SHARING YOUR VOICE CENTERING YOUR PURPOSE

4TH ANNUAL GRAD WIE NETWORK SYMPOSIUM

FEBRUARY 25, 2025

Abstract Booklet

PURDUE UNIVERSITY | Women in Engineering Program

SHARING YOUR VOICE, CENTERING YOUR PURPOSE

FEBRUARY 25, 2025

ABOUT THE WOMEN IN ENGINEERING PROGRAM

Mission

To provide strategies within a supportive community for women engineering graduate students to advance personally, academically, and professionally.

Objectives

Community | To establish an inclusive network that affirms, inspires and supports women and gender minorities throughout their engineering graduate career.

Strategies | To provide opportunities to develop skills and introduce strategies for professional and personal development

Advancement | To provide an enriching experience that encourages individual growth, and furthers the community of women engineers

ABOUT THE WOMEN IN ENGINEERING PROGRAM

Dr. Suzanne Zurn-Birkhimer, Senior Associate Director, Women in Engineering Program

Cathy Deno, Senior Administrative Assistant, Women in Engineering Program

Reshma Chandrasekar, M.S. Student, Aeronautics and Astronautics Engineering

Allison Komrska, M.S. Student, Nuclear Engineering

Burla Ondes, Ph.D. Candidate, Industrial Engineering

Raquel Ruiz, Ph.D. Candidate, Civil Engineering

Morgan Smith, Ph.D. Student, Materials Engineering

Shanmukhi Sripada, Ph.D. Candidate, Mechanical Engineering

PRESENTERS

PRESENTERS

PRESENTERS

PRESENTERS

PRESENTERS

PRESENTERS

EVALUATION OF HIGH SCHOOL SEMICONDUCTOR AND MICROELECTRONICS SUMMER PROGRAM

Shauna Adams

PhD Student, Engineering Education, adams532@purdue.edu

Other Authors: Cristian Eduardo Vargas-Ordonez (Purdue University), Morgan M Hynes (Purdue University), Kerrie A Douglas (Purdue University), Peter Bermel (Purdue University), David R. Ely (Ivy Tech Community College), Hayley Joy Grisez (Ivy Tech Community College)

This talk presents an overall evaluation of the READI High School Semiconductor Summer Program, which aims to cultivate semiconductor awareness and interest among high school students. In response to the imperative for a skilled workforce in this industry, where semiconductor research, design, and fabrication occur, a large mid-western university and a local community college co-developed and implemented the first version of a 2-week summer program for local high school rising juniors and seniors. This initiative strives to increase students' knowledge of, awareness of, and interest in semiconductors by introducing them to the associated technology, manufacturing, applications, and careers within this ecosystem.

In particular, the program engaged fifty-three high school students from six regional counties in hands-on activities in electronics and manufacturing, visits to local companies using semiconductors in their production lines, tours of local higher education fabrication and experimental lab facilities, and designing and prototyping various microelectronic systems. The program and participant experience were evaluated based on understanding students' change in their sense of belonging and self-efficacy, career aspiration, and knowledge and skills associated with the semiconductor ecosystem. Data collection involved pre-post survey results, students' daily evaluations of the program activities and reflections, and focus group responses.

The analysis, employing inductive coding of responses and related pairs analysis on pre- and post-survey sections, revealed positive outcomes. These findings indicate that participants' knowledge of semiconductors and sense of belonging in the semiconductor ecosystem improved, and there was an increase in participant awareness of semiconductor career paths. While acknowledging the program's success in meeting its objectives, participants offered valuable insights for refining the program's curricular design in future iterations. These results increase awareness of an emerging field in the community, potentially serving as a model for precollege engineering summer programs associated with workforce development initiatives across different industries in the country.

A Study on Motivation and Supports for Volunteers in Engineering Youth Programs

Shauna Adams

PhD Student, Engineering Education, adams532@purdue.edu

The purpose of this talk is to understand the demographic of long-term volunteers in structured engineering programs and the supports they use or have access to. There has been a giant effort over the last several years to increase the number of people entering engineering and technology-related fields. One of those efforts has been to create formal and informal ways to incorporate engineering and technology in youth spaces. Informal engineering-related structured program experiences are a growing area and behind many of these programs, especially community-based programs, are a small number of staff and/or long-term volunteers who are the backbone of these programs. Volunteers play an integral role in the success of many pre-college engineering programs and fill different capacities within the organizations they volunteer for. Though vital in the function of these programs, little is known about who these volunteers are and the support and resources they have access to. Utilizing self-determination theory, researchers designed a survey and semi-structured interview protocol to capture volunteer demographics and measures for volunteer motivation, engagement, and perceived supports for volunteers with 2 or more years of experience with an informal pre-college structured engineering program. This talk will review the results of our expert review of both the survey and interview protocol in preparation for wider dissemination and the analysis methods using descriptive analysis, ANOVA, and thematic analysis. Results from this study will add to the body of knowledge on who is volunteering in vital positions impacting youth engagement in structured engineering programs and continue the conversation of formal and informal pathways for volunteer training and resource support.

PROCESS INTENSIFICATION FOR END-TO-END SYNTHESIS AND PURIFICATION OF ONCOLOGY DRUGS

Ilke Akturk

PhD Student, Chemical Engineering, iaydin@purdue.edu

Other Authors: Giulia Murbach-Oliveira, Attila Tamas Csathy, Zoltan K. Nagy (Purdue University)

The importance of continuous manufacturing and digital modeling in pharmaceutical processes is growing, driven by their ability to reduce equipment footprint and processing time, while increasing throughput (Grover et al., 2023.; Sundarkumar et al., 2023). The degeneration of the pharmaceutical manufacturing supply chain during the COVID-19 pandemic highlighted the need for smaller-scale, domestic pharmaceutical manufacturing near raw material sources and hospitals (Sharma et al., 2020). Advancements in small-scale platform development have allowed for the integration of various unit operations like reaction, extraction, and crystallization, offering improved efficiency, safety, scalability, and adaptability to the pharmaceutical industry in the form of end-to-end manufacturing (Nagy et al., 2021). The integration of small-scale, distributed, continuous manufacturing platforms with digital simulations can further help advance pharmaceutical manufacturing while ensuring the quality and availability of essential medications (Casas-Orozco et al., 2023).

This work focuses on small-scale modular pharmaceutical manufacturing for anti-cancer drugs integrated with digital modeling. This small-scale modular setup, called mini-pharm, is useful due to its modularity, transferability, and robust operation. The individual modules can be used for the implementation of design of experiments (DoE), design space exploration, digital process design and model validation. The development and implementation of the mini-pharm end-to-end manufacturing platform were demonstrated on the high-value, low-demand oncology drug, Lomustine. Lomustine, an orphan drug affected by monopoly induced price gauging, was successfully manufactured in the mini-pharm platform, and the manufacturing process underwent process intensification in combination with digital simulations. The synthesis reactions were followed by a continuous solvent switch distillation (CSSD) to introduce the antisolvent and evaporate the reaction solvent. Batch reaction experiments in combination with process analytical technology (PAT) tools were conducted following a systematic DoE for dynamic concentration data. Lomustine was purified via continuous combined cooling and antisolvent crystallization and a novel drug product formation module was utilized. The end-to-end continuous manufacturing of Lomustine was successfully modeled using Python. The study demonstrates the feasibility and benefits of small-scale modular pharmaceutical manufacturing for orphan drugs, such as Lomustine, showcasing end-to-end continuous manufacturing improvements applicable even for hazardous molecules like oncology drugs. Overall, this research contributes to advancing pharmaceutical manufacturing methodologies, providing insights into digital modeling's role in enhancing process efficiency, safety, and scalability.

NEIGHBORHOOD-LEVEL ELECTRIFICATION: STRATEGIC APPROACHES FOR EQUITY AND ENVIRONMENTAL BENEFITS

Nadah Al Theeb

PhD Student, Mechanical Engineering, naltheeb@purdue.edu

Other Authors: Prof. Kevin Kircher, Aadit Kumar (Purdue University)

Building electrification plays a key role in reducing emissions, but the transition from natural gas presents equity challenges. As households electrify, utilities tend to spread gas pipeline operation and maintenance (O&M) costs across a shrinking customer base to maintain infrastructure. This results in higher bills for "left-behind" customers and disproportionately impacts low-income households. A strategic electrification plan is essential to ensure timely pipeline decommissioning, prevent methane leaks, and lower costs for left-behind customers while addressing environmental and equity concerns.

This study uses a mathematical model to simulate neighborhood-level electrification with two targeted policy approaches - savings Priority and Equity Priority - compared to an Untargeted Policy. Savings priority focuses on neighborhoods with fewer remaining gas users to maximize savings, while Equity Priority prioritizes low-income areas to address equity concerns.

Results show that the Untargeted Policy electrifies homes one year earlier than targeted policies but incurs the highest total costs for users. The Savings-Priority Policy reduces cumulative ratepayer costs by 30%, while the Equity-Priority Policy electrifies low-income users 8 years faster and lowers their gas costs by 60%. Additionally, targeted policies cut O&M costs and methane emissions by 42% but decreased utility profits by 40%. This study demonstrates that targeted electrification can achieve environmental goals while alleviating financial burdens, especially for low-income households. Policymakers can use these insights to design strategic, neighborhood-level electrification policies that balance economic, social, and environmental goals.

STUDENTS' VIEWS OF THE CHALLENGES AND STRATEGIES ENCOUNTERED WHEN ENGAGED IN COMPUTATIONAL MODELING AND SIMULATION

Joreen Arigye

PhD Student, Engineering Education, jarigye@purdue.edu

Other Authors: Alejandra J. Magana

Computational modeling and simulation play an increasingly vital role in engineering education, equipping students with essential skills to analyze and solve complex, real-world problems. Despite its importance, students often encounter significant challenges when navigating the interconnected domains of conceptual, mathematical, and computational representations within modeling tasks. This study aims to investigate these challenges and explore the strategies students employ to overcome them. Guided by the research question "What are the challenges students experience when mapping between conceptual, mathematical, and computational representations and the strategies they employ to overcome those challenges while engaging in computational modeling and simulation practices?" the study analyzes reflection data from undergraduate engineering students engaged in a computational simulation project focused on pharmacokinetics of perfluoroalkyl acids.Our findings reveal that students face multifaceted challenges when translating concepts into mathematical equations and implementing those equations in Python code. Key obstacles included unfamiliarity with Python syntax, difficulty aligning units and variables within complex mass balance equations, and troubleshooting errors that propagated across stages of the project. The iterative nature of these tasks often required students to backtrack across representations to identify and correct foundational errors. To address these challenges, students utilized a range of problem-solving strategies categorized into self-directed, peer-directed, and professor/TA-directed approaches. Self-regulated learning strategies, such as trial-and-error and using online resources, fostered independence, while peer collaboration allowed students to share insights and collectively troubleshoot issues. Professor and TA support provided structured guidance on technical and conceptual complexities.These findings suggest that fostering students' fluency between conceptual, mathematical, and computational domains requires a balanced approach that includes both autonomous and collaborative learning strategies. Implications for teaching emphasize the importance of structured support and peer learning opportunities to aid students in navigating these interdependent challenges. This study highlights the need for educational interventions that support technical skill development alongside conceptual understanding.

