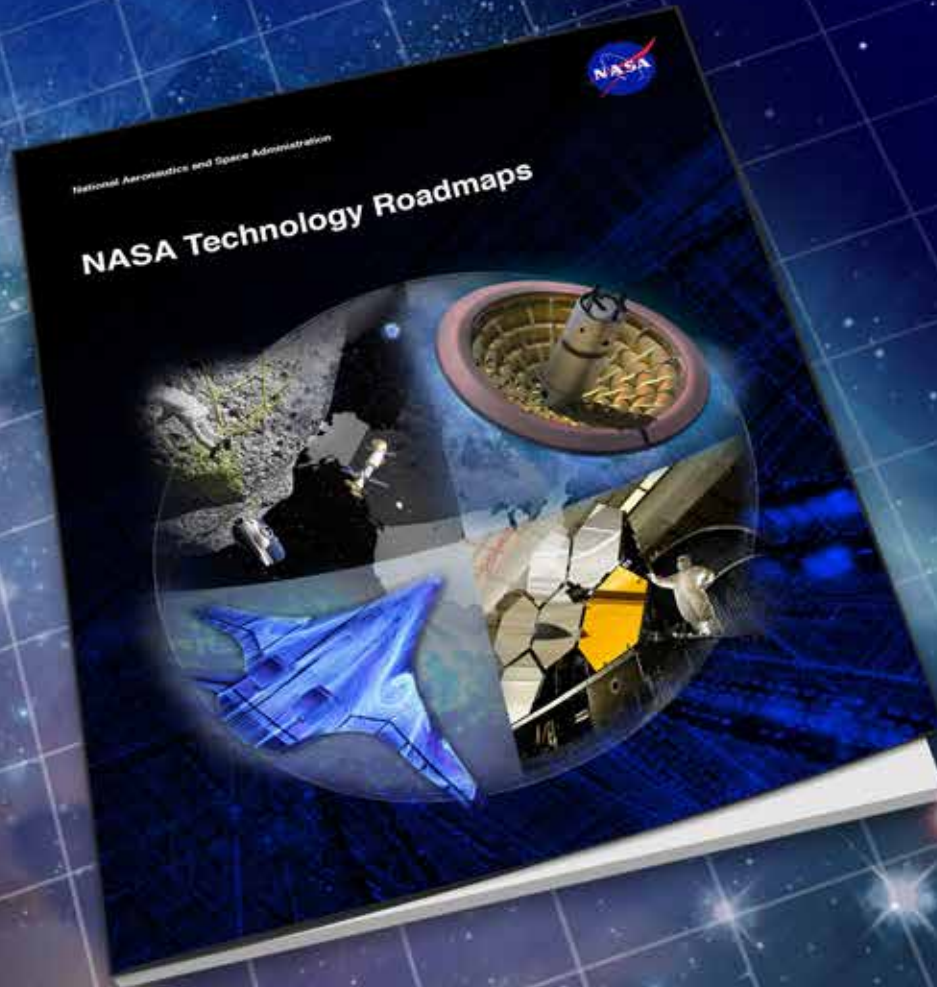


National Aeronautics and
Space Administration



NASA EPSCoR **Stimuli**

2016-17

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001



March 2, 2017

Reply to Attn of: Office of Education

Greetings,

On behalf of the National Aeronautics and Space Administration's Office of Education, I welcome you to *Stimuli*, a summary of college and university research administered by NASA's Experimental Program to Stimulate Competitive Research, or EPSCoR.

Within NASA, EPSCoR funded research addresses technology areas identified within NASA's Technology Road Map. Each of the Technology Area chapters in *Stimuli* showcase the practical and successful research being conducted.

NASA EPSCoR has far-reaching and long-term benefits for our nation and NASA. EPSCoR's congressionally-mandated funding pays for advanced aeronautical and aerospace research and development (R&D) at institutions of higher learning in twenty-four states and three U.S. commonwealths. Through this program, many scientists and researchers have acquired patents or achieved technical transfer of their research. Moreover, several EPSCoR scientists and researchers will even see applications of their efforts tested aboard the International Space Station.

As you browse through *Stimuli*, remember that NASA EPSCoR research helps keep our nation at the forefront of aeronautical and aerospace technology, strengthens our long-term economic well-being, and advances the goals of America's Space Program.

Sincerely,

A handwritten signature in blue ink, appearing to read "Donald G. James".

Donald G. James
Associate Administrator for Education

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001



March 2, 2017

Reply to Attn of: **Space Technology Mission Directorate**

Greetings,

NASA plays a key role in our nation's technology leadership. To achieve current and future missions, NASA relies on the Space Technology Mission Directorate (STMD) to engage and collaborate with experts from industry, academia, and the NASA centers. Another pathway to accomplishing this mission is through the NASA Office of Education's EPSCoR program.

STMD utilizes Technology Areas to provide extensive details about anticipated NASA mission capabilities and provide guidance to our mission directorates for development of needed technologies. The EPSCoR program is working with STMD to increase agency awareness by sharing examples of how on-going EPSCoR research directly supports the NASA Technology Roadmap.

In this edition of *Stimuli*, we demonstrate how the relationship between the NASA Office of Education's EPSCoR program and STMD results in research that directly supports each of NASA's Technology Areas.

Sincerely,

A handwritten signature in black ink, appearing to read "Stephen G. Jurczyk".

Stephen G. Jurczyk
Associate Administrator
Space Technology Mission Directorate



NASA EPSCoR **Stimuli**

2016-17

Table of Contents

4	TA 1	Launch Propulsion Systems
6	TA 2	In-Space Propulsion Systems
7	TA 3	Space Power and Energy Storage
17	TA 4	Robotics and Autonomous Systems
23	TA 5	Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
25	TA 6	Human Health, Life Support, and Habitation Systems
43	TA 7	Human Exploration Destination Systems
52	TA 8	Science Instruments, Observatories, and Sensor Systems
69	TA 9	Entry, Descent, and Landing Systems
74	TA 10	Nanotechnology
80	TA 11	Modeling, Simulation, Information Technology, and Processing
87	TA 12	Materials, Structures, Mechanical Systems, and Manufacturing
99	TA 13	Ground and Launch Systems
101	TA 14	Thermal Management Systems
107	TA 15	Aeronautics

TA1

LAUNCH PROPULSION SYSTEMS

TA 1 Launch Propulsion Systems addresses technologies that enhance existing solid or liquid propulsion technologies or their related ancillary systems. The updated 2015 NASA Technology Roadmaps includes both enabling (pull) and enhancing (push) technologies that are essential to the pursuit of NASA's aeronautics, science, and human exploration missions, and achievement of national goals.

TA 1 is organized around six primary technology areas: 1) solid rocket propulsion systems, 2) liquid rocket propulsion systems, 3) air-breathing launch propulsion systems, 4) ancillary propulsion systems (which include subsystems for existing systems, as well as smaller rocket systems like reaction control systems (RCS) and abort systems), 5) unconventional and other propulsion systems, and 6) balloon systems for scientific payloads.

Solid and liquid rocket propulsion systems have been used since the dawn of spaceflight and are comprised of fuel and oxidizers in solid or liquid form. These technologies are reaching the limits of theoretical efficiency and performance using conventional propellants. Air-breathing launch propulsion systems extract their oxidizer from the atmosphere and could be part of an integrated system that includes more conventional rockets to reach the vacuum of space. Hypersonic air-breathing systems, as demonstrated by X-43 and X-51, are still in the experimental stage. Improvements in ancillary propulsion systems would include the supporting subsystems for conventional propulsion systems, including controls and smaller rockets not directly responsible for lift to orbit. Unconventional launch technologies include systems that do not rely solely on onboard energy for launch or that use unique technologies or propellants to create rocket thrust. Included in this area are technologies that are at a very low technology readiness level (TRL) or that do not map into the other propulsion taxonomies. Balloon lift systems are used for high-altitude science and observation flights and may be considered a mature technology. For balloons lift systems, advances are needed to improve payload lift capability, altitude capability, trajectory control capability, and mission duration.



p5 Experimental Investigation of Noise and Thermo-acoustic Instabilities in Low-emission, High-Efficiency Combustion Systems for Aviation

Experimental Investigation of Noise and Thermo-acoustic Instabilities in Low-Emission, High-Efficiency Combustion Systems for Aviation

University of Alabama/NASA Glenn Research Center, Langley Research Center, Marshall Space Flight Center, Aeronautics Mission Directorate



Low-Emission Combustor Setup in Engine and Combustion Laboratory at University of Alabama.

This research in the Department of Mechanical Engineering (ME) at the University of Alabama is producing innovative concepts, supplemented with experimental data, to enable lean direction injection or LDI combustion for next generation aviation gas turbines to meet stringent emissions, noise, and efficiency goals established by NASA and regulation agencies. The LDI combustion is prone to thermoacoustic instabilities or large-amplitude pressure oscillation that can severely damage the engine. UA team has developed and patented a porous insert concept to address these problems. We are exploring methods to create highly functional porous inserts from aviation grade materials using 3D additive manufacturing techniques. We are working with NASA Glenn Research Center (GRC) where LDI combustion research has been extensively investigated. The project is housed in UA's state-of-the-art Engine and Combustion Laboratory (ECL). Key accomplishments of the project are: (1) a competitive multi-year research award on a related combustion/engine project, (2) opportunity to collaborate with three different federal laboratories (NASA, DOE, and NRL). Presently, we are working to transition the UA technology to gas turbine, power generation, and/or burner industry, (3) a high-level delegation from a well-known US company visited our laboratory to develop plans for collaborative research and educational opportunities, (4) record enrollment of students in Mechanical Engineering undergraduate, Masters' and PhD programs, (5) STEM course "Introduction to Combustion" was revised and led to record enrollment of undergraduate and graduate students, who are interested in fuels, energy and environment. ✨



*Dr. Ajay K. Agrawal, Science PI,
The University of Alabama*

*NASA Technical Monitor:
Dr. Kathy Tacina, Glenn Research Center*

TA 2

TA 2

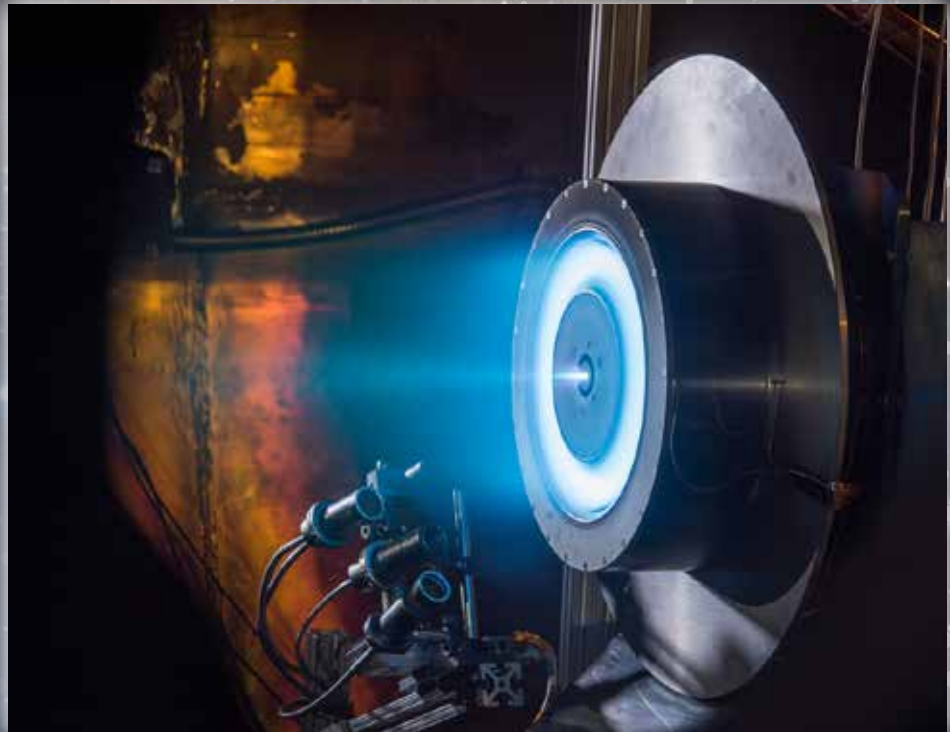
IN-SPACE PROPULSION SYSTEMS

TA 2

A large fraction of the rocket engines in use today are chemical rockets; that is, they obtain the energy needed to generate thrust by chemical reactions to create a hot gas that is expanded to produce thrust. Thrust-to-weight ratios greater than unity are required to launch from the surface of the Earth, and chemical propulsion is currently the only flight-qualified propulsion technology capable of producing the magnitude of thrust necessary to overcome Earth's gravity.

Numerous concepts for advanced in-space propulsion technologies have been developed over the past 50 years. While generally providing at least an order of magnitude higher specific impulse (I_{sp}) (thrust efficiency) compared to chemical engines, the advanced concepts typically generate much lower values of thrust. Advanced propulsion technologies, such as electric propulsion, are commonly used for station keeping on commercial communications satellites and for prime propulsion on some scientific missions because they have significantly higher values of I_{sp} .

There is no single propulsion technology that will benefit all missions or mission types. The requirements for in-space propulsion vary widely due to their intended application. The technology candidates described herein will support everything from small satellites and robotic deep-space exploration to space stations and human missions to Mars.



TA3

SPACE POWER AND ENERGY STORAGE

TA3

Many state of the art (SOA) power systems are too heavy, bulky, or inefficient to meet future mission requirements, and some cannot operate in some extreme environments. The technology developments presented in this roadmap can produce power systems with significant mass and volume reductions, increased efficiency, and capability for operation across a broad temperature range and in intense radiation environments. The different components of a power system—power generation, energy storage, and power management and distribution (PMAD)—each require technological improvements to meet these requirements. Most of the power technologies discussed in this roadmap are used, in some form, on current crewed or robotic missions. These technologies need incremental and unique improvements in performance and mission durability in order to enable or enhance the missions currently in NASA's plans. However, in a circumstance that is unique for the power and propulsion TAs (TA 1 Launch Propulsion Systems, TA 2 In-Space Propulsion Technologies, and TA 3 Space Power and Energy Storage), there are some low technology readiness level (TRL) power technologies that could (often when integrated with certain advanced propulsion technologies) offer NASA radically improved mission capabilities.

- p8** Functionalization of Nanomaterials for Photovoltaic Devices
- p9** Next Generation Lithium Sulfur Batteries for Mission Enabling Energy Storage Systems
- p10** Nanostructured Solid-State Energy Storage Devices for Wide-Temperature Applications in Space Exploration
- p11** Nanostructured III-N Solar Cells for Space Applications
- p12** High Performance and Durable Lithium-ion Battery for NASA Space Applications
- p13** SiGeSn Based Photovoltaic Devices for Space Applications
- p14** 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
- p15** High Efficiency Dilute Nitrides Solar Cells for Space Applications
- p16** Advanced Bioelectrochemical Module (BEM) for Waste-to-Electricity Generation During Long-term Space Exploration



Functionalization of Nanomaterials for Photovoltaic Devices

University of Arkansas/NASA Ames Research Center, Space Technology Mission Directorate



*Omar Manasreh,
Science PI,
University of Arkansas,
Fayetteville*

The NASA project enhanced the research program at the University of Arkansas at Fayetteville, led by the PI, in creating infrastructures including growth of the facility and device fabrication. In particular, the electron-beam evaporator purchased by the NASA funding is extremely helpful in producing high quality solar cells with excellent power conversion efficiency. The project also helped the PI in generating a procedure to investigate solar cells from materials growth to device fabrication and testing. New growth methods were followed including sol-gel methods, which are used to fabricate antireflection coating. Our procedures resulting from this grant was adopted by other professors at the University of Arkansas at Fayetteville who are involved in renewable energy related research. Our approach also helped a local company (Pico Solar. LLC) in creating new approaches to measure the dopant profiles in solar cell materials and to determine the external quantum efficiency in Si-based solar cells. ✨



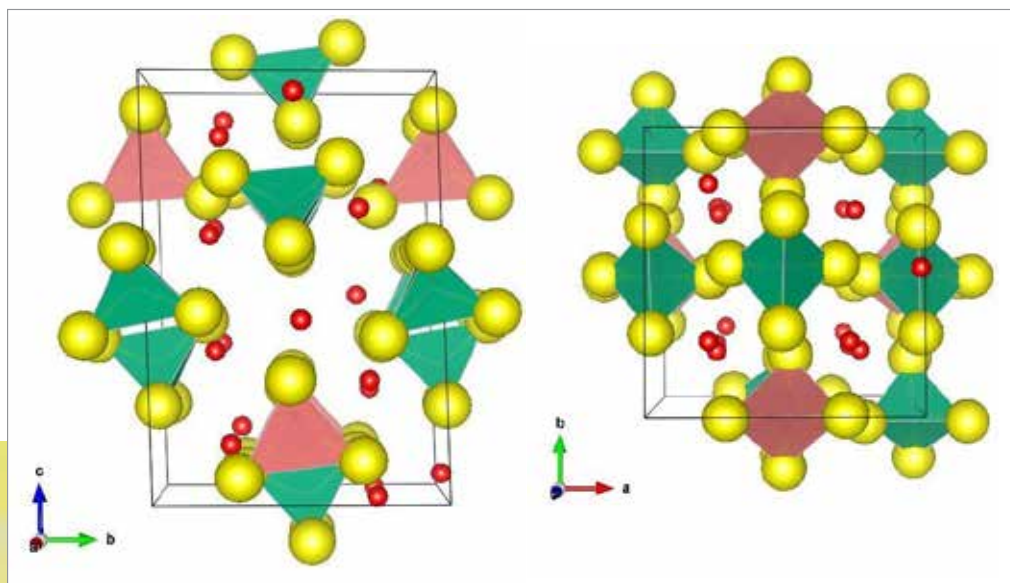
*Meyya Meyyappan, Ph.D.,
NASA Technical Monitor,
Ames Research Center, STMD*



An LED powered by InAs quantum dots solar cells fabricated in the PI-Lab.

Next Generation Lithium Sulfur Batteries for Mission Enabling Energy Storage Systems

Iowa State University/NASA Glenn Research Center, Johnson Space Center & Jet Propulsion Laboratory/Human Exploration & Operations Mission Directorate, Space Technology Mission Directorate, Science Mission Directorate



Sc-I Martin, bottom right, with his battery research group. All but one of these students is funded in part or in whole by the new battery research funding that Professor Martin has received due in part to the Iowa NASA EPSCoR grant NNX13AD36A.



*Dr. Steve Martin,
Science PI,
Iowa State University*

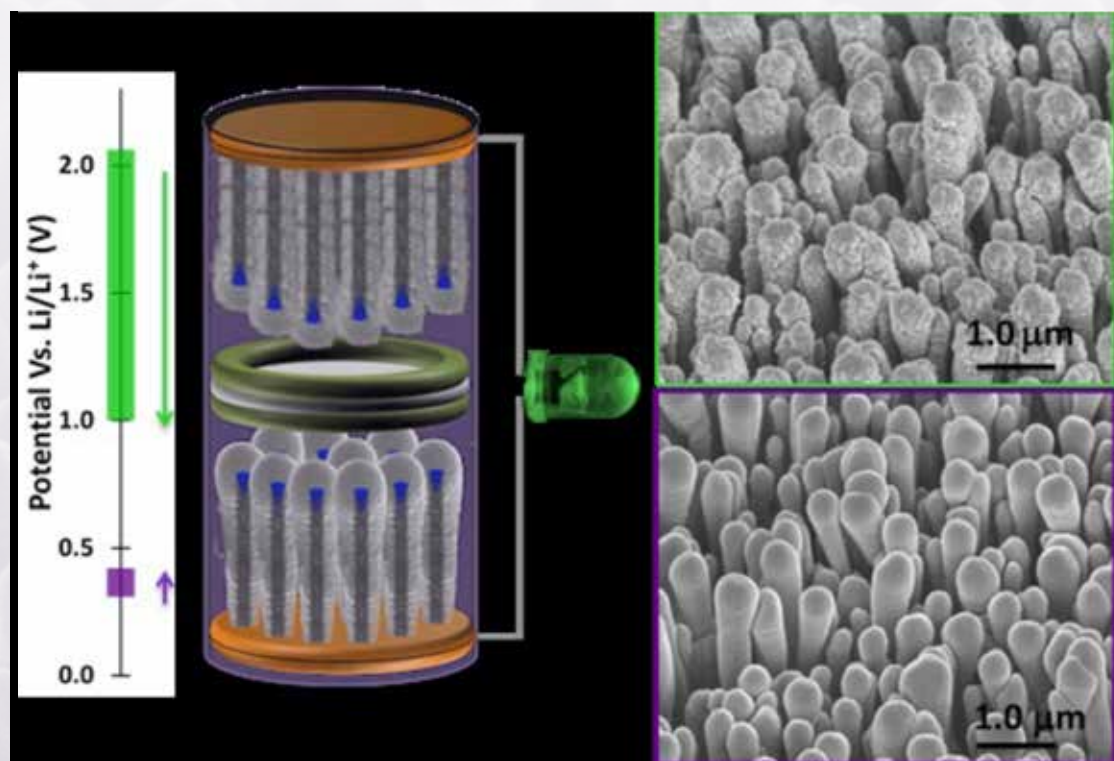


*Dr. Vadim Lvovich,
NASA Technical Monitor,
Glenn Research Center*

This NASA EPSCoR grant in Iowa has been a catalyst for more than \$8 million in additional battery research to Iowa State University. While Sc-I Martin has conducted basic research on battery related materials for more than 30 years at Iowa State University, all of this nearly \$15 million in research funding was directed towards only examining materials from which batteries could be made. It could never be spent on building and studying actual new batteries. This all changed when Professor Martin and his students were awarded a NASA EPSCoR grant in 2012. The core mission of this new research program was to not only develop new materials for mission extending and vastly safer batteries, but to then use these new materials to assemble and test a new type of high energy and safe battery based upon lithium and sulfur. A planned, yet none-the-less unexpectedly strong, goal of this research infrastructure improvement grant has been the large windfall of additional battery research grants that Sc-I Martin has received following his NASA EPSCoR grant. A total of nearly \$8M in additional research funding, from the NSF, DOE ARPA-E, car manufactures, and other sources has been secured by Professor Martin to accelerate his battery research and now battery development efforts. He credits the NASA EPSCoR program in part for jump starting and then enabling this strong development in research funding for battery research. ☼

Nanostructured Solid-State Energy Storage Devices for Wide-Temperature Applications in Space Exploration

Wichita State University/NASA Ames Research Center, Human Exploration & Operations Mission Directorate,
Space Technology Mission Directorate



Dr. Jun Li,
Science PI,
Wichita State University



Meyya Meyyappan, Ph.D.,
NASA Technical Monitor,
Ames Research Center, STMD

The schematic and electron microscopic images of a Lithium-ion battery - supercapacitor hybrid cell consisting of a TiO_2 -coated VACNF cathode (top) and a Si-coated VACNF anode (bottom).

Lithium-ion batteries (LIBs) and supercapacitors represent two distinct electrical energy storage devices. LIBs are known to have very high specific energy due to the large amount of Li involved in intercalation or alloying reactions in the bulk of electrode materials, but their deliverable power is rather low, limited by the slow reaction rate due to the slow Li^+ diffusion in solid materials. In contrast, electrochemical supercapacitors, particularly pseudocapacitors, can charge/discharge at much higher rates based on fast electrochemical reactions occurring at the electrode surface or in a thin layer near the surface, but the specific energy is limited. Here an electrochemical cell representing a battery-supercapacitor hybrid is demonstrated with a Si anode and a TiO_2 cathode based on Lithium chemistry. Both materials are fabricated as a nanoporous coaxial shells on vertical aligned carbon nanofiber arrays. The Li^+ ion transport and electrical connection is greatly enhanced, leading to battery-supercapacitor hybrid characteristics which present a decent energy density comparable to a normal battery and a remarkably high specific power matching the state-of-the-art supercapacitors (*Electrochimica Acta* 2015, 178, 797-805). ☀

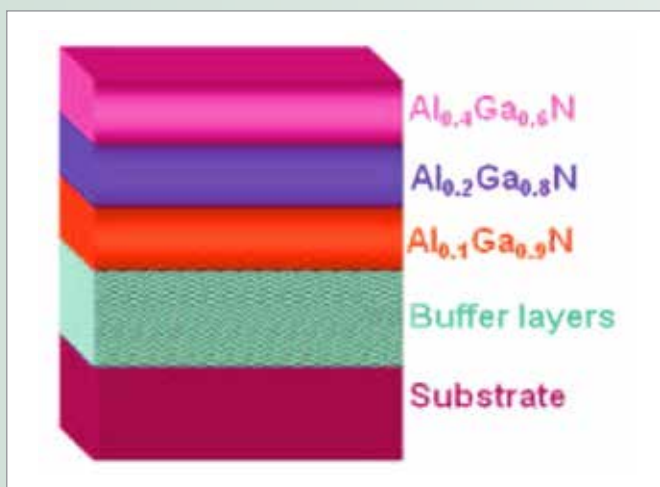
<http://www.k-state.edu/chem/people/grad-faculty/jli/lab/junli-group/index.html>

Nanostructured III-N Solar Cells for Space Applications

University of Puerto Rico, Mayaguez/NASA Human Exploration & Operations Mission Directorate



Prof. Ratnakar Palai and Student Adriana Rivera-Morales working on the Molecular Beam Epitaxy System at the University of Puerto Rico, Rio Piedras Campus.



Schematic of the $Al_{1-x}Ga_xN$ ($x = 0.6, 0.8$ and 0.9) heterostructures grown on $Si(1\ 1\ 1)$ substrates.

Wide bandgap semiconductors of III-nitrides (InN , GaN and AlN) are capable of greater electronic functionality in extreme environments (high temperature and high radiation) than silicon, which could benefit a variety of important applications, especially in the aerospace electronics, automotive, power generation (turbine engine) and energy production industries. Heterostructures with a 3D-configuration (columnar films/nanostructures) will be very useful for flexible optoelectronic devices. 3D structures can minimize the interfacial strain due to the lattice mismatch between the film and substrate and reduction in the threading edge dislocation density. The major problem is to control composition due to interdiffusion at the interfaces because of the presence of the same elements in each layer, the strain produced by threading dislocation, and its relaxation in multilayers, phase fluctuation.

3D nanostructures of $Al_{1-x}Ga_xN$ ($x = 0.6, 0.8$ and 0.9) were fabricated on Si and sapphire substrates using plasma assisted molecular beam epitaxy (MBE). The main objective of this work is to understand and control the growth mechanism and epitaxial quality of 3D-columnar nanostructures and study its structural, microstructural, interface, transport and optoelectronic properties. ☀



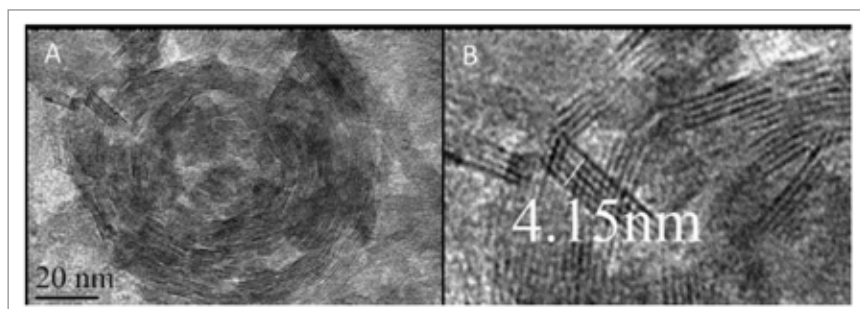
*Maharaj S. Tomar,
Science PI,
University of Puerto Rico,
Mayaguez Campus*



*Dr. Ravi Margasahayam,
NASA Technical Monitor,
Kennedy Space Center*

High Performance and Durable Lithium-ion Battery for NASA Space Applications

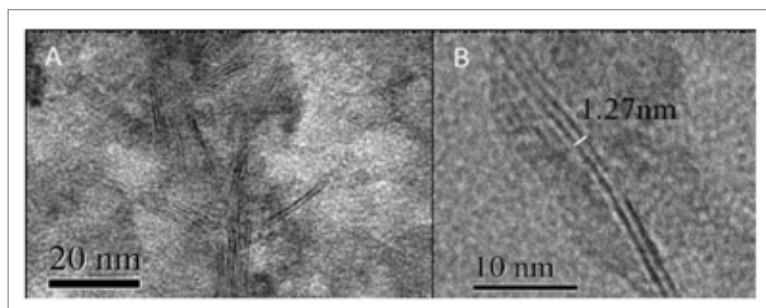
*South Dakota School of Mines and Technology/NASA Glenn Research Center,
Human Exploration & Operations, Space Technology and Science Mission Directorates*



Graphene-like turbostratic silicene layers (A) synthesized at SDSMT by hydrothermal approach with indicated inter-layer distances (B).



*Dr. Alla Smirnova,
Science PI, Assistant Professor,
South Dakota School
of Mines and Technology*



Structure of single wall silicene nanotube synthesized at SDSMT (A) and its diameter of ~1.27nm indicated in (B).



*Dr. James J. Wu,
NASA Technical Monitor,
Glenn Research Center*

The Year II NASA EPSCoR efforts from three South Dakota universities (South Dakota School of Mines and Technology, University of South Dakota, and South Dakota State University) were focused on development of the lithium-ion battery components, such as anode, cathode, non-flammable electrolyte, and separation membrane supported by modeling and simulations for evaluation of the electrochemical cell cyclability and durability. New approaches in terms of lithium-ion battery components, such as a new electrically conducting polymer for lithium-ion battery anode and a new separation polyacrylonitrile membrane have been developed and tested. Furthermore, silicene as a low-dimensional allotrope of silicon with expected broad area of applications including microelectronics and lithium-ion battery anodes has been synthesized. In comparison to bulk silicon currently investigated as the most promising anode material with the highest specific capacity, silicene can be considered as an ideal material due to its metallic conductivity, layered structure, and mechanical stability in lithiation-delithiation cycles. To understand the silicene properties in terms of lithium-ion transport, a collaboration with Pacific Northwest and Brookhaven National Laboratories was initiated and is currently in progress. ✱

<http://www.sdsmt.edu/Research/Profiles/Smirnova/Research/Lithium-Ion-Battery-for-Space-Applications/>

SiGeSn Based Photovoltaic Devices for Space Applications

University of Arkansas/NASA Glenn Research Center, Space Technology Mission Directorate

Photovoltaic (PV) devices are used extensively to power the space sciences and manned exploration missions. Future space science and human exploration missions require solar powered systems with significantly higher performance and efficiency. NASA has set an aggressive goal for space PV to reach 45% efficiency after 15 years. The solution to improve the efficiency of the PV device is through increasing the number of absorbing layers in order to cover a wider range of solar spectrum. Current technology uses three layers of different materials to boost the efficiency of the PV device up to ~30%. However, these layers are not enough to cover the full range of solar spectrum and finding a compatible material to serve this purpose has not been successful. Researchers at the University of Arkansas have recently been able to develop a novel alloy from Silicon, Germanium and Tin that can be used as the fourth layer in high efficiency PV devices. These alloys are able to boost the performance of the solar cell while using a low cost manufacturing route. They are currently working on a NASA funded project to incorporate these alloys to build the next generation high efficiency of PV devices. ✨



Researchers Dr. Aboozar Mosleh (postdoc), Dr. Shui-Qing (Fisher) Yu (Science PI) and Joshua Grant (graduate student) from the University of Arkansas at Fayetteville working on SiGeSn material growth.

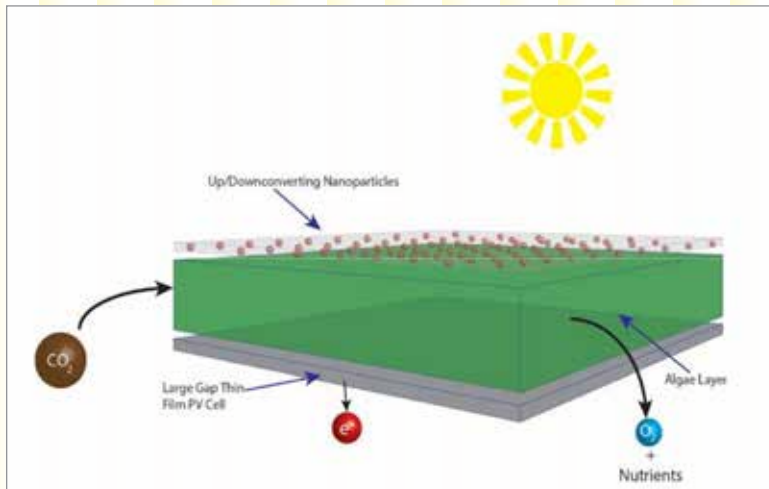


*Dr. Sang H. Choi,
NASA Technical Monitor,
Senior Scientist,
NASA Langley Research Center*



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

University of Tulsa/Johnson Space Center, Human Exploration & Operations Mission Directorate



Algae reactor with up/down conversion and PV cell.

The main goals of this study are achieved by developing a new biologically based life support system, capable of increasing microorganism production by converting normally unused wavelengths of sunlight into those useful by photosynthetic microorganisms. To demonstrate the feasibility of the algae growth for extended flight, we designed a laboratory prototype with a layer for absorbing and converting harmful ultraviolet and infrared light into wavelengths that facilitates algae growth. During the first year of this study, a prototype bio reactor with three specific components was designed and fabricated. This first component is the lynchpin of the proposed technique, the algae growth layer, where cultures of edible microalgae are grown using wavelengths that are either supplied directly from the sun or have been converted to useful ones by the other subsystems. The second component is a thin film of photonic up/down converting nanoparticles, which take wavelengths in the near ultraviolet and infrared ranges, and converts them into wavelengths useful for the algae layer. Finally, the third component is a large band gap photovoltaic thin film, which allows for power cogeneration for the other subsystems. ✨



The University of Tulsa graduate student, Indresh Badrinayan, preparing algae solution for growth study.



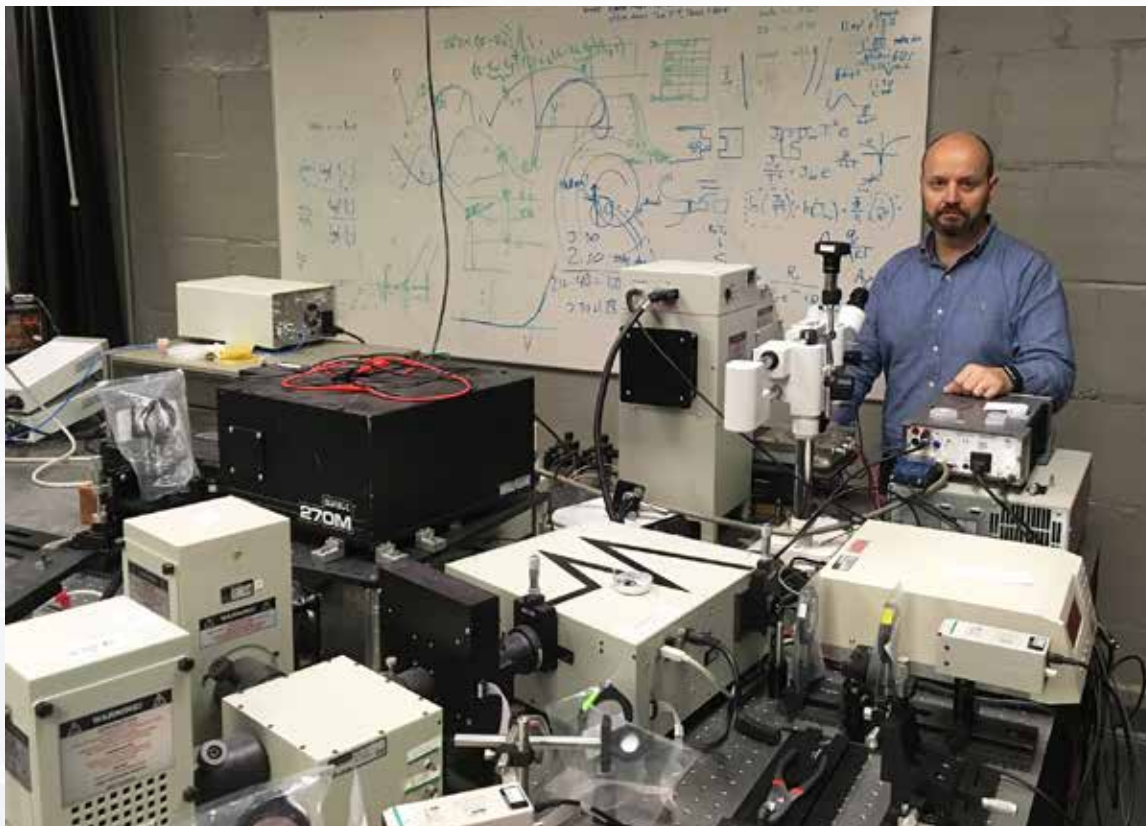
Parameswar Hari, Ph.D.,
Science PI,
Professor, University of Tulsa,
Nanotechnology



Jeremiah McNatt
Electrical Engineer
NASA Glenn Research Center

High Efficiency Dilute Nitrides Solar Cells for Space Applications

The University of Oklahoma, Space Technology Mission Directorate, Glenn Research Center



Dr. Ian R. Sellers, Science PI, in the solar cell characterization lab at the University of Oklahoma, Norman.

Dilute nitride semiconductors have promise for next generation multi-junction solar cells (MJSC). This potential lays in the fact that this alloy can be lattice matched to GaAs and tuned to the important 1 eV absorption window. Despite this potential, several serious materials issues remain unresolved. These issues center on the low solubility of nitrogen in the system, and the formation of larger nitrogen related defect centers. Recently we have shown that deleterious nitrogen-nitrogen clusters and donor impurities localized to isoelectronic centers can be selectively passivated using a UV-activated hydrogenation process, significantly improving the solar cell performance. Here it is proposed to investigate the potential of leveraging these important results to develop next generation MJSCs incorporating these materials.

High performance solar cells are attractive for space applications since they offer the potential for high power generation at lower payloads. These PV systems are also excellent candidates for CubeSat applications in which high power, light, low payload systems are desirable. It is proposed to investigate the potential and suitability of hydrogenated GaInNAs cells for flexible MJSCs via a rigorous investigation of the nature and stability of the H-N bond when subjected to thermal cycling and accelerated lifetime measurements, and under high-energy irradiation. ✨

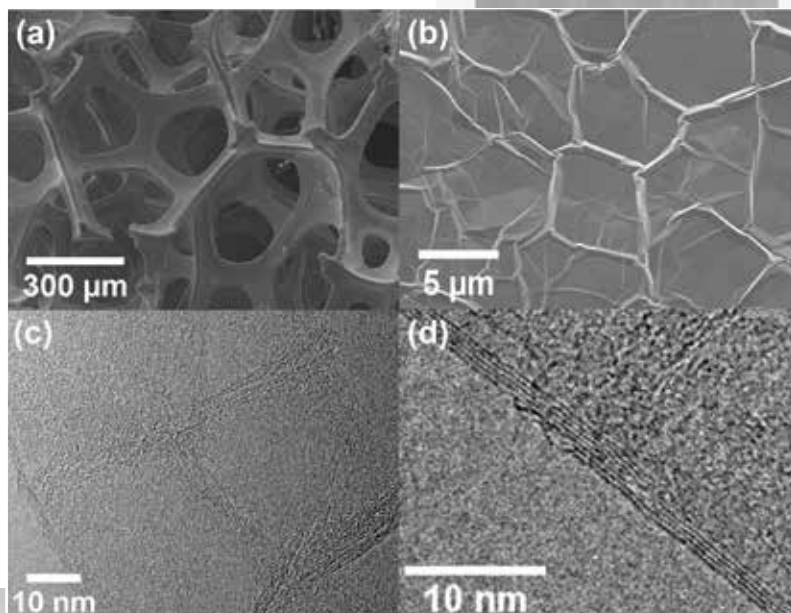


*Jeremiah McNatt
Electrical Engineer
NASA Glenn Research Center*

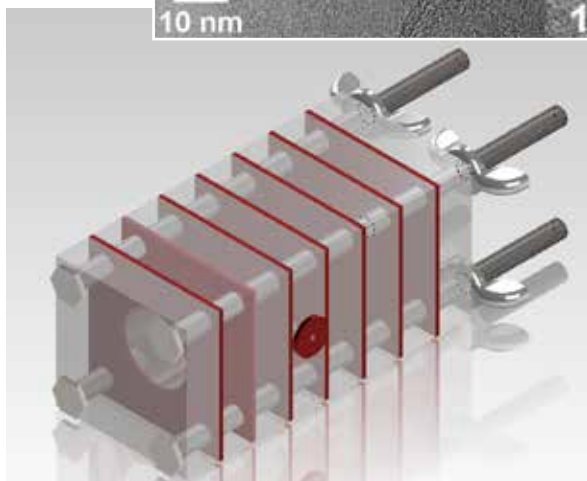
Advanced Bioelectrochemical Module (BEM) for Waste-to-Electricity Generation During Long-term Space Exploration

South Dakota School of Mines and Technology, NASA Kennedy Space Center, Ames Research Center, Jet Propulsion Laboratory, Space Technology and Human Exploration & Operations Mission Directorates, International Space Station

The BEM will use extremophiles isolated from the deep levels of the Sanford Underground Research Facility (SURF) in SD. The SURF is considered to be similar to extraterrestrial space in that it is seemingly uninhabitable, yet its biosphere harbors an enormous range of extremophiles that thrive in the challenging subsurface environments. Our team has isolated *Geobacillus* sp. strain DUSELR7 from the SURF biosphere that synthesizes hydrolytic enzymes with remarkable properties; it shows optimum activity at >65 deg. C, thermal stability (e.g., >50% of cellulase and xylanase activity was retained after 35 and 23 days of incubation at 60 deg. C, respectively), and can function in a broad pH range (pH 4-8). Compared to previous reports, the DUSELR7 cellulases and xylanases are among the most thermostable enzymes produced by *Geobacillus* spp. and other thermophilic microbes. Another SURF isolate, *Enterobacter* RC202, is a hydrocarbon degrading bacteria capable of utilizing a broad substrate repertoire including plastic degradation products. Preliminary results confirmed the electricity-producing (exoelectrogenic) capabilities of DUSELR7 and *Enterobacter* RC202. The RC202 was found to degrade lignocellulosic polymers and generate electricity. The BEM project is a unique scientific study that uses the monocultures of SURF extremophiles for treating unprocessed solid organic and polymer wastes in space missions, inhibiting pathogens in human waste, and generating remote power. We will take advantage of nanotechnology (e.g., graphene electrodes), thermophilic fermentation, and design concepts to minimize BEM footprint in space, and use extraterrestrial UVB and UVC radiation for treating synthetic polymers. We will also use TiO₂/MnO₂-graphene composites to develop a graphene supercapacitor for storing the charges from BEM, using a modified maximum power point circuit that integrates digitally controlled potentiometer with hysteresis-based energy converter and metal oxide semiconductor field effect transistor. The project will collaborate with experts at National Laboratories and industry to develop a stacked BEM that supports low-powered electronics including a Mars microrover. ✱



*Venkataramana Gadhamshetty, Ph.D., P.E.,
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*Dr. Ali Shaykhian,
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TA4

ROBOTICS AND AUTONOMOUS SYSTEMS

In the coming decades, robotics and autonomous systems will continue to change the way space is explored in even more fundamental ways, impacting both human and science exploration. For human exploration, the goal is to leverage robots in all phases: as precursor explorers that precede crewed missions, as crew helpers in space, and as caretakers of assets left behind. As humans continue to work and live in space, they will start relying on intelligent and versatile robots to perform

mundane activities, freeing human and ground teams to tend to more challenging tasks that call for human cognition and judgment. For science exploration, future generations will continue to send space robots to blaze new trails on distant and hostile worlds, extending the reach of the human race. Smarter and more agile space robots will be better equipped to sense and react to anomalies onboard, making them less dependent on the ground crew. Robots will play a key role

in the surveying, observation, extraction, and close examination of planetary surfaces, their natural phenomena, their terrain composition, and their resources. The information they gather will further our understanding of the origins and dynamics of our solar system and expand our knowledge of the universe. For both human and science missions, robots will also play a crucial role in in-space operations, whether it be for assembling a large space telescope, capturing and returning an asteroid, repairing a satellite, deploying an infrastructure on a planetary surface for subsequent human arrival, mining space resources, or deploying assets for a scientific investigation.



p18 A Highly Dexterous Modular Robot with Autonomous Dynamic Reconfigurations for Extra-Terrestrial Exploration

p19 Responsive Autonomous Rovers to Enable Polar Science

p20 Advanced Electroactive Polymer Actuators and Sensors for Aerospace Robotic Applications

p21 Web-Scale Assisted Robot Teleoperation

p22 Research Capacity Building Using a New Dual-frequency Airborne Radar System in Support of NASA GPM and ACE Ground Validation Experiments

A Highly Dexterous Modular Robot with Autonomous Dynamic Reconfigurations for Extra-Terrestrial Exploration

University of Nebraska at Omaha/NASA Johnson Space Center, Human Exploration & Operations Mission Directorate



Figure 1. Hardware module of ModRED.

