Ohio Space Forum 2024
Student Poster Contest Abstracts

Monitoring of Soil Health with Geospatial-Based Spectral Decomposition of Optical Response Signals

Mohammed Braimah, Sarah Eichler and Joseph Ortiz; Department of Earth Sciences and Department of Biological Sciences, Kent State University

Monitoring of soil health and nutrients requires a series of sampling and laboratory measurements which are expensive and laborious. The use of satellite technologies to map soil properties minimizes cost- and labor-intensive traditional methods with high efficiency. The present seeks to utilize Kent State University's decomposition of spectral response signals of the visible and near-infrared spectrum to estimate chemically determined soil carbon and nitrogen. The KSU decomposition approach also known as the varimax-rotated principal component analysis (VPCA) has the potential to reduce the noise-to-signal ratio by up to 20 times. The component scores of spectral decompositions were calculated and applied to map the amount of carbon and nitrogen in an agricultural field in Ohio. The R2 values for 4 VPCA scores as a function of soil carbon (% C) were 0.67, 0.66,0.64, and 0.56 respectively. A similar pattern is observed in the estimation of percentage nitrogen (% N). Four (4) VPCA scores plotted as a function of nitrogen generated R2 values of 0.63, 0.61, 0.58, and 0.54 respectively. The moderate to high correlation of soil carbon and nitrogen to the transformed reflectance data demonstrates the potential of KSU's VPCA remote sensing approach to monitor the amount of nutrients and health of the soil for agricultural production and climate sustainability.

Structurally Tunable Lipid Nanoparticles for Timed Release Delivery of Life-Sustaining Vitamins

Sydney Dobler, Kaylyn Mitchell, Destiney Giles, Meghan Mozzone, Jay Lam, Precious Akinnusi and Briana L. Simms, Department of Chemistry, University of Cincinnati

In this work, I will be presenting on the synthesis and characterization of structurally tunable lipid nanoparticles for timed release delivery of life-sustaining vitamins for our astronauts in space. These lipid nanoparticles consist of a hydrophobic lipid bilayer and a hydrophilic polymer surface and inner cavity. The goal is to load this cavity with hydrophobic vitamins (A, D, E, and K) that are essential for the upkeep of health. We analyzed the size, and surface charge density of the particles through dynamic light scattering (DLS), assessed the thermodynamic stability using fluorescence spectroscopy, and gained insight on the bilayer morphology by measuring the decomposition temperature of the lipid and polymer through thermogravimetric analysis (TGA). All these characterization techniques were studied together to provide a holistic understanding of what structural features of lipid nanoparticles are critical to obtain the desired properties for a nanocarrier to improve vitamin delivery.

Effects of High Salt on Ability to Perform in Stressful Environments

E.M. Hallal, G.A. Sonick, A.E. Crites, A.K. Hite, A.J. Ross, A.L. Shafer, M. Simões Rodrigues and T.L. Gilman, Kent State University

Under various gravity environments, micronutrients influence physiology, e.g., sodium's (Na) effects upon bone strength and kidney stone formation. Salt (NaCl) is a non-caloric flavor enhancer and preservative for long-term space mission foods. Yet, how salt and stress interact to impact learning, memory, and work effort on procedures where behaviors affect outcomes (i.e., performance) remains understudied for normal gravity conditions, let alone other gravity environments. We assigned rats to low (0.4% NaCl), high (4.0%), or mixed (access to both) diet conditions for two studies. Study 1: Rats ate their assigned diet for 6 wks. At 2 wks, they underwent training to avoid an aversive stressor; 4 wks later, their memory was tested. Study 2: Rats ate their assigned diet for 5 wks while learning to lever press for salty + sweet pellets; lever pressing and diet continued while rats underwent 4 wks of mild stressors, then another 4 wks after stress exposure. Access to high salt did not affect learning, but reduced work effort for pellets during and after stress. Conversely, high salt rats had initially accelerated learning to avoid an aversive stressor versus low salt access rats. Over time, avoidance performance equalized across diets, persisting through the long-term memory test. These data indicate high salt intake attenuates 'wanting' of salty + sweet food during and after stress, while augmenting initial adaptation to learning stressor avoidance. Therefore, high salt intake may confer cognitive and behavioral flexibility advantages in normal gravity. Further research is required to evaluate the implications, particularly under high stress conditions, of how salt intake could affect work performance, endurance, and efficiency in space.

