development of Web-Enabled GIS Interface for SAFE Oyster System; Task 7: Development of Cyberinfrastructure and Mobile App for SAFE Oyster System.

This project will be undertaken by an interdisciplinary team of researchers from Louisiana State University, Louisiana Tech University, Louisiana State University Health Science Center, and Southern University. The project will focus on Louisiana oyster harvesting areas along the U.S. Gulf of Mexico coast and synergistically combine AI-based modeling tools, geospatial mapping technologies, epidemiological investigations, field sampling and laboratory analyses, and NASA satellite remote sensing products within a cyberinfrastructure framework.

KS-20-EPSCoR-Research-0017

Artificial Intelligence Assisted Spacecraft Trajectory Optimization and Planning

Wichita State University

Director/PI: Dr. Leonard Miller

Science PI: Dr. Atri Dutta

NASA MD: STMD

Alignment with NASA: The proposed research efforts align with the objectives of NASA Space Technology Mission Directorate (STMD). Specifically, the proposal aims to develop collaborations with the Mission Architecture and Analysis Branch of NASA Glenn Research Center, and with the Outer Planet Mission Analysis group of Jet Propulsion Laboratory.
Proposal Area: Astrodynamics, low-thrust trajectory optimization, machine learning, intelligent control

Motivation: Spacecraft trajectory optimization is a critical aspect of space mission analysis. In recent years, there has been an increased interest within NASA in applying machine-learning algorithms to improve the performance of trajectory optimization solvers. Optimization of trajectories for spacecraft employing solar-electric propulsion is a challenging problem because it requires the solution of a nonlinear, non-convex mathematical programming problem. This problem is even more complicated when the spacecraft is located close to a planetary body. First, the low-thrust propulsion system provides a small acceleration relative to the local gravitational acceleration, making the transfer long and complex. Second, the presence of the planets shadow prohibits thrust generation by electric thrusters, thereby making the transfer multi-phase. Third, gravitationally trapped radiation degrades the spacecraft solar array that powers the electric thrusters.

Proposal: The proposed research considers the development of a new, machine-learning assisted optimization tool for on-ground mission design. The automated, fast and robust nature of the proposed methodology makes the tool suitable for onboard implementation as well. The architecture of the proposed software allows for sequential progression of fidelity by incorporating increasingly rigorous force models at different levels of trajectory optimization; this facilitates the improvement of lower-fidelity solutions, while simultaneously managing the computational complexity of the underlying problem in an automated manner. Proposed modular architecture allows for application of the proposed software in two different settings, such as preliminary mission analysis by ground personnel and onboard mission planning. The overall trajectory design is modelled as a two-level process, with the low-level trajectory optimization phase, and a high-level planning that allows for the application of machine learning techniques to trajectory optimization.

The proposal considers the following innovations: using dynamical coordinates in trajectory optimization, a modified state observer to estimate unmodeled acceleration, and the use of an artificial neural network for adaptive tuning of planning variables. Additionally, in the context of onboard implementation, we consider data driven updates of the neural networks based on information obtained for sensors. The proposed project will also consider the addition of atmospheric drag models for analysis of aero-capture and atmospheric entry.

Team: The team has the following expertise required for the research. Sc-I Atri Dutta has expertise in astrodynamics and spacecraft trajectory optimization, Co-I/Institutional PI Arslan Munir (Computer Science, Kansas State University) has expertise in artificial intelligence and dynamic data driven applications, Co-I James Steck (Aerospace Engineering, WSU) has expertise in intelligent control systems, and Co-I/Institutional PI Craig McLaughlin (Aerospace Engineering, University of Kansas) has expertise in orbit determination and atmospheric drag models. The proposed research efforts will be complemented by educational efforts that focus on student training, engaging K-12 students in astronautics, and dissemination through public outreach events.