Autonomous Dynamic Reconfigurations for Extra-Terrestrial Exploration The objective of the ModRED (Modular Robot for Exploration and Discovery) project was to develop an autonomous robot that would improve existing techniques for automated exploring of initially unknown and unstructured environments such as extra-terrestrial surfaces on the Moon or Mars. ModRED was designed as a Modular Self-reconfigurable Robot that consists of individual units or modules which can connect with each other in several ways to form different configurations in terms of size, shape and/or function. This shape-related adaptability of ModRED makes it very dexterous and suitable for exploring extra terrestrial environments.

For the research in the project, a highly dexterous module design capable of mobility along 4 degrees-of-freedom (DOF) was developed. Each module was made from 3D-printed, ABS (Acrylonitrile Butadiene Styrene) plastic and included a processor and sensors to enable mobility-related functions, along with a novel connector mechanism called RoGenSiD (Rotaryplate Genderless Single-sided Docking) to enable modules to dock on four different faces of each module (Fig. 1). Following the module's design, control techniques and software algorithms were developed to ensure autonomous reconfiguration and mobility of ModRED modules over different terrains. Research results were successfully validated using theoretical analyses and simulation experiments, along with some tests on physical ModRED modules. ✱

<http://cmantic.unomaha.edu/projects/modred/index.htm>



*Raj Dasgupta,
Science PI,
University of Nebraska
at Omaha*



*Dr. James G. Mantovani,
NASA Technical Monitor,
Kennedy Space Center*

Responsive Autonomous Rovers to Enable Polar Science

Dartmouth College/NASA Goddard Space Flight Center, Science Mission Directorate



*Dr. Laura Ray,
Science PI,
Professor, Dartmouth College*

Scientists study climate change by observing the Earth from remote satellites and from permanent ground stations sparsely distributed through the Earth's ice sheets. These observations provide data from which scientists develop models to predict the effect of climate change on sea level and global temperature. This NASA EPSCoR project aims to fill in the gap between point observations from ground stations and remote sensing from satellites by using a solar-powered robot to measure important characteristics of snow and ice. In this way, measurements made by the robot can ground truth measurements made remotely. We develop instruments for measuring albedo – the amount of the sun's radiation that is reflected by the surface; and accumulation and compaction of snow and ice, which relate directly to the net mass accumulated in the Earth's largest ice sheets.

These instruments are deployed on Dartmouth College's Cool Robot, which can operate unattended during the summer at high latitudes. The project involves researchers at Dartmouth College, NASA, the University of New Hampshire, and the U.S. Army Cold Regions Research and Engineering Laboratory, and Dartmouth College. During the first year of the project, we 15 focused on engineering the instruments for deployment on a robot and improving reliability of the solar power system. ✨



Graduate candidate Joshua Elliot preparing for a radar survey, Summit Camp Greenland, July 2016.



*Graduate candidate
Joshua Elliot and Science
PI Laura Ray mounting a
radiometer.*



*Dr. Brooke Medley,
NASA Technical Monitor,
Physical Scientist,
Cryospheric Sciences Laboratory,
Goddard Space Flight Center*

http://www.nasaepscor.unh.edu/ray_polar.shtml

Advanced Electroactive Polymer Actuators and Sensors for Aerospace Robotic Applications

University of Nevada, Las Vegas/NASA Jet Propulsion Laboratory, Johnson Space Center, Langley Research Center, Human Exploration & Operations, Science, and Space Technology Mission Directorates

The Universities of Nevada Las Vegas and Reno and the Truckee Meadows Community College are engaged in a project focusing on the development of ionomer materials with improved thermal properties and good ion-conductivity for space and robotic applications. This is being achieved by blending Nafion®, a high ion-conductivity ionomer, with Polyimide (PI), which is known for its superior thermal and mechanical properties. Several factors were found to be significant in producing homogenous blends, such as the concentration ratio and casting temperature. Blended films of Nafion®/PI at several concentration ratios are shown in Figure 1.

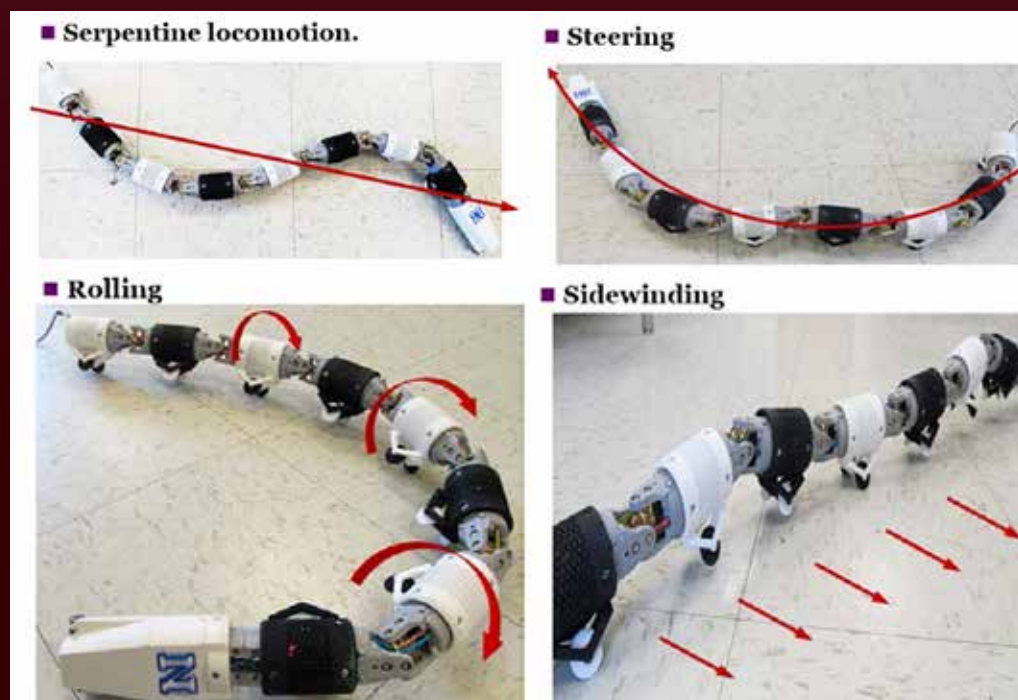
One of the significant accomplishments for this project demonstrated the incorporation of PI in Nafion® with a bottom-up approach for the first time. The developed blend films show improved thermal and mechanical properties while maintaining good ion conductivity. This research is of great importance to the further development of advanced materials,

and is expected to facilitate research and development in the fields of smart materials, robotics, aerospace and other industrial applications. Additionally, new teaching material was developed as a parallel effort. Course content was developed for a special course at UNLV, taught in Spring 2016, which focused on characterization methods and instrumentation to investigate active materials system applications.

Another significant result this year was the continuing development of an ionic polymer–metal composite (IPMC) driven earthworm-like soft robot system and its advanced sensing and control methodologies. Three-dimensional (3-D) printing was used to build an earthworm-like robot that has two muscle-like structures that mimic the longitudinal and circular muscles of a biological earthworm. Four controlled locomotion modes were enabled by these two “muscle” types, namely serpentine, steering, rolling and sidewinding as shown in Figure 2. ✨



Figure 1: Optimized Nafion®/PI blends ranging from 6 wt% PI (NPI 6) to 30 wt% PI. Nafion® on left.



Prof. Kwang Kim, Science PI,
University of Nevada, Las Vegas



Dr. Kumar Krishen,
NASA Technical Monitor,
Johnson Space Center

Figure 2

Web-Scale Assisted Robot Teleoperation

Brown University/NASA Glenn Research Center, Ames Research Center, Goddard Space Flight Center, Space Technology and Science Mission Directorates

Computer vision applications have gained significant popularity in mobile, battery powered devices. While the image processing required by these applications may be transferred to the cloud, because of real-time computing requirements and limited data transfer capabilities, it is desirable for computation to be handled locally whenever possible.

Feature detection and feature description are key building blocks of many computer vision algorithms, including image retrieval, object detection, tracking, motion estimation and 3D reconstruction. Efficient feature extraction and description are crucial due to the real-time requirements of such applications over a constant stream of input data. High-speed computation typically comes at a cost of high power

dissipation. Therefore a computationally efficient means of detection and analysis of image features is a critical first step in the development of energy-efficient, single-chip solutions for these applications.

We compare embedded CPU-based, GPU-accelerated, and FPGA-accelerated embedded platforms and explore the implications of various architectural features for the acceleration of these fundamental computer vision algorithms. We show that, due to its extra customization and flexibility, our FPGA-accelerated implementation in particular offers attractive solutions for both performance and power, with a 98% power advantage over the CPU implementation and a 90% over a GPU implementation. *



*Dr. R. Iris Bahar
Science PI
Professor, Brown University*



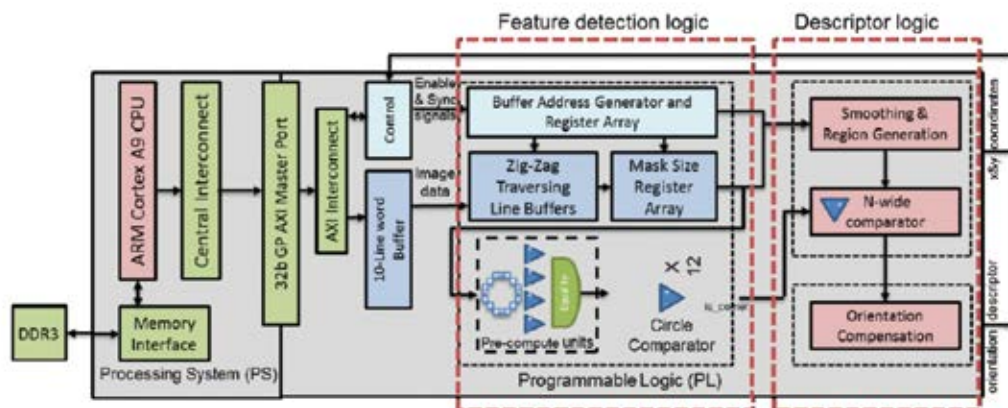
*Dr. Kimberly A. Hambuchen,
NASA Technical Monitor*

Block diagram representing the main functional components of the feature detection and description algorithms implemented on the Xilinx Zynq board. The red dash block indicated computation implemented on the reconfigurable FPGA logic.

	FPGAs		GPUs	
	Xilinx Virtex 6	Xilinx Zynq 7020	1532 core NVIDIA GeForce GTX 680	192 core NVIDIA Jetson TK1
Power	15 W	<5W	195 W	<12W



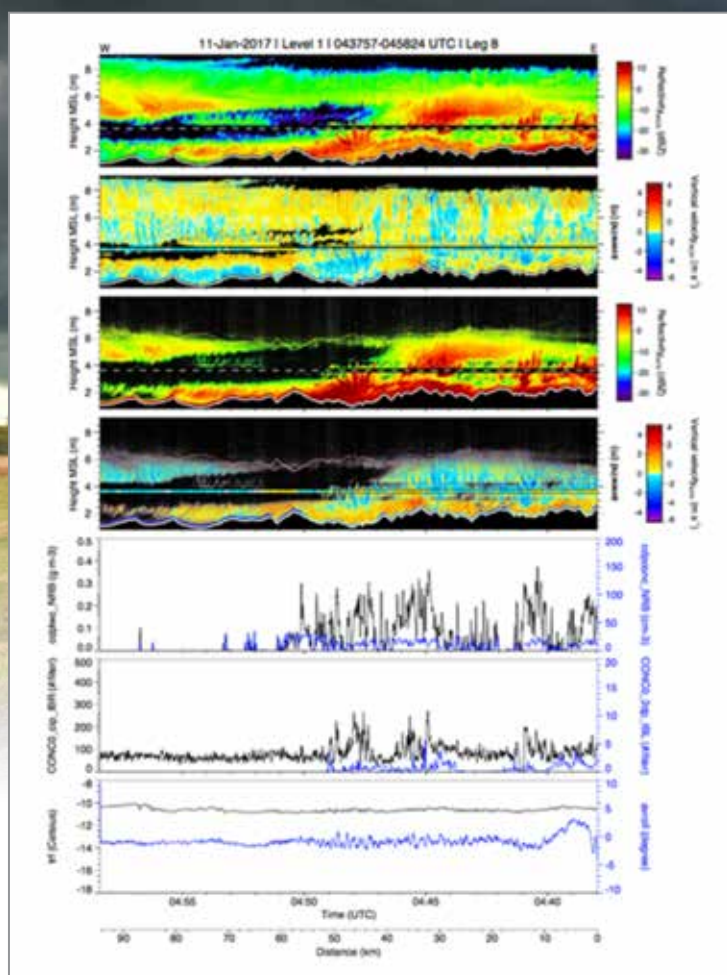
We compare embedded CPU---based, GPU---accelerated, and FPGA---accelerated embedded platforms and explore the implications of various architectural features for the acceleration of these fundamental computer vision algorithms. We show that, due to its extra customization and flexibility, our FPGA-accelerated implementation in particular offers attractive solutions for both performance and power, with a 98% power advantage over the CPU implementation and a 90% over a GPU implementation.



Research Capacity Building Using a New Dual-frequency Airborne Radar System in Support of NASA GPM and ACE Ground Validation Experiments

University of Wyoming/NASA Johnson Space Center, Glenn Research Center, Science Mission Directorate, Space Technology Mission Directorate

The Ka-band Profiling Radar (KPR) on the wing of the University of Wyoming King Air, together with several in situ cloud particle probes. This award funded the design, hardware, software, and deployment of the KPR.



Example of a vertical transect of WCR and KPR reflectivity and vertical velocity data along a flight leg through a winter storm, together with data from in situ probes. The strength of this proposal lies in the dual-frequency radar data in close proximity to cloud and precipitation particle measurements.

Science PI: Dr. Bart Geerts, University of Wyoming

NASA Technical Monitor: Dr. Walt Petersen, MSFC-ZP11

The Ka-band (1.2 cm) Profiling Radar (KPR), funded by this project, will be combined with the W-band (0.3 cm) WCR (Wyoming Cloud Radar) whose profiling capability was funded by a previous NASA EPSCoR grant. The signal returned to the radar receiver (radar reflectivity) is attenuated differently by cloud and precipitation particles at these two frequencies. The basic principle of dual-frequency radar measurements, as used on the NASA GPM (Global Precipitation Measurement) mission, is that the difference in reflectivity between the two radars relates to precipitation rate and other cloud properties along the path between the radar and the target. Our measurements will allow the evaluation and improvement of dual-frequency algorithms, not so much for NASA GPM, but rather for the future NASA ACE (Aerosol, Clouds, and Ecosystems) mission, which will use exactly the same radar pair (Ka and W bands).

The platform used for this work in the UW King Air (UWKA) research aircraft. This platform has been used for many years, mainly for NSF-funded projects (Fig. 1). The WCR nadir port (Fig. 2) was funded by a previous NASA EPSCoR grant (Geerts, PI, 2001-2004). The KPR will be mounted on the aircraft's right wing. ✱

TA5

COMMUNICATIONS, NAVIGATION, AND ORBITAL DEBRIS TRACKING AND CHARACTERIZATION SYSTEMS

TA 5 supports all NASA space missions with the development of new capabilities and services that make missions possible and safe. NASA's space communications and navigation infrastructure provides the critical lifeline for all space missions. It is the means of transferring commands, spacecraft telemetry, mission data, and voice for human exploration missions, while maintaining accurate timing and providing navigation support. Orbital debris can be tracked and characterized by some of the same systems used for spacecraft communications and navigation, as well as by other specialized systems. Advancements in communications and navigation technologies will allow future missions to implement new and more capable science instruments, greatly enhance human missions beyond Earth orbit, and enable entirely new mission concepts. This will lead to more productivity in science and exploration missions, as well as provide high- bandwidth communications links that will enable the public to be a part of NASA's exploration and discovery programs. Orbital debris tracking and characterization systems can be improved using radio frequency and optical techniques similar to those used in communications and navigation systems, as well as other dedicated systems, and will make crewed and robotic missions in Earth orbit safer for longer durations.

p24 A New Paradigm for Efficient Space Communications: Rateless Coding with Unequal Error Control and Data Fusion



A New Paradigm for Efficient Space Communications: Rateless Coding with Unequal Error Control and Data Fusion

University of Mississippi/NASA Jet Propulsion Laboratory, Goddard Space Flight Center, Science Mission Directorate

University of Mississippi and Jackson State University, with scientists in Jet Propulsion Laboratory, have established a site of Broadband Wireless Access and Applications Center (BWAC) through a 2015 NSF grant and successfully hosted a BWAC workshop at Oxford, Mississippi. A number of collaborative projects have been started with companies including Intel, Qualcomm, Raytheon and X2 Biosystems. Three new courses at the graduate level have been developed, and four undergraduate students have been supported to gain hands-on research experience in coding, signal detection and wireless networks. Specific to this NASA project, techniques to improve both the quantity and quality of information obtained through deep space exploration are being developed. Fountain codes are being designed that may result in substantial improvements in data transmission over the space-to-earth channel, and strategies utilizing the improvements to increase the rate of image collection are being developed. Efficient methods of fusing data to improve the quality of information derived from the collected data are also being developed. The research has generated interesting outcomes that are documented in both journal and conference publications. ✨



Meeting at JPL. From left to right: Drs. Kenneth S. Andrews, Ramanarayanan Viswanathan, John N. Daigle, Jon Hamkins, Dariush Divsalar and Lei Cao.



NSF I/UCRC Broadband Wireless Access & Application Center (BWAC) workshop, University of Mississippi, Nov. 3, 2015.



*Dr. Lei Cao, Science PI,
Associate Professor,
University of Mississippi*



*Jon Hamkins, Ph.D.,
NASA Technical Monitor,
Supervisor, Information Processing
Group Communications Architectures
and Research Section
Jet Propulsion Laboratory*

https://engineering.olemiss.edu/~lcao/research/NASA_index.html

TA6

HUMAN HEALTH, LIFE SUPPORT, AND HABITATION SYSTEMS

TA6

This roadmap provides a summary of key capabilities and technologies for the Human Health, Life Support, and Habitation Systems TA, which include game-changing or breakthrough items. These capabilities and technologies are deemed necessary to achieve predicted national and Agency goals in space over the next few decades. The sub-TAs included in the roadmap are Environmental Control and Life Support Systems (ECLSS) and Habitation Systems; Extravehicular Activity (EVA) Systems; Human Health and Performance (HHP); Environmental Monitoring, Safety, and Emergency Response (EMSER); and Radiation.



p26 A Vertical Comet Assay for Measuring DNA Damage to Radiation

p27 ISS: Improved EVA Suit MMOD Protection Using STF-Armor Tm and Self-Healing Polymers

p28 A Paradigm-Shifting Therapy for Mitigating Cellular and Tissue Damage in Humans Exposed to Radiation

p29 Joint Leak Detection and Localization Based on Fast Bayesian Inference from Network of Ultrasonic Sensors Arrays in Microgravity Environment

p30 GEANT4 Simulations for Astronaut Risk Calculations

p31 ISS: Space Flight Demonstration of a Radiation Tolerant, FPGA-Based Computer System on the International Space Station

p32 Multi-Purpose Research Station in North Dakota in Support of NASA's Future Human Missions to Mars

p33 Large Volume Crystal Growth of Superoxide Dismutase Complexes in Microgravity for Neutron Diffraction Studies

p34 Enabling Technologies for Water Reclamation in Future Long-term Space Missions: Wastewater Resource Recovery for Energy Generation

p35 Mechanical Unloading and Irradiation-induced Musculoskeletal Loss and Dysfunction: Molecular Mechanisms and Therapeutic Nanoparticles

p36 ISS: Time Course of Microgravity-Induced Visual Changes

p37 ISS: Demonstration of the OSU Tissue Equivalent Proportional Counter for Space Crew Dosimetry Aboard the ISS

p38 Characterization and Modeling of Biofilm Development by a Model Multi-species ISS Bacterial Community

p39 Development of Dust Free Binders for Spacecraft Air Revitalization Systems

p40 Novel Smart Skin Biomedical Sensor for Monitoring Crew Health Parameters in a Wireless, Passive, Lightweight, Robust, and Non-invasive Fashion

p41 Experimental and Numerical Investigation of Terrestrial Stable Cool Flames for Improved Understanding of International Space Station Droplet Combustion Experiments

p42 ISS: Elucidating the Ammonia Electrochemical Oxidation Mechanism via Electrochemical Techniques at the International Space Station

A Vertical Comet Assay for Measuring DNA Damage to Radiation

University of Alaska/NASA Glenn Research Center, Human Exploration and Operations Mission Directorate, International Space Station

New radiation technology helps researchers evaluate molecular damage. Radiation is bad. At its best, exposure causes sickness while at its worst it undermines the health of DNA, mutating healthy DNA strands into cancerous ones. However, before cells turn rogue, they exhibit signs of change. DNA strands within cells begin to break. The more strand breaks, the likelier the chance of excessive (and permanent) damage.

Examining the impact of radiation on an individual is often a cumbersome and time-consuming endeavor. Current methods demand a laboratory. However, researchers at the University of Alaska Fairbanks are developing portable, time-saving technologies

that will allow researchers to measure DNA damage in the field.

In the first year of a three-year NASA EPSCoR project, scientists have developed new testing procedures and mechanical prototypes to determine radiation damage to DNA. The ability to easily and accurately determine the level of damage at the molecular level is a necessity across a wide-range of circumstances: astronauts engaged in exploratory missions, marine biologists off the coast of Alaska investigating the health of aquatic life post-Fukushima, and armed forces personnel exposed to radiation at nuclear storage sites. Developing such simple and sensitive technologies will impact industry and research around the globe. ✨



Robert Williams, a graduate student assistant, assembles the early prototype at the team's laboratory inside the University of Alaska Fairbanks.



*Cheng-fu Chen,
Science PI,
University of Alaska,
Fairbanks*



*Dr. Yuri Griko,
NASA Technical Monitor,
Ames Research Center,
Life Science Division*

Improved EVA Suit MMOD Protection Using STF-Armor™ and Self-Healing Polymers

University of Delaware/NASA Johnson Space Center, Human Exploration & Operations and Space Technology Mission Directorates



Prof. Norman J. Wagner,
Science PI,
University of Delaware



Willie Williams,
NASA Technical Monitor,
Johnson Space Center



As NASA propels science, technology and exploration forward, the need for spacesuits composed of lightweight, long-lived and flexible materials becomes increasingly urgent. In space, micrometeorites and orbital debris (MMOD) can compromise the air barrier of a space suit, causing pinhole punctures that are difficult to identify and repair. Our work focuses on developing healing materials capable of regenerating functionality after damage. In our approach, we are synthesizing fundamentally new, self-healing polymers in which a dynamic bond is built into the network architecture to enable a light-activated secondary polymerization, increasing the modulus by two orders of magnitude and strengthening the network by over 100%. This work has been recently published in *Advanced Materials* (2015, 27, 8007–8010). We demonstrated that the material can be completely severed and then remended with increased material strength and no visible scarring. Moreover, our approach confines healing and strengthening to the damaged area; thus, an EVA suit could maintain flexibility in unaffected areas. By developing healing polymer networks, the safety and service lifetime of the material are enhanced. This material was selected by NASA to be tested on the exterior of the International Space Station in 2017 to test its response the extreme environment of outer space. ✨

<http://video.pbs.org/viralplayer/2365517750/?chapter=3>

<https://www.acs.org/content/acs/en/acs-webinars/technology-innovation/fluids.html>

<http://www.delawareonline.com/story/life/did-you-know/2015/03/03/liquid-armor21university-delawares-innovation/24354971/>

A Paradigm-Shifting Therapy for Mitigating Cellular and Tissue Damage in Humans Exposed to Radiation

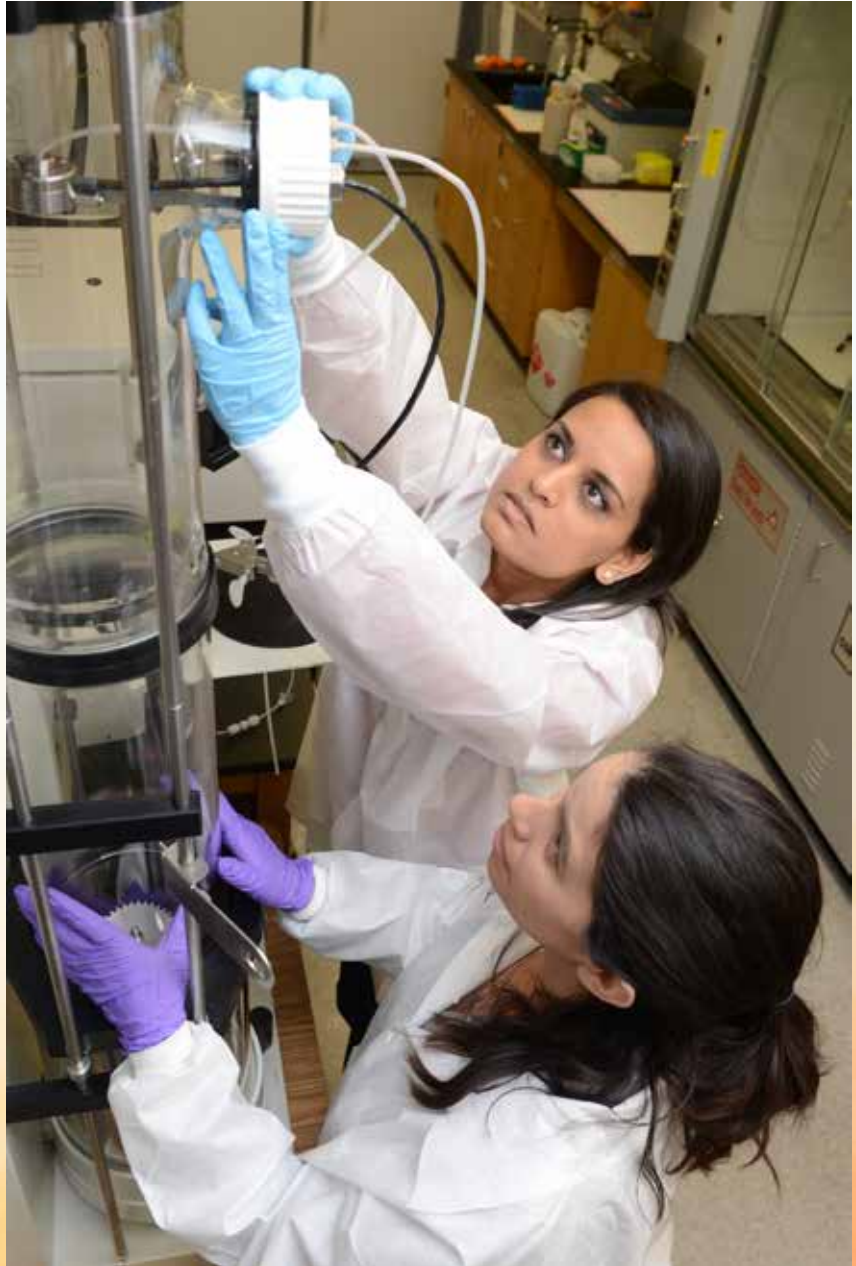
University of Louisville/NASA Johnson Space Center, Human Exploration & Operations Mission Directorate

As humans inhabit space for longer periods of time and prepare to explore Mars, critical safety challenges must be addressed. Important among these are effects of space radiation on the human body. Researchers at the University of Louisville are examining techniques for mitigating damage from exposure to space radiation through medical therapies that deliver radio-protective agents via precise drug-delivery methods utilizing nanotechnology. Ensuring the safety of astronauts exposed to increased amounts of ionizing radiation beyond Earth's magnetosphere is a major technical challenge for NASA, with potential application to Earth-based situations such as nuclear power plant disasters.

The research conducted under this grant has provided educational and research opportunities for undergraduate, graduate, and post-doctoral students in multiple disciplines at the University of Louisville. Due to the interdisciplinary nature of this research, students in bioengineering, pharmacology and toxicology, and chemistry have all participated in this work. This advanced training has provided a stepping stone for two students to receive internships at Johnson Space Center. This past year one of these students was selected for a National Space Biomedical Research Institute internship at Johnson Space Center, where he examined the effects of radiation on chromosomes. The student was able to learn techniques during his internship that have been beneficial to the goals of this project and helped foster new collaborations. ✨



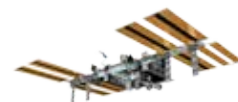
*Dr. Thomas Goodwin, Ph.D.,
NASA Technical Monitor,
Johnson Space Center*



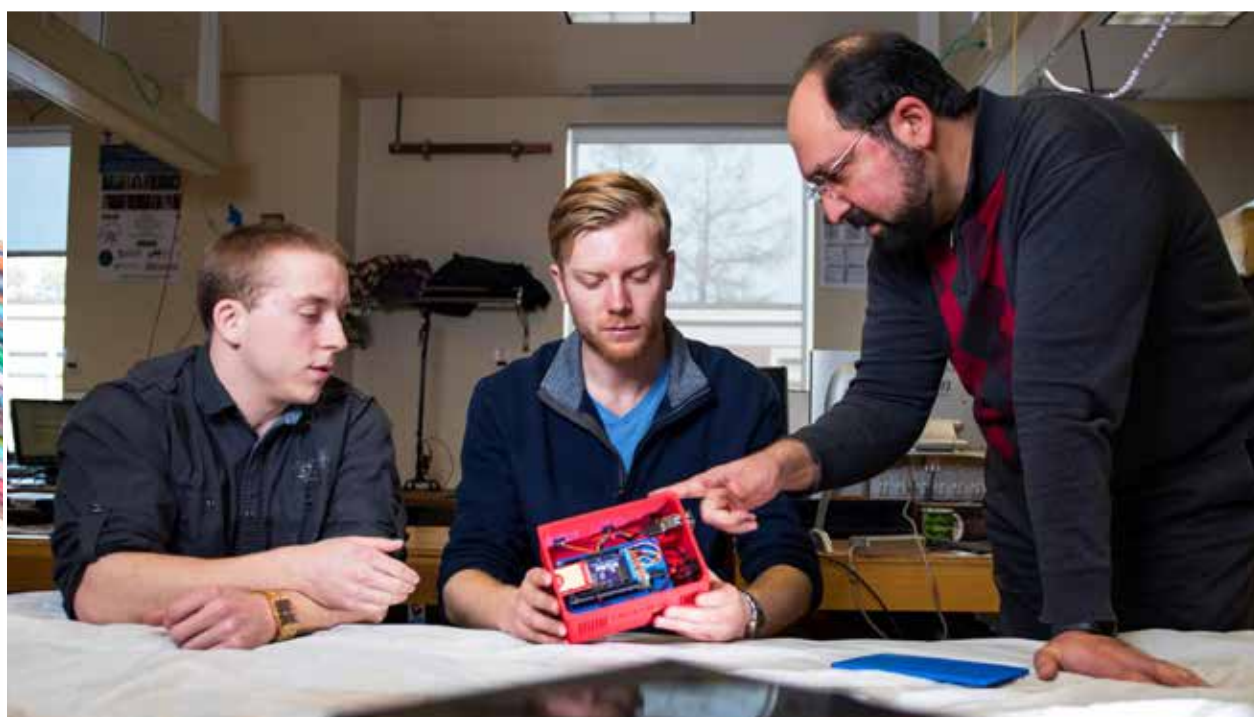
Dr. Patricia Soucy, Primary Science Investigator, Assistant Professor, and graduate student Ishita Jain of the University of Louisville use a Spray Dryer to prepare nanoparticles for a NASA EPSCoR research project investigating new therapies to treat human exposure to radiation, such as the exposure astronauts may experience during long-term space travel.

Joint Leak Detection and Localization Based on Fast Bayesian Inference from Network of Ultrasonic Sensors Arrays in Microgravity Environment

University of Maine/NASA Johnson Space Center, Human Exploration & Operations Mission Directorate



Leaks causing air and heat loss are a major safety concern for astronauts. A wireless leak detection system created by University of Maine researchers is scheduled to board a SpaceX rocket bound for the International Space Station in August 2016. The prototype, which was tested at the Wireless Sensing Laboratory (WiSe-Net Lab), will lead to increased safety of space missions. Electrical engineering graduate students Casey Clark and Lonnie Labonte will test the payload at NASA Johnson Space Center in Houston, Texas in April 2016. The project involves the development of a flight-ready wireless sensor system that can quickly detect and localize leaks based on ultrasonic sensor array signals. The device has six sensors that detect the frequency generated by the air as it escapes into space and triangulates the location of the leak using a series of algorithms including stochastic signal processing and estimation theory principles. The device then saves the data on a SD cards that are sent back to Earth. The device is fast, accurate and capable of detecting multiple leaks and localizing them with a lightweight and low-cost system. ✱



From Left: Lonnie Labonte of Rumford, ME (PhD Student, Payload Engineer), Casey Clark of Old Town, ME (MSEE Student, Project Manager), and Professor Ali Abedi (Science PI).



*Willie Williams,
NASA Technical Monitor,
Johnson Space Center*

<https://umaine.edu/wisenetlab>

<http://sites.ieee.org/wisee/>

<http://phys.org/news/2016-04-wireless-leak-bound-international-space.html>

<https://umaine.edu/news/blog/2016/04/14/umaine-researchers-wireless-leak-detection-system-bound-international-space-station/>

GEANT4 Simulations for Astronaut Risk Calculations

University of Southern Mississippi/NASA Marshall Space Flight Center,
Human Exploration and Operations Mission Directorate

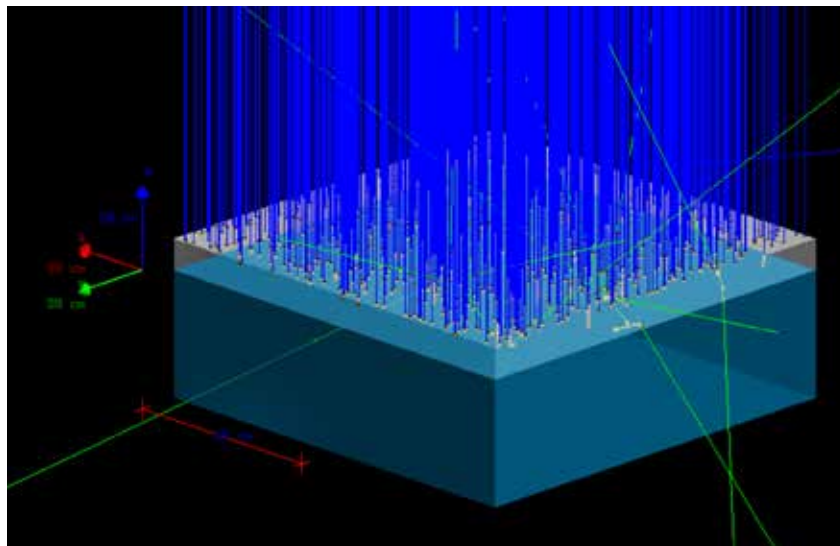


Figure 1: A visualization of solar particle event protons incident on an aluminum shield as visualized using Geant4 software. The particles emitted from the shield were recorded for input to a Geant4-DNA simulation.

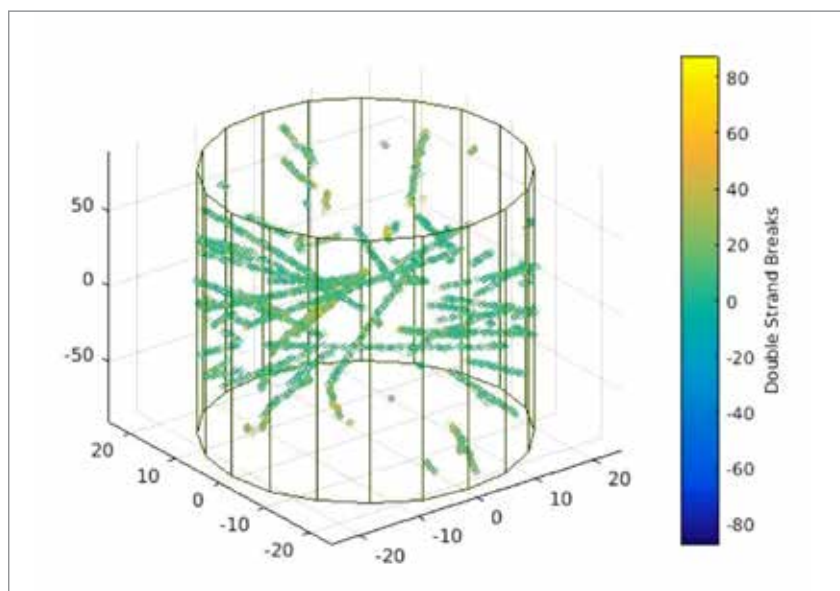
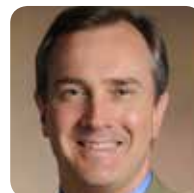


Figure 2: Double-strand DNA break positions in a cylindrical water phantom for 100 incident particles sampled from radiation emitted from a spherical aluminum shield under SPE proton irradiation.

