GW | Engineering

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

Engineering towards a better world

THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

LETTER FROM THE DEPARTMENT CHAIR

From plasma medicine used to treat cancer to decarbonization, the technologies that are vital to human life and prosperity rely on engineering innovations happening in GW's MAE Department. GW Engineering creates a collaborative, interdisciplinary environment for students, faculty, and community stakeholders to innovate and create together – all while leveraging our dynamic location in Washington, D.C.

The Department of Mechanical and Aerospace Engineering embodies this spirit of collaborative innovation. Our "Engineering and…" approach connects mechanical and aerospace engineering with the many aspects of our diverse, complex lives. With a deep understanding of how thermal and fluid sciences, manufacturing, materials science, robotics, and design form a foundation for infrastructure and technologies that touch all aspects of our lives, our department's faculty and students build on that foundation to impact business, law, policy, and health. It is common to see us collecting data in the hospital, developing frameworks for technology regulation in the law school, analyzing scientific frontiers with government agencies, and creating global solutions with international NGOs. We share a few representative examples here to demonstrate how our partnerships with doctors, companies, and government agencies allow us to create relevant, meaningful solutions that impact human life and our environment.

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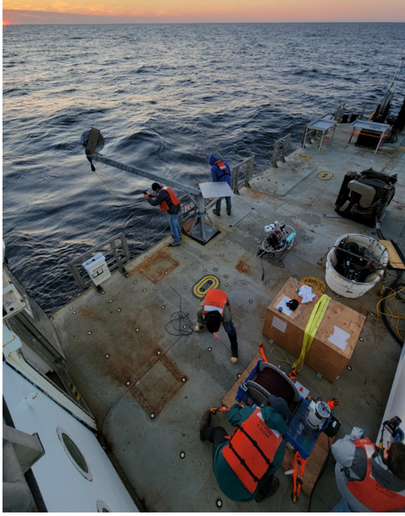
I welcome you to explore our commitment to leveraging engineering research and education to improve human life and serve our global society by reading the profiles and stories that follow.

Michael Plesniak, Ph.D.
Chair, Department of Mechanical and Aerospace Engineering

FROM CAR NUT TO MECHANICAL ENGINEER: INTRODUCING PROFESSOR MATTHEW RAU



Growing up, Prof. Matthew Rau was a big car nut. Hence, Mechanical Engineering was a natural fit as the science and prospect of applying it to design new things particularly interested him. As he gained more experience, he began to appreciate how broad the field is. Now, what excites Prof. Rau about Mechanical Engineering is how it can be used to work on large, interdisciplinary problems. His research areas of expertise involve fluid mechanics and heat transfer, and he has worked in a number of areas, including boiling heat transfer and bubble breakup and coalescence.

Prof. Rau's most recent research focuses on cohesive particles in nature, such as sediments, microplastics, and freshwater and marine phytoplankton. He is currently working on several multidisciplinary projects that aim to discover how fluid flow and turbulence affect how these particles move through the environment; for example, in one project he is working with oceanographers to better understand how carbon material is sequestered in the ocean. In another project, he is focusing on measuring suspended microplastic particles in Lake Erie. It is not yet understood how small microplastics interact with their surrounding ecosystems and are transported through the water column, so this project seeks to better understand those processes and provide remediation guidance.

LAUNCHING ROCKETS AND CAREERS THROUGH THE GW ROCKET TEAM

The GW Rocket Team is one of the unique project teams offered at GW Engineering that helps undergraduate students develop invaluable skills that aid them academically, professionally, and personally. GW Rocket is a hands-on engineering project larger than anything they may tackle in their classes that is devoted to designing and building a rocket to compete with at the Intercollegiate Rocket Engineering Competition and Spaceport America Cup. Senior Phoenix Price joined as a first-year with the ambition to spend one year on every project team. However, the complexity and pace of the projects hooked him, and four years later, Price is serving as GW Rocket Team Captain.