INORGANIC-RICH SOLID-ELECTROLYTE-INTERPHASE ENABLED BY FLUORINATED ETHER ELECTROLYTE DESIGN FOR SILICON-BASED ANODES

Esin Aydemir

PhD Student, Chemical Engineering, eaydemir@purdue.edu

Other Authors: Esin Aydemir (Purdue University), Zheng Li (University of Maryland), Vilas Pol (Purdue University)

Despite the great effort for adapting lithium metal (LM) anodes to secondary batteries after their promising results with primary batteries back in the 1970s, the commercialization of lithium ion batteries (LIBs) realized after graphite anode discovery. Passivation layers form because of the parasitic reactions between the electrodes and the electrolyte, which referred as solid electrolyte interphase (SEI) and cathode electrolyte interphase (CEI) on the anode and cathode surfaces, respectively. Graphite is relatively more stable than LM anode and can be passivated by conventional ethylene carbonate (EC) based electrolytes. However, the energy density that can be attained with graphite as an intercalation-type anode is limited as its theoretical specific capacity (372 mAh/g for LiC6) is only one-tenth of that of LM anode (3860 mAh/g).Silicon (Si) based anodes, on the other hand, promises high-energy density LIBs due to its very high theoretical capacity (3580 mAh/g). However, the severe volume expansion (~300%) of Si particles during cycling requires a mechanically robust and compact SEI to prevent the active material loss as well as to passivate surface to prevent further electrolyte decomposition. To address the issues of Si-based anodes collectively, this study introduces a weakly solvating electrolyte (WSEE) based on a partially fluorinated ether (FE) solvent paired with lithium bis(fluorosulfonyl)imide (LiFSI) salt. The featured anion-rich solvation structure promotes formation of an inorganic-rich, compact inner SEI layer. The unique solvation environment fostered by the partial fluorination of FE enables a much faster reaction kinetics, extending its operation to ultra-low temperatures when combined with FE's low viscosity and high ionic conductivity. FE based Si/Gr||NMC811 full cells showed a superior electrochemical performance at room temperature (RT) with 87% capacity retention over 100 cycles. The excellent low-temperature performance of FEME was verified by Si/Gr||NMC811 full cells retaining 63% and 40% of their RT capacity at -60°C and -80°C, respectively, with a Coulombic efficiency exceeding 99%. The improvements in the electrochemical performance of silicon anode are attributed to a unique, anion-rich solvation structure at low salt concentrations and an inorganic-rich, robust SEI layer on the silicon anode.

DECISION-SUPPORT TOOL FOR COMMERCIAL SPACE INTEGRATION IN CIVIL SPACE EXPLORATION MISSIONS

Dalia Bekdache

PhD Student, Aeronautics and Astronautics Engineering, dbekdach@purdue.edu

Other Authors: Dr. Daniel DeLaurentis

As the space industry matures, the private sector's involvement in space exploration has significantly grown. The has led the US Department of Defense (DoD) and NASA to more strongly advocate for commercial participation in civil space exploration efforts. The strategies and efforts of government agencies aim at adopting a paradigm shift towards leveraging technology from private partnerships for space missions. These advancements potentially enable rapid deployment of emerging innovative solutions, but they also introduce complex integration challenges. One example of these challenges is the use of Boeing's Starliner capsule, which NASA selected to transport crew to and from the International Space Station (ISS). Integration hurdles and delays have extended NASA astronauts' visit to the ISS, as the spacecraft was not cleared for a safe, crewed re-entry to Earth. This situation illustrates the complexities and setbacks of integrating commercial space solutions, where unforeseen technical or operational issues can lead to cascading effects on mission objectives and decision-making. The integration of commercial systems and services into space missions involves navigating complex interdependencies among policies and incentives to the private sector, multi-stakeholder input, decentralized authority, supply chain logistics, and other qualitative metrics. Decision-makers face hurdles in aligning these factors with cost structures, risk assessment, technology capabilities and readiness, and integration compatibilities. Despite research efforts made by organizations like RAND and the Aerospace Corporation, there are clear gaps in providing open-sourced comprehensive tools to guide these integration and implementation efforts. Therefore, my research focuses on developing a decision-support tool that systematically evaluates how the percent ('degree') and type ('level') of commercial space integration affect costs, risk, and utility, and enable stakeholders to make informed decisions. This tool leverages a unique pipeline of lab-developed tools that can handle portfolio architecture, functional analysis, risk assessment, and technology prioritization. By incorporating these elements, the framework provides robust support for make-buy decisions, promotes best practices for sustainable implementation, and ultimately guides stakeholders in achieving mission success with reduced complications

EXPLORING FACTORS INFLUENCING CREW RESILIENCE IN M:N (MULTI) SMALL UNMANNED AIRCRAFT SYSTEMS (SUAS) BEYOND VISUAL LINE OF SIGHT (BVLOS) SURVEILLANCE OPERATIONS

Radhika Bhopatkar

PhD Student, Environmental and Ecological Engineering, rbhopatk@purdue.edu

Other Authors: Dr. John Howarter (Purdue University)

Introduction: Multi (m:N) small Unmanned Aircraft Systems (sUAS) beyond visual line of sight (BVLOS) operations is an example of a complex sociotechnical system where the system and operational complexity grows with the presence of more than one sUAS (N>1), a larger team of crew members (m=>1), and higher levels of automation. In such complex operations, resilient crew performance is crucial for managing multiple disruptions occurring simultaneously at multiple sUAS and thus, sustaining safe operations. Resilient performance is an important property of complex sociotechnical systems as it prevents them from breaking down in the face of anticipated and unanticipated challenges.

Research Significance and Gap: NASA is developing the In-time Aviation Safety Management System (IASMS) to meet growing air traffic demands and influx of new aircraft technologies, such as the sUAS, while maintaining safety. A key goal of the IASMS project is to study the resilient performance of the human-machine system. Currently, there is a lack of understanding of what resilient crew performance is and how can it be assessed for m:N sUAS BVLOS operations. Thus, in this study, I aim to investigate (1) What system and operational factors affect the crew's potential to exhibit resilient performance? and (2) How do these factors influence the crew's resilient performance? during m:N sUAS BVLOS operations.

Methodology: I characterize the crew's resilient performance in terms of their ability to monitor, respond, learn, and anticipate. To carefully capture and assess the interaction between the human-in-the-loop, automation, ground control station controls, sUAS, and other environmental factors, I used pre-operations survey and post-operations semi-structured interview data collected during a project sponsored by the Federal Aviation Administration. I thematically analyzed the interview data gathered from the flight test crew members to better understand what factors of the m:N sUAS BVLOS flight test operations influence their ability to exhibit resilient performance. Further, I collated the identified themes with the crew competency data (from the pre-operations survey) to understand how these factors played a role in influencing the crew's potential for resilient performance.

Key Findings: Themes generated from my analysis primarily focused on the system and operational factors that positively or negatively influenced the crew's potential to exhibit resilient performance. The ringing of multiple simultaneous alerts and overlapping communications negatively impacted the crew's potential of resilient performance, while flexibility to arrange information on the workstation screens and trust in the systems automation had a positive effect.

ROLE OF HYDROLOGIC MODELING GOALS ON EVALUATION OF SOBOL' SENSITIVITY INDICES FOR MODEL PARAMETERS

Rishitha Bikkumalla

PhD Student, Civil Engineering, rbikkuma@purdue.edu

Other Authors: Dr. Rao S. Govindaraju (Purdue University)

Sensitivity analysis plays a crucial role in hydrologic modeling studies by supporting calibration, uncertainty evaluation, and potential model refinement. In particular, global sensitivity analysis (GSA) methods, which explore parameter impacts across their entire distribution, offer a more holistic understanding of model behavior. Among these, variance-based methods such as Sobol' analysis are widely recognized for their efficacy in decomposing the output variance into contributions from individual parameters and their interactions.

Sobol' sensitivity analysis quantifies the relative influence of model parameters through the computation of first and higher-order sensitivity indices, which are useful for identifying influential parameters and enhancing model robustness. However, the analysis is affected by the choice of the model, dimensionality of the parameter space, data availability, and the purpose of the modeling exercise. These factors act in combination to confound sensitivity analyses and subsequent inferences. In this study, authors explore the relative roles of these factors by using the HEC-HMS model over several watersheds and multiple rainfall events, and offer recommendations for efficient evaluation of Sobol' sensitivity indices. The role of modeling goals in estimating model sensitivity is highlighted through these examples.

EVALUATING THE DEGRADATION OF THERMAL INTERFACE MATERIALS IN LIQUID IMMERSION COOLING SYSTEMS USING ULTRASONIC METHODS

Jacey Birkenmeyer

MS Thesis Student, Mechanical Engineering, jbirkenm@purdue.edu

Other Authors: Bijay Chhetri, Dr. Shubhra Bansal, Dr. Luz D. Sotelo (Purdue University)

Immersion cooling systems for data centers are significantly more energy efficient and use less water than traditional air- or water-cooled systems. However, the long-term mechanisms of degradation of Thermal Interface Materials (TIMs) and the effects of the interaction between coolant fluid and TIMs have not been thoroughly studied and there are currently no nondestructive/noninvasive approaches to monitor degradation. Ultrasonic nondestructive evaluation uses high-frequency sound waves to detect defects in a part and characterize its material properties. This paper will discuss the use of ultrasonic nondestructive evaluation to detect changes in material properties in coolant fluids and TIMs as well as scanning acoustic microscopy to map defects in the TIMs. For this purpose, combinations of various commercially available coolant fluids and TIMs were evaluated. TIM samples were placed in coolant fluid and heated at 150 degrees C for 500 hours and 1000 hours (in accordance with JESD22-A103C test standard) to simulate an immersion cooling system in a data center. Then, sound wave speed and attenuation measurements were collected and compared with optical spectroscopy and visual inspection methods to identify the sound metrics most sensitive to material changes. While established chemical and physical experimental characterization was used to provide insight into the fundamental mechanisms of degradation for each TIM-coolant combination, ultrasonic approaches enable more rapid, accessible, and nondestructive characterization. This information may provide the industry with additional methods of degradation characterization which may be leveraged for periodic and/or continuous monitoring.

LEVERAGING ADDITIVE MANUFACTURING TO BETTER UNDERSTAND NONDESTRUCTIVE EVALUATION

Jacey Birkenmeyer

MS Thesis Student, Mechanical Engineering, jbirkenm@purdue.edu

Other Authors: Harshith K. Adepu, Partha Pandit, Dr. Luz D. Sotelo (Purdue University)

In recent years, ultrasonic nondestructive evaluation (NDE) has increased in popularity as a way to detect defects and determine material properties in additively manufactured (AM) components. When completing ultrasonic scans, it can be difficult to fully resolve internal structures in a component; generally, resolution increases with frequency up to a certain point, when scattering from the microstructure causes interference. In ultrasonic transducer beam models, many assumptions are made about the beam geometry inside the sample; however, interactions with the material may result in important discrepancies between the model and the experiment. In this study, a simple internal structure, a spherical cavity, is printed through laser powder bed fusion (LPBF) inside a cubical block of SS316L. Each sample cube is printed with a different laser power and scanning speed, with a constant energy density, in order to vary the microstructure of the block. These samples allow us to compare experimental beam mapping inside the sample to preexisting ultrasonic beam models. By leveraging additive manufacturing technologies, we can validate and further our understanding of nondestructive evaluation techniques.

CANONICAL SURFACE PHASE DIAGRAMS FOR DISORDERED COMO ALLOYS

Zuhal Cakir

PhD Student, Chemical Engineering, zcakir@purdue.edu

Other Authors: Liangbing Hu (Yale University), Chao Wang (Johns Hopkins University), Jeffrey Greeley (Purdue University)

The use of periodic DFT calculations and advanced synthesis techniques has accelerated the understanding and development of multimetallic alloy catalysts, including high-entropy alloys (HEAs). HEAs, composed of many elements with mixed atomic structures, offer attractive catalytic properties such as improved stability and tunable active site structures. Carbothermal shock synthesis enables the formation of such nanoparticles with many elements incorporated into a single solid-solution phase, with high-resolution STEM-based elemental mapping revealing a homogeneous distribution of the elements. However, uncertainty remains regarding the distribution of elements in the surface region, especially for elements with large miscibility gaps present in the phase diagram. In particular, fluctuations in local composition can lead to surface strain effects that alter catalytic performance. Understanding these effects in HEAs is crucial for designing effective catalysts and optimizing their activity and selectivity.

This study employs cutting-edge computational methods to elucidate the impact of strain and local surface compositional fluctuations of disordered CoMo bimetallic alloy surfaces, providing insights into the design of high-entropy alloy (HEA) catalysts. By analyzing canonical surface phase diagrams, we identify thermodynamically stable surface compositions that deviate from the bulk, emphasizing the importance of considering strain relaxation in random alloy surfaces. These strain relaxations often occur when the local surface composition deviates from the bulk composition, in our case, $Co_{50}Mo_{50}$. The resulting stable surface structures are also used to calculate descriptors for NH_3 decomposition and to screen for reactivity properties. This work lays the foundation for understanding surface stability and strain effects in disordered alloys, facilitating the rational design of HEA catalysts with optimized surface properties for enhanced catalytic performance.

