



ARL-SR-0388 • DEC 2017



# 2017 ARL Summer Student Program, Volume II: Compendium of Abstracts

Compiled by Rose Pesce-Rodriguez

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# **2017 ARL Summer Student Program, Volume II: Compendium of Abstracts**

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| <b>14. ABSTRACT</b><br>The US Army Research Laboratory (ARL) Summer Student Symposium is an ARL Director’s Award Program for all the students participating in various summer scholarship and contract activities across ARL. The goal of the program is to recognize and publicize exceptional achievements made by students and their mentors in support of Army science.<br><br>All undergraduate and graduate interns are encouraged to submit an abstract summarizing their accomplishments and to participate in the symposium. Presentations given by all directorate finalists are published in Volume I of the Proceedings (“Symposium Presentations”; ARL-SR-0387), while abstracts are collected in Volume II (“Compendium of Abstracts”; ARL-SR-0388). |                                    |   |   |  |  |
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## **Contents**

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|                            |            |
|----------------------------|------------|
| <b>Director's Foreword</b> | <b>v</b>   |
| <b>Introduction</b>        | <b>1</b>   |
| <b>Distribution List</b>   | <b>163</b> |

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## Director's Foreword

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The US Army Research Laboratory (ARL) mission is to “provide innovative science, technology, and analyses to enable full spectrum operations.” As the Army’s corporate laboratory, we provide the technological underpinnings critical to providing capabilities required by our current and future Soldiers.

Our nation is projected to experience a shortage of scientists and engineers. ARL recognizes the criticality of intellectual capital in generating capabilities for the Army. As the Army’s corporate laboratory, addressing the projected shortfall is a key responsibility for us. We have, therefore, identified the nation’s next generation of scientists and engineers as a key community of interest and have generated a robust educational outreach program to strengthen and support them. We have achieved many successes with this community. We believe that the breadth and depth of our outreach programs will have a significant positive effect on the participants, facilitating their journey toward becoming this Nation’s next generation of scientists and engineers.

A fundamental component of our outreach program is to provide students with summer research experiences. During the summer of 2017, ARL hosted more than 170 undergraduate and graduate students. Many of these students chose to participate in directorate-level competitions with the goal of being selected as a directorate finalist and competing at the ARL-wide Summer Student Symposium; others participated in the symposium by presenting posters. I applaud symposium participants and all summer interns who contributed to the ARL mission.

We are very pleased to have hosted this outstanding group of students for the summer. It is our hope that they will continue their pursuit of technical degrees and will someday assist us in providing critical technologies for our Soldiers.

Philip Perconti  
Director

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## Introduction

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The ARL Summer Student Research Symposium is an ARL Director's Award Program for students participating in various summer internship opportunities across ARL. The goal of the program is to recognize and publicize exceptional achievements made by the students and their mentors in the support of Army science.

All undergraduate and graduate interns are eligible to compete for a finalist position and give an oral presentation at the symposium. All students, including high schoolers in the Science and Engineering Apprentice Program (SEAP), are encouraged to present posters at the symposium and submit abstracts summarizing their accomplishments.

Oral presentations at the symposium are given by finalists selected based on directorate-level competitions. Each directorate can send one graduate student and one undergraduate finalist to the symposium. The Sensors and Electron Devices Directorate and Weapons and Materials Research Directorate have a relatively large number of interns and can each send 2 undergrad finalists.

This year's symposium was held at the Mallette Center at Aberdeen Proving Ground, Maryland, on Thursday, 10 August 2017. Oral presentations were judged by a panel of senior ARL scientists (including ARL Fellows, and Chief Scientists). Students with the top three presentations ("Corporate Medalists") were awarded the ARL Summer Student Research Gold (\$500), Silver (\$300), and Bronze (\$200) awards in the undergraduate and graduate student levels.

This volume of the Summer Student Symposium Proceedings contains abstracts submitted by most of our student interns. Volume I (ARL-SR-0387) includes the presentations for all finalists, as well as the agenda and photos from the awards ceremony.

## **Augmentation and Analysis of Threat Profiles for Survivability Suite Engineering Simulation (SSES)**

Abrahamian, Anthony

The objective of this research was to investigate if an increase of an adversary's threat profiles leads to higher fidelity of threat classification and identification. It was hypothesized that if the threat database was expanded and additional exceptional characteristics were leveraged it would be possible to differentiate between threats more precisely. Based on Assistant Secretary of the Army (Acquisition, Logistics and Technology) and Missile and Space Intelligence Center weapon system guidebooks, a total of 95 threats including rocket-propelled grenades (RPGs), anti-tank guided missiles, and reduced residual radiation (RRR) weapons were populated into an Excel spreadsheet with a number of key characteristics. Subsequently, an Access database was generated with this information, which could be retrieved using queries. An analysis was then performed to identify unique characteristics from the data set. It was found that the range characteristic may be used as a discriminant since the largest ranges of the RPGs and the RRRs were all less than 4,750 m, which could classify up to 55% of the threat database. With Bayes' theorem, the hypothesis can be validated that the probability of obtaining the discriminant will be higher with the augmentation of the threat database, increasing the likelihood of knowing an incoming threat.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Michael Chen.

### **Student Bio**

Anthony Abrahamian is a high school sophomore at Musselman High School in West Virginia. His past research experience includes participating in national mathematics competitions (Math Counts, American Math Contests, and Kangaroo Math), ranking in the 70–90<sup>th</sup> percentile nationally. He was a Math Kangaroo Top Scorer in the state of West Virginia (2017); a participant in NASA-sponsored robotics tournaments (2015–2017); and state finalist in a NASA-sponsored robotics tournament (2017). He is also the Sophomore Class President for the Graduating Class of 2019, a student council member (2016–2017), soccer team captain (2017), West Virginia Olympic Development Soccer Team Starter (2015–2017), and Travel Soccer Club Team Captain (2014-2017). Anthony Abrahamian plans to major in engineering and work toward a PhD.

## **CLIVE v2.0**

Abdali, Syed

Electroencephalography (EEG) is a neuroimaging method that allows the measurement of electrical activity created by the firing of neurons using electrodes placed on the scalp. The measurements are recorded at the micro-volt level, and thus are immensely susceptible to noise and muscle artifacts. The Customizable Lighting Interface for Visualization of EEG signals (CLIVE) was designed as a translucent head implanted with an array of LEDs with the purpose of assisting a general, non-expert audience in visualizing and interpreting brain signals measured with an EEG headset. Due to EEG's stochastic properties, simply displaying raw EEG without extracting features is not meaningful to a non-technical audience, such as in STEM situations. This work focused on extracting features that allow the audience to detect whether the subject's eyes are opened or closed through the means of alpha and beta frequency bands. Parallel processing through Python avoided data loss through simultaneous data collection and heavy computation. The full system consists of an EEG headset, laptop for processing, and a microprocessor to communicate a mapping between the feature extractor and the CLIVE visualization tool.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Dave Hairston and Dr Justin Brooks for their guidance through the project, thus allowing the project to progress steadily. I would also like to acknowledge Dr Courtney Bradford for her presentation and poster critiques, ensuring that my information is being communicated efficiently.

### **Student Bio**

Syed Abdali recently graduated from University of Maryland, Baltimore County, with a degree in computer engineering and a minor in mathematics. He decided to focus his minor on coursework that helps visualize the real world, such as partial differential equations and mathematical modeling. Syed Abdali also decided to complete both tracks offered in computer engineering—the electronics track and the communications track—to gain experience in both the equipment and the concepts needed for research in the future. Previous work at the US Army Research Laboratory included using a microcontroller to create a mapping between EEG headsets and an LED array. Currently, Syed Abdali is applying digital signal processing concepts to accurately represent EEG signals in a lighting interface. Syed Abdali plans on getting a master's degree and possibly a PhD in electrical engineering.

## **Fabrication and Characterization of Silicon Nanoparticles for Energetic Applications**

Adams, Sarah K

The physical and combustive properties of silicon nanoparticles (SiNP) fabricated from porous silicon (PSi) films are explored for their energetic applications. PSi film has been studied extensively as an energetic material, demonstrating excellent combustion performance, with reported flame speeds in excess of 3 km/s. The impressive combustion characteristics of PSi are attributed to its nanoscale pores, large surface area ( $>800 \text{ m}^2/\text{g}$ ), and hydrogen-terminated surface. However, the applications of the film have been limited by its on-chip nature and the synthesis process, which uses a galvanic etch in hydrofluoric acid. In this work, SiNP are fabricated from PSi films by a simple and inexpensive sonication process. In the first in-depth study of high-surface area particles created from PSi for energetic materials, BET porosimetry, bomb calorimetry, TEM, DSC, FTIR, EDS, and high-speed imaging are used to analyze the physical and energetic qualities of the nanoparticles. The sonication process has been tuned to retain the hydrogen-terminated surface of the silicon, which is critical for a high-performing combustion reaction. Open-channel combustion experiments yield flame speed in excess of 2.5 km/s, and bomb calorimetry produces heats of combustion in the range of 7.5 kJ/g. TEM/STEM imaging reveals particle diameters of less than 5 nm. These energetic nanoparticles create several new avenues for energetic applications of silicon, including additive manufacturing and fuel additives.

## **Wireless Networks**

Addison, Gary

Wireless local area networks (LANs) consist of wireless technology and Institute of Electrical and Electronics Engineers standards that provide convenient accessibility and the ability to roam between network nodes while maintaining a connection. Wireless networks are computer networks that allow Internet access over frequencies emitted from a wireless access point. This key feature can be a weakness as well as a strength. Wireless frequencies can be blocked or weakened by various factors such as other frequencies, weather, and objects in their path. They can have low latency and responsiveness in comparison to a wired connection. Lightweight wireless networks use devices such as a wireless access point and wireless LAN controller for configuration, software, and layer 2 management. Most often Dynamic Host Configuration Protocol (DHCP) addressing can be used to assign client and access point IP information. DHCP automatically assigns IP addresses to devices that pass the security credentials to connect to the network. Wired is generally faster and more secure; however, wireless networks are continuously evolving to meet the demand for high availability as well as secure and convenient networks.

## **Scalable Database Design of End Game Model with Decoupled Countermeasure and Threat Information**

Akole, Decetria

The objective of the research was to investigate if the end-game model (EGM) of an active protective system (APS) is more adaptable to proliferation of threats when a relational database (RDB) is implemented. At present, the EGM data set is handled through Excel spreadsheets where countermeasure (CM) and threat information is coupled in the same file. Consequently, one emerging threat of interest will result in 3 separate Excel files when Trophy, Iron Fist, and Iron Curtain (IC) APSs are considered. In the research, the author developed a consolidated entity relationship diagram for available CIAPS, SRCM and IC warheads along with certain threat information. Accordingly, a relational schemas leading to the creation of an Access database with enforced referential integrity was implemented. Subsequently, the EGM data was populated in accordance with the design of table hierarchy, and later retrieved with the execution of SQL queries that were embedded in C++ code as demonstrated in the investigation. The author validated the hypothesis that one additional threat of concern merely requires an extra record in the Threat table, and concluded that the RDB is scalable to rapidly evolving threats and evolutionary CM technologies.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Michael Chen.

### **Student Bio**

Decetria Akole is currently working toward his master's degree in computer science at Alabama A&M University. He plans to complete his master's degree in summer 2018. After graduating, he plans to work full time for the Department of Defense. Decetria Akole completed his undergraduate studies at Faulkner University, where he earned a bachelor's degree in management of human resources. His past research experience includes comparative study sorting algorithms, an applied research paper on teamwork and communication in the workplace, and Cybersecurity Fundamentals Projects 1 and 2. He was also the 2nd Place Winner in the National Society of Black Engineers Fall 2016 Region III (Hackathon) in Atlanta, Georgia. His future plans include using his experiences and education to give back to the community by opening an educational center in an urban community working with at-risk youth, focusing on spiritual and individual growth, life skills, and computer science.

## **The Effects of Imperceptible Vibratory Stimulation on the Spinal Reflex**

Alander, Maxwell

Imperceptible vibratory noise stimulation (STIM) has shown performance benefits such as increased sensorimotor control, stability, and decreased tremor. The neurological, physiological, or mechanical mechanism by which STIM enhances performance is unknown. The goal of this study is to determine if STIM modulates the spinal motor reflex, a key pathway known to enhance motor performance. Twelve male subjects participated in this study. A Hoffman reflex (H-reflex) recruitment curve was gathered for each subject. Ten H-reflexes were then collected at a standardized intensity with subjects receiving 3 seconds of STIM or sham prior to each H-reflex. Data were assessed with a generalized estimating equation, clustering for multiple observations. STIM produced a 1.73% increase in H-reflex amplitude ( $p = 0.0016$ ). Our results show that STIM mechanisms are modulated, in part, by the spinal reflex. Increases in the spinal reflex are correlated with increases in rate of force development and reduced reaction times. Determining which motor centers mediate STIM is an important step toward understanding the optimal parameters for application of this technology. Future work should aim to understand the interaction of STIM and other motor centers.

### **Acknowledgments**

I would like to thank Dr Matthew Tenan and Dr Courtney Haynes for the guidance, expertise, and mentorship.

### **Student Bio**

Maxwell WH Alander made the trip from Missouri to Maryland this summer after graduating with his Master of Athletic Training degree from Saint Louis University. The year prior he received his BS in exercise science from the same institution. Originally a mechanical engineering major, his passion for physiology and performance led him to change his focus. Throughout college, he participated in Division I athletics and Greek life, and served as an assistant to strength and conditioning coaches in the athletics department. His future plans are to explore opportunities in research and sport performance that would allow him to continue contributing to the scientific community in a military setting.

## **The Examination of Flight Time and Endurance with Maximum Payloads on 3 Open-Sourced Unmanned Aerial Vehicles (UAVs)**

Alexandroff, Shemaya; Conroy, Joe; Nothwang, William; Girma, Yonatan

The US Army Research Laboratory has been developing a set of readily modifiable aerial testbeds based on open-source hardware and software. These testbeds will serve a multitude of experimental integrations going forward. One purpose of this project is to continue the modification of commercial-off-the-shelf (COTS) quadrotor hardware to accommodate open-source sensing and computing. Instead of using DJI's A2 flight control, Hex's PixHawk 2.1 autopilot-on-module will be integrated and deployed for stabilization, altitude hold, and position lock. The Pixhawk 2.1 has additional features with numerous configuration options, which allows for a fine-tuned customization based on the aerial platform. Different computer motorization programs open access to many customization options that can be supplied to the autopilot. Benefits of continued work include platforms with the latest COTS hardware and platforms with additional processing power for testing. The information gathered from test flights will be extremely useful for equipping quadrotors with advanced capabilities, such as running deep learning networks.

A second purpose of this project is to quantify the tradeoff between flight endurance and payload for 3 different vehicle classes. This will facilitate choosing a specific vehicle and battery for a generic sensor integration setup and help a user to predict flight time of the vehicle.



## **Robust Adaptive Control of Unmanned Aerial Systems**

Anderson, Blake

The goal of this summer's internship at the US Army Research Laboratory was to implement a robust adaptive control technique on a quadrotor vehicle. First, an adaptive sliding mode controller was implemented and tested in MATLAB. Using a nonlinear control technique allows for control gains that are not fixed as well as constant adjustment for uncertainties in the system such as changing masses and inertias. Hardware in the loop simulations performed ran all the flight code successfully and used artificially injected IMU data, which allowed for direct application of the same setup to real flight. On first experimental flight the vehicle was stable, but the controller still had to be fine-tuned to reach smooth flight and accurate holding of position. Position hold was shown to be accurate to within an average error of 5 cm in the x, y, and z axes. Trajectory following was also successful with the vehicle following a 2-m-wide circle in the x-y plane with an average error of less than 10 cm all while holding constant altitude with a z error of less than 2 cm. The next steps will be to test disturbance rejection as well as retuning the simulation to more closely match the experimental flights.

### **Acknowledgments**

I would like to give a special thank you to my mentors for the summer, Harris Edge and Jim Dotterweich. I am very grateful for the wealth of knowledge and expertise that they have been willing to share with me, and this summer has made me both a better student and researcher.

### **Student Bio**

Blake Anderson is currently a senior majoring in engineering physics at the University of Oklahoma (OU). He began doing research in May of 2016 at the Advanced Control Systems Lab located on OU's North Campus site. His research group focuses on nonlinear control of multirotor vehicles and creating applications for both simulation and actual flight experiments.

After graduation, Blake Anderson plans to pursue a master's degree in aerospace engineering.

## **Autonomous Phase-locking or Arbitrary Waveform Generators**

Anderson, Konrad

The US Army Research Laboratory's electric- and magnetic-field sensing team uses a magnetic-field (B-field) "Cage" to characterize and test B-field sensors. The 10-coil system requires 10 phase-locked signals to generate uniform magnetic fields from DC to 1 MegaHertz, which is very time and labor intensive when done manually. To expedite and standardize this phase-locking process, a LabVIEW-based system that autonomously phase locks 2N channels from N arbitrary waveform generators together has been developed. This system was first developed for the 2 channels contained within 1 function generator to determine the characteristics and the ability of 1 generator to phase-lock its channels together. Next, 2 function generators were connected through a common reference clock signal and 4 separate techniques for phase syncing were investigated. From this investigation, it was determined that a feedback system was needed in order to offset the natural phase drift that occurs when phase syncing 2 or more generators together. This feedback system uses the characteristic phase drift of each function generator to start waveforms at different initial phases and thereby lock them closer together. This presentation/paper details the background, methods, and results for the autonomous phase-locking algorithms.

### **Acknowledgments**

I would like to acknowledge Sean Heintzelman (mentor).

## **Low Latency Random Graph Topology for HPC Cluster**

Arvizu-Law, Natasha

The fat-tree networking cluster has been the most widely used topology in high performance computing (HPC) and data centers. However, recently several new network topologies were proposed for low latency and loop-free communications that can offer better performance for HPC workloads. One such new topology is based on random graph functions and it is called the jellyfish. This new topology scheme has been proven to offer a greater bisection bandwidth, better throughput, easy incremental expansion, and low latency. A topology that exhibits outstanding properties and an effective routing scheme that fully deploys its resources is essential to meeting some of the design goals of network architectures and will certainly enhance the computational efficiency of the HPC systems. In this work we describe and evaluate the differences between the commonly used fat-tree topology and the new jellyfish topology for building efficient HPC clusters using the Mininet network simulator.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Venkateswara Dasari.

### **Student Bio**

Natasha Arvizu-Law is a senior undergrad student attending Fayetteville State University, majoring in computer science. Following graduation she plans to pursue her MS in computer science.

## **The Effect of Photoreactive Benzophenone on Mechanical Properties of 3-D Printable ABS**

Bank, Sarah

The effects of adding photoreactive benzophenone (BP) to acrylonitrile butadiene styrene (ABS) polymer were investigated for application in fused deposition modeling (FDM) 3-D printing. It was expected UV light would affect the mechanical properties of the material, like rigidity and yield stress. This material could be treated during printing to allow spatial control of these properties. Thin films of neat ABS and ABS with embedded BP were fabricated by solvent casting. Samples were treated with a UV light and tensile tested. Samples with embedded BP tended to be less ductile than neat untreated polymer. Neat, UV-treated samples showed a decrease in rigidity and yield stress compared to neat, untreated samples. 1 wt% BP, untreated samples decreased in elastic modulus compared to neat untreated samples. 1 wt% BP, UV-treated samples displayed an increase in elastic modulus and yield stress compared to the 1 wt% BP, untreated samples. It is believed that this increase in rigidity occurs due to the interaction of BP with the butadiene monomer, which inhibits butadiene's elastomeric behavior. Future goals include determining what BP concentration and UV treatments optimize the increase in rigidity and using this material to develop more advanced nanocomposites.

### **Acknowledgments**

I wish to thank Dr Frank Gardea and Dr Bryan Glaz for their mentorship throughout this project.

### **Student Bio**

Sarah Bank is an undergraduate student studying mechanical engineering at the University of Maryland, College Park. She will start her junior year in the spring of 2018, after a co-op with Textron Unmanned Systems in the fall. She has experience working with 3-D printers at Terrapin Works, her on-campus job. Sarah Bank plans to enter the workforce after graduating with her bachelor's degree.

## **Characterizing the Oxide Particles in FeNiZr after Mechanical Testing**

Barton, Dallin

Oxide-dispersed-strengthened (ODS) ferrous alloys are well-known in the nuclear industry due to their ability to resist radiation damage because of the high number density of nanometer-scale  $Y_2O_3$  particles. These  $Y_2O_3$  particles provide tremendous strength to the ODS alloys, which peaked the Army's interest in the materials for structural applications. US Army Research Laboratory (ARL) researchers have developed their own ODS alloy, FeNiZr, by mechanical alloying elemental powders of Fe, Ni, and Zr through ball milling. This processing technique generates grain sizes less than 100 nm, increasing the alloy's strength via the Hall-Petch relationship. Additionally, ZrO-based particles are generated rather than the  $Y_2O_3$  particles seen in previous alloy systems. In this study, ARL's new local electrode atom probe (LEAP) 5000-XR system was used because of its high mass-to-charge resolution to determine the true chemistry of these nanometer-scale ZrO-based particles since no other characterization technique is capable of this task. Multiple samples were run in the LEAP 5000-XR generating large data sets (hundreds of millions of ions composing hundreds of cubic nanometers of material) for analyzing the evolution of the ZrO particles' chemistry and number density after mechanically testing. These results give insight to the material's response in possible high rate applications.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Kris Darling and Dr Chad Hornbuckle for the opportunity to interact and work onsite at ARL on this project.

## **Medium-Caliber Armament System Lethality Enhancement using VBS3**

Begaye, Nicholas; Tapaha, Hansen

Improved lethality and accuracy from airburst munitions would require accurate range estimates and optimal firing patterns for different types of scenarios. These scenarios are much more cost efficient when created in a simulation environment. This is helpful in studying another problem as well. Depth perception while down range is very inaccurate; using available tools would also be time consuming. When incorporating Virtual Battle Space 3 (VBS3), data is collected and helps in refining the process of maximum lethality for specific weapons type.

## **Biohybrid Fuel Cells for Power Generation Directly from Fermentations**

Benyamin, Marcus S; Jahnke, Justin P; LeFors, Hannah M; Mackie, David M

Using unrefined biofuels with fuel cells (FCs) can potentially reduce the costs of purification and transport for ethanol and other biofuels, especially at smaller scales. However, long-term operation requires strictly preventing the fermentation and FC from harming each other. Here we discuss various approaches to closely coupling FCs and fermentations (creating a “biohybrid” fuel cell), with a particular focus on extracting ethanol from yeast fermentation with a carrier gas (N<sub>2</sub>). This protects the FC anode from the catalyst poisons in the fermentation (which are non-volatile), and also protects the yeast from harmful FC products (notably acetic acid) and from build-up of ethanol. Reducing the build-up of ethanol is particularly beneficial when using non-yeast-based fermentations or operating yeast in consortia with other organisms to break down a wider range of substrates. Since vapor-fed direct ethanol FCs at ambient conditions have never been systematically characterized (in contrast to vapor-fed direct methanol FCs), we first show that over a wide range of ethanol partial pressures (2–8 mmHg) power densities are comparable to those for liquid-fed direct ethanol FCs at the same temperature, with power densities greater than 2 mW/cm<sup>2</sup> obtained. We then demonstrate the continuous operation of a vapor-fed biohybrid FC with fermentation for 5 months, with no indication of performance degradation due to poisoning (of either the FC or the fermentation).

This research was presented by the student (first author) at the August 2017 meeting of the American Chemical Society in Washington, DC.

## **Fundamental Limits of Detecting Subpixel Motion in Video Cameras**

Benyamin, Minas

The objective of this work is to determine the fundamental limits of detecting subpixel motion of objects using a video camera. For this project, we recorded the known oscillation of a ridge rod and detected subpixel shifts in consecutive frames. Using a bank of adaptive match filters, we first identified the edges of the rod. Next, using polynomial interpolation near the location of the rod's edges, we estimated the location of the highest gradient and the position of the rod. From the location of the rod, we computed PDFs of the change in pixel values along the edge of an oscillating rod and a static rod. Then, we randomly sampled the PDFs to generate receiver operating curves to evaluate detection statistics for different levels of subpixel motion.

### **Acknowledgments**

I would like to acknowledge the mentorship of Geoffrey Goldman, Sensors and Electron Devices Directorate.



## **Optimizing ezAFM Scanning Processes**

Bisoi, Satwik

The US Army Research Laboratory (ARL) aims to advance technology in the area of land power. Of the many advancements being made, one of the keys is the sensor development for Army applications. In order to understand the quality of device fabrication process, surface profiling of the semiconductor materials with the Atomic Force Microscope (AFM) is essential. The AFM allows for a high-quality scan on a material on the nanoscale. It is a key in device processing, where an AFM is used to scan nano-devices and surface profiling. The ezAFM by NanoMagnetics Instruments is a much more compact AFM that proves to have the same capability as other AFMs. We manipulated the various parameters on the ezAFM, mainly the proportional-integral-derivative (PID) variables, until we were able to display an image that was nearly optimized in quality. We conclude that depending on sample characteristics, we have to use correct PID numbers in AFM setting for better pictures.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Naresh Das and Dr Eric Decuir in ARL's Sensors and Electron Devices Directorate.

## **Physical Manifestation of Dynamic Scaling Laws**

Blackman, Daniel

Designing dynamic legged robotic systems is a nontrivial task. It involves an evaluation of kinematic leg design, actuation properties, and controller setup in order to produce viable walking and running gaits on the final product. Even further, the monetary and time cost of this increases significantly when working toward developing larger systems with the intent of performing dynamic tasks and behaviors. One solution to this issue is to design a smaller scale system to work with in order to prove the concept necessary for funding and exploring development of a larger system. This, however, requires that the limitations of the larger system of interest be well defined in order to ensure dynamic similarity between the 2 robots. In this study, collaborative efforts are made to develop a large dynamic system, determine the limitations of its motors during a set of defined dynamic behaviors, and then scale these limitations in order to perform controller optimization on a smaller-scale platform. Verification of the proposed method will be performed through scaling the optimized controller parameters up from the small-scaled system and comparing key aspects of the resulting behaviors between the 2 systems using the dynamic scaling laws.

### **Acknowledgments**

I wish to acknowledge the mentorship of Jason L Pusey in RDECOM-ARL-VTD-ASD.

### **Student Bio**

Daniel Blackman is a doctoral student in mechanical engineering at Florida State University. He earned bachelor's degrees in physics and biochemistry at Edinboro University in 2013 and completed his master's degree in biomedical engineering at Cornell University in 2014. His past research experience includes work in bio-inspired robotics and cellular biomechanics. Daniel Blackman plans to pursue a medical degree and postdoctoral research in the fields of biomechatronics prosthetics and therapeutic exosuits.

