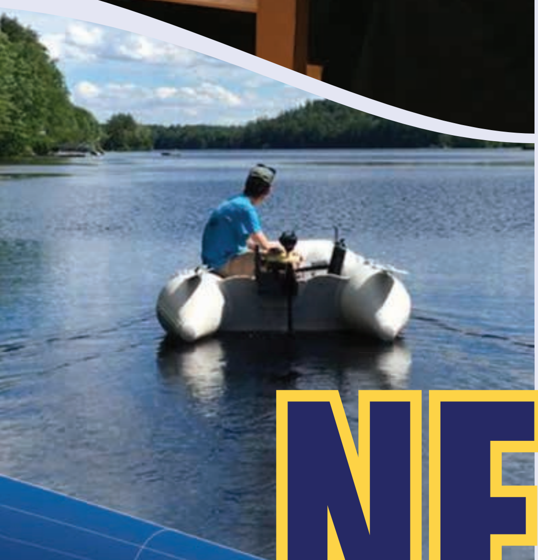
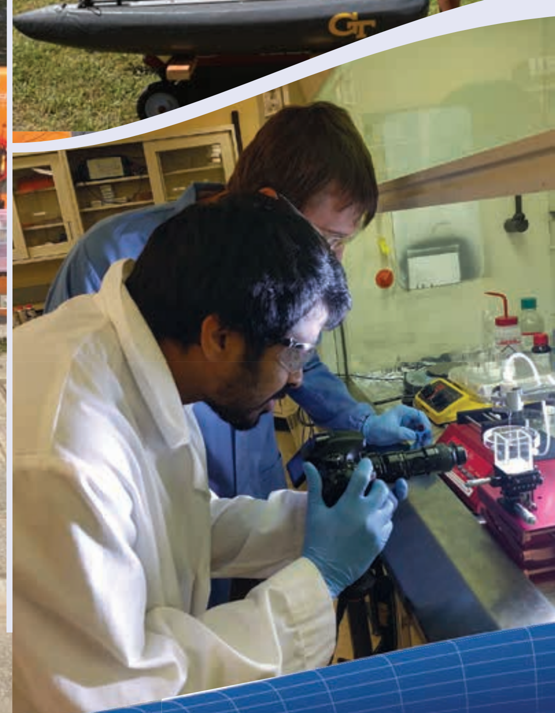
NAVAL ENGINEERING EDUCATION CONSORTIUM PROCEEDINGS

2018





NEEC

NAVAL ENGINEERING EDUCATION CONSORTIUM

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NUWC-18-GRA/0198

Message from the Executive Director

Welcome to the second annual Proceedings of the Naval Engineering Education Consortium (NEEC). This edition captures the 2017 highlights of our NEEC activities, documenting the research products to date and describing ongoing and future projects.

This year's NEEC efforts were all about improving upon our 2016 accomplishments. We changed our approach to award grants to participating universities (rather than contracts) to complement the business agreements and nurture collaboration between university researchers and Navy mentors. We increased the number of projects funded via the consortium by more than 10% from the previous year by including the Space and Naval Systems Center (SSC), NAVSEA program offices, and the Office of Naval Research as partners. I am also pleased to report that the Naval Air Systems Command (NAVAIR) is showing a keen interest in participating with us next year. A great advantage of the NEEC is that the model easily translates to benefit the entire Navy research and development enterprise.

A challenge that I posed to my team this past year was to emphasize hiring students that participated in the NEEC research. As these projects align with our future technical capabilities, the student researchers are getting critical experience to address Navy challenges. I am pleased that the NEEC team worked closely with our hiring managers to help refresh our workforce with new technical talent we will need in the future.

We continue to gain momentum with our academic institutions across the country, with 36 current university partners in the consortium. The list of partners continues to be refined as we seek to include those that are best suited to produce research results and help us incorporate graduates for the Navy's technical workforce.

As a whole, this NEEC Proceedings portrays a broad team effort to recognize the people that make NEEC successful: university professors and students, scientists and engineers, mentors, government contracting officers, recruiters, and NEEC Division Directors at the NAVSEA Warfare Centers. I offer a sincere "thank you" to these individuals that filled key roles, as well as to my leadership team. I also extend my appreciation to the NEEC Board of Visitors, who offered their valuable expertise, support, and assistance. We look forward to further developing these productive relationships well in the future!

Sincerely,

Donald F. McCormack
Executive Director
Naval Surface & Undersea Warfare Centers

About NEEC

The Naval Engineering Education Consortium was established by the Naval Sea Systems Command (NAVSEA) to develop and attract new professionals into the broad technical fields associated with current and future U.S. Navy ships and submarines. The purpose of NEEC is to increase and maintain a knowledge base for increasingly sophisticated technologies critical to the design and operation of complex, interrelated systems for the Naval and Defense acquisition communities.

NEEC engages relevant project-based research within academia to target the Navy's acquisition-technology needs and cultivates a future science and engineering workforce. Through NEEC, the Navy funds research and development projects at academic institutions to actively engage professors and their students to work alongside knowledgeable personnel familiar with the Navy's technology challenges.

Participating students must be US citizens and should be motivated to seek employment within NAVSEA or a sponsoring Navy command upon graduation. Select Navy personnel, acting as mentors, work in partnership with professors to identify those students interested in Navy civilian service. As opportunities arise, students are alerted to internships at Navy Centers that are designed to help them grow their potential to become part of the Navy's science and engineering workforce. The objectives of NEEC are:

- Acquire academic research results to resolve the Navy's technological challenges
- Hire students graduating with naval engineering research and development experience
- Develop/and maintain exceptional working relationships with naval engineering professors

The NEEC team is looking forward to seeing many years of productive research, extended relationships with academia, and students transitioning to new professionals who will develop into future technology leaders for the nation.

Sincerely,

Kirk E. Jenne
NEEC Director
NAVSEA Warfare Center Headquarters

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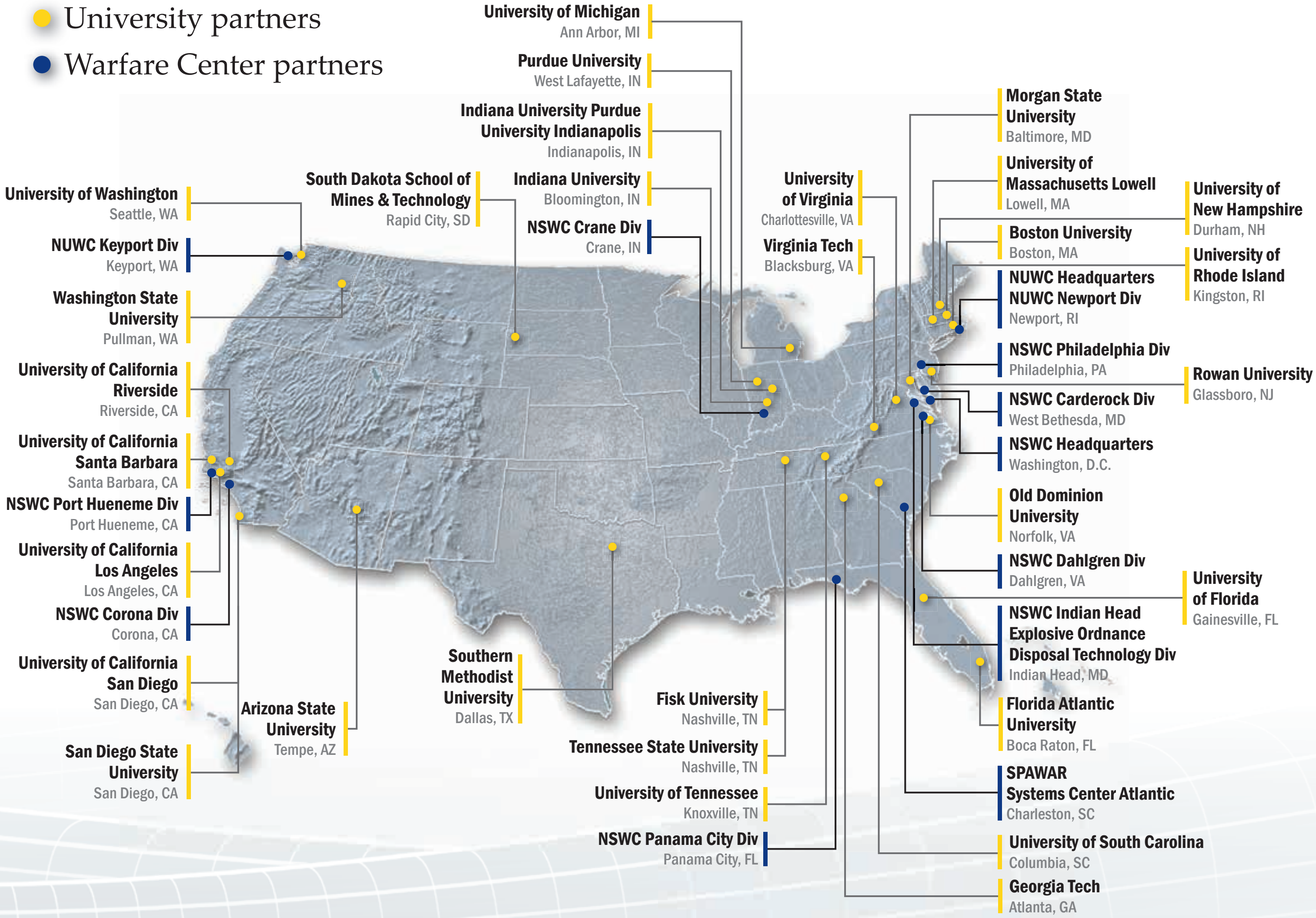
NEEC

NAVAL ENGINEERING EDUCATION CONSORTIUM

About Warfare Centers at the Naval Sea Systems Command (NAVSEA)

Scientists and engineers at NAVSEA and the Warfare Centers perform research, build, and further the technologies installed on America's Fleet of ships and submarines. NAVSEA's Warfare Center Enterprise comprises the Naval Surface Warfare Center (NSWC) and the Naval Undersea Warfare Center (NUWC). With eight Surface Warfare and two Undersea Warfare sites (Divisions) across the United States, these Warfare Centers supply the technical operations, people, technology, engineering services and products needed to equip and support the fleet and meet needs of the warfighter. These Warfare Centers are the Navy's principal research, development, test and evaluation (RDT&E) activities for surface ship and submarine systems and subsystems.

The Consortium



NSWC Carderock

High Resolution Quantification of Turbulent Boundary Layer Flows along Biofilms and their Associated Drag

Professors: Steven L. Ceccio and Marc Perlin

Technical Capability Alignment: Hydrodynamics

Students:
- **Undergraduate:** 5
- **PhD:** 2

Publications/Presentations:

1. Hartenberger, J., Gose, J., Perlin, M., and Ceccio, S. "Drag and Flow Measurements over Soft Biofilm." 32nd Symposium on Naval Hydrodynamics, 5-10 August 2018, Hamburg, Germany. -In preparation

2. Hartenberger, Joel. "Measurements of Drag and Flow over Biofilm." 70th Annual Meeting of the American Physical Society Division of Fluid Dynamics, 21 November 2017, Denver, CO.

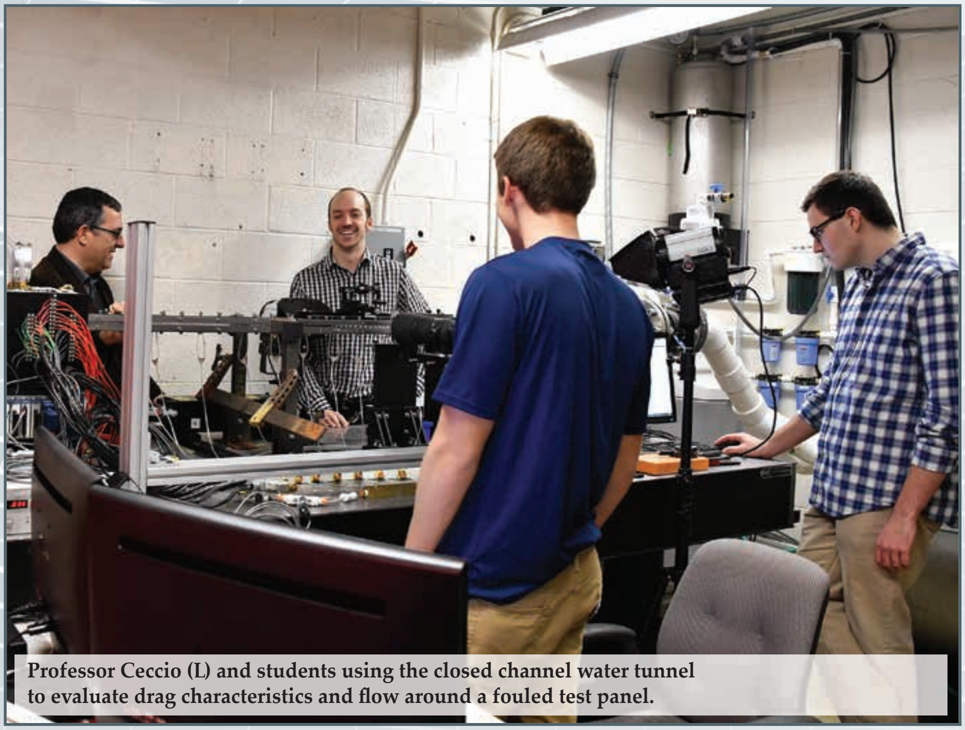
3. Callison, Elizabeth. "Characterization of Mechanical Properties of Microbial Biofilms." 70th Annual Meeting of the American Physical Society Division of Fluid Dynamics, 21 November 2017, Denver, CO.

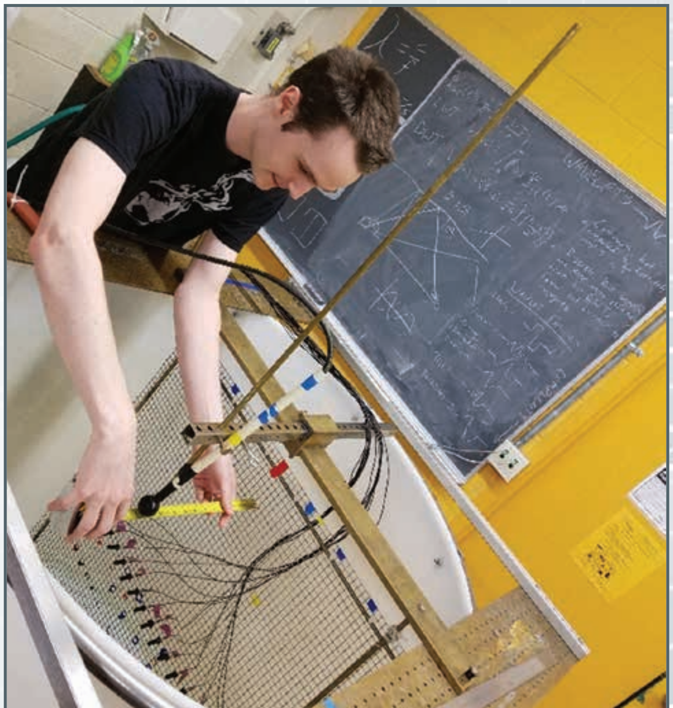
4. Hartenberger, Joel. "High Resolution PIV of flow over Biofilm Covered Walls." 69th Annual Meeting of the American Physical Society Division of Fluid Dynamics, 21 November 2016, Portland, OR.

University of Michigan

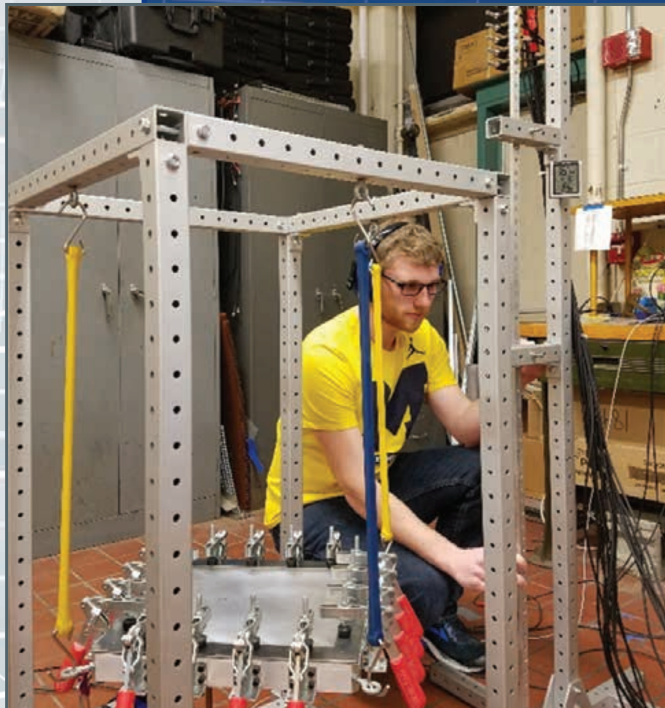
Biological fouling (biofouling) of ship hulls leads to increased drag which affects vessel performance, results in significant added fuel costs, and increases pollution. The Navy is investigating antifouling coatings and other methods to combat this problem, but understanding of the fundamental drag production mechanisms remains lacking. The aim of this project is to reveal the ways in which biofouling leads to increased drag production such as through added form, the compliant nature of the growth, and complex interaction with the flow by features such as streamers. Diatomaceous biofilm is grown on smooth acrylic test panels in a specially built growth flow loop then studied in a closed channel water tunnel. The drag experienced by each surface and the flow around it are measured and the surface profile of each panel recorded using a laser scanner. Rigid replicas of the compliant biofilm surface are 3D printed before being evaluated in the same manner. Comparisons of the drag and flow for the live biofilm and rigid replicas provide an estimate of the contributions of form and compliance to the overall drag. The findings of this project will help inform hull husbandry and update design tools used by naval architects.


