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Enhanced Active Tissue Equivalent Dosimeter (eATED) for Space Crew Dosimetry

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The Radiation Physics Laboratory at Oklahoma State University proposes to develop and demonstrate an enhanced version of the Active Tissue Equivalent Dosimeter (ATED) previously flown aboard the ISS in 2018 under NASA EPSCoR grant NNX6AD50A, ""Demonstration of the OSU Tissue Equivalent Proportional Counter for Space Crew Dosimetry aboard the International Space Station."" Although this previous flight experiment met most of the objectives listed in our 2016 proposal, the length of the experiment, originally planned for 6 months, was significantly reduced due to damage to the instrument following deployment on ISS. The 2018 flight of the ATED led to a number of lessons learned that will be addressed in the enhanced Active Tissue Equivalent Dosimeter (eATED) proposed herein. More significantly, the eATED will possess a new, unique capability not available in previous space radiation dosimetry instrumentation--the ability to discriminate between measurements produced by charged particles (energetic protons, alpha particles and heavy ions) and secondary neutrons.

Charged particle/neutron discrimination is a unique capability not available in any tissue equivalent dosimeter that has previously operated aboard manned spacecraft like the ISS. This capability will permit validation of radiation transport models, as well as providing a better understanding of the relative contributions of different particle types to the absorbed dose and biologically weighted dose equivalent received by crew members during space flight. Finally, it will permit assessment of the contributions from secondary neutrons to crew radiation exposure as a function of different space weather conditions, e.g. solar particle events or geomagnetic storms.

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Microgravity Demonstration of a Novel In-Space Food Production System

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Montana Space Grant Consortium

The overarching goal of this project is to demonstrate the use of a novel bioreactor technology for growing high-protein food on the International Space Station (ISS). The bioreactor technology has been demonstrated on Earth to efficiently convert mission-relevant feedstocks, like plant, human and food waste, into thick (> 6 mm) high-protein, edible, fungal biomats. A flight experiment is now needed to demonstrate bioreactor efficacy under low-Earth orbit conditions, and thus evaluate the effects of both micro-gravity and space radiation on bioreactor performance. The bioreactor is relatively simple, does not require energy during fermentation (other than possibly temperature control), requires little water, and rapidly grows dense, easily harvested, consolidated biomats for food with little to no remaining waste. The technology capitalizes on the unique growth characteristics of an extremophilic, filamentous fungus isolated from a geothermal spring in Yellowstone National Park, named strain MK7. Strain MK7 is an FDA Generally Recognized as Safe (GRAS) food ingredient and is now available to the US public as a breakfast sausage, with the product line expected to significantly expand by the end of the year.

The bioreactor technology was developed by Sustainable Bioproducts LLC (SBP), Montana State University (MSU) and BioServe Space Technologies during a NASA supported collaborative research project titled A Robust Biofilm-Biomat Reactor for Conversion of Mission Relevant Feedstocks to Products (NASA STTR Phase I and II Award # 80NSSC20C0031). The Aim of the ongoing NASA STTR-supported research is the advancement and scale-up of the proprietary bioreactor technology so that it can be used in space for food production. The bioreactor is currently at Technology Readiness Level (TRL) 5, with the prototype bioreactor successfully demonstrated on Earth.

The flight study will require no crew involvement other than installation and removal of a Plate Habitat (PHAB) into an ISS incubator. PHABs are robust, flight-proven containers used for performing spaceflight biology experiments with more than 100 individual PHABs successfully flown. The PHAB technology will serve as a safe secondary containment box for housing the MK7 fungal bioreactors. The final hardware validation and safety evaluation steps are anticipated to be completed, with the system ready to fly, in less than one year. The mission approach is to preload the bioreactor with inoculum and nutrient medium, seal the bioreactor within a PHAB, freeze the PHAB at -20 �C to place culture in stasis, and handover the payload to NASA for transport to the ISS in a frozen state. The PHAB can be stored frozen onboard the ISS for up to one month before initiation of the experiment to allow for maximum operations flexibility. To initiate the experiment, the PHAB will simply be placed in a Space Automated Bioproduct Lab (SABL) incubator and incubated at + 27 �C for five days. After incubation and growth, the PHAB will be refrozen and stored in a freezer until the eventual return to Earth in a frozen stable state. Retrieved biomat samples will be evaluated by MSU students, staff and faculty, and by SBP scientists. Parameters to be evaluated include those most relevant to food, such as, nutrient and metabolite composition, biomat macro- and micro-structure, and textural analysis. The requested EPSCoR funds will support collaborative research among academia and industry in Montana, and would foster procurement of additional grant funds to advance this promising novel technology for space.

