2015 NASA EPSCoR Research CAN Proposal Abstracts

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MO - 15-EPSCoR2015-0003

Learning Algorithms for Preserving Safe Flight Envelope under Adverse Aircraft Conditions

Government and industry agree on the potential of learning algorithms in providing flight safety in the presence of adverse conditions (resulting from, e.g., degraded modes of operation, loss of control, and imperfect aircraft modeling) and reducing aircraft development costs. A major roadblock to their widespread adoption is the lack of a-priori, user-defined performance guarantees to preserve a given safe flight envelope in general and commercial aviation. Current practice relies heavily on excessive flight testing as a means of performing verification and/or development of the tools to validate existing learning algorithms. Besides the cost, the major drawback of excessive flight testing is that it only provides limited performance guarantees for what was tested; the fixed set of initial conditions, pilot commands, and failure profiles.

The drawback of current tools to validate existing learning algorithms is that such tools can only provide guarantees if there exists a-priori and complete structural and behavioral knowledge regarding any and all anomalies that might occur. The proposed research will address this fundamental gap in the utilization of learning algorithms for aerospace applications by:

(1) establishing a new theoretical framework along with necessary and sufficient conditions for guaranteed flight control safety and resilience in the presence of aircraft adverse conditions. Learning algorithms developed using this framework will keep the aircraft trajectories within this a-priori determined envelope (set) in the presence of anomalies. Analytical expressions for robustness margins of the proposed algorithms will also be developed.

(2) Methods will be developed to use these algorithms effectively in the pilot decision support display of NASA Ames that indicates the proximity of the aircraft to safe flight boundaries caused by adverse conditions. As a complementary effort to flight control, a set theoretic learning approach will be utilized in estimation theory to support of pilot decision-making via providing real-time aircraft flight health and prediction.

(3) The proposed algorithms will be demonstrated in flight tests using CJ-144 fly-by-wire Bonanza aircraft. This research direction will allow the investigators to revisit the proposed theoretical approaches and relax assumptions, if necessary. The novel feature of this research is that the proposed algorithms will have the capability to preserve a given, user-defined safe flight envelope through formal analytical synthesis at the pre-design stage, instead of excessive flight testing during the post-design stage.

The proposed research will:
(1) impact a broad range of applications utilizing learning algorithms that involve but are not limited to safe and effective aircraft control, crew decision-making in complex situations, and CEV/CLV vehicle control,

(2) make the general and commercial aviation community aware of the safety benefits of advanced adaptive flight control and estimation methods,

(3) disseminate NASA and DoD research into the aviation community,

(4) establish a new partnership between flight controls research at MST and WSU,

(5) increase the ability of researchers and industries in the states of MO and KS to successfully compete for research funding,

(6) give the MO and KS aviation industry a global leading role in using intelligent aviation technologies on civil aviation aircraft, and

(7) contribute to the advanced workforce by educating students in advanced flight controls and pilot warning systems.

The research outcomes, which include advancement of the theory on verifiable learning algorithms for flight control and pilot awareness systems, simulations at multiple levels of granularity, data collected from ground and flight testing, publications in highly regarded journals and conferences, online seminars, an invited session, and a workshop, will significantly contribute to the current and future NASA research and technology priorities.
David Riggins, Missouri University of Science & Technology

ARMD
ARC
Aeronautics
Wing morphing
UAS

KS - 15-EPSCoR2015-0024

Active Wing Shaping Control for Morphing Aircraft

The objective of this proposal is the design, development and testing of certifiable control laws for active wing shaping of the VCCTEF (Variable Camber Continuous Trailing Edge Flap) aircraft. This aircraft has been conceptualized by NASA and is a high priority for the NASA ARMD Fixed Wing Project. Design of control laws for this aircraft is still very much an open topic since the use of active wing shaping control, in addition to traditional flight path control, is required in order to achieve the enhanced performance (in terms of higher lift-to-drag ratio) that the VCCTEF is capable of generating.

The wing shaping control increases the complexity of the flight control laws as it must make use of active sensing and feedback of wing shape to continuously modulate the camber across multiple sections of the wings so as to ensure that the local angle of attack distribution over the wing is optimal for every flight condition.

The research tasks outlined in this proposal are:
(1) Development of certifiable adaptive decentralized control laws for active wing shaping,
(2) Optimal number and placement of sensors on the wing to measure the wing shape,
(3) Distributed sensing system for real-time wing shape monitoring and feedback of the wing shape to the control laws, and
(4) Development of a testbed morphing UAV for testing the wing shaping control laws in the wind tunnel and in flight.

Morphing and the use of low-weight elastic aircraft is an enabling technology that has the potential to lead to reduced aircraft drag and thus significant reduction in aircraft fuel consumption. This has a direct societal benefit since it leads to potentially cheaper and more affordable air transportation, and has a positive impact on the environment.

In addition to this, the broader impacts of the proposed research include:
(1) Making the general aviation community aware of the performance benefits of morphing aircraft,
(2) Disseminating NASA morphing aircraft research into the general aviation community,
(3) Giving the KS and MO aviation industry a global leading role in using morphing control technology on civil aviation aircraft, and
(4) Contributing to the development of a technologically advanced workforce by educating KS and MO students in advanced nonlinear robust flight control systems and morphing aircraft.
Leonard Miller, Wichita State University

HEOMD
KSC
Analog Research Station
Planetary Research

ND - 15-EPSCoR2015-0012

Multi-Purpose Research Station in North Dakota in Support of NASA´s Future Human Missions to Mars

The University of North Dakota (UND) Human Spaceflight Laboratory is proposing the development of a Multi-Purpose Research Station in North Dakota designed to expand NASA-relevant research opportunities for students and faculty within the state, as well as project collaborators.

