A Census of Supermassive Black Holes in the Universe

Submitting Organization: UNIVERSITY OF ARKANSAS, LITTLE ROCK

PI: Dr. Mitchell Hudson

Co-I/Science: Dr. Daniel Kennefick, University of Arkansas, Fayetteville

Proposal Summary

Objectives: In its report, NASAs Beyond Einstein Program: An Architecture for Implementation, the Space Studies Board of the National Academies identified the need to perform a census of black holes throughout the Universe as a relevant science goal. Perhaps the most interesting category of black holes in such a census will be supermassive black holes (SMBHs), which reside at the centers of most galaxies. Measuring SMBH masses as a function of lookback time is of importance in the study of how SMBHs form and the role they play in the evolution of their host galaxies and the history of structure in the Universe.

Methodology: We propose three lines of research to estimate masses of SMBHs in galaxies: (1) We will exploit a new relation, recently discovered by this collaboration, between the arm pitch angle of spiral galaxies and the masses of their central SMBHs. (2) We will look for evidence for binary SMBHs in starburst galaxies, which may be the result of galactic mergers. Discovery of binary SMBHs will be relevant to the Laser Interferometer Space Antenna (LISA) mission, as LISA will be able to observe gravitational waves between binary SMBHs as they merge. (3) We will use proven spectroscopic techniques to estimate the mass of SMBHs in quasars, at distances of 10-12 billion light-years, to investigate whether the strong evolution in quasar luminosity observed over this epoch is reflected in the SMBH mass function.

Significance: Using existing data, from a range of cosmic epochs, we will determine the SMBH mass function. This will provide information on (1) the period of peak quasar luminosity, during which presumably the largest SMBHs grew most rapidly, and (2) quiescent SMBHs, which are the assumed modern day companions to the bright quasars of earlier epochs.

Infrared Instrument Development for In-Situ Organic Detection

Submitting Organization: NEW MEXICO STATE UNIVERSITY

PI: Dr. Patricia Hynes

Co-I/Science: Dr. Nancy Chanover, New Mexico State University

Proposal Summary

We will develop and field-test a point spectrometer based on acousto-optic tunable filter (AOTF) technology that will be used for the screening and corroboration of samples collected in situ from planetary surfaces. Samples that indicate the presence of organics or other biomarkers of astrobiological interest will be further analyzed using a NASA/GSFC miniature time-of-flight mass spectrometer (TOF MS), which will characterize trace levels of complex organics. An AOTF is a solid-state device that allows the measurement of a spectral/spatial cube of a scene or object. AOTFs have tremendous potential for application to other areas of interest to NASA such as spacecraft and/or lander systems with an astrobiology focus. The combination of an AOTF IR point spectrometer with a TOF MS provides a biological sensing system that is practical, rugged and efficient for a lander platform targeted for Mars, an asteroid, or icy moons of the outer solar system. Our objective is to produce flight-qualifiable instrumentation necessary for astrobiological investigations, enabling participation in flight programs and strengthen the technical and human resources capabilities within New Mexico.

This program will make significant contributions to NASA's Science Mission Directorate. It will address several of the fundamental science questions outlined in NASA's 2006 Solar System Exploration Roadmap, which reflect the exploration goals of the President's Vision for Space Exploration. These questions include: How did the Solar System evolve to its current diverse state? What are the characteristics of the Solar System that led to the origin of life? How did life begin and evolve on Earth and has it evolved elsewhere in the solar system? Spectral sampling of various solar system bodies provides a unique way to characterize their chemical composition.

Development of a Novel High Spectral Resolution Lidar for Studies of the Effects of Aerosols on the Earth's Climate System

Submitting Organization: MONTANA STATE UNIVERSITY

PI: Dr. William Hiscock

Co-I/Science: Dr. Kevin Repasky, Montana State University

Proposal Summary

Aerosols play an important role in the Earth's complex climate system. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, the radiative forcing due to aerosols has a low level of scientific understanding, resulting in the largest uncertainties in our understanding and modeling of the climate system. Lidar measurements of aerosol properties can provide important information and help lead to a better understanding of the role aerosols play in the climate system. The proposed research plan aims at developing a high spectral resolution lidar (HSRL) in collaboration with scientists at NASA Langley Research Center (LaRC). The successful development of the HSRL combined with other remote sensing instruments already developed and operating at Montana State University (MSU) will allow the study of the radiative forcing resulting from coupled atmospheric aerosols, water vapor, and clouds.

