2023 ANNUAL NEWSLETTER

MATERIALS SCIENCE IN EXTREME ENVIRONMENTS

MSEE

MATERIALS SCIENCE IN
EXTREME ENVIRONMENTS
UNIVERSITY RESEARCH ALLIANCE

Attendees learn about impact research experiments in JHU's Hypervelocity Facility for Impact Research Experiments (HyFIRE) as part of the Impact Research Workshop and Short Course.

FROM THE DIRECTOR

On May 14, 2023, we celebrated the third anniversary of the Materials Science in Extreme Environments University Research Alliance (MSEE URA), in which we undertake scientific research to counter weapons of mass destruction in support of the Defense Threat Reduction Agency (DTRA).

Since I last wrote 12 months ago, MSEE has expanded its footprint by forging new partnerships with multiple entities. Researchers from the Air Force Institute of Technology joined the consortium and are supporting ongoing efforts in Research Area 1: Material Properties and Failure. We increased our engagement with ROTC programs at URA universities and the U.S. service academies at West Point and Annapolis, resulting in more cadets participating in research internships and gaining information on potential military assignments within DTRA. Lastly, we formalized partnerships through cooperative research and education agreements with the U.S. Army Combat Capabilities Development Command Chemical Biological Center (DEVCOM CBC) and the Naval Postgraduate School. These exciting new partnerships highlight the impact of MSEE research and provide novel opportunities for collaboration, workforce development, and translational activities.

In June, we held our Annual Technical Review (ATR) in Baltimore, Maryland. Rhys Williams, Executive Director of DTRA, provided keynote remarks and addressed the importance of MSEE URA research to DTRA's mission. Sarah Nelson, Director of the National Nuclear Security Administration's Office of Experimental Sciences, provided a stimulating lecture at our banquet covering the NNSA's Inertial Confinement Fusion (ICF) portfolio. The review was attended by more than 120 individuals and included 43 technical presentations and 52 posters led primarily by our students and postdocs. Members of two external review committees, the Science Advisory Board and the Research Management Board, attended the ATR as well. These formal entities provide critical feedback which will assist MSEE leadership in drafting our 2024–25 biennial program plan.

Throughout these activities, two DTRA military officers have been particularly helpful to MSEE: Col. Cory Lane, Enabling Capabilities Division Chief, and Capt. Rafael Mata, Cooperative Agreement Manager. Their efforts have been instrumental to the success of the program, and I want to take this opportunity to thank them for their leadership and support of the MSEE URA.

As one would expect, many other individuals also deserve thanks. The growth and success of the MSEE URA is the direct result of our dedicated URA leadership, principal investigators, postdocs, graduate students, scientists, and technicians who have embraced the collaborative nature of MSEE and perform the URA's daily research activities. Our technical points of contact at DTRA have proven to be valuable collaborative partners guiding our research and workforce development activities. Lastly, staff throughout the URA have advanced our research by addressing many administrative and contractual requirements. To all of these individuals, I say thank you.

I look forward to the URA's continued growth and success as we enter our fourth year of research in support of DTRA.

TIM WEIHS
Director, MSEE URA
Professor, Department of Materials Science and Engineering, JHU

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PROGRAM GOALS

- Advance the fundamental understanding of materials and chemistries under extreme conditions of pressure, temperature, and radiation
- Create state-of-the-art diagnostic tools, high-fidelity models, and advanced materials while facilitating their transition to DTRA applied research programs
- Manage and foster a comprehensive, collaborative research environment
- Train, mentor, and inspire the next-generation workforce

To achieve these goals, the MSEE URA has four distinct research areas and a cross-cutting research initiative. Research is focused on understanding, predicting, and controlling the behavior of materials in extreme conditions caused by weapons of mass destruction. The URA is expected to understand fundamental aspects associated with conventional weapon behavior, develop advanced materials that can be applied to the destruction of chemical and biological agents, and advance the understanding of nuclear explosion behavior and the material response to nuclear weapon generated and simulated environments.