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Reliability evaluation of the integrated photonic receiver subsystems with all-optical signal processors

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While the radiation environment in low-Earth orbit, e.g. aboard the International Space Station (ISS), has been studied in great detail, a similar level of detail is lacking regarding the ionizing radiation environment in the Earths atmosphere. To put it bluntly, we know far more about the radiation environment 400 km above our heads than at 40 km above our heads. Suborbital flight provides an opportunity to measure the steady state atmospheric ionizing radiation environment (SSAIRE) between 20 and 120 km, thereby providing important information regarding the SSAIRE that have seldom been addressed in the past. Such measurements will allow us to validate computer models of the SSAIRE and will provide important information regarding the impact of the SSAIRE on thehealth of high altitude aircrew and passengers and on possible effects of the SSAIRE on radiation sensitivity avionics. In addition, suborbital tourism is on the cusp of becoming a reality and passengers on flights to the highest altitudes in our atmosphere will naturally be concerned about their radiation exposure during such flights. Measurements made aboard suborbital flights can directly address and alleviate their concerns regarding radiation exposure in the upper atmosphere. We propose to demonstrate a version of the Active Tissue Equivalent Dosimeter (ATED) designed specifically for measuring ionizing radiation exposure in the atmosphere aboard a Blue Origin New Shepard suborbital flight. ATED is a tissue equivalentproportional counter (TEPC) developed by the Oklahoma State University (OSU) Radiation Physics Laboratory (RPL) under a 2007 NASA EPSCoR grant NNX07AT66A, Tissue Equivalent Detectors for Space Crew Dosimetry and Characterization of the Space Radiation Environment. ATED previously operated aboard the ISS in 2018 under NASA EPSCoR grant NNX6AD50A Demonstration of the OSU Tissue Equivalent Proportional Counter for Space Crew Dosimetry aboard the International Space Station. Figure 1 shows a representative sample of the results obtained during the 2018 ISS ATED experiment. The atmospheric ionizing radiation version of ATED, henceforth referred to as AirTED, is designed to be produced in larger numbers so that it may be deployed for radiation monitoring purposes aboard multiple commercial, business and military aircraft, as well as high altitude UAVs, balloons and suborbital vehicles. For this reason, numerous changes to the design have been made in order reduce instrument cost, size and mass, as well as implement a number of lessons learned from the ISS flight. In addition to the AirTED, we propose to fly a Liulin-b21 Mobile Dosimetry Unit (MDU), a compact Si spectrometer produced by the Space Research and Technology Institute, Bulgarian

Academy of Sciences (SRTI-BAS). In terms of their sensitivity to ionizing radiation, the Liulin b21 and the AirTED can be seen as complimentary. The AirTED is sensitive to radiation of LET e1 keV/mm including heavy ions, secondary neutrons and lower energy protons. LET or linear energy transfer is the amount of energydeposited by a radiation particle per unit path length as it traverses a material (sensitive volume of a detector in this case) and is directly proportional to absorbed dose, the principal quantity used in measuring ionizing radiation. The Liulin-4 is sensitive to charged particles and energetic x/g-rays with signal between 0.1 to 40 keV/mm, including high energy protons, electrons and positrons, charged pions and muons encountered in the upper atmosphere. By using both of these compact detectors together, we will be able to measure the total absorbed dose and other biologically-weighted dosimetric quantities over the whole of the LET spectral range relevant to radiation protection of passengers and crew in the upper atmosphere.

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NASA EPSCoR ISS: Microgravity Experiment to measure the Speed of Sound inside simulated Asteroid Regolith in the ISS environment (MESSAR)

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Many of the small asteroids in the Near-Earth space (so-called Near-Earth Asteroids or NEAs) are known to be rubble piles, i.e. composed of a granular material. The understanding of the strength and dynamics of these rubble piles is strongly linked to unraveling the mysteries of the formation of our Solar System, supporting on-going NASA missions to small bodies (e.g. OSIRIS-REx, Lucy), as well as evaluating planetary defense options in case of an impact threat.

