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21-ISS 2021 -0003

Appendix G - Three-Dimensional Plume-surface Interaction and Crater Formation Dynamic Measurements in Reduced Gravity Environments

University of Alabama in Huntsville

Dr. Lawrence Thomas

Summary not submitted in NSPIRES.

21-ISS 2021-0005

Thermal transport characterization of phase-change material (PCM) infused in annular passage filled with additively manufactured metal foam obtained through Octet-shaped unit cell reticulation under micro-gravity conditions

The University of Mississippi

Dr. Nathan Murray

This proposal is aimed towards understanding the melting-solidification dynamics of phase change materials in the presence of porous mesh under terrestrial and micro-gravity conditions. A comprehensive experimental and computational program will be executed where firstly, the direct numerical code will be validated against our in-house experimental data under terrestrial conditions, which will be followed by a topology optimization program to tune the Octet-unit cell structure for superior charging and discharging capabilities under both terrestrial and micro-gravity conditions. The proposed concept of reticulating the Octet topology and infusing the void space with phase change material is expected to enhance the effective thermal conductivity of the composite by over 25 times compared to PCM-only configuration, which will be a significant enhancement in PCM capabilities and will open new lines of research in the area of microgravity science and technology involving tunable lattice frame materials infused with PCM.

Above objective is not possible with the current state-of-the-art computational models since the experimental data of transient response of PCM infused in porous media under microgravity conditions does not exist in the literature. Through this program, we will deploy a payload weighing less than 1 kg with overall external dimensions within 100mm x 100mm x 340 mm, comprising of four different configurations of additively manufactured lattice with infused PCM, on-board data acquisition of transient temperature response, on-board video recording facility and storage. The payload will be carried by our flight service provider Zero-g where 4 parabolic flights with 30 parabolas per flight will be executed in a Boeing 727-200F aircraft. For each of the maneuvers, a micro-gravity time frame of 17 seconds is expected, and, in this duration, the four configurations will be heated such that their melting-solidification phases can be captured under micro-gravity condition.

A comprehensive data analysis and direct numerical model training and validation program will be executed following the flight testing. The project will provide a validated computational model, a topology optimization strategy, and real-time transient thermal response experimental data, all under micro-gravity condition. Above deliverables are expected to significantly enhance our fundamental understanding of the phase change process and interfacial heat and mass transport characteristics under micro-gravity conditions."

21-ISS 2021-0006

Suborbital Flight Demonstration of Ionizing Radiation Dosimeters for use in the Upper Atmosphere - Appendix G

Oklahoma State University

Dr. Andrew Arena

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 Earth s 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 the health 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 equivalent proportional 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 energy deposited 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.

21-ISS 2021-0013

3-D printing of flexible electronics for in-space manufacturing and investigations via microgravity parabolic flight tests: EPSCoR Suborbital Flight Opportunity

Iowa State University - Iowa Space Grant Consortium

Dr. Tomas Gonzalez-Torres

Our groups at Iowa State University (ISU) will collaborate with NASA Marshall Flight Research Center (MSFC) and Zero Gravity Corporation (Zero-G) on developing and validating electrohydrodynamic inkjet (EHD) printing for in-space manufacturing via parabolic flight tests. EHD printing utilizes the electrical force to drive the printing mechanism without the need for gravity. The project will pave the path for manufacturing sensors and electronics on a flexible substrate and/or mounted onboard the International Space Station (ISS).

Our team has been working with MSFC as part of NASA s Exploration Campaign efforts, aligned with the key focus area of in-space manufacturing and STEM education strategic plan. NASA MSFC is leading an effort to send a 3D printer to the ISS in 2025. Our team has been down-selected to validate the feasibility of integrating EHD printing into nScrypt for this mission. So far, we have established NASA collaborations via a seed grant from Iowa NASA EPSCoR, and a NASA EPSCoR supplement grant. We have successfully initiated preliminary research work, developed a portable EHD printer, and promote STEM education and outreach. This EPSCoR ISS Suborbital project will give us opportunities to run flight tests and contribute significantly to accomplish NASA missions.

The overarching goal is to develop and validate EHD printing via suborbital flight tests, and to ensure this technique is capable of manufacturing sensors and electronics for use as wearable devices at ISS. The experimental validation in the flight test will help simulate printing in space and optimize our design of the printing system. More specifically, the objectives are 1) establish an integrated computational and experimental tool to model EHD printing in microgravity; 2) create new nano-inks and provide fundamental knowledge on how ink formulation influences the printing process; 3) validate the portable EHD printer via parabolic flight tests (Zero-G microgravity environment); 4) utilize in-situ data analytics for quality assurance; 5) establish feedback control schemes via artificial intelligence tools; 6) promote the STEM education and outreach activities between Iowa and NASA through the EPSCoR program.

The benefits of a microgravity environment to the research include: 1) Calibrate the performance of EHD printing under gravity-free environment; 2) Further develop theoretical and simulation studies to model the printing process under microgravity; 3) Study how ink formulation and property affect the printing quality in microgravity; 4) Design new protocol for both materials development and printing process to optimize printing performance; 5) contribute to the economic development, science, research and education infrastructure in Iowa. Upon success, we will establish research infrastructure towards long-term and self-sustaining capabilities in aerospace between Iowa and NASA. The project will lead to the following deliverables: 1) models of the EHD printing process; 2) nanoink synthesis and formulation; 3) performance of the printed patterns; 4) knowledge of the structure-property relationship of the nanoink and printed materials; 5) flight test and result analysis. Our long-term goal is to integrate the proposed printing technique into NASA s current nScrypt system by 2025.

The Sc-I Dr. Hantang Qin has a long track record in EHD printing process modeling, control and optimization. The Co-I Dr. Shan Jiang has expertise in material synthesis, with a particular focus on nanomaterials and ink formulation. He has also held US patents for fabricating different types of particles and ink formulation. The NASA PI Tomas Gonzalez-Torres will supervise the progress and promote the idea with NASA colleagues. Dr. Curtis Hill provides a support letter for this proposal.