The effects of radiation on astronaut health are among the principal drivers of risk for longduration space missions. Assessing this risk is typically based on calculating expected astronaut radiation exposures, for example from solar particle events (SPEs) or galactic cosmic rays (GCRs), and then correlating the dosage received to cancer incidence and mortality rates. This project seeks to extend radiation risk analysis all the way to the impact on an astronaut's DNA. Newly developed mathematical models for DNA and DNA-chemistry are being implemented in radiation simulation software known as Geant4. Simulations run in Geant4 can track direct damage to the DNA structure or the radiation-induced formation of free radicals and free electrons that can also damage DNA. Rather than only correlating risk with dose, this approach seeks to correlate risk with specific DNA damage mechanisms. The figures below help to illustrate how this approach works. Figure 1 depicts the impact of SPE protons on an aluminum shield. Geant4 simulates the radiation that is emitted from the shield, and records it for input to Geant4-DNA simulations. Figure 2 depicts the positions of significant DNA damage along particle tracks emitted from the shield and incident on a simple water "phantom". ✴



Dr. Chris Winstead, Science PI,
Professor and Chair,
Department of Physics
and Astronomy,
University of Southern Mississippi



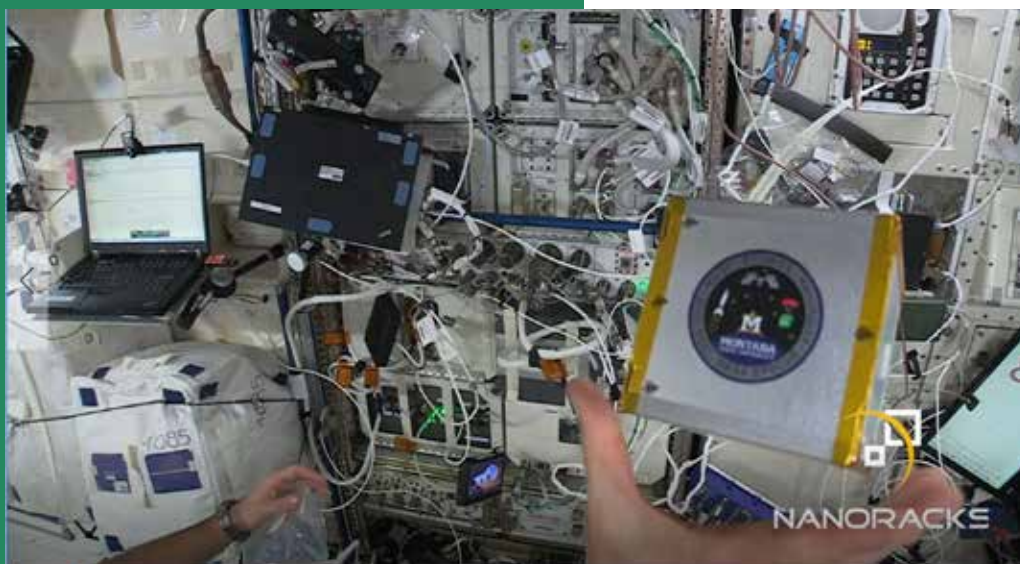
Dr. Kerry Lee,
NASA Technical Monitor,
Johnson Space Center

Space Flight Demonstration of a Radiation Tolerant, FPGA-Based Computer System on the International Space Station

Montana State University – Bozeman/NASA Marshall Space Flight Center, Glenn Research Center, Human Exploration & Operations and Space Technology Mission Directorates



MSU's Radiation Tolerant Computer System has launched and is aboard the ISS! The project, named "Radiation Tolerant computer Mission on the International Space Station" (RTcMISS, pronounced Artemis) flew on the Japanese's Aerospace Exploration Agency's (JAXA) H-II Transfer Vehicle (HTV). The HTV is an unmanned cargo spacecraft that delivers supplies to the ISS. HTV-6 arrived at the ISS on December 14th. It was grabbed by the Canadarm2 and berthed to the bottom side of "Harmony" (Node 2). The ISS crew unloaded the capsule and stowed the experiments. Artemis is now plugged into its experiment frame and is collecting data. This experiment is about the size of a Rubik's Cube and contains a logo designed by a 2nd grade class in Bozeman (both pictured). MSU is hoping to get data back before the new year.



Researchers at Montana State University developed an experiment currently on the International Space Station that will demonstrate a new type of computer technology that can withstand the harmful effects of radiation. RTcMISS uses a novel approach to mitigating radiation-induced faults using spare processors that are continually reconfigured in real-time. This approach allows processors that are faulted by radiation to be repaired without halting the computer. This increases performance and improves reliability by giving the system backup processors it can rely on. The NASA EPSCoR program gave this program its initial start in 2010 through a research initiation grant and again by providing the means to reach its highest level of maturation by going to the International Space Station. ●



Willie Williams,
NASA Technical Monitor,
Johnson Space Center



Dr. Brock J. LaMeres,
Science PI,
Associate Professor,
Montana State University

SRMS captures KOUNOTORI6 Carrying MSU's Artemis. Onboard astronaut Shane Kimbrough captured KOUNOTORI6 with the station's robotic arm (Space Station Remote Manipulator System: SSRMS) at 3:39 a.m. (MST), December 13. KOUNOTORI6 was transferred and berthed to Harmony (Node 2).



<http://www.abcfxmontana.com/story/34283253/msu-has-invaded-the-international-space-station>

<http://www.montana.edu/news/16665/msu-researchers-test-computer-technology-on-international-space-station>

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

University of North Dakota/NASA Kennedy Space Center, Human Exploration & Operations Mission Directorate

The University of North Dakota (UND) Human Spaceflight Laboratory is working to develop a Multi-Purpose Research Station in North Dakota designed to expand NASA-relevant research opportunities for faculty within the state, as well as project collaborators. The new project received a 3-year NASA EPSCoR grant to add four additional modules to the existing habitat.

The research includes a collaborative effort between numerous departments throughout UND campus and several 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). So far, three crewed analog missions were completed, the most recent being a ten-day isolation mission with an all-female crew in April 2016.

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

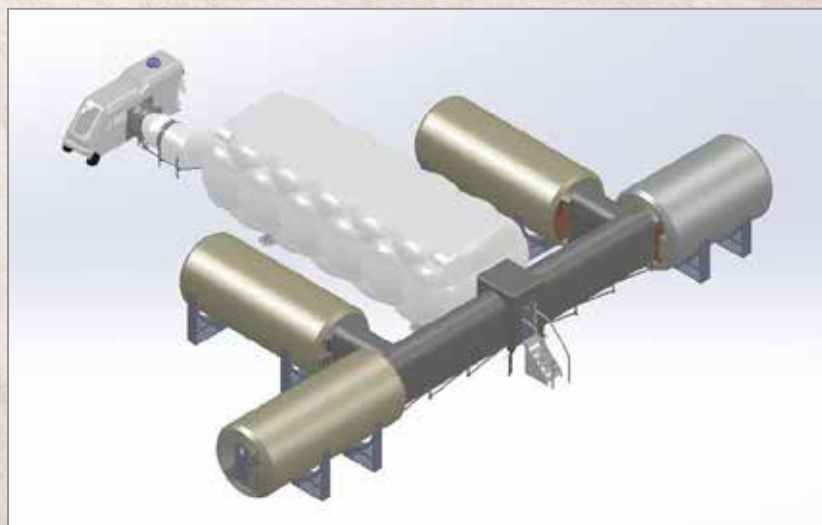
These factors make North Dakota an optimal location for these simulation studies so integral to NASA's preparation for deep space missions. This permanent experimental station will help our next generation of explorers reach new worlds beyond Earth. ✨



*Dr. Pablo de León,
Science PI,
Associate Professor,
University of North Dakota*



*Mr. Douglas Gruendel,
NASA Technical Monitor,
Kennedy Space Center*



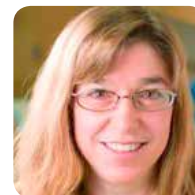
<http://www.human.space.edu/>

<http://und.edu/news/2016/04/all-female-habitat-team.cfm>

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

University of Nebraska/NASA Johnson Space Center, Human Exploration & Operations Mission Directorate, International Space Station

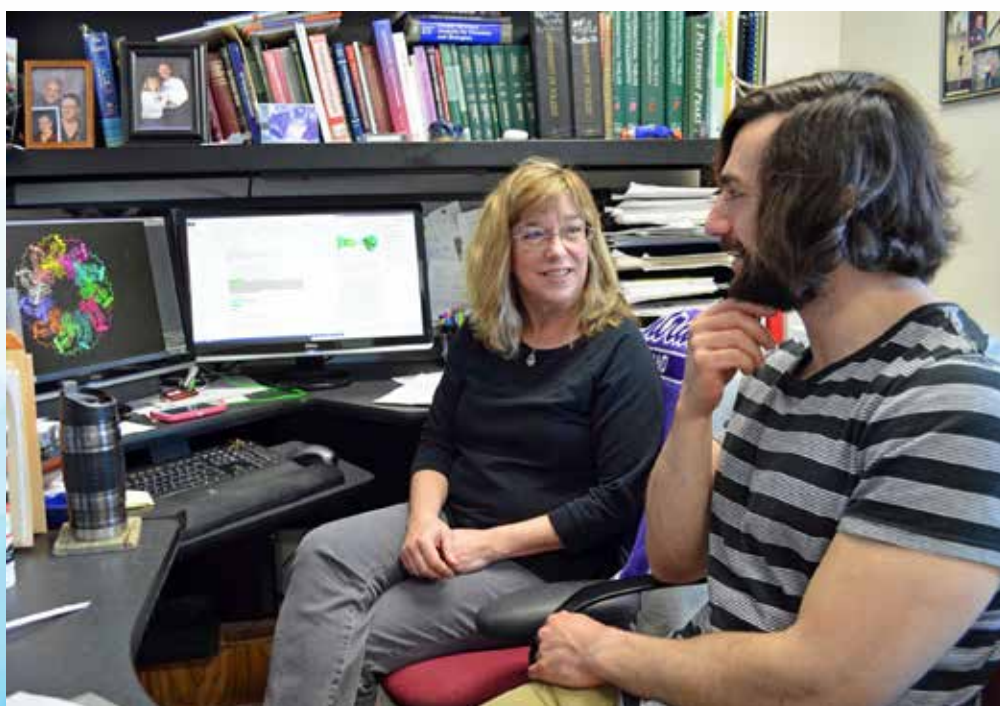
Radiation on earth and that encountered by astronauts and natural cellular metabolism produce reactive oxygen species (ROS) that damage the macromolecules of life and deteriorate human health. This research studies how the macromolecular defenders, or enzymes, within our bodies protect us against ROS and protect us from disease. This research will reveal the atomic basis for the enzymatic mechanisms of protection. This basis will be provided with neutron crystal structures. Outstanding progress has been made towards the purification of the enzymes in large quantity and the growths of the extremely large crystals, that are essential for our overall goal, have been achieved. Importantly, a team of technical staff and students has been assembled for the project. In the future the microgravity environment on ISS will allow us to grow large volume crystals for this project that will be of superior quality to crystals grown on Earth. ✨



*Gloria Borgstahl, Ph.D.,
Science PI,
Professor, Eppler Institute,
University of Nebraska Medical Center*



*Sridhar Gorti, Ph.D.,
NASA Technical Monitor,
Marshall Space Flight Center*



Dr. Gloria Borgstahl and her doctoral student Jahaun Azadmanesh discussing structural biology with the aid of computer graphics in her office at UNMC.

Enabling Technologies for Water Reclamation in Future Long-term Space Missions: Wastewater Resource Recovery for Energy Generation

University of Puerto Rico/NASA Ames Research Center, Human Exploration & Operations and Space Technology Mission Directorates



Prof. E. Nicolau, Science PI, and Graduate student Perla Cruz working on next-generation water purification membranes for NASA exploration missions at UPR's Molecular Sciences Research Center.



Dr. Michael Flynn, NASA Technical Monitor, Ames Research Center

The research goal of this project is to develop multifunctional water purification membranes for the removal of contaminants from wastewater. These membranes are fabricated with dual function to withstand bacterial growth and also serve as a catalytic platform. The purpose of this is to generate purified water while generating electricity and other valuables from wastewater, but also preventing membrane biofouling to achieve long-term operation.

This project is performed in direct collaboration with the NASA Ames Research Center and is aligned to the Human Exploration and Operations Mission Directorate that states as a goal: to perform basic research proving new insights into problems affecting people on the Earth and understanding and developing the systems and protocols necessary for humans to venture beyond low Earth orbit for extended durations.

Through this project, we have been able to leverage our previous efforts in the area of water purification while generating electrical

current as a next-generation of technology to support life on earth and beyond. This project has enabled the acquisition of state of the art instrumentation that is unique to the University of Puerto Rico at Rio Piedras campus. This allows for collaborations with other researchers in Puerto Rico and Mainland U.S. Moreover, the instrumentation acquired is of interest to the local industry, thus opening up new venues for collaboration and possible revenues for reinvestment. Last but not least, students working on this project have been able to successfully compete for other research opportunities, such as fellowships and internships.

This NASA EPSCoR project was featured in the local newspaper El Nuevo Dia on April 16, 2016. This is the newspaper with the highest circulation in PR and the article exposed to the general public part of the work that that corresponds to this NASA EPSCoR project. ✨

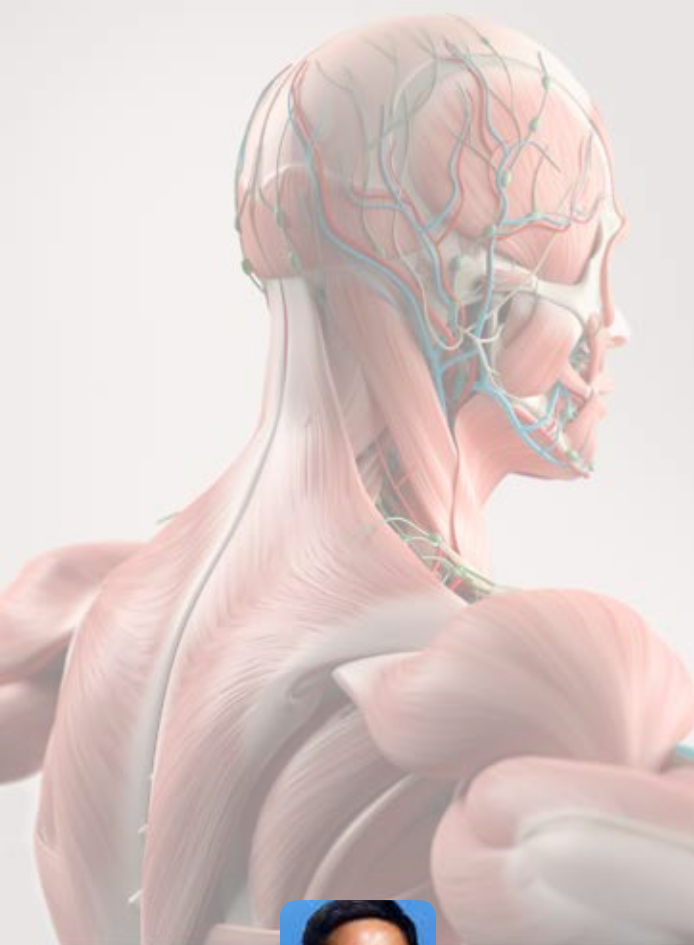
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Mechanical Unloading and Irradiation-induced Musculoskeletal Loss and Dysfunction: Molecular Mechanisms and Therapeutic Nanoparticles

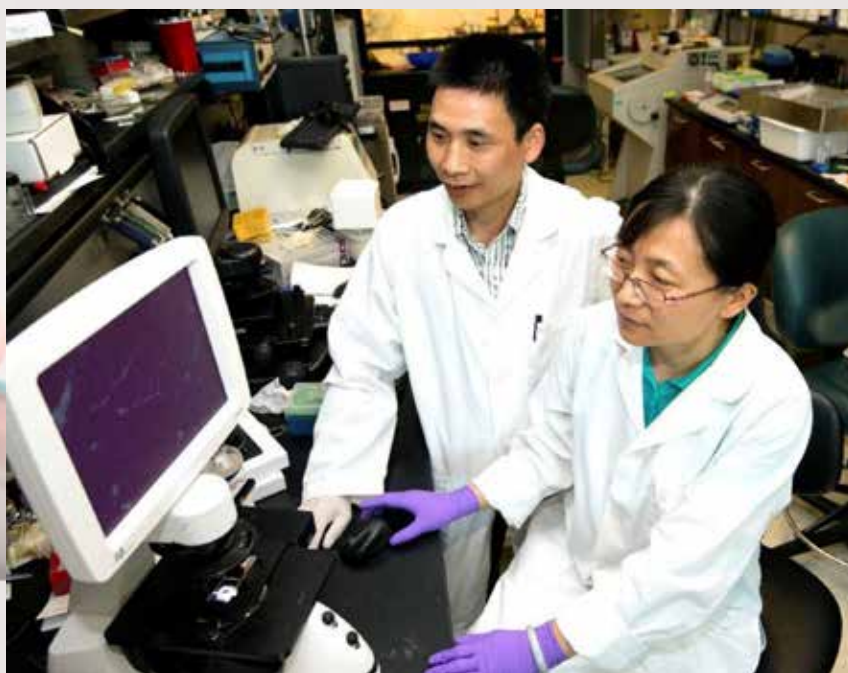
West Virginia University/NASA Johnson Space Center, Marshall Space Flight Center

The occupational health of astronauts has great impacts not only on their life quality, but also on human's capability to accomplish space exploration missions. They work under a dangerous and extreme environment, expose to radiation and microgravity, and have limited access to medical resources. Supported by NASA EPSCoR, we have identified three compounds, including cerium oxide nanoparticles, zinc oxide nanoparticles, and acetaminophen, having beneficial

effects on the attenuation of musculoskeletal loss associated with space risk factors. Our findings have been published at peer review journals, including the Cellular Physiology and Biochemistry and the Journal of Occupational Health, and presented at professional conferences including Health Physics Society 60th Annual Meeting and Safety 2016 Annual Meeting. The grant helps us developing productive collaboration with industry (Akina, Inc.) and professional society (Bioscience Association of West Virginia), and advances our R&D capabilities. In addition to our scientific and technical achievements, the EPSCoR grant greatly promotes our STEM education and research interests: new course (Space Biology and Nanomedicine) has been developed, four junior faculties have been supported to develop their research career, and twelve students and trainees have been successfully trained to possess research skills in space biology and medicine. ✨



*Dr. Honglu Wu,
NASA Technical Monitor,
Johnson Space Center*



*Science PI Dr. Miaozong Wu (left) and postdoctoral fellow
Dr. Cuifen Wang (right) discuss research findings.*

ISS: Time Course of Microgravity-Induced Visual Changes

Geisel School of Medicine at Dartmouth/NASA Johnson Space Center, Marshall Space Flight Center, Human Exploration & Operations Mission Directorate



This research project will allow us to measure the time course of the changes to the length of the eye (axial length) in space. The mechanism for the axial length changes in space is unknown, and we are using numerical modeling to develop hypotheses about how these changes could occur. One key missing element in the model, however, is the time course for the changes. It is not known if axial length changes are linear or nonlinear over time. Different time courses suggest different mechanisms for the changes, and so critical axial length information must be known to build an accurate model. Our project aims to provide a simple, on-orbit way to track changes in axial length. As the length of the eye changes, the location where light focuses in the eye changes. We plan to measure this using a portable autorefractor (a type of device often used in the eye clinics to determine the prescription strength needed for glasses). Sending this type of device to the International Space Station will enable us to measure and understand how the length of the eye changes in space and to determine the time course of those changes. Additionally, the autorefractor could be used as a clinical tool by NASA flight medicine to help evaluate astronauts' vision and determine changes to their glasses prescriptions. ✨



Kseniya Masterova making an eye measurement with an autorefractor in the prone position. We are using the prone position to make the autorefractor measurements since staying in this posture can cause small changes in the length of the eye, similar to what happens in space.



Jay C. Buckey, M.D.,
Science PI,
Professor of Medicine,
The Geisel School of Medicine
at Dartmouth



Willie Williams,
NASA Technical Monitor,
Johnson Space Center



Demonstration of the OSU Tissue Equivalent Proportional Counter for Space Crew Dosimetry Aboard the ISS

Oklahoma State University, NASA Human Exploration and Operation Mission Directorate, International Space Station, NASA Johnson Space Center



Exposure of astronauts to elevated levels of ionizing radiation is one of the major hazards of spaceflight—especially long duration space missions such as the human exploration of Mars. Real time monitoring of the radiation levels that space crews are exposed to will be essential on human exploration missions. The Active Tissue Equivalent Dosimeter (ATED) currently being developed by the Radiation Physics Laboratory at Oklahoma State University and scheduled for flight on ISS in late 2017 measures the absorbed dose and biologically weighted dose equivalent during space flight due to ionizing radiation exposure in space. Because the detector used in ATED is made of a plastic that is similar to tissue, its sensitivity to radiation is nearly the same as that of the human body. We are developing ATED to be a low cost, low power, compact instrument for use on a variety of both manned and unmanned spacecraft, as well as on high altitude aircraft and balloons. Data from ATED will enable mission planners to better estimate the radiation exposure of astronauts of future missions, as well as providing data on radiation levels aboard the ISS. ✨

OSU Grad Student Oliver Causey working on the ATED power supply.



Detector head (cylindrical canister), spectrometer, computer and power supply with ATED enclosure.



*Dr. Eric Benton, Science PI,
Associate Professor
Radiation Physics Laboratory
Oklahoma State University*



*Willie Williams,
NASA Technical Monitor,
Johnson Space Center*

Characterization and modeling of biofilm development by a model multi-species ISS bacterial community

Human Exploration and Operations Mission Directorate, International Space Station, Johnson Space Center, University of Vermont

All human habitation in space will take place in a non-sterile environment for two reasons: humans are colonized on every surface and mucosal membrane with upwards of 10,000 different bacterial inhabitants, and there are few surfaces and components that can withstand complete sterilization. In addition to being potential pathogens, bacteria provide important ecosystem functions in air, water, and soil that would be beneficial to exploit during long-term space travel and eventual off-world colonization. Therefore, it is imperative that we improve our understanding of these co-habitants on our space-going vessels. Colonization of spacecraft by bacteria is of particular interest for the systems involved in the water cycle including condensers, potable water dispensers, and storage containers. In these systems, the bacterial communities can form biofilms that persist and replicate despite substantial effort and cost involved in removal and monitoring. These water system biofilms are important for two different reasons: crew health and system engineering. From the standpoint of crew health, many bacteria that are common members of potable water communities are also opportunistic pathogens capable of causing infection if the immune system is compromised. From an engineering standpoint, growing biofilms can change water flow, surface roughness, and surface tension, interfering with proper operation of valves and regulators. These two aspects of the potable water biofilms will be magnified during long-duration space travel, where equipment must function properly for long durations and where the immune system of the crew will not be fully functional.

Prior work by a subset of our team focused on a low-mass bacterial biofilm eradication strategy using targeted ultrasound-assisted delivery of liposomes loaded with antibiotics to the biofilm. We have demonstrated killing of the majority of bacteria (>80%) on the surface and shown the primary mechanism is ultrasound-driven acoustic streaming and enhanced liposome penetration into the biofilm. During these investigations we made three key observations that lead to this proposed study: (i) the International Space Station (ISS) bacterial isolates can interact to form a reproducible community in vitro, (ii) the bacteria interact with each other to drive community biofilm formation, and (iii) the interactions between these bacteria and the complex and viscous biofilm matrix are amenable to examination using mathematical models.



*NASA Technical Monitor:
Dr. Mark Ott,
Johnson Space Center*

*Dr. Matthew J. Wargo,
Science PI,
University of Vermont, Burlington*

Given the issues related to bacterial biofilms during space flight, we must understand how complex microbial communities will develop and impact systems and astronauts. The mixed species community isolated from the ISS water reclamation system, including members of the *Sphingomonas*, *Burkholderia*, *Methylobacterium*, and *Ralstonia* genera provides our model of a bacterial community proven to survive and thrive during space flight. The specific project goals are to:

- (1) Characterize bacterial interactions between species in this community including community development in the absence of specific members.
- (2) Quantify bacterial species interactions using single-cell analyses to inform the computational models.
- (3) Develop three agent-based computational models that simulate (i) initial interaction and surface attachment, (ii) biofilm growth after initial attachment, and (iii) particle and diffusive movement through the biofilm.
- (4) Test aspects of the numerical models, including particle movement through the matrix and in situ removal of bacteria, using ultrasound-mediated particle delivery.

These studies will allow us to gain insights into both fundamental questions regarding bacterial biofilm communities and practical questions regarding the stability and resilience of biofilms, aiding in the development of improved mediation strategies for long-duration space travel. ✨

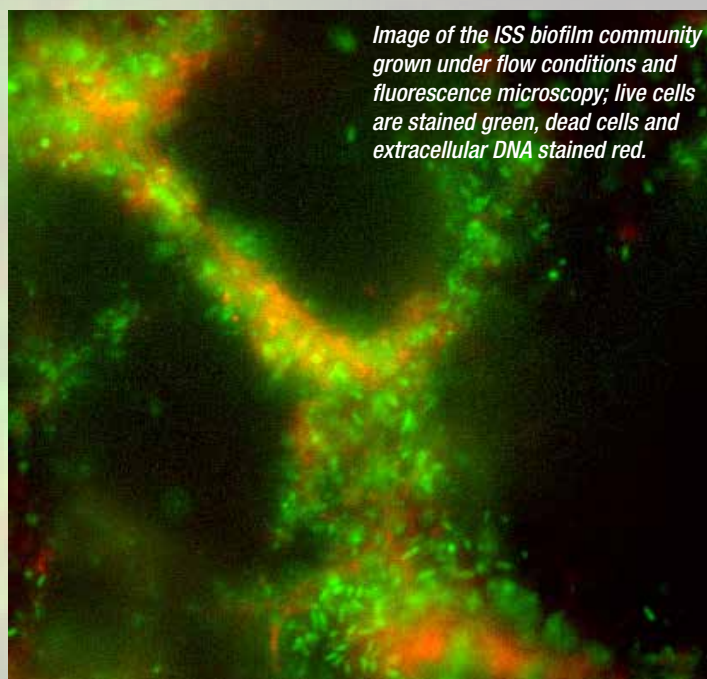
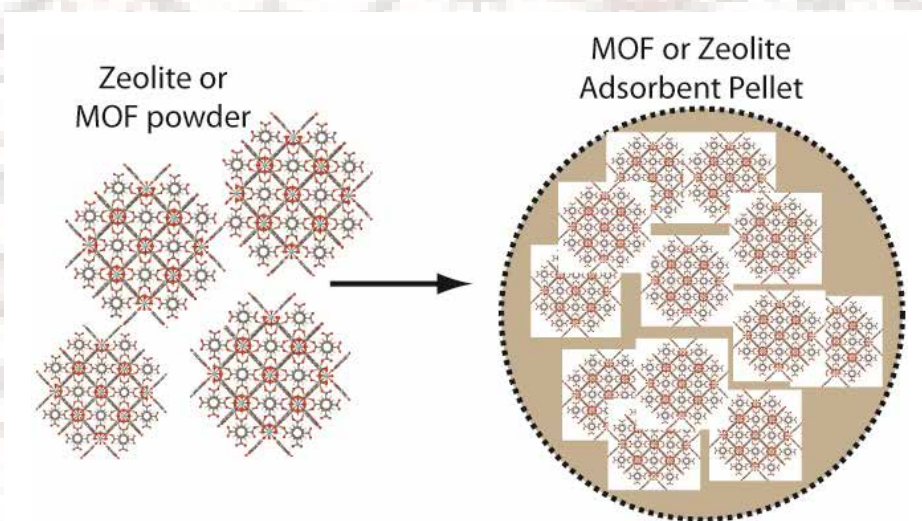


Image of the ISS biofilm community grown under flow conditions and fluorescence microscopy; live cells are stained green, dead cells and extracellular DNA stained red.

Development of Dust Free Binders for Spacecraft Air Revitalization Systems

T. Grant Glover University of South Alabama, Mobile, AL, Human Exploration and Operations Mission Directorate, NASA Johnson Space Center, Marshall Space Flight Center

The International Space Station's air revitalization system currently removes CO₂ from the station using adsorbent beds. Unfortunately, during operation the adsorbent pellets contained in the system breakdown and produce a fine dust that is carried downstream of the adsorbent bed and causes mechanical failures in the air revitalization system. Therefore, this project will develop binders for traditional zeolites and MOF adsorbent powders that will provide effectively zero dusting when regenerated numerous times under vacuum and heat. The work is collaborative with the Marshall Space Flight Center, the Johnson Space Center, the Ames Research Center, the University of Alabama, and the University of South Alabama. To eliminate dusting, adsorbent pellets will be formed using novel binder materials. The effectiveness of pellet at eliminating adsorbent dust will be quantified by measuring the pressure drop across an adsorbent bed containing the novel pellets during numerous adsorption and regeneration cycles. Novel adsorbent pellets will be provided to NASA for evaluation and it is anticipated that NASA scientists and the Glover Research Group will work collaboratively to produce academic publications detailing the results of this program. Additionally, the project will partner with existing University of South Alabama outreach programs to identify two students from underrepresented groups. The Glover Research Group will provide these students paid internships. Additional details about the Glover Research Group can be found at www.gloverresearchgroup.com ✱

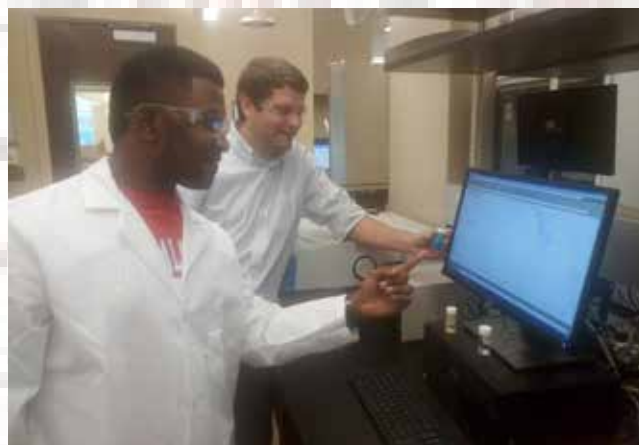


Adsorbent materials are commonly engineered into pellets. This project will investigate the production of binders for the formation of pellets that are more well suited for NASA's specific life support applications than current commercial products.



*T. Prof. Glover,
Science PI,
T. Grant Glover University of
South Alabama, Mobile*

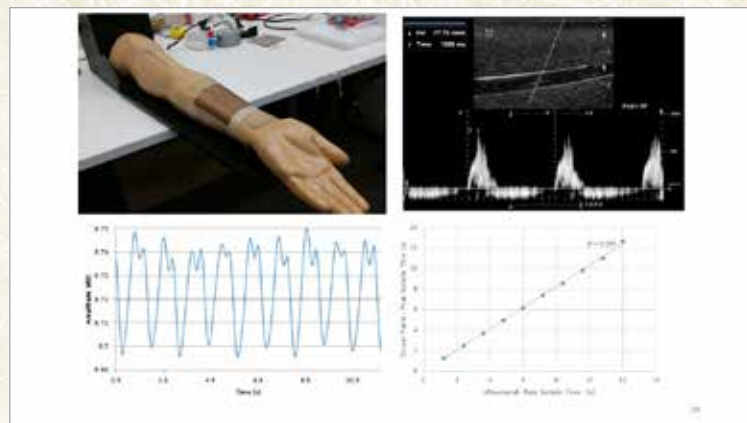
*NASA Technical Monitor:
Dr. John C. Graf,
Johnson Space Center*



Graduate student Aniebiet Udoh and Prof. Glover examine the FTIR spectra of a novel adsorbent material.

Novel Smart Skin Biomedical Sensor for Monitoring Crew Health Parameters in a Wireless, Passive, Lightweight, Robust, and Non-invasive Fashion

Wichita State University, Human Exploration & Operations Mission Directorate, Johnson Space Center, Langley Research Center, International Space Station



This project is focused on an innovative bio-monitoring sensor that may serve as a simple yet sophisticated method for monitoring multiple mission critical physiological parameters such as blood-flow, intracranial pressure, body temperature, blood gas concentration, and fitness of the EVA suit in a novel fashion. The objective of this proposal is to develop a bio-monitoring sensor which is passive (does not require batteries), robust and lightweight (does not have electrical components), and able to wirelessly monitor multiple physiological parameters related to astronaut health and performance. We will evaluate our central hypothesis that biological electrical and magnetic properties can be leveraged to detect physiological parameters using a novel micro-coil sensor - applied like a small adhesive bandage or woven into garments. Guided by promising preliminary data, we will attain the objective of this application by pursuing the following specific aims: Aim #1: Develop and achieve the necessary sensor impedance, capacitance, inductance, and sampling rate to measure physiological parameters on human tissue. Aim #2: Investigate the sensor capability to measure multiple physiological parameters such as intracranial pressure, blood flow, temperature, and blood gas CO₂. Aim #3: Determine if physiological parameters can be identified when subjects are wearing a Liquid Cooling Ventilation Garment (LCVG) and if the sensor can be used to measure how well the EMU suit fits to gauge performance. Broader Impacts of this proposal include: 1) new partnerships with industry and NASA personnel, 2) dissemination of

this work by offering an exhibit and educational sessions at the Kansas Cosmosphere and Space Museum, 3) a partnership with Project Lead the Way to provide a research experience for underrepresented high school students.

This project addresses NASA research interests in wearable health monitoring systems to address the gaps and risks that are critical to crew health and performance during long duration space missions. Specifically, our research fits well with the directives of the National Space Biomedical Research Institute to develop Smart Medical Systems and Technology. The capability to measure multiple physiological parameters in a single sensor is highly appealing because auxiliary resources are at a premium in a space station or in an EMU suit. This research may provide a foundation for a novel strategy for monitoring mission critical crew health parameters in point-of-care fashion. ☼



*Dr. Kim Cluff,
Science PI,
Assistant Professor,
Biomedical Engineering,
Wichita State University*

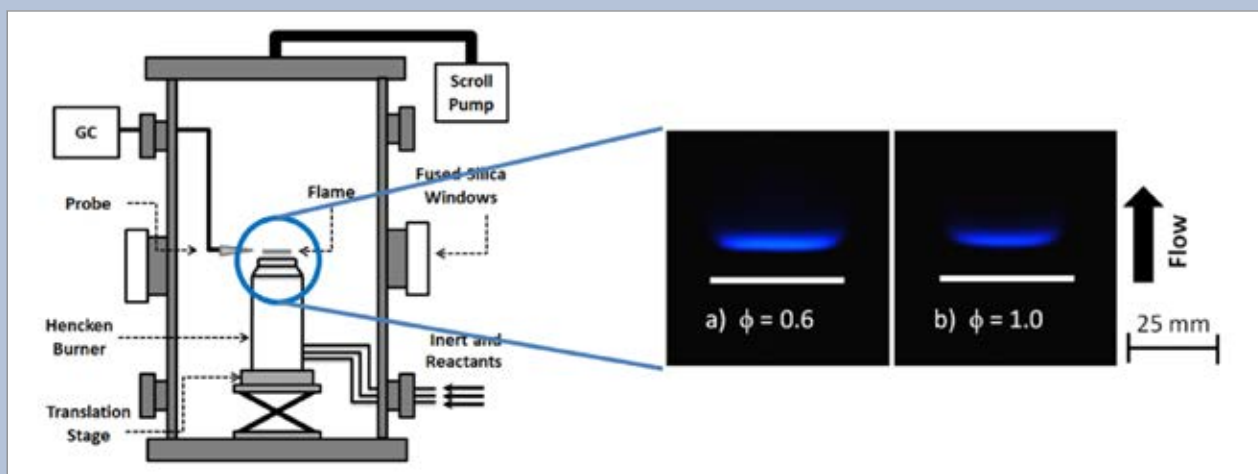


*Dr. Ali Shaykhian,
NASA Technical Monitor,
Kennedy Space Center*

Experimental and numerical investigation of terrestrial stable cool flames for improved understanding of International Space Station droplet combustion experiments

University of Wyoming, NASA Glenn Research Center,
Human Exploration & Operations Mission Directorate/International Space Station

The proposed research will utilize a flat flame burner facility constructed by the Science PI at the University of Wyoming (UW) and numerical modeling for the study of low temperature flames, called cool flames. This research will complement and provide terrestrial insights into ongoing research being conducted by the Combustion Branch at the NASA Glenn Research Center (GRC) on cool flame droplet experiments in microgravity aboard the International Space Station (ISS). The fuels that will be investigated include liquid alkane fuels, heptane and decane, which are important components and surrogates of logistical fuels. Furthermore, heptane and decane have been studied by GRC combustion researchers in ISS experiments because of their logistical importance. The proposed research will provide insights into the chemistry and stability of cool flames, including those aboard the ISS, using an experimental platform at UW that permits stable cool flame characterization over long burning times and a range of conditions, including lean to rich equivalence ratios and sub- to above-atmospheric pressures. The Science PI and co-PI will utilize existing experimental tools and develop laser diagnostic techniques for the quantification and visualization of cool heptane and decane flame structures, and will compare experimental results to numerical flame simulations to evaluate the accuracy of existing and derived full and reduced chemical kinetics models. Kinetics models will then be applied to ISS cool burning droplet data to evaluate their ability to predict temporal droplet diameter changes. ✱



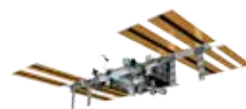
Flat flame experimental apparatus includes a Hencken burner mounted inside a pressure vessel with optical ports for visualization and measurement. Exploded images show DME cool flames at $\phi=0.6$ and $\phi=1.0$, taken with a Nikon D90 camera with shutter speed of 4 seconds and aperture of f/1.8 (Hajilou et al., 2016)

Science PI:
Dr. Erica Belmont,
Department of Mechanical Engineering,
University of Wyoming

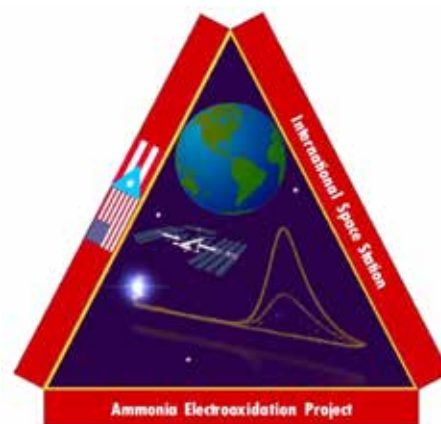
NASA Technical Monitor:
Dr. Daniel L. Dietrich,
Glenn Research Center

Elucidating the Ammonia Electrochemical Oxidation Mechanism via Electrochemical Techniques at the International Space Station

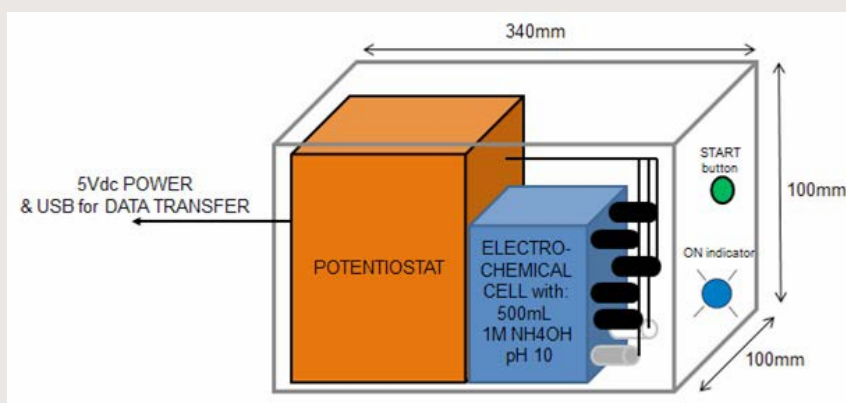
University of Puerto Rico, Ames Research Center, Human Exploration & Operations Mission Directorate, International Space Station



This project is a collaborative effort in conjunction with NASA Ames Research Center (ARC) to specifically address the Forward Osmosis Secondary Treatment (FOST) technology of urine reclamation. A key subsystem of the FOST is the so called Electrochemical Ammonia Removal (EAR) subsystem. The EAR is an ammonia electrochemical removal system with a setup similar to a fuel cell. In the electrochemical process ammonia molecules are oxidized to gaseous nitrogen (N_2) while reducing oxygen molecules from air at the cathode producing hydroxide molecules (OH^-), which are diffused through an anion exchange membrane to the anode side to produce water. The formation of stagnant nitrogen gas on the catalyst materials occurs under microgravity conditions causing a decrease on the EAR system energy production. The nanostructuring of catalyst materials is necessary to enhance nitrogen gas moving away from the catalysis site responsible for the ammonia oxidation and energy production. ✱



UPR-ISS Logo



Schematic drawing of the electrochemical experimental setup to be placed at the ISS.



UPR-ISS Team:
Prof. Eduardo Nicolau,
Graduate Students Camila
Morales- Navas, Juan
Corchado, Jessika Pazol,
and Luis Betancourt, and
Prof. Carlos R. Cabrera,
Science PI.



Willie Williams,
NASA Technical Monitor,
Johnson Space Center

<http://www.pridco.com/industries/Pages/Aerospace.aspx>

TA7

HUMAN EXPLORATION DESTINATION SYSTEMS

Human Exploration Destination Systems covers the broad range of technology candidates associated with enabling successful human activities in space, from missions operations to in-situ resource utilization (ISRU). The TA 7 Human Exploration Destination Systems Technology Area Breakdown Structure (TABS) consist of six Level 2 technology focus areas. They include: 7.1 In-Situ Resource Utilization; 7.2 Sustainability and Supportability; 7.3 Human Mobility Systems; 7.4 Habitat Systems; 7.5 Mission Operations and Safety; and 7.6 Cross-Cutting Systems. The technological goals and challenges that will be required to safely and cost effectively enable human exploration missions of discovery for our nation, the planet, and for the benefit of all humankind are documented.



p44 Stereo-Derived Topography for the Last Frontier and the Final Frontier

p45 Investigations of the Potential for Microorganisms Residing on Mars-Based Spacecraft to Inhabit Mars and Pose Planetary Protection Challenges

p46 Genetic Assessment of the Space Environment Using MEMS Technologies

p47 Understanding the Atmospheres of Hot Earths and the Impact on Solar System Formation

p48 Neutron Voltatics for Deep Space Missions

p49 Advanced Computer Vision, Robotics, and Visualization Algorithms for Improving Planetary Exploration and Understanding

p50 Temporal and Spatial Variability of Floodplain Currents by In-Situ Observations, Radar Interferometry and Numerical Simulations

p51 Multi- and Hyperspectral Bio-optical Identification and Tracking of Gulf of Maine Water Masses and Harmful Algal Bloom Habitat

Stereo-Derived Topography for the Last Frontier and the Final Frontier

University of Alaska, Fairbanks/NASA Goddard Space Flight Center, Science Mission Directorate

While it's easier to see the contours of geographic features on Earth, it's not easy seeing similar features on other planets. Using an imaging technique called structure from motion (SfM), Robert Herrick has spent decades mapping celestial bodies.