DOMESTIC GRAPHITE MINING IN THE U.S.: A CASE STUDY ON THE EXTRACTION OF CRITICAL MATERIALS IN ALASKA

Camila Cassunde

PhD Student, Environmental and Ecological Engineering, ccatheri@purdue.edu

Other Authors: Dr. John W. Sutherland

To achieve 2050 sustainability's climate goals of limiting the global temperature increase to less than 2 degrees Celsius and coping with climate change-induced volatility, the demand for critical raw materials (CRMs) in clean energy technologies is increasing fast. The achievement of domestic production of essential materials, especially minerals, faces frequent challenges around community acceptance due to economic, social, and environmental concerns. In this sense, one of the most important minerals nowadays is graphite, which is implemented in many Sustainability goals, including clean energy and transmission systems. Despite the efforts, the US hasn't mined natural graphite for almost 20 years and the production of artificial graphite is being thoroughly explored by research to be implemented soon, most of the national supply depends on importation from China. To ensure the sustainability of the supply chain in the next 200 years, graphite has to be internally processed, rather than by mining or artificial production. This project focuses on understanding social and economic perspectives around critical mineral extraction in the United States by analyzing the case study of Graphite One's implementation in Alaska. Using the systematic literature review method, this project states the importance of economic, ecological, and social analysis involving government, industry, and community before any decision-making within the critical materials supply chain. To estimate possible circumstances, environmental, economic, and social impacts are addressed by LCA, TEA, and S-LCA techniques in a preliminary approach. Other important matters such as policies and market issues are also evaluated to construct a better understanding of the impacts involved in the domestic graphite mining situation.

PROTEIN THERAPEUTICS MOVEMENT IN THE VITREOUS HUMOR: MEASUREMENT AND IMAGING OF INTRA MATRIX IGG DIFFUSION

Riya Debbarma

PhD Student, Agricultural and Biological Engineering, rdebbarm@purdue.edu

Other Authors: Dr. Antonio C.F. dos Santos (Boston College), Dr. Diana Ramirez Gutierrez (Purdue University), Dr. Kendra Erk (Purdue University), Dr. Fernanda da Cunha (Purdue University), Dr. Michael Ladisch (Purdue University)

Intravitreal administration of therapeutics for treating ocular diseases such as age-related macular degeneration and diabetic retinopathy is key in achieving peak intraocular drug concentration. The transport of protein therapeutics after intravitreal injection to the target tissues is driven by diffusion whereas convection plays a significant role for nanoparticles. Hyaluronic acid (HA) is a major constituent and determines the key attributes of the vitreous humor of the eye. The tracking of bovine IgG movement over time in an in-vitro hyaluronic acid matrix simulates protein diffusion in the vitreous humor and informs a fundamental understanding of the diffusion properties of injected IgG type protein therapeutics.

Our work provides a pre-clinical in-vitro tool to screen protein therapeutics and measure their diffusion in a HA matrix formulated to represent the injection site and correlate it with their in-vivo behavior. Our previously reported work has shown concentration dependent IgG diffusion in a high molecular weight HA matrix (1.5 MDa) that represents the SQ environment. The current work explores IgG diffusion in a low molecular weight HA matrix (0.5 MDa) with a viscosity of 0.2 Pa.s representing the vitreous humor. The measurement was done using our previously reported method where a repurposed cell culture chamber was filled with 6 mm deep HA and the movement of triplicate 20 uL bovine IgG injection in the HA matrix was imaged by using gel imaging scanner. The imaging of bovine IgG is done label-free by activating the tryptophan residues at 280 nm and capturing the protein auto-fluorescence at 384 nm for 3-5 mins. We report the measurement of diffusion coefficient of IgG in a low molecular weight HA matrix by analyzing images of the protein boluses that tracks its movement over time. The IgG diffusion increased from our previously reported values due to the decrease in the molecular weight of the HA matrix.

Both diffusion and convective effects are important for the transport of intravitreal therapeutics. In older population, there is evidence of age-related reduced viscoelasticity of the vitreous due to its liquefaction (synchysis) which influences the in-vivo transport of the injected therapeutic.

Our work provides a facile approach to screening preclinical candidates for ocular diseases as well as correlating diffusion properties of therapeutics to age-related changes in viscoelasticity of the vitreous humor.

RELIABILITY TESTING FOR COUNTERFEIT DEVICES WITH INTRINSIC ODOMETER APPROACH

Archana Dharanipragada

PhD Student, Electrical and Computer Engineering, adharani@purdue.edu

Other Authors: Prof. Saeed Mohammadi (Purdue University)

Commercial counterfeit recycled parts result in significant financial losses for the semiconductor industry, raising reliability, performance, security, and economic concerns. Identifying recycled parts can be achieved by determining device age through "intrinsic odometers" - circuits with measurable characteristics indicating age, such as clock generators, phase-locked loops (PLLs), oscillators, I/O pads, and other mixed-signal blocks. Commercial FPGAs, including those with multiple on-chip PLLs, can undergo AC and DC domain performance assessments to verify if a device is new. Burn-in tests on a Xilinx Artix-7 FPGA demonstrate that device age estimation is feasible with existing circuit components. Furthermore, microcontroller-based test circuits offer an alternative qualification method for transistor technology. Also, at the device level, Reliability measurements on MOSFETs, applying acceleration factors like higher voltage or temperature, help characterize degradation mechanisms such as Negative-Bias Temperature Instability (NBTI), Positive-Bias Temperature Instability (PBTI), and Time-Dependent Dielectric Breakdown (TDDB), excluding hot carrier effects (HCI).

To address the issue of counterfeit recycled parts in the semiconductor industry, device age can be estimated through intrinsic circuit components like clock generators and PLLs. Testing methodologies, such as burn-in tests and reliability measurements on MOSFETs under accelerated conditions, help determine device age and predict lifetimes. These approaches improve device verification and provide alternative qualification methods for transistor technologies.

GRAND CHALLENGES: HEALTH - DYNAMIC GRANULAR HYDROGELS AS AN IN VITRO CANCER MODEL

Ellen Frahm

PhD Student, Biomedical Engineering, frahme@purdue.edu

Other Authors: Chun-Yi Chang, Chien-Chi Lin (Purdue University)

Stiffening of extracellular matrix (ECM) is a hallmark of aggressive pancreatic ductal adenocarcinoma (PDAC). A few hydrogel models have been developed to study the effect of matrix stiffening on PDAC cell behaviors, but recapitulating the spatiotemporal changes in tumor matrix properties remains a major challenge. Granular hydrogels are an emerging biomaterial platform that can be adapted to overcome this challenge. Assembled from micron-scale hydrogel particles through physical or chemical crosslinking, granular hydrogels have micro/macroscopic pores that facilitate molecular transport and cell migration. However, current granular hydrogels are typically fabricated with defined features (stiffness, porosity, compositions, etc.) that do not recapitulate the dynamic nature of native tissues. Hence, the current models are inaccurate to the native tissue behavior. To address this challenge, we report here the development of dynamic granular hydrogels formed by gelatin-norbornene-carbohydrazide (GelNB-CH) microgels. GelNB-CH microgels were first prepared from a microfluidic droplet generator coupled with thiol-norbornene photo-click gelation. The microgels were annealed via inverse electron-demand Diels-Alder (iEDDA) click reaction, and dynamically stiffened via hydrazone bonding. Uniquely, adjusting the concentration of stiffening reagent (i.e., oxidized dextran or oDex) afforded dynamic stiffening of the granular hydrogels to exhibit uniform stiffness without affecting scaffold void fraction. PDAC cell spheroids encapsulated in the granular hydrogels with gradient stiffness demonstrated enhanced invasion in the regions with higher stiffness. This work improves the design of granular hydrogels and provides a highly adaptable biomaterial platform for disease modeling. Thus, the implication of this work is that patient-derived cells could be used in this platform to provide unique insights about the tumor behavior and their response to therapeutic treatments.

ASSESSING ALGORITHM BIAS IN CLINICAL DECISION SUPPORT TOOLS FOR ACUTE MYOCARDIAL INFARCTION PATIENTS: A MIMIC IV COHORT STUDY

Emily Garcia

PhD Student, Industrial Engineering, garci611@purdue.edu

Other Authors: Zachary J. Hass (Purdue University)

Machine learning (ML) algorithms are increasingly becoming integrated into clinical decision support systems (CDSS), offering significant potential to enhance healthcare decision-making. However, concerns remain regarding their ability to exacerbate existing health disparities. Previous studies indicate that ML algorithms may inadvertently introduce bias, which can negatively impact access to and quality of care for vulnerable populations. Despite this, there is a lack of evidence on whether ML-based CDSSs, particularly those for cardiovascular diseases, amplify healthcare disparities among these groups. This study aims to evaluate algorithm bias in the Controlled Abciximab and Device Investigation for Lower Late Angioplasty Complications (CADILLAC) risk score - a CDSS designed to predict major adverse cardiovascular events (MACE) within one-year post-hospitalization for patients admitted with acute myocardial infarction (AMI). The CADILLAC risk score was selected due to its emerging application in identifying low-risk MACE patients suitable for early discharge presents an understudied area that warrants further investigation regarding potential algorithm bias. To assess algorithm bias in both primary and secondary applications of the CADILLAC risk score, we conducted a retrospective study involving a cohort of first-time MIMIC IV AMI patients hospitalized. We predicted both MACE occurrence and early discharge suitability. To address common data gaps, we employed multiple imputation based on parameter distributions derived from prior studies on hospitalized AMI patients, stratified by gender and/or race. This methodological approach ensured a more comprehensive and equitable analysis. We evaluated the CADILLAC's predictive accuracy across various demographic groups, focusing on age, gender, race, and insurance status. We assessed algorithmic bias by calculating four group-based fairness metrics: statistical parity difference, predictive rate parity difference, equalized odds difference, and equal opportunity difference. Our results revealed statistically significant differences in the CADILLAC's predictive performance across demographic groups. Group-based fairness metrics confirmed bias presence, with disparities pronounced more among Hispanic/Latino and Medicare-insured patients. Overall, our research highlights the importance of assessing algorithm bias in CDSS before their widespread adoption to ensure health equity.

3D SIMULATION OF IGNITION CHARACTERISTICS IN THE HEAD VORTEX OF HOT JETS FOR WAVE ROTOR COMBUSTION

Shahrzad Ghadiri

PhD Student, Mechanical Engineering, sghadiri@purdue.edu

Other Authors: Dr. M. Razi Nalim (Purdue University)

Wave rotor combustors (WRCs) are a promising technology for sustainable energy and propulsion, using unsteady pressure waves to improve fuel efficiency and lower emissions. Unlike traditional combustors, WRCs use these pressure waves to compress and ignite the air-fuel mixture more effectively. This process increases thermal efficiency and produces more power for the same amount of fuel, directly helping to reduce carbon emissions. By using less fuel, WRCs support global sustainability goals, especially in aviation and power generation, where higher fuel efficiency can significantly cut emissions.

WRCs are also versatile in the types of fuel they can use, including options like hydrogen and hydrogen-enriched fuels, which produce little or no CO2. This flexibility makes WRCs an attractive choice for the shift away from traditional fossil fuels while still allowing high-performance combustion. Additionally, WRCs produce less noise than many standard combustors, which can reduce noise pollution and make them more suitable for use in populated or sensitive areas.

The high-frequency, cyclic nature of WRCs requires fast and dependable ignition, which can be achieved using transient turbulent hot jets that mix hot reactive gases with the fuel-air mixture. This rapid mixing enables ignition at multiple points throughout the combustor. The reactive jet includes two main regions: a near-field area with a high-speed trailing jet and a far-field area dominated by a head vortex ring. This research focuses on the head vortex ring, where detailed 3D simulations are used to study its composition and ignition behavior in a methane-air mixture across different fuel ratios.

Another advantage of WRCs is their potential to work well with renewable-based or hybrid power systems. As we rely more on variable renewable energy sources like wind and solar, WRCs could serve as a steady, high-efficiency power option to help balance energy demand and supply. This makes wave rotor technology not only useful for improving efficiency and reducing emissions now but also a flexible solution that can grow alongside cleaner energy systems. Overall, WRCs could play an important role in achieving a low-carbon, sustainable energy future.