The research to be conducted will be a collaborative effort, including a number of departments across UND campus, colleges and universities from across the state, and multiple NASA centers. This research station will include geological studies, extra-vehicular activity (EVA) research and operations, plant production studies, and human factors research (both physiological and psychological studies).

For effective NASA-relevant analog studies, the location of the research station is key to the success and effectiveness of the research conducted. North Dakota offers a unique environment for this type of research; there is no NASA center or related industry in the area, the climate offers extremes ideal for testing performance of equipment to be used in similar conditions on other planetary surfaces, and isolated yet accessible locations are plentiful in the area.

The combination of these factors makes North Dakota an optimal location for these simulation studies, of which there is a significant need to NASA in furthering human space exploration.
The end goal of this permanent experimental station will be to make significant strides in better preparing the nation for future human planetary exploration.

Santhosh Seelan, University Of North Dakota, Grand Forks

HEOMD
MSFC
Space Radiation
Modelling & Simulation
Life Science

MS - 15-EPSCoR2015-0013

GEANT4 Simulations for Astronaut Risk Calculations

Objectives:
The key objective of the proposed work is to develop a novel approach for REID (Radiation Exposure Induced Death) risk assessment using GEANT4, a radiation transport code developed at CERN (European Organization for Nuclear Research).

Methods/Techniques:
The proposed research involves two tasks that will accomplish the stated research objectives. The first task will establish an expert GEANT4 user group in collaboration with NASA MSFC and compare the results from GEANT4 with results from HZETRAN (a 1-D deterministic transport code current used for REID calculations at NASA LaRC). We will study the effects of uncertainties in the Quality Factor, Low LET Risk model and uncertainty in nuclear cross sections for galactic cosmic rays and solar particles. This first task will evaluate GEANT4's promise in REID calculations and apply the considerable capabilities of GEANT4 directly to current NASA needs in statistical evaluations related to mortality data. The second task of the project is to extend the REID focus to include the health effects of the radiation flux on the DNA of the astronauts. The GEANT4 community is actively involved in the development of databases related to radiation-induced DNA effects [1]. Although the physics related to the initial space radiation and the secondary particles it generates typically involves high-energy interactions, low energy interactions are critical in when considering effects on biomolecules.

Significance:
This project is directly applicable to research priorities defined by the Human Exploration and Operations Mission Directorate. As noted in NASA's Human Research Program Integrated Research Plan [2], radiation health effects and radiation protection for astronauts are among the most important issues encountered in deep space missions. The assessment of health risk can ultimately dictate the design and composition of the spacecraft.[3] NASA's current method utilizes HZETRAN, which has virtue in that it is deterministic and computing time is much faster compared to Monte Carlo codes, but the compromise is that several assumptions must be made including the "straight ahead approximation"?, which essentially makes the code 1-dimensional. Incorporation of GEANT4 into REID assessment will advance the state-of-the-art with its extremely effective Monte Carlo framework, 3-D modeling capability, radiation transport, and many atomic and nuclear databases. Finally, perhaps the most exciting outcome of the proposed research would be the bridging of the two tasks described above. Namely, success in both tasks will allow for evaluation of correlations between the REID calculations (GEANT4 or HZETRAN) and the DNA effects predicted by GEANT4 simulations. Connection between the macroscopic statistics and microscopic DNA impacts could yield fundamentally new insights into radiation-induced DNA damage.

References:
[1] Z. Francis, S. Incerti, M. Karamitros, H.N. Tran, C. Villagrasa, Stopping power and ranges of electrons, protons and alpha particles in liquid water using the Geant4-DNA package, Nucl. Inst. Meth. Phys. Res. B 269 (2011) 2307"“2311.

[2] Human Research Program Integrated Research Plan, HRP-47065, July 2014, Revision F, http://humanresearchroadmap.nasa.gov/Documents/IRP_Rev_F.pdf.
[3] B. G. Drake (ed.), Mars Architecture Steering Group, Human Exploration of Mars Design Reference Architecture 5.0, NASA/SP"“2009"“566, July 2009.
Nathan Murray, The University of Mississippi

HEOMD
ISS
JSC
Life Sciences
Biology
Crystal growth
Microgravity

NE - 15-EPSCoR2015-0015

Large Volume Crystal Growth of Superoxide Dismutase Complexes in Microgravity for Neutron Diffraction Studies

Superoxide dismutases (SODs) are important antioxidant enzymes that protect all living cells against toxic oxygen metabolites, also known as Reactive Oxygen Species (ROS). SODs are one of the fastest known enzymes and are rate-limited only by the diffusion of the substrate and products. SODs are the first line of defense to protect organisms against metabolic- and ionizing radiation-induced ROS. SOD protects cells by dismuting two molecules of superoxide anions to form hydrogen peroxide and molecular oxygen via a cyclic oxidation-reduction reaction. SODs contain metal ions in their active sites. Humans have Cu/ZnSOD in the cytosol and extracellular spaces and MnSOD in their mitochondria. Mutations in SOD lead to degenerative diseases such as amyotrophic lateral sclerosis (ALS), diabetes, and cancer.