Observing growth of biofilm on a test panel.


Professor Ceccio (L) and students using the closed channel water tunnel to evaluate drag characteristics and flow around a fouled test panel.



Measuring source location for water tank array measurements.



Setting up for acoustic array measurements of a vibrating plate.

University of Michigan

Understanding acoustic signatures to protect Naval platforms and identify threats is a core Navy capability. The goal of this research project is to develop and test methods for determining remote sound source characteristics from acoustic array measurements made in noisy and reverberant environments. The project currently has four tasks: (i) improving methods for source localization and source level estimation in noisy and/or reverberant environments, (ii) detecting transient signals at low SNRs, (iii) quantifying source levels in a Lloyd's mirror environment, and (iii) remotely identifying and localizing defects in vibrating mechanical structures. The project's four tasks consider both airborne sound measurements made in a one-story, 500 sq. ft. laboratory that lacks acoustic treatments and water-borne sound measurements made in a 42-inch diameter and depth cylindrical water tank. Advanced array processing techniques are applied to experimental data and computer simulations in order to advance performance capability in these areas.

NSWC Carderock

Acoustic Array Technology for Noisy and Reverberant Environments

Professor: Dr. David Dowling

Technical Capability Alignment: Acoustic Signature Technology

Students:
- **Undergraduate:** 2
- **Masters:** 2
- **PhD:** 2

NSWC Carderock

Integrated Simulation and Testing for the Qualification of Composite Parts Fabricated through Additive Manufacturing

Professor: Dr. Stephanie TerMaath

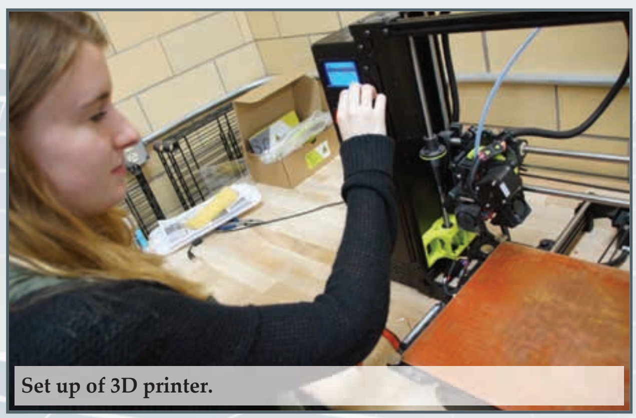
Technical Capability Alignment: Materials Technology

Students:
- **Undergraduate:** 4
- **PhD:** 1

University of Tennessee - Knoxville

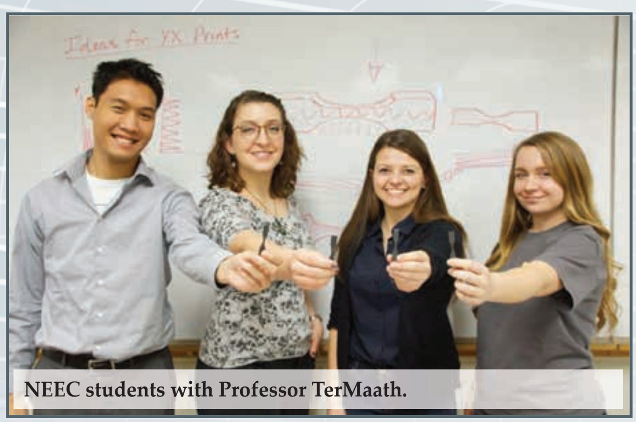
Additive manufacturing provides the capability to rapidly design and produce parts as needed to reduce a ship's downtime and improve maintainability at sea. This project is demonstrating a comprehensive approach encompassing computational simulation, additive manufacturing demonstration, and experimental testing to investigate the feasibility of an integrated Building Block Approach for the qualification of chopped fiber reinforced composites fabricated with fusion deposition modeling. Phase I demonstrated this approach at the coupon level to predict stiffness and strength, identify the most important manufacturing parameters for repeatability, and minimize variation in mechanical properties. Current efforts are focused on crack growth investigation and demonstration of a representative Navy part using both desktop printers and Big Area Additive Manufacturing (BAAM). Custom produced filament enables the investigation of varied fiber percentage and type to create materials suited for a marine environment. Computational simulation is performed using resources provided by the Department of Defense High Performance Computing Modernization Program so that models and methodology are readily shared with Navy stakeholders.

Student with 3D printer.

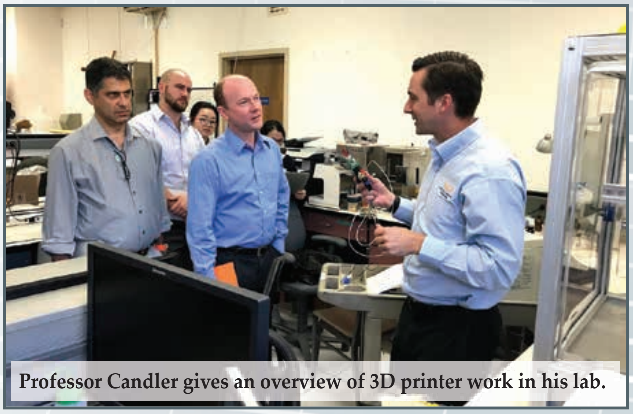


Set up of 3D printer.

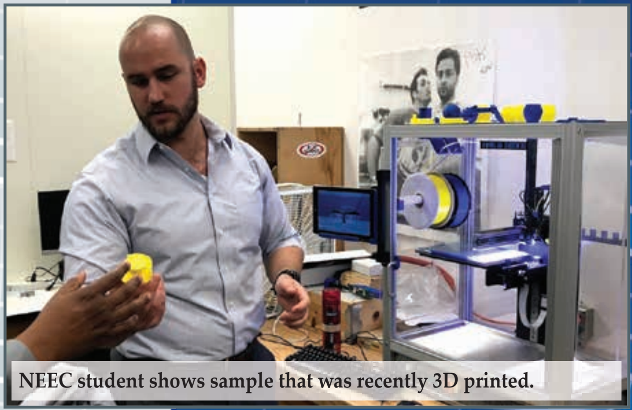
Student designing 3D printing test coupon.



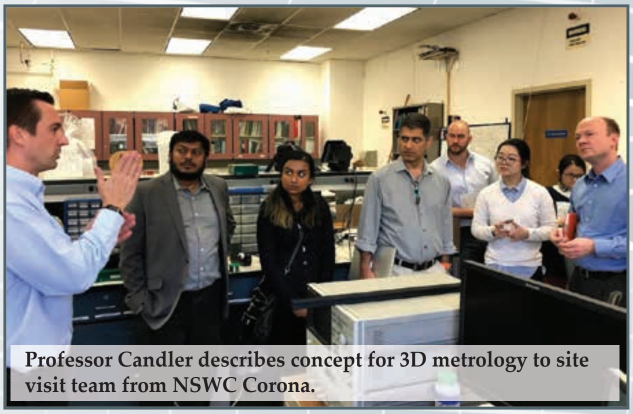
NEEC students with Professor TerMaath.



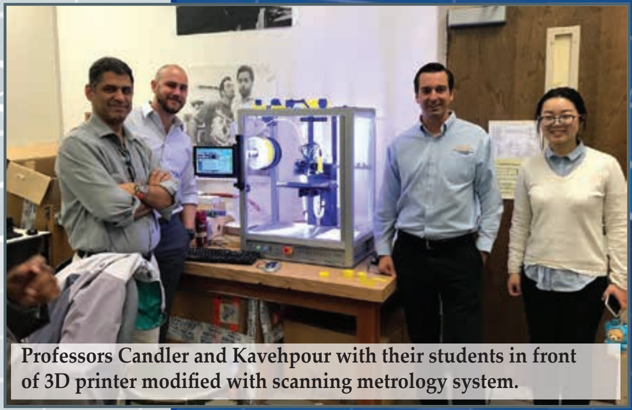
Professor Candler gives an overview of 3D printer work in his lab.



NEEC student shows sample that was recently 3D printed.



Professor Candler describes concept for 3D metrology to site visit team from NSWC Corona.



Professors Candler and Kavehpour with their students in front of 3D printer modified with scanning metrology system.

University of California Los Angeles

UCLA
University of California, Los Angeles

The goal of this project is to develop a scanning system that can create a layer-by-layer model of a 3D printed structure concurrently with the printing process. Additive manufacturing is rapidly moving from a system for prototype and visualization toward a flexible, cost effective method for low volume manufacturing. In order to be fully adopted, systems are needed that can perform metrology on the internal and external geometry of printed structures to ensure they are within specifications. Toward that end, our team is using a high-precision laser scanning sensor to reconstruct a layer-by-layer model of printed structures. This scanning information will be used to qualify the geometry after manufacturing as well as make in situ corrections to print errors during manufacturing.

NSWC Corona

Metrology & Calibration (METCAL) for Additive Manufacturing (AM)/3D Printing Technologies: Precision Enhancement of 3D Printing via in situ Metrology

Professor: Dr. Rob Candler

Technical Capability Alignment: Metrology, Test, and Monitoring Systems Assessment

Students:
- **Undergraduate:** 2
- **PhD:** 2

NSWC Corona

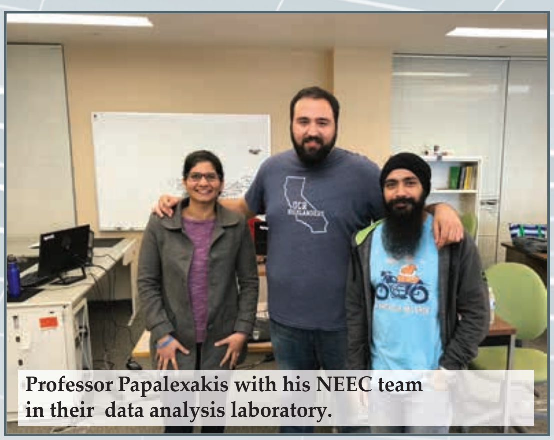
Big Multi-Aspect Data Mining via Scalable and Incremental Tensor Decompositions and Applications to Social Network Analysis

Professor:
Dr. Vagelis Papalexakis

Technical Capability Alignment:
Warfare Systems Performance Assessment

Students:
- **Undergraduate:** 3
- **PhD:** 1

Students discussing the algorithms and tools for multi-aspect data analysis.



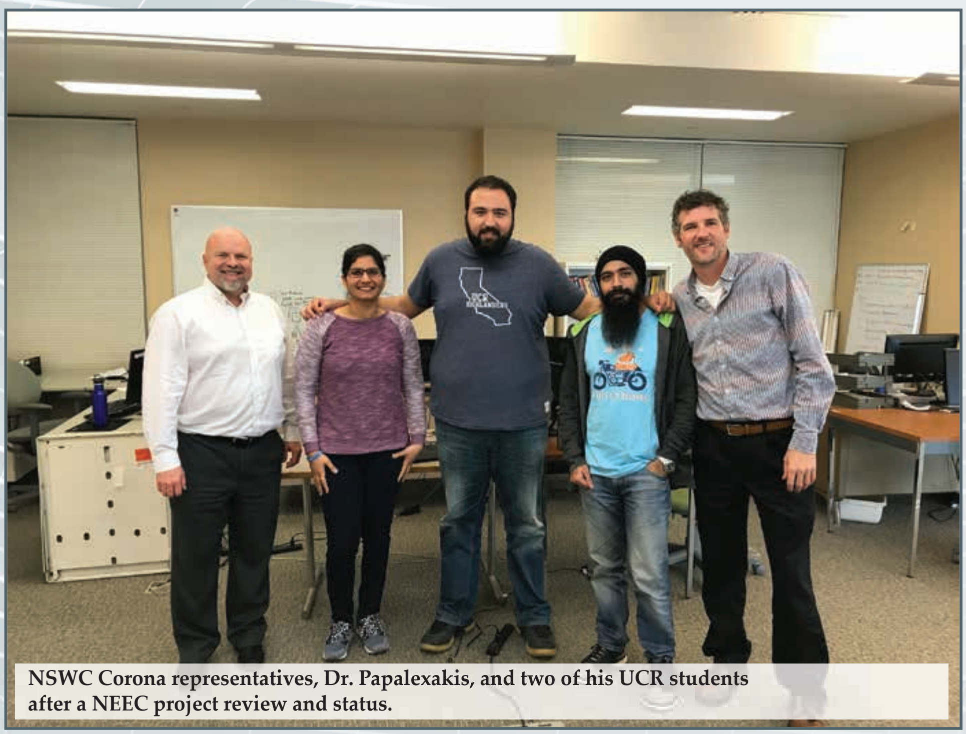
Professor Papalexakis with his NEEC team in their data analysis laboratory.

University of California Riverside

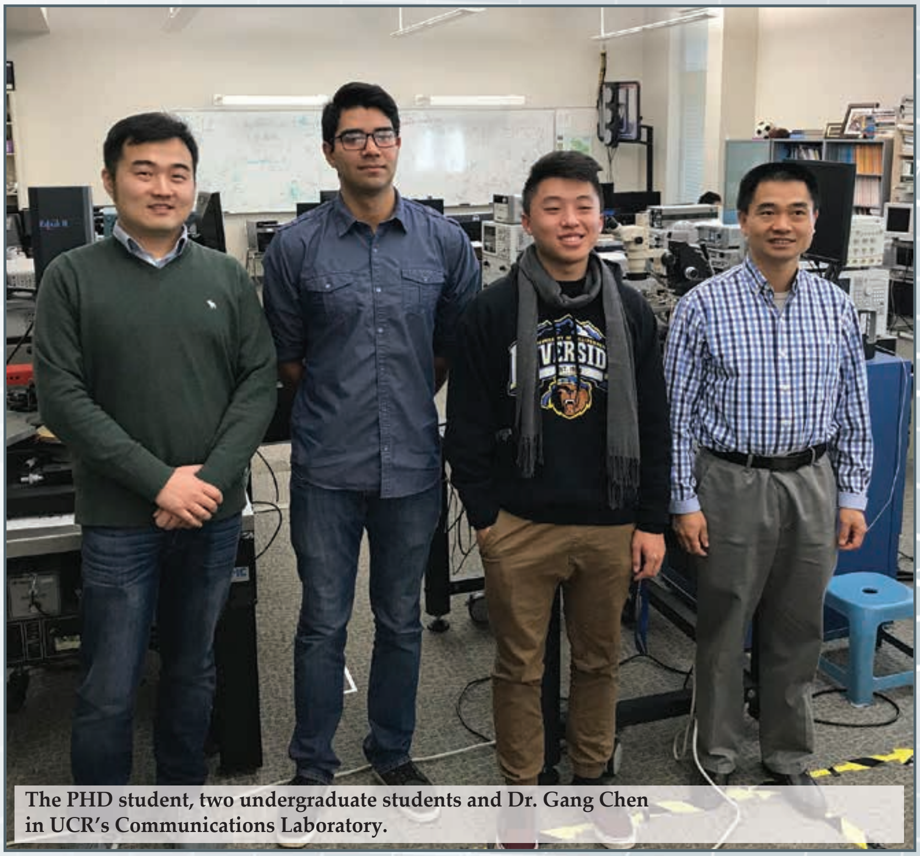
Many real-world processes and phenomena produce big data with multiple aspects. For instance, in Social Networks a who-calls-whom graph and a who-messages-whom graph are different aspects of human communication. Modeling and mining such multi-aspect data is shown to yield more accurate results compared to studies that focus on a single aspect.

Prof. Papalexakis and his team are creating algorithms and tools for multi-aspect data analysis that are scalable and interpretable, enable incremental computation for continuously updated data, and most importantly are easy-to-use for practitioners. The algorithms developed in this project are applied to a high-impact real-world multi-aspect data scenario of Multi-Aspect Social Networks, where the task is to identify communities, and patterns of normal and anomalous behavior from multi-aspect social network data.