The proposed HSRL will utilize a novel confocal interferometer to spectrally filter the molecular and backscatter signals so that each can be monitored independently. The advantages of using the novel confocal interferometer rather then the conventional atomic absorption cells based on iodine for spectrally filtering the lidar backscatter signal is the better frequency fidelity that can translates into better instrument performance and the ability to build confocal interferometers from a variety of wavelengths opening the door to the development of multi-frequency HSRL systems.

The proposed collaborative research program draws on the strengths of scientists at MSU and NASA LaRC to develop an HSRL instrument based on novel confocal interferometers. Scientists at MSU have experience developing high performance interferometers for a variety of applications and have developed active and passive methods for stabilizing these interferometers. Scientists at NASA LaRC have experience developing and deploying HSRL instruments using atomic absorption cells. Each group provides important skills needed to develop and demonstrate the proposed HSRL.

Spacecraft Component Sterilization using Supercritical Carbon Dioxide

Submitting Organization: UNIVERSITY OF IDAHO

PI: Dr. Jean Teasdale

Co-I/Science: Dr. Ronald Crawford, University of Idaho

Proposal Summary

This proposal outlines a research program aimed at developing a novel spacecraft component sterilization technique based on the use of supercritical carbon dioxide (SCCD) as a sterilizing agent. The project will directly address the objectives of NASA Strategic Plan goal #6, to establish a lunar return program having the maximum possible utility for later missions to Mars and other destinations. The project will emphasize in the area of Planetary Protection (PP) and will be specifically focused on Forward Contamination Avoidance in future missions to Mars where scientific objectives will include the possible detection of extant life in Martian soil. It will directly address the need, as recently summarized by the NAS National Research Council, for new techniques for sterilization to meet international requirements established by the Committee on Space Research (COSPAR) (Paris, France). Present sterilization techniques such as the use of chemical disinfectants, radiation, or strong oxidizing agents such as hydrogen peroxide are not effective in killing certain resistant microbial forms such as bacterial endospores that have been observed in spacecraft assembly facilities and on the surfaces of spacecraft such as the Mars Odyssey orbiter. Thus, more effective sterilization procedures are needed to reach required levels of sterility (Category IVb-equivalent) for future surface landed Mars science missions. These new procedures must be effective in killing of highly resistant endospores while not causing damage to sensitive spacecraft components. The use of SCCD appears to fit these needs.

Building and Enhancing a Competitive and Sustainable Remote Sensing Infrastructure for Critical Zone Studies and Cutting Edge Research

Submitting Organization: UNIVERSITY OF DELAWARE

PI: Dr. Dermott Mullan

Co-I/Science: Dr. Xiao-Hai Yan, University of Delaware

Proposal Summary

Physical, chemical, and biological processes transform bedrock and sediments into soil at the Earth's surface. All terrestrial life on Earth is supported in the aptly named "critical zone", where air, water, rock materials, and biota interact. The critical zone is bounded at the top by the vegetative canopy and at the bottom by the lower limits of groundwater, including the coastal ocean and wetlands. Processes within this zone regulate the transformation of minerals, solubilize nutrients for biota, buffer toxins, create water pathways, and ultimately sculpt the landscape and the coastline. Remote sensing is one of the most powerful and optimal tools for critical zone and earth surface layer research. Building and supporting this research will help address many of the Delaware's environmental issues thereby bringing social, educational and economic benefits to both Delaware and the Nation.