This proposal will study SODs from the model system Escherichia coli as they are easy to produce, stable, and the active sites are identical with human homologs. Bacteria have both Fe and MnSOD. Despite the biological and medical importance of SOD, the enzymatic mechanism is still unknown. Precise structural data are needed to understand the enzymatic mechanism of SOD. The binding sites of the diatomic substrate and product as well as the source of the protons in the reaction have been studied but their exact identification has not been possible.

This detailed information can only be determined by neutron diffraction. Complexes of the Fe and MnSOD including structural intermediates and mutants will be the targets for large volume crystal (1 mm cubed) growth for structure determination by Neutron Macromolecular Crystallography (NMC). The quiescent environment afforded by microgravity is known to grow crystals large enough for neutron studies and in 2001, the Borgstahl laboratory successfully grew large crystals of SOD using microgravity conditions on the International Space Station (ISS).

With NASA's renewed interest in implementing the microgravity environment on the ISS for protein crystal growth we would like to move forward with these exciting early microgravity crystallization results for SOD. Existing crystallization facilities, such as the Granada Box Facility (GBF) that employs capillary counterdiffusion protocols or the Protein Crystallization Facility (PCF) that uses vapor diffusion methods will be used to achieve these goals.

A microgravity environment is essential to form a stable supersaturation gradient to obtain the large crystals required for NMC. NMC will be performed with collaborators at Oak Ridge National Laboratory. The principal outcome will be to identify the role of hydrogen atoms in enzymatic activity, discern superoxide from peroxide and water from hydroxide ion by their protonation state and decipher a structure-based mechanism for Mn and FeSODs more precisely than from previous X-ray crystallographic models determined from Earth-grown crystals.

These contributions will provide criteria needed for protein engineering desirable properties into enzymatic metal centers.

Scott Tarry, University of Nebraska at Omaha

HEOMD
ISS
GRC
Life Science
Space Radiation
Cellular processes

AK - 15-EPSCoR2015-0018

A Vertical Comet Assay for Measuring DNA Damage to Radiation

Space radiation detrimentally affects biological systems and individual organisms. Earth's magnetic field provides protection to terrestrial inhabitants. However, space missions beyond the low Earth orbit poses increased risk to the health of humans because of radiation in space. Both components of space radiation, chronic exposure to low-dose to galactic cosmic rays and random short-term exposures to the energetic particles from the Sun, might increase risk of malignant transformation.

Damage to the genetic material of cells, its DNA, is considered to be the first and most important step in the malignant transformation of normal cell into cancerous one. As this concern is addressed in NASA's 2012 roadmap in the domain of Human Health, Life Support and Habitation Systems (HLHS), however, currently we do not have reliable techniques to measure DNA damage on a board of spacecraft. A reliable and sensitive technique to collect data at ground and in flight for radiation risk assessment is in demand by NASA.

When exposed to radiation, single and double strand-breaks in cellular DNA are produced. The amount of strand-breaks can therefore be correlated to the extent of damage to cells under radiation. One of the most convenient models to study DNA damage and repair process in the live cells is the comet assay, or single cell gel electrophoresis technique. This technique is currently configured to conduct a measurement on live cells under laboratory set-ups.

Therefore, quite often the existing comet assay is not suitable for "in field"� applications. Development of a simple and sensitive technique would allow researchers to study crucial cellular processes outside of laboratory boundaries and open possibilities for evaluating many environmental exposures currently unobtainable, such as DNA damage during short space flight or long-term interplanetary explorations within the scope of NASA's missions.

In this project we are aimed at developing a new technique, we call it vertical comet or v-comet, to measure the level of DNA damage in live cells or fix-preserved cellular DNA samples. This new assay will be prototyped and tested using the microfluidics technique.
We will
(a) develop a microchamber containing live cells or preserved cellular DNA;
(b) use electrophoresis to sample damaged DNA by pulling broken strands into a circulating buffer in a closed-loop;
(c) electrophoresis is continuously applied while the buffer is circulating to accumulate the broken strands; and
(d) the amount of DNA will be measured by a sensitive fluorescent labeling. By taking the advantages of small scales of microchamber configuration, in this proposal we will design and test an integrated approach combining sensitivity of traditional comet-assay technique with the versatility and subtle precision of microfluidics technique.

We envision that this new technique will allow researchers to measure DNA damage in the field conditions, such as .to help astronauts avoid overexposure to space radiation, and construct a correlation between the doses of chronic space radiation and the extent of cumulative DNA damage.

This project explicitly addresses NASA missions within the area of space radiation, as evidenced by two letters of support from NASA: the Space Biosciences Branch at the NASA Ames Research Center, and the Radiation Biophysics Laboratory at Johnson Space Center. This project will enhance the research infrastructure by engaging faculty and students crossing the disciplines at the University of Alaska Fairbanks.

The project will be self-sustained by developing a few proposals to NSF and NIH during and after the project phase. The innovation of a v-comet assay is on either live cells or sampled cells in a conserved, dried platform to study DNA damage not bounded by the laboratory environment. Commercialization will be pursued for licensing and patenting the proposed technique.

