ARL-SR-0435 ● FEB 2021

2018–2020 DEVCOM Army Research Laboratory Summer Student Program, Volume II: Compendium of Abstracts

Compiled by Danell Diggs

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Compiled by Danell Diggs
Outreach Office, Plans and Programs, Laboratory Operations,
DEVCOM Army Research Laboratory

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14. ABSTRACT

The US Army Combat Capabilities Development Command Army Research Laboratory Summer Student Symposium is a DEVCOM Army Research Laboratory 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 the students and their mentors in the support of Army science. All college undergraduate and graduate students receiving research appointments and conducting summer studies at ARL are automatically enrolled in the symposium program. As an integral part of their summer study, all students are required to give a presentation summarizing their major activity and its end product. The program is conducted on two separate competitive levels: undergraduate and graduate. While technical presentations followed the same format, the evaluation considered the difference in academic level. All students presented their work orally and directorate judging panels selected two technical presentations from each competition category for the annual laboratory-wide competition at the Summer Student Symposium, held on August 9, 2018, August 8, 2019, and 6 August 2020. At the symposium, the students presented their technical presentations to the ARL Director and an ARL Fellows panel. This volume contains many of the abstracts for the technical presentations prepared from FY2018 through FY2020.

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Director's Foreword

The US Army Combat Capabilities Development Command Army Research Laboratory 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. DEVCOM Army Research Laboratory 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 research experiences at ARL. During the summer, we supported research experiences at ARL for over 300 undergraduate and graduate students. Each of these students writes a paper describing the results of the work they performed while at ARL. All of the technical presentations were of high quality, but only a few could be presented at our student symposium. Many of the abstracts for the technical presentations prepared this summer are contained in this volume of the proceedings, and they indicate that there were many excellent research projects with outstanding results. It is unfortunate that there was not enough time for us to have all of the technical presentations presented. We would have enjoyed hearing them all.

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.

Patrick Baker
Director

Introduction

The US Army Combat Capabilities Development Command Army Research Laboratory Summer Student Symposium is a DEVCOM Army Research Laboratory 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 the students and their mentors in the support of Army science.

All college undergraduate and graduate students receiving research appointments and conducting summer studies at ARL are automatically enrolled in the symposium program. As an integral part of their summer study, all students are expected present an oral presentation on their work, which summarizes their major activity and its end product.

The program is conducted on two separate competitive levels: undergraduate and graduate. The format of the paper in both levels is the same. However, the evaluation will take into consideration the difference in the academic level of the students.

All students present orally during a directorate review. Directorate judging panels selected one or two technical presentations from each competition category for the annual laboratory-wide competition at the Summer Student Symposium, held on August 9, 2018, August 8, 2019, and 6 August 2020.

At the symposium, the students presented their technical presentations to an audience of ARL scientists and engineers, including the ARL Director and an ARL Fellows panel.

This volume of the Summer Student Symposium Proceedings contains many of the abstracts for the technical presentations prepared for the Summer Student Symposium Program from FY2018 through FY2020.

FY2018 Student Abstracts

Human-in-the-Loop Route Planning for Human–Robot Teams

Carlos Andrade

Traditional path planning systems do not take into consideration risk and effort factors of an environment that may contribute to the success of an Army mission. A new path planning algorithm was developed at ARL that more intelligently analyzes the environment by incorporating risk and effort weightings based on human users' preferences toward those factors. The goal of this project is to demonstrate the algorithm's behavior on a physical system (a robot) and study the human–robot interaction in real time when a previously unknown obstacle or threat is detected along the originally generated path and must be updated. A system of three parts was designed to implement the algorithm, ensure an autonomous mode, and facilitate human–robot teaming: 1) the robot was built using Lego Mindstorm hardware running Linux and communicates via Bluetooth; 2) AprilTag, a visual fiducial tracking system, was used to implement the robot's localization and obstacle/threat detection in the environment; and 3) the interface to interact with the robot is a Raspberry Pi with a touchscreen in which the user communicates with the robot. Overall, the project has a potential application for studying how global path planning for missions can be optimized and how to improve local navigation of current semi-autonomous systems.

I wish to acknowledge the mentorship of Dr Margaret Duff for her help in the implementation of the object/threat detection system with AprilTag, and Dr Brandon Perelman for his assistance in the implementation of the path planning algorithm on a robot, as well as their guidance on this project.

Design and Tolerance Analysis of a Narrow-Wall Resonant Inclined Slot Array

Ryan Assi

A tolerance analysis was conducted on a narrow-wall slot waveguide antenna array for C-band radar applications utilizing a maximum tolerance of 10 mil due to the available manufacturing process, with $\pm 5\ mil$ and $\pm 10\ mil$ tolerances for depth and spacing, as well as 1°, 2°, and 5° tolerances for tilt angle to realize the sensitivity of the design. Utilizing Ansys' High-Frequency Structure Simulator (HFSS) software, these tolerances and variations were used to perturb the slot parameters: depth, width, spacing, and tilt angle. The resonant spacing is critical for effective radiation in the operating band. The tilt angle is the main perturbation of waveguide surface currents to achieve radiation, and alternating slot tilts match the polarity of the radiation from each slot. A small change in tilt angle mostly affects the impedance, while larger changes additionally affect the element phasing. The depth is critical for radiation over the target bandwidth, as it helps realize an effective slot length corresponding to the target frequency. Overall, the depth and tilt of the slots are the most important parameters. The optimal fabrication does not always correspond to the optimal design, as tolerances can help further the understanding of considerations to better meet the objectives due to unavoidable manufacturing tolerances.

I wish to acknowledge the mentorship of Dr Charles Dietlein and Mr Seth McCormick, with the additional honorable help of Dr William O'Keefe Coburn and Mr Theodore Anthony.

A 3-D Sensitivity Study of a Human Surrogate Model for Ballistic Impact

Ryder Babik

The current understanding of the relationship between bullet impacts to Soldier helmets and resulting behind-helmet brain trauma is limited. While injury criteria on the allowable backface deformation of helmets may soon be implemented, a greater understanding of the causes of brain injuries due to bullet impacts and ways to best limit these injury effects must first be achieved. Through the use of finite element analysis, a parametric study was conducted to analyze the effects of skull and skin thicknesses on the pressures, forces, and strains in the brain. With the inability to compare theoretical to experimental results for human simulations, the parametric study was conducted on nine Yucatan pig models. The initial model was first developed from a segmented computed tomography scan, and then the skin and skull were stretched along the projected shot line to the desired thicknesses (skin: 6, 9, and 14 mm; skull: 6, 9, and 12 mm) to develop nine total models, representing all combinations of three skull and three skin thicknesses. To reduce simulation runtime and complexity, the bullet and helmet were replaced by a single impactor, as constructed from a helmet backface deformation layer extracted from another simulation previously run with the helmet and bullet. Simulations are currently still being run and analyzed.

I wish to acknowledge the mentorship of Kimberly Thompson and Samantha Wozniak.

Experimental Method for Dynamic Single-Fiber Transverse Impact

Robert Bass

A novel method for high-strain-rate transverse loading of single fibers has been developed, allowing in situ quantitative visualization of fiber deformation. Understanding single-fiber complex loading is crucial to understanding the response of more complex fiber-based systems such as yarn and fabric. As far as we know, the state of the art for smallest-length-scale quantification of the high-rate impact response is the yarn. Only recently at ARL, a quasi-static indentation method was developed for transverse loading of single fibers by O'Neill et al. In the high-rate single-fiber impact method, the specimen-end of the 0.25-inch-diameter input-bar was fitted with a plastic sleeve, allowing different impact head configurations to be installed. For the first time, high-speed cameras captured fiber deformation during impact; and a method of measuring the fiber deformation and axial force during impact was implemented, up to 28-m/s velocity. The deformation of fiber and force response is to be used to describe and model the mechanical response of the fiber during transverse impact. As the impact velocity is increased, and with different impactor geometries, the measurements and observations will allow refinement of current computer models, as well as greater understanding of the transition of failure mechanisms from shear to tensile.

I wish to acknowledge the mentorship of Dr Tusit Weerasooriya. The contributions of Dr Subrimani Sockalingam, Stephen Alexander, and Alan Gunnarsson were also vital in researching this topic.

Applying Semi-Supervised Learning to German Automatic Speech Recognition

Oliver Bentham

Semi-supervised learning is a type of machine learning that makes use of unlabeled data for training, and has been shown to work in automatic speech recognition. A model is trained from labeled data and is then used to predict "pseudo-labels" for unlabeled data. The pseudo-labeled data are then reincorporated with the labeled data into the learning process to generate a stronger model. This method can be applied to the US military's German Köln corpus, which has 14.7 h of transcribed (labeled) data and 2.8 h of non-transcribed (unlabeled) data. We used the open-source toolkit Kaldi to create speaker-adapted triphone models. We normalized the labeled data to more closely reflect spoken language, generated a language model from German text, and adjusted hyperparameters in the learning phase to tune the model. The word error rate without the pseudo-labeled data was 41.41% and it rose to 48.93% after the pseudo-labeled data was included in training. This is due to an insufficient language model and many out-of-vocabulary terms in both the lexicon and the language model. Semi-supervised learning is also typically applied when the amount of unlabeled data drastically exceeds the labeled data.

I wish to acknowledge the mentorship of Dr Stephen LaRocca and Mr John Morgan.

Nickel-63 Isotope Decay in Low-Flux Environments

Viola Berman

Radioisotope power sources are capable of decades-long power delivery because of the long half-lives of beta-emitting isotopes. Damage on wide-bandgap semiconductors has been measured for high-flux space applications. Less effort has been put into damage from lower-flux environments. The electrical output from indium gallium phosphate photovoltaic cells with 50-mCi of nickel-63 exposure have been measured for a period of 18 months. While the energy conversion efficiency for this geometry is only 0.1%, the electrical output is compared to the isotope decay over time. No measureable damage is observed within calculated statistical variation.

I wish to acknowledge the mentorship of Marc Litz, who continually guides me through this whole process.

Mapping Deep Neural Networks on Field-Programmable Neural Arrays

Melissa Bezandry

The purpose of this research is to develop software that maps deep neural networks (DNNs) on a field-programmable neural array (FPNA). Compared to other implementations of DNNs on-chip, FPNAs offer the flexibility to cover varying neuron structures and more energy efficiency. FPNAs consist of three components: neurons, synapses, and configuration. The main focus of this research are the neurons, which compute the DNNs. The neuron structures were built in Python through classes that have an input map function. The function map sources neurons' IDs and data indices into its destination neurons. These input maps change in size to accommodate given neuron memory limits. Once the neural network is generated, its mapping is exported to an Extensible Markup Language file, which can be fed into synapse routing software. This software is extensible so that in the future it can accommodate other DNNs.

I wish to acknowledge the mentorship of Peter Gadfort and Oluseyi Ayorinde.

Substantiation of Dynamical Behaviors at Different Scales

Daniel Blackman

Through leg design and neuromuscular control, animals have demonstrated the ability to traverse rough terrain and overcome obstacles at a variety of scales. In engineering, achieving similar results requires an understanding mechanical leg design and limb coordination, energetic properties realized through actuation, and controller coordination and design. When working with larger systems, the prescribed cost of these requirements increases at a nearly exponential rate, through both the time and money required to realize these necessary components. One solution is to mitigate the process through prototypical scaling, as is often done with development of large vehicles such as aircrafts. This can be done, but it is compulsory that an understanding of system limitations is understood at the large scale first to enable the offloading of design principles to a smaller system. In this study, the properties of dynamic similarity and scaling are applied to produce analogous behaviors between comparable legged platforms that differ in leg length and mass. A series of tests in one dimension are utilized to execute system identification of damping and actuation input and the results are applied to running dynamics, producing preliminary results toward scalable gait development.

I wish to acknowledge the mentorship of Jason L Pusey in the Vehicle Test Directorate.

Robust Adaptive Control of a Thrust Vectoring Unmanned Aerial Manipulator

Anderson Blake

The goal of this summer's internship was to continue developing an advanced autopilot for unmanned aerial manipulators. Previously, we had coded and tested an advanced nonlinear control algorithm, which successfully flew on a small quadrotor. This year, the vehicle is the propulsion core; a large thrust vectoring octorotor, which has eight motors that can all tilt allowing for forces to be placed in multiple directions. In addition, this vehicle has a telescoping robotic arm (designed by University of Pennsylvania and ARL), which allows the vehicle to manipulate payloads or apply forces to the environment. Complicated control challenges arise, such as now having an unsteady center of mass and aerodynamic disturbances, which occur from flying close to buildings or walls. To control this vehicle, a novel control algorithm is presented, which is a modified version of Model Reference Adaptive Control. To test the control law, a physics-based simulation of the vehicle and its scenario were created in MATLAB's Simscape Multibody environment. Successful simulations have shown rejection of wall effect disturbances (modeled after real experimental data), moving center of mass, and controlled flight maintained even after the total loss of two of the vehicle motors.

I wish to acknowledge the mentorship of Jim Dotterweich. I am very grateful for the wealth of knowledge and expertise that he has been willing to share with me, and this summer has made me both a better student and researcher.

Isotope Battery Geometry Optimization for Maximum Power

Samuel Blumenthal

Isotope batteries enable decades-long power for sensors because of the long half-lives of many isotopes. The goal of this research is to determine the optimal volume of selected isotopes for maximum power output per centimeters squared. The three isotopes evaluated were tritium (^{3}H), nickel-63 (^{63}Ni), and promethium-147 (^{147}Pm) in a silicon carbide (SiC) energy converter. Isotopes are applied to a SiC energy converter in the volume of an etched or as applied to the top surface (cap). General Monte Carlo N-Particle was used to model the nuclear scattering in a device structure and to calculate energy deposited in the SiC energy converter. MATLAB was used to analyze the resulting energy deposition data and visually preview the pattern within the device. Parametric investigation of etch hole size and isotope cap thickness was performed. Excel was used to organize the data and evaluate optimized power output. The thinner the isotope cap, the more efficient the energy transfer to the SiC energy converter. The optimal hole etch size was determined to be approximately 11 μm. These data will be used in the creation of optimized geometries on a wafer to generate the maximum power output of isotope batteries per centimeters squared.

I wish to acknowledge the mentorship of Marc Litz.

Implementing a Data Collection System to Capture Human Variability

Saoirse Bodnar

Human behavior is widely recognized to be highly variable both between and within individuals, meaning that general-purpose approaches to both perceiving and predicting the behavior of individual humans are usually constrained, particularly in time. This human variability presents a gap requiring technology to adapt to the individual for enhanced human–system performance. Enabling high-speed responses or adaptations to the individual necessitates treating the human as a sensor. This project demonstrates a mobile data collection system to capture and leverage human variability by continuously recording and computing dynamic physiological signals, particularly heart-rate variability, from two different sensors (Samsung Gear S3 and Zephyr Bioharness). Separate wearable and mobile applications were developed to stream, analyze, and visualize the heart-rate data. The native wearable application records heart-rate data and sends it to the smartphone hub, which analyzes and visualizes the data while archiving it on the server. This system was developed for implementation in ARL's Innovation Commons, a pervasively sensed space for longitudinal, real-world data collection. Future plans include projecting data visualization onto proximate available screens within the Innovation Commons. The end goal is to compile and analyze longitudinal data from many users to enable adaptive systems that leverage human variability.

I wish to acknowledge the mentorship of Mr Jonroy Canady and Dr Amar Marathe. Additionally, I would like to thank Dr Kelvin Oie, Mr Ian Egland, and Ms Marilynn Peterson for their time and expertise with this project.

Visualizing Behind-Armor Blunt Trauma Injury

Skylar Bodt

A thorough understanding of the specific mechanisms for behind-armor blunt trauma (BABT) injuries is critical in advancing body armor design. Because the complex body does not have a uniform injury risk, it is important to consider the specific impacted areas of the body when investigating the injury outcomes. Therefore, a visual tool to display the impact locations of BABT cases can help to convey subject-specific factors that may have contributed to the injury outcomes. Several different media platforms for creating the visual tool were examined. Ultimately, Adobe Animate CC was chosen to create a web page with a concise and interactive visualization of an anterior/posterior human torso displaying each BABT impact point. Further, each point contains a dynamic link providing details about the case when the cursor is placed over the point. The opacity for the skeletal and organ structures can also be adjusted to allow certain parts of the body to be seen more clearly. Additionally, an Abbreviated Injury Scale mode displays each impact with a color-coded injury severity. This interactive visualization tool enables researchers to infer relationships among BABT injuries, body systems, and armor response to the threat in a more accurate and efficient manner.

I wish to acknowledge the mentorship of Karin Rafaels and Autumn Kulaga for the past three summers.

Investigating the Unique Sensing Technique of Embedded Ferromagnetic Particles in Epon-828 Epoxy

Jonathan Bolanos

Currently, various sensing techniques such as acoustic emission, pitch catch ultrasonic sensors, strain gages, and accelerometers can all provide structural health monitoring. This paper is focused on the investigations of embedding ferromagnetic Terfenol-D particles into an epoxy to provide on-demand interrogation of the structure to determine its current state of health. The permeability, saturation magnetization, coercive fields, and torque measurements were provided by a torque magnetometer and vibrating sample magnetometer. The results confirm that the alignment of the magnetic domains of the Terfenol-D in the Epon-828 epoxy shows little to no hysteresis, indicating their principle axis of anisotropy are collinear with the induced magnetic field. Additional experiments will be presented to validate that adding ferromagnetic particles to epoxy can provide a unique sensing capability.

I wish to acknowledge the mentorship of Asha Hall, Michael Coatney, Natasha Bradley, and Todd Henry. I would like to give special thanks to my team leader Dr Asha Hall, for her guidance, encouragement, and inspiration. I am grateful for ARL at Aberdeen Proving Ground, Maryland; none of this research would be possible without the efforts of the ARL staff whose support and guidance are deeply appreciated.

Jackal Sensor Mount

Madelyn Brainard

To operate in a human-designed world, the US Army's autonomous ground vehicles rely on a large number of sensors to detect objects and threats of significance to the humans around them. The purpose of this project was to design and fabricate a multi-sensor mount for such a robot that allowed the robot to sense objects at tabletop height. The mount for the robot was designed in a 3-D computer program and was then manufactured using extruded aluminum, rubber, reinforced plastic, and an optical breadboard for interchangeability between different robots. To test the strength of the mount, the axial force and shear force were calculated per rod. With the current sensor payload, the mount can withstand 7.7145 psi and up to 35000 psi of vertical force as well as 5.998 psi of horizontal force. After further analysis of the mount, vibration dampening rubber was added to the parts of the mount that directly house the sensors in an attempt to compensate for the height of the sensors. Future research with this multifaceted sensor mount includes cognitive and vibrational research as well as perception and object detection.

I wish to acknowledge the mentorship of Dr MaryAnne Fields and Mr Jeff Westrich. I would also like to thank all of the Intelligent Control Team who assisted this project and helped me develop my knowledge of robotics and mechanics during my time here.

Quantification of Morphological Changes of Hippocampal Neurons In-Vitro Following Stretch Injury: The Effects of Injury Severity

Mikirra Bullard

The occurrence of traumatic brain injury (TBI) in the armed forces has become more prevalent over the past two decades. The Army needs a better understanding of the mechanism of brain injury and the link between the mechanical parameters of an insult and the corresponding biological injury. This investigation focuses on how increasing levels of injury affect the morphology of neurons to determine a threshold value, or minimum mechanical parameters that result in a detectable injury, to help improve computational models and evaluate future protective equipment needed to help decrease the incidence of TBI in Warfighters. In this study, TBI was simulated in vitro using hippocampal neurons. The neurons were mechanically stretched at the following pressures: 0, 10, 20, 30, 40, and 50 psi, using the Cell Injury Controller II device. Phase contrast images were taken before and after injury to observe changes in neuronal morphology of a single cell over time. The images were processed using the FIJI software plugin Simple Neurite Tracer,[1] and changes in neuronal morphology were quantified using the Sholl Analysis plugin. Preliminary results show critical values decreased following injury at strains higher than 20%.

I wish to acknowledge the mentorship of Dr Ann Mae DiLeonardi, and I would like to thank Erika Matheis for her assistance throughout the internship program.

[1]Longair MH, Baker DA, Armstrong DA. Simple Neurite Tracer: open source software for reconstruction, visualization and analysis of neuronal processes. Bioinformatics. 2011 Sep 1;27(17):2453–2454.

Developing and Validating a Computational Model of Passive Electric Properties in the Head

Benjamin Burke

Electrical activity in the brain has been shown to correlate with human performance. Understanding how this electrical activity is filtered by the passive properties of the head and skull, including frequency-based impedance, is critical to inferring how brain signals are filtered. Creating a computational model of the passive electrical properties of the brain is essential for linking neural imaging to brain activity. To accomplish this, we developed a finite element model of the distribution of electric current within the skull. We used MATLAB to simulate the voltages recorded from the flow of current through the brain. The model was validated through the creation of ballistics gelatin blocks that emulate the electrical properties of the human head. A wire at the center of the gelatin was used to propagate current as the dipole. The voltages of the gelatin were compared to the voltages in the model to evaluate the model's accuracy. The model will undergo continuing validation and verification. This model will be useful for demonstrating how current is related to brain activity and improving the ability to correlate brain activity with performance.

I wish to acknowledge the mentorship of Drs J Cortney Bradford, W David Hairston, and Dave Boothe.

Refining Finite Element Human Surrogate Model for Ballistic Impact

Quinton Burke

Traumatic brain injury (TBI) arising from ballistic impact on the battlefield has become a major focal point for researchers and engineers within the US Army. Current work relies on comparing experimental data from porcine to a finite element model (FEM). The FEM can be used to simulate real-life behavior and can help to better understand TBI in the human brain, where experimental testing is unavailable. In this research, the primary concern is improving the model and determining the most ideal and efficient way to create the FEM. First, a 2-D convergence study was created to determine significant trends related to wave interaction and pressures in the brain, as well as to determine an ideal and efficient element size for meshing. Based on these results, a 3-D cerebrospinal fluid (CSF) study was conducted to determine the influence of a CSF layer around the brain and further improve the model. Using the ANSYS program ICEM CFD, tri-meshes were created to accurately represent the geometry of the porcine head. Material properties as well as boundary conditions were set using the LS-DYNA software LS-PrePost. The results were then analyzed and plotted using a MATLAB script.

I wish to acknowledge the mentorship of Kimberly Thompson and Samantha Wozniak.

Predicting Thermal Decomposition Temperatures: A Machine Learning Approach

Mark S Butrico

In this work, we use machine learning techniques to create a model for prediction of molecular thermal decomposition temperatures. A detailed experimental data set was created for model training. Multiple descriptors including Morgan fingerprints, sum over bonds, and estate fingerprints were used as vector inputs for the machine learning model. The model was trained and tested using nested cross-validation to analyze the error metrics, including mean absolute error, root-mean-squared error, Q^2, and Pearson correlation of the machine learning model. Four separate algorithms were tested: least absolute shrinkage and selection operator, Gaussian process regression, random forest, and the multilayer perceptron. The predictive accuracy was evaluated for each regressor/descriptor combination, concluding the best combination of regressor and descriptor was the Gaussian process regressor and the Morgan fingerprints descriptor.

I wish to acknowledge the mentorship of Brian C Barnes.

Test-Rig Design for Examining the Electrical Component of a Hybrid-Electric Propulsion System

Kyle Callaghan

Hybrid-electric propulsion systems allow an airframe engine to be sized for maximum continuous performance instead of maximum peak performance. This allows the use of smaller, more efficient engines for cruise, with an electric motor to boost the power output when needed, namely takeoff. A testing rig was designed for the electric component of this drive system. An Emrax 208 motor, controlled by a Unitek Bamocar PG-D3 Servo Amp, and a National Instruments cRIO are the tested components. The parameters for the power bus are obtained from an Opal RT simulation, while the propulsion load comes from an Opal RT simulation in conjunction with a Flight Lab profile. This serves to provide field-realistic parameters for the motor. While the test rig currently sits in a small-scale version, the full-scale version is just a swap of components, with the leg work of programming the cRIO complete.

I wish to acknowledge the mentorship of Dr Brian Dykas.

Neural Machine Translation for an Android Device

Gerardo Cervantes

There is a need for a translation system for communication between people when there is no access to an Internet connection. Neural machine translation (NMT) has recently achieved state-of-the-art results on this difficult task. Gathering appropriate data is usually an expensive and time-consuming task, and an NMT requires a substantial amount of data. Luckily, there are many parallel text translations through movie subtitles that are publicly available for anyone to download. Unfortunately, movie subtitles are in a different domain than the military domain we need the device for, so they lack military terms. Movie subtitles are also notoriously noisy, which includes inaccurate translations, profanity, or erroneous words. We also have in-domain data with many military terms, but we have a small amount of this data. This in-domain data will give us a good indicator of how well the NMTs will work with just movie subtitle data. We found encouraging results that subtitle data can be used for good translation, though adding in-domain data to the training is needed for improving the NMT system for a military setting.

I wish to acknowledge the mentorship of Stephen A LaRocca.

Driving Influence and Containing Misinformation

Pedro Cisneros-Velarde

Social networks are ubiquitous in our lives, and the advent of online social media has changed the dynamics of interpersonal relationships. Particularly, the spread of information has different timescales compared to a physical social network and usually has a wider geographical coverage. One topic of concern is the spread of misinformation, as most "fake news" is born as a simple online post (e.g., a shared "tweet" or content on Facebook), but with the potential of a huge impact due to the information dissemination dynamics of the underlying online social network. My research objectives are two-fold. First, I investigate how is it possible to change the interpersonal relationships between members of an online social network such that it is possible to drive their final opinion to a desired state. Second, I investigate how the spread of misinformation can be contained due to policies assessing the quality of information from a central entity.

I wish to acknowledge the mentorship of Kevin Chan.

Developing a Coarse-Grain Equation of State

R John Clark

There is a strong desire to understand energetic materials and what affects their sensitivity and performance. Microstructure has been found to play a significant role in determining these characteristics. As a result of the decline in computational cost and the expensive cost of running a large number of experiments, there is a shift to perform simulations to obtain the relevant information. The long timescales and large length scales required for these systems are unobtainable by running fully atomistic simulations. Coarse-grain methods allow us to probe these micro length and time scales effectively by representing a molecule as a single site. However, with the reduction in the number of degrees of freedom, information about the system is lost. This internal energy can be recaptured in constant energy dissipative particle dynamics. A mesoparticle equation of state can be incorporated to recapture the internal energy of the particle. We are working on a method to obtain this coarse-grain equation of state for single- and multisite coarse-grain models that can be extended across coarse grain systems regardless of complexity.

I wish to acknowledge the mentorship of Drs John Brennan and James Larentzos, as well as the valuable contributions of Dr Patrick Lafond and my fellow intern Jonnathan Ruffley.

A Comparison of Two Factor Separation Methods

Judah Cleveland

Modeling the atmosphere necessarily involves properly representing the interactions of many factors. Because of these manifold interactions, Numerical Weather Prediction codes can become quite complex; consequently, properly sampling the codes is the only computationally tractable means of identifying an optimal configuration. Two sampling methods are currently available to attribute model response to particular factors: 1) the method of factor separation in current use in the atmospheric science community and 2) statistical design of experiments (DOE) in extensive use in other communities. We found that while these methods produce different outputs, they appear to be mathematically related, an equivalence that heretofore was unknown. It is known that DOE effects are twice the regression coefficients when using effects coding (1 for when a factor is present and –1 for absent). The factor separation results appear to be the same as the regression coefficients when using dummy coding (1 for when a factor is present and 0 for absent). Establishing this relationship allows for the use of other statistical methods when using factor separation, such as significance tests and confidence intervals.

I wish to acknowledge the mentorship of Dr Jeffrey Smith and the input of Dr Louiza Fouli.

Machine Learning Approaches to Identifying Aerosol Particles Based on Raman Spectra

Raymond Clubb

Atmospheric aerosol particles have a significant effect on human health and visibility. In order to make useful predictions on the state of the local atmosphere, robust aerosol identification systems are needed. However, due to the small size and relative impurity of atmospheric aerosol particles, methods of chemical analysis are unreliable. In this project, we assess the effectiveness of various machine learning methods and preprocessing procedures for identifying atmospheric aerosols and attempt to create a robust classifier based on Raman spectra. Airborne mineral species have distinct Raman spectra, which can be used for differentiation.

I wish to acknowledge the mentorship of David Doughty and Steve Hill.

Improving the Test Methods and Efficiency of the Test, Reliability & Evaluation Branch's Vapor Simulant Testing

Christina Compton

The objective for this summer's internship was to improve the efficiency and test methods of the Test, Reliability & Evaluation Branch's (TREB) vapor simulant testing. MIRAN vapor samplers are used to sample methyl salicylate vapor from a test chamber during protection factor testing of chem/bio protective shelters and remain a critical part of TREB's mission to fulfill customer needs. Recently rebuilt MIRANs were tested and calibrated to ensure that, in the event of failure, TREB may instantly replace the MIRAN and continue testing for the customer. Due to the discontinuation of the MIRAN, a MiniRae 3000 vapor sampler was tested to determine if it could be a viable replacement for TREB's vapor sampler. The MiniRae 3000 has enhanced data outputs, better computer integration, and will enhance TREB's ability to perform customer testing if determined to be a viable replacement. Experiments were also performed using the MIRAN and various types of sampling tubing to validate TREB's Test Operating Procedures. This validation ensures that TREB's Protection Factor vapor testing equipment gathers the most accurate readings possible in order to correctly evaluate customer products.

I wish to acknowledge the mentorship of Mr Steven Yurechko from the Test, Reliability & Evaluation Branch as well as his supervisor, Mr Do Nguyen. Along with Mr Eugene Vickers, I appreciated their expertise in the field and their continuing encouragement. This internship has heightened my interest in pursuing a career in chemistry. Also, working at the US Army Edgewood Chemical Biological Center this summer has shown me the value of teamwork and made me a better student.

ROSBAG Collection and Post-Analysis with Robots

Pascal Conroy

There are generally two types of data analysis: real-time analysis and post-analysis. Real-time data analysis allows the operator to monitor the constant stream of data from sensors on a monitor. The drawback to this is that the operator will inevitably lose much of the information in the output stream. Post-analysis allows an operator to look at specific data points by searching through .bag files (a.k.a. bags). Bags are files that store collected data from the various sensors and modules of a robot. Commonly referred to as bags, these files are key to the post-analysis of data. By using algorithms to search through bags, one can find a specific data point easily. Bags also have the capability to be visualized with graphs, tables, and charts. The resulting capabilities of post-analysis are, for instance, storing image data from the red–green–blue–depth sensor whenever an autonomous vehicle encounters an obstacle, compiling them into a video, and analyzing and improving the current algorithm for obstacle detection and avoidance. The work that I did is validating the utility of bags and their impact on the development of robots capable of navigating through environments ahead of the Warfighter.

I wish to acknowledge the mentorship of Mr Marshal Childers for mentoring me this summer. I would also like to thank Mr Matt Kaplan and Dr MaryAnne Fields for helping me with my summer project.

Automation of Mesh Generation and Solution Analysis for Arbitrary Airfoil Geometries

Alexander Costenoble

Two-dimensional airfoil tables provide necessary data for lower-fidelity aerodynamic models, such as blade-element momentum theory. While these tables are available for many common airfoils, the tables must be generated for novel airfoil shapes and configurations. Rapid-analysis tools, which provide a simple user experience, typically rely on lower-order aerodynamic models and may not be able to handle complex airfoil geometries. Full computational fluid dynamics (CFD) simulations can capture complex flow around arbitrary geometries, but typically require the user to be an expert in the tool and spend considerable effort in meshing. Additionally, full CFD simulations are computationally intensive. This work, largely developed at the University of Maryland (UMD), couples a strand/ advancing front mesh generator in the near-body region to capture the boundary later with an unstructured off-body mesh. User effort is reduced by providing simple inputs and default meshing parameters based on best practices. The flow is solved using the HAMSTR flow solver developed at UMD, a Navier–Stokes solver that has been shown to accurately model airfoil flows, including transition. High-performance computing systems are used to allow a large number of cases to be run simultaneously, so that the time to produce an airfoil table is reduced to that to conduct a single simulation.

I wish to acknowledge the mentorship of Drs Rajneesh Singh, Phuriwat Anusonti-Inthra, and Matthew Floros of ARL, and Dr James Baeder of UMD. I also wish to acknowledge the DOD High-Performance Computing (HPC) Modernization Program for their support of the HPC Internship Program.

Damage Adaptive Maneuvering Resilient Structures for Extended Maintenance-Free Operations

Michael Davies

The overarching goal of the project is to achieve resilient system performance through information fusion, probabilistic diagnosis and prognosis, and system control and reconfiguration. Information fusion involves fusion of information gained from heterogeneous sources of data, such as ultrasonic sensors, strain gages, and so on. Probabilistic diagnosis and prognosis require construction of dynamic Bayesian networks and enable quantification of aleatory and epistemic uncertainty. System control and reconfiguration is achieved by optimization of system parameters under diagnosis and prognosis uncertainty. For the College Qualified Leaders program, nondestructive testing assessing the fatigue crack growth in an Al 7075 specimen using ultrasonic pitch-catch was studied. Specifically, crack growth detection in 6- by 15-inch aluminum plate that is subjected to cyclic loading was performed. The results of ultrasonic pitch-catch data were compared to the "true" value of the crack length estimated using a high-resolution image of the cracked specimen. The results can be used to build a damage-index-to-damage map that will allow us to accurately and easily determine the state of existing damage in both land and air vehicles.

I wish to acknowledge the mentorship of Dr Mulugeta Haile and Natasha Bradley. I wish to acknowledge the mentorship of Dr Haile for providing guidance and knowledge throughout the course of my research. His expertise and professional manner provided me a valuable experience. Also, I wish to acknowledge the mentorship of Ms Bradley, Mr BJ Northington, and Mr Michael Cotney for their due diligence, engineering advice, and insight during my experience as well. Finally, I would like to acknowledge the team at Vanderbilt University, under the direction of Dr Sankaran Mahadevan, for their supporting tests, engineering experience, guidance, and continued support that was vital to the success of this project.

Adapting a Leg Testing Apparatus and Robotic Leg

Matthew Davis

Legs are proving to be the most robust form of transportation for ground robots, much more effective than wheels for varying terrains. This summer, we are designing a fluidized test bed to be used for testing robotic gait movement in a fluid-like granular media. In addition to this project, we are testing and calibrating OptoForce 60- and 200-N force sensors to be used for robotic leg data collection.

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

Effect of Surface Reconstruction and Passivation on Electronic Properties of Diamond Surface Field-Effect Transistor (FET)

Bishwajit Debnath

Diamond, being an excellent wide-bandgap semiconductor, superior thermal conductor, and exemplary field-emitter even in harsh environments and temperatures, has attracted much attention for its potential in electronic and thermal applications. Depending on the surface termination, the diamond surface can be metallic or insulating. Besides, the outermost atoms often reconstruct themselves to create sp^2-bonded surface channels, and hence improve the carrier mobility. Among all the unique properties, formation of 2-D p-type surface conducting layer due to charge transfer between the passivated surface and atmospheric adsorbates is very intriguing. Though the fundamental understanding of these properties is key to the realization of high-frequency, high-power diamond surface FET, study correlating surface termination type and surface reconstruction mechanisms to electronic properties is still limited. In addition, understanding these surface-dependent electronic properties and their effects on the charge transfer process is crucial in explaining the temperature-dependent electronic properties observed in experiments. To answer these fundamental questions, in this study, I utilize ab initio density functional theory and establish correlation between surface reconstruction and electronic properties such as surface states, surface energies, work functions, effective masses, and surface channels mobilities.

I wish to acknowledge the mentorship of Dr Mahesh R Neupane.

Parametric Design with Phase-Change Materials

Michael Deckard

As the Army becomes more electrified, there is an ever-increasing demand for higher power densities. The packaging of electronics, and particularly thermal management, is limiting further improvements. Improving the tools used to design device packaging presents the opportunity to explore a wider design space with greater efficiencies and performance. Here, the ParaPower design tool, which simulates thermal gradients and stresses over a variety of parameters, has been enhanced with greater user friendliness and robustness, as well as the ability to perform simulations that incorporate phase-change materials (PCMs) for thermal management. PCM simulation was incorporated by introducing an enthalpy-based melting in elements using an inverse Euler scheme and the materials library was expanded to handle multiple necessary materials properties to easily add future PCMs. Initial investigations show that ParaPower converges with previously validated code with PCM simulation and initial experimental results. Research into choosing a solver that best matches the goals of ParaPower is ongoing.

I wish to acknowledge the mentorship of Lauren Boteler, Mike Fish, Morris Berman, Bruce Geil, and Claude Pullen.

System Identification of a 40-mm Tube-Launched Coaxial Unmanned Aircraft System

Hunter Denton

Small unmanned aircraft systems generally have poor range and endurance, so if a vehicle must fly to a target, the amount of time it can survey will be reduced. If a vehicle can be tube launched to a target, it can spend more time observing a target. The current system is a thrust-vectored, coaxial helicopter intended to be launched from a 40-mm launcher. A dynamic model of the vehicle was developed to test different control strategies. A proportional-derivative feedback controller proved capable of stabilizing the pitch and roll of the vehicle. In parallel, a test bed was designed to determine the effect of center of mass and gimbal location on the stability and controllability of the system. A telemetry module was integrated into the flight controller to record the angular rates and control inputs during the flight tests. No flight test data have been collected, but initial flight tests have proved that a gimballed, coaxial helicopter is feasible for the tube-launched system. Once the data is collected from the flight tests, it can be used to validate and improve the dynamic model. The insight gained from the testbed can be used to improve the stability and controllability of the 40-mm platform.

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

Sensitivity Analysis of the On-Demand Small Unmanned Aircraft System (ODSUAS) Based on Magnetic Noise

Matthew Dick

The ODSUAS program has not yet been expanded into the micro-small unmanned aerial system (sUAS) scale due to limitations imposed by magnetic interference (otherwise known as magnetic "noise") of the guidance system. The purpose of this project is to identify and quantify sources of magnetic interference within a sUAS in order to discover ways to mitigate magnetic noise. Three different prototypes were designed and 3-D-printed to investigate the proper placement of individual components and magnetically permeable shielding. The first prototype tests the effectiveness of shielding the motors' magnetic components from the rest of the system, which only works to a certain extent due to the limited magnetic permeability of the shielding. The second prototype investigates the effectiveness of shielding the global positioning system (GPS) module from all other components. The results indicate that the relative length of wires between components significantly increases the magnetic interference of the GPS (in accordance with Biot–Savart's Law). The third prototype reduces the lengths of current-distributing wires in the system, separates the GPS module from other components, and does not include piezoelectric components due to their latent magnetic field. Therefore, results indicate that current lower bound upon the size of GPS-guided sUASs is influenced by the motors' relative distances, the availability of GPS-compatible flight-controllers, and the thickness of the magnetic shielding.

I wish to acknowledge the mentorship of John W Gerdes.

Cold Spray on Ceramic Substrates for Power Electronics Packaging

Marco J Echeverria Iriarte

Power electronics are used in various Army applications, from energy storage to power conversion, where thermal management becomes a critical aspect to determine their lifespan. Aluminum nitride is used in power electronics packaging because of its high thermal conductivity and high dielectric strength. Owing to its electrical properties, this ceramic has the potential for use in high-voltage applications. The current direct bond copper process hinders reliability due to the high temperature needed to bond copper onto aluminum nitride and mismatch of their coefficients of thermal expansion, and limits voltage usage because of the ceramic thickness restrictions. In order to increase their capabilities, a cold spray additive manufacturing process is being investigated as an alternative, which improves performance. Cold spray is a deposition method that sprays metal particles at high velocities onto ceramic substrates, surpassing a critical velocity to plastically deform them and achieve bonding, without reaching melting temperatures. Nozzle dimensions, temperature, and pressure play key roles on reaching the critical velocities. This work aims to provide a 1-D numerical model to map the parameters needed, via comparison with experimental results, to reach said velocities whilst maintaining the integrity of the substrate.

I wish to acknowledge the mentorship of Dimeji Ibitayo, Pedro Quintero, and Lauren Boteler. This project is a collaboration of ARL with University of Puerto Rico – Mayagüez. As part of the experimental efforts, the Kostas Research Institute at Northeastern University (NE) played a key role lending their facilities. I wish to thank Ozan Ozdemir and Tricia Schwartz from NE for their help in modeling and experiments, and Claude Pullen from ARL for his help throughout the project.

Conductive Filament

Kendall Ellison

The primary objective of this research is to characterize filaments capable of electrical conduction used by 3-D printers based on the fused deposition modeling (FDM) principle. A generalized model of conductive FDM filaments is built to describe the operational characteristics and feasibility in a small unmanned aircraft system application. By coupling models of the electrical, mechanical, and thermal performance, areas of the design space with the potential for practical application are explored. In addition, technological limitations preventing further adoption of conductive FDM filaments are highlighted to provide insight into the most productive areas for future research in materials development.

I wish to acknowledge the mentorship of John Gerdes and Eric Spero.

Feasibility of Abstract Meaning Representation (AMR) for Human–Robot Dialogue and Information Extraction

Jessica Ervin

Natural language processing tools provide an effective interface between humans and computational systems for improving the user's situational awareness. This research focused on facilitating effective natural language communication between humans and two types of computational systems: 1) an information extraction (IE) system designed for analyst use, and 2) a human–robot dialogue system to support human–agent teaming in search and navigation tasks. For this, we used AMR to create computer readable representations of natural language. AMRs are directed graphs, where nodes are concepts and edges are relations between concepts. We leveraged two state-of-the-art AMR parsers to automate the creation of AMRs. These parsers were then evaluated within an IE pipeline for detection and labeling of named entities (as a person, organization, etc.); one parser was found to exceed the performance of a previous IE pipeline, although comparison was hindered by differences between the two annotation schemes. The two parsers were also evaluated for use within a human–robot dialogue system, creating AMRs to transition between natural language and domain-specific templates, with the goal of eliciting appropriate actions/responses from the robot. Future research to train the parsers on domain-specific data will improve performance and allow further advancements in situational awareness.

I wish to acknowledge the mentorship of Claire Bonial and Clare Voss, as well as Lucia Donatelli and the rest of the Multilingual Computing Branch here at the Computational and Information Sciences Directorate.

Performance Modeling and Capability Space Exploration of Small Unmanned Aircraft Systems

Spencer Folk

Researchers in the development of small unmanned aircraft systems (sUASs) have turned to additive manufacturing and commercial off-the-shelf electronics to design on-demand vehicle architectures that are reconfigurable and scalable for varying missions. A typical architecture may have thousands of possible designs depending on combinations of sizing, batteries, motors, and propellers; these designs, which may differ drastically in size and performance, constitute a capability space for the architecture. This research seeks to build upon existing performance modeling software for sUASs by analyzing how mission requirements, such as payload and flight duration, place constraints on a vehicle architecture's capability space. In order to accomplish this, three sample architectures are considered: fixed wing, hybrid vertical takeoff and landing, and multicopters. Empirical data on commercial parts and aerodynamic properties are combined with a scaling procedure and constraint analysis to generate feasible designs. Two test cases vary mission payload and duration separately, and acceptable vehicle designs computed from the software are tabulated for each mission. The results of this research are graphical interpretations of constrained capability spaces as the mission payload or duration is increased, demonstrating a method of assessing a vehicle architecture's sensitivity to the specified mission requirements as well as its overall robustness as a candidate for deployment.

I wish to acknowledge the mentorship of Mr Nathan Beals.

Investigation of Single Fiber–Matrix Interphase

Sarvenaz Ghaffari

The performance of carbon-fiber-reinforced polymer (CFRP) composites is significantly controlled by the properties of the fiber–matrix interface, in particular, interface strength and toughness. Good interfacial bonding can help efficient load transfer from the matrix to the reinforcement, which helps reduce stress concentrations and improve overall mechanical properties. Fracture toughness, fatigue life, compressive strength and strain to failure, and impact properties are mainly sensitive to the strength of the fiber–matrix interface. Therefore, optimization of the fiber–matrix interface can only occur if reliable methods for measurement of fiber–matrix interfacial strength are available. Despite the importance of this topic, there is not any standards technique available to accurately characterize the interface mechanical properties. The objective of this work is to develop a test method for pushing out fibers in CFRP composite material using nano-indentation and use this method to characterize the fiber–matrix interface. An improved method for preparation of the samples for the push-out test is proposed. Multiple experiments were performed to verify the accuracy and repeatability of the test method. Comparison between load-displacement data simulated from finite element analysis and the experimental result from a nano-indentation test is provided as well.

I wish to acknowledge the mentorship of Dr Dan Cole for his valuable guidance, assistance, encouragement, and immense knowledge throughout this project. It has been a great pleasure working with him. I could not have imagined having a better mentor for my internship. I want to extend my genuine appreciation to Dr Todd Henry for helping me with finite element model simulation and understanding the theoretical part of this project and his insightful comments. I also wish to thank Dr Robert Haynes for considering me for this internship opportunity and his valuable time and advice in the review of this project.

Finding the Refractive Index and Extinction Coefficient of Mercury Cadmium Telluride (MCT) Using a Fourier Transform Infrared (FTIR) System

Harun Gopal Ganesan

MCT is a very important infrared (IR) detector material. At cold temperatures, it can cover a large part of the IR spectrum and remains thermally stable. However, to quantify the absorbance of the material, the transmittance and reflectance is measured. One method to measure transmittance is by using a FTIR spectroscopy system. The advantage of using this method is the accuracy of the data obtained, as well as the ability to obtain the absorption coefficient (α), refractive index (n), and the extinction coefficient (k), all at once. However, this is at the cost of simplicity. For the films measured here, measured spectra include thin-film interference, which result in constructive and deconstructive waveforms, making it difficult to resolve n and k.