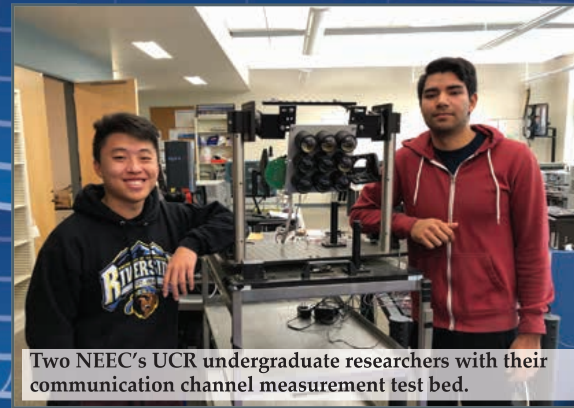
The work of the team has, so far, resulted in two publications in one of the most prestigious data science venues, the 2018 SIAM International Conference in Data Mining.



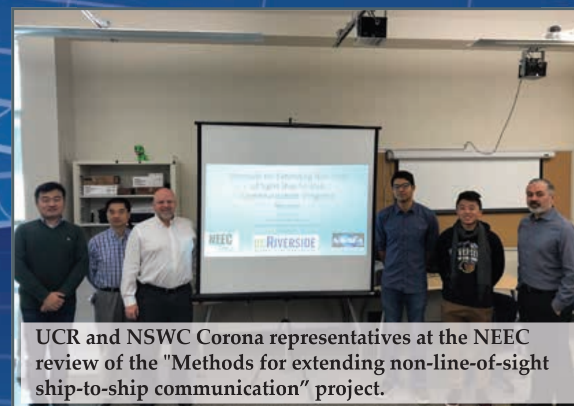
NSWC Corona representatives, Dr. Papalexakis, and two of his UCR students after a NEEC project review and status.



The PHD student, two undergraduate students and Dr. Gang Chen in UCR's Communications Laboratory.



Two NEEC's UCR undergraduate researchers with their communication channel measurement test bed.



UCR and NSWC Corona representatives at the NEEC review of the "Methods for extending non-line-of-sight ship-to-ship communication" project.

University of California Riverside

To investigate the unique channel condition for Navy's non-line-of-sight (NLOS) ship-to-ship communication system, a high fidelity simulation on the characteristics of overwater NLOS ultraviolet (UV) communication channel which include scattering and turbulence effect were modeled using single scattering and Monte Carlo multiple scattering simulation. Three geometrical parameters including transmitter elevation angle, receiver field of view and transceiver separation distance along with airborne humidity and temperature were taken into considerations as key parameters which affect the distribution of the receiving signals. The UCR group's simulation results have been published in 2017 SPIE conference. A channel measurement test bed with field testing plan to verify the simulation result is their next step. All the research and students learning opportunities are taking place in the spacious and well-equipped UC-Light center at the University of California, Riverside (UCR).

NSWC Corona

Methods for Extending Non-Line-of-Sight Ship-to-Ship Communication

Professor: Dr. Gang Chen

Technical Capability Alignment: Naval Surface & Air Range Systems Engineering

Students:
- **Undergraduate:** 2
- **PhD:** 1

NSWC Crane

Smart Separators with Embedded Sensors and Superior Thermal Conductivity

Professors: Dr. Richard Mu and Dr. Akira Ueda

Technical Capability Alignment: Advanced Electronics & Energy Systems

Students:
- **Undergraduate:** 6
- **Masters:** 2
- **PhD:** 2

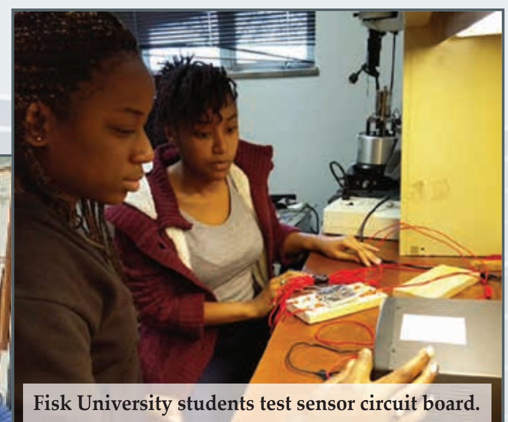
Publications/Presentations:

1. "Fabrication and Raman Analysis of Aligned Electrospun PVDF Nanofibers", A. Ueda, O. Ali, A. Zavalin, S. Avanesyan, W.E. Collins, R. Mu, S.K. Hargrove, (2018), Biosens Bioelectron DOI: 10.29011/BBOA-111. 100011, (in Print)

2. "Structural and Thermal Treatment Evaluation of Electrospun PVDF Nanofibers for Sensors", A. Parker, C. Marvinney, A. Ueda, F. Williams, K.S. Hargrove, R. Mu, J Polymer Sci & Appl, JPSA-17-39.(2018) (In Print)

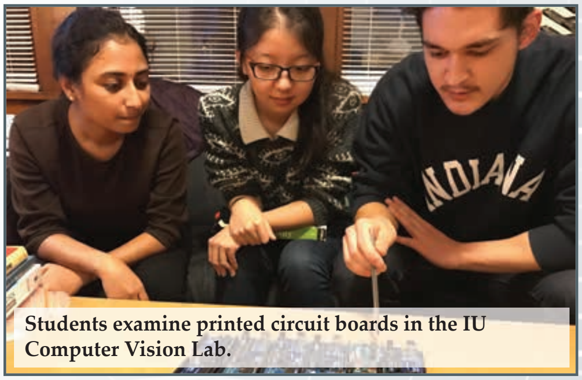
Fisk University

Abstract: Lithium ion batteries have not reached their full potential for safe energy conversion and storage processes. The separator is a critical, multi-functional component in lithium ion batteries that can play a key role in the performance and safety of energy conversion and storage processes. Managing and monitoring both the production and transport of heat at the separator is very important for minimizing cell temperature and avoiding dangerous thermal runaway. This requires a fundamental understanding of heat generation and distribution (mapping) within the battery cell on both a local and global scale. Building a highly thermally conductive separator with imbedded sensors (temperature and pressure) may hold the key to fault-tolerant battery technology. To achieve this, Fisk University collaborated with Tennessee State University and Vanderbilt University to contribute unique research skills and experience to a broad and relevant knowledge base. In addition, all members of the team have a strong experience in providing research training to undergraduate and graduate students within a minority student population.

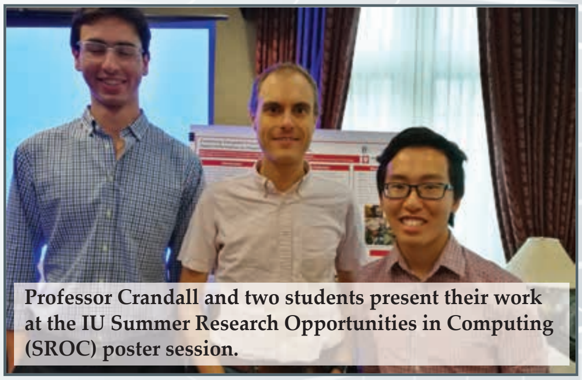


Fisk University students test sensor circuit board.

Fisk University, Tennessee State University and Vanderbilt University professors and students meet with NSWC Crane mentors.



Students examine printed circuit boards in the IU Computer Vision Lab.



Professor Crandall and two students present their work at the IU Summer Research Opportunities in Computing (SROC) poster session.

Students keep up-to-date with the latest computer vision and machine learning research through reading group meetings.

Indiana University

Microelectronics are at the heart of nearly all modern devices, ranging from small embedded integrated circuits (ICs) inside household products to complex microprocessors that power critical infrastructure systems. Ensuring the quality, safety, and security of these components is a critical challenge. One possible solution is to develop automated imaging techniques to check devices' physical appearance (including both external packaging appearance and microscopy images of the internal silicon itself) against known reference models in order to detect counterfeit or malicious components. This analysis is very challenging, considering that modern devices can contain billions of transistors. We are investigating and developing novel algorithms based on state-of-the-art machine learning to this problem. In our work so far, we have collected a large-scale dataset of photos of IC packages, annotated through Amazon Mechanical Turk, to use as training and testing data. We have developed a Siamese Convolutional Neural Network architecture that learns to match and identify irregularities between pairs of IC images. We have also developed a neural network-based technique for localizing and identifying ICs as well as lower-level visual features, such as specific logic gates.

NSWC Crane

Advanced Computer Vision Analysis of Micro Electronic Imagery

Professor: Dr. David Crandall

Technical Capability Alignment: Strategic Systems Hardware

Students:
- **Undergraduate:** 7
- **Masters:** 3
- **PhD:** 1

NSWC Crane

Particle Swarm Optimization (PSO) for Asset Allocation in a Dynamic Electronic Spectrum

Professor: Dr. Lauren Christopher

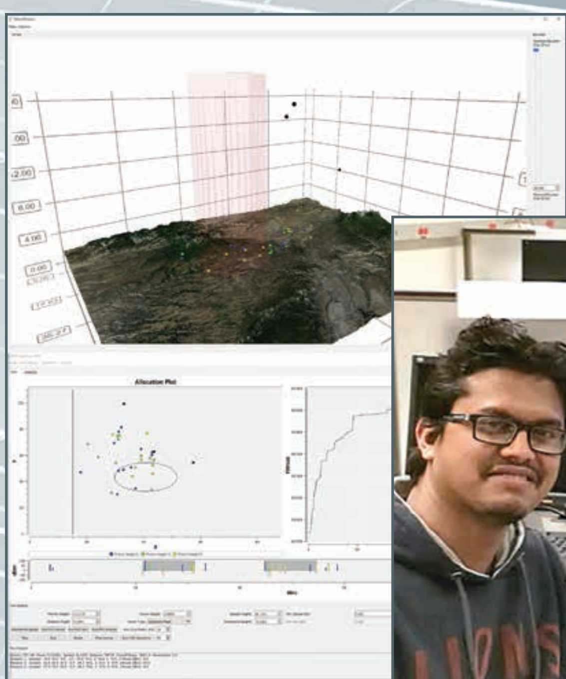
Technical Capability Alignment: Electronic Warfare Systems RDT&E/Acquisition/Life Cycle Support

Students:
- **Masters:** 3

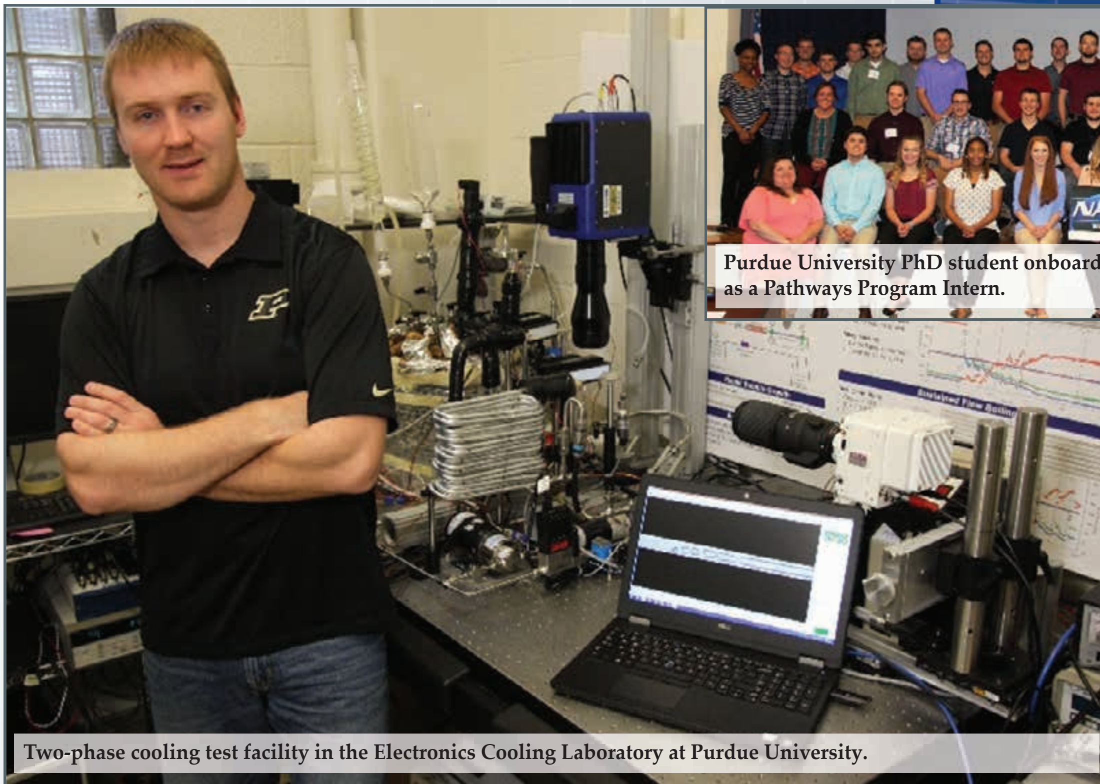
Indiana University/Purdue University Indianapolis

IUPUI

Abstract: Electronic Warfare (EW) assets that communicate or jam battlefield radios need optimal placement in 3 Dimensional (3D) space and in frequency. The optimization problem must be solved in near-real-time, with constantly updating complex naval battlefield conditions. This project uses a bio-inspired technique for the solution to the non-Polynomial (NP) problem of asset allocation: Particle Swarm Optimization (PSO). This project is a continuation of prior work in which frequency assignments and multi-dimensional asset placement was performed. Further work has been completed to integrate 3D elevation data from a Geographic Information System (ArcGIS) database, implement a propagation model of transmitters and receivers with respect to line of sight (LOS) constraints, provide improvements to pheromones performance and control, implement parallel computation of the PSO algorithm, and implement a new power loss function based on geometric mean. This project simulates the PSO environment using 3D data visualization. Improvements have been made to the visualization, such as terrain simulation and pheromone placement. The Graphical User Interface (GUI) has received additions, such as: loading elevation files, loading terrain images, and displaying power received on assets. This project is able to converge to an approximate solution while maintaining below a 1 second runtime benchmark with default parameters.



Students illustrate their research on Swarm Optimization for EW.



Two-phase cooling test facility in the Electronics Cooling Laboratory at Purdue University.

Purdue University PhD student onboarding at NSWC Crane as a Pathways Program Intern.

Purdue University

Abstract: Thermal control of high-power systems installed on Naval platforms is crucial to sustaining system performance and maintaining longevity of critical components. Gallium Nitride (GaN) is a breakthrough semiconductor technology for active electronically scanned arrays (AESA), which can house thousands of high-power amplifiers (HPA) in a system. Meeting the thermal management demand of these next-generation radar-frequency electronics will likely rely on embedded cooling strategies that operate in a two-phase regime and are subject to flow non-uniformities and instabilities. It is critical to evaluate the impact of temporal and spatial heat generation non-uniformities on the performance of two-phase microchannel heat sink technologies. This work will enable performance prediction and design of thermal management systems for next-generation Naval platforms.

NSWC Crane

Evaluation of the Effects of Dynamic and Nonuniform Operation of Radar-Frequency Electronics on High-Power-Density Thermal Management Strategies

Professor: Dr. Justin Weibel

Technical Capability Alignment: Sensors and Surveillance Systems

Students:
- **Undergraduate:** 2
- **PhD:** 2

NSWC Crane

GPS Spoofing Detection using Innovations Testing

Professors: Dr. Liang Hong and Dr. Lee Keel

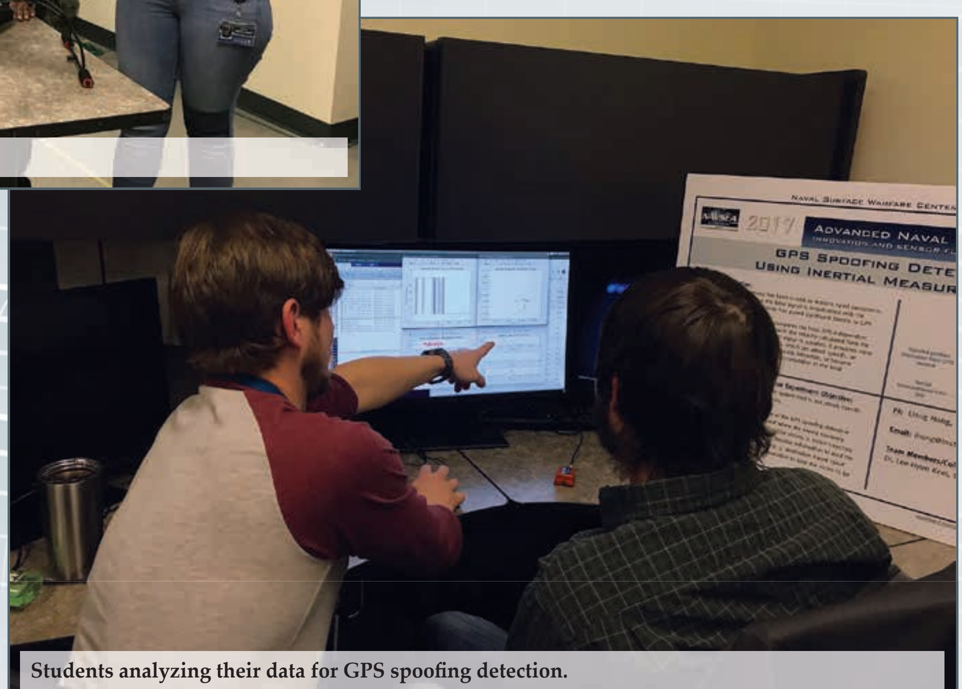
Technical Capability Alignment: Electronic Warfare Systems RDT&E/Acquisition/Life Cycle Support

Students:
- **Undergraduate:** 4
- **Masters:** 1
- **PhD:** 1

Tennessee State University

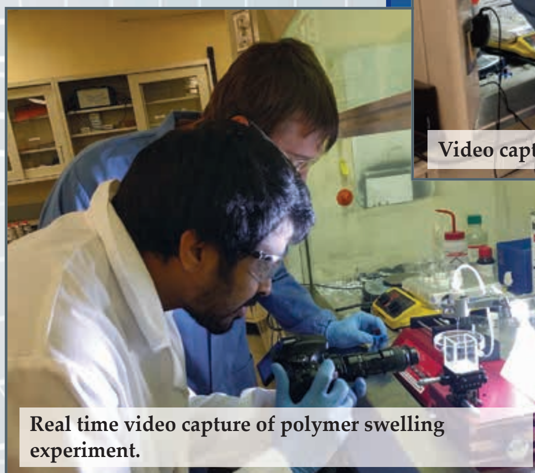
Abstract: Location awareness with GPS system has been crucial to modern naval operations. However, GPS spoofing, where the false signal is broadcasted with the intent to mislead the victim receiver, has posed significant threats to GPS integrity. Such attacks can easily be launched by exploiting the knowledge of the authentic GPS signal and its relation to the victim's location, and can be undetectable without using sophisticated techniques. This research develops a self-detection technique that is not attack specific so that it can be applied to any spoofing attacks. New theoretical framework and hardware and software innovations has been developed by using the "nature" of a signal in conjunction with locally available information. The testing during the 2017 Annual Naval Technology Exercise (ANTX) show that the GPS spoofing can be detected if the GPS of the spoofing detector is spoofed.