The SfM process estimates the size and shape of 3D objects using 2D images. The idea is that if you take enough photos from enough angles, you can more accurately determine the topographical makeup of a given area.

Most recently, Herrick – a geophysicist at the University of Alaska Fairbanks – has studied lava flows on Mars. His studies into the behavior of lava and its impact on geography provide clues to Mars' past.

During his project, Herrick worked with volcanologists at the Goddard Space Flight Center and also created the UAF Photogrammetry Lab. The lab provides needed infrastructure to more effectively create and share these complex topographic images on a local, national and international scale.

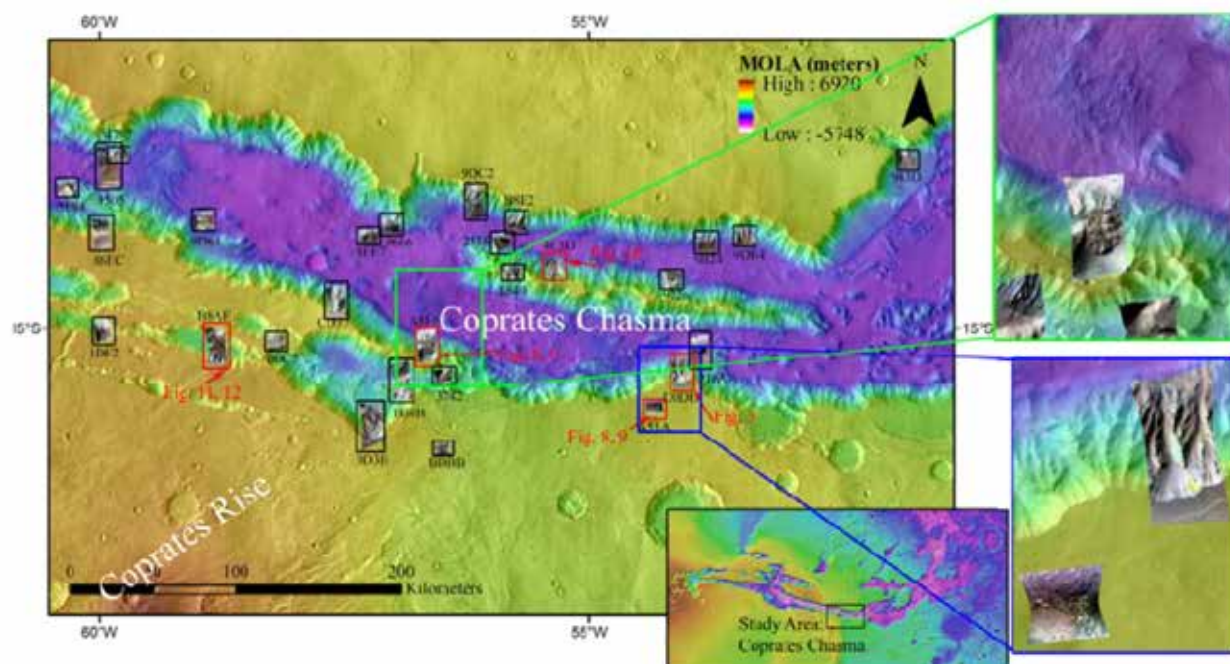
With this infrastructure, scientists can better study geological morphology, engineers will have enhanced visualization for new projects, and exploration firms will have a clearer picture of where to drill or dig. Herrick's research on Mars has real-world impact on Earth, as our planet still has much to reveal. ✨



*Dr. Robert Herrick,
Science PI,
Research Professor,
University of Alaska Fairbanks,
Geophysical Institute*



*Dr. Lori Glaze,
NASA Technical Monitor,
Planetary Studies*

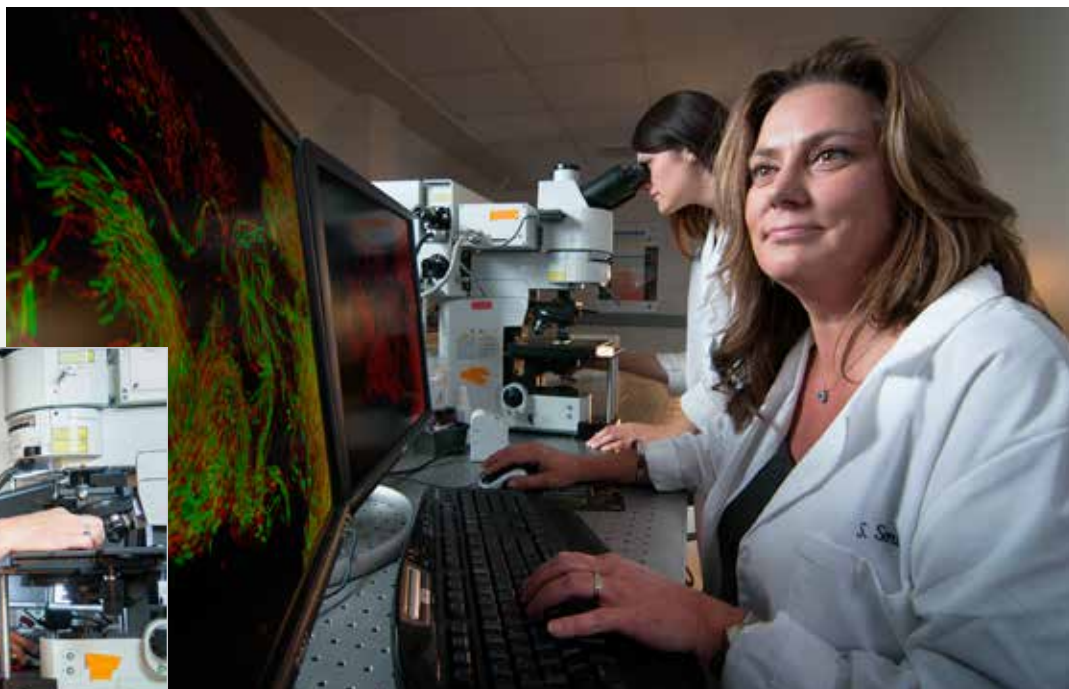


Context map of Coprates Chasma composed of MOLA topography and THEMIS daytime IR data clipped to the area of interest. CRISM scenes with clear spectral signatures are overlain on the map. Red boxes are the areas of interest.

Investigations of the Potential for Microorganisms Residing on Mars-Based Spacecraft to Inhabit Mars and Pose Planetary Protection Challenges

University of Idaho/NASA Ames Research Center, Science Mission Directorate

Dr. Stephanie Smith and graduate researcher Alissa Tenuto perform confocal microscopy on Viking isolates. Dr. Smith completed her Ph.D. while participating as a researcher on this investigation. Alissa Tenuto will complete her Ph. D. in Spring 2016.



The Martian environment is home to a wide range of extreme environmental conditions including frigid temperatures, lack of water, high salt concentrations, and intense radiation. Despite these conditions, Mars also harbors niches within its environment which could support microbial life. The search for life on other planetary bodies introduces another challenge; microbes from Earth hitch-hiking on the spacecraft. This is a challenge that must be addressed when exploring potentially habitable planetary bodies. Results from our studies have provided the basic beginnings of understanding microorganisms that reside on pre-launch spacecraft and their potential impact on space exploration of habitable worlds. In accordance with planetary protection regulations, spacecraft surfaces underwent extensive sampling to evaluate the microbial bioburden prior to launch. This study was intended to further identify and characterize the microbial isolates collected from the surfaces of the Mars-bound spacecraft, and determine survival after exposure to conditions similar to those on Mars. Our studies have found that many (~30%) of the microbial isolates are non-spore-forming organisms and approximately 8% of isolates were able to grow under more than one extreme aerobic condition (pH ≥ 9 , 20% NaCl, and 4°C). A handful of microbial isolates tolerated UV-C irradiation at doses of 2000 J/m². Many of these bacteria grow under anaerobic conditions using sources known to be available on Mars, such as sulfate, perchlorate, and iron. Results from our study are providing insight as to whether the terrestrial organisms that contaminate spacecraft surfaces have the potential to survive and grow on Mars, and if these organisms can truly inhabit other worlds, ways to mitigate their initial contamination of spacecraft, and provide knowledge as to the limits of life as we know it. ✨



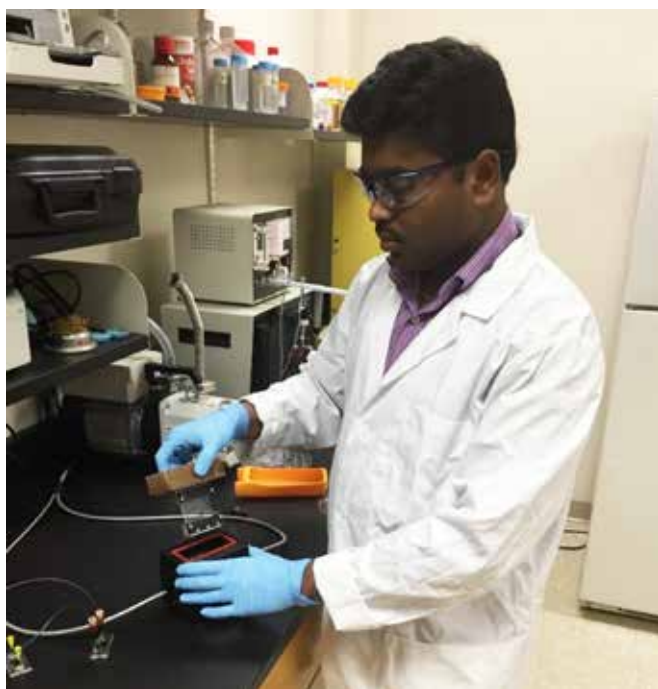
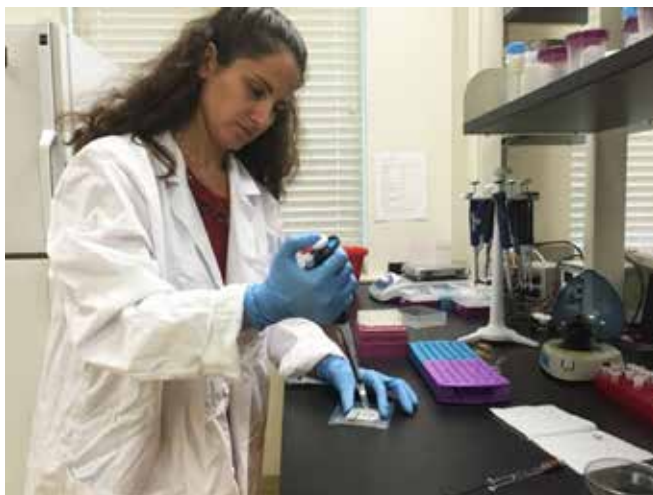
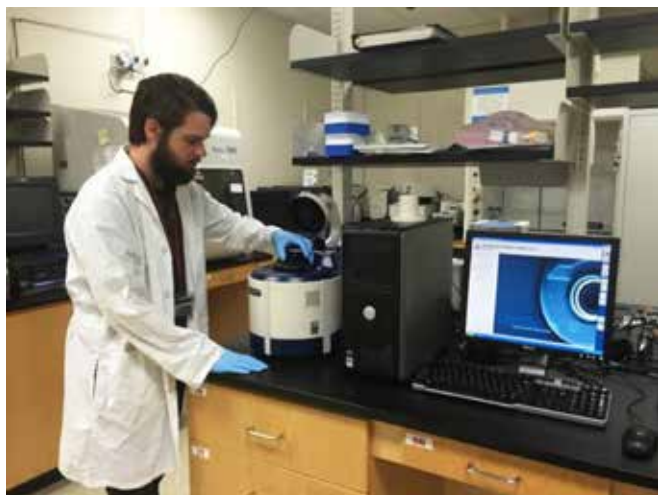
*Dr. Andrzej Paszczynski,
Science PI,
University of Idaho*



*Dr. David J. Smith,
NASA Technical Monitor,
Ames Research Center*

Genetic Assessment of the Space Environment using MEMS Technologies

Louisiana Tech University/Grambling State University/University of Louisiana at Lafayette/NASA Kennedy Space Center, Ames Research Center, Johnson Space Center, Human Exploration & Operations Mission Directorate, Space Technology Mission Directorate



This project, “Genetic Assessment of the Space Environment using MEMS Technologies,” has as its crowning objective the creation of a next-generation tool that will allow scientists to better explore the effects of radiation on humans. This has certain application for space travel, but also for many other areas of technology, such as power generation and disaster recovery. However, the several new technologies that are being developed for this instrument can have their own independent impact on much broader scale. These fields include cancer diagnostics, genetically modified plant research, and nuclear weapons tracking and disarmament verification. By integrating and developing these several cutting-edge components toward this NASA technical objective, diverse research teams across Louisiana are being synergized. Beyond the strength this brings to research, this is also promoting an upswing in NASA interest as well as general STEM awareness for communities that are historically underrepresented in the scientific fields most critical to our nation’s future. ✨

Clockwise from top left:

PhD Student, Collin Tranter (funded by a Louisiana Space Grant Fellowship), performing control experiments in the research laboratory.

Post-doctoral researcher, Gergana Nestorova, performing quantitative analysis of the pinpoint mRNA extraction technique developed as part of this project.

PhD student, Varun Kopparthy, assembling the housing for the microfluidic thermal reactor.



*Dr. Niel Crews,
Science PI,
Louisiana Tech University*

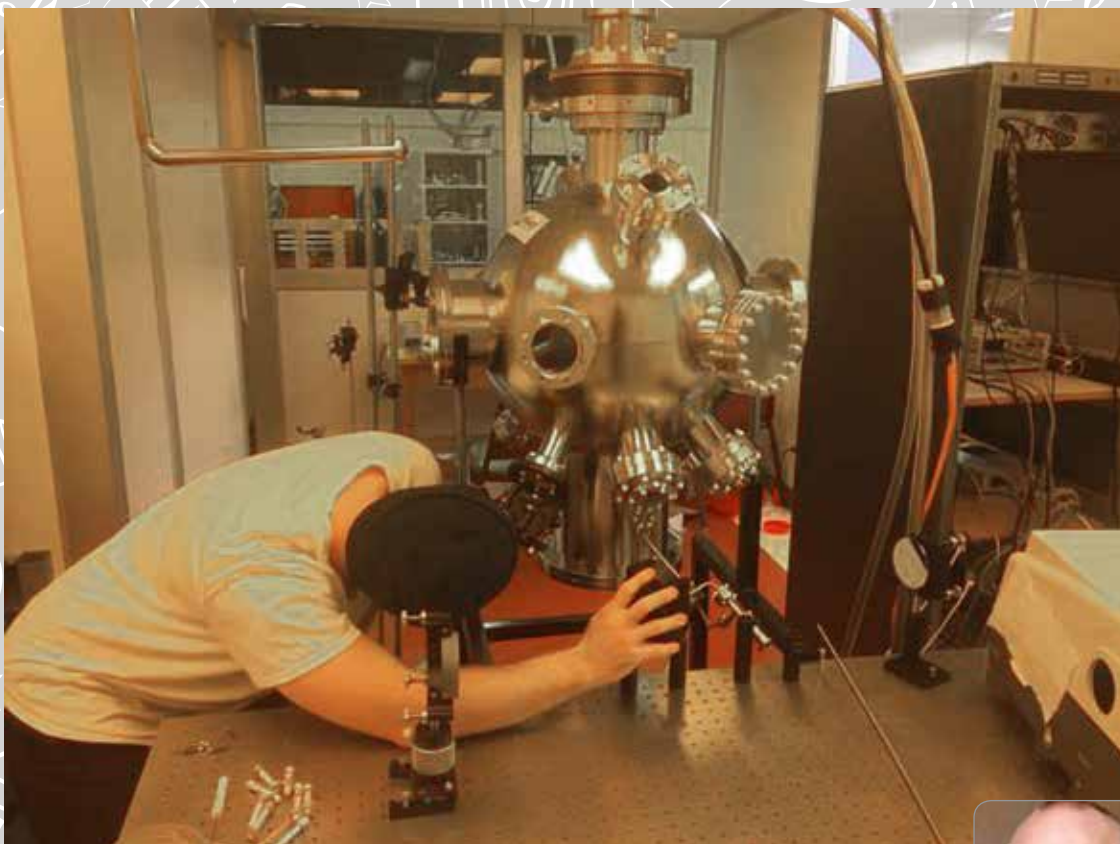
*NASA Technical Monitor:
Dr. Ralph F. Fritsche*



Understanding the Atmospheres of Hot Earths and the Impact on Solar System Formation

Missouri University of Science & Technology/NASA Glenn Research Center, Science Mission Directorate

It has recently been determined that nearly every star in the sky has at least one planet in orbit around it. However, we know very little about conditions on these planets, including how they were made. We do know that quite a few are extremely close to their stars, and so heated the point where even some rocks can vaporize. As part of our grant, we have set up a high-temperature lab where we will be able to reproduce those conditions and understand what these places are like. By understanding their chemistry, we hope to understand how they were made, and by extension how solar systems form. This lab, in concert with one at NASA's Glenn Research Center, is on the cutting edge of what we can do technologically. ✨



Graduate student Heath Gemar makes an adjustment in the high-temperature lab.

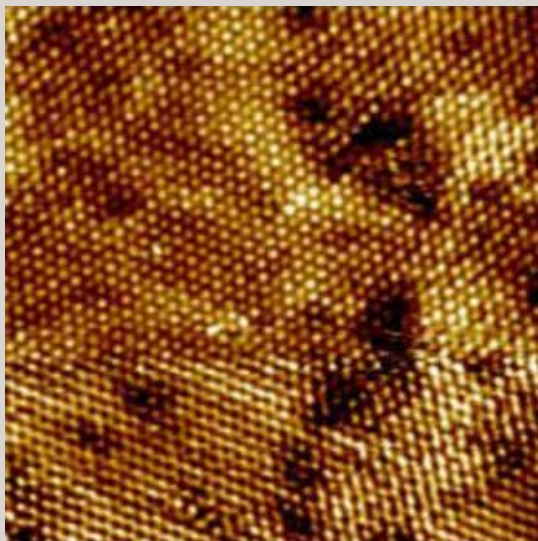


*NASA Technical Monitor:
Dr. Pamela Marcum, PhD,
Ames Research Center*

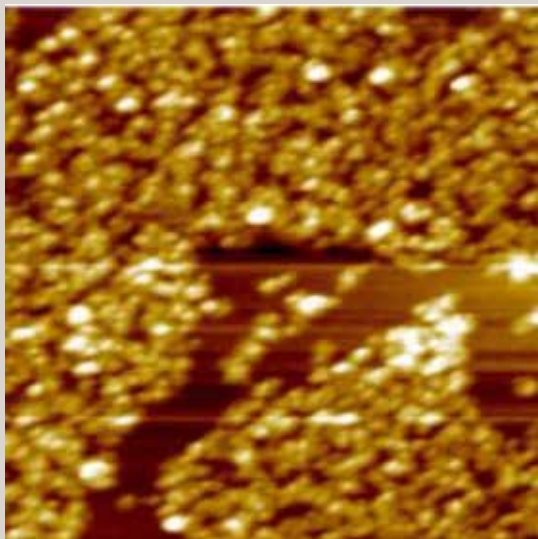
*Dr. Mike Reed,
Science PI,
Missouri State University*

Neutron Voltaics for Deep Space Missions

University of Nebraska at Lincoln/NASA Marshall Space Flight Center, Goddard Space Flight Center, Glenn Research Center, Ames Research Center, Jet Propulsion Laboratory, Human Exploration & Operations Mission Directorate, Science Mission Directorate, Space Technology Mission Directorate



Scanning tunneling microscopy image of a monolayer of fluorinated orthocarborane, 1,2- B₁₀C₂H₁₂, on a Au(111) surface. The molecules are clearly visible as circular dots. The fluorine functional group is necessary for surface attachment. The molecular packing depends on coverage but closely-packed layers are observed as the surface coverage approaches one full layer. Layers like those are the starting point for our studies of electron bombardment induced crosslinking. Image width: 60 nm.



Scanning tunneling microscopy image of a monolayer of Bis BN-cyclohexane on Ag(111). Upon annealing to 800 K the molecules decompose on the surface, forming 3 distinct structural phases, including a boron nitride monolayer, graphene, and boron carbide. The three phases can be clearly distinguished with STM and their electronic properties can be probed separately using the tip of the STM. Band gaps between 0 and 4 eV have been identified. Ultimately, these Bis-BN cyclohexanes are used as cross-linkers to connect the orthocarboranes shown in figure 1. Image width: 60 nm.



Prof. Axel Enders,
Science PI,
University of Nebraska, Lincoln



Dr. Sheila G. Bailey,
NASA Technical Monitor,
Glenn Research Center

“DANSON” - Lincoln Detector for the Analysis of Solar Neutrons

A team of experimental and computational material scientists have investigated design strategies for new types of semiconducting boron carbide materials that can be used to build a neutron voltaic device. Such a device, if available, would be able to generate electricity similar to a solar cell, but from neutrons instead of photons, to power NASA's future deep space probes. A crucial step in the materials development is the test of the material's radiation hardness under exposure to solar neutrons. The team therefore is currently preparing an experiment to measure materials aboard the International Space Station. The experiment, under the payload name DANSON, will be delivered to ISS on the Space-X 10 flight in November 2016.

Preparation of this payload has provided unique training opportunities for undergraduate students at UNL, who were involved in all stages from project planning, design and manufacturing, to flight readiness certification. Students were integral part in the collaboration with NASA personnel at both Johnson Space Center and Kennedy Space Center, importantly the payload integration manager at JSC. Also, this project is based on active collaboration with an industry partner, Rhombus Power Inc., who is a developer of neutron detector devices and who has provided expertise in the moderation of solar neutrons and sample packaging here. ✨

<http://www.unl.edu/physics/news/dowben-team-experiment-headed-iss>

Advanced Computer Vision, Robotics, and Visualization Algorithms for Improving Planetary Exploration and Understanding

University of Nevada at Las Vegas/NASA Ames Research Center, Space Technology Mission Directorate



Figure A: Rover localization using the horizon line.



Figure B: Human-robot collaboration.

This project enabled Nevada to build research capacity in areas of strategic importance to NASA while at the same contributing to NASA's research priorities. Specifically, a team of experts from the University of Nevada, Reno (UNR), the University of Nevada, Las Vegas (UNLV), and the Desert Research Institute (DRI), in collaboration with the Intelligent Robotics Group (IRG) at NASA Ames developed new techniques for robot localization, landmark detection, human-robot collaboration, and terrain characterization. The horizon line was leveraged for rover localization in outdoor environments (Figure A) while new localization capabilities were developed for the SPHERES robotic system which is available on the International Space Station (ISS). More robust algorithms were also developed for detecting important landmarks for autonomous spacecraft navigation and control such as craters, rocks, and sand dunes. To support future planetary missions where teams of humans and robots are envisioned to work together, we designed adjustable autonomous control and interaction capabilities for robots working with human users, in collaborative teams, either in side by side or in remote location scenarios (Figure B). Finally, we developed an approach for mapping rover mobility of a landscape that exhibit variable surface lithology and geometries by combining image and elevation analysis with geophysical characterization of the soil surface terrain (Figure C). ✱

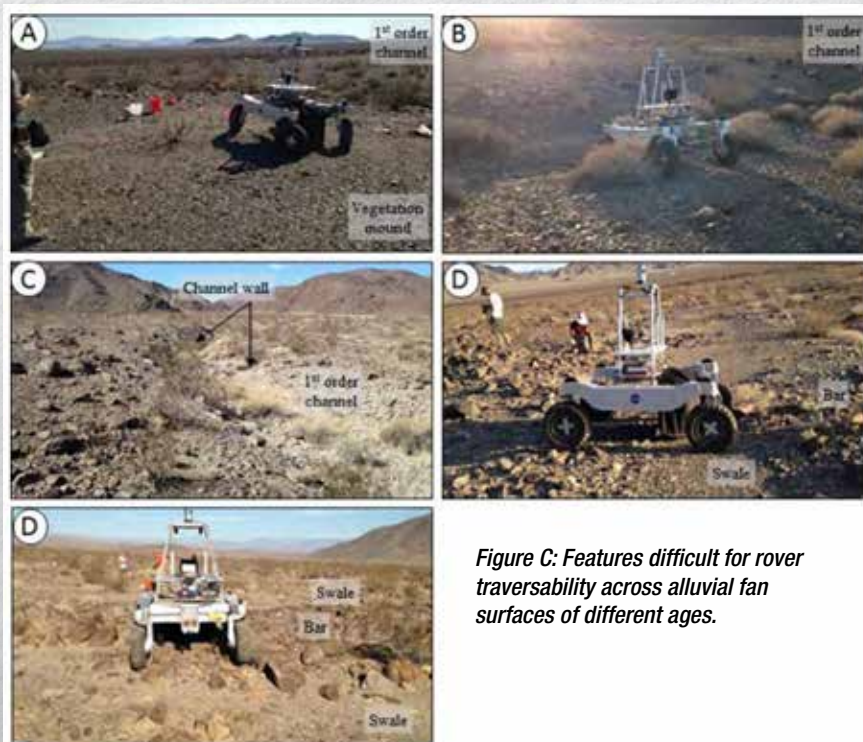


Figure C: Features difficult for rover traversability across alluvial fan surfaces of different ages.



Dr. George Bebis, Science PI,
Nevada System of
Higher Education



Terry Fong,
NASA Technical Monitor,
Ames Research Center

Temporal and Spatial Variability of Floodplain Currents by In-Situ Observations, Radar Interferometry and Numerical Simulations

University of South Carolina, Science Mission Directorate, Goddard Space Flight Center, Science Systems and Applications, Inc., Congaree National Park

The multidisciplinary research described here is in accordance with NASA SMD priorities because the planned activities will improve our understanding of the consequences of climate change and sea level rise on a critical Earth system, floodplains. Floodplains are important because they perform many functions that benefit humans while supporting high biodiversity, and they are important components of the terrestrial carbon cycle. Floodplain services are accomplished by water overflowing the channel banks to help maintain extant wetlands, to create temporary aquatic habitat, and the transport of particulate and dissolved carbon and other nutrients. This research will help advance our scientific understanding of how floodplains function, and how they are likely to respond to natural and human-induced perturbations. We propose to use airborne radar, numerical simulations and in situ observations to quantitatively assess the temporal and spatial dynamics of flow paths and water fluxes over the inundated floodplain of the Congaree National Park, South Carolina. Remote sensing studies have shown that floodplain circulation is highly complex and in this study we endeavor to quantify controls on flow complexity by answering the question: How do inundation flow paths and flow path connectivity, and water residence times vary with flood stage? The Unmanned Airborne Vehicle Synthetic Aperture Radar (UAVSAR) will provide data for interferometry analyses to observe water level at a one to two day cycle during annual flood conditions. The

numerical model DELFT3D will be used to simulate water depths, flow directions and fluxes, and conservative tracer dynamics. Initial simulations will guide velocity profiler and stage meter placement, and they will help constrain topographic and vegetation roughness estimates. Later, more refined simulation results will be compared with airborne radar interferometry and in situ observations of velocity and stage. This project represents a major step toward establishing a Coastal Plain Observatory at U.S.C. that is dedicated to understanding large coastal plain systems of which the floodplain is the principle component. Moreover, the methods, findings and inferences resulting from this work will have important implications for all river systems that traverse the U.S. coastal plain, the low gradient landscape that extends from New Jersey to Texas, and to the 5.7x106 km2 of coastal plain worldwide. In addition to the scientific benefits to society we propose to mentor a new female assistant professor at a predominantly undergraduate institution, as well as graduate and undergraduate students. Moreover, this work advances a broader initiative of creating the first U.S. Coastal Plain Observatory and finally, this proposal is timely because South Carolina and the Congaree National Park recently experienced a “1000 year flood” (October, 2015) and results from this project will improve flood response planning and land management practices, and the development of best management practices for floodplain systems world-wide. ✨



*Raymond Torres,
Science PI,
University of South Carolina*

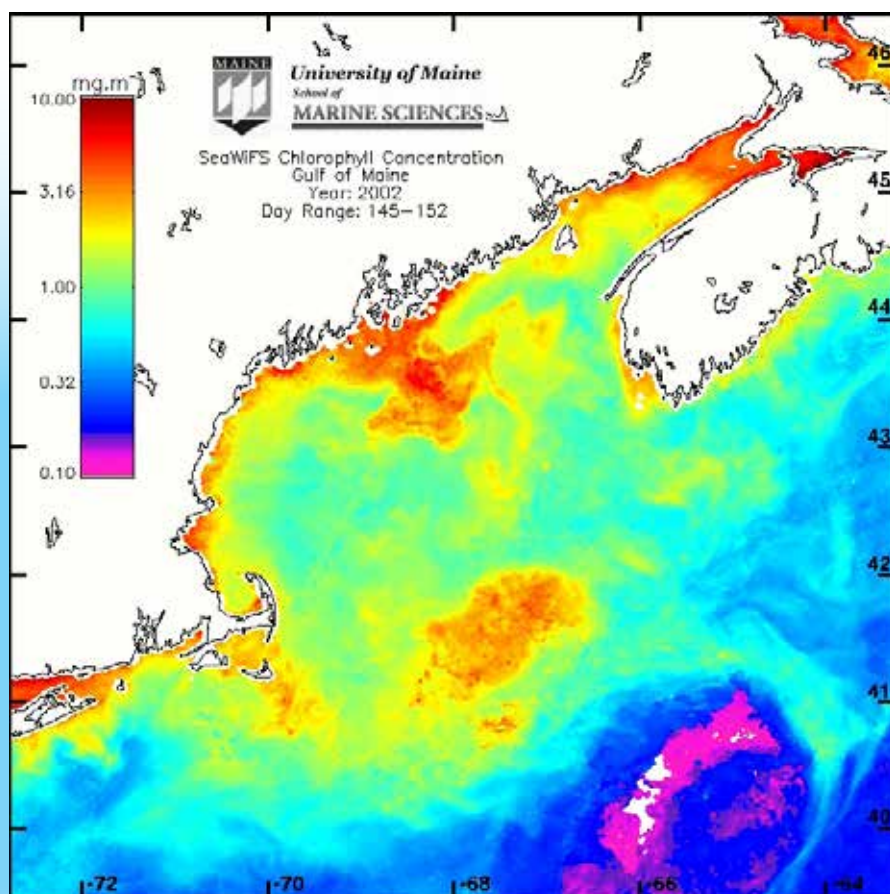
*NASA Technical Monitor:
Thomas R. Holmes,
Goddard Space Flight Center*



Wetlands of Congaree National Park, South Carolina.

Multi- and Hyperspectral Bio-optical Identification and Tracking of Gulf of Maine Water Masses and Harmful Algal Bloom Habitat

University of Maine, Science Mission Directorate, Goddard Space Flight Center



Ocean color satellite image of the Gulf of Maine, where we will be decomposing multi spectral and hyper spectral ocean color data to investigate the ocean bio-optical properties of harmful algal blooms.

Dr. P. Jeremy Werdell,
NASA Technical Monitor,
Goddard Space Flight Center



Dr. Andrew J. Thomas,
Science PI,
Professor of Oceanography,
School of Marine Sciences
at the University of Maine

Each summer, extensive areas of Maine coastline are closed to shellfish harvesting due to *Alexandrium*, a toxic dinoflagellate, costing millions of dollars in lost commercial revenue and monitoring efforts. Unlike the harmful algal blooms of other coastal waters, *Alexandrium* is dangerous even as just a minor part of the phytoplankton community, at concentrations too low to be detectable with current remote sensing technology. However, extensive previous research has shown that these organisms are widespread, have strong spatial and temporal patchiness, are associated with specific temperature and nutrient regimes, and are transported by local physical processes. The waters of the Gulf of Maine, especially those close to shore, are optically complex due to varying amounts, sources and characteristics of colored dissolved matter, suspended sediment, and varying concentrations and diversity of phytoplankton. A systematic investigation of the capability of multispectral satellite data to isolate and monitor the oceanic habitat of *Alexandrium* has not been carried out. In this proposal, we use NASA multispectral and SST data and new hyperspectral field data to bio-optically classify different Gulf of Maine surface water masses, identify those water masses that are preferred *Alexandrium* habitat, track these water masses and map their interaction with, and impact on, coastal shellfish harvesting sites. We bring a multi-institution and multi-disciplinary team to address this problem. ✱

TA8

SCIENCE INSTRUMENTS, OBSERVATORIES, AND SENSOR SYSTEMS

The Science Instruments, Observatories, and Sensor Systems TA 8 roadmap leverages previous roadmapping activities from the 2010 Space Technology Roadmaps and the 2005 NASA Advanced Planning and Integration Office (APIO) assessments, Advanced Telescopes and Observatories and Science Instruments and Sensors. The technologies for TA 8 allow information to be gathered about Earth's atmosphere, space, and other planets. TA 8 technologies are organized into remote sensing instruments and sensors, observatories, and in-situ instruments and sensors. Remote sensing instruments and sensors include components, sensors, and instruments for measuring the spectral, spatial, and other observable properties of a remote target of interest, both passively and actively, such as through laser- and radar-based approaches. Observatories include technologies for next-generation telescope systems that collect, concentrate, or transmit photons. In-situ instruments and sensors include components, sensors, instruments, and sampling technologies for detecting fields, waves, and particles in the space environment, and for characterizing planetary exospheres, atmospheres, and surfaces. Technology needs and challenges identified in this document are traceable to specific NASA missions recommended by the most recent Earth, Planetary, Astrophysics, and Heliophysics decadal survey reports ("pull technologies"), but some allow new science capabilities and mission concepts ("push technologies").



- p53** Agricultural Soil Erosion and Carbon Cycle Observations in Iowa: Gaps Threaten Climate Mitigating Policies
- p54** Investigating Terrestrial Gamma Flash Production from Energetic Particle Acceleration in Lightning Using TETRA-II
- p55** Development of a Large Area Standoff Bio-Finder and Chemical Analyzer for Planetary Exploration
- p56** Development of the Miniaturized Infrared Detector for Atmospheric Species (MIDAS) Instrument
- p57** Developing a Capability at the University of Hawaii for Multiple UAV Observations of Active Volcanism
- p58** Monitoring Earth's Hydrosphere: Integrating Remote Sensing, Modeling, and Verification
- p59** Validation of a Cubesat Stellar Gyroscope System
- p60** Minerva: A Dedicated Observatory for Exoplanet Science
- p61** Passive Microwave Detection of Snowmelt and Runoff
- p62** Jovian Interiors from Velocimetry Experiment in New Mexico (JIVE in NM)
- p63** Virtual Telescope for X-ray Observations
- p64** Development of the Virgin Islands Center for Space Science at Etelman Observatory: Research, Education, and Economic Development Through Promotion of NASA's Vision
- p65** Using NASA's Ocean Color Sensors to Identify Effects of Watershed Development and Climate Change on Coastal Marine Ecosystems of the US Virgin Islands
- p66** Initiating a Bold New Generation of Astronomical Surveys at the Wyoming Infrared Observatory
- p67** Nanostructured Polarization Optics for Atmospheric Remote Sensing
- p68** Nanosatellite Constellations for Space Science Applications

Agricultural Soil Erosion and Carbon Cycle Observations in Iowa: Gaps Threaten Climate Mitigating Policies

University of Iowa/NASA Science Mission Directorate



Ben Abban, a student from the University of Tennessee, is measuring the time it takes for soil and carbon to move across a floodplain using rainfall simulators. The travel time of material across a floodplain has implications to carbon budgets and sequestration.



Thanos Papanicolaou, Science PI, formerly of University of Iowa, now at University of Tennessee

of long-term land management starting from the introduction of row crop agriculture to present. The interplay of tillage intensity (moldboard plow vs. no-till), changes in fertilizer management, and improved crop varieties with different climate conditions was captured and detailed in a recently accepted paper in the Journal of Geophysical Research – Biogeosciences. An important conclusion here is that it is not a single factor that drives carbon budgets but it is how the factors are grouped together. The next step is to couple this framework with larger regional scale models to calculate carbon budget for the Midwest. To our knowledge this is one of the few projects that systematically examine the collective role of runoff and tillage induced erosion on SOC redistribution and CO₂ fluxes using different scaling approaches (bottom-up and top-down) combined with direct in-situ flux and biogeochemical observations. ✱

*NASA Technical Monitor:
Ransook C. Evanina,
Glenn Research Center*

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

Louisiana State University/Southern University/Xavier University of Louisiana/NASA Glenn Research Center,
Science Mission Directorate, International Space Station



Google Earth satellite view of ten white TETRA-II detector boxes on the roof of Building B of the University of Puerto Rico – Utuado. The location of the detectors are marked by the yellow arrow.



*Dr. Michael L. Cherry,
Science PI,
Professor, Louisiana State
University*

Lightning is of great interest to NASA, in part because of the potential damage due to strikes to space vehicles at launch. Terrestrial Gamma Flashes (TGFs) are intense millisecond-long bursts of gamma rays associated with lightning. TGFs are detected by satellite detectors, and a recent ground-based measurement has suggested that there may be a close connection between the particle acceleration that leads to the TGFs and the basic structure of the thunderstorm. The TETRA-II (TGF and Energetic Thunderstorm Rooftop Array) array of gamma ray detectors recently installed at ground level in Puerto Rico is designed to provide detailed and close-up information about nearby (< 5 km) thunderstorms producing TGFs. ☼



*Nasser Barghouty,
NASA Technical Monitor,
Manager, Astrophysics Office
at NASA-Marshall
Space Flight Center*

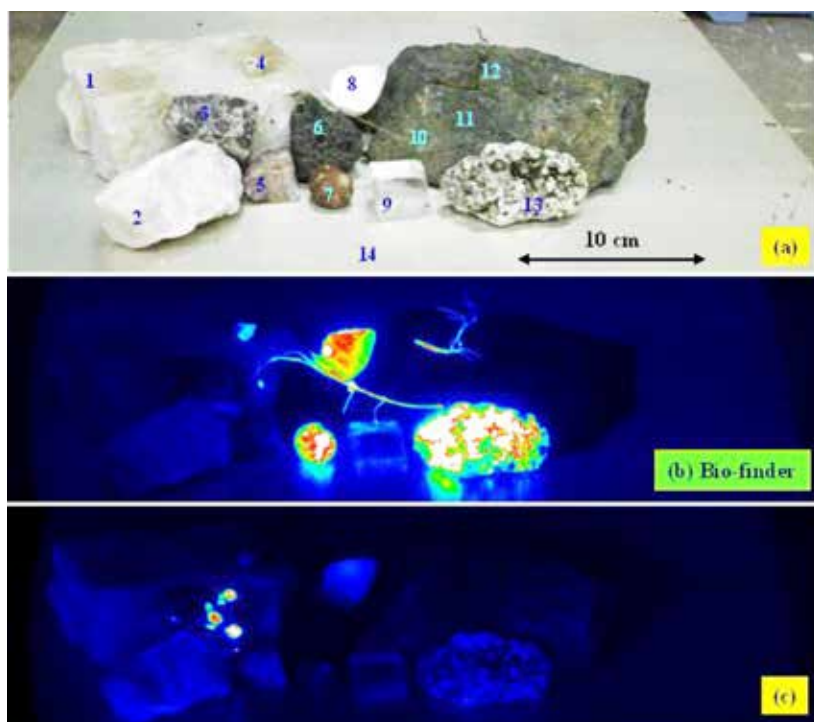
<https://cosmologyandspace.wordpress.com/?s=Investigating+Terrestrial+Gamma+Flash+Production+from+Energetic+Particle+Acceleration+in+Lightning+using+TETRA-II>

Development of a Large Area Standoff Bio-Finder and Chemical Analyzer for Planetary Exploration

University of Hawai'i/NASA Goddard Space Flight Center, Ames Research Center, Jet Propulsion Laboratory, Science Mission Directorate, Space Technology Mission Directorate



Remote Raman detection of minerals from 430 meters distance with 1 second integration. (Ph.D. Student seen in the image is Tayro Acosta-Maeda and is expected to graduate in Aug. 2016).



Fast (0.1 second) remote detection of biological materials in a large area.

