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22-2022 ISS-0001

Real-Time Assessment of In Orbit Space Vehicles

New Mexico State University

Director/PI: Dr. Paulo Oemig

A significant step in addressing safety of commercial space vehicles is the development and testing the flight information recorder or black box . It is envisioned, that structural health monitoring system (SHM) would be an integral part of the black box and would record information on structural integrity during all stages of spaceflight and provide the real-time assessment. Consideration of SHM data is useful in pre-flight diagnostics, in-orbit operation and tuning and in the analysis of structural behavior (or disintegration) during the spacecraft reentry. SHM information would also play a prominent role in space vehicle re-certification for the next flight. This project builds on a previous experiment on ISS and is aimed to improve our understanding of space environment effects on SHM sensors, representative structure and system's damage detection capability by collecting structural dynamic information in real time. Rather long exposure to the space environment is necessary to infer these effects, which can be achieved by utilizing capabilities of the National Lab on ISS. Our previous experiment on MISSE-12 platform was only partially successful as no power was supplied to our payload by the platform s operator. Nevertheless, our experimental hardware has demonstrated flawless operation during pre-launch and post-flight diagnostic experiments confirming the utility of hardware after 1 year in orbit. The new experiment proposes to collect real-time diagnostic data and conduct the structural dynamic experiment using newly developed miniaturized electro-mechanical impedance hardware not available on the previous flight. It is proposed that the vibration response of space structure is measured using the electromechanical impedance and the elastic wave propagation methods. It is anticipated that the proposed flight opportunity will enable development of methodologies for structural integrity assessment in space and determine diagnostic features for damage evaluation in the space environment. Data collected in the proposed experiment would benefit commercial space industry, government entities and academic institutions. Principal investigator is a mechanical engineering professor that has experience with payload analysis, development, integration and launch (1 stratospheric flight, 2 conducted and 1 underway (NASA FOP) suborbital flights and one partly successful ISS 1 year LEO flight.

22-2022 ISS-0003

Turbulence decay of a bubble/sediment laden liquid in ISS microgravity

University of Delaware

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Science PI: Dr. Tyler Van Buren

NASA MD: ISS

To better understand the fundamentals of turbulence particle interaction, we propose to quantify turbulence decay in a microgravity environment, provided by the International Space Station (ISS), using a liquid laden with particles that are both more and less dense than the base fluid.

There are numerous natural phenomena and applications impacted by turbulence particle interaction. On the coast, sediment beds and turbulent flow alter optical clarity, affect fauna, and control beach erosion. In the ocean, surface air-sea interactions through bubble injections and sea spray ejections play a crucial role in controlling synoptic scale meteorology and climatic trends. In the atmosphere, water droplet interaction with turbulence leads to droplet coalescence and warm rain precipitation. In space, the wake of comets has turbulent flow characteristics in the presence of smaller comets and plasma clouds. Additionally, as we do more space exploration we will encounter more fluid transport in low gravity environments. Understanding the fundamental characteristics of turbulence particle interactions is vital in advancing our ability to explain and predict such phenomena.

In gravity, particles with relatively large or small density settle or rise in the surrounding liquid, making it hard to measure the impact of these particles on the underlying turbulence. Without gravity, we can focus on the turbulence-driven particle trajectories leading to an improved understanding of turbulence cascade. Currently, micro or no-gravity experiments are limited to numerical simulations or parabolic trajectory flights. The former lacks validation data and the latter lacks sufficient time (up to 20 s per parabola) to observe long-term decay and reach statistical convergence. We propose an experiment to quantify the decay and statistical characteristics.

The proposed experiment will be launch ready within one year, will be completely automated requiring no crew intervention, require less than 75 W of power, and fit inside a traditional 3U CubeSat volume (100 by 100 by 350 mm). The experiment consists of two liquid-filled cylinders, one having a concentration of dense sediment and the other having a concentration of gas bubbles. Flow velocities will be measured with Particle Image Velocimetry using a set of miniature high-speed cameras and an LED light sheet for illumination.

Turbulence will be created by counter-rotating bladed plates at the ends of the cylinders creating a von K rm n flow. Both steady-state and decaying turbulence flow states will be measured. The experiment will be entirely automated, minimizing effort from space station personnel.

Of particular interest are how the particles impact the turbulence decay rate and how energy is transferred between turbulence scales. Proper statistical convergence requires multiple trials for each case, making the ISS with constant true microgravity an ideal environment for the experiments as compared to parabolic flights. An exact replica of the experiment with trials conducted at the University of Delaware will provide an opportunity to fully test the facility and provide data in a gravity environment to compliment the ISS experiments.

22-2022 ISS-0004

Miniature Robotic Surgery Technology Demonstration During Orbital Spaceflight

The University of Nebraska at Omaha

Director/PI: Dr. Scott Tarry

This proposal outlines a technology demonstration to test robotic surgery in flight on the International Space Station (ISS). Interventional surgery will become necessary as humans travel farther and longer in space. These experiments will utilize a new miniature surgical robot and robotic endoscope camera that could enable an Operating Room in a Shoebox. The surgical robot has been developed with years of NASA support and is now part of a startup company that is in an FDA-approved clinical trial for use in terrestrial applications.