Students with their drone systems.



Students analyzing their data for GPS spoofing detection.


Polymer sample preparation.


Real time video capture of polymer swelling experiment.


Video capture set up for experiment in fume hood.

Arizona State University

Current MOPP garments work by posing a continuous, physical barrier to penetration of most hazardous chemicals. While this scheme does provide adequate protection against hazardous aerosols, it also prevents evaporative cooling of the user. As a result, without specialized cooling equipment, users can experience dangerous thermal stresses even after a short use of such garments. To address this problem, this NEEC project aims to develop stimuli responsive polymers that will provide the basis of breathable, self-sealing MOPP suits. Specifically, we aim at developing breathable, open mesh polymer-modified fabrics that allow for natural body thermoregulation through perspiration until they are exposed to a target range of hazardous chemicals. Once exposed, the polymer rapidly swells to create an impermeable membrane. Consequently, thermal stresses on the user are minimized by occurring only during actual exposure to hazardous materials. So far, we have developed a novel, selectively swelling polymer, poly(N,N-butylphenylacrylamide), which we plan on integrating into typical fabrics used in MOPP gear to create the adaptive, smart composite materials. In parallel with the material science efforts, we are also developing a computational model to guide development of an optimal superabsorbing polymer-modified fabric design. Specifically, a customized finite element model was developed to describe aerosol droplet-polymer interactions and polymer swelling kinematics. A concurrent fluid permeation and large deformation theory combined with constitutive relation based on Flory-Rehner theory was considered. A 2D axisymmetric model has been benchmarked with the experimental data obtained during swelling experiments of PDMS with n-hexane (bath as well as droplet exposure). This high-fidelity model will be implemented to predict swelling of different characteristic shapes, sizes, and configuration of the novel super-absorbent polymer. In combination with the experimental data, we will use this model to optimize the fabric design for maximum breathability while retaining the required protection levels for the user.

NSWC Dahlgren

Stimuli Sensitive Superabsorbing Polymer-Coated Fabric for Adaptive MOPP Suit Development

Professors:
Dr. Konrad Rykaczewski

Technical Capability Alignment:
Expeditionary and Other Weaponry Systems Research, Development, Test & Evaluation

Students:
- **Undergraduate:** 3
- **Masters:** 1
- **PhD:** 1

NSWC Dahlgren

Development of Agent-based Weapons and Sensor Models for Directed Energy Weapon Systems

Professor: Dr. Dimitri N. Mavris and Dr. Alicia Sudol

Technical Capability Alignment:
Surface Combat Systems Engineering and Integration
Research Development Test & Evaluation

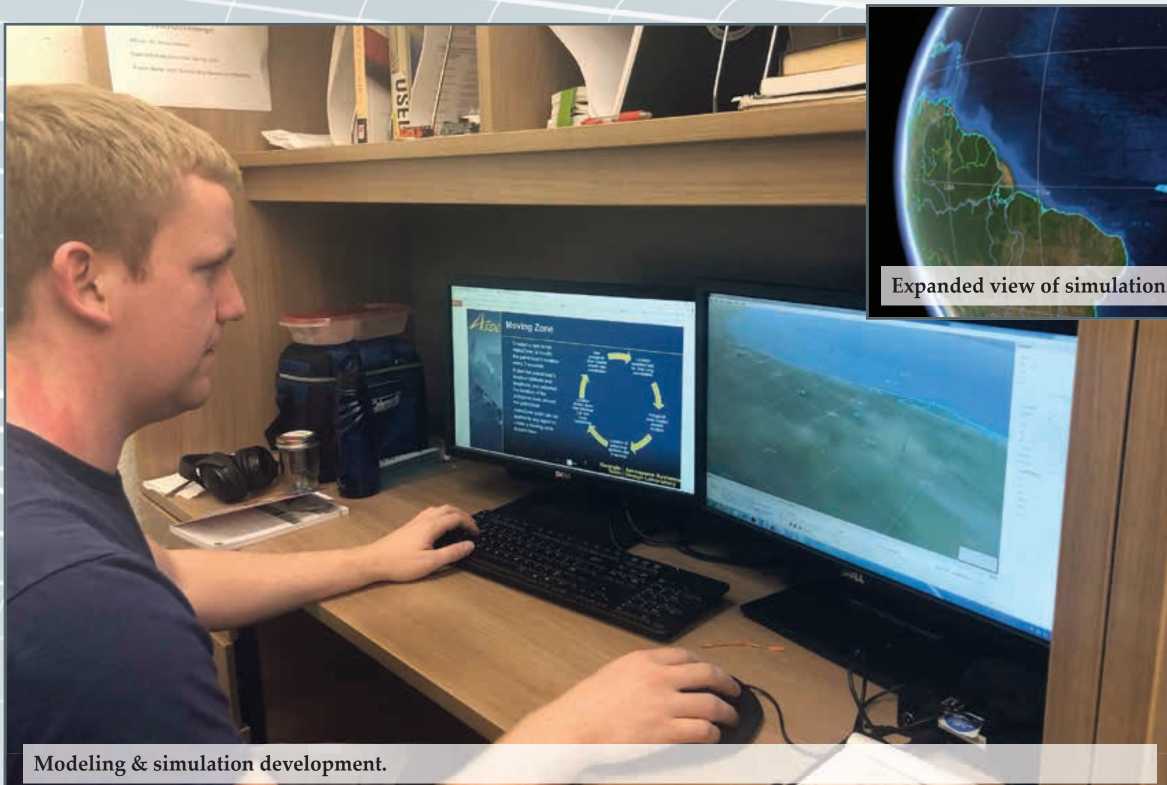
Students:
- **Undergraduate:** 3
- **Masters:** 1
- **PhD:** 1

Georgia Tech

As the naval battlespace evolves, ship self-defense systems must adapt to new, asymmetric threats including fast attack craft, UAV swarms and anti-ship missiles. The Directed Energy Weapon (DEW) program is one such effort that aims to combat these threats while operating at a significantly reduced cost per shot. Evaluating the performance of this system from the ship-level perspective is critical to progressing toward this goal. This project focuses on developing agent-based weapons and sensor models for the DEW system and integrating them into a modeling & simulation environment to enable such analysis.

Selected arsenal options are run through engagement scenarios that include geography, atmospheric conditions, and threat types to evaluate mission effectiveness and cost. The weapon models include the Navy's Laser Weapon System (LaWS), conventional Close-In weapon systems (CIWS) and missile systems, allowing for comparison between engagement methods. The laser is unique in its dependence on atmospheric conditions and required time on target, which necessitates its pairing with a high-fidelity sensor model. Composed of radar and electro-optical/infrared packages, the sensor model handles detection and tracking of targets within the engagement scenario. This environment allows for analysis of new threat scenarios to better inform the design and integration of DEWs into future fleet architectures.

Expanded view of simulation.



Modeling & simulation development.

Discussion of the Navy's Data Analytics research challenge.

PI explains discussion topic.

Indiana University

How do science and technology fields emerge and evolve? This project aims to analyze the interplay between paper citation networks and author collaboration networks to predict the success and demise of a field. By detecting topical communities in the citation and coauthorship networks, we will mine early signals associated with the onset of an emerging field. The goal is to uncover quantitative patterns that would enable us to predict the future development of a field.

In the first phase of the project, we have focused on identifying a set of fields that can be used as ground truth to evaluate our algo-algorithms. This has proven a challenging task, because existing field labels from datasets such as WoS and APS are inadequate. As a way to address this challenge, we propose the use of categories manually picked by authors, such as PACS or keywords, as proxies for disciplines. In this approach, the birth of a new scientific field could be determined by finding specific signals in time series obtained by measuring the popularity of these categories. Such indicators could be defined, for instance, in terms of thresholds or abrupt increases in number of publications, citations, or authors using a certain category.

NSWC Dahlgren

Network Data Analytics for Predicting the Emergence of Science & Technology Fields

Professors: Filippo Menczer (PI) with Alessandro Flammini, Santo Fortunato, and Stasa Milojevic (co-PIs)

Technical Capability Alignment:
Surface Combat Systems
Engineering and Integration
Research Development
Test & Evaluation

Students:
- **PhD:** 1

Exploration of Additive Manufacturing in Naval Applications for Expeditionary Warfare

Professors: Dr. Jennifer Michaeli (PI), with Dr. Gene Hou and Dr. Sanjeevi Chitikeshi

Technical Capability Alignment: Surface Combat Control Systems Science and Technology, Research Development, Test & Evaluation

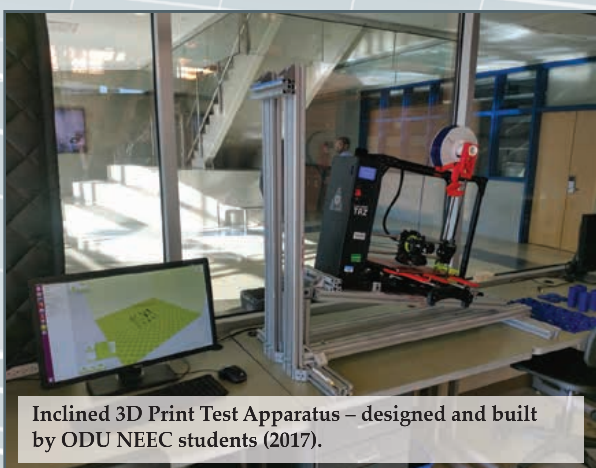
Students:
- **Undergraduate:** 10
- **Masters:** 3

Old Dominion University

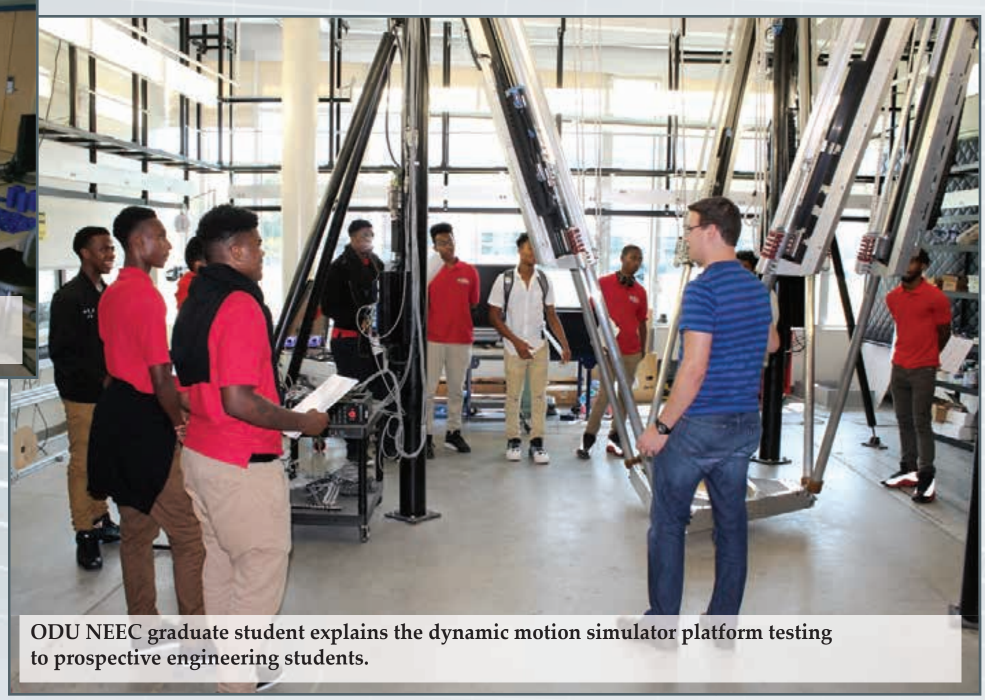
The purpose of this Naval Engineering Education Consortium (NEEC) funded project is to investigate the extent to which ship-like motions affect the quality of 3D printed parts, with an emphasis in this project on dimensional accuracy. This project provides an excellent opportunity to engage with engineering undergraduate and graduate students in a research setting to expose them to science and technology needs and opportunities associated with the US Naval Enterprise and to encourage students to consider an exciting career in this field.

The project is divided into three phases. The first phase of the project was a review of printing processes including 3D metal printing, and processes affecting part quality. The second phase of the research involved investigating the dimensional accuracy of parts created from a reverse engineering application combining 3D scanning and 3D printing. Phase 1 was completed in Year 1. Phase 2 was initiated in Year 1 and completed in Year 2. Lessons learned for Phase 2 will be applied to ongoing efforts through Years 2 and 3. Phase 3 was initiated in Year 2 and will continue through Year 3 and is focused on experimentation to assess the effects of ship dynamics on dimensional accuracy of parts. This phase initially involved developing a multi-functional test coupon design, printing coupons at static angles of inclination and testing to create a benchmark for test specimens, and will continue in Years 2 and 3 with dynamic testing using ODU's multi-axis motions simulator, in which the impact of various combination of ship-like dynamic motions will be simulated during the print process so that students and faculty can analyze the effect on print quality.

This project funds undergraduate and graduate engineering students. Students have applied for internships through NREIP and shipbuilding/ship repair industry. Students also participate in outreach events and professional development activities.

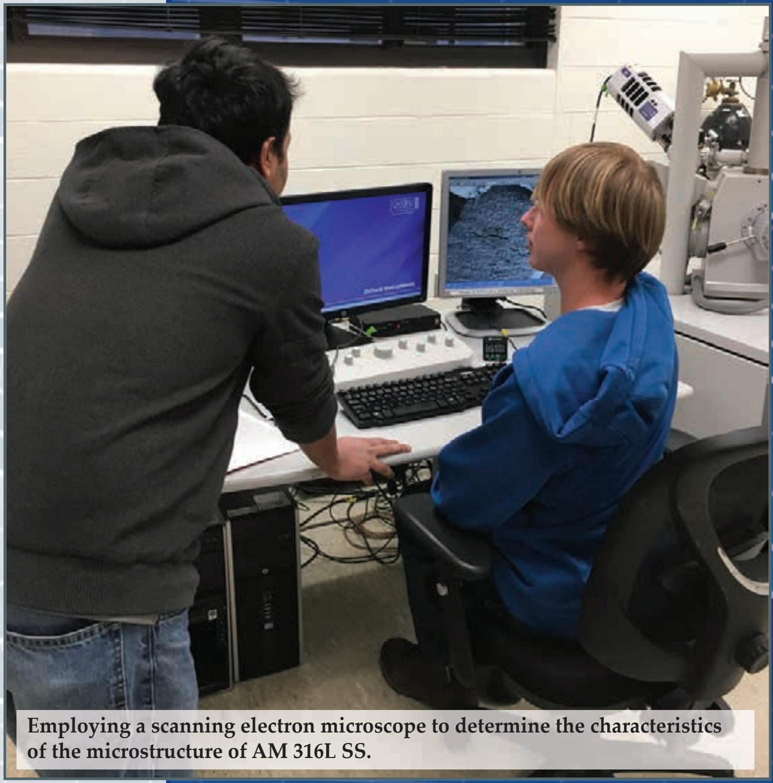


Inclined 3D Print Test Apparatus – designed and built by ODU NEEC students (2017).



ODU NEEC graduate student explains the dynamic motion simulator platform testing to prospective engineering students.

Employing x-ray diffraction-based line profile analysis to quantify the high density of crystal defects that exist within the as-built, AM 316L SS.