WV-20-EPSCoR-Research-0020

3D Printable Soft Actuators with embedded Smart Sensors for Extraterrestrial Applications

West Virginia University

Director/PI: Dr. Majid Jaridi

Science PI: Dr. Konstantinos Sierros

NASA MD: STMD, SMD

In this work we are proposing to set a novel paradigm for the design and manufacturing of smart soft robotic actuators for space applications. Space is an unknown and challenging environment that represents hard constrained design and manufacturing challenges. Current efforts to address them are based on preset mechanical compliance and biomimetic designs which are not highly effective for addressing open-ended design and manufacturing questions in space.

Instead, we propose to remove such hard design constraints and manufacturing challenges by focusing on smart building blocks. We introduce PneuHinge (pneumatically activated hinge); a space-compatible silicone building block that exhibits pre-programmed stiffness and embedded tactile and temperature sensing capabilities. We are using tessellations (e.g. Origami) as versatile design platforms to achieve various soft actuator designs/geometries that are able to perform various actions when pneumatically actuated. The PneuHinge blocks are seamlessly assembled, to match the respective tessellation, using a novel additive manufacturing method based on microreactor enabled direct ink writing (multimaterial and single nozzle) that we will develop in this work. The advantages of our manufacturing approach, compared to traditional soft robot manufacturing (i.e. casting), include design freedom, no tooling, and more importantly the ability to tune the stiffness of the silicone matrix using particulate phases produced on the fly as well as embedding sensing capabilities in one step.

We have four main aims for this project:
(i) Formulation and characterization of space-compatible silicones for 3D printing.
(ii) Printing and characterization of embedded sensors.
(iii) Development of microreactor-enabled single nozzle multimaterial printer.
(iv) Demonstration of a PneuHinge-enabled soft smart robotic tool.

At the end of the project we expect to demonstrate a PneuHinge enabled soft smart tool that will be based on the Yoshimura origami pattern and will be able to perform gripping, grasping, and grappling actions while exhibiting tactile and temperature sensing capabilities. In addition, we will be demonstrating a prototype microreactor-enabled direct ink writing system (3D printer) that is multimaterial, single nozzle, and produces nano/micromaterials on demand.

Finally, we are a very competitive research and development team from West Virginia University, Oregon State University, NASA Langley Research Center, and NASA Marshall Space Flight Center. This team of experts will work closely and in a highly collaborative fashion and will interact at every stage of the project to ensure successful completion.

IA-20-EPSCoR-Research-0021

Research Capacity Building Program In Iowa: Developing New High Energy Density Extremely Safe All Solid State Lithium-Sulfur Batteries

Iowa State University, Ames

Director/PI: Mr. Tomas Gonzalez-Torres

Science PI: Dr. Steve W. Martin

NASA MD: STMD

Key Central Objectives: The Sc-I, Dr. Steve W. Martin, proposes to use NASA EPSCoR funding to develop a sustainable research program in the State of Iowa that will conduct new research on developing new All Solid State Lithium-Sulfur Battery (ASSLSB) materials, chemistries, and architectures that will help NASA meet critical battery requirements in manned and unmanned space exploration missions. This sustainable research program will build upon the research strengths at ISU in developing new materials for Lithium Batteries (LBs). To build research capacity at ISU, we propose a program to address the problem most urgent to NASA in meeting the high-power densities required for mission goals. This will be achieved by enabling high-energy-density sulfur cathode materials in combination with lithium metal (LM) anodes, separated by a high Li+ ion conductivity and electrochemically and thermally stable glassy solid electrolyte (GSE). This proposal aligns with the Space Technology Mission Directorate, focused in Battery and Materials science.

Concise Statement of Methods: Specifically, we will develop entirely new mixed oxy-sulfide-nitride (MOSN) GSEs that Sc-I Martin has shown optimally combine the low cost and chemical, thermal, and mechanical stability of oxide GSEs; the high Li+ ion conductivity of sulfide GSEs; and the high electrochemical stability of nitride GSEs. We propose to use these MOSN GSEs to create new high-energy-density LM anode and sulfur cathode ASSLSBs that will exceed NASAs requirements by achieving expected energy and power densities (cell level) of 900 Wh/kg, 800 Wh/l, and 5 kW/m3, respectively. The proposed research has four objectives: (1) to form the first ever thin-film (microns) mixed glass former (MGF) MOSN GSEs; (2) to create a new Li2S-based nanocomposite cathode (LSNCC); (3) to form a new Ni/Cu nanowire current collectors (NCNWCC) for a LM anode; and (4) to assemble and test cells made from the GSE, LSNCC, and the NCNWCC/LM anode.