Remote laser based chemical detection at the University of Hawai'i: University of Hawai'i researchers are developing several laser based systems for remote chemical analysis of minerals with funding from NASA and ONR. The researchers have built systems which can perform chemical analysis of targets from a distance of few meters to hundreds of meters in daytime with fast detection time of 1 s using a green 532 nm pulsed laser. The University of Hawai'i has collaborated with NASA AMES and NASA Langley Research Centers, and Los Alamos National Laboratory for this effort. Two of the researchers funded by this EPSCoR program were selected to be team member for upcoming NASA's Mars 2020 mission for developing the "SuperCam" instrument in collaboration with LANL. The Hawai'i researchers are also collaborating with USA based laser company Q-Peak, Inc. from Bedford, Massachusetts under the NASA STTR program to develop a compact laser for space applications. The State of Hawai'i typically known for its tourism industry is systematically changing to open doors for space science and high tech industry. Educating and training new students in space science and technology and developing new instruments are one of the goals of the NASA EPSCoR program. ☀



Dr. Anupam Misra,
University of Hawai'i,
Honolulu



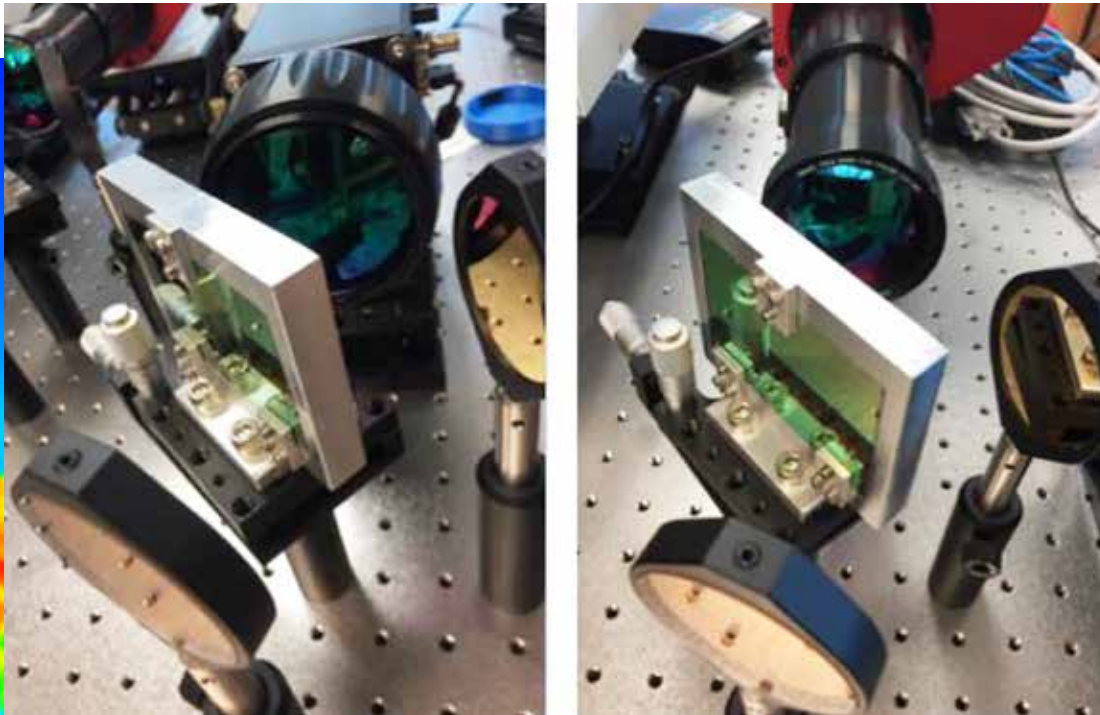
Dr. Chris McKay,
NASA Technical Monitor,
Ames Research Center

<https://www.youtube.com/watch?v=TX71B3-QtAc>
(Tech Talk with A. Misra)

<https://www.youtube.com/watch?v=ZREUCvjYvPM>
(Tech Talk with S. Sharma)

Development of the Miniaturized Infrared Detector for Atmospheric Species (MIDAS) Instrument

University of Hawai'i, Honolulu/NASA Ames Research Center, Science Mission Directorate



These images show the microbolometer and photon detector with their re-imaging lenses looking through the Sagnac interferometer.

The Miniaturized Infrared Detector for Atmospheric Species, or MIDAS, is a small, low-cost infrared instrument designed to detect greenhouse gases, such as carbon dioxide and methane, from remote platforms such as UAVs and high altitude balloons here on Earth to cubesats and planetary missions to Mars, Titan, and beyond.

Current, state-of-the-art technologies for remote detection of trace gases are accurate but limited in range, resolution and how their data can be displayed. These systems are not miniaturizable due to physical and power constraints or are not powerful at large working distances. They are also too expensive for smaller missions and their platforms.

With miniaturization, MIDAS has significant advantages: from UAVs and, ultimately, cubesats, this low-cost, adaptable infrared system can make higher spatial resolution measurements and classification of these gases for climatological and hazard studies, such as from leaks in gas pipelines.

The proposal team has a great deal of experience in developing instruments for thermal infrared remote sensing of solid and gaseous targets such as CO₂ and CH₄. MIDAS builds on previous EPSCoR- and NASA R&D-funded developments of space-born microbolometers to produce a miniaturized solution suitable for deployment on a large number of future mission architectures. ✨



*Dr. Brendan Hermalyn,
Science PI,
University of Hawai'i, Honolulu*



*Dr. Anthony Colaprete,
NASA Technical Monitor,
Ames Research Center*

Developing a Capability at the University of Hawai'i for Multiple UAV Observations of Active Volcanism

Hawai'i Institute of Geophysics and Planetology/NASA Jet Propulsion Laboratory, Science Mission Directorate

This NASA EPSCoR project will show University of Hawai'i (UH) faculty and research staff how to utilize unmanned aerial vehicles (UAVs) for science projects, with a specific focus on analyzing the active Kilauea volcano. NASA has long studied the volcanoes in Hawai'i using different remote sensing techniques that include satellites, aircraft and, more recently, unmanned aerial vehicles such as the UAVSAR.

Although Hawai'i was selected in 2013 (along with Alaska and Oregon) to be part of one of six national Federal Aviation Authority (FAA) UAV Test Sites, the UH is poorly prepared to take advantage of this opportunity for new research. Learning how to conduct research under formal Federal flight rules, including the flight certification of sensors, training the UAV operators, and meeting FAA range safety rules will be an important part of this project. In addition, novel techniques, such as UAV formation-flying for "stereo viewing" of volcanic plumes, will open up many new science research opportunities.

This specific project, to be mentored by Dr. Dave Pieri at NASA's Jet Propulsion Laboratory, will investigate the connection between the thermal properties of active lava flows and the changes in flow topography at Kilauea on an hour-by-hour basis. The team also wants to estimate the gas flux from the volcanic plumes associated with these flows. To accomplish these science objectives, they will use multiple UAVs to make simultaneous measurements of Kilauea's active lava flows and volcanic plumes.

These concurrent measurements will be coordinated through the adaptation of the UH COSMOS small-satellite software to control UAVs. Through mentoring by Dr. Matt Fladeland (NASA Ames), the team will learn the operational aspects of UAV research and how they relate to NASA's broader research objectives. Thus, the Team will become more competitive with our future research proposals to be submitted to NASA. ☀



Many active pahoehoe lava flow lobes spill out of the crater of the Pu'u O'o vent. Note also the amount of gas being released from the partially broken crater. Photo credit: Pete Mougini-Mark, Univ. Hawai'i.



*Pete Mougini-Mark,
Science PI,
Hawai'i Institute of
Geophysics and Planetology*

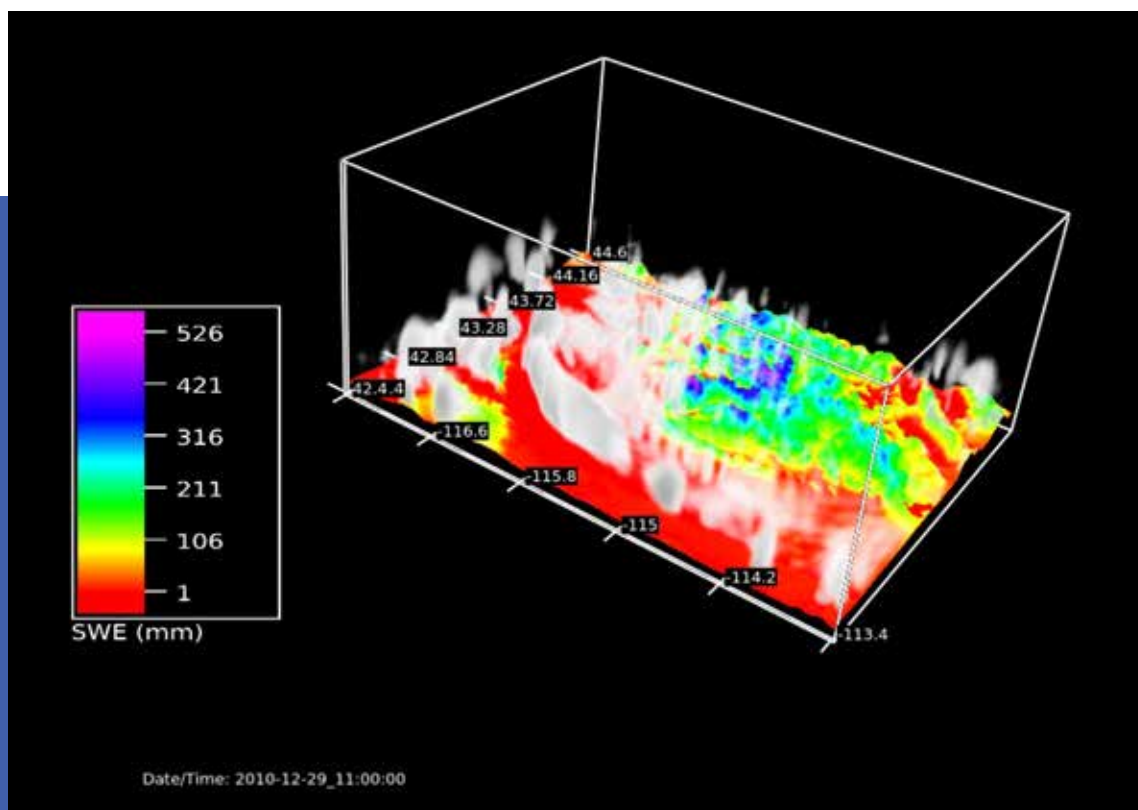


*Dr. Matthew Fladeland,
NASA Ames Research Center,
Earth Science Division*

<http://www.hsf1.hawaii.edu/>

Monitoring Earth's Hydrosphere: Integrating Remote Sensing, Modeling, and Verification

Boise State University/NASA Goddard Space Flight Center, Jet Propulsion Laboratory, Science Mission Directorate



A simulation of atmospheric water vapor content and simulated snow water equivalent on December 29, 2010 over southern Idaho from a high-resolution regional climate model.

Researchers at Boise State University are using NASA data and advanced models to make better predictions of weather, climate, and water resources in mountain landscapes of the world. Mountainous watersheds, where winter snowfall dominates yearly precipitation, are often referred to as the “water towers of the world” because they store water as snow that supplies cities and farms during hot, dry summers. These regions are often sparsely observed because they are rugged. Data from NASA satellites and advanced prediction models are critical to making better predictions of snowfall and snowpack volumes for water supply and documenting how they are changing as the climate warms. Using Idaho as a testbed, these researchers are applying regional climate and weather models to make predictions of precipitation, temperature, winds, and other climate variables at spatial scales that are significantly finer than available global products. They are simultaneously developing better algorithms to extract information about snowpack and vegetation characteristics from NASA remote sensing data and innovating less expensive sensor networks to measure these variables on the ground. This research will fundamentally advance in the modeling and remote sensing of the world’s water towers and lead to more reliable predictions in the future. ☀



*Dr. Alejandro N. Flores,
Science PI,
Boise State University*



*Dr. Gail Skofronick-Jackson,
NASA Technical Monitor,
Goddard Space Flight Center*

<http://dx.doi.org/10.18122/B2LEAFD001>

Validation of a CubeSat Stellar Gyroscope System

Coll University of Kentucky/NASA Johnson and Kennedy Space Center/Human Exploration and Operations and Space Technology Mission Directorates, International Space Station



Students and Faculty at the University of Kentucky Space Systems Lab have developed a system called a stellar gyroscope that can determine the orientation of a small satellite in space using consecutive pictures of star fields to determine how the satellite is moving through space. Normally this implies heavy power and computational requirements; however, by identifying similar stars between image frames and conducting all processing onboard the satellite, this approach dramatically increases the utility of small satellite missions. The advantage of this approach is the potential for lower-cost attitude determination and control systems for all small satellites with limited computing and power resources. A team of students and faculty have prepared the CubeSat, called SGSat/KySat3, for launch into low-Earth orbit from the International Space Station. This project gives researchers in Kentucky access to space to test their concepts and hardware, while also providing Kentucky students firsthand experience with spacecraft testing and operations. ✨



*Dr. James E. Lumpp, Jr.,
Science PI, Professor,
University of Kentucky*

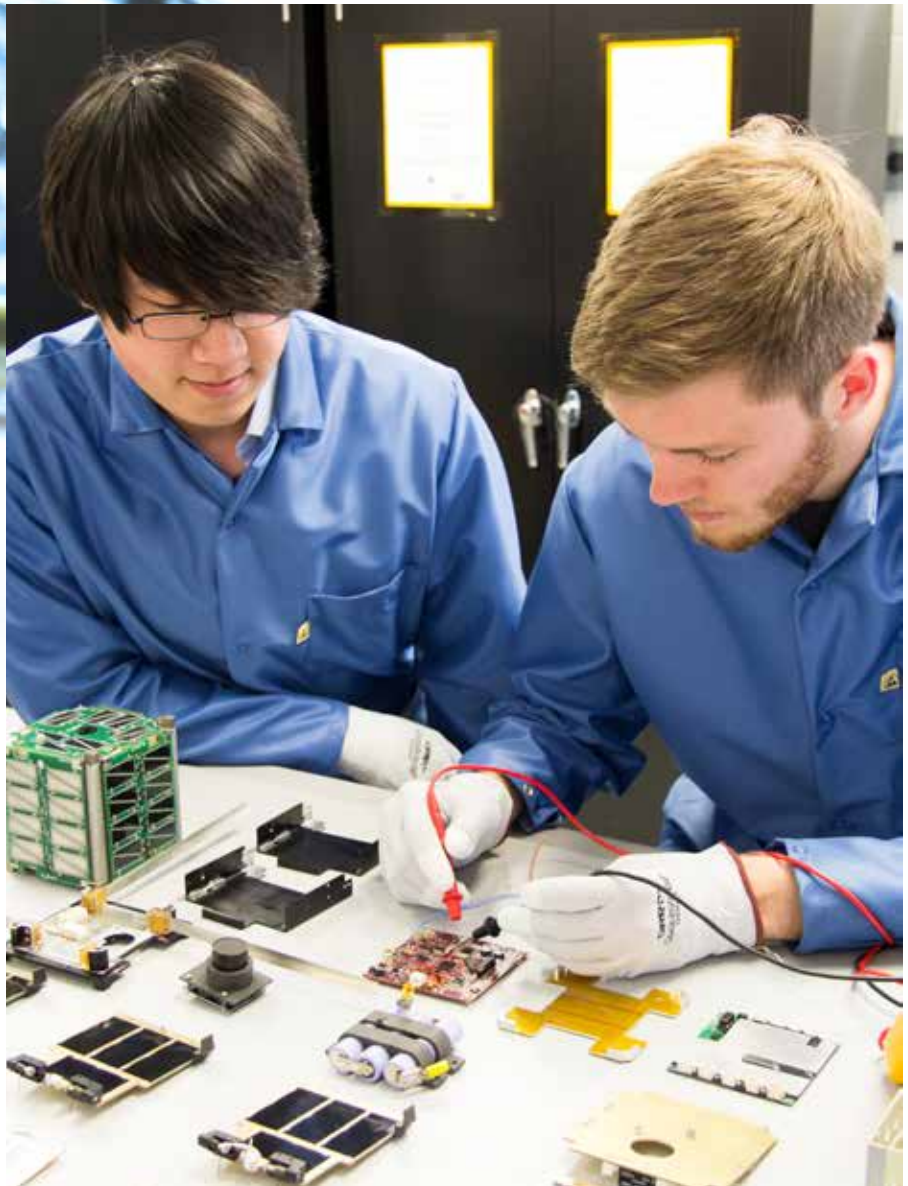
University of Kentucky students Timothy Lim and Zachary Porter perform subsystem upgrade testing for a CubeSat that will be launched into orbit from the International Space Station to test an experimental stellar gyroscope method for small spacecraft attitude determination developed by the UK Space Systems Lab.



*Willie Williams,
NASA Technical Monitor,
Johnson Space Center*

Mission updates and status will be displayed along with results of the research at:

<http://ssl.engineering.uky.edu/sg-satkysat-3/>



Minerva: A Dedicated Observatory for Exoplanet Science

University of Montana, Missoula/NASA Goddard Space Flight Center, Glenn Research Center, Jet Propulsion Laboratory, Ames Research Center, Science Mission Directorate

MINERVA science aligns with the NASA Exoplanet Exploration Program (ExEP) in the Astrophysics Division of the NASA Science Mission Directorate (SMD). The goal of detecting nearby habitable planets was established by the 2004 report *The Vision for Space Exploration*, which directed NASA to “Conduct advanced telescope searches for Earth-like planets and habitable environments around other stars.” The 2010 Science Plan for SMD reaffirms the ultimate goal of extending exoplanet “exploration to the detection of habitable, Earth-like planets around other stars... and to search for indicators that they may harbor life.”

MINERVA research at the University of Montana has significantly enhanced research infrastructure in Montana. UM faculty and undergraduate students are now using world-class telescope and imaging equipment, both in person (at the MINERVA observatory site at Whipple Observatory in Arizona) and remotely via the Internet. EPSCoR funding has established an exoplanet research group at UM, led by Sci McCrady. ✨



*Dr. Nate McCrady,
Science PI,
University of Montana, Missoula*

*NASA Technical Monitor:
Dr. Charles Beichman*



The four telescopes of Project MINERVA are located at Fred Lawrence Whipple Observatory in Arizona. The University of Montana telescope, funded by a NASA EPSCoR grant, is at the far right of the image. These four telescopes observe targets together or separately to search for rocky, Earth-analogue exoplanets around nearby Sun-like stars. The fifth telescope, in the foreground, is the related project MINERVA-Red, which will search nearby low-mass stars for exoplanets.

<http://hs.umt.edu/physics/minerva.php>

<https://www.cfa.harvard.edu/minerva/News.html>

Passive Microwave Detection of Snowmelt and Runoff

University of New Hampshire/NASA Science Mission Directorate

The Red River of the North Basin (RRB), bordering eastern North Dakota and western Minnesota, is very vulnerable to frequent snowmelt floods historically due to its flat terrain and low permeability soil. Catastrophic floods in 1997 and 2009 were two of the largest spring floods in recent years, and have caused huge social and economic impact to the societies in North Dakota and Minnesota in U.S. and Province of Manitoba in Canada. Accurate prediction of the snowmelt flood occurrence using satellite observations can reduce the loss of life and damage to property for the citizens living in the region. As recently as 2013, with the information (e.g. snow water equivalent from SNODAS and gamma ray flights) and models that were available at the time, forecasted peak floods exceeded the observed by 70%. The actual 2013 flood stage was several feet below the predicted level due to poor forecasting results. The City of Fargo and the U.S. Army Corps of Engineers (USACE) each wasted millions of dollars on sandbags and dikes in preparation for a flood that did not happen. Satellite instruments, which have provided the observations needed to measure the water in a snowpack since 1987, are being used to improve flood predictions and, in the future, analyses of the socioeconomic impacts of the improved forecasts are being planned. ✨



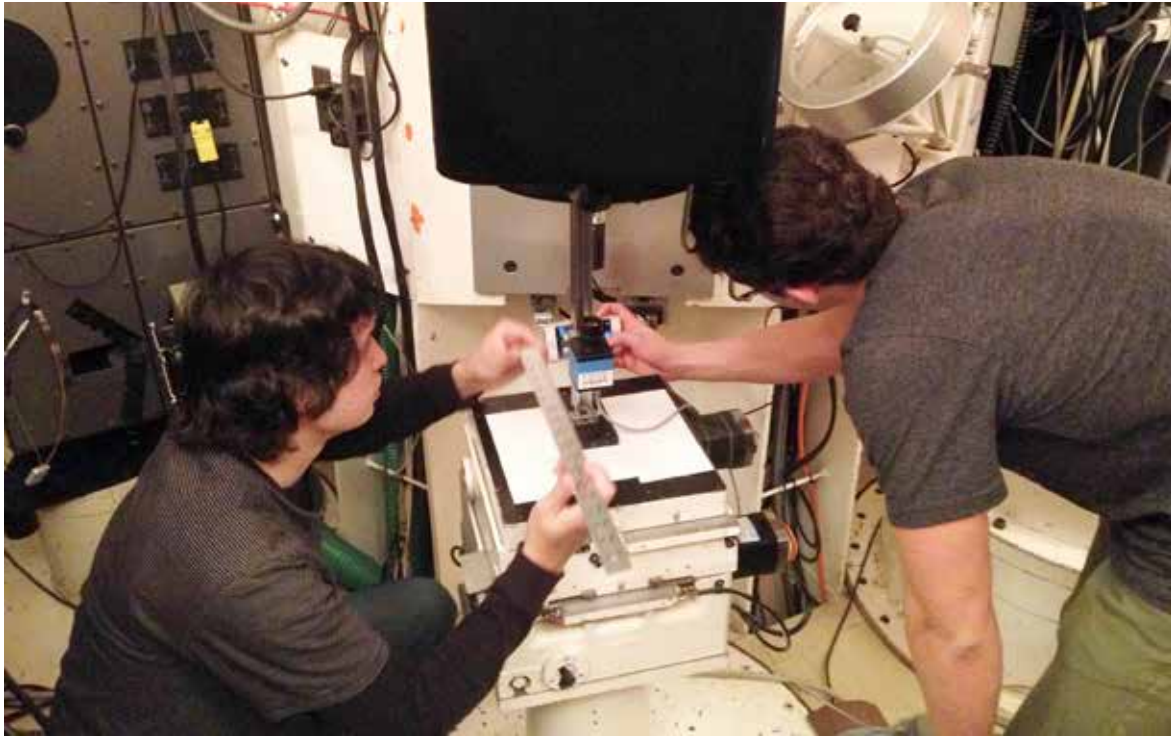
*Robert Freeman,
NASA Technical Monitor,
Kennedy Space Center*



Prof. Jennifer Jacobs, Science PI, University of New Hampshire, visits her snow experiment site in Fargo, ND; this recently tilled field is representative of the Fargo clay soils and flat terrain in the region.

Jovian Interiors from Velocimetry Experiment in New Mexico (JIVE in NM)

New Mexico State University/NASA Ames Research Center, Jet Propulsion Laboratory, Goddard Space Flight Center, Science Mission Directorate



Testing of new guiding camera at the Dunn Solar Telescope at Sunspot, NM. Pictured are NMSU engineering students Christopher Trujillo and Samuel Horst measuring the focal plane of the telescope. Photo credit: Ethan Dederick.

Jupiter is the most massive planet, representing 70 percent of the mass in the solar system apart from the Sun, yet still presents many mysteries about its structure. New Mexico State University is leading an international team of researchers in the “Jovian Interiors from Velocimetry Experiment (JIVE) in New Mexico,” a ground-based instrument and part of a global network that will decisively measure oscillations on Jupiter for the first time. Its results will help us understand the interior structure and composition of the planet and the solar systems formation.

A key component of this project is the use of a proper telescope. The JIVE team has done feasibility studies and has decided to use the large Dunn Solar Telescope, located at Sacramento Peak, NM and operated by the National Solar Observatory. The use of a “daytime” telescope for nighttime observations of Jupiter will be very unique. One of the key aspects currently being tested is how well the telescope will be able to “track” Jupiter to keep it in view over the course of a night, since it’s much smaller than the Sun. The photo shows testing being carried out in early 2016 by NMSU students and faculty. ✨



*Dr. Mark S. Marley,
NASA Technical Monitor,
Ames Research Center*



*Dr. Jason Jackiewicz,
Science PI,
New Mexico State University*

<http://astronomy.nmsu.edu/JIVE/> - JIVE homepage

https://www-n.oa.eu/jovial2016/Kick-off_Avril2016/index.html
JOVIAL kickoff meeting (2016) website with information on the JOVIAL project

Virtual Telescope for X-ray Observations

New Mexico State University/NASA Goddard Space Flight Center, Science Mission Directorate, International Space Station

Tiny Satellites Doing Big Things

New Mexico State University, the University of New Mexico and NASA's Goddard Space Flight Center are teaming to find a way for two CubeSats, toaster sized spacecraft, to work together to produce big science. The Virtual Telescope for X-ray Observations (VTXO) mission is developing the next generation X-ray telescope using a diffractive optics lens and a high-tech camera sensitive to X-rays. The lens is based on the design of a Fresnel lens, often seen added to the rear windows of RVs, but modified to work with X-rays. This type of lens offers superior resolution but requires a focal length, lens - camera distance, longer than a football field. To work around this physical challenge, VTXO will divide the telescope over two satellites with one carrying the lens and the second a camera. The two satellites must be precisely controlled to maintain alignment not only with each other but with a distant X-ray source. When completed, the VTXO Mission will provide a much clearer view for astrophysicist to study X-ray sources in the Universe. Much of the work for VTXO is performed by students from New Mexico, who are getting the opportunity to be at the forefront of NASA sponsored innovation. ✨



Schematic showing the alignment of the imager-satellite with the optics-satellite. The direction of the X-ray source target would be along the line of sight between the two satellites and out of the paper.



*Dr. Steve Stochaj,
Science PI,
Klipsch School of Electrical
and Computer Engineering,
New Mexico State University*



*Dr. Rainee N. Simons, PhD,
NASA Technical Monitor,
Glenn Research Center, SMD*

Development of the Virgin Islands Center for Space Science at Etelman Observatory: Research, Education, and Economic Development Through Promotion of NASA's Vision

University of the Virgin Islands/NASA Goddard Space Flight Center, Science Mission Directorate



UVI students Jamar Liburd, Rafael Almonte, and Omani Tuitt presenting their research at the August 2015 Goddard Space Flight Center Summer Intern Research Symposium, Greenbelt, MD, August 3rd.

Thanks in large part to the increase in visibility and physics research activity supported through this NASA EPSCoR project, The University of the Virgin Islands (UVI) is experiencing a dramatic increase in demand for physics and astronomy courses.

Enrollment in calculus-based introductory physics courses increased from a typical 25-30 students to approximately 40 students last semester while enrollment in second year courses like Classical Mechanics and Modern Physics have increased from typical classes of four and eight (respectively) to classes of 11 and 16 (respectively). We welcome the increased interest in physics and astronomy but UVI's physics faculty is presently understaffed to handle the increase in interest. To meet this need, the science PI has secured funding through the NASA MUREP Institutional Research Opportunity to support the development of a four-year major in physics and astronomy at UVI, including the hiring of two additional physics teaching and research faculty. This will be the first time any four-year degree in physics or astronomy has been offered in the Virgin Islands. We anticipate a first year (to graduate in 2018) class size of approximate 4-8 students. We will continue to actively promote the program in order to increase class sizes and to promote retention in STEM disciplines throughout UVI. ☀



*Dr. David Morris,
Science PI,
University of the Virgin Islands*



*Dr. J. Hakkila,
Co-PI,
College of Charleston*



*Dr. Chryssa Kouveliotou, PhD,
NASA Technical Monitor,
Marshall Space Flight Center*

<https://www.youtube.com/watch?v=aXN2rcEA8PA>

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

*College of Charleston/University of The Virgin Islands/Ames Research Center,
Science Mission Directorate, International Space Station*

Climate change is increasingly affecting coral reefs globally through warming ocean water temperatures resulting in coral bleaching and disease. Recent studies have suggested that corals living in environments with better water quality are more resilient to warming events. Understanding and characterizing how local water quality factors influence the resilience of different coral reefs is therefore key to predicting how reefs will respond to climate change. Yet collecting water quality data in the field requires significant human and financial resources, which many small island communities lack. The use of remote sensing tools can be a less resource-intensive way to collect this information. In this project, we are integrating data obtained from NASA satellites with field measurements to determine bio-optical properties and quantify water quality parameters in the coastal waters of the US Virgin Islands. Our goal is to analyze these data in relationship to long-term data on coral health and community structure in order to develop appropriate water quality assessment tools that can be used to predict coral reef response to global and local stressors.

Dr. Marilyn Brandt and Dr. Tyler Smith, coral reef ecologists at the University of the Virgin Islands (UVI), are working with remote sensing expert Dr. Liane Guild from NASA Ames Research Center and bio-optical modelling experts Dr. K. Adem Ali from the College of Charleston and Dr. Joseph Ortiz from Kent State University to develop the tools and understand how the diverse reefs of the US Virgin Islands variably respond to local and regional stressors. In the summer of 2016, Drs. Ali and Ortiz and their students travelled to St. Thomas, US Virgin Islands, to work with Drs. Brandt and Smith and UVI students to collect data on the bio-optical properties of the water column and on water quality that will then be used to guide the interpretation of images of water quality from Landsat and Sentinel-2 (Figures A and B). ✨



*Dr. Marilyn Brandt, Science PI,
Research Assistant Professor,
Member, Center for Marine and
Environmental Studies,
University of the Virgin Islands*



*Liane S. Guild, PhD,
NASA Technical Monitor
Research Scientist,
Ecosystem Science,
Earth Science Division,
NASA Ames Research Center*



Figure A. Dr. Joseph Ortiz demonstrates to University of the Virgin Islands undergraduate Tia Rabsatt how to use a GER 1500 spectroradiometer to collect data on the optical properties of the water above a coral reef near St. Thomas, US Virgin Islands.



Figure B. University of the Virgin Islands masters student Joe Sellers looks on while Kent State University undergraduate Karli Hollister works with Dr. Adem Ali (foreground) and Dr. Joseph Ortiz (with computer) to take data on the bio-optical properties of the water column at a coral reef site near St. Thomas, US Virgin Islands. College of Charleston masters student David Flanagan is taking water samples off the back of R/V Garuppa.

Initiating a Bold New Generation of Astronomical Surveys at the Wyoming Infrared Observatory

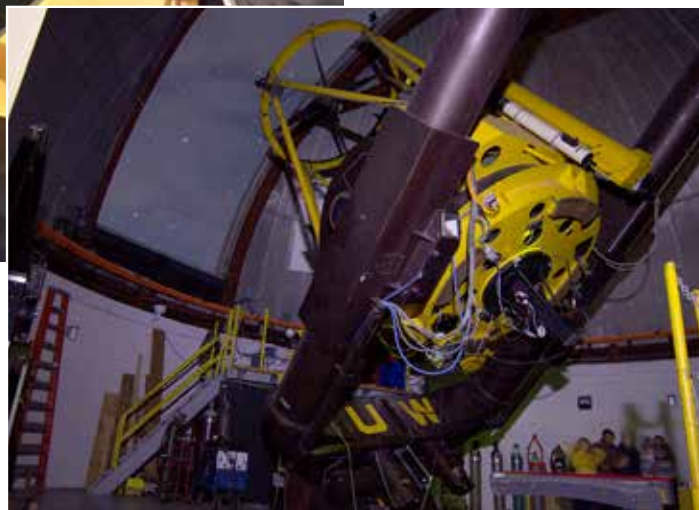
University of Wyoming/NASA Goddard Space Flight Center, Science Mission Directorate



Students from Colorado College using the new Prime focus imaging camera and examining themselves in the 2.3 meter primary mirror (Photo credit Shane Burns, Colorado College).



Interior night dome photo of the Wyoming Infrared Observatory (Photo credit Matt Bryant) ▼



Adam D. Myers,
Science PI,
University of Wyoming



Dr. Matt Greenhouse, NASA
Technical Monitor, Goddard
Space Flight Center, STMD

Upgrades to the University of Wyoming's 2.3 m telescope at the Wyoming Infrared Observatory (WIRO) have launched a new generation of science and outreach programs. A new 4096x4096 pixel ultraviolet-sensitive camera images a 39.1 arcminute square field, enabling graduate and undergraduate students to conduct thesis projects across large portions of the sky. Ancillary upgrades to the Observatory's internet link to campus allows astronomers to transfer hundreds gigabytes of data per day even while supporting fast video links for remote telescope operation and public virtual participation with astronomers on site. The project has enabled new collaborations for teaching and research throughout Wyoming and nationwide. WIRO hosted a week-long observing run for the junior/senior observational methods class at Colorado College taught by Prof. Shane Burns. WIRO provided observing experience for four students and Prof. Bill Welsh from San Diego State University while delivering spectroscopic data in support of NASA's Kepler spacecraft science goals.

WIRO was featured in a documentary chronicling a science investigation of close binary stars involving faculty Prof. Larry Molnar and several students at Calvin College. ✨

Nanostructured Polarization Optics for Atmospheric Remote Sensing

*Montana State University – Bozeman/NASA Jet Propulsion Laboratory, Goddard Space Flight Center,
Ames Research Center, Science and Space Technology Mission Directorates*

The overall goal of this project is to develop new tools for polarimetry and polarimetric imaging using nanotechnology. An enhanced ability to “see” polarized light and at wavelengths outside the visible range (e.g. in the infrared) can provide a wealth of new information, and has potential applications in remote sensing, environmental monitoring, and medical applications. In this project, we are developing a new family of infrared wavelength and polarization filters based on nanostructures in silicon and compatible materials. This approach builds on existing knowledge of silicon micro- and nano-fabrication to achieve customized optical polarization filters in the infrared. Another important advantage of this technology is that it can be readily adapted to different wavelengths and polarization configurations, making it a flexible platform for the development of filters optimized for

a range of applications. The first application goal for this project is a study of polarimetric imaging for the discrimination of cloud phase (ice/water), addressing one of the most significant open questions in current climate models. Once this technology platform is developed, it can be used extended to a broad range of further applications involving polarization-based sensing and imaging. ✱



*Dr. David J. Diner,
NASA Technical Monitor,
Jet Propulsion Laboratory*



Undergraduate REU students learn to launch radiosondes for measuring vertical profiles of atmospheric temperature and humidity in support of cloud phase measurements.



*Dr. Wataru Nakagawa,
Science PI,
Montana State University*

MSU graduate students perform SWIR sky polarization measurements during an episode of extremely thick wildfire smoke while MSU film student (left) obtains photographs and video.

<http://nasaepscor.montana.edu/current/group/nakagawa2014.html>

Nanosatellite Constellations for Space Science Applications

Utah State University/NASA Glenn Research Center, Space Technology Mission Directorate



The student engineers Jaden Miller (standing left), Anthony Swenson (standing right) and Erik Stromberg (seated pointing) show off some of the displays available in the ground station including live orbital tracking (left), real-time visualization of scientific instrument data and satellite housekeeping data (middle), and a visualization of the spacecraft orientation (right).



*Dr. Jacob Gunther,
Science PI,
Utah State University*



*Dr. Rainee N. Simons, PhD,
NASA Technical Monitor,
Glenn Research Center, SMD*

Because of their low cost of production and placement in orbit, NASA, other government agencies and laboratories, and industry are increasingly turning to “cube” satellites (cubesats) to accomplish scientific and other missions. Miniaturization of scientific and other instruments has made the transition from large satellites to cubesats possible. The dimensions of cubesats are typically measured in small multiples (1, 2, 3, 6) of the basic cubesat unit, which is a 10 centimeter cube. However, don’t let the size of the spacecraft or the onboard instruments lead to thinking that the data volumes are also small. Quite the opposite is true. These small sensors are capable of collecting large volumes of data. Thus there is a need for both high-speed and low-power data downlinks to Earth stations.

Student engineers, faculty and other mentors have developed a ground station capable of supporting missions involving constellations of cubesats. Constellations enable multi-point measurements in the space environment, which enables science experiments not possible with a single satellite. This system has already been used for one cubesat mission (MicroMAS) and is planned for use in ten upcoming missions. Our team (Utah State University, the Space Dynamics Laboratory, and L-3 Communications-West) supports the cubesat community by providing a turnkey solution for high-speed (greater than 1 megabit/second using 1 Watt of transmit power) data downlinks. L-3’s Cadet cubesat-sized flight radio and USU/SDL’s software-defined receiver make this possible. The availability of this off-the-shelf solution for data communications and missions operations using SDL’s ground station system frees mission planners to focus on the science mission and science instrumentation. ✨

TA9

ENTRY, DESCENT, AND LANDING SYSTEMS

NASA developments in fundamental atmospheric flight and entry, descent, and landing (EDL) technologies in the 1960s and 1970s serve as a basis for many of our current EDL capabilities of today. For example, the state of the art (SOA) for a fully reusable capability supporting human-scale Earth entry is defined by the Shuttle Orbiter, constructed in the 1970s. In addition, multiple Apollo-derived technologies are being extended to the scale required for the Orion crewed exploration vehicle. Mars Science Laboratory, NASA's flagship Mars mission launched in 2011, defines the SOA for Mars EDL systems. MSL used Viking-derived EDL technologies and architecture with heatshield material developed for the Stardust mission, augmented by the Sky Crane touchdown delivery system, to deliver approximately 1 metric ton (t) of surface payload. Current estimates on the extensibility of the MSL architecture indicate that it is limited to roughly 1.5 t delivered mass. In contrast, estimates for human scale Mars missions, the ultimate goal in NASA's human space exploration plans, will require 20-60 t of landed payload mass. NASA cannot continue to rely on the EDL technology investments of the 1960's and 1970's as a baseline to enable future missions. NASA must develop new and innovative technologies to solve this problem, and this roadmap provides the strategy for achieving this goal.



- p70** Improving Heat Shields for Atmospheric Entry: Numerical and Experimental Investigations for Modeling Ablative Thermal Protection System Surface Degradation Effects on Near-Wall Flow
- p71** Behavior and Optimization of Hypersonic Inflatable Atmospheric Decelerator Devices for Spacecraft Re-Entry
- p72** Prediction and Monitoring of Ablation of Thermal Protective Systems Under Atmospheric Reentry Conditions
- p73** Flexible Thermal Protection Systems: Materials Characterization and Performance in Hypersonic Atmospheric Entry

Improving Heat Shields for Atmospheric Entry: Numerical and Experimental Investigations for Modeling Ablative Thermal Protection System Surface Degradation Effects on Near-Wall Flow

Human Exploration & Operations Mission Directorate, Science Mission Directorate, Space Technology Mission Directorate/Langley Research Center, Goddard Space Flight Center, Marshall Space Flight Center, Ames Research Center, Johnson Space Center, University of Kentucky and Kentucky State University

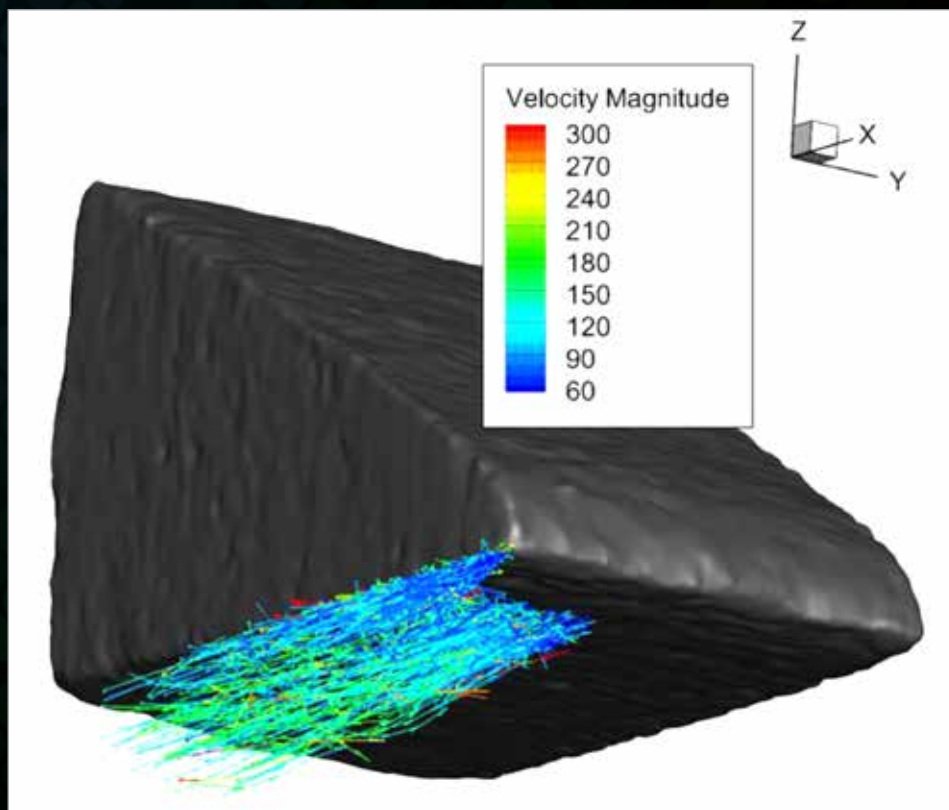
Research is underway at two Kentucky universities to study and improve the performance of heat shield materials that enable spacecraft to survive extreme temperatures of atmospheric entry. The project is advancing the technology of thermal protection systems, also known as heat shields, for spacecraft that travel from Earth and enter the atmosphere of other planets, like Mars, or that go to space and return to Earth, such as astronaut crew vehicles.

This project uses an approach of numerical modeling combined with experimentation to develop computer simulation capability that is optimized and validated with heat shield performance measurements conducted under simulated atmospheric entry conditions in a high-temperature arc-jet facility. Researchers at the University of Kentucky and Kentucky State University collaborating with multiple NASA Centers (Ames, Langley, and Johnson) have conducted test campaigns with the NASA Langley HYMETs (Hypersonic Materials Environmental Test System) arc-jet facility in which FiberForm heat shield materials were subjected to high temperature heat flux in a Mach 5 airflow. Multiple journal and conference publications as well as follow-on research projects have resulted.

The material response (MR) code developed as part of this project is being used to investigate NASA test articles and performance of full-scale thermal protection systems, including for NASA's new crew vehicle Orion. GPU-processing techniques developed to run the code are advancing computer science programs at both participating Kentucky universities. Kentucky students who have completed or are on track to complete graduate degrees have benefitted from technical skills gained in this research program and opportunities to conduct unique research in state as well as at NASA facilities, such as Ames Research Center in California's Silicon Valley.



*Dr. Alexandre Martin,
Science PI*



University of Kentucky researchers reconstruct the trajectory of particles ejected from heat shields samples when subjected to high heat fluxes.