Employing a scanning electron microscope to determine the characteristics of the microstructure of AM 316L SS.

University of Virginia

Structure-property relationships of an additively manufactured (AM) 316L stainless steel are being explored at the University of Virginia. Graduate students are employing the scanning electron microscope (right image above) to determine the characteristics of the microstructure. They are also employing X-ray diffraction (left image above) line profile analysis to quantify the high density of crystal defects that exist within the as-built material. Analytical modeling has revealed a correlation between the observed microstructure and the high strength of the as-built material. In addition to the high strength, a high ductility is observed in the AM material and this is observed to correlate with a sustained strain hardening capacity. Ongoing research aims to determine how such strong material retains this ability to resist plastic instability. Because of the experience gained in this NEEC project, the PI has been able to develop collaborative relationships with researchers at Cornell, Missouri University of Science and Technology, Tufts, as well as 3 Australian universities (Monash, Deakin and RMIT). During the fall, this team of universities submitted a MURI proposal in response to Topic 22 "In situ Microstructural and Defect Evolution below the Micron Scale in as-Deposited Metal Alloys," within ONR Announcement #N00014-17-S-F006.

NSWC Dahlgren

Developing an Understanding of the High Strength and Ductility of Additively Manufactured 316L Stainless Steel

Professors: Sean R. Agnew
Co-PI: James M. Fitz-Gerald

Technical Capability Alignment:
Surface and Expeditionary Conventional Weapon Control Systems Research, Development, Test & Evaluation

Students:
- **Masters:** 1
- **PhD:** 1

NSWC Dahlgren

Popcorn Linux: System Software for Heterogeneous Computer Hardware

Professor: Dr. Binoy Ravindran

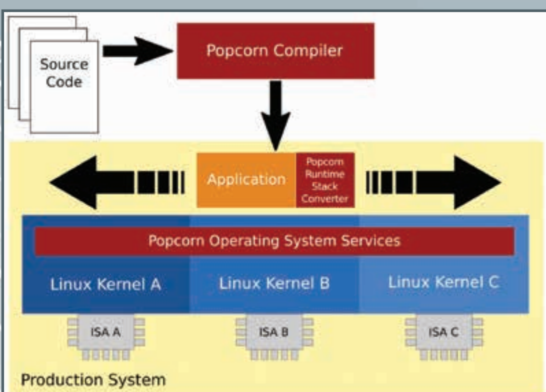
Technical Capability Alignment:
Surface Combat Systems Engineering and Integration
Research Development Test & Evaluation

Students:
- **Undergraduate:** 3
- **Masters:** 2
- **PhD:** 2

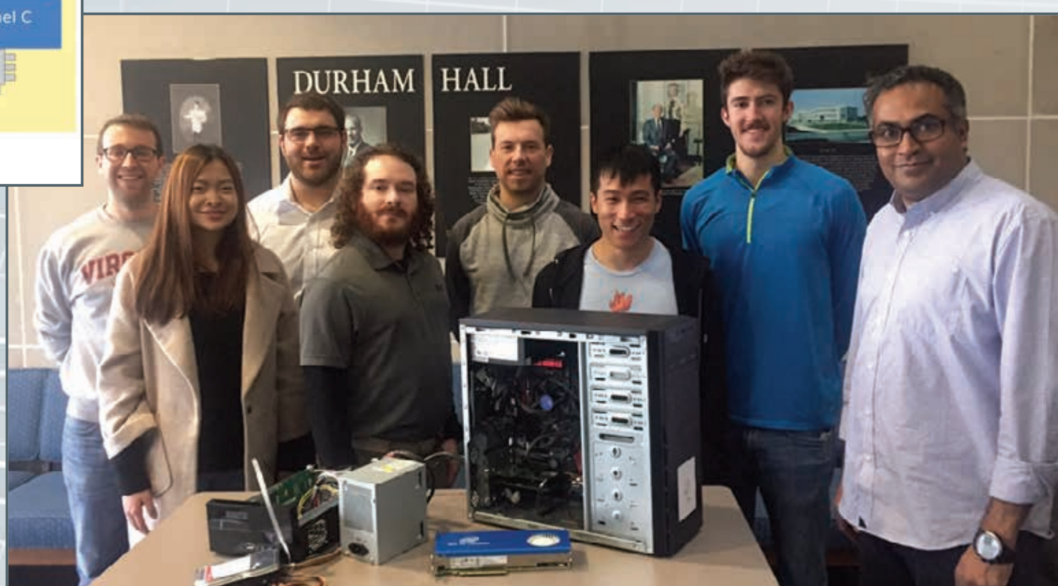
Virginia Tech

As computer hardware (HW) has reached a limit on the single-threaded CPU performance, chip vendors are designing multi-core architectures with heterogeneous computing cores. Programming emerging heterogeneous cores is difficult, especially when they use different instruction-set architectures (ISA) - i.e., the set of instructions which the processor understands, and defines the interface between the software (SW) and the HW. In addition, traditional single-image OS (e.g., Linux, Windows) cannot run on heterogeneous-ISA HW as-is. These HW trends pose a particular challenge for Navy's SW systems (e.g., combat system SW), as they undergo HW refreshes in their current and emerging code baselines.

Virginia Tech's NEEC project is developing a novel SW architecture and concomitant SW infrastructure that aims to improve the programmability of emerging heterogeneous HW. The project is developing the Popcorn Linux OS by running a separate instance of the Linux OS on each available ISA in the platform. The OS instances dynamically coordinate to determine which applications or components thereof should be migrated between ISA-different processors, at run-time, for improved performance, energy, and security properties. In addition, Popcorn Linux uses a customized compiler based on LLVM that translates application code from C/C++ to machine instructions for all available ISAs in the platform. Since the program run-time stack which stores the dynamic program state - i.e., the program's function parameters, function local variables, etc - is customized for a single ISA, Popcorn Linux implements a run-time system that transparently converts the run-time stack between ISA-specific formats when migrating between processors.



The Popcorn Linux software stack.



Student built experimental computer system running the Popcorn Linux software stack.
For details, visit: popcornlinux.org.

Students gathered in VT's mini-railgun laboratory.

VT mini-EMRG team.

Virginia Tech

The main focus of this NEEC effort is to engage graduate and undergraduate engineering students with the Virginia Tech Electromagnetic Launcher program, which is a technical, research-oriented effort in the Energy Conversion Systems Laboratory to design, develop, and operate a reduced-scale version of a Navy railgun. The scope of technical work includes demonstrating the inductive energy recovery system, intelligent controls to maximize pulse-forming network lifetime and reliability; Diagnostics and Health Monitoring System software for minimizing interference, articulation breach concept development, rail-armature contact optimization; and small projects to measure injection forces and bore-riders for measuring bore dimensions.

NSWC Dahlgren

Student Exposure to the Operation, Testing, and Related Research of a Reduced-Scale Rail Gun

Professor: Dr. Hardus Odendaal

Technical Capability Alignment:
Directed Energy Systems
Research, Development,
Test & Evaluation

Students:
- **Undergraduate:** 25
- **Masters:** 2
- **PhD:** 1

Optimization of Conditions for the Synthesis of Li-ion Batteries

Professor: Dr. Kadir Aslan

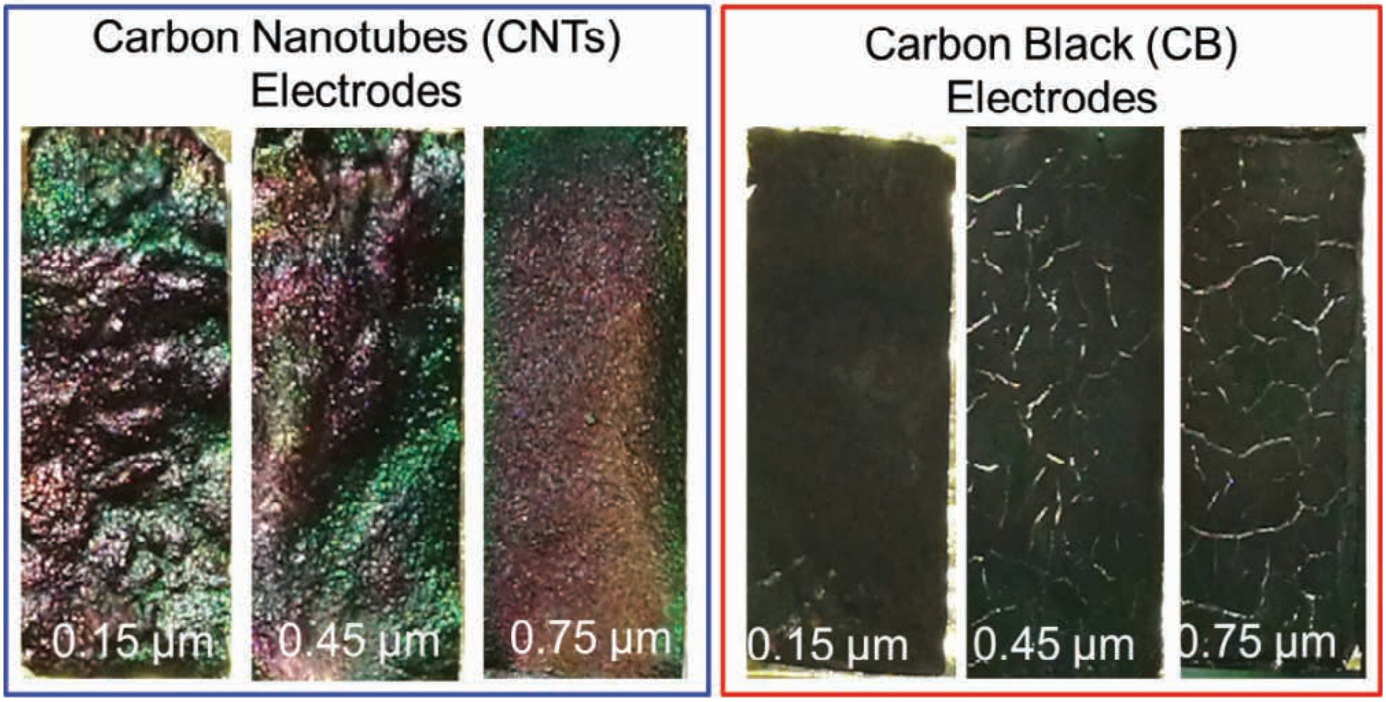
Technical Capability Alignment: Energy Storage

Students:
- **Undergraduate:** 4
- **PhD:** 1

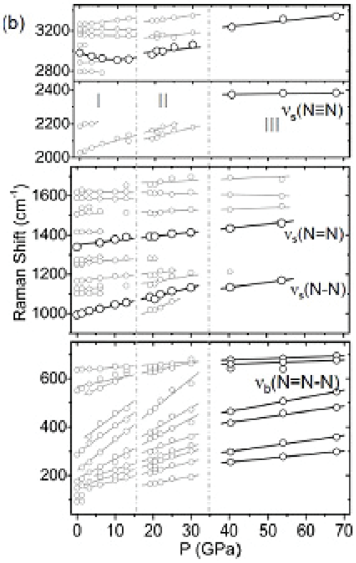
Morgan State University

Energy management and storage is of great importance for department of defense applications. Today soldiers carry devices such as smartphones, optical sights, radios, night vision, GPS, thermal imagers, computers, etc. that need batteries. The battery weight on soldiers can represent 20% of a soldier's load. Reducing size and weight of the batteries by increasing the energy/power density is very useful for the warfighters. Lithium ion batteries (LIBs) are the most commonly used rechargeable batteries. The electrodes of choice for LIBs must be able to intercalate lithium ions between their layers and spaces. The quantity of lithium ions that are intercalated in the electrode determines its storage capacity.

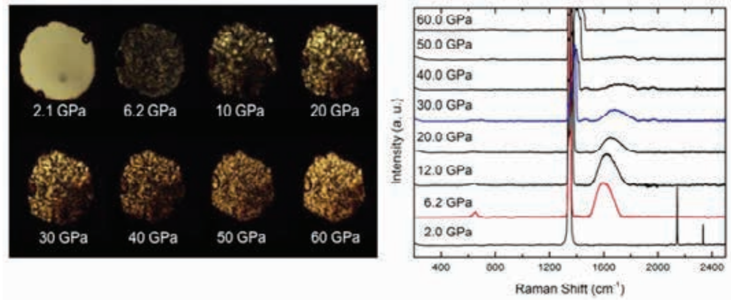
The currently used electrodes are made of bulk materials such as graphite for anode and lithiated transition metal oxide such as $LiCoO2$ for cathode. These LIBs suffer from low power density because their electrodes have slow lithium ion diffusion, poor electron transport, and high resistance at the interface of electrode with the electrolyte. Graphite is currently used as the anode in commercial LIBs because it can efficiently intercalate lithium ions. The objective of this work is to develop electrodes with better properties than graphite. Carbon nanotubes (CNTs) have very large surface areas and can intercalate large quantities of lithium. This project is developing CNTs and CNT-functionalized carbon nanotubes as replacement for graphite in LIBs. These electrodes are then coated with metals such as copper to generate a thin layer of current collector on them. In order to find the best conditions to make electrodes the experiments were first tried on carbon black because it is very inexpensive and the work was then transitioned to CNTs.



2 cm x 1cm carbon nanotubes (blue enclosure) and carbon black (red enclosure) electrodes.



Pressure-dependent Ramn peak shifts of HA showing the phase/ chemical transformation of HA-1 to II at 13 GPa and to III at 40 GPa. The large symbols highlight significant Raman modes.



Microphotographic images of 30% nitrogen doped CO (left), showing the pressure-induced polymerization process analogous to those observed in pure and hydrogen-doped CO. Raman spectra of 30% nitrogen doped CO to 60 GPa (right), showing the spectral evidence for the pressure-induced polymerization. At 2.0 GPa, Nitrogen transform from fluid to non-molecular solid phase (β-phase). It is interesting to note that the pure nitrogen solidifies into δ-phase at 4.9 GPa; however, similar to hydrogen doped CO, there was no δ-phase observed in CO-N2 binary mixture.

Washington State University

Goal: The goal of this project is to develop polymeric N2 and/or nitrogen-rich polymer at relatively low pressures and can be recovered at ambient conditions.

Approach: Our approach is to use various forms of nitrogen-rich compounds as the precursors to synthesize similar forms of nitrogen polymers. Those include nitrogen-rich molecules, ionic nitrogen salts, metal nitrides, and simple azides. The rationale for these efforts follows the concept that these precursors are considerably higher in density (1.52 gm/cm^3) than N2 molecules (~1 g/cm^3) and, thereby, can be considered as intermediates toward high density (>3.5 gm/cm^3) nitrogen-rich polymers.

Objectives: A wide range of novel nitrogen products have been reported based on the computational structural search and optimization, which include N5 rings, N5+ chain, N6 chains, N6 rings, polymeric nitrogens, and N8 molecule (Fig. 1). Considering the similar nitrogen arrangement and stoichiometric considerations, we have investigated Hydrazinium Azide (HA; (N2H5)+N3-) at high pressures aimed at the synthesis of predicted stable molecular nitrogen allotropes (such as N8 or N6 in particular) or similar nitrogen dominant ionic products (such as N5+ ring or V-shaped N5+ ions) at high pressures.