## **Residue and Exterior Ballistics of M855, M855A1, and MK318 Fired from the M4 Carbine**

Blaudeau, Lauren B

Three collection tubes from 3 different propellants were analyzed for M4 carbine efflux residues using Fourier Transform Infrared – Attenuated Total Reflectance (FTIR-ATR) and FTIR microscopy. As with previous gun fouling studies, ambient and UV photographs were taken, and the amount of luminescent material noted. With the microscope, spectra were taken every 2 centimeters, and ATR was done to acquire an estimate of graphite levels using baseline elevation. With the spectra and the photographs, a preliminary spatially-dependent mapping of residues was completed, and 2 major zones identified: the incandescent zone and the flash zone. Comparisons among the 3 collection tubes revealed the usage of potassium nitrate versus potassium sulfate as flash suppressant was striking and apparent, with the potassium nitrate tube comparable to the tube without any potassium. The UV photographs followed the reasoning of previous studies, with propellants that left the most luminescent residue inside the weapon leaving the least on the collection tube, and vice versa. Although only a preliminary analysis, this study showed the collection tubes hold promise for studying efflux from the M4 carbine.

### **Acknowledgments**

I would like to thank Dr Rose Pesce-Rodriguez for all her help this summer, and Paul Conroy for creating and providing the resultant condensation witness collection tubes.

## **Addressing Human Variability with Individualized System Responses**

Bodnar, Saoirse

Human behavior is known to be highly variable both within and across individuals. The inability to understand and predict human variability and its consequences necessitates that systems for human use be designed for average or below-average human performance, which leaves a large reserve of human capabilities untapped. To address this issue, we have begun efforts to develop novel approaches to model and predict variability in human behavior, and demonstrate how those methods can be used to develop novel adaptive technologies. In this project, we show an early demonstration of a system that identifies when a new individual enters an environment, and adapts that environment to the individual based on personal preferences. The creation of an individualized environment involves adjusting numerous elements available within the workspace itself, such as lights and sounds. A laptop and mobile application-based system was created with the intention of greeting individuals entering their work space, integrating Philips Hue lighting and the previously developed ARPI network. A custom-made Android app running on a Samsung Galaxy S7 sent the identity of the individual across the network to a desktop program, which in turn played a personal MIDI file and changed the lights according to previously expressed individual preferences. A demo was created and installed on an Android device, which sent data over a network when an individual came within WiFi broadcast range of the work space. This project provides an initial framework for a larger demonstration that illustrates how sensing and predicting changes in human behavior can be used to customize environmental factors.

### **Acknowledgments**

I would like to acknowledge the mentorship of Amar Marathe, and also give a special thank you to Dr Kelvin Oie, Jonroy Canady, Ian Eglund, and Marilyn Peterson.

## **The Development and Evaluation of a Dry Comb-Style EEG Electrode**

Bottomley, Summer

Currently, 2 styles of electroencephalography (EEG) electrodes are recognized: a wet and a dry style. Wet EEG electrodes use an electrolyte gel to act as a conductive bridge, unlike the dry style that makes direct contact with the scalp. In recent years, the dry style has become of great interest for EEG testing because of its simplified application process and extended data collection time. Both of these elements are pivotal to allow data collection in real-world scenarios that have uncontrolled responses in uncontrolled environments. However, the current vertical multi-pin style dry electrode has limitations with accommodating different types and styles of hair, making adequate contact with the scalp difficult, as well as causing discomfort due to pressure applied over a small surface area. This report focuses on the development and evaluation of a dry comb-style EEG electrode. We changed the direction of the pins from vertical to horizontal to run parallel with the scalp. These electrodes are able to push through the hair while having a larger contact area with the scalp. This design also allows for alterations to the height, width, and directions of the pins to accommodate different types of hair. We evaluated the design by measuring the impedance of the electrode-scalp interface.

### **Acknowledgments**

I wish to acknowledge my mentors Dr J Courtney Bradford and Dr W David Hairston for their direct involvement in the design process of the comb-style electrode, Mike McBrearty for his assistance in making the electrode conductive for testing impedance, and Ian Eglund for his assistance with the maintenance and execution of printing our prototypes.

### **Student Bio**

Summer Bottomley is a sophomore majoring in biology at Harford Community College. Her past research experience includes an internship at Harford Community College, working on DNA barcoding as well as microbiome analysis. Summer Bottomley plans to continue her internship into the fall while finishing her associate's degree in biology.

## **Building and Testing a Thermal Conductivity Setup to Measure Laser Gain Materials**

Boyd, Matthew

Thermal conductivity is the physical property of a material gauging how well it can transfer heat. High thermal conductivity is advantageous in laser gain materials because it allows for efficient removal of waste heat generated during high-power pumping. We developed, built, and tested a thermal conductivity measuring station designed around custom fixtures installed inside a commercial cryogenic refrigerator system that can measure the thermal conductivity of samples in the temperature range of 12–350 K. A set of calibrated temperature sensors were used to measure the thermal gradient across the tested samples, and thin-gauged wire was crucial to minimize thermal leakage around the sample. LabVIEW programs were written to efficiently control the entire setup and extract all data generated. Initial tests were done with well-known samples as benchmarks (e.g., fused silica and yttrium aluminum garnet [YAG]) to ensure the cryogenic refrigerator was operating correctly and returning accurate results. With the sufficiently tested setup, thermal conductivity measurements were performed on a variety of laser gain materials across a wide range of temperatures.

## **Establishing Sculptured Thin Film Deposition Using Glancing Angle Deposition at the US Army Research Laboratory**

Boyd, Montez

One objective of the US Army is to incorporate new fabrication capabilities into the Army's ever-growing repertoire. This project seeks to add a new fabrication process to create sculptured thin films (STFs) using glancing angle deposition (GLAD). By using GLAD in conjunction with a stepper motor and an evaporator, it is possible to engineer the structure of a thin film during the deposition process. Unlike thin films deposited by conventional means, GLAD offers more control of the desired outcome. With full control of the rotational speed of the stepper motor, we were able to fabricate helical structures of different materials, thicknesses, pitches, and diameters, with each variation producing unique optical properties. The capabilities of GLAD does not end with helical structures. It is possible to make any shape using GLAD and a stepper motor, thus opening countless opportunities for future use of STFs in the Army. STFs can be developed for applications such as optical filters, sensors, and absorbers. By using GLAD with precise substrate motion control, it is possible to create a helical structure that has multiple pitch angles throughout the thickness of the STF, which can be fine-tuned to react to specific wavelengths in a certain range. The freedom GLAD gives the user will allow the user to make a wide arrangement of different STF morphologies and the possibilities are only limited by the user's creativity and imagination.

## **Joule-Heated Shape-Memory Alloy Actuators V2**

Brine, Jeremy P

Shape-memory alloys (SMAs) have seen increased interest in microelectromechanical systems (MEMS) since they can “remember” their original shapes after initial deformation when heated. We report on our investigations of various thin-film bilayer SMA stacks developed for micro-actuation cantilevers. Three film stacks were characterized (nickel-titanium [NiTi] on platinum, NiTi on Su-8 photoresist, and NiTi on silicon) using a variety of investigation methods. The stress versus temperature response of the films was used to confirm SMA properties, and fatigue life was investigated using a confocal microscope. Laser Doppler vibrometry (LDV) characterized the frequency, voltage, and duty cycle response of released cantilever actuations, and we found that using a duty cycle of 12.5% led to the highest frequency of operation of about 10 kHz, with a maximum frequency of 14 kHz. Using the van der Pauw 4-probe method, a power and volume relationship was investigated along with the maximum power of the devices of 20 mW. Furthermore, using a parametric investigation of the deposition of the thin films within a sputter tool, a methodology was developed for both NiTi-copper (NiTiCu) and NiTi thin films with repeatable stoichiometric composition control. These investigations will lead to future applications for smaller, faster, and thinner MEMs device actuation.



## **Design Methodology for Linkage Morphology**

Brown, Jason

The maximum performance of current legged robotic platforms is defined by power limits, primarily in terms of the limited power density of motors. To simplify the mechanical and electrical design process, many designers use the same motors at each joint. However, the kinematics of the leg also impact the power output, so maximizing the total to work out an even work distribution among the motors is beneficial. By examining the work percentage between the actuators for several kinematics and across several gaits, we demonstrate the application of an additional design metric for leg kinematics, as well as a dynamically inspired design process.

### **Acknowledgments**

I wish to acknowledge the mentorship of Jason Pusey.

### **Student Bio**

Jason Brown is a third-year PhD student at Florida State University. He has an undergraduate degree in mechanical engineering. His future plans are to continue to work in and define the field of legged robotics.

## **Melt Spinning and Characterization of Recycled Polymer Blends**

Burckhard, Zachary

Our troops are burdened by the immense amount of waste plastic that must be disposed of to be most effective. These plastics have potential to be turned into a beneficial material in forward operating bases; however, new processing methods are needed to convert the large volume of plastics in the waste stream into valuable working materials. In this work, polyethylene terephthalate, polystyrene, and polypropylene were recycled from plastics available in abundance to the Warfighter, the primary sources being food containers, such as water bottles and yogurt containers. These plastics were spun into fibers from a melt using a centrifugal spinning technique. Monocomponent fibers, as well as blends of plastics combining fillers and compatibilizers, were evaluated. Fiber morphology and chemistry, along with thermal and mechanical properties, were probed. Nano- and microfibers from both pure and mixed waste streams are expected to have applications in myriad areas such as ultra/microfiltration, composites, and tissue engineering.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Nicole Zander.

## **Developing a Paradigm for Comparing Electroencephalography (EEG) Electrode Characteristics**

Burke, Benjamin

There are several types of electroencephalography (EEG) electrodes that can be used to record brain electrical activity. These electrodes vary in factors such as composition and design, which can influence recording quality and convenience. To observe how changing electrode characteristics can affect electrode recording, an US Army Research Laboratory-designed silver/silver chloride (AgCl)-coated carbon polymer electrode was tested alongside a gold-coated pin electrode and a conductive gel electrode using human brain signals. A headset was created that positioned each electrode design in 4 different locations on the scalp. The headset was placed on a subject's head to measure electrical activity on the scalp as each subject completed a baseline measurement of electrical signals with eyes open and closed. These signals were analyzed to determine the power spectra for the baseline task, and then compare the results from each electrode to determine their functionality. It was determined that the polymer electrode performed about the same as both the conductive gel and the pin electrode in picking up the alpha power band. Future research in this direction will focus on using this paradigm to compare the functionality of other electrode types and adjusting the carbon electrode design based off the results obtained.

### **Acknowledgments**

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### **Student Bio**

Benjamin Burke is a senior currently attending the University of Maryland, College Park, majoring in biological studies. He has previously been a member of the Gains in the Education of Mathematics and Science (GEMS) and Student Engineering and Apprenticeship Program (SEAP) programs at Aberdeen Proving Ground (APG), Maryland, and is currently in his third summer working with the Human Research and Engineering Directorate in the College Qualified Leaders (CQL) program. His future goals include pursuing a career in neuroscience after graduate school.

## **Microstructure Simulation of Ramp-Released Material Spall**

Callaghan, Kyle

Spall characteristics were examined through direct numerical simulation within an arbitrary Lagrangian-Eulerian, 3-D multiphysics code to provide information for improved modeling for large-scale simulations. Loading of the profile and space and size distributions of void nucleating particles was systematically varied over a range of deformation conditions. Void fraction, stress, and pressure values were averaged over 20- $\mu\text{m}$  segments as well as 5- $\mu\text{m}$  segments around peak stress for each time state. These simulations revealed that failure location is primarily dependent upon void nucleating particle locations at the rates simulated, although the rate does have an increasing effect on peak stress. It has also been observed that particle distribution has little effect on material strength, despite large differences in failure pattern. The state relationships extracted are found to have significant disagreement from the Gurson model, supporting an argument for a modified or alternative flow potential.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Richard Becker for the past few years in robotics and material failure.

### **Student Bio**

Kyle Callaghan is a rising freshman at the University of Maryland, majoring in aerospace engineering. His past research has included numerical simulation of ductile material spall at the US Army Research Laboratory. His future plans are to attend the University of Maryland in aerospace engineering and astronomy, and later work on space and satellite systems.

## **Autonomous Detection of Point Defects in a Solid**

Chan, Joseph

Spin defects (color centers) in diamond and silicon carbide have potential applications in nanoscale electric and magnetic-field sensing, quantum information processing, and bioimaging. Particularly, nitrogen-vacancy (N-V) centers can be seen as an isolated quantum system with a nonzero intrinsic magnetic moment. Electron spins can then be manipulated by applying electromagnetic fields, microwave radiation, or light resulting in sharp resonances in the photoluminescence (e.g., quantum entanglement). Such applications rely optically controlling and probing a single defect. To facilitate the identification of isolated single-color centers, we automated and streamlined the optical excitation and detection process. A laser beam is reflected off and steered by a scanning mirror, passes through a pair of lenses to expand the field of view, and is then focuses to a submicrometer-radius spot via an objective. A Python-based graphical user interface (GUI) was designed with Tkinter so a user can input the resolution and dimensions of a scan. At each position, the luminescence from the sample is collected and fiber-coupled to a single-photon counter. When the scan is complete, the GUI builds and displays a 3-D representation of the photon counts per x-y location. The scans be rerun for areas of abnormal photon counts with increased resolution to better pinpoint the exact locations of the defect. Automated defect detection allows researchers to focus on the use of defects, for quantum computing, cryptography, and spintronics, rather than on the manual process of locating defects.

### **Acknowledgments**

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## **Characterization of (001) Textured Sputtered Lead Zirconate Titanate (PZT) Thin Films**

Cheng, Christopher

Highly oriented (001) lead zirconate titanate (PZT) thin films are necessary for high-quality piezoelectricity and a wide variety of applications, such as piezoelectric actuators and ultrasound transducers. The current research is to develop and optimize a sputter process to yield crystalline (001) PZT thin films using sputtering systems at the US Army Research Laboratory and The Pennsylvania State University. While parameter changes of gas flows, pressure, and temperature, and matching network series-capacitance in the bulk deposition step of the PZT sputtering process yield minor changes, it was found that the nucleation step is critical for achieving high (001) orientation. Initial ferroelectric and dielectric response were evaluated on (001) textured PZT sputtered on both silicon (Si) and R-plane sapphire substrates. The PZT films on sapphire are in compression in contrast to the films on Si, which are in tension. As a result, the ferroelectric hysteresis loops on sapphire exhibit a squarer loop compared to the films on Si with  $P_{\max}$  of approximately  $50 \mu\text{C}/\text{cm}^2$  and a coercive field of approximately 50–60 kV/cm. Ongoing research is focused on eliminating a minor secondary phase in the X-ray diffraction pattern at  $30^\circ$ , which is suspected to be caused by excess lead in the nucleation layer. Eliminating this secondary phase is anticipated to increase breakdown strength and improve the electrical and ferroelectric response of the resulting PZT thin films.

## **Design and Development of a Micro Air Vehicle for Grenade Launched Deployment**

Christensen, Andres

Recently, there has been a push for micro air vehicles (MAVs) to become smaller and more compact for tactical missions. The goal of this project is to design and develop an MAV grenade round with a minimum flight time of 30 min. The MAV will fit within the size constraint of a 40-mm grenade so that Soldiers can deploy it through a grenade launcher for surveillance missions. The design uses a thin-walled shell to house the components of the vehicle and maximizes the use of the internal volume of the shell to securely mount all components. It features a coaxial rotor with folding propellers to produce enough thrust to fly the vehicle while remaining compact. Research for a future design involves a powered parafoil, which would draw less power than the coaxial rotor, eliminating the need for a larger battery within the size constraint.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Hao Kang and Mr John Gerdes.

### **Student Bio**

Andres Christensen is a junior at the University of Maryland majoring in aerospace engineering. His past research experience includes work as an undergraduate research assistant at the Alfred Gessow Rotorcraft Center. He also developed an MAV for package pickup and delivery for the AHS MAV student challenge. His future plans are to obtain a master's degree in aerospace engineering and work in the rotorcraft industry to develop future rotary-wing vehicles for military applications.

## **An Examination of Transitions from Rigid Body to Eroding Penetrators: Effects of Penetrator Velocity, Nose Shape, and Length**

Cler, Timothy

In the field of terminal ballistics, much research has gone into the study of making kinetic energy (KE) penetrators more efficient, cost effective, and practical to the Warfighter. It has been proven that the penetrating capability of KE projectiles is affected by velocity, length, and nose shape and that rigid-body penetration is more efficient at any given velocity than a similar rod at the same velocity that erodes. There is a threshold velocity for any given penetrator where it will begin to deform and erode. There are many factors that affect at what velocity this erosion will occur. Theoretically, there is a region just below this threshold velocity where the rigid-body projectile will achieve greater penetration than projectiles shot just above the threshold velocity. It is then more efficient to fire a projectile at a lower velocity to achieve better efficiency and performance. To better understand this transition and this region of velocities, tests were conducted to map out how a penetrator transitions from rigid body to eroding over this region and ultimately maximize the effectiveness of rigid-body penetrators.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Lee Magness.



## **Characterization of Millimeter Wave Propagation at 94 GHz for Vulnerability and Survivability Assessments**

Codina, Luis

This project was conducted at the Electromagnetic Vulnerability Assessment Facility (EMVAF) at White Sands Missile Range (WSMR), New Mexico, by doing research on millimeter-wave systems specifically at a frequency of 94 GHz. The US Army Research Laboratory (ARL), Survivability/Lethality Analysis Directorate (SLAD) is currently interested in millimeter waves due to emerging technologies that are being integrated with these high frequencies. Three models to characterize millimeter-wave propagation were considered: free space, 2-ray multipath, and multipath interference. The free space model was characterized by simulating the Friis transmission equation. The 2-ray multipath and multipath interference models were simulated. An empirical test was designed using a signal generator, source module, attenuator, mixer, and spectrum analyzer. The attenuator was used to simulate range with power attenuation. The sensitivity of the spectrum analyzer that was used for measurements was  $-73$  dBm. Therefore, measurements below the receiver sensitivity were not possible. A solution for this would be to have a higher power output and higher antenna gain. Further testing is required to find which multipath model is better to characterize millimeter-wave multipath. Future work will be conducted in the anechoic chamber at ARL-SLAD at WSMR to characterize the millimeter-wave system in free space.

### **Acknowledgments**

I wish to acknowledge my mentor Dr Berenice Verdin.

### **Student Bio**

Luis Codina is a sophomore in electrical engineering at the University of Texas-El Paso. This is his first time doing research. His future plans are to attend the Hispanic Engineer National Achievement Awards Conference (HEENAC) in fall 2017 and get selected for another internship at WSMR. Upon graduation, he hopes to obtain an engineering position at WSMR.

## **High Performance Computing Modernization Program (HPCMP) Enterprise Software License Analytics**

Cohen, Jacob

Running research jobs through various software applications on the Department of Defense (DOD) supercomputers is a resource-intensive effort. Resources and central processing unit (CPU) hours must be allocated, and, as a general effort, a proportionate number of licenses must be purchased from the respective software vendors. Having to make long-term license purchasing decisions is a process, which, to be cost-effective and accurate, requires insight into various facets of how research jobs are being run. Until now, the tools used to track usage of licensed software within the High Performance Computing Modernization Program (HPCMP) provided only very basic information. Given the amount of money spent by the HPCMP on acquiring software licenses, a correct and careful approach to overseeing long-term software usage is vital. This work details the process used to create tools to analyze the overall software license usage on HPCMP systems.

### **Acknowledgments**

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### **Student Bio**

Jacob Cohen is a sophomore in computer science at University of Maryland, College Park. His previous research experience includes HIP summer 2016 and winter 2017. His future plans are to work within the cybersecurity field.

## **Neural Correlates of Gamification for Enhancing Training Effectiveness**

Cohen Hoffing, Russell

Gamification research has sought to harness the motivational power of games to enhance training effectiveness. While promising, research indicates that gamification yields mixed effects on training outcomes. We propose that trait-based differences moderate training outcomes and underlie the mixed results of gamified training. In this study, we investigate the neural correlates of trait-based differences and gamification on training. Specifically, we examine the influence of pointsification on learning when taking into account regulatory focus, which indicates whether a person is either motivated by achieving gains (promotion focused) or avoiding losses (prevention focused). Participants were randomly assigned to one of 2 pointsification conditions: gain condition where points are received or loss condition where losing points is avoided. We present electroencephalogram data from 17 promotion-focused (9 gain, 8 loss) participants taking part in a go/no-go training task. Our results indicate that neural responses differ by go and no-go trials as function of performance and the fit between pointsification condition and regulatory focus. Finally, we find a neural response related to learning across training. Our results suggest that neural responses shed light on the effect of trait-based differences and gamification on learning and can potentially serve as predictors of training effectiveness.

### **Acknowledgments**

I wish to acknowledge Antony Passaro, Ben Files, and Pete Khoosabeh for their outstanding mentorship.

### **Student Bio**

Russell Cohen Hoffing is a 5<sup>th</sup> year PhD candidate in psychology at University of California (UC) Riverside. His past research experience includes working in the UC Riverside Brain Game Center studying fundamental mechanisms of learning and how to use this to help people learn new behaviors. His future plans are to submit the work at US Army Research Laboratory (ARL) to an academic journal. He intends to defend his dissertation next year; the topic is on investigating how mechanisms of perceptual learning apply to executive function training. He hopes to collaborate in the future with ARL.

## **Systems Integration for the Real-Time Analysis of Streaming Cardiovascular Data**

Cohenour, Joshua

Multimodal processing of physiological signals can help to classify a person's state by using the information from the set of modalities to identify the context of the situation. As part of a US Army Research Laboratory study, different physiological sensing modalities such as electroencephalogram (EEG) data, Myo armband (electromyography and inertial measurement unit data), and Biopac (cardiovascular data) are being recorded to predict a person's state. However, physiological signals operate at different timescales and sensing systems often operate at different frequencies. Also, with the increasing use of physiological sensing systems that enable pervasive sensing, new complexities arise in synchronization and multiresolution modeling within and across modalities. The focus of this project is to design and implement a software system to for the real-time analysis of cardiovascular signals. This research project focuses on the use of a lab streaming layer (LSL) framework to pull live data from a Biopac stream and send those data to the moving ensemble analysis pipeline (MEAP) for further calculations and the visualization of the data via live graphs while simultaneously recording the live data to a comma-separated value (CSV) file for further offline analysis use.

## **Characterizing Operational Performance of Rotary Subwoofer Speaker**

Conn, Caitlin

The US Army Research Laboratory (ARL) is investigating using high-speed video cameras to measure vibrations of objects excited by sound waves. Preliminary data were collected by ARL's Acoustics and Electromagnetic Sensing Branch to characterize the operational performance of a rotary subwoofer speaker, to be used in a field test conducted by ARL and Booz Allen Hamilton in summer 2017. The speaker generated low-frequency tones within ARL's Building 406 producing 2 data sets. The first test used an oscilloscope to make 6 measurements of the peak-to-peak voltage, stepping the input frequency and varying the fan speed. During this test, the waveform generator outputted a constant voltage of 100 mV, with the amplifier was set to a gain of 5. The fan speed was stepped from 10 to 45 Hz in 5-Hz increments at a fixed frequency for each measurement. The measurements were stepped with a sinusoidal input frequency of 1 to 20 Hz in increments of powers of 2. The results indicated that the optimal fan speed is dependent on the input frequency used to modulate the blades. For frequencies below 8 Hz, an output fan speed of approximately 15 Hz should suffice for near-maximum performance. The second data set varied the input voltage on the waveform generator and gain on the amplifier. For each run, the input frequency signal was set to a constant value between 1 to 16 Hz, and the fan speed was set to previously determined optimal values between 15 to 40 Hz. The results indicate that the waveform generator should output a voltage of 500 mV and the amplifier be set to a gain of 1 for the subwoofer to generate a 101-dB signal. Users can expect to see a 3–5 dB gain compared to alternate configurations.

### **Acknowledgments**

I wish to acknowledge my mentor, Geoffrey Goldman (Sensors and Electron Devices Directorate, Acoustics and Electromagnetics Branch).

## **Solving Vertex Cover via an Ising Spin Model on a Neuromorphic Processor**

Corder, Kevin

Neuromorphic architectures can possibly solve nondeterministic polynomial (NP) problems faster than von Neumann architectures due to their different computational models. The IBM TrueNorth processor is a highly distributed, low-power chip modeled after the brain with neuron and axon connections. We propose to use it to efficiently and optimally solve the NP-hard problem Vertex Cover. To solve Vertex Cover on TrueNorth, we redefine Vertex Cover as an Ising spin model formulation, where the distributed Metropolis-Hastings simulation of the models' spin states represents probabilistically trying different vertex covers. The states converge to a solution by lowering the exploration probability over time. Each graph node becomes a circuit in the TrueNorth architecture for updating its state given the states of its adjacent nodes. Since adjacent nodes cannot update their states simultaneously, each group of nodes that can be parallelized corresponds with its color in a graph coloring problem. For space efficiency in TrueNorth, the node circuits of highly connected subgraphs should share cores, so we fit the nodes by recursively partitioning the graph with minimum cut. We use greedy solutions for these 2 NP-hard problems at initialization, only decreasing our space and time efficiency by a constant factor without degrading solution quality.

### **Acknowledgments**

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### **Student Bio**

Kevin Corder is a 3<sup>rd</sup> year computer science PhD student at the University of Delaware (UD). He has a BS and MS in computer science from UD. His research focuses on multiagent systems and distributed artificial intelligence (AI), specifically in cooperative game theoretic problem solving. He is also interested in neuromorphic computing, natural language processing (NLP), and machine learning. He hopes to work in a research lab with an AI focus.

## **Coupled Computational Fluid Dynamics (CFD)/Computational Structure Dynamic (CSD) Predictions of Semi-Span XV-15**

Corle, Ethan

The US Army is actively in the process of procurement for the next generation of vertical take-off and landing (VTOL) platforms. The work here focuses on the tiltrotor configuration in which the vehicle takes off like a helicopter and then transitions to cruise in a similar manner to a propeller aircraft. One aeroelastic instability that is of particular interest for this vehicle in cruise is called whirl-flutter and is a result of a coupling between in-plane rotor motion and the vertical beam bending mode of the wing. Current tiltrotor platforms, such as the V-22, or its precursor, the XV-15, use a thick wing to increase the stiffness in this mode and avoid whirl-flutter; however, this leads to a compromised aerodynamic design and significantly impacts the cruise performance of the vehicle. To design better ways of increasing the speed at which the onset of whirl-flutter occurs, improved analysis techniques need to be developed. This work leverages and tests new capabilities introduced to the Computational Research and Engineering Acquisition Tools and Environments (CREATE)-Air Vehicles (AV) software Helios to model a fully elastic semi-span model of the XV-15 using the high fidelity aerodynamics in Helios coupled to the Rotorcraft Comprehensive Analysis System (RCAS).