The GW Rocket Team features a separate Payload, Propulsion, Aerostructure, and Recovery Sub-System Team, each supervised by a student leader. The team is advised by Professor Murray Snyder but operates largely hands-off and is free to make decisions without external input. They first competed at the Spaceport America Cup in 2014 with a rocket 3 inches in diameter and 5 feet tall. In 2023, they competed with an 18-foot dual-stage rocket that is 6 inches in diameter and was the only team whose second stage successfully ignited as expected.

Competing at various competitions for four consecutive years offers Rocket Team members countless opportunities to network with individuals working in their desired fields. In fact, Price has been employed for the past three summers because of connections made through GW Rocket. This is typical for Rocket Team members, as many graduates now work for top aerospace companies, including Blue Origin, Lockheed Martin, Northrop Grumman, and Raytheon.

IDENTIFYING AND IMPLEMENTING ALTERNATIVE ENERGY SOURCES

Studies have shown chronic exposure to the rising levels of CO_2 in the Earth's atmosphere poses numerous potential health risks for humans, including inflammation, reductions in higher-level cognitive abilities, bone demineralization, kidney calcification, oxidative stress, and endothelial dysfunction. The Department of the Navy alone emits approximately 16.7M metric tons of CO_2 per year, of which 70% is from operations and more than 95% of that results from burning fuel. This statistic illustrates why energy efficiency and alternative energy sources are key pillars of decarbonization as they help curb CO_2 emissions in both the short and long term. Professor Saniya LeBlanc is aiding the Office of Naval Research (ONR) as well as the Department of Energy (DOE) in its mission to identify and efficiently implement alternative energy sources.

The Navy's current research on individual technologies, such as engines that use low-carbon fuels, will be complemented by Prof. LeBlanc's work as she aims to design an energy analysis tool used to compare multiple technologies simultaneously to understand the collective impacts they could make and evaluate the tradeoffs involved with selecting each technology. It is vital the Navy is aware of how these technologies would collectively impact space, weight, and performance so they may choose the most feasible ones for each ship and across various implementation timeframes.

Cities are another major polluter, accounting for 40 to 50% of greenhouse gas emissions worldwide. For the past three years, Prof. LeBlanc and her team have been working with the DOE to determine how to integrate and enhance electricity generation and energy storage components in an urban district energy system (DES). Using GW's DES as a case study has allowed them to determine the most efficient technologies for improving resilience, reliability, vulnerability, and return on investment; for example, they found that hot thermal and ice storage has the highest return on investment as they lower the yearly operation cost by about \$15,000 and \$100,000 for cases without grid sell back and with grid sell back, respectively. To determine this, they created an Energy Management System (EMS) that can optimize energy resource dispatch based on cost alone or cost under resilience operation constraints. The team will develop a user interface for the EMS so users may evaluate their own DESs, including options for incorporating renewable generation and storage, in the project's final phase. By aiding major polluters such as the ONR and DOE in lessening their carbon footprint, Prof. LeBlanc is helping to mitigate the harmful effects of additional CO_2 in the atmosphere on human health.

Prof. LeBlanc (right) works collaboratively with GW's Executive Director of Engineering (middle) and then Director of the Office of Sustainability (left) in the university's combined heat and power plant to connect the energy research to campus energy systems.

