2019 International Space Station Flight Opportunity Proposal Abstracts

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18-2018 ISS-0001

Demonstration of Radiation Tolerant Memory Synchronization Within a Reconfigurable Flight Computer

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The overall goal of this project is to conduct a satellite mission to demonstrate the reliability and synchronization of the memory sub-system of a radiation tolerant flight computer. The computer technology employs a novel fault-mitigation strategy that uses redundant processing cores and real-time reconfiguration of the hardware to quickly recover from radiation-induced failures. NASA EPSCoR has enabled this technology to be matured from its initial conception at TRL-1 in 2008 to its current level of TRL-7. In 2017, the EPSCoR International Space Station (ISS) Flight Opportunity program funded a 1-year demonstration onboard the ISS to test the real-time reconfiguration of the processing cores of this computer in a space environment.

In 2018, the EPSCoR ISS Flight Opportunity program funded a 1-year stand-alone satellite mission deployed from the ISS to test the core recovery procedure in an operational environment. In the proposed project, we will conduct a second ISS-deployed small satellite mission to test the final sub-system required by the computer, the fault tolerant memory system. Our memory system consists of redundant storage arrays configured in triple modular redundancy (TMR) with sophisticated error correction circuitry. Each of the active processing cores use this fault tolerant memory system as they run in parallel. The advantage of this architecture is that as processing cores are brought online after a fault, they can immediately access the memory system without needing to re-initialize it (i.e., reboot). This allows the new core to be quickly put into normal operation while only needing to restore its internal CPU registers. In this project we will demonstrate the fault tolerant memory system and the core synchronization procedure at the same time. We will leverage the existing 3U satellite design funded by the 2017 EPSCoR ISS Flight Opportunity program to reduce the risk of the mission. The satellite will be carried to the ISS on a commercial resupply mission and then put into orbit using the NanoRacks CubeSat Deployer (NRCSD). This deployment mechanism will provide up to 12 months of satellite operation in Low Earth Orbit (LEO) where telemetry information will be continually downlinked to the MSU ground station in Bozeman, MT.

18-2018 ISS-0003

Assessment of Whole Genome Fitness of Bacteria Under Microgravity

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The conditions of spaceflight are stressful on living organisms, yet many people believe that bacteria, being so small that they are virtually weightless already, have no particular physiological response to microgravity. However, years of research have shown that bacteria do behave and live differently aboard space-faring vehicles. This is important because bacteria aboard such vessels have been shown to degrade material components and clog critical fluid systems before, as well as potentially pose a disease threat to astronauts. Unfortunately, most studies of bacteria in microgravity either have to use simulated microgravity on Earth which does not match all the various conditions of actual spaceflight, or only focused on one or two specific bacterial characteristics such as attachment to surfaces or stress tolerance.

There have been few attempts to assess global bacterial physiological responses to spaceflight. The experiments outlined in this proposal aim to assess every gene in the genome of several bacterial organisms with regard to the fitness they provide for growth during spaceflight. This will be accomplished by using a technique referred to as Comparative TnSeq. In this technique, a target organism is mutagenized to create a library of hundreds of thousands of different mutants. Samples from this library are then grown under two conditions: in this case the first condition is aboard the International Space Station and the second condition is grown in a laboratory on Earth. Genomic DNA is then extracted from each culture and mutations mapped by Next Generation Sequencing. By comparing which mutations become under-represented in the ISS libraries, we can determine which genes are particularly important for growth during spaceflight. This will be done on several bacterial organisms to see how bacteria from different environments and with different physiologies respond to spaceflight, and if there is a gene or process that is universally important to bacterial growth in space-faring vehicles. The more we understand how bacteria respond to spaceflight, the more intelligently we can design mechanisms for their control.

18-2018 ISS-0004

FY18 Alabama ISS Flight Opportunity

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Science PI: Richard Michael Banish

University Of Alabama, Huntsville

This proposal addresses research emphasis to enable the eventual production of high-silicon-transition metal alloys. The thermophysical property measurements will use the Japan Aerospace Exploration Agency Electrostatic Levitation Furnace. The casting simulation requires precise and accurate thermophysical and physical properties during the entire solidification process. Among the required thermophysical properties are the viscosity, surface tension, density, and heat capacity, among others.

Metals and metallic alloys often have high melting temperatures and highly reactive liquid states. Thus, processing these liquids in containers leads to significant contamination and uncontrolled under-cooling behavior. The above is especially true for molten silicon and its alloys. Thermophysical properties of these reactive materials can be determined by using an electrostatic levitator (ESL) which levitates and suspends a sample between two electrodes and subsequently analyzing (high-speed) video and temperature (pyrometer) data of the molten levitated samples, rather than using traditional contact techniques. This measurement technique eliminates many sources of experimental error, due to the inherent non-contact nature of the ESL. There is minimal contamination between the sample and its container, due to the levitation, and the experiments are done under vacuum, limiting the effects of surrounding gases. The ESL also offers the advantages that a single sample can be heated and cooled multiple times between a wide range of temperatures; samples can be under-cooled to a high degree; viscosity and surface tension can both be obtained from a single transient signal; and with a single axisymmetric oscillation induced in the sample, the data analysis becomes clear and relatively straightforward.