### **Acknowledgments**

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### **Student Bio**

Ethan Corle is a 2<sup>nd</sup> year PhD student in aerospace engineering at The Pennsylvania State University. He has a BA in physics from Slippery Rock University, and a BS and MS in aerospace engineering from The Pennsylvania State University. His research interests include rotorcraft aeromechanics, computational fluid dynamics, optimization. His future plans are to finish his PhD studies.

## **Atmospheric Renewable Energy – Study #2 (ARE2): Power/Solar Radiation**

Curtice, Michael

The optimal integration of renewable energy into traditional fossil fuel power generation grid resources is critical for battlefield and disaster relief applications. To attain this capability, the Atmospheric Renewable Energy Study is #2 (ARE2) project at the US Army Research Laboratory (ARL)/White Sands Missile Range (WSMR) is researching the dynamic effects of the atmosphere on photovoltaic (PV) power production. The objectives of the study are to acquire data for an assessment of the atmospheric impact on PV power generation, acquire atmospheric image data for machine-learning cloud assessment, and quantitatively describe the ARE2 PV power train. As an ARE2 team member, my research focused on acquiring, processing, and conducting a preliminary analysis on power and solar radiation data. During my internship, I was responsible for the acquisition and analysis of data, which were sampled daily at multiple locations along a power train design, and the acquisition and analysis of coincident solar radiation data. The results of my research will be correlated with coincident sky conditions, which will ultimately determine the PV power production. This research will enable the efficient integration and optimal distribution of PV power into future forward operating base hybrid power grids.

### **Acknowledgments**

I wish to acknowledge my mentor, Gail Vaucher.



## **Effect of Mechanical Anisotropy of Silicon and Gallium Nitride in Stretchable Electronics**

Curtis, SM; Tompkins, RP; Lazarus, N

The US Army is interested in developing a soft human exoskeleton. Semiconductors used in power management, such as silicon (Si) and gallium nitride (GaN), are brittle materials, which deters their use in stretchable applications. These semiconductors are mechanically anisotropic materials, with elastic moduli dependent upon its crystallographic orientation. To study the mechanical anisotropy of (100) Si and (0001) GaN, finite-element analysis (FEA) (COMSOL Multiphysics 3.3) has been used to determine the effect in-plane crystallographic rotations on the von Mises peak stresses of common stretchable waveforms embedded within Si. To further investigate the anisotropic effects of Si, a more advanced FEA study using COMSOL Multiphysics 5.2 was conducted. Improving discretization of the wave forms with curved edges allowed for a more accurate representation of the local stress concentration. Our results suggest that these semiconductors had nearly half the amount of stress (~2 vs. ~4 GPa for Si), meaning these can achieve even larger strains prior to fracture, than previously predicted. Additionally, for Si, peak stresses for stretchable systems patterned in the  $\langle 110 \rangle$  direction were found to be up to 21% higher than that of the  $\langle 100 \rangle$  direction. To experimentally verify these contradictory FEA results, we measured the local peak stress using micro-Raman spectroscopy and digital image correlation. Initial results on microprocessing development of the stretchable structures for experimental verification of the local peak stress are presented.

## **Adapting a Leg Testing Apparatus and Robotic Leg**

Davis, Matthew

Legs are proving to be the most robust form of transportation for ground robots—much more effective than wheels for varying terrains. This paper describes leg design adaptations combining multiple materials for Minitaur, a powerful 4-legged robot by Ghost Robotics. It also describes the redesign of an apparatus for testing leg strength. The testing apparatus was analyzed for strength, durability, and deflection, and changes in structure were implemented iteratively according to test results. Improvements in accuracy will be assessed, and the testing apparatus will be used to evaluate design revisions to the Minitaur leg.

### **Acknowledgments**

I wish to acknowledge the mentorship of Harris Edge and Jason Pusey.

### **Student Bio**

Matthew Davis is a freshman majoring in mechanical engineering at the University of Maryland, College Park. His past research history includes a senior design project with ARL in Summer 2016. He plans to attend graduate school, then get a civilian job with the US government.

## **Hydrogen Sintering Treatments for Mechanical Property Enhancement in Cold Spray Titanium-6-4**

Davis, Shyla R; Barnett, Blake D

One of the main obstacles for the US armed forces is configuring research of new materials in cold spray that would eventually be used in the combat environment. The cost associated with the research and testing can be quite extensive. Heat treatment in titanium (Ti-6Al-4V) will provide a lower-cost cold spray solution by using nitrogen processing gas instead of expensive helium. By using powder metallurgy to understand the powder, cold spray, and heat treatment, we would essentially provide a low-cost alternative for coatings, repairs, and making new materials. The requirements for this experiment are the following: prepare specimens which are sprayed with Ti-6Al-4V, determine if we could cure the porosity in a deposit produced with pure-nitrogen-based gas, improve the overall mechanical properties of the specimen, and see the same results when using pure helium. In our research we made samples of Ti-6Al-4V sprayed with helium and nitrogen. We sprayed these titanium samples using a number of different parameters from our previous research with the powder. Consolidated samples will be tested for mechanical properties in the as-sprayed and heat-treated conditions. We would like to see if we could make a higher-quality titanium product that would allow us or combat troops to be able to machine or repair parts using nitrogen cold spray instead of helium, thus reducing the high cost of purchasing helium. The Army would then be able to use this in the field when needed. However, the heat treatment and testing phases are still in progress and are beyond the scope of this abstract.

## **Ultra-Low-Power Sensing and Processing**

Deaville, Peter

The ARL ARTEMIS-Mobile Power Meter (MPM) phasor measurement system consumes approximately 2 W of active power. An ultra-low-power (targeting 1 mW) electric and magnetic sensing and processing solution can be implemented to act as a wake-up for the MPM upon detection of significant events. This results in much lower active power consumption without the risk of missing significant data. Analog and digital processing options are under consideration for ultra-low-power operation. The analog processing option under consideration is the Aspinity Reconfigurable Analog/Mixed-Signal Processor (RAMP), which can perform continuous phasor extraction and event detection for about 20  $\mu$ W. The RAMP is compared with a digital solution employing a Texas Instruments MSP430 microcontroller and 16-bit analog-to-digital converter. Results from the digital prototype show that a continuous operation of 2.32 mW can be achieved, with a 1-kHz sample rate per channel and a 1024-point fast Fourier transform after every 1024 samples. Three TI DRV5053 linear Hall-Effect magnetic sensors were utilized, with an ARL D-Dot electric field sensor yet to be added.

### **Acknowledgments**

I wish to acknowledge the mentorship of David Hull.

## **Optimizing Training Data and Autoencoder Architecture for Atari Game Images**

Dedhia, Ray

An autoencoder is a type of neural network that reduces data dimensionality by passing the data through layers that decrease its size and then training to reduce the difference between the original data and the reduced data, or the loss. For applications such as reinforcement learning, using data that has a large feature-space is time-consuming and inefficient, as is hand-crafting features for every data set, so a versatile program that can reduce the dimensionality of a variety of data can be extremely useful.

I hypothesized that as the amount of training data input to an autoencoder increased, the loss of the autoencoder would decrease and gradually approach a set minimum value. To test this hypothesis, I trained my autoencoder with a variable architecture, a variable amount of training data, and a set amount of validation and testing data. For my initial autoencoder architecture, as the amount of training data increased, the loss of the autoencoder decreased and approached a set value. However, with more-complex autoencoder architectures, I was not able to reproduce this trend between training data and accuracy, likely because the training algorithm got stuck in local minima, a problem that is known to occur with highly parameterized models.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Ethan Stump.

### **Student Bio**

Ray Dedhia is a rising sophomore majoring in EECS at MIT. He also interned at ARL Adelphi during the summer of 2015 through the Science and Engineering Apprentice Program (SEAP). He plans to study machine learning as an undergrad, and is considering going to graduate school and going into research.

## **Simulations of Quantized Routing Games**

Dixon, Ricky

Routing games are formulated on a collection of source-sink pairs in a directed graph. Players choose how much information to pass along each edge in continuous units. Each edge has time delay, or latency. The selfish routing case is where the players will try to minimize their own latency. This is often different from the socially optimal case that optimizes the global cost. The goal of this research is to utilize quantum correlations to improve the equilibrium flow from the classical case. Because of previous research done on quantizing classical game theory, we believed routing games would benefit from these correlations.

Initially we used a best response method with four strategy choices and attempted to find a Nash equilibria (NE). After finding that the NE was the same as the classical condition, we decided to use a simulation of the routing game. In each iteration of this simulation, players calculate a difference in latency and update their quantum strategy choices in attempts to converge on an equilibrium based on the selfish routing case. We also used a simulation where we introduced a factor of randomness, in which there would be a random amount of latency in each iteration of the simulation.

### **Acknowledgments**

I wish to acknowledge the mentorship of Neal Solmeyer and Radhakrishn Balu.

### **Student Bio**

Ricky Dixon is a graduate student majoring in mathematics, and wishes to obtain doctoral degree in mathematics and pursue a career in scientific research.

## **Vortex Identification Using Machine Learning**

Dobson, Benjamin

In the field of fluid dynamics, it is difficult to quantify vortices with current analytical methods. The issue is that many of the current metrics for vortex identification do not adequately identify an entire vortex. These metrics tend to be accurate at identifying the center of circulation but less accurate at identifying the boundary area. This research project attempts to solve vortex identification and tracking using machine learning instead of analytical methods.

By using user-identified vortices as targets, we trained multiple convolutional neural network (CNN) architectures using velocity vectors and an initial guess based on vorticity measurements. Vorticity describes the local spinning motion of a particle in the flow field. CNNs use filters or “windows” to look at smaller portions of the image in order to compare identifiable features across the spatial dimension. We continue to refine the estimate by recursively applying similar network structures.

This project aims to evaluate the accuracy of the network by calculating error and accuracy and comparing them with mathematical measures that already exist. Identifying the entirety of the vortex allows future researchers tools such as circulation to better understand drag and lift behaviors in a variety of environments.

### **Acknowledgments**

I wish to acknowledge the mentorship of John Hrynuk and Michael Dorothy.

### **Student Bio**

Benjamin Dobson is a junior aerospace engineering undergraduate student at the University of Maryland College Park. Working at ARL is his first research experience. After graduation he will commission as a second lieutenant in the United States Marine Corps as an aviator, and look to return to school following retirement from the armed forces.

## **Optimization of Test Conditions for Localization Ability Measurement Standard**

Domanico, Morgan

To optimize the test conditions for a proposed American National Standards Institute/Acoustical Society of America standard for measurement of auditory localization while wearing tactical communications and hearing protection systems (TCAPS), localization performance of 12 participants was measured for several loudspeaker configurations. Localization performance was compared for 3 different angular separations between pairs of loudspeakers in Method 1 (screening test using four loudspeakers pairs placed at 90° increments). In Method 1 for loudspeakers separated by 8°, 10°, and 12°, acuity errors decreased as the angle increased.

Spacing did not affect the number of front-back confusions or the ability of the test to discriminate between bare-head and TCAPS performance. A comparison of Method 1 data with Method 2 (which uses a full horizontal array of 36 loudspeakers) showed that both methods were successful in distinguishing between bare-headed and TCAPS conditions. However, Method 2 showed a higher percentage of trials in which errors occurred than Method 1. This may be due to Method 1 having fewer response options, reducing errors due to chance. Future testing is planned to determine whether Method 1 screening can discriminate between types of hearing protection and to quantify the effects of number of loudspeakers and whether their location is known (marked).

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Angelique Scharine and Dr Nancy Vause.

### **Student Bio**

Morgan Domanico is a junior biology major at Washington College. Her past research experience includes a prior appointment to the ORISE Student Research Participation Program (2016), an ongoing collegiate study on decision-making and moral dilemmas, as well as various biology and chemistry experiments as part of her coursework. After graduation she aims to pursue a Master's degree in a more specific field of biology.



## **Real-Time Energy Audits for B-hut Efficiency Enabled by Machine Learning**

Drummond, Zachary

Temporary buildings, such as the US Army's "B-hut," at forward or contingency operating bases are not designed for efficiency. Consequently, cost savings can be realized by redesigning or replacing them (Pagan-Vazquez, et al. *Comparison and Analysis of Energy Performance of Baseline and Enhanced Temporary Army Shelters*). The Electric and Magnetic Field sensing team at ARL is interested in using noninvasive power monitoring to produce real-time energy consumption information. This information can supplement and inform existing cost-saving strategies as well as provide real-time information for increasing efficiency or predicting future energy consumption. As proof of concept, a controlled environment system was constructed from a Pelican case, temperature-controlled heater, and microcontroller outfitted with temperature, illuminance, and current sensors. Three base conditions were used to train a machine learning model: 1) a closed lid and no external light (baseline conditions), 2) an open lid and no external light (anomalous, inefficient, "door open" conditions), and 3) a closed lid with 200-W external lamp (anomalous, efficient, "solar heating" conditions). High-level features were generated from the raw data including energy consumption, duty cycle, and illuminance. A Support Vector Machine (SVM) was trained on this data and achieved 100% accuracy using a shuffled split-cross validation method. To further test the SVM, data were collected of transitions from closed lid to open lid and vice versa. The SVM correctly identified the change in state within one heater cycle. This shows that the baseline operating conditions for a building can be learned and anomalous operating conditions identified. In the context of temporary Army buildings, these results can inform which temporary buildings to replace or upgrade first and provide real-time feedback for increasing the energy efficiency during operation.

### **Acknowledgments**

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## **Toward Printing Molecularly Imprinted Polymers (MIPs) for Integrated Photonic Wearable Sensor Development**

Edwards, Fatima

The US Army Research Laboratory's research goals are to discover, innovate, and transition science and technological advancements in an efficient and effective means to better protect and serve the Army Soldier, first responder, and support staff. To meet these goals, researchers are increasingly merging several technology areas, creating new sensor systems with increased detection, identification, and adaptation (chemical, biological, explosive hazards) capabilities in smaller, more-robust sizes. One way this can be achieved is by merging the small size of integrated photonic sensors with the selectivity and sensitivity of molecularly imprinted polymers (MIPs). MIPs are biomimetic nanomaterials that allow for the penetration and reception of specific molecular targets. They are small, easy to prepare, and are tailored to the specific target molecule (current and emerging hazards). To achieve optimal trace level sensing, it is necessary to deposit the MIP layer onto a specific sensing region on the integrated photonic chip. Potentially, this can be achieved by using an inkjet printing system.

Photonics is the science of creating, moving, and sensing photonic applications by the manipulation of light. The integrated photonic chip is a microscopic device that will provide more-efficient sensory detection to benefit the Soldier. MIPs) are biomimetic nanomaterials which allow for the penetration and reception of specific molecular targets. MIPs are designed to overcome the limitations of the natural receptors, such as antibodies, and can be used for applications in drug delivery, hazard detection, and Soldier performance information. Current research includes merging these 2 technologies onto an integrated photonic chip that will enable molecular level selection, increased sensitivity, and concentrating via the MIP layer, and provide target identification via Raman spectroscopy. Thus, the MIP integrated photonic sensor could become a powerful sensing tool (for the Soldier).

### **Acknowledgments**

I would like to acknowledge my mentors, Mikella Farrell and Ellen Holthoff.

## **Detection of Early Stage Damage in Composites Using Thermophysical Properties**

Eure, Amber

This research focuses on using infrared thermography (IT) to monitor changes in thermophysical properties of polymer composites during the early stage of service-induced damage. Early stage damage in composites is generally characterized by the onset of crazes and microcracks in the matrix. Such damage may affect the heat conduction rate, heat capacity, and other thermophysical properties of the material. If measured accurately, it may provide information regarding the extent of internal damage. In this study, composite test specimens were subjected to an increasing tensile load while acquiring thermography images. An initial image was taken at 0 kN and then the specimen was loaded to 5% of the ultimate tensile strength, then another thermography image was taken. Images were taken every 5% until failure. IT images include a high-intensity flash that heats the specimen's surface, and the heat intensity is recorded with a high-speed IR camera. The intensity measurements from thermography images inspect changes in thermal diffusivity and heat capacity. Ultimately, as the heat conducts through the specimen, the corresponding rate of dissipation is dampened over time.

### **Acknowledgments**

I wish to acknowledge the mentorship of Natasha Bradley. Thank you for your insight and helpful hands in guiding me in the right direction for my research and as well as my future education plans. I want to thank Dr Mulugeta Haile for all the help during the process of analyzing the data. You have both been a great help during my summer research experience.

### **Student Bio**

Amber Eure is a senior at Frostburg State University majoring in materials engineering. She had previously worked at Aberdeen Proving Ground as College Qualified Leaders Intern for the US Army Research Laboratory's Vehicle Technology Directorate. Her future plan is enter the workforce and eventually earn a Master's degree in material science and engineering.

## **Pythonic Approach to Numerical Weather Prediction and Design of Experiments**

Filmore IV, Thomas

Weather is one of the greatest obstacles our military faces on a daily basis. Numerical weather prediction uses computing power to model, forecast, and provide weather conditions for many different variables. There are many methods that can be used to understand numerical weather prediction codes including using design of experiments via design matrices, which can potentially be used to estimate how the model performs at unmeasured points. In an effort to improve numerical weather prediction, I used existing R code based on the design of experiments method developed by my mentor and translated this code into Python. By writing the code in Python, I would be able to cross-verify the current R code. This would also allow for discussion on what improvements could be made in both code bases. Research thus far has allowed me to obtain a working proficiency in both R and Python. In relation to recreating the design matrices, I have been able to translate parts of design matrices code including the balanced sample size and utility function codes into Python. This project will be considered a success on the basis of progress made in recreating the design matrices code in Python. This will allow for verification of the original R code while also sparking conversation on how the code can be improved in terms of efficiency and effectiveness to improve our weather prediction models.

## **Developing Unmanned Aircraft Systems via Additive Manufacturing**

Folk, Spencer

The purpose of this research is to improve on a family of mission-tailored unmanned aircraft systems (UAS) that utilizes both additive manufacturing and off-the-shelf consumer electronics. The modern battlefield necessitates not only a highly adaptable and responsive logistics chain, but also Soldier equipment with sophisticated capabilities, including UAS. This research meets these needs by developing a 3-D-printable vehicle architecture that is customizable with parametric design scaling. A vehicle customization software tool currently in development is used to adjust vehicle design based on mission needs, manufacturing constraints, and available part inventory. This research also seeks to maximize the benefits of additive manufacturing via elimination of support material, reduction in part count and fastening hardware, and improvement in assembly time and complexity. These objectives are met by presenting several design prototypes to Marines in the II Marine Expeditionary Force to obtain feedback, and by conducting instrumented flight experiments to evaluate vehicle performance. Thus far, the vehicle designs resulting from this work demonstrate improvement in user feedback scores, part count and fastener use, and flight functionality.

### **Acknowledgments**

I wish to acknowledge the mentorship of Mr John Gerdes and the help of Mr Ryan Rogers, Mr Larry Holmes, Jr., and Mr Eric Spero.

### **Student Bio**

Spencer Folk is a rising junior pursuing a BS in mechanical engineering at Lafayette College (Easton, PA). His future plans include further research into additive manufacturing technology and the design of UASs. He hopes to have a future in either the aerospace or defense industry.

## **Atmospheric Renewable Energy Study No. 2 (ARE2): Background Research**

Forrester, Cadet Jenna

Renewable energy is becoming increasingly important in the everyday lives of Americans especially the US armed forces deployed overseas. In an effort to increase the survivability of and to support those Warfighters on the front lines, research has shifted toward creating a “greener” fighting force. Soldiers rely heavily on fossil fuels to power their operations at forward operating bases (FOBs) in Iraq and Afghanistan. This heavy reliance on nonrenewable energy requires other Soldiers to transport the fuel to the FOB in long convoys. These convoys are prime targets for the enemy, who reason that if they can destroy the supply of fuel, they can destroy the fighting force. The research conducted in ARE2 directly supports a resolution of this vulnerability. The ARE2 research, which includes atmospheric and power measurements and modeling, will help FOBs budget their fuel more appropriately and reduce the current fossil fuel requirements by integrating renewable energy resources such as solar power. The net result will be a reduced number of fuel convoys, putting fewer American lives in danger.

### **Acknowledgments**

I wish to acknowledge the mentorship of Ms. Gail Vaucher and her endless support and guidance.

### **Student Bio**

Jenna Forester is Second Class Cadet (junior) at the US Military Academy (Advanced Individual Academic Development), majoring in mathematical sciences, with a subfocus in nuclear engineering and a pre-med track. Her future plans include earning a commission as an Engineer Officer and then continuing her education in a physician’s assistant program or medical school.

## **Using Computational Tools to Aid in Understanding the Effects of Microstructure Heterogeneity in Energetic Materials**

Fortunato, Michael

Energetic materials are highly microstructured with significant heterogeneity. Coarse graining techniques are required to model these materials on a time and length scale necessary to observe the effects of microstructure heterogeneity on sensitivity. Using a reactive variant of the dissipative particle dynamics method, decomposition of the energetic material RDX was studied on the micrometer-length scale. This work describes the development of computational tools required to build RDX–polymer composite materials and detect void volume in those materials with a specific emphasis on maintaining computational performance when scaling to system size  $O(10^9)$  particles. The tools were built leveraging the parallel efficiency available in the open-source LAMMPS software package. Supplemental Python scripts make use of efficient vector computation provided by numpy and pandas and message passing interface (MPI) implementation provided by mpi4py.

### **Acknowledgments**

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## **Breakdown Voltage Geometry Dependence of Aluminum Gallium Nitride/Gallium Nitride (AlGaN/GaN) High-Electron-Mobility Transistors**

Franklin, L Nouketcha

The material properties of gallium nitride (GaN) make it an excellent material for the fabrication of future electronic devices in the power range of 0 to 10 kW. Figures of merit show superior performance of GaN transistors over their silicon (Si) counterparts in terms of breakdown voltage and operational frequency. GaN is exceptionally relevant because of its piezoelectric nature, which enables the formation of a quantum well at the aluminum gallium nitride/gallium nitride (AlGaN/GaN) interface. Depending on the Al content of the AlGaN layer, the quantum well can have a high concentration ( $10^{13} \text{ cm}^{-2}$ ) of electrons with high mobility ( $2000 \text{ cm}^2/\text{v}\cdot\text{s}$ ). Enhancement-mode GaN high-electron-mobility transistors (HEMTs) with breakdown voltages of 650 V are currently commercially available from vendors such as GaN Systems, EPC, and Transphorm. Despite the successful development of GaN HEMTs, current state-of-the-art GaN transistors perform significantly below expected theoretical limits. The primary challenge for the fabrication of GaN HEMTs is the capability of modulating the quantum channel without degrading device performance. In this work, we use the drain-current-injection technique to measure the breakdown voltage of depletion-mode devices. As opposed to the conventional high-voltage sweep methodology, the drain-current-injection method is nondestructive, independent of the gate-to-source voltage, and bypasses the challenge of finding the precise threshold voltage of the transistor. The devices for this study include GaN-on-Si devices with transition layers and GaN-on-sapphire devices without transition layers. Results reveal that GaN-on-Si devices with transition layers have  $10\times$  larger breakdown voltage; however, observed trans-conductance is  $3 \times$  lower for devices with transition layers. Experiments show that the drain-to-source breakdown voltage increases with the field plate overhang, gate-to-drain spacing, gate length, and gate width. Deeper data analysis reveals that the gate integrity likely plays a critical role in the drain-to-source breakdown voltage of GaN HEMTs, suggesting that the metal insulator semiconductor HEMT (MISHEMT) is likely the most favorable device topology for power electronic applications. Future work includes the simulation and modeling of MISHEMTs to investigate the appropriate dielectric material to be used for the fabrication of GaN transistors.



## **Vorticity Muffler Design Improvement**

Fry, John

Limiting vehicle noise plays a vital role in military acoustic stealth and commercial noise abatement. The US Army Research Laboratory's muffler patent uses fluid dynamic vorticity to manipulate exhaust gas velocity and pressures, reducing excessive exhaust noise. ARL's pursuit of military applications coupled with New Mexico's interest in stimulating oil and oil-dependent local economies resulted in a cooperative research and development agreement CRADA with New Horizons Foundation (NHF) to prototype commercial engine mufflers using ARL designs. The design criteria targets sound reduction, manufacturing efficiencies, and unit cost, while maintaining acceptable backpressure. Version 3 of the design refines Version 2 by applying a hydraulic diameter and flow impedance analysis to minimize performance degrading back pressure. An ARL-produced design package is being analyzed by the CRADA partner to evaluate fabrication requirements prior to creating the finalized 3-D computer-aided design models and prototype construction. Provisions for a test bed have already been supplied by NHF in the form of a 12-L diesel engine. Temperature and pressure sensors are being used to collect data at various rpm/engine load points. Version 3 design has been completed and is ready for prototyping. The goal with Version 3 was to maintain the favorable performance seen in Version 2 while reducing the back pressure created in the exhaust.

### **Acknowledgments**

I wish to acknowledge the mentorship of Mr William Ludwig. Mr Ludwig's experience in commercial industry have been a vast resource in my design and development process.

## **High-Performance Liquid Chromatography (HPLC) Analysis of Fermentation Metabolites**

Fu, Adele

High-performance liquid chromatography (HPLC) is an analytical chemistry technique used to separate, identify, and quantify each part in a mixture. It has been widely used in pharmaceutical manufacturing, drug detection in urine, research, and for medical purposes. Currently, research is being conducted on mechanisms that different bacteria and yeast use to break down food waste (which are rich in carbohydrates and other nutrients) in order to manage waste and to create energy that may be used on the battlefield (for example, butanol—a gasoline alternative—or ethanol). HPLC analysis is integral to the discovery of how quickly each organism can break down certain foods and how quickly food waste can be fermented. Concentrations of each metabolite from every fermentation are calculated based on external standard curves that are created with pure known compounds. Each type of sugar from the samples is analyzed as sources of energy. As the main source and subunit of energy for organisms, glucose has been suggested as a potential alternative source of energy (as opposed to fossil hydrocarbons). In addition to glucose, gluconate, galacturonate (a carbohydrate derivative), and grass have been experimented as sources of energy. These sugars have been studied separately but also in combinations of 2–3 sugars. Different time points and progressions of food waste and sugar breakdown is another condition that is varied to analyze each conditions effect on the fermentation process. The ultimate goal is to find the best organism and strategy to optimize the amount of desired energy rich products.