I wish to acknowledge the mentorship of Dr Priyalal Wijewarnasuriya, Mr Kevin Santiago, and Dr Brenda VanMil.

Feasibility of Additive Manufacturing for Major Internal-Combustion Engine Components

Jamee Gray

Additive manufacturing (AM) is an emerging technology that uses a layer-by-layer process to build parts from the bottom up. Because AM does not have the same constraints that limit traditional methods (such as casting or computer numerical control milling), it enables the inclusion of additional features to enhance performance (e.g., port swirl for turbulence in an internal-combustion [IC] engine). Additionally, when used in conjunction with topology optimization, it allows for the production of lightweight designs capable of increased specific strength and/or stiffness. Hence, it could be valuable in facilitating the reduction of part weight and quantity of engine components, which would result in better fuel economy and increased reliability. In this study, a Saito-FG11 10-cc four-stroke spark-ignition engine is considered. The components that make up the majority of its weight are the crankcase and cylinder head; therefore, they could benefit most concerning weight loss from using AM. Dimensional analysis of the AM crankcase revealed all critical tolerances were within acceptable ranges. Moreover, the AM crankcase had significantly less porosity than the cast part, 0.0002% to 0.0280%, respectively, showing promise of a functional part. Further comparative testing of the IC engine with AM components against the stock engine using a dynamometer will help to fully determine AM's feasibility in this application.

I wish to acknowledge the mentorship of Kyu Cho, who brought me in this summer to further my research here while getting hands-on experience learning about additive manufacturing. I would also like to thank everyone in the Additive Manufacturing Branch, especially Dr Jennifer Sietins, Ryan Rogers, and Joshua Taggart-Scarff. Each of these individuals went the extra mile to help me during my time here.

Robust Controller Analysis and Synthesis of a Ventral Gimbal for Robotics Applications

Sangjin Han

Stabilized ventral gimbals are critical to enabling on-platform machine vision for applications such as positioning, navigation, and timing, in order to be able to generate motion stabilized video without the need for computationally expensive postprocessing. Ventral gimbals are subject to disturbances such as vibrations of the frame due to the dynamics of the gimbal and the robot. The research presented here addresses the stability of the gimbal and disturbance attenuation to unknown perturbation during operation. We implement both a 2- and 3-axis ventral gimbal with multiple imagers on an unmanned aerial vehicle (UAV). Our analysis of the gimbal system, the plant, with a first-order plus time delay model and synthesized proportional-integral-derivative (PID) controller gains with an H-infinity criterion for each axis of the gimbal demonstrates a substantial reduction of vehicle-induced motion in the video collected. The performance of our method is significantly better in terms of the error between target and measured rotor angle compared with that of the state-of-the-art automatic PID tuning method. Integration of our motion stabilized multi-axis, multi-sensor, central gimbal enables advanced machine vision on small UAVs.

I wish to acknowledge the mentorship of Drs William Nothwang, Joseph Conroy, and E Jared Shamwell.

Metabolic Engineering of a Bacterial Chassis for the Production of Plastic Precursors

Caleb Hellman

The Army needs to be more modular and expeditious, and have a near-zero logistic demand to enable Soldier activity in a deep future operational environment. Currently, the production of commodity chemicals and material precursors at the point of need, while relying on waste streams and native resources, is limited at best. Present technologies are not cost effective and are unable to use the available inconsistent resources. To bypass this, a robust microbe, capable of metabolizing a wide range of carbohydrates and able to naturally produce Army-relevant chemicals of interest, was selected to reduce the need for excess genetic manipulation to synthesize a desired product. Propane, a volatile gas under most conditions, is of primary interest for synthetic manufacturing as it is already known for its properties as a clean-burning fuel, refrigerant, and importance as a chemical precursor in plastics production. Presently, the production of propane is a laborious and cost-prohibitive endeavor through crude oil refinement. However, when produced from bacterial cultures, propane's volatility facilitates separation as it accumulates in the reactor headspace. Subsequent selective dehydrogenation of propane yields propylene, a chemical used in the production of polypropylene, a thermoplastic found in Army-relevant textiles and equipment.

I wish to acknowledge the mentorship of Dr Katherine Germane.

External Feedback into High-Power Continuous-Wave Lasers

Ciara Hingston

The experiments that were performed this summer were to further the knowledge we are gaining about the vulnerability of high-power continuous-wave (CW) lasers. The first of the experiments involved perfecting the cleaving and splicing parameters of a 25/250 micron fiber. It is important that a fiber has a flat edge after it is cleaved, with no end face damage. The cleave tension that gave the best results was 540 g and the power used in splicing was 100 W. The goal of the second experiment performed was to measure the loss through each component that will be used in the setup so that an estimate of the total loss in the system could be obtained. The total loss in the system was found to be 7.999 dB. According to the specification sheets, the total loss through the system should be 3.7 dB so the percent error in the measurement is 115.946%. The goal of the third experiment was to measure how much light could be reflected back into a 25/250 fiber. A series of mirrors and irises were aligned so that a beam from a 1064-nm, 20-mW CW laser would be reflected and coupled back into a fiber. A circulator and power meter were used to find the amount of power that was able to be coupled back into the fiber. The amount of power that was measured was too small to be accurately measured. Lastly, the end objective of this project was to find the power at which, when coupled back into the fiber, the Master Oscillator Power Amplifier (MOPA) that was created stops functioning properly. To do this, four 60-W diodes and a Nufern fiber amplifier were used to make a MOPA so that the signal from the laser beam would be amplified. From this, the power at which the MOPA stops functioning properly could be determined.

I wish to acknowledge the mentorship of Dr John McElhenny.

Experimental Studies of Flow Separation over a NACA 0012 Airfoil for Micro-Air Vehicle (MAV)-Scale Wings

Ja'Kira Jackson

The influence of freestream turbulence on flow separation over a NACA 0012 airfoil at low Reynolds number (Re = 12,000) was investigated. Particle image velocimetry (PIV) experiments were performed at an angle of attack $0° \leq \alpha \leq 15°$. Four grid turbulence generators of different sizes were used to introduce turbulence into the flow. PIV was used to roughly characterize turbulence levels of the flow. Results have shown there to be approximately 2% to 4% turbulence intensity provided by the turbulence generators. The wind tunnel has been previously characterized using hot wire anemometry to have a freestream turbulence intensity on the order of 0.1% to 0.3%. Results have shown that by introducing turbulence vorticity in the boundary layer the flow increased and stall was delayed. Flow fields for the baseline (no turbulence) and low-turbulence generator are compared with the wing at 0° and 8°. While the flow around the wing in the no turbulence case was separated at 8°, the flow remained attached when a small amount of turbulence was introduced. These results have implications for the separation behavior and stall characteristics for small unmanned aerial vehicles flying at low Reynolds numbers.

I wish to acknowledge the mentorship of Dr John Hrynuk.

Enhancing Batch Loading Data Process of the Product Data Management System (PDMS)

Kayla Johnson and Shanice Hopson

Database management systems are software systems used to create, retrieve, update, and manage data. The PDMS serves as an engineering database for US Army Edgewood Chemical Biological Center (ECBC) technical data. PDMS is ECBC's product lifecycle management data manager for specific commodities and spares for smoke, individual protection, collective protection, contamination avoidance, decontamination, bio equipment, riot control/support equipment, and Natick items. PDMS enables users to review and update technical documents such as drawings, specifications/ standards on all Defense Logistics Agency, and Tank-Automotive and Armament Command technical data package procurement requests. This system makes it possible for data to be available for government and contractor user access 24 h a day, 7 days a week. However, the process to store the data requires time and resources to provide users with fast and efficient retrieval of the information. Batch loading is utilized to import and export the large amounts of data to save time and resources. The database can take numerous of files and information and load the data in a short period of time. Overall, this method improves performance for importing and exporting large amounts of data.

I wish to acknowledge the mentorship of Eugene Vickers, Jarell Johnson, Jo Dorsey, and the rest of the Product Data Management team for all the support this summer. We have networked and created lifelong connections. We really appreciate everything we learned this summer thanks to the Thurgood Marshall College Fund.

Object Tracking in Dynamic Scenes with Light Detection and Ranging (LIDAR)

Wyatt Jordan

Our main goal this summer was to track moving objects from a moving platform with a 3-D LIDAR sensor. Object tracking presents difficult challenges related to distinguishing between the perceived movement from the robot's motion and the actual movement of objects in the scene. Two parallel approaches to motion detection were investigated. First, a 2-D range matrix was built for calculating the difference in identical rays across scans, which would facilitate fast image-processing algorithms for object tracking. The approach proved unsuited to tracking due to sensor angular drift across scans, but did prove useful for identifying 3-D edges in an environment. The second approach was to convert the range image into the 3-D representation of an octree, a spatially divided data structure, and perform background subtraction across consecutive frames. This approach proved much more effective for motion identification. Filtering and ray tracing were implemented using the Point Cloud Library to remove unwanted noise and shadow points. After unwanted points are removed, the cloud is segmented into objects, which are then tracked by their center points. Future work will include using Kalman filters to track objects over time, camera integration for object matching, and future frame point cloud predictions for dynamic platforms.

I wish to acknowledge the mentorship of Phillip Osteen for taking me on as a student this summer and for his guidance throughout the project.

Optimal Diffusion Strategies

Maya Kedem

We study relaxation to equilibrium of the persistent random walk in a finite space. The persistent random walk is a diffusion model where the walker moves with a constant speed while changes in direction occur according to a persistence-level control parameter. As the walker's persistence increases, it walks for a longer period of time on average before changing direction, therefore changing its diffusion pattern. At short times, the process exhibits ballistic transport, while at long observation times, the process displays diffusive transport. The goal is to find the optimal persistence level that provides a balance between ballistic and diffusive transport for a given environment and equates to a short equilibration time. The environment refers to any space through which the particles are moving. The optimal persistence value is associated with particles exploring space efficiently. We study these equilibration times by numerically evaluating the persistent random walk particle distribution in a given environment for different persistence levels. This work has applications related to engineering active matter to quickly diffuse through an environment.

I wish to acknowledge the mentorship of Dr Adam Svenkeson and the Vehicle Applied Research Division.

High-Temperature Digital Image Correlation for Propulsion Materials Testing

John Kershner

Increasing the power and efficiency of modern gas-turbine engines requires advanced materials that can operate at increased temperatures. While strain gauges and extensometers can be used at high temperatures, they only provide single point measurements. However, strain fields tend to be nonuniform[1] and this nonuniformity can be affected by temperature, fatigue, and creep. Digital image correlation (DIC) is a noncontact, optical technique to measure displacements over the full field of view (FOV). This technique is well established at room temperature and moderate temperatures (up to 500 °C), but using DIC at higher temperatures can be affected by the degradation of the high-contrast pattern, blackbody emission from the furnace and/or the specimen, and reflection from the viewport window into the two-section furnace. Here, several methods to solve these problems were explored: pattern degradation was addressed, various light-blocking filters were used, and correlation settings optimized. High-temperature DIC presents many challenges, but also many opportunities to gain a better understanding of the materials used in gas-turbine engines. The methods discussed here will be of tremendous benefit to the propulsion community as they characterize component materials at high temperatures, which are relevant to engine operating environments.

I wish to acknowledge the mentorship of Dr Michael Walock, along with Drs Muthuvel Murugan and Anindya Ghoshal. Thank you greatly to Ms Natasha Bradley for her assistance with the experimental rig.

[1] Berke RB, Lambros J. Ultraviolet digital image correlation (UV-DIC) for high temperature applications. Rev Scientific Instruments. 2014;85.

Computational Investigation of an Adaptive Gas-Turbine Engine

Nikita Kozak

The objective of this work is to investigate the influence of combined rotor and stator blade articulation on gas-turbine engine performance. Currently, gas-turbine engines are designed and optimized to operate at maximum efficiency for a single operating condition. When the engine operates at an off-design condition, the flow may begin to separate, which causes reduced power and efficiency. This limitation on engine design, caused by fixed-geometry blading, places a limitation on the engine's versatility and capabilities. To overcome this limitation, the idea of articulating the stator and rotor blades has been proposed. This study provides new knowledge on the impact of blade articulation on turbine efficiencies at varied operating speed conditions. These insights could provide valuable information that would influence future turbine design. The investigation is carried out using a novel computational fluid dynamics fluid-structure interaction code to model the complex aerodynamics in an annular single-stage turbine. Also, data are collected on the aerodynamic forces acting on the blades, which could assist in developing blade articulating mechanisms. With an overall mission to maintain the US Army's superiority in warfighting technology, this project could provide essential insights on future propulsion technology capabilities.

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

Doppler Light Detection and Ranging (LIDAR) and Interpreting Aerosol Backscatter with Skew-T Soundings to Gather Atmospheric Conditions

Corwin Largo

In atmospheric remote sensing and meteorology, a LIDAR system and weather balloons measure atmospheric components including wind profiles to improve aerial operations for the Army. Atmospheric wind profile measurements were collected using a Halo Photonics Streamline Pro coherent Doppler LIDAR for the period of June 17–19, 2018. The LIDAR was operated at ARL located in Adelphi, Maryland. The balloon measurement was retrieved twice daily from Washington-Dulles International Airport. LIDAR-based 5-min interval data were compared ultimately to weather balloon-based documents. Both instruments gathered and produced data that provided visualizations of wind profiles to study horizontal wind speed, wind direction, and the backscatter cross section to determine accurate characteristics turbulence, gust fronts, and wind shear. Both displayed similarities in data, although they required two different technology software to interpret their data.

I wish to acknowledge the mentorship of David Ligon.

Values of Heat of Reaction for Materials Used in Photo-Cure Additive Manufacturing

Jaida Lewis

Additive manufacturing (i.e., 3-D printing) is a process where a physical object is made from computer-generated models. In photo-cure additive manufacturing, the materials used are (meth)acrylate resins. (Meth)acrylates cure rapidly and can be formulated to have properties ranging from soft and flexible to hard and rigid. Isosorbide methacrylate (IM) is a bio-based resin that was synthesized to increase the thermal operating window of (meth)acrylate additive manufacturing resins. The goal of this research was to find the heat of reaction of IM, find if the heat of reaction changes with the composition, and see if the heat of cure for bisphenol A dimethacrylate (BPAM) and isosorbide acrylate (IA) are significantly different than IM. Differential scanning calorimetry was used to measure the heat of cure but was corrected based on the extent of cure as measured using Fourier transform infrared spectroscopy and sol content measurements. The heat of the reaction for IM is about 40 kJ/mol, for isobornyl acrylate (IBOA) about 80 kJ/mol, for IA about 65 kJ/mol, and for BPAM from 50 to 79 kJ/mol. Mixtures of IM and IBOA have higher heats of reaction than IM and a lower heat of reaction than IBOA.

I wish to acknowledge the mentorship of John La Scala.

Playing Video Games to Learn Absolute Visual-Inertial Odometry of Unmanned Aerial Vehicles

Kyle Lindgren

Traditional visual-inertial odometry (VIO) methods require stringent, known sensor models to accurately perform absolute trajectory estimation. The work presented here utilizes a modern game engine to assess the limits of our unsupervised deep neural network approach's (VIOLearner's) ability to learn configuration parameters online. Variations on inertial measurement unit (IMU) intrinsic parameters and the extrinsic calibration between the IMU and camera on an aerial drone vehicle are explored while flying through a wide array of virtual environments. Error measures gathered from VIOLearner's trajectory estimates and the known game engine ground truths are compared with state-of-the-art VIO methods evaluated on similar trajectories using the KITTI Odometry data set. Continued development of these methods in virtual environments will explore the feasibility of further minimizing inputs by extending VIOLearner to learn scale (necessary for absolute trajectory estimation) without access to depth imagery. VIOLearner's performance demonstrates that there is a path toward significantly more robust state estimation with substantially reduced calibration and tuning.

I wish to acknowledge the mentorship of Jared Shamwell.

Incidence of Mortality from Blunt and Penetrating Injuries

Marisa Lizins

The purpose of body armor is to protect the Soldier from penetrating injuries. Even when body armor stops the bullet, a Soldier can still sustain injury from behind-armor blunt trauma—a mechanism of injury that is caused from the deformation of armor pushing into the body. Optimizing current body armor designs for penetration protection can diminish blunt-trauma protection. To help inform the tradespace for armor designs, it is important to compare the relative risks of blunt and penetrating mechanisms. Using the National Trauma Data Bank Research Data Set 2013, thoracic injuries, including injuries to the ribcage, cardiovascular and respiratory organs, thoracic spine, and scapula, of patients aged 17–55 were analyzed. This subset was selected to represent the area generally covered by the body armor in a Soldier-aged population. Out of 230,760 thoracic injuries, 190,531 were blunt and 36,923 were penetrating. There were 98,629 incidents of blunt injury and 19,310 of penetrating injury out of 119,880 total incidents. Further, 1,843 of the incidents with blunt injuries died, and 1,488 of the incidents with penetrating injuries died. Those with penetrating injuries died at a rate over four times higher than those with blunt injuries.

I wish to acknowledge the mentorship of Karin Rafaels. I would also like to thank Erika Matheis and Kathryn Loftis for their guidance and support.

Tube-Launched Multi-Flight Mode Drone

Ryan Manning

Current capabilities of tube-launched unmanned aerial systems are limited to fixed wing flight, which limits endurance and versatility. While there are a few unmanned systems that are capable of being launched from an aircraft such as the Raytheon Coyote, they are limited to one flight mode. This is the inspiration for the research done on the tube-launched multi-flight-mode drone. The objective of this project was to create a concept design of an unmanned aerial system that can be launched from a tube on a helicopter while switching between fixed wing and helicopter modes. We conducted surveys of different unmanned systems such as the Lockheed Martin Outrider and Raytheon Coyote to determine size constraints of the concept design so that it can be folded into a common launch tube. The multi-flight-mode capabilities are accomplished by a controllable thrust vector coaxial system, which gives the drone the ability to hover in helicopter mode. The results of this research produced three different sketches of the concept design, all with different wing designs. Also a SolidWorks model of fixed wing flight mode was created.

I wish to acknowledge the mentorship of Dr Hao Kang for all his help over the summer.

Achieving Timing Coherency Using Chip-Scale Atomic Clocks (CSACs)

Aaron Marinkovich

Achieving coherency among distributed antenna elements (i.e., elements with separate clocks) is of interest for wireless systems. Isolated antennas, like those in cellphones, vehicles, and sensors from the Internet of Things, could act as arrays, giving way to gains in channel diversity, coherent processing, and beamforming. The challenge of achieving coherency lies within the inherent timing discrepancies between clocks. One solution to this problem is synchronizing the elements' oscillators. Atomic clocks are fit for this solution because of their precise and reliable timing performance. Here, the drift tendencies of atomic clocks are characterized. Tests show that synchronized atomic clocks experience a short-term drift (within seconds) of picoseconds and long-term drift (within 24 h) of microseconds.

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Development of a Computational Toolkit for Simulations of Polycrystalline Materials

Joseph Mattson

A polycrystal is a class of molecular crystal structure in which many individual crystals, called grains, are combined to form a more complex configuration. Researchers use certain Python tools to analyze the efficacy and best use of certain materials that have these complex structures. The goal of this project was to modify these applications to enable more sophisticated control over and analysis of these simulations. Specific modifications added to these applications included autonomous generation of randomized gaseous and vacuous intragranular voids in polycrystalline models and the randomization of crystal structures among individual grains of polycrystalline models. To complete these tasks, polycrystal_builder, the existing software library, was modified to include these capabilities. Once the improvements were developed, they underwent rigorous testing to ensure that the expected output matched the actual program output. In the modifications to the polycrystal_builder code, sample polycrystals that were generated by this code were visualized and analyzed to ensure that the expected output was achieved. These tools were employed to generate virtual models of cyclotrimethylenetrinitramine (RDX) polycrystals in order to test the effects of various individual crystal structures, as well as different types and sizes of voids on the behavior of RDX. More analysis has yet to be completed, but the trends seem to show that a polycrystalline structure has the greatest impact in increasing the reactivity of RDX, followed by intragranular voids of greater size. The impact of voids with gaseous contents on the behavior of RDX has yet to be determined through analysis. Further research to be completed will include determining the effects of grain sizes on reaction zones related to polycrystalline grain boundaries.

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Machine Learning a 1,1-Diamino-2,2-Dinitroethene (FOX-7) Potential Energy Surface

Amol Menon, Brian C Barnes, and DeCarlos E Taylor

In this work, machine learning (ML) methods are explored for providing accurate representations of ab initio potential energy surfaces of FOX-7. Using high-fidelity reference data previously computed using the combined density function theory (DFT) and symmetry adapted perturbation theory approach [SAPT(DFT)], two descriptor sets are generated, one based on the dimers' relative position and orientations, and the other based on the molecular Coulomb matrix. Both sets of descriptors are tested using four ML algorithms: kernel ridge regression, support vector regression, radial basis function neural network, and feedforward neural network. The results show that both descriptor sets are effective at interpolating noncovalent interactions between energetic molecules, with feedforward networks trained on the Coulomb matrix resulting in the most accurate model.

I wish to acknowledge the mentorship of Brian Barnes.

Statistical Analysis: Real-World Metrics, Virtual Simulation Variables

Cassie Micucci

Virtual training for Soldiers is becoming an increasingly popular technique for battle readiness; however, sometimes this training fails to translate into real-world performance improvement. To discover the relevant links between simulated training and actual effectiveness, we analyze a data set generated from baseball players' use of a simulated baseball batting game along with their on-field performance. This data set includes information about players' virtual response times, accuracy in different scenarios, and standard baseball statistics that measure the decision-making and aggression of the players. Using various regression methods from statistical learning, we gain insight into drivers of performance metrics in both scenarios. Variable selection methods provides further information about these relationships, while statistics derived from these analyses provide validation for the procedures. Hypothesis tests show the differences in performance between players who improved in the simulated environment and those who did not improve. Together, these methods show significant connections between the virtual variables and real-world performance that can be applied to Soldier training for tasks that require optimization of response time, judgment between aggressiveness and restraint, and accuracy of a physical response.

I wish to acknowledge the mentorship of David Boothe.

Sonic Characterization and Measurement for Better Understanding Space Usage in the Innovation Commons

Joshua R Miller

As part of a large-scale project to understand and predict human variability that continuously monitors individual physiological signals, movements, and interactions in the Innovation Commons (IC), this project aims at providing an engineering solution to enable real-time continuous collection and analysis of sound data of the common spaces and audio recording of the individuals. The project's goal is to better understand how ARL employees utilize this new space and create content for a common data-sharing interactive dashboard. Our initial focus is on the collection of sound data to provide insight into the spaces most often used throughout the day.

Twelve omnidirectional microphones were placed across the commons spaces of the IC to capture sound data. Two eight-channel preamplifiers served as the audio interface for recording. The audio data was then streamed in real time over Lab Streaming Layer to be used for the IC interactive dashboard. For this internship, the focus was on calculating decibel values per channel to visualize volume across the space, as well as exploring speech transcription to map out and understand the interaction of IC users in terms of information transfer rates. All of these calculations are to be performed in real or semi-real time.

I wish to acknowledge the mentorship of Dr Jeremy Gaston and Mr David Chhan for their continued feedback and assistance throughout the project, Mr Paul Groves for his Python expertise and assistance connecting the various pieces of this project, and all those who offered their time to help with the project.

Plasma Surface Functionalization/Engineering of Aluminum Nanoparticles as Energetics

Kelsea Miller

Aluminum nanoparticles (Al-NPs) have great potential for energetic applications. However, the native oxide shell (alumina [Al_2O_3]) prohibits efficient energy release and reduces the chemical energy content. Therefore, efficiently passivating Al-NPs to reduce or eliminate the alumina shell has been an active area of research. An energetic oxidizing salt, aluminum iodate hexahydrate (AIH), has been previously demonstrated to enhance the energetic performance of Al-NPs[1]; however, microscopic studies revealed severe particle coalescence and residual Al_2O_3. This work explores a new method to engineer the surface of Al-NPs by utilizing atmospheric plasmas to simultaneously reduce particle agglomeration and oxide thickness. Al-NPs were treated using argon plasmas under different conditions, followed by immediate suspension in iodate-containing solutions to functionalize the treated Al-NPs with AIH. Transmission electron microscopy images revealed 30% reduced oxide shell thickness and laser-induced air shock from energetic materials experiments indicated a significant enhancement in the energy release for the resultant AIH-Al-NPs compared to commercial Al-NPs or untreated AIH-Al-NPs. These preliminary results demonstrate the tremendous potential of plasma engineering to develop passivated Al-NPs with enhanced energetic properties compared to traditional wet chemistry techniques alone.

I wish to acknowledge the mentorship of Dr Chi-Chin Wu for her mentorship, Dr Jennifer L Gottfried for her valuable contributions on lab-scale tests, as well as Dr Scott D Walck for his technical assistance in microscopy.

[1]Gottfried JL, Smith DK, Wu CC, Pantoya ML. Improving the explosive performance of aluminum nanoparticles with aluminum iodate hexahydrate (AIH). Scientific Reports. 2018;8:8036.

A New Data Acquisition System for Gamma-Gamma Coincidence Measurements after Neutron Capture

Gabriel Mintzer

At the National Institute of Standards and Technology (NIST) Center for Neutron Research, a cold-neutron-beam instrument for neutron activation analysis, primarily for material characterization, is adapted for nuclear-structure studies. To date, the standard measurements are performed with a setup utilizing a single high-purity germanium (HPGe) detector. Selectivity can be improved via the addition of another HPGe detector and the use of coincidence counting to reduce background and provide clearer isotopic identification. To accommodate the upgrade to a gamma-gamma coincidence system, a new data acquisition system was necessary. In this joint ARL/NIST project, a custom-built application was developed within Kmax 10, a Java-based data acquisition environment with features for data management, visualization, and reporting, to interface with computer-aided measurement and control analog-to-digital converters and time-to-digital converters. Analog pulse processing is performed using nuclear instrumentation module modules. The status of initial tests of this new implementation is discussed.

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Capturing Damage Detection in a Flocked Carbon Fiber in Glass-Fiber-Reinforced Polymer Composite

Nelson Mohammed

An experimental study was performed to investigate the change in electrical resistance as a function of damage of a carbon-flocked glass-fiber-reinforced polymer with 0.3 wt% of carbon nanotubes (CNTs) embedded in the composite. An electric-up flocking technology was employed to add carbon fibers vertically between each composite laminate. Micro X-ray computed tomography has been performed to confirm the postprocessing orientation of the flocked carbon fibers between each laminate layer. The addition of CNTs provided a three-dimensional conductive network to allow for the measurement of electrical resistance. The resistance measurements were performed with a Keithly four-probe setup under a quasi-static tensile load to track the change in electrical properties as damage was induced. Acoustic emission and thermography measurements were also captured simultaneously to provide further validation of different damage modes and a correlation to the increased resistivity response as a function of damage.

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Configuring and Characterizing the Capabilities of a Radio-Frequency (RF) Reconfigurable Circuit Array

Mary Monroe

We researched a multi-channel configurable RF integrated circuit chip. Digital RF technology can be used as a component of highly integrated, multifunction Army systems to support RF applications (communications, radar, and electronic warfare). This technology is widely tunable and reconfigurable, enabling easier paths toward new functionality, upgradability, and lower nonrecurring engineering (NRE) costs through hardware repurpose. The chip contains capabilities for transmit and receive paths through onboard mixing of RF and microwave frequencies, configurable local oscillator (LO) generation, filtering, and amplification. We used a software graphical user interface over a universal serial bus/FTDI interface to control registers on the chip for hardware configuration. We tested different capabilities in order to characterize performance of the technology's components. We characterized reliability of the hardware interface, LO signal generation, S-parameters (gain, return loss) of paths through microwave and RF amplifier blocks, and mixing capabilities using both onboard and external LO signals. In general, gain and return loss properties show good performance over narrower frequency ranges than the chip was designed to support. This may be due to properties of the chip's external evaluation kit. Moving forward, we plan to write our own drivers to improve communication with the chip.

I wish to acknowledge the mentorship of Abigail Hedden.

The Synthesis and Characterization of Phosphorescent Iridium Complexes

Autumn Moore

The use of organometallic iridium(III) complexes as phosphorescent dopants in organic light-emitting diodes (OLEDs) has become widespread. Their photochemical properties have guided researchers toward observing these complexes' nonlinear optical (NLO) properties. By coupling a family of 3-nitrophenyl boronic acids with a family of chloroisoquinolines, we synthesized four new ligands within the $[Ir^{III}(C^N)_2(O^O)]^0$ family, where C^N is the cyclometallating ligand and O^O is acetylacetonate (acac). Each ligand governs the functionality, broadband ground state, and transient absorption spectral features of its respective cyclometallated complex. In order to synthesize these new compounds, we used the Suzuki Coupling method to produce the 3-nitrophenyl isoquinoline ligands. Thin-layer chromatography was used to assess their purity and polarity. Afterward, they were complexed to iridium(III) chloride hydrate to produce four iridium dichlorodimers via a microwave-assisted organic synthesis reaction. The products collected were filtered via vacuum filtration, dried, and then converted into the acac complexes via microwave reaction. A second set of 4-nitrophenyl isoquinoline–derived acac complexes was synthesized and compared to the 3-nitrophenyl isoquinoline ligands. Proton nuclear magnetic resonance confirmed the purity and identity of these compounds. Ultraviolet/visible and photoluminescence measurements were taken to assess the iridium(III) complexes' photochemical properties.

I wish to acknowledge the mentorship of Dr Ryan O'Donnell.

Composite Hinges with Variable Stiffness

Lauren A Moore

In recent years, the US Army has become increasingly interested in methods to boost lethality, reduce fatigue, and improve marksmanship of the dismounted Soldier. Previous research ventures within ARL have developed mechanisms to achieve these goals. One such mechanism is the Third Arm, an exoskeleton for weapon stabilization. The current design of this exoskeleton comprises carbon-fiber plates connected by aluminum hinges. This study focuses on possible replacements of the present metal hinges through the use of composite materials and novel manufacturing methods. Vacuum-assisted resin transfer molding was used to produce composite panels consisting of carbon fiber in alternating sections of flexible polyurethane and stiff epoxy matrices. Ply orientations, ply count, and polyurethane area dimensions were varied to determine the effects on the mechanical behavior of the composite hinge. Next, panels were cut into test strips and each strip was subjected to compression testing to evaluate the bending capacities of the polyurethane section. Each test specimen experienced five loading cycles to obtain and analyze the average load values. After testing, it was recognized that the panels using carbon fibers with a 0/90 fiber orientation were able to withstand a significantly larger load compared to those with ±45 fiber orientation. Also, it was discovered that after repeated loading cycles, the maximum load capacity of the specimen decreased, possibly indicating delamination and damage in the flexible polyurethane section of the composite.

I wish to acknowledge the mentorship of Dan Baechle.

Testing and Evaluation of Ultraviolet 4H-Silicon Carbide (SiC) Avalanche Photodiodes (APDs)

Jonah Ng

Many applications such as bio-aerosol detection require accurate ultraviolet (UV) photon detection, for which the silicon (Si) APD does not adequately give the required performance. To provide the desirable UV photo-detection, 4H-SiC APDs have been developed at ARL. Testing and evaluation were performed for two batches of SiC APDs with different fabrication conditions as well as a UV-enhanced Si APD. Current-voltage characteristics were obtained with and without illumination at a wavelength of 270 nm. Linear mode characterization was carried out with voltages below 170 V. The SiC APD performed better than the Si APD in the UV spectrum: the quantum efficiency was 2.43 times larger. However, the dark current density of the Si APD was lower than that of some SiC APDs, due to the Si APD having 91% larger effective area. The dark current density for one of the batches showed a greater variation in its values and a minimum that was smaller than that of the other batch by 3115 nA/cm^2 at a gain of 1000. In the future, more devices with different fabrication conditions will be tested and evaluated.

I wish to acknowledge the mentorship of Drs Anand Sampath and Eric DeCuir Jr.

Gait Development for a Dynamic Quadruped Robot and Compliant Leg Design

John Nicholson

This summer's work focused on two main projects, gait development for the Legged Locomotion and Movement Adaptation (LLAMA) platform currently in development and design of a legged system that utilizes both physical compliance through springs and virtual compliance through actuators. The LLAMA project involves designing a dynamic simulation environment to create a 3-D model of the LLAMA legged platform. I then developed optimized gait controllers utilizing this model. For the compliant leg design project, I developed a reduced-order model that captures the dynamic properties of running and modified the simulation to capture different spring configurations.

I wish to acknowledge the mentorship of Jason Pusey.

Characterizing Damage Modes in Carbon-Fiber-Reinforced Polymers through Thermal Diffusivity Measurements

Benjamin Northington

Carbon-fiber-reinforced polymer composites have rose in many industries as a viable resource, but are extremely susceptible to damage. Therefore, it is important to effectively detect the onset of failure. The focus of this study is to devise a theoretical and experimental model of how damage modes, in particular, affect thermal diffusivity. Analysis techniques were performed using dynamic mechanical analysis, acoustic emissions, infrared thermography, and digital image correlation. Those techniques were used to devise a plan of analysis and provide conclusive data as to how the thermal diffusivity is indicative of damage modes, which can be used effectively to predict failure. In this study, it is shown that the damage mode can be characterized, in part, by reflection and transmission measurements of the damaged areas versus the structurally sound areas.

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Interface Characterization and Analysis of Gallium Nitride (GaN) Metal Insulator Semiconductor (MIS) Structures

Franklin Nouketcha

Given its material properties, GaN is among the best semiconductors for fabricating future electronic devices. Its large bandgap infers the possibility of high-power operation at extreme temperatures. Conjointly, the presence of 2-D electron gas in the GaN technology implies the possibility of high-frequency operation. GaN high-electron-mobility transistors (HEMTs) are already commercially available and expected to modernize electronics for communication, radar, and military systems, to name a few. Despite their promising features, GaN devices currently perform below their theoretical limits, and it is challenging to achieve enhance mode (E-mode) operation without compromising other device performance metrics. The MIS-HEMT structure is preferred for achieving E-mode operation, because it safeguards the integrity of the gate. In this work, we extract the density of interface traps in aluminum gallium nitride/GaN MIS-HEMTs and capacitor structures. This exercise is a preliminary step in evaluating one of several types of traps that can affect material quality and device performance. The ultimate goal is to systematically characterize the gate insulator–semiconductor interface to determine the most suitable dielectric material and deposition technique.

I wish to acknowledge the mentorship of Dr Ron Green.

Machine Learning Techniques for Anomaly Detection in Cyber–Physical Systems

Subrina Noureen

The constant advancement of technologies employed in alternating current (AC) power grids presents a dilemma to most power center managers. These new technologies present opportunities for the introduction of malicious cyber attacks such as malware, denial of service, and a number of additional attacks in both the generation and distribution segments of the power grid. Both physical and cyber security threats must be identified and dealt with before the grid is compromised. Synchrophasor measurements generated by phasor measurement units (PMUs) provide AC voltage, current and frequency magnitude, and phase angle measurements at a rate of 30–120 samples/s. This work analyzes simulated PMU data and cyber events generated by an Opal Real Time Digital Simulator running a MATLAB/Simulink model of the IEEE 39 Bus. The PMU data are transferred to openPDC via a C37.118 link, where it is then stored in a MySQL database and processed by machine learning (ML) algorithms executed as a Python script. This work explores not only the infrastructure of the test setup, but the logistic regression and k-nearest-neighbor classifier as well. Data sets were generated to "train" and test the ML algorithms with future efforts focusing on transmission latency effects in a cyber-compromised grid.

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A Comparative Study of Fuel Tribology by High-Frequency Reciprocating Rig (HFRR) ASTM D6079-11 Using a UMT-3 Tribometer

Allison Osmanson

Uncertain fuel sourcing in the field can have a grave impact on the performance of equipment used by US Army Soldiers. Particularly, fuel systems in unmanned aerial vehicles and ground combat vehicles can degrade rapidly with lower-viscosity fuels and contaminants. Fuel systems are lubricated by fuels to reduce the effects of friction in two moving parts in contact, as found in fuel pump pistons, valves, and injectors. Herein, a study of fuel lubricity is initialized to investigate the appearance of the wear scars, wear rate, and oxidation, among other chemical changes in surfaces resultant of friction at contact. Lab-created results using methods similar to ASTM D6079-11 standards are compared to defects found in failed fuel system components, identifying the tribological consequences and benefits of each fuel. An improved method for measuring tribological performance of materials beyond the capabilities of the HFRR and ASTM D6079-11 standards is introduced by measuring void volumes in addition to wear scar diameters and depriving the system of oxygen during testing, simulating the oxygen levels in a fuel system. Fuel samples tested include ethanol, JP-8, F-24, DF-2, POS-12341, a field fuel, alcohol-to-jet, and two HFRR standard diesel fuels with high and low lubricities.

I wish to acknowledge the mentorship of Dr Stephen Berkebile. Thank you for your guidance and support throughout this project. I would also like to thank Dr Jon-Erik Mogonye for teaching me how to use the CETR UMT-3, guiding me through image analysis of my samples, and sharing your MATLAB codes with me. Thank you also to Nikhil Murthy for your patience while training me on safety, scanning electron microscopy, and the Zeiss LSM700. The assistance of Matthew Porter and Dave Gondol is gratefully acknowledged.

Raman Characterization of Black Carbon Particle Size

Francis Oyebanjo

Raman spectroscopy (RS) is a spectroscopic technique that relies heavily on the rotational and vibrational properties of a molecule. Similar to infrared spectroscopy, RS can be used to identify compounds such as black carbon. Black carbon is a component of particulate matter in the atmosphere. These particles can deposit in respiratory airways and lead to severe health issues. Previous studies have detected large amounts of black carbon Raman spectra in ambient measurements. This project aims to determine the correlation between the size of a given particle of Printex 90 (an analog for black carbon) and its Raman intensity, for particles between 100 and 500 nm. In this experiment, different size samples and concentrations of black carbon will be measured and their Raman intensities are identified. Furthermore, this study attempts to establish what concentration of particles and sampling conditions results in single particle deposition. Raman spectra consistent with 100-nm particles have been detected, but additional tests are needed for verification. Concentrations of fewer than 100 particles per cubic centimeter have shown weak or no Raman intensities in the D and G bands, while larger concentrations (>100 particles/cc) result in strong Raman intensities and the formation of Printex agglomerates.

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Raising Online Visibility and Recognition for ARL through Science Writing on Wikipedia and Other Platforms

Steven Park

The predominance of the Internet has made the online presence of ARL crucial to its growth and influence in today's digital era. While passivity in this domain may hamper the growth of any lagging institution, an extensive online presence has the potential to significantly boost the support of current and future research projects through increased public interest, funding, and status. One major platform is Wikipedia, a popular reference website that garners more than 370 million unique visitors per month. On Wikipedia, ARL's article page has a relatively weak presence. From June 1, 2017, to June 1, 2018, the ARL page has collected a daily average of 6 views and a total of 2,188 page-views. In that same timeframe, the article page for the Defense Advanced Research Projects Agency has amassed an average of 1,172 views per day and a total of 429,100 page-views in 1 year. The objective of this project is to enhance the online visibility of ARL on Wikipedia by creating new articles for the scientific milestones accomplished by ARL. This project intends to give recognition to the works of ARL scientists and further promote the organization's mission.

I wish to acknowledge the mentorship of Joyce Martin.

Troubleshooting Aerosol Generators and Gas Chromatography Machines

Cayman Pearsall

The purpose of the projects was to troubleshoot and fix the aerosol generators and the gas chromatographer (GC) attached to the mass spectrometer. The methodology to complete these two tasks involved working cooperatively with other staff members to get the parts replaced and cleaned for all the machines. The results consisted of one aerosol generator working completely according to baseline tests and the GC not being completely fixed; therefore, baseline testing was not completed.

I wish to acknowledge the mentorship of Jonathan Sabol.

Disambiguating PropBank Rolesets with Deep Neural Network Classifiers

Nhien Phan

Semantic role labeling (SRL) is a task where phrases are assigned labels describing their relationship to the predicate of a sentence. PropBank, a text corpus used in SRL, defines frames for predicates (e.g., verbs) in the Penn Treebank, a syntactically annotated text corpus used in natural language processing. In PropBank, a set of roles for a predicate is called a roleset, and a predicate may have multiple possible rolesets (i.e., the roleset for “firing an employee” vs. “firing a missile”). Disambiguating rolesets enables Army analysts to extract and filter relevant information from text sources. This work implements a TensorFlow four-layer neural network classifier for each PropBank verb with more than one roleset. The classifiers are trained on sentences from the Penn Treebank and English Web Treebank, using features extracted from dependency-based syntactic n-grams. A synonym replacement strategy is used to augment the training data. The models use the Adam optimizer and are regularized with early stopping and 50% dropout for each hidden layer. The models were tuned on a development set and correctly classified 91.2% of ambiguous predicates in the development set and 90.1% of ambiguous predicates in the test set.

I wish to acknowledge the mentorship of Dr Stephen Tratz.

High-Performance Computing (HPC)-Enabled Simulation of Cavitation Phenomena in a Hydrocarbon-Fueled Nozzle

Joshua Piehl

Shear-driven cavitation plays an important role in many technological applications, particularly in fuel injectors for piston and gas-turbine engines. Cavitation affects the performance and longevity of fuel injectors; hence, it is desirable to understand and predict its behavior. Although there have been a vast number of studies, a full understanding or theoretical framework describing its behavior has not yet been achieved. This is due to the complexities associated with cavitating flows including internal flow physics, turbulence, two-phase flow, and nonequilibrium thermodynamics. In this work, an unstructured, computational fluid dynamic solver coupled to the Eulerian–Eulerian cavitation model is utilized on ARL's supercomputers to investigate cavitation onset and transport in a benchmark nozzle. The pressure drop across the nozzle is modeled at 20, 40, 60, 70, 75, 80, and 85 bar for a heavy hydrocarbon fuel. The results are in good agreement with experimental data from the optical nozzle, and are useful for identifying the potential damage zones. The models captured the cavitation process near the boundary region and were able to predict the critical cavitation as well as the choked flow regions. These findings could be useful to guide the design of innovative Army propulsion technologies with improved engine endurance.

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Mixed Reality for Data Visualization

Austin Pierce-Ptak

The purpose of this project was to research, experiment with, and implement new approaches for modeling and representing data in a nontraditional way. Not all data can be quickly and effectively communicated via a 2-D image. As a 21st-century solution to an age-old problem, the Army can greatly benefit from utilizing the technology of today for data visualization. Using a digital format gives versatility in a way not possible with 2-D imaging because modeling 3-D data in a 3-D digital space can be manipulated as if it were right in front of the user. Often, visualizing 3-D data in a 2-D environment is difficult and ineffective at conveying meaning to the user. Thus, a 3-D space for 3-D data manipulation is needed. Using the Unity game engine and the HoloLens toolkit, an augmented reality application was developed to model and simulate an explosion involving thousands of data points. Each data point represents a concentration-level reading in a 3-D grid space at some timestep within the explosion sequence. These readings are determined by multiple sensors that are stationed within the 3-D environment. The application allows a HoloLens user to plan where sensors should be stationed in the 3-D environment, as well as play back a simulation of the chemical cloud explosion as recorded by the sensors. The planning phase is more interactive for the HoloLens user, whereas the simulation phase of the application reads in test data to show an actual 3-D chemical cloud explosion. Utilizing Unity and the HoloLens toolkit, a 3-D interactive application was created to support a more intuitive representation of dynamic 3-D assets and data.

I wish to acknowledge the mentorship of Vince Perry, who has experience with Unity and Mixed Reality, and helped with the creation of this application.

Robust Distributed and Decentralized Observer Design for Uncertain Nonlinear Networked Systems

Dimitrios Pylorof

It is often difficult or even impossible to accurately measure the entire state vector of a stand-alone or networked dynamical system; however, such information is typically necessary to control the underlying process and stabilize it to a desirable equilibrium, set, or reference trajectory. Observers are purpose-built dynamical systems that use knowledge of the system's dynamical and measurement models, the uncertainty characterization, as well as the current control inputs and measurements, to ultimately converge, in some sense, to the actual but unknown state of the system. We study the observer design problem for nonlinear polynomial systems subject to bounded modeling and measurement uncertainty. A Lyapunov-based observer is designed for this class of systems using sum-of-squares optimization techniques that lead to semidefinite programs. The proposed solution is applicable to stand-alone, distributed, and decentralized contexts. The observer is guaranteed to bring the state determination error to a vicinity of the origin, starting from some larger set, both of which are explicitly calculated during the design process. The practically quantifiable robustness and performance bounds also enable the possibility for output feedback control, by fusing the herein proposed methods with our earlier results on nonlinear stabilization with imperfect state feedback.

I wish to acknowledge the mentorship of Dr Kevin S Chan.

Improving ARL's Online Visibility through Wikipedia

Rafael Reyna

While the US military laboratory system has historic achievements dating back to the early 19th century, limited online information is available describing ARL's role in past military research. The purpose of this project was to address this vacuum by developing the online visibility and presence of ARL's scientific and technical accomplishments, both historic and recent, specifically by targeting Wikipedia, an online free encyclopedia. In collaboration with ARL's Chief Scientist, Public Affairs Office, and other researchers, our team of four science writers developed articles and press releases over the course of four months. Daily tasks included researching neutral sources, assembling supporting material, conducting interviews, and writing short online articles and science news press releases. Products appeared on the ARL's website, EurekAlert!, and Wikipedia. As of July 20, 2018, our team completed 77 articles with 61 published on Wikipedia. ARL's online visibility can be heightened through nontraditional venues such as Wikipedia, improving public access to ARL's history and scientific endeavors.