Hardware Tests of 3D Tumbling Motion Estimation of a Satellite

Conrad Kent and Ou Ma, Department of Aerospace Engineering, University of Cincinnati

The poster will demonstrate a research effort for testing vision sensors by pointing them at a tumbling satellite mockup whose fully controlled 3-axis rotation was physically rendered by a robotic arm. The purpose of these experiments is to develop and demonstrate the capabilities of different visual sensors and algorithms in estimating the rotational velocities and attitudes of a satellite in orbit. A mobile ground robot is used to move the tested sensor to different relative locations with respect to the tumbling mockup. 3D motion tracking techniques are used to mask out the background and robotic arm from the sensor data. The motion tracking is also used to assess the accuracy of the tested sensors and estimation algorithms. Test results using an Iterative Closest Point (ICP) algorithm with a commercial Light Detection and Ranging (LiDAR) sensor will be presented. The poster will include pictures of the hardware setting, graphical representations of the ICP algorithm at work, and plots showing accuracy of the tested sensor and algorithm.

Facilitated Transport Membranes for Selective Separation of CO_2 at Low Concentration

Yun-Yang Lee, Aidan Klemm, Muhammad Zeeshan, and Burcu Gurkan, Department of Chemical and Biomolecular Engineering, Case Western Reserve University

CO_2 capture technologies are essential to achieve the global goal of carbon neutral and carbon negative. Membrane separations are energy-efficient compared to the adsorption/absorption processes with sorbents/solvents. However, little attention has been given to CO_2 separation from cabin air by membranes. In this work, a thin film composite type of facilitated transport membrane (FTM) with a functionalized ionic liquid (IL) carrier is developed. The selective layer is an IL-rich gel nanoconfined within the graphene oxide (GO) nanosheet framework. The IL mobile carrier, incorporated into the membrane increased the CO_2 solubility and enhanced the mobility of CO_2-complex within the FTM in comparison to the Poly-IL fixed carrier. The nanoconfined IL-rich PIL-IL gel was stabilized through the intermolecular interactions among the PIL, IL, and GO components of the selective layer over the poly(ethersulfone)/poly(ethylene terephthalate) substrate. High performance of CO_2 carrier-facilitated transport at conditions relevant to cabin air (620 Gas Permeation Unit and CO_2/N_2 selectivity of 250) was demonstrated at 22 °C and 40% relative humidity.

Fire Behavior and Material Flammability in Reduced Pressure Environments

Robin Neupane and Ya-Ting Liao, Department of Mechanical and Aerospace Engineering, Case Western Reserve University

Ambient pressure is an important parameter in buoyant flow that governs burning behavior of solid materials. Reduced pressure has been used in previous studies to simulate flames in micro- and partial gravity environments, based on pressure modelling approach that conserves the Grashoff number (i.e., by keeping p^2g constant). Based on this concept, this experimental study investigates extinction and upward flame spread process of a thermally-thin solid fuel in different pressure and oxygen conditions. Experiments are performed in a combustion chamber in air at different pressures, ranging from 100 mbar to 1,000 mbar. As pressure increases, different burning behaviors are observed: no ignition, partial flame spread, steady flame spread, and accelerating flame spread. It is also observed that in partial pressures (e.g., 250-500 mbar), flames exhibit characteristics that are typically observed in micro and partial gravity environments: blue and dim. Burning characteristics (e.g., ignition time, sample burn length, and flame spread rate) are deduced and compared between different pressures. Overall, the burning intensity and the flame spread rate decrease with the ambient pressure. This is attributed to the thickening of flow viscous boundary layer, leading to an increased flame standoff distance and reduced convective heat flux to downstream unburnt solid fuel. Near the low-pressure extinction limit, ambient pressure also plays an important role in the gas-phase kinetics, further contributing to the reduction of flame intensity. In the next steps, oxygen percentage will be varied 1) to obtain the low oxygen extinction limit at different pressure levels, and 2) to study the flame spread characteristics in future space exploration atmosphere (i.e., reduced pressure, enhanced oxygen environment). The results will help assess fire safety in future space missions.