Denise Thorsen, University of Alaska, Fairbanks

HEOMD
JSC
Photosynthesis
Photovoltaics
Quantum dots
Photon up/down conversion
Nanotechnology
Microbiology

OK - 15-EPSCoR2015-0026

Extracting the Photonic Spectrum for the Long Range Exploration of Space: A Hybrid Photovoltaic Photon Upconversion and Biological System for Energy Production and Life Support

The specific NASA Directorate with the most direct parallel with this proposal is Human Exploration and Operations. The proposed research would be a useful synergy between NASA's interests in biologically supported life support with other light harvesting projects interested in technologies such as photovoltaics, quantum dots (Power and Onboard Propulsion Technology, Glenn Research Center) and spectral conversion (Luminescence-Based Diagnostics of Thermal Barrier Coating Health and Performance, NASA Glenn and NASA Ames Research Centers).

Primary objectives of this proposal are:
a) Optimize the production of algae using the maximum possible wavelength spectrum. Cultures of microalgae and cyanobacteria will be grown using different electromagnetic wavelengths. Our preliminary results show that a 28% increase in algae biomass production can be achieved by using Gro-Lux lamps compared to the Cool White lamps. The basic premise of the proposed system is to increase biomass production by shifting wavelengths to those more useful to photosynthesis.
b) Integration of Spectral Up- and Down-conversion for Optimal Biomass Productivity. We will build upon existing research into photonic up/downconversion, here tuned specifically for the wavelength window needed for chlorophyll absorption.
c) Development of a PV system tuned for enhanced photovoltaic absorption in the range of 650-800 nm. We will build upon previous results in the construction of PV cells with colloidal quantum dots (CQDs) on ZnO thin film nanorods. Previous research at The University of Tulsa and The University of Oklahoma suggests these CQDs structures and ZnO nanostructures will result in tenfold increase in absorption of radiation within the desired wavelength range.
d) Broaden underrepresented student participation from undergraduate-serving institutions in space research. This project promotes the involvement of underrepresented groups, specifically Native American, in space research by cooperating with the Oklahoma Louis Stokes Alliance for Minority Participation (OK-LSAMP) program and Oklahoma Space Grant member Southeastern Oklahoma State University.

The ultimate goal of this proposal is to design, fabricate and test an autonomous, portable algae bioreactor for long-distance space travel, capable of biomass production from nanoparticles to convert the unused portions of the solar spectrum to wavelengths needed for algae photosynthesis.

To achieve these goals, we will bring together a diverse group of multidisciplinary, multi-university research teams with established collaborative experience in solving complex interdisciplinary science and engineering challenges and will provide the framework to be highly competitive for funding outside the NASA EPSCoR program.

Achieving the proposed work will also support the Oklahoma Space Grant Consortium in improving science, technology, engineering and mathematics education through building infrastructure in higher education and economic development in Oklahoma.

Victoria Snowden, University of Oklahoma, Norman

SMD
JPL
UAV
Remote Sensing
Volcanism

HI - 15-EPSCoR2015-0004

Developing a Capability at the University of Hawaii for Multiple UAV Observations of Active Volcanism

The goal of this NASA EPSCoR proposal is to enable University of Hawaii (UH) faculty and research staff to learn how to utilize unmanned aerial vehicles (UAVs) for science projects, with a specific focus on the analysis of the active Kilauea volcano. NASA has long studied the volcanoes in Hawaii using different remote sensing techniques and has used satellites, aircraft and, more recently, unmanned aerial vehicles such as the UAVSAR to study the active volcanism on the island.

In late 2013, Hawaii was selected to be part of (in addition to Alaska and Oregon) one of six national Federal Aviation Authority (FAA) UAV Test Sites. But the UH is poorly prepared to take advantage of this opportunity for new research, and through this project we hope that we will become more competitive with our future research proposals to be submitted to NASA.

The science objective for this proposal, to be mentored by Dr. Dave Pieri at the Jet Propulsion Laboratory, is to use multiple UAVs of the active lava flows and volcanic plumes at Kilauea volcano. Specifically, we want to investigate the connection between the thermal properties of active lava flows and the changes in flow topography on an hour-by-hour basis. We also want to estimate the gas flux from the volcanic plumes associated with these flows. To accomplish the science objectives we need to make simultaneous measurements from multiple UAV platforms.

We need to learn how to conduct UAV formation-flying because this would open up many new science research opportunities due to stereo-viewing. These concurrent measurements would be coordinated through the adaptation of the UH COSMOS small-satellite software to control UAVs. Through mentoring by Dr. Matt Fladeland (NASA Ames), we will learn the operational aspects of UAV research and how they relate to NASA's broader research objectives.

This project would enable our Team to:
(1) Purchase UAVs and optical/thermal instruments to conduct innovative geological research on the active Kilauea volcano, Hawaii;

(2) Develop UAV formation-flying capabilities using the UH-developed COSMOS software. This software has been developed under earlier NASA EPSCoR funding to control multiple small satellites (cubesats) in Earth orbit. The analogy between cubesats and UAVs is strong as they are both small data collection platforms, so that it is possible to adapt COSMOS to control UAVs in a coordinated way.

(3) Explore the certifications necessary to fly UAVs under the regulations imposed on NASA-funded projects, and educate UH faculty researchers so that they too can use UAVs as science platforms. We will inform these researchers of the FAA and State regulations controlling the flights.

(4) This knowledge transfer will be accomplished by holding two multi-day UAV Applications Workshops on the Big Island for UH faculty we will fund to attend from around the State (i.e., Kauai, Oahu and Maui).