In objective 1, we will optimize the MGF MOSN GSEs for improved battery performance, stability in contact with LM and high, > 0.1 mS/cm at 25 C, Li+ ion conductivity and strong resistance to crystallization. These optimized MGF MOSN GSEs will then be melted and cast into 30 cm long x 5 cm wide x 0.5 microns thick preforms from which thin, 20-50 microns, and long, 5m, ribbons will be drawn.

In objective 2, we will use electrochemical deposition techniques to develop NCNWCCs that are optimized to plate and strip planar LM without forming dendrites and at an aereal capacity of >10 mAh/cm^2.

In objective 3, we will use nano-precipitation techniques to prepare LCNCCs that in conjunction with our MGF MOSN GSEs are optimized to completely solve the polysulfide shuttle problem and enable Li2S to be used as both a source of Li so that the cells can be safely assembled at low cost and as a high capacity sulfur cathode material. In objective 4, we will assemble symmetric, asymmetric, and full cells of ASSLSBs to evaluate and then optimize the performance of the ASSLSBs to meet and exceed the aggressive NASA requirements for energy density, power density, cycle life and safety.

Statement of Perceived Significance: The success of planned and future NASA missions critically depends upon the use of portable energy sources, such as batteries. As the goals of these missions increase in complexity and duration, so do the demands for greater battery energy and power densities. This project will develop new ASSLSBs that will meet and exceed NASA mission requirements. The proposed ASSLSBs will create a new paradigm of performance and safety that will not only be mission enabling for specific planned Venus and Mars missions for extravehicular activities and rovers, they will also foster new battery systems that will significantly enhance the performance of LBs for nearly all terrestrial portable energy needs and applications.

DE-20-EPSCoR-Research-0024

NASA EPSCoR Research Project: Building a Competitive and Sustainable Delaware Remote Sensing Big Data Center for Cutting-Edge Coastal and Environmental Change Research and Workforce Development

University of Delaware

Director/PI: Dr. William Matthaeus

Science PI: Dr. Cathy Wu

NASA MD: STMD

Environmental change and coastal sea level rise pose new challenges. Large-scale variability (global environmental change) and mesoscale processes (such as regional sea level rise and eddies close to the continental shelf) influence coastal ecosystems and adversely affect water supply and quality, with consequences for coastal communities and population across Delaware. To address these issues requires state-of-the-art information of how the coastal ocean responds to large- and mesoscale variability. Remote sensing is one of the most powerful tools for improving understanding of the coastal ocean and land-aquatic interface. Meanwhile, advanced computational methods and data infrastructure are essential to identify patterns, detect trends, and derive actionable knowledge from the complex and massive remote sensing data.

Delaware is the most instrumented State in the U.S. for collecting weather, climate and ocean remote sensing data. Delaware's size and connectivity make it an ideal laboratory as a national model for remote sensing big data center for cutting-edge coastal and environmental change research. We have conducted multiple exploratory studies that demonstrate the importance of remote sensing data for understanding environmental variations. The University of Delaware (UD) is developing the next-generation computational and data science cyberinfrastructure through the Data Science Institute, including a new NSF MRI grant to implement an advanced high-performance computing and data system for transformative research and training. This project will leverage UDs expertise and infrastructure to develop the Delaware Remote Sensing Big Data Center and support research initiatives that will address critical environmental issues, bringing broad social, educational and economic benefits to Delaware and the Nation.