I wish to acknowledge the mentorship of Tom Moyer, Chief of Public Affairs.

Initial Assembly and Testing of the Adelphi Laboratory Center (ALC) Pelletron Accelerator

Lennie R Reynolds Jr

Particle accelerators produce primary beams of charged particles, such as protons and other light ions, at high energies and the production of secondary beams of fast neutrons. A wide range of basic and applied research topics can be studied with these beams, including materials modification and damage, nuclear physics, directed gamma energy, novel radiation detectors, and quality assurance of Army dosimeters. In 2017, the Naval Surface Warfare Center, Carderock Division, transferred to the US Army Research Laboratory's* Adelphi Laboratory Center (ALC) a National Electrostatic Corporation tandem Van de Graaff accelerator of the "Pelletron" type, with a maximum terminal voltage of 3 MV and capable of accelerating a wide variety of ions, along with considerable supporting instrumentation. Residing in the Energy and Power Division, initial placement, assembly, and testing of the Pelletron components has begun and this poster describes these steps toward commissioning the accelerator at ALC.

I wish to acknowledge the mentorship of Dr James J Carroll, Dr Abraham Meles, Dr Christopher Chiara, Dr Jeffery Vanhoy, and the Office of the Under Secretary of Defense for Research and Engineering DOD Historically Black Colleges and Universities and Minority-Serving Institutions Program Office.

*At this time, the US Army Research Laboratory (ARL) was part of the US Army Research, Development, and Engineering Command (RDECOM). As of 31 January 2019, the organization is now part of the US Army Combat Capabilities Development Command (formerly RDECOM) and is now called DEVCOM Army Research Laboratory.

Quantification of Morphological Changes in Hippocampal Neurons In Vitro Following Stretch Injury: Effect of Glia

Meaghan Richardson

Traumatic brain injury (TBI) incidences have become increasingly prevalent in the Army over the past two decades, particularly the incidence of mild traumatic brain injury (mTBI). This research seeks to establish a link between mechanical loading and cellular injury in order to improve computational models and develop protective equipment to reduce the incidence of mTBI among Warfighters. This study focuses on the effect of glia, supporting cells that interact with neurons, on morphological changes in hippocampal neurons in culture following injury. The results of this study will determine the glia condition most relevant for future injury studies. To study the effect of glia, hippocampal neuron cells were plated with different media conditions that result in distinct glia conditions: no glia, sporadic glia, or confluent glia. The cultures were stretched using the Cell Injury Controller II device to simulate TBI, and were imaged using phase contrast microscopy both before and after injury. The images were traced using Simple Neurite Tracer[1] and neuronal branching patterns were quantified using a Sholl analysis. Preliminary results show that branching is similar for no glia and sporadic conditions at DIV12, but is less for the confluent condition. Post-injury, both the no glia and sporadic conditions show a decrease in branching, whereas there is no change for the confluent condition. This suggests that decreased branching is a result of local support of glia and that the confluent glia protect neurons during injury.

I wish to acknowledge the mentorship of Dr Ann Mae DiLeonardi and Erika Matheis.

[1]Longair MH, Baker DA, Armstrong JD. Simple Neurite Tracer: open source software for reconstruction, visualization and analysis of neuronal processes. Bioinformatics. 2011 Sep 1;27(17):2453–2454.

Improved Storage in Primary Lithium Cells

Alex Robinson

The Army utilizes large quantities of primary lithium (Li) batteries to conduct various Soldier operations, namely, powering the squad radio and other equipment. These batteries are purchased in bulk and stored for periods of up to 5 years. Ten years of research to improve Li-ion battery performance has resulted in numerous electrolyte additives being synthesized, evaluated, and applied to commercial cells. These same additives can be directly applied in Li metal batteries as they utilize many of the same base electrolytes. This research is focused on investigating recently developed electrolyte additives for improved storage and rate performance in Li metal cells stored at elevated temperatures. The initial experiment consists of constructing individual Li batteries with two different electrolyte additives in two different base electrolytes: propylene carbonate: dimethoxyethane and ethylene carbonate: dimethyl carbonate (EC:DMC). Initial results indicate that EC:DMC Lithium hexafluorophosphate is the optimal base electrolyte. Furthermore, both fluoroethylene carbonate and trimethylsilyl phosphate show benefits of reduced impedance growth. In addition to impedance, testing of the discharge capacity for each Li battery cell will be conducted.

I wish to acknowledge the mentorship of Dr Jeffrey Read.

Microelectromechanical System (MEMS) Device for the Determination of Material Properties with the Use of Various Test Structures

Marquis Rogers

A 3-D microscopic device with test structures was printed and fabricated to determine the mechanical properties of two materials. The test structures were understood by means of research involving the study of stress measurement techniques for thin films. The structures of interest included Vernier pointers, diaphragms, and cantilever beams that provided information useful in determining stress, deflection, and other properties. After printing and development, the device underwent a fabrication process that involved the use of a sputter coater that deposited chrome uniformly onto the surface of the structures of interest. Measurements were taken before and after the deposition process using a laser confocal scanning microscope. After using equations related to stress, strain, and deflection, it was concluded that the Young's modulus of acrylic resin is 2.8 GPa and that chrome has a tensile stress of +270 MPa when deposited unto an acrylic resin substrate.

I wish to acknowledge the mentorship of Dr Paul Sunal.

Dynamics of Decomposition Products of Energetic Materials Using Coarse-Grain Models

Jonathan Ruffley

There is a need for the capability to simulate the decomposition of cyclotrimethylenetrinitramine (RDX) to gain insight into how defects affect the reactions of this material. Time and size scales of interest preclude the efficient use of atom- or molecule-explicit molecular dynamics for this purpose. We seek to develop a coarse-grain model that appropriately captures the thermodynamic and transport properties of RDX decomposition simultaneously to meet this need. In previous work, we evaluated the performance of several coarse-grain models at predicting the thermodynamic properties of RDX product gas mixtures through the use of dissipative particle dynamics. Here, we assess whether these models correctly predict the mass and momentum transport properties of such mixtures.

I wish to acknowledge the mentorship of Drs John Brennan and James Larentzos, my fellow intern R John Clark, and funding from the DOD High-Performance Computing Modernization Program Internship Program. In addition I would like to acknowledge computational resources at the DOD Supercomputing Resource Center (Excalibur).

Additive Manufacturing of 3-D Copper Nanolattices

Bradley Sanchez

Current additive manufacturing processes in the ARL Specialty Electronic Materials and Sensors Cleanroom (SEMASC) have a limited feature size of about 50 μm, making it difficult to be able to manufacture complex 3-D nanostructures. A two-photon lithography (TPL) process was developed to create 3-D copper (Cu) nanolattices with the capability of approximately 220-nm resolution in other 3-D nanostructures. First step was to synthesis the Cu acrylate and IP-Dip liquid photoresist by sonicating, then use TPL to sculpt 3-D nanolattices with Cu infused into the structure, followed by a pyrolysis process performed in a high-temperature furnace with the goal of volatizing the organics and producing a Cu-containing architecture. We produced nanolattices with octet geometries that were measured to be 4-μm unit cells made of grained nanocrystalline, nanoporous Cu. Overall, this work presents an efficient pathway to 3-D print nano-architected metals with submicron resolution.

This research was experiment was supported by the SEMASC and Sensors and Electron Devices Directorate. Valuable discussions with Dr Paul Sunal and Brant Hempel were greatly appreciated.

Femtosecond Laser Eyewear

Spencer Schill

Ultrashort pulse lasers are seeing more widespread use in industrial, medical, and research and development fields, thus protective eyewear is important in order to perform experiments safely. Safety goggles made for these high-powered short-pulse lasers do not always protect the user the way they should and need to be tested on before they can actually be used for research. Ultrafast lasers can exhibit spectral sidebands that can change the central wavelength of the beam and cause damage to the goggles as well as the eye. For this experiment, a single-pulse, titanium:sapphire femtosecond laser was used at 800 nm to test the durability of five sample filters provided by an unnamed vendor and are compared to their measurements to see if they actually meet the specified optical density at the given wavelength.

I wish to acknowledge the mentorship of Chris Morrone, Nancy Vyas, Michael Borisky, and Trenton Ensley.

Highly Maneuverable Airframe (HMA) Test Projectile

Franklin Shedleski

HMA uses a four-canard control actuation system (CAS) and a camera for guidance. Camera images and inertial measurement unit data are fed to a Nvidia Tegra TX2, which uses machine learning algorithms to detect a target in the image and generate flight control commands. These commands are sent to a Texas Instruments C2000 series embedded processor (DSP) that sends real-time updates to the canards. The DSP also handles calibration and stabilization of the CAS. The goal of HMA is to provide a projectile that can seek an un-illuminated moving target in global positioning system-denied zones through use of vision-based navigation systems.

Software packages and embedded device drivers were designed to allow wind tunnel testing of the HMA platform. A state machine was implemented to coordinate testing routines on the projectile during deployment on a three-axis gimbal in a wind tunnel. A FAT32 file-writing library was integrated to allow the DSP to log CAS and gimbal data to an SD card in real time. The ability to read and write to a micro SD card allows testing routines to be both easily configured and logged.

I wish to acknowledge the mentorship of Dr Bethany Allik and Mr James Maley.

Molecularly Imprinted Polymers (MIPs) on Photonic Sensor Chip

Tara Sherbondy

ARL is developing sensors for chemical and biological material detection via target-specific sensing. The sensors consist of a selective MIP layer integrated with a photonic chip as the device/platform. Molecular imprinting is used for enhancing target selection. MIPs are desirable because they are rugged (able to be used in a range of environments), are optically transparent, and can be tailored to a variety of targets. The MIP-based photonic sensor could be used to monitor Soldier performance in the field and/or psychological state, therefore identifying performance risk factors and ultimately improving team mission execution.

This summer, I fabricated and demonstrated MIPs for the chemical target cortisol. Cortisol is released when the human body is under stress. During that time, the body undergoes the fight-or-flight response. Cortisol can be found in sweat or saliva, which makes it a good candidate for testing. I focused on MIP development for deposition onto a photonic sensing chip. The MIP solution was spin-coated onto a photonic sensing chip, then tested to determine if the material was there and measure the thickness. This was repeated with many different solutions to determine the best formulation for the sensor integration.

I wish to acknowledge the mentorship of Ellen Holthoff, Zac Quine, and Mikella Farrell.

Laser Characterization of a Highly Erbium-Doped Alumina-Silica Fiber

Brady Simon

A *ytterbium*-free, erbium-doped, alumina-silica fiber was evaluated for laser performance. As high as 2 wt% of erbium were doped in the silica core synthesized by the surface plasma chemical vapor deposition process. We used an innovative fiber cut-back setup to determine the absorption spectra of the single-mode fiber. Both white light and narrowband diode laser sources were used as probe lighting in the measurement, yielding the same absorption value of 600 dB/m at 1532 nm. We also measured the fluorescence lifetime of the erbium in the material to be approximately 3 ms, indicating a strong ion cluster in the silica material. A short piece of the single-mode fiber (17 to 59 mm long) was used in the master oscillator power amplifier setup for the optical gain measurement. The laser operation feasibility is discussed in the work.

I wish to acknowledge the mentorship of Drs Jun Zhang and Radha Pattnaik.

Identifying Research Gaps Related to Visualizing Geospatial Data in 3-D

Mark Simpson

The goal of this project was to illustrate challenges and potential solutions for displaying geospatial information with immersive virtual reality (VR) technology. Three-dimensional visualizations in VR may be more intuitive than traditional 2-D visualizations, such as 2-D statistical graphs or paper maps. Nevertheless, there are several known limitations of 3-D maps and other 3-D visualizations, such as perspective distortion, occlusion, and the difficulty of navigating 3-D space. However, most research has examined 3-D visualizations only through 2-D displays. Immersive VR technology allows 3-D visualizations to be viewed in stereoscopic (true) 3-D, which may overcome those limitations by taking advantage of our natural abilities to perceive and experience 3-D objects, spaces, and environments. To investigate potential benefits and issues when visualizing 3-D information in immersive VR and lay the groundwork for future experimental evaluations, we implemented a platform for users to explore different visualization methods within immersive VR. We created three sets of artificial data from which we derived analogous 2- and 3-D versions of three common visualization types for displaying geospatial information (e.g., point, heat map, and choropleth), or 18 data visualization layers total. This platform will be used for future experiments evaluating visualization types for different Army applications.

I wish to acknowledge the mentorship of Dr Michael Geuss.

Neural-Inspired Robotic Grasping and Manipulation

Andrea Sipos

Current robotic systems rely heavily upon vision tools to perform grasping and manipulation tasks, with limited integration of tactile and proprioceptive feedback. However, there are many potential robotics applications in which vision tools cannot be exclusively relied upon. By focusing on and developing tactile and proprioceptive methods for robotic grasping and manipulation tasks with a brain-inspired approach, we expect to discover generalized and robust solutions to problems that vision alone cannot solve. In the duration of my internship, I developed a platform for data collection and analysis in pursuit of this goal. I designed and manufactured an extended gripper system for a robotic arm, a custom and inexpensive shear force sensor to detect slip events in grasping and manipulation tasks, and the objects to be used in these tasks. I also implemented control and planning software on the robotic arm and prepared neural network development software. These tools provide a basis for researching neural network control processes for robotic grasping and manipulation tasks.

I wish to acknowledge the mentorship of Dr Chou Hung (Human Research and Engineering Directorate [HRED]), Dr Paul Fedele (HRED), and Mr Jason Pusey (Vehicle Test Directorate).

Uncertainty Quantification in Computational Fluid Dynamics (CFD)

Brendan Smith

CFD allows for single values to be input and corresponding singular values to be output. This is less than ideal considering that cases in the real world do not operate with set values, and so introducing some uncertainty to the models is beneficial. The CFD program used was Create AV Helios, a high-fidelity CFD package that was run through the high-performance computing systems. Due to high simulation times, a different method of modeling uncertainty besides running thousands of cases must be considered. The alternative used to model this uncertainty, polynomial chaos expansion (PCE), forms an equation using basis functions in random space that can express the uncertainty in a term. Select cases were run that would allow a PCE equation to be built for the output, in this case, rotor power, based on the uncertain input, in this case, rotor speed.

I wish to acknowledge the mentorship of Phuriwat Anusonti-Inthra.

Smart Sensor Data Viewing Application User Interface

Abigail Snellman

To intelligently measure and asses electric power consumption at Army bases and facilities, ARL has developed the ARL Real-Time Electric and Magnetic Integrated Sensor (ARTEMIS), a mobile smart sensor that can process electric and magnetic field data and communicate multiple levels of data to a cloud-based server. Data can be accessed, viewed, and downloaded through a smart-sensor node web application built on the distributed Live Animated Multi-Phasor (dLAMP) software. Previously, the primary form of input for this application was text-based, which heavily restricted the user's ability to find, understand, and interact with the data of interest. This restriction was solved by utilizing the principles of design to create a clean web-app design that allows the user to directly interact with the available data. All text-based inputs were replaced with graphical solutions including in-line calendars for date selection and date range selector displaying years of hourly power data. In addition to this, several options to display current and voltage in addition to power data in both local time and Coordinated Universal Time were added. These additions greatly improved the accessibility of the dLAMP web application by giving the user more control over their own data-viewing experience.

I wish to acknowledge the mentorship of Brandon Parks.

Active Matter Transport

Zachary Stockwell

Active matter transport is a new research field in physics that incorporates independent motor forces within molecules into transport processes traditionally governed by passive forces. Each molecule moves by itself through a substrate, colliding with other molecules. Given a continual supply of internal energy, these active molecules will move for a designated run length before arbitrarily changing direction, provided no collision has occurred. When obstacles are present, however, it is difficult to predict how the active molecules will behave on timescales larger than the average time between collisions. To investigate this problem, we developed a basic molecular dynamics simulation to map coordinate points of a certain number of molecules as they collide with and move through a slab of obstacles. Each particle has a randomly chosen direction and a constant motor force. Collisions are modeled by a harmonic interaction force that acts to separate nearby particles. After long periods of time, particles tend to cluster. Engineering control of the cluster can be used in many applications, such as mounts and deformable bodies. Through this research, characteristics of active matter transport can be understood.

I wish to acknowledge the mentorship of Adam Svenkeson for his tremendous help with this new and intriguing research topic.

Optical Spectroscopy of Erbium (Er^{3+}):Barium Fluoride (BaF_2) for Mid-Infrared (IR) Laser Applications

Hannah Tack

We explored the spectroscopic properties of Er^{3+}:BaF_2 for both the 980-nm and 2.7-μm mid-IR transitions. We studied the temperature dependence of absorption and fluorescence from room temperature (300 K) to as low as 8 K. We then calculated the absorption cross sections of the material for a given thickness. For the emission spectra, we pumped with an 800-nm laser and observed both the 980-nm and 2.7-μm transitions. Branching ratios were then calculated for the two transitions at 300 and 77 K, and were used to determine the stimulated emission cross section. We found the stimulated emission cross section of the 2704.5-nm peak increased by a factor of 4.73 from 300 to 77 K. Finally, the radiative lifetime and quantum efficiency of the 2.7-μm transition were calculated at both 300 and 77 K. The quantum efficiency decreased by a factor of 2.57 from 300 to 77 K.

I wish to acknowledge the mentorship of Dr Zackery Fleischman. I would also like to thank Dr Ei Ei Brown for her help throughout the summer.

Development of Control Software for Frequency Resolved Optical Gating (FROG) Laser Diagnostic System

Erik Ter-Gabrielyan

For my time as a Science and Engineering Apprenticeship Program student at ARL in Adelphi, Maryland, I developed a program in the graphical programming language LabVIEW that would complete FROG tests. FROG is a diagnostic test for femtosecond lasers. The program that runs it will automatically measure spectra along with frequency and delay by controlling the spectrometer and motor for the delay stage. To successfully complete this project, I had to research what the FROG method was, learn the basics of LabVIEW so I could branch out into more difficult structures, and research the individual LabVIEW virtual instruments provided by the manufacturers so I could understand how to utilize and apply them in my project. In addition to the program, in the lab, I took measurements to characterize filamentation (high-intensity nonlinear optical interaction) in a range of glass materials and explored relationship of frequency broadening of the generated supercontinuum with several parameters including laser power, material composition, and sample thickness.

I wish to acknowledge the mentorship of Zachary Quine.

Fabrication of Electrodes for Flexible Aqueous Lithium-Ion Batteries

Robinson Tom

Soldiers in the battlefield rely on their rechargeable battery-based equipment to complete their mission. The weight and stiff packaging, combined with the safety concerns of current lithium-ion batteries (LiBs), put a strain on the Soldiers' ability to use LiBs in or out of combat situations. LiBs are lightweight and have higher energy density compared to other battery chemistries, such as nickel-metal hydride. LiBs use organic-based electrolytes that are flammable and can generate toxic products when burned. Therefore, safety is an urgent concern for organic LiBs. Recently, ARL developed a family of aqueous electrolytes for LiBs that are nonflammable and can support battery operation up to 4 V. Shifting to aqueous-based LiBs will remove the risk of fire and the need for dry manufacturing facilities required by organic LiBs. Our work focused on a specific variety of aqueous electrolyte called hybrid aqueous/nonaqueous electrolyte (HANE), which has a larger electrochemical stability window compared to a water-only electrolyte. HANE can also be made into a polymer gel electrolyte, enabling the design of fully flexible and conformal LiBs.

To fabricate an aqueous LiB, we focused on the composition of the electrode and ways in which to make a beneficial electrode–electrolyte interface. Here we focus on fabricating a suitable electrode material that will reduce electrolyte decomposition and improve Li^+ transfer at the electrode–electrolyte interface. LiB electrodes have three components: active material, electrically conductive material, and binder. We have selected lithium vanadium phosphate fluoride ($LiVPO_4F$) and lithium cobalt oxide ($LiCoO_2$) as our anode and cathode active material, carbon nanotubes as the conductor, and poly(vinylidene fluoride) as the binder. We were able to fabricate an electrode material that successfully performed charge–discharge cycling. Optimization of our electrode composition should allow more charge–discharge cycles, higher capacity, and will facilitate the fabrication of flexible, aqueous LiBs.

I wish to acknowledge the mentorship of Arthur Cresce and Thiagarajan Soundappan.

Defect Density Characterization in Silicon Carbide (SiC)

Khava Tsarni

In this study, our goals were to identify and quantify different crystal defects in a large area of a SiC sample for further development of SiC-based avalanche photodiodes (APDs) as sensors for ultraviolet light. APDs are very advantageous in light with their high sensitivity, low noise, high-speed response, high gain factor, and capability of low-light-level measurement. We used an optical microscope software application that allowed us to count over a large area to account for low defect densities. We used a DM2700 Leica microscope to obtain the surface defects and a scanning electron microscope to view electrically active defects through using electron beam–induced current imaging. It was the goal to identify which defects influenced the dark current and avalanche onset for previously obtained current-voltage curves for APDs.

I wish to acknowledge the mentorship of Drs Brenda VanMil and Anand Sampath.

Actuation at the Nanoscale Using 3-D Lithography

Joshua Tyler

We investigated actuation with nanoscale additive manufacturing, implementing recent developments in 3-D lithography. We studied two different mechanisms for nanoscale actuation: hydraulic actuation through microfluidic compression and thermal actuation of hollow shape-memory-alloy (SMA) nanolattices. Hydraulic actuation was achieved using the unique features of the Nanoscribe GmbH. Bellows-like hydraulic pump structures were printed that were designed to encapsulate the photo-reactive resin. Loading and unloading under a probe station microscope confirmed actuation. This demonstrated the ability for single print microscale fluidic actuators. For the second mechanism, we sputtered SMA nickel-titanium (NiTi) onto Nanoscribe printed lattice structures. We hypothesized the recoverable properties of SMA NiTi would allow us to compress the lattice structures and thermally restore to the original structure, showing the ability of nanoscale thermal actuation. Though stress in the material and conformity needs optimization, the feasibility to make functional SMA nanoscale lattices with the Nanoscribe was shown. The resulting lattices were conformally deposited with SMA NiTi, then we etched away the original polymer structure, leaving behind a hollow nanolattice of SMA NiTi. The high-strength nature of these nanolattices combined with the recoverability of SMA NiTi offers a wide range of applications for functional mechanical metamaterials at the nano- and microscale.

I wish to acknowledge the mentorship of Gabe Smith.

Learning Aspects of Different High-Rate Material Experimentation Techniques

Travis Wagner

Working with the Impact Physics Branch, I learned about high-rate material experimentation by performing a variety of the procedures required for specimen preparation and experiment setup. These include polishing specimens for mini Kolsky bar experiments, polishing flats on Kolsky bars for diffraction gratings, assisting in conducting Kolsky tests, and preparing for gas gun test shots and troubleshooting various parts of the gun. A highlight was participating in the first hypervelocity research shot at the Experimental Facility-11 where the two-stage capability has been reestablished. At lower pressures, I helped execute Kolsky bar experiments on various materials, prepared the MAX phase specimen, added laser interferometry features to aluminum Kolsky bars for polymethyl methacrylate testing, and added an infrared heater temperature regulation assembly for high-temperature experiments on Kolsky bars.

I wish to acknowledge the mentorship of Richard Becker, along with Christopher Meredith, Cyril Williams, Daniel Casem, David Ayers, Eric Wilson, Logan Shannahan, and Jermaine Bradley for working with me this summer.

Convergence Study of ParaPower

Justin Wang

Numerical methods are commonly used to solve problems in heat transfer. Commercially available numerical solvers emphasize high-fidelity, high-accuracy models, with computational resources and user efficiency being a secondary consideration. At ARL, we have developed a numerical solver known as ParaPower, which emphasizes computational efficiency and user friendliness at some expense of accuracy. The goal of the project is to quantify the tradeoffs between the methods so that users will be able to make informed decisions as to which model—high fidelity with low efficiency or lower accuracy with higher efficiency—is more appropriate for a given application.

We tackle this problem by performing a convergence study with the two parameters—spatial and temporal discretization—that are most influential in determining the accuracy of the numerical solution. As of this writing, the temporal convergence study has been implemented, which shows first-order convergence. We continue to understand the spatial convergence behavior to determine an acceptable mesh density and accuracy level. Both parameters play crucial roles in determining an appropriate level of tradeoffs in accuracy and efficiency between high-fidelity models such as ANSYS and more efficient models such as ParaPower.

I wish to acknowledge the mentorship of Mr Morris Berman, as well as Dr Michael Fish, Dr Lauren Boteler, and Mr Michael Deckard.

Understanding Next-Generation Multifunctional Thin Films

Brandon Whitaker

In 2011, ferroelectricity in hafnium(IV) oxide (HfO_2)-based materials was identified, making it incredibly promising for Army-relevant applications such as position, timing, and navigation applications using the piezoelectric properties and energy harvesting based on the pyroelectric properties. Since the polarization switching mechanism continues to be unknown, this study focuses on investigating the influence of film composition on polarization. A series of HfO_2-zinc oxide (ZrO_2) films (HZO) were grown by atomic layer deposition with various coequal binary compound layer ratios. Samples were annealed at temperatures ranging from 300 to 600 °C and tested under different environment temperatures, voltages, and frequencies. For all ratios, HZO films annealed at 300 °C were noted to behave as linear dielectrics. With increasing annealing temperature, HZO films begin to show ferroelectricity at room temperature, except for those with high layer ratios. Asymmetric and symmetric ferroelectric hysteresis loops were measured, along with a noticeable increase in remnant polarization with changing frequency. This frequency-dependent dispersion was reduced during cryogenic dielectric tests (200–300 K), indicating that polarization switching in HZO is strongly aided by thermal energy. This work can expand our knowledge on the behavior of ferroelectric HfO_2, a critical step toward material development and device engineering.

I wish to acknowledge the mentorship of Milena Graziano and Brendan Hanrahan.

Towards In Situ Monitoring of the Microstructure of Magnesium WE-43 Using Laser Ultrasound

Ja'Maya Wilson

Magnesium has a high strength-to-weight ratio, which makes it an attractive material for light-weighting Army vehicles. Its light weight allows for increases in fuel efficiency and decreases in fuel emissions. Magnesium can be a challenge to design with due to low overall strengths and anisotropic behavior. WE-43 is an alloy that incorporates the rare-earth (RE) elements yttrium and neodymium to improve mechanical properties. Heat treatments alter the microstructure and also improve mechanical properties. RE precipitates present in WE43 after heat treatment are chemically complex and hard to identify. Characterization of the microstructure during thermal cycling is critical for understanding of the alloy. One technique to monitor microstructural changes in situ is the Laser Ultrasonic Sensor for In-Situ Metallurgical Studies (LUMet). LUMet uses laser-induced ultrasonic waves to monitor microstructural changes such as grain size, recrystallization, and precipitate formation. LUMet measurements were made on WE43 samples in the T6 condition. Samples were heated to 480 °C then cooled at cooling rates of 50, 0.06, and 10 °C/s. The overall volume fraction and size of precipitates were measured and correlated to LUMet results. This is the first known attempt to use LUMet to track microstructural changes in a magnesium alloy.

I wish to acknowledge the mentorship of Kyu Cho.

Stacked Power Module with Integrated Thermal Management

Jessica Wilson

Standard planar power electronics packaging is bulky and limits contemporary electronic devices from realizing their full capabilities due to challenges regarding thermal management and reliability. Moving away from an approach where the electrical, mechanical, and thermal domains are considered independently and toward a co-designed approach can solve these challenges by eliminating single-function components in favor of multifunctional components (MFCs). The novel packaging approach presented in this research stacks devices between machined copper structures that act as MFCs and improve power density 40 times.

Due to the departure from a standard planar packaging paradigm, existing practices and procedures cannot be relied upon during this module fabrication. As such, an unexplored fabrication sequence was developed and implemented during which multiple challenges arose, including gate leaking, lead detachment, and galvanic corrosion. This work presents the ongoing effort to resolve these issues through minimized device handling, reduced fabrication steps, and identification and removal of material incompatibilities. Device characteristics are monitored at each manufacturing step to identify and modify compromising conditions, developing a robust fabrication procedure. In addition, a novel lead configuration that reduces packaging steps and manufacturing costs was implemented. Utilizing a co-designed approach to packaging improves the size, weight, and performance of power electronics for Army applications.

I wish to acknowledge the mentorship of Lauren Boteler for her excellent mentorship and guidance throughout this experience.

3-D-Printed Interface Strengthening via Post-Print Annealing

Justin Wolff

The difficulty of obtaining mission-essential parts in a timely manner is a real issue for Soldiers. In the search for a solution to this problem, a process known as "manufacturing at the point of need" uses additive manufacturing as a technique to quickly produce parts for missions without the hassle of waiting for parts to arrive. One method to circumvent this obstacle is to anneal the sample after the print. By raising the component temperature just above the glass transition temperature, not only may discrete boundaries between rasters be erased, but residual stresses that accumulate during the print process may be eliminated. In this study, an annealing post-print-process method was established to enhance the mechanical performance in 3-D-printed materials. Short-beam shear fatigue tests with and without an annealing step will be performed. Furthermore, in an effort to expand the mechanical range of 3-D-printable components beyond common 3-D-printed thermoplastic polymers such as polylactic acid and acrylonitrile butadiene styrene, a new class of poly(urethane-urea) materials has been synthesized.

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

Classification of Direct Versus Reflected Acoustic Emission Waveforms Using Deep Learning Techniques

Travis York

In the case of using acoustic emissions testing for structural health monitoring, one common problem that occurs is the noise of reflection waves in the way of processing direct waves. This can cause localization problems and inappropriate data, and creates a classification problem while trying to make use of acoustic emission data. Neural networks have proven to be an efficient way to optimize classification problems. There are many types of neural network frameworks that implement different techniques. In other studies, machine learning techniques such as long short-term memory recurrent neural network (LSTM-RNN) were used to study a given data set and learn the distinction between the two types of waves. This was a successful method due to the memory-like functions of an LSTM-RNN. This research will show the results of more traditional machine learning techniques such as deep neural networks and support vector machines on the time-series data of acoustic emission data.

I wish to acknowledge the mentorship of Mulugeta Haile, Edward Zhu, and Natasha Bradley.

A Framework for Data Collection and Analysis in Unstructured Environments

Matt Young

Artificial intelligence (AI) in the automotive industry is characterized by the homogeneity of platforms in planned, controlled surroundings (e.g., self-driving cars on roads). The images required for this type of data set exclude poor lighting and unstructured environments—the hallmark of the Army's challenge in achieving autonomy using unmanned ground vehicles in novel territories. In order to train AI algorithms to achieve partial or full autonomy, exposure to a unique collection of features (e.g., humans, woods, buildings, water) provides a significant data pool with which machine learning (ML) algorithms can be trained. Proper labeling and identification of the environmental properties are crucial to successful and accurate learning models. Potential exists for training to be done using neural networks in order to take in massive amounts of data and further expand upon ML models. This work addresses the different stages of data collection for military-relevant situations, from robot platform design to labeling the ground truth of the collected data.

I wish to acknowledge the mentorship of Maggie Wigness, Cory Hayes, and Julia Donlon for their help with this research project.

Fitting of Neural Networks to Field-Programmable Neural Networks

Max Yu

The purpose of this research is to develop and implement a process to fit a neural network within the hardware constraints of a field-programmable neural array (FPNA). An FPNA consists of an array of neurons and synapses that perform calculations and move data, respectively. To program an FPNA with a given neural network, software must determine where to place the neurons, configure the synapses to pass data between the neurons, and schedule when that happens in a way that reflects the function of the original network. An object representation of the FPNA, and an extensible framework for implementing placement, routing, and scheduling algorithms, was implemented in Python. A basic set of algorithms was also implemented to form an initial solution.

I wish to acknowledge the mentorship of Drs Peter Gadfort and Oluseyi Ayorinde.

FY2019 Student Abstracts

Controls Development for Dynamic Interactions with the Environment

Blake Anderson

The goal of this internship was to develop an advanced autopilot that can provide new capabilities for unmanned aerial systems. To achieve this goal, a quadrotor called a tilt rotor, capable of thrust vectoring, was chosen. The vehicle has a servo attached to each motor, allowing the vehicle to place force along the horizontal plane without tilting the entire vehicle. The goal was to use this vehicle to demonstrate placing a sensor on a wall or pulling a heavy cable, both of which significantly change the center of gravity of the vehicle. Complicated control challenges can arise, such as having an unsteady center of mass and aerodynamic disturbances that occur from flying close to buildings or walls. We used a novel control algorithm—a modified version of Model Reference Adaptive Control—that allows for user-defined constraints on the trajectory tracking error and the adaptive control gains. The algorithm was successfully implemented on the tilt rotor, and several capabilities were demonstrated, including pitching the vehicle over 45° while maintaining position, autonomously mounting a camera to a vertical wall, and successfully pulling a cable even when the cable repeatedly got stuck.

I wish to acknowledge the mentorship of Harris Edge and Jim Dotterweich. I am very grateful for the wealth of knowledge and expertise that they have been willing to share. This summer has made me both a better student and researcher.

Self-Healing Yttria-Stabilized Zirconia (YSZ)-Alumina (Al_2O_3)-(Silicon Carbide [SiC], Niobium Pentoxide [Nb_2O_5], Tantalum Pentoxide [Ta_2O_5]) Thermal Barrier Coating in a Corrosive Calcia-Magnesia-Alumina-Silicates Environment

Bailey Ashmore

Closed and tortuous pores result in decreased thermal conductivities, which can increase the thermal barrier coating's (TBC's) ability to protect the superalloy turbine blades from the high operating temperatures of gas-turbine engines (GTEs). More effective, highly porous TBCs will allow future GTEs to increase their inlet temperature, resulting in greater efficiency. Porosity, however, is detrimental to the durability of TBCs as it provides paths for oxygen diffusion through the ceramic top coat, leading to the rapid growth of the thermally grown oxide[1] as well as increased infiltration of calcia-magnesia-alumina-silicates (CMASs),[2] both generating internal stresses that can result in catastrophic failure. The goal is to fabricate a TBC doped with an efficient self-healing additive to form a protective layer at pores and cracks to slow oxygen diffusion and CMAS infiltration. In this research, YSZ-Al_2O_3-(SiC, Nb_2O_5, Ta_2O_5) blends are exposed to short-term cyclic testing with a high thermal gradient to examine CMAS's effects on the healing product and the material's thermal conductivity.

I wish to acknowledge the mentorship of Dr Michael Walock and Dr Anindya Ghoshal at ARL for their support and guidance. This research was done under College Qualified Leaders, a program sponsored by the Army Educational Outreach Program.

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Density Functional Theory (DFT) Study of the Impact of Impurities in Silicon Carbide (SiC) Bulk and Grain Boundaries

Cassidy Atkinson

DFT was performed to determine the favorability of defects in SiC systems. Vacancy, substitutional, and interstitial defects were developed for bulk crystalline SiC and ∑9 {122} SiC tilt grain boundaries. Ten elemental dopants were tested in varying configurations to understand their influence on the SiC system. Impurities of carbon, silicon, and silver were examined before other dopants in order to compare experimental values to literature values and validate parameters used in calculations. All systems were relaxed, and the resulting energy difference was related to non-defected structures to determine the formation energy of the impurity. Lower values of formation energy determined stable, and therefore favorable, systems. Carbon vacancies in bulk were found to be more stable than silicon vacancies. Interstitial formation energies in bulk were found to be the highest of the recorded energies. This project was performed with the intention of predicting situations that are likely to be encountered during processing of SiC. This research will allow probable cases to be further examined and classified as being beneficial or hazardous to the mechanical properties of the material. Processing procedures can then be developed.

I wish to acknowledge the mentorship of Shawn Coleman and Matt Guziewski. I would like to thank the High-Performance Computing (HPC) Modernization Program HPC Internship Program (HIP-19-009) for funding this research and the College Qualified Leaders and Army Educational Outreach Program for this opportunity.

Enhancement of Input Deck with JavaScript Object Notation (JSON) Technology for Active Protection System (APS) Modeling and Simulation

Dheeraj Bandaru

The modeling and simulation of APS for combat vehicles, which have been developed in the Vehicle Protection Software Suite (VPSS) program at ARL, require selection and construction of a series of APS components and events. The tasks are currently accomplished by the adoption of an input deck based on a number of four-letter keywords along with their associated parameters in the VPSS. The present data structure exhibits readability issues due to keyword limitations and provides very restrictive data format in the specifications of parameter values. To improve the usability and readability of an input model, JSON technology is employed, which is a lightweight data-interchange format, easy for humans to read and write, and for machines to parse and generate. Since JSON is a language-independent text format, its implementation can be easily integrated into the VPSS C++ code. Specifically, the author developed a JSON schema that enables users to populate the attributes of each APS component and event from a list of all possible values, greatly streamlining the model construction process and mitigating potential human errors. In short, many user-friendly JSON features are leveraged, significantly enhancing the VPSS input deck.

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Metamaterial Lens

Ryan Banks

The design and implementation of a focusing lens using a negative-refractive index with metamaterials was investigated. The foundation for the theory of metamaterials and left-handed medium (LHM) is based on the work of Veselago.[1] In the 1960s, Veselago theorized the concept of simultaneous negative permittivity and permeability. LHMs are characterized by a negative index of refraction. The first paper to demonstrate LHM research from theoretical to experimental work was Smith and Kroll.[2] In that work, a medium with simultaneous negative permittivity and permeability was created with a periodic array of interspaced conducting nonmagnetic split ring resonators (SRRs) and continuous wires. In Pendry,[3] a lens with negative refraction was created to improve focus compared to dielectric lenses that are limited by wavelength. This method of focusing waves was examined for the application of replacing a dielectric lens in a focused lens beam system with a metamaterial lens. This work is an extension of Zaghloul and Lee,[4] where wave focusing in a waveguide was simulated. An electromagnetic simulation of the SRR and wire was conducted to observe the S-parameters. Using the S-parameters, the metamaterial structure's properties were extracted with the retrieval methods. Good agreement between published work in Smith et al.[5] and the electromagnetic simulation was demonstrated.

I wish to acknowledge the mentorship of Dr Amir Zaghoul, as his expertise has guided me throughout this internship experience. Also, I would like to thank Dr Quang Nguyen and Theodore Anthony for their technical advice and support.

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Learning and Identifying Coordination between Agents in a Game-Theoretic Multiagent Environment

Michael G Barron

Explicitly training agents to coordinate and cooperate within multiagent systems is an immense challenge in the fields of artificial intelligence, machine learning, and human–agent teaming. Solutions to this coordination problem have been found in gaming environments using exhaustive "brute force" computational techniques[1,2] that are impractical in the real world, where necessary resources like time and computational power may not be available. The work presented here evaluates observable measures obtained from agent behaviors in a multiagent game-theoretic environment. In conjunction with human behavioral data, this work is intended for eventual use in training learning agents to rapidly adjust their own behavior to coordinate with their partners. Specifically, a multiagent reinforcement learning algorithm was embedded in a simulation environment. Different combinations of humans and agents collaborated to complete a predator–prey pursuit task. We then analyzed various observable and emerging features extracted from the actions of agents to better understand how the agents learned to work together and coordinate group behaviors.

I wish to acknowledge the mentorship of Sebastian S Rodriguez, computer science PhD student from the University of Illinois at Urbana–Champaign, who contributed substantially to the work presented. Furthermore, this work was funded in part by a Basic Refresh Research project titled Agents Leveraging Learning for Intelligent Engagement with Soldiers.

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Development of Energetic Monomers for Additive Manufacturing

Alexander Bassett

Polymer bonded explosives (PBXs) are used in a variety of military applications including propellants. Typically, PBX formulations are cast-cured and consist of low glass transition temperature and low-energy polymer binders that can ultimately reduce the energy of the bulk material when cured. Additive manufacturing (AM), more commonly known as 3-D printing, has gained significant traction due to the ability to quickly create customizable, complex parts on demand. AM has become of high interest for the development of energetic materials due to the potential capability to control burn rates via geometric factors of the bulk material, a process that is otherwise unachievable through cast-cure methods.

In this study, energetic monomers were prepared to assess their viability in AM processes. Energetic diols were prepared for evaluation in additive reactive extrusion–based technologies. Additionally, energetic diacrylates were prepared for evaluation for additive reactive extrusion as well as photo-curable AM techniques. This study demonstrates the ability to prepare energetic monomers for AM.

I wish to acknowledge the mentorship of Dr Joseph Banning as well as the entire Energetic Synthesis and Formulation Branch for their advice and support.

An Optimal Control Approach to Flocking

Logan Beaver

The study of emergent behavior is a key challenge in the control of decentralized autonomous systems. The ubiquitous emergent behavior in the natural world is flocking, whether in herds of land animals, schools of fish, or flocks of birds. In his seminal 1987 paper, Reynolds[1] proposed three heuristic rules for simulating flocks: 1) move toward the center of the flock, 2) match the velocity of your neighbors, and 3) do not collide with anything. Thus far, the study of flocking has relied on virtual potential fields, where attractive–repulsive forces form agent aggregates without collisions. While computationally simple, the potential field approach can never be energy optimal. This work proposes a novel flocking algorithm based in optimal control, which takes flock density and aggregate velocity as input parameters. A differential form of the optimal trajectories are presented, with closed-form analytical solutions available for a special case of the problem.

I wish to acknowledge the mentorship of Chris Kroninger for his valuable support over the summer. I would also like to acknowledge Mike Dorothy for our stimulating discussions on optimal control.

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Domain Adaptation for Speech Recognition through Semi-Supervised Learning

Oliver Bentham

Semi-supervised learning is a type of machine learning that makes use of unlabeled data for training and has been shown to work in automatic speech recognition. A model is trained from labeled data and used to predict "pseudo-labels" for unlabeled data. This pseudo-labeled data is then reincorporated with the labeled data into the learning process to generate a stronger model. In this research, we used the open-source toolkit Kaldi to create lattice-free maximum mutual information (LF-MMI) chain models. We use semi-supervised learning to adapt the model's domain from clean broadcast speech (Wall Street Journal [WSJ] corpus) to noisy conversational speech (Switchboard phone corpus), where the WSJ corpus is labeled while the Switchboard corpus is not. The aim is to find the smallest quantity of labeled WSJ data to train from, whereby the model's reintegrated "pseudo-labels", which are generated for an unlabeled training set from the Switchboard corpus, will still improve the system's accuracy on a held-out test set from Switchboard. The research is still ongoing, but the accuracy of the system before semi-supervised learning evaluated on the Switchboard test set results in 60.85% word error rate.

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Visualization and Simulation of an Active Protection System (APS) Engagement Lifecycle

Russell Binaco

An APS pertains to a tank's defense system against anti-tank guided missiles and rocket-propelled grenades. The lifecycle of an engagement driven by APS is a situation where one or more hostile missiles are detected by the APS, responded to with a hard or soft countermeasure, and neutralized. In this research, a simulation was constructed in Unreal Engine (UE4) to simulate and visualize this engagement lifecycle. Previous simulations of similar engagements were limited to a single tank and a single incoming missile. The current solution uses UE4's particle system and physics engine to render a high-quality navigable simulation of multiple engagement types for incoming missiles. Virtual reality was integrated into the simulation to provide an immersive experience for the user. Also, while the simulation is driven by UE4's physics engine, it can also interact with external processes and be driven by data streaming or static data files instead. The purpose of the simulation is to monitor the post-engagement environment and analyze how the different modes of engagement affect collateral damage caused by missile fragmentation. Ultimately, UE4 was used to apply advanced visualization techniques that better inform analysts and enable more effective gathering of information from such simulations.

I wish to acknowledge the mentorship of Simon Su and Michael Chen, as well as the support and advice of Vincent Perry. Also, I appreciate the High-Performance Computing (HPC) Internship Program and HPC Modernization Program for their sponsorship and the ARL DOD Supercomputing Resource Center for providing resources.

Self-Reformation Using Micro-Ionic Propulsion Engines

Jonathan Bolanos

This paper describes the development of exploiting mathematical techniques to generate an analytical overview of the amount of accumulated thrust produced by an array of microscopic ionic engines. By integrating the microfabricated skin-like material to a specific configuration, the characterized velocity profiles created by the micro-ionic engines can describe the type of velocities needed to produce enough thrust to lift the specific configuration. Furthermore, understanding the types of velocities that are being trajected parallel to its surface, we can fully investigate the velocities at diverging altitudes. When comparing the micro-ionic reformation technology to biological ecosystems, such as a colony of army ants, we note that these species have the ability to form collective self-assemblages to produce functional "bridges". Thus, statistical mechanics can only permit stationary reconfigurations of different structures as opposed to the integrated micro-ionic technology, which can possess ionic thrust to lift an object to have 3-D localized mobility.

I wish to acknowledge the mentorship of Dr Bryan Glaz, for his guidance, encouragement, mentorship, and pioneering inspiration. I am also grateful for ARL at Aberdeen Proving Ground. None of this research would have been possible without the efforts of the Vehicle Technology Directorate. All who have supported and guided me to reach higher potential are deeply appreciated.