IMPROVING CANCER THERAPY THROUGH ADAPTIVE COLD ATMOSPHERIC PLASMA DEVICES

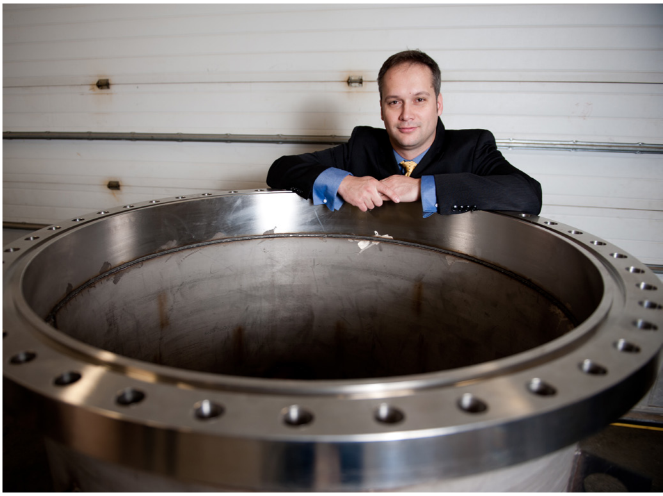
Many diseases, such as cancers, are dreadful because even when therapy is a treatment option, it often involves debilitating side effects. Recent progress in atmospheric plasmas has led to the development of adaptive cold atmospheric plasma (CAP) devices that have applications in various settings, such as synthesis and microfabrication, with the most promising one being cancer therapy. Prof. Michael Keidar, a pioneer in cold plasma research and the A. James Clark Professor of Engineering, has been exploring the effect of CAP on cancer therapy for over a decade through his research in the multidisciplinary field of plasma medicine, which combines plasma physics and engineering, medicine, and bioengineering.

Prof. Keidar focuses on the interaction of the reactivity produced by CAP with cancer cells and tissues since his goal is to develop a new highly selective and non-toxic cancer treatment based on cold plasma, particularly novel adaptive plasma platforms capable of modifying treatment in real-time. He demonstrated the efficacy of cold plasma in a pre-clinical model of various cancer types. Both in-vitro and in-vivo studies revealed cold plasma kills cancer cells highly selectively. More importantly, they can do so without damage to normal cells and will significantly reduce tumor size in vivo. He translated this discovery into a device that delivers cold plasma to patients following tumor removal to prevent tumor cells missed in the surgery from causing remission. The novel CAP device generates an Electromagnetic Field and Reactive Oxygen and Nitrogen species to induce cancer cell death in a selective manner.

In 2020, he entered a $3.2 million corporate research agreement with US Patent Innovations (USPI), LLC, to support further development of adaptive CAP devices for cancer therapies through the clinical testing of this device. Between March 2020 and April 2021, twenty patients, ages 26 to 85, received intra-operative CAP treatment following surgical macroscopic tumor removal by USPI. This initial clinical trial ended in May 2022, and the results were recently published, showcasing promising findings that demonstrate CAP's ability to control residual disease and improve patient survival. Prof. Keidar's recent work focuses on non-invasive brain tumor treatment in collaboration with Duke University. To this end, a new cold plasma modality has been discovered and implemented. Through each of his CAP research efforts, Prof. Keidar is tackling the critical healthcare challenge of reducing the toxicity of existing cancer treatment modalities.

Prof. Keidar observes the use of his cold plasma therapy in a treatment session for the technology's FDA trial.

IMPROVING NAVAL ENTERPRISE'S WORKFORCE DEVELOPMENT PATHWAYS



Prof. Bardet is pictured with a component of equipment used for fluid dynamics experiments that can be used to train students in naval research topics.

Diversifying the science, technology, engineering and math (STEM) workforce is crucial for creating a more inclusive and innovative industry. The Naval Research & Development Enterprise (NR&DE) seeks to diversify its own workforce by establishing a research pipeline to recruit engineers and scientists from underrepresented groups interested in joining the naval engineering workforce long-term. As Washington, D.C., is a hotbed for maritime research, the NR&DE believes D.C. universities are uniquely suited to start a nationwide consortium to help them reach this goal and two others, addressing the risks of their aging workforce through the transfer of knowledge and training future candidates in relevant skills and expertise for Navy careers, through this pipeline.

GW will lead the multidisciplinary team formed from key institutions within D.C. in creating this consortium, with Prof. Phillipe Bardet serving as the Principal Investigator. The strategies they will utilize include interviewing current members of the NR&DE, improving existing education pathways through activities such as mentorship programs, and proposing new course development. To get STEM students interested in naval engineering specifically, the team proposes developing a GW-led National Security and Naval Power Bootcamp, introducing a Certificate in National Security Studies to the graduate certificate programs offered by the Elliott School of International Affairs, and recreating a concentration in Naval Engineering offered by GW Engineering's Mechanical and Aerospace Engineering Department. Due to the interdisciplinary design of naval platforms, each program will provide students with generalist training to give them the broad education necessary for a successful career in the NR&DE.