Durability Assessment of Inconel Alloy 718's Response to Tensile Loads through Combined Experimental FEA Simulations and DIC Validation Using PLA Specimens

Mubaraq Onifade, Abdul Aziz Ali, Satha Sivanantham and David Dreyer, Materials Research Laboratory, College of Aeronautics and Engineering, Kent State University,

This investigation undertakes a comprehensive examination of Inconel superalloy 718, a crucial aerospace material used for manufacturing of turbine engine hot section components, focusing on its behavior under tensile stress through the dual methodologies of Finite Element Analysis (FEA) and Digital Image Correlation (DIC). By employing explicit dynamics within ANSYS code for FEA, we effectively simulated the material's complex deformation under high-rate loading, a scenario common in aerospace applications. The approach employed in this study broadens comprehension of Inconel superalloy 718's mechanical properties and lays a robust foundation for future material science research within the aerospace sector at Kent State University, College of Aeronautics and Engineering. The superiority of Inconel 718 under specified engine complex loading conditions, substantiated by FEA and observed through DIC, underscores the material's reliability. This in return will offer a deep understanding of the materials mechanical and structural behavior, its impact on turbine engine components failure mishaps and on aviation safety as whole. Lastly, this exercise of combined analytical and experimental techniques offers valuable insights into the material's behavior, durability with findings traits such as stress-strain correlations of both PLA and Inconel 718 poised for by an in-depth discussion and presentation.

Physics Informed Machine Learning for Phase Change Heat Transfer Systems

Logan M. Pirnstill and Chirag R. Kharangate. Department of Mechanical and Aerospace Engineering, Case Western Reserve University

Next generation space technologies require advanced thermal management systems for various high energy density tasks such as the cooling of rocket nozzles, hypersonic reentry vehicles, and cryogenic fuel storage. A promising tool for these thermal management systems is two-phase convective heat and mass transfer, as these systems effectively combine the sensible heat transfer of convection with the latent heat transfer of phase change. Convective two-phase flows are complex thermal-fluid systems that are difficult to characterize due to mass, momentum, and heat transfer at the vapor-liquid interface, making traditional modelling tools, such as CFD, black box machine learning, correlations, and semi-empirical modelling difficult to utilize. These difficulties make component engineering difficult and thus fast, accurate, and reliable predictive tools must be developed to sufficiently model important heat and mass transfer parameters. This research proposes physics informed machine learning through physics informed neural networks (PINNs) as a new tool for engineers to utilize in conjunction with some of the more traditional methodologies. PINNs combines traditional black box machine learning with physical theory to learn and infer previously difficult to measure quantities, and ensures outputs are physically consistent. We explore PINNs by three different ways: (1) to compute a forward simulation of the 1D Stefan problem similar to CFD, (2) to compute a 2D inverse problem to infer fluid flow fields from the evolution of a bubble interface, and (3) as a surrogate for empirical parameters in control volume models. In general we find PINNs to be adequate at all three of the aforementioned tasks and we would like to lead further research into applying PINNs to different two-phase convective heat and mass transfer problems.

PRO-based Trajectory Planning for Spacecraft Close-Distance Flight around a Client Satellite for Proximity Operations

Dylan Roach, Andrew Barth and Ou Ma, Intelligent Robotics and Autonomous Systems Lab, University of Cincinnati