The Training Gap: How Complex Questions Can Alter Interpretations and Affect Mission Readiness

Meaghan Bowman

Soldiers are taught the importance of effective communication with repetition of the phrase "communication is key". They receive training in preparing for, and carrying out, interactions between foreign and domestic leaders to gain crucial information about a mission. These interactions are known as Key Leader Engagements (KLEs). For the training of KLEs, doctrine mandates the skills needed to conduct these "engagements", such as how to behave appropriately, identify key leaders, and employ effective strategies. Army officers in training learn how to confront leaders, what information to gain, and how to respectfully ask questions. Unfortunately, Soldiers rarely learn how to optimally formulate questions. Since less-complex questions are easier to understand, we hypothesize that semantic complexity affects content understanding, and that age and education levels may have an effect on one's ability to form paraphrases and judge their quality. In this study, we looked at paraphrases of queries as well as judgments of both the paraphrases' naturalness and their semantic similarity to the query. Queries were divided into three complexity categories based on the number of relations (the first number) and the number of knowledge graph edges (the second number). Two crowd-sourced tasks were completed by Turkers in order to answer the questions 1) Are more complex queries harder to paraphrase and judge? and 2) Do age and education level affect the ability to understand complex queries? We ran statistical tests as follows: multivariate analysis of variance (MANOVA) for query understanding and two-way ANOVA to understand the relationship between query complexity and education and age. A probe of the number of given-level queries selected for paraphrasing by crowd-source workers in seven age ranges yielded promising results. We found significant evidence that age plays a role and marginally significant evidence that education level plays a role. These preliminary tests, with output p-values of 0.0002 and 0.068, respectively, suggest the importance of content understanding in a communication skill set. This basic ability to communicate, which may differ by age and education, permits reproduction and quality assessment and is crucial in training Soldiers for effective participation in KLEs.

I wish to acknowledge the mentorship of Dr Michelle Vanni as well as the entire Multilingual Computing and Analytics Branch for the constant support, feedback, and mentoring that I have received while completing this project. Special thanks to Dr Sue Kase at Aberdeen Proving Ground for her willingness to have teleconferences and for the multitude of time spent editing.

Optimization of Nickel Titanium Alloy (NiTi) Thermal Properties as a Phase-Change Material (PCM) for Heat Exchangers

Jack Brody

Directed energy (DE) laser applications experience heat transfer issues during continuous use. These issues can be mitigated using the latent heat storage involved in PCMs. One recently discovered subset of PCMs includes a NiTi due to its ability to release and absorb large quantities of latent heat during its martensite to austenite and vice versa transformation. The purpose of this research project is to achieve peak efficiency of a heat exchanger for directed energy use through the better understanding and optimization of thermal and material properties of NiTi. Under certain conditions, NiTi can form precipitates of Ti_3Ni_4, Ti_2Ni_3, and $TiNi_3$, which may negatively impact the properties, so the optimal solution anneals and heat treatments must be determined for tuning. To achieve this, samples of a 50.28% Ni alloy were solution-annealed at 850 °C for 12 different times and quenched. Using differential scanning calorimetry, the optimal solution anneal was determined to be 10 min due to its highest latent heat of 27.1 J/g. Heat treatments were done at five temperatures between 300 and 700 °C at 0.5, 1.25, 3.5, 10, and 23 h using the solution-annealed samples. It was determined that 500 °C for 3.5–23 h produced the highest latent heats of 26.5278–26.9812 L/g and greatest shifts in austinite start, peak, and final transformation temperatures. To round out the material characterization, thermal conductivity measurements are underway using frequency-domain thermo-reflectance. This work represents critical advances in qualifying NiTi base materials for thermal energy storage applications.

I wish to acknowledge the mentorship of Darin Sharar.

Designing a Simulated Cyber Scenario with Integration of Cyber Attacks

Aniya Brown

Cyber attacks are the use of malicious code to exploit computer systems/networks resulting in organizations losing valuable data. In the last decade, cyber attacks have occurred frequently in increased volume and variety due to vulnerabilities within organizations' networks. Such attacks have resulted in organizations spending billions of dollars and resources to recover. Given the importance of skilled cyber professionals for successful threat detection and response, it is crucial to evaluate what factors make cyber-defenders successful in protecting critical resources from cyber attacks. The purpose of my project was to develop the capabilities for reproducible and repeatable cyber attacks within a unique human-in-the-loop simulated environment that will be used to analyze the components that make cyber-defenders successful at conducting an analysis. Moreover, this experimentation could help enhance the performance of specialists and help develop an understanding of features that suggest a cyber attack was conducted on a network.

I wish to acknowledge the mentorship of Norbou Buchler, Blaine Hoffman, Jason Ellis, and Claire La Fleur for helping me develop my idea into a feasible research project. In addition, I would like to thank them for helping me develop a methodology and providing the resources to conduct this research for the Human Research and Engineering Directorate.

Synthesis of Iridium Complexes Using Cyclometallated Ligands

Alexis Burnette

This project involved the synthesis of cyclometallating ligands that were used to create iridium dimers, which were subsequently combined with acetylacetone. The syntheses were performed using an Anton Paar microwave reactor, which greatly shortened reaction time and allowed for more complexes to be synthesized. Each ligand differed by its substituent position on the phenylbenzothiazole ring. After the complex was synthesized, purification was required to remove the remaining starting material. Column chromatography was often used to remove impurities from the product. Once purification was complete, the complex could then be confirmed by thin layer chromatography and nuclear magnetic resonance spectroscopy. Other characterization methods were used as well, such as X-ray crystallographic analysis, ultraviolet-visible spectroscopy, and photoluminescence spectroscopy.

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Pulsed Light Sintering of 3-D-Printed Electronic Materials

Jorge A Cardenas

Additively printing electronically functional 3-D components and tools on demand can enable a more effective avenue toward providing the Army Warfighter with supplies onsite. However, 3-D-printed conductive materials typically require time-consuming postprocessing baking steps at temperatures above 200 °C and/or result in conductivities far lower than their bulk counterparts[1]. These constraints can add significant time to fabrication and limit the performance and potential uses for 3-D-printed devices. In contrast, pulsed light sintering is a method that can mitigate the time and material constraints associated with baking through the use of rapid, short-pulse exposure to high-intensity white light[2]. In this work, we investigated and optimized the pulse light sintering of direct-write (DW) 3-D-printed conductive materials. A Novacentrix PulseForge 1200 was used to photonically sinter syringe-dispensed conductive pastes and fused filament fabrication (FFF) conductive filament. For DW pastes, it was found that exposure parameters consisting of a high number of low-energy pulses yield the most robust (in flexibility and adhesion) and conductive films, with 2.5 times improvements in conductivity compared to thermally dried samples. For FFF filaments, it was discovered for the first time that filament conductivity can be improved by up to 10 times using high-energy pulse exposures.

I wish to acknowledge the mentorship of Harvey Tsang and Nathan Lazarus.

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Recreation of Field Cases for Additional Assessment of Backface Deformation

Madeleine Chen

Behind-armor blunt trauma (BABT) occurs when a projectile impact causes armor deformation, which then causes a localized, nonpenetrating injury. Given ballistic conditions taken from police records, recreating BABT cases with known injuries allows us to evaluate injury thresholds corresponding to the National Institute of Justice 44-mm standard. However, real-world cases lack sufficient information and require additional assessment to identify unknown conditions for an accurate recreation. Here we reconsider nine previously tested cases with unknown threat weight, threat manufacturer, and shot obliquity. To match threat weight, we recreate each case with the highest and lowest possible grain for the exact threat type used in the field. Testing consists of shooting each body armor on a preconditioned clay block and collecting deformation depth and volume as detailed in previous studies. Comparison between deformations obtained through the tests of possible impact conditions provides bounds for analysis of the correlation of clay response and injury potential, as well as insight into future testing if a particular parameter, such as threat weight, is unknown. Identification of the clay response with various ballistic conditions associated with injury can aid in the understanding of the sensitivity of clay as a tool to assess the injury risk behind armor.

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Effects of Variable Powder Blasting Techniques on Bond Strength in Cold Spray Aluminum 7050

Anthony Chin

A critical aspect in successful cold spray depositions is their ability to support and distribute load. Optimizing this will not only reduce maintenance costs, but will also allow for future applications in structural repair. In hopes of understanding and improving the mechanical characteristics of cold spray, a study was conducted on powder blasting and its effect on shear adhesion strength in aluminum (Al) (selected due to its strength and prevalence in the aerospace industry). A powder blast is a surface pretreatment in which powder is sprayed at a low temperature and pressure to roughen the surface. Using a VRC Gen 3 max system, 7050 Al powder was blasted onto 7050-T7451 Al substrates at variable temperatures and pressures ranging from 50 to 300 °C and 220–580 psi, respectively. Afterwards, substrates were cold-sprayed, machined, imaged, and tested. Lug shear testing saw a positive correlation between pressure and shear strength, with a plateau around 25 ksi. Increasing temperature also saw an increase in shear strength until 300 °C where shear strength dropped significantly, suggesting a local maximum. Micrographs of substrate interfaces found no correlation between interface mixing and shear strength. Future research should examine high-temperature powder-blasting scenarios as well as mixing.

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Continuous Integration and Delivery for Visualization and Processing for Embedded Research Systems (ViPERS)

Kathleen Coen

This project is the application of a continuous integration/continuous deployment (CI/CD) pipeline with an expansion of automated testing and utilization of Docker images for updating ARL software. ViPERS allows the user to configure, process, and visualize live data from an Internet of Things (IoT) device such as a Raspberry Pi or Snickerdoodle. ARL has further customized this code for their mobile power meter and mobile unattended ground sensor power-sensing IoT devices. The software and data analysis tools of this project are continuously in flux. Reintegration of branches can introduce bugs, create bottlenecks, or even bring development to a complete halt. The CI/CD pipeline helps to alleviate these issues by implementing a workflow that helps ensure changes correctly integrate. This identifies bugs, reduces merge conflicts, and improves confidence that the software is working as intended. When a developer adds new work to a branch, the server will automatically build and test the code. This project featured the expansion of multiple forms of test scripts. Tests were added to ensure that web pages on ViPERS rendered correctly and provided expected feedback when configuration files were changed or services were restarted. Additionally, hardware tests were introduced by creating raw signals via a simulator and testing the values being read in. Once software passes these tests, CI paves the way for continuous delivery. CD is the practice of developing software in such a way that one could release it at any time. It lets the user develop features with modular code in more manageable increments. Since pushes are being made so often, I made the code into a Docker image to reduce the size of the file due to units placed in areas with intermittent and low-bandwidth communications. By using Docker containers and a CI/CD pipeline, and expanding the automated test suite, the ViPERS code can be updated faster and more reliably to ensure longevity and ease of use.

I wish to acknowledge the mentorship of Kevin Claytor.

Robotic Mobility with Husky9 and ROS

Pascal Conroy

The purpose of robotics on the battlefield is to assist the Warfighter by performing various tasks for them. Many of these tasks involve movement in crowded urban environments. One of the issues with moving in such an environment is floor debris and general obstacles. In order for the robot to be able to perform its task effectively, it must be able to avoid obstacles using an algorithm to take an input from a scanning sensor, detect a point within a predetermined distance from the robot, and avoid it, whether by turning before touching, or climbing over it.

I wish to acknowledge the mentorship of Mr Marshal Childers, Dr Robert St Amant, Mr Matt Kaplan, and Mr Trevor Rocks.

Characterizing Electroencephalography (EEG) Artifacts During Physical Activity

Megan Cowie

EEG measures brain activity through electric potentials at the scalp. It is one of the few brain imaging modalities that can allow insight into brain function outside of traditional laboratory scenarios. For example, EEG can be used to understand how the brain functions during physical activity, but it can be corrupted by artifacts caused by the movement. The purpose of this study was to determine if the signal power of EEG is correlated to ground reaction forces at heel strike during walking. Subjects walked on a treadmill instrumented with force plates at three speeds (1.5, 2.0, and 2.5 mph). We recorded ground reaction forces and used standard approaches to determine heel strike events and peak forces. We also used a 32-channel BioSemi ActiveTwo system to record EEG during walking. We computed the correlation between EEG signal power and peak force across every heel strike and gait speed. We found a small but significant positive relationship between ground reaction force and EEG signal power at channel locations across the scalp. Understanding the sources of artifact in EEG during movement will help inform the development of techniques to mitigate artifact and improve the interpretability of brain signals during these scenarios.

I wish to acknowledge the mentorship of Dr J Cortney Bradford, as well as Michael Nonte for his participation in data collection and assistance in BioSemi ActiveTwo data collection.

Microstructural Design through Application of Magnetic Field during Electrodeposition

Cassidy Culver

Magnetic fields affect electrochemical reactions (mass transport, electrode kinetics) and film thickness/morphology during electrodeposition of metal and composite coatings. Connecting other microstructural changes such as phase formation, phase evolution, and texture to magnetic processing parameters could lead to developing field-assisted processing methods to create coatings with improved corrosion and wear. The change in thickness/morphology suggests possibilities for more-efficient plating and the increase in twin fraction presents more opportunities for grain-boundary engineering. One of the challenges presented is identifying the required field strength to effect changes in material texture (in this case, cobalt deposition) and the robustness of materials through second-phase incorporation (in this case, nickel–diamond composites) that are responsive to field effects. Earlier work at ARL used large permanent magnets to effect changes, while here we use smaller permanent magnets to determine the lowest field strength to observe microstructural effects. This will help in developing and extending to application-size systems some sort of microstructure-magnetic processing tool kit necessary for relevant material systems for Army requirements.

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Realistic LTE Radio-Frequency Interference (RFI) Emulation for Cognitive Radar Testing and Demonstration

Jordan A DeVault

The RF Signal Processing and Modeling Branch is developing a cognitive radar system for advanced spectrum access in highly congested electromagnetic environments (EMEs). Evaluation of the radar requires realistic congested EMEs. The objective of this project is to emulate realistic RFI for training, testing, and demonstration purposes. The advantage of emulating RFI over replaying a recorded spectrum is the ability to control the congestion and complexity to better assess the capabilities of the radar. Based on statistical analyses of measured data (obtained from MITRE), specific extractions from the same data, and a user-specified complexity/congestion level, realistic RFI can be generated on an National Instruments vector signal transceiver. This allows controllable “easy”, “medium”, and “hard” RFI to be generated for use in testing as well as the January demonstration. The Federal Communications Commission has suggested spectrum sharing between radars and LTE communications in the 3.1- to 3.5-GHz band, the same band that the radar in development operates in. Therefore, LTE RFI is of particular interest.

I wish to acknowledge the mentorship of Jake Kovarskiy, Austin Egbert, and Jason Zsak. For their constant advisement and support I would like to extend a special acknowledgement to Dr Tony Martone (ARL mentor), Kelly Sherbondy (ARL manager), and Dr Ram Narayanan (advising professor).

Two-Phase Composite Heteroepitaxial Thin-Film Growth

Michael DeVito

Motivation for this research includes the strain engineering and 3-D epitaxial arrangement of different perovskite-spinel, two-phase, composite thin films. Strontium titanate (STO) and magnesium oxide (MgO) have been selected to serve as substrates for biaxial strain-engineering of the perovskite/spinel thin film. Perovskite and spinel complexes, barium titanate (BTO), and magnesium aluminate (MAO), respectively, have been selected due to potential lattice-matching capabilities and similar coefficients of thermal expansion. MAO thin films have been grown from a stoichiometric target on MgO and STO substrates. X-ray reflectometry and profilometry characterization methods were used to determine film thickness and growth rates. X-ray diffraction was used to determine crystal phase, lattice orientation, and d-spacing of MAO films. X-ray photoelectron spectroscopy (XPS) was conducted to determine the chemical compositions of the surface of MAO films. XPS experiments yielded stoichiometric MAO, but with surprisingly high amounts of molybdenum contamination, which may have affected MAO growth rates. However, co-sputtering BTO with MAO has proven to be an inefficient method to form two-phase composite films due to incompatible growth rates. Therefore, examination of alternative solutions has been considered to fabricate the desired configuration. Future areas of interest, specifically the reactive co-sputtering of aluminum and MgO, have been sought after to form MAO on the surface of STO substrates.

I wish to acknowledge the mentorship of Daniel Shreiber.

Utilizing Rolling to Enable Dynamic Transitions

Matthew Dick

Traditional mobility efforts have been limited by the need for highly tuned, specialized appendages to dissipate impact energy after a fall and slow transitions between falling, leaping, and running. By using body morphology to their advantage, robots can be much more dynamic and robust, save energy, and survive a higher fall or leap. Dynamic whole-body self-manipulation via rolling can effectively leverage body morphology to lend increased robustness and capability to biology-inspired systems. Current synthetic systems severely underutilize their own morphological dynamics and environmental affordances that may be available to enhance motion. While steady-state motions and gaits are increasingly well understood, transitions between locomotion states like leaping, falling, and running, and even between static poses, remain a current subject of investigation within the robotics and scientific community. We seek to move beyond flat-ground gaits and transitions between them. Real-world environments provide a rich set of opportunities to utilize dynamic transitions. Using rolling to interact with the environment provides useful opportunities for energy redirection, transfer, storage, recovery, and/or dissipation. Ultimately, such utilization could enhance the mobility of robotic systems through improved transition speeds, reduced energy expenditure, and greatly expanded workspaces.

I wish to acknowledge the mentorship of Dr John Gerdes.

Indium Gallium Phosphate (InGaP)-Based Hybrid Photovoltaic (PV)-Betavoltaic (BV) Device Characterization

Mohamed Doumbia

We have measured the electron beam (eBm)-induced currents in InGaP diodes. These devices represent a hybrid combination of PV and BV processes. A parametric study of applied voltage (e^- energy) was performed from 1 to 16 keV. The applied eBm current (simulating isotope activity) was varied from 0 to 1.1 Ci. The energy conversion efficiency was calculated for the monoenergetic incident electron beams. The measured energy conversion efficiency (P_{elec}/P_{nuc}) was calculated.

I wish to acknowledge the mentorship of James Carroll.

Imaging Objects with Very-Low-Frequency (VLF) Electromagnetic Fields and Neural Networks

Zachary Drummond

This research investigates the application of deep neural networks (DNNs) to imaging with VLF electric and magnetic fields. VLF electromagnetic fields are not typically used in imaging applications because, unlike other sources such as X-rays, lower-frequency electromagnetic fields exhibit highly nonlinear behavior around objects, making them unsuitable for traditional imaging methods such as backpropagation. However, VLF electromagnetic fields have a large skin depth, allowing them to penetrate thick containers such as shipping containers. This property provides the opportunity for imaging objects where methods relying on other sources such as X-rays might fail. Using a custom-designed electric-field boundary element method solver developed at ARL,[1,2] a large data set of random objects and their associated electric-field distortions was generated to train and test a DNN.[3] The DNN was trained to use one plane of electric-field measurements to predict what object would have caused the observed distortions. This process was completed using separate data sets with either thin or thick simulated objects. For both data sets, the reconstructed objects produced by the DNN matched ground truth with prediction errors for the thin object case of approximately 6% root-mean-square error (RMSE) and the thick object case of approximately 19% RMSE (compared to 100% RMSE for random guessing in both cases). These results are promising and indicate that artificial intelligence and machine learning are good options for this task while making predictions nearly instantaneous once training is completed. Moving forward, DNN prediction error will be performed on real data collected with a sensor array currently being designed by the ARL E/H-Field Sensing Team in their large electric- and magnetic-field cages.

I wish to acknowledge the mentorship of Dr David Allee for his continued support and ideas while away from Arizona State University. I would like to acknowledge the mentorship of Dr Kevin Claytor for his help, ideas, and sound boarding during this project. I want to thank Dave Hull and the rest of the E/H-Field Team for their help and direction during this work. Finally, I would also like to thank Mike Fiddy and the Defense Advanced Research Projects Center's Imaging Through Almost Anything Anywhere program for their support of the E/H-Field Sensing Team.

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Building E-3510 Laboratory Demolition/Renovation

Mark Eldridge, Jr.

The US Army Combat Capabilities Development Command Chemical Biological Center was established in 1917, and over the years, many advancements have been made and safety protocols have improved. To ensure that we stay up to date, moderation is key for the safety of scientist engineers and others while conducting business on base. Building 3510 is a lab created for chemical, radiological, and biological threat research and one of the buildings that requires updates. When the building was designed, the hoods were installed with a vacuum fan, which was a one-motor system. This was the safety protocol during early 1900s, but today the updated guidelines require an improved vacuum fan system as well as the hoods. To begin this project, the designs of the building are required so that they can be updated to accommodate the remodeling. Also, they are used to ensure that contractors are following the guidelines and building the hoods up to industry standards. Negotiating is useful when working with contractors. This allows everyone to be on the same page and establishes the workflow for the project.

I wish to acknowledge the mentorship of Troy Neville and Fred Hirtzel.

Are Women Having the Same Experiences as Men in Cyber Competitions?

Pebbles Eppes

Cyber defense is fundamentally dependent on skilled human agents, with a number of documented cases espousing the way that humans have contributed to the reliability and resilience of complex, safety-critical systems. However, there is a shortage of professionals who can sufficiently detect and respond to cyber incidents. In particular, women are notably underrepresented in the field, in part because of 1) cultural conditioning that men are more suited to technology-focused professions, 2) imposter syndrome, 3) initial technological illiteracy, and 4) a desire to work with other people as opposed to things. Collegiate cyber competitions could help ameliorate both the overall shortage and the gender difference by providing hands-on experience for the incoming cybersecurity workforce to hone critical "hard" (technology focused; that is, forensics, IDs) and "soft" (nontechnical or interpersonal; that is, team lead, policy documentation) cybersecurity skills. However, it is not clear whether men and women have similar experiences in gaining these skills.

I wish to acknowledge the mentorship of Norbou Buchler, Claire La Fleur, Blaine Hoffman, and Jason Ellis. I would not have been able to complete this project without your assistance.

Can You Understand Us Now? Technical Science Writing Made Clear

Jordan Dreher and Maduforo Eze

The purpose of this project was to extend online visibility and presence of ARL's scientific and technical accomplishments by developing easily accessible articles.[1] The strategy was to publish articles through Wikipedia, a free, multilingual online encyclopedia known as the largest and most popular general reference work on the World Wide Web.[2–3] Wikipedia is also known to be one of the most popular websites overall, as there are 35,146 million users, 1,500 new articles added daily, and 280 different language options.[4,5] The secondary goal of the assignment was to evaluate technical content of our articles against mission objectives that are nested with the US Army Futures Command. Over the course of this project, we researched nonpromotional sources, conducted interviews with researchers, translated technical terminology, assembled supporting material, edited and revised drafts, processed articles through the Form One system, and finally published the articles online.

We wish to acknowledge the mentorship of Dr Alexander Kott, and our mentors Tracie Dean and Joyce Martin from Public Affairs.

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Using Augmented Reality (AR) in Mission Planning and Rehearsal

Isadora Fink

AR systems are becoming increasingly prevalent in society, especially in gaming. AR can be used within the US Army to revolutionize training and combat operations,[1] including mission planning, allowing for greater accessibility for geographically dispersed teams to collaborate. Currently, the effectiveness of AR as an operational tool for US Army Soldiers is not thoroughly understood. This study compared the use of a smart tabletop (tablet) and Microsoft HoloLens during a dyadic simulated mission planning scenario. Participants completed self-report questionnaires on team performance, task workload, and shared situational awareness in association with various performance metrics. Results show that self-reported team performance for the tabletop condition predicted mission performance $F(2, 5) = 6.166$, $p < 0.05$, adjusted $R^2 = 0.712$. People experienced significantly lower levels of frustration ($T(11) = 2.426$, $P < 0.05$) and higher mental demand ($T(11) = –2.355$, $P < 0.05$) with AR compared to the tabletop. Given the pervasive use of tablets in our daily lives (e.g., smart phones) and therefore the ability to intuitively interact with them with little training, future studies should consider increasing the training time with AR systems to increase participants' familiarity with these technologies.

I wish to acknowledge the mentorship of Heather Roy.

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Pyocyanin Degradation

Kory Fleming

This poster presents experimental results regarding pyocyanin degradation. Pyocyanin is produced by a bacteria called *Psuedomonas aeruginosa* and is a critical first step in biofilm production. Biofilm is a problem for the US Army because it causes corrosion. The objective for this experiment was to screen environmentally isolated bacteria for their ability to break down pyocyanin. Pyocyanin has an original color of blue; when degraded, the color will change from blue to red. The data indicated that the isolated bacteria, which had readings over 0, were able to degrade pyocyanin with the higher numbers indicating more degradation.

I wish to acknowledge the mentorship of Dr Bryn Adams, Dr Randi Pullen, and Monica Chu.

Machine Learning Strategies for Power Modeling of Small Unmanned Aircraft Systems

Spencer Folk

Small unmanned aircraft systems (sUASs) are rapidly becoming an integral companion to the modern Warfighter, serving needs of reconnaissance, situational awareness, and payload delivery. However, current systems lack higher-level awareness of power consumption and, as such, vehicle performance (i.e., effective range and endurance) is heavily dependent on the pilot's abilities. This research aims to relieve pilot responsibility by instilling in the sUAS knowledge of its power consumption over a range of airspeeds. A neural network was applied to flight data to develop a generalized power model of a multirotor sUAS. The power model was used in conjunction with physical constraints to estimate optimal stable flight behavior for minimal power consumption. The results of this study confirm that even a rudimentary neural network is capable of estimating power usage with an average accuracy above 85%, and can automatically identify behavior resulting in minimum power use. A tool kit was also developed that uses the model to both predict mission feasibility and optimize speed and climb rate for a mission to reduce power consumption. Future work will consider midflight retraining of the network with incoming flight data to adapt the model for changes in payload, flight conditions, and even aircraft health.

I wish to acknowledge the mentorship of Dr John Gerdes.

Defect Characterization in Silicon Carbide (SiC) by Cathodoluminescence

Harun Gopal Ganesan

Defects propagate from the substrate into epilayers of SiC during the growth process, specifically threading edge dislocations (TEDs) and screw dislocations (SDs). Identifying the locations of such defects traditionally involved a destructive etch process. Albrecht et al.[1] reported a method by which to nondestructively locate defects in gallium nitride by the lower intensity of the bandedge cathodoluminescence (CL). This study uses this approach to characterize defects in SiC. Maximenko et al.[2] reported CL of stacking faults (SFs) in SiC epilayers. Panchromatic CL images are taken of epilayers and compared to optical images before and after potassium hydroxide etching to determine the correlation between the CL images and defect locations. Spectral scans show peaks in the CL correspond to SFs in the material; however, the bandedge CL is typically near or at background. Of note is that SFs that can and cannot be discerned by an optical microscope are observable by the CL. Initial investigation has not found a correlation between SD and TEDs and the panchromatic CL. Future work will find samples with higher bandedge CL and determine if the 4° offcut of the SiC may result in the CL washing out the lower-intensity CL associated with dislocations.

I wish to acknowledge the mentorship of Dr Brenda VanMil.

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Visualization and Analysis of Postengagement Threats for Optimization of an Active Protection System (APS)

Wendy Gao

An APS consists of the software and hardware installed in a combat tank to defend Army personnel from ballistic missiles. On a battlefield, an APS detects, tracks, and neutralizes an incoming threat in an active fashion. During an APS event, an engagement between a deployed interceptor and a hostile missile may result in explosive shrapnel scattering in the surrounding area. In this research, Unreal Engine was used to demonstrate the end-game scenario of a hard-kill countermeasure against a missile in a navigable high-quality environment. The visualization is also viewable in virtual reality to immerse the observer within the scene. The trajectory of the postengagement threat residuals was simulated using Unreal Engine's physics engine to analyze potential risks from the missile debris with varying variables such as distance, height, and projectile approach angle. The variations present an optimization problem to maximize survivability of friendly forces and minimize collateral damage on the battlefield. Given static data files, Unreal Engine has the ability to produce a visualization to simulate the conditions of an externally defined engagement. Three-dimensional and immersive visualization techniques performed herein seek to improve analysts' abilities to extract information from simulations and other data sources.

I wish to acknowledge the mentorship of Drs Simon Su and Michael Chen, as well as the support and guidance of Vincent Perry. I would also like to thank the DOD High Performance Computing (HPC) Modernization Program and HPC internship program for their funding, and the ARL DOD Supercomputing Resource Center for providing resources.

Synthesis of Nitroguanidine-Based Novel Energetic Molecules

Melissa Garner

Currently, several common military explosive formulations include 2,4,6-trinitrotoluene (TNT) or cyclotrimethylenetrinitramine. While these molecules perform adequately, they suffer from two major pitfalls: availability and toxicity. Both of these molecules are very well known, thus making it readily available for adversaries of the United States to access, which does not benefit our land forces, and TNT poses health risks due to its toxicity. In order to begin to remedy these issues, the molecules MMD and NID have been synthesized and explored as potential alternatives to traditional explosives. While both of these molecules are predicted to outperform TNT, they are plagued by thermal instability, which eliminates them as potential alternatives. Despite this, the synthesis of these molecules has paved the way for promising research to be done on similar systems.[1–7]

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Advance Composite Interphase Study

Sarvenaz Ghaffari

There has been a strong demand in using high-modulus (HM) carbon-fiber composites, potentially enabling lightweight aircraft structures with significant weight savings. However, extremely low fiber-direction compressive strength has been a well-recognized weakness of HM carbon-fiber composites, prohibiting their implementation in aircraft platforms. Fiber-direction compressive strength of HM and intermediate-modulus (IM) carbon-fiber-reinforced polymer's (CFRP's) targeting structural applications is presumably governed by microstructural stability. However, strong decrease in fiber-direction compressive strength of HM carbon-fiber composites, compared to their IM counterparts, contradicts predictions from available microstructural buckling theories. This work looks into weak fiber–matrix interface as a major mechanism driving the fiber-direction compressive strength decrease of the HM CFRPs. In-situ scanning electron microscopy–based experiments pushing out carbon fibers show an approximately 40% decrease in the average values of the fiber–matrix interface shear strength for a selected HM composite compared to a legacy IM composite with the same toughened epoxy matrix. Such a strong reduction correlates with decreasing fiber-direction compression strength predicted by a microstructural buckling model, which properly accounts for the fiber–matrix interface shear strength behavior. The results support the idea of integrating off-the-shelf IM carbon fibers with stronger fiber-matrix interface and higher shear modulus into a HM carbon-fiber composite to improve fiber-direction compressive strength of the HM composite material system.

I wish to acknowledge the mentorship of Drs Dan Cole and Frank Gardea for their valuable guidance, assistance, encouragement, and immense knowledge throughout this project. It has been a great pleasure working with them. I would like to thank my supervisor, Dr Makeev, whose expertise was invaluable in the formulation of the research topic and methodology in particular. I also wish to thank Dr Haynes for considering me for this internship opportunity and his valuable time and advice in the review of this project.

Face Tracking in Visible and Infrared Videos

Robert Goldman

Face detection and tracking research has focused primarily on the visible spectrum, with relatively few studies conducted in the infrared spectrum. This work focused on face detection and tracking in the thermal infrared spectrum and compared them with performance in the visible spectrum. We leveraged a standard pretrained Viola–Jones detector to detect faces in the first frame of each video, and then used a Kanade–Lucas–Tomasi algorithm to track the face in each subsequent frame of the video. The algorithms were run on previously collected single-face video sequences as well as videos with multiple faces collected for the purposes of this study. Results show significantly higher performance in the visible band than in the infrared band, primarily because the Viola–Jones face detector was pretrained on visible spectrum face imagery. In addition, we conducted an initial assessment of partially obscured/occluded faces (e.g., glasses). Initial qualitative analysis on several video sequences shows no noticeable performance differences between non-occluded and partially occluded faces.[1,2]

I would like to acknowledge the mentorship of Matthew Thielke.

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Study of Structure–Property Relationship in Diamond 111 Surface

Hector Gomez

Diamond possesses high thermal conductivity, large energy bandgap, and high carrier mobility, and, hence, is proposed as a potential next-generation semiconductor electronics material for high-power, ultra-fast electronics.[1] A fundamental understanding of surface reconstruction mechanisms and resultant surface-dependent electronic properties is crucial for the realization of diamond surfaces in the surface field-effect transistor (FET) and quantum computing applications.[2,3] Motivated by this, we have performed a systematic theoretical/computational study of structural transformation of the diamond (111) surface from a cleaved, bulk-like surface to fully reconstructed Pandey-chain structure. Using GPAW,[4] a density functional theory, structural and electronic properties were calculated for the structural pathway between bulk-like 2x1 diamond (111) and 2x1 reconstructed polycrystalline (PC) diamond (111) to determine possible intermediates and transition states. PC reconstruction yielded a difference from the bulk-like 2x1 structure in per-atom total energy of –0.1085 eV/atom. The favorability of the PC reconstruction suggests that 2x1 diamond (111) will follow this configuration instead of the bulk-like terminated surface. Our observation is consistent with the temperature-dependent phase transition observed in experiments. Consequently, the observed structural phase transition from bulk-like to reconstructed PC surface results in an electronic phase transition from an unstable metallic to a stable, semi-metallic phase.

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Investigating the Effect of Methylcellulosic Binder Systems on the Rheology of Carbide Suspensions for Direct Ink Writing

Brennan Gray

Current research has shown that heterogeneous carbide ceramic armor exhibits improved ballistic performance to monolithic ceramics. However, there is a need to develop processing methods for mesoscale tailoring of heterogeneous armor. Direct ink writing is an additive manufacturing method that permits the extrusion of multiple materials into complex structures. This expands the processing space of armor ceramics to develop mesoscale structures with gradients and interfaces of varying ceramics that can exhibit unique fracture paths unlike those found in monolithic structures. However, extruding silicon carbide (SiC) and boron carbide (B_4C) into accurate shapes with minimal slumping remains a challenge. This issue becomes especially prevalent when attempting to combine and alternate materials within a print. This project focuses on rheology and the critical effect solids loading, methylcellulosic binder type, and binder content has on both B_4C and SiC suspensions. Samples were tested on a rotational rheometer to determine viscosity as a function of shear stress as well as yield stress values in an effort to identify an optimal suspension composition for printing.

I wish to sincerely thank my mentors Drs Nicholas Ku and Jerry LaSalvia for their guidance.

Spectroscopic Evaluation of Holmium-Doped Barium Fluoride as Potential Mid-Infrared (Mid-IR) Laser Material

William Haller

There has been great interest in developing new solid-state laser sources for possible applications in laser remote sensing, material processing, medicine, and free-space communication. Recently, research has focused more on materials with low phonon energies that are doped with rare-earth ions to be used as gain media for potential mid-IR lasers.[1] For this research, holmium (Ho^{3+}) was used because of its rich energy levels and its capability to emit at wavelengths of approximately 2, 2.8, and 3.9 μm. In this work, spectroscopic properties of Ho^{3+}-doped barium fluoride (BaF_2) crystals were investigated under 890-nm excitation. The literature value for maximum phonon energy for BaF_2 is approximately 330 cm^{-1}[2], which can lead to small nonradiative decay rates for rare-earth ions. To compare, a material with a higher maximum phonon energy—yttrium orthovanadate—was studied to show that traditional oxide crystals have higher nonradiative decay rates, which hinder their emission properties in the mid-IR region. The Ho^{3+}:BaF_2 sample had a peak emission cross section of 0.76×10^{-20} cm^2 at approximately 3.9 μm, which is comparable to other reported Ho-doped fluorides (Ho:BaY_2F_8, Ho:$LiYF_4$).[3]

I wish to acknowledge the mentorship of Drs Ei Ei Brown and Zackery Fleischman for their invaluable mentorship and guidance this summer. I would also like to acknowledge Jenny Rosen for her thoughtful discussions and assistance working through our research projects.

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Aerodynamic Prediction of the Tiltrotor Aeroelastic Stability Testbed Using Computational Fluid Dynamics

Richard Healy

This study investigates the design and aerodynamic performance of the Tiltrotor Aeroelastic Stability Testbed's fuselage fairing. The fairing is modified from its existing geometry in an effort to reduce separation and exhibit relatively steady flow in the blade passage region. A region of constant thickness is added at the blade passage region and a convex fillet at the wing junction is removed. High-fidelity computational fluid dynamics simulations are performed using HELIOS on the original and modified fuselage designs at five freestream velocities ranging from 100 to 200 kt. A small stagnation region at the leading edge and separation region at the trailing edge is observed for both designs. Flow velocities are higher at the mid-chord of the modified geometry due to increased curvature required to accommodate the constant thickness region. The increased flow velocities in this region create a region of low pressure not observed on the original geometry. Minimal separation is observed on both the original and modified geometry, indicating additional modifications for this objective are unnecessary. However, modification to the constant thickness region is required to achieve uniform flow in the blade passage region.

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Chalcogels: An Emerging Class of Conversion-Based Electrode Materials for Lithium-Ion Batteries

Eli Hodge

Chalcogels are an emerging class of aerogels that have been proven in this study to serve as a potential electrode for lithium (Li)-ion batteries. Chalcogels exhibit a 3-D interlocking network of aggregated aperiodic nanoparticles with random meso- to nanoscale porosities, which might allow improved electrode−electrolyte interaction, shorter Li diffusion paths, and decreased electrode volume change. This study details the synthesis and characterizations of a series of chalcogels including $NiMoS_x$, $NiMoS_x \cdot S_x$, and $CoMoS_x$. Furthermore, the fabrication of coin cells and investigation of their charge and discharge cycling at several different c-rates was done. $NiMoS_x$, $NiMoS_x \cdot S_x$, and $CoMoS_x$ were identified as promising owing to their high specific capacity (500 ~ 950 mAh/g) upon first discharge. However, the capacity declined approximately 50% during the first 10 cycles. Unlike sulfur (S) cathodes for Li-S batteries, the cyclic efficiency is significantly higher. This is due to the presence of shorter polysulfide chains as well as metal cations that act as "glue" to prevent polysulfide dissolution into the electrolyte, which is one of the major shortcomings of Li-S batteries. Further research on material design and cell fabrication to enable improved cyclic efficiency and reduced capacity fade is needed.

I wish to acknowledge the mentorship of Drs Jan Allen and Saiful Islam (Jackson State University) and ARL and the DOD Historically Black Colleges and Universities/Minority Institutions program for allowing me the opportunity to diversify and experience professional research.

Multiagent Reinforcement Learning for Navigation and Control in Complex Environments

Christopher Hsu

Reinforcement learning (RL) is a promising approach to learn control for robotic systems in complex environments. Yet, the majority of current RL research is done in the single-agent setting. We proposed a novel multiagent approach for solving the active information acquisition problem, which requires an agent to choose a sequence of actions in order to acquire information about a process of interest using onboard sensors. We developed a multiagent environment in which to train a group of agents to navigate and track multiple targets of interest. We also proposed a framework to use and extend reinforcement learning target-tracking algorithms to the multiagent setting.

I wish to acknowledge the mentorship of Dr Mulugeta Haile (ARL), and Ms Heejin Jeong and Dr George Pappas (University of Pennsylvania).

Transfer-doped Diamond Test Structures under Harsh Thermal Environments

Chun Yu "Tammy" Huang

DOD radar systems required to detect, classify, and track threats would benefit significantly from radio-frequency power transistors that advance thermal and output power capabilities. This is due to the ever-increasing demands placed on the systems' control electronics by harsh thermal environments and the output power requirements of the microwave sources. As a result, next-generation electronics employed for radar could be diamond-based due to the superior thermal performance of diamond over current semiconductor technologies (e.g., gallium nitride). However, it is difficult to introduce mobile charge carriers into diamond (e.g., by standard impurity doping). Transfer doping of hydrogen-terminated diamond (H-D) via electron acceptor layers (e^-ALs), such as molybdenum trioxide (MoO_3), provides a path to circumvent this problem.[1,2] Besides providing the required charge carriers, the e^-AL needs to be nonconductive with a high breakdown field and stable over a wide temperature range. The purpose of this work was to test the thermal stability of MoO_3 encapsulated by silicon dioxide (SiO_2) by annealing under atmospheric conditions to the point electrical conduction becomes negligible. We found our H-D/MoO_3/SiO_2 test structures stable up to approximately 220 °C. Beyond this point, electrical conduction degraded along with chemical and physical changes as evidenced by light-scattering spectroscopies.

I wish to acknowledge the mentorship of Dr Glen Birdwell. I also sincerely appreciate the support and advice from many other members of the Electronic Technology Branch, ARL: Dr Dmitry Ruzmetov, Dr Mahesh Neupane, Mr James Weil, Dr Kevin Crawford, Dr Pankaj Shah, and Dr Tony Ivanov. I would also like to acknowledge support from the DOD Historically Black Colleges and Universities/Minority Institutions Summer Program for the financial and travel support.

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Evaluation of the Performance of a NACA 0012 Airfoil Shape at Micro Air Vehicle (MAV) Scales and Speeds

Ja'Kira Jackson

Vehicle performance and future design tools have a critical reliance on accurate lift and drag data from the airfoils they use. At MAV scales, the airspeed and turbulence levels have critical influences on the lift and drag. The influence of freestream turbulence on the performance of an NACA 0012 airfoil at low Reynolds number (Re = 12,000) was investigated. Particle image velocimetry experiments were performed at angles of attack from $0° \leq \alpha \leq 15°$. Four grid-turbulence generators of different sizes were used to introduce turbulence into the flow. Hot wire anemometry was used to characterize the turbulence levels, and showed turbulence varied from 0.5% (baseline) to 7%. Results have shown that by introducing turbulence the vorticity in the boundary layer increased and stall was delayed. Flow fields for the baseline and varying turbulence levels are presented along with lift and drag data. At MAV scales, turbulence levels that better reflect the real world showed increased performance compared to typical lab conditions.

I wish to acknowledge the mentorship of Dr John Hrynuk.

Modeling Requirements for Modern High-Speed Coaxial Rotors

George Jacobellis

The modeling requirements for a high-speed coaxial helicopter at a realistic flight condition are investigated. Particle count and timestep requirements for a mid-fidelity viscous vortex particle method are determined, and the impact of turbulence transition modeling on a computational fluid dynamics simulation is investigated.

I wish to acknowledge the mentorship of Rajneesh Singh.

Effects of Pulse Agility in Cognitive Software-Defined Tracking Radar

Benjamin Kirk

Wartime environments can bring about congested radio-frequency (RF) channels where RF interference (RFI) can disrupt typical radar operation. Cognitive and adaptive radar systems may be employed to allow radar operation while sharing the spectrum with other signals by avoiding interference. This requires pulse agility that can mean the center frequency, bandwidth, or modulation type of the transmitted radar waveform can change rapidly. In tracking radar systems that use Doppler information to measure target velocity, this pulse agility can cause distortion that reduces the system's detection performance. Since it is common for tracking radar systems to form range-Doppler images from a matrix of received radar data, it is possible to utilize image processing techniques to address this distortion. The problem can be framed as a classic image processing dilemma, where an image is corrupted (in the form of blurring and/or additive noise) by imperfect lenses or other effects. The adaptation pattern of the radar pulses over time can be considered to introduce a corrupting point spread function (PSF). This PSF can be found if the adaptation pattern is tracked, and it has been shown that the PSF can then be removed from the range-Doppler image using deconvolution techniques.

I wish to acknowledge the mentorship of Anthony Martone, Kyle Gallagher, and Kelly Sherbondy.

Low-Complexity, Image-Based Localization in Urban Environments

Johnathan Knox

Image-based localization is an important technique for identifying a Soldier's precise location when a global positioning system is not available. This research presents a novel image-based method for locating a Soldier in an urban environment using a smartphone camera. There are two inputs for the program, the first is Light Detection and Ranging (LIDAR) data from a unmanned aerial vehicle, which is turned into a digital elevation model (DEM) of the area where a mission will take place. The second is a panoramic image a Soldier could take from their smartphone. Using image processing, the program extracts the outline created by the buildings and objects within the panorama and calculates azimuth and elevation angles at certain pixels locations along that contour. The algorithm then simulates on the DEM how shadows would fall if the sun was at those angles in the sky and does this for every pair. Once the program has created all the resulting images, the pixel location where "N" shadow edges intersect is the Soldier's position. This position is marked on the DEM and displayed on the Soldier's phone. A simulation in the Unity Engine is being used to show how the algorithm would work in a real-life scenario.

I wish to acknowledge the mentorship of Dr CC Borel-Donohue.

Evaluation of Real-Time Predictive Spectrum Sharing for Cognitive Radar

Jacob Kovarskiy

Growing demand for radio-frequency (RF) spectrum access poses new challenges for next-generation radar systems. To operate in a crowded electromagnetic environment, radars must coexist with other RF emitters by avoiding interference while maintaining system performance. This work evaluates the performance of a cognitive radar that shares the spectrum by predicting radio activity in real time. The system applies a cognitive perception-action cycle that senses RF interference (RFI), learns RFI behavior over time, and adapts the radar's frequency band of operation. Through cognition, the system learns a stochastic model describing RF activity to predict the likelihood of frequency subbands becoming available during radar operation. This cognitive radar predicts RFI activity in real time and may share the spectrum with communications signals of various timescales. A set of synthetic interference signals combined with real measured RF spectra is used to evaluate the performance of this predictive spectrum sharing scheme. For deterministic interference, bandwidth underutilization and waveform collisions are minimal. As RFI busy and idle time variance increases, the bandwidth utilization and collision tradeoff worsens. This predictive approach gives the system appreciable signal-to-interference plus noise ratio improvement over full-bandwidth operation.

I wish to acknowledge the mentorship of Dr Anthony Martone, Dr Kyle Gallagher, Kelly Sherbondy, and Dr Ram Narayanan. A special thanks to Benjamin Kirk for his role in the development of the predictive SDRadar system.