### **Acknowledgments**

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### **Student Bio**

Adele Fu has earned a bachelor of science in the biological sciences at the University of Maryland Baltimore County (UMBC). She previously interned at the National Institute of Drug Abuse in the summer of 2012. In the fall, she will enter the University of Maryland School of Pharmacy to begin a doctorate in Pharmacy and hopes to continue researching in the pharmacy field.

## **Using Optimization to Discriminate Brain Data**

Gauff, Ashton

In this project, we utilized optimization to discriminate brain data. Participants completed 2 cognitive tasks while ongoing brain activity was recorded from electrodes on their scalp. Our analysis examined whether we could identify what task the participant was performing from differences in the recorded brain time series. We modeled the relationship between input data (brain time series) and output labels (task A and task B) as an unknown function, and we found an optimal approximation of that function from among a family of functions. We employed stochastic gradient descent to minimize the estimation error known as the loss function. The optimal function from among our family of approximate functions, EEGNet, successfully discriminated brain data from a single participant with approximately 90% accuracy. Future research will apply EEGNet on data from more participants as well as develop approaches to adapt its architecture for the non-Euclidean domains.

### **Acknowledgments**

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### **Student Bio**

Ashton is a graduate student at Southern University A&M. He plans to receive his Master's degree in mathematics and physics with a concentration in mathematics. Ashton's past research includes work in stochastic processes and models with the NASA West Virginia Space Grant Consortium at West Virginia State University (WVSU) and mathematical models for financial markets with the Honors College at WVSU. Ashton is developing his thesis on optimization techniques with fuzzy stochastic parameters.

## **Investigate Qt-based 3-D Rendering System with Modern Open-GL context**

Gause, Benjamin

Many applications at the US Army Research Laboratory (ARL) that use 3-D graphic rendering to provide a simple, clear way to display data. Recently, the OpenGL application programming interface has deemphasized many of its original features like the fixed function pipeline and immediate mode. They have been replaced with modern software that can more efficiently exploit the parallelization of newer hardware. Qt, a cross-platform application framework, has classes that can handle this modern context of OpenGL. To explore the functionality of these classes, software was developed to render a 3-D object using Qt and OpenGL. The software can render any object specified in WaveFront OBJ file format and can rotate it with a click and drag of the mouse. The software developed in this project should be able to be integrated into many projects at ARL in order to provide better efficiency for graphic rendering.

## **Power Line Sensor Weatherproof Housing**

George, Alex

Energized electrical cables generate measurable magnetic and electric fields representative of the voltages and currents present in the conductors. The ARL Power Line Sensor (PLS) plates behave as an inherent DDOT electric-field sensor, while also housing additional sensors for magnetic-field monitoring. An embedded ARTEMIS-Mobile processing board is contained within to process, analyze, store, and transmit the electric and magnetic-field measurements in real time. Continuous power surveillance requires Warfighters to “drop-and-forget” the PLS under powerlines in potentially inhospitable environments.

This project explores the development of PLS weatherproof housing. 3-D printing was adopted as the primary means of manufacturing to minimize prototyping lead time and to improve characterization of cradle-to-grave design. Fused deposition modeling (FDM) and stereo lithography (SLA) are prominent 3-D printing technologies that circumvent historically expensive manufacturing processes through desktop adoption. FDM printer resolution is typically limited by nozzle diameter, whereas SLA printer resolution is only limited by the laser spot size. In addition to the ARTEMIS-Mobile, the housing must accommodate flux coils, signal amplification board, input/output ports, 2 BB-2590 batteries, and cable run-throughs for master–slave configurations as well as solar panel integration. The design addresses potential shorts between terminals of the DDOT sensor by adopting ribbed walls to prevent a continuous conductive path. Furthermore, the sensors are precisely placed to minimize magnetic-field distortions due to permeability of the components. After narrowing the scope of internal components, a FormLabs Form 2 SLA printer is used to develop 40% scale models of the PLS housing prior to outsourcing for large-scale FDM services. The assembled units will be tested in a number of environments to simulate the model’s ability to meet aspects of MIL-STD 810G and Ingress Protection. Additionally, internal electronics will be modeled to evaluate effects on magnetic flux. Once vetted, the PLS housing will be expected to protect embedded electronics from environmental elements and allow continued functionality.

### **Acknowledgments**

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## **A Tethered Drone System for Multifunctional 3-D Experimentation**

Girma, Jonathan

Tactical ad hoc communications and networking in austere infrastructure-poor Army-relevant environments, including dense urban, indoor, and subterranean scenarios, pose a significant challenge. To tackle this challenge, innovative and unconventional communications and networking capabilities are required. A key aspect of this research effort is experimentation involving various stationary and mobile network nodes in relevant scenarios. To conduct outdoor experiments and demonstrations, a hexacopter flyer system (DJI s900) will be outfitted with various sensors, surveillance, and communications hardware. The flyer will be attached to and powered by a tether system (LIGH-T system from Elistair). It will carry several types of radios, including Xbee 802.15 radios and software-defined radios, while recognizing that the overall weight of the system should be minimized. It will also consist of an onboard computer, a TX1 with a Leopard Imaging (LI) carrier board, and an LI camera. The drone consists of a hexacopter, inertial measurement unit, GPS receiver, and flight controller.

Building this system will require the integration of several stock components that are not included in the flyer assembly kit. A handheld radio transmitter will be paired with a radio receiver on the flyer for teleoperation. A power distribution system will be implemented to power peripheral sensors on board the flyer with the use of a lithium polymer battery. A single-board computer will also interface with sensors and provide computation power. Another radio transmitter and receiver pair will provide telemetry and video from the flyer down to the operator on the ground. In close collaboration with US Army Research Laboratory employees, I will be contributing to this project and demonstrating a networking experimentation with surveillance using this platform as well as other stationary and ground robotic platforms. The results of this effort will be documented as a conference paper and/or a technical report.

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## **CyberSteer: Cyber-Human Approach for Safely Shaping Autonomous Robotic Behavior in Real-World Applications**

Goecks, Vinicius G; Gremillion, Gregory M; Nothwang, William D

Modern approaches to train intelligent agents rely on prolonged training sessions, high amounts of input data, and multiple interactions with the environment. This restricts the application of these learning algorithms in robotics and real-world applications, in which there is low tolerance to inadequate actions, interactions are expensive, and real-time processing and action is required. This paper introduces CyberSteer, a novel approach to efficiently combine available human resources and deep reinforcement learning algorithms to reduce time and interactions required to shape meaningful behavior in robotic intelligent agents performing real-world tasks. CyberSteer combines nonexpert human operators for initial demonstration with intrinsic rewards-driven deep reinforcement algorithms for efficient state exploration and exploitation of combined intrinsic and human feedback signals. CyberSteer is tested in a hardware-in-the-loop unmanned aerial vehicle simulation environment, performing collision avoidance tasks taught by the human operators with minimal intervention and no external reward signal returned by the environment. This approach shows that the behavior of hardware-in-the-loop robotic systems can be shaped in a reduced amount of time when guided by a nonexpert human, who is only aware of the high-level goals of the task. Decreasing the amount of training time required and increased safety during training maneuvers will allow faster deployment of intelligent robotic agents in dynamic real-world applications.

## **Consolidation of Random Number Generation and Coordinate Transformations in Survivability Suite Engineering Simulation (SSES)**

Goel, Aniket

The SSES features comprehensive system-level modeling and simulations of active protection systems (APSs) for combat vehicles, which employs Monte Carlo sampling techniques to account for the stochastic nature of sensor measurements and component dynamics. In addition, information gathered from many disparate APS entities must be processed with respect to a common reference frame to maintain data fidelity. Given the disorganized structure of the APS legacy code, the research objective was to investigate potential solutions for the 2 critical aspects in the simulation process. A hypothesis was formulated that the reliability of random number generation and coordinate transformations can be improved if the called functions are restructured, centralized, and consolidated. The author leveraged a singleton design to ensure the existence of one and only one instance of a “random” class and developed wrapper functions to enhance abstraction and facilitate debugging for the heterogeneous information processing. It is concluded that generation of pseudo-random numbers can reliably represent the uncertainties encountered throughout an end-to-end APS event and yield reproducible results. Additionally, the code for coordinate transformations, which are handled through the operations of an abundance of vector translations and rotations, has become substantially comprehensible and manageable because of the consolidation efforts.

### **Acknowledgments**

I wish to acknowledge the funding from the Army MAPS program, and the mentorship of Dr Michael Chen throughout the course of my internship.

### **Student Bio**

Aniket Goel is a junior majoring in aerospace engineering, with a minor in engineering Leadership Development, at the University of Maryland, College Park. Goel’s previous experience includes an internship at the National Institute of Neurological Disorders and Stroke (NINDS) at the National Institutes of Health (NIH). Goel’s future plans are to attend graduate school, likely pursuing an advanced degree in aerospace engineering.



## **Study and Development of Highly Manufactural Direct Transfer and Patterning Technique for High-Quality Layered Material Processing**

Gramling, Hannah

Single layers (monolayers) of molybdenum disulfide ( $\text{MoS}_2$ ) are direct band gap semiconductors, with numerous potential applications in high-performance electronics and optoelectronics. Thus far, no method exists for transferring patterns of monolayer material from multilayer sources, including naturally occurring sources that provide material with lower defect density than grown material. The ability to transfer patterned monolayers is critical to building heterostructures of layered materials for devices. We introduce a method for the spatially controlled transfer of patterned single-layer  $\text{MoS}_2$  flakes, directly from mined crystals to a standard substrate. By using a slow, fluorine-based plasma etch in conjunction with an offset layer, we are able to isolate a single monolayer of the source material while still using conventional pressure-sensitive adhesive tape for transfer to the substrate. We demonstrate the successful use of this method to transfer monolayer patterns at the hundred-micron scale, showing that the transfer of large-area monolayers is possible. Back-gated transistors and transfer length method features made on the deposited material confirm good electronic quality after transfer to the substrate. The method could easily be scaled down to produce smaller features and would be straightforward to apply to grown material. This advance demonstrates the scalability of direct monolayer production from multilayer sources for mass device creation.

## **Photo-Cured Urethane Acrylate Resin Formulation for Additive Manufacturing**

Gray, Sydney (SEAP Student Army Research Laboratory)

UV-cured resins are polymers commonly used in additive manufacturing, specifically stereolithography (SLA). Urethane-acrylate (UA) resins are an interesting class of materials for SLA manufacturing because of superior toughness and the ability to control reactivity and materials properties by changing the number of double bonds per molecule and the chemical structure of the polymer backbone. However, most UAs are extremely viscous and require blending of small-molecule, low-viscosity monomers to reduce viscosity to a level suitable for SLA printing. Several UA monomers with differing chemical structures and properties, reactivity, and viscosity were surveyed for their applicability to the SLA approach. The UAs were blended with 2 monomers to reduce viscosity, which included isobornyl acrylate and isosorbide methacrylate. All formulations were cured by adding 1 wt% photo-initiator (Irgacure 184) to the formulation and exposing to a UV light source (320–390 nm wavelength, 75 mW/cm<sup>2</sup>) for 1 min. The formulations were investigated using dynamic mechanical analysis to evaluate the influence of the monomer composition on polymer network structure. The uncured formulations were measured for viscosity using a rheometer. The average viscosity, loss modulus, storage modulus, and tan delta (first derivative analysis) values were then plotted and compared to assess the feasibility of each formulation for 3-D printing applications. Ebecryl 230 was the UA monomer identified with the best combination of properties for SLA manufacturing. It had a low glass transition temperature and a homogenous network structure when mixed with isobornyl acrylate and retained toughness when inorganic fillers were added. Future evaluation of Ebecryl 230 will explore adding higher solids loadings and measuring tensile and fracture and tear properties. When we compared the reactive diluents, the isobornyl acrylate reacted well with the UA monomers by exhibiting a fairly narrow breadth in the loss modulus peak. However, isosorbide methacrylate resulted in nonhomogenous network structures when combined with UA monomers, likely a result of poor co-reactivity of the 2 monomers.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr E Jason Robinette and Dr Joshua A Orlicki.

## **Components for a Mobile Wireless RF Communication System**

Griffin, Lee

The combination of piezoelectrics and microelectromechanical systems (MEMSs) can result in devices with a wide range of applications, including resonators, energy harvesters, and various sensors. Currently, improvement of MEMS devices designed to operate in the RF regime has been of particular interest because of their use in both commercial and military satellites and aerospace systems. The work presented characterizes and analyzes new designs for various RF MEMS devices produced at the US Army Research Laboratory. Their integration to a proposed mobile RF wireless communication system was investigated via electrical characterization and developing a proof-of-concept demonstration of the proposed system. The RF circuitry of the proposed system consists of various RF MEMS, including switches, filters, and resonators. The electrical characteristics of these constitutive devices were independently probed via a vector network analyzer at both room and high temperatures. Furthermore, a customized smartphone modification was used to demonstrate the functionality of the RF circuitry.

## **Multiscale Study of the Pearlitic Microstructure in Carbon Steels**

Guziewski, Matthew C

Classical atomistic simulations and continuum models are used to predict the structure and mechanics of ferrite and cementite interfaces found in pearlitic steels. Atomistic models are constructed for cementite-ferrite interface orientation relationships that are commonly found in experiments. While all models show the formation of interfacial dislocation arrays, the structure and energy varies significantly between the orientations and different interfacial chemistries. Atomistic models show that the interface microstructures influence the mechanical properties. Tension and compression simulations reveal the effects of lamella thickness and ferrite-to-cementite ratio on both the elastic and plastic response of the systems. Results from the atomistic simulations are used to train a continuum model based on O-lattice theory and anisotropic continuum theory to quantify the Burgers vectors and stress fields. Additionally, tension and compression stress-strain relations are fit to an elasto-plastic continuum model based on composite theory, size effects, and yield point phenomenon allowing the prediction of mechanical responses. Additionally, work in the development of a synthetic driving force method to model grain boundary mobility and how it could be applied to pearlite in the future is also discussed. Using data acquired from atomistic simulations to train continuum models will greater enable microstructurally informed mesoscale prediction of steel performance.

## **Sub-millisecond Synchronization of a Drone**

Han, Sangjin

In sensor fusion, timing metadata are as important as the sensor data, itself. Each clock in each sensor runs freely and so every clock of a sensor may drift apart from the others over time. We propose a way to synchronize clocks such that the timestamps can be translated into a consensus timescale. Messages are exchanged over wired connections, timestamps are published via Robot Operating System topics, and the collected timestamps are used to build pairwise time-mapping functions in terms of drift rate and offset. If the network digraph of clocks is strongly connected such that there exists at least 1 returning path that connects all nodes, then we can compute the synchronization tolerance by the mapping functions along the path. An experiment with an embedded computer, a flight controller (Pixhawk), and 2 embedded cameras shows that the standard deviation of synchronization tolerance is less than 0.5 ms. Compared against the conventional “offsetonly” synchronization method, there is not only an improvement in terms of standard deviation of the synchronization tolerance, but this new method also mitigates the sudden change of clock offsets known as hard set synchronization.

### **Acknowledgment**

I wish to acknowledge the mentorship of EJ Shamwell.

## High Strain Rate Hardness of Tungsten Carbides

Hanner, Luke A; Swab, Jeffrey J; Pittari III, John

Tungsten carbide (WC) is used in the M993 and M995 armor-piercing rounds, giving individual soldiers antiarmor capabilities. WC is a cemented carbide composed of a hard WC main phase and a softer, ductile, binder phase. This study examines the role of the binder composition and percentage in the Knoop hardness at quasi-static and dynamic strain rates. In this investigation, 7 different binders were tested: 4 tungsten carbide-cobalt systems containing 10%, 15%, 20%, and 25% binder; 2 cobalt-free chromium nickel binders; and 1 binderless WC. Quasi-static Knoop hardness testing was performed at strain rates of  $10^{-3} \text{ s}^{-1}$  using a Wilson Tukon 3000 indenter. Dynamic Knoop hardness testing at strain rates of  $10^3 \text{ s}^{-1}$  were performed using a Dynamic Indentation Hardness Tester. This high-strain-rate testing bridges the gap between normal laboratory strain rates of  $10^{-3} \text{ s}^{-1}$  and ballistic strain rates of  $10^5$  to  $10^6 \text{ s}^{-1}$ . Therefore, the hardness response observed during dynamic testing is used to better understand what factors affect the performance of WC during ballistic events.

## **WebGL Build of ATLAS**

Harrigan, Hasani

ATLAS (Aerial Terrain Line-of-Sight Analysis System) is an application created in the Unity Game Engine; ATLAS is being created as part of the One World Terrain (OWT) project at the University of Southern California's Institute for Creative Technologies. OWT focuses on the collection of terrain data using drones and the use of that data. ATLAS allows a user to place red (enemy) and blue (friendly) units onto a 3-D mesh; the application can show a unit's line of sight (LOS), change the height of a unit, and plan a route for a unit to hit waypoints while concealing itself from an enemy unit's LOS. Currently, ATLAS is built as a Windows standalone application; however, Unity is a cross-platform game engine, so ATLAS can be built as a Web Graphics Library (WebGL) application. WebGL applications can only use a limited amount of random access memory (RAM); ATLAS uses a large amount of RAM to load meshes. Currently, ATLAS loads each tile with a high level of detail (LOD); then, the user can use ATLAS's functions. The basic idea of the new algorithm is to calculate the distance between the camera and each tile that is being loaded, use the distance to calculate the LOD to load each tile, load the tiles, and recalculate each time the camera moves.

## **Tribochemical Analysis of Silicon Nitride against Various Steels under Dry Sliding Conditions**

Harris, Michael D

Hybrid silicon nitride on steel tribological pairs is increasingly used in mechanical systems, especially when lower weight, higher working temperatures, and chemical inertness are desired. Transitions in the friction and wear behavior are associated with tribochemical reactions that occur when sliding and vary with different contact conditions. This study sought to understand this behavior under high-speed and high-temperature dry sliding conditions. Experimental results revealed the presence of a low-friction low-wear regime occurring at sliding speeds above 5 m/s. It is hypothesized that this reaction may be dependent on sliding speed and the frictional temperature rise at the point of contact. The temperature rise was analytically estimated to be greater than 1400 °C, which correlates well with the temperature rise necessary for a diffusive, potentially molten reaction between silicon nitride and steel. Experiments are ongoing to observe the speed-dependent transition to the lower-wear regime in situ and to determine if the same tribochemical reaction can occur at low sliding speeds with a high specimen temperature. This presentation reports the friction and wear behavior, tribochemical phase information, and estimated flash temperature rise for the dry sliding of silicon nitride on steel.

### **Acknowledgments**

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### **Student Bio**

Michael Harris holds a BS in materials science and engineering from the University of North Texas, and is currently pursuing an MS in the same field. Harris' past research experience includes tribochemistry of Ni-WC cold spray under elevated temperatures and tribochemical analysis of wear tracks of silicon nitride on C64 steel. His future plans include concluding experiments related to the behavior silicon nitride on steel at high temperatures and high sliding speeds.



## Meals Ready to Eat to ABE through CAC

Hellman, Caleb

### Commodity

Waste disposal, even in the most rural locations, is of utmost importance and becoming increasingly difficult. For example, on a Forward Operating Base (FOB), waste disposal might be limited to local municipalities, burial, or incineration, the latter potentially becoming dangerous. Due to the hazardous and limiting conditions faced on smaller and larger FOBs alike, biochemical systems are being researched to help with waste mitigation. A significant attribute of these systems is that they provide a method for point-of-need production of commodity chemicals or material precursors. To create these compounds, the degradability of the waste must be taken into account. A commonly encountered food waste, Meals Ready to Eat (MREs), are a high-energy food source containing a wide range of carbohydrates used by fermentative bacteria. In this study, MRE food scraps are being studied for their ability to act as a substrate for fermentation by *Clostridium acetobutylicum* for chemical production. In general, the use of *C. acetobutylicum* to degrade organic waste is a safer, more environmentally friendly alternative for the synthesis of chemicals and fuels. If proper systems are put into place, resources will not have to be allocated to the creation or isolation of such compounds already being accumulated with the use of *C. acetobutylicum* made through the degradation of waste.

## **Toward Efficient Human-Robot Dialogue Collection: Moving Fido into the Virtual World**

Henry, Cassidy

Our research program aims to develop a natural dialogue interface between robots and humans. We describe 2 focused efforts to increase data collection efficiency toward this end: creation of an annotated corpus of language interaction data (dialogue moves, structure, and relations) and robot simulation. This allows 1) faster, parallel data collection, 2) multiple site experimentation without physical robots, and 3) simpler control for human operators. Annotated corpus data supported the development of a graphical user interface to facilitate constrained interactions from the dialogue management perspective, which helps to serve as tractable training data for an automated dialogue system as well as increase the rate of dialogue collection. Our overall program objective is to provide more natural ways for humans to interact and communicate with robots using language and multiphase data collection experiments to incrementally automate the system toward the goal of full automation. This corpus will help address many issues encountered in understanding and processing situated human-robot dialogue. The simulation replicates our physical experimental environment while allowing greater flexibility in running experiments and allows validation of simulated results in a physical environment after completed data collection.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Kimberly Pollard of HRED, as well as Dr Matthew Marge of CISD, and the effort of all of our collaborators on the Bot Language project.

### **Student Bio**

Cassidy Henry is a senior undergraduate student in computational linguistics at the University of California, Los Angeles (UCLA) and a student research apprentice at the US Army Research Laboratory, West (ARLW). Her research at ARLW focuses on human-agent interaction under the scope of linguistics and dialogue. Her other research interests include phonetics, phonology, prosody, and she is currently building a spoken corpus of Kazan Tatar. Cassidy plans to move onto a PhD in Linguistics starting Fall 2018 and is a 2017 SMART Scholar who will continue on with ARL following completion of her degrees.

## **Super-Resolution for Color Imagery**

Herold, Isa

Super-Resolution Image Reconstruction (SRIR) is a method that can improve image resolution using a sequence of low-resolution images without upgrading sensor's hardware. In this work, we consider an efficient approach of super-resolving color images. The direct approach is to super-resolve 3 color bands of the input color image sequence separately. However, this direct approach requires 3 times of computation on super-resolution. We use an approach to transform images in the default RGB color space to another color space, where the SRIR could be used efficiently. Digital color images can be decomposed into 3 grayscale pictures, where each represents a different coordinate of its color space. In common color spaces, one of the coordinates (i.e., grayscale pictures) contains luminance information while the other 2 contain chrominance information. Then, only the luminance component is super-resolved using the US Army Research Laboratory's (ARL's) SRIR algorithm while the chrominance components are up-sampled based on ARL's alias-free image up-sampling using Fourier-based windowing methods. A reverse transformation is performed on these 3 pictures to produce a super-resolved color image in the original RGB color space. Five color spaces, including CIELAB, YIQ, YCbCr, HSV, and HIS, are considered to test the merit of the proposed approach. The results of super-resolving real world color images will be provided.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr S Susan Young.

### **3-D Visualization Applications for Android and Microsoft HoloLens**

Hossin, MD

In today's world, 3-D is becoming increasingly popular. Using a 3-D model helps us to explain details of what is inside and outside of an object. If we can develop apps for the 3-D objects and deploy them into Android operating systems, it will help us to better understand the objects. Furthermore, if we move forward 2-D to 3-D screens, it becomes more realistic to us. Microsoft HoloLens gives us the chance to get that experience. HoloLens is essentially a holographic computer built into a headset that lets us see, hear, and interact with holograms within an environment such as a living room or an office space. It is called mixed reality. Mixed reality, sometimes referred to as hybrid reality, is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects coexist and interact in real time. The main goal of my research was to develop apps for Android and Microsoft HoloLens using Unity 3-D Engine. We used the US Army Research Laboratory building 120 as the 3-D model. Different C# scripts are added in Unity to make zoom, pinch, and movement for user-friendly operation to get an idea of what is inside and around the building.

#### **Acknowledgment**

I wish to acknowledge the mentorship of Simon Su.

## **Enhanced Permethrin Adhesion via Atmospheric Plasma**

Hotvedt, Douglas

Permethrin is an insecticide that is nontoxic to humans. Army battle dress uniforms are treated with permethrin upon production to kill and ward off mosquitoes. According to MIL-DTL-44411E, uniforms can only be treated one time, and the treatment lasts for 50 launderings before the treatment is no longer effective. This means that uniforms must be replaced after 50 launderings whether or not the uniform itself is still sound. Atmospheric plasma treatment has been used to clean and activate materials, both organic and inorganic. Previous research showed that treating fabric with plasma allowed the fabric to retain a significantly greater amount of permethrin than traditional treatment methods. By testing different plasma treatment methods and their retention rates after laundering, we were able to observe a much greater retention rate in samples treated with plasma that had water vapors added to enhance the pretreatment cleaning process. Fabric treated with this method had enough permethrin to stay viable 40% longer than factory treated samples.

### **Acknowledgments**

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## **Pyroelectric Behavior of Ferroelectric Materials**

Howard, Michael; Espinal, Yomery; Hanrahan, Brendan

One of the objectives of the US Army is to be able to wirelessly transfer power to logistically challenging locations. Lead zirconate titanate (PZT) materials currently used for energy conversion are prone to high leakage current and electrical losses due to imperfections in the material. To combat this problem, we are developing ferroelectric-dielectric (FE-DE) composites to obtain thin films with low leakage current and low dielectric constants. Multiple thin film samples were created containing different PZT and hafnium oxide ( $\text{HfO}_2$ ) compositions. PZT was chemically deposited onto a silicon substrate.  $\text{HfO}_2$  layers were deposited using an atomic layer deposition system at 250 °C. Top and bottom electrodes of platinum were sputtered on at 500 °C. Finally, dielectric and pyroelectric tests were conducted on the samples. Initial results show that leakage current and dielectric constant values decrease as the dielectric material's thickness increases. This work shows that it may be possible to use an FE-DE composite material with tunable pyroelectric behavior as a base material to be used in Soldier power generation.

## **Using Diagram to Design an Arcsin Circuit**

Ivans, Robert

An automatic circuit design tool (Diagram) was used to design an arcsin circuit composed of 17 devices in Taiwan Semiconductor Manufacturing Company 0.25  $\mu\text{m}$  technology. Simulations of the resulting arcsin circuit indicated that the circuit required 280  $\mu\text{W}$  of power.

### **Acknowledgments**

I wish to acknowledge the mentorship of Kurtis Cantley and Justin Shumaker.