In the proposed project, we aim at understanding how seismic waves travel through these rubble-piles, modifying their shapes and surfaces. Impact-induced seismic waves are a surface modification process that is particularly important on small asteroids due to their low surface gravity and small volume. Seismic disturbances can destabilize loose material resting on slopes, causing downhill flows; generate crater degradation and erasure, which impacts surface dating techniques; segregate and sort particles via the Brazil Nut Effect; and potentially lift particles off the asteroid surface, generating activity as observed by OSIRIS-REx on asteroid Bennu. In addition, seismic waves can modify the shape of small rubble-piles, heightening equatorial ridges or generating local peaks.

A key parameter characterizing seismic waves is their travel speed in a given material, the speed of sound. In granular materials, this speed of sound has been shown to depend on the grain composition and size, and in particular on the force chains developing under a confining pressure. For this reason, the speed of sound also depends on the ambient gravity level, which is on the order of 10-5g, g being the acceleration of gravity at the surface of the Earth, at the surface of small rubble-pile asteroids.

Due to the above, it is proposed to develop an experiment on the ISS to characterize the speed of sound in high-fidelity simulants reproducing material composing these rubble-pile asteroids, in the relevant gravity conditions.

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KRUPS: ISS Flight for Instrument 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, test instruments, 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 three sounding rocket sub-orbital flights, aimed at testing various sub-systems. Three of these capsules are currently on their way to the ISS, to test them at orbital velocities. The overall objective of the proposed project is to take the project one step further by reconfiguring the capsule to qualify instruments. More specifically, a spectrometer will be used to monitor the composition of the atmosphere around the capsule, during an ISS return.

The proposed project leverages NASA EPSCoR 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. It is also a direct follow-on of an ISS EPSCoR 2018 project."

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Properties and Performance of Solder Joints Produced in Reduced-Gravity Environments: ISS Flight Opportunity

Dr. Tomas Gonzales-Torres

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"A study combining experiment and modeling is proposed to study how solidification defects (porosity) are produced during soldering of electrical contacts under reduced gravity. Soldering is a rapid process in which the solder material is molten for only a few seconds, and the molten metal is used to metallurgically bond two components together without melting the components themselves. Solder joint porosity is a common but undesirable feature naturally arising from the use of fluxes and is more insidious in soldering joints formed under low-gravity conditions. Commercial soldering processes require the use of fluxes to suppress oxidation and promote wetting, which is necessary for effective solder spreading and joint-gap filling during solder reflow. Under typical soldering conditions, rapid reflow temperatures results in flux volatilization and bubble formation. Under the presence of gravity, liquid solders tend to mix vigorously during the reflow period due to buoyancy-driven natural convection. This is beneficial, as any voids or bubbles that form due evaporated fluxes are quickly swept to free surfaces, and are thus removed from the solder joint. In the absence of gravity, fluid motion is greatly reduced, driven mainly by solidification volume change, thermally induced density gradients, and Marangoni effects. With slower mixing, voids and bubbles are not swept away and become entrapped in the interior of the solder joint upon solidification. This entrapped porosity dramatically degrades the thermal and electrical properties of the solder and severely reduces the mechanical integrity of the joint. Such porosity is seen in conventional (Earth gravity) solder joints, but is much more prevalent in solder joints produced under reduced-gravity conditions. As a result, any solder joints made under reduced gravity (such as in-orbit repair of electronic devices, tubing, and mechanical joints) are at risk of having their electrical or mechanical performance characteristics substantially degraded by entrapped porosity, increasing the manifold associated risks of subsequent device failures on astronauts and equipment in the unforgiving environment of space.

The present proposed work builds on an existing NASA Physical Sciences Informatics (PSI) grant for studying solders in terrestrial vs. microgravity environments, and will utilize the MaRVIn test platform to conduct controlled soldering experiments on ground vs. onboard the International Space Station (ISS). This study, in addition to applying novel materials characterization methods that quantify the negative impacts on the joint performance, will extend the earlier efforts to minimize joint defects through rational design of the soldering process parameters and through active mitigation techniques using acoustic vibration of the molten solder during the soldering process. This is hypothesized to help remove voids and bubbles before they are frozen in place as the solder joint cools (in essence, this is the core problem that we seek to solve). To best design and test this mitigation technique, we will model the process through simulations that permit us to identify as many of the optimal process parameters as we can before we seek to conduct tests under reduced gravity.

The understanding gained from this work will allow us to develop electronics repair capabilities essential for future long-duration human exploration missions in (and beyond) low Earth orbit (ex: Moon, Mars). We will engage in comprehensive STEM professional development activities that leverage and feed back into the technical activities at Iowa State University and contribute to NASA and STEM workforce development.