NSWC Indian Head

Three Dimensional Network Polymers for Chemical Energy Depository

Professors: Dr. Choong-Shik Yoo

Technical Capability Alignment: High Energy Density Materials

Students:

- **Undergraduate:** 4
- **Masters:** 2
- **PhD:** 1

Development of Autonomous Control for Multiple Vehicle Platforms

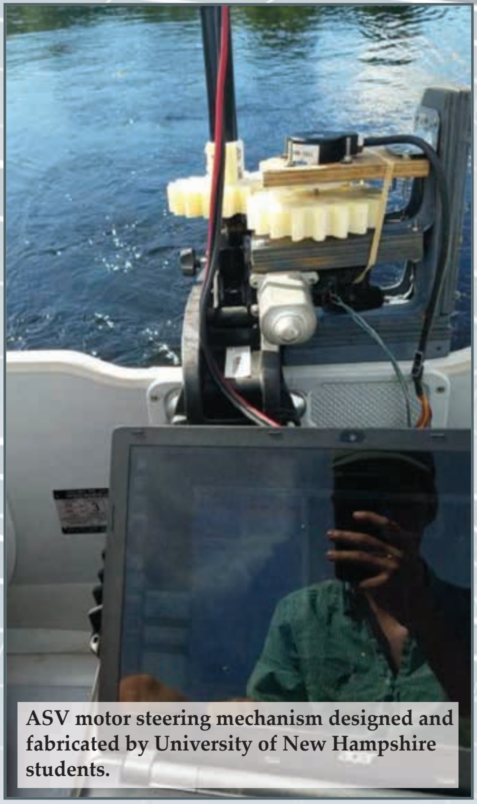
Professor: Dr. May-Win Thein

Technical Capability Alignment: Independent USW Systems Test and Evaluation and Experimentation

Students:
- **Undergraduate:** 4 (Plus 12 senior design students)
- **PhD:** 1

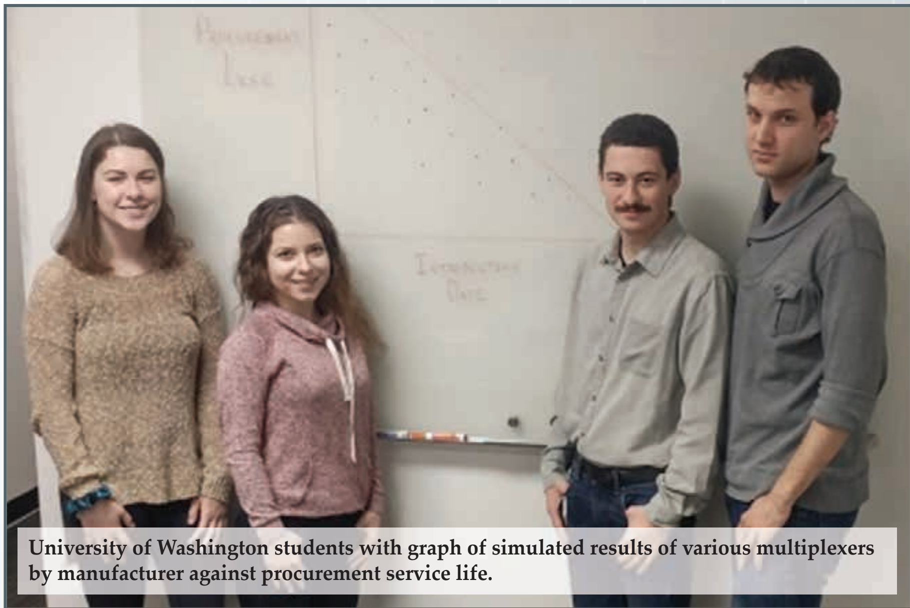
University of New Hampshire

The goal of this project is to develop vehicular platforms for testing autonomous command and control software with a specific focus on the vehicles, the low-level dynamic control of the vehicles, and providing the minimum information necessary to enable testing autonomy. To accomplish this, autonomous underwater Remotely Operated Vehicles (ROVs) are being built as a senior design project with the mission of enabling detailed survey of a sea-floor location in a littoral environment. Also, autonomous surface vehicles (ASVs) are being developed to provide an additional platform for autonomy testing with the mission of hosting an ROV, and providing the sensors for lower resolution survey of the seafloor in a littoral environment. To gain insight and demonstrate the vehicles' utility, rudimentary autonomy with path planning and reactive behaviors is being implemented through Mission Orientated Operating Suite, a reactive behavior based autonomy developed by Michael Benjamin at MIT and NUWC Division, Newport, in the first year. In previous years, operations involving ROVs and two ASVs were demonstrated. A small ASV was built for indoor testing during the winter that uses the same computer hardware and software architecture. Perception sensors are based primarily on Lidar with the goal of demonstrating the capability to avoid collisions and obstacles.

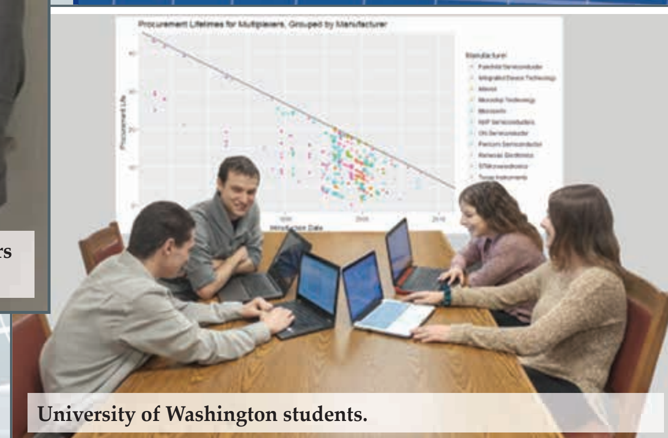


ASV motor steering mechanism designed and fabricated by University of New Hampshire students.

Student riding on the ASV during operations on the test lake at University of New Hampshire's campus. (Student was riding to provide onboard safety oversight/controls to the ASV).



University of Washington students with graph of simulated results of various multiplexers by manufacturer against procurement service life.



University of Washington students.

University of Washington

Diminishing Manufacturing Sources and Materials Shortages (DMSMS) describes a form of obsolescence where a given part is no longer manufactured or available due to a lack of vendors and/or materials, or may not be soon. This causes problems for organizations that manage long-lived systems, such as vehicle fleets, telecommunications infrastructure, and weapon systems. Historical approaches to managing the risk associated with DMSMS have commonly been reactive; either when the needed item is no longer available, or when the Navy has learned about an impending lack of availability.

This project is developing predictive methodologies using modeling and simulation to generate likelihoods of a part or system becoming obsolete before manufacturers report obsolescence. Since historical data lacks the necessary quality, is not available for all part types, may be sparse, or incomplete, a simulation-based test environment is used to generate data, test algorithms, and evaluate forecasts for the project. Using the predictive methodologies to generate a probabilistic forecast of part availability and obsolescence will provide program managers earlier opportunities to develop system supportability plans and a wider array of options.

NUWC Keyport

DMSMS Obsolescence Management: Refining Forecasts with Simulation

Professor:
Dr. Christina Mastrangelo

Technical Capability Alignment:
Obsolescence Management for Undersea Warfare Systems

Students:
- **Undergraduate:** 4
- **Masters:** 1
- **PhD:** 1

NUWC Newport

Wave-Based Analysis of Distributed Acoustic Sensor Networks

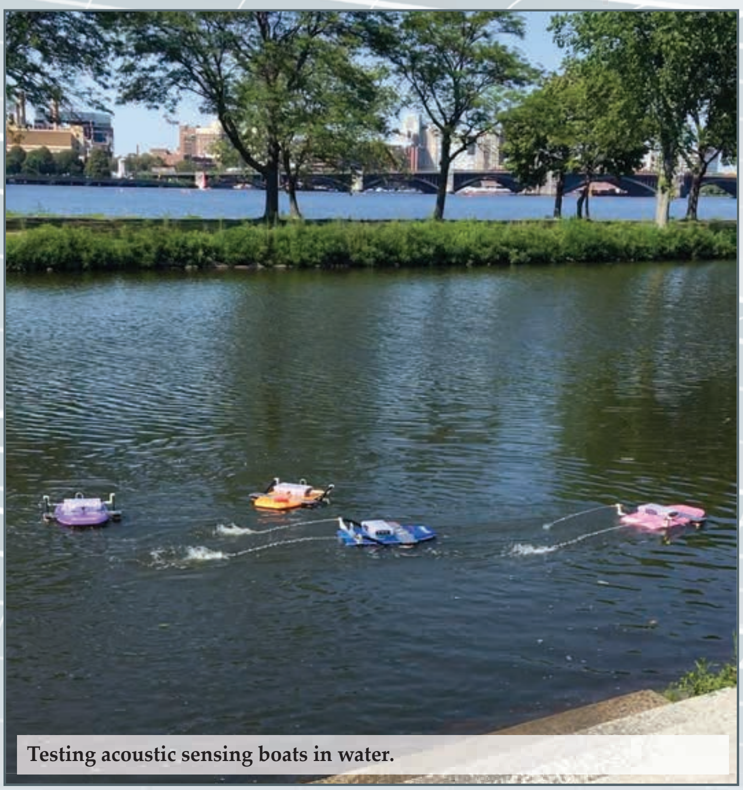
Professor: Dr. J. Gregory McDaniel

Technical Capability Alignment: Undersea Surveillance Systems

Students:
- **Undergraduate:** 2
- **Masters:** 2
- **PhD:** 1

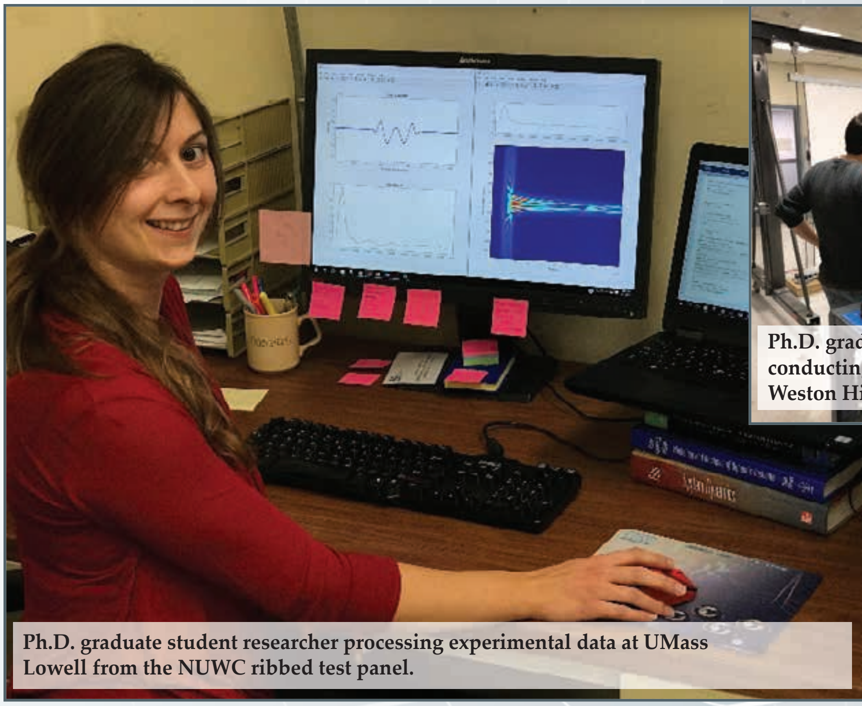
Boston University

Boston University is creating swarms of small autonomous boats that sense underwater sound and develop a collective intelligence and memory about their acoustic environment. The boats communicate their positions and measured sound to each other over a wireless mesh network. Each boat carries a hydrophone suspended below the boat as well as onboard electronics that include batteries, computer, digital acquisition system, GPS, autopilot, wireless radio. The boat and its electronics are constructed almost entirely from commercial off-the-shelf parts, resulting in the least expensive oceanic mobile acoustic sensing platform known to us. Each boat is jet propelled and turns by differential thrusting. Students are creating and testing algorithms that determine the optimal motion of each boat in real time. The final product of this research will be a fully autonomous system that localizes, classifies, and tracks sources of underwater sound in the presence of noise.



Testing acoustic sensing boats in water.

Boston University undergraduate students preparing to test three acoustic sensing boats.



Ph.D. graduate student researcher processing experimental data at UMass Lowell from the NUWC ribbed test panel.

Ph.D. graduate student (right) presenting the NUWC research project while conducting a laser scan of the panel (left) to a tour group of students from Weston High School on December 8, 2017.

UMass Lowell

Research at UMass Lowell is investigating a way to improve hull-mounted transducer arrays that can achieve better source localization and/or detection. If equally-spaced ribs are embedded in the arrays, the array signal excited by an acoustic source is reflected from the ribs, scatters, and combines to create a shorter-wavelength replicate signal. It has been proposed that the replicate signal can be used to estimate the bearing of the original noise source. The research is focused on characterizing the benefits that these replicate signals can provide for underwater localization. Closed-form Matlab models, Comsol FEA models, and experimental tests are used to study the replicate signals. To help validate the models and simulations, a NUWC ribbed test panel is being experimentally tested within the Structural Dynamic and Acoustic Systems Laboratory at UMass Lowell. The potential benefits of this project include improved localization precision, better source signal to noise ratio, and reduced array size.

NUWC Newport

Modeling and Analysis of Bragg Scattering in Periodic Structures

Professor: Dr. Christopher Niezrecki

Technical Capability Alignment: Undersea Warfare Sensor and Sonar Systems

Students:
- **Undergraduate:** 2
- **PhD:** 1

NUWC Newport

High-Performance Control of Undersea Vehicles

Professor: Dr. Stephen Licht

Technical Capability Alignment:
Undersea Warfare Autonomous Vehicles

Students:
- **Undergraduate:** 2
- **PhD:** 1

Publications/Presentations:

- Matthew Perkins, Dane Elles, George Badlissi, Amin Mivehchi, Jason Dahl & Stephen Licht, “Rolling and pitching oscillating foil propulsion in ground effect,” Bioinsp. Biomim., 13, September 2017.

University of Rhode Island

Conventional propeller driven autonomous underwater vehicles (AUVs) cannot operate in dynamic environments, near obstacles, or close to the bottom; they have high roll stability and low actuator authority, and use a decoupled linearized control approach which produces slow moving vehicles with poor agility. In an effort to improve AUV agility, the U.S. Navy has funded the development of a number of oscillating foil driven AUVs. Oscillating foils are a class of biologically inspired thruster which can vector propulsion forces more rapidly -- and with higher authority -- than conventional propellers. Foil driven AUVs have the propulsion authority to perform aggressive maneuvers such as banked turns, rolls, and flips. However, since existing linearized AUV control approaches assume small attitude angles and slow angular rotations, they cannot exploit these new vehicle capabilities. Furthermore, vehicles operating near boundaries (whether at the bottom or near the surface) are subject to hydrodynamic forces that are not accounted for in standard empirical maneuvering models.

The purpose of the proposed effort is to develop and validate control algorithms and hydrodynamic models for foil driven AUVs which take full advantage of their novel propulsion capabilities, enabling them to perform aggressive, large angle maneuvers and operate efficiently and safely at boundaries. Target naval applications for agile vehicles include payload delivery, intelligence/ surveillance/reconnaissance (ISR) and mine counter-measures (MCM) in shallow waters and rivers. Razor, currently at NUWC, a four fined 200kg AUV developed for hostile swimmer interdiction, will be used as the nominal target for simulation and experiment. Experiments with full scale foils at NUWC-Newport and at the Narragansett Bay Campus of the University of Rhode Island will be used to develop and validate foil propulsion models, which will then be incorporated into 6-DOF simulation of the vehicle itself. In year two, the primary effort will be centered around foil response to close proximity to a hard bottom, while year three will be centered around foil response to the free surface.

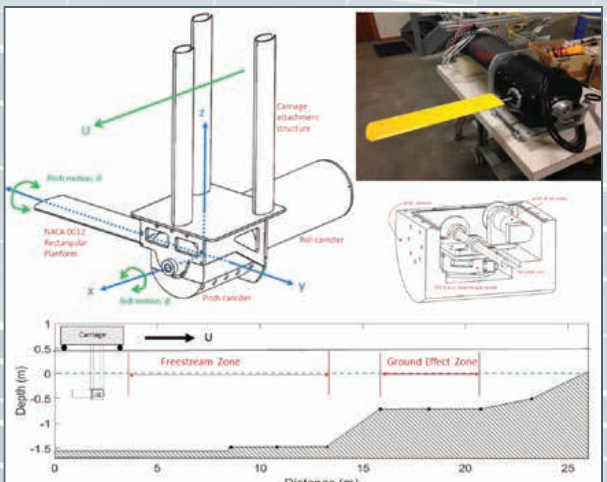
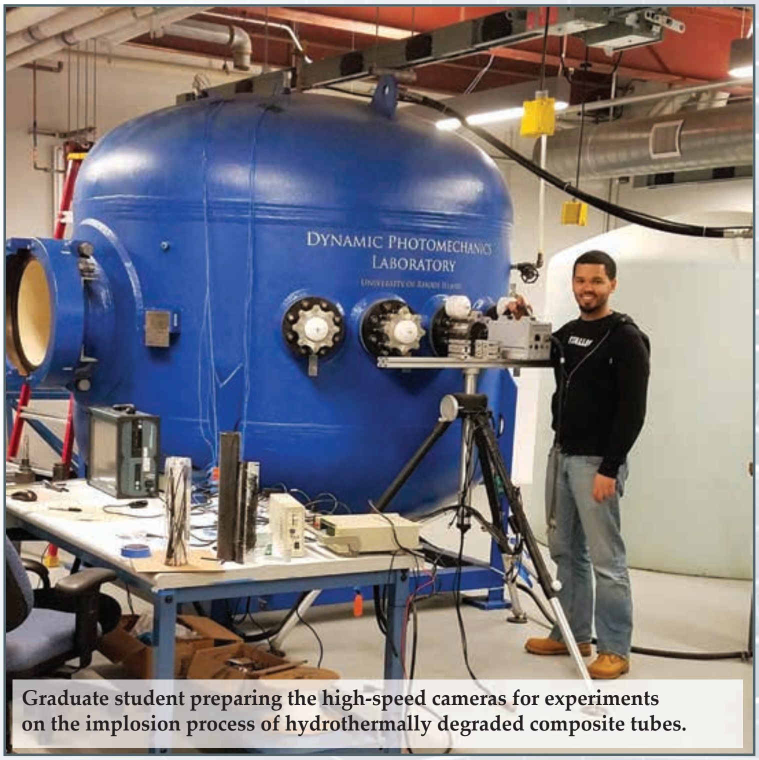


Figure 1: Details of experimental apparatus for near bottom trials of oscillating foil propulsor. (top-left) Model of foil apparatus as mounted to moving carriage. (top-right) Foil mounted to apparatus. (middle-right) Internal detail of force measurement location (bottom) Tank bathymmetry allowing for free stream and near bottom operation of foil.

