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Proposal # 23-2023 ISS-0001

Impact of temperature cycles and outgassing on the fiber-packaged silicon photonic transceivers

University of Delaware

PI Name: Matthaeus, William

Proposal Summary: "Objectives: Reducing the form factor while retaining the radiation hardness is the goal of all avionics. While a compromise between a transistor's size and its radiation hardness has reached consensus in micro-electronics, the size-performance compromise for their optical counterparts has not been quested but eventually will limit the space-borne optoelectronic instruments capacity. Based the results from prior ISS flight opportunities, we have verified the detailed performance matrix comparison after the silicon photonic integrated circuits after the one-year exposure on low earth orbit. For the bare chips of photonic integrated circuits (PICs), high transmission of the cm long waveguides is retained, and the optoelectronic bandwidth of the silicon photonic modulators remains high.

For graduating the foundry manufactured chips towards stand-alone instruments, the delicate fiber-chip coupling becomes the next bottleneck. The high-refractive index of silicon allows the dense integration of silicon photonic circuits on chip, but the light source needs to be fed onto the chip through optical packaging. The packaging replies on epoxy for fixing the relative position between single mode fiber and on-chip couplers. Even a few micrometers drift and drastically increase the insertion loss for tens of dB. With the potential concerns of induced material degradation and temperature cycle related mechanical drift, a passive flight test of those optical and electronically packaged PIC component is required.

Methods: Based the collaboration with Dr. Dostart and Dr. Nehrir from NASA Langley Research Center, we plan to evaluate the impact of space flight on the packaged navigation doppler lidar with frequency-modulated continuous wave Lidar system, which is designed for real time capture of spacecraft attitude and velocity during descent (<1cm/s velocity resolution, 10cm range resolution and >5km operational range). Those packaged optical component will be tested in PI's lab first and compared to the performance matrix after radiation exposure on low earth orbit, with focus on the insertion loss of fiber-chip coupling and high-speed electronic-optical interface.

For the payload preparation, a miniaturized (less than 10cm×10cm×5cm) and weight (~tens of grams) of the packaged component comply with the 3U CubeSat is ready in PI's lab. No crew time, impediment effort or power is required.

Perceived significance and NASA relevance: The proposed optical component is primarily targeting the entry descent landing, to enable Lunar/Mars global access with payloads to support human missions by developing technologies to multiple landers within 50-meter accuracy and avoid landing hazards in agile.

The proposed integrated photonic interface with high throughput data rates also expands the bandwidth to support increased sensor data rates for future missions.

Currently, the PIC product development in aerospace applications focuses on reliability, efficiency, and lifetime. The device performance and stability evaluation on MISSE will addresses those concerns. The proposed photonic components and subsystems potential impact on remote sensing missions and optical communication missions operating on low earth orbit, such as Laser Communications Relay Demonstration Mission and Earth Science Observation Missions on ISS. Especially, pulsed laser Lidar has been implemented in a few missions to generate precise, three-dimensional information for the earth surface contour and real-time tracking of distance between flighting vehicles.

The proposed effort on integrated photonics directly contribute to a few technologies highlighted in NASA's Technology Taxonomy (TX). The PIC Lidar are "efficient structures and structural systems using new and innovative approaches to develop beyond-state-of-the art mass reductions for affordable, enhanced performance, reliable, and environmentally responsible aerospace applications." (TX12.2.1 Lightweight Concepts)."

Proposal # 23-2023 ISS-0002

Effect of microgravity and higher radiation on healing and metastasis potential of omentum - ISS Flight Opportunity

University Of North Dakota, Grand Forks

PI Name: Milera, Caitlin

Proposal Summary: "The 'Omentum' is a large sheet-like fatty tissue on the surface of the intra-peritoneal organs connecting the stomach and duodenum with other organs in the abdominal area.