### **Student Bio**

Robert Ivans is a first-year PhD student majoring in electrical engineering. Ivans obtained a BS electrical engineering from Boise State University. His past research experience has resulted in 2 publications: “Spatio-Temporal Pattern Recognition in Neural Circuits with Memory-Transistor-Driven Memristive Synapses,” which was presented at the International Joint Conference on Neural Networks (IJCNN 2017), and “A CMOS Synapse Design Implementing Tunable Asymmetric Spike Timing-Dependent Plasticity,” which will be presented at the Midwest Symposium on Circuits and Systems (MWSCAS 2017). Ivans’ future plans are to continue investigating hardware implementations of learning machines.

## **Aerodynamics of a Modern Coaxial Rotor in High-Speed Flight**

Jacobellis, George

A model of the X2TD was constructed and validated with dynamics testing data and flight performance data (up to 260 kt) using the Rotorcraft Comprehensive Analysis System (RCAS). The viscous vortex particle method (VVPM) was incorporated into the RCAS model and run up to 260 kt. The stability of different trim procedures was investigated, revealing that certain choices of trim variables led to problems with convergence, and an appropriate trim procedure was chosen. The blade loads from the RCAS model were compared with flight test data, revealing that the lookup-table-based methods used in RCAS were lacking accuracy. A computational fluid dynamics mesh for the X2 blades is currently being constructed. An abstract for the American Helicopter Society's Aeromechanics technical meeting was written (will be submitted upon OPSEC approval).

### **Acknowledgments**

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### **Student Bio**

George Jacobellis is a fifth-year PhD student majoring in aerospace engineering. He obtained his BS and MS from the University of Texas (UT) at Austin, and is pursuing his PhD at the Rensselaer Polytechnic Institute. His previous research experience includes work with circulation control rotors, high-speed coaxial helicopters, optimization, and computational fluid dynamics. He plans to work full-time at the US Army Research Laboratory Vehicle Technology Directorate starting next year.



### **3-D Visualization for Designing View-Dependent Materials and Patterns**

Jefferson, Darius

For decades, the US Army has conducted studies to improve camouflage's effectiveness and has taken several different approaches to this. In most cases, either the camouflaged object was not moving or the people observing it were not moving. That demonstrates a need for further studies incorporating the effects of camouflage under motion. This research focuses on developing a simulated environment featuring camouflage patterns that change based on the user's point of view (i.e., view dependent). The purpose of this is to determine what is needed for seamless and unnoticed transitions between the different camouflage patterns as the observer moves around them. The simulation will also allow for the parametric adjustment of the number of viewpoints (also known as perspectives) supported by the camouflaged object. By doing so, the relationship between the number of object perspectives and camouflage-detection distance can be determined.

#### **Acknowledgments**

I wish to acknowledge my mentor, Andre Harrison.

## **Implementing Brain–Computer Interface (BCI) Using Open-Source Hardware**

Johnson-Bey, Ishmael

Brain–computer interface (BCI) systems allow for the direct communication between a user and a machine, allowing the human to send commands to the machine using brain activity. These systems pose a unique opportunity to expand the realm of human–computer interaction. However, conventional BCI systems comprise expensive and cumbersome hardware for processing electroencephalograph (EEG) data and require lots of time to set up. Open-source alternatives, such as OpenBCI, decrease the amount of hardware required for setup and the retrieval of EEG data. The utilization of open-source hardware to implement BCI was explored by deploying a P300 speller on a Raspberry Pi, using OpenBCI hardware. P300 spellers allow users to type text on a device using brain activity. They use the P300 event-related potentials (ERP), generated by the highlighting of characters in a grid, to determine which character the user wishes to type. The OpenBCI Cyton board reduces the amount of hardware necessary to conduct EEG recordings, only requiring the board itself and dry electrodes to read scalp voltages. The ability to deploy effective BCI systems on low-cost, small form-factor platforms is crucial to the development and adoption of BCI systems in real-world scenarios.

### **Acknowledgments**

I wish to acknowledge the mentorship of Brent Lance. I would also like to thank anyone who assisted on this project. Finally, thank you to ARL and Oak Ridge Associated Universities (ORAU) for the opportunity.

### **Student Bio**

Ishmael Johnson-Bey graduated with a bachelor’s degree in computer science and a bachelor’s in Neuroscience from the University of Delaware. He currently is a first-year biomedical engineering graduate student at Carnegie Mellon University. He plans to pursue a doctorate.

## **“Fatigue-Free” Platforms for the US Army: Exploring Damage Precursors and Prognostics System Implementation**

Joshi, Ghanashyam

Researchers from the US Army Aviation and Missile Research, Development and Engineering Center and Army Research Laboratory (ARL) have developed a holistic systems approach, Virtual Risk-informed Aviation Maneuver Sustainment (VRAMS), that integrates a wide range of technologies to achieve “zero-maintenance” goal. The VRAMS vision is more far reaching and inclusive than a similar effort by US Air Force researchers, named “Digital Twin”. The proposed research vision will fit in the Army’s science and technology efforts related to a) understanding of damage precursors and exploring advanced sensing strategies to catch them prior to the onset of rapid growth of microcracks or degradations and b) developing a robust risk-assessment and prognostics capability to help achieve “fatigue-free” capability with nearly zero maintenance over an acceptable useful life. The project will be focused on understanding and enhancing the current efforts of ARL research mentors and collaborators. The proposed effort will develop an aluminum 7075-T6 rivet-hole-fatigue prognostics system. The best practices from 2 ARL papers and related efforts by NASA and others will be used as foundation to make further progress.

### **Acknowledgments**

I wish to acknowledge the mentorship of Drs Robert Haynes and Jaret Riddick.

### **Student Bio**

Dr Ghanashyam Joshi received his doctorate in mechanical engineering from Michigan Technological University. He has served on faculty fellowships at the Air Force, NASA, Oak Ridge National Laboratory, National Institute of Standards and Technology, Boeing, Hewlett-Packard, and Ford. His current research is in the areas of fatigue, fracture, and damage of aerospace structural and high-temperature materials.

## **Dynamics of Active Matter**

Kiess, Alexander

We study single-particle dynamics in active-matter systems and observe similar phase transition behavior between local and global levels. Numerical simulations were performed in Matlab using the Vicsek model, which consists of self-driven particles that determine their velocity according to the average direction of their neighbors, plus some noise factor. Vicsek et al. documented phase-transition behavior in the global alignment of the particles with increasing noise. This effort studies local observables of a single particle and compares the results to the global alignment. It adapts a local order parameter from one used to study the glass transition, which samples the distance travelled by a particle in certain time intervals. We use this to identify ballistic and diffusive scaling regimes of particle trajectories, with a crossover near the critical point of the phase transition. Two other local parameters are used to track the direction of the particle's velocity instead of distance covered. Each produces similar phase-transition behavior as the global observable, indicating that macroscopic properties of the system can be inferred from single-particle tracking. This may contribute to studying properties of large active-matter systems, such as flocks of birds or drones, by following a single particle.

### **Acknowledgments**

I wish to acknowledge the mentorship of Adam Svenkeson.

### **Student Bio**

Alexander Kiess is a junior studying mechanical engineering at the University of Notre Dame. He might pursue a graduate degree in mechanical engineering or a related field.

## **Development of Extensible Markup Language (XML) Parser to Process Web Coverage Service Response**

King, Kamberlin

The Global Air–Land Weather Exploitation Model (GALWEM) is a unified model run by the US Air Force to improve military decision-making and advance nationwide capability. GALWEM’s unique quality is its capability of both regional and global modeling. GALWEM’s coverages were collected from Web Coverage Service (WCS), a web-based retrieval of coverages. The WCS Core and MetOcean Extension schemas established the basics for spatial and sequential extraction. The primary request type for the WCS Core used was GetCapabilities. GetCapabilities delivers an XML that is an encoded description of service properties and the data holdings offered by the server requested. In addition, the MetOcean adds the ability to list the base reference time for each coverage. After the coverage information is obtained, My Weather Impacts Decision Aid (MyWIDA) comes into play. Java programming language was used to create the program that parsed GetCapabilities.xml from WCS. The file was parsed in the coverage class comprising 3 methods: getCoverageID, getReferenceTime, and LatLongBox. The getCoverageID extracted all of the GALWEM coverage IDs; getReferenceTime extracted all of the GALWEM reference times; and LatLongBox extracted latitude and longitude for the model’s upper and lower corners. Then, the class was placed inside the interface IGetCoverage and implemented.

### **Acknowledgments**

I wish to acknowledge the mentorship of Subing Zeng.

### **Student Bio**

Kamberlin King is a senior pursuing a bachelor’s degree in Computer Science with the goal of a career in scientific research.

## **Understanding Changes in Medial Impulse during Load Carriage**

Koller, Corey

Dismounted Soldiers carrying approximately 100-lb loads while performing various tasks have increased risks of falls and stress-fractured feet. Increases in medial impulse—a by-product of heavy load carriage—indicate lower-extremity stresses. It is important to understand the relationships between changes in Soldiers' gait and increases in medial impulse during load carriage. This study develops a regression model to help understand relationships among medial impulse and key gait and anthropometric parameters. A stepwise multiple regression model using step width and cadence, total mass and height, and step-width variability as independent variables predicted medial impulse. Data from 6 Soldiers ( $24.5 \pm 2.65$  years;  $1.74 \pm 0.09$  m;  $80.35 \pm 14.82$  kg) walking on an instrumented treadmill for 5-min periods between 3-mile laps of a cross-country course (up to 4 repetitions, 12 miles total) were analyzed. A strong relationship between medial impulse and the combined independent variables ( $R^2 = 0.967$ ) was found. Step width had the highest relative importance. Leave-one-out cross-validation resulted in a root-mean-square error of approximately 8%. Future research validating the regression model and determining which predictor variables are modifiable to develop techniques (e.g., exoskeletons) manipulating these variables could improve medial impulse and reduce Soldiers' injuries and fall risks.

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### **Student Bio**

Corey Koller is a third-year graduate student at the University of Delaware pursuing an MS and PhD in biomechanics and movement science. He received his bachelor's degree in bioengineering at the University of Maryland–College Park in 2015. Koller hopes to continue in military biomechanical research.

## **Risk-Aware Sequential Decision-Making under Model Uncertainties: Applications in Smart Grids**

Kuppannagari, Sanmukh R

Real-world Army applications require rapid decision-making under tight timing constraints over a short- or long-term horizon using uncertain data, and the decisions need to consider the risk of tail-end “black swan events”. Such events can be rationalized in hindsight but come as a surprise while making decisions and have a significant impact. The current optimization frameworks (convex optimization, Markov decision processes, etc.) fail to model such applications. Hence, the objective of this work is to develop a theoretical framework that will perform “sequential decision making” in a “risk aware” manner using “uncertain” information. The framework will consist of fast approximate-dynamic-programming-based algorithms to perform decision-making within the timing constraints, a data-driven model to qualitatively capture the uncertainties, and a terminal cost function to model the tail-end risk. The framework will be validated by modeling the problem of net load balancing in a smart grid with high solar photovoltaic penetration and integrated storage.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Rajgopal Kannan for his continued support and guidance in carefully defining the problems and developing the solutions.

### **Student Bio**

Sanmukh R Kuppannagari is a fourth-year doctoral candidate in computer engineering at the University of Southern California. He received his Bachelor of Technology degree in computer science and engineering from the Indian Institute of Technology, Guwahati. His future plans are to continue research in developing optimization frameworks for various applications.

## **Web-Based Interface for Distributed Smart Sensor Nodes**

Lawler, Brendan

Electric power is a critically important resource for the operation of US Army bases; thus, the Army is looking for ways to measure and analyze its consumption. To that end, the US Army Research Laboratory is developing the ARL Real-Time Electric and Magnetic Integrated Sensor (ARTEMIS), a mobile power-sensing platform that can measure power and voltage in a current by sensing the electric and magnetic fields. A web application that has been created to analyze and display the information from the ARTEMIS sensors sends data to the user via WebSockets. However, computers on networks run by the US government or other large organizations are behind comprehensive firewalls, set up to prevent web connections other than the standard hypertext transfer protocol (HTTP) port and other explicitly listed standard exceptions. These firewalls block WebSocket connections, preventing data transfer to clients on more restrictive networks. After other options were considered, the application was configured to connect to the database via a series of recursive asynchronous Javascript and XML (AJAX) calls, allowing it to function on any network with standard web-based ports. Utilities have been created to view data from distributed power-sensing nodes in a variety of ways, including calendar views that illustrate trends over longer time scales. Additionally, sensor-side development has produced new application programming interfaces (APIs) for communications with deployed sensors.

### **Acknowledgments**

I wish to acknowledge the mentorship of Brandon Parks.



## **Loop Closure in Landmark-Based Navigation**

Lee, Jaden

One of the most challenging problems in robot visual navigation is how to learn to generalize, to be robust across environments. A novel approach to developing robust, autonomous landmark-based navigation is to leverage behavioral and brain signals from human navigation. Previously, the Symbolic and Sub-symbolic Robotics Intelligence Control System (SS-RICS), a correlation-based novelty-detection algorithm comparing the input images against a library of previously seen images, was developed. Here, SS-RICS was applied to analyze segmented navigation videos from a video-mediated scene-recognition task. A previous analysis (Files et al. 2016) compared human landmark recognition from these videos against the FAB-MAP 2.0 algorithm but not the SS-RICS algorithm. This author's research began by labeling 418 robot navigation videos from a military operations in urban terrain (MOUT) training site using SS-RICS. In each video, novelty quotients were collected after every 10 frames; results were compared across 5 gradient levels (change-detection thresholds). Increasing the gradient increased the proportion of "novelty" quotients versus "boredom" quotients. In the future, these SS-RICS novelty quotients will be compared to human behavior and electroencephalography (EEG) signals from the same videos.

### **Acknowledgments**

I wish to acknowledge the mentorship of Chou Hung, Troy Kelley, Benjamin Files, Sean McGhee, and Jonroy Canady.

### **Student Bio**

Jaden Lee will be graduated in 2018 from the Thomas Jefferson High School for Science and Technology in Alexandria, Virginia. His previous research experience is in salamander ecology and in Botball robotics. Lee plans to major in engineering in college.

## **Mold–Yeast Consortia Convert Food Waste to Alcohol for Vapor-Fed Biohybrid Fuel Cells**

LeFors, Hannah M; Jahnke, Justin P; Benyamin, Marcus S; Mackie, David M

Some naturally occurring molds secrete abundant amounts of enzymes that can break down components of food waste (or biomass, generally). Moreover, the molds' hyphae penetrate deeply into the waste, eliminating the need for mechanical grinding. Simple sugars are thereby produced in solution, and yeasts can turn these sugars into alcohols faster than the molds can absorb them. For example, consortia of *Aspergillus oryzae* and *Saccharomyces cerevisiae* on uncooked rice achieve concentrations of 13% ethanol in 10 d at room temperature. Fourier-transform infrared spectroscopy can track the concentrations of various metabolites such as sugars (e.g., glucose and maltose), longer chain carbohydrates, and ethanol. Fuel cells (FCs) can be directly coupled with these mold-enabled yeast fermentations but, in order to do this effectively, one must ensure the fermentation and the FC do not harm each other. This can be accomplished using either a reverse-osmosis membrane or gas bubbling. Such “biohybrid FCs” (BHFCs) combine the best of biological and abiological components. BHFCs can continually extract ethanol from ongoing consortia, producing electricity and either purified water or feedstock chemicals. Mold–yeast BHFCs can run for weeks or even months with no attention other than the addition of water and waste. Importantly, BHFC current densities are comparable to those from the same FCs run on pure ethanol–water mixtures, which are orders of magnitude higher than those achievable with microbial FCs.

This research was presented by coauthor Hannah M LeFors at the August 2017 meeting of the American Chemical Society in Washington, DC.

## **Positional Control of Trapped Ions in Paul Traps**

Leslie, Torian

Trapped ions have several desirable features for use as a node of a quantum network. Their long-lived internal states, ultraviolet/visible photon emission, and the well-established mechanisms for control/readout make them attractive systems for use within quantum networks. Although these systems have seen remarkable progress with positional control, there are still significant challenges in integration with optical elements. Positional control of the ion with respect to an optical fiber allows for photons from the ion to be efficiently collected and could offer a path to improvement of photon collection. Improved collection efficiencies translate directly into improved data rates in a multinode quantum network. Given the various trap geometries in use (grouped into symmetric and asymmetric traps), it would be beneficial to develop a model, useful for any trap, that predicts the fractional positional change with respect to a fractional change in the trapping potential. This work began with testing electric-field calculations against published works on a planar symmetric trap. After confirming the simulation worked properly, the next step was in-depth analysis of a rod trap. Various aspect ratios were tested in order to find the optimum geometry that gives the most control when moving ions. This work presents a scaling of the fractional positional change to the fractional potential change over range aiming to reveal a universal scaling of the ion's motion.

### **Acknowledgments**

I wish to acknowledge the mentorship of John Hannegan II, Dr James Siverns, and Dr Qudisia Quraishi.

### **Student Bio**

Torian Leslie is a senior majoring in electrical engineering at Morgan State University. Leslie plans to continue pursuing a bachelor's degree in electrical engineering with hopes of pursuing a career in robotics.

## **Synthesis of Aldehyde-Functionalized Phenolics for High-Performance Coatings**

Lyon, Carly B; Lastovickova, Dominika N; Sibi, Makund; La Scala, John J

In collaboration with researchers at the North Dakota State University (NDSU), this study explores the development of aldehyde-functionalized crosslinkers for its utility in the production of biobased polyurethane materials without the use of harmful isocyanates in applications such as coatings, foam cushioning, and biomaterials. The specific crosslinkers that were studied include one comprising a benzene core and the other a furan core. The furan-based crosslinkers were synthesized by the researchers at NDSU while the development and optimization of the phenyl-based crosslinkers was performed at the US Army Research Laboratory. Initially, the phenyl-containing crosslinkers were synthesized by formylation of bisphenol A with paraformaldehyde under extremely dilute conditions. Different variations of Duff reactions were also explored but resulted in a less than 5% yield. The formylation with paraformaldehyde was then optimized to produce the desired phenyl-based crosslinker on a 20-g scale with an 85% yield. The next step in this study will explore preparation of polyurethane polymer and measurement of thermal and mechanical properties. Differences in the polymers properties between the 2 crosslinkers will enable measurement of structure–property relationships for these materials and help to identify formulations of isocyanate-free polyurethane materials for various Department of Defense and commercial applications.

## **Macro-Scale Fabrication of Nickel–Titanium (NiTi) Shape-Memory Lattice Structures**

Maio, Andrew

Extensive research exists on potential applications for shape-memory alloys in areas including actuators, medical implants, and structural dampers. Recent development of hollow-tube, metallic-lattice structures exhibiting unprecedented strength–density ratios allows for the implementation of shape-memory alloys in lattices capable of exhibiting these enhanced mechanical properties in addition to reversibility of plastic deformation through advantageous martensite-to-austenite phase-change temperatures. This work presents the implementation of nickel–titanium (NiTi) hollow-tube lattices with octahedral geometry and varying tube-wall thickness. These structures were produced through sputtering NiTi onto a polymer lattice, which was etched away leaving hollow-tube geometry. Analysis of theoretical buckling and yielding stresses for NiTi lattices determined that parameters for lattice-cell geometry can be tuned to fail in yielding or buckling. It is expected that compression testing of NiTi lattice structures will exhibit high failure stress at low density, while also adding shape memory at low transformation temperatures. With the implementation of this study, there is promise for low-density, tunable shape-memory materials to be used in high-strain applications. High-energy loading could be dissipated and deformation recovered to allow for further use. Possible future warfighter applications include robotic actuators and low-density bulletproof materials.

### **Acknowledgments**

I wish to acknowledgment my mentor, Gabriel Smith.

## **Acceleration Feedback Control for Small Fixed-Wing Unmanned Aircraft Systems**

Maio, Angela; Gremillion, Gregory; Nothwang, William; Humbert, Sean

Rejection of external disturbances is vital for aircraft flying in environments with dynamic flow fields and especially for small aircraft, which are particularly sensitive to these disturbances. Fixed-wing vehicles are generally controlled using successive closure of position- and velocity-state feedback loops. The successive loop-closure method ignores aerodynamic coupling and fails in the presence of strong gusts or aircraft damage. Existing multi-input–multi-output (MIMO) control methods may include aerodynamic coupling and provide more robust performance but still respond slowly to high-speed gusts because they feed back lower-order states like position and velocity.

This study aims to develop a MIMO control methodology to feed back translational and rotational acceleration-state estimates from distributed accelerometers on a simulated fixed-wing aircraft, enabling quicker rejection of disturbances. The novelty of this research is in its use of these acceleration states in inner feedback loops to perform disturbance rejection on a fixed-wing vehicle with distributed acceleration sensing and estimation. The acceleration-feedback approach can be implemented on any fixed-wing vehicle by mounting accelerometers to the body and wings and adding an inner feedback loop to the existing autopilot to reject disturbances before they propagate to lower-order states. Using a small Unmanned Aircraft System (UAS) model and robust control-analysis tools, flight simulations were performed with and without acceleration feedback and quantified the improvement in disturbance rejection. This work also examined the effects of sensor placement and noise on acceleration-state-estimation uncertainty and how this uncertainty impacts the effectiveness of acceleration feedback. The resulting augmented autopilot enables a small fixed-wing UAS to fly through turbulent, gusty environments by improving disturbance rejection.

## **Quantifying Visual Perception Before, Upon, and After an Eye Fixation**

Mallick, Rohit

Most of the past research in visual attention has been within eye-fixation-constrained paradigms. However, eye movements are an essential component of visual perception in real-world tasks. Visual search, in particular, requires a clear understanding of the relationship between eye movements and target detection. It is within this context that visual perception, quantified by behavioral accuracy and response time, in close temporal proximity to an eye fixation, was investigated. A gaze-contingent experimental paradigm was created where subjects were instructed to saccade to and fixate a location. At various intervals relative to fixation onset, a target stimulus (Gabor pattern) was presented at the location requiring a speeded discrimination response based on the stimulus orientation. Stimuli appeared during the saccade before fixation (trans-saccade), upon or after (50–600 ms) fixation onset. Overall, the results showed target-reaction time was faster shortly (~100 ms) after an eye fixation compared to trans-saccadic and longer (300–600-ms) post-fixation intervals. Despite differences in reaction time, accuracy was near ceiling in all conditions. The results suggest visual perception as assessed with reaction time may be enhanced shortly after fixation, but is short-lived. Future research will investigate the temporal resolution of post-fixation enhancement using more perceptually demanding paradigms.

### **Acknowledgments**

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### **Student Bio**

Rohit Mallick will be a sophomore at Purdue University in 2018. His internships with the US Army Research Laboratory and Oak Ridge Institute for Science and Education, as well as classes taken at Purdue, have encouraged him to pursue a bachelor's degree in computer science and to aim later for a master's degree.

## **Modeling RDX Decomposition Products with Mesoscale Particles**

Mansell, J Matthew

The properties and behaviors of energetic material (EM) composites are believed to be heavily influenced by their microstructure, including the sizes, shapes, and densities of EM grains, binder-filled regions, voids, cracks, and dislocations. These features have dimensions on the order of several micrometers to hundreds of micrometers. Their influence on the initiation process is difficult to measure experimentally and, hence, poorly understood. Therefore, predictive models of EM composite chemistry and mechanics at this scale would provide enormous value to manufacturers and users by enabling material optimization and quality assurance. EM models that explicitly include every molecule have been shown to be far too computationally demanding to be useful at this scale for the near future. Therefore, this work develops software tools to utilize the Dissipative Particle Dynamics (DPD) method—a single DPD particle represents many molecules—which is extended to include chemical reactions. A major component of these tools is a Product Gas Model (PGM), which handles the effects of reaction products on the properties of the DPD particles. Previously, the PGM has suffered from inaccurate reproduction of thermodynamic and structural properties as well as a computationally expensive scaling algorithm. Here, this work discusses the development of a new version of the PGM that is intended to overcome the deficiencies of the prior version; also, it compares the performance of the 2 methods in simulating the product gas generated by the EM known as RDX (1,3,5-trinitro-1,3,5-triazinane).

### **Acknowledgments**

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## **Computational Investigation and Design Study of Adaptive Gas-Turbine-Engine Turbomachinery Rotor Blades**

Mares, Seth

The objective of this research is to explore the relationship between gas-turbine-engine performance during off-design conditions and the incidence angles of turbomachinery rotor blades. Gas-turbines engines are generally optimized to operate at nearly a fixed speed with fixed-blade geometries for a unique operating condition. When the engine operates at conditions away from the design points, the aerodynamics are significantly altered and can lead to a degraded performance. A possible way to increase the operating range is to articulate the rotor blades and adjust the nozzle vanes to maintain the flow-incidence angle. This work utilizes a state-of-the-art computational fluid dynamic tool to model a single-stage turbine with articulating rotor blades. The study is performed using a Reynolds-averaged Navier–Stokes turbulence model coupled to a rigid body fluid–structure-interaction code. The study is performed at 2 operating points including the baseline and off-design condition with a range of fixed blade-incidence angles for each. The key variables of interest include the forces and moments on the blade surface, torque, power, and efficiency. The results will be used to guide viable smart-material solutions for turbine-blade articulation for novel engine designs.

### **Acknowledgments**

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### **Student Bio**

Seth Mares currently is a fifth-year undergraduate majoring in mechanical engineering at Michigan Technical University. Mares plans to continue his research engagement with the US Army Research Laboratory through a Cooperative Research and Development Agreement, complete his Bachelor of Science degree, and possibly attend graduate school.

## **Cognition-Driven Sampling for Scientific Visualization (SciViz) Analytics**

Masiane, Moeti

Even though the use of high-performance computing (HPC) is highly beneficial, HPC's use presents challenges. The high costs associated with procuring and running the HPC systems, vast benefits of HPC, and long execution time of scientific simulations running on these systems lead to a "perfect storm" in which computer hours are in high demand. Scientific Visualization (SciViz) is used to visualize the results of these simulations. Long execution times associated with SciViz are made even longer by the inherent iterative nature of simulation. Waiting for weeks for the results of simulation is not unheard of in the world of SciViz. This paper presents a case study, user study, and proposal for a technique for reducing the overall run time of SciViz applications in order to reduce the impacts of SciViz on organizations' financial bottom line. This technique allows scientists to control how long their simulations and visualizations run. The result is a decrease in the amount of generated simulation data and an expansion of the capabilities of SciViz on HPC. Using results from these studies on human cognition, this work generates metrics that help place SciViz decisions surrounding the cognition versus risk trade-off into the scientists' hands.