EXPLORATORY RESEARCH ON PRE-COLLEGE TEACHERS' EXPERIENCES IMPLEMENTING ENVIRONMENTAL JUSTICE CURRICULUM

Rachel Higbee

PhD Student, Engineering Education, rgehr@purdue.edu

Other Authors: Rachel Gehr, Tamara Moore, Kerrie Douglas (Purdue University)

Environmental justice (EJ) is the concept that everyone has the right to a clean and healthy environment, regardless of their demographics, geographic location, or socioeconomic status (SES). However, the groups that are statistically most likely to experience environmental injustice in the United States are marginalized groups, including people of low SES, people of color, rural and Native American communities, and immigrants. While these groups are at a disproportionate risk of public health concerns, only 37 percent of American households believe that there is environmental racial disparity. One of the approaches to continue relieving the disproportionate environmental risk is to educate people about EJ and who is impacted, with the hope of increasing the mere 37 percent of American households that understand the topic. My avenue for increasing environmental justice education is to embed the content into existing middle school science curriculum to foster motivation to pursue justice in our society's youth. To be successful, this approach requires participation from motivated and empathetic teachers who believe EJ is an important topic to introduce to their students, despite the controversy about EJ's place in the classroom. My research explores the perspectives and experiences of K-12 teachers who have implemented environmental justice curriculum in their classrooms. Preliminary results show that teachers have had a positive experience despite the pushback from politicians. This research has the potential to directly and indirectly impact people who can foster societal and cultural changes for the pursuit of environmental justice. This work may also indirectly impact policymakers as they review relevant research when making informed decisions. Again, as more people continue to research this issue and discuss how we can right these inequities, we hope to spark additional government initiatives to make systematic changes that will help victims of environmental injustice.

RAPID DIAGNOSTIC TESTS: A GAME-CHANGER FOR CERVICAL CANCER SCREENING IN LOW-RESOURCE SETTINGS

Sayeh Jalali Dowlatshahi

PhD Student, Biomedical Engineering, sjalalid@purdue.edu

Other Authors: Scott C. Bolton, Lucy Tecle, Francesca Hamacher, Samrin Habbani, Jacqueline C. Linnes (Purdue University)

Cervical cancer (CC) is the fourth most common cancer in women and the fourth leading cause of cancer-related deaths among them globally. The incidence and mortality rates of this disease are considerably higher in low- and middle-income countries (LMICs); roughly 84% and 88% of CC cases and deaths occur in these regions, respectively. Current gold-standard screening techniques are expensive and time-consuming, possess low sensitivity or specificity, and require trained personnel and infrastructure, limiting their implementation in these areas. During the COVID-19 pandemic, rapid diagnostic tests played a crucial role in detecting SARS-CoV-2 early, being one of the most effective interventions in reducing the COVID-19 burden in LMICs and worldwide. Therefore, similarly, to fundamentally transform CC screening programs in resource-limited settings, there is an urgent need for a low-cost, rapid, sensitive, and specific point-of-care early-stage CC diagnostic assay. Topoisomerase II alpha (TOP2A), an enzyme innately involved in DNA replication, is overexpressed in CC patients, making it a promising CC protein biomarker. This study focuses on developing a TOP2A lateral flow immunoassay (LFIA) for CC screening. The test's colorimetric labels are 40-nm gold nanoparticles (AuNPs) conjugated to mouse anti-TOP2A detector antibody (dAb) molecules. Conjugation efficiency was assessed through commercial quality control dipstick assays and dynamic light scattering. Of the tested dAb-to-AuNP molar ratios, 100:1 produced the highest grayscale intensity. It was also the most stable throughout a 7-day study and was accordingly chosen as the optimal conjugate for the LFIA. This conjugate was then used with in-house dipsticks to optimize the test and control lines. 1.5 mg/mL anti-mouse immunoglobulin G was selected as the LFIA control line's antibody concentration. So far, the test line has detected as low as 50 ng/mL of TOP2A, showing promise that the platform will work in the 20-100-ng/mL clinical range. The optimized parameters will be incorporated into the TOP2A LFIA design and its performance will be evaluated with clinical samples. Furthermore, multiplexing TOP2A with other known CC protein biomarkers and machine learning (ML)-assisted result interpretation will be studied. This low-cost rapid test coupled with the cytology data-informed ML model will enable sensitive and specific CC screening in LMICs, leading to more timely diagnosis and earlier effective treatment.

BONE PLATE DESIGN OPTIMIZATION USING FEA ANALYSIS

Aishvarya Joshi

MS Thesis Student, Aeronautics and Astronautics Engineering, joshi270@purdue.edu

Other Authors: Dr Zherui Martinez-Guo (Purdue University)

Bone plates are critical in orthopedic surgery for stabilizing fractures and aiding in bone healing, particularly in load bearing and anatomically complex regions. Traditionally, straight rigid bone plates are used, which are attached to the fractured bones at the fracture interface using screws. Tubular bone plates, which are curved and encircle the bones, provide better rigidity and performance than these traditional plates. Currently, in commercially available tubular plates, the screws are inserted perpendicular to the bone surface.

However, traditional tubular plates may not provide optimal fixation around complex bone structures with the current screw setup, potentially affecting both stability and patient recovery outcomes. Modifying the design of tubular plates, particularly with innovative screw placement configurations, could help address biomechanical limitations in these anatomically challenging areas.

To enhance the performance of a tubular bone plate, screws are inserted at an angle to the bone in a triangular placement pattern. The screws proposed for use are locking head screws, featuring threads along both the length and the head of the screw. This design minimizes slippage between the screw and plate, enabling more effective load transfer from the bone to the plate. A standard 3.3 mm thick straight bone plate serves as a reference to evaluate axial, torsional, and bending stiffness under 1 mm bone movement across loading conditions. Tubular plates of 3.3 mm, 2.8 mm, and 2.3 mm thicknesses are assessed on these metrics and compared to the straight plate's performance. Finite element analysis (FEA), including quasi-static and dynamic simulations, is used to simulate and compare maximum stresses and strains on the plates.

The key findings indicate that tubular plates demonstrate superior design performance under all loading conditions. The 2.3 mm thick tubular plate exhibits strain values similar to those of the straight rigid plate. Therefore, a tubular plate with a thickness of 2.3 mm and efficient screw placement provides comparable performance to a straight rigid plate of 3.3 mm thickness.

These findings offer insights for improving bone plate design to enhance stability in complex fractures. Reducing the plate thickness by 1 mm lowers surgical costs, manufacturing expenses, and plate weight while increasing load resistance on fractures and advance tubular plate capabilities in orthopedics.

DYNAMIC FRACTURE INITIATION AND PROPAGATION IN NOTCHED SPECIMEN OF TITANIUM (TI-6AL-4V) AND ALUMINUM (AL 2024) ALLOYS

Aishvarya Joshi

MS Thesis Student, Aeronautics and Astronautics Engineering, joshi270@purdue.edu

Other Authors: Dr Zherui Martinez-Guo (Purdue University)

Aircraft components, particularly turbine blades, experience extreme high-speed and impact loads in operation. These parts require materials with exceptional strength, high strength-to-weight ratios, thermal resistance, and fracture toughness. Titanium and aluminum alloys, such as Ti-6Al-4V and Al 2024, offer these qualities, making them ideal for aerospace applications. However, over time, flaws from manufacturing or foreign object damage can emerge, significantly weakening structures and risking catastrophic failure. Given the aerospace industry's emphasis on safety and cost, it is crucial to understand how Ti-6Al-4V and Al 2024 respond to defects under rapid loading conditions. Improved failure prediction could lead to safer, more reliable structures and reduce costs by extending the lifespan of critical components.

While the quasi-static behavior of these materials are well understood, their dynamic behavior remains largely unexplored, where structures are subjected to high loads over short durations. This research focuses on the deformation and fracture response of Ti-6Al-4V and Al 2024 alloys under dynamic loading by examining the impact of small notches on overall performance.

My research uses rectangular bar-shaped specimens designed to ASTM E399 standards, with "U"-shaped notches ranging from 0.15 mm to 1.5 mm in radius which represent flaws. These specimens undergo high-speed impacts in a four-point bending setup with a Split Hopkinson Pressure Bar (SHPB), where long steel bars collide with the specimen positioned between them and are fired by a gas gun to replicate dynamic conditions. Digital Image Correlation (DIC), a high-resolution optical camera technique, captures local strain data to observe material deformation and fracture growth around the notches. This data correlates fracture strain to the force measured by the SHPB.

The key findings are expected to correlate fracture strain values with the applied force at varying strain rates. These findings will also be linked to stress triaxiality values obtained from computational models simulated through finite element analysis (FEA) in ABAQUS.

This research aims to advance fracture prediction technology by enhancing simulation performance and reducing damage costs from small notches in large structures. It will help industries design safer, more durable aerospace structures with fracture properties as a key fail-safe criterion.

REVOLUTIONIZING AUTONOMIC DYSREFLEXIA DETECTION: RAT-TO-HUMAN TRANSFER LEARNING FOR PERSONALIZED MODELS

Seeun Kim

PhD Student, Biomedical Engineering, kim4627@purdue.edu

Other Authors: Dr. Sidharth Pancholi

Health: Autonomic dysreflexia (AD) is a severe, potentially life-threatening condition frequently occurring in individuals with spinal cord injuries above the T6 level. Triggered by noxious stimuli, AD results in a rapid and extreme rise in blood pressure, which can lead to stroke or even death if not managed promptly. Current AD detection methods, including blood pressure monitoring, are limited by intermittent data collection and lack of real-time predictive capability. Thus, there is a pressing need for a non-invasive, continuous monitoring solution that can predict AD episodes before they become critical.

This study leverages transfer learning to adapt a deep neural network initially trained on rat data for human application, focusing on skin nerve activity (SKNA) signals as a primary indicator of AD. Using transfer learning, we fine-tune the rat-based model with human data, allowing us to retain the essential features learned from extensive animal data while accommodating the differences in human physiology. This approach allows for efficient use of limited human data, enabling robust prediction of AD events with minimal false-negative rates. The model processes SKNA signals in real-time, aligning with the goal of continuous, non-invasive AD monitoring.

Initial results show promising accuracy in predicting AD episodes in human subjects, demonstrating both generalizability across individuals and computational efficiency. This research thus provides an essential advancement in AD detection, offering a potential clinical solution for proactive management of AD episodes in spinal cord injury patients. By supporting early intervention, this model could significantly enhance patient safety and quality of life.

In conclusion, this work advances the application of machine learning in healthcare, underscoring the utility of transfer learning for real-time medical monitoring. These findings highlight the potential impact of computational approaches on improving non-invasive, personalized healthcare solutions for vulnerable patient populations.

CONTROLLED GROWTH OF 2D PEROVSKITE FOR LOW-THRESHOLD LASER

Jeong Hui Kim

PhD Student, Chemical Engineering, kim4017@purdue.edu

Other Authors: Dr. Wenhao Shao, Jeffrey Simon, Prof. Letian Dou (Purdue University)

Two-dimensional (2D) perovskites are emerging as promising semiconducting materials featuring inherent quantum well structure, which holds significant potential for next generation electronic and optoelectronic applications. At the same time, achieving 1D structures from 2D semiconducting materials is crucial for device miniaturization but remains a significant challenge due to high costs, processing complexity, and scalability issues associated with traditional methods. In this context, 2D perovskite nanowires present a promising alternative for next-generation devices. Compared to conventional 2D materials like transition metal dichalcogenides (TMDs), they offer superior solution processability and potential for large-scale fabrication, along with easier integration into existing fabrication processes.

In this project, we hypothesize that strong secondary interactions between molecules in 2D perovskites, which disrupt in-plane symmetry, guide the growth direction of the 2D perovskite crystals. To achieve nanowires, we designed novel organic molecules that, when integrated into the perovskite structure, introduce strong hydrogen bonding interaction, leading to the formation of nanowires. Based on these, we systematically investigated the growth direction and mechanism of these 2D perovskite nanowires using single-crystal X-ray diffraction and selected-area electron diffraction. Our findings demonstrated that COOH dimers, originally employed to restrict directional connectivity, play a crucial role in this process. In the assembled system, surface-dangling COOH moieties protect facets through hydrogen bonds with aqueous solvent molecules, significantly influencing the growth and morphology of the nanowires.

Building on the successful controlled growth of 2D perovskite nanowires, the next step is to explore their application in nanowire laser devices. The unique optical properties of our nanowires such as waveguiding effect make them ideal candidates for efficient nanowire lasers. Our research aims to identify and optimize key factors influencing light-matter interactions for enhanced laser performance. We correlated crystal structure, charge carrier dynamics, and lasing device performance through time-resolved photoluminescence and optically pumped lasers. This led to the development of high-performance lasing devices with low thresholds and excellent stability.