Also described as the 'policeman of the abdomen,' it migrates in the peritoneal cavity to heal wounds. It is a rich source of fibroblast growth factor (FGF) and vascular endothelial growth factor (VEGF). Although naturally beneficial for tissue regeneration, omentum is also a preferred site of metastasis for ovarian, gastric, and appendiceal carcinomas. The extensive capability of omentum to create vasculature is often attributed to its existence as a metastasis site. The longer-term human missions into space necessitate the evaluation of omentum's behavior in cancer and tissue healing under extended periods of microgravity and radiation Recent NASA studies indicate changes to humans' physiological, molecular, and cognitive changes from exposure to microgravity and radiation. Microgravity causes changes to the metabolic and functional aspects of the human body. There is also experimental evidence for changes in cancer growth and progression due to the effects of microgravity. Yet the impact of microgravity on the role of omentum in cancer metastasis and tissue healing is largely unknown. Through this project, we will design in vitro models and experiments that are flight ready at the end of the award period. We also detail all experiments undertaken in space to achieve answers to two important questions: (1) Is omentum an improved tissue healer in a microgravity environment? and (2) Is omentum an enhanced metastasis magnet in a microgravity environment?. Omentum tissue models are being investigated in literature but these co culture systems are much too complex for experiments possible on the ISS. Through this project we will design unique omentum in vitro models that can be tested for microgravity and radiation experiments on the ISS.

A team of scientists comprising of a materials scientist (K. Katti), clinical oncology surgeon (S. Ganai) and mechanics engineer (D.Katti) undertake this project collaboratively to develop flight-ready experiments to evaluate the wound healing and metastasis potential of omentum under microgravity and radiation. The completion of the project will result in development of a simplistic in vitro model of omentum made using patient derived adipocytes and commercial human endothelial cells and human mesothelial cells along with novel bioreactors fabricated at NDSU. Omentum tissue models appropriate for evaluating wound healing and metastasis potential will be prepared in this project with the plan that such model systems will be prepared at NDSU (on earth) followed by the simulated microgravity and radiation experiments at the NASA Space Radiation Laboratory at Brookhaven National Laboratory at the end of the project period. Year 3 of the project will primarily be focused on building contacts with the simulated microgravity and simulated experiments and procedures for access."

Proposal # 23-2023 ISS-0003

A compact, non-invasive, and efficient vision screening system for long-term spaceflight missions

Nevada System of Higher Education

PI Name: Wilcox, Eric

Proposal Summary: "Unique neuroocular changes affect a subset of astronauts who have completed prolonged spaceflight missions. Recent studies observed several changes to the ocular structure including, globe flattening, choroidal folds, cotton wool patches, and optic disc edema. Due to its unique pathophysiology, a new case definition was proposed and the condition was renamed Space flight Associated Neuro-ocular Syndrome (SANS). Although currently hyperopic shift is the only observed functional change during long-term spaceflight, it is unclear whether other and more severe functional vision deficits such as changes in color perception, contrast sensitivity deficit, visual field defects, or metamorphopsia develop and/or progress due to microgravity or other spaceflight related exposures. Unlike hyperopic shift, many of these functional and perceptual changes to astronaut's vision cannot be resolved with corrective lenses and have the potential to become mission critical challenges.

A significant barrier in determining the etiology of SANS while monitoring its risk of development and progression is the lack of technologies onboard long-term spaceflight missions that are capable of measuring crew member's vision in-flight, objectively, quickly, and reliably. This knowledge gap that prevents further studying the onset of visual impairments caused by SANS is specifically outlined by the National Aeronautics and Space Administration (NASA) Human Research Program (HRP) as SANS 3- availability of validated and minimally intrusive diagnostic tools. Due to this lack of onboard technologies for comprehensive vision evaluation, scientists studying SANS mainly employ terrestrial analogs. Currently, there are two major terrestrial analogs identified for SANS: (1) idiopathic intracranial hypertension (IIH) and (2) head-down tilt bed-rest (HDTBR). Although some of the physiological changes seen in neuroocular structure are also observed in these analogs, recent studies brought to light limitations in considering IIH and HDTBR as analogs for studying SANS. In fact, researchers have demonstrated that there are several critical features of SANS that do not complement any reported case of IIH. Moreover, a recent study of HDTBR has highlighted several limitations, including small sample size, lack of similar training and conditioning protocols between HDTBR subjects and astronauts, and general variability in conditions, that need to be addressed in order to consider it as a true analog for SANS.

Limitations of terrestrial analogs and the unknown factors contributing to SANS, such as microgravity, elevated CO_2 levels, or other spaceflight exposures, present a significant unmet need in collecting physiological and functional data related to astronaut vision during long-term spaceflight. Therefore, the subject and main objective of this proposal is to deliver a payload to the International Space Station

(ISS), comprising technologies that are designed to measure various aspects of astronauts' vision quickly and reliably. The proposed technology integrates a fully developed battery of user-friendly vision tests into a compact screening device, e.g., a virtual reality head-mounted display (VRHMD). After deployment onboard the ISS, our team will be able to utilize the time allocated to the EPSCoR projects in crew members' schedule to validate the capabilities of our system in performing various visual assessments in-flight and during microgravity exposure. This in-flight vision screening data will be an invaluable asset to help scientists better study SANS and develop and monitor the effects of countermeasures. A long-term goal of this project is to establish a suitable protocol for integrating this vision screening platform into the future spaceflight missions to be able to monitor crew member's visual health in real-time and with frequencies currently not possible."