### **Acknowledgments**

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### **Student Bio**

Moeti Masiane is a third-year doctoral student majoring in computer science. His past research experience was in Security and Information Visualization.

## **Simulation in the Loop for Navigation and Control in a Dynamic Real-World Environment**

Maxey, Christopher

Developing and testing on hardware can be a limiting task due to restrictions in the testing environment, sensor capability, or data set available in regard to training. Simulation can offer benefits that real-world testing cannot, such as flexibility of environment and objects simulated within; however, such simulated environments often make sacrifices and assumptions that make them less than ideal when compared to the real world. This paper proposes to combine the 2 testing paradigms in order to leverage the flexibility of simulated environments with the high fidelity and realistic settings of real-world environments. The methodology employed involves the collection of sensor data from real-world robots that are controlled via navigation planning through a simulated environment in Gazebo. A highly accurate Virtual User Concept (VICON) system is used as a bridge between the real and simulated worlds, which is necessary in order to keep the 2 worlds synced. Navigation planning and obstacle sensing are done within the simulation, and motor commands are sent back to the physical robots. Accurate control of the physical robots can be achieved solely by updating the pose of the simulated robots via the VICON system as the physical robots move in response to the commands. This can free up restrictions the real-world environment may place on testing, such as limited sensing capabilities. Furthermore, objects can be added entirely within simulation that do not have a corollary within the real-world environment, providing further flexibility in what can be done with testing.

## **Electron Transport in Monolayer Molybdenum Disulfide (MoS<sub>2</sub>) Field Effect Transistors**

Mazzoni, Alex

2-D semiconductors such as molybdenum disulfide (MoS<sub>2</sub>) are uniquely qualified for flexible electronics due to their extremely high elastic strain limit and sizeable bandgap. To investigate the viability of US Army Research Laboratory (ARL) in-house MoS<sub>2</sub> for electronic applications, radio frequency (RF) transistors using ARL-grown MoS<sub>2</sub> were previously fabricated and tested to extract a low-field mobility and high-field carrier velocity. In this work, electron transport is investigated using the Monte Carlo method to better understand the transport and ultimate device performance limitations. A space-dependent Monte Carlo program was written in MATLAB following a deformation potential model that included all relevant phonon scattering mechanisms for electrons in both the K and Q valleys. Results are analyzed for various values of  $E_{qk}$ , the energy separation between the 2 conduction band valleys. Results indicate current mobility and carrier velocity in ARL transistors are substantially below the theoretical maximum, likely due to impurity scattering.

## **Marksmanship Performance as a Function of Magazine Type**

McGinnis, Kaitlin

A 30-round magazine may be limiting when Soldiers need to engage numerous targets. Thus, a plausible solution would be to increase magazine capacity (e.g., 60 round drum). The current investigation measured accuracy, performance, workload, shot hit interval, and task completion time of 2 magazine conditions to determine if increasing magazine capacity leads to decreased performance. Four US Army Research Laboratory (ARL) participants completed 3 trials for each of the conditions (drum vs. magazines) following a repeated measures design. During the marksmanship task, each participant fired 60 shots, focusing on accuracy and speed. To index workload each participant wore an electrocardiogram (ECG) monitor to measure heart rate variability (HRV) and completed a workload questionnaire after each trial. There was no difference in the subjective measure of workload; however, HRV was greater during the drum magazine condition ( $p < .001$ ). There was no difference between the conditions for either of the accuracy measurements or shot hit intervals. However, a significant decrease in task completion time was shown for the drum magazine ( $p = .002$ ). This study did not show impairment in performance of the 60-round drum over the 30-round magazine and would, therefore, be a reasonable option for engagements requiring more than 30 rounds.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr James Head.

### **Student Bio**

Kaitlin McGinnis is a PhD student at Auburn University majoring in kinesiology. She works in Auburn's Warrior Research Center under the direction of Dr Jo Ellen Sefton. She completed her undergraduate degree at Slippery Rock University and master's degree at East Stroudsburg University, both in athletic training. Her goal is to work in a research laboratory examining human performance and injury prevention in the military population.

## **EEG Sonification in a 3-D Virtual Environment**

Miller, Joshua R.

Electroencephalography (EEG) is a neuroimaging method that allows researchers to measure the electrical activity of neurons using electrodes placed on the scalp. However, EEG activity is difficult to interpret by a general, non-expert audience, especially with large numbers of electrodes. This project uses virtual reality to place the viewer “within” someone else’s brain where they can both see and hear virtual representations of EEG signals in real time. An initial prototype of this system uses the wireless g.Nautilus EEG headset for data streaming via lab streaming layer (LSL) and Python scripts for data processing. These data are sent to a virtual 3-D environment designed in Unity, converting data to power light and audio sources with frequency-band-specific power measured from the EEG cap. A large section of this project was sonification of these EEG signals and the most effective method was to modulate the audio with some type of larger feature. For an initial test of the system, the ratio between alpha (8–13 Hz) and beta (13–30 Hz) frequency power in EEG signals was used to determine instrument selection (percussive or melodic) and volume level for each audio source mapped to electrode locations projected in 3-D audio space.

### **Acknowledgments**

Mentors Dr Jeremy Gaston and Dr W David Hairston are acknowledged for their continued feedback and encouragement throughout the project; Mr Paul Groves for creating the visualizations in Unity; Mr Syed O Abdali for his work on EEG signal processing; and all those who offered their time to help with the project.

### **Student Bio**

Joshua Miller is a junior at the University of Rochester majoring in audio engineering. He attended programs for audio engineering and computer music at both the University of Rochester and Goucher College. At the US Army Research Laboratory he worked on Project CLIVE. He hopes to earn a master’s degree in electrical engineering and continue his passion for audio.

## **The Efficient Prediction of Molecular Dynamic Simulation Potentials**

Moghe, Ryhan

Molecular dynamics simulation is computationally expensive due to variance of inputs for the Newtonian motion equation. Inputs with high frequency take magnitudes more steps to solve potentials, and it is nonlinear in all degrees of freedom. The purpose of this project is to create an optimized way to determine machine-learned potentials based on an atom's trajectory, energy, and force. To decrease the number of degrees of freedom and increase the computational efficiency of molecular dynamics simulation there are 2 methods used: coarse graining and predicting potentials. For course graining the main focus is temporal separation, parsing the inputs into degrees of freedom based on frequency. Solving for high frequency associated degrees of freedom can yield inefficient and time-consuming results, but solving for only low frequency associated degrees of freedom yields only efficient results. Once the low frequency associated degrees of freedom are obtained, the potentials can be found. Current requirements for potentials are that they must be low complexity, reproduce forces given new data, and predictive. Since the high frequency data was thrown out and the potential cannot be solved exactly, it must be predicted. There are 2 ways to do this: through a nonlinear mathematical solver or through machine learning.

### **Acknowledgments**

Mentor Christopher Rinderspacher is acknowledged.

## **Gear Tooth Crack Propagation**

Mohammed, Nelson

Gear tooth crack propagation research contributes to the ongoing drive for innovation and improvement of the Army's vehicle technology to ensure the safety of Soldiers. As gears are subject to degradation due to a number of factors, there is an increased focus on early damage detection. This research is to improve the current methods of crack detection in gears as well as predicting the remaining lifespan of a gear once a crack is initiated. The first phase of the project involves initiating a fatigue-induced crack into the root of a spur gear tooth by using an MTS Systems Corporation single-tooth bending fixture. Once initiated, the crack is verified using an acoustic microscope. Propagation sensors are then placed on both faces of the gear to monitor the spread of the crack while the gear is tested in a gearbox. Accelerometers are also used to monitor the vibration signals while the damaged gear is in testing. The goal is to propagate the crack so that a damage assessment can be conducted as well as monitor the conditions under which the crack propagated.

### **Acknowledgments**

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### **Student Bio**

Nelson Mohammed holds a bachelor's degree in applied engineering technology from North Carolina Agricultural and Technical State University. His post-baccalaureate studies were at Central Piedmont Community College, and he conducted research at the US Army Research Laboratory's Human Research and Engineering Directorate. He plans to pursue a master's degree in mechanical engineering at the University of North Carolina at Charlotte.



## **Advance Design and Manufacturing (ADM) Efforts**

Mohammodu, Zachary

When it comes to communications between an unmanned aerial vehicle (UAV) and a base station on the ground, range of communication is vital. To simulate how far a UAV can travel while maintaining connectivity with its base station, WIFI (802.11 waveform) parameters from the US Army's Edgewood Chemical Biological Center (ECBC) Array Configurable of Remote Network Sensor (ACORNS) were entered into the US Army Research Laboratory's (ARL) connectivity analysis instrument SAGE.

## **Acknowledgments**

Mentors David Amaral and Chika Nzelibe are acknowledged.

## **Evaluating Robot Behavior in Response to Natural Language**

Moolchandani, Pooja

There is interest in understanding natural robot behavior in response to a natural language instruction, and more broadly, the relationship between language and robot behavior. Due to a limited understanding of what people expect robots to do in response to natural language, the “naturalness” of robots is defined. The goal is to determine what variations of execution constitute as natural robot behavior. Many parameters exist that are criteria under what it means to be natural. Given an instruction, variations of these parameters constitute a majority of possible robot actions. A survey was conducted with a robot executing 8 instructions. For each of 8 instructions, the robot executed 3 possible variations of interpretation. It was hypothesized that robots behaving in a predictable manner will be rated as more natural by humans. How a robot approaches navigation in various situations from natural language was examined, and the responses gathered were analyzed to determine what variations exhibited natural robot behavior. The goal is to gain greater understanding on what the qualifying factors are for being natural. This research aims to better understand the open question about naturalistic algorithms that can be executable for a robot in human-robot interactions.

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### **Student Bio**

Pooja Moolchandani is a junior at the University of Southern California majoring in mechanical engineering and minoring in technology commercialization. She previously researched for Medtronic, Inc. in their medical device design division. She was also a summer intern at the US Army Research Laboratory in Los Angeles, California, where she worked for the Bot Language project in developing the simulation platform to further research in human-robot dialogue and teaming.

## **A Comparison Study of Carbon Polymer Electrodes for Electroencephalography (EEG) Recording**

Nguyen, Christina

Electroencephalography (EEG) is the measurement of brain activity via electric potentials on the scalp. Many EEG systems lack adequate translation into the real world due to discomfort and setup complexity. The US Army Research Laboratory (ARL) developed a soft, polymer electrode that reduces setup complexity while improving comfort and safety. Bench testing was performed prior to testing the ability of the polymer electrodes to record quality EEG in human models. Using a custom headset, polymer and commercial electrodes were placed at 10 to 20 locations on the subjects' heads (n=5). A rapid serial visual presentation (RSVP) decision-making task was used to elicit known brain signals while recording EEG using a commercial EEG amplifier. An event-related potential (ERP) was computed for each type of stimulus presented in the task. Preliminary data suggests that the polymer electrode was able to measure expected differences in brain signals elicited by each stimulus; however, these results were not significant ( $p=0.029$ ,  $\alpha=0.017$ ). The commercially available electrodes were able to significantly discriminate brain signals ( $p=0.009$ ), which may suggest polymer electrodes do not perform as well as commercially available electrodes. However, these results are from a very small sample size (n=5). Data collection is ongoing.

### **Acknowledgments**

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### **Student Bio**

Christina Nguyen is a senior at Temple University majoring in Neuroscience. Her research projects include "Project Sleep" with Chantelle Hart at the Center for Obesity Research and Education and "Fatty Acid Taste Strips" with Professor Gregory Smutzer at Temple University. She plans to apply to medical school and continue pursuing research in conjunction with future clinical work.

## **Thermodynamic Analysis of Carbon Fiber Reinforced Polymer (CFRP) for Early Detection of Failure**

Northington, Benjamm

Carbon fiber reinforced polymer (CFRP) composites are trending lightweight materials used in aircrafts due to favorable characteristics. However, aeronautical structures are subjected to continuous cyclic loading and are highly susceptible to damage by impact. Impact damage is considered the relative cause of fatigue in the composite; fatigue is the major mode of failure within aircraft structures. Developing theoretical and experimental methods for characterizing early stage failure in CFRP composites subjected to cyclic loading was the primary focus of this work. Experimentation requires quasi-static testing using tensile testing paired with nondestructive inspection (NDI) techniques, acoustic emissions (AE) and infrared thermography (IT), to study structural behavior of the CFRP. Correlating detection of failure from quasi-static testing allows interpretation of parameters needed for fatigue testing. Analysis techniques involve evaluating the structure as it experiences cyclic loadings using data obtained from thermography and acoustic emissions with tensile testing. AE and IT provide energy data relevant to balance of interactive energy in the system. Understanding energy balances through structural changes can be derived with analysis of dissipated energy proportional to the overall energy balance of the system. Interpretation provides a new scope for analyzing energy accumulated through AE detection and IT to understand failure onset.

### **Acknowledgments**

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### **Student Bio**

Benjamm (BJ) Northington is a first-year graduate student studying mechanical engineering at Tennessee State University. His undergraduate degree was completed at the University of Tennessee-Martin.

## **Laboratory Test on Cisco Wireless Bridge**

Oboye, Oluwadmailola (Dami)

In a collaborative effort between the US Army Research Lab (ARL) and Edgewood Chemical Biological Center (ECBC), an 802.11g waveform was tested to show the receiver sensitivity values of different data rates for a Cisco wireless bridge. To maintain connectivity between ECBC's Array Configurable of Remote Network Senses (ACORNS) unmanned aerial vehicle (UAV) and its base station, an understanding of the receiver's sensitivity is vital. Threshold values, receiver sensitivity, and corresponding data rates from a test like this can be used in ARL's SAGE connectivity analysis tool to predict range of communication.

## **Automated C81 Table Generation for Comprehensive Rotorcraft Analysis**

Passe, Bernadine

A C81 table consists of the aerodynamic coefficients of lift, drag, and moment as functions of the angle of attack and Mach number. C81 tables are important for preliminary design of helicopter blades and few C81 tables exist. A new 2-D computational fluid dynamics (CFD) analysis program, C81 Generator from Iowa State, was created to automatically generate a C81 table for any arbitrary airfoil shape. XFOIL, a program from the Massachusetts Institute of Technology (MIT) with the same capability, is known for only being reliable up to the high subsonic regime. Both programs were evaluated against experimental data from the National Advisory Committee for Aeronautics (NACA) airfoil report and current C81 tables available. It was found that C81 Generator produced more accurate data than XFOIL, especially for the lift and moment coefficients. After the capabilities and limitations of C81 Generator were further analyzed, it is recommended for future use at the US Army Research Laboratory.

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### **Student Bio**

Bernadine Passe is a first-year graduate student studying aerospace engineering at the University of Maryland where she also received her bachelor's of science degree in aerospace engineering. She conducted her honors thesis research for the Collective Dynamics and Control Laboratory at the University of Maryland. She plans to obtain her master's degree and work in the aerospace and defense industry.

## **Improving Accuracy of Human Behavior Modeling for the Soldier Systems Engineering Architecture**

Patton, Colleen

The development and testing of equipment often fails to consider the limitations of Soldiers and the way they interact with their equipment on tasks. Thus requirements, specifications, and designs lack critical information that results in requirement creep and wasted resources. Representing the relationship between Soldiers, tasks, and equipment is critical for engineers to consider early in their processes, which requires more encompassing and accurate models. This project is an expansion of a technique, in use in the training community, to represent the soldier-task-equipment relationship and integrate it into a system engineering architecture. The expansion includes critical missing elements and addresses ways in which information can be implemented by engineers.

### **Acknowledgments**

I wish to acknowledge the mentorship of Sam Napier.

### **Student Bio**

Colleen Patton is a junior Psychology major at the University of Maryland. She conducted research for the Natural Resources and Agricultural Sciences Magnet Program and plans to obtain a masters in research statistics.

## **Development of High Throughput Tools for Rapid Identification and Discovery of Corrosion-Resistant Magnesium Alloys**

Paul, Joshua

Magnesium is exciting for structural applications due to its low weight and high strength. However, any defects or dopants within the material cause it to become extremely prone to corrosion. This can be circumvented by designing magnesium alloys with secondary phases and surfaces that are less prone to corrosion. In this work, magnesium and magnesium alloys for surfaces with low susceptibility to corrosion are investigated. This is done by developing software that can generate and analyze materials and their surfaces for stability. This software also automates the placement of molecules involved in the corrosion reaction on these surfaces, allowing for investigation of the energetics of the corrosion reaction. With these tools, high throughput investigation of magnesium alloy surfaces is made feasible and has been used to begin investigating magnesium alloys and corrosion.

### **Acknowledgments**

I would like to acknowledge my mentor, Krista Limmer, PhD.



## **Solar Power Application in Matlab**

Pawlukovich, Phillip J. 2<sup>nd</sup>

Solar power systems (SPS) that keep sensor assets powered continuously have advantages in scenarios where battery swapping is inconvenient or impossible (such as extended sensor deployments). The Solar Power Application in MATLAB (SPAM) was created to simplify the design of such systems. Solar power delivered to a sensor depends on time of year and weather conditions, and creating an accurate simulation is essential to the design of any SPS. When solar irradiance is known, an SPS can be engineered to give a certain probability of system up-time. SPAM requires only the system location, power consumption, and component efficiencies (found from their datasheets) to quickly calculate the probability. Using an extensively validated solar model from the National Renewable Energy Laboratory (NREL), the application generates a simulated year of solar power at a given location in the continental United States. The ultimate result is the estimated up-time of any SPS. An experimental SPS was designed to deploy in Adelphi, Maryland, with SPAM. Measurements of the system's power will be recorded to check the accuracy of the simulation. After validation, engineers will be able to use SPAM to minimize the cost or size of a SPS while maintaining constant up-time.

### **Acknowledgments**

I would like to acknowledge the mentorship of David M Hull and Kevin E Claytor.

## **Effect of B:B<sub>2</sub>O<sub>3</sub> on Reactive Hot-Pressing of Boron Suboxide**

Payne, Howard

Boron suboxide (B<sub>6</sub>O) is a low density, high hardness ceramic, whose properties make it ideal for armor applications. Boron suboxide powders are typically produced by a high temperature (1400 °C) reaction of partially oxidized amorphous boron. To consolidate powders into fully dense ceramic bodies, B<sub>6</sub>O is typically hot-pressed at 1850 °C and a pressure of 53.6 MPa. The goal of reactive hot-pressing is to combine the reaction step with the sintering step to streamline the process and leverage the thermodynamics of the reaction to reduce the needed temperature for typical densification. The B:B<sub>2</sub>O<sub>3</sub> plays an important role due to the volatilization of boron trioxide (B<sub>2</sub>O<sub>3</sub>) below the reaction temperature of 1400 °C. In this study, samples were mixed with a 0–10 mol% excess B<sub>2</sub>O<sub>3</sub>. The effects of varying the amount of B<sub>2</sub>O<sub>3</sub> during reactive hot-pressing was studied using a linear variable differential transformer (LVDT) to record ram displacement during densification, X-ray diffraction (XRD) to determine phase, microscopy to determine microstructure, Archimedes and helium pycnometry to calculate density, and Knoop indentations to measure hardness. The XRD results showed phase purity comparable to hot-pressed as-received B<sub>6</sub>O powders.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Kris Behler, Dr William Shoulders, and Dr Lionel Vargas for all their help throughout my internship.

## **A Dependency Tree Annotation Interface for Crowdsourced Active Learning**

Phan, Nhien

Syntactically annotated text is an important resource for many applications in computational linguistics, such as information extraction. Manual annotation of large corpora is a time-consuming, expensive task usually performed by trained linguists, and although automatic syntactic parsers exist, they are more error prone than human annotators. Active learning, a type of machine learning, can augment automatic parsers by selectively identifying instances the model is most uncertain about and sending them to an oracle (e.g., human annotator) to label. To leverage work from multiple human oracles, a sentence annotation tool was implemented on Amazon Mechanical Turk (MTurk), a website where Human Intelligence Tasks (HITs) can be crowdsourced to human workers. Workers manipulate an intuitive drag-and-drop dependency tree interface without needing to download specialized software, and their annotation data is sent to an active learning model running in the background. Training materials, written for a nonspecialist audience, instructed workers, and the MTurk application programming interface was used to automate worker prescreening, HIT creation and processing, payment delivery, and data processing. Using an online workforce to annotate selected sentences reduces the costs of annotation and offers researchers the opportunity to gather annotations for novel corpora or low-resource languages of Army interest.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Stephen Tratz.

### **Student Bio**

Nhien Phan is a senior computer science major and linguistics minor at the University of Maryland. She interned with the Application Management and Development Branch of the US Army Research Laboratory where she worked on automated, end-to-end regression tests for Department of Defense web applications. She was also an undergraduate research assistant at the Center for Addictions, Personality, and Emotion Research. She plans on pursuing a career in the software industry.

## **HPC-Enabled Simulation of Jet Fuel Combustion for High-Efficiency Gas Turbine Engine Development**

Piehl, Joshua

The objective of this work is to investigate the complex modeling uncertainties present in engine spray combustion models and demonstrate its performance on a realistic aviation gas turbine combustor. The Army's power generation platforms operate on jet-propellant (JP-8) fuel mainly due to the single fuel forward policy aimed at reducing the logistical battlefield footprint. Emulating the physical and chemical behavior of jet fuel constituents is therefore essential to accurately model the combustion dynamics. To meet these objectives, a sensitivity analysis was performed using chemical kinetics to identify reactions most critical to combustion property targets of interest. The most critical reactions were selected and 6 new kinetic mechanisms were created on this basis and coupled to a state-of-the-art turbulent combustion computational fluid dynamics tool. A parametric investigation was performed with the proposed kinetic submodels to quantify the effect on non-premixed spray combustion behavior including global combustion parameters. Subsequently, a well characterized gas-turbine combustor with complex chemical kinetics was investigated to demonstrate the ability to compute lean-blow-out phenomena and fuel sensitivity with previously reported measurements. This detailed modeling approach from first principle chemical kinetic modeling to applications is crucial for accurate modeling and evaluation of futuristic innovative engine designs.

### **Acknowledgments**

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### **Student Bio**

Joshua Piehl is a first-year PhD student studying mechanical engineering at Wayne State University. He has conducted research for Fiat Chrysler Automobiles, Detroit Diesel, and DENSO International. He plans to continue engagement with the US Army Research Laboratory in combustion modeling and experimentation through the Wayne State PhD program.

## **Understanding the Plasma-Enhanced Atomic Layer Deposition of Dielectrics on Highly Inert Surfaces of Layered Materials**

Price, Kate

Nanomaterials, such as transition metal dichalcogenides (TMDs), are attractive for a variety of applications due to their thinness, substrate independence, mechanical robustness, and unique quantum confinement. Most applications require the 2-D material to be passivated with a dielectric layer—either for protection from degradation or as an integral part of the device. The best established approach to deposit thin, uniform dielectrics is using a process called atomic layer deposition (ALD). However, the chemically inert surface of 2-D crystals prevents uniform growth of a dielectric using ALD. Recently, it has been shown that the use of a plasma-enhanced ALD (PEALD) substantially improves nucleation on 2-D crystals, such as molybdenum disulfide and tungsten diselenide, and enables the uniform deposition of 3.5 nm hafnium dioxide and aluminum oxide. In this work, the study is expanded by depositing and examining a wider range of PEALD films (e.g.,  $\text{TiO}_2$ ,  $\text{ZrO}_2$ , etc.) onto a variety of TMDs (e.g.,  $\text{ZrS}_2$ ,  $\text{GaSe}$ , etc.) as well exploring in more detail how PEALD high-k dielectrics nucleate on TMDs and the resulting interface. Atomic force microscopy was used to examine nucleation. Back-gated transistors before/after PEALD were fabricated and tested to determine impact of PEALD on the TMD's electrical characteristics.

## **Orders of Magnitude Reduction in Acoustic Resonator Simulation Times via the Wide-Band Rapid Analytical/Finite Element Analysis Technique**

Puder, Jonathan

Spurious mode excitation is one of the largest obstacles to the widespread adoption of piezoelectric microelectromechanical systems (MEMS) resonator technology. This is in large part due to the lack of a wide-band and computationally efficient simulation solution to model the frequency response of complex 3-D geometries. Current simulation methods can take hours to days to complete. To solve this problem, a new modeling methodology—the Rapid Analytical/FEA Technique (RAFT)—has been developed. The RAFT combines the accuracy of finite element analysis (FEA) with the speed of analytical evaluation. For simulations with similar total degrees of freedom and frequency resolution, the RAFT simulation completes approximately 14,000 times faster than traditional FEA while accurately predicting the behavior of hundreds of spurious modes. The approach of the RAFT allows the use of FEA as an efficient design tool, rather than analysis tool, for in- and far-band spurious modes.

### **Acknowledgments**

I would like to acknowledge my mentors, Ron Polcawich and Jeff Pulskamp

### **Student Bio**

Jonathan Puder is pursuing his PhD degree in mechanical engineering at Cornell University where he also received his bachelor's and master's degrees in mechanical engineering. He is a graduate research assistant with the Cornell University OxideMEMS research group and is also an ORAU research intern in the PiezoMEMS group at the US Army Research Laboratory. His research interests include piezoelectric MEMS resonant-based devices.

## **Visualization of Human Vulnerability in Virtual Reality**

Raber, Tiffany

This research investigates techniques for visualizing human vulnerability data in a virtual reality (VR) environment. Implementing models in VR will allow analysts to further explore results of modeling and simulation (M&S) events and data recorded from theater. Using the HTC Vive VR system, analysts can investigate the Operational Requirements Casualty-based Assessment (ORCA) model injury output to reveal patterns resulting from specific injury input conditions that are not apparent using current analysis techniques (textual and 2-D image-based plots). This research results in a demo human vulnerability VR experience, which will be a valuable tool for Department of Defense analysts to evaluate human system-level survivability and lethality studies.

## **Parametric Power Module Design (ParaPower)**

Rego, Michael

With Army requirements to reduce the physical size and weight of power modules, mechanical and thermal management systems must be improved as to not limit high-performing power devices. In order to meet these requirements, there is a need to fully understand the complete parametric space of thermal and mechanical effects in a power device to reduce overdesign and improve size, weight, and power. To enable this, a low order model, ParaPower, was developed in MATLAB using numerical analysis and a 3-D nodal thermal resistance network to calculate device temperatures and thermal stresses in a generic power module configuration. Current design methods focus on limited parametric analysis due to computational limitations. This research focuses on how device temperatures and stresses are influenced by parameters including device dimensions, number of devices, device layout, material stack, cooling solutions, etc. With reasonable accuracy, this tool is able to provide a solution >100X faster than traditional finite element analysis solutions; when thousands of different designs are to be considered, this time differential becomes significant, allowing the ParaPower tool to be vastly superior in understanding a design space.