The demonstration will consist of four simulated surgical tasks using a miniature surgical robot aboard the ISS. Two tasks require the robot to manipulate and cut simulated tissue of known loads, to determine the impact of weightlessness on the forces and torques required. The remaining two tasks will help determine how robot precision and dexterity is impacted by zero-gravity. Both capabilities are critical to successful surgical outcomes.

Data collection will be conducted on earth as well as on the ISS using identical equipment. Finally, key metrics for each environment will be quantified and compared using the data recorded during each experiment, so the impact of zero-gravity can be determined. The system is designed to fit inside an Express Rack Locker and be performed autonomously requiring only installation/removal from the flight crew. This demonstration will be the culmination of years of NASA sponsored projects including terrestrial testing, Zero-G flight testing, and teleoperation between a NASA astronaut at JSC and the University of Nebraska.

22-2022 ISS-0006

Evaluation of Biofilm Resistant Coatings for Spacecraft Water Systems

University of Idaho

Director/PI: Dr. Matthew Bernards

Novel biofilm mitigation strategies for incorporation into spacecraft water systems are desired by NASA, to prevent the formation of biofilm during long duration exploration missions. One approach for preventing biofilms is to eliminate the adhesion of bacteria to surfaces via nonfouling polymers, which have demonstrated bacteria resistance in Earth-based investigations. Our hypothesis is nonfouling thin film polymer coatings will demonstrate enhanced resistance to bacteria adhesion and biofilm formation for water system components under microgravity conditions. This hypothesis will be directly assessed in this ISS investigation for stainless steel substrates using Ralstonia pickettii and Burkholderia cepacia bacteria strains.

Phase one of the project will consist of the design of the experimental payload and it will last nine months. The starting point for the payload design is an existing ISS payload, which is currently onboard the ISS. The current design will be updated to include increased dimensions and three total bacteria growth chambers. These chambers will be used to evaluate bacteria adhesion and biofilm formation for both single and co-culture of the two species under investigation in the proposed work. Phase two of the project encompasses the NASA Flight Safety Review. This phase includes the completion of all safety paperwork and additional demonstration experiments to validate the experimental design. This phase will overlap Phase 1 and is anticipated to take six months. The payload is expected to be cleared for flight within the first year of project activities. The final Phase of this project is the final payload assembly effort, launch activities, and evaluation of the results upon payload return. This phase is critical as it will include the evaluation of the adherent bacteria and biofilms via fluorescent staining and confocal microscopy approaches. The final phase is anticipated to take up to one year, resulting in an overall project timeline from initiation through final characterization of two years.

Critical differences between the proposed effort and an ongoing ISS experiment by the PI include the use of stainless steel substrates which are applicable to the water recovery system, an improvement to the nonfouling chemistry through the incorporation of a novel cross-linker molecule, and the evaluation of two bacteria species which have been routinely identified in isolates from the ISS water recovery system. The successful demonstration of the bacteria resistance of nonfouling thin film polymer coatings has the potential to be a transformative approach for reducing bacteria born disease transmission for both space and Earthbased applications.

22-2022 ISS-0007

EPSCoR ISS Solar Flare Acceleration Investigation through X-rays (EISSFLAIX)

Montana Space Grant Consortium

Director/PI: Dr. Angela Des Jardins

PROPOSAL SUMMARY

EISSFLAIX Investigation: The EPSCoR ISS Solar Flare Acceleration Investigation through X-rays (EISSFLAIX (pronounced ice flakes)) investigation is a transformative mission to reveal intricate morphology of solar flare acceleration at high spectral resolution and at unprecedented spatiotemporal scales by deploying a high cadence, high-sensitivity, dedicated full-sun hard X-ray (HXR) burst detector on International Space Station

(ISS). Montana State University (MSU) will build and deliver the scientific instrument that will reveal fast temporal variations in solar hard X-ray flux over a period of 12-months near the maximum of Solar Cycle 25 at an unprecedented cadence revealing fine-scale details of solar particle acceleration during solar flares. The instrument operates for 1-year on ISS returning a treasure trove of high time resolution HXR bursts on hundreds of solar flares ranging from GOES C- to X-Class. When combined with simultaneous high-resolution imaging observations of the solar transition region/upper chromosphere in optical or ultraviolet passbands obtained by space- or grounded-based telescopes like (IRIS) and (DKIST) the EISSFLAIX investigation will provide crucial information of the spatial structure and magnetic environment of HXR spikes, and lead to progress in understanding properties of source regions and acceleration mechanisms of non-thermal electrons. EISSFLAIX observations and metadata is to be made available through the Virtual Solar Observatory, an element of NASA Open Data Portal. Results will be published in the open scientific literature.

The investigation contributes to the internationally recognized research infrastructure in solar and space physics at Montana State University (MSU) and provide additional experiential training opportunities for undergraduate students. High tech activities like these provide economic development within the state of Montana, which is evolving from being historically a ranching and resource extraction jurisdiction.