*Dr. David J. Chato,
NASA Technical Monitor*

<http://meetings.aps.org/Meeting/DFD15/Event/254746>

http://www.interpore.org/images/8th_conference/abstracts/1376.pdf

http://www.interpore.org/images/8th_conference/abstracts/1235.pdf

Behavior and Optimization of Hypersonic Inflatable Atmospheric Decelerator Devices for Spacecraft Re-Entry

University of Maine/NASA Langley Research Center, Human Exploration & Operations Mission Directorate, Space Technology Mission Directorate

The University of Maine (UMaine) is working closely with NASA Langley Research Center to help improve our understanding of the structural behavior of Hypersonic Inflatable Aerodynamic Decelerators (HIADs). HIADs are an enabling technology for new space exploration opportunities such as a manned mission to Mars. UMaine's role is to help fill existing knowledge gaps. This is being achieved through a rigorous component-level experimental program, full-scale element level experiments, and the development of computationally efficient 3D beam-based finite element models to complement existing high fidelity 3D shell-based finite element models developed by NASA. Ultimately the goal is to validate the modeling methods using experimental data and then optimize the HIAD structure by performing trade studies. Significant infrastructure improvements have occurred through this NASA EPSCoR grant that put UMaine in a position to continue supporting NASA's efforts in the future. This project assisted 2 PhD students, 1 MS student, and more than a dozen undergraduate students majoring in STEM fields. ✱



*Dr. William Davids,
Science PI
University of Maine,
Advanced Structures and
Composites Center*



*Dr. Anthony Calomino, PhD,
NASA Technical Monitor,
Langley Research Center*

UMaine researchers with torus test article. Back row left-to-right: Cody Sheltra, Josh Clapp, and Andy Young. Front row left-to-right: Science PI Bill Davids and Dana Pride

Media coverage: <http://www.wcsh6.com/story/news/2015/08/24/umaine-research-aims-to-help-nasa/32290369/>

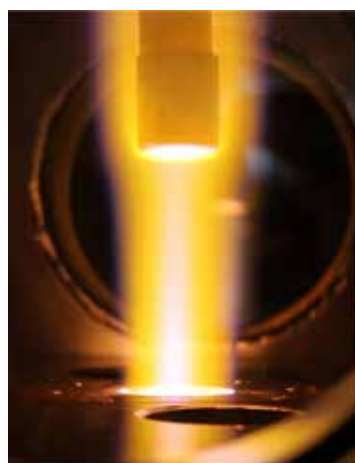
Media coverage: <http://bangordailynews.com/2015/08/24/news/bangor/umaine-research-could-help-nasa-put-man-on-mars/>

Prediction and Monitoring of Ablation of Thermal Protective Systems Under Atmospheric Reentry Conditions

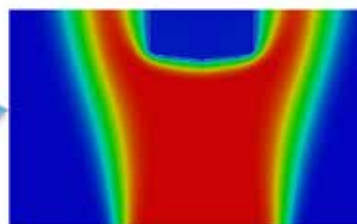
University of Vermont/NASA Ames Research Center, Aeronautics Research Mission Directorate

The thermal protective system (TPS) is critical to the mission of any space mission with atmospheric entry, e.g. Earth or Mars. The performance characterization of TPS is nearly impossible in real conditions due to the harshness of the environment during atmospheric entry. Ground facilities like the inductively Couple Plasma (ICP) of the University of Vermont are designed to reproduce atmospheric entry conditions of any planet and allows for the testing of TPS. The present NASA EPSCoR award successfully developed a predictive numerical simulation tool that can reproduce ICP torch experiments and access critical data that cannot be measured. This high-fidelity algorithm solves the flow and gas-surface interactions

on the surface of the TPS and is now incorporated in the ICP torch experimental protocol. Additionally, the award supported (i) theoretical work in data assimilation and uncertainty quantification of experimental data to improve the predictability of numerical simulation, (ii) a multiscale algorithm to inform macroscopic models from information at the microscopic scale and (iii) a novel method for in-situ health monitoring of TPS using acoustic waves was also developed. This award contributed to the graduation of one PhD student, three MS students and a Postdoctoral fellow.

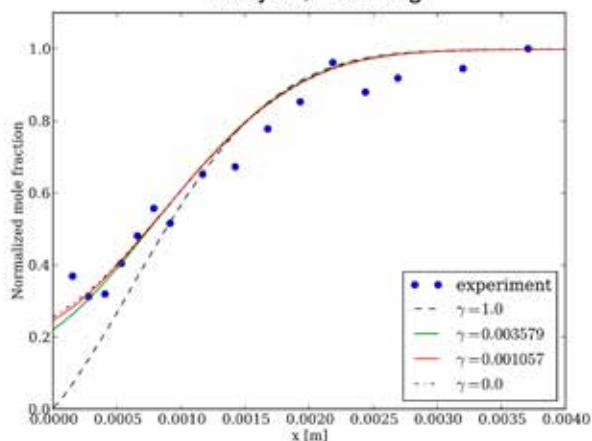


Experiment



Simulation

Analysis, modeling



Thermal Protection System Testing via a Synergy Between Experiment and Simulation



Dr. Yves Dubief, Science PI
University of Vermont &
State Agricultural College



Nagi Nicolas Mansour, NASA
Technical Monitor,
Ames Research Center

Overview of the synergistic experimental and numerical studies of the performance of thermal protection system materials.

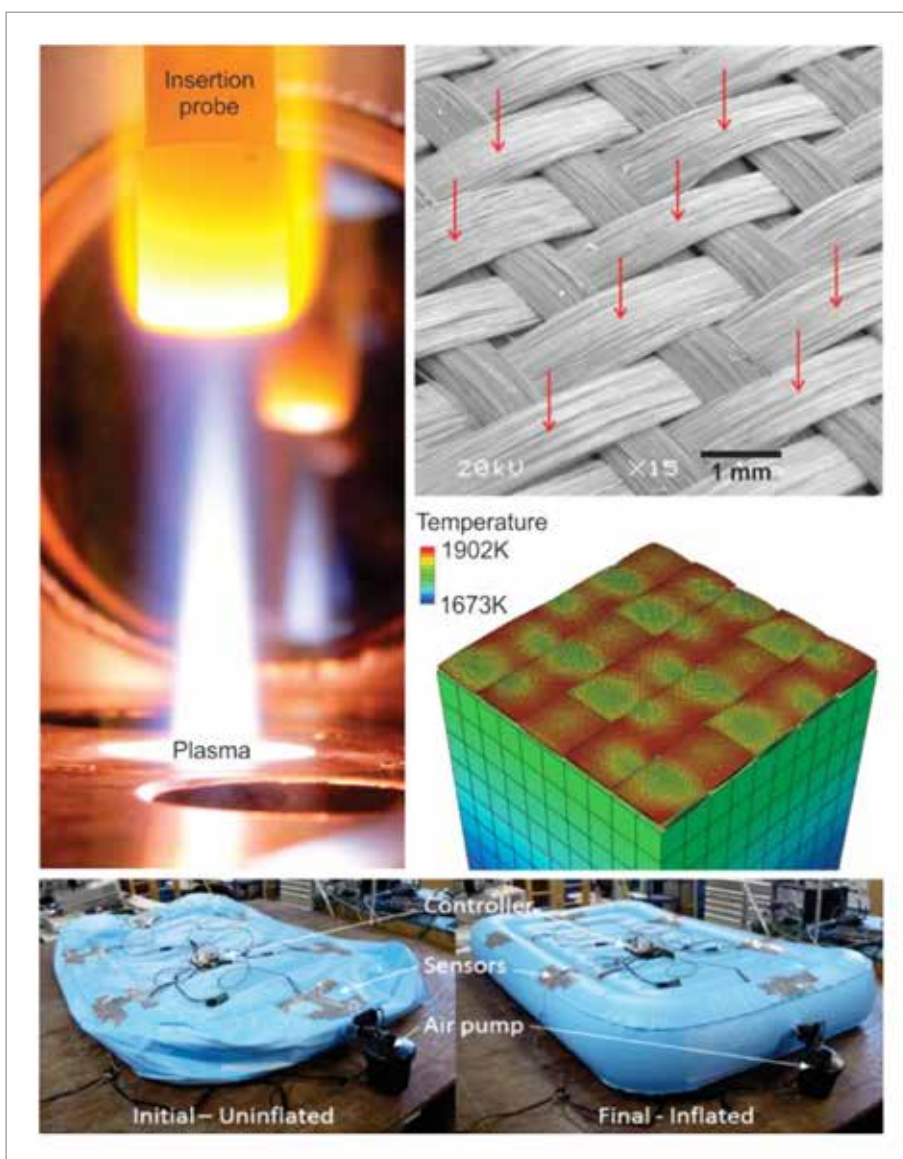
<https://github.com/andyreagan/julia-openfoam>

Contains all data assimilation and Uncertainty Quantification software developed by Andrew Reagan.

Flexible Thermal Protection Systems: Materials Characterization and Performance in Hypersonic Atmospheric Entry

University of Vermont/NASA Ames Research Center, Langley Research Center, Human Exploration & Operations and Space Technology Mission Directorates

This research used high-temperature aero-thermal heating in a 30 kW inductively coupled plasma torch to replicate the effects of harsh oxidizing environments during hypersonic atmospheric entry on fracture behavior and microstructure of two-dimensional woven siliconcarbide fibers. Silicon-carbide and carbon woven fibers were exposed to surface temperatures over 1400°C with different high-enthalpy dissociated oxygen and nitrogen plasma flows, and were mechanically deformed at room temperature. This research demonstrates that oxidizing plasmas play a more damaging role on fracture strength of 2-D woven-fiber ceramics than conventional static heating at equivalent temperatures. Our experiments showed that exposure to high oxygen atom concentration in air and oxygen plasmas results in a more severe embrittlement over shorter time scales, corresponding to degradation rates up to 200 times higher than those reported for static heating in conventional furnaces where only molecular oxygen is present. The origin of the accelerated embrittlement in oxidizing plasmas was found associated with the formation of a viscous silica surface layer leading to critical flaws at hightemperature. These findings are important for developing outer fabric material for new flexible thermal protection systems in NASA space applications. Our current efforts are focused on developing in-situ mechanical experiments with integrated fiber-optic sensors, and multiscale computer simulations to study embrittlement of these flexible TPS materials during flight conditions. ✱



*Prof. Frederic Sansoz,
Science PI,
University of Vermont*



*Dr. Anthony Calomino, PhD,
NASA Technical Monitor,
Langley Research Center*

TA 10

NANOTECHNOLOGY

TA 10

Nanotechnology involves the manipulation of matter at the atomic level to impart materials or devices with performance characteristics that far exceed those predicted for bulk materials and single atoms or molecules. This roadmap is focused on areas where such phenomena can provide solutions to technical challenges.

For example, quantum confinement in nanoscale semiconductor particles, quantum dots, gives rise to novel optical behavior, making it possible to tune the color of their fluorescence simply by changing their diameter. Nanoscale texturing of surfaces can allow for control of adhesion properties, leading to biomimetic (Gecko-foot) self-healing adhesives and self-cleaning surfaces. The unusual combination of superior mechanical, electrical, electronic, and thermal properties of carbon-based nanostructured materials can change the design paradigm of future aerospace systems by enabling lightweight, multifunctional structures. Although nanomaterials are typically considered emerging systems with performance payoffs in the far future, several of these technologies have already proven to be beneficial in applications relevant to aerospace needs. Recent advances in nanotechnologies warrant an expansion of opportunities to evaluate their performance in environments that will permit their integration into NASA missions. Accelerated maturation and insertion of these nanotechnologies in many relevant aerospace applications can be realized more efficiently and rapidly by coupling experiments with computational analysis.



p75 Miniature Space Weather Sensors for Pico and Nano Satellites

p76 Influence of Gravity on Electrokinetic and Electrochemical Colloidal Self-Assembly for Future Materials

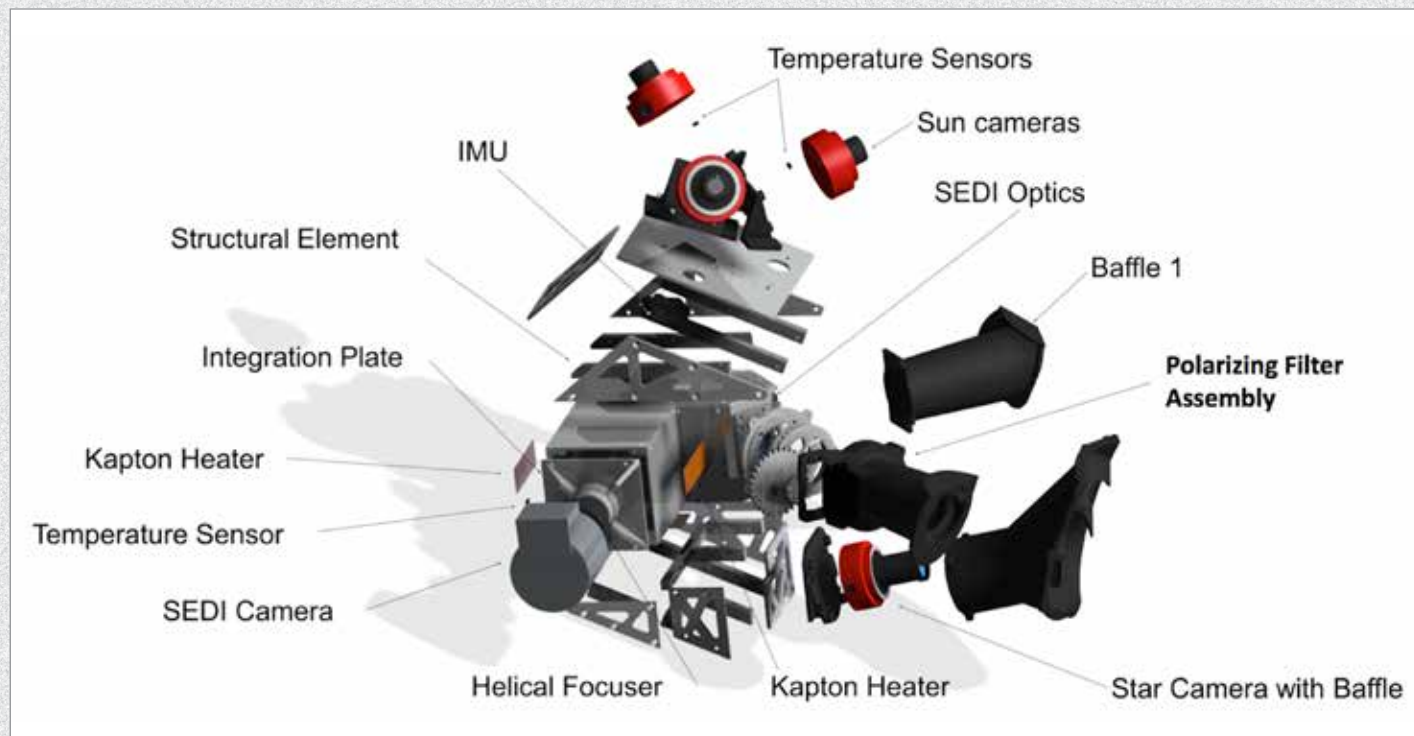
p77 Hyper Velocity Impact - Environmental Resistant Nano Materials in Space Applications

p78 Radiation Smart Structures with H-rich Nanostructured Multifunctional Materials

p79 A Nanostructured Energy Harvesting and Storage System for Space and Terrestrial Applications

Miniature Space Weather Sensors for Pico and Nano Satellites

Utah State University/NASA Goddard Space Flight Center, Space Technology and Science Mission Directorates



An exploded model of the Red Line Air Glow Sensor and supporting instrumentation.

The Active CryoCubeSat program will demonstrate an advanced thermal control system for a 6U CubeSat platform. A miniature, active thermal control system, in which a fluid is circulated in a closed loop from thermal loads to radiators, is being developed. A miniature cryogenic cooler will be integrated with this system to form a two stage thermal control system. Key components will be miniaturized by using advanced additive manufacturing techniques resulting in a thermal testbed for proving out these technologies.



*Charles Swenson,
Science PI,
Utah State University*

The active fluid loop will support removing more than 30 watts from a thermal load and a commercially produced cryocooler, suitable for CubeSats, will provide cooling for detectors to the 75-100K range. Since the LEO environment is generally too warm for passive cryogenic radiators; the approach of heat lifting with a combined active thermal system and a cryocooler will support the greatest

diversity of future missions. Ultrasonic Additive Manufacturing in aluminum will be used to construct fluid channels and other elements within the structural chassis of the CubeSat to produce a compact system.

Previous CubeSat missions have not attempted active thermal control nor have they utilized cryogenic instrumentation. Active CryoCubeSat will expand the possibilities of CubeSat missions through the addition of advanced thermal control and management systems. This includes the ability to regulate increased power loads from elements such as high data rate telemetry, electric propulsion, or computational systems. Such thermal control systems are needed to support future scientific missions on CubeSats requiring cryogenic cooling of miniature scientific instruments. ☼



*Dr. Lawrence Kepko,
NASA Technical Monitor,
GSFC, STMD, SMD*

Influence of Gravity of Electrokinetic and Electrochemical Colloidal Self-Assembly for Future Materials

University of Louisville/Western Kentucky University/NASA Glenn Research Center, Marshall Space Flight Center, Human Exploration & Operations and Space Technology Mission Directorates, International Space Station

*Science PI:
Dr. Stuart Joseph Williams,
University of Louisville*



Dr. Gerold Willing (left), University of Louisville, and Dr. Hemali Rathnayake (right, back), Western Kentucky University, are interacting with NASA scientists at Glenn Research Center to observe and provide feedback from real-time observation of the ACE-H2 advanced colloid experiments onboard the International Space Station.



*Dr. William V. Meyer,
NASA Technical Monitor,
Glenn Research Center*

Scientific experiments prepared by two Kentucky universities successfully completed 85 days in orbit this past March. Launched onboard an Atlas V rocket from Cape Canaveral, then circling Earth at more than 17,000 miles per hour inside the International Space Station (ISS) National

Laboratory under “weightless” or microgravity conditions, these experiments allowed a research collaboration between Kentucky universities, NASA, and industry partners to study aggregation of colloids – liquids like milk that contain suspended particles – in isolation from the force of gravity.

The project, Influence of Gravity on Electrokinetic and Electrochemical Colloidal Self-Assembly for Future Materials, is designed to investigate how to precisely control colloids and develop the potential for new materials with enhanced energy, thermal, optical, chemical, and mechanical properties. The opportunity to conduct experiments in space, funded through the NASA and Kentucky EPSCoR programs, allowed researchers to test fifteen different samples of microfluids and obtain over 20,000 digital images for qualitative and quantitative analysis.

On the ground, extensive experimentation and sample characterization are currently being conducted to properly compare on-earth observations with results acquired from the ISS.

Professors from the University of Louisville and Western Kentucky University are incorporating this experience with space-based research into their classes and student research programs. New equipment acquired for this project enhances existing infrastructure at the UofL Micro/Nano Technology Center, providing specialized multidisciplinary laboratory tools for Kentucky researchers and regional industrial partners. ✨

<https://www.youtube.com/user/ULmicrofluidics>

<https://twitter.com/Ulmicrofluidics>

<http://insiderlouisville.com/business/uofl-researchers-studying-fundamentals-of-physics-in-space/>

https://www.youtube.com/watch?v=Jg-uBgDdZ_w

Hyper Velocity Impact – Environmental Resistant Nano Materials in Space Applications

University of Mississippi/NASA Marshall Space Flight Center, Human Exploration & Operations Mission Directorate, Space Technology Mission Directorate

The current EPSCoR funded research is aimed at developing and testing a new class of ultra-lightweight nano-composite sheet that can provide significant improvement in the shock absorption/attenuation and dispersion of modern debris shields. These new shields could be retrofitted on ISS and also used on spacecraft destined for planetary missions.

The long-term strategic vision of the UM research activities (which has been enriched by the EPSCoR opportunity) is to provide an integrated, interdisciplinary research environment to foster academic and industrial partnership, and to educate a globally competitive science and engineering workforce to advance the engineered systems. Four new graduate courses were developed as part of this initiative

and a new graduate degree in nano engineering and science has been proposed to the school of engineering at UM. Various research programs within the University of Mississippi (UM), and partner Universities, are poised to contribute discoveries and innovations in the modeling, synthesis, characterization, and production of advanced materials with new and exciting characteristics applicable to the fields of engineering, physics, chemistry and pharmacy. A number of academic courses and programs are preparing innovative professionals and scientists, knowledgeable leaders, and literate citizens for a “materials” world. By working together, those involved in these programs can pool their talents and resources to amplify their collective impact. ✨



*Dr. Ahmed Al-Ostaz,
Science PI,
University of Mississippi*



*Dr. Marisabel Lebron-Colon PhD,
NASA Technical Monitor,
Glenn Research Center*

<https://engineering.olemiss.edu/~alostaz/nano/index.html>

Radiation Smart Structures with H-rich Nanostructured Multifunctional Materials

Oklahoma State University/NASA Marshall, Johnson and Langley, Human Exploration & Operations and Space Technology Mission Directorates

A team of Oklahoma State University students has been awarded a \$20,000 grant to help prepare the development of a tougher, more reliable carbon fiber reinforced composite for commercialization.

The team is composed of undergraduate student Kevin Keith and post-doctoral fellow Kunal Mishra from the School of Materials Science and Engineering, graduate student Haley Marie Kurtz from the School of Entrepreneurship and Nathaniel Evans, graduate research assistant at Helmerich Research Center.

The group is one of seven university teams nationwide selected to receive the grant from Venturewell, a nonprofit organization that supports science and technology innovators and entrepreneurs.

The students developed a simple and affordable way to toughen carbon fiber composites used in aerospace and automobile applications. Current materials are highly sensitive to low velocity and localized damage that can result in cracks between layers of the composite. The students developed nanofillers that can easily be incorporated into existing manufacturing processes to increase the stability and reliability of carbon fiber composites.

Haley Kurtz and Kevin Keith also won \$20,000 Oklahoma Governor's cup for the best business plan for commercializing this technology. ✨



Haley Kurtz and Kevin Keith of the MITO Materials Solutions team receiving first place at the Oklahoma Governor's Cup Competition.



*Dr. Ranji K. Vaidyanathan,
Science PI*

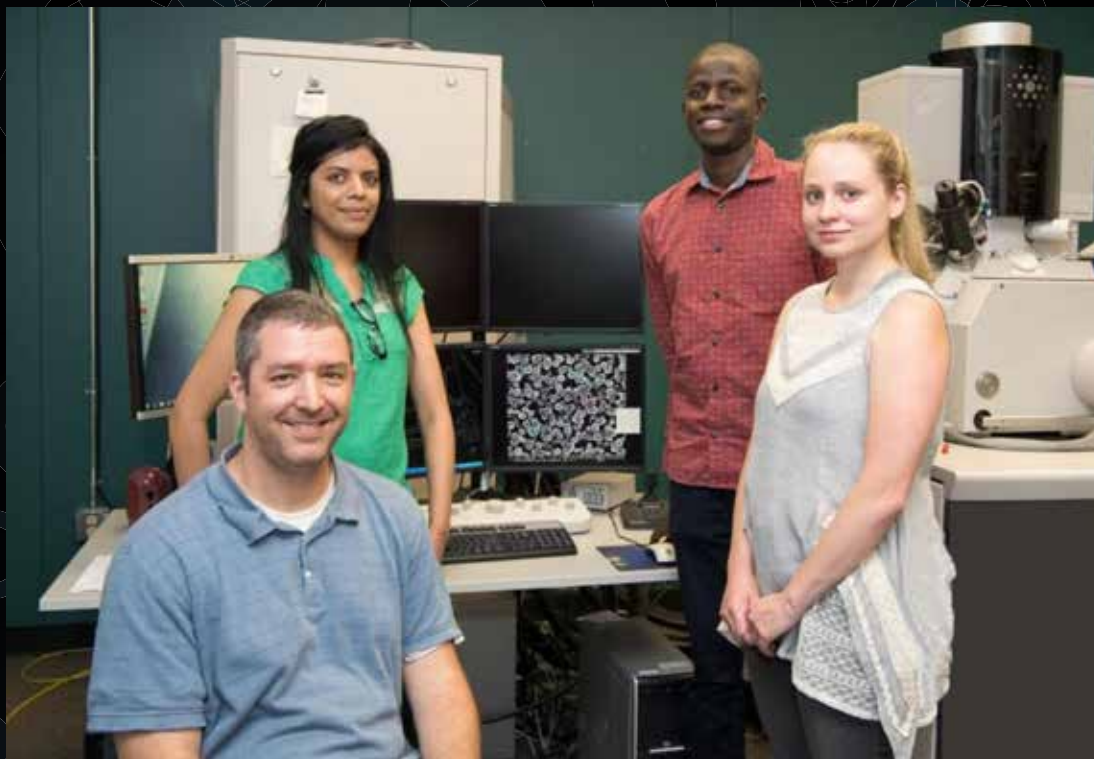


*Dr. Sheila Ann Thibeault,
NASA Technical Monitor,
Langley Research Center,
HEOMD*

<https://spears.okstate.edu/news/2016/04/18/osu-student-led-teams-place-first-third-in-i2e-governors-cup-competition/>

A Nanostructured Energy Harvesting and Storage System for Space and Terrestrial Applications

The University of Tulsa/NASA Human Exploration & Operations Mission Directorate/Glenn Research Center



John Ostrander, Indumini Jayasekara, Ebrima Tunkara, and Echo Adcock Smith, PhD students, pictured with nanorods. Photo courtesy of John Lew.

Researchers at The University of Tulsa, in collaboration with others from Oklahoma State University and The University of Oklahoma, studied, tested and fabricated a nanostructured photovoltaic (PV) system combined with nanostructured batteries in order to create an efficient energy storage system. Solar cells, comprised of ZnO nanorods “decorated” with gold nanoparticles, harvest light and convert it into useful energy. Upon collection, the energy travels through a controlled crossbar and multiplexer circuit to the membrane containing the nanostructured battery system. The nano-engineered batteries, composed of billions of individual battery cells, have the ability to be scaled to the desired battery size, both large and small. These high-functioning nanostructured PVs and batteries will increase efficiency in NASA satellites and rovers while maintaining a low cost per watt. In conclusion, all of the nanostructures can be enlarged and fabricated in a device on a macro-scale energy harvesting and storage system. ✱



*Dr. Dale Teeters,
Science PI,
The University of Tulsa*



*Jeremiah McNatt
Electrical Engineer
NASA Glenn Research Center*

TA 11

TA 11

MODELING, SIMULATION, INFORMATION TECHNOLOGY, AND PROCESSING

The Modeling, Simulation, Information Technology, and Processing TA focuses on advances in foundational capabilities for flight computing and ground computing; physics-based and data-driven modeling, simulation, and software development; and information and data processing frameworks, systems, and standards.

Taken as a whole, TA 11 has impact on most of the NASA technology portfolio. The foundational modeling, simulation, information technology, and processing technologies in this area enable the development of application-specific modeling, simulation, and information technologies as found throughout the other technology roadmaps. TA 11 technologies also form the base of Agency-wide capabilities needed to meet the ever-increasing modeling, simulation, information technology, and processing demands of NASA's missions in exploration, science, and aeronautics. Hence, these technologies are an important component of solutions to NASA's greatest challenges.



p81 New Computer Vision Methods for NASA Robotic Planetary Exploration

p82 Earth System Data Solutions for Detecting and Adapting to Climate Change in the Gulf of Maine

p83 Enhancement of NASA's Polar Missions: Adjoint Data Assimilation into Numerical Models to Reveal Physical Properties of the Greenland Ice Sheet

p84 Integrated Modeling of Microgravity-Induced Visual Changes

p85 Building Capacity in Interdisciplinary Snow Sciences for a Changing World

p86 Testing New Methods to Assess the Environmental and Floral/Faunal responses to Impacts on Earth

New Computer Vision Methods for NASA Robotic Planetary Exploration

University of Arkansas/NASA Jet Propulsion Laboratory, Human Exploration & Operations, Space Technology, and Science Mission Directorates

The research results from the NASA EPSCoR project in robotic navigation have been applied to a co-robot cane for the visually impaired. As a navigation aid, the co-robot cane has two modes, co-robot mode and white cane mode. The cane may detect human intent by sensing the cane user's compliance to the robot motion and switch between the two modes automatically. The two computer vision components, device pose estimation and 3D object detection, are the spin offs of the NASA EPSCoR research. Dr. Ye received a research grant from the NIH through the National Robotics Initiatives (NRI) program in 2013 to further develop the computer vision

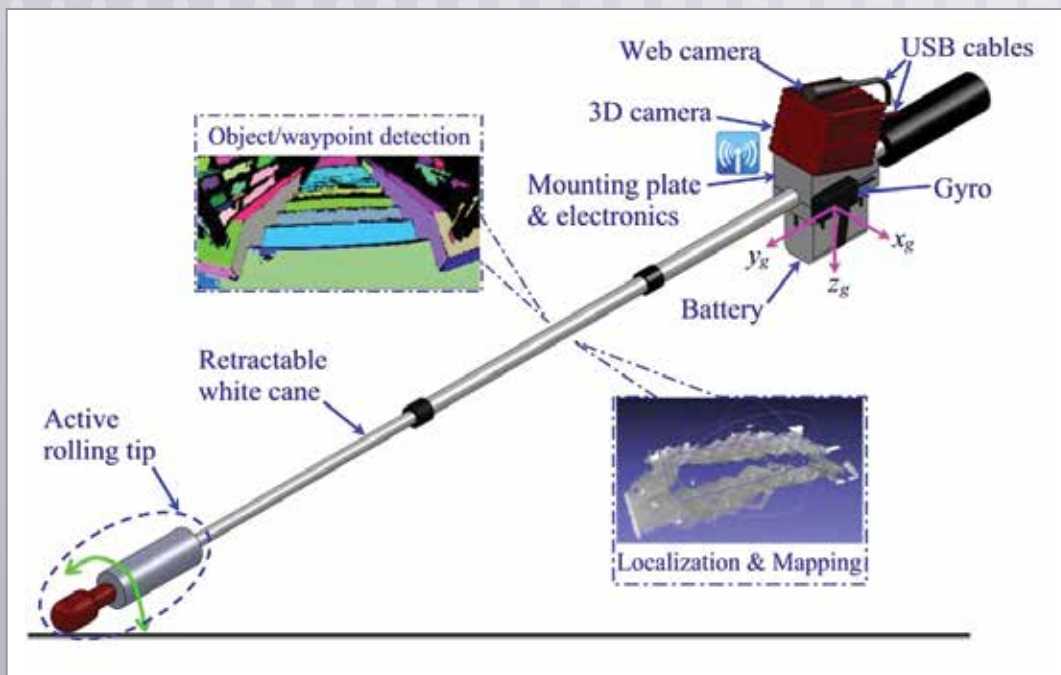
methods for reliable and real-time application in the co-robot cane. Recently, Dr. Ye has also extended the computer vision methods and applied them to a wearable assistive device that can guide a visually impaired person in grasping an object and a quadrupedal assistive robot that can assist an older adult in walking. He has been awarded two more NIH grants in 2015 from the NRI program to develop the two assistive robotic devices. The NASA EPSCoR project has made positive impact on robotic assistive technology that has potential in improving the quality of life of people with visual/physical disabilities. ✨



Dr. Cang Ye,
Science PI,
University of Arkansas,
Little Rock



Ali Shaykhian, Ph.D.,
NASA Technical Monitor,
Kennedy Space Center,
Information Technology (IT) Directorate



Concept image of the co-robot cane: the computer vision methods allow the robot cane to localize itself, map the environment in 3D, and detect objects and obstacles for wayfinding.

<http://sun0.cs.uca.edu/~yusun/NASA%20Website/index.php>

Earth System Data Solutions for Detecting and Adapting to Climate Change in the Gulf of Maine

Gulf of Maine Research Institute/NASA Jet Propulsion Laboratory, Science Mission Directorate

Maine has a reputation for high quality seafood. Seafood, especially lobster, is an important part of the state's economy. Recently, scientists have documented that the waters in the Gulf of Maine are warming rapidly. The rapid warming, estimated at four times the global average, is causing shifts in where and when fish and lobster are found.

With funds from NASA's EPSCoR program, scientists at the Gulf of Maine Research Institute, Bigelow Laboratory for Ocean Sciences, and the Jet Propulsion Laboratory are working to build models that can predict changes in fish and lobster in the Gulf of Maine. These models use a variety of NASA data products, including advanced sea surface temperature data sets and space-based observations of chlorophyll.

The team has found that temperature is a useful predictor of where mackerel, an important commercial and recreational species, is found in the spring. Although temperature remains

important, chlorophyll becomes more important later in the summer. The team is currently working to develop models for other highly-mobile species including herring and squid. The ultimate goal is a system where fishermen can report where they encounter a species, and then the model will update to produce a forecast for the near term.

Although herring, mackerel, and squid are important both commercially and ecologically, their fisheries are dwarfed by the state's \$500M lobster fishery. In 2012, unusually warm temperatures led to an early shift into the summer high-landings mode. The supply chain was not prepared for the influx of lobsters, leading to a challenging summer for many in the industry.

In order to give people in the industry time to prepare for conditions like 2012, the team has developed a model that predicts when the fishery will shift into summer mode based on

water temperatures in March and April. Very warm conditions during this winter resulted in a forecast for a 2012-like start to the season. However, the team does not expect the same economic impact as in 2012, since the lobster industry has expanded its capacity to process, store, and transport lobster.

The policy in the US is that fisheries should be managed in a way that accounts for changes in the ecosystem. Climate change will increasingly challenge fisheries managers with conditions beyond their prior experience. Thus, forecasts and information tools that tell where an ecosystem is going, not where it has been, will be increasingly important. ✱



*Dr. Andrew J. Pershing,
Science PI,
Gulf of Maine Research Institute*

*NASA Technical Monitor:
Edward M. Armstrong, Jet Propulsion Laboratory*

www.gmri.org/lobster-forecast

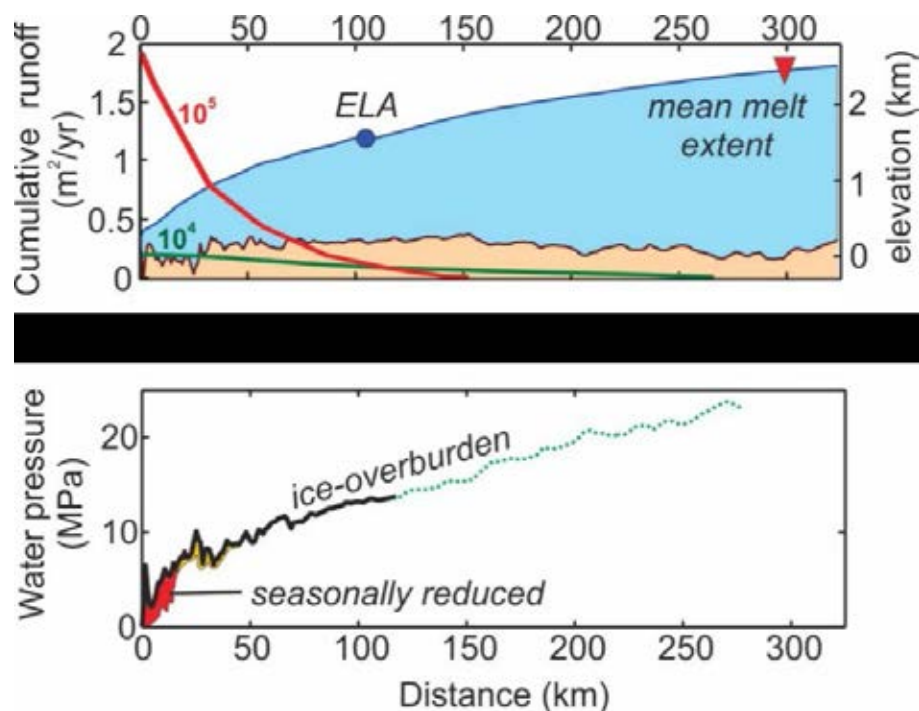
https://twitter.com/Sci_Officer

<https://twitter.com/SeascapeScience>

Enhancement of NASA's Polar Missions: Adjoint Data Assimilation into Numerical Models to Reveal Physical Properties of the Greenland Ice Sheet

The University of Montana/NASA Goddard Flight Research Center

Our work on Greenland ice sheet has discovered the water pressure under the ice is higher than portrayed by pre-existing computer models. This is because the melting power of flowing water is less effective than thought, and so the enormous pressure under 1000 meters of ice inhibits large water-carrying channels from opening. This does not necessarily mean the ice will move faster due to enhanced lubrication as more melt water reaches the bed. We have also discovered ways the water flows in smaller channels and sheets much more quickly than previously thought. We are retrofitting our computer models to include these physics. Our ultimate goal is to improve simulations of Greenland's future contributions to sea level. Our discoveries are not relevant to tomorrow's sea level or even next year's, but nailing down these processes is important for knowing what will happen over upcoming decades to centuries. ☼



Joel T Harper and Jesse Johnson,
Co-Science Pls,
Montana State University



Thomas Wagner,
NASA Technical Monitor,
NASA Headquarters

Integrated Modeling of Microgravity-Induced Visual Changes

*Geisel School of Medicine at Dartmouth/NASA Johnson Space Center, Marshall Space Flight Center,
Human Exploration & Operations Mission Directorate*



Participants in our 2nd parabolic flight campaign: Back row – Jacob Gaba, Mike Zegans, Sean Oh, Brent Berwin, Albert Lomanda, Jay Buckey, Patrick Magari, Catherine Rieke, Allie Anderson, Ariane Chepko. Middle row: Gautam Babu, Torri Lee. Front row: Christine Toutain-Kidd, Judy Ptak, Helen Gu, Abigail Fellows

Our research team investigated the effects gravity has on the eye to better understand the changes to vision that occurs in long duration space flight. We participated in two parabolic flight campaigns aboard NASA's specially designed aircraft that was able to generate multiple periods of ~15-25 seconds of microgravity by flying a parabolic flight pattern. Our results show that even short periods of microgravity produce measurable changes in the eye. These data were used to build and test a numerical model of the eye's structures we developed. This research could be used on Earth to better understand the basic physiology of the eye and improve treatment of glaucoma or hypotony, for example. This work was a coordinated effort between the research team from the Geisel School of Medicine at Dartmouth College, the engineering firm Create LLC, and the crew at the Reduced Gravity Office at Johnson Space Center. Eight undergraduate students participated in the experiments from 4 different colleges across New Hampshire. ✨

<http://www.nasaepscor.unh.edu/eyes.shtml>



*Dr. Jay C. Buckey, MD,
Science PI,
Geisel School of Medicine*

*NASA Technical Monitor:
Dr. William J. Tarver, MD MPH,
Johnson Space Center*

Building Capacity in Interdisciplinary Snow Sciences for a Changing World

Desert Research Institute/NASA Goddard Space Flight Center, Ames Research Center, Science Mission Directorate

Snow algae such as *Chlamydomonas nivalis* can reach very high population densities in snow, at times with over one million algal cells per ml. Dense algal blooms strongly impact the radiation environment of snow, strongly increasing light absorption. These effects need to be considered in numerical albedo models to improve global energy balance and effects on climate. Snow algae face many challenges for survival in their environment, including water limitation during frozen periods, high UV irradiation, temperature extremes, and nutrient limitation. We aim to understand the diversity of actively growing snowpack microorganisms, and how snow algae are able to reach such high concentrations in the low nutrient environments of Sierra Nevada snow. This will facilitate development of a critical understanding of snow algal diversity, survival factors, impacts on snow albedo, and feedbacks to global warming. Towards this goal, we collected pigmented snow algae samples in early summer snowpack in two Sierra Nevada sites from which spectroscopic signatures were recorded, macro and micronutrient data are being determined, microscopic evaluation suggested multi-algal species assemblages, and recently extracted total RNA will reveal the potentially active microbial members of the snowpack. ✨



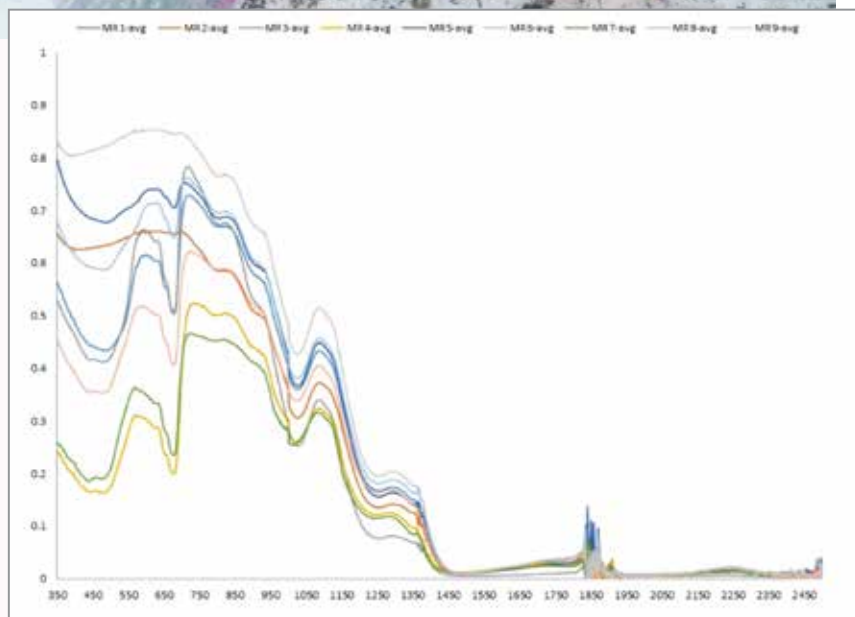
*Dr. Daniel Obrist,
Science PI,
Desert Research Institute*



*Dr. Brian Cairns,
NASA Technical Monitor,
Goddard Space Flight Center*

Top: Photograph of algae on snow (red area) in the Sierra Nevada. Provided by Elisabeth Hausrath, University of Nevada, Las Vegas.

Bottom: Initial spectra of snow reflectance over different snow sites with a presence of snow algae. Y-axis shows reflectance, x-axis shows the spectral wavelength in nm.



Testing New Methods to Assess the Environmental and Floral/Faunal responses to Impacts on Earth

University of Rhode Island, Brown University, Science Mission Directorate, Goddard Space Flight Center



Left: Science PI: Clifford W. Heil, Jr., Ph.D., Research Scientist, Paleomagnetism and Environmental Magnetism, Graduate School of Oceanography, University of Rhode Island.