### **Acknowledgments**

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## **Evaluating Bacteria-Surface Interactions under Variable Shear Environments**

Reidy, Thomas

In order to better serve the Soldier of the future, equipment must be able to adapt and to respond to changes in its environment independently. Nature has often been the best inspiration for engineering designs, and the unison of biology and technology is a natural progression for better, smarter equipment. The first step for integrating biology and technology is finding suitable materials for the biology; in this case, the biology is represented by genetically modified strains of *E.coli*. The bacteria have been designed to display different peptides that have affinities for different substrates. The challenge becomes sorting large libraries of strains for the best binders. The affinity for the substrate arises from specific interactions, the engineered peptides, and non-specific interactions. The ideal sorting methodology only selects strains that have the strongest affinity due to the engineered peptides and not non-specific interactions. We propose a sorting method of bacteria with different display peptides using changes in shear conditions. Our method ensures that only the specific interactions between the peptide and substrate are selected, and not other forces. Moreover, our system allows for screening against multiple substrates, allowing for a wide variety of applications.

### **Acknowledgments**

I would like to acknowledge the help of my advisor, Justin Jahnke.

## **Neural Correlates of Gamification for Enhancing Training Effectiveness**

Richardson, Matthew

Gamified training seeks to incorporate game-like elements into training programs to enhance motivation and improve learning outcomes. However, trainees vary in individual traits that determine what motivates them in a task. We propose that training effectiveness is mediated by regulatory focus, whether a person is motivated by achieving gains (promotion focused) or by avoiding losses (prevention focused). In this study we use EEG to investigate neural correlates of learning in a training task where game-like point structures are framed to match or mismatch participants' regulatory focus. Seventeen promotion-focused participants performed in a go/no-go paradigm, and were assigned to 1 of 2 conditions: the gain condition where points are received (match) or the loss condition where losing points is avoided (mismatch). Evoked-potentials reveal a performance-related P3 response that indicates neural differentiation of no-go from go stimuli. The P3 reflects reduced reaction time over training, and occurs earlier and with greater magnitude for high performers compared to low performers. Importantly, the P3 also distinguishes participants in the gain and loss conditions. These findings suggest neural responses provide information that can be used to monitor and adapt gamification to individuals' traits, thereby enhancing training effectiveness.

### **Acknowledgments**

I wish to acknowledge the mentorship of Antony Passaro, Benjamin Files, and Pete Khoosabeh.

### **Student Bio**

Matthew Richardson is a fifth-year PhD Student majoring in cognitive science at the University of California, Irvine. His past graduate research has been in the field of auditory cognitive neuroscience using human electrophysiology and non-invasive neuro-stimulation to understand and treat changes that occur in the auditory brain following hearing loss and other types of hearing damage. After defending his dissertation, Richardson plans to use the skillset he has developed in cognitive neuroscience, both as a graduate student and as an ARL intern, to pursue a research career in improving and expanding the use of neurotechnologies for medical interventions and augmenting healthy human performance.

## **Additive Manufacturing (Liquid Deposition) of Thermoset Polymers**

Roberts, Issac

Current additive manufacturing techniques of thermoset polymers produce parts that have limitations in material properties. The goal of this research was to test the augmented properties of epoxy samples manufactured via Liquid Deposition Modeling (LDM). The epoxy resin and curing agent used were Epon 828 and Epikure 3055, respectively. Additives were nanoclay particles and chopped carbon fibers with a 5- $\mu\text{m}$  diameter and an average aspect ratio of greater than 100. A syringe extruder print head was designed to extrude this mixture using existing hardware and software. The mixture was loaded into a syringe and various Luer lock tips were tested using the new print head. Shear thinning behavior was exhibited by the mixture: low viscosity at shear rates experienced during extrusion, higher viscosity after deposition on the build platform. Because of the shear stress experienced during extrusion through the tip, the fibers are expected to be highly oriented in the direction of the printing motion. Interpenetrating bonds are expected to develop between the deposition layers during the curing process. This material research enables the additive manufacturing of structural composites for multifunctional applications.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Bryan Glaz and Dr Frank Gardea, in addition to technical assistance from Mr Albert Tran.

### **Student Bio**

Issac Roberts is pursuing a Bachelor's degree in aerospace engineering at the University of Maryland, College Park. He has several years of experience in mechanical design using various CAD packages. After graduation, he intends to enter the workforce to design and optimize aerospace systems and components for additive manufacturing.

## **SMART Safety Database**

Robinson, Julian L.

The purpose of the SMART Safety Database project was to increase the efficiency of recording potential safety hazards by modernizing the process through developing a Windows Forms Application and a Microsoft Access Database Library. Efficiency can be measured through the time it takes to complete and import a form to a database. Manually recording data not only takes a significantly longer time during the inspection, but the process of being able to refer to previous inspections is lengthier. Adding the ability to export specific parts of a report to an email was designed to increase efficiency. Research was comprised of determining which programming language would be suited to meet the proposed requirements, understanding data grid view properties, establishing connections strings, the ability to write queries from a Windows Forms Application to a Microsoft Access Database, and transferring data from a mobile platform. The results of this research have led to successfully coding the SMART Safety Database with functions to create, import, edit, delete, search, and export data. This database will continue being used to manage and export safety data more efficiently than the previous method of manually recording it.

## **Development and Qualification of Novel Heat Treatments for Additive Manufacturing of Ti-6Al-4V**

Saenz, Nathaniel F.

Additive manufacturing of metals offers distinct advantages over traditional manufacturing of metals; however, the applications of additively manufactured metals are currently limited by the unreliable mechanical integrity and reproducibility of various powder-based additive manufacturing technologies. The mechanical properties of Ti-6Al-4V are heavily determined by the microstructure formed by the heat treatment it receives, and thermohydrogen processing offers a unique method for normalizing the microstructure of titanium alloys. The objective of this research project is to qualify a heat treatment process, developed at the US Army Research Laboratory, that will improve ductility, eliminate remaining isotropy, and normalize mechanical properties of additively manufactured Ti-6Al-4V. Samples were tested with a miniature tensile apparatus and used digital image correlation to eliminate the effects of machine compliance on the data. Subscale testing methods offer a unique opportunity to test the effects of directionality on components. However, given the uncommon size of testing samples, these methods required validation to ensure that measurements were representative of the bulk behavior. Preliminary results show that thermohydrogen processing can be applied to a wide array of additive manufacturing methods (e.g., direct metal laser sintering, electron beam melting, cold spray, and binder jet manufacturing) with notable improvements in ductility, particularly in the build direction.

## **Improving Human-Robot Interaction**

Salvatierra, Edward

As modern technology continues to increase the amount of autonomous systems in use, especially in the military, the interactions between autonomous and human agents must be closely considered. This research was split into 2 main sections. The first was developing a Java Applet game to distribute and collect pathfinding and decision-making data from participants. This information can be used to better instruct people, robots, and most importantly both working together, in navigating difficult situations. The other section of the research was developing a Latent Semantic Analysis program to build a conceptual network of a corpus of text. This network can be used to build models of certain texts, which can be used for a multitude of purposes. It can group terms based on similarity, and discern the implicit meanings of new texts by comparing them to the model. This second capability is extremely useful to allow robots to better understand natural language commands. The program will later be integrated with other robotics systems in order to allow the system to respond to realistic and naturally phrased queries, drastically improving its interactions with humans.

### **Acknowledgments**

I wish to acknowledge the mentorship of Kristin Shaefer-Lay, Troy Kelley, and Ralph Brewer in this research.

### **Student Bio**

Edward Salvatierra is a sophomore at the University of Maryland in College Park, majoring in electrical engineering. His research experience has been through the Gemstone program at University of Maryland, where he and a team of undergraduate students are attempting to develop an inexpensive optical light communication network, and at the US Army Research Laboratory, where his work was focused in robotics.

## **Experience with PRISM**

Sam, Donovan

PRogramming In Statistical Modeling (PRISM) is a language that integrates probability and logic programming. PRISM has been erected on a language called B-Prolog and supports random computations. PRISM is useful for describing probabilistic models in the areas of bioinformatics, information retrieval, linkage analysis, and probabilistic constraint solving. In addition, it has also been shown to be useful for parameter learning, which is relevant for gene sequence analysis, user modeling, and obtaining probabilistic information. For example, its use in biological data can determine a new technique for medication and drug dosage. The proteins in Genetic Regulatory Networks (GNRs) are targeted to find a cure for diseases and disorders. Kishore, Balu, and Karna modeled GRNs, and have used PRISM in their research. Running examples in PRISM gave me insight into logic programming and probabilistic reasoning. Learning logical programming gave me a sound foundation to continue learning PRISM.

## **High Strain Rate Mechanical Behavior of Mg Alloys**

Savino, Nicholas

There is a growing demand for lightweight materials for armor and other defense applications, where impact conditions create a complex, multiaxial loading environment. Magnesium (Mg) and its alloys are the lightest structural metals, but the mechanical behavior is usually anisotropic, with relatively low strength and ductility, due to the deformation mechanisms imposed by the hexagon close-packed crystal structure and compounded by the crystallographic texture introduced by the manufacturing process. High strain rate experiments were conducted to probe the mechanical anisotropy by fabricating samples where the loading type and direction are varied with respect to the principle processing directions. The first set of experiments, on Mg alloys AZ31B and AMX602, used a sample geometry that induces shear-dominated loading using a Kolsky bar setup. The shear direction was oriented perpendicular or parallel to the dominant texture to measure the anisotropic responses. AZ31B showed consistent differences in the yield strength and subsequent flow stress depending on the shearing direction, but the AMX602 behavior was inconsistent between shearing directions. The second set of experiments are to determine the tensile mechanical behavior of AMX602 using a tension Kolsky bar currently being fabricated. This presentation will detail the most recent fabrication progress and future experimental plans.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Christopher Meredith.

### **Student Bio**

Nicholas Savino is entering his fifth year as a BS/MS mechanical engineering major at Drexel University. He has spent the last year conducting research in the Dynamic Multifunctional Materials Laboratory at Drexel University, and his future plans include pursuing a Master's degree on the dynamic behavior of high entropy alloys.



## **The Effect of Bio-Rubbers on the Properties of UV-Curable (Meth)acrylate Systems**

Schmalbach, Kevin M; Lastovickova, Dominika N; La Scala, John J

In recent years, there has been a large push towards further developing the additive manufacturing industry to quickly and efficiently produce small parts. However, there has been limited focus on UV-curable polymers with high glass transition temperature ( $T_g$ ) and high toughness. One crosslinker of interest is isosorbide methacrylate (IM), a bio-based, nonaromatic monomer with high  $T_g$  and low viscosity. Crosslinkers were blended with isobornyl acrylate (IBA), a reactive diluent. Methacrylate functional soybean oil-derived rubbers were added to the crosslinker/diluent system to increase the polymer toughness. Although the inclusion of bio-rubbers increases the resin viscosity, IM:IBA resins possessed viscosities in the range of 10–20 cP, far low enough for stereolithography (SLA). Polymers containing bio-rubbers had similar or better initial degradation temperatures than samples without bio-rubbers. However, the presence of bio-rubber in IM:IBA samples decreased the  $T_g$  of IM:IBA from 150–170 °C to as much as 90 °C. Unfortunately, IM:IBA polymers are still extremely brittle after adding bio-rubbers. An alternative crosslinker system containing a commercially available vinyl ester was used with the soybean oil-derived rubbers and IBA. The resulting material was far less brittle than the IM polymers, but had reduced glass transition temperature (60–80 °C) and higher viscosities. The measured viscosities (0.3–0.8 Pa s) were acceptable for SLA processing.

## **Development of a 30-kV Charger for a Marx Capacitor-Bank**

Schroen, Erik

Recently, a 30-kV Marx capacitor-bank charger was designed and fabricated. A first iteration of the charger performed well at a fixed input voltage. However, as the battery discharged and its output voltage dropped, the output voltage of the charger drifted. To remedy this, the charger controller was redesigned to use a microcontroller. This microcontroller is programmed to read the voltage of the battery pack before each charging cycle, and calculate and provide the corresponding pulses for converter operation. This method was effective after calibration of the output voltage based on the pulse width values, allowing the charger to nominally output 30 kV consistently across a range of input voltages. Additionally, at startup, the charger drew a large amount of current from the battery. To mediate this, a soft-start feature was implemented on the microcontroller, which limits the initial charge rate and increases the rate as the charger output voltage climbs and the battery output current lowers. This reduces the peak output current of the battery pack without significantly increasing the total charge time. During tests with the Marx capacitor-bank, triggering of the bank's spark gaps caused protection circuitry within the battery pack to disable the battery due to an overvoltage constraint, preventing further operation of the charger. By modifying the battery protection circuitry, continuous charger operation was achieved. The battery, combined with the charger, retains all protection modes. Over-current protection is provided by a resettable fuse, under-voltage protection by the charger controller, and over-voltage protection during battery recharging.

### **Acknowledgments**

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### **Student Bio**

Erik Schroen is currently a junior at Capitol Technology University in Laurel, Maryland. He is pursuing a Bachelor's degree in aeronautical engineering and may pursue a double major in electrical engineering and/or a Master's in aeronautical engineering after graduation. After graduation, Erik plans to pursue a career in the field of Aeronautics or Electrical Engineering while continuing his education.

## **Terahertz Spectroscopy**

Shah, Sahil

Terahertz (THz) radiation is important for applications such as communications, biomaterials sensing, and nondestructive evaluations. THz radiation occupies a middle ground, known as the terahertz gap, where technology for its generation and manipulation is in its infancy. Design of components for the future communications systems in THz spectrum is an emerging field of research. One such proposal is the reconfigurable antenna, an antenna capable of dynamically modifying its frequency and radiation properties in a controlled and reversible manner. The approach is to include quantum dots (QD) that can change the resonant response of the antenna upon application of UV light. In this work, we tested the effects of application of UV light on QDs when QDs are deposited on the surface of a metamaterial. Quantum dots tightly confine electrons or holes and exhibit properties that are intermediate between those of bulk semiconductors and those of discrete molecules. Their optoelectronic properties change as a function of size and shape. Upon application of THz wave on metamaterial, transmitted wave shows resonant peak at certain frequency as a function of the metamaterial unit cell dimensions. Our ultimate goal during this process was to examine whether or not there was any shift in this peak location when UV light is applied on the deposited QDs. The data analysis showed resonant frequency shift when the QD were deposited on the metamaterial surface and a smaller one when UV light was applied.

### **Acknowledgments**

I would like to acknowledge my mentor, Daniel Shreiber.

## **Robust and Automated Coupling of RCAS and PSU-WOPWOP**

Sharma, Kalki

Over the summer I have been working on RotorCraft Comprehensive Analysis System (RCAS), a rotorcraft analysis software, and PSU-WOPWOP, a noise prediction software. Specifically, I have been working on developing a system to couple the 2 tools. With robust coupling, an RCAS user will have the capability to compute the acoustic signature of the rotorcraft being analyzed for user specified flight conditions. This coupling system has been developed for other research endeavors, but the methods of coupling used prior were not generic enough to be applicable for the every RCAS configuration. In this effort, a robust and automated coupling system is being developed for the express purpose of being able to work with any RCAS configuration.

### **Acknowledgments**

I wish to acknowledge the mentorship of Phuriwat Anusonti-Intra and Matt Floros in the pursuit of my summer projects at the US Army Research Laboratory.

### **Student Bio**

Kalki Sharma is pursuing a PhD in aerospace engineering at The Pennsylvania State University (Penn State), already having obtained both a BS and an MS the same field at Penn State. Sharma has also been a Research Assistant for 3 years in the Vertical Lift Research Center of Excellence at Penn State and was an Aeromechanics Intern for 6 months at NASA's Ames Research Center.

## **Detector Calibration and Spectral Characterization of Propellant**

Shevchuk, Ariana

The successful detection of threats such as rocket-propelled grenades (RPGs) and anti-tank guided missiles (ATGMs) relies on properly calibrated optics and accurate knowledge of the spectral features of launch flashes. The first half of this work focuses on the calibration of the visible light Mark II panoramic optic. To calibrate the optic, a NIST lamp GE30A/T24/13 is placed in front of a 0.381-mm aperture through laser alignment. By shining the lamp through the small apertures, one can create a point source to mimic the flash from a threat. The optic is then positioned in front of the aperture and the remaining light from the lamp is blocked. A computer program allows the location of the point source to be located and filmed at various exposures from which the background is subtracted. The second portion of this work uses spectroscopic techniques to explore launch flash signatures through the deflagration of ejection motor propellant. Mid-wave infrared (MWIR) detection schemes for RPGs and ATGMs rely on the consistent appearance of certain spectral features. However, if additives to the propellant can change these spectral features, it becomes fairly simple for the enemy to avoid detection. Our goal is to discover what additives, if any, can create a significant enough change in the MWIR features of the threat to avoid detection. We investigate the effects of 5 different additives using a MWIR spectrometer system.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Laura Vanderhoef, Dr Chris Wolfe, and Dr George Thompson.

## **The Effect of Perspective on Immersiveness**

Sinfuego, Vincent

Virtual Reality (VR) is a rapidly expanding field of technology that is being applied as a medium for riskless training for dangerous tasks (e.g., to provide Soldier training en route to target). However, it is not clear whether VR can provide a sufficiently realistic training experience that might generalize to the battlefield. The VR horror genre is surging in popularity, with VR enhancing its fear-inducing themes by creating a more lifelike experience. Here, we show that changing user perspective from third-person to first-person during a VR horror scenario results in increased heartrate, which may provide an objective measure of immersiveness. Whereas the third-person perspective produced static levels of heartrate compared to baseline, the first-person perspective induced a 20% higher average heartrate. In addition, several spikes in heartrate were detected at times of high stress, such as when a zombie surprised the subject. The results show that increasing immersion through a first-person perspective evokes more powerful reactions from the human body. We anticipate that this increased immersiveness of VR will result in more real-world variations in physiological responses and better translation from training to the battlefield.

### **Acknowledgments**

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### **Student Bio**

Vincent Sinfuego is a senior at Montgomery Blair High School in Silver Spring, Maryland. His previous research includes experience in FIRST Robotics and nanotechnology; he plans to major in cognitive science or computer science when he attends college.

## **Comparison of YOLO Object Detector Performance on Open Source Video/Image Feeds**

Singh, Avik

Many military applications require analysis of big data, which involves acquisition of large amounts of raw data, such as photos/images and video footage, storing it onto a single database, and processing it to output relevant information. Researchers at the US Army Research Laboratory are developing systems and algorithms to gain scene understanding and situational awareness from such data. Although there is not much Army-collected data easily available for use in the development of these algorithms, there are publicly available, open-source data collections from video sensors such as traffic cameras and from social media sites. A subroutine is written in the Python programming language to request relevant data from the Application Program Interface (API) for each respective social media site server. The API responses are further processed to download and store the imagery data as well as the corresponding metadata in JavaScript Object Notation format. Personal identification information is deleted prior to the data storage. The program can be organized and implemented by using grid-based location tracking and timetables for fully optimized performance. Once the imagery data are collected, pre-trained Deep Neural Networks based on the YOLO object detector are used to analyze the images and to identify different objects in the scene.

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## **Streamlined Electroencephalogram (EEG) Data Processing and Analysis Scripts in MATLAB**

Sipos, Andrea

Neuroscience research that employs electroencephalogram (EEG) imaging has surged in recent years because of advancements in analysis methodologies to better understand and predict individual and group behavior. My summer project provides streamlined analysis tools to enhance data analysis of neuroimaging research that examines individual behavioral variability in tasks to identify physiological markers that predict performance fluctuations. The analysis tools were implemented in MATLAB and incorporate 3 publicly available toolboxes—EEGLAB, SIFT, and Dynamic Graph Metrics. The tools streamline 3 critical components of EEG data processing and analysis: 1) independent component analysis, dipole fitting, data preprocessing, multivariate model fitting, validation, and connectivity; 2) visualization of connectivity as graphs; and 3) visualization of connectivity in a 3-D head model. These tools operate without the use of a graphical user interface to avoid version conflict between MATLAB and script dependencies, and they can be used on large data sets with minimal user input. The tools also include optional and default parameters to enable rapid use across multiple types of EEG data and analysis goals, and will allow implementation of a variety of analytical tools on the Cognitive Resilience and Sleep History dataset with minimal user input.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Jean Vettel and Dr Javier Omar Garcia.

### **Student Bio**

Andrea Sipos is a rising sophomore at Carnegie Mellon University. She plans to major in mechanical engineering with an additional major in robotics. Andrea's past research includes work in nuclear robotics with the Field Robotics Center at Carnegie Mellon's Robotics Institute. Andrea is excited to continue her work for the US Army Research Laboratory (ARL) in the coming academic year at Carnegie Mellon and plans to return to ARL next summer.



## **Microstructural Evolution of Nanocrystalline CuTa Alloys**

Smeltzer, Joshua A; Hornbuckle, B Chad; Darling, Kristopher A

Recently, CuTa nanocrystalline alloys have been of high research interest due to their high strength, hardness, and thermal stability. A series of alloy compositions varying from 0.25 to 10 at.% tantalum (Ta) have been produced through mechanical alloying. Microhardness data demonstrated an increase in strength with increasing Ta content. Because all compositions provided equivalent grain sizes, the increase in hardness could not be explained by the Hall-Petch relationship. Scanning transmission electron microscopy (STEM) was used to determine the microstructural features responsible for this variance in the microhardness data. STEM analysis showed evidence of nanoscale Ta particles in each alloy, whose number density increased as a function of Ta content. Despite the increased Ta content, the average Ta particles remained constant for all alloy compositions (< 10 nm). Interestingly, long-term anneals provided the alloy composition with the greatest thermal stability contained 3 at.% Ta, not 10 at.% Ta. Further microstructural analysis found this result to be the lack of coarsening of the Ta particles in 3 at.% versus 10 at.% Ta. In other words, a high number density of small coherent particles is better at preventing deformation mechanisms than a lower density of larger semi-incoherent particles.

## **Detachment of Bacterial Cells from Gold through Manipulation of Peptide-Gold Interactions**

Smith, Austin

The adhesion of bacteria to a variety of surfaces is an integral behavior in the formation of biofilms. The binding affinity depends strongly on the properties of the bacterial surface, the binding surface, and the environmental conditions. The ability to control the attachment and detachment of bacteria is a crucial step towards manipulating both the formation and the composition of biofilms. Incorporating gold-binding peptides on to cell surface proteins allows for the selection of cells based on affinity for gold. The detachment of cells may be initiated by shear stress in a microfluidic device, chemical agents that react with gold-binding peptides, or electrochemical signals to increase repulsive forces. In this project, cells expressing certain gold-binding peptides were selected for removal primarily through the use of reducing agents. In a reverse scenario, a weak-binding cell may be made to bind strongly with the presence of a certain chemical. Electrochemistry was used to attempt to influence removal of peptides by varying electrical potential. The use of electrochemistry to remove bacteria from a surface would be particularly useful in bioengineered devices, where reactive chemicals could potentially damage components.

### **Acknowledgments**

I would like to acknowledge the help of my advisor, Justin Jahnke.

## **Hologram Reconstruction using a Spatial Light Modulator**

Smith, Desmond

The US Army Research Laboratory's (ARL's) mission is to discover, innovate, and transition science and technology to ensure dominant strategic land power. In order to fulfill ARL's mission statement, researchers have developed methods for holographic projection of precalculated light fields using a spatial light modulator (SLM). Even though the Army's current use of holograms is limited, this research is important for our future warfighters. What is being presented is just one in a long series of steps that would allow the Army to use holograms to project realistic 3-D images for a variety of possible applications. In order to achieve optimal reconstructed image resolution, I decreased the error margin through increasing the number of iterations of my code written from a phase-determining algorithm. By testing the necessary amount of iterations needed to reduce the error margin, not only will time be saved from computing the code, but an ideal phase image will be produced.

### **Acknowledgments**

I would like to thank Karl Klett Jr. for his mentorship and also ARL for hosting me as an intern this summer.

## **Modes of Autonomic Control: A Measure of Performance**

Spaulding, Benjamin

Soldiers must regularly perform their tasks under exceedingly stressful conditions. Learning to adapt to these extremes levels of stress encountered in military operations is nontrivial and requires an objective measure of stress that could be used as input to adaptive training technologies. In this project, we developed a new measure of the autonomic nervous system (ANS) to determine the level of stress, which we call the modes of autonomic control (MOC). We then compared its ability to characterize performance under stress to a traditional measure of the ANS, heartrate variability (HRV). Specifically, we examined classification accuracy in predicting high and low performers in a stress-inducing Stroop task using the ANS measures. Our results demonstrate that our new measure, MOC, had the highest classification accuracy (75%), while HRV alone had an accuracy of 62.5%, and combined (HRV and MOC) had a chance level performance of 50%. These preliminary results are encouraging and suggest that the new measure, MOC, may be able to better predict performance under stress. Future studies will validate this measure in a greater variety of tasks and subject populations.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Justin R. Brooks.

### **Student Bio**

Benjamin Spaulding is a senior majoring in mechanical engineering at the University of Maryland, College Park. His future plans include graduate school to continue his studies in mechanical engineering. He is also interested in vehicle design and futuristic technologies, particularly robotics.

## **Rate Activated Tethers for an Energy Absorbing Helmet Suspension System**

Spinelli, Devon

A critical component in helmet design is the interface between the head and the helmet shell. Two strategies are typically employed: a “suspension” of flexible straps, or foam pads. Helmet suspension design, largely unchanged for over 30 years, was once the standard for military helmets. It remains a popular choice for industrial helmets such as those used in construction, fire rescue, welding, and tree trimming. Energy absorption of helmets across American industries must be certified by ANSI/ISEA Z89.1. In suspension helmets, the ability to attenuate impact energy is a direct function of the strapping material, conventionally nylon webbing. In this presentation, a new helmet suspension system will be reported. The suspension straps are composed of rate activated tethers (RATs), a speed-sensitive, energy-absorbing strapping material whose force characteristics can be tuned via component geometry and material characteristics of an enclosed shear thickening fluid (STF). A series of 6 different RAT designs has been systematically characterized in a “ring test,” where a headform was dropped at 4 target impact velocities on each tether to simulate the displacement of a suspension around a head when impacting the crown of a helmet. An integrated RAT-based suspension system for a hard hat has been designed, and will be undergoing testing per ANSI/ISEA Z89.1 in early August.

### **Acknowledgments**

I wish to acknowledge the mentorship of Eric Wetzel.