Luke Flynn, University of Hawaii, Honolulu

SMD
ISS
GRC
Atmospheric Radiation
Climatology
Terrestrial Gamma Flashes

LA - 15-EPSCoR2015-0008

Investigating Terrestrial Gamma Flash Production from Energetic Particle Acceleration in Lightning using TETRA-II

Intense millisecond-scale fluxes of gamma rays associated with terrestrial lightning (Terrestrial Gamma Flashes TGFs) were discovered by NASA's Compton Gamma Ray Observatory and have been observed, as well, by detectors on the AGILE and Fermi spacecraft up to 100 MeV energies. These observations indicate that electrons are accelerated to very high energies by the electric fields in lightning, producing showers that radiate high fluxes of x-rays and gamma rays via bremsstrahlung and produce positrons via pair production.

The currents associated with these electromagnetic showers are a significant but not yet completely understood component of the electric structure of the thunderstorms. Lightning is a major concern for NASA, in part because of the potential damage due to strikes to space vehicles at launch and in protecting launch and assembly infrastructure. Lightning is also the main science target of NASA's space-based Lightning Imaging Sensor (LIS) aboard the EOS TRMM satellite and the upcoming LIS instrument scheduled to be launched to the International Space Station in 2016. Further, understanding the details of TGF production and its relationship to the energetic particle "lightning"� accelerator are a high priority science topic for the Fermi gamma ray observatory.

This aspect of the project is best aligned with NASA Strategic Goal 2 (Advance Understanding of Earth) and Objective 2.2 (Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet.) from the 2014 NASA Strategic Plan.

A first, albeit limited, catalog of TGFs observed at ground level has now been published by our Louisiana State University (LSU) group. Ground-based observations of nearby thunderstorms provide a new capability for associating the high energy emission with the detailed structure of the storm observed by local radar and correlating observations with Earth-orbiting gamma ray detectors.

TETRA-II (the TGF and Energetic Thunderstorm Rooftop Array II) is a new experiment, currently under construction in collaboration with the University of Puerto Rico “Bayamón” using seed support from the Louisiana Board of Regents and Louisiana Space Grant Consortium, involving expanded, higher resolution, detector arrays to be deployed in Puerto Rico and Jamaica where lightning activity is extremely high and where the prime orbiting TGF detector (the Gamma ray Burst Monitor on NASA's Fermi mission "“ GBM) also indicates that the rate of TGFs is high.

The goal of this proposal is to expand the project to include Climatology and Weather Aspects, involve Southern University and Xavier University (two HBCUs), and commission/ operate the new arrays as well as analyze the resulting data. The research involves measuring TGFs from the ground, complementing observations from the NASA Fermi mission, and analyzing/modeling the physical processes by high energy astrophysicists, climatologists, thunderstorm researchers, electrical engineers, and computer scientists. In addition to first-rate science, the project will build research infrastructure at three minority institutions in two EPSCoR jurisdictions and train underserved minority students. This aspect of the project is aligned with NASA 2014 Strategic Plan objectives 2.4 (Advance the Nation's STEM education and workforce pipeline) and 3.1 (Attract and advance a highly skilled, competent, and diverse workforce.)

The overall product from this proposed project will be new understanding of the formation and evolution of lightning-producing storms that can become a part of climate models and predictive systems.

T. Gregory Guzik, Louisiana Board of Regents

NM - 15-EPSCoR2015-0014

Virtual Telescope for X-ray Observations

This proposal requests funding to develop a space-based Virtual Telescope for X-ray observations. This system will consist of two 6U-CubeSats; one carrying a Phased Fresnel Lens and the second an X-ray sensitive camera. The two CubeSats will fly in precision formation to form a very long focal length (> 100 m) telescope: a Virtual Telescope. This is intended as a demonstration flight that will showcase the feasibility of the Virtual Telescope approach and raise the Technology Readiness Level to the point where the technique can be proposed for a much larger NASA mission.

This multidisciplinary project involves researchers from New Mexico State University and the University of New Mexico working in collaboration with researchers at NASA's Goddard Space Flight Center. The project addresses two Technology Areas from the NASA Space Technology Mission Directorate's Technology Roadmap: X-ray optics and multi-spacecraft formation flying, navigation, and control. The science enabled by this technology is closely tied to the Strategic Goals of NASA's Science Mission Directorate in the Heliophysics and Astrophysics Divisions.

This project aligns with two areas listed in A Science and Technology Roadmap for New Mexico's Future:
1) Challenge #4 Producing more technologists to satisfy projected workforce needs and
2) New Mexico's Major Technology Clusters - Aerospace. In addition, this proposal supports the workforce needs of LANL, Sandia, AFRL and the Spaceport America.

Goals and Objectives:
The program's overarching goals are to:
1. develop expertise and research capacity within New Mexico that increases the State's national competitiveness in the area of instrument development and astrophysics.
2. increase the number of faculty engaged in research partnerships NASA while growing research opportunities for students that prepare them for the workforce needs of NASA and the commercial space industry.