RESEARCH AREAS AND LEADS

1: Material Properties and Failure

2: Materials and Manufacturing for Synergistic Effects

3: Chemistry in Extreme Environments

4: Photon-Material Interactions

5: Cross Cutting Research Initiative

TODD HUFNAGEL
Research Area 1 Lead and Associate Director of the MSEE URA

MICHAEL ZACHARIAH
Research Area 2 Lead

NICK GLUMAC
Research Area 3 Lead

FARHAT BEG
Research Area 4 Lead

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Cross Cutting Research Initiative Coordinator

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DEFENSE THREAT REDUCTION AGENCY

CAPT. RAFAEL MATA
Collaborative Alliance Manager (CAM)

JACOB CALKINS
Technical Point of Contact (TPOC) for RA1, RA4

JEFF DAVIS
Technical Point of Contact (TPOC) for RA1, RA2, RA3

DAVE PETERSEN
Technical Point of Contact (TPOC) for RA3

MSEE URA INSTITUTIONS

Johns Hopkins University · UC Riverside · UC San Diego · University of Illinois Urbana-Champaign

Washington State University · South Dakota Mines · AFIT Air Force Institute of Technology · University of Rochester · Pacific Northwest National Laboratory · CRAFT Tech · Lawrence Livermore National Laboratory · NJIT New Jersey Institute of Technology · DEVCOM Army Research Laboratory · The University of Arizona · Morgan State University · Georgia Institute of Technology · VCU

GOVERNMENT AND CORPORATE AFFILIATES PROGRAM

To facilitate government and industry collaborations, the MSEE URA established the Government and Corporate Affiliates Program (GCAP).

The GCAP goals include:

» Facilitating the transfer of scientific and technological advances to partners;
» Providing a network to enhance collaboration among academia, industry, and government organizations; and
» Assisting members in recruiting and workforce development.

The GCAP benefits include:

» First look at **science and technological advances** supported by DTRA through MSEE URA network and events

» Invitations to **Annual Technical Review** to network, provide visibility of GCAP organizations, and recruit students

» Opportunities to host **graduate and undergraduate students for internships** to facilitate recruiting and workforce development initiatives

» **Recognition of GCAP organizations** with placement of their logos on the MSEE URA website, promotional materials, and annual reports to DTRA

» Ability to **advertise job openings** on MSEE URA website

» Access to **facilities and equipment** at MSEE URA consortium locations

» Early notification for **MSEE URA special events** including short courses, workshops, and seminars

GCAP MEMBER INSTITUTIONS

AFRL Eglin	Fluid Gravity	NNSA
Air Force Inst. of Tech.	IARPA	NNSS Special Tech. Lab
AMG	Innovative Sci. Sol. Inc.	NSERC
Applied Research Assoc.	Inst. for Defense Analyses	NSWC Dahlgren
Battelle	JHU Applied Physics Lab	NSWC Indian Head
CRAFT-Tech	Lawrence Berkeley NL	Pacific Northwest NL
DEVCOM ARL	Lawrence Livermore NL	Sandia NL
DEVCOM CBC	Leidos	Savannah River NL
DIA	Los Alamos NL	U.S. Air Force Academy
Draper	Missile Defense Agency	U.S. Department of State
DSTL	Naval Research Lab	U.S. Military Academy
DTRA	NAWS China Lake	U.S. Naval Academy
Energetics Technology Ctr.	NIST	USANCA

MSEE BY THE NUMBERS FOR 2022-23

INDIVIDUAL PARTICIPANTS

37 PRINCIPAL INVESTIGATORS	40 UNDERGRADUATES	52 GRADUATE STUDENTS	18 POSTDOCS
8 FOCUS AREA COORDINATORS (INCLUDES CCRI)	6 ROTC CADETS	1 DoD SMART SCHOLARS	5 FROM MSI INSTITUTIONS
30 SCIENTISTS/ENGINEERS/ TECHNICIANS	3 ACTIVE-DUTY MILITARY	11 FROM MSI INSTITUTIONS	4 ADMIN STAFF AT JHU DIRECTLY SUPPORTING URA
4 RESEARCH AREA LEADS	9 FROM MSI INSTITUTIONS		

PROFESSIONAL DEVELOPMENT OPPORTUNITIES

232 PARTICIPANTS IN NINE SEMINARS	109 PARTICIPANTS IN SIX WORKSHOPS	95 PARTICIPANTS IN FIVE SHORT COURSES/SYMPOSIA	28 INTERNSHIPS AND APPRENTICESHIPS AWARDED ACROSS SIX PROGRAMS

Our seminars are held on the first Tuesday of each month at 3–4 PM ET.
For more information about MSEE's upcoming seminars and other professional development opportunities, please visit our website: **hemi.jhu.edu/mseeura**.