Proposal # 23-2023 ISS-0006

KRUPS: ISS Flight for Telemetry and Recovery

University Of Kentucky, Lexington

PI Name: Alexandre Martin

Proposal Summary: Thermal protection systems (TPS) are required to mitigate 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. KRUPS has been designed to test TPS material and instrumentation, recently completing one orbital flight and three sounding rocket sub-orbital flights, aimed at testing various sub-systems. The overall objective of the proposed project is to take the project one step further by using a different ejection mechanism where the capsules are attached the exterior of the demise vehicles, instead of being inside.

The proposed project leverages NASA EPSCoR Research 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 continuation of the ISS EPSCoR 2018 and 2021 projects.

Proposal # 23-2023 ISS-0007

Effect of synergistic space effects on properties of novel polymer composite materials

Oklahoma State University

PI Name: Arena, Andrew

Proposal Summary: "As NASA's missions continue to evolve further from LEO, it brings about concerns regarding the effects of space on composites (UV and thermal cycling under stress while also being under vacuum, exposure to low energy electrons and protons found in LEO and in the solar wind). This is critical, since new space craft such as the Boeing Starliner commercial crew vehicle and the Space-X Dragon capsule have outer composite shells (Figure 1) that will be exposed to space effects. These materials are also dynamically cycled in the presence of space exposure. Effect of such synergistic conditions have not been fully studied or understood. It is understood from prior studies, that there are effects such as cross-linking, chain scission, oxidation degradation and minute changes in glass transition temperature that occur in the composite matrix even in low dose environments. However, with the knowledge that these same composites are now going to be required to experience these conditions and resulting degradation for longer periods of time and have continued dynamic loads placed on them, there is an increased risk in using these composite parts. This requires experiments to know how to evaluate the risk to future missions as well as the need to simulate the effect on composites long-term through the changes in the interphase between the fibers and the matrix.

We have developed a composite material SC2020 (Space Composite 2020) that is primarily carbon fiber epoxy that was deployed as part of an earlier MISSE experiment. These experiments on the MISSE-11 platform exposed outside the ISS was successful in demonstrating the Space Composite 2020 (SC2020) material developed at OSU as a multifunctional material for use in the fabrication of pressurized tanks for consumables and for pressure vessel walls in future spacecraft and planetary surface habitats; while not possessing shielding properties as good as polyethylene, it does have superior radiation shielding properties when compared to Aluminum.

To both assess the effect of the space environment on the materials properties of SC2020 and to measure the changes in the interphase in SC2020 due to the space exposure, we propose to expose two panels of approximately 4" x 6" x 1/8" thickness of the SC2020 material, directly to the space environment on the exterior of the ISS. Both the panels will be placed on the same sample holder. The material exposures will be made using the existing Materials for ISS Experiment Flight Facility (MISSE-FF)9 platform. The SC2020 samples will be of sufficiently large area and thickness to permit the sample to be cut into specimens meeting the ASTM D303910 and ASTM D347911 standards for post-flight materials testing in tension and fatigue respectively10-11. The samples should ideally be placed in either Zenith or Ram positions, i.e., all of them should be placed in the same position and exposed to similar synergistic conditions. For comparison, we also plan to conduct ground-based experiments by exposure to low energy particles at an electron LINAC and assess the damage to the interphase and results from mechanical testing (fatigue and tension for example) to the test results from samples flown on MISSE.

The preliminary focus could be high-performance epoxy (862, 977-3 or 8552) reinforced graphite fiber composites. These systems will be selected based on discussions with the TPOC on the ISS project and could be primarily a prepreg system or carbon fiber fabric prepregged with the selected resin for ease of fabrication.

The goal will be to demonstrate the use of SC2020 Composites for use in spacecraft by measuring the structural and other material property changes due to space exposure, and, measuring the changes in the properties of the constituents including the fiber/matrix interphase and using these properties in simulation and FEA modeling. These results will be compared to the samples from ground-based testing."