The specific goals that will be achieved through a close collaborative effort with GSFC are to:
1. develop the attitude control & determination and maneuvering technologies needed to precision fly two 6U CubeSats. Provide the 6U structure and bus for the CubeSats. This effort will culminate in a demonstration flight of the Virtual Telescope.
2. develop and characterize the X-ray optics (lens and camera) needed to image X-ray sources. For the demonstration flight, the observing targets include X-ray producing solar flares and bright, astrophysics X-ray sources such as the Crab Nebula.
3. understand and quantify the scientific gains enabled by the development of the Virtual Telescope technology and develop science goals for future, larger scale missions.
4. develop the spacecraft bus for both 6U CubeSat elements.

5. engage students in research experiences that will provide real world applications of their STEM skills while encouraging degree completion and degree advancement (Masters and PhD's).

Patricia Hynes, New Mexico State University

SMD
GSFC
Remote sensing
Robotics

NH - 15-EPSCoR2015-0016

Responsive Autonomous Rovers to Enable Polar Science

The proposed research builds on Dartmouth's success in developing autonomous robots to expand ground-based remote sensing in Polar regions. We specifically seek to develop protocols and conduct autonomous studies using ground-penetrating radar (GPR) and robotic-mounted albedo sensors to provide data that link to firn compaction and surface mass balance of the Greenland ice sheet and associated climate models. Autonomous positioning and operation of ground instruments using robots expands opportunities for terrestrial scientific discovery through remote sensing. Robotic surveys can provide high-resolution spatiotemporal data to improve ice sheet mass-balance models, provide ground truth for aerial and satellite data, and more broadly provide paradigms for extra-planetary ground-based science.

We have demonstrated the value of autonomous robots through Antarctic and Greenland field deployments totaling over 1000 km of autonomous operation. Through these deployments, we have gathered data via GPS-guided grid surveys conducted with Dartmouth's two polar robots "“ Yeti and Cool Robot "“ towing instruments. Dartmouth has collaborated with scientists at the Universities of Maine and New Hampshire, and the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) on these projects. This collaborative NASA EPSCoR project between Dartmouth College, Univ. of New Hampshire, CRREL, and NASA Goddard scientists now extends the science impact of autonomous robots as roving science platforms and develops new capabilities within New Hampshire to compete for non-EPSCoR funding.

We propose robotic operation of instruments to support science objectives described above:
1) repetitive GPR surveys of a specified region over a full summer season in the vicinity of Summit Camp, Greenland to provide accumulation data and measure firn compaction rates in a dry-snow zone and to develop techniques for robotic acquisition of such data; and
2) development of instrumentation, infrastructure, and measurement protocols to map albedo, specific surface area, and snow temperature using robot-towed instruments. These objectives require a new robotic capability to measure and respond autonomously to the data collected in order to adjust robot trajectory on-the-fly. This capability will enable closed-loop mapping of snow and firn characteristics and thus will enable efficient use of field time and limited energy resources compared with broader grid surveys.

Dartmouth's Polar robots will be used for these tasks. On-board data processing and response algorithms to be developed in this project will allow the robots to position scientific instruments dynamically based on preliminary data or to respond to specific events or measurements. Data from these autonomous robotic surveys provide measurements for identifying parameters as inputs to numerical models of mass balance, accumulation and ablation, and also can provide ground truth for NASA IceBridge measurements and MODIS radiographic measurements.

The proposed research builds infrastructure and capacity for Dartmouth College and University of New Hampshire students in Polar science and engineering that is linked to NASA's remote sensing products and for extending collaborations to include scientists in other states. Dartmouth was recently awarded an NSF grant for the Joint Science and Engineering Program (JSEP), a federal education and outreach program between the U.S., Greenland, and Denmark that inspires high school students through science and engineering by traveling to Greenland to explore international polar research.

This EPSCoR project will leverage this outreach grant and provide opportunities for many students to work with faculty on robotic-based remote sensing.

Antoinette Galvin, University of New Hampshire, Durham

SMD
ISS
ARC
Remote sensing
Oceanography
Climate change
Ocean biology

SC - 15-EPSCoR2015-0021

Using NASA's Ocean Color Sensors to Identify Effects of Watershed Development and Climate Change on Coastal Marine Ecosystems of the US Virgin Islands

This project proposes a scientific partnership between the University of the Virgin Islands (UVI), the College of Charleston (CofC), Kent State University (KSU) and NASA's Ames Research Center (ARC). We propose to quantify the relationship between observations of water optical properties by high resolution Visible and Near - Infrared (VNIR) sensors aboard NASA's space vehicles and Optically Active Constituents (OACs) measured in situ on coral reefs. This relationship will be tested against long-term records and targeted assessments of coral health in order to identify potential water quality stressors on coral reef ecosystem health. Our project goals are directly relevant to NASA Strategic Goals and Objectives 2.2 "Advance Earth system science to meet the challenges of climate and environmental change".

The shallow, clear waters of tropical regions of the world support the photosynthesizing microalgae that live symbiotically within reef-building coral animal tissues. This symbiosis allows for the growth of the coral skeleton and therefore serves as the basis for the development of complex reef structures, providing coastline protection from wave action and supporting nursery grounds for fisheries. This symbiosis is disrupted by thermal stress resulting in coral bleaching and coral mortality, with extreme thermal events contributing to a shift from coral to macro-algal dominated states in Caribbean.

Water quality decline from urbanization may be compounding these effects and/or hindering recovery from mass bleaching events. Coral reefs have low tolerances to changes in nutrient, sediment, and phytoplankton concentrations. These changes have been shown to cause a range of physiological and ecological impacts to coral reefs and studies suggest the need for more effective monitoring protocols. Current assessment methods of water quality are based on in situ measurements.