In-space or On-orbit Servicing, Assembly, and Manufacturing (ISAM or OSAM) activities require spacecraft to fly around a client satellite or another orbiting object in a proximity range from 10's to 0 meters in distance. When flying within such a close distance, it becomes extremely important for the servicing craft to not only avoid collision but at the same time also minimize fuel consumption, especially since such fly-around spacecraft will likely be low-cost and less-capable CubeSats. Therefore, planning a Passive Relative Orbit (PRO) becomes essential for safe, reliable, and energy-efficient operations. Most research efforts have focused on planning trajectories for rendezvous and docking from 100's of km away, and much less work has been done regarding flying around a client with a minimal but nonzero distance. For many close distance ISAM tasks, such as surveying or inspecting a client satellite, one needs to plan one or more trajectories around the client body due to various requirements. These may include specific image resolution, safety distance, an interesting feature, full coverage of the entire body, etc. Therefore, planning a safe and fuel-efficient circumnavigation trajectory becomes necessary. This work first studied the characteristics of PROs around a client and proposed how to use these characteristics to plan a desirable task trajectory around the client. Then it solved the problem of how to deploy a spacecraft to a task trajectory along a two-burn PRO-based transfer trajectory and return from the task trajectory with minimal fuel consumption with or without a time constraint. Finally, further work was undertaken to add more real-world effects and perturbations to increase the realism of the PRO trajectory planning method.

Design and Analysis of a 3U CubeSat

Nicholas Taranto, Department of Mechanical and Aerospace Engineering, Case Western Reserve University

This poster presents a design and analysis of a 3U CubeSat project which will capture images of the Great Lakes region to enable environmental monitoring in real-time. The work was carried out by a senior undergraduate student at Case Western Reserve University in collaboration with Comsat Architects in Rocky River, OH. The project involves designing a CubeSat that adheres to the size constraints of a 3U configuration, ensuring compatibility with existing CubeSat hardware and standard deployment systems. The design process begins with the CubeSat structure, followed by the integration of subsystems such as power, communication, and an imaging payload. A significant focus is placed on the imaging payload, which will test how AI and machine learning technologies can improve the capabilities of CubeSat class satellites. The student carried out 3U CubeSat research using computer aided design and analysis tools on the structure and power subsystems of the small satellite. The CubeSat Design Specifications document was used as a standard to design the CubeSat. SolidWorks was used to create assemblies of all CubeSat components, ensuring fitment with third-party components and potential in-house components designed by Comsat Architects. Systems Tool Kit (STK) was used to test the CubeSat's performance across differing orbits around Earth to measure radiation from the Van Allen belts in total ionizing dose and solar panel effectiveness to determine power requirements. Lessons learned from other CubeSat projects are incorporated into the design and analysis process to enhance the mission's likelihood of success. In conclusion, the student's work significantly contributed to the plan to deploy a 3U CubeSat design and analysis over the Great Lakes in the near future. The work will continue as the student joins Comsat Architects in the fall. This work contributed to the student's educational and professional development while advancing design of 3U CubeSat capable of monitoring the Great Lakes region.

Employing Remote Sensing Techniques to Understand Seasonal Changes in Water Quality in the Muskingum Watershed Conservancy District

Spencer Williams and Joseph Ortiz, Kent State University

My project is focused on addressing the negative impacts that anthropogenic activities in industry, agriculture, and mining have had on aquatic environments. Increased use of synthetic fertilizer, livestock waste, and pesticides, along with global climate change, has caused nutrient oversaturation and heightened phosphorus load in local reservoirs, leading to an influx of seasonal algae growth. My research area houses several reservoirs surrounded by land use applications that could cause significant degradation to water quality over time. In this research project we've employed novel remote sensing approaches to water quality analysis to investigate the effects that such contaminants have had and introduce a low cost, non-intrusive and time saving procedure for monitoring the proliferation of algal blooms and recognizing changes in water quality over time.

Effect of Thruster Uncertainties on a Deep Space Mission Using Electric Propulsion

David L Walker[1], Bryan Schmidt[1], and John Yim[2]
[1]Department of Mechanical and Aerospace Engineering, Case Western Reserve University
[2]NASA Glenn, Electric Propulsion and Power Laboratory, NASA Glenn Research Center

As deep space missions expand in scope and distance, the efficiency of propulsion systems becomes paramount. This thesis analyzes the impact of small measurement errors in the thrust profiles of Hall-Effect Thrusters, a common type of electric propulsor, known for increased efficiency compared to traditional chemical propulsion despite lower thrust. Due to their prolonged operational times, these errors compound, affecting trajectory and mission success. Through analyzing the AEPS Hall-Effect Thruster prototype, designed for NASA's Artemis Program's Gateway space station, using curve fitting and a Monte Carlo simulation, we assess the effects of these errors on an example mission to Alpha Centauri. Results show plasma dynamics cause the majority of error, but cause minimal trajectory deviation and propellant loss. This reinforces electric propulsion's suitability for long-distance space travel. This work informs spacecraft mission design, providing valuable insights into fuel efficiency and system selection, as well as building upon NASA Glenn Research Center's Electric Propulsion and Power Laboratory's prior research.