DESIGN OF TIES AND TIE-TO-FACEPLATE CONNECTIONS FOR STEEL-PLATE COMPOSITE (SC) STRUCTURES

Kaitlyn Kondos

PhD Student, Civil Engineering, kkondos@purdue.edu

Other Authors: Dr. Amit Varma (Purdue University), Dr. Lisa Choe (PARI)

Steel-plate composite (SC) walls are emerging as a leading alternative design choice to conventional reinforced concrete (RC) for structural applications, including high-rise structures and nuclear power plants. SC structures demonstrate enhanced ductility, strength, and a reduction in construction time compared to RC structures. Each SC wall has two external steel faceplates connected by steel ties and filled with concrete. The steel ties provide stability during transportation, resist concrete casting pressures, and transfer shear forces to ensure composite action between the steel module and concrete infill. Under large loads, SC structures are designed to undergo significant yielding before failure. Therefore, the ties and tie-to-faceplate connections must demonstrate significant ductility. The Specification for Safety-Related Steel Structures for Nuclear Facilities requires designating ties as 'yielding' or 'nonyielding' when designing SC structures. Ties classified as 'yielding' are assumed to develop the full yield strength before the tie-to-faceplate connection fails. However, ties classified as 'nonyielding' are designed to account for only half of the tie strength in shear calculations. Therefore, understanding how the ties and tie-to-faceplate connections perform when loaded in tension is critical when designing SC structures. Experimental pullout tests were conducted to investigate the yielding behavior, failure mode, and strength of the tie and tie-to-faceplate connections. Each pullout specimen included one tie welded to a faceplate on each end. Each specimen was loaded in tension until rupture, and data on the displacement, strain, and load were collected for the duration of the test. Successful tests underwent significant tie yielding before failure, regardless of the failure mode. The data revealed that pullout specimens with carefully detailed and overdesigned weld connections demonstrated the greatest ductility. This work aims to provide additional guidance on the design of ties and tie-to-faceplate connections in SC structures to maximize the structure's ductility under significant loading.

QUANTIFYING THE INTERCELLULAR PROCESSES OF EBOLAVIRUS TRANSMISSION USING MULTI-SCALE AGENT-BASED MODEL

Himabindu Kovvali

PhD Student, Biomedical Engineering, hkovvali@purdue.edu

Other Authors: Himabindu Kovvali, Elsje Pienaar, Robert Stahelin (Purdue University)

Ebola Virus Disease (EVD) is caused by an Ebolavirus (EBOV) infection and is associated with fatal hemorrhagic fever. It has caused more than 30 outbreaks, some with 100% mortality. There is a gap in our knowledge of the protein-protein and lipid-protein interactions that drive effective viral production, making it challenging to develop therapies. Matrix protein VP40, when expressed independently, can produce virus-like particles (VLPs) with similar size, shape, entry, and cell attachment properties as EBOV virions. The production of VLPs is enhanced when VP40 is co-expressed with NP, nucleoprotein, which forms NP inclusions encapsulated in the VP40 VLP matrix. The production of VLPs has been quantified in individual cells with a subcellular differential equation model. Here, we employ this existing data to develop a multi-scale Agent-based model to represent the VP40-NP system in a population of cells using a Java-based modeling system called Repast Simphony. The model has five agent types: Transfected Kidney cells, IB-free-VLP (no NP inclusions), IB-containing-VLP (with NP inclusions), Healthy Kidney cells, and VLP-entered cells. Kidney cells are assumed to be adherent. VLP's have movement via Brownian motion. VLP agents are budded from Transfected Kidney cells and enter Healthy Kidney cells through contact. We stochastically quantified the number and type of VLPs that enter Healthy Kidney cells in a population of cells. Preliminary results suggest that irrespective of the type of VLPs produced, their entry into a healthy cell is defined primarily by the number of VLPs in the environment. The findings provide valuable insights to elucidate how single-cell VP40 and NP interactions propagate across a population of cells to sustain robust viral proliferation. This study introduces a novel framework of multi-scale Agent-based modeling in the context of computational virology.

DEVELOPMENT OF A SUSTAINED-RELEASE DORZOLAMIDE IMPLANT FOR LONG-TERM INTRA-OCULAR PRESSURE REDUCTION IN GLAUCOMA

Samridhi Kulshrestha

PhD Student, Biomedical Engineering, kulshrs@purdue.edu

Glaucoma, a leading cause of irreversible blindness, results from increased intraocular pressure (IOP) that damages the optic nerve, essential for transmitting visual information to the brain. With more than 2.7 million people in the U.S. currently affected - a figure expected to increase to 4.2 million by 2030 - advancing effective glaucoma treatments has become increasingly urgent. Current therapies, primarily eye drops & oral medications, face challenges including poor patient compliance, rapid drug clearance, off-target side effects, and high recurring costs. Despite advancements like ILUVIEN and Durysta implants, limitations such as side effects and a lack of implants for carbonic anhydrase inhibitors persist. Our research focuses on developing a novel, biodegradable ocular implant to address these issues. Our methodology involves the systematic investigation of the effects of polymer composition and drug loading on release kinetics. Previous findings indicate that polymer chemistry and concentration are critical in modulating the drug release profile. The implant's ability to maintain therapeutic levels of the drug while minimizing systemic exposure has significant implications for patient outcomes. By incorporating dorzolamide, a carbonic anhydrase inhibitor (CAI) drug into a biodegradable poly(lactic-co-glycolic acid) (PLGA) matrix, our implant aims to release the drug over 6-12 months, reducing dosing frequency and enhancing patient compliance. PLGA, already FDA-approved for various medical applications, degrades into lactic and glycolic acid, which are naturally metabolized by the body. Our innovative approach leverages hot melt extrusion, a solvent-free technique ensuring consistent drug-polymer mixing and controlled drug release. The significance of this work lies in its potential to improve glaucoma management by providing a sustained-release implant using dorzolamide, which is often prescribed for glaucoma treatment.

Our research aligns with global healthcare goals by offering a long-term, cost-effective glaucoma treatment that could decrease vision loss rates and enhance quality of life. The development of this implant supports the overarching aim of reducing the burden of irreversible blindness worldwide. Future work will include optimizing the release profile and conducting in vitro and biocompatibility studies to ensure safety and efficacy.

CONSTRUCTING A DECELLULARIZED EXTRACELLULAR MATRIX CONTAINING INTERPENETRATING NETWORK HYDROGEL TO PROBE CELL-MATERIAL INTERACTIONS

Tuba Marjan

PhD Student, Biomedical Engineering, tmarjan@purdue.edu

Other Authors: Dr. Taimoor H. Qazi (Purdue University)

Although biomaterials have been used as in vitro platforms to probe cell behavior, current synthetic scaffolds often lack the instructive biochemical signals otherwise present in native tissues. Using decellularized extracellular matrices (dECMs) as scaffolds has been a widely applied strategy to overcome this issue. However, scaffolds prepared with pure dECM lack mechanical stability for long-term cell culture. The objective of this study was to create interpenetrating network (IPN) platforms for cell culture by incorporating dECM into synthetic photo-crosslinkable hydrogels to permit the study of cell-material interactions in the context of a biochemically complex wound healing environment. Norbornene-modified hyaluronic acid (Nor-HA) was synthesized as previously reported and porcine skeletal muscle tissue was decellularized using sodium dodecyl sulfate (SDS). Oscillatory shear rheology was performed at 1 Hz and 0.5% strain to evaluate Nor-HA's crosslinking kinetics and viscoelastic properties with different concentrations of dECM. Hydrogel cryosections were stained with Picrosirius Red to visualize collagen distribution. Cell adhesion and spreading on 2D hydrogel IPNs (containing a base concentration of 0.5 mM RGD) were evaluated using NIH-3T3 fibroblasts stained with Alpha-SMA and DAPI.The results from the rheology time sweep experiments show that the addition of dECM increases the storage modulus of IPN hydrogels from ~500 Pa for pure Nor-HA hydrogels to ~1200 Pa for Nor-HA IPN containing 2.5 mg/mL of dECM. Interestingly, at higher concentrations of 5 and 10 mg/mL, the storage modulus decreases significantly, suggesting that excessive dECM likely inhibits the crosslinking of Nor-HA resulting in a softer polymer network. Picrosirius red staining of the hydrogel cryosections showed heterogeneity in the distribution of dECM likely due to the tendency of dECM to form aggregated particles during processing. Fibroblasts that adhered to the 2D hydrogels showed the highest spreading area on IPNs containing 2.5 mg/mL dECM and the lowest spreading area on those containing 5 mg/mL dECM. Interestingly, these are also groups with the highest and lowest mechanical moduli, respectively, suggesting that there may be confounding effects of biochemical and mechanical cues. Taken together, we report photo-crosslinkable and biochemically active IPNs as in vitro platforms to study cell-material interactions.

EARLY POINT-OF-CARE HEPATITIS C DETECTION THROUGH A PORTABLE AMPLIFICATION ASSAY

Samantha Mata-Robles

PhD Student, Biomedical Engineering, smatarob@purdue.edu

Other Authors: Mia Nair, Natalia M. Rodriguez, Jacqueline C. Linnes

Hepatitis C virus (HCV) is a global problem causing hundreds of thousands of deaths each year. The main mode of HCV transmission is through sharing injection needles, exposing people who use drugs (PWUD) to high-risk of infection [1] and is reflected in the HCV prevalence that is 60-times higher among PWUD than the average population in the US [2,3]. Treatment options exist and have a cure rate of over 95%; however, their success is contingent upon timely diagnosis and integrating people with active HCV infection into care [4]. Current testing guidelines involve a two-tiered testing protocol that introduces barriers for PWUD to even obtain a diagnosis.

To tackle this problem, I'm working with community stakeholders to develop a rapid and portable nucleic acid amplification test (NAT) for true point-of-care detection of active HCV infection.

To achieve this, three main goals must be met (1) Determine the design specifications of our test and device through feasibility and usability studies to understand and translate the needs of our stakeholders (2) Develop an HCV RNA amplification assay (3) Integrate the assay and readout into our portable device.

I conducted the feasibility study with people and organizations who perform HCV testing to high-risk populations. The consensus was that directly detecting the virus would be ideal and facilitate integration to care. Additionally, ongoing analysis indicates that detection must occur within 60 minutes in order to be amenable to testing sites. The assay I have developed is capable of detecting and amplifying synthetic HCV under 30 minutes.

By developing this assay with a human centered design approach, we enable professionals to detect Hepatitis C at the forefront of where the spread of the disease is happening. By doing so we facilitate an improved public health response to outbreaks and better integrate current cases into care.

PROGNOSTICS OF LITHIUM-ION BATTERY LIFE DERIVED FROM EARLY CYCLE PERFORMANCE METRICS

Pretty Mitra

PhD Student, Mechanical Engineering, mitra57@purdue.edu

Other Authors: Abhinand Ayyaswamy, Dr. Bairav S. Vishnugopi, Dr. Partha P. Mukherjee, Purdue

Accurate battery lifetime prediction is crucial for improving the reliability and efficiency of energy storage systems, particularly under varying usage conditions. This study introduces new features derived from the early cycle performance data of a series of lithium-ion (Li-ion) cells. These cells, which include a Nickel Cobalt Aluminum (NCA) cathode and a graphite anode, vary across different form factors and configurations, making the dataset uniquely comprehensive. The core of our study involves the application of a sophisticated array of machine learning techniques and understanding the key factors that influence the accuracy of battery life predictions. By analyzing early-cycle data, which encompasses metrics such as voltage, temperature, and capacity, our predictive models forecast the remaining useful life (RUL) of Li-ion batteries. Leveraging an eclectic mix of machine learning techniques, we interrogate key factors affecting prediction accuracy.

A notable highlight of our approach is its ability to predict the remaining useful life of Li-ion cells for a disparate range of cycles and cell form factors, showcasing the adaptability and accuracy of the proposed prognostic approach derived from a limited set of early-cycle performance metrics. This adaptability is crucial for applications that demand high reliability from their energy storage solutions, such as electric vehicles and renewable energy systems, where battery performance can significantly impact overall system efficiency and operational costs. Furthermore, our findings underscore the importance of integrating diverse machine learning strategies, from regression analysis to more complex ensemble methods, to enhance predictive accuracy. This extensive methodological approach allows for a more nuanced understanding of how early battery performance metrics correlate with long-term degradation patterns. The potential implications of this research are vast, offering critical insights that can drive future innovations in battery technology.