General Goals: (1) align with NASA EPSCoR goals to build competitive and sustainable remote sensing big data infrastructure for climate and environmental research, (2) enhance the competitive research and technology for aerospace related Ocean/Earth sciences, (3) address State needs, (4) foster interdisciplinary research, inspiring and training postdocs, graduate and undergraduate students for the future workforce, and (5) promote research excellence with partnerships between university and NASA scientists, government agencies, the private sector, and small businesses.

Specific Objectives: (1) develop real-time remote sensing big data center for environmental change research and for aquatic-terrestrial environments across the coast of Delaware, (2) carry out advanced research in: (a) coastal ocean and sea level response to environmental change, (b) remote sensing of hydrological, coastal resources, wetlands and land resources including coastal carbon (terrestrial-aquatic) and soil moisture, and (3) further develop machine learning/deep learning analyses, data fusion, semantic computing, image modeling and visual analytics through remote sensing research results and knowledge visualization.

Merits and Impacts: The project will promote multidisciplinary research collaborations and data-driven discoveries on environmental changes, allowing scientists to measure effects of environmental change and the pulse of ecosystems in Delaware, diagnose problems, and prescribe the courses of action. To positively impact policy making, we will convert the large amounts of technical data into useful visual information for the public and decision-makers. In addition to infrastructure and research, this project will contribute to STEM workforce development by training new scientists: supporting and inspiring postdoctoral scientists and graduate and undergraduate students, and sparking their interest in NASA related research. We expect that this project will enhance the security and environmental quality of Delaware, making the State more attractive to residents, businesses and tourists, and ultimately improving the State economy.

NV-20-EPSCoR-Research-0026

Self-Adaptive Lubricants for Extreme Space Mechanism Applications

Desert Research Institute

Director/PI: Dr. Lynn Fenstermaker

Science PI: Dr. Pradeep Menezes

NASA MD: STMD, SMD

The research goal is to develop self-adaptive lubricant coatings for moving mechanical assemblies (MMAs), such as bearings, bushings, and gears, operating in extreme conditions. The successful operation of MMAs critically depends on adequate lubrication. Improper lubrication can lead to MMAs and overall mission failure. From Moon to Mars, surface conditions have wide temperature and atmospheric ranges. For example, the Moon has a very thin and tenuous atmosphere, where temperature varies from -232°C to 122°C. On Mars, the temperature can vary from -140°C to 30°C with high pressure up to 610 Pa, a carbon dioxide environment and a minor amount of water. Both Lunar and Martian atmospheres are harsh and dusty. Extended bearing life and lubrication systems in mechanical systems technology are desirable for long-duration Moon and Mars missions.

The proposed research will support NASA missions by developing a self-adaptive solid lubricant coating that can provide adequate lubrication in both cryogenic and extreme environments. We hypothesize that taking advantage of preferential phase transformations that self-adaptive capability with improved performance for lubrication in the ceramic matrix can be achieved. It is expected that by controlling phase transformations by engineering the crystal chemistry and composition, we can engineer the lubrication performance of ceramic coatings over a wide temperature range. To address the various technical challenges associated with the development of the self-adaptive lubricating system, we have two research thrusts: A) Technology and Experimental Validation; and B) Modeling and Analytics. We also organized Bridge to Graduate School (Thrust C) to develop the workforce and increase student intake and retention in engineering for mission success.

Through these thrusts, we will develop an experimentally validated approach as a viable lubrication technology to enable long-life MMAs, and will train students to become sophisticated, educated workers in aerospace, defense, and materials and manufacturing. This proposal will address the key factors for developing self-adaptive lubrication technology to support NASAs short-, mid-, and long-term missions to the Moon and Mars, thus aligning with NASA and Nevada's strategic plans. To do this, we will pursue the following objectives. (1) Via experiments, develop a self-lubricating composite coating, characterize its microstructure and friction and wear behavior, and test its feasibility for space applications. (2) Via detailed computational modeling, predict the phase formation, and characteristics of phases in terms of crystal structure needed to provide lubrication. Develop modeling and data analysis tools to determine the specific metal dopant that provides easy shearing (layer structure). We will do this using information about the effective cohesive enthalpy of the respective oxides and the structure. (3) Develop a demonstration and educational module about the importance and challenges of materials, design, and manufacturing in NASAs mission to create a skilled workforce.