Application of Surrogate-Modeling and Machine Learning Frameworks to Optimize Gas-Turbine Engine Operation for Future Vertical Lift Propulsion

Nikita Kozak

The Army's Future Vertical Lift program calls for an efficient and effective tool that optimizes the performance of a proposed variable-speed gas-turbine engine (VSGTE). Traditional optimization methods like parametric sweeps require many iterations to arrive at solution, which is problematic in the application to gas-turbine engines as the high-fidelity simulations used have expensive computational costs and depend highly on designer interpretation and interaction. In a campaign to alleviate these shortcomings, two novel gas-turbine engine optimization tools are proposed. The first tool couples surrogate management framework with a mathematical algorithm and a finite element fluid–structure interaction model to arrive at the optimal gas-turbine design in a less costly and less complex manner without sacrificing accuracy. The second tool employs supervised Gaussian-based machine learning to create a reduced-order model that explores the design space and furthers our understanding of the complex internal flows found within the turbine stage. Presented are these two optimization tools that together provide valuable insight on gas-turbine stage concepts that can revolutionize propulsion systems and enable the proposed VSGTE.[1,2,3,4]

I would like to thank the High-Performance Computing (HPC) Modernization Program and the HPC Internship Program for this opportunity. Also, I would like to thank the people at ARL for making this internship so great and providing me access to the necessary tools needed for this internship. In addition, I would like to thank my colleagues at Iowa State University. Finally, I would like to acknowledge my mentors Drs Luis Bravo, Simon Su, Anindya Ghoshal, and Muthuvel Murugan who provided me with guidance throughout this entire internship.

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3-D Modeling for Unmanned Aircraft System Analysis

Shaayal Kumar

The purpose of this project is to generate new drag capabilities for an innovatively designed Group 3 unmanned aerial vehicle (UAV). These capabilities are critical in optimizing the sizing and power of the vehicle for efficient mission performance. Open Vehicle Sketchpad (Open VSP) was utilized to obtain total drag convergence, local drag coefficients, and parasitic drag for components of the UAV. More specifically, OpenVSP was used to indicate the difference in measurements of drag as angle of attack and flow velocity varied. The results illustrate that at higher angles of attack, the local drag coefficients are around 0.05 at the tips and 0.025 toward the center of the wing. At lower angles of attack, the local coefficient of drag is 0.005 at the tips of the wing and 0.0025 at the center of the wing. OpenVSP also utilized the Horner equations to calculate the parasitic drag of complex geometries such as the fuselage, airframe, and full assembly. The 3-D modeling tools of OpenVSP help further the analysis of this powerful UAV.

I wish to acknowledge the mentorship of Michael Avera, Rajneesh Singh, and the College Qualified Leaders program for giving me an opportunity to gain invaluable knowledge and allowing me to contribute to impactful work.

Thermal Characterization and Calibration for Improved Power Electronic Packaging

Vincent Lan

The Army is actively seeking power modules with greater power densities to operate an increasing electrification of equipment. Greater power density results in lighter, smaller, and faster Army equipment. Although the performance of electronic devices improve with each iteration, electronic packaging typically does not. Most packages are bulky and use space inefficiently. However, through a co-designed approach and by implementing multifunction components, packages can improve efficiency and performance. The "power tower", dubbed for its vertical stacking, is one such novel package. The power tower offers a reduction in size and weight compared to commercial modules. In pursuit of an experimental performance comparison, power towers must be fabricated, calibrated, and tested. Recent improvements to the fabrication process include aluminum–silver galvanic corrosion prevention and an upgrade to the power tower housing. The printed circuit board used for testing is updated to better accommodate the diameter of the power tower's electrical leads and enable in situ temperature measurement. The current-voltage curves generated from electrical calibration of the recently completed power tower modules demonstrate the metal-oxide-semiconductor field-effect transistors and diodes are functional within the power tower and it is ready for thermal and dynamic characterization.[1,2]

I wish to acknowledge the mentorship of Lauren Boteler, Claude Pullen, Morris Berman, and Mike Fish for their expertise both inside and outside the lab. Additionally, I would like to thank Franklin Nouketcha and Rachel McAfee for their assistance during calibration and Richard Thomas for his help with testing.

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The Mechanical Process to Build a Hyperspectral Imager

Corwin Largo

The objective of this project is to construct a handheld, low-cost hyperspectral imager for implementation to analyze natural resources. For each pixel in an image, a basic image produces red–green–blue spectral signatures, three wavelengths for each pixel. Our hyperspectral sensor will consist of 10 to 100 narrow and adjacent wavelengths per pixel to provide spectral detail and information. Our camera integrates a variety of components. We determine the calibration of the optical design, where we use a fluorescent lamp to acquire information to build our optical design. The optical components are subassembled in a pipe tube that is mounted to the camera. The electronic components of the hyperspectral imager house a credit-card-sized computer board call Raspberry Pi 3 for networking. The inertial measurement unit is soldered onto a microcontroller, Arduino Uno, with connectors to configure both cameras (Raspberry Pi Camera Module and the ArduCam Mini Camera Module Shield with 5 megapixels) of their position, movement, and time. The computing platform is built with Visual C# to visualize and analyze the data. With computer-aided design software, we design a clamshell box where a MarkerBot 3-D machine can print our parts to house all of the components.

I wish to acknowledge the mentorship of Shasha Han, Dr David Ligon, and Steven Chischilly, and the peer mentorship of Lyman Pinto.

BooM-VIO: Bootstrapped Monocular Visual-Inertial Odometry (VIO) with Absolute Trajectory Estimation through Unsupervised Deep Learning

Kyle Lindgren

Machine learning has emerged as an extraordinary tool for solving many computer vision tasks by extracting and correlating meaningful features from high-dimensional inputs in ways that often exceed the best human-derived modeling efforts. However, the area of vision-aided localization remains diverse with many traditional, model-based approaches (i.e., filtering or nonlinear least-squares-based) often outperforming deep, model-free approaches. In this work, we present BooM, a scaled monocular VIO solution that leverages the complex data association ability of model-free approaches with the ability to exploit known geometric dynamics with model-based approaches. Our end-to-end, unsupervised deep neural network simultaneously learns to perform VIO and estimate scene depth while scale is enforced through a loss signal computed from velocity magnitude estimates from a traditional method. We evaluate our network against the state-of-the-art traditional VIO approach that aided training on a driving data set we collected in the AirSim simulation environment. We further demonstrate the benefits of our combined approach through robustness tests on trajectories that exhibit common challenges to computer vision methods, including image brightness, blur, weather effects (rain), and lens flare.

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A Novel Methodology to Measure Clay Backface Parameters and their Relationship to Behind-Armor Blunt Trauma Events

Marisa Lizins

Behind-armor blunt trauma (BABT) is currently evaluated by measuring depth in clay, but displaced clay volume should better represent the amount of energy available to cause injury. A selection of molds capturing the clay craters from recreated law-enforcement cases of BABT was analyzed. The maximum height (clay depth), backface volume (volume of depression), and total volume of displaced clay (volume of depression and crater lip) of each mold was calculated with a custom MATLAB[1] algorithm and/or measured with Mimics[2] from computed tomography images of the molds. The primarily external injuries sustained by the officers were classified as minor, moderate, or severe (includes internal organ/skeletal) by a board-certified plastic surgeon. The maximum height was correlated with both volume measurements. There were significant differences ($p < 0.05$) between minor and moderate and minor and serious injuries for the maximum height, backface volume, and total volume. None of the clay backface parameters was significant between moderate and severe injuries. Clay depth was the most significant predictor of the injury severities for these cases. However, when evaluating a subset of similarly shaped craters, the total volume then became the most significant parameter for minor and moderate and minor and serious injuries, indicating that injury is not dependent on just energy, but how the energy is deposited.

I wish to acknowledge the mentorship of Drs Karin Rafaels and Cynthia Bir for their work in obtaining law-enforcement data, recreating the cases, and generating the molds for this project. I would also like to acknowledge Dr Kathryn Loftis for reviewing the medical records and classifying the severity of the injuries sustained.

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The Synthesis and Analysis of Iridium 2-Phenylbenzothiazolate (pbt) Complexes

Shamya London

Cyclometallated ligands were used to created iridium complexes. These complexes were synthesized using a three-step reaction process and were performed in a microwave reactor. Once the synthesis was completed, purification was used to remove any unwanted and remaining materials that could potentially stop the reactions from being pure. After purification, characterization was used to confirm the purity and structure of each complex.[1,2]

I wish to acknowledge the mentorship of Dr Ryan O'Donnell and assistant mentor Dr TJ Rohrabaugh.

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Anti-Jam Global Positioning System (GPS) Antenna Algorithms for Dismounted Soldier Positioning, Navigation, and Timing Systems

Jeffrey A Maloney

Signal acquisition and tracking for Army GPS receivers is severely impacted by the presence of radio-frequency interference and jamming. One solution for mitigating jamming and maintaining receiver tracking and navigational accuracy is to dynamically steer reception pattern nulls of a GPS antenna array in the direction of incoming jammers. This is accomplished by taking a weighted sum of the output from multiple antenna elements, where the complex valued weights are determined by a gradient descent algorithm. A non-real-time implementation of Frost's algorithm applied to measured data in postprocessing, is used to generate the complex valued weights. Commercial off-the-shelf phase shifters and variable attenuators are utilized to apply these weights, and reception pattern measurements are taken in an anechoic chamber.

I wish to acknowledge the mentorship of Dr Steven Keller, whose guidance has been indispensable during my professional development. Also, I wish to thank Theodore Anthony, John Clark, Russel Harris, and Arthur Harrison for their contributions to this work. Their efforts and expertise have profoundly improved this project.

Alcohol-Based Solutions as Liquid Electrolytes for Safe Batteries

Natalie Martin

Highly concentrated electrolytes have gained attention for improving the ionic conductivity, safety, and electrochemical stability window of corresponding pure solvents. In this work, the electrochemical stability window of super-concentrated alcohol-based solutions—isopropanol, ethanol, and methanol—were expanded using lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) and lithium triflouromethanesulfonate (LiOTF) as salts. Despite the flammability of each pure solution, at high concentrations none of the solutions are flammable due to decreased solvent vapor pressure. Nuclear magnetic resonance-proton and Fourier transform infrared data confirms the suppression of the active proton on the OH group of each of the alcohols, suggesting improved Li+ ion transport. Ionic conductivity data confirms this claim. Overall, methanol-based solutions outperformed both isopropyl alcohol and ethanol, suggesting a new frontier for safe liquid electrolytes.

I wish to acknowledge the mentorship of ARL Team Leader Dr Conrad Xu, Dr Marshall Schroeder, Dr Lin Ma, and Dr Arthur Von Cresce.

Characterization of Tribologically Relevant Fuel System Interfaces

Caleb Matzke

Wear and scuffing due to low fuel viscosity are problems present in fuel pumps, injectors, and valves because viscosity directly affects lubricant film thickness and friction between contacting surfaces. Lubrication of components with tight tolerances is also difficult and can lead to catastrophic failure in which the component may stick or seize due to localized scuffing.[1] Baseline data such as surface roughness were measured as an indication of wear and other possible surface damage of relevant interfaces. Surface characteristics of tribologically relevant surfaces were determined using a white light interferometer on a pristine, moderate, and long-term use set of components.[2] Smoothing of the surface was observed in locations where reciprocating motion occurs on the moderate set of components. Roughening of the surface was observed in areas of reciprocating motion in the long-term use set of components and tended to result in pump failure. An understanding of component properties could allow for material selection that improves fuel component robustness. Initial roughness of MAX phase specimens provided by the University of North Dakota was measured and compared to 52100 hard steel, a material commonly used in fuel pumps. Next, MAX phase specimens will be experimented with under fuel lubrication to determine their resistance to scuffing.

I wish to acknowledge the mentorship of Oak Ridge Associated Universities, University of North Dakota, Kelly Jacques, Stephen Berkebile, Jon-Erik Mogonye, Nikhil Murthy, and Surojit Gupta.

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Navigation and Collision Avoidance with Human-Augmented Supervisory Training and Fine Tuning via Reinforcement Learning

Christopher Maxey

Robust navigation and orientation under complex conditions is a must for autonomous drones operating in new and varied environments. Creating drones with adequate behaviors can be a challenge from both a training standpoint and a generalization standpoint. Using human expertise data is an option to help bootstrap the learning process; however, using the human data can lead to side consequences that are not immediately intuitive. This study focuses on applying varying levels of human input to an agent to determine how this input affects the agent's performance. The Unreal Engine and the AirSim plugin are used to train a quadcopter agent in an abstract "blocks world"–type environment. Six agents in total are trained, with the first five having increasing amounts of human input and the sixth agent having no human input. A variety of metrics are looked at, including total goals achieved and time to achieve some number of goals.

I wish to acknowledge the mentorship of Dr E Jared Shamwell.

Current-Voltage and Monte Carlo Transport Analysis of Top-Gated, Monolayer-Molybdenum-Disulfide (MoS_2) Metal–Oxide–Semiconductor Field-Effect Transistors (MOSFETs)

Alex Mazzoni

Standard MOSFET current-voltage equations are applied to experimental results of ARL-fabricated radio-frequency transistors that use monolayer molybdenum disulfide as the channel material. A method to accurately extract the key device parameters of threshold voltage, contact resistance, and transconductance is introduced and discussed. The experimental transistor curves deviate from the transistor models in regions of operation with both a high gate and drain bias. According to related literature, significant device self-heating occurs at these operation regimes, causing significant velocity saturation/mobility degradation.[1] To study this velocity saturation, we build upon a previously defined deformation potential model[2] and perform high-temperature electron transport analysis using the Monte Carlo method.

I wish to acknowledge the mentorship of Robert Burke for growing the MoS_2, Matthew Chin for the assistance in device fabrication and testing, and Neil Goldsman's group at the University of Maryland for providing feedback on the device modeling.

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Development of a Pulsed-Power Electronics Package and Test Bed

Rachel McAfee

Transient high-power system thermal output is mitigated with by increasing the thermal capacitance of the proposed device package. A package incorporating metallic phase-change materials in direct contact with a semiconductor heat source is developed. Applications for this system include laser diodes for use in directed-energy weapons. Within this study, surrogate bare Zener diodes are used in place of the laser diodes for early package development and thermal testing. Thermal characterizations test methods were developed based on existing JEDEC standards. Temperature-sensitive parameters of the surrogate diodes are used to define I-V-T surfaces for calibration. The package is tested to demonstrate electrical package effectiveness, thermal testing procedure accuracy, and direct-contact metallic phase-change material (PCM) viability. The developed package and testing procedure enables direct-contact metallic PCM integration with an active device surface.[1–3]

I wish to acknowledge the mentorship of Dr Lauren Boteler, Dr Mike Fish, Morris Berman, Claude Pullen, and Melissa McCann of ARL for their expertise and time. This project would not have been successful without them.

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Transient Thermal Mitigation: Microencapsulated Organic Phase-Change Materials Embedded in a Metallic Matrix for High-Rate Pulse Applications

Melissa McCann

As the demand for smaller and faster electronics increases, challenges emerge to manage the generated heat. The typical steady-state focus is on peak loading conditions and generated temperature regimes that occur less than 5% of the time.[1] The transient thermal solution proposed in this project is intended for the average temperature conditions.[2]

This study aims to mitigate the overdesign of packaging applications by incorporating melamine-microencapsulated paraffin spheres embedded in a Field's metal (32.5bismuth [Bi]/51indium[In]/16.5tin[Sn] wt%) matrix to dissipate chip-heat generation. This approach proposes to decrease the packaging size, limit associated weight, and increase system performance. Four concentrations were synthesized with paraffin volumetric fraction concentrations of 21.8%, 40.3%, 50.1%, and 61.2%. The collected data was compared with composites comprising organic phase-change materials (PCMs) and metallic structures in literature.[3–4]

To characterize the PCM composites, differential scanning calorimetry, scanning electron microscopy, micro-computed tomography, and frequency-domain thermoreflectance techniques were employed. These physical experiments were supported with computer-modeled simulations. A low-fidelity model was created to characterize the interactions among the size of the particles, heat flux, and heat propagation in an explicit system. A coupled two-temperature model tracked distinct matrix and particle temperatures in the domain.

I wish to acknowledge the mentorship of Dr Lauren Boteler for broadening my understanding of the real-world applications of this project. To both Dr Mike Fish and Morris Berman, your programming knowledge is unparalleled and I am thankful for our thoughtful conversations. Thank you to Claude Pullen for your technical advice and ability to keep a smile on my face. I am grateful for this summer research experience and all of the support I have had from my colleagues at Washington University in St. Louis, Missouri.

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Synthetic Microstructure Generation via Adversarial Networks in a Data-Sparse Environment

Levi D McClenny

It is well known that material microstructure greatly influences the physical properties of a material, such as strength, ductility, hardness, high- and low-temperature behavior, and so on. Lately, informatics approaches such as machine learning have begun to find applications in materials-related research, specifically in the form of microstructure informatics. However, current machine/deep-learning techniques require robust data sets that are difficult to find in a materials context. Here, we have identified generative adversarial networks as a means of generating high-quality synthetic data that could potentially be used in microstructure applications to augment existing data and allow for more robust deep-learning experimentation. Such generation techniques could enable data-driven learning techniques that could bridge key gaps in understanding the processing–structure–property relationships. This could result in a better understanding of the influence of microstructure in material properties, potentially leading to stronger, lighter, and more durable materials in the future.

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Legged Locomotion and Mobility Adaptation (LLAMA) Reactive Control Development

Gregory McCutcheon

With a new and improved LLAMA robot being assembled this summer, possible controller improvements and knowledge of its limitations are desired. Using MATLAB and SIMULINK to create simulations that stayed within the speed, torque, and power limits of LLAMA 1.0, it was found that a 1.7-m/s velocity, over triple the normal gait tested on LLAMA 1.0 (0.5 m/s), was feasible by just increasing the gait frequency. Then, a linear correlation between gait frequency and maximum velocity was found. With a new max speed, the stopping distances for different speeds were determined. To test the robustness and stability, disturbances were applied to the center of mass and obstacles were put in LLAMA's path. These displays, as expected, showed that the recovery time decreases with increased gait frequency. Lastly, the maximum payload, 25 kg (~55 lb), was determined. Studies to improve LLAMA's speed, response time, and recovery time are still being completed. Once these studies are completed, the controller will be transitioned to Jet Propulsion Laboratory software for further testing prior to being installed onto LLAMA 1.0 or LLAMA 1.1.

I wish to acknowledge the mentorship of Dr Christian Hubicki and Jonathan Clark and my mentor, Jason Pusey.

Referencing Human Research Protection Program (HRPP) Data

Stefan Mermagen

Storing and referencing databases are crucial when working with large amounts of data. The HRPP database is a large collection of projects that involve human test subjects and it keeps track of all of the different components of each project. The current way to search for data in Excel is slow and cumbersome to the user. A major advantage of using a searchable database over an Excel spreadsheet is the data can be easily pulled up and can show all of the relevant results with a few clicks of the mouse. I am using Hypertext Markup Language (HTML) and Personal Home Page (PHP) for the front end and Structured Query Language (SQL) for housing the data. I first sorted through the data to build a basic database. Afterward, I started the front end where the user would actually query the data. The next steps are to make sure the database is fully built to encase the entire data and that the front end has the proper query and appending functions. This project has the potential to increase the speed, ease, and accessibility of the data. For future projects, this database could be rebuilt and customized for different projects that require a database and front end.

I wish to acknowledge the mentorship of Drs Bill Evans and Jeremy Gaston in this opportunity to work on this project.

The Production of Energetic Aluminum Nanoparticles via Atmospheric Plasma Surface Treatment

Kelsea Miller

This work explores the mitigation of the parasitic native-oxide shell for aluminum nanoparticles (nAl) via atmospheric plasma surface treatment techniques. The subsequent improvement of nAl reactivity is important due to the appealing features of nAl such as the increased surface-area-to-volume ratio and high-energy content that are ideal for use in energetic applications. Previous efforts conducted at ARL showed plasma processing of the nAl significantly reduced the parasitic oxide barrier and increased reactivity when functionalized with aluminum iodate hexahydrate (AIH) for application as fuel and oxidizer composites. A comparative study of treating nAl in plasmas is conducted between two different plasma glow discharges using argon (Ar) and helium (He) gases and reactor configurations with consistent plasma conditions (i.e., 10- and 30-min durations, power, and gas-flow rate). An additional experiment was conducted to study the potential hydrolytic effect on nAl particles by repeating Ar–plasma treatments twice for 10 min. The plasma-treated particles are immediately suspended either in acetonitrile for material characterizations or an iodate solution to synthesize AIH on the surface for enhanced reactivity. The particles are evaluated by transmission electron microscopy, laser-induced air shock for energetic materials (LASEM), and powder X-ray diffraction. Transmission electron micrographs revealed nonuniform shells with significantly reduced oxide thicknesses on the plasma-treated samples with an average thickness of 4–6 nm to 3 nm. Chemical analysis also demonstrated the sporadically decorated AIH on the nAl surface for the coated particles. LASEM results suggested enhanced energy-release performance for AIH-coated nAl samples obtained by both reactors with Ar and He.

I wish to acknowledge the mentorship of Dr Chi-Chin Wu. The technical assistance provided by Mr Kevin Bare and the X-ray diffraction training given by Dr Victoria Blair are appreciated. This work was supported by the ARL Research Associateship Program's Summer Student Experience under contract No. W911NF-16-2-008 and the Technology Management Training Group's Historically Black Colleges and Universities/Minority Institutions Summer Program.

Chamber Built for Testing of Chemical–Biological Filter Unit's Fan Assembly

Zachary Mohammodu

The Joint Project Manager–Protection (JPM-P) funded the DEVCOM Chemical Biological Center (CBC) to test the new main fan assembly in the M93 Gas Particulate Filter Unit according to current electromagnetic-interference standards. To enable testing at a system level, DEVCOM CBC designed and built a test chamber that would simulate shelters found on missile-defense systems that use the M93. Using a systems engineering approach, verification and validation (V&V) activities were performed to mitigate risks and gain confidence that the test chamber was built according to specifications (verification) and that it can be used as intended (validation). Successful completion of the V&V step supports full system testing.

I wish to acknowledge the mentorship of Janet L Betters, Ryan A Bearekman, Monicia R Hall, and John D Clayton.

High-Speed Vibration Measurement of Aviation Engines Using Real-Time Fast Fourier Transform (FFT) Signal Processing

Jovany Mojica

Many US Army unmanned aerial vehicles use compression-ignition engines that were designed for automotive use and not optimized for aviation applications. This can cause hardware failure during long-range missions, at full power and high altitude, where ambient pressure and temperature are low. ARL is implementing new instrumentation to enhance its ability to monitor and analyze engine vibrations that may cause propulsion-system failure. Our team set up, calibrated, and installed a new real-time accelerometer signal analyzer and synchronized this hardware to correlate the accelerometer vibrations to the engine and turbocharger speeds. The team performed a series of experiments by running a four-cylinder, aviation compression-ignition engine in our Small Engine Altitude Research Facility over a range of operating and ambient conditions. The signal analyzer provides FFT, power-spectral-density, and order-tracking analyses, which are used to identify and characterize engine and turbocharger vibrations. This new capability will be crucial in the design of more reliable engine calibrations by indicating dangerous operating conditions to avoid. The capability will ultimately contribute to new engine and turbocharger designs that enable multifuel-capable hybrid electric propulsion.[1–5]

I wish to acknowledge the mentorship of Mr Kurt Kruger and Dr Michael Szedlmayer.

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Deep Ultraviolet Solar-Blind Sensing: Surpassing Cesium Telluride Photomultiplier Tubes' Sensitivity Limits with Silicon Carbide Avalanche Photodiodes

Suhaas Narayan

In this experiment we test silicon carbide (SiC) avalanche photodiodes (APDs) as a possible replacement for the current gold-standard cesium telluride (CsTe) photomultiplier tubes (PMTs) for deep ultraviolet (DUV) single-photon counting. Currently, CsTe PMTs are used for solar-blind single-photon detection but their low quantum efficiency in the DUV and sensitivity in visible wavelengths require the use of filters that further reduce their sensitivity in the DUV in order to cut out the contribution at visible wavelengths. SiC rejects wavelengths above 380 nm, thus eliminating most of the solar spectrum. Combined with the high quantum efficiency of SiC and narrower bandpass filters with higher transmissivity, this makes SiC APDs good candidates for DUV photon detection. We have modeled and measured the APD and PMT quantum efficiency and single-photon detection efficiency with different degrees of filtering in the UV range of 280–400 nm when subjected to direct sunlight. Our results show a SiC APD measures the same signal as a CsTe PMT eight times larger in area while reducing the detected solar background by five orders of magnitude.[1,2]

I wish to acknowledge the mentorship of Anand Sampath.

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Modeling and Control of Dynamic Legged Robots

John Nicholson

The major work I performed this summer was on two projects: 1) gait development for the Legged Locomotion and Mobility Adaptation (LLAMA) platform currently in development and 2) design of a system to study legged locomotion in fluids. The LLAMA project involves designing a dynamic simulation environment to create a 3-D model of the LLAMA legged platform. I then developed optimized gait controllers using this model. For legged running in fluid, I helped design a reduced-order model to capture the dynamic properties of the symmetric 5-bar leg used on Minitaur, a quadruped robot, and developed controllers on a physical platform to test in a fluidized substance: couscous.

I wish to acknowledge the mentorship of Jason Pusey.

Investigation of Breakdown Voltage and Critical Field in Wide-Bandgap Semiconductors and Silicon

Franklin Nouketcha

This work compares the breakdown voltage and critical field of various wide-bandgap semiconductors (gallium oxide, gallium nitride [GaN], and 4H-silicon carbide [SiC]) relevant for power electronics, as well as silicon (Si). Gauss's law is used to solve the electric-field profile within p-i-n structures, where the i-layer is doped n^-. Field-dependent impact-ionization coefficients are obtained from the literature to compute the breakdown voltage of those p-i-n structures as a function of doping and thickness of the blocking i-layer. Instead of treating the critical field as a constant material property, it is shown that the critical field varies not only as a function of doping but also with device geometry. Furthermore, this work shows that even though GaN has a higher critical field, it does not necessarily lead to a larger maximum blocking voltage than that of SiC. These results demonstrate the critical importance of accurately determining impact ionization coefficients, given their effect on breakdown voltage.[1–4]

I wish to acknowledge the mentorship of Dr Aivars Lelis, Dr Ron Green, and Prof Neil Goldsman. I also express my gratitude to the Oak Ridge Associated Universities for funding my research.

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Implementation and Analysis of Notched FM Noise Waveforms on Software-Defined Radar (SDR)

Jonathan Owen

The radio-frequency (RF) spectrum continues to become more congested due to rapidly increasing commercial demand for wireless applications (data, video streaming, etc.). Radar may be forced to share spectrum in order to operate, and emerging 5G use-cases will require radar to become far more nimble, robust, and responsive to dynamic interference.

Proliferation of wireless devices and required spectrum sharing will necessitate robust RF interference (RFI) rejection in the radar receiver and mitigation of interference the radar causes to other spectrum users. Here, a cognitive approach is considered wherein a spectral notch is placed in the radar spectrum based on RFI sensed in the environment. Leveraging the fast-spectrum-sensing algorithm to enable detection of in-band RFI and its spectral location(s),[1,2] spectral notches coinciding with the sensed RFI are incorporated into nonrepeating, random frequency-modulation (FM) waveforms. These waveforms maintain a transmitter-amenable FM structure[3] and have been experimentally demonstrated to physically realize different forms of random FM waveforms.[4–5]

This research includes a performance analysis between the "sense & notch" and other cognitive paradigms, implementation of a complete "sense & notch" system on an SDR, and assessment of the practical latency between sensing new/changed RFI and generating new waveforms with coinciding spectral notches. A recently developed method, denoted zero-order reconstruction of waveforms, performs the optimization to incorporate spectral notches into the FM noise radar waveforms while accounting for the zero-order hold model of the digital-to-analog converter of the SDR.

I wish to acknowledge the mentorship of Benjamin Kirk, Dr Anthony Martone, and Mr Kelly Sherbondy for their support and insights on the research performed. The author would like to thank academic advisor Dr Shannon Blunt for his guidance.

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Neuromorphic Computing for Artificial Intelligence

Ashley Owens

Neuromorphic computing is a computing architecture based on the human nervous system and the way our brains process information and make decisions. It is an alternative to the traditional von Neumann architecture, which is powered by a central processing unit (CPU) and operates sequentially on data fetched from memory. Moreover, CPU performance increases are slowing as Moore's Law is said to be coming to an end. In contrast, neuromorphic computing systems combine both computation and memory through "neurons", each communicating with hundreds, even thousands, of other neurons through "synapses". Because of their low power consumption and parallel structure, they are able to handle the increasingly large and scientific data sets for data processing, artificial intelligence, and machine learning. The purpose of this study is to get a thorough understanding of the current state of the art of neuromorphic computing and use a prototype (General Vision NeuroMem) to demonstrate the neuromorphic architecture for artificial intelligence and machine learning.

I wish to acknowledge the mentorship of Ms Natasha Bradley, Dr Mulugeta Haile, Dr Tzi-Kang Chen, and all of ARL's Vehicle Technology Directorate for giving me the opportunity to work on this project. My completion of this project would not have been accomplished without them.

Insight into the Structure and Nature of Aluminum (Al) Covetic Material Using Computational Methods

Andrew Palughi

Covetic nanomaterials, a form of metal-matrix nanocarbon composite produced via a single-step electrocharge-assisted process, have been shown to exhibit increased mechanical and electrical properties over parent alloys. This process has been demonstrated with a variety of metals, with a recent focus on Al and copper for aerospace and power-transmission applications. Exploiting the superior properties of Al covetics could allow for stronger and lighter vehicle components than those currently available. Scalability and consistency issues with the process limit its widespread adoption and drive the need for a fundamental understanding of process–structure–property relationships. The need to understand these fundamental relationships combined with difficulty in acquiring samples of covetic material make atomistic computational methods a useful tool to study covetics. Knowledge of process–structure–property relationships can be used to engineer materials at the nanoscale with tunable multifunctional properties.

This work uses density functional theory to study the metal–carbon interfaces and bonding in covetics. This work also attempts to gain fundamental insight into the structure, stability, and mechanical and electrical properties of covetics using a variety of computational tools and ab initio data. Results indicate the quality of the nanophase carbon has an important role in the stability and macroscopic performance of covetics.

I wish to acknowledge the mentorship of Dr Chris Shumeyko for his exceptional guidance and support in this project.

Handheld Hyperspectral Line Imager Built for the Analyses and Correlation of Drought Stress and Foliar Canopy's Density

Lyman Pinto

In our project, we built an inexpensive, handheld line-imaging spectrometer for correlating drought stress and a foliar canopy's density through collection of statistical spectral data using the system based on techniques that employ diffractive optics and image-processing algorithms to detect spectral information about objects in the scene of the camera. The hyperspectral camera is built with the Raspberry Pi 3 computer board and Arduino Uno R3 microcontroller. In addition, we are using an inertial measurement unit breakout board to determine camera motion for 2-D image reconstruction. The cameras we are using are the Raspberry Pi camera module and the ArduCam mini camera module shield with 5 MP. Hyperspectral imagers produce images like a traditional color camera but detect several hundred colors instead of the three detected by normal cameras. Each pixel of a hyperspectral image contains information covering the entire visible spectrum, providing data that can be used for spectral characterization. Traditional hyperspectral imagers can cost tens of thousands of dollars and are very bulky and heavy. The lightweight strength of 3-D printing is used for the construction of the housing of the optics and camera. The printed thermoplastic material is durable and cost efficient.

I wish to acknowledge the mentorship of Dr David Ligon. I also acknowledge my peer Corwin Largo and faculty mentors Steven Chischilly and Sasha Han.

Assembly of the Adelphi Laboratory Center's Pelletron Accelerator for Heavy-Ion Beams and Fast Neutrons for Materials Studies

Lennie R. Reynolds, Jr.

Preparation of the Energy and Power Division's charged-particle accelerator laboratory proceeded this summer with the testing of components and assembly approaching a commissioning phase. In addition, calculations of the anticipated neutron radiation fields were performed and the results are presented. Accelerators of this type produce primary charged-particle beams of protons or nearly any ion in the periodic table, and can produce secondary fast neutrons, photons, or positrons. Advanced applied-research topics can be studied, such as ion implantation to improve the crack and corrosion resistance of surfaces; isomer-depletion studies for energy and power applications; bulk material modification, damage, and failure modes; quality assurance of Army dosimeters; quality factors for neutron dose calculations; and an accelerator-based positron source to study structural and electronic properties of advanced materials.

I wish to acknowledge the mentorship of Dr Abraham Meles (Navajo Technological University), Dr Jeffrey Vanhoy (US Naval Academy), Dr James J Carroll (ARL), Dr Christopher J. Chiara (Oak Ridge Affiliated Universities/ARL), and Mohamed Doumbia (Howard University). I also acknowledge the American Indian Higher Education Consortium and financial support from the Office of the Under Secretary of Defense for Research and Engineering and the DOD's Historically Black Colleges and Universities/Minority Institutions Program Office.

Injury Thresholds: Structural Alterations to Cultured Hippocampal Neurons following Increasing Strains

Meaghan Richardson

The Army seeks to understand the injury tolerance of brain tissue to design better protective equipment to prevent traumatic brain injury (TBI). In-vitro models of TBI offer a higher degree of experimental control and simplify the complex structural and functional interactions observed in vivo. Cultures of primary pyramidal neurons and astrocytes were grown on BioFlex plates and stretched at different strains (0%–37%) using the Cell Injury Controller II. Phase-contrast images were collected prior to stretch and at several time points after. For fluorescence, cells were fixed at 4 or 24 h and incubated with microtubule associated protein 2 (MAP2). Morphological changes in the cells following injury were quantified using two methods. A fragmentation index provides a measure of neurodegeneration and a Sholl analysis provides a measure of arborization. MAP2 fragmentation-index measures did not demonstrate a statistically significant difference among the strain levels or time points. However, Sholl analysis revealed that the number of maximum intersections significantly decreased following 28% and 37% strains compared with sham. The Sholl analysis was the most sensitive measure evaluated for describing morphological alterations following injury. Finally, this study identified a threshold of structural injury between 20% and 28% strain using the morphological metrics described.

I wish to acknowledge the mentorship of Dr Ann Mae DiLeonardi, Karin Rafaels, Erika Matheis, and Deena Silton and their contributions to this project.

Investigation of the Mid-Infrared (Mid-IR) Laser Potential of Dysprosium (Dy^{3+})-doped Barium Fluoride (BaF_2)

Jenny Rosen

Mid-IR solid-state lasers are particularly interesting due to their wide range of applications such as in medical surgery, atmospheric sensing, and pumping of longer-wavelength lasers. The purpose of this research was to evaluate Dy^{3+}:BaF_2 crystals as mid-IR laser gain materials with a focus on the 2.9-μm emission from the first excited state to the ground state. BaF_2 was chosen due to its low maximum phonon energy, while dysprosium was chosen due to its prominent mid-IR emissions at approximately 2.9- and 1.7-μm characteristics. In particular, the temperature dependence of the absorbance and fluorescence characteristics was determined for this crystal. Absorption spectra were acquired at temperatures ranging from 9 to 293 K (room temperature) and absorption cross sections were calculated. Additionally, fluorescence lifetime measurements were performed across the same temperature range, and stimulated-emission cross sections were determined for the first two excited states. Finally, the gain cross section was determined as a function of the percent inversion for 77 K and room temperature.

I wish to acknowledge the mentorship of Drs Zackery Fleischman and Ei Ei Brown for their guidance, support, and instruction this summer. I would also like to acknowledge William Haller for his insightful discussions and help throughout this research experience.

Hybrid-Electric Propulsion Test Bed

Keith Roussel

The US Army seeks to build unmanned aircraft systems (UASs) that use hybrid-electric propulsion technology. Research has shown that incorporating this technology is the most effective way to enhance UAS capabilities, making it a more effective tool for the military. A test bed will be constructed for gathering data on various parameters that affect a hybrid-electric system in parallel. Such parameters include the following: combining of torque, motor control, power consumption, battery efficiency, and propeller noise. Design of the test bed has led to the creation of four systems that are key to its operation: mechanical powertrain, electric-power distribution, controls network, controls programming. This one-of-a-kind system will be completed by the end of 2019. Its diverse capabilities will make it a useful research tool in the advancement of hybrid-electric technology.[1]

I wish to acknowledge the mentorship of Dr Constandinos Mitsingas, Dr Cherish Qualls, Adan Garcia, Garrett Allison, Matt Resurreccion, and Albert Adcock.

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Machine-Learning-Assisted Threat Prediction for Active Protection Systems

Shaina Rudman

Due to rapidly growing number of antitank guided missiles equipped with various guidance mechanisms and rocket-propelled grenades with different warhead types, accurate prediction of incoming threats for active protection systems is necessary for proper use of countermeasures. The research objective was to develop timely predictive capability of adversary weapon systems based on sensory data. The author proposed a Gaussian Naive Bayesian predictive model along with elements of hypothesis testing to evaluate the conditional probability that an incoming threat falls into a specific class. The proposed model used a recursive Bayesian updating scheme. Velocity profiles and launch-signature data on incoming threats were used to evaluate the efficacy of the model. Due to limited access to data, a randomization scheme was employed to leverage existing data to produce sufficient training and testing data for machine learning. The author evaluated the convergence of learning parameters and determined the probability of occurrence over the time-series data among five classifiers of study. The training models accurately predicted threat classes based on velocity profile within minimal time after threat launch. Because of sparse available data, launch signatures proved to be a less-illuminating discriminant, but in combination with velocity profile, they improved minimum classification time slightly.

I wish to acknowledge the mentorship of the DOD High-Performance Computing (HPC) Modernization Program and HPC Internship Program for funding and the mentorship of Dr Michael Chen throughout the course of my internship.

Distributed Smart Sensor Node (SSN) Web Viewer

Nicholas Ruei

The US Army's concerted efforts to modernize its Warfighters and overall infrastructure at a 21st-century pace have been accompanied by a rapidly increasing demand for power. Robust and maintainable power systems and delivery are essential to the operation of nearly all equipment and advanced technology employed by the Army.

The Distributed Live Animated Multi-Phasor (dLAMP) software suite is designed to complement SSNs: devices capable of reducing fast data streams into easily distributed information. The web-based distribution of dLAMP offers a streamlined visualization of sensor data, is device agnostic, and can be easily viewed and understood. Information regarding power use and consumption can be used to drive informed decision-making. However, this requires quick analysis of historical power-data trends and assessment of power quality across a network of sensors, conducted at any time in any place.

A detailed summary report was developed for each SSN that offers comparisons to trends based on monthly data and alerts users to anomalies regarding power usage and quality. The data-retrieval methods and mobile layout of the web application were rebuilt using indexed database timestamps and down sampling, which sped up response times by over 300%, substantially improving the overall user experience.

I wish to acknowledge the mentorship of Dr Brandon Parks for his mentorship and overall guidance.

Evaluation of 10% Ordnance Gelatin for Use in Studying Behind-Armor Blunt Trauma (BABT)

Noah Schneider

Due to its mechanical and optical properties, ordnance gelatin (10% by weight) has been used for the testing of BABT as a surrogate for the human body.[1] The main focus of this study is to characterize the repeatability of gelatin blocks for BABT impacts. First, the repeatability of the single-use blocks versus blocks exposed to multiple impacts (five in this study) of the same nominal impact velocity on the same armor model was evaluated and compared. Fresh blocks had average backface deformation (BFD), BFD-velocity, and bullet-velocity values of 34.99 ± 2.80 mm, 59.53 ± 4.60 m/s, and 323.76 ± 6.78 m/s, respectively. Reused blocks had average BFD, BFD-velocity, and bullet-velocity values of 36.23 ± 3.17 mm, 59.53 ± 6.70 m/s, and 317.47 ± 6.46 m/s, respectively. Comparing with a two-tailed t-test, there was no statistically significant difference in BFD or BFD velocity when using a fresh gelatin block versus a pretested block in a controlled setting. The next phase of the study will investigate the repeatability of the gelatin block across several different velocities and whether the response of the gelatin is linearly correlated to those velocities. The results from this study will improve the confidence in our models of BABT loading to evaluate the potential for injury from BABT impacts.

I wish to acknowledge the mentorship of Dr Cynthia Bir, Keck School of Medicine, University of Southern California (USC); Dr Karin A Rafaels, ARL; Rodrigo Vilallta, Keck–USC/ARL West, Playa Vista, California; and Madeline Chen, University of California, Riverside.

[1]Cronin D, Falzon C. Characterization of 10% ballistic gelatin to evaluate temperature, aging and strain rate effects. Exp Mech. 2010;51(7):1197–1206.

Additive Manufacturing (AM) of Chopped Carbon-Fiber (CF)-Reinforced Epoxy Composites

Caleb Schurman

Typical AM of plastics uses thermoplastic extrusion to create a part. These parts usually display anisotropic material properties and voids between rasters, and possess inferior mechanical properties as compared with injection-molded parts. CF-reinforced epoxies provide increased mechanical strength and elastic modulus over thermoplastics; however, it becomes difficult to use these CF–epoxies for AM since they remain liquid in their uncured state, leading to the loss of form of the printed part. Manipulating the rheological properties of CF–epoxy may allow for the printing and retention of shape necessary for AM of structural parts. The goal of this research is to develop an epoxy-reinforced system with the appropriate pot life and rheological properties such that the resulting printed part will not only retain its shape, but will show enhanced mechanical performance over traditionally manufactured chopped-CF–epoxy composites. Initial material properties and fabrication parameters, such as neat epoxy viscosity, weight percent of chopped CF, and CF aspect ratio, were varied to control the composite rheological properties. Mechanical characterization was performed to determine the strength and elastic modulus of the printed samples.

I wish to acknowledge the mentorship of Dr. Frank Gardea

Optical Properties of Plastics

Tara Sherbondy

ARL is developing a catalog of materials and their corresponding optical properties through the wavelengths of 190 nm to 15 μm. This catalog will be helpful for easy access to the optical properties of these materials for simulations or other purposes. To acquire the ultraviolet (UV)-to-infrared spectra and fluorescence spectra in the UV-to-visible range, the samples were placed in each measuring instrument and scanned as is. Some of the samples were too thick to get an accurate transmission spectrum, so they were milled down by varying amounts to ultimately reduce the amount of material absorbing the light and gain clearer transmission spectra for selected samples. The instrument used to obtain the transmission spectra was the UV-3101 spectrophotometer made by Shimadzu. The instrument used for collecting spectra in the IR wavelengths was the Fourier transform infrared made by Thermo Fisher Scientific. The fluorescence data was collected from a FS5 spectrofluorometer made by Edinburgh Instruments. The data from these instruments was saved and analyzed by plotting the spectra together to establish unique or shared spectral features to help identify the different materials. The data collected showed that materials that are opaque in the visible due to dyes are opaque at all wavelengths measured. Density of polyethylene is reflected in the different spectra of low-density, high-density, and ultra-high-molecular-weight polyethylene. It can also be said that all samples, regardless of dyes, are fluorescent to some degree.

I wish to acknowledge the mentorship of Zachary Quine for his guidance and technical support during my internship at ARL this summer.

Conducting Cyber-Force Mission for Cybersecurity on Cyber Virtual Assured Network

Dawn Silverman

The evolution of networks and devices, their use in distributed open architectures, and the sophistication of cybercriminals interact in ways that expose the Army's critical infrastructure to worrisome cybersecurity attacks. In response to this growing risk, survey missions are performed to search for network vulnerabilities and ensure that assigned security duties will be performed in accordance with Army standards and regulations. The humans' role in completing these survey missions is critical, so it is important to be able to assess their performance and determine what factors makes them effective. An assessment methodology is proposed with some recommendations for methodically securing government networks in general. A specific option for assessing cyber protection teams would be to create a realistic scenario using a virtual network. This will allow for the facilitation of attacks against a virtual network and the exploitation of vulnerabilities. It will also allow for the exploration of protective measures for the defense of network devices to ultimately assist researchers in protecting the Army's critical infrastructure. The long-term objective is to better secure the future of Army networks, the critical infrastructures that depend on this technology, through more focused cybersecurity assessments.

I wish to acknowledge the mentorship of Norbou Buchler, Blaine Hoffman, Claire La Fleur, and Jason Ellis. For all of their support and encouragement, I extend my deepest gratitude.

Smart Sensor Data Viewing and Access Application

Abigail Snellman

In order to intelligently measure and assess electric power consumption at Army bases and facilities, ARL has developed the Autonomous Real-Time Electric/Magnetic Integrated Sensor (ARTEMIS) Mobile Unattended Ground Sensor (MUGS), a smart sensor that can process electric- and magnetic-field data. The MUGS units are capable of storing up to 10 days of raw data on onboard micro secure-digital (SD) cards. Additionally, they are embedded with the Visualization and Processing for Embedded Research Systems (ViPERS) web application, which provides a framework for implementing custom software modules. Raw data could previously only be retrieved by physically removing the SD cards from the system and accessing the data files directly. To allow users to view, access, and analyze the data, a new page was added to ViPERS. From this page, users view all files currently on the SD cards and download them through their web browser. Users are also provided options to automatically back up data from the SD cards or directly stream raw data files to a hard disk drive if one is attached to the system. This feature enables months of additional data storage. Finally, an application programming interface was created to allow users to search for a time window of interest, then read, process, and visualize the data.

I wish to acknowledge Brandon Parks for his mentorship throughout the summer as well as for teaching me all of the phasor-processing and ARTEMIS–MUGS system architecture knowledge that I needed to accomplish my goals for this project. I would also like to acknowledge Kevin Claytor for providing me with all the ViPERS assistance that I needed to integrate my code into the working web application.