LEFT VENTRICULAR KINETIC ENERGY AND ENERGY LOSS AS NOVEL ECHOCARDIOGRAPHIC BIOMARKERS IN SEPSIS PROGNOSTICATION

Shailee Mitra

PhD Student, Mechanical Engineering, mitra57@purdue.edu

Other Authors: ABrett Meyers (Purdue University), Shravan Kethireddy (Cleveland Clinic), Siddharth Dugar (Cleveland Clinic), Pavlos Vlachos (Purdue University)

Introduction: Sepsis is dysregulated immune response to an infection. In the USA, about 1.7 million suffer from sepsis, with 270,000 annual deaths. Prior studies utilizing conventional echocardiographic markers to ascertain cardiac dysfunction in sepsis outcomes have produced inconsistent results.

Research significance: This study seeks to address this gap by investigating the potential of novel echocardiographic biomarkers to identify cardiac dysfunction in sepsis patients. We investigated novel echocardiographic biomarkers, kinetic energy (KE) and energy loss (EL) using 2D echocardiography (echo). These biomarkers, not typically measured with standard 2D echo, have the potential to better differentiate cardiac dysfunction across sepsis severity.

Methodology: We retrospectively analyzed echocardiogram of 68 patients admitted to Quaternary ICU with sepsis (33.8%) or septic shock (66.2%). We measured traditional measurements ejection fraction, cardiac output and novel parameters KE and EL from color Doppler imaging in apical 4-chamber views.

Key findings: Ejection fraction, stroke volume, cardiac output, and global longitudinal strain (GLS) did not show notable distinction between patients with sepsis and septic shock. The novel echocardiographic biomarkers were distinct between these two groups. The EL value was lower in septic shock, with the EL/KE ratio markedly decreased ($p<0.050$) in both the left ventricle (LV) and left atrium (LA) in septic shock compared to sepsis.

Conclusion: The novel biomarkers EL and EL/KE offer a more detailed insight into the cardiovascular changes based on severity of sepsis. These markers may have a role at the bedside for risk prediction and stratification in sepsis.

BENCHMARKING THE EFFECTS OF MECHANICAL STIMULATION IN CHONDROCYTE-SEEDED COLLAGEN-AGAROSE HYDROGELS

Hong-Anh (Alex) Nguyen

PhD Student, Biomedical Engineering, nguye382@purdue.edu

Other Authors: Clarisse Zigan, Aaron Coppeta, Deva Chan (Purdue University)

Osteoarthritis is a degenerative joint disorder that affects more than 250 million individuals worldwide. It can be characterized by degradation of the articular cartilage, the soft tissue that lines the ends of diarthrodial joints and functions to cushion the everyday motion of the bones. Due to the avascular, aneural nature of the articular cartilage, its cells (chondrocytes) are responsible for taking in mechanical and chemical cues from the environment to regulate the extracellular matrix which provides the tissue with its mechanical functionality. The cartilage has a limited capacity for repair so disruptions in mechanical stimuli lead to larger downstream degradation. The current state-of-the-art treatment is a matrix assisted chondrocyte implantation (MACI), but the matrices used in this procedure fail to recapitulate the mechanical environment for the cartilage and thus lead to longer recovery times. Additionally, this procedure requires two surgeries with around 6-8 weeks in between to allow for the cells to proliferate before implantation which further extends recovery time and increases patient discomfort. One way that these MACIs can be enhanced is through mechanical stimulation, as it has been shown to increase matrix production in chondrocyte seeded agarose hydrogels. However, this still requires 6-8 weeks between surgery due to preculturing time and would require transport to a specialized facility which increases the cost for the patient and heightens the risk of contamination. In our study, a composite collagen-agarose hydrogel was employed with a custom, low-cost and easy to implement compression bioreactor to increase matrix production and enhance the mechanical environment of the MACIs. The addition of collagen provides integrin binding motifs that allow for the chondrocytes to sense their environment and respond to mechanical stimuli without a preculturing period. After seeding, the hydrogels are subjected to physiological strains over one week. After 1, 3, 5, and 7 days, the gels are examined for biochemical content, gene expression, and material properties (stress relaxation, nanoscale compression behavior). Outcomes from this study will enhance our understanding of chondrocyte mechanobiology with respect to mechanical microenvironment and time, leading to better treatments for cartilage degradation due to osteoarthritis.

TISSUE EXPANSION AFTER MASTECTOMY MITIGATES RADIATION-INDUCED SKIN FIBROSIS IN A PORCINE MODEL

Laura Nunez

PhD Student, Biomedical Engineering, lnunezal@purdue.edu

Tissue expansion (TE) is the primary method for breast reconstruction after mastectomy. In many cases, mastectomy patients undergo radiation treatment (XR). Radiation is known to induce skin fibrosis and is one of the leading causes of complications during post-mastectomy breast reconstruction. TE, conversely, induces a pro-regenerative response that culminates in the growth of new skin. However, the combined effect of XR and TE on skin mechanics is unknown. Here, we used the porcine model of TE to study the impact of radiation on skin fibrosis through biaxial testing, histological analysis, and kinematic analysis of skin deformation over time. We found that XR leads to stiffening of skin compared to control based on a shift in the transition stretch (transition between a low stiffness and an exponential stress-strain region characteristic of collagenous tissue) and an increase in the high modulus (modulus computed with stress-stretch data past the transition point). The change in transition stretch can be explained by thicker, more aligned collagen fiber bundles measured in histology images. Skin subjected to both XR+TE showed a microstructure similar to controls and a similar biaxial response, suggesting that physiological remodeling of collagen induced by TE partially counteracts pro-fibrotic XR effects. Skin growth was indirectly assessed with a kinematic approach that quantified an increase in permanent area changes without a reduction in thickness, suggesting the production of new tissue driven by TE even in the presence of radiation treatment. Future work will focus on the detailed biological mechanisms by which TE counteracts radiation-induced fibrosis.

DESIGN AND VALIDATION OF TEST STRUCTURES FOR SPACE MANUFACTURING

Chelsea O'Donnell

MS Thesis Student, Mechanical Engineering, odonne42@purdue.edu

Other Authors: Benjamin Volpe, Harshith Adepu, Salil Bapat Ph.D., Luz D. Sotelo Ph.D.(Purdue University)

Space debris has grown to over 25,000 known human-made objects that are congesting orbits, damaging satellites, and posing a threat to the safety of astronauts and future missions. Much of this waste is composed of valuable metals with the potential to be recycled and repurposed for sustainable in-space manufacturing and construction. Additive manufacturing is ideal for space applications because existing debris can be processed into feedstock and used to create new parts, maximizing efficiency while producing near zero waste. Nonetheless, qualification of AM parts remains a challenge in space as it continues to be constrained to earth. The development of test structures and standards for in-space additive manufacturing is an essential first step in the journey toward safe and sustainable human activities in space. For this purpose, the objective of this work is to design, manufacture, and validate test structures for destructive and nondestructive mechanical characterization. A build plate with a set of maraging steel test samples was successfully printed with Laser Powder Bed Fusion. From the build plate, cube, cylinder, and dogbone samples were selected for evaluation from various print orientations, to account for discrepancies in structure, position, and observed performance. Nondestructive ultrasound wave speed and backscatter tests, as well as X-ray CT scans were collected to identify microstructural features that may affect material behavior. Destructive mechanical tests were used to produce stress-strain curves that inform material properties and potential weaknesses correlated with microstructural defects and grain patterns inherent to Laser Powder Bed Fusion and identified through nondestructive evaluation. Finally, these grain patterns and pore defects are visually observed and characterized via optical microscopy. The results from the nondestructive and destructive evaluations will be applied to the development and validation of finite element models. The results of this model validation are critical to move forward with modeling and testing the behavior of regolith-metal and regolith-polymer products made of space-debris. Such models are an essential baseline to understand the macroscopic behavior of additively manufactured parts in a space environment and inform nondestructive and destructive space-viable test protocols and ground demonstrations. This information is pivotal for the next giant leap toward sustainable space exploration.

SEISMIC STABILITY OF LUNAR LAVA TUBES

Juliana Pereira

PhD Student, Civil Engineering, jpereira@purdue.edu

Other Authors: Antonio Bobet (Purdue University)

Government agencies and now private commercial companies are carefully looking at the potential of space exploration. The Moon brings interest from different industries. However, the Moon has many inhospitable characteristics, including the Moonquakes. Future astronauts will need shelter to facilitate the next lunar exploration. Lunar lava tubes have been studied for over half a century, and their existence has been proven by technological advances and recent discoveries. Multiple lunar lava tubes have been studied, and their sizes and overburden depths can differ. To evaluate their potential to be used as a shelter, it is important to assess their capacity to withstand Moonquakes.

This research includes the results of numerical simulations of lava tubes on the Moon subjected to seismic loading. It is intended to provide insight into the performance of the openings, as well as the effects of size and depth of the lava tubes. The analysis considers that the rock behaves within its elastic regime and that the input is a (simple) uniform sinusoidal motion.

Developing numerical models to evaluate the seismic stability of lunar lava tubes is an available method to study the rock structures located on the subsurface of the Moon. Most finite element software used in the construction industry assumes the project is developed on Earth, and for that, the value assumed and calculated for gravity is the Earth's gravity. Looking for software with sufficient flexibility for different modeling scenarios, ABAQUS© and Plaxis© were possible options. However, appropriate boundary conditions in ABAQUS for seismic analysis are user-defined, which adds complexity to the simulations and the need for verification of the suitability of the adopted boundary conditions. The PLAXIS software was selected due to its simple application of geotechnical engineering concepts, especially the free field boundary conditions that are efficiently applied to seismic models.

A simplified overview of the results suggests that the bigger the tunnel, the more deformation will occur. Yet larger tunnels with a small overburden present even more significant deformations that can be correlated to instability. The deeper the structures are, the more similar the behavior will be to the free-field models.

SOLVING THE AUTOMOTIVE RECYCLING DILEMMA

Alyson Pickering

MS Thesis Student, Materials Engineering, pickera@purdue.edu

Other Authors: Scott Hartung (Purdue University), Jan-Anders Mansson (Purdue University), Patrick Blanchard (Ford), Jeff Dahl (Ford), Shane Skop (Ford), Steven Prascius (Ford)

The push towards sustainability in the automotive industry is driving interest in lightweight materials as a reduced vehicle weight is crucial for manufacturers, as it lowers both fuel consumption and emissions. Compared to metals, polymeric composites can achieve significant weight reduction while delivering the high-performance required for automotive applications.

However, challenges arise as fiber-reinforced polymer composites undergo recycling. Unlike metals, which retain performance after re-melting and reprocessing, fiber-reinforced composites face two major issues when recycled: polymer degradation and fiber length attrition. Initially composed of short discontinuous fibers in a polymer matrix, these composites experience fiber breakage during recycling processes such as mechanical recycling and repelletization. As a result, the recycled product contains shorter fibers, diminishing the material's mechanical performance and introducing variability due to a range of fiber lengths.

To address these challenges and enable the perpetual recycling of fiber-reinforced composites, a hybrid molding process has been developed. This method involves overmolding a continuous unidirectional fiber preform (60% GF PP) with a short fiber-reinforced polymer matrix (45% GF PP) via injection molding. During recycling, virgin material is incorporated into the molding material to mitigate polymer degradation, while chopping the continuous fiber preform supplements the fiber length distribution as the lengths of the short fibers diminish across cycles.

To evaluate this process, multiple configurations of the part were produced and tested across three recycling rounds. This included parts with and without a continuous fiber preform insert, chopped preform in the molding material, and the addition of virgin material, all of which were compared to baseline recycled material. Mechanical and rheological testing, along with analysis of manufacturing process data, allow comparison of the performance of these recycled parts.

Preliminary work suggests that this hybrid molding process can help maintain the mechanical integrity of fiber-reinforced composites over multiple recycling rounds, offering a viable pathway toward sustainable, high-performance composite materials in automotive manufacturing.