GENERAL GOALS: The general goals of this proposal are: (1) closely aligned with NASA EPSCoR goals and objectives, and build a globally competitive and self-sustainable remote sensing infrastructure for critical zone research, (2) focused on enhancing the core strengths needed to develop competitive research and technology for aerospace related sciences, (3) to produce results which meet State needs, (4) to emphasize interdisciplinary research, and inspiring and training of postdocs, graduate and undergraduate students for the future aerospace related workforce, and (5) to promote partnerships between university scientists, NASA scientists, government agencies, the private sectors, small businesses and international counterparts to enhance research excellence.

SPECIFIC OBJECTIVES OF PROPOSED RESEARCH: Our specific objectives are: (1) develop real-time remote sensing capability for Delaware's coastal and critical zone environment, (2) carry out cutting edge research in three areas: (2a) remote sensing of hydrological and coastal resources, (2b) remote sensing of wetlands, and (2c) remote sensing of land resources, and (3) further develop and enhance a decision support system through Earth science remote sensing research results. Unique and innovative methods and advanced technologies will be further developed and applied to achieve our goals and objectives.

MERITS AND IMPACTS: The research results will allow scientists to measure the pulse of ecosystems in Delaware, correctly diagnose any problems, and then prescribe the best course of action. The proposed effort will also be useful for managers and the general public by converting large amounts of technical data into useful information for decision-makers. In addition to building and enhancing infrastructure and conducting the cutting edge research, this project will contribute to the development of the Science, Technology, Engineering and Mathematics (STEM) workforce. This project will contribute to the training of new scientists through support and inspiration of postdoctoral scientists and graduate students. New insights from this project will be integrated into our upper-level graduate courses on critical zone research and remote sensing taught at the Delaware. We will also offer parallel summer intern programs for undergraduates, and involve and spark their interest in NASA aerospace related research. We believe this project will help balance the needs of the region's various users, determine the best way to plan sustainable development with minimal environmental damage, and provide a quick response to environmental problems. We expect the results of this project to enhance the security and environmental quality of Delaware, making the State more attractive to residents, businesses and tourists, and consequently will improve the economy of the State.

Climate Variability and Glacial Recession in the Wind River Range and Grand Teton Range, Wyoming

Submitting Organization: UNIVERSITY OF WYOMING

PI: Dr. Glenn Tootle

Co-I/Science: Dr. Glenn Tootle, University of Wyoming

Proposal Summary

The proposed interdisciplinary study will investigate climate impacts on glacier recession in the Wind River Range and Teton Range, WY (USA). Remote sensing data [LandSat imagery, aerial photographs, NASA Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover data] will be utilized to investigate area and volume (mass balance) change. Stable isotopes of water (deuterium, oxygen-18) will be utilized as hydrologic tracers to estimate the contributions of different water sources to streamflow, including rain, snowmelt, and glacier ice-melt. The two unique and differing approaches (mass balance through remote sensing and stable isotopes) will directly address the research priorities of the NASA Climate Variability and Change (CVC) Roadmap in the areas of: (1) NASA's role in characterizing, understanding, and predicting climate variability and change focuses on global observations of the more slowly responding components of the system (primarily oceans and ice); (2) Critically-needed new measurements including decadal change in ice mass over land; (3) NASA provides observations on temporal and spatial scales to detect change that link climate to areas such as snow cover; (4) Current measurements of ice mass over land must be followed by future missions to determine longer-term change in ice mass and its contribution to sea level. The scientific objective of the proposed research is to evaluate glacier variability due to climate change utilizing an interdisciplinary approach by integrating NASA Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover data with stable isotope data.