Although these measurements provide good background data, they are labor intensive, costly and lack the spatial and temporal coverage needed to better understand changes in such a highly dynamic environment.

Remote Sensing (RS) technology can provide timely and spatially explicit information regarding changes in the aquatic systems once the data is calibrated using in situ measurements. This capability can further provide possibilities for early warning of detrimental ecosystem changes and can set inputs into decisions about management and mitigation of negative effects. Application of RS techniques in the coastal waters of the US Virgin Islands (USVI) is primitive and to date no bio-optical models have been applied that can accurately characterize local biochemical processes.

We will develop regionally tiered and calibrated models for assessment of water quality by more accurately determining the VNIR RS signatures. The role of water quality in influencing coral health outcomes during and after mass bleaching events will be assessed using water quality metrics acquired from RS integrated with records of coral reef thermal histories, bleaching, and mortality, as well as results of targeted assessments of coral health across sites exposed to a known range of water quality. This research is extremely important in the US Virgin Islands where coral reef-dependent tourism is the primary driver of the economy and declines in reef related services would have significant economic impacts.

The educational plan of our program will inspire students to become engaged in learning about water quality and its impact on coral reef ecosystems through interactive, field and laboratory-based activities including satellite image data processing and data analysis techniques that directly address and support NASA's education goal 2.4 "Advance the Nation's STEM education and workforce pipeline."

This objective also ties in with Federal Science, Technology, Engineering, and Mathematics (STEM) education directives, with a focus on underrepresented minorities.

Cassandra Runyon, College of Charleston

STMD
JPL
3D Printing
Engineering

SD - 15-EPSCoR2015-0017

Development of Direct-Write Materials, and Electronic and Electromagnetic Devices for NASA Printable Spacecraft

The objective of this project is to develop the necessary research base that will enable printable spacecraft to become a reality. Printable spacecraft is a futuristic, potentially game-changing endeavor envisioned by NASA Jet Propulsion Laboratory (JPL) for use in future space exploration missions. The printable spacecraft vision is for the creation of thin, ultra-lightweight, and flexible substrate sheets with customized, embedded sensors and electronic modules for data gathering, communication, and micro-propulsion.

Various electronic components and devices will be printed on these sheets, which, when deployed, will flutter like falling leaves to a target surface, collecting data throughout their journey. Deployment in this manner would eliminate the need for complex landing systems. Upon reaching their destination, the sheets will act as a large wireless network of sensors that transmit collected data back to the host spacecraft. A multi-disciplinary team of 10 subject experts from five disciplines (materials science, electrical engineering, chemistry, chemical engineering, and physics) and three South Dakota (SD) universities will collaborate to achieve this ambitious goal.

The SD team emerges from a longstanding teaming ecosystem that has extensive research on all facets of printing technology, one that is ideally suited for support of the printed spacecraft initiative. The SD team will be joined by NASA and industry partners in this research endeavor.

The research is very well aligned in three programmatic theme areas:
(1) Printable Space Compatible Materials,
(2) Printed Electronics and Electromagnetic Devices, and
(3) Printable Power and Propulsion.

The following research subtasks are distributed under these theme areas:

- Gaining a fundamental understanding of the relation between processing, microstructure, and mechanical/electrical performance of printed materials in space environments.
- Utilizing overcoatings for printed electronics use in harsh space environments.
- Developing functionally gradient flexible substrates with coefficient of thermal expansion (CTE) matched to that of printed components for use in space environments.
- Synthesizing nanoinks for accurate, direct-write printing of interconnections, sensors, and electromagnetic devices with fine features.
- Designing and direct-write printing electronics and electromagnetic devices and modules for space applications.
- Synthesizing and deploying reactive inks for chemical propulsion systems.
- Developing a printed photovoltaic power generation technology using ultra-lightweight, robust and highly efficient perovskite solar cells and luminescent solar concentrators.

In addition to the printed spacecraft initiative, the research will contribute to the strategic research and technology development priorities of NASA's Space Technology and the Human Exploration and Operations Mission Directorates.

Another objective of the project is to enhance state research infrastructure. To achieve this, the project will add new critical equipment (e.g., a research-grade profilometer) that will greatly enhance the research capabilities at SD universities. Also, this project will support five PhD programs (out of which three are new) in STEM areas in SD.

The research will create new knowledge providing critical content for two relevant graduate courses, as well as the printed spacecraft initiative. The research has significant state fidelity through its alignment with SD's Science and Technology Plan.

Furthermore, this project will support two early-career faculty, facilitate undergraduate research, and train six graduate students, including a graduate internship where students will work side-by-side with NASA researchers at JPL and Glenn Research Center.

Finally, the project will deliver NASA-relevant outreach activities to Native American high school students in SD through visits to the Pine Ridge and Rosebud Reservations.

Edward Duke, South Dakota School of Mines and Technology

STMD
GRC
Solar power
Photovoltaic (PV) systems
Power and Energy Storage
Thermophotovoltaic devices

AR - 15-EPSCoR2015-0022

SiGeSn Based Photovoltaic Devices for Space Applications

Future space science and human exploration missions require solar power photovoltaic (PV) systems with significantly higher performance such as higher efficiency, higher radiation tolerance, and lower cost than the state-of-art technology based on triple-junction solar cells. Although the recently published Space Power and Energy Storage Roadmap by NASA has set an aggressive goal for space PV to reach 35%, 40%, and 45% efficiency after 5, 10 and 15 years, respectively, the prevailing triple junction PV technology has reached its efficiency upper limit. This project aims to address this issue by developing the next generation high efficiency four junction solar cells for space applications.