THE EFFECT OF WEIGHTED TAPE ON TENNIS RACKET SWEET SPOT SIZE AND LOCATION

Adeline Ripberger

PhD Student, Materials Engineering, aripberg@purdue.edu

Other Authors: Dr. Jan-Anders Mansson (Ray Ewry Sports Engineering Center)

In tennis athletes consistently seek means to improve their performance. One such method is adding weighted tape to locations around the perimeter of the frame. The two primary locations are the top and sides of the racket. The main objective of weighting the top of the frame is increasing the swingweight and in turn the effective mass behind the ball to increase ball velocity. Tape is added to the sides of the frame to increase the stability by reducing the rotation due to off center impacts. Adding tape to the sides is also purported to increase the sweet spot size.

While there is extensive popular literature and colloquial knowledge regarding the effects of weighted tape on performance and the sweet spot there is limited academic literature. To fill this gap experimental modal analysis was used to determine the shock ratio or maximum force at impact for twenty-three locations across the racket string-bed, providing a proxy for the "sweet spot". This process was repeated for four composite rackets with five grams, 10g, and 20g added to the top, the sides, and both.

Adding weighted tape to the top of each racket shifted the sweet spot higher on the stringbed and increased the swingweight. The extent of upward movement was largely dependent on the initial mass distribution of the racket. Rackets with more mass distributed towards the head took more tape to move the sweet spot. The addition of weighted tape on the sides of the racket had little measurable effect on sweet spot size or location. Therefore, the main effect of adding weighted tape to the sides of the frame is the increase in twistweight or stability. The effect of adding weighted tape to both locations is still being explored; however, it is predicted that the sweet spot will remain in the same location while both swingweight and twistweight are increased.

Recommendations for tennis players regarding where and how much weighted tape to add to their frame are often blanket statements that do not account for the initial racket mass distribution. For instance, adding a few grams of tape to the top of a frame will not cause an appreciable shift in the sweet spot in a head-heavy racket; however, it will on a head-light frame. The results of this work can provide players with concrete and specific guidance on how to customize their frames for improved performance.

CONTROL EFFECTIVENESS: THE PROBABILITY OF AVAILABILITY

Megan Rush

MS Thesis Student, Aeronautics and Astronautics Engineering, rush39@purdue.edu

In the unforgiving environment of space, astronauts must be prepared to handle any disruption, foreseen or unforeseen, that threatens the safety and integrity of their habitat. From micrometeorite impacts to moonquakes, these disruptions can lead to catastrophic consequences if not addressed quickly. The challenge lies in ensuring that the necessary repair strategies are available when needed - without exceeding the limited cargo space of the spacecraft. This presentation focuses on the concept of the probability of availability, an important parameter that helps mission planners determine how much inventory, such as flexible patches, tape, or other tools and supplies, should be packed for long duration space missions. Using probability models, we explore how different probabilities of disruptions and multiple repair strategies can affect the availability of repair tools and supplies. We have developed a model that identifies the initial inventory of implementation strategies required to mitigate various hazards. Our findings reveal that balancing crew safety with inventory constraints is not straightforward. Packing too few repair materials, even with a low probability of disruptions, could lead to disastrous outcomes. Conversely, overpacking wastes cargo space. This research demonstrates how the probability of availability model allows mission planners to make data-driven decisions that ensure a crew's safety while taking cost and weight limits into consideration. Ultimately, the implications of this research extend beyond space exploration. The probability models for the inventory management of implementation strategies can be applied to other industries where inventory management is crucial. We emphasize how careful planning of the initial inventory, informed by probability models, could mean the difference between life and death in extreme environments.

ENHANCING ENERGY EFFICIENCY IN POLYSULFIDE REDOX FLOW BATTERIES BY USING NI, CU, AND CO AS CATALYSTS

Mahla Sarfaraz Khabbaz

PhD Student, Mechanical Engineering, msarfara@purdue.edu

Other Authors: Prof. Xiaoliang Wei (Purdue University)

Nowadays, as renewable energy sources like solar and wind become more widespread, efficient energy storage applications are essential to manage their intermittent nature. Redox flow batteries (RFBs) are promising candidates for storing renewable energy, enhancing grid stability, and reducing power outages according to their high capacity, safety, and scalability. Among various types of RFBs, vanadium redox flow batteries are widely used; however, they face challenges such as high costs and toxicity, creating an urgent need for alternatives. Polysulfide redox flow batteries (PRFBs) have gained attention as a potential replacement due to their low cost, abundant sulfur resources, and high theoretical capacity (1672 mAh). Despite these advantages, PRFBs face challenges like sluggish sulfur reaction kinetics on electrode surfaces and limited reversibility, reducing energy efficiency and power density. Additionally, sulfur can form species that cross the membrane and precipitate insulated sulfur on electrode surfaces, stopping electrochemical reactions and decreasing battery lifetime.

To address these limitations, this study investigates using graphite felts coated with various transition metal catalysts, including nickel (Ni), copper (Cu), and cobalt (Co), to accelerate sulfur reaction kinetics in PRFBs. Each catalyst improved the energy efficiency of the batteries by up to 60% in polysulfide/ferrocyanide flow batteries. Cobalt showed the highest efficiency, achieving around 70% at a current density of 20 mA cm-2.

Furthermore, this study compares electrode materials, carbon paper, graphite felt, and AvCarb1186 (HCB) to investigate the effect of surface area on sulfur reactions. Results indicate that HCB has a higher energy efficiency than other electrodes, highlighting its potential for future RFB applications to enhance efficiency and power density.

HOW DO SAFETY INTERVENTION TOOLS, SUCH AS EXOSKELETONS, IMPACT COGNITIVE AND PHYSICAL PERFORMANCE IN CONSTRUCTION?

Hyewon Seo

PhD Student, Civil Engineering, seo38@purdue.edu

Other Authors: Behzad Esmaeili, Sogand Hasanzadeh (Purdue University)

An exoskeleton is a wearable robotic device designed to enhance a user's movement through its durable structure and power-assisted springs. In construction, exoskeletons are particularly valuable, as workers face a high prevalence of work-related musculoskeletal disorders (WMSDs) due to the physical demands of manual, repetitive tasks. Previous studies have demonstrated their effectiveness in providing physical assistance; however, understanding the cognitive interaction between the exoskeleton and the user is essential, as the brain processes stimuli into coordinated body movement prior to full application. This cognitive fit ensures that the exoskeleton supports the wearer's mental processes, which is vital for construction workers who rely on sustained attention and cognitive control in dynamic, high-noise environments where physical tasks can increase mental load, impacting safety and well-being. The authors aim to investigate neuro-physical interactions with the exoskeleton in a post-fatigue stage and consider its kinematic design for future development across three stages. In the first study, 30 experienced construction workers were recruited to identify construction hazards before and after repetitive lifting of concrete blocks - one day using the exoskeleton and one day without - to test brain dynamics before and after fatigue. The findings from statistical analysis indicate a significant difference in brain activation during hazard identification with and without the exoskeleton after lifting, suggesting that reduced physical fatigue from the exoskeleton allowed for greater cognitive capacity during cognitive tasks (p-value = 0.019). The second study aims to test regulatory standards and enhance exoskeleton design by assessing the biomechanical interactions of workers with current exoskeleton designs using 3D motion capture and simulations to verify long-term biomechanical effects. The findings could reveal insights into optimizing exoskeleton design for better ergonomic support, improving safety, and informing regulatory standards in construction.

EXTREME SHOCK ABSORPTION USING MULTISTABLE MECHANICAL METAMATERIALS

Sneha Srikanth

PhD Student, Mechanical Engineering, srikan10@purdue.edu

Other Authors: Dr. Andres Arrieta (Purdue University)

Shock impulses from sudden impact in cases like car crashes and rocket launches can cause extensive structural damage and compromise safety of passengers. Protecting a target (such as payloads in spacecrafts) from impact loads requires a material that is both shock-absorbing (like foam), and stiff enough to provide structural support (like metals). This leads to the problem of a trade-off between structural stiffness and shock absorption capability. Additionally, impact loads contain a broad range of frequencies, and thus we need a damping mechanism that is frequency-independent. To address these two problems, we explore bistability, i.e., the ability of a system to switch between two stable states (like a switch, a hairclip, or a buckled beam).

In this study, we connect multiple bistable elements to form a chain, called a multistable metamaterial. A metamaterial is a structure consisting of repeated units designed to exhibit unique mechanical properties. We achieve extreme shock absorption using multistable metamaterial through two mechanisms: Energy locking and energy splitting.

Under impact, a bistable unit can snap between its stable states, and thereby cause subsequent units in the chain to snap. This domino-effect through which energy is transferred through between units in the chain is called a transition wave. By designing the metamaterial to stop the transition wave at a specific point in the chain, we lock energy from the impact load and protect the target. We provide a scaling law relating design parameters to the range of impact loads for optimal damping performance through energy locking mechanism.

Our simulations also reveal a second damping mechanism at high impact loads - namely energy splitting. In this mechanism, the high energy from the impact is split into multiple smaller "parcels". As a result, the response amplitude is always maintained below a threshold. This is contrary to conventional shock absorbers, where larger impact loads result in a proportionately larger response amplitude.

Both energy locking and energy splitting are frequency-independent damping mechanisms. Moreover, the mechanisms depend on the structural design, rather than the material used to manufacture the metamaterial. Thus, multistable metamaterials can serve as excellent shock absorbers, while providing structural support.

QUANTIFYING CARBON FOOTPRINT IN INDUSTRIAL HEAT TREATMENT PROCESSES THROUGH LIFE CYCLE ASSESSMENT

Lakshmi Srinivasan

PhD Student, Mechanical Engineering, lsriniv@purdue.edu

Other Authors: Dr. Fu Zhao (Purdue University)

Heat treatment processes are crucial in manufacturing for enhancing the hardness and durability of metal parts across various industries. However, these processes are highly energy-intensive due to the high temperatures required, extended cycle times, and substantial reliance on natural gas as the primary energy source for heating. The U.S. Department of Energy's recent 'Industrial Decarbonization Earthshot' targets an 85% reduction in emissions by 2035, urging the adoption of energy-efficient solutions for heat treatment furnaces and alternative energy sources, including electricity, low-carbon fuels, or carbon-free options. This goal underscores the need for accurate emissions estimation in current heat treatment practices.

This study investigates the carbon footprint associated with industrial heat treatment, particularly focusing on carburizing. Carburizing is a method that strengthens iron and steel surfaces by exposing them to a carbon-rich atmosphere in a furnace, increasing hardness and wear resistance. The process generates direct emissions (Scope 1) due to natural gas combustion used for heating and the carbon-enrichment of the furnace atmosphere. Limited quantities of natural gas are directly injected into the furnace to create this carbon-rich environment, and additional natural gas is processed in endothermic gas generators to produce a neutral hardening gas (CO/H2/N2), maintaining the controlled atmosphere required for surface hardening.

Indirect emissions (Scope 2) come from electricity use in the process, while broader supply chain activities, such as natural gas transport and material sourcing, contribute to indirect Scope 3 emissions. To evaluate the environmental impact, a Life Cycle Assessment (LCA) is applied across all emission scopes, focusing on gas carburizing cycles in batch furnaces where heating is provided by natural gas combustion in radiant tubes. This research develops a detailed life cycle inventory (LCI) for carburizing, documenting all inputs, outputs, and emissions at each stage.

Emissions are calculated by estimating total natural gas usage per cycle through radiation heat transfer analysis within the furnace and combustion in gas generators. This systematic framework for estimating carbon emissions in gas carburizing provides valuable insights to optimize processes, minimize emissions in heat treatment operations, and evaluate alternative process heating solutions, supporting broader industrial decarbonization efforts.