Active Surface Technologies for Dust Mitigation in Martian and Lunar Environments

Submitting Organization: UNIVERSITY OF VERMONT & STATE AGRICULTURAL COLLEGE

PI: Dr. William Lakin

Co-I/Science: Dr. Darren Hitt, University of Vermont

Proposal Summary

The presence of fine soil particles poses a significant threat to human health and machine reliability during Martian and lunar exploration and habitation. This fine dust (with particle diameter as small as 10 nm) can quickly foul electrical equipment, cover solar panels, and penetrate through seals on space suits and hatches. The fine particles tend to be electrostatically charged, so that collision of the particles with space suits, vehicles, or machinery can transfer this charge to these objects, leading to rapid adhesion of dust particles onto the objects in question. Dust mitigation technology for lunar or Martian habitations must be effective for particles of diameter ranging from 0.01-100 microns and it must require small amounts of energy and material, which are highly restricted for space applications. The proposed project will explore the concept of an active surface, i.e., a surface with integrated dust sensors and dust detachment and removal actuators, which is designed to provide mitigation of fine adhesive dust particles with minimal energy expenditures. The active surface will utilize a combination of acoustic radiation, surface vibrations, or electromagnetic pulsing to induce dust detachment, which will be accompanied by a repulsive electrostatic field or fluid flow to remove the detached dust particles. A wireless sensor network will be utilized to regulate the system, ensuring minimal energy usage and maintenance time. Application will be explored for cleaning of solar panels, space suits, hatch covers, heat exchanger surfaces, and filters. The project will be conducted with the aid of a combination of discrete-element modeling and a variety of laboratory experiments, using specialized facilities already in place at the University of Vermont. The project will team with two Vermont companies and two other academic institutions to ensure a high degree of student and industry engagement.

Real-time Wireless Shape Monitoring of Space Structures

Submitting Organization: MAINE SPACE GRANT CONSORTIUM

PI: Dr. Terry Shehata

Co-I/Science: Dr. Ali Abedi, University of Maine

Proposal Summary

This project establishes an integrated, multidisciplinary research and educational program in the state of Maine involving collaborators from the University of Maine, the University of Southern Maine, two NASA field centers, the Challenger Learning Center (CLC), and ILC Dover. The proposed effort combines wireless network development and shape monitoring of space structures resulting in a real-time wireless shape monitoring system serving research and educational objectives for NASA and the state of Maine. New challenging space related applications addressed in this proposal include:

- Wireless shape and dynamic response validation of deployed space structures.
- Wireless real time monitoring of space habitats capable of addressing structural integrity that can be extended to structural health monitoring of the State of Maine civil infrastructures.
- Wireless monitoring of inaccessible or inhospitable locations in aerospace vehicles and building structures.

This proposal focuses on the research and development of a robust wireless system to address NASA's needs in shape and dynamic response validation of deployed space structures. The system offers attractive features, namely: embedded tag design, coded access for the interrogation of multiple tags; dynamic response of deployable space structures; multiple level communications to improve the robustness and power efficiency of the data transfer link.

The proposed project is developed in collaboration with NASA Johnson Space Center (JSC) and NASA Glenn Research Center (GRC) to ensure that it contributes significantly to NASA¿s research priorities. The proposed research area falls under Space Communications and Navigation program of the Space Operations Mission Directorate. Direct support of research assistantships will be provided for 15 undergraduate students, 4 graduate students and 1 engineer, which is critical to uniquely position the state to be competitive in the state-of-the-art wireless sensing systems. The proposed project will significantly contribute to the overall research and education infrastructure and economic development of the state.

Versatile Biosensing Platform for Monitoring Bone Markers for Space Medicine

Submitting Organization: WESTERN KENTUCKY UNIVERSITY RESEARCH FOUNDATION INC.

PI: Dr. Karen R. Hackney

Co-I/Science: Dr. Leonidas Bachas, University of Kentucky

Proposal Summary

The space environment, including microgravity, is known to induce metabolic changes that could have a negative effect on astronaut health and performance, especially during extended duration missions, such as the establishment of a lunar exploration base and a manned mission to Mars. The safety and success of these missions requires efficient management of astronaut health, which can be accomplished by monitoring a range of physiological parameters that are indicators of the health status of the astronauts. Accelerated bone loss due to skeletal unloading has been identified as an area of critical importance to the well being of astronauts. In that regard, there is a need for diagnostic devices that could be used to monitor biomarkers associated with bone demineralization for use during human exploration missions. Such devices should be small in size, of low-weight, low-maintenance, low power consumption, and be highly reliable over long periods of time. A team consisting of a diverse group of investigators and NASA collaborators will work together to address this need by developing a universal diagnostic system for bone physiology. The proposed health-monitoring system will integrate (bio)chemical sensing principles with a microfluidics platform designed to monitor bone biomarkers in physiological fluids. The developed technologies could be adapted for other space medicine applications, as well as to monitor the expression of biomarkers in surrogate organisms in low-Earth orbit using the NASA Ames small satellite payload platform; understanding the impact of space travel on biological mechanisms is among the goals of the small satellite program.