PUBLICATIONS AND PROCEEDINGS

45 PEER REVIEWED JOURNAL ARTICLES	8 CONFERENCE PAPERS	84 EXTERNAL PRESENTATIONS	5 DISSERTATIONS/ THESES	2 INVENTIONS/PATENT APPLICATIONS	689* CUMULATIVE CITATIONS

*THIS NUMBER IS CUMULATIVE FROM THE START OF THE PROGRAM.

PERSONNEL SPOTLIGHT

CDT. TREVOR SUMLIN

Undergraduate Student, University of North Carolina at Chapel Hill
Nuclear Science and Engineering Research Center (NSERC)
summer intern at Johns Hopkins University
ROTC Cadet

MSEE TASK

Research Area 1—Focus Area 2: Materials Constitutive Models

I learned a lot from my experience as an NSERC intern. I enjoyed seeing the collaboration between academic departments, agencies, and lab groups, as well as the state-of-the-art facilities being used by scientists in the MSEE URA. The combination of world-class researchers and cutting-edge technology made the work environment unparalleled for a scientist in training. This internship has exposed me to all sorts of new interests for my own academic studies and has allowed me to make numerous connections with the scientists who support our warfighters. As I enter the military after graduating, I will remember this experience and all the hard work it takes to develop the tools we use daily.

YOUSSEF ABOUHUSSIEN

PhD candidate, Virginia Commonwealth University
Travel Research Fellowship Awardee

MSEE TASK

Research Area 4—Focus Area 1: X-Ray Induced Blow-Off and Plasma

I've been working as a part of RA4-FA1, which focuses on the blow-off of materials by X-ray impulse. We are investigating the effects of the thermal pulse (X-ray pulse) from high-altitude nuclear detonations that can reach satellites. By using mathematical models and experiments, we can study the response of materials under these extreme conditions. Working with MSEE has been a very interesting and fulfilling journey as I get to work on cool projects and interact with top experts in the field. MSEE also gave me the opportunity to perform experiments at Pacific Northwest National Laboratory for 10 weeks to learn more about RA4-FA2 and connect it to RA4-FA1.

2LT ISAIAH QUEEN

Graduate student, Johns Hopkins University
U.S. Army Officer, Chemical Corps
Weihs Research Group

MSEE TASK

Research Area 2—Focus Area 2: Tailoring Chemistry Via Materials

As an MSEE collaborator, I'm able to leverage my experiences in the classroom and lab to understand how best to support the warfighter. As an Army Chemical Corps officer, I'm currently engaged in research that has direct implications for reducing the threat of chemical and biological agents in challenging environments. My investigation analyzes the comparison of reactive metal powders to understand ignition and combustion properties. This research establishes the foundational knowledge base to tune the reaction to reach temperatures with the capability to neutralize target compounds. The lessons I continue to learn from my mentor and supervisor, Dr. John Fite, under my PI, Prof. Tim Weihs, and others within the Weihs Group have been instrumental in driving me to continue pursuing an education in materials science.

ELLA IVANOVA

PhD candidate, New Jersey Institute of Technology
Best Poster winner at 2023 Annual Technical Review

MSEE TASK

Research Area 3—Focus Area 2: High Temperature Properties and Chemistry of Agents and Simulants

I am grateful for the opportunity to be a part of MSEE. As part of this program, my advisor Gennady Gor and I participated in a project to study the surface tension and viscosity of chemical warfare agents (CWAs) using molecular dynamics simulation supported by an MSEE seed grant. At first, I felt like a fish out of water during our virtual MSEE meetings, as the focus was on experimental work. But through regular discussions with the RA3-FA2 team, working with experimentalists, and attending annual conferences, I have gained a deeper understanding of the subject. It has been inspiring to see that with the support of each other's efforts, we were able to validate our results, thus bridging the gap between simulations and actual experiments. Participating in MSEE has provided me with invaluable research experience.

MSEE RESEARCH SPOTLIGHT

COMPARING EXPERIMENTAL AND THEORETICAL ION PROPERTIES IN SIMULATED NUCLEAR BLASTS

Written by Mathew Polek, PhD candidate, University of California San Diego

In MSEE Research Area 4 – Focus Area 2, the primary goal of our research is to better understand the physics of high-energy interactions with materials, such as those seen in nuclear blasts and high-explosive detonations. To this end, we utilize direct laser impulse, an experimental method in which we hit a material target using a high-power laser and study the resulting plasma.