IT WAS BROKEN WHEN I CALLED YOU... IMPLICATIONS OF NO FAULT FOUND EVENTS IN AEROSPACE SYSTEMS AND A TOOL FOR DECISION MAKING

Zofia Stawiarska

MS Thesis Student, Aeronautics and Astronautics Engineering, zstawiar@purdue.edu

Other Authors: Dr. Karen Marais (Purdue University)

One of the most frustrating tasks maintenance technicians face is when a user has reported an error, but the technician cannot replicate the error. Such events are called "no fault found" events, or NFFs. NFFs occur for a range of reasons, including being unable to replicate the operating environment or degradation such as a loose connection that fails intermittently. In aviation, when an NFF occurs, the aircraft component is labelled as an NFF and returned to the parts pool, from where it can be installed into an aircraft, perhaps failing again. NFFs can be dangerous, as in the case of a Bombardier aircraft operated by the British airline Flybe in 2010. During landing, an input/output processor stopped working, completely removing the aircraft's speed and altitude information from the cockpit display. These parameters are essential to safe flight. The pilot restarted the sounded. Now realizing that they were about to crash into the ground, the co-pilot performed a sharp maneuver and managed to land the aircraft safely. The subsequent investigation found that such issues with the avionics input/output processor had been found multiple times before, but ground testing could not replicate the issues. This behavior, and the possible consequences of it, is signature of No Fault Found events.

Not all NFFs have such life-threatening outcomes, but all NFFs incur downtime and require technician resources. When is it worth it to invest in attempting to find the root cause? For stakeholders, their desire will be to ensure operations of any technology go as smoothly as possible since revenue is nominally only made when the technology is online. However, the decision is not simple because there is a fine balance between choosing to continually incur smaller maintenance costs (rebooting) versus paying for an expensive root cause analysis (eliminating) when faced with many uncertainties.

By borrowing from similar dilemmas in economics, we calculate the Net Present Value of both the decision to reboot and the decision to eliminate. Our proposed decision scheme considers the uncertainties around the No Fault Found problem and identifies, at each point in time, which decision is more likely to lead to a higher NPV. Such rational and analytically supported decisions can help reduce unnecessary costs incurred by aerospace system operators.

INVESTIGATING EMBEDDED SENSING IN METAMATERIALS FOR THERMAL MANAGEMENT APPLICATIONS

Amanda Stone

PhD Student, Mechanical Engineering, stone178@purdue.edu

Other Authors: Dr. Justin Weibel, Dr. Davide Ziviani (Purdue University)

In the field of thermal management solutions, pumped two-phase cooling can significantly improve heat dissipation capabilities, but can also cause maldistribution problems and yield to fluid flow instabilities. In-situ and real-time flow monitoring and detection of these anomalies is challenging and not feasible with traditional sensing methods, leading to a lack of knowledge of the true behavior of these occurrences. To this end, functional metamaterials can be employed to react to different thermal and mechanical stimuli to provide signals to enable control capabilities. Metamaterials can be made of a variety of materials and configurations, including bistable and multistable structures, and these structures can react to external stimuli and record the information based on interactions. When connected in a network, these metamaterials act as a health monitoring system that is low-cost and low-power.

Our research is exploring the design space and functionalities of memory-enabled metamaterials. Specifically, this presentation will focus on analyzing the memory capabilities of 3D-printed polymer-based bistable beams embedded with conductive polymer when exposed to various temperature fields. Using the mismatch of coefficient of thermal expansion, snap-through between stable states will be achieved and the inverse design problem will be used to design these structures to change in shape at desired temperatures. Then, the change in strain field on the conductive polymer will be used to store the amount of times that snap-through occurs within the structure. The goal is to ultimately create a system of bistable passively actuating sensors that can respond to temperature and pressure inputs and create a more robust and resilient thermal management system.

ENHANCED PERFORMANCE AND THERMAL STABILITY IN LITHIUM-ION BATTERIES THROUGH PHOSPHATE-INTEGRATED ELECTROLYTE

Annie Sun

PhD Student, Chemical Engineering, sun1064@purdue.edu

Other Authors: Vilas Pol (Purdue University)

The safety-related performance of LIBs still remains as a major issue even after more than three decades of commercialization. When typical electrolytes composed of flammable organic liquid decompose exothermically during thermal runaway, they pose serious risk to human health and infrastructure. Conventional lithium-ion batteries (LIBs) are energy storage devices subject to highly dynamic electrochemical reaction phenomena. As scale and pervasiveness of this technology increases, recent efforts in academia and industry alike have endeavored to replace volatile and flammable conventional liquid electrolytes with intrinsically nonflammable liquid electrolytes. Simultaneously, solid-state electrolytes have been touted as an avenue to not only wholly replace the liquid component of the cell to improve safety, but also as a higher-energy density next-generation battery electrolyte.

Of particular interest is the radical recombination of phosphorus compounds to nullify hydrocarbon oxidation and subsequent heat production. However, these strategies are often examined as materials-level design choices for improving "built-in" safety and not as changes to a dynamic and multiscale electrochemical system. This work focuses on combining electrochemical studies with spectroscopic techniques and thermal analysis to elucidate the dependency of the intrinsic safety of a battery system upon the interfacial degradation pathways of the electrode-electrolyte configuration, which act as a direct complement to the thermal behavior which may result in thermal runaway. This study encompasses the behavior of a phosphate integrated semisolid electrolyte system with lithium metal anodes as well as carbon-based anodes. Through detailed thermal analyses of selected electrolyte chemistries and characterization of the interfacial composition, this work subsequently questions the concept of intrinsic flammability that does not account for downstream heat generation from interfacial reactions.

A FRAMEWORK FOR FLIGHT RESOURCE OPTIMIZATION: SAFETY, TECHNOLOGY, WELL-BEING, AND INFRASTRUCTURE FOR NORTHERN GEOGRAPHY

Suzanne Swaine

PhD Student, Aeronautics and Astronautics Engineering, swaines@purdue.edu

Other Authors: Dr William A. Crossley

Many communities in the Canadian North rely on small aircraft for the transportation of people and crucial supplies (food, fuel, medicine, etc.). Unfortunately, these aircraft face significant safety risks and operate with slim profit margins, leaving minimal funding for infrastructure or equipment. Many remote northern communities struggle to build and maintain adequate infrastructure due to the high costs and logistical difficulties of transporting materials in a timely manner. Broader community well-being and quality of living are also impacted by community accessibility. Emerging technologies, including those under the Advanced Air Mobility (AAM) umbrella, could substantially and positively impact these communities. This is a complex socio-technical system-of-systems (SoS) problem, often called a "wicked problem", that requires consideration of metrics addressing both the social and technical aspects of aviation-based support.

A northern aviation framework and MATLAB-based computational model called FROSTWING (Flight Resource Optimization: Safety, Technology, Well-being, and Infrastructure for Northern Geography) is in development to address this wicked problem. FROSTWING uses a mixed-integer linear programming problem formulation to solve a multi-commodity network flow problem and model the delivery of passengers and supplies to northern communities by air. This framework enables the exploration and understanding of how conventional and emerging technologies can address safety and operational challenges that exist in remote northern regions. To the author's knowledge, no similar northern community aviation model currently exists. The use of community well-being metrics further sets this model apart from most aviation models as few, if any, published aircraft systems analyses focus on community-centric metrics. In the future, the FROSTWING framework could inform decisions on which technology investments could result in the highest value impact for under-served northern communities in parallel with improved aircraft operations factors.

This presentation will describe the Northern communities and their air taxi operations as well as emerging technologies that could disrupt the status quo, the modeling methods required to build the framework, and the metrics that will be used in the optimization model. Preliminary results from the proof-of-concept model will show the relationships between community well-being, aircraft safety, and operator profitability.

A DIFFERENTIAL GAME BASED APPROACH FOR MANAGING OPIOID CRISIS

Monika Tomar

PhD Student, Industrial Engineering, tomarm@purdue.edu

Other Authors: Prof. Mario Ventresca

As the opioid epidemic in the United States continues to evolve, the challenges faced by policymakers in managing the epidemic are multi-faceted. The recent increase in addiction as well as overdose deaths due to synthetic opioids, despite increased regulations on prescription practices, warrant a more long-term forward-looking approach which can incorporate the responses of the other stakeholders while determining the strategies to tackle the epidemic. In this work, we model the interactions between the multiple stakeholders, as a three player non-cooperative differential game between the government, health-care providers and the illicit drug mafia. The state dynamics for our differential game approach is built upon a recent data-driven epidemiological model on opioid crisis in Tennessee, extending it to include the effects of the controls or strategies of the three players. The government is modeled to possess to two separate controls to capture regulation and harm reduction policies. The healthcare providers and illicit drug mafia are provided with one control each to optimally influence the supply of opioids in the system.

We first compute the open loop Nash Equilibrium using the maximum principle and analyse the equilibrium control strategies of the three players. Similarly, we calculate and analyze the Feedback Nash Equilibrium. For both equilibria, the optimal state trajectory of the system is compared with that of the uncontrolled system and insights are drawn from comparison of the evolution of states under different equilibrium strategies. Finally, we use these insights to draw strategic policy recommendations to aid management of this public health crisis.

SUSTAINABILITY: PUSHING PHOTOVOLTAICS FORWARD : THE PROMISE AND CHALLENGES OF CHALCOGENIDE PEROVSKITES

Kiruba Catherine Vincent

PhD Student, Chemical Engineering, vincen24@purdue.edu

Other Authors: Shubhanshu Agarwal, Rakesh Agrawal (Purdue University)

According to the international energy agency (IEA), solar is the new king of the global energy market, growing at an unprecedented 44% every year. For the first time in 2022, the installed PV capacity surpassed all other forms of energy. Though the current photovoltaic market is dominated by silicon technology, the search for other novel materials is still on the rise. Researchers are looking for materials that can achieve higher efficiency and provide unique capabilities such as flexibility and aesthetics, while being nontoxic and environmentally friendly.

One such material that has garnered the research community's attention is chalcogenide perovskites. Chalcogenide perovskites are materials with the chemical formula ABX3 and a perovskite crystal structure. A well-known example is BaZrS3. Chalcogenide Perovskites are known for their stability and more importantly abundance in nature, and non-toxicity, which are essential for the next generation of photovoltaic materials. They have also shown promising optoelectronic properties. For instance, this polycrystalline material has the highest reported absorption coefficient (~10^5 cm-1) which can translate to ultra-thin flexible solar cells with absorber thickness of just around 200nm. Despite such potential, the rudimentary synthesis methodologies of these materials have hindered commercialization. Traditional synthesis methodologies have been limited to high temperatures of 800 to 1200°C and extending periods from hours to days.

In this work, we present a novel strategy utilizing amine thiol chemistry and organometallic precursors to develop a fully solution processed route for BaMS3 (M=Zr, Hf, Ti) chalcogenide perovskites. We successfully dissolved Ba and Zr precursors in a ink, blade coated and sulfurized to synthesize BaZrS3 at remarkable 575°C and 2hr in contrast to the higher temperatures reported traditionally. This method was successfully extended to BaHfS3 and BaTiS3 perovskites. Comprehensive material, morphological, and optoelectronic characterizations conducted on these films, provide valuable insights for future device fabrication of chalcogenide perovskites.

THE FUTURE OF CEMENTITIOUS MATERIALS: UTILIZING NATURAL POZZOLANS FOR SUSTAINABLE AND RESILIENT INFRASTRUCTURE

Bibigul Zhaksybay

MS Thesis Student, Civil Engineering, bzhaksyb@purdue.edu

Other Authors: Dr. Raikhan Tokpatayeva, Dr. Jan Olek (Purdue University)

Climate change and air pollution are critical challenges threatening the sustainability of human civilization. As one of the most widely used construction materials, concrete is responsible for approximately 8% of global CO2 emissions, exacerbating environmental impact of construction. A promising approach to mitigate this impact is the utilization of natural pozzolans (NPs), such as volcanic ashes and calcined clays, as alternatives to conventional cement. These materials are abundant and currently underutilized, however, they can contribute to a circular economy by reducing waste. Previous studies have demonstrated their ability to improve long-term strength and durability in controlled laboratory environments, but their performance across varying conditions remains unexplored.

This study investigates the hydration kinetics of volcanic ash and calcined clays under extreme temperatures using isothermal calorimetry and thermogravimetric analysis. Understanding hydration kinetics is crucial, as it governs the development of strength and durability in cementitious materials, particularly under varying environmental conditions. Results indicate that, even in harsh conditions, these NPs exhibit performance equal to or better than traditional cement mixtures. Their use can significantly reduce carbon emissions, enhance infrastructure resilience, and lower costs of construction materials - particularly in regions where these materials are locally sourced. Additionally, incorporating NPs into concrete contributes to sustainable construction practices, while also ensuring critical infrastructure that can withstand future environmental stressors. This research highlights the potential for NPs to transform the concrete industry and reduce its environmental footprint of concrete production, paving the way for further innovations in green building materials.