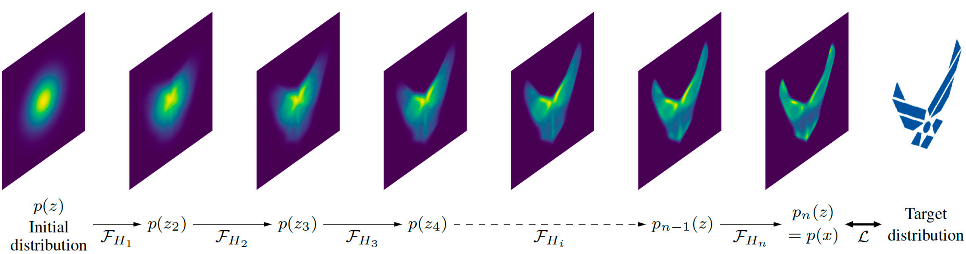
Tracking engagement with these activities can improve their impact and promote diversity and inclusion. Prof. Megan Leftwich will use research-based best practices to ensure diverse community members participate in the consortium's STEM opportunities and succeed in a program with assistance from Prof. Saniya LeBlanc. Prof. LeBlanc will also work closely with the Educator Directors to design and execute each program's strategy, ensure metrics are collected, and assess those metrics. Ultimately, this project will facilitate the recruitment and retention of engineers and scientists from historically underrepresented groups to bolster the NR&DE workforce by creating dedicated pathways starting in the greater D.C. area.

DEVELOPING NOVEL FRAMEWORKS FOR OPEN HYBRID DYNAMICAL SYSTEMS

There is no lack of examples of hybrid systems in our current world since, due to their unifying framework to describe complex behaviors, they are used to model a wide range of dynamic systems, including robotics, biology, chemistry, social networks, and much more. Hybrid systems are dynamical systems that exhibit both continuous and discrete behaviors, meaning they are systems that may instantaneously switch between various modes of operation depending on specific events or even randomly. That intricate interplay between continuous evolution and instantaneous switching causes them to manifest complex and rich dynamic characteristics that are challenging, or even formidable, to analyze with conventional apparatuses of dynamic system theory.

In May 2023, Mechanical and Aerospace Engineering Professor Taeyong Lee received an award from the Department of Defense (DoD) as part of the Multidisciplinary University Research Initiative (MURI) Program to develop theoretical and computational frameworks to analyze and certify the intriguing behaviors of complicated open hybrid dynamical systems so we may better analyze the countless existing hybrid systems. GW will lead the team of investigators from the University of Michigan, Rutgers University, and the University of Florida. Out of the total budget of $7.5M, GW's share is about $1.6M. Their study aims to identify and construct the inherent structures of hybrid dynamics, such as topological properties and invariances, that can be preserved under interaction with uncertain environments and composition over a complex network.

The team will develop this framework through multidisciplinary research that integrates recent developments in applied mathematics, computer science, engineering, and data-driven computational techniques. The novelty lies in establishing a trustworthy computational foundation that is carefully constructed in conjunction with the underlying geometry, leading to significant generalization capacity and computation efficiency to handle non-trivial and non-conventional hybrid systems. This intrinsic framework for open hybrid dynamical systems is of interest to the Air Force Office of Scientific Research (AFOSR). AFOSR solicited proposals from the MURI program in 24 topic areas of strategic importance to the DoD. In creating a proposed scalable and composable framework, Prof. Lee and his team will provide more accurate, reliable, and efficient algorithms for the modeling, simulation, and design of complex systems, enabling the Air Force to complete their missions under uncertain, complex, and adversarial environments.



The image depicts the mathematical analysis Prof. Lee utilizes for the MURI research.