Development of a Delaware Center for Study of Space Radiation Effects: an EPSCoR Research and Education Initiative

Submitting Organization: UNIVERSITY OF DELAWARE

PI: Dr. Dermott Mullan

Co-I/Science: Dr. William Matthaeus, University of Delaware

Proposal Summary

We propose to establish an interdisciplinary Center for Space Radiation Effects that will build on existing Delaware expertise. It will involve Delaware industry immediately, and will squarely address National priorities (Exploration Initiative) and both present and future needs of NASA (Exploration Systems and Science Mission Directorates.) Involvement of military and commercial aviation is possible. The plan will also substantially enhance space-related education in Delaware.

The proposed Center will build upon basic science expertise at the University of Delaware (UD) in solar and space physics, astrophysics, and cosmic rays. Interdisciplinary connections will emanate from the focus on radiation in and from space. A major feature will be an attempt to make a target of opportunity faculty hire in the Department of Physics and Astronomy, to bring a very successful young space scientist to Delaware, who will augment Delaware Space Physics education and research, will be a central participant in the Center, and will be active in NASA flight programs. Activities in the Center will involve collaboration with Geography, Chemistry, Mechanical Engineering, Materials Science, Marine and Earth Studies, Atmospheric Sciences, and notably, industry (ILC Dover).

The Center will be involved in studies in three related areas:

- Nature of the space radiation environment and its effects on humans. These studies are of great relevance to human space exploration.

- Short-term variability of cosmic rays of solar and galactic origin, and the influence of these changes on Earth and the geospace environment, including effects on humans and technological assets. This "Space Weather" is of great interest for communications satellites, aviation, and the power industry.

- Long-term possible effects of particle radiation from space on terrestrial climate. This is a new and complex problem that interfaces with climate modeling, atmospheric chemistry, cloud chemistry and physics, and studies of global change.

Differential Symbolic Execution: Supporting Evolution of High-Assurance Software

Submitting Organization: THE UNIVERSITY OF NEBRASKA AT OMAHA

PI: Dr. Scott Tarry

Co-I/Science: Dr. Matthew Dwyer, The University of Nebraska

Proposal Summary

NASA systems increasingly depend on software to enable more demanding and cost-effective missions. Ensuring the reliability of such software is critical to NASA’s success.

Consequently, significant effort has been devoted to the development and application of the latest software validation technologies to assure, with very high-confidence, that software deployed n NASA systems will work correctly.

Unfortunately, little research has gone into understanding what happens to that confidence when a system changes. Change happens all the time: Mars rovers receive software patches with new capabilities, aircraft avionics computers are replaced or upgraded, and, of course, bugs are fixed. It is cost-prohibitive to completely re-analyze or re-validate systems for every change and, furthermore, the time required to do that could significantly delay mission deployment and upgrades to fielded systems.

We propose to address this problem by investigating a novel technology for analyzing the differences between versions of a software system. Our approach, which we call differential symbolic execution (DSE), performs behavioral differencing of programs to detect and precisely characterize "when" and "how" a new software version will operate differently. DSE will help to guide re-validation efforts on the potentially small portion of a system's behavior that has changed, greatly reducing the cost of re-validation and accelerating deployment, while retaining the benefits of full validation.

This proposal seeks to solidify the theoretical foundations of DSE, develop a series of increasingly capable prototype implementations of DSE applications, and conduct a family of empirical evaluations within contexts valuable to NASA to assess the cost-effectiveness of DSE-based maintenance and validation.