The research team includes four researchers from three Arkansas institutions and is supported by four experts from three NASA research centers and four industry partners, in which NASA Glenn Research center and SolAero (formerly Emcore) are the key research and manufacture sites for space PV in US.

The team has been historically supported by NASA which resulted in fruitful outcomes and strong collaborations among members leading to this proposal. The team members are world leading researchers on GeSn materials and devices currently maintain almost all world records in this area ranging from material growth to device performance.

The team proposes to utilize their world leading research expertise on GeSn materials and devices to develop SiGeSn based PV devices, which could be monolithically integrated with the existing triple-junction cells by providing an optimized 1eV bandgap cell. This approach provides both boosted performance and a low cost manufacture route. The additional benefit is the high radiation tolerance due to the use of SiGeSn material system.

The team proposes to extend the concept of MJ solar cells to develop SiGeSn two junction thermophotovoltaic devices, which could provide much higher energy conversion efficiency in radioisotope power systems than thermoelectric converters.

A systematic research plan includes:

i) Device design and simulation;
ii) SiGeSn material growth and characterization;
iii) Optical characterization of SiGeSn materials;
iv) Development of SiGeSn photoconductor;
v) Development of SiGeSn PN junctions.

The proposed research is strongly relevant to NASA's current missions and is expected to bring significant impacts to NASA's long term goals. The short term relevance is achieved by aligning the major research tasks in this project with that of current NASA contacts and NASA contractors.

The research has much broader impacts beyond just PV applications. Since Silicon now is a platform for both integrated circuits and integrated photonics, a Si based optoelectronic material such as SiGeSn with broad wavelength coverage could lead to the implementation of a new vision of "Silicon-based Longwave Integrated Optoelectronics"� with a variety of applications such as imaging, sensing, and optical communications, which are highly desirable for future NASA missions.

In addition to the research activities, this project also includes intensive interactions among Arkansas researchers, NASA experts, and industry partners. The project aims not only to develop long-term partnerships with NASA research centers to contribute to NASA missions but also to promote state economic growth and work-force development through technology transfer to industry.

The project will foster the growth of the overall research infrastructure and therefore enable the team to emerge as a nationally outstanding group to obtain substantial supports from sources outside of the NASA EPSCoR program. A solid sustainability plan within and after the award period is presented with a clear strategy to approach different funding agencies.

The team plans to work closely with Arkansas Space Grant Consortium to seamlessly integrate the research with a large variety of education and outreach activities.

Mitchell Hudson, University of Arkansas, Little Rock

NV - 15-EPSCoR2015-0025

Advanced Transport Technologies for NASA Thermal Management/Control Sytems

Thermal management of NASA life-support, high-power electronics, and measurement systems enables a wide variety of crucial space, air-flight, and monitoring technologies. These systems employ fluids to cool heat-generating modules and efficiently transport that energy to components that either make use of it or reject it to space.

Current heat exchangers at the interfaces between the thermal management system and components that reject or receive energy rely on single-phase convection. As a result, these heat exchangers are relatively large and heavy. Augmented single-phase and phase-change (in which the fluid boils and/or condenses) heat exchangers hold promise to reduce the size and enhance the performance of these systems, if reliability issues can be resolved.

A highly-integrated, statewide research and educational advancement program is proposed among four Nevada System of Higher Education (NSHE) institutions: the University of Nevada, Reno (UNR), the University of Nevada, Las Vegas (UNLV), Truckee Meadows Community College (TMCC), and the Desert Research Institute (DRI). The program objective is to develop advanced single-phase and phase-change loop heat transfer technologies that will enhance the performance and reliability of the NASA thermal management/control system.

In addition, this work will be the bases for the development of innovative and interactive educational modules as well as technology transfer. The proposed work will fund four faculty members and four Ph.D. students who will gain experience in areas of interest to NASA.

Specifically, this program will:
1) Develop surface treatments for advanced single-phase, boiling, and condensation passages, including the following:
    a. Grooves that trigger flow instabilities and enhanced mixing
    b. Thin hydrophobic film coatings to create enhanced drop-wise condensing surfaces
    c. Non-covalently assembled nano-tubular porous layers for high-critical-heat flux boiling surfaces

2) Integrate these technologies into feedback-controlled pumped and capillary-driven loops with high heat transfer, stability, and cold-startup performance

3) Perform proof-of-concept tests to demonstrate applicability of these heat transfer technologies for NASA and other thermal management systems

4) Help Nevada meet its need for a well-trained and diversified work force by the following:
    a. Training multiple Ph.D. students in experimental heat transfer research

b. Integrating the unique challenges posed by NASA thermal management systems and the solutions developed by the current research program into interactive educational modules

5) Improve the collaborative research infrastructure within four NSHE research institutions, making them more competitive for funding through a wide range of NASA and other aerospace, science, and engineering programs

6) Foster development/licensing of intellectual property and spinoff companies based on the technologies developed in this work

Miles Greiner, Science-I

Lynn Fenstermaker, University Of Nevada, Reno