Field testing of conventional autonomous underwater vehicles was included in project activities in order to provide University of Rhode Island undergraduate and graduate students with hands on experience using critical naval technologies.



Graduate student preparing the high-speed cameras for experiments on the implosion process of hydrothermally degraded composite tubes.

Undergraduate student completing the setup for experiments on the blast response of glass fiber / vinyl ester composite plates.

University of Rhode Island

Within the navy there is an interest in constructing new lighter vehicles and structures from composite materials. These structures are subjected to aggressive marine environments during their service life, including high salinity water and/or salt spray and ultraviolet radiation that can significantly degrade their performance over time. These effects are of particular concern when composite vehicles are deployed in a military setting where they may be further subjected to shock and/or blast loading. Therefore, there is a need to investigate how composite materials that have been exposed to marine environments respond to shock events, and how these responses differ from an equivalently loaded virgin structure. The emphasis will be on understanding the fundamental mechanisms of damage evolution and their relationship with the dynamic loading and aggressive marine environments. The goal will be to quantify the effect of prolonged exposure to aggressive conditions on the shock response of a composite structure. This will be accomplished using underwater explosive (UNDEX) loading experiments and accelerated life weathering techniques in collaboration with air driven shock tube experimental methods developed by researchers at the University of Rhode Island (URI).

The composite materials will be chosen with navy relevance as a criterion and will include E-Glass/ vinyl ester and carbon fiber/epoxy composites. Both underwater explosion and air blast loading of the virgin and weathered/aged structures will be conducted using shock tube and pressure vessel facilities at URI. Non-destructive evaluation methods will be used to determine damage present in each case. This will further aid in understanding the weathering of these materials, as it will show which modes of damage are enhanced in the process. Computational simulations incorporating the physics from the experiments will be performed utilizing finite-element software. The successful completion of this project will result in an experimental methodology for the effects of prolonged seawater exposure on composite panels subjected to shock loading, as well as a modeling methodology for the prediction of the response of aged composite materials subjected to shock loading.

NUWC Newport

Shock Response of Composite Materials Subjected to Aggressive Marine Environments: An Experimental and Computational Investigation

Professor: Dr. Arun Shukla

Technical Capability Alignment: Launcher Systems and Payload Integration

Students:
- **Undergraduate:** 2
- **PhD:** 1

Publications/Presentations:

- Helio Matos, Carlos Javier, James LeBlanc & Arun Shukla, "Underwater nearfield blast performance of hydrothermally degraded carbon-epoxy composite structures", Multiscale and Multidiscip. Model. Exp. and Des., January 2018.

NUWC Newport

Bio-inspired Dynamic Broadband Sonar

Professor: Dr. Rolf Mueller

Technical Capability Alignment: Undersea Warfare Sensor and Sonar Systems

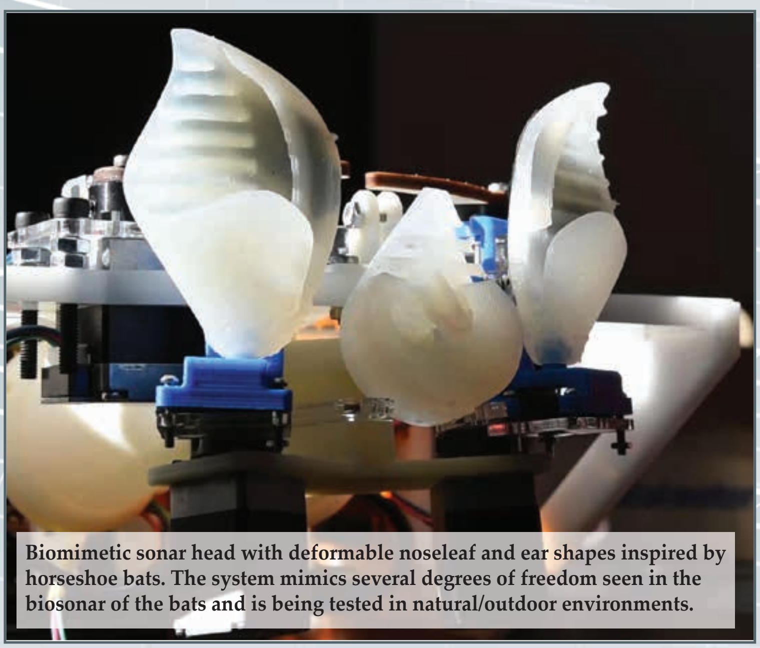
Students:
- **Undergraduate:** 6
- **PhD:** 1

Publications/Presentations:

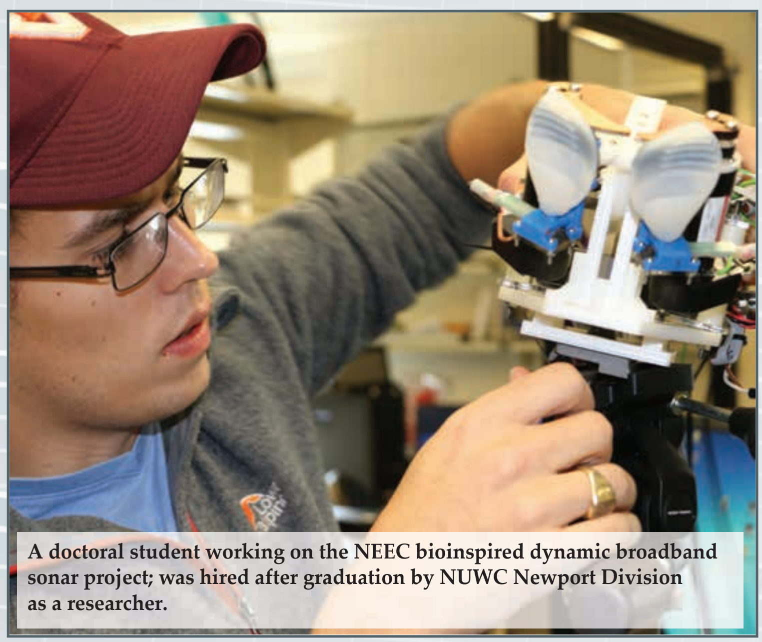
- Bryan D Todd & Rolf Müller, "A comparison of the role of beamwidth in biological and engineered sonar," Bioinsp. Biomim., 13(1), December 2017.

Virginia Tech

Bat species with particularly sophisticated biosonars have a unique dynamic periphery in which sound-diffracting baffles (i.e., noseleaves and ears) change shape during the emission of the ultrasonic sonar pulses/reception of the echoes. At the same time, bats with this dynamic are able to navigate in highly dense, highly complex natural environments - a capability that is not found in other bat species or man-made sonars. The goal of the project is to gain insight into the unique dynamic properties of these sophisticated bat biosonar systems and how functional principles may be used for naval applications such as guidance for autonomous underwater vehicles. To better understand the functional properties of a dynamic periphery, a biomimetic in-air sonar head is being developed. The sonar head mimics the non-rigid deformation of the noseleaves and ears. It is being tested in a laboratory context as well as in outdoor environments using a drone and a zip-line platform. The biomimetic system is used to assess the dynamic encoding of sensory information in the systems periphery, especially with regard to target localization (direction finding) and target identification. Research conducted so far has demonstrated that non-rigid motions of biomimetic noseleaf and pinna shapes result in very substantial improvements to target direction finding and the latest pilot data indicates the dynamic encoding of information on target class. If these dynamic principles for sensory information encoding can be implemented in technical sonars, they could lead to much more compact and computationally parsimonious sensors that would yet be more much capable in delivering the information that is needed for navigation and guidance in complex environments.

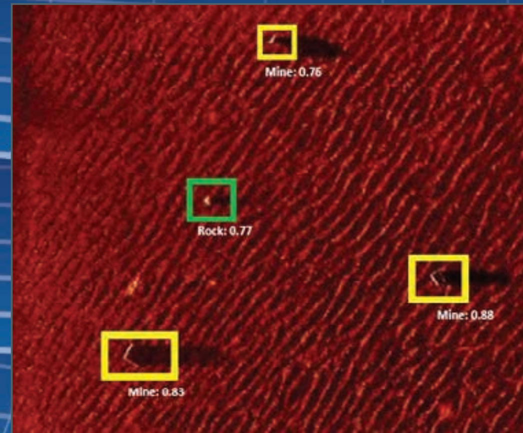


Biomimetic sonar head with deformable noseleaf and ear shapes inspired by horseshoe bats. The system mimics several degrees of freedom seen in the biosonar of the bats and is being tested in natural/outdoor environments.



A doctoral student working on the NEEC bioinspired dynamic broadband sonar project; was hired after graduation by NUWC Newport Division as a researcher.

The NEEC team lead for the calendar year 2017 effort, with one of the AUVs and sensors used on the project.



Example of ATR in a side-scan sonar image, and classification of detected objects.

Florida Atlantic University

Cooperative operations between AUVs are still in their infancy. Simple coordinated behaviors between dissimilar AUVs have been demonstrated, in detecting objects of interest. However, fully cooperative autonomy needed to develop an effective sensing network, involving multiple autonomous vehicles acting as a team. The overall goal of the proposed effort is in support of development of affordable unmanned maritime systems in the form of marine networks of mobile, adaptive, and cooperating sensor platforms, for improved volumetric in-situ sensing in challenging ocean environments. Building on previous work and using vehicles and sensor systems available at FAU, a multi-vehicle sensing system comprising two AUVs is being developed in conjunction with NSWC Panama City. A scenario including two AUVs, one equipped with a side-scan sonar, other with a magnetometer, conducting autonomous complementary surveys as they search for objects on the seabed is being pursued. Work involves modeling and simulation, implementation of localization and classification algorithms on the AUVs and field experimentation.

NSWC Panama City

Adaptive Sensing in Challenging Underwater Environments Using Multiple Autonomous Vehicles

Professor: Dr. Manhar Dhanak

Technical Capability Alignment:
PC30 Unmanned Systems Engineering & Integration, Autonomous Operations, Joint Interoperability and Common Control

Students:
- **Undergraduate:** 15
- **Masters:** 2
- **PhD:** 2

Publications/Presentations:

- Real-Time Localization of a Magnetic Anomaly: A Study of the Effectiveness of a Genetic Algorithm for Implementation on an Autonomous Underwater Vehicle" Harryel Philippeaux. 2017 MS Thesis at FAU, OCEANS 2018

NSWC Panama City

Design and Implementation of Communications-Constrained Path Planning Algorithm for Unmanned Vehicles Operating in Littoral Environments

Professor: Dr. Michael Steffens

Technical Capability Alignment: PC30 Unmanned Systems Engineering & Integration, Autonomous Operations, Joint Interoperability and Common Control

Students:
- **Undergraduate:** 25
- **PhD:** 2

Publications/Presentations:

- Meyer, Patrick, et al. “ARCS: A Unified Environment for Autonomous Robot Control and Simulation”, MTS/IEEE Oceans 2017, Anchorage, Alaska, USA. September 18-21, 2017.

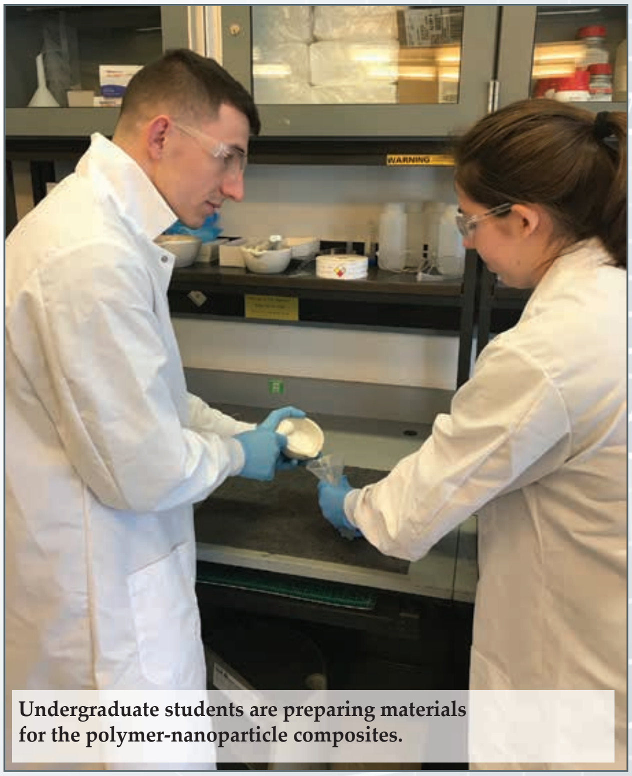
- Ramee, Coline, et al. “ARCS: A Unified Environment for Autonomous Robot Control and Simulation”, RobotX Forum, Sydney Australia. Dec 13-15, 2017.

Georgia Tech

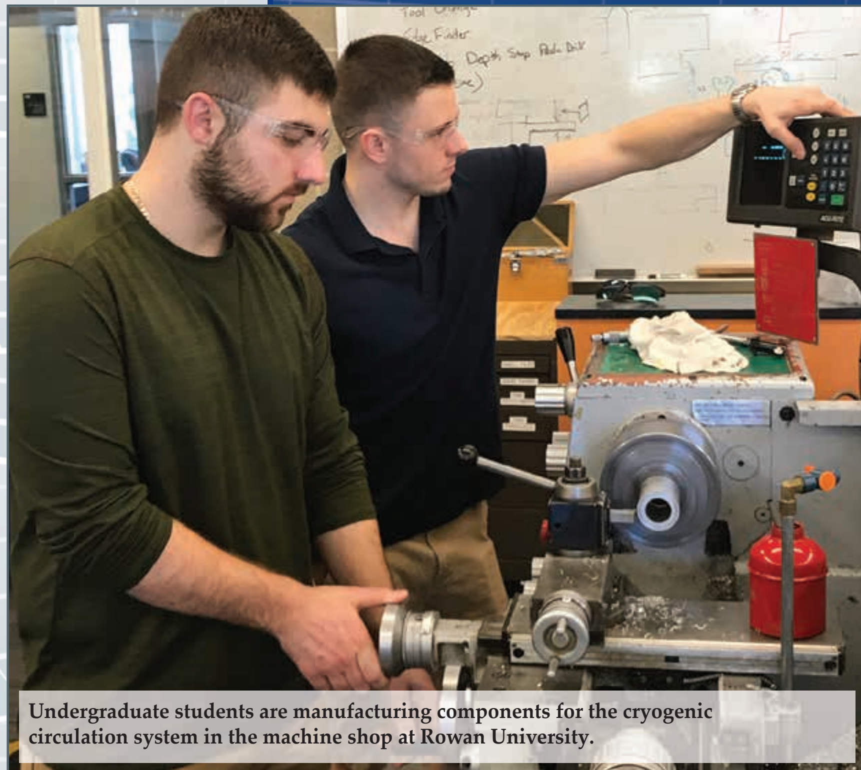
With the rise of unmanned technologies and strong desire to use these technologies in Naval missions, it is critical to resolve key challenges to using these vehicles operationally. One such challenge is the need to account for unreliable communications with the unmanned vehicle (or vehicles), which can be particularly common in maritime operating environments. The maritime communication environment is characterized by a myriad of challenging environmental limitations that cause signal attenuation and skip zones in communication signals. Various phenomena can affect the quality of transmission channels during intermittent communication between multiple unmanned assets, which can compromise mission success. Therefore, the Navy would greatly benefit from the ability to better predict and plan for these effects, which will depend on the specifics of the given mission scenario. The goal of this proposed effort is to help mitigate this operational challenge by developing path-planning algorithms that use information about the weather, geography, and communications technology aboard unmanned vehicles to perform path planning that increases confidence in having successful communications channels while still meeting key mission objectives. Furthermore, the project is designed to include key educational objectives, thus preparing the next generation of Engineers to be ready and able to work in Navy-related careers upon graduation.

Part of the NEEC team after placing 3rd at the 2017 AUVSI RoboBoat competition in Daytona Beach, FL with the autonomous surface vehicle.

Part of the NEEC team after placing 5th at the 2017 AUVSI RoboSub competition in San Diego with the autonomous sub.



Undergraduate students are preparing materials for the polymer-nanoparticle composites.



Undergraduate students are manufacturing components for the cryogenic circulation system in the machine shop at Rowan University.

Rowan University

The research team at Rowan University is investigating advanced dielectric materials that can be used in cryogenic superconducting power systems on Navy ships. Due to the low operating temperatures (40-100 K) associated with superconducting systems, traditional insulators have limited capabilities and they do not possess the desired material properties for these applications. The materials under research in this project are polymer nanocomposites designed for high-temperature superconductor (HTS) cables, cooled via gas helium. The new materials will mimic the thermal behavior of the cable core element, typically copper, while maintaining high dielectric strength. Polymers and insulating nanoparticles are used to ensure the overall dielectric strength in the composite. Their thermal properties are selected to create a compensation effect that results in composites with reduced thermal expansion coefficients. We are currently performing electrical breakdown tests to quantify the dielectric strengths of the new composites at room temperature. In order to fully characterize the materials at cryogenic temperatures, our team is designing and building an in-house cryogenic circulation system that can be integrated into other equipment for electrical, thermal, and mechanical testing. We anticipate that the new dielectric materials will be flexible, mechanically strong, and have outstanding insulating performance and matching thermal contraction (approximately 0.3%) with the cable core at cryogenic temperatures. This new dielectrics will provide some critical benefits for applied superconductor systems, including wider temperature windows, additional design flexibility, higher current density, and large power capacity.