Density and heat capacity are performed as a separate but paired set of experiments. Silicon-transition metal alloys maintain the lower density, high compressive strength, and mitigate the brittleness of pure silicon. While silicon itself is corrosion resistant, it wets and dissolves all but a few materials; molten silicon is commonly called â€œthe universal solventâ€• . The development of low-density (low-mass), high strength, compression alloys for space missions would enable lower mass components resulting in less vehicle mass and higher durability. The wetting ability of molten silicon coupled with its high melting point makes the determination of its thermophysical properties experimentally challenging. Silicon and silicon-transition metal alloys are systems that can take advantage of the benefits of container-less processing, or levitation facilities in a low gravity environment. Silicon is a semiconductor or semi-metal depending on the temperature. The levitation and melting of silicon in terrestrial Electrostatic Levitator systems requires close attention and adjustment of the sample size, heating and levitation parameters. Off-eutectic alloys are particularly difficult to process since during melting there is a mixture of liquid and solid. The determination of thermophysical properties such as viscosity, surface tension, density, and heat capacity of silicon alloys is well-suited to electrostatic levitation in a low gravity environment due to the lower electrostatic forces required for sample.

18-2018 ISS-0005

One-Step Gene Sampling Tool to Improve the ISS Bioanalytical Facility

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Science PI: Niel D. Crews, Louisiana Tech University

Louisiana Board of Regents

This proposal is to request an ISS flight for validation of a solid-phase genetic sampling device that will be a powerful addition to the instruments that are already on-station. This implementation of the technology will reduce crew time for RNA extraction by nearly two orders of magnitude, provide sampling that will be less invasive than existing methods, and provide repeated sampling of specimens. These enhancements represent a significant improvement for space biologists. The small size reduces mass and enhances sampling precision as select tissue volumes can be analyzed.

The aim to support extended human presence in space has led to the establishment of NASA's GeneLab, which combines a data base repository dedicated to ISS biological experiments and corresponding ground-based studies. Superior analytical tools such as the proposed technology will enhance genetic analyses at variable intervals without destroying the specimen as is required for traditional technology. The solid-phase extraction avoids transfer of biopsy material is minimally invasive and does not require sacrificing of the specimen. Most valuably, though, the probes need no further processing to separate RNA from the tissue. Based on probe preparation either a sample of all available mRNA or specific mRNA hybridizes to the surface of the probe. In either case no tissue or nuclear contamination occurs. Sampling is completed after a one-minute insertion into the specimen and the probe can be analyzed directly in the ISS genetic testing hardware.

The components of the Wetlab-2 tools have been validated on the ISS and includes a RT-qPCR system (a modified Cepheid SmartCycler) in which RNA is reverse-transcribed and analyzed. Part of the lab suite is a rather complicated suite of sample preparation hardware that is used to extract and purify RNA from biological material. Although functional, the sample preparation relies heavily on crew time. Furthermore, the amount of liquid handling required for the sample preparation requires two levels of containment for those steps. To simplify the sample prep for specimens, we propose that our technology that has been validated by numerous publications be used in the WetLab-2 RNA work flow. Instead of using the conventional liquid-based process, the purification of genetic material can be performed dry, utilizing a functionalized metal pin. The technique, which is relatively mature, was recently adapted for compatibility with the ISS environment and analytical tools. This technology development was funded by a NASA EPSCoR research project entitled, Genetic Assessment of the Space Environment Using MEMS Technologies.

18-2018 ISS-0006

KRUPS: ISS Flight for Heat Shield Testing

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Thermal protection systems (TPS) are required to mitigate the extreme heating encountered during hypersonic entry into the Martian, Venusian, and outer planet atmospheres as well as for manned and sample-return missions into the terrestrial atmosphere. The design of an efficient TPS remains one of the most challenging tasks of planetary exploration missions. Over the last 50 years, only a handful of high-speed entry experiments have been performed. Not only were these flights part of elaborate and costly exploration programs, but the TPS tested were at the final stage of design. In order to reach that stage, extensive ground test campaigns had to be performed, using arc-jet and hypersonic tunnel facilities, but none were flight proven. There is clearly a need to provide a low-cost test-bed to quickly and reliably evaluate TPS materials, and provide orbital flight validation data.

The Kentucky Re-entry Universal Payload System (KRUPS) is a small entry capsule designed as a technology test-bed, built at the University of Kentucky. For this first incarnation, KRUPS has been designed to test TPS material and instrumentation. KRUPS recently completed two sounding rocket sub-orbital flights, aimed at testing various sub-systems. After completion of these prior tests, the KRUPS capsule is matured and ready for more extensive tests, this time at orbital velocities. The overall objective of the proposed project is to launch a KRUPS capsule from the International Space Station, and use the capsule to obtain orbital entry data for numerical model validation.

The proposed project leverages NASA EPCSoR RA investment by 1) using the modeling codes developed through these investments to design and size the TPS of the capsule and 2) gathering flight data acquired to provide additional validations for these codes.