## **Pythonic Approach to Numerical Weather Prediction and Design of Experiments**

Thomas, IV, Filmore

Numerical weather prediction uses computing power to model, forecast, and provide weather conditions for many different variables. There are many methods that can be used to understand numerical weather prediction codes, including using a design of experiments via design matrices, which can potentially be used to estimate how the model performs at unmeasured points. In an effort to improve numerical weather prediction, I used an existing R code based on the design of experiments method developed by my mentor and translated this code into Python. By writing the code in Python, I would be able to cross-verify the current R code. This would also allow for discussion on what improvements could be made in both code bases. Research thus far has allowed me to obtain a working proficiency in both R and Python. In relation to recreating the design matrices, I have been able to translate parts of design matrices code, including the balanced sample size and utility function codes into Python. This project will be considered a success on the basis of progress made in recreating the design matrices code in Python. This will allow for verification of the original R code, while also sparking conversation on how the code can be improved in terms of efficiency and effectiveness to improve our weather prediction models.

## **Finding a Solution to a Denial of Service (DoS) Attack**

Thompson Jr, Stephen-Michael

Recently, companies and their information technology (IT) infrastructure have experienced many problems in this data-filled world. With frequent hacking of data and personal information being captured, safeguards and IT security measures must be in place to prevent cyber-attacks. One attack that is frequent is a Denial of Service (DoS) attack. Despite the complexity during the aftermath of an attack, there are multiple tools that can help mitigate the attack. In a collaboration with the US Army Research Laboratory and Edgewood Chemical Biological Center, this presentation will display methods of handling a system that has been affected by a DoS attack, as well as displaying potential measures that could prevent attacks in the future.

## **Investigation and Study for the Design and Development of a New Ultra-Wideband (UWB) Antenna**

Tran, Nghia

The US Army Research Laboratory (ARL) is moving towards developing highly capable imaging radar technologies suitable for deployment on small unmanned air and ground vehicles for a variety of Army applications. ARL is executing the cooperative research and development agreement between itself and the Catholic University of America (CUA) on the area of development of ground-penetrating radar. Specifically, this collaboration will enable the investigation and study for the design and development of a new ultra-wideband antenna. The newly design antenna shall be fully polarimetric, including horizontally-horizontally transmit and receive, as well as horizontally transmit-vertically receive, vertically transmit-horizontally receive, and vertically-vertically transmit and receive. The antenna also shall operate from 300 MHz to 2000 MHz, with a low voltage standing wave ratio (less than -10 dB) and with a gain of 4–8 dBi. The antenna should also be small, low-profile, and compact. The antenna will be used in support of the next generation of advanced Army airborne- and ground- unmanned ground penetrating synthetic aperture radar systems for detecting buried-improvised explosive devices, for sensing through the wall, and for detecting targets under tree canopy.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Canh Ly in ARL's Sensors and Electron Devices Directorate and Dr Ozlem Kilic (CUA).



## **HPC-Enabled Simulation of Internal Nozzle Flow and Its Impact on Dense Spray Atomization Dynamics**

Trettel, Benjamin

We propose using high performance computing to study the influence of needle motion on the atomization of diesel fuel. Presently, the influence of nozzle geometry on atomization is understood moderately well qualitatively, but rarely quantitatively. The impact of the unsteady needle motion and starting jet dynamics are more poorly understood. We intend to model the internal flow coupled to the atomization with a finite volume interface tracking code which can handle deformable meshes. A novel capability to model deformable meshes (in this context) is currently under development under a US Army Research Laboratory project and will be demonstrated in this work. X-ray images that allowed measurement of the movement of the needle in a diesel injector, along with droplet-sized measurements, were obtained through a collaboration with Argonne National Laboratories' Advanced Photon Source. This dataset will be used to validate the code's prediction. Then, we propose conducting a systematic study on the effects of the needle motion on the internal flow of the nozzle and the subsequent atomization of the jet. Comparison with simpler theories with lower computational cost also will be conducted. Decision makers may find the accuracy of simpler theories to be adequate for design purposes.

### **Acknowledgments**

I wish to acknowledge the mentorship of Drs Luis Bravo, Muthuvel Murugan, and Anindya Ghoshal.

### **Student Bio**

Benjamin Trettel is a 4th-year PhD student in mechanical engineering at the University of Texas, Austin. He obtain his undergraduate degree at the University of Maryland. His previous research experience include work at the National Institute of Standards and Technology, and the Los Alamos National Laboratory in New Mexico.

## **Synthesis of Few-Layer Rhenium Disulfide Via Chemical Vapor Deposition**

Valentin, Michael; Guan, Alison; Nguyen, Ariana; Lu, I-His; Merida, Cindy; Gomez, Michael; Bartels, Ludwig

Transition metal dichalcogenides (TMDs) are exciting new materials that have received much attention due to their semiconducting properties in the direct bandgap. Well-studied TMDs, such as molybdenum disulfide and tungsten diselenide, exhibit a direct bandgap at the single-layer limit and an indirect bandgap in the bulk form; however, rhenium disulfide (ReS<sub>2</sub>) is a new TMD that is unique in its ability to retain a direct bandgap even in the bulk form. By using the method of chemical vapor deposition, few-layer ReS<sub>2</sub> is synthesized and characterized by Raman spectroscopy, atomic force microscopy, x-ray photoelectron spectroscopy, and electrical transport. ReS<sub>2</sub> has great promise for industrial integration due to facile film synthesis, layer independence, and environmental stability.

## **Enhancing Context Awareness in Affective Computing systems through Ensemble**

Vlachostergiou, Aggeliki; Dennison, Mark; Khooshabeh, Pete; Harrison, Andre

The research field of Human Computer Interaction is moving towards more natural, sensitive, and intelligent paradigms. Especially in domains such as Affective Computing (AC), incorporating interaction context has been identified as one of the most important requirements towards this concept. Nevertheless, research on applying ensemble strategies to enhance context awareness in AC systems in terms of analysis results is quite scarce. This work delves on presenting the current state-of-the-art research in terms of context awareness in AC systems, along with the so-far applied ensemble strategies. Additionally, the aspects ranging from the datasets used and the emotional class, to the features used, the followed approach, and the analysis results, are discussed in terms of the challenges and the open issues they comprise. Overall, the paper aims to both document the present status, as well as comment on lessons learnt with regard to the evolution of the upcoming topic of enhancing context awareness in AC systems through ensemble strategies.

## **Development of a High-Sensitivity Compton-Suppressed Gamma-Spectroscopy System**

Walker, Alexzander; Sowels, Grant V

Basic research into a potential new class of high-energy-density materials for Army applications requires laboratory capabilities for highly sensitive gamma-ray spectroscopy. The objective of this research project was to design, build, and test a system to achieve these capabilities. Our main goal was to mitigate the effects of background radiation caused by Compton scattering. This is a physical process that cannot be prevented; however, it is possible to suppress the recording of these background events in a spectrum. Specialized electronics, as well as sodium iodide scintillators, were calibrated and configured in a system in which the deleterious readings in spectra from a high-purity germanium semiconductor detector could be reduced. This poster will delineate the functionality and performance of this system.

### **Acknowledgments**

We wish to acknowledge the mentorship of James J. Carroll.

## Python Implementation of XYData

Wang, Justin

To improve the analysis of experimental shock and vibration data, XYData—a MATLAB-based toolbox—was developed to achieve 3 goals: 1) providing a common analysis framework for heterogeneous data sources generated by the shock and vibration community; 2) supporting tight coupling of measured data and their metadata; and 3) keeping track of what procedures have been applied to the data for future replication. Given the stated goals and high-level walk-through of the existing toolbox, I was tasked to port the MATLAB code into a Python-based framework using Python 2.7 and highly vectorized SciPy libraries such as NumPy and Matplotlib. The motivation for this conversion between languages stemmed from the compatibility between MATLAB and Python’s OOP capabilities, as well as Python’s being an open-source, low-cost software. I have accomplished the following tasks: 1) I have implemented 20 basic data analysis functions such as *sqrt*, *min*, *max*, *add*, *times*, *power*, and 2 more complicated signal-processing functions, namely, *downsample* and *decimate*; 2) I have figured out how to make a “deepcopy” of an XYData object, which can serve as the pristine version of the original data while the loaded data undergo a variety of transformations; and 3) I have accomplished the design and implementation of 4 “loader” functions to load data stored in 4 different file formats—*kfilecurve*, *glstat*, *nodout*, and *elout*.

### Acknowledgments

I would like to thank my mentor, Mr Berman, for the instruction that he has provided in helping me with this project.

## **Analysis of Survey Systems and Data Reduction for Spark Shadowgraph Ranges**

Will, Ellen

Aberdeen Proving Ground's 2 spark shadowgraph ranges, the Aerodynamics Experimental Facility and the Transonic Experimental Facility, are used to test and determine the aerodynamic coefficients of projectiles in free flight. A survey was created to calibrate the ranges so they are able to accurately produce the requested data. It is recommended that the surveys be conducted to the ranges every 2 years to reverse damage from weather and age. Unfortunately, the last survey was done in 1968. The inaccuracy of the survey data has consistently shown high residual in the yaw and swerve fits of certain stations. When the last survey was completed, survey files, which hold the survey data for both ranges, were created. The unknown numbers in the survey files have caused confusion. The goal is to figure out what is measured during the survey and how these numbers are used in the range reduction process to determine the projectile's position at each station and the orientation of its axis of symmetry with respect to some fixed coordinate system. This information can then be used to review the survey techniques and look for potential improvements.

### **Acknowledgments**

The author would like to thank the following individuals for their contributions and support during this project:

- Mr Ilmars Celmins for his knowledge and guidance throughout the mentorship
- Dr Sidra I Silton for providing the survey information and support throughout the project

### **Student Bio**

Ellen Will spent her first 2 years of college at St Mary's College of Maryland studying computer science and mathematics. She will continue her education as a rising junior at Towson University to focus in computer security. She plans on working in government security, exploring ethical hacking. She later plans on attending graduate school to pursue a master's degree in computer engineering.

## **Terfenol-D Carbon Fiber–Reinforced Polymers (CFRPs) Embedded Sensing for Early Damage Detection**

Williams, Brandon

Carbon fiber–reinforced polymers (CFRPs) play a vital role in modern engineering and design of lightweight rigid bodies, predominantly in the aerospace and automotive industries. Typical epoxy-based CFRPs exhibit virtually no plasticity, with less than 0.5% strain to failure. Although CFRPs with epoxy have high strength and elastic modulus, the brittle fracture mechanics present unique challenges to engineers in failure detection since failure occurs catastrophically. This paper explores a method for solving this problem by investigating the possibility of embedding Terfenol-D, a magnetostrictive material, into the CFRP for structural health monitoring. The sensing is based on a phenomena called the Villari Effect, which defines the induced stress by an irreversible change in magnetostriction. When the particles are mechanically strained, they generate an induced voltage allowing them to be used as a sensor. For our baseline results, the average percent voltage RMS change from the magnetostriction sensor was only 0.2% for an applied load of 0%–70% of the UTS. For typical quasi-static testing procedures, we observed voltage RMS readings from the magnetostriction sensor increase by more than 47% for an applied load of 0%–70% of the UTS. Terfenol-D-embedded CRFPs have shown promising result for SHM. Acoustic emission and X-ray CT scanning were used to validate the observed results.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Asha Hall and Mr Michael Coatney.

### **Student Bio**

Brandon Williams is a first-year graduate student at Clemson University, majoring in mechanical engineering. He plans to pursue his doctorate in mechanical engineering, become a researcher, and conduct basic and applied research for the US Army Research Laboratory.

## **Polyurethane/Polyurethane Urea Extrusion with Embedded CNTs for 3D Printing and Radiation Detection, Dosimetry Abstract**

Wolff, Justin

Polyurethane (PU) and polyurethane urea (PUU) plastics have research interest because of their unique properties, which include a wide range of hardness, flexibility, and electrical insulation. Carbon nanotubes (CNTs) have also been sought after because of properties such as high tensile strength, elasticity, and electrical conductivity. The thought of combining these 2 phenomena indicates a potential breakthrough that allows a plastic material to transport an electrical current. This potential technology could be useful in shaping various electrical devices, without the mess of wires and with an increase in strength and durability. The combination of a thermoplastic polymer (i.e., PU and/or PUU) with CNTs for 3D-printable conductive filament is examined through testing and data analysis. The difference between the PU and PUU is replacing the DETA, in the PUU, with 1,3 CHD, in the PU. This difference causes the PU to be a thermoplastic and the PUU to be a mixture of a thermoplastic and thermoset. This research leads to a functioning polymer-CNT composite, robotic dosimeter via the ease of using 3D-printing software and filament extrusion techniques. Testing includes DMA and rheology. We will also test the wt% of CNTs in the polymer through the use of an MTS machine and dogbone specimens; the wt% 's tested are 0.3% wt and 0.5% wt (the testing of ideal dispersion techniques is also included).

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Asha Hall and Dr Jeff Gair.

### **Student Bio**

Justin Wolff is a sophomore undergraduate at Penn State University studying Mechanical Engineering. Past research experience includes taking a first-year seminar course at Penn State called Mechanical Engineering 97, which is an introductory research course where students can visit and learn about various research labs on campus. Future plans include studying abroad, getting more internship experience, and obtaining a job that will help me become a successful engineer while helping others.



## **Collision Avoidance Robot Using Neuromorphic Hardware**

Wong, Clarence

Moore's law states that the number of transistors that fit on a chip and computing performance doubles around every 2 years. In recent years, studies show that Moore's law has begun to tail off and produce diminishing returns. Thus, new computing paradigms, such as neuromorphic computing, overcome Moore's law by using low-power architectures that run on hardware with the fraction of the size and weight of a traditional computer. Many researchers have demonstrated the versatility of low-power neuromorphic architectures in theory and simulation; however, few bridge the gap between the ideal nature of simulation and the complexity of the real world. In this project, we develop a neuromorphic robotic driving platform that avoids colliding into objects. The platform is used to verify and test different forms of neuromorphic hardware and architectures using off-the-shelf components and sensors.

### **Acknowledgments**

I wish to acknowledge the mentorship of Manny Vindiola. Additional thanks to Bryan Dawson and Jamie Infantolino for helping debug issues. As well, thank you to Elizabeth Klier for assisting in the neuromorphic aspects of the project.

### **Student Bio**

Clarence Wong is a first-year master's student, beginning in Fall 2017 as an electrical engineering major. He is studying at the University of Tennessee–Knoxville (UTK), where he also received his undergraduate degree. His past research experience includes Neuromorphic Circuit Design and Computing, also at UTK.

## **Photoluminescence Characterization of Polarized Emission from InGaN/AlGaN Multiple Quantum Wells and Emission Efficiency of InN/GaN Superlattice Structures**

Wraback, Elizabeth

Nonpolar (10-10) and semipolar (20-21)  $\text{In}_{0.03}\text{Ga}_{0.97}\text{N}/\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$  multiple quantum wells (MQWs) are studied to understand their polarized optical emission, due to their crystal orientation, to improve future optoelectronic devices. Also, InN/GaN superlattice (SL) structures, a possible topological insulator, are investigated for the optimization of materials. For both of these structures, the photoluminescence (PL) was extensively studied to identify optimized growth conditions. The dependence of full-width at half maximum (FWHM) with the polarization ratio was studied for the polarized MQWs, while the peak PL emission wavelength as a function of the InN and GaN thicknesses was studied for the SLs. The PL measurements were taken at room temperature using a 325-nm He-Cd laser, for both the MQWs and SLs, and at low temperatures, 12.5 K, for the SLs. It was determined, by finding the most intense PL and the PL peak closest to the ideal wavelength of 390 nm, that the optimal structure for the SLs is for the layers to have thinner InN wells, approximately 1.7 nm, and GaN barriers that are approximately 9 nm. Additionally, the peak PL emission wavelength shifted from 3.2627 eV to 3.1791 eV to the longer wavelengths when the ratio of InN to GaN is smaller, such as 1.73/9.2 nm. For the MQWs, where we are interested in a narrow line width, samples grown on a nonpolar plane with decreased growth pressure and increased growth temperature of the QB showed the narrowest FWHM. The correlation between wavelength and polarization ratio is that as the polarization ratio increases, the MQW's PL emission shifted to a longer wavelength, due to the growth pressure decreasing from 150 to 100 Torr. However, the correlation between FWHM and polarization ratio is that as FWHM decreases from 0.1399 eV to 0.2722 eV, the polarization ratio increases from 0.1092 to 0.4754. In conclusion, the SLs were found to have narrower barriers, which allowed for a stronger PL emission, while the nonpolar growth plane and decrease in growth pressure allowed for a narrower PL linewidth in the MQWs.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Gregory Garrett and Dr Roy Chung.

## **Effect of Porosity on Synthetic Sand Infiltration within Yttria-Stabilized Zirconia Pellets**

Wright, Andrew

Yttria-stabilized zirconia pellets of varying composition (3 mol% and 8 mol% yttria) and porosity (0.5%–60%) were processed by pressureless sintering, cold sintering, and spark plasma sintering. The consolidated pellets were characterized nondestructively through X-ray diffraction (XRD), scanning acoustic microscopy, confocal laser scanning microscopy, and with a scanning electron microscope equipped with an energy dispersive X-ray spectrometer preceding and following testing. Each pellet was exposed to AFRL-02 synthetic sand at high temperature ( $\approx 1300$  °C) through means of either stationary or accelerated contact with an exposure time of approximately 15 min/pellet. Posttest characterization results were compared to the corresponding pretest data to draw conclusions on the degree of infiltration and mechanism. Density measurements were calculated through Archimedes' method and compared to the pretest values to determine the mass/volume of sand infiltration along with any clues hinting at possible sintering. XRD results show the introduction of new crystal structures suggested to be synthetic quartz along with a negative peak shift of  $2\theta = 0.5^\circ$ , which may be compressive strain.

### **Acknowledgments**

I wish to acknowledge the mentorship of Michael Walock, Anindya Ghoshal, and Andy Nieto. I would also like to thank Dr Victoria Blair for her help and the use of her facilities.

### **Student Bio**

Andrew Wright is a first-year chemical engineering grad student at the University of California (UC), San Diego. He obtained his undergraduate degree at Washington State University. His past research experience was in the field of electrochemical separations, and his work involved microchip fabrication and testing coupled with 2-D and 3-D modeling. His future plans are to obtain his doctorate from UC San Diego and either look for a postdoc position or look for work, possibly with military applications.

## **Investigation of Advantages and Limitations of THz Spectrometry for Nondestructive Evaluation (NDE) Applications**

Xiao, Geoffrey

Since 1983, the Army has mandated that all deployed equipment be coated with chemical agent-resistant coatings (CARCs). A 2-layer system of primer and topcoat, CARCs are engineered to provide maximum protection against environmental conditions, corrosion, and chemical agents. Currently, however, few nondestructive evaluation (NDE) techniques exist to determine the performance of either the protective coating or the material underneath the coating. Oftentimes, it is necessary to completely remove the CARC paint using caustic and harmful paint strippers before the material under the paint can be inspected. To this end, time-domain terahertz spectroscopy is proposed as a method capable of nondestructively detecting the onset of corrosion under CARC paints. More penetrating than visible or infrared radiation but less harmful than high-energy ionizing X-ray radiation, terahertz occupies a niche in NDE techniques. Here, terahertz spectroscopy is shown to reliably identify corrosion under a variety of CARC systems and on different materials. This project further explores the limitations of the method, the nature of the image contrast between the artificially induced corrosion and the metal surface, and acquisition parameters required to successfully image the defect. The correlation between dielectric properties and CARC quality is also examined.

## **Optical Characterization of Crystalline-Core, Crystalline-Clad Fiber for Laser Performance**

Xu, Michael

Fully crystalline double-clad fibers, or “crystalline-core/crystalline-clad” fibers are best suited for major further laser power scaling out of single-fiber aperture because of their higher thermal conductivity, higher peak absorption and emission cross-sections, and low stimulated Brillouin scattering (SBS) gain coefficient. Reported here are the measurements of the optical transmission and scattering loss of 2 crystalline core crystalline clad fibers. The 70-mm- and 85-mm-long fibers were fabricated using a liquid phase epitaxial growth (LPE) of undoped single-crystalline YAG cladding around the 100- $\mu\text{m}$  single-crystalline Yb:YAG core separately grown by a laser-heated pedestal growth (LHPG) technique. These new developmental fibers are 1% YAG-doped and have the potential for high-power laser operation in the 1- $\mu\text{m}$  wavelength range. The tests were performed with 2 laser sources such as a 633-nm Helium Neon laser and a 1550-nm Santec ECL laser. Both diffraction-limited lasers have been optically coupled into the crystalline fiber. The laser performance of the 2 fibers are also presented as a result of the overall loss figure measurement.

### **Acknowledgments**

I wish to acknowledge the mentorship of Dr Jun Zhang and HEL JTO Directed Energy internship.

## **Using Phase Lock Loops and an Optical Frequency Comb to Generate Low-Noise Microwave Signals**

Yeh, Malachi

A low-noise frequency comb is desirable because when using the unique properties of the comb and a photodiode, one can easily generate a low-noise microwave radio frequency signal. This summer I worked on understanding, designing, and building a phase lock loop that would lock an optical frequency comb to a low-noise 1550-nm laser. After many design iterations, I successfully achieved a lock between the frequency comb and the laser. By attaining a lock between the frequency comb and the laser, the comb obtained the low-noise characteristic of the 1550-nm laser and generated a 10-GHz microwave radio frequency signal. By locking the comb to the laser, I lowered the phase noise of the microwave signal by up to 20 dB between the 10-Hz and 7-kHz frequency range. Also while in the 30-kHz to 1-MHz frequency range, most of the time the noise floor remained the same, but occasionally the noise floor was lowered by up to 10 dB. Even though these results show that the phase lock loop achieved its purpose, an interesting peak occurred between 7- and 30-kHz frequencies. I believe this peak arises because of devices controlling the carrier envelop offset frequency of the optical frequency comb because this peak is only seen when the carrier envelop offset frequency is locked. Future research will involve locating the source of this anomaly and determining how to eliminate the peak.

### **Acknowledgments**

I wish to acknowledge the mentorship of James Cahill.

## **Atmospheric Renewable Energy – Study #2 (ARE2) – Cloud Characterization**

Young, Renea

Future military and disaster relief power grids will consist of both traditional and nontraditional power resources. To optimize the integration of renewable energy resources, such as photovoltaic (PV) systems (a nontraditional power resource), into these state-of-the-art power grids, knowledge of current and future solar radiation conditions are needed to estimate PV production. During my internship, I worked with a team of intern researchers and my mentor on the Atmospheric Renewable Energy Study #2 (ARE2) project at White Sands Missile Range to research the impact of clouds on PV production during seasonally clear, overcast, and partly cloudy conditions. In particular, I acquired and processed hourly Simulated Whole Sky Imager (s-WSI) data, as well as supported the team members who focused their efforts on solar radiation modeling and measurements of power/solar radiation. During my internship, I learned how to operate and maintain the s-WSI, document sky conditions (after learning the 9 major cloud types, along with their many variations), and process and analyze the hourly images. I was also responsible for co-leading the ARE2 data management. The culmination of my cloud characterization research will be presented to the US Army Research Laboratory (ARL) workforce on 9 Aug 2017 and my work will be documented in an ARL Technical Report.

### **Acknowledgments**

I would like to acknowledge my mentor , Gail Vaucher.

## **Synthesis of Self-Healing WiSE Gel Electrolytes for Use in Li-Ion Batteries**

Zhang, Dean

Nonhydrolysable lithium salt dissolved in water at a high concentration has the potential to form a conductive, nonflammable, aqueous electrolyte alternative to the organic Li-ion battery electrolytes prevalently used today. These are called water in salt electrolytes (WiSEs). Implementing WiSE in the form of a gel polymer would make them both flexible and durable. Pure urethane gels based on poly-vinyl alcohol, WiSE, and cross-linker diisocyanates of varying carbon chain lengths were synthesized and examined for mechanical and conductive properties. The use of hexamethylene diisocyanate (6-carbon chain), in particular, yielded a free-standing, flexible, tough electrolyte gel that contained high Li-ion conductivity and the greatest potential to be implemented into a durable Li-ion battery. Synthesis of urethane gels using diisocyanates with shorter carbon chains tended to result in more fragile gel properties, while synthesis using longer carbon chain diisocyanates formed a viscous liquid rather than a gel. In order to further improve upon the durability of these gels, urea-urethane gels were also investigated for their self-healing properties. Essential to batteries, these self-healing properties would be essential for ensuring the maintenance and repair of the electrolyte between the battery's cycles of charge and discharge. These urea-urethane gels were synthesized through the reaction between a diisocyanate and a hindered diamine. The resulting gel was able to quickly re-form after being cut or torn but was relatively fragile and less flexible than the pure urethane gel. As such, a combination of hexamethylene diisocyanate and self-healing urea-urethane gel was formed to create a flexible, tough, self-healing gel.



## **Er-Nanoparticle-Doped Fiber Amplifier Performance and Automated Test**

Zhang, Harrison

A nanoparticle (NP) doping technique of fabrication erbium-doped fibers helps to significantly mitigate both Er up-conversion and clustering effects in silica glass. This technique thus enables much higher Er doping levels, which is critical for laser power scaling. Er-NP doping also somewhat increases the Er-ion emission cross-section due to a modified Er-ion environment versus conventional silica glass. Reported here are the results of core-pumped single-mode fiber-amplifier performance based on these Er-NP fibers. Several Er-doped fibers, drawn at NRL, have been tested, and the efficiencies of the fiber amplifiers are reported. A cutback procedure was used to determine the optimal length for each fiber. Efficiencies for the fibers at their respective optimal lengths generally varied. Labview software has been developed to control the diode drivers and optical power meter for the test automation.

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## **Probabilistic Logic-Based Modeling of Opponent's Strategy in Games**

Zhang, Jenny

In game theory, human strategies and actions are studied to find the most beneficial payoff in a scenario. With growing sets of data, machine learning can be an effective way to analyze patterns and compute the most likely result based on the properties of game theory. In this research, a program will predict the most likely hand of an opponent in a game of Texas Hold'em. A Bayesian network will be implemented to learn patterns in a data set and predict outcomes based on those patterns. A Bayesian network will be modeled using PRISM, a probabilistic logic-based language based on B-prolog used for machine learning. Probabilistic logic programming utilizes first-order logic and declarations of rules to apply probabilities to the relationship of entities. Using the logic, probabilities will be assigned to the results of different sequences of actions. When predicting the hand of an opponent, the sequences and probabilities are examined to find the most probable outcome. It is hoped that the program will present machine learning as a quick and valuable tool in analyzing an opponent's strategies in games.

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