After materials evaluation in a laboratory setting, testing of the coating will be conducted in NASA Glenns Extreme Environments Chamber. The anticipated outcome is that after reliable correlations between phase formation in given operating conditions and lubrication performance of the composite coating are established, a new multifunctional, self-adapting lubricating system can be developed for extreme MMA applications. Stakeholder industries have agreed to evaluate the self-lubricating composite technology for commercialization potential.

ID-20-EPSCoR-Research-0027

CryoIdaho: Building Idaho's Cryosphere Research Community through Analysis of Terrain Effects on Snow and Ice Meltwater Fluxes

University of Idaho, Moscow

Director/PI: Dr. Matthew Bernards

Science PI: Dr. Ellyn Enderlin

NASA MD: SMD

The seasonal accumulation of snow and melting of snow and ice exert important controls on the hydrology of mountain regions and glacier mass balance. Projections of snow and ice meltwater fluxes in a changing climate require both accurate estimates of snow and ice meltwater fluxes as well as process-based understanding of controls on snow accumulation and snow and ice melt. Snow accumulation and melt vary over a variety of length scales due to variations in terrain (topography, vegetation, roughness, etc.). Large-scale terrain effects can be approximated using empirical parameterizations, but the processes controlling smaller-scale variations in snow accumulation and melt and the influence of these variations on basin-scale meltwater fluxes remain poorly understood. For glacierized regions, our ability to predict meltwater fluxes is further complicated by the complex interplay between surface melting, glacier hydrology, and glacier sliding that can enhance or mitigate glacier mass loss. As such, improved understanding of snow accumulation and melt will advance our understanding of glaciers, and will improve streamflow forecasts for agriculture, flood, and hydropower.

This collaborative project addresses the pressing scientific need reduce uncertainties in estimates of snow and ice meltwater fluxes through interdisciplinary research on snow and ice at Boise State University and the University of Idaho. The project leverages existing observational networks, including NASA SnowEx and USGS Benchmark Glacier programs, extends in situ and remotely sensed observations, and incorporates models to explore interactions between snow and underlying terrain. Importantly, the project will seek out process-based understanding of 1) micro-topographic effects on snow accumulation and melt and 2) feedbacks between glacier melt, hydrology, and sliding. The project will also test the performance of empirical and numerical models for mapping seasonal snow and will develop a workflow to optimize in situ observations needed to validate satellite- and model-derived meltwater flux estimates. The project will develop methodologies to use NASA ICESat-2 observations to map seasonal snow in mountain regions spanning a range of terrain characteristics and constrain uncertainties in the data, quantify biases and uncertainties in NASA ITS_LIVE glacier velocities, and reduce uncertainties in snow and glacier meltwater flux estimates. Thus, the success of this project will result in more accurate and low-cost quantification of seasonal snow and glacier meltwater fluxes using a novel NASA dataset and inform future NASA spaceborne missions with snow and ice applications.

This project will bring together Idaho scientists with expertise in snow and ice geophysics, remote sensing, hydrology, and atmospheric modeling to work across disciplinary boundaries to better directly address the NASA 2017 Earth Science Mission decadal surveys priority to [q]uantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variabilityin order to better predict snow and ice meltwater changes in mountain regions. The project will involve several federal collaborators, including NASA ICESat-2 Project Scientist Dr. Tom Neumann and Dr. Shad O'Neal at USGS Anchorage.

Through this project, we will strengthen Idaho's capacity and reputation for cryospheric research and equip a number of graduate and undergraduate students with a diverse array of expertise that will make them well equipped to enter the STEM workforce. Students will gain valuable experience in interdisciplinary scientific research, science communication, and education, making them well prepared to enter the STEM workforce. The public will be engaged in the research through citizen science performed at the McCall Outdoor Science School and through the Winter Wildland Alliance Snow School, introducing K-12 students to snow science and winter ecology.