Demonstration of Fluid Dynamics for Plant Growing Systems in Varied Gravity Environments Through Scaled Capillary Models

Cassidy Brozovich[1], Dr. Peter Ling[1], Tyler Hatch[2], and John McQuillen[2]

The Ohio State University[1] and NASA Glenn Research Center[2]

The development of reliable and bioregenerative crop growth production systems is vital for human exploration into deep space. As humans prepare for space travel beyond LEO, scientists need to find a way to provide reliable and adequate water delivery for all stages of the plant's life cycle. Past production systems struggled with this and often led to overwatering in the system. To better understand this issue, NASA's Plant Water Management (PWM) experiments were able to model fluid flow through granular substrates, specifically a clay-based material arcilite, in 0-G. The PWM study can help researchers to predict fluid flow through the systems, however their model only works for an arcilite based system and was unable to account for different stages of plant growth. For future missions, payload requirements to support crop production system will need to be limited, leading to the use of *in situ* resources. This project aims to validate the PWM experiments as well as incorporate various materials into the design for growth systems. To meet these objectives, a series of terrestrial experiments will be deployed to mimic all gravities. By modifying the material, fluid, and size of the test subjects, the effect of Earth's gravity can be minimized. This project will aid researchers in the design of future crop production systems for surface missions by creating a refined model that can be used at all stages of plant growth and utilize *in situ* resources.

The Viability of Robotically Enabled Cold Welding in Orbit To Accelerate Space Manufacturing Technology

Edward Lui, Dr. Glenn Daehn (HAMMER), Dr. John Horack (Starlab-GWCSP), Matthew Nichols, The Ohio State University

Unprecedented increased access to space and the importance of spaceflight has driven demand for non-terrestrial manufacturing technologies needed to sustain human presence in LEO, the Moon, and beyond. The 2023 US National Academies decadal survey on Biological and Physical Science in space states "learn how materials and energy interact in the non-terrestrial environment and use that knowledge to design the infrastructure for space exploration." In keeping with this recommendation and in fortification of this strategic thrust, our research explores the advancement of the ‘state of the practice’ in two essential areas: 1) the use of robotics in spaceflight and 2) innovative research and advanced manufacturing methods for materials in LEO. The main manufacturing method we aim to explore and develop is the process for cold welding. Cold welding is a known process that joins metals without using heat thus not altering material properties resulting in extremely clean and strong welds. To accomplish this, a vacuum is typically required. In space, we benefit from having a clean, natural vacuum environment. Our ultimate goal is to implement a standardized robotics platform that can manufacture scalable space structures and be adaptable to other research fields. These capabilities will further anchor the future human presence in low-Earth orbit (LEO) and enable sustainable exploration to the Moon and beyond.

Spectral Sensing for Biofilm Mitigation in Controlled Environment Agriculture Applications in Space

Lindsey Shimoda, Dr. Peter Ling, and Dr. Soledad Benitez-Ponce, The Ohio State University

Biofilms pose significant challenges to controlled environment agriculture (CEA), particularly in hydroponic systems that are being developed in microgravity environments. These biofilms refer to a consortium of microorganisms that form resilient communities on surfaces, resisting environmental changes, including cleaning efforts. Their presence often leads to premature degradation of equipment, either through clogging or surface damage. Moreover, biofilms raise safety concerns by potentially harboring pathogens and facilitating the transfer of antibiotic resistance genes. A detection system is needed for timely cleaning requirements and addressing biofilms before the problem is exacerbated especially in microgravity applications with limited resupply missions and semi-closed loop life support systems. Microgravity applications need this detection system to be nondestructive and offer real-time responses. In the ongoing work, the aim is to develop a nondestructive biofilm detection method for applications in CEA on Earth and plant growth habitats in space. This will be achieved by developing a spectral sensing method, evaluating the efficacy overtime, and comparing the limit of detection to the industry standard of colony forming units to obtain biofilm data. The current focus is on comparing the ability of a spectroradiometer to a spectrophotometer on detecting biofilm using machine learning to analyze the hyperspectral data for a higher classification accuracy.