From Waste Steel to Materiel: Agile Production Enabled by Additive Manufacturing

Karl Sundberg

There is a need to improve self-sustainability of the Warfighter in theater, increase operational readiness, reduce the logistics tail, and enable manufacturing on demand at the point of need. The presented work is part of a Strategic Environmental Research and Development Program project to demonstrate that metal waste streams generated at forward operating bases and battlefield scrap can be reused by field-capable manufacturing processes and enable the fabrication of replacement parts in the field through stereolithography-enabled investment casting. The benefits of this project will reduce the military's logistical effort by enabling the reuse of scrap steel, prove the feasibility of field-capable manufacturing, reduce equipment downtime, and increase operational readiness.

I wish to acknowledge the mentorship of Jian Yu.

Improved Automated Nondestructive Characterization of Ceramic-Armor Microstructures

Braden Thomas

Nondestructive characterization of ceramics is an important tool in determining the future direction of the materials and processes used and for creating better armor. Variability in ceramic-armor performance necessitates that engineers design armor around the statistical chance of a low-performing part. If every manufactured part were fully characterized, the manufacturers could implement quality control to minimize this variability. Although traditional microstructural characterization is slow and destructive, ARL has previously developed automated technology that determines ceramic microstructures through electrical measurements. This unique and complex robotic system needed to be moved to a larger lab for updating and streamlining of the wiring. In addition, construction began on a second system capable of processing larger curved parts common to the ceramics used in Soldiers' torso plates. After updating, the existing system characterized hundreds of silicon-carbide samples from an industrial manufacturer's multiple batches. The trends in the data showed significant variability within and between the batches that could equate to variability in the performance. Future work will determine the root cause and minimization of this variability as these samples are used in control targets for the development of projectiles.

I wish to acknowledge the mentorship of Michael Golt for his guidance and input. Special thanks to Kris Behler, Bobby Gamble, and Taylor Shoulders for technical support. I would also like to thank the Army Educational Outreach Program–College Qualified Leaders program for giving me the opportunity to perform research with ARL.

Characterization and Modeling Commercially Available Components for Stirling Cycle Heat Engine's Cooling Loop

Kevin Thompson

The Army is interested in providing Soldiers with greater flexibility in sourcing energy for equipment ranging from robots to radios. Using thermal-energy conversion technologies—specifically, the Stirling cycle engine—a conceptual propulsion system is being developed and integrated into an Army-relevant vehicle (e.g., Squad Mission Equipment Transport). This work focuses on characterization efforts for a cooling loop to identify whether commercial off-the-shelf (COTS) hardware provides adequate performance or if specialized materials and hardware must be explored. The goal of this work is to develop a function to predict thermal efficiency of the cooling loop by characterizing heat-transfer performance as a function of ambient temperature, flow rate, and air flow. The cooling loop's components for the heat engine consist of a radiator, fan, pump, sensors, and controller. The data acquired determines the cost function of the radiated heat using ambient temperature, flow rate, fan power, and desired delta T (between radiator inlet and outlet ports) as the variables. The initial cooling loop will be built using COTS components to determine size, weight, power, and cost to identify baseline performance.

I wish to acknowledge the mentorship of Justin Shumaker, Dr Jaret C Riddick, and Wosen Wolde for their continued mentorship, patience, and support throughout this research project. I am also thankful to all members of the Vehicle Technology Directorate for helping make this a memorable experience.

Fabrication and Characterization of Non-Explosive, Nonflammable Aqueous Lithium-Ion Batteries

Robinson Tom

Nonaqueous lithium-ion batteries (LiBs) play a major role in portable electronic devices and micro-grid-scale energy storage. Due to the high nominal cell voltage, reasonable energy density, in-depth charge/discharge cycles, lack of memory effect, and low self-discharge rate, nonaqueous LiBs are the most preferred energy-storage devices in many technology sectors. At the same time, nonaqueous LiBs are directly affected by safety issues; they may catch fire and explode at any time if the device has manufacturing defects or is used improperly. Aqueous LiBs have no flammability-related safety issues, compared with nonaqueous LiBs. Aqueous LiBs are non-explosive and nonflammable, and promise to provide equivalent amount of energy density, cycles, and shelf life as state-of-the-art LiBs. Herein we present the fabrication and characterization of aqueous gel electrolytes for nonflammable aqueous LiBs. We have tested various related monomers and cross-linkers coupled with the aqueous electrolyte to fabricate battery electrolyte material. We studied the lithium-ion conductivity, impedance properties, electrochemical stability, and battery functionality of the synthesized gel-electrolyte material. Aqueous gel batteries were constructed using our synthesized gel electrolytes and common battery electrode materials. Our results show that the choice of monomers affects the ability of the solution to form a solid gel, and the polymer fraction of the gel has a direct effect on the conductivity of lithium ions and the charge/discharge functionality of the battery.

I wish to acknowledge the mentorship of Drs Thiagarajan Soundappan and Arthur von Wald Cresce.

Coating Behavior Prediction and Monitoring Using Terahertz Time-Domain Spectroscopy (THz-TDS)

Lucas Tommervik

Chemical agent–resistant coatings (CARCs) are required on all deployable US military equipment and are subject to degradation through extended use. The goal of this project was to establish THz-TDS as a valuable tool for monitoring CARC viability and predicting CARC failure. CARC failure can be a result of chemical inhomogeneity, defects in the CARC–substrate interface, or defects resulting from sample-surface preparation. Prediction of CARC failure from CARC–substrate interface defects can be accomplished by directly imaging the CARC and underlying substrate. Terahertz wavelengths are long enough to penetrate most materials, while still short enough to provide a high-resolution image. Several samples have been investigated to show the viability of terahertz imaging for CARC failure prediction. CARC viability can also be determined by characterizing CARCs for their dielectric properties in terahertz and correlating outliers in these properties to chemical inhomogeneity of the coating. We also investigated environmental effects on CARCs using THz-TDS. The THz-TDS response of a coating treated with 400 h of ultraviolet radiation was compared with that of an untreated coating. The results suggest that THz-TDS is a reasonable and valuable tool in the nondestructive evaluation of CARCs through both prediction and monitoring.

I wish to acknowledge the mentorship of Daniel Schreiber.

Dual Gate Driver for Power Transistors in a Half-Bridge Configuration

Candice Tranks

The goal of this project was to develop a new universal gate driver to replace and provide improvements over a presently used dual insulated gate bipolar transistor (IGBT) gate driver. The gate driver provides the transients for turn-on and turn-off of switch-mode power transistors. The gate-driver circuit's schematic was developed through a comprehensive review of conventional designs and the analysis of various component datasheets. The most favorable features of these conventional designs were adopted for the new design. Autodesk Eagle and SolidWorks modeling and design software was used to optimize component placement and minimize volume. The circuit was rated to drive gate currents of up to 9 A and was developed to mechanically mount to a 300- or 400-A half-bridge IGBT module. For versatility, terminations for the common TO-247 device package (used for both metal–oxide semiconductor field-effect transistors [MOSFETs] and IGBTs) was integrated into the new design. An adjustable negative voltage regulator and potentiometer were incorporated into the design to provide a user-selected turn-off bias to accommodate IGBTs and both silicon and silicon-carbide MOSFETs. There is also the option of dividing the circuit into two single gate drivers. An optocoupler and DC–DC converter provide galvanic isolation of greater than 1200 V between the control circuit and the power components. Protection from reverse polarity of the input power connections was also provided. Two Zener diodes were added for protection from transient gate voltages. Component footprints were added to optionally implement reduced turn-on or turn-off gate-transition times. Compared with the gate driver presently in use, the new gate driver provides more functionality, versatility, a 25% reduction in circuit board area, and a 62% reduction in volume. The new design also reduces cost by over 40%.[1–7]

I am grateful to my mentor Damian Urciuoli, who taught me discipline, determination, professional manners/respect, and so much more that has and will continue to help me succeed. I want to thank Don Porschet, who always encouraged me to do my best. And, I extend a very special thank you to Dr Wes Tipton.

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Reducing Vibrations by Implementing and Augmenting Nonlinear Structures

Chinonso Ude

A resonance frequency is the unique frequency that a material vibrates at, at which the amplitudes of vibration are the highest and, in the case of Army vehicles, most severe. Most traditional dampers are built to counteract a single major resonance frequency for the devices they are attached to, but with the application of nonlinear structures, a wide range of stiffnesses can be taken on by a single material, thereby counteracting many frequencies of vibration that an aircraft might experience (resonance frequency is a function of stiffness). This study intends to examine how nonlinear structures can be effectively applied, improve their deployment by designing unique structural configurations, and test the further application of another emerging vibration-damping technology (magnetorheological fluid) to understand how the two concepts might work in tandem.[1,2]

I wish to acknowledge the mentorship of Dr Robert Haynes. I am grateful to Dr Jaret Riddick and to my university advisor, Dr Norman Wereley. Lastly, I thank Dr Asha Hall.

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Calibration of Commercial FlexiForce A301 Sensors for Biomechanical Research

Alexandra Marion Vest

FlexiForce A301 sensors (FF sensors) are used for injury-biomechanics research at ARL, but a rate-dependent calibration for voltage drop to force or incident stress is currently lacking and limiting their function. For this research, FF sensors were tested under various conditions: 1) as received, 2) covered with Kapton tape, 3) covered with Kapton tape and adhered to aluminum 7075-T6 with Loctite cyanoacrylate adhesive, and 4) covered with Kapton tape and adhered to 5-mm polymethyl methacrylate (PMMA) discs. Uniaxial compression testing was conducted at quasi-static strain rates (10^{-3} to 10^{-1} s^{-1}) on a load frame (Instron 8871) and at higher strain rates (10^{3} to 10^{5} s^{-1}) on a split-Hopkinson pressure bar. Bare FF sensors returned the highest voltage drop to incident stress ratio, thus having the lowest force range of all conditions. Kapton-covered sensors with and without the Loctite adhesive increased the overall force range of the FF sensors. The lower-impedance PMMA backer material further decreased the voltage drop to incident stress ratio. Lastly, the calibration curve's behavior became increasingly linear with increasing strain rate. Future testing will incorporate machined angled platen pairs to investigate the effects of increasing shear stresses on the response of FF sensors at low- and high-strain rates.[1–7]

I wish to acknowledge the mentorship of Drs Andrew Brown and Karin Rafaels for their continued support and guidance and thank Allan Gunnarsson for his help with the experiments.

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Drowning Out the Noise: Refining Analytic Reporting with Enhanced Content Processing

Myah Vogt

Information overload, or difficulty in effectively handling information due to its sheer quantity, is a common occurrence today and it is no surprise: 90% of the data in the world has been generated in just 8 years.[1] General-purpose information processing technology can withstand only so much of this technological tsunami and ends up having limited effectiveness for specific technical domains and genres, and is unlikely to have the ability to identify noisy input and recover from its effects. This, in turn, reduces situational awareness for troops in time-sensitive missions. To address this problem, we propose adapting lexical parameters for domain, genre, and research facet. This approach permits automata to operate as designed, and provide the requisite functionality.

We test the extent to which we can improve the accuracy of analytic reporting for military decision support by mimicking enhanced content processing to deliver programs that meet the needs of users like Soldiers and commanders. We hope to create a framework that incorporates the concept of "second-mile service" for models that will intuitively identify, preprocess, process, and post-edit data into easily interpreted results that mitigate risk, with the potential outcome of improving the timeliness and accuracy of information delivery, ultimately reducing uncertainty on the battlefield.[1]

I wish to acknowledge the mentorship of colleagues at ARL/Adelphi for their wisdom and expertise on this project, with special gratitude to Meaghan Bowman.

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System-Level Modeling of Phase-Change Material Composites Using a Two-Temperature Model

Justin Wang

At a system scale, explicit thermal modeling of paraffin–metal composites is computationally expensive since millions of individual elements must be simulated on the subscale level to understand the local material interactions. One solution to this challenge is to model an effective medium—or theoretically equivalent material with homogenized properties—allowing a much coarser element size. However, effective media with a single-temperature degree of freedom are unlikely to capture the full range of dynamic responses due to the widely disparate transient responses of the metal and paraffin. We propose a new, coupled two-temperature material model (TTMM), where each distinctive element therein is designed to simultaneously track the temperatures of both metal and paraffin. The Nelder–Mead algorithm is used to tune the TTMM in conjunction with a separate explicit model in ARL ParaPower to arrive at a best-fit K, the energy-coupling coefficient that depends only on subscale composite structure and material. The objective is to determine a threshold on K (i.e., subscale structure) for any given set of environmental conditions that necessitates a TTMM in place of a single-temperature effective medium to model the dynamic system-level thermal response.[1,2]

I wish to acknowledge the mentorship of Mr Morris Berman, Dr Michael Fish, and Ms Melissa McCann.

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Optimal Sensor Placement Using the Art Gallery Theorem

Todd Welch

The Art Gallery Problem is one of the earliest and most influential problems in sensor placement. Therefore, it is a method used in determining optimal sensor placement. The focus of this study is to create an algorithm that could be used in creating a code that will give one the optimal location for an observer to be placed. Many techniques have been performed using the Art Gallery Theorem. Those techniques were used to create different theorems to solve the problem at hand. In this study, it is shown how one can use different theorems to reach one ultimate goal. I use different theorems to show how they work hand in hand to eventually develop a code that will help in optimal sensor placement.

I wish to acknowledge the mentorship of Ms Natasha Bradley and Dr Mulugeta Haile. With their guidance and leadership I was able to achieve all of my goals for the summer, and I am thankful for my experience in the Vehicle Technology Directorate.

Parallelized Uncoupled Fluid-Structure Interaction (FSI) Analysis of Adaptive Structures

Trent D White

The ability to adapt to a sensed change in environment or obstacle is a fundamental capacity of biological systems that enables survival in harsh conditions and avoidance of predators.[1] While there are numerous technological challenges to the development of complex adaptive air vehicles,[2] several involve the design and analysis of the vehicle structure. One of these challenges, and the focus of this research, is rigorously analyzing the structural response of the vehicle through the morphing process due to the coupled relationship between the exterior shape of the structure and the pressures acting on the structure.[3] Fortunately, a potentially revolutionary method called Uncoupled Fluid-Structure Interaction (UFSI) being developed at Texas A&M University enables parallelizable analysis and limits the number of job submissions to the fluid solver, both of which reduce computational time significantly. The objectives for this summer internship program were to continue the development of UFSI by incorporating a new fluid solver (i.e., Star-CCM+), restructuring the code to enable parallelization on a high-performance computing (HPC) cluster, and extending the algorithm to 3-D UFSI analysis of a NACA 0012 airfoil. The work accomplished this summer lays the foundation for incorporating this new method of FSI analysis to 3-D adaptive wing structures.

I wish to acknowledge Dr Todd Henry for mentoring me this summer and his dedication to ensuring my time at Aberdeen Proving Ground was successful. I would also like to thank the HPC Internship Program for providing the funds that gave me the opportunity to come to Aberdeen Proving Ground. I would like to thank Dr John Hrynuk for assisting me with computational fluid dynamics simulations, Dr Chris Shumeyko for assisting me with the HPC cluster, and my faculty advisor Dr Darren Hartl for his guidance on this project.

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Smart Materials Integrated into a Carbon Fiber Polymer for Measuring Structural Damage

Brandon Williams

Carbon-fiber–reinforced polymers (CFRPs) have become an essential part of designing and engineering lightweight rigid bodies, predominantly in the aerospace and automotive industries. Typical epoxy-based CFRPs exhibit virtually no plasticity, with minimal strain to failure. Although CFRPs with epoxy has high specific strengths and elastic moduli, the brittle fracture mechanism presents unique challenges in failure detection for the Army's vertical lift vehicles since failure occurs catastrophically. Current state-of-the-art structural health monitoring is intrusive to the surface of the part and requires electrical connectivity. The Army uses a "safe-life" interval-based service methodology where components are replaced with a usage spectrum rather than the component's actual state of structural health. This paper explores a method for solving this problem by investigating the possibility of embedding Terfenol-D (~100 μm in diameter), a magnetostrictive material, into the CFRP for embedded noncontact structural health monitoring. For baseline results, the change in localized (32 mm^2 field of view) magnetic flux was only 0.02% for an applied load of 0%–100% of the material's ultimate tensile strength (UTS). For quasi-static testing procedure of specimen 5714 (15 wt% Terfenol-D embedded CFRP) on a 0%–40% loading interval of the material's UTS, there was an observed localized (32 mm^2 field of view) magnetic flux gradient of more than 5 mT (4%) with a reversible flux of 100%. For quasi-static testing procedure of specimen 5714 (15 wt% Terfenol-D embedded CFRP) on a 0%–70% loading interval of the material's UTS, there was an observed localized (32 mm^2 field of view) magnetic flux gradient of more than 3 mT (2%) with a reversible flux of only 25%. Terfenol-D embedded CRFPs have shown promising results for detecting instantaneous levels of degradation. Acoustic emission, X-ray computed tomography scanning, finite element analysis, and analytical modeling were used to validate the observed results.

I wish to acknowledge the mentorship of Dr Myers and my mentors Dr Asha Hall and Mr Michael Coatney, as well as the staff and facilities of ARL for their mentorship and inspiration as well as for support in completing my research. I am highly thankful for Clemson University and ARL; without the support of these two institutions, the completion of my research wouldn't be possible.

Deep Reinforcement Learning for Autonomous Navigation with Light Detection and Ranging (LIDAR)

Carter Wilson

State-of-the-art robotic navigational methods currently require manually constructed policies to determine what action to take, which are difficult to create and often do not account for every case. This research aims to develop and assess the success and feasibility of a method to train mobile robots to navigate unfamiliar environments with deep reinforcement learning. This allows a robot to develop policies on its own based on trial and error and would be a continuous function that can interpolate unknown values. Research was conducted using a Jackal robot in an indoor office environment with a LIDAR sensor to detect the environment. The model was trained in a simulation, using double deep Q-Learning[1] on a neural-network architecture designed to take raw point clouds as input, inspired by Pointnet.[2] Many variations of the model, parameters, and reward system have been trained, with the latest still in training. While some models were ineffective, the latest versions are very successful in the simulation. Transfer from the simulation to the real world is also mostly successful in both hallway environments similar to the training environment and in a cluttered room, which was not in the training environment. The robot goes forward while avoiding walls with a bit more inconsistency and jittering than in the simulation. Although reinforcement learning still has many limitations for this application and does not allow the fine-grained control that is sometimes needed, this research demonstrates great promise for its application to general navigation and exploration.

I wish to acknowledge the mentorship of Phillip David.

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Hybrid Electric Optimization Tool for Unmanned Aerial Vehicles (UAVs)

Jamaya Wilson

Hybrid electric propulsion systems are of increasing interest in the development of efficient aircraft powertrains, particularly for UAVs used for surveillance tasks. By taking advantage of both an electric motor and internal-combustion engine, hybrid-electric propulsion systems provide not only a benefit in fuel savings but also a reduction in takeoff noise and emission levels. However, the addition of another source of energy increases weight and space limitations, which can cause vast problems in aerial vehicles. These constraints make optimization essential to the functioning of the vehicle, which is often needed to achieve the operational goals of range, endurance, and other specific mission requirements. In this study, we used an optimization tool created in collaboration with the Korea Advanced Institute of Science and Technology to further study various configurations of a hybrid-electric powertrain. Understanding of the tool is critical not only for using it but validating the data collected. The program was tested for irregularities and then integrated with additional data from various electric motors and internal-combustion engines.

I wish to acknowledge the mentorship of Dr Constandinos Mitsingas for his valuable and constructive suggestions during the planning and development of this research project.

Synthesis and Characterization of Conductive Polymers

Catherine Wraback

Miscible blends of ionically and electronically conductive polymers were synthesized. Post-sulfonation of thermoplastics was carried out to enhance ionic conductivity and improve solubility in organic solvents. These thermoplastics have inherently large tensile moduli that impart mechanical stability to the brittle electronic domain. The degree of sulfonation can be optimized by controlling reaction time, reactant concentration, and temperature. Measuring conductivity as a function of these parameters provides a deeper understanding of the role of the various sulfonation parameters. Blending highly sulfonated thermoplastics with electronically conductive polymers can result in greater conductivity and improved mechanical properties. Semi-interpenetrating polymer networks, or the polymerization of a monomer in the presence of cross-linker, initiator, and elastomeric polymer, is another promising method to achieve tunable mechanical and electrochemical responsiveness. Alternating-current impedance was measured to test conductivity of the various blends and polymeric networks in dry, hydrated, and acidic environments. Mass uptake and volume change were investigated by weighing and measuring thickness before and after exposure to acidic and neutral conditions. Morphology and phase were characterized using a scanning electron microscope and X-ray diffraction, respectively. This combination of mechanical robustness and conductivity make these materials promising in soft actuation and flexible electronic applications.

I wish to acknowledge the mentorship of Drs Alex Langrock, Haval Kareem, Luther Mahoney, Dat Tran, Daniel Hallinan, and David Mackie.

Signal-Processing Algorithms to Extract Heart Rate from an Accelerometer-Based Sensor and Convert to Musical Notes

Julie Young

The project's goal is to develop algorithms converting heart-rate frequencies to musical note values. The Advanced Acoustical-Mechano (ADAM) sensor consists of a three-axial accelerometer embedded in a soft, flexible membrane that can be adhesively applied to the body like an adhesive bandage. Since it is comfortable, wireless, and simple to use, the ADAM sensor is a promising wearable device for studying human physiology and behaviors. The device can be placed in various locations, measuring different biosignals; if placed directly below the left pectoral muscle, the sensor extracts strong heartbeat signals, having minimal interference from general body motion, talking, and other biosignals such as respiratory rate. The accelerometer signal is collected and filtered to reduce noise. The filtered signal is stored into a list and compared with musical note frequencies that are associated with notes that are two octaves higher to return a list of transposed notes that each point is closest to. The program can be used for future studies as a nonintrusive method of receiving a unique representation of the wearers' heart rate.

I wish to acknowledge the mentorship of Timothy Mermagen, David Chhan, and Jeremy Gaston. I would also like to thank Joshua Miller, Paul Groves, and Thomas McCarty-Gibson for assistance in comprehension and development of the program.

Variations in Indentation Hardness Due to Indenter Tip's Geometry, Material Class, and Testing-Rate Regime

Ryan Zegarski

In the materials research community, the hardness of materials is determined via indentation testing. Hardness testing uses diamond, steel, or carbide indenter tips that create an imprint under a known load. The load, indenter tip's geometry, and indent size are then used to calculate the material's hardness. Of the four major indenter geometries used in hardness testing, the diamond-tipped Knoop and Vickers geometries are primarily used in ceramic research. The Knoop tip has a lower stress concentration and utility at higher loads, making it preferable compared with the Vickers tip. However, the Vickers tip has been used for both quasi-static and high-strain-rate (i.e., dynamic) testing of a variety of materials, while no high-rate data has been recorded using the Knoop indentation method. This research aims to collect both quasi-static and dynamic hardness data using a Knoop indenter tip on a variety of materials to compare with the available Vickers indentation data. This data is compared with other hardness data to establish credibility in the experimental setup and procedure. Subsequently, comparisons across three topics are drawn for the collected data: 1) Knoop versus Vickers hardness, 2) response of metals versus ceramics, and 3) quasi-static versus dynamic response.

I wish to acknowledge the mentorship of Michael Golt.

FY2020 Student Abstracts

Machine Learning Frameworks for UH-60 Bearing Data Analytics

Benjamin Albia

Helicopter test bearings were monitored via an acoustic emission sensor and accelerometer over a period of several hundred hours. The acoustic emission and vibration data gathered was used to train various deep learning frameworks to reliably predict bearing age and/or classify bearing stage of life. Six deep neural network structures were developed, including fully connected, 1-D convolutional, and 1-D dilated convolutional networks for bearing age regression and stage classification. The developed data-analytics frameworks demonstrate salient performance: 99% accuracy in stage classification and a root-mean-square error of only 20 h in age prediction using acoustic emission data.[1]

I wish to acknowledge the mentorship of Natasha Epps-Bradley, Asha Hall, and Adrian Hood.

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Experimental Methods for Image Analysis of Two-Phase Metallic Microstructures

Nathaniel Bass

In many metals, there are two phases at room temperature after heat treatment to form them into a desired shape: alpha and beta. Traditionally, the process of categorizing visual features by phase has been performed manually according to ASTM (or other) standard methods of counting and measuring microstructural elements. The benefit of this approach is that humans can easily recognize phase patterns, but the work is tedious and puts practical limits on the quantity of data available for analysis. However, much current research involves digital image processing. Many of the current automated methods can easily create large quantities of data, but sometimes at the cost of quality because almost all automatic processes to improve clarity, vary brightness, or highlight edges actually reduce the amount of information in the image. Here, we employed a combination of machine learning and standard image processing techniques to attempt to provide large quantities of high-quality data. By training a segmentation classifier on features from several images, we delineated between the alpha and beta phases with higher accuracy than in previously used operations and collected the size, shape, and orientation data desired.[1–4]

I wish to acknowledge the mentorship of Dr Brady Butler, Dr James Paramore, Dr Jon-Erik Mogonye, Trevor Hastings, and Daniel Lewis for their advice and guidance on this project. I would like to further thank Trevor Hastings for supplying the images on which the work was tested. Finally, none of this would have been possible without the funding and support of the US Army Educational Outreach Program's College Qualified Leaders training.

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Planning for Emergent Unmanned Aerial Vehicle (UAV) Swarm Aggregation

Logan Beaver

The study of emergent behavior is an open question in the field of control and decentralized autonomous systems. As an extension of our research last year on optimal flocking behavior,[1] we have proposed a general version of the flocking problem to drive a swarm of uncrewed aerial vehicles to a target point in finite time. To achieve this behavior, we have implemented a constraint-driven optimal control approach, where the agents seek to minimize energy consumption while system-level behavior is imposed through trajectory constraints. The primary benefit of this approach is that the system- and agent-level objectives do not align. Thus, the system-level behavior is expected to be robust to disturbances at the agent level. We present a generalization of the results presented in Beaver et al.[1] and a strong theoretical result that significantly simplifies the process of generating energy-optimal trajectories.

I wish to acknowledge the mentorship of Chris Kroninger for his valuable support this summer. I would also like to acknowledge Mike Dorothy and John Gerdes for their helpful technical discussions and guidance.

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Mending the Gap: Team Resilience and Team Cohesion in Human–Autonomy Teams

Samantha Berg

This paper investigates the role of team cohesion and team resilience in human–human teams and seeks to expand these concepts to human–autonomy teams, which consist of both human and autonomous team members. In recent years, there has been increased interest in adopting human–autonomy teams (HATs) into the military; however, it is important to consider that human teams interact and function differently than HATs, and as such, there is a need to understand how these differences impact the development of team cohesion and resilience as both are critical to effective teams. Specifically, the inclusion of autonomous agents into teams fundamentally changes the team dynamic, so there is a need to understand how critical team processes such as team cohesion and resilience emerge within HATs, and subsequently, how they can be measured. Although there are valid and reliable subjective scales for measuring cohesion and resilience in small human teams, they are not applicable in the context of HATs. This paper documents a brief survey of literature on team cohesion and resilience in human teams and current measurement scales, and concludes with recommendations for items that should be incorporated into a HAT cohesion scale.

I wish to acknowledge the mentorship of Dr Andrea Krausman and members of the HAT project team, Drs Cathy Neubauer, Shan Lakhmani, and Kristin Schaefer-Lay, who supported this work.

Learning for Event-Triggered Control with Remote Sensors and Actuators

James Berneburg

Event-triggered control is used to reduce communication cost when communication is a limited resource, such as when sensors and actuators are not collocated, by updating the control input only when necessary, as opposed to continuously or periodically. However, these are usually designed using an emulation approach, where an event trigger is applied to an existing controller, so that the controller and the event trigger are designed separately. Instead, we wish to design both simultaneously to optimize a cost function for greater efficiency. Unfortunately, solving such optimization problems is often intractable, and so we turn to Q learning as a way to approximate the solution. However, learning results for control systems often do not provide guarantees for performance or even stability. Therefore, we wish to design Q learning for systems with remotely located sensors and actuators in order to learn both a control input and an event trigger, with theoretical guarantees on the stability of the system.

I wish to acknowledge the mentorship of Alec Koppel.

Artificial Intelligence (AI)-Driven Creativity

Brittney Booker

Neural networks (NNs) have a remarkable ability to learn and generalize from data. This lets them excel at tasks such as image classification, speech recognition, reinforcement learning, robotic dexterity, and so forth. But can NNs learn to be creative? Recent work on deep generative models, such as generative adversarial networks (GANs), has shown that NNs can create data that mimic the sample (population) that it has been trained on (e.g., Deepfake images and fake news). An autocomplete in Google search with the keyword "AI-created" results in several interesting suggestions, such as AI-created music and art. But can AI be creative of something much more novel and useful without significant input from humans? This project is part of an effort addressing this and related questions with an emphasis on the creative design of physical systems. The report presents an extensive literature survey on the current state of the art and art of the possible on AI-driven creativity, innovation, and discovery. The reviews are multidisciplinary so as to include current efforts in the sciences and arts.[1–5]

I wish to acknowledge the mentorship of Dr Qian for encouraging me to pursue this opportunity with the ARL. I would also like to that Dr Mulugeta Haile and Ms Natasha Bradley for mentoring me. The opportunity with ARL has been an eye-opening experience. For that, I am appreciative and grateful.

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Technical Report and Literature Survey on Microwave-Assisted Synthesis for Cyclometallated Iridium Complexes

Alexis Burnette

This summer's virtual project was a continuation of the work performed in the laboratory last year. Tasks to be completed included a technical report of the current standard operating procedure (SOP) and a general literature survey for microwave synthesis of cyclometallated iridium complexes. Highlights of the technical report included step-by-step images to follow with written instructions for simple replication of this procedure. In addition, important characterization methods were emphasized such as thin layer chromatography, nuclear magnetic resonance, and X-ray crystallography. The completed SOP will be useful for replication of the microwave synthesis process and comparison to traditional methods. The second goal was to compose a general literature survey of microwave synthesis for similar cyclometallated complexes. This included exploration of both dimer and acetylacetonate (acac) complexes with ruthenium or iridium metal cores. Prior knowledge and experience with microwave synthesis allowed for preparation of the survey article. Additionally, study of this topic assisted in a greater understanding of microwave synthesis along with a desire to further research sustainable methods of synthesis reactions.[1,2]

I wish to acknowledge Dr Ryan M O'Donnell, Dr Thomas N Rohrabaugh Jr, and the Laser Protection Team for their mentorship during this virtual summer student experience.

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Modeling of Human Behavior

Elliot Burns

The objective of this research is to better understand how human performance and behavior is measured using automated systems. There are five basic models in the understanding of human behavior: biological, psychoanalytic, behaviorist, cognitive-behavioral, and humanistic. It is a difficult task to figure out which of the five basic models would help better understand human behavior in measuring the effectiveness of socio-technical systems in command and control (C2). Human behavior modeling is a key component in application domains such as healthcare and social behavior research. Risk and decision-making play a major role in working an environment using automated systems such as C2 systems. These are areas in which the Soldiers will be taking risks with decision-making. For this research, the goal is to find models that can be coded and demonstrated. There are many ways to measure and understand human behavior in using automated systems, but this work focuses on the most effective ways to measure and model human behavior.

I wish to acknowledge the mentorship of Adrienne Raglin and Somiya Metu.

Protein-Catalyzed Capture Agent–Based Biosensor for the Detection of SARS-CoV-2

Alexis Butler

Protein-catalyzed capture (PCC) agents are synthetic, peptide-based ligands using synthetic epitope target proteins, or SynEp, screened against one-bead-one-compound (OBOC) libraries. The screening process promotes the formation of covalent bonds between SynEp and the OBOC library via in situ azide-alkyne click chemistry for a selected few, resulting in high affinity and selectivity toward the target protein. PCCs have been used in studies as alternatives to antibodies in protein detection because of their proven nature of high sensitivity, selectivity, and affinity. In this study, PCC agents are used as a biosensing device to capture the coronavirus disease 2019 (COVID-19) virus, *severe acute respiratory syndrome coronavirus-2* (SARS-CoV-2). COVID-19 is a global pandemic that has few tests available and diagnoses are not instant. A PCC-based biosensing device will permit for real-time detection of SARS-CoV-2. In this research, a PCC is attached to the surface of the bioreceptor by covalent immobilization. An azide group attached to a silicon nanowire (SiNW) surface through silane chemical modification allows for a stable bond between SiNW and the PCC. PCC agents are most preferred in this case because of their strong stability in various thermal and chemical environments as well as being cheaper and more time efficient to produce.

I wish to acknowledge the mentorship of Sanchao Liu.

Designing a Modular Pathway for the Production of Engineered Chlorophyll

Monique Carver

Chlorophyll, the main photosynthetic pigment found in plants, is a promising molecule to incorporate into military equipment due to its spectral properties and widespread abundance in the environment. However, it is difficult to use when purified from natural sources due to instability. Biosynthesizing chlorophyll in an engineered microbe may enable the production of variant molecules with unique spectral properties or increased stability. We are developing a chlorophyll biosynthesis pathway that uses modular cloning techniques.[1] A proof-of-concept chlorophyll biosynthesis pathway has been previously demonstrated in E. coli[2]; however, it is low yield and inefficient to modify due to how it has been constructed. Our research aims to use Type IIS restriction enzymes and modular part construction to simultaneously assemble multiple chlorophyll synthesis gene fragments and parts into plasmids, and enable mixing and matching of customized genetic modules. This system should support the rapid testing of variant biosynthetic pathways to optimize chlorophyll expression and explore variant chlorophyll molecules. We have adopted the YTK cloning framework[3] to design a set of chlorophyll biosynthesis genes flanked by BsaI restriction sites so that they can be rapidly joined with genetic regulatory elements. We designed sets of standardized genetic "part" modules made of inducible promoters, terminators, and smart algorithm-designed ribosome binding sites to optimize each of the chlorophyll gene's expression. These parts will be assembled using hierarchical assembly methods to generate individual gene expression cassettes and larger pathways with different combinations of genes. The YTK standard ensures compatibility with libraries of parts generated by ARL's Biotechnology Branch, enabling further reuse and modification. Our initial aim is to achieve efficient functionality of the resulting construct in E. coli, enabling on-demand production of chlorophyll. This pathway will be a starting point for further studies into the production of chlorophyll. By swapping genes involved in specific steps of the synthesis pathway we hope to generate chlorophyll variants with different absorbance spectra or improved properties for integration into equipment. The modular genetic pathway will also enable the rapid transfer of this pathway to other organisms, such as bacteria or fungi suited to real-world conditions. This may provide another route for the stabilization of chlorophyll or engineered variants.

I wish to acknowledge the mentorship of Godwin O Ifere, Deborah A Sarkes, and Thomas H Segall-Shapiro.

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Atomistic Probing of Catalytic Activities in Hydrogen- and Oxygen-Terminated Diamond (100) Surfaces

Jenille Cruz

A conductive p-type diamond semiconductor is most commonly used for state-of-the-art radio-frequency field-effect transistors because of its immense surface conductivity when exposed to terminating species such as hydrogen adsorbates. To create a high-conductive p-type diamond surface, it is crucial to understand the surface properties at the atomistic level. Therefore, this research computationally simulates hydrogen- and oxygen-related species on a diamond (100) surface using density functional theory methods to provide an insight into the mechanism of conductive layer (channel) formation. A combination of hydrogen and oxygen species as surface terminators were examined and revealed favorable geometries to understand the most energetically stable structures. Furthermore, these stable surfaces are used to simulate and analyze the electronic properties. The findings of this study will provide insight to the structural as well as chemical interactions of H and OH adsorbates with the diamond surface and ultimately determine the electronic properties that will lead to further improvement of these types of devices.

I wish to acknowledge the mentorship of Drs Mahesh Neupane and Michael Groves.

Characterizing Conductive Properties of Agarose Gel to Use as a Skin Surrogate Phantom

Nate Dimick

Ongoing work is developing a phantom head model to replace the need for humans in testing encephalography (EEG) equipment. A challenge with creating physical models is finding a material that approximates the original, especially in this case, where to be appropriate, the skin of the phantom must be conductively similar to that of humans. Here, we propose use of salt-doped agarose gel and describe characterizing the electrical properties as a function of molecular weight and salt concentration in the context of a human skin surrogate. We are currently searching for materials to serve as a phantom surrogate for the conductivity of human scalp skin, to replace the need for live humans during testing and validation of novel EEG devices. Agarose gel is a material commonly used in processes such as gel electrophoresis. This process utilizes a charge to carry information through a material, and this use of agarose signifies that the gel is a good conductor through its use as a capacitor. This also signifies that agarose could be a good material to use for creating a phantom model of a human head. To get the right material for this model, the electrical properties of the material must be tested to ensure they match the properties one is trying to recreate. In the case of EEG, the most important electrical properties are the components of the constant phase element (CPE): charge transfer resistance, quasi capacitance, and the CPE constant (α). Together, these properties represent how a material works as an imperfect capacitor. Because the electrical conduction between human skin and a typical electrode is based on the charge transfer of chloride ions, it is necessary to characterize how the relative concentration of ions within an agarose substrate changes the observed CPE model. This will then provide an appropriate recipe for mimicking scalp tissue.[1,2]

I wish to acknowledge the mentorship of Dave Hairston.

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Microstructural Evaluation of Additive Manufactured Metals

Lara Draelos

Knowing when a material will fail can save time, money, and most importantly, lives. The ability to predict a material's lifetime can be attained using machine learning. An image of a material's microstructure can be input into the machine learning algorithm and a prediction of the lifetime can be realized. However, this requires training of the machine learning algorithm. To train the algorithm, thousands of images of a material's microstructure taken at known points in a material's lifetime must be taken. To this end, in situ tensile and fatigue tests of 3-D-printed 17-4 PH stainless steel under a high-resolution optical microscope will be carried out, in which images will be taken at various levels of deformation. These images will then be sent to a machine learning group to train the machine learning algorithm. This process can be repeated for any material and can eventually lead to safer, more reliable military machines.

I wish to acknowledge the mentorship of Dr Todd Henry for his guidance and support.

Understanding the Effects of Carbon Coating on the Oxidation of Aluminum Nanoparticles Using Molecular Dynamics Simulations

Benjamin Evangelisti

Core-shell metallic nanoparticles such as nano-aluminum (nAl) are promising candidates as energetic additives for improved combustion and detonation effects because of the high heat of combustion for aluminum (Al) and potentially rapid burning due to their reduced sizes. Previous efforts conducted at ARL have shown the presence of carbon-containing species on nAl surfaces following various plasma surface treatments leading to higher reactivity when compared with non-plasma-treated nAl. This work studies the effects of organic coatings on the oxidation of nAl via reactive molecular dynamics (MD) simulations by representing the amorphous aluminum oxide shell of nAl with a uniform alumina slab using the reactive force field (ReaxFF) method. A Python-based software package, Composite Model Builder and Analysis Toolkit (COMBAT), was utilized in conjunction with the Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS) to generate models and perform MD simulations utilizing the Al/oxygen ReaxFF potential. The models were then simulated in an oxygen-rich environment, and their rates of combustion and resultant products were analyzed. Preliminary results validate the uniform distribution of surface carbon species on the alumina shell of nAl consistent with experimental findings and provide insights to advance understanding of the effects that the surface carbon coating has on nAl oxidation, which showed inhibiting effects against oxygen diffusion into the alumina. Findings from this work suggest that other experimentally identified factors such as surface morphology and alumina phase transformation, which were unable to be taken into account in this work due to MD limitations, should be considered as an ongoing effort.

I wish to acknowledge the mentorship of Dr Chi-Chin Wu. I would also like to thank Mr Dylan Anstine for his technical assistance. The work conducted for ARL was supported by the 2020 DOD High-Performance Computing Internship Program (HIP-20-003) and the ARL 2020 Summer Student Experience Program.

Investigation of Valve Interfaces in Low-Viscosity Fuel Environments

Monica Ferrera

In the realm of unmanned aerial systems (UASs), many areas of research are being investigated to improve current performance in this relatively new field. We explore the realm of low-viscosity, commercially available fuels and their practicality for use in UASs. Despite attempts to move toward fuels that are more easily accessible in combat regions, problems arise with the lubrication capabilities of fuels with low viscosity because they do not operate within the same section of the lubrication regime. Investigating the components of the pump that supplies fuel to the injectors has become the target of our project, specifically valve wear and performance with fuels such as F-24 (a common army jet fuel), ethanol, and dodecane. We are also using tribological methods to find possible coatings and materials that will fare better given the new conditions.

While the high-pressure fuel pump is the source of high-pressure fuel for the internal-combustion engine allowing for many sources of wear, we focus on developing a test rig and procedure for establishing the performance of valves, which are more susceptible to failure than other points of failure. We used both academic and practical use sources to narrow the scope of failure points within this system. Under consideration for the test rig were a Hammer impact method, a voice coil, a purely push solenoid, and then a push-pull solenoid. We established that a push-pull solenoid coupled with an Arduino actuator was the ideal method for this application. Factors under consideration in reaching this decision were calculated values for mechanical requirements such as impact energy and length of actuation, shape and angle of intended wear to most closely replicate that of a real test valve, and fiscal requirements given that this rig would need to be constructed in a non-ARL location and then replicated later.

Next steps for this research field will be assembling the rig from parts ordered, establishing and refining the testing procedure, evaluating the current state-of-the-art materials used in compression side check valves, establishing what characteristics cause failure within the testing substrate, identifying other materials and coatings to improve material performance, and making a recommendation for types of materials or material properties for future testing.[1,2]

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Study of Thermal and Vibrational Properties of Terminated Diamond Surfaces from First-Principle Calculations

Erick Guzman

Diamond is an attractive ultrawide-bandgap semiconductor with properties such as high electron/hole mobility, thermal conductivity, and surface power density, which lend themselves well to radio-frequency applications. Diamond properties surpass current wide-bandgap semiconductors in areas such as electron mobility, breakdown field, thermal expansion, and hole saturation velocity. In diamond surface field-effect transistors (SFETs), surface-based vibrational properties are thought to be the limiting factors in device performance. However, there are limited studies on vibrational properties such as phonon dispersion and Raman spectra on these surfaces, and on thermal properties such as thermal conductivity. Motivated by this, we aim to model the thermal and vibrational properties of diamond surfaces using a modified version of the VASP tool in conjunction with PHONOPY and ShengBTE. These tools successfully predict vibrational properties, within ±5% error for diamond material systems. We present thermal and vibrational data that support the reasoning that different surface terminates modulate the maximum frequency of our structures, and we find that terminate elements with higher mass lead to a higher thermal conductivity. We aim to use our results as a predictive model to make informed decisions on surface types for diamond SFET devices for desired device performance.

I wish to acknowledge the mentorship of Dr Mahesh Neupane (University of California Riveside/DOD) for the continuous support and advice. I would also like to acknowledge support from the DOD Historically Black Colleges and Universities/Minority Institutions Summer Program for the financial and travel support.

The Influence of Dynamic Visual Scene Statistics on Pupil Size

Peter Hanson

Pupillometry is a method for measuring and analyzing changes in the size of the eye's pupil over time, which has potential to contribute to future Army technologies as a source of physiological data to help predict human states. Prior research suggests that the pupil is an effective way to track particular mental activities such as mental load and decision-making. However noncognitive factors such as luminance or scene brightness can also influence pupil size. We evaluated two approaches to determine the influence of scene statistics on pupil size during a 12-min navigation task within a naturalistic 3-D environment. We computed the mean intensity of red–green–blue (RGB) channels within circular windows around the gaze point ranging from 50 to 700 pixels, and then used a pixel-by-pixel approach to examine the relative influence of RGB pixels on pupil size. Our results revealed that blue and green channels had the strongest influence on pupil size within a broad window around the gaze point, whereas the red channel had a much weaker and more focal influence. Pixel-by-pixel correlation maps further revealed that blue pixels above the gaze point had a disproportionate influence, suggesting a "blue sky effect" in the modulation of pupil size.

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Fuel Property Effects on Ignition

Alyssa Hawe

In order to achieve multi-fuel-capable compression ignition engines, the goal of the Versatile Tactical Power and Propulsion (VICTOR) Essential Research Program, we need to understand the complex relationship between a fuel's physical and chemical properties and their effects on autoignition. In this study, computational kinetic modeling was used to analyze the autoignition process of n-heptane and Jet A. This will help assist in building up a database of kinetic models of fuels with a wide range of ignition properties and initial conditions, including equivalence ratio, compressed pressure and temperature, and even fuel composition. Different combustion conditions affect the ignition delay and combustion products. Therefore, it is important to do sensitivity and rate of production analysis because in high-temperature combustion, there is a rapid increase in temperature at ignition, but for low-temperature combustion, there is a more gradual increase in temperature before the large spike in temperature at ignition. At high temperatures (1200 K), oxygen participated in the reaction after some decomposition of the fuel was processed. At low temperatures (800 K), the fuel reacted with oxygen first before decomposing. The kinetic model studies for n-heptane and Jet A in this study can offer understanding of overall autoignition of fuels in practical combustion systems.

I wish to acknowledge the mentorship of Dr Jacob Temme.