NASA's Lunar and Martian Surface Communications Systems with Efficient Miniature Antennas

Submitting Organization: WICHITA STATE UNIVERSITY

PI: Dr. Leonard Miller

Co-I/Science: Dr. Hyuck Kwon, Wichita State University

Proposal Summary

Efficient miniature antennas and efficient communication systems will play a critical role in future NASA Lunar and Martian (L&M) surface communication because available space and power place stringent requirements on mobile communication systems at the surface communication frequencies (i.e., astronaut suits, probes, rovers). The objective of this project is to develop novel communication systems and novel miniature antenna structures that are capable of supporting the communication needs of future L&M surface exploration activities and competing with existing on-going non-EPSCoR techniques. Key expected contributions of this project are listed as follows: (1) Ferrite and meta-material will be investigated to scale antenna, and a single multimode antenna will be employed to increase overall system capacity; (2) Efficient iterative communication skills will be investigated to improve performance of L&M surface communication assets; (3) Robust receiver skills will be investigated for L&M surface communication assets to operate efficiently under time-varying electromagnetic interference such as solar energetic particles; (4) Efficient partner selection skills among ad-hoc wireless L&M surface cooperative diversity networks will be investigated to increase the coverage of an access point tower (i.e., a deployable communication tower). Two NASA centers (NASA/GRC and NASA/JSC), three universities (The University of Alabama, The University of Kansas, and Wichita State University), two multi-jurisdictions (Alabama and Kansas), and three industries (one from Kansas and two from Alabama) will collaborate for fabrication and commercialization of developed miniature antennas and miniature systems. The experience gained from the project will enable the PIs and their wireless communication research group to compete effectively for federal research grants available from the NASA, NSF, Army, Air Force, Navy, and DARPA. A minimum of seven proposals related to this project will be submitted to these agencies per year. Preliminary results indicate that a minimum of four U.S. patents can be issued.

Development and Automated Drinking Water Disinfection System

Submitting Organization: VANDERBILT UNIVERSITY

PI: Dr. Alvin Strauss

Co-I/Science: Dr. Gary Emmert, The University of Memphis

Proposal Summary

The goal of this proposal if to develop a compact chemical analysis system that can be interfaced with current water reclamation/recycling systems used for long-term space flight missions. This device will be able to simultaneously monitor both disinfectant and disinfection by-product concentrations and via auto-reconfigurable operation, it will be able to respond to changes in these concentrations to lead to higher quality and safe drinking water for crew members. Since the amount of potable water is currently one of the factors that limit the duration and number of crew members on long-term space flights, this research is key to NASA meeting objectives set fourth by the President.

Water is essential to human life and the ability to maintain a source of high quality drinking water is fundamental to any plan of long-term space travel and ultimately colonization. The laboratory of the Science Co-Investigator at the University of Memphis is dedicated to applying the principles of chemical measurement, equilibria and kinetics toward a better understanding of water disinfection and the removal of undesirable by-products and contaminants in drinking water. Our belief is that rigorous analytical instrument development lays the foundation for a better understanding by providing reliable data upon which to base chemical kinetic models of disinfection chemistry.

The overall goal of this proposed research is to construct a #capillary electrophoresis on a valve# chemical analysis system #called CEOV. This single miniaturized system will be able to simultaneously monitor in near real-time the concentration of the iodine species acting as water disinfectants (or other common drinking water disinfectants that might be used in the future by NASA) while also monitoring the concentration of drinking water disinfection by-products. Such a device will be useful in developing an auto-reconfigurable self-contained drinking water disinfection system that provides safe and good tasting drinking water for mission personnel.

There are numerous approaches that have been used by NASA in combination to process wastewater including: vapor compression distillation, thermoelectric integrated membrane evaporation, vapor phase catalytic ammonia removal, air evaporation, multifiltration, reverse osmosis, and electrodialysis. Our proposed chemical analysis system would be a functional component of any or of a combination of these processing systems.