Materials Joining in Space

E. Choi, A. Brimmer, W. McAuley, B. Panton, A. Ramirez, Welding Engineering Program, Department of Materials Science and Engineering, The Ohio State University

HED EBW (High energy density electron beam welding) enabled the first and, to date, only American weld performed in space during the M551 experiment on Skylab in 1973. Even though weld joining process is critical to 90% of durable goods manufacturing in America, there is no application of welding processes to the In-space Servicing, Assembly, and Manufacturing (ISAM) sector. Because of this disconnection, fundamental studies are needed to develop basic capabilities to enhance fundamental process knowledge, which will support follow-on efforts to mature in-space welding for use in commercial, defense, and other aerospace applications. The current work seeks to build on past flights and improve understanding and quantification of materials joining in space conditions using LBW (laser beam welding). LBW offers several advantages over the electron beam welding of Skylab, amongst others: reduced electromagnetic interference, less exposure of operators to ionizing radiation, and flexible delivery through optical fibers supporting unique workpieces and joints.

Our team have retrofitted an LBW experimental apparatus that can simulate the vacuum and, during a parabolic flight, the reduced gravity & microgravity conditions of in-space welding. A team of PhD and undergraduate students modified the setup, originally developed by NASA Langley Research Center for electron beam free-form fabrication, to replace its electron gun with a 1.5 kW, 1070 nm Yb fiber laser. The apparatus was further instrumented with temperature sensing and high-speed welding cameras to monitor and record changes in the thermal state of the workpiece, the melt pool, the laser penetration level, and the development and orientation of spatter & plumes. The system will operate autonomously, demonstrating its utility to uncrewed missions during our first parabolic flight this August 2024. This data will guide future computational modeling efforts of laser welding in space and help to qualify in-space welding as a viable ISAM technique.

Dynamic Surveillance with Ground and Flying Sensors for Advanced Air Mobility Using Optimization and Computer Vision

Esrat Farhana Dulia and Syed A. M. Shihab, College of Aeronautics and Engineering, Kent State University

Advanced Air Mobility (AAM) enables uncrewed aerial vehicles (UAVs) operations in low-altitude airspace, requiring a surveillance network to detect and track UAVs for safe operations and public security. Relying solely on the existing surveillance network for AAM is inadequate for two main reasons: 1) its limited ability to track smaller UAVs in lower airspace, and 2) its placement in restricted areas, primarily near airports and critical zones, whereas AAM necessitates city-wide coverage. To address this gap, we propose an optimization model to determine the optimal number of AAM-specific ground sensors and their optimal placements within the city for developing an AAM surveillance sensor network. This study considers various terrain types within the city, as well as different sensor types and characteristics (e.g., range, field of view, signal and noise energy, misdetection probabilities, false alarm rate, etc.). We implement a mixed conditional logit model to estimate demand for AAM trips across various areas within a city and a route planning model to connect routes and schedule AAM flights between origin and destination pairs. To enhance the robustness of the AAM surveillance sensor network, we consider sensors equipped on UAVs as mobile flying sensors capable of detecting other UAVs nearby. These ground sensors and flying sensors combined make our model dynamic, serving two purposes: 1) increasing redundancy in the network, providing backup detection capabilities in case of ground sensor failure; and 2) enabling fusion between mobile and ground sensors, allowing for more accurate determination of positions and other necessary information about UAVs flying over the city. We utilize computer vision to process the positions and other information of other UAVs from images captured by flying sensors and employ the extended Kalman filter for ground and flying sensor fusion. Preliminary results suggest that the dynamic surveillance sensor network enhances accuracy in detecting both authorized and unauthorized aircraft. It enables AAM operators to guide authorized UAVs with updated flight paths, avoiding potential collisions. Additionally, it allows AAM operators to observe unauthorized aircraft and take necessary actions, potentially preventing unwanted incidents and increasing security of the city.