NSWC Philadelphia

Polymer Nanocomposites with Enhanced Dielectric Strength and Reduced Thermal Contraction for Superconductor Cables

Professors: Dr. Wei Xue and Dr. Robert Krchnavek

Technical Capability Alignment: Surface and Undersea Vehicle Electrical Power and Propulsion Systems

Students:

- **Undergraduate:** 14
- **Masters:** 2

A Computationally Efficient Distributed Shipboard Condition Prognostics System

Professors: Dr. Bin Zhang, Dr. Paul Ziehl and Dr. George Vachtsevanos

Technical Capability Alignment: Advanced Logistics Concepts and HM&E Life Cycle Logistics Support

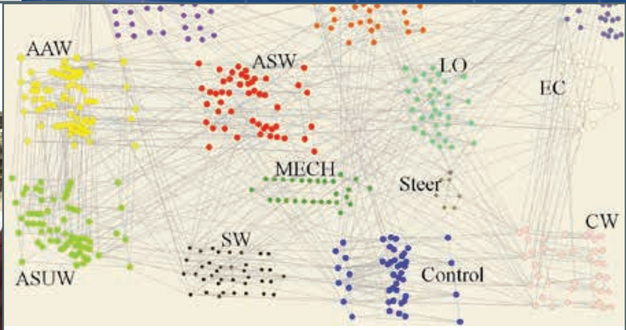
Students:
- **Undergraduate:** 1
- **Masters:** 2
- **PhD:** 1

University of South Carolina

University of South Carolina, teaming with Georgia Institute of Technology, is developing a shipboard machinery prognostics and health management system. The proposed solution has a hierarchical structure that includes data processing, feature extraction, distributed fault diagnosis and prognosis, and probabilistic reasoning and is designed to achieve assessment of system health condition and operational risk. For such a system, fault diagnosis and prognosis, nondestructive evaluation, and structural health monitoring are fundamental enabling technologies. To enable shipboard implementation, computationally efficient algorithms must be developed. It is expected that the proposed solution will improve the health management and enable a transition from diagnostics based reactive strategies to prognostics based proactive strategies. We also aim to develop scalable, generic, and easy-to-implement, and mathematically rigorous system monitoring and maintenance solution, which can be applied to a variety of navy applications. The proposed solution will be developed, tested, and demonstrated with laboratory data, models, and testbed.

NEEC students work on the experimental testbed.

VT Team Dr. Brown and students.



Ship System of Systems Multiplex Architecture.

Virginia Tech

The objective of our Naval Engineering Education Consortium (NEEC) project is to develop design and analyses tools to identify ship system architectures that are affordable, survivable, available, and operable in support of future naval ships with high energy weapons and sensors. We use network-based methods to assess and optimize interdependent electrical, mechanical, fluid, thermal, and combat system architectures for improving total ship operability, reducing vulnerability, and increasing availability in distributed systems for Naval ships as defined in a Leading Edge Architecture for Prototyping Systems (LEAPS)/Smart Ship Systems Design (S3D) product model. Tools are being developed to extract directed network descriptions from LEAPS data and the resulting network descriptions will be used to generate system deactivation diagrams and network diagrams and to perform network analyses and optimization using Non-Simultaneous Multi-Constraint Parallel Commodity Flow (NSMCPCF) optimization methods.

NSWC Philadelphia

Network-Based System Architecture Assessment and Improvement In Support of S3D/ LEAPS Ship System Design

Professor: Dr. Alan Brown

Technical Capability Alignment:
Surface and Undersea Vehicle Machinery Systems Integration

Students:
- **Undergraduate:** 3
- **Masters:** 2
- **PhD:** 2

Atmospheric Turbulence Generation in Multiphase Flows with Density Stratification and Phase Change

Professor: Eckart Meiburg

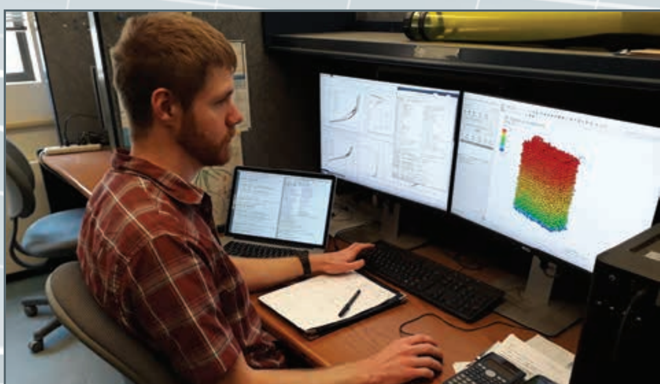
Technical Capability Alignment: PH09 Directed Energy and Electric Weapon Systems ISE, T&E, and IPS

Students:
- **Masters:** 1
- **PhD:** 2

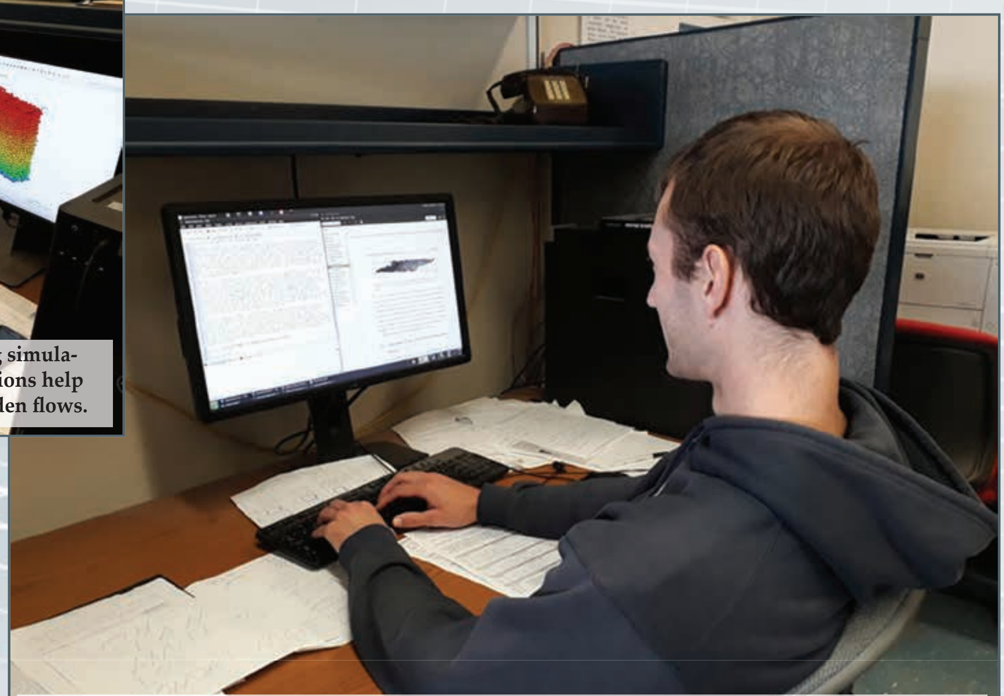
University of California, Santa Barbara

In the first part of the project, we investigate the influence of shear on double-diffusive and settling-driven instabilities, by means of a transient growth analysis. Employing Kelvin waves within a linearized framework allows for the consideration of time-dependent waveforms in uniform shear. In this way, the effects of boundaries and of shear-driven instability modes can be eliminated, so that the influence of shear on the double-diffusive and settling-driven instabilities can be analyzed in isolation. Shear is seen to dampen both instabilities, which is consistent with previous findings by other authors. The shear damping is more pronounced for parameter values that produce larger unsheared growth. These trends can be explained in terms of instantaneous linear stability results for the unsheared case. For both double-diffusive and settling-driven instabilities, low Pr-values result in less damping and an increased importance of the Orr mechanism, for which a quantitative scaling law is obtained.

In the second part of the project, we conduct fully-resolved simulations of dense particle-laden flows under laminar conditions in order to better understand the rheology of such flows. Carrying out a detailed momentum balance for the fluid and particle phases, we find that the stresses remain in equilibrium even during unsteady flow conditions. We also investigate the rheology of the particle-laden flows under two frameworks: effective viscosity and the macroscopic friction coefficient, or $\mu(I)$ rheology. While the results collapse better under the effective viscosity framework, none of the models considered can fully describe the rheology of the observed results. The tangential lubrication force acting between particles also plays a large role in the results and should be investigated further.

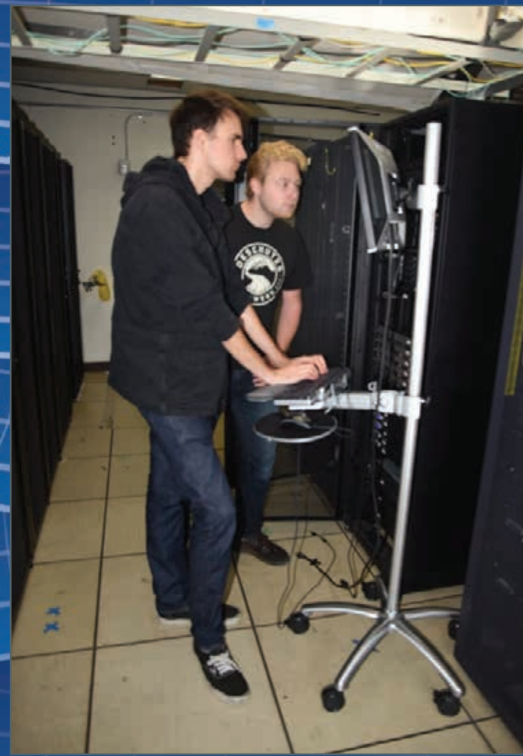


Student performing three-dimensional, grain-resolving simulations of two-phase flows. Such high-resolution simulations help us understand and quantify the rheology of particle-laden flows.



Student employing computational fluid dynamics (CFD) tools to analyze the effect of shear on double-diffusive and settling-driven instabilities in the ocean.


Students diagnose a MANDRAKE infrastructure problem.



University of California, Santa Barbara

The goal of MANDRAKE is to leverage the recent breakthroughs in commercial analytics and cloud computing to predict functionality and performance failures from critical software and hardware infrastructure systems. To accomplish this goal, MANDRAKE must meet three key objectives. It must:

1. develop prediction methodologies that are specifically designed to predict hardware and software systems failure in an automated ``lights out'' manner,
2. be able to support the plethora of new analytics technologies that are available (largely as free open source) that can be brought to bear on the problem of failure prediction, and
3. itself be robust and failure resilient to a greater extent than the systems it monitors.

Our recent work has focused on the research that is needed to meet these objectives. Specifically, the team has been working on the "lights out" deployment problems that will allow the MANDRAKE platform to work as an appliance. In edition, the team has been studying the robustness characteristics of the initial platform prototype. The recent fires in the Santa Barbara area provided an excellent real-world opportunity to investigate the effect of intermittent power availability on the stability of the platform.

The team also studies new adaptive algorithms for deadline-driven cloud execution of machine learning codes. In particular, one student developed a model for executing the stochastic gradient algorithm (used at the heart of many machine learning applications) that allows a user to predict the level of convergence the application will achieve by a specific future deadline.

Students diagnose a MANDRAKE infrastructure problem induced by power fluctuations experienced by UCSB during the recent Thomas Fire incident.

NSWC Port Hueneme

MANDRAKE: a Maintenance AND Remediation Anticipatory Knowledge Environment

Professor: Rich Wolski

Technical Capability Alignment:
PH02 Surface and Expeditionary Combat Systems ISE, T&E, and IPS

Students:
- **Undergraduate:** 1
- **Masters:** 2

NSWC Port Hueneme

Actionable Intelligence-Oriented Cyber Threat Modeling

Professor: Bongsik Shin

Technical Capability Alignment: PH02 Surface and Expeditionary Combat Systems ISE, T&E, and IPS

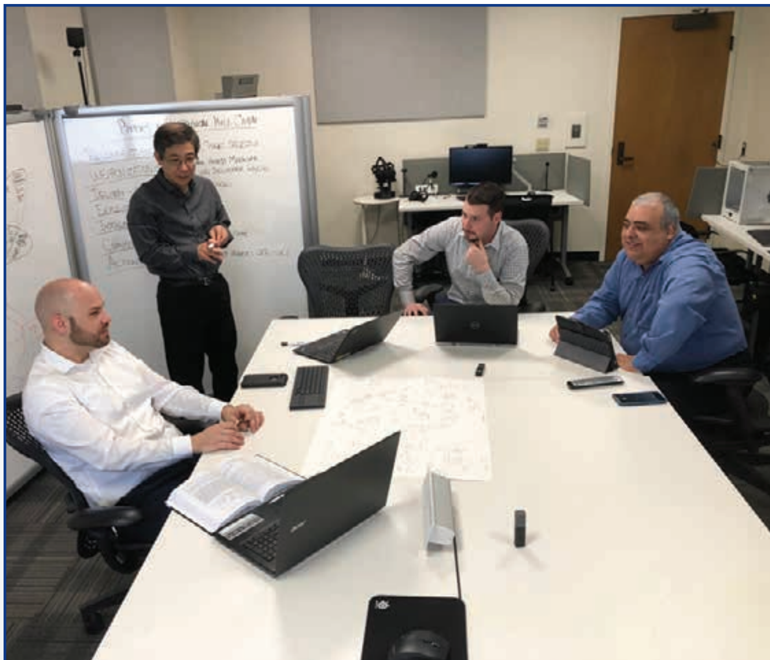
Students:
- **Masters:** 3

San Diego State University

We propose a threat intelligence-driven modeling framework anchored on four key enabling technology components: (1) open source threat intelligence; (2) big data; (3) artificial intelligence (AI); and (4) knowledge/rule base. Conveniently called TIME (for threat intelligence modeling environment), it is composed of continuous cycles of six high level actions: (1) collect asset data; (2) gather vulnerability data; (3) agglomerate threat data; (4) correlate vulnerabilities and threats with assets; (5) derive threat intelligence and interpret its effects on assets; and (6) share threat intelligence with the community. Each of which is, by nature, highly dynamic (rather than static) as changes continuously take place on (1), (2), and (3), and the changes will have ripple effects on (4), (5) and (6). The TIME framework is built on various NIST standards (e.g., CVE, CVSS) for vulnerability and threat management, and is closely aligned with the NIST Framework designed to improve Critical Infrastructure Cybersecurity.

In the proposed project, a test-bed will be designed according to TIME and will be implemented in a scoped setting. Then, the test-bed's effectiveness is assessed in terms of (1) its potential for timely detection of threats & vulnerabilities and (2) the quantity and quality of threat intelligence recovered. The key contribution of this project is that the traditional risk assessment based on the asset-threat-vulnerability triangulation can be scaled vertically and horizontally along an organization's defense line enabled by the four promising technologies. Although the automation of threat intelligence discovery is localized in this project, that of the entire process remains technically viable if the value of TIME is proved.

Brainstorming for the Logical Modeling of Cyber Threat Intelligence.




employing a novel electrode material
NEEC
ABSTRACT
MATERIALS & METHODS
HYPOTHESIS
RESULTS
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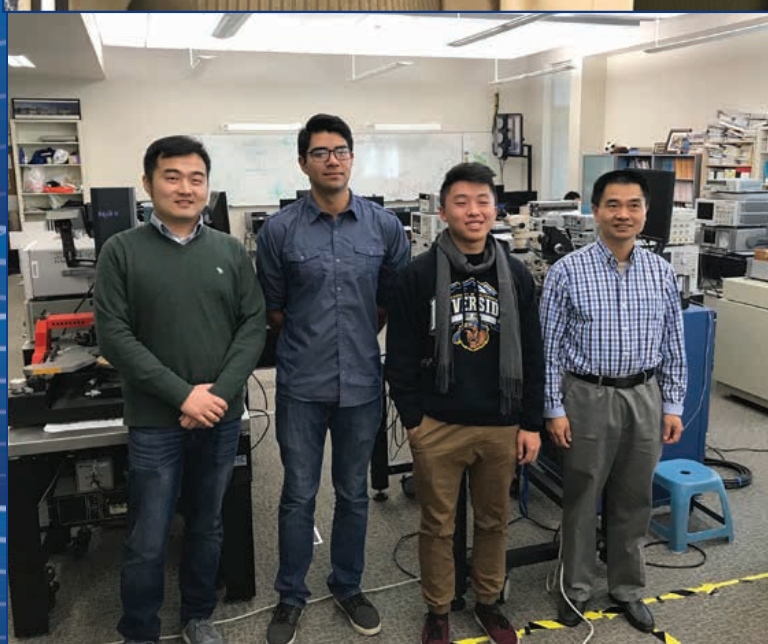

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