Optic Spectroscopy Characterization of III-Nitride Semiconductor Materials for Lasers

Lesly Henrriquez-Saravia

By studying the active regions of III-nitride materials, we can create more efficient semiconductor lasers that will help enable new position, navigation, and timing technology. Cubic-gallium nitride (GaN) and m-plane (nonpolar) hexagonal-indium gallium nitride (h-InGaN) are theorized to have efficiency advantages over polar h-GaN. In this study, we focus on the potential growth of cubic-GaN and also on the internal quantum efficiency (IQE) of m-plane h-InGaN multi-quantum wells (MQWs). GaN samples were grown on 3C-silicon carbide substrates using plasma-assisted molecular beam epitaxy and were analyzed using Raman and photoluminescence (PL) spectroscopy to characterize the samples as hexagonal or cubic. Cubic-GaN exhibits a Raman LO mode peak at about 740 cm^{-1} and a TO mode peak at about 553 cm^{-1}, while h-GaN has an E_2 peak at about 570 cm^{-1}. Collected data show a band-edge PL peak at about 380 nm for cubic-GaN, which is consistent with literature. We also studied the optical efficiency of m-plane InGaN MQWs. Sample studies had a varying percentage of indium. The MQW active regions showed an IQE of 35%–37% as determined by comparing the room-temperature to low-temperature PL spectra. The central peak of the PL curve reflects the percentage of indium and the width of the quantum wells, while the full width at half maximum shows the local uniformity of the percentage of indium and the thickness of the well.[1–4]

I wish to acknowledge Dr Yuanping Chen at ARL, where the cubic-GaN samples were grown, and Prof Dan Feezell's group at the University of New Mexico, where the InGaN samples were grown.

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Modifying the Thermodynamic Stability of Crystalline Silica through Metal Ion Doping

Leah Hlubb

Stishovite is a rare, high-pressure, metastable polymorph of silica (SiO_2). This material is predicted to have properties that may be suitable for Army applications, including high toughness, hardness, strength, and elastic properties. There continues to be manufacturing challenges because of stishovite's high transformation pressure. Typically, stishovite is only found where meteors have struck the Earth, generating the high pressure and temperature needed to transform sand to the metastable polymorph. The goal of this work was to improve the stability of stishovite by doping the crystal structure with various metal ions. Doping ions into the structure could potentially lower the pressure needed to convert quartz to stishovite, thus making the material easier to manufacture. Crystal chemistry data obtained from X-ray fluorescence measurements indicate nickel was successfully incorporated into the silica crystal structures after 3 days of soaking in an aqueous nickel nitrate solution. Future research will focus on experimental confirmation of density functional theory models that indicate aluminum as a candidate to lower the energy necessary to form stishovite.

I wish to acknowledge the mentorship of Drs Taylor Shoulders and Victoria Blair for their tireless support and encouragement as I navigate the world of material science and develop my skills as a budding research scientist. I would also like to thank the rest of my team assisting me in day-to-day operations and teaching me what it means to be a research scientist outside the classroom and in the real world.

Identification of Collaborative Behaviors in Multiagent Systems

Bryson Howell

Multiagent reinforcement learning (MARL) has been used to allow groups of agents to perform in complex cooperative tasks.[1] While MARL-trained agents may be either homogeneous or heterogeneous in both ability and behavior, previous work has shown that groups that are trained to exhibit heterogeneous behavior outperform those that are homogeneous in behavior.[2] This could be because heterogeneous agents are capable of leveraging their differences to collaborate with each other.

However, the extent to which MARL-trained agents are capable of collaborating with each other is not yet known. To investigate the degree of collaboration between MARL-trained agents, we train a team of physically homogeneous agents in a 2-D particle environment using the Multiagent Deep Deterministic Policy Gradient algorithm.[3] Agents are trained in a predator–prey pursuit game, where a team of three predator agents are tasked with capturing a smaller, faster prey agent. We have tracked various behavioral metrics from this game related to team strategy in an attempt to qualitatively differentiate between collaborative and noncollaborative teams. In the future, we would like to perform cluster analysis on these metrics to classify the different strategies that are produced by our training method.

I wish to acknowledge the mentorship of Drs Reginald Hobbs and Steven Russel of the Content Understanding Branch, Information Sciences Division, Computational and Information Sciences Directorate. This project was funded by Advanced Resource Technologies, Inc.

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Cloning Design of SpyCatcher/SpyTag Fusion Proteins for Cellulose Self-Assembly

Donald Hughes

Microbial cellulose is a compelling material with a porous, nanofiber composition. Furthermore, cellulose has many biological tools available for simple self-assembly processes toward hierarchical composite materials, where precise interactions at the molecular scale impact the material properties at the bulk scale. This work expands the biofabrication tools available for cellulose self-assembly by providing a methodology designed to engineer key fusion proteins that bind to cellulose. We use the SpyCatcher/SpyTag system, a recombinant protein pair that forms a robust isopeptide bond upon interaction; this simple yet powerful interaction can be harnessed for introducing strong interfibril bonds by fusing each protein with a cellulose-binding domain. To support our hypothesis, we focus on a genetic engineering design to generate fusion protein candidates in *E. coli* and computational analysis for hypothetical self-assembly of the resulting SpyCatcher/SpyTag-cellulose-binding fusion proteins. Our methodology mostly consists of manipulating a pET plasmid precursor already containing the cellulose binding domain gene from *C. thermocellum* fused with superfolder green fluorescent protein (sfGFP). Cloning strategies were developed to ligate the SpyCatcher/SpyTag gene to replace sfGFP. Using A Plasmid Editor, we analyzed both the plasmid backbone and gene inserts for restriction sites, stop codon placement, protein size, and primer design to allow gene insertion at both the N- and C-terminal ends of the cellulose-binding domain. Implementing these fusion proteins with cellulose nanofibers will yield facile, nanoscale self-assembly strategies of cellulose-based materials, with tunable cross-linking and porosity. This capability could enable fiber reinforcement, filtration materials, or tissue engineering scaffolds.[1–7]

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Standardized Design of Fluorescent Timer Proteins for Time-Dependent Molecular Sensing

Jamison Jenkins

In order to understand an organism, it all narrows down to understanding the cell. Since the discovery of the green fluorescent protein in the early 1960s, fluorescent proteins have been used to study cellular processes in organisms. Fluorescent proteins can attach to and mark another protein with fluorescence, enabling scientists to see the presence of the particular protein in an organic structure. Fluorescent proteins essentially work as a marker, but what if they also worked as a timer?

Mutants of fluorescent proteins have developed the ability to change their fluorescence over time, from one color to another. This can be used to determine how long certain processes take within the cell. Specifically, the length of time of the up and down regulation of genes. Here we used Golden Gate assembly to develop the fluorescent timer proteins, drFP583 and mCherry, into a modular toolkit component for rapid combinatorial assembly and testing.

I wish to acknowledge the DOD and ARL for granting me this wonderful opportunity. I learned and gained so much from this experience. I would also like to thank my mentor, Dr Randall A Hughes, for being remarkably patient and helpful, and an all-around wonderful mentor. Thank you to my peers for being an incredible team, and I wish you all the best.

Consistent Compression and Pseudo-input Search for Online Gaussian Processes (GPs)

Andi Johnson

In the advent of the information age, improvement of machine learning techniques is imperative across multiple settings. We consider nonparametric Bayesian inference using Gaussian processes (GPs). More specifically, we aim to use GPs in the online setting where training samples continuously arrive. However, computational burdens with increasingly large data sets typically render GPs intractable. We focus on implementations of statistically consistent compression schemes for online GPs and extensions that include pseudo-input search. The challenge is that pseudo-input search can cause algorithm instability if it occurs on the same timescale as GP parametric updates, so we propose a two-timescale scheme: parametric updates and model point selection occur on a slower timescale while pseudo-input search occurs on a faster timescale only when model order stays nearly constant in a time interval. We evaluate this approach on some canonical data sets and observe it outperforms several state-of-the-art benchmarks.[1]

I wish to acknowledge the mentorship of Dr Alec Koppel for his devotion to his mentoring role throughout the entirety of the internship. I would specifically like to thank him for his guidance, patience, and encouragement along with the vast amount of knowledge he portrayed this summer. Next, I would like to thank Dr Amrit Singh Bedi for his correspondence and help throughout the summer. I truly appreciate his dedication despite a significant time zone difference. I also give my best acknowledgement to Ms Evelyn Kent for sponsoring this program and being the senior government official responsible. Next to thank is Dr Patrice Collins at ARL for hosting weekly meetings and providing interns with resources and information to continue their successes through. Finally, I would like to thank Dr James McDonald for being the liaison and ensuring successful administrative aspects of the program as well as providing support through the 2020 DOD Historically Black Colleges and Universities/Minority Institutions Summer Research Program.

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Research and Education Program for Historically Black Colleges and Universities and Minority-Serving Institutions (HBCU/MSI)

Cristal Johnson and Steven Powell

In collaboration with and resourced by the Office of the Under Secretary of Defense for Research and Engineering (OUSD-R&E), the ARL DOD HBCU/MSI undergraduate summer student interns ensured the successful execution of $6.5 million toward establishing Centers of Excellence (CoE) at multiple HBCU/MSIs. These CoEs will be located at multiple institutions and will be used as a vessel to promote research that benefits both the institution and the Army. This effort grants CoE students' access to receive research topics, mentors, funding, research-based courses, and an experience beyond working on a research team. Assessments were delivered by each institution's submitted proposal based on a given evaluation criteria, and then the evaluations were deliberated to make thorough funding recommendations. Exposure to the program management and business activities provided us the knowledge and understanding of how universities packet their research and the importance of beneficial outreach programs geared toward students.

We wish to acknowledge the mentorship of Dr Patrice Collins.

Summer Student Engagement Program Products

Cristal Johnson and Steven Powell

In the days of social distancing and virtual working environments, how does one inspire, engage and encourage networking? The rational of the DOD summer student engagement program is to give interns a platform to receive important program information and openly and effectively network. The program includes Virtual Town Halls, Virtual Social Events, an Outreach Instagram Page, and a Weekly Newsletter. These products are available to over 300 interns throughout a 10-week timeframe. The program was highly successful, 80% of interns participated in the weekly events and interns engaged in discussions and information sharing during the events.

We wish to acknowledge the mentorship of Dr Patrice Collins.

How to Engage Historically Black Colleges and Universities to Maximize their Ability to Compete for DOD Funding

Azariya Jones

For more than a decade, the DOD has been providing support to Historically Black Colleges and Universities (HBCUs) in the form of grants to conduct basic research and acquire equipment to teach the next generation of scientists and engineers. However, not all HBCUs are in a position to compete for the funding available. In particular, smaller HBCUs are missing opportunities to compete and actively apply for DOD grants because of several systemic issues. Smaller HBCUs, defined by enrollment numbers, endowment amounts, and tuition prices, are not incapable of applying for DOD grants, but find themselves facing several challenges such as 1) lack of institutional support in the form of sponsored program's offices, 2) recruitment and retention of innovative principal investigators, and 3) limited graduate-level programs (master's degree and PhD) in science, technology, engineering, and mathematics (STEM). These issues limit successful participation in DOD funding opportunities for smaller HBCUs. Obtaining DOD grants can enable smaller institutions to move to the next level of institutional capacity to more successfully compete with larger HBCUs who have mastered the art of applying for and obtaining DOD funding. My research involves a study of 10 HBCUs (small and large) and tracking their activity as it relates to obtaining DOD funding over 15 years.

I wish to acknowledge the mentorship of Patricia Huff.

Mechanical Modulator Designs for Q-Switching for Mid-Wave Infrared (MWIR)

Sameer Kamath

Laser Q-switching is used to generate nano- or microsecond pulses of high energy and peak power by modulating the intracavity losses. Solid-state lasers operating in MWIR ($\lambda_{LAS} > 3$ μm) ranges typically rely on weak optical transitions in rare earth (RE^{3+}) ligands and therefore require modulators with low optical transmission loss. There are not many optical materials suitable for acousto-optical (AO) and electro-optical (EO) modulators with adequate transparency in the longwave infrared (LWIR) domain. In addition, driving voltage for the EO modulators and radio-frequency (RF) power of the AO modulators are proportional to the laser wavelength that often makes their use impractical in the LWIR range.

An inexpensive alternative is a stable mechanical modulator, where a mirror is attached to the antinode of a mechanical oscillator. This oscillator often takes on the form of an "arm", or flat beam that is cut out of a sheet of spring steel. These mechanical devices result in slower switching speeds, causing relatively long pulse durations on the order of microseconds (rather than nanoseconds, like with AO and EO modulators). Also, oscillation stability is an important design consideration so that unwanted modes do not occur, which cause pulse instability.

Two types of oscillators were explored: a cantilever beam fixed at one end and a truss-type beam fixed at both ends. Both oscillators are designed for a 3-mm neodymium magnet attachment, so that vibrations can be forced through a sinusoidal input current into a coil placed under the magnet. Finite element models were created of the assembled mechanical modulators, and modal analysis was performed to find resonant modes. The devices were designed so that overtones occurred at much higher frequencies and were unlikely to prevail even with a slightly imbalanced driving force. Harmonic analysis with a set driving force was performed to show the trend in how the amplitude changes at frequencies approaching the modulator resonant frequency through a range of probable damping values for steel. Also, the modulators were designed to avoid stress concentrations that could lead to maximum principal stresses above 35% of the ultimate tensile strength, which guarantees that fatigue failure will never occur.

I wish to acknowledge the mentorship of Nikolay Ter-Gabrielyan.

Fast and Reliable Power Signal Analysis with Field-Programmable Gate Arrays (FPGAs)

Mason Kline

Assured, reliable high-quality electric power is critical to nearly every aspect of the Army and the military. Poor power quality can cause substantial problems including unplanned outages, damaged equipment, and fires from problems such as arc faults. Identifying these issues accurately, quickly, and reliably is vital so that problems can be corrected and device operability is assured. To this end, the analysis of signals in a power system is a real-time endeavor requiring the processing to be done as quickly as possible. Bottlenecks with traditional central processing unit (CPU)-based signal processing systems can arise when the amount of data collected by the system outstrips the system's ability to process it. FPGAs are specifically designed co-processors that not only relieve the CPU from having to perform expensive tasks like computing fast Fourier transforms (FFTs) but also can be designed to perform parallel operations well beyond the abilities of a traditional CPU. The co-processors that were designed as part of this project focused on three common signal processing algorithms: total harmonic distortion, signal-to-noise and distortion, and synchrophasor estimation. Additionally, the co-processor implemented some associated signal processing algorithms like the application of a window function and the computation of an FFT. The benefits of this co-processor were measured as a sizable decrease in the computation time taken to perform the required calculations and a massively increased data throughput. The increased data throughput was achieved by using eight parallel channels to perform eight simultaneous calculations.

I wish to acknowledge the mentorship of Brandon Parks.

Enhanced Annotation for Semantic Segmentation to Support Robotic Navigation

Christine Kwon

Methods of visual perception provide identification of landmarks and terrain that can help improve the intelligence of the robot for efficient path planning. Semantic segmentation is a type of perception task that applies labels to every pixel within an image after being rigorously trained on large data sets that are accurately annotated.[1] Due to human error, there are bound to be annotated images with mislabeled or unlabeled pixels that can distort learning, affecting the visual perception of a robot.[2] To address and correct these errors, we propose automated relabeling algorithms. We do this by noticing minute changes in object location between consecutive frames in a video sequence. We reference and compare pixels in the former and latter images; if the label values of those pixels in the neighboring images match, then we correctly label the unlabeled pixel at the corresponding location in the image of interest. Furthermore, we observe and compare peripheral pixels in the neighboring images using a sliding square window centered at the corresponding location of the unlabeled pixel. We show that with our automatic pixel-wise labeling solutions and analyses we can identify and correct annotation errors without any human intervention. In future work, we hope to show that this ultimately improves machine learning algorithmic models used on intelligent robots.

I wish to acknowledge the mentorship of Dr Maggie Wigness for giving me this opportunity to intern with her this summer. Working with her in such an incredible and advanced field in machine learning opened up new research interests I could pursue in the future. She has constantly given me advice and encouragement to create new approaches to problems related to the research I am pursuing. Her guidance and supervision was integral to my experience interning at ARL.

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Metabolic Modeling of *Pseudomonas putida* KT2440 to Understand and Improve the Breakdown of Plastic Waste

Leah Lewis

Polyethylene terephthalate (PET), the polymer used to manufacture plastic beverage bottles, is the world's highest production-volume synthetic plastic.[1] While synthetic polymers are typically resistant to biodegradation, organisms have been discovered that can decompose PET into soluble but toxic monomers, ethylene glycol (EG) and terephthalic acid (TPA).[2] *Pseudomonas putida* (*P. putida*) is a soil bacterium known for its receptiveness to genetic engineering and ability to metabolize a wide assortment of organic compounds and pollutants.[3] We seek to understand the pathways by which *P. putida* can metabolize EG and/or TPA and whether its growth on these compounds could be improved by genetic modification. Our analyses are based on whole-genome metabolic models of *P. putida* accessed with the web platform KBase and locally implemented in a Python programming environment, COBRApy. These models are used to generate flux balance analysis (FBA)[4] outputs that allow us to quantitatively predict the organism's growth in different media. FBA results indicate that *P. putida* KT2440, described by the model iJN1463,[5] is capable of biomass formation on EG. We are currently investigating growth on TPA. Our research has uncovered metabolic "bottlenecks" that, if alleviated by genetic engineering, could improve the ability of *P. putida* to metabolize these carbon sources.

I wish to acknowledge the mentorship of Drs Alexander Tobias and Matthew Perisin, ARL's Sensors and Electron Devices Directorate, Biotechnology Branch. Funding for my summer internship was provided by the DOD Historically Black College and Universities/Minority-Serving Institutions Summer Researcher Program.

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Scene Recognition Using Associative Logic and Naive Bayes Classification

Michelle Liu

Image scene classification is a complex problem of great interest in the field of computer vision. This is particularly true in the context of fast-paced Army field operations, where a computer's ability to recognize locations accurately may support a Soldier's ability to react quickly. While standard object-informed scene classifiers have shown good success, the detection of each object within an image is typically done independently, and object recognition confidence measures are not informed by the detection of other objects within the image. We present a scene recognition system that uses associative logic to strengthen confidence in potential objects and a Naive Bayes classification algorithm to provide location category suggestions provided in an expanded list of objects. Given an image, we implemented a set of pre-trained object detection models to identify a set of objects. We then format the object information as a triplet (object label, confidence score, and object bounding box location) to be forwarded to a reasoning engine. Using the SUN2012 database's scene and object annotations, we train a Naive Bayes classifier to suggest potential scene categories for a set of objects. We can predict with high accuracy "coarse" scene categories (indoor; outdoor, natural; or outdoor, manmade), but the prediction of "finer" scene categories (abbey, air base, access road, etc.) had a much lower accuracy.[1–4]

I wish to acknowledge the mentorship of Drs Andre Harrison and Adrienne Raglin for giving me the opportunity to work on this project and for their guidance throughout the process. Their support, advice, and encouragement were invaluable to me over the course of the summer.

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Generation of a Reverse Saturable Absorption (RSA) Chromophore Database

Shamya London

Nonlinear optical (NLO) materials interact strongly with incident light. Two common NLO mechanisms are two-photon absorption (2PA), where a chromophore instantaneously absorbs two photons at a specific irradiation wavelength, requiring femtosecond time scales; and reverse saturable absorption (RSA), where two sequential photons are absorbed, a process that typically occurs on the picosecond to nanosecond timescales. Each individual NLO material is characterized by several important photophysical parameters including its linear absorption spectrum, luminescence properties, excited state lifetime, transient absorption spectrum, and strength of excited state absorptions. ARL is working to develop new RSA materials through synthetic chemistry and photophysical characterization.

There are many RSA chromophores, both organic and inorganic materials, reported in the literature. However, no database currently exists that summarizes the wide variety of photophysical data that describes these chromophores and relates the data to their chemical structure. To this end, a literature survey was performed to find published data on relevant RSA chromophores. The literature data were then grabbed from different journal articles and digitized using WebPlotDigitizer. The digitized spectra, photophysical parameters, and chemical structures were captured to build a scientific database of interest to the Army and the photophysical community at large.[1,2]

I wish to acknowledge the mentorship of the DOD Historically Black Colleges and Universities/Minority Institutions Summer Research Program managed by TMT Group Inc. and Drs Ryan M O'Donnell and Thomas N Rohrabaugh Jr (ARL).

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Three-Dimensional Numerical Simulation of Evanescent Optical Coupling toward Design of Quantum Network Elements

Priscilla Lopez

Quantum information processing technologies offer capabilities for secure communication and computation tasks believed to be unattainable with any currently existing "classical" technology. Development of quantum network elements capable of distributing fragile quantum information will play an important role in enabling these powerful capabilities. A promising platform for these elements is surface nanoscale axial photonic microresonators, which offer ultralow loss and exquisite sub-angstrom fabrication precision. We investigate use of a 3-D numerical simulation to simulate a system containing a fiber waveguide and a microresonator in order to observe the evanescent optical coupling and investigate if this can replicate and improve upon the 1-D model that is typically used. Analyzing Maxwell's equations, a finite-difference, time-domain method is used to obtain transmission spectra of the systems. Comparing transmission spectra allows for validation of the model against experimental results and enables exploration of how variations in the 3-D geometry affect device performance.

I wish to acknowledge the mentorship of Dr Dashiell Vitullo.

Custom Internet of Things (IoT) Module for Modernizing Low-Frequency Sensors

Kira Loshin

Many state-of-the-art, low-frequency electric (E)-/magnetic (H)-field sensor designs have limitations with modern Internet of Things (IoT) networks (analog outputs, no digital communication capability, no local analog-to-digital converters, etc.). This requires additional components to turn the sensor output into actionable data, which can become very costly for wide-scale deployment of these sensors. My summer project used commercially available IoT technologies to create one composite "IoT module". The module added the low-power digitization of the analog sensor data, inter-integrated circuit (I2C) wired communications, and wireless communication capability to the sensors. An MSP430F47197 microcontroller is used to take sensor measurements, perform basic signal processing, and locally store the results. A CC2650 LaunchPad provides both I2C communication and Bluetooth low-energy wireless communication to transmit data to a central device up to 10 m away. The IoT module was demonstrated to transmit data via I2C up to 44 kB/s and transmit data wireless at 250 B/s, with a peak power consumption under 300 mW. Custom services were incorporated into the IoT module to allow for dynamic sensor data to be sent wirelessly by only changing two 16-bit values in the software, easing the integration process with a variety of sensors designs.

I wish to acknowledge the mentorship of Sean Heintzelman for his guidance this summer as my mentor, as well as David Hull, Brandon Parks, and the rest of the E/M Field Sensing Team.

Acoustic Emission Analysis of Fuel Pumps

Roman Madoerin

The function of unmanned aerial vehicles is critically dependent upon high-pressure fuel pump systems. Fuel pumps can fail from varying tribological phenomena at various locations within the pump. To detect these failures, acoustic emission (AE) may be used. AE is a noninvasive technique that measures the ultrasound vibration waves emitted by mechanical interfaces. The sensor detects the vibration signature and outputs a signal, which is analyzed to determine how the interfaces in the pump are running. AE signals were analyzed to determine the speed and patterns that can be used to indicate failure. Fourier transforms and bandpass filter calculations were performed to observe the signal activity at different frequencies. The AE signal was compared to a tachometer signal to determine the angle of rotation in the fuel pump where the AE signal peaks occur. Strong, regular signal patterns in a functioning fuel pump were established to identify failure mechanisms during future research.[1]

I wish to acknowledge the mentorship of Dr Stephen Berkebile and Nikhil Murthy.

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Tribological Behavior of Novel Polyether Ether Ketone (PEEK)-MAX or PEEK-MAB Composites during Fuel-Lubricated Sliding

Caleb Matzke

Wear and scuffing due to low fuel viscosity are critical problems in fuel pumps, injectors, and valves because viscosity directly affects lubricant film thickness and friction between contacting surfaces. Lubrication of components with tight tolerances is also difficult and can lead to catastrophic failure in which the component may stick or seize due to localized scuffing.[1] Since the lubricating properties of the fuel depend on its chemical content, which can vary by batch and source, identifying materials that behave well under various fuel-lubricating conditions can be an effective route to increasing fuel component reliability. Previously, our group has designed PEEK MAX- or MAB-phase-reinforced specimens. As a background, MAX and MAB phases are novel layered ternary compounds that have shown the ability to act as solid lubricants in PEEK composites.[2,3] During this study, tailored compositions of pure PEEK, PEEK-10% chromium aluminum carbide (Cr_2AlC), and PEEK-10% molybdenum aluminum boride (MoAlB) were used for tribology experiments by using a CSM Instruments tribometer. A custom-made syringe pump was used to feed ethanol and F-24 directly on to the surface of each composition during the experiments at a controlled feed rate. The effect of differing loads, for example, 5, 10, and 20 N, was also investigated. Wear of the specimen was determined by measuring the mass before and after the experiments.

I wish to acknowledge the mentorship of Stephen Berkebile, Surojit Gupta, Nikhil Murthy, and the Army Education Outreach Program College Qualified Leaders program.

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Development of a Toughened Vinyl Ester Photolithography Thermoset Resin for High-Performance Additive Manufacturing (AM)

Jaclyn McLaughlin

High-performance vinyl ester (VE) thermosets produced by AM are often brittle. A well-known method of toughening these materials is by the addition of a liquid rubber modifier. However, this method has yet to be applied to thermosetting resins in AM because the rapid cure kinetics of most printable systems would prevent sufficient phase separation of the modifier from occurring, resulting in network plasticization. In this study, a bio-based rubber is added to a photosensitive VE resin containing bisphenol A glycidyl methacrylate and *p*-methyl styrene. The bio-derived modifier used here is a functionalized triglyceride, grafted with methacrylate groups to promote covalent bonding between the second phase and surrounding network. Resulting blends maintained good processability at rubber loadings between 0% and 20%. Phase separation was examined in all modified samples printed using digital light processing. By altering layer heights of prints, average dose rates applied to the resin are controlled to directly affect rate of polymerization. All modified samples exhibited increased fracture toughness, and samples with slower polymerization rates had a larger degree of phase separation. However, improvements in toughness were not as drastic as those reported in the literature for thermally cured resins and were not affected by dose rate. Additionally, the glass transition temperature was reduced by up to 10%. These results indicate that the toughening observed was predominantly caused by matrix toughening rather than through second-phase rubber toughening. Flory–Huggins theory was used to engineer bio-based rubbers to increase phase separation, toughening, and minimize effect on glass transition temperature in AM resins.

I wish to acknowledge the mentorship of Dr John J La Scala, who welcomed me to the team here at ARL and took the time to ensure that I got the most out of this opportunity. The other immediate members of the team, Dr Anthony Clay and Joshua Mitchell, were also integral to my research experience here at ARL, and I'd like to thank them as well. Finally, I would like to acknowledge my advisor at Drexel University, Dr Giuseppe R Palmese. He introduced me to this position for my co-op and continues to inspire me throughout my research experience.

Network Data Curation

Stephanie Medina

Cybersecurity network data curation is the collection, labeling, and packaging of data sets that contain artifacts that are important in the cybersecurity domain. These assets are essential for cybersecurity research and key for Army technologies to survive and function in the presence of adversaries. However, data curation and related technologies are lacking, not only in the enterprise space, but especially in the tactical military field. Curation fuels empirical research and validation related to protection, detection, and prevention. Closing the gap will require the development of research-driven tools and technologies that facilitate and enforce not only collection and labeling, but also standardization and distribution. This is the focus of my summer project.

I am developing a novel tool, called the ECELd data curation manager, which simplifies the process of collecting network traffic, keystrokes, and mouse clicks; allows network packet labeling; automatically generates intrusion detection rules; and provides a visualization of results. Moreover, the tool has a built-in mechanism for exporting all data into a single distributable file. I currently have a working prototype and several samples demonstrating the effectiveness of this tool. Future work will incorporate more efficient packaging mechanisms and more advanced analysis features, such as automated similarity analysis and annotation.[1–3]

I wish to acknowledge the mentorship of Dr Jaime Acosta for the continuous support and guidance that he has provided me throughout the course of my graduate studies and this research opportunity. He has been someone that I can count on for any questions or concerns that I've had with these projects. I will always be thankful for his time and attention that he has given me. In addition, thank you to the DOD, the Historically Black Colleges and Universities/Minority Institutions, and the US Army.

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Numerical Simulation of Erbium (Er)-Doped Cascade Laser

Nicholas Merke

Er-doped materials are well suited for lasing in various infrared emission bands. Typically Er lasers are designed for operating at one of the primary luminescent transitions, ${}^4I_{13/2} \rightarrow {}^4I_{15/2}$ at approximately 1.6 μm or ${}^4I_{11/2} \rightarrow {}^4I_{13/2}$ at 2.6–2.95 μm. Both of these processes heavily depend on the upper-laser-level lifetime and the strength of energy transfer- and cross-relaxation processes that redistribute energy across the whole Er level's structure. Recently, a cascade lasing process was developed to utilize ${}^4S_{3/2} \rightarrow {}^4I_{9/2}$, ${}^4I_{11/2} \rightarrow {}^4I_{13/2}$, and ${}^4I_{13/2} \rightarrow {}^4I_{15/2}$ transitions to provide for so-called cascade-assisted 3-μm lasing (1.7 + 3 + 1.6 μm).[1]

Due to the complexity of the Er^{3+} energy level structure and concentration dependent, energy redistribution processes, there is a need for a reliable numerical model that can predict which Er host material will perform better in continuous wave or Q-switching mode of laser operation. It should also predict if the ultimate, ${}^4S_{3/2} \rightarrow {}^4I_{9/2} \rightarrow {}^4I_{11/2} \rightarrow {}^4I_{13/2} \rightarrow {}^4I_{15/2}$ cascade could be achieved in the laser host material, yielding an additional 3.5-μm laser emission and reducing thermal impact usually associated with the quantum defect of a typical single wavelength operation.

We developed a MATLAB program based on a system of differential equations describing population of the major Er levels, and intracavity photon densities of pump and laser emission. It takes into account finite bandwidths of pump and absorption bands, up-conversion, and cross-relaxation parameters. The system of 10 equations was solved with a standard fourth-order Runge–Kutta method.

I wish to acknowledge the mentorship of Nikolay Ter-Gabrielyan.

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Fluorescence Spectroscopy and Judd–Ofelt Calculations for Rare-Earth-Doped Crystals

Cameron Moneypenny

The research goal is to develop mid-infrared laser sources from rare-earth-doped low-phonon crystalline materials that can be efficiently pumped by diode lasers. These lasers have a variety of uses whether in communications, sensing biochemical agents, or even in medical fields. When developing rare-earth-doped laser materials, one of the main considerations is storage lifetime for the upper-laser level. It is advantageous for the emission lifetime to be as long as possible, so that the population inversion can be maximized. In rare-earth-doped systems, radiative lifetimes are not easy to measure because it is hard to separate out nonradiative processes. There are several methods to predict radiative lifetimes; the most popular being Judd–Ofelt theory, which has been used for over 50 years for the analysis of spectroscopic properties of rare-earth ions. Alternatively, another method called reciprocity of absorption and emission (the cross-section comparison method) provides a way to cross-check the values determined from the Judd–Ofelt theory. In this work, MathCAD was employed to solve for the Judd–Ofelt parameters while Originlab was used to calculate the reciprocity method. Then we compared the two results to find reasonable agreement in order to know whether the rare-earth doped gain materials are suitable for use in the mid-infrared laser applications.[1–3]

I wish to acknowledge the mentorship of Dr Ei Ei Brown for her invaluable mentorship and guidance this summer. Even though we were online, I learned a lot about solid-state lasers and gained experience in analysis spectroscopy of rare-earth ions.

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Density Functional Theory Study of Organic Bipyridine Linkers and 2-Phenylbenzoazole Cyclometallating Ligands

Dan Morphet

Fully conjugated organic bipyridyl-based molecules have demonstrated strong absorbance and emission characteristics in the ultraviolet/visible region.[1] Furthermore, pyridyl-based chromophores allow for complexation to yield metal-organic frameworks (MOFs) and self-assembled metallacycles.[1] In addition, the absorption and emission characteristics of 2-phenylbenzothiazole cyclometallating ligands and their subsequent iridium(III) complexes indicate the presence of both ligand-centered (^{1}LC) and metal-to-ligand charge transfer (^{3}MLCT) excited states, with some complexes exhibiting dual emission (fluorescence and phosphorescence).[2] In light of the ongoing global COVID-19 pandemic, computational methods were employed in order to explore the electronic structures of the aforementioned linkers and ligands. Through the use of density functional theory, the photochemical characteristics of a set of bipyridine-based linkers, as well as a set of 2-phenylbenzoazole-based ligands and their corresponding mononuclear iridium(III) acetylacetonate complexes, were studied. The results of the study suggest the possibility for constructing a library of multinuclear iridium(III) metallacycles with varying linkers and ligands. Such complexes, based on the results of this study, would be expected to exhibit strong photochemical characteristics, as well as being likely candidates for MLCT events.

I wish to acknowledge the mentorship of Dr Ryan O'Donnell, Dr Thomas Rohrabaugh, Prof Timothy R Cook, Gregory Sokolow, and Matthew Crawley.

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Using Artificial Intelligence in Tacotron

Jerral Murray

There are thousands of languages in the world and all are unique. It is important to bridge the communication gaps among the different languages. For Soldiers in the field, it means being able to understand languages in foreign lands. For ethnic groups, it means preserving the culture by preserving the language of their ancestors. To shrink the communication gap, the fellowship focused on learning text-to-speech (TTS) synthesis. TTS systems utilize artificial intelligence, machine learning, and neural networks to enhance communication and create a bridge between different languages. The fellowship involved learning the Keith Ito implementation of Tacotron in TensorFlow. We explored the system code written in Python, using the Pycharm integrated development environment. We experimented with the Tacotron model by tuning hyperparameters to see how the system would react. We further explored the Tacotron environment by training the neural network with an alternative set of training data. In these experiments, we evaluated the results by reviewing the tones, pitches, and frequencies created during speech synthesis. Overall, I have learned about the technology behind TTS that will allow me to use these systems for different languages to bridge additional communication gaps.[1,2]

I wish to acknowledge the mentorship of the ARL Outreach Program for giving me this learning opportunity through this summer internship and the platform to broaden my future research as a student.

Special thanks to Stephen LaRocca (ARL, Battlefield Information Systems Branch), Vince Iglehart (United Tribes Technical College), John Morgan (ARL, Battlefield Information Systems Branch), Zakariya Al Sagheer (ARL, Battlefield Information Systems Branch), and Katherine Blake (Cornell University, Department of Linguistics) for all the support and feedback they have shown me through this research experience.

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Commercial Survey of Avalanche Photodiode Performance Metrics

Suhaas Narayan

Silicon carbide (SiC) and gallium nitride (GaN) avalanche photodiodes (APDs) are currently being tested for deep ultraviolet (DUV) single-photon counting. One of the big problems concerning APDs is their dark count rate (DCR), which is the count rate of carriers generated in the absence of light. The DCR increases as the optical area of the APDs is increased. A performance comparison was made for SiC and commercial devices including GaN, mercury cadmium telluride (HgCdTe), and indium gallium arsenide phosphide (InGaAsP) APDs operated in Geiger mode and analysis of methods to reduce DCR. The comparison shows commercial specifications; one of the specifications for Si APDs operated in the DUV provided by Hamamatsu is that their bias voltage is approximately 130 V, gain is in the range of 10^2–10^3, and sensitivity is 0.42 A/W.[1] A common application of APDs is in Light Detection and Ranging (LIDAR) systems, so companies are trying to manufacture off-chip electronic components such as amplifiers to be as close to the chip as possible, with the goals of increasing signal-to-noise ratio and reducing timing jitter. Among SiC, GaN, and HgCdTe, SiC APDs are the more practical option for DUV sensing because of their high quantum efficiency. GaN APDs are more useful in the UVA spectrum, while HgCdTe APDs are more sensible for infrared photon sensing.

I wish to acknowledge the mentorship of Dr Anand Sampath for allowing me to work in his branch for the last two summers.

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Perfused Liver Health Assessment Employing Raman Spectral Analysis: A Review

Trinity Neal

Challenges with diagnostic instrumentation during organ transplant pose potential life–death consequences and hence the need for a label-free and predictive monitoring system. In this publication review, a novel Raman-based diagnostic tool is proposed for use in monitoring the overall health and degradation over time of ex vivo perfusion of porcine livers. The Raman-based approach involved Raman spectral analyses of perfusate fluids from pigs. A combination of multivariate statistical analyses, including principal component analysis and linear discriminant analysis, was employed on the spectral data to infer degradation profiles for perfusates collected over different conditions of pressure, temperature, and over time. This study shows that the technique was sensitive to detect transitions between healthy livers and the gradual transition to unhealthy or degenerate state over time. The technique, when optimized, has potential applications in perfusion and diagnostic instrumentation for on-the-go analysis during organ transit and in operating rooms to help with quick identification pre-transplant of organ health.

I wish to acknowledge the mentorship of Theresah Zu.

Application of 3-D Tensegrity Metamaterial on Span-Wise Morphing Wing

Daniel Okegbu

Tensegrity has emerged as an ideal candidate for metamaterials. Metamaterials are artificially engineered structures with unique material properties, designed by harnessing controllable parameters such as dimensions and patterns. One of its characteristics includes the ability to remain stable while sustaining large deformation, even beyond its elastic limit. In this study, a tensegrity structure is leveraged to design the internal core of an unmanned aerial vehicle wing for span-wise wing morphing. Recent studies on span-wise morphing have proven to meet the desired design objectives of weight reduction, flexible axial stiffness, and an ability to control surface area to improve aerodynamic efficiency. However, the tradeoff for the characteristics mentioned is unwanted low bending stiffness. This study seeks to discover an internal core design with flexible axial but rigid bending stiffness that can support the wing's transverse loading. A tensegrity offers the ability to manipulate axial and bending stiffnesses independently. We wish to take advantage of such ability to obtain the desired axial and bending stiffness for the span-wise morphing wings.

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Wide-area-network to Access Distributed Data and Devices Securely (WAD3S)

Christopher Olin

Internet of Things (IoT) sensors deployed in almost any context will produce a steady stream of data that needs to be stored. At scale, the amount of data can become immense, leading to huge storage costs. Additionally, with an effective IoT deployment, access to nodes (sensors, devices, etc.) should be straightforward and standardized. However, remote sensors may need special network configurations in order to be interfaced with. This is not realistic in many scenarios, where networks are limited or require expertise to configure. The Wide-area-network to Access Distributed Data and Devices Securely (WAD3S) uses a virtual private network (VPN) to provide a secure network for a web of sensors or other IoT devices. It allows complete control over necessary network settings, while not requiring extra setup or permissions onsite. It also makes network configuration uniform, allowing setup to be automated. It provides a central access point for user and administrator interfaces on all nodes, giving one entryway to multiple interfaces. At the same time, it does not infringe upon a device's ability to operate locally, allowing it to be accessed both onsite and through the VPN. WAD3S greatly simplifies the issue of data storage: instead of streaming all collected data to the cloud for centralized storage, data storage can be distributed to each of the nodes that generate the data, and access to the data can be routed through the VPN. This cuts back on the amount of cloud resources needed, driving costs down.

I wish to acknowledge the mentorship of Brandon Parks.

Classifying Radio-Frequency (RF) Waveforms in Nonstationary Environments Using Transfer Learning and Convolutional Neural Networks as Feature Extractors for Parametric and Nonparametric Models

Anthony Paris

There is limited space in the RF spectrum, and it is a critical communications resource. As RF devices get smaller and more accessible, sharing the RF spectrum without interference becomes a challenge due to crowding. One proposed solution is to enable dynamic spectrum access using cognitive RF systems. It is perceived that a major component of a cognitive RF system is the ability to classify the active RF waveforms in nonstationary environments. This implies a need for adaptive clustering and classification techniques to identify the different RF waveforms. Our research focuses on RF waveform classification by using transfer learning with convolutional neural networks (CNNs) as feature extractors. The CNNs used were AlexNet, GoogleNet, InceptionV3, ResNet50, and MobileNet. The feature vectors are obtained by extracting the activation outputs of the last layer of the CNNs and using them as inputs to the three clustering and classification techniques: K-means, Gaussian Mixture Model (GMM), and most importantly, the nonparametric Dirichlet Process (DP). We experimented with each clustering technique on the CNN features. Using an iterative process, the results showed that K-means and GMM algorithms can accurately cluster the waveforms when provided the number of clusters a priori. Preliminarily, we also demonstrated that the DP can provide some level of accuracy clustering RF waveforms without having prior knowledge of the number of unique waveforms.

I wish to acknowledge the mentorship of Marvin A Conn.

Improved Algorithm for Estimating Pulse Repetition Intervals (PRIs) of an Interleaved Pulse Train

Mark Pawelski

Different PRIs are often used in active radar systems to perform different tasks, such as searching, acquiring, and tracking targets within their field of view. PRI is simply the spacing between transmit pulses. Since active radar systems transmit a pulse and "listen" for an echo off a target, the PRIs of the transmit pulses are directly proportional to the unambiguous range of the system. A change in the PRI can mean the system has changed modes, from acquisition to tracking, for example, which can become very useful with respect to electronic warfare. This paper describes state-of-the-art techniques for deinterleaving multiple PRIs and estimating modulations of PRI patterns. For the purposes of investigation, I assume that a preprocessing stage has successfully detected leading edges of all pulses and that a relatively strong signal-to-noise ratio is present. The deinterleaving algorithm has a few drawbacks when dealing with timing jitter (PRI jitter) and missing pulses. If a pulse is not detected within the preprocessing phase, the missing pulse will add estimation error that will manifest as false alarms. PRI jitter causes the phase factor of the PRI transform to be enlarged while spreading the PRI value over an interval containing the true PRI value, thus increasing the error. Both drawbacks are not addressed in my preliminary investigation. The next iteration of this investigation will include more techniques to account for jittered PRI trains, along with the possibility of missing pulses stemming from the preprocessing phase. These techniques include shifting of time origins for the absorption of missing pulses and threshold detection for increased detection performance and robustness against false alarms. The PRI modulation estimator is a multihypothesis detection algorithm that calculates statistical features based on characteristics of hypothesized modulations and compares them to experimentally determined thresholds. The pulse stream is declared to belong to the class producing the highest score. Future work will attempt to combine deinterleaving strategies and PRI modulation estimation to produce a more detailed description of a potential radar emitter.[1–6]

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Artificial Noise-Aided Multiple-Input and Multiple-Output (MIMO) Authentication via Fingerprint Embedding

Jake Perazzone

Fingerprint embedding at the physical layer is a highly tunable authentication framework for wireless communication that achieves information-theoretic security by hiding a traditional hash-based message authentication code (HMAC) tag in noise. In a multiantenna scenario, artificial noise (AN) can be transmitted to obscure the tag even further. The AN strategy, however, relies on perfect knowledge of the channel-state information (CSI) between the legitimate users. When the CSI is not perfectly known, the added noise leaks into the receiver's observations. In this presentation, we explore whether AN still improves security in the fingerprint-embedding authentication framework with only imperfect CSI available at the transmitter and receiver. Specifically, we discuss and design detectors that account for AN leakage and analyze the adversary's ability to recover the key from observed transmissions. We compare the detection and security performance of the optimal perfect CSI detector with the imperfect CSI robust matched-filter test and a generalized likelihood ratio test. We find that using AN can greatly improve security but suffers from diminishing returns when the quality of CSI knowledge is poor.

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Examining Social and Cyber Effects of Decision-Making

Aditi Periyannan

In a future battlefield where humans interact seamlessly with autonomy, we expect decision-making to be dramatically modified by potential threats both in the field and in the cyber domain. The goal of this study is to examine the impact of information and context (e.g., social vs. cyber) on decision-making where there is both reliable and unreliable informational content. As part of the Defense Advanced Research Projects Agency's (DARPA's) SocialSim project to simulate online social behavior and study information spread and evolution, this data set was acquired by Advanced Brain Monitoring's research team. Each participant went through four scenarios of the simulated social media environment while electroencephalography was recorded. On this platform, they interacted with related real and fake news articles, and then discussed the topic with other participants. They were also given a questionnaire at the beginning of each scenario, after interacting with the simulated social media platform, and after the discussion group to evaluate if their opinion changed in different contexts. Participants were then split into groups based on whether they were "cyber influenced", "socially influenced", both, or neither, to evaluate the hypothesis that variability in opinions is linked to variability in neural behavior. Variability in neural data was analyzed by separating data into five frequency bands and then using two methods: 1) traditional power analysis and 2) connectivity strength using a neural networks' approach that measures statistical relationships among nodes. The group that was both highly socially and cyber influenced was easily distinguishable from other groups of participants using alpha power and delta strength. The ability to identify individuals who are influenced by misinformation in different contexts can assistant us in preparing Soldiers for the future cyber-integrated battlefield and inoculate them from false information so they can confidently make robust and rapid decisions.

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Training Reinforcement Learning Models to Achieve Analytically Derived Optimal Solutions

Jake Perret

Reinforcement learning algorithms have trained collaborative agents in tasks such as a predator–prey or high-value target. Collaboration is defined as the intersection between coordination and cooperation.[1] In other words, collaboration is when agents work together to achieve a common goal. A turret task, as used in this study, is more likely to be experienced in a military application than the other tasks mentioned. In the task, two reconnaissance (recon) agents are teamed against a turret agent. The recon agents attempt to touch the turret before the turret can hit them. The turret tries to stop the recon agents from achieving their goal by rotating and attempting to hit the recon agents before they can touch it. This task produces an adversarial solution where agents drive each other's behavior. By intermixing policies in the task, we can see how agents behave with policies they were not trained with. This is valuable information because in application the agents will most likely not have trained with the adversary they are up against. There are various methods to measure collaboration between agents. One is to identify an optimal and collaborative policy for the team and look for how much of that policy the agents learn. Through mathematical reasoning, an optimal policy for the recon agents has been developed for this task, where they enter on opposite sides of the turret so that the turret can hit, at most, one of them.[2] We look at how much of the task's optimal policy is learned through reinforcement learning. With this information, we can estimate how much of the optimal policy will be learned in a task too complex for an analytical solution. Reinforcement learning is a mix of exploration and exploitation, making it useful for both finding and implementing solutions. The recon agents showed collaboration, but not the full optimal policy produced from the analytics. This is expected since most machine learning algorithms do not achieve perfection.[3] By increasing the number of agents and intermixing the policies of those agents, we hope to find the most cost- and performance-effective way to solve a given task with a given number of agents.