The loess/loessoid sequences of Buenos Aires province of Argentina span the last 10-12 Myrs. The sequences contain an unprecedented meteorite impact record as well as abundant fossil assemblages. The potential for these sequences to archive geologic, biologic and climatologic changes in a terrestrial environment is immense. In addition, understanding these changes in the context of meteorite impact events and their local and/or regional environmental effects can significantly improve our understanding of impact processes and their effect on our surroundings. Prior and on going work (funded through an NASA EPSCoR-RID award) has helped to develop environmental magnetic and organic geochemical proxies that can be used to characterize these loess sequences. The study proposed here, however, will use these new environmental proxies to test their use to characterize the environmental conditions before, during, and after one specific impact during the mid-Pliocene in Argentina (3.3Ma) near Mar del Plata. This event occurred nearly coincident with a major faunal turnover when 37% of all genera and 53% of all endemic species

became extinct. This period of time is of great interest because it was during the mid-Pliocene Warm Period Optimum (period of global warmth ~2.9-3.3 Ma often used as an analog for future climate change. Hence this proposed effort will address the following questions: (a) Can the multi-proxy (organic geochemical and environmental magnetic) methods developed and used successfully in more recent sediments provide equivalent results from older loess/loessoid sediments in Argentina? (b) What are the paleoenvironmental and biological consequences for the Mar del Plata meteorite impact recorded in the loess/loessoid sequence at Chapadmalal? (c) And was the mid-Pliocene faunal turnover impact-related or climate-related? Specifically, we propose to acquire two shallow drill/cores (40m) across this period in a know section of Argentina near Mar del Plata as well as recover more limited sampling across the impact horizon in selected outcrops. This period of time is also of great interest because it was during the mid-Pliocene Warm Period Optimum (period of global warmth ~2.9-3.3 Ma often used as an analog for future climate change. Our study will provide a case study of how one impact event can affect the local and/or regional environments and the aspects of life and ecology in those environments. If successful, then these results can be applied to other important transitions in environmental conditions. This effort directly addresses EPSCoR objectives by continuing and strengthening the collaborative research between jurisdiction universities (University of Rhode Island and Brown University), demonstrating the use of a new tracer of the biologic response to an impact, providing the opportunity to involve graduate and undergraduate students in an international, multidisciplinary research program, and creating and enhancing other funding opportunities (e.g., National Science Foundation, NASA Exobiology). ✱

NASA Rechnical Monitor:
Dr. Cynthia Evans,
Johnson Space Center

TA12

MATERIALS, STRUCTURES, MECHANICAL SYSTEMS, AND MANUFACTURING

The TA 12 roadmap will provide technological progress through partnerships with other government agencies, industry, and academia. The roadmapping effort will identify and leverage industry and commercial cutting-edge technologies that advance NASA and national interests. Materials are the enablers behind the structures, devices, vehicles, power, life support, propulsion, entry, and many other systems that NASA develops and uses to fulfill its missions. New materials are required as are materials with improved properties, combinations of properties and reliability. Mechanism systems are essential to performing the functions required at virtually every stage of spaceflight operations in order to achieve specified mission objectives. They must be designed to be robust, long-lived, and capable of performing in the harsh environments encountered in space. Embedded sensors in mechanisms will enable the acquisition of real-time data and the ability to monitor system performance, improving system reliability, and leading to improved designs. Health monitoring will give us real data from mechanisms operating in their environment, which will lead to improved confidence in analytical tools and ultimately digital design certification. Advanced manufacturing technological advancements are key to bridge the gap of cross-disciplinary advances over the entire research and development (R&D) continuum from R&D to full-scale production and ensure that manufacturing capabilities are available for significant improvements in cost, schedule, and overall performance.

- p88** Flexible, MMOD- and Puncture-Resistant Shear Thickening Fluid/Textile Composites for EVA Suits
- p89** Fabrication of Advanced Materials for Space Applications
- p90** Investigation of Fatigue Due To Solar Neutron and Other Radiation Absorption in New Materials For Neutron Voltaic Devices
- p912** Carbon Dioxide Storage and Sustained Delivery by Porous Pillar-Layered Structure Coordination Polymers and Metal Organic Frameworks
- p92** Design, Manufacture, Evaluation, and Multi-physical Modeling of Aerospace Composite Materials for Enhanced Reliability
- p93** Flexible Electronics for Space Applications: Development of New Materials and Device Processing Technologies
- p94** Development of Direct-Write Materials, and Electronic and Electromagnetic Devices for NASA Printable Spacecraft
- p95** Improving Carbon Nanotube Fibers through Crosslinking and Densification
- p96** Biofilm Mitigation by Ultrasound-Enhanced Targeted Liposome Treatment
- p97** Development and Characterization of a New Hybrid Polymer-Nanoparticle Composite Coating for Corrosion Protection in Aerospace Applications
- p98** Damage Healing of Polymer Composite Structures under Service Conditions



Flexible, MMOD- and Puncture-Resistant Shear Thickening Fluid/Textile Composites for EVA Suits

University of Delaware/NASA Johnson Space Center, Human Exploration & Operations and Space Technology Mission Directorates

UD Researchers are Protecting Astronauts from Micrometeoroid and Orbital Debris

Astronauts are exposed to life-threatening micrometeoroid and orbital debris (MMOD) threats during extravehicular activities. Working on the lunar or Martian surface exposes astronauts to additional physical hazards such as sharp edges on tools and equipment, as well as rocks. Flexible, lightweight, multi-threat protective materials are needed to provide the durability and protection that will be required for human exploration of our solar system. This includes enhancing both puncture resistance and MMOD resistance, as well as self-healing functionality in the event of a suit breach. University of Delaware (UD) researchers have developed STF-Armor™ nanocomposite textiles that in testing with NASA's Marshall Space Flight Center, Johnson Space Flight Center and White Sands Hypervelocity Test Facility show exceptional puncture and hypervelocity impact resistance. Further research on novel, self-healing materials developed at UD provides a means to repair damage and restore pressure bladder integrity should the TMG be compromised.

The UD research team has been selected for an upcoming experiment on the International Space Station (ISS) to evaluate the stability and efficacy of advanced TMG suit lay-ups containing advanced nanocomposite textiles and self-healing materials in the extreme thermal, vacuum, atomic oxygen and radiation environment of low-earth orbit (LEO) using the MISSE test station. ✱

<http://video.pbs.org/viralplayer/2365517750/?chapter=3>

www.sites.udel.edu/wagnergroup



Prof. Norman J. Wagner,
Science PI,
University of Delaware



Richard W. Russell,
NASA Technical Monitor,
Marshall Space Flight Center



Dr. Richard Dombrowski and Prof. Norman Wagner of UD and STF-Technologies LLC visit the David Clark Company working together to integrate STF-Armor™ technology into the next generation space suit.

<https://www.acs.org/content/acs/en/acs-webinars/technology-innovation/fluids.html>

<http://www.delawareonline.com/story/life/did-you-know/2015/03/03/liquid-armor21university-delawares-innovation/24354971/>

Fabrication of Advanced Materials for Space Applications

Missouri University of Science & Technology/NASA Langley Research Center,
Aeronautics Research & Space Technology Mission Directorates

During the course of the investigative efforts, various fundamental inspections were carried out to identify the feasibility, compatibility, and outcome of FGM fabrication using blown powder based additive manufacturing technology. The experimental studies involved fabrication and characterization of copper-nickel, Al2024-Al4047, Ti6Al4V-316L SS, Ti6Al4V-TiC, and Ti6Al4V-Ti6Al4V1B FGM systems. Modelling efforts included development and analysis of Pre-Mixed Multi-Powder flow through the powder feed circuit. A Digital Image Correlation (DIC) method was developed to measure material deformation. This method was instrumental in analyzing the tensile deformation of miniature FGM tensile specimens. The key project impacts are summarized below:

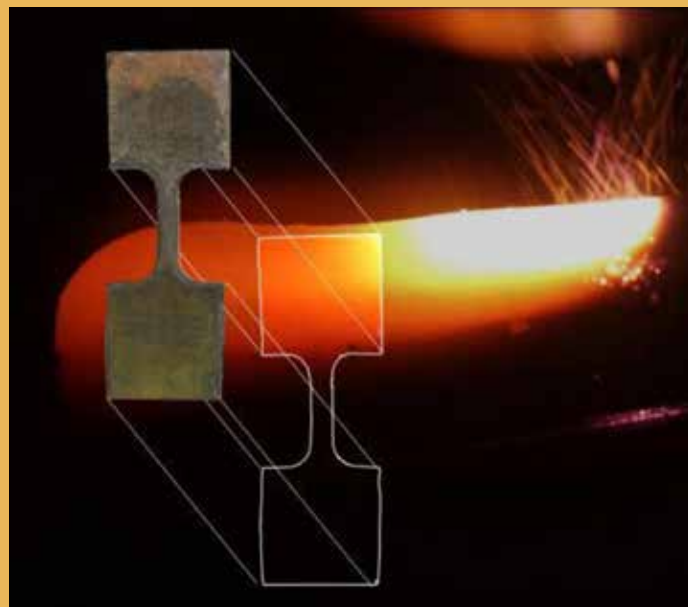
- A methodology to fabricate FGM materials, that are traditionally difficult to produce, has been developed. As an example, a steel-titanium FGM has been successfully graded using this methodology.
- A DIC (Digital Image Correction) technique has been developed to measure the tensile strength and coefficient of thermal expansion. For example, it is critical for FGM materials, since within an FGM sample, each point could have different coefficient of thermal expansion, thus DIC is the ideal method. DIC can also be used for many other measurement devices for FGMs.
- A novel methodology has been used to feed and deliver mixed powders. In producing FGM materials, mixed material powders need to be uniformly pre-mixed and delivered for processing. However, during the powder delivery process, the pre-mixed powders are naturally separated. The developed methodology can specify the size of each powder for smooth delivery, thus is an enabling technology for future FGM processing. ✱



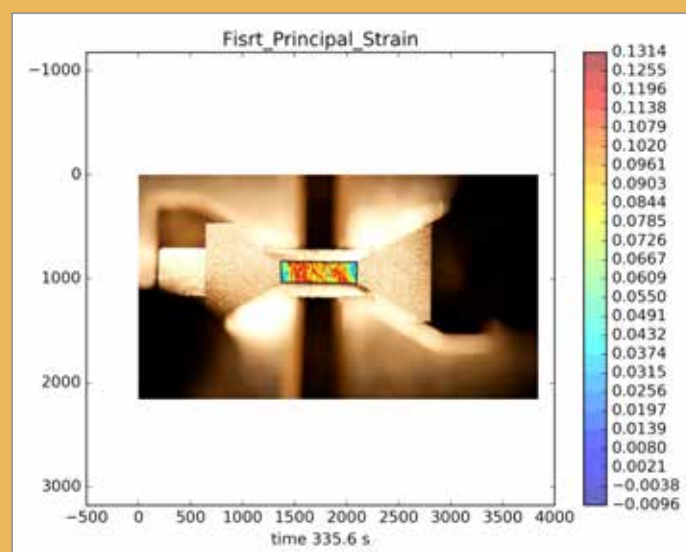
Dr. Frank Liou,
Science PI,
University of Missouri, Rolla



Dr. William J. Seufzer,
NASA Technical Monitor



An example SS316 and In625 FGM sample produced by Missouri S&T. The FGM sample was heat treated so that different materials reveal different colors.



A DIC (Digital Image Correction) technique has been developed to measure the tensile strength of an FGM sample. Principal strain is shown during processing.

Investigation of Fatigue Due to Solar Neutron and Other Radiation Absorption in New Materials for Neutron Voltaic Devices



University of Nebraska, Lincoln/NASA Glenn Research Center, Goddard Space Flight Center, Science Mission Directorate, International Space Station

The first NASA EPSCoR ISS Flight Opportunity research project, DANSON, an Investigation of Fatigue Due to Solar Neutron and Other Radiation Absorption in New Materials for Neutron Voltaic Devices, to be conducted onboard the International Space Station launched Oct 17, from the Mid-Atlantic Regional Spaceport Pad 0A at NASA's Wallops Flight Facility in Virginia. The Cygnus cargo spacecraft was berthed to the Unity module of the ISS on Oct 24, at 10:53 a.m. EDT. The Expedition 49 crew has begun unloading approximately 5,000 pounds of food, supplies and science investigations, including Dr. Axel Enders', University of Nebraska-Lincoln, NASA EPSCoR Research Project. The official project name for the payload is the University of Nebraska Detector for the Analysis of Solar Neutrons (DANSON). The operational nomenclature is Simple Solar Neutron Detector and the payload integration contact is Nicole Benker, a graduate student at the University of Nebraska - Lincoln. Jeppie Compton, National Project Manager, established the NASA EPSCoR International Space Station Flight Opportunity program in 2013 and this mature EPSCoR project was a pathfinder through solicitation, selection, integration and now launch process here at Kennedy Space Center, Johnson Space Center, Huntsville and Wallops Flight Facility in Virginia. Seven additional NASA EPSCoR research projects are schedule to fly between January 2017 and September 2020.

The specific goal of this NASA EPSCoR ISS Flt Op project is to test boron rich neutron absorbing materials under space conditions outside the Earth's atmosphere to establish the effects of radiation damage in those materials upon absorption of radiation and particles provided by the space environment. ✱



1. The Ar/o-carborane plasma, at left, and a Si wafer with 177nm of boron carbide deposited on it at right.



*Prof. Axel Enders,
Science PI,
University of Nebraska, Lincoln*



2. DANSON in place aboard the ISS.



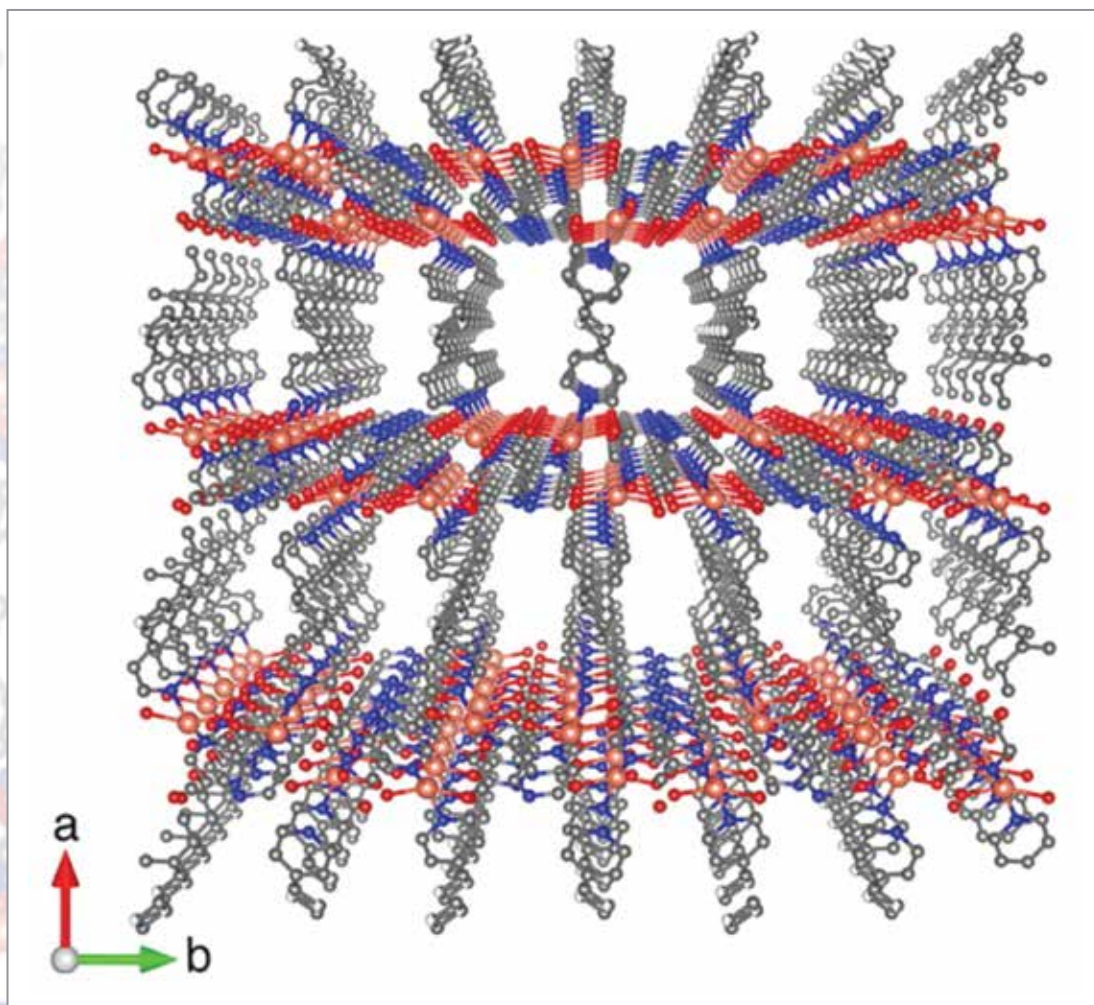
*Willie Williams,
NASA Technical Monitor,
Johnson Space Center*

https://www.nasa.gov/mission_pages/station/research/experiments/2296.html

Carbon Dioxide Storage and Sustained Delivery by Porous Pillar-Layered Structure Coordination Polymers and Metal Organic Frameworks

University of Puerto Rico/NASA Ames Research Center, Marshall Space Flight Center, Human Exploration & Operations Mission Directorate

A significant challenge for long-term space exploration is providing mission crews with efficient life support systems. A crucial component is the production of both water and even methane (i.e., natural gas). Carbon dioxide, which is naturally and abundantly produced by a mission crew, can be used as a source for such purpose. Still, the storage and delivery of this gas within the limitations and confinements of a spacecraft and with minimal energy input requires the development of novel approaches. A group of scientists from the University of Puerto Rico - Mayaguez (lead) and Florida International University have developed technology that relies on the use of nanoporous materials to achieve superior carbon dioxide storage capacities at near ambient pressure and without limiting its on-demand delivery. The effort from these scientists combines both advanced synthetic chemistry and computational theory to design the nanoporous materials from the bottom up, ensuring high efficiency and compatibility with the needs of NASA. Furthermore, these materials are capable of effectively capturing carbon dioxide from the cold Martian atmosphere and therefore help with the eventual supply of precious water and methane during ground exploration activities. ✱



Snapshot of the molecular-scale crystal structure of a material developed by UPRM scientists under a NASA grant. The material is capable of storing significant amounts of carbon dioxide at ambient conditions and delivering it on-demand. Source: Hernández-Maldonado and co-workers, 2015.



*Dr. Arturo Hernandez-Maldonado,
Science PI,
University of Puerto Rico,
Mayaguez*

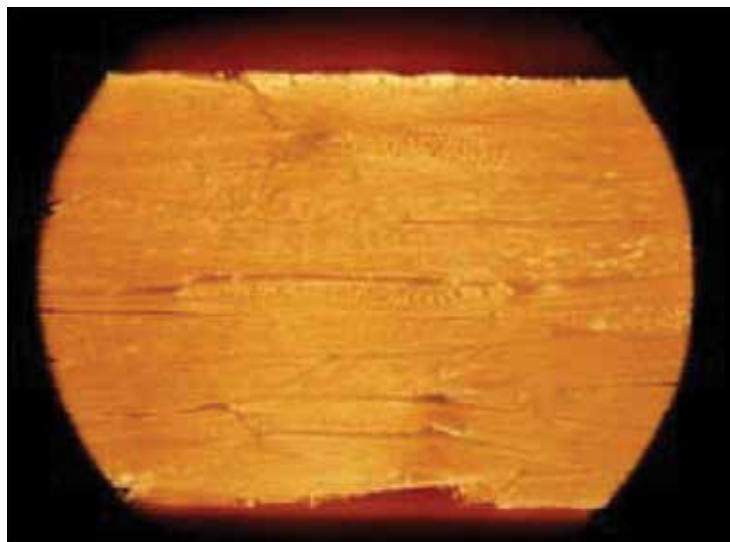


*Jay Perry,
NASA Technical Monitor,
Marshall Space Flight Center*

Design, Manufacture, Evaluation, and Multi-physical Modeling of Aerospace Composite Materials for Enhanced Reliability

University of South Carolina/NASA Langley Research Center, Human Exploration & Operations, Aeronautics, and Space Technology Mission Directorates

Carbon fiber reinforced composite materials are used in a variety of applications such as aerospace, civil infrastructure, and bio-medical applications. During service, these materials undergo degradation which starts at the microstructure level. However, microstructural changes accumulate and lead to catastrophic failure. It is important to understand how local changes happen prior to global failure in real life structures. This NASA EPSCoR research have developed novel techniques to capture such changes very early and also during a latent stage when no significant global property degradation occur. The outcome of the research will provide a better understanding of material state changes and may help develop more damage tolerant structures for enhanced life in the future. ✨



We have taken x-ray images at two different energy levels to visualize what is going on as a result of large changes in dielectric properties. 3D X-ray images taken at 4X magnification of the 16J and 18J impacted specimens respectively.

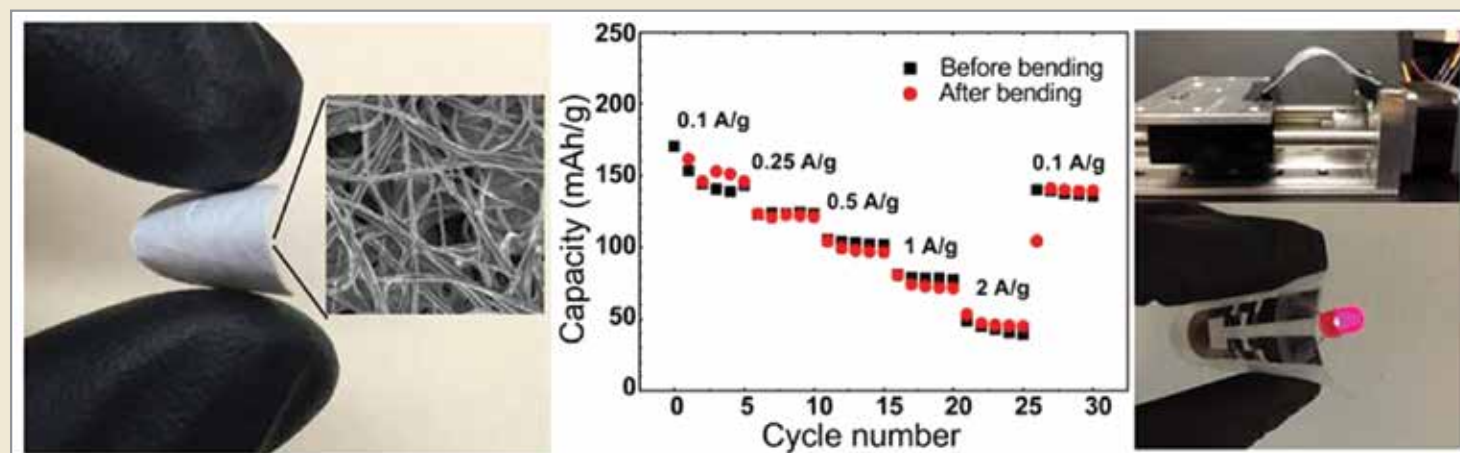


*Dr. Prasun Majumdar, Science PI,
Assistant Professor,
University of South Carolina*

*Dr. Cheryl A. Rose, PhD,
NASA Technical Monitor,
Langley Research Center*

Flexible Electronics for Space Applications: Development of New Materials and Device Processing Technologies

*South Dakota School of Mines and Technology/NASA Glenn Research Center, Jet Propulsion Laboratory,
Langley Research Center, Space Technology Mission Directorate*



Lithium-ion battery of the flexible composite anode lights up a red light-emitting diode.

Scientists from South Dakota School of Mines and Technology have developed a flexible anode material for lithium ion batteries. Using an innovative dual-spinneret electrospinning technique, the team has prepared a flexible mat consisting of electrospun anatase TiO_2 and amorphous SiO_2 nanofibers together with anatase TiO_2 nanoparticles. The composite mat is designed to process three unique properties simultaneously. The TiO_2 nanoparticles with large specific surface area are essential for high battery performance, the SiO_2 nanofibers render the mechanical flexibility, and the TiO_2 nanofibers enhance electrochemical properties (through facilitating charge transport). The test results show that the binder-free composite mat maintains superior flexibility/robustness and good electrochemical performance after 5,000 continuous bending cycles. It is envisioned that the flexible/bendable mat consisting of three functional components are promising as advanced anode materials for developing the next-generation of flexible lithium ion batteries. ✱



*Dr. Zhengtao Zhu,
Science PI,
South Dakota School
of Mines and Technology*



*Dr. William C. Wilson,
NASA Technical Monitor,
Langley Research Center*

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

University of Alaska, Fairbanks/NASA Goddard Space Flight Center, Science Mission Directorate

Findings from this research will lead to better and smaller devices that are space-qualified, as well as to new or improved techniques to fabricate them. Printable spacecraft has been a vision for NASA for the past five years, and we are helping it become a reality. Printable spacecraft will allow humanity to explore planet surfaces as well as remote and difficult to approach areas of Earth.

This research is well on its way to making an impact beyond the bounds of science, engineering, and the academic world. It also provides opportunities for research and teaching in the related fields of materials science, electromagnetics, energetics, solar cells and chemistry.

Moreover, this research is making an impact on the physical, institutional, and information resources of the South Dakota infrastructure through new state-of-the-art equipment.



*Dr. George E. Ponchak,
NASA Technical Monitor
FIEEE, NASA Glenn Research Center*



*Measurement of an antenna by Prof.
Dimitris Anagnostou, Science PI, in the
anechoic chamber of the South Dakota
School of Mines and Technology.*

<http://www.sdpb.org/blogs/science-and-technology/south-dakotas-role-in-space-exploration/>

<http://listen.sdpb.org/post/direct-write-printable-spacecraft#stream/0>

<https://www.facebook.com/sdsmt/posts/10153567050517704>

<https://www.facebook.com/sdsmt/posts/10153580632527704>

Improving Carbon Nanotube Fibers through Crosslinking and Densification

University of Tennessee/NASA Glenn Research Center, Aeronautics Research, Human Exploration & Operations and Space Technology Mission Directorates

Individual carbon nanotubes (CNT) are among the strongest materials known, exhibiting exceptional mechanical, electrical and thermal properties. CNTs thus offer considerable opportunity for the development of a new generation of advanced lightweight materials based on CNT-reinforced

plastics. However, due to difficulties in dispersing pristine CNTs into polymer composites, attention is being increasingly drawn to direct assembly of CNTs into macroscopic fibers (yarns) or sheets. However, commercial CNT yarns exhibit low tensile strength as compared with conventional high performance carbon fibers due to the facile sliding of CNTs past one another.

To overcome this problem, various polymers bearing benzocyclobutene groups were synthesized and crosslinked with CNTF to improve the tensile properties of CNT-based carbon fibers. The optimum crosslinker is a poly(styrene-co-4-vinylbenzocyclobutene) with 80% mol. styrene. Infiltration of carbon nanotube fibers in a solution of this polymer at 1.0% wt., followed by thermal crosslinking, improved the tensile strength by 230% and modulus by 250%. These new ultrastrong and lightweight materials have potential to result in new lightweight aircraft, vehicles, multifunctional protective garments, etc. that will impact many facets of day to day life. ✱

Members of the University of Tennessee team examine the structure of the benzocyclobutene-modified carbon fibers under an electron microscope.



*Dr. Jimmy Mays,
Science PI,
University of Tennessee, Knoxville*



*Dr. Michael A. Meador, PhD,
NASA Technical Monitor,
Glenn Research Center*

Biofilm Mitigation by Ultrasound-Enhanced Targeted Liposome Treatment

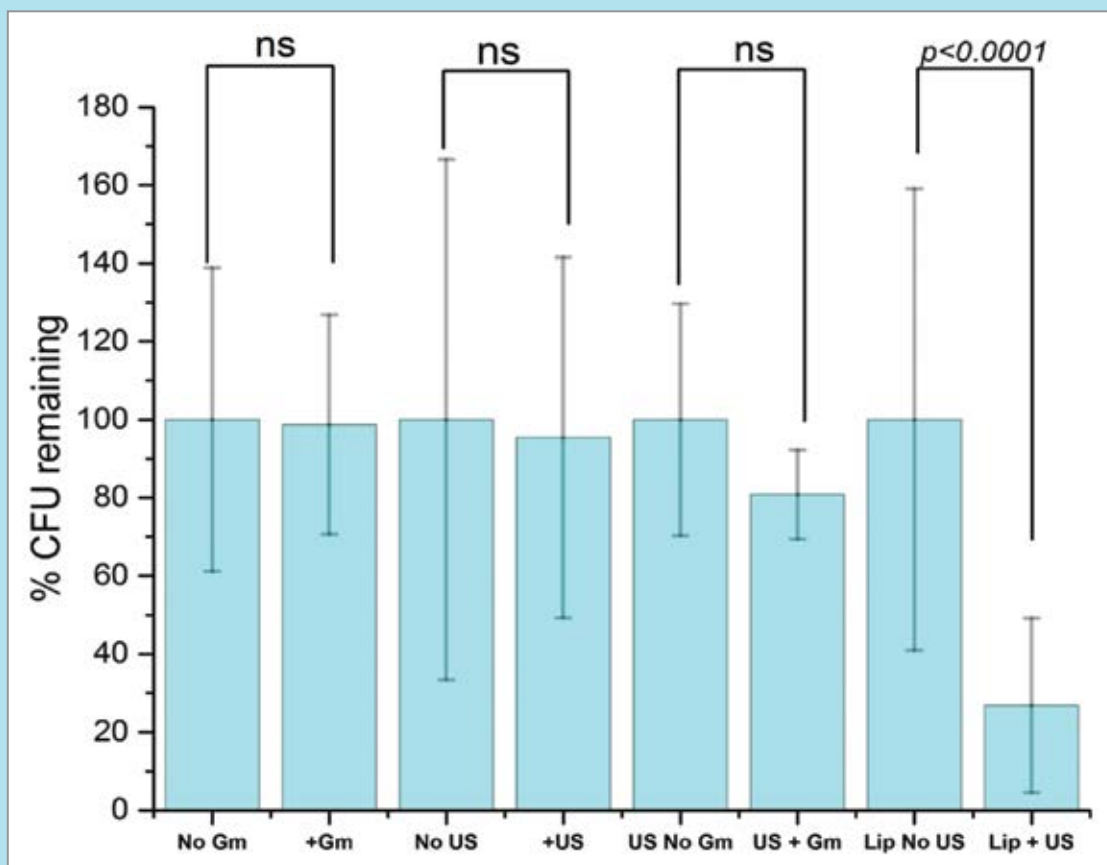
University of Vermont/NASA Johnson Space Center, Marshall Space Flight Center, Human Exploration & Operations Mission Directorate

Since biofilms have resistance to antibiotics, their control using minimum amounts of chemicals and energy becomes a critical issue particularly for resource-constrained longterm space and deep-sea explorations. This study shows moderate intensity ultrasound promotes penetration of antibiotic-loaded liposomes into alginate-based bacterial biofilms, resulting in enhanced bacterial (*Ralstonia insidiosus*) killing. Nano-sized liposomes are used as a delivery vehicle for the antibiotic gentamicin. Alginate-based synthetic biofilms filled with liposome solution are formed at the bottoms of six-well Petri dishes and exposed to ultrasound. Gentamicin is released from liposomes after they are lysed using small amount detergent solution. After the alginate biofilm is dissolved and diluted, counting of colony-forming units shows that about 80% of the bacteria are killed. The liposome-capture density by the alginate film is observed to increase linearly with the ultrasound intensity, reaching an approximately threefold increase compared to that without ultrasound. Measurement by using particle-image velocimetry has demonstrated that acoustic streaming flow, modified by thermal convection, controls the enhancement of the liposome capture rate. *



Dr. Junru Wu, Science PI,
University of Vermont

Dr. Duane Pierson, PhD,
NASA Technical Monitor
Johnson Space Center, HEOMD

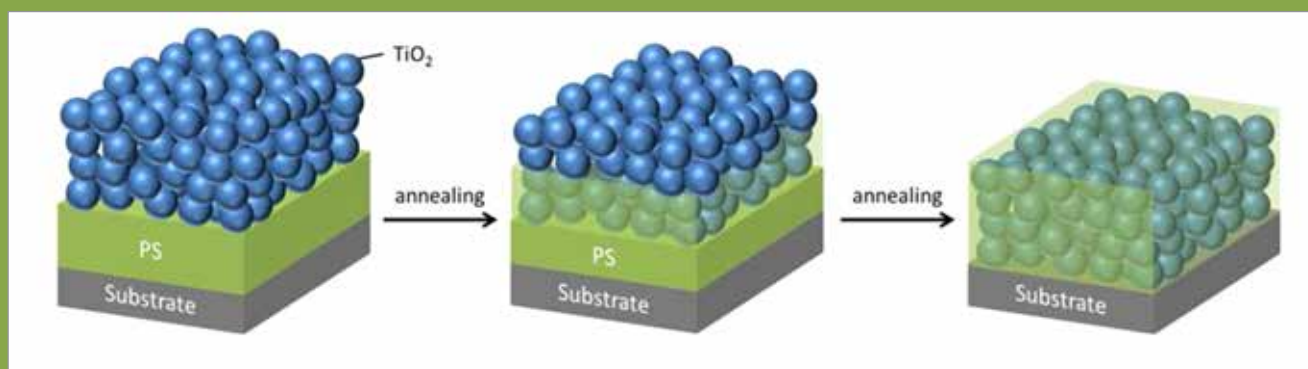


Experimental results show survival percentage of bacteria under different combinations of exposure to ultrasound (US), antibiotics in solution (soluble gentamicin, Gm) and antibiotic-loaded liposomes (Lip); only under Lip +US, about 80% of the bacteria were killed.

Development and Characterization of a New Hybrid Polymer-Nanoparticle Composite Coating for Corrosion Protection in Aerospace Applications

University of Alaska-Fairbanks, Kennedy Space Center, Space Technology Mission Directorate

Much effort has been expended to develop coatings to replace toxic chromates used as pretreatments or pigments in aircraft coatings. There have been many claims for chromate replacement in primer or pretreatment for aircraft, although few functioning systems meeting specifications are presently in use. Polymer nanocomposite coatings (PNCCs), which use nanoparticles as fillers in polymers, possess synergistic properties of nanoparticles and polymers. Because of this unique feature, PNCCs have potential to meet the demand in replacing chromate coatings. Properties of PNCCs are greatly determined by the degree of nanoparticle dispersion within the polymer, which is a key to improving mechanical and barrier properties in nanocomposite coatings over pure polymer coatings. In particular, PNCCs with extremely high concentrations of nanoparticle fillers are promising for corrosion protection in various applications. However, it is still challenging to prepare uniform PNCCs with high loadings of nanoparticles because a high loading of nanoparticles tends to aggregate in an uncured and viscous polymer matrix. This problem is especially exacerbated when mixing with non-spherical nanoparticle fillers, even after reducing the viscosity of polymer at an elevated temperature.



Schematic illustration showing the process of PNCC formation by capillary infiltration of polystyrene (PS) into the nanopores of TiO₂ nanoparticle layer.

This project will develop a new process for producing PNCCs with uniform distribution of nanoparticles at extremely high filler concentrations via polymer capillary infiltration into a dense packing of nanoparticles without any mechanical mixing. New coating techniques derived from PNCCs would be used to protect ground/launch systems and spacecraft from degradation in high saline environments. This project will address NASA's Space Technology Mission Directorate mission roadmap technical area 13.2.1 "Corrosion Prevention, Detection, and Mitigation to develop new corrosion prevention technologies that provide environmentally friendly corrosion resistant/protective materials, coatings, and systems that last longer, require lower maintenance costs, and create less environmental contamination. This research strongly aligns with Alaska's S&T Research Priority 7 "Land transport, shipping, aviation, aerospace, and telecommunications technology". NASA personnel in the Kennedy Space Center Corrosion Technology Laboratory agreed to collaborate with us on this project. ✨

*Science PI:
Dr. Lei Zhang,
University of Alaska, Fairbanks*

*NASA Technical Monitor:
Dr. Luz M. Calle,
Kennedy Space Center*

Damage Healing of Polymer Composite Structures under Service Conditions

Louisiana State University, Johnson Space Center, Langley Research Center, Aeronautics Research and Human Exploration & Operations Mission Directorate, International Space Station

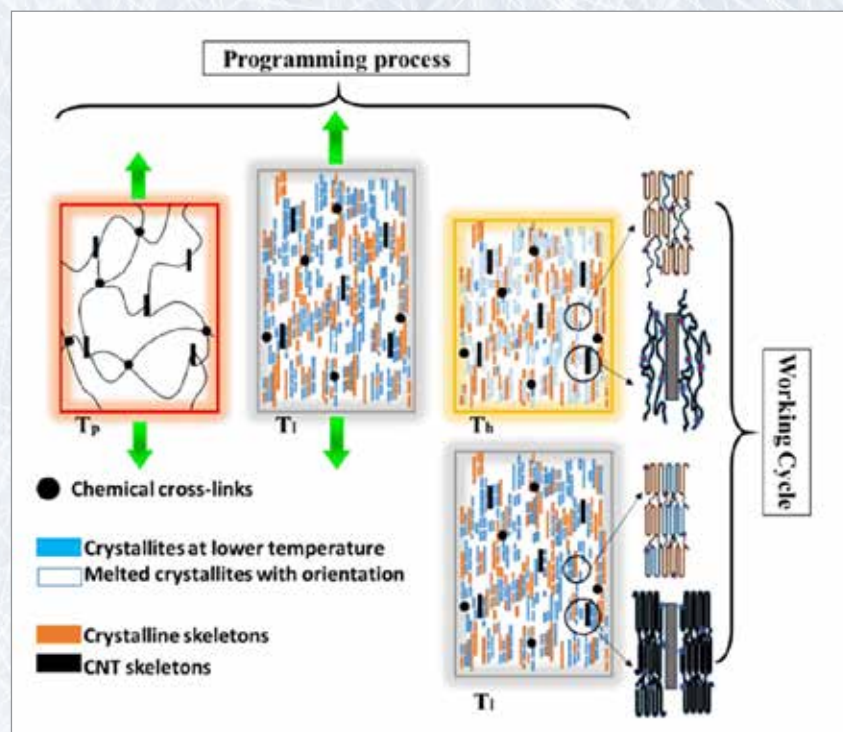
The research objective of this project is to develop new polymer composite panels for in-service damage healing through (1) design, synthesis, characterization, and manufacturing of two-way shape memory polymers (2W-SMPs), that expand when the temperature drops, even without external tensile load; (2) multiscale modeling of the smart composite structures; and (3) additive manufacturing using 3D printing and experimental evaluation of the smart composite panels for impact mitigation and in-service crack healing. The material to be investigated will be a smart self-healing composite with 2W-SMP particles dispersed in an ionomer matrix. The basic idea is that we will use low temperature expansion of the embedded 2W-SMP particles to close the impact-induced crack and the ionomer itself to heal the closed crack. This project targets several programs in the NASA Aeronautics Research Mission Directorate (ARMD) and Human Exploration & Operations Mission Directorate (HEOMD), and responds to State and Institution research priorities. This project brings together researchers from Louisiana State University (LSU) – the Louisiana flagship institution, and Southern University (SU) in Baton Rouge-the primary campus of the largest HBCU system in the nation, supported by NASA researchers at a variety of centers and industries, for a collaborative project that will provide exciting new results for NASA along with developing an important new capability in Louisiana. ✱



*Dr. Isiah Warner,
Science PI,
Louisiana State University*



*Dr. John H. Vickers,
NASA Technical Monitor,
NASA Center for Advanced Manufacturing*



True two-way shape memory effect of a semi-crystalline two-way shape memory polymer with stable crystalline and carbon nanotube networks through tensile programming: crystallization during the programming process and morphology change during working (T_p : programming temperature, T_h : highest working temperature, and T_i : lowest working temperature.).

TA13

TA13

GROUND AND LAUNCH SYSTEMS

TA13

Ground operations and maintenance are significant contributing factors to the high rate of success associated with NASA's missions. NASA developments in TA 13 Ground and Launch Systems technology candidates enable new and more frequent exploration missions and reduce the costs associated with operations and maintenance through application of automation, conservation, and situational awareness tools. A small sampling of these technologies includes self-learning planning systems, self-healing coatings, self-repairing systems, additive manufacturing of spare parts, helium waste stream recovery and reuse, robotic assistants for assembly, unmanned aerial vehicles (UAVs) for range operations, networked weather stations, anti-icing cryogenic couplers, and counterfeit part countermeasure processes.

p100 Advanced Digital Radar Techniques for the Next Generation of Synthetic Aperture Radar (SAR) and Student Training



Advanced Digital Radar Techniques for the Next Generation of Synthetic Aperture Radar (SAR) and Student Training

The University of Oklahoma/NASA Goddard Space Flight Center, Space Technology and Science Mission Directorates

The University of Oklahoma team is partnering with NASA's Goddard Space Flight Center to develop advanced digital radar techniques for Goddard's Ecological Synthetic Aperture Radar (EcoSAR). These digital radar techniques will enable a new class of radar operations that improves science, enhances system performance, facilitates a path for space-borne implementation, and pushes technology beyond the current state-of-the-art, while keeping the costs low. EcoSAR is a new polarimetric, interferometric, synthetic aperture radar (SAR) system that will provide unprecedented two- and three- dimensional fine scale measurements of terrestrial ecosystem structure and biomass. The radar measurements that will be produced by EcoSAR directly support science requirements for the study of the carbon cycle and its relationship to climate change, recommended by the National Science Foundation's Decadal Survey (2007) and highlighted in NASA's Plan for a Climate-Centric Architecture (2010). For example, the polarimetric radar (i.e., transmits both horizontally and vertically polarized electromagnetic waveforms) will be able to help discriminate twigs vs. leaves, burnt vegetation vs. healthy vegetation, etc. The photo depicts some examples of high bandwidth waveforms that are needed to produce the fine-scale radar imagery that the EcoSAR radar will produce. ✨



*Dr. Mark Yeary,
Science PI,
University of Oklahoma*



*Dr. Rafael Rincon, PhD,
NASA Technical Monitor,
Goddard Space Flight Center*



Hands-on, student-led laboratory measurements of radar waveforms at the Radar Innovations Lab at OU confirm our success with the new digital predistortion methods that are needed for the next-generation of phased array radars.

http://www.oudaily.com/news/nasa-grants-ou-researchers-for-radar-technology-improvements/article_b39d8454-9c2d-5050-afa4-3a7177bc02ad.html

TA 14

THERMAL MANAGEMENT SYSTEMS

The Thermal Management Systems technology area (TA) crosscuts and is an enabler for most other system-level TAs. As such, the design of thermal management systems inherently requires that nearly all other spacecraft systems for both human-based and robotic spacecraft be considered. Technology development in TA 14 is centered on systems with reduced mass and/or enhanced performance. Increased reliability and survivability in hostile environments are also critical goals.