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Fluctuations in Social Experiences Shape Individual Decision-Making under Risk

Eri Phinisee

Soldiers are humans, inherently vulnerable to internal biases especially when making decisions carrying heavy risk. Previous research suggests that risky decisions may be shaped by social experiences and subject to social influence.[1,2] Yet, there is a lack of studies that directly investigate the relationship between natural fluctuations in risk-taking and natural fluctuations in social interaction. This study capitalizes on daily ecological momentary assessment of risky decisions (elicited through an adapted economic lottery task) and subjective self-reported social experience from 44 participants (73% males, 27% females) in the Real-World Driving Study. We explore what the effects of daily social interactions are on risk-taking behavior and how intra-individual variability in social interactions relates to intra-individual variability in risk-taking behavior. The results show that low ratings of enjoyableness or supportiveness of social interactions significantly moderate the negative relationship between frequency of social interactions and risk-taking, with specificity in the gain domain. When an individual deems their social interactions as not supportive or enjoyable, increasing such social interactions leads to less risk-taking. Furthermore, an increase in intra-individual variability in supportiveness or enjoyableness ratings is significantly associated with a decrease in fluctuation in risk-taking behavior.

I wish to acknowledge the mentorship of Dr Nina Lauharatanahirun for her insights and patient guidance and Yue Qin for her generous support throughout the process.

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Modeling Fusion Peptide Extensions of Cellulose-Binding Proteins Toward Nanoparticle Immobilization on Cellulose

Alexis Pigg

Bacterial cellulose is a high-strength material that is readily fabricated by bacteria into a complex 3-D nanofiber structure and can serve as a scaffold composed of nanofibers, on which composite materials can be assembled. In this project, the cellulose nanofibers provide a backbone structure for nanoparticle hybridization to create functional composite materials. Our approach uses genetically engineered proteins to immobilize nanoparticles, taking advantage of peptides that have strong affinity for various inorganic materials. The cellulose-binding domain (CbD) connection allows subsequent binding to the cellulose scaffolding. The use of genetic engineering allows building custom fusion proteins by manipulating the genetic sequence. For this work, we sought to obtain a better understanding of the structure and configuration of such fusion proteins required for nanoparticle hybridization. First, we obtained insights about the CbD itself, where protruding extension sites are present implicating extension upon the backbone. Then, we analyzed the physical structure of an added functional linker (StrepTagII for streptavidin binding) and metal-binding peptides (a metal-chelating His6 tag and gold-binder M6G9), each of which might be of interest to fuse to CbDs. All peptide structures were predicted using a peptide structure prediction server and visually analyzed using Visualization Molecular Dynamics (VMD). In addition, alignment techniques in VMD were used to understand peptide flexibility, relative length with linker, and exposure when connected to a CbD. We observed interesting sequence-based structural patterns across all models for the highest probability conformations, including extended structures in the proline/threonine-rich linkers, helical structures for histidine repeats, and abundant curvature in the methionine/glycine-rich segments. Additionally, by noting the relative folding of each segment and consequent length, we inferred the relative size and peptide exposure once fused to cellulose-binding proteins. These findings allow computational biology and cloning biology to cross boundaries between structure prediction and engineered design to support CbD-peptide display systems.[1–5]

I wish to acknowledge the mentorship of Maggie Hurley and Meagan Small.

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Metabolomics Analyses of Fermentation Cultures Using Raman Spectroscopy: A Review

Carlos Posada

A major challenge in biological experiments is the ability to observe real-time changes as they occur in a system/body. Unfortunately, real-time observations are often difficult because sampling may skew results by injecting error, especially within sensitive systems/bodies. The utilization of predictive models is a potential alternative that circumvents this problem. This is secondary to the ability to calibrate predictive models using chemometrics. As a result, predictive models are especially attractive in that they subsequently allow for 1) better/quicker characterization of biological organisms and/or systems, 2) process control, and 3) optimization of these processes. In this publication review, Raman spectral data were used as training sets in a partial least squares (PLS) model system to predict the output of accumulated metabolites from a bacterial fermentation culture. The results of the PLS model were then validated with quantitative data from high-performance liquid chromatography (HPLC) analysis, which is an established technique used for metabolite analyses of fermentation cultures. The developed model was executed in real time for new fermentation cultures and the predicted outputs compared well with quantitative data from HPLC runs. The results showed good correlation between predicted and measured data with corresponding model parameters R2Y = 0.99 and Q2Y = 0.98.

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Building a Chip-Sized Brain: Optimizing Transistors with Ion-Gated Neuromorphic Devices

Zuri Rashad

In this research project, I surveyed material choices to replace gate material in 2-D transistors with electrolytes with suitable ion and electron transport properties to design novel ion-gated neuromorphic devices. Modern-day electronic devices are dependent on hardware designs, von Neumann architecture, invented in the 1960s, with separate logic and memory units. This paradigm and the challenges with power scaling are a roadblock to future progress in computing and hinder their versatile use at the tactical edge. As a result, the advances in artificial intelligence and neural networks that are increasingly impacting our daily lives will require smarter, compacter, and more efficient processors. Brain-inspired computers and neuromorphic devices provide an innovative path forward in solving major challenges with existing technologies. In this effort, ion-gated neuromorphic devices are a promising device candidate that have shown significant potential in bridging the gap in development of in-memory devices with scalable memory states and control of weight in brain-inspired computers. I worked on identifying electrolyte material choices that can be integrated into 2-D devices to develop a unique 2-D ion-gate device. Two primary classes of organic and inorganic material were researched and potential candidates for the electrolyte were identified. A focus on 2,7-dioctyl[1]benzothieno[3,2-b][1]benzothiophene (C8-BTBT) integrated with polystyrene (PS), and lanthanum nickelate ($LaNiO_3$) atop strontium titanate ($SrTiO_3$) demonstrate great promise in functions that can be achieved and routes possible for development of circuits and back end of line integration. Utilizing the specific properties that these compounds provide for our devices, such as rapid ion transfer, stability of compounds, and low power consumption, I came up with two device architectures to be tested. These efforts can transform the ion-gated device research efforts at ARL and allow development of devices that can learn and remember concepts using processes similar to the brain.

I wish to acknowledge the mentorship of Sina Najmaei.

Technology Impact Assessment of an X2 Rotorcraft

Shilpa Ravoory

Tradespace exploration has been used for the development of aircraft, rotorcraft, and space systems to understand and communicate the impact of requirements and design decisions. Using this process, one can analyze complex resources and costs involved in a large project, such as the development of a rotorcraft. The X2 is a high-speed compound rotorcraft with coaxial rotors developed by Sikorsky and the precursor to the similarly sized Sikorsky Raider and much larger Sikorky-Boeing SB>1 Defiant, which is a Joint Multi-Role Technology Demonstrator program participant. As companies begin to design the next generation of rotorcrafts, tradespace exploration provides information on technology impact, readiness, and cost. An analytical model of the X2 aircraft was created using the NASA Design and Analysis of Rotorcraft (NDARC) code, an aircraft design and performance analysis tool that supports technology impact assessments. Once this model was created, a Monte Carlo simulation was run with the X2 NDARC model to characterize the probability of different design perturbations from technology insertion. Response surface equations were then fit to simulation data to enable rapid estimation of the change in performance based on the technology inputs. These equations were then integrated into the Capability Assessment and Tradeoff Environment (CATE) Excel-based dashboard developed by the Georgia Institute of Technology. The CATE dashboard supports decision-making by allowing quick evaluation and visualization of vehicles design and technology tradeoffs, off-design performance assessment, and interfaces of results from NDARC using a custom wrapper. Ultimately, this process allows one to easily understand and visualize the impact of design requirement decisions.[1–6]

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ARL Spectral Fitting

William Roberts

The ARL Spectral Fitting application provides a free, publicly accessible, and fully transparent method for performing Franck–Condon Lineshape Analysis (FCLSA) on spectral data. While other applications currently exist within academic research groups that perform this type of analysis, no other possesses all three of these attributes. This program was written in MATLAB, using its App Designer tool, and is intended as a standalone, graphical user interface-based application for use by the average laboratory researcher without requiring any coding knowledge. FCLSA augments the information found in luminescence spectra, providing meaningful insight into the relationship between the ground and excited states of photoactive species. This insight is achieved by modeling spectra with two versions (modes) of an equation that are characterized by either four or six parameters, depending on which mode is used. Once optimized, the value of each of these parameters can be used to gain insight into the molecule, as well as to perform further analysis (for example, the free energy content of the excited-state molecule). This application provides tools for easy by-hand fitting of imported data, as well as two methods for optimizing this fit—damped least-squares fitting, powered by the Levenburg–Marquadt algorithm, and derivative-free fitting utilizing the Nelder–Mead simplex algorithm.[1–4]

I wish to acknowledge the mentorship of Dr Ryan O'Donnell (ARL), Dr Thomas (TJ) Rohrabaugh (ARL), and Dr Timothy Cook (State University of New York at Buffalo).

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Modeling Thermal Conductivity in Rare-Earth-Doped Laser Crystals

Jenny Rosen

Solid-state lasers have many applications ranging from long-range communication to medical technology. The lasers operate by converting pump energy into a desired wavelength of light while also producing unwanted heat. To prevent thermal fracture or lensing, this heat must be managed. The physical property of thermal conductivity governs how well heat is transferred out of the material. The purpose of this research is to develop a model for calculating thermal conductivity that takes into account both temperature and rare-earth-doping ion concentration. By performing an extensive literature search, two technical presentations were used in the focus of developing this model. The first paper derived a simplified model of thermal conductivity that is physically reasonable and allows for fitting the concentration dependence of experimental data, but does not cover the entire range of typical laser operating temperatures (77–300 K).[1] Another drawback to this model is that it requires seven fitting parameters. The second model was more applicable in the desired temperature range and stemmed from fundamental phonon physics, ensuring that it was a physically reasonable model.[2] The model only had one fit parameter and thus is a simpler choice to use moving forward.

I wish to acknowledge the mentorship of Zackery Fleischman for his leadership, guidance, and support throughout the course of this project.

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Quadrotor Biplane: Wind Tunnel Setup and Flight Testing

Peter Ryseck

To meet the endurance and range requirements for modern unmanned aerial vehicle Army operations, a hybrid vehicle that takes advantage of the mission effectiveness of hover and efficiency improvements of forward flight is necessary. One such hybrid air vehicle is the quadrotor biplane, a vehicle consisting of four rotors and a set of biplane wings.[1] A wind-tunnel rig was designed for an existing quadrotor biplane coupled with a sting balance to investigate the lift-and-drag characteristics associated with the propeller–wing interactions at a wide range of pitch angles. Additionally, an array of data collection sensors was implemented on an experimental 200-g quadrotor biplane to measure the performance characteristics of the vehicle in straight-line and turning flight. The results from this test show that a quadrotor biplane, when compared with a standard quadcopter at this scale, has a peak power reduction of 30% at low-speed flight, but a similar or worse power consumption at high-speed flight.

I wish to acknowledge the mentorship of George Jacobellis, John Gerdes, and Mike Avera for their support in this research.

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Detrending Nonlinear Data: Extending Analysis of Variance Concepts to Numerical Weather Prediction

Rigo Salazar

Numerical weather prediction involves studying forecasts, the qualities of codes that influence said forecasts, and the actual recorded observations. Of course, these are massive data sets with a myriad of interacting factors and attempting to identify what factors, or interactions thereof, drive the bias is a complex task. With clever usage of statistical design of experiments, constructing a data set that is conducive to isolating such factors is possible. Although it is the ultimate project goal to correctly quantify the variance stemming from the parametrization schemes of the atmospheric process via trained emulators, we found it is essential to first remove the temporal component of the bias. There are several ways to effectively detrend data, but characteristics like the data's nonlinearity and its other contributing factors made finding an optimal method more difficult.

I wish to acknowledge the mentorship of Dr Jeffrey Smith of the Physical Modeling and Simulation Branch of the Battlefield Environment Division at White Sands Missile Range for his patience and mentorship, and Dr Daniel Kowal, Statistics Professor of Rice University and his graduate student Qian Chen for their work on the emulators.

Tracking Data Nonstationarity via Adaptive and Stochastic Gradients

Dylan Scott

We consider supervised machine learning in the online setting, where a learner seeks to optimize an accumulating sum of costs on the basis of instantaneous observations. We conduct a numerical study of 1) gradient, 2) online gradient, and 3) adaptive gradient (Adagrad), as well as extensions of Adagrad that are better attuned to local shifts in the data distribution. Our numerical study demonstrates that tuning step sizes to local instantaneous gradient variance, as in Adagrad and its extensions, significantly boosts performance on data sets with nonstationarity and jump changes.

I wish to acknowledge the mentorship of Alec Koppel.

Target Detection from Pupil Data using EEGnet

Anubhab Sen

Introducing intelligent agents into human teams allows the possibility of detecting when the humans are paying attention (and when they are not) as a result of task fatigue and other potential factors that influence situational awareness. Using physiology to indirectly measure and anticipate human states would allow a dynamic approach for intelligent agents to shift strategies and adapt to human needs. Within the context of the Human Interest Detector experiment, electroencephalogram (EEG) data has been used previously with great success in detecting whether the subject is looking at a "target" or not. This project investigated an alternative physiological signal, changes in the pupil's size over time, or pupillometry, to try and achieve similar results. This would be favorable as the equipment used for capturing pupil data is much more field deployable. We used a modified version of EEGNet (used to predict target detection using EEG data) and trained the model using only pupil-size data. This yielded a 94% accuracy of target detection on the baseline task that involved responding to pictures of castles (nontargets) and fountains (targets) with a button press. Next, we assessed generalization between the baseline task and the live navigation task through a 3-D environment (targets were Humvees, helicopters, etc.) and found that the trained model did not generalize across tasks well due to the model predominantly representing the pupil constrictions. Our next set of analyses will examine target classification by training the model on data from the live task and assessing performance on the live task using a leave-subject-out cross-validation procedure. Overall, pupil size appears to be a good indicator as pupils show a marked response to visual stimuli and various cognitive tasks.

I wish to acknowledge the mentorship of Russell Cohen Hoffing and Steven Thurman.

Ultrasonic Motors for Reconfigurable Radio-Frequency (RF) Circuits

Brian Shi

The Motion-Enabled Reconfigurable Circuits (MERC) program has demonstrated filter reconfigurability across wide frequency ranges; however, the form factor is incompatible with many applications. Piezoelectric ultrasonic motors are compact in size, have excellent positioning resolution, and can replace the current motors in the system to improve the form factor. This work focused on creating a motor assembly and developing a low-profile MERC system to exploit the compact form factor of the ultrasonic motor. Assembly design and 3-D modeling was performed in SolidWorks, and physical components were 3-D printed on a Formlabs Form 3 resin printer. The feature accuracy, repeatability, and necessary assembly tolerances for the Form 3's printed parts was investigated. Numerous actuators were considered and incorporated into the assembly design to allow the filter components to make and break contact with the RF circuit. In addition to contact-based approaches, noncontact capacitive coupling was also modeled, focusing on insertion loss at various frequencies. Finally, a rotary encoder was designed to enable position feedback and control of the ultrasonic motor for filter component selection.

I wish to acknowledge the mentorship of Mary Beth Galanko, Ryan Rudy, and Jonathan Puder.

Investigating Containerization for Scalable and Reproducible Artificial Intelligence/ Machine Learning Research on Department of Defense High-Performance Computing Systems

Matthew Simoni

Artificial intelligence and machine learning (AI/ML) has recently achieved great success in many applications due to the rise of deep learning. Deep learning-based AI/ML generally requires extensive computation over large data sets. High-performance computing (HPC) systems allow training of large-scale ML models in a highly distributed fashion. A key challenge arises in how to convert ML code that can run on one computer onto a multitude of computers, as well as ensuring reproducibility of ML outputs and results across different software/operating system (OS) environments. One way to address this challenge is through containerization. Programs like Docker and Singularity take code, together with all necessary dependencies, and store it in a software container, allowing it to be downloaded on other computers in a reproducible manner independent of the OS. The goal of this internship was to investigate and understand the capabilities of Singularity, and begin to build and deploy software containers enabling scalable and reproducible AI/ML research on DOD HPC systems.

I wish to acknowledge the mentorship of Nick Waytowich and Vernon Lawhern for helping me, as well as my parents for everything they do.

Modified Flux Methods: Synthetic Control for Performance Enhancement of Lithium-Ion Battery Active Materials

Kennedy Smith

Lithium-ion battery technology needs to be innovated to successfully design safe, long-lasting, fast-charge materials. Using modified flux methods, the basic crystal-growth mechanism can be finely tuned to obtain certain physical and chemical properties. Molten salt synthesis allows the growth of crystals below the melting points of the constituent reactants and desired products, thereby allowing lower reaction temperatures.[1] During synthesis of lithium-ion battery materials, it is imperative that lithium ions are "intercalated" or inserted into the layers of the crystal structure. Summarizing the various methods of synthesis will pinpoint the most effective production of materials to meet the criteria. It is hypothesized that synthetic control of crystal growth for battery materials will lead to improved charging speed. If successful, these materials will enable technology with the ability to charge devices in minutes, not hours.

I wish to acknowledge the mentorship of this work sponsored by ARL's Historically Black Colleges and Universities/Minority Institutions Summer Student Internship Program.

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Socket-Based C++ Analysis and Development Environment (SCADE) for MATLAB

Abby Snellman

MATLAB is often considered the premier tool for signal processing due to its relatively easy programming language and extensive features for data visualization. However, its heavy processing overhead, high computing requirements, and license requirements make it difficult to run in systems with limited resources or an inability to license. MATLAB does allow C++ functions to be integrated into MATLAB programs using MATLAB executable (MEX) functions. However, because MEX functions must use specific data types, the C++ code portability is limited.

The Socket-Based C++ Analysis and Development Environment (SCADE) overcomes these deficiencies by enabling data to be streamed from MATLAB into a standalone C++ program for fast and efficient processing using the performance boost from multithreading. Analysis results are subsequently returned to MATLAB over socket connections for visualization and/or further processing. This development environment enables 1) multithreaded applications to run alongside MATLAB, 2) MATLAB visualization tools to be directly accessible for data produced by C++ programs/algorithms, and 3) a standalone processing environment that is readily portable to deployable hardware.

This software package was applied to address the Army's need for stable and enduring power solutions at bases and installments both domestically and abroad. SCADE was used to develop a C++ application for harmonic analysis and power event detection. This readily portable program includes features such as efficient implementations of fast Fourier transform and total harmonic distortion (THD) computation algorithms, as well as several real-time detectors looking for changes in THD that indicate and alter to unhealthy power conditions.

I wish to acknowledge Brandon Parks for his mentorship throughout the summer and for all his help in getting me the tools and information I needed to accomplish my goals for this project, especially in the face of a global pandemic.

Network Data Curation

Oscar Solis

Data are a critical asset in the realm of cybersecurity as they provide empirical and proven technologies in specific domains. Data are scarce and very rarely labeled, which inhibits empirical research and validation. My project aims to provide a solution to this problem. I am using machine learning techniques, specifically clustering and bag of words, to make a model capable of automatically filtering and adding labels to malicious network packets. This will greatly decrease the amount of manual labor required for an individual to identify and annotate larger data sets (which are commonly terabytes in size). Instead, by labeling a small, targeted data set, this model is able to automatically, and with some explicit confidence thresholds, label similar packets in other network packet captures. Preliminary results show that by annotating a small, publicly available network capture consisting of JBoss exploit traffic, the model is able to identify, through clustering, malicious packets from other captures.

I wish to acknowledge the mentorship of ARL for the opportunity to participate in meaningful research that will hopefully benefit our Armed Forces. A special thank you to Dr Jaime C Acosta for his guidance and help during this project.

Development of an Electroencephalogram Analysis Pipeline for Human and Physical Augmentation System Interactions

Seongmi Song,

Lower-limb exoskeletons have been developed to augment human capability and proposed to assist Soldiers for the battlefield. There is evidence that suggests brain signals may track how well humans are adapting to exoskeletons and that these signals may be used to improve the human–machine interface. We plan to use electroencephalography (EEG) to measure electrical brain activity while people walk on a treadmill as they adapt to an exoskeleton. EEG is known to have a poor signal to noise, and it is critical to develop a sufficient signal-processing pipeline to ensure that these artifacts are extracted while not distorting the brain signal. The objective of this work was to develop a custom signal-processing pipeline to extract brain signals from noisy EEGs collected during our novel study paradigm. By combining previously tested signal-processing steps to generate a custom EEG-processing pipeline, we were able to extract brain components as identified by power spectrum, topography, and good dipole fit. The identification of brain components is an indication that our pipeline was able to successfully separate brain signals from artifacts. The development of the EEG preprocessing pipeline will help us to understand brain dynamics while the human adapts to the exoskeleton.

I wish to acknowledge the mentorship of Courtney Haynes, Anna K McGough, Christian Poindexter, and J Cortney Bradford, the real-world neurotechnology team members who provided insight and expertise that greatly assisted the research.

Design of a Molecular Toolkit for Plastic Degrading Enzymes

Amya Sowell

Over the last 50 years, the adoption of plastic materials for a variety of commercial and consumer applications has created a major environmental problem for the planet. For the Army, logistical demands posed by the transport and disposal of plastic wastes from packaging materials adds to the cost of operations and expands the footprint of a deployed force. Many types of plastics are nonbiodegradable, which has caused plastics to linger in the environment. A potential solution to these problems is through the engineering of enzymes that can break down plastic polymers in a manner in which they could be available for biodegradation. In this work, we mined some candidate enzymes that show putative activity on polyurethane. From these enzyme sequences, a molecular toolkit was designed for the production and testing of plastic-degrading enzymes. The DNA sequences found for each enzyme were made into modular "parts" using the "Golden Gate" design method to be quickly transferred to a variety of microorganisms for testing.

I wish to acknowledge the mentorship of the DOD for allowing me to be a part of this opportunity. The DOD funds my scholarship, as I am in the STEM Scholars Program at Hampton University, which guarantees an internship with them. I am appreciative of this research experience, even though I was not able to participate in person. I am grateful for the experience I had during this summer, and have learned a lot of valuable information. I would also like to thank Dr Hughes for the knowledge I have learned from his mentorship. At the beginning of the summer, I was apprehensive about participating in a research internship virtually, but Dr Hughes made the process very easygoing. Lastly, I would like to thank my lab mates for going through this journey with me. They were all very willing to help when needed and I am very glad to have had this experience with them.

Integration of Biological Material for Multifunctional Applications

Kourtney Steen

Melanin is a high-molecular-weight pigment that can be derived from a variety of biological, natural, and synthetic sources. Melanin has many unique properties, such as high ultraviolet (UV) absorbance, radical scavenging, antioxidant, radiation shielding, redox, and metal chelation. These properties can be translated into the development of multifunctional materials. In this presentation, the applications of melanin for UV protection, polymer stability, and energy storage are reviewed. Natural melanin and synthetic melanin were incorporated into polymers, and significant enhancement in UV shielding was achieved in both UVA and UVB regions. Since melanin is known for its radical scavenging and antioxidative functions in living systems, it was tested as a thermal stabilizer with synthetic polymers, where the polymers demonstrated improved thermal stability. Melanin was also used as electrodes for batteries and supercapacitors because of its metal chelation and redox activities, and when compared with pristine anodes, the sodium anode with melanin showed a higher peak in the cathodic currents.[1–4]

In summary, melanin is an effective shield when in contact with UV light. It improves the thermal stability of polymeric materials. It is also an attractive material for environmentally friendly, energy-storage solutions.

I wish to acknowledge the mentorship of Dr Hong Dong for working diligently with me and supporting me throughout this research. I want to recognize TMT Group for supporting this research and allowing me an opportunity to work for this summer internship. Thank you for the encouragement and the tools needed to prepare me for a virtual research opportunity.

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Quantitative Analysis of Microstructural Flaw Populations and Their Implementation into Parametric Simulations of Dumbbell-Shaped Ceramic Compression Specimens

Adam Taylor

The role of ceramics in armor systems is to attenuate the kinetic energy from a high-velocity projectile by leveraging their high hardness to erode the projectile and high compressive strength to resist penetration and fracture the incoming projectile. However, when dispersing this energy, the inherent flaws in these brittle materials are activated as fracture initiation sites, the timeliness of which determines defeat versus penetration. Micro-computed tomography (μCT) enables nondestructive examination of these flaw populations, from which quantitative measures of the critical size and spacing can be determined via image processing codes. Mechanical testing, such as uniaxial compressive strength, can be used to examine the failure processes in a controlled environment. Current compression specimen geometries (cuboids/cylinders) promote undesirable stress concentrations at the specimen-platen interfaces, which can lead to an underestimation of performance. Dumbbell-shaped specimens have recently been used to overcome these shortfalls. A parametric study of simulated compression tests via finite element analysis has been performed with this geometry. The final step, currently in progress, is simulation of the dumbbell compression tests specimen with a reconstructed microstructural flaw population derived from μCT scans of actual ceramic specimens.

I wish to acknowledge the mentorship of John Pittari, Brian Powers, Jennifer Sietens, Jeffrey Swab, and Zachary Wilson.

Synthetic Data Acquisition: An Approach to Artificial Intelligence Machine Learning in a Virtual Environment

Matthew Thomas

Artificial intelligence machine learning has risen as a powerful tool for a multitude of challenges including that of object and vehicle detection. However, there is a significant inhibitor to its efficiency in the need for large quantities of high-quality data. This presentation forwards synthetic data acquisition (SDA) as a viable approach to the aforementioned problem while also reducing the resources required for data collection. This approach employs virtual environments, such as Unity, to autonomously procure large quantities of data on desired targets within the environment. The YOLOv4 algorithm and a suite of various data augmentation methods are used to train the detector with the acquired synthetic data sets supplemented by minimal real-world data. The training process acts as a testing mechanism for the data acquisition method, with the precision of the detector providing initial evidence of the effectiveness and utility of SDA in deep learning. Continued development and the integration of the Robot Operating System has the potential to produce a system in which unmanned aerial vehicles in the field could efficiently detect vehicles and determine their pose with minimal real-world data.[1,2]

I wish to acknowledge the mentorship of Nassy Srour, Dr Joseph Conroy, Dr Kyle Lindgren, and Christopher Maxey.

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Design of a Split-Fluorescent-Protein Toolkit for the Genetic Selection of Error-Free Synthetic Constructs

Kaayla Tippins

Protein-encoding DNA sequences (CDSs) encode the information necessary to make an amino acid sequence during the translation process. Similar to a sentence, these sequences have words and punctuations, with the genetic sequence starting at a "start" codon (ATG) and the ending marked with a "stop" codon (TAG, TGA, TTA) with three-letter codons representing the "words" that are decoded into the primary amino acid sequence of a protein. Making DNA CDSs synthetically leads to some sequences that contain errors. Removing error-containing sequences from synthetic genes that contain insertions and/or deletions in their nucleotide sequences is a time-consuming process that often involves multiple rounds of treatment with error-targeting proteins. Herein, we have begun the development of a toolkit consisting of the known split-fluorescent reporters for use in developing a translational reading frame selection to screen for synthetic CDSs that lack insertions or deletions introduced during synthesis. This toolkit takes advantage of a powerful DNA assembly method known as Golden Gate assembly to allow for the standardizable, modular, and combinatorial construction of synthetic components together for automatable assembly and assay. The Golden-Gate-compatible split-fluorescent parts designed in this work can also be used to specifically label proteins for studying protein–protein interactions within a cell.

I wish to acknowledge the mentorship of Dr Randy Hughes, who presented to me this rare opportunity as an intern in the 2020 DOD's Historically Black Colleges and Universities/Minority-Serving Institutions (HBCU/MSI) Summer Research Program. To continue, I cannot put into words how grateful I am for being a part of a program designed for individuals like myself. Although plans have changed due to this unpromising time in history, the best part about learning virtually is having the flexibility to learn from home on a desired schedule, leaving more time on the clock to manage other duties. I could go on about how this program, the team, and how my mentor helped make this experience great, but I will end to say I highly recommend HBCU/MSI science, technology, engineering, and mathematics majors to take on interning with this program because I am highly interested in joining ARL.

Potential Real-Time Detection of Toxicity in Bacterial Cells through Raman Spectral Analyses of Intracellular Amino Acid: A Review

Danielle Torres

Biofuel optimization through fermentation is largely limited by product toxicity—a process where accumulating biofuel becomes toxic to the organism producing it and thus limits yield. Several approaches have been explored, such as product stripping and engineering the organism toward a higher tolerance of the desired bioproduct. The ideal strategy of bacterial engineering requires better understanding of how and why the organism elicits the specific responses when exposed to the bioproduct. In this publication review, Raman spectral analysis was employed in characterization of the phenotypic changes of *E. coli* cells when exposed to butanol, which is a desired bioproduct made during fermentation of the organism. The scope of butanol toxicity was founded with 1) fatty acids content, 2) membrane fluidity, and 3) protein and amino acid content. The results suggest that Raman spectral analyses, when optimized, may be suited for approximating metabolic and physiological changes in the phenotype of bacterial cells exposed to toxic bioproducts. This knowledge, when paired with fermentation systems for real-time decision-making, could ultimately lead to increased bioproduct yields.

I wish to acknowledge the mentorship of Theresah Zu.

Modeling Multiaxial Vibration of 3-D-Printed Liquid Crystal Elastomers (LCEs)

Nicholas Traugutt

LCEs are a class of smart polymers with multiple functionalities attributed to the combined anisotropic molecular order of liquid crystals and the elasticity of a cross-linked polymer network.[1–3] LCEs have often been looked at for their potential as actuators, but researchers have also begun seeing a lot of potential for using them in biomedical applications.[4,5] Their rate-dependent and damping properties could provide necessary contributions to biomedical devices, as well as protective equipment and other antivibrational applications.[6,7] Currently, no known constitutive model has been developed that accurately simulates and predicts the complex, and often unusual, properties and behaviors of LCEs during mechanical testing. This project focuses on developing a constitutive and predictive model for small strains, since the stress responses of LCEs at less than 10% strain is typically linear, which is a trend seen in most elastomers. The 3-D printed structures will be manufactured and tested on a multiaxis vibration system with 6 degrees of freedom. An analytical model will be fit to the test data and necessary material properties that are derived from the analytical model will be used to define the material properties in Abaqus. Abaqus will be used to create a predictive simulation for the mechanical responses of LCEs and assist with manufacturing structures for specific applications.

I wish to acknowledge the mentorship of Todd Henry.

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Fourier Analysis of Raman Spectra from Individual Ambient Aerosol Particles

Lillian Uhl

Understanding the types and concentrations of ambient aerosol particles should be helpful in determining environmental health and safety risks to Soldiers and other citizens. Semi-continuous analysis of such particles would benefit from automated data analysis of spectral features to reduce interpretation bias. Raman spectra from the automated aerosol Raman spectrometer now in use exhibit spectral noise that can interfere with peak identification. Some of the noise appears quasi-periodic, as if from interference within the instrument. Identifying sources of spectral noise and designing filters to reduce them could clarify identifiable Raman peaks. Fourier analytic-based filtering can be used in an attempt to reduce this noise. Four filters are herein applied: zeroing, quartering, average, and average phase preserving. These filters display varying advantages and disadvantages depending on the specific spectral characteristics. Although some filters are aggressive and reduce Raman peaks, others preserve more of the original Raman peak.

I wish to acknowledge the mentorship of David Doughty.

Intensity-Based Identification and Tracking of Airplane Wingtip Vortices

Carlos Velazquez

In this work, intensity-based techniques to detect and track large aircraft vortices from wind Doppler Light Detection and Ranging (LIDAR) measurements are investigated. The ground-based Doppler LIDAR system allows the ability to track an aircraft's wingtip vortices for several minutes after a flyby. Once identified, the characteristics of the vortices can be examined, including core separation, velocity, and radial size. The variability of the near-ground-surface conditions can change the vortices drop rate, as well as cause the vortex to twist and deform unpredictably. Correlation techniques are applied to LIDAR scans to identify a region of interest with wingtip vortices. To estimate the spatial shift of the vortices, a block-matching (BM) algorithm is employed to obtain the vortices' displacement between a pair of sequential LIDAR scans. Thereafter, feeding the BM results into a Kalman filter, the position of the wingtip vortices is tracked to the near-ground surface. Comparisons between apparent and estimated positions of the wingtip vortices are presented.

I wish to acknowledge the mentorship of Sandra Collier.

Development of a Miniature Fatigue-Testing Instrument for Use on Novel Research Materials

Travis Wagner

The miniature fatigue tester aims to add to the ARL Metals Branch's suite of mechanical testing instrumentation. The miniature fatigue tester was adapted from an existing design at the University of North Texas—it serves to reduce the size of the specimen required for fatigue testing. The device uses a motor-powered crank-based linkage to produce a linear displacement, bending a plate-based "dogbone" specimen with a tapered gauge length and fully reversed loading. The small-scale nature of this tester allows materials with small volumes to be tested that otherwise would not be amenable to full-scale testing. Metal can be sourced from a large variety of stock, sectioned into around 1-mm-thick plates and then milled into the specimen's shape. After milling, the specimen must be polished to reduce surface defects that can be the site of stress concentrations, which would negatively affect the fatigue life. The device tests the specimen to failure and produces a data file that documents the stress amplitude under each cycle. This recorded data is used to characterize the material's fatigue properties, particularly fatigue lifetime, an essential part of understanding the lifespan of materials used in the field.

The project presented here is a continuation of prior work completed by the same student through the College Qualified Leader's program. This summer, the focus was on documentation of the fatigue instrument through 1) an ARL technical report and 2) a comprehensive user's manual.

I wish to acknowledge the mentorship of Dr Denise Yin and the Metals Branch for having me this summer.

Internalizing Compressed Gaussian Processes for Smoothed Policy Search in Reinforcement Learning

Bingjia Wang

We consider policy search in reinforcement learning as defined by an infinite-horizon discounted Markov decision process. Standard policy gradient considers a parameterized family of policies, and executes stochastic gradient ascent as defined by the product of the score function and Q function, where the stochastic approximation is taken with respect to the ergodic state-action occupancy measure. We consider a radical departure from this scheme by fitting a compressed Gaussian process (GP) to directly estimate this occupancy measure. Then, we numerically integrate policy search directions via Bayesian quadrature according to this constructed occupancy measure estimate to internalize the "experience" of past visited trajectories according to their contribution to the population policy gradient. Experimentally, we observe an order of magnitude reduction in sample complexity when using compressed GPs and Bayesian quadrature to integrate the policy gradient estimate on a few canonical OpenAI environments.

I wish to acknowledge the mentorship of Alec Koppel.

Comparing Test Results Obtained in Accelerated Corrosion and Real-World Exposure

Kenneth Watts

Armor alloys and variations of the chemical agent–resistant coating (CARC) stack-up, including pretreatment, primer, and top coat, are continuously evaluated at ARL to ensure conformance with military specifications. Accelerated corrosion testing such as ASTM B117 Neutral Salt Fog and GMW14872 Cyclic Corrosion is used to simulate outdoor environments and obtain results at much-shorter timescales. The differences between the real-world exposures seen at Cape Canaveral Air Force Station and Kennedy Space Center and the accelerated exposures are explored and discussed. After reviewing the given data, it was found that some pretreatments, when comparing failure ratings at the scribe, are similar among the three tests. There were also instances in which both the ASTM B117 and GMW14872 were consistent with outdoor exposure. However, the results from comparing the two accelerated tests were not consistent. The major finding in this research is that there is no overall trend that can be applied to the accelerated and static outdoor exposure. While some of the pretreatments tested performed similarly in all three phases of testing, there were many more instances in which one or more test method of a given pretreatment provided incongruent results.

I wish to acknowledge the mentorship of Thomas Considine.

Determining the Hazards of Different Forms of Isomer-Bearing Materials for Future Novel Power Sources

Darlene Wilson

Nuclear isomers store about 100,000 times the energy density of chemicals and may eventually enable a novel type of power source that moves “beyond fossil fuels”, providing maneuver without resupply. Considerable basic research is needed to develop methods for controlling the energy release from isomers and, at present, it is premature to identify the physical form of the isomer material, for example, as a metal foil or oxide. A wide range of hazards may be presented by isomers in different forms and mitigating the associated risks will be important to any eventual application. Here, we initiated an examination of the potential radiological, chemical, and biological hazards associated with various different chemical forms of elements for which long-lived nuclear isomers exist, for a subset of isomers of principal interest for Army energy and power. Americium and bismuth were selected for initial examination; this study describes the state-of-the-art information on their exposure and health effects. Understanding the different chemical and radiation health effects, and routes of exposure, helps to determine the associated health risks. In particular, gaps in the available data were identified for some materials in this initial search and point to the need for further literature and laboratory research.

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One-Dimensional Model of Electron and Injected Cation Behavior in a Polymer Electrolyte Membrane

Catherine Wraback

Developing a 1-D model describing electronic and ionic species movement aids in understanding the transport in polymer-based actuators, a type of artificial muscle. Based on experiments, the actuation rate and kinetics of chemically powered, polymer-based actuators are slow compared to the desired values comparable to human muscles. By developing a model, we can determine which materials and parameters will optimize the transport of various species through the polymer electrolyte membrane. The 1-D model developed focuses on the drift and diffusion of electrons and protonated water in a polymer electrolyte membrane moving from the anode electrocatalyst layer to the cathode electrocatalyst layer. A numerical procedure was adapted from the drift-diffusion, continuity, and Poisson's equations and formulated using MATLAB. A simple 1-D diffusion model was created to verify this approach. The drift component was then incorporated into the simple diffusion model to improve model accuracy and determine the ideal method of transporting these species. Future work includes combing the drift-diffusion model with a polymer swelling model (from a collaborator) to determine the swelling that occurs in the polymer electrolyte membrane upon chemically powered "injection" of protonated water.

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The Production and Study of Topological Materials

Maria Wraback

Topological materials were studied from the perspective of a nonspecialist for the purpose of enabling more-effective communication to general society. These materials are critical for creating new lower-power electronics such as transistors, which exhibit increased battery life because their components only conduct electricity in an ultra-thin sheet on their surfaces. Topological materials are unique because they host a special Dirac cone in their band structures, which occur due to strong spin-orbit coupling and band inversion. Because of the Dirac cone's presence, electrical current only flows on the surface, and the electrons in the current have their spin locked in the direction in which they are travelling, causing unusual magneto transport phenomena. Topological materials are synthesized by growing crystals of topological compounds onto substrates through the use of molecular beam epitaxy (MBE). Pure and doped crystals grown in ultra-high vacuum in the MBE contribute to the differing properties of certain materials and alloys. Important characterization techniques are then completed that capture these properties, such as the structural perfection and special behavior of valence electrons that give rise to the unique behavior of topological materials. From these measurements, topological devices can be adjusted and improved, making them more efficient for deployed Soldiers.[1,2]

I wish to acknowledge the mentorship of Drs George De Coster, Charles Rong, Patrick Taylor, and Owen Vail for teaching me about the different aspects of topological materials regarding their properties, growth, and applications.

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Arbitrary Waveform Generation for Simulating Electric- and Magnetic-Field Anomalies

Alice Xue

ARL's E/H-Field Sensing Team studies various anomalies in quasi-static fields. These anomalies can occur in the currents and voltages of power systems, perturbations in uniform magnetic fields by metallic objects, changes to a uniform electric fields by liquids, and so on. A simulation architecture for replicating these anomalies, as well as easily creating new anomalies, will enable faster, cheaper, and more versatile testing of sensor systems for future applications. Both MATLAB and LabVIEW commercial software, respectively, can be used to create a complex waveform and produce the waveform on real hardware. The MATLAB graphical user interface (GUI) offers three basic waveform types: periodic pulses, noise, and sinusoids. The MATLAB GUI lets the user choose zero to four filters to apply to their waveform, and then export the waveform as a text or Excel file. The accompanying LabVIEW GUI then reads in waveform files, reformats the file to fit the arbitrary waveform profile of an Agilent 33522A arbitrary waveform generator, and outputs the waveform continuously on the function generator. The presentation details background, methods, and experimental results of arbitrary waveform simulation.

I wish to acknowledge the mentorship of Sean Heintzelman, as well as Brandon Parks and David Hull for their additional guidance.

Nondimensionalization and Numerical Analysis of Fluid and Structural Dynamics in Aviation Turbomachinery

Bohan Yao

Aviation turbochargers are used to increase the performance capabilities of compression-ignition engines on aircraft by increasing their efficiency and allowing for smaller and lighter designs. To maintain an effective and reliable turbocharger, we must understand the failure modes associated with blade fatigue and vibrations. Additionally, the need for a nondimensionalized model to recreate similar dynamic events has arisen to more accessibly study the fluid–structure interaction. By nondimensionalizing the relevant governing equations pertaining to fluid–structure interactions in a turbocharger, several nondimensional groupings of structural and fluid parameters can be obtained. In addition to the typical nondimensional numbers, such as Reynolds, Prandtl, and Mach numbers, a number of relevant groupings involving aeroelasticity, thermodynamics, and flow steadiness were found. To create a dynamically similar turbocharger model, these nondimensional groupings must be matched to those of the original model to produce relevant results. This nondimensional model can then be studied in computational fluid dynamics numerical simulations to predict flow patterns that cause pressure oscillations, blade vibrations, and ultimately, failure modes. Since aviation turbochargers are operating at extreme conditions found in the atmosphere, this work will be useful in making them safer and more reliable.

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Graphical Evaluation of Incomplete Ionization in Silicon, Wide-Bandgap, and Ultrawide-Bandgap Semiconductors

Jonathan (Jay) Yun

This internship project investigated incomplete ionization in silicon, wide-bandgap, and ultrawide-bandgap semiconductors (mainly 4H-silicon carbide, gallium nitride, and diamond) as a function of temperature. Wide- and ultrawide-bandgap semiconductors have not been studied as much as silicon. They have potential for high-power and high-temperature applications, but are immature, and careful studies are needed to fully understand the electrical performance of devices fabricated with those new materials. Incomplete ionization is an important factor that influences the functionality of semiconductor devices; this phenomenon must be investigated on wide- and ultrawide-bandgap materials. Since those materials are targeted for high-temperature application, our study includes the temperature dependence of incomplete ionization. To complete this, I graphically solve the equilibrium fermi level and use it to evaluate the concentration of ionized dopants. Accurate knowledge of incomplete ionization is important to more precisely simulate semiconductor devices. Having correct models for incomplete ionization will help establish the maturity of wide- and ultrawide-bandgap materials, which are targeted for fabricating power-efficient devices useful for power conversion and power switching.[1–8]

I wish to acknowledge the mentorship of Franklin Nouketcha for working with me throughout the summer. He helped me get a better understanding of how bandgaps and semiconductors function, how to implement complex MATLAB coding, and what it takes to be a part of the ARL team, as well as what it means to be a researcher and how much work researchers put into projects. I also thank Anand Sampath for putting in the time and effort to catch up on what I have accomplished and what my next goals would be for each part of the project. They have really helped make my time at ARL something to remember and consider as a possible career choice.

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Evaluation of an Analytical Model for Silica Particles Irradiated by a Carbon Dioxide (CO_2) Laser

Ryan Zegarski

This research focuses on evaluating an analytical model for the laser-based heating and evaporation of silica particles. This work begins with recreating the numerical model from Elhadj et al.[1] To recreate the model, three problems needed to be solved. First, the absorption efficiency, Q_{abs}, of a sphere in an electric field had to be calculated and compared to the 2-D surface in the Elhadj et al. paper, assuming Mie scattering. Then, the coupled equations had to be solved via MATLAB to calculate the temperature and radius of the silica particle. Finally, the values in the supplemental data had to be converted to the correct units, which also had to be found, to obtain the correct scale of the temperature gain and loss. The values of Q_{abs} were successfully recreated and the modeled temperature verses time resembled the results of the reference paper. However, further work will explore alternate differentiation solvers that may minimize error. This model will then be applied to submicron particle sizes to attempt to explore how fine particles will interact with a laser in material processing experiments.[2]

I wish to acknowledge the mentorship of Michael Golt (ARL).

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Phase-Field Modeling of Diamond–Silicon Carbide Composites

Jacob Zorn

Diamond–silicon carbide composites have been identified as a potentially high-strength and fracture-resistant material. To understand the effect of grain-boundary phases on the strength of this advanced ceramic body, phase-field simulations are performed on the composite structure with impregnated grain-boundary phases. Idealized synthetic microstructures are used from experimental sweeps to construct finite element meshes, and then a variety of displacement conditions are imposed and solved using state-of-the-art algorithms. The results indicate the introduction of graphitic-like structures and pores into the grain-boundary regions lowers the peak stresses attained by the composites. Additionally, this trend is seen across the samples when considering the strain energy density and other mechanical properties. This knowledge will be used to help guide future experimental efforts to help guide the fabrication and processing of such materials.

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