Thermal management systems acquire, transport, and reject heat, as well as insulate and control the flow of heat to maintain temperatures within the specified limits. Virtually all spacecraft and related equipment require some level of thermal control, some much more tightly controlled than others, and the design approach and technologies employed vary widely depending on application. Additionally, from a thermal perspective, spaceflight hardware is highly coupled to its radiative environment per the basic laws of physics such as the Stefan-Boltzmann law. A spacecraft's radiative environment generally varies over time, and for planetary applications, the ambient atmosphere may have a significant impact. Environments may be corrosive, abrasive, high pressure, or high temperature.

Technologies within TA 14 are organized into the three traditional sub-areas of Cryogenic Systems, Thermal Control Systems, and Thermal Protection Systems. Each of these sub-areas has unique design drivers, devices, materials, test facilities, and analytical techniques. This document addresses such technologies and is focused on the new or improved ones needed to meet NASA's future mission requirements. Performance goals are generally very specific to each technology.



p102 Highly Permanent Biomimetic Micro/Nanostructured Surfaces by Femtosecond Laser Surface Processing for Thermal Management Systems

p103 Advanced Transport Technologies for NASA Thermal Management/Control Systems

p104 Structural Thermal Insulation Composites

p105 Shape Memory Alloys for High Temperature and Surface Morphing Applications in Aerospace Industry

p106 Explore a Unified, Ultra-efficient and Gravity-insensitive Flow Boiling Pattern for Space Missions

Highly Permanent Biomimetic Micro/Nanostructured Surfaces by Femtosecond Laser Surface Processing for Thermal Management Systems

University of Nebraska at Lincoln/NASA Glenn Research Center, Space Technology and Aeronautics Research Mission Directorates

This NASA EPSCoR grant has been the catalyst for over \$1.5 million in non-EPSCoR funded research on FLSP surfaces and applications that includes: a study on drag reduction and heat transfer enhancements (ONR); a study on anti-icing properties (Boeing); a study on antibacterial properties (Nebraska Research Initiative); four NASA grants, and a DURIP grant to purchase a new high-powered femtosecond laser with spectral tuning capabilities. The success of our group has been the catalyst for a 500K investment of the College of Engineering in a new 6 mJ femtosecond laser and a laser scanning confocal microscope. Our group is currently negotiating two major industry research grants on FLSP applications for an additional \$1.4 million. We expect more grants and successes over the next few years. The NASA EPSCoR funding also had a significant role in the reorganization of the Center for Electro-Optics CEO; (a well-established and well-funded center within UNL) to the Center for Electro-Optics and Functionalized Surfaces (CEFS; CEFS.unl.edu) to reflect the interdisciplinary nature of current research activities. CEFS is a multidisciplinary group of over 30 Faculty, Post-Docs, and graduate and undergraduate students, working on the grand challenge of creating permanent functionalized surfaces for a wide range of applications. ✱



Sarah Wallis (left) and Anton Hassebrook (right) working on an experiment to study the heat transfer characteristics of a metal surface functionalized using femtosecond laser surface processing.



*Prof. George Gogos,
Science PI,
University of Nebraska Lincoln*



*Dr. Michael C. Halbig,
NASA Technical Monitor,
Glenn Research Center*

<http://CEFS.unl.edu>

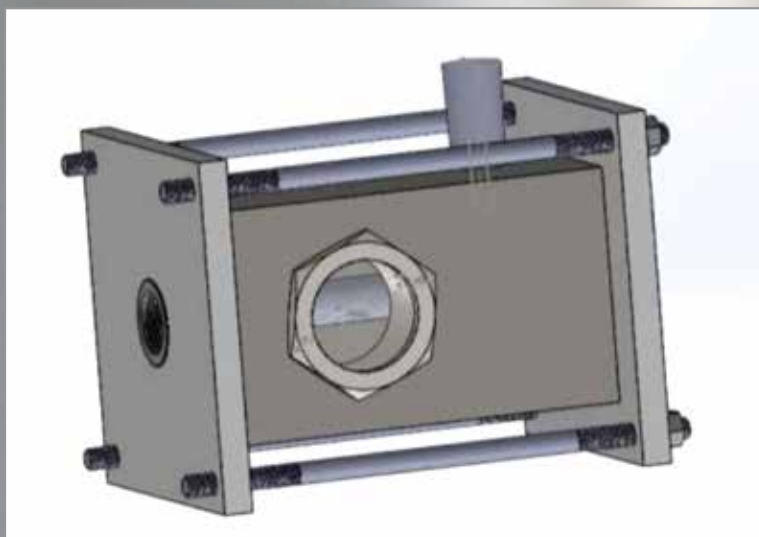
<http://Laserlab.unl.edu>

<http://nmrl.unl.edu/>

Advanced Transport Technologies for NASA Thermal Management/Control Systems

University of Nevada, Reno, NASA Glenn Research Center, Space Technology Mission Directorate

The design for this research is based on an experimental set up that was used for similar previous research that was conducted. The nucleate pool boiling experimental apparatus is rectangular in shape and has a stainless steel housing that is 101.6 mm in width, 101.6 mm in height, and 177.8 mm in length. The two ends consist of Teflon PTFE plates that are 152.4 mm in height and length and 12.7 mm in thickness; O-rings are used to seal the boiling chamber. The Teflon plates each have four 9.5 mm holes that are 12.7 mm away from the width and height edges. These holes were machined so that four aluminum rods can be placed through these holes. Eight aluminum hex nuts are used to keep the Teflon plates tight to the stainless steel housing. The top of the stainless steel housing has a hole for a fitting to attach the reflux condenser – the reflux condenser will have be attached to a constant temperature controller. The reflux condenser will be used to condense the vapor formed from boiling.



Two stainless steel through-wall sights are used to give the capability to view the sample surface as boiling occurs. One sight glass is attached along the length of the housing, and the second sight glass is attached to the Teflon plate that is on the opposite side of where the sample will be located. The other Teflon plate has a spot for a PTFE fitting that will be used to attach an aluminum alloy test section and a thermocouple. ✱



Design (top) and flow-visualization experiment (bottom) for pool boiling.



*Miles Greiner, Ph.D.,
Science PI, ASME Fellow,
University Of Nevada, Reno*



*Dr. Eric Sunada,
NASA Technical Monitor,
NASA Jet Propulsion Lab*

<https://www.youtube.com/watch?v=sRrcsKkdWUQ>

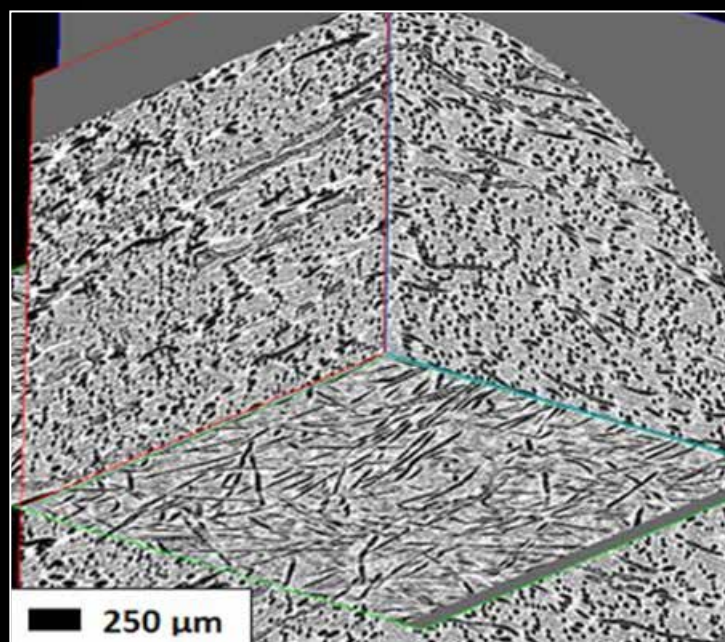
Structural Thermal Insulation Composites

South Dakota School of Mines & Technology/NASA Kennedy Space Center, Human Exploration & Operations Mission Directorate



As NASA gears up for long duration human space flights, one challenge to overcome is the wide temperature variations to which astronauts and equipment are exposed. On Mars, for example, the night to day temperature swing at the equator can be between about 20°C and -75°C. To help mitigate this extreme heat flux, new thermally insulating, reinforced polymer composites have been developed. These new composites exploit advantages of nanotechnology to create enhanced thermal insulation capabilities, while achieving reinforced mechanical properties at low densities.

<http://www.sdsmt.edu/CAPE/>



Micro-x-ray CT of 0.6 volume fraction micro-channels in epoxy matrix.



*David R. Salem,
Science PI,
South Dakota School
of Mines & Technology*

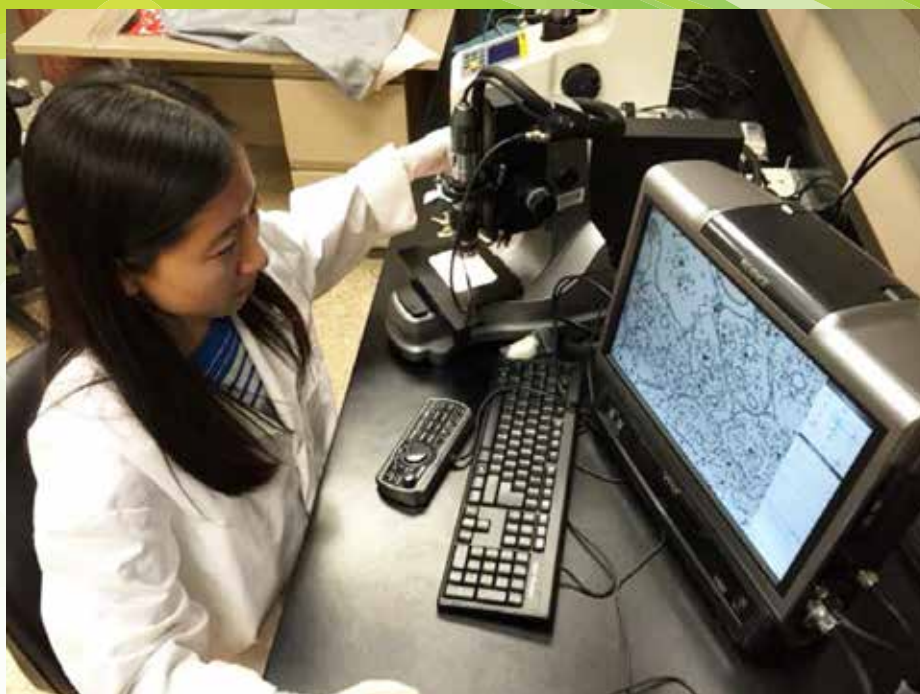
*NASA Technical Monitor:
Robert G. Johnson,
Kennedy Space Center*

Shape Memory Alloys for High Temperature and Surface Morphing Applications in the Aerospace Industry

University of Kentucky/NASA Glenn Research Center, Aeronautics Research Mission Directorate



*Dr. Haluk Ersin Karaca,
Science PI,
University of Kentucky*



University of Kentucky PhD candidate Peizhen Li uses a digital microscope to analyze Nickel-Titanium shapememory alloy samples.



*Dr. Ronald Noebe,
NASA Technical Monitor,
Glenn Research Center*

Demand for aircraft with better fuel efficiency, lower emissions and quieter operation continues to grow. University of Kentucky faculty and graduate students along with industry partners and NASA researchers are collaborating to develop advanced high-temperature shape memory alloys (SMAs) that will enable better, “greener,” and more versatile air vehicles in response to a crossagency initiative called the Next Generation Air Transportation System (NextGen). SMAs have the ability to change shape depending on applied temperature, stress or magnetic field, representing an important new class of materials that offers increased versatility and drag reduction compared to today’s aircraft that have fixed aerodynamic surfaces and structures.

The primary goal of this research is to bridge the gap between the astonishing properties of SMAs and the challenging requirements of the aerospace industry. This research is also strongly aligned with one of Kentucky’s five priority research areas: Materials and Advanced Manufacturing.

Research conducted for this project, both in Kentucky as well as at NASA Glenn Research Center, has actively pursued SMAs with higher transformation temperatures and strength than previously developed. Dozens of alloys were investigated for performance characteristics suitable for application in the aerospace industry, resulting in many joint publications and conference presentations. This project has built the infrastructure to further characterize and research SMAs at the University of Kentucky, leading to additional shape memory alloy study. ✨

Explore a Unified, Ultra-efficient and Gravity-insensitive Flow Boiling Pattern for Space Missions

University of South Carolina/NASA Jet Propulsion Laboratory, Goddard Space Flight Center,
Human Exploration & Operations Space Technology and Science Mission Directorates

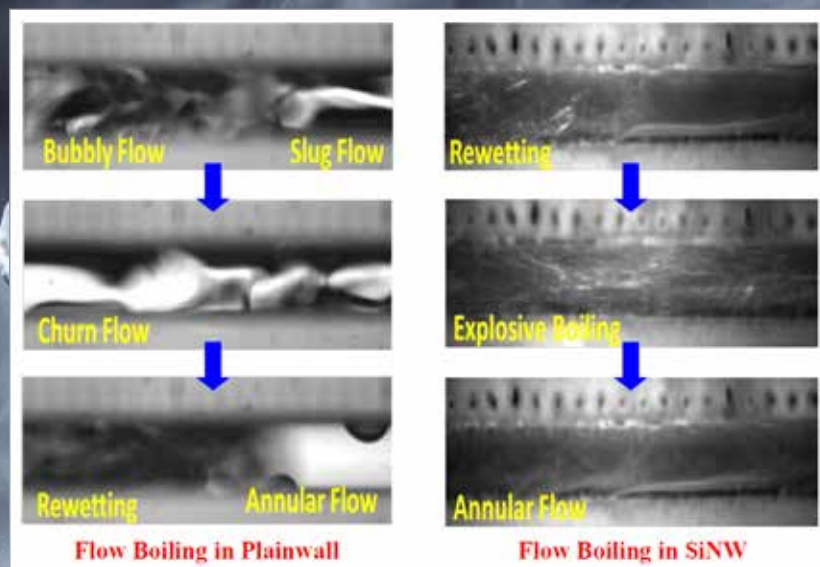
- Silicon Nanowire (SiNW) reduces transitional flow boiling regimes (slug/intermittent/churn) to a single annular flow regime by introducing explosive boiling.
- Explosive boiling is a process where a superheated liquid undergoes an explosive liquid-vapor phase transition due to a massive homogeneous nucleation of vapor bubbles.
- Therefore, gravitational/orientation effects on nucleating bubble departure frequency and diameter now can be controlled by this improved system and SiNW shows excellent gravity insensitivity.
- Thus, flow boiling SiNW microchannels can meet NASA's needs for efficient high density next generation electronics cooling solution in space applications and terrestrial systems like military/avionics operations.
- Significant improvements in electronics cooling have been observed using SiNW microchannels in small scale domain. Currently, we are working on scaled up system to fit this new technique in practical applications.



*Dr. Chen Li,
Science PI,
Associate Professor,
University of South Carolina*



*Theodore Swanson,
NASA Technical Monitor,
Goddard Senior Fellow,
Goddard Space Flight Center, STMD*



Transitional flow regime reduction using SiNW microchannels.



Potential application area of flow boiling SiNW cooling solution

TA15

AERONAUTICS

TA15

This is the first Aeronautics technology roadmap. It reflects previous Aeronautics Research Mission Directorate (ARMD) technology planning work that complies with Executive Order 13419, signed December 20, 2006.

The Executive Order required a comprehensive research and development policy to guide U.S. aeronautics research and development programs through the year 2020. This TA is intended to align with the NASA Aeronautics Strategic Implementation Plan (SIP) to be published in 2015. NASA Aeronautics organized the technology roadmap around six current Strategic Thrusts with inputs from other organizations, industry, and academia. Because of the dynamic nature of the Aeronautics program, the material in this roadmap will be updated regularly.

The Aeronautics planning framework consists of Strategic Thrusts, Research Themes, and Challenges. The six Strategic Thrusts are: 1) safe, efficient growth in global aviation, 2) innovation in commercial supersonic aircraft, 3) ultra-efficient commercial vehicles, 4) transition to low-carbon propulsion, 5) real-time system-wide safety assurance, and 6) enable assured machine autonomy for aviation. Each thrust represents several Research Themes, or long-term research efforts. The Technical Challenges are addressed in the work conducted under the Research Themes. Organizing long-term research efforts under these themes helps ensure that research remains strategic.



p108 Active Wing Shaping Control for Morphing Aircraft

p109 Integrated Trajectory Information Processing and Management for Aircraft Safety (ITIPS)

p110 Development of Turbulence Models, Uncertainty Quantification and Optimization Tools for Aircraft and Turbomachinery Analysis and Design

p111 Learning Algorithms for Preserving Safe Flight Envelope Under Adverse Aircraft Conditions

p112 Experimental and Computational Investigation of Low Pressure Variable-Speed Turbine Aerodynamics: Benchmark Data Set and Predictive Tool Development

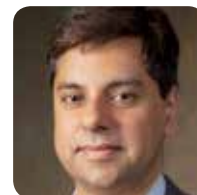
Active Wing Shaping Control for Morphing Aircraft

Wichita State University/Ames Research Center, Aerospace Research Mission Directorate



A prototype morphing UAV in the WSU Wind Tunnel.

This project is developing certifiable active wing shaping control laws for NASA's conceptualized Variable Camber Continuous Trailing Edge and Flaps (VCCTEF) aircraft. Use of active wing shaping control is required in order to achieve the enhanced aerodynamic performance (in terms of higher lift-to-drag ratio) that the VCCTEF is capable of generating. The wing shaping control laws make use of active feedback to continuously modulate the camber across multiple sections of the wings so as to ensure that the local flow distribution over the wing is optimal for every flight condition. This project is developing novel wing shape sensing and control techniques towards meeting these objectives. ✨



*Dr. Animesh Chakravarthy,
Science PI,
Wichita State University*



*Dr. Nhan T. Nguyen,
NASA Technical Monitor,
NASA Ames Research Center*

Integrated Trajectory Information Processing and Management for Aircraft Safety (ITIPS)

*University of New Orleans/Louisiana State University/Southern University/Ames Research Center,
Aeronautics Research Mission Directorate*

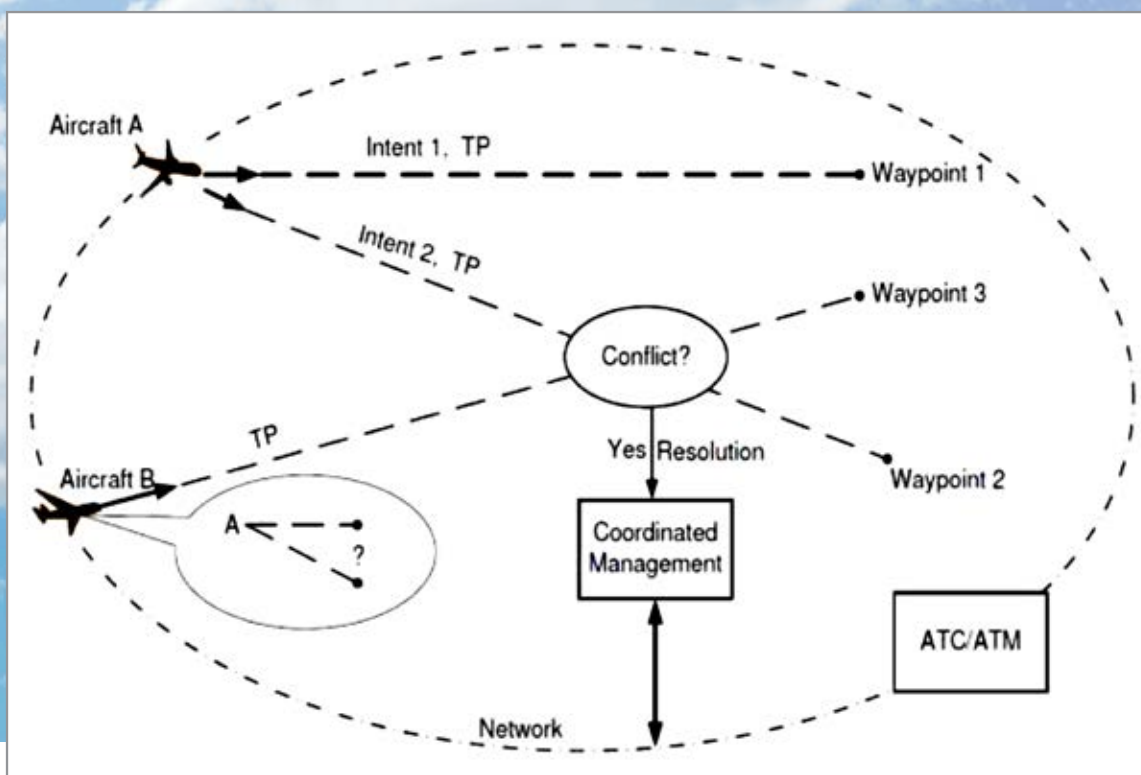
Air traffic demand has been forecast to double by the year 2025. Unfortunately, the present Air Traffic Control (ATC) system is already strained and cannot scale to meet this demand. The situation may deteriorate even more rapidly with the advent of unmanned aerial systems. To restructure the ATC system, NASA is working with FAA and other government agencies to develop the Next Generation Air Transportation System (NextGen). "Enabling heavier yet safer air traffic" is a simplistic description of project ITIPS ("Integrated Trajectory Information Processing and Management for Aircraft Safety"), yet it is the key goal for NextGen. To greatly increase the capacity, efficiency, safety, flexibility, and environmental protection, NextGen calls for a transformation from ATC to air traffic management. It is centered on trajectory-based operations, which rely critically on reliable and accurate information processing and judicious management. ITIPS brings together researchers at the University of New Orleans with expertise at Louisiana State University and Southern University into a highly qualified team to research information processing and network-centric management for trajectory prediction, intent inference, conflict detection and resolution, separation assurance, and conformance monitoring. ITIPS results provide significant technical solutions to related important problems in NextGen. ✨



*Dr. X. Rong Li,
Science PI,
Research Professor,
University of New Orleans*



*Dr. Kai Goebel, Ph.D,
NASA Technical Monitor,
Ames Research Center*



Trajectory prediction, intent inference, networked management, and conflict detection and resolution for air traffic control and management.

<http://www.uno.edu/coe/electrical-engineering/news.aspx>

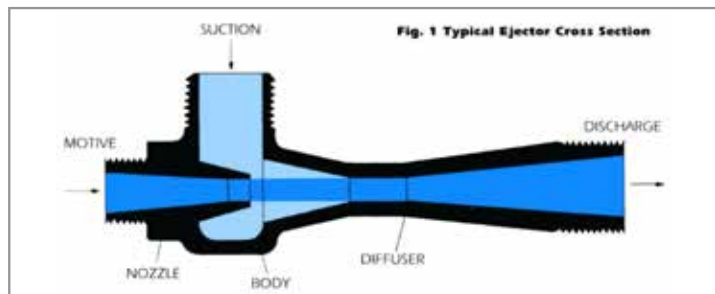
Development of Turbulence Models, Uncertainty Quantification and Optimization Tools for Aircraft and Turbomachinery Analysis and Design

Washington University in St. Louis/NASA Glenn Research Center, Langley Research Center, Ames Research Center, Aeronautics Research Mission Directorate

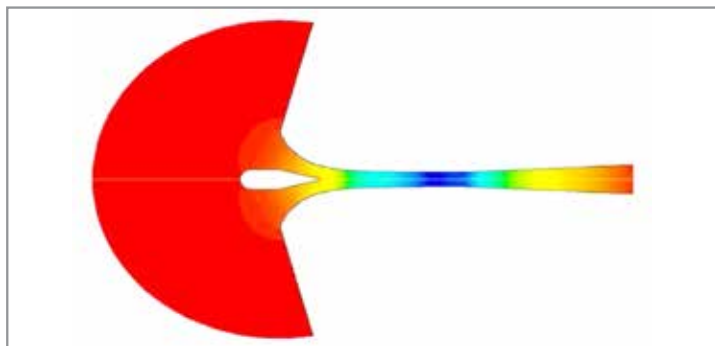
One of the key goals of this research project has been to develop an improved turbulence model for RANS equations that can significantly increase the accuracy of flow simulations for separated flows, rough wall flows, flows with rotational and curvature effects, and flows with compressibility effects and temperature dependent eddy-viscosity. Development and implementation of rigorous and comprehensive uncertainty quantification (UQ) methodology was another main goal of this research project. The third objective of the project has been to conduct the aerodynamic shape optimization studies using both the deterministic adjoint approach and the stochastic surrogate approach. The research project directly addresses the critical areas listed under NASA's Aeronautics Research Mission Directorate - Fundamental Aeronautics Program's R&D priorities. In particular it addresses the NASA's "CFD Vision 2030" goals. A strong interaction has been established with the researchers in the Computational Aerosciences branch of NASA Langley Research Center and with CFD researchers at Boeing-St. Louis and UTRC. This project is serving as an important catalyst in improving

the research and higher education infrastructure in the state of MO. It is allowing major improvements in research infrastructure at Washington University in St. Louis (WU), Missouri University of Science and Technology (MS&T) and Lincoln University. The CFD simulation capability has significantly enhanced addressing research in important areas of Turbulence Modeling, Uncertainty Quantification and Aerodynamic Optimization. At Lincoln University (HBCU), the students are being trained in CFD technology for the first time in its history. The computing infrastructure has also enhanced with the installation of GPU computers at WU. As a result of these major improvements in research infrastructure, it has been possible to develop a new more accurate and very efficient turbulence model for RANS equations of fluid dynamics used in CFD simulations and development of a new methodology for uncertainty quantification and sensitivity analysis. New advanced CFD courses are being developed including the results of this research and students are being trained. Such a trained work force in advanced CFD is very much needed by the aerospace industry.

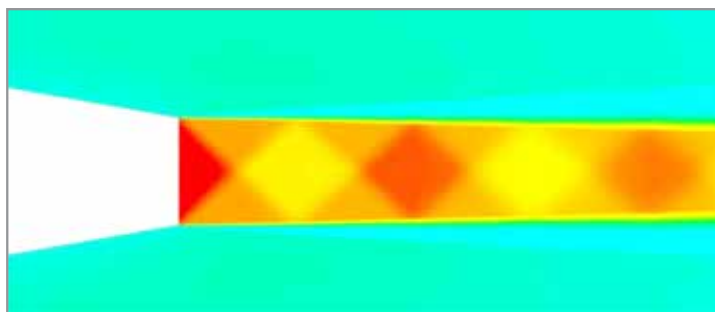
Example to the left describes the simulation of two-dimensional supersonic flow in a slot nozzle ejector which has application in Short Take-off and Landing (STOL) aircraft and other future aerospace vehicles. ✱



Schematic of slot nozzle ejector configuration.



Static pressure contours in the entire computational domain.



Shock formation in the supersonic jet exiting from the nozzle.



*Dr. Ramesh K. Agarwal,
Science PI, Bayly Lab,
Washington University in St. Louis*



*Dr. Mujeeb Malik,
NASA Technical Monitor,
Langley Research Center*

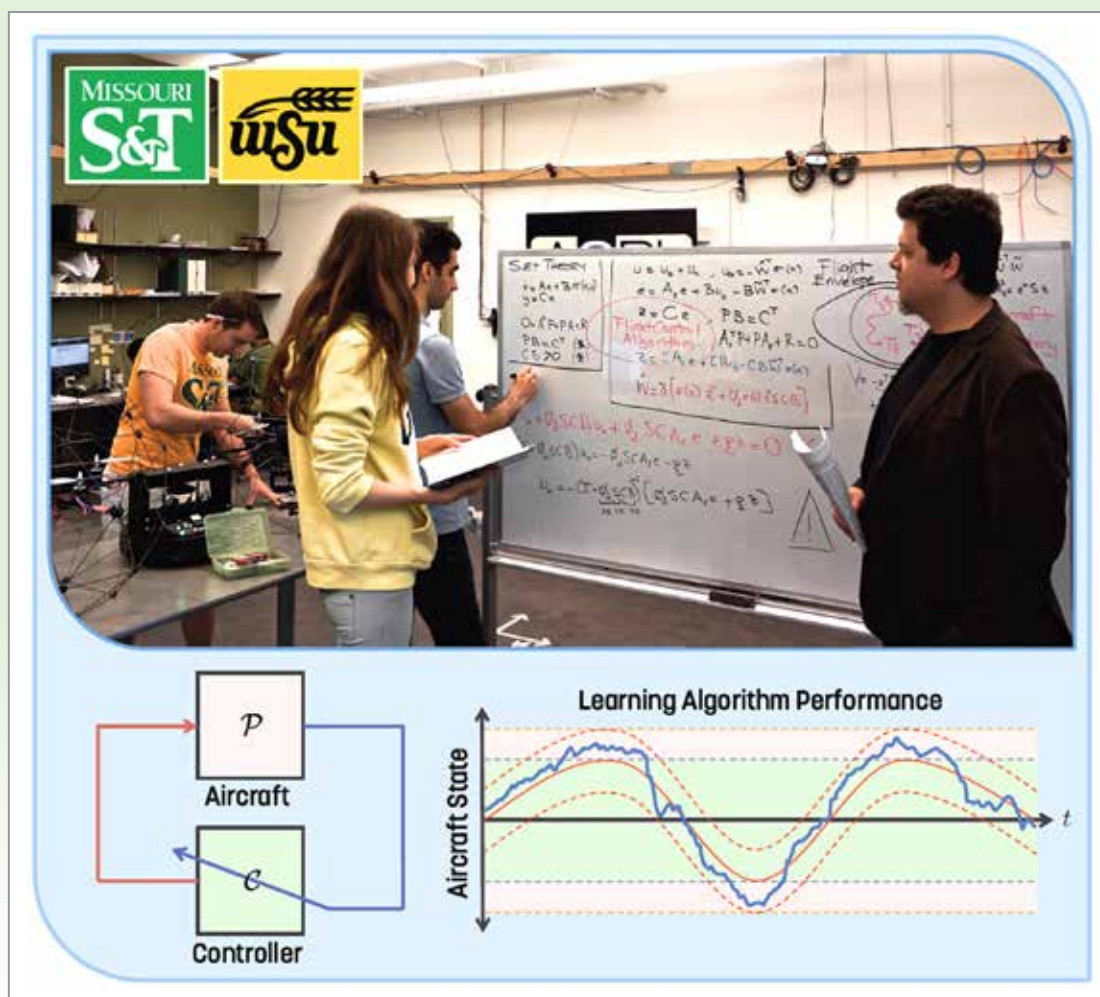
http://scholarsmine.mst.edu/masters_theses/7480/

<http://turbmodels.larc.nasa.gov/>

Learning Algorithms for Preserving Safe Flight Envelope Under Adverse Aircraft Conditions

Missouri University of Science & Technology/NASA Langley Research Center, Aeronautics Research Mission Directorate

Government and industry agree on the potential of learning algorithms in providing flight safety in the presence of adverse conditions (resulting from, for example, 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 envelop in general and commercial aviation. This highly collaborative NASA EPSCoR Missouri project has been addressing this fundamental issue in the utilization of learning algorithms for aerospace applications by 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 have the capability to keep the aircraft trajectories within this a-priori determined envelope in the presence of anomalies. Furthermore, we have been developing methods to use these algorithms effectively for the purpose of pilot support as well. In addition to theoretical advancements, flight tests using CJ-144 fly-by-wire Bonanza aircraft will be performed as a part of this project. This research has a high potential to impact a broad range of aerospace and non-aerospace applications utilizing learning algorithms that involve safe and effective vehicle control and crew decision-making in complex and abnormal situations. ✱



*Dr. S.N. Balakrishnan,
Principal Investigator,
Missouri University of
Science & Technology*



*Dr. Susan Frost,
NASA Technical Monitor,
Intelligent Systems Division,
NASA Ames Research Center*

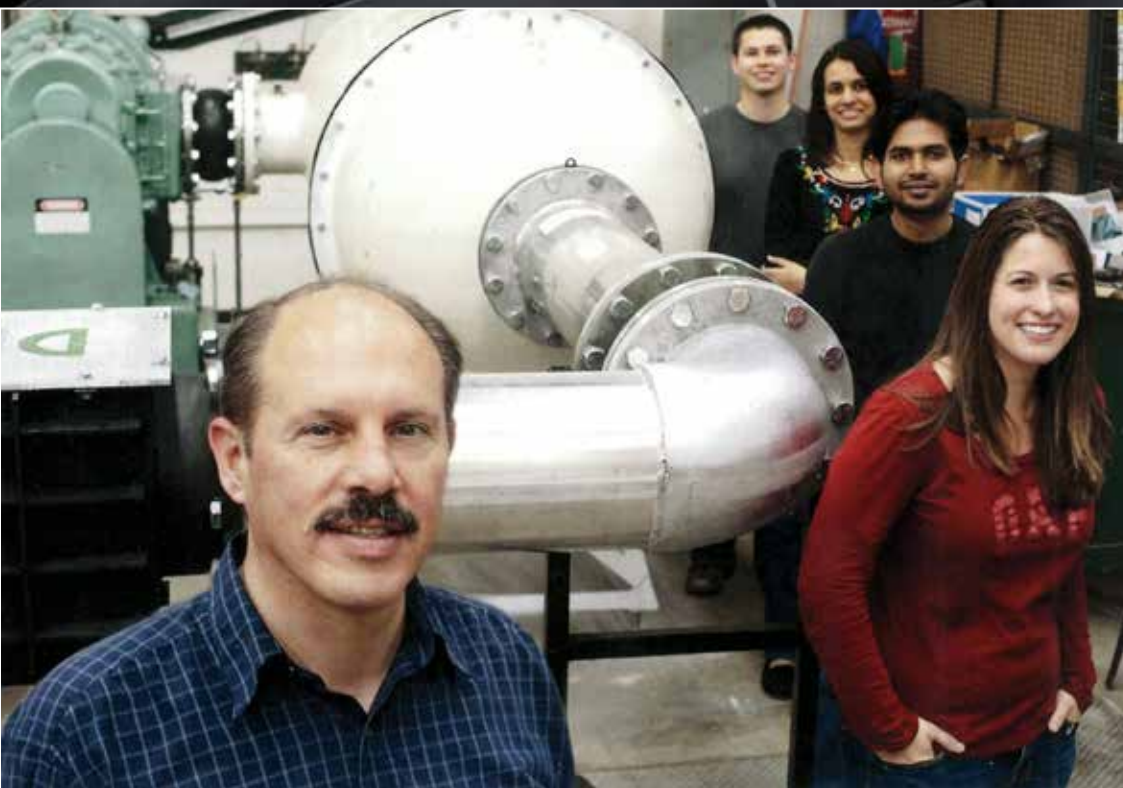
*Dr. Tansel Yucelen and
two graduate students,
Merve Dogan and
Ehsan Arabi, working
on learning algorithms
for safe flight control.*

Experimental and Computational Investigation of Low Pressure Variable-Speed Turbine Aerodynamics: Benchmark Data Set and Predictive Tool Development

University of North Dakota/NASA Glenn Research Center, Aeronautics Research Mission Directorate

The design of variable speed power turbines (VSPT) is particularly challenging due to their highly loaded blades, and often widely varying incidence angles combined with low Reynolds number during normal operation. Moreover, the thermodynamic efficiency of gas turbines is strongly dependent on power turbine efficiency. A combined experimental and computational investigation on VSPT flows was conducted under this grant. This work supports NASA's Aeronautics Research Mission Directorate (ARMD) Fundamental Aeronautics Program in the area of Subsonic Fixed Wind and Subsonic Rotary Wing Projects. This was a collaborative project, pairing the experimental capabilities of the University of North Dakota (UND) with the computational capabilities of North Dakota State University (NDSU) to pursue VSPT research of direct interest to the Turbomachinery and Heat Transfer Branch of NASA Glenn Research Center as well as to Rolls Royce of North America. The UND

experimental research has acquired aerodynamic loading and loss data in their new high-speed low Reynolds number facility. The NDSU study has addressed transition, separation, and unsteadiness using both conventional and more advanced methods in CFD. This effort has been used to further build experimental and computational methods, defined as crucial needs by NASA and the gas turbine industry for advancing understanding of complex VSPT flows to improve VSPT efficiencies. This research has also begun building collaborations with the US aviation gas turbine industry (Rolls Royce, Pratt and Whitney, and Honeywell) and the Air Force Research Laboratory. Further, the project has developed outreach activities to local Tribal Colleges and high schools to improve the demographics of underrepresented groups in engineering in order to help supply the workforce needs of the gas turbine and aerospace industries.



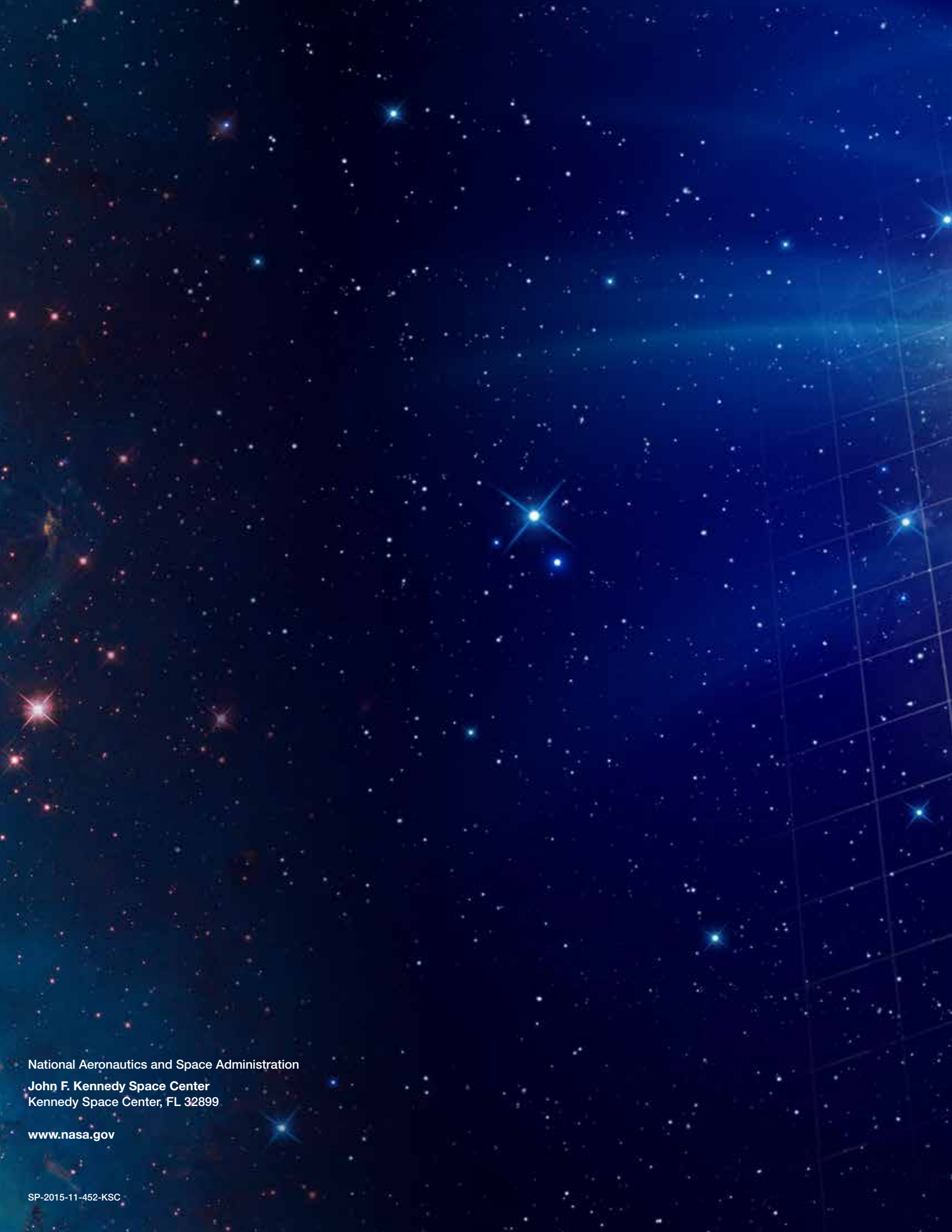
Pictured is the University of North Dakota's compressible flow facility. Counterclockwise starting with the bottom left is Dr. Forrest Ames, and students: Juli Pearson, Nifiz Chowdhury, Preethi Gandavarapu, and Matthew Mihelish.



*Suzen Yildirim Bora,
Science PI,
University of North Dakota*



*Dr. Gerard E. Welch,
NASA Technical Monitor,
Glenn Research Center*



National Aeronautics and Space Administration

John F. Kennedy Space Center
Kennedy Space Center, FL 32899

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SP-2015-11-452-KSC