Researchers at Pacific Northwest National Laboratory (PNNL) carry out small-scale experiments on direct laser impulse using nanosecond and femtosecond lasers, resulting in intensities on the order of 1E10-1E15 W/cm^2—or 10 billion to 1 quadrillion watts of energy per square centimeter—at the surface of the material. Lasers of that intensity focus incredibly high amounts of energy on a small area. When shot at target materials, these lasers allow us to simulate high-energy interactions and study how materials react under the resulting conditions.

However, due to the short timescales, small volumes, and high temperatures involved in these experiments, direct measurements studying the evolution of materials under these conditions are typically not possible. Instead, we must use indirect methods. By measuring shock pressures or plasma properties several pico- or nanoseconds after the arrival of the laser pulse, we aim to predict the initial properties and behavior of the material. Methods for gathering indirect measurements include:

- **Faraday cup measurements**—using a conductive metal Faraday cup to measure captured ions in a vacuum;
- **Spectroscopy**—identifying and investigating the electromagnetic spectra emitted during high-energy interactions;
- **Interferometry**—studying the interference of superimposed waves; and
- **Shadowgraphy**—studying the shadows created during high-energy interactions.

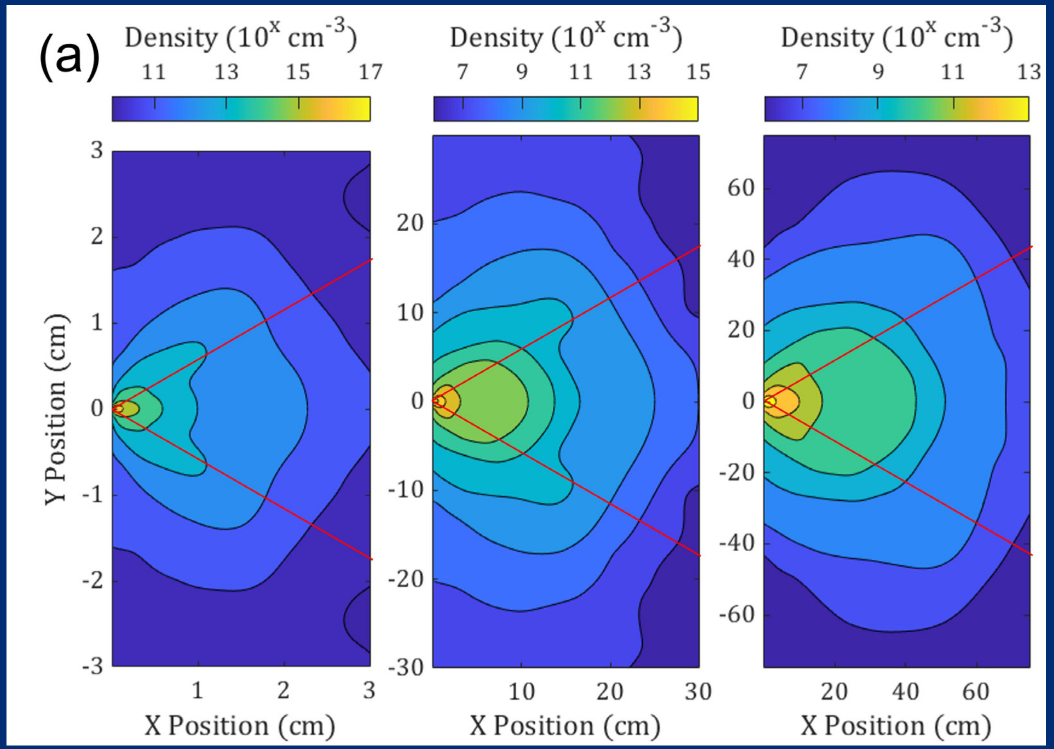
In our initial experiments, we used a Faraday cup to study the properties of ions emitted from the plasma. Our study found that the ions had several interesting properties as a function of laser energy, angle, and distance away from the target. Ultimately, we found that the ion profiles obtained using the Faraday cup consisted of multiple ion peaks with distinct velocity distributions.

These different ion velocity distributions were attributed to various expansion mechanisms occurring during the laser-material interaction, including sheath acceleration, self-similar isothermal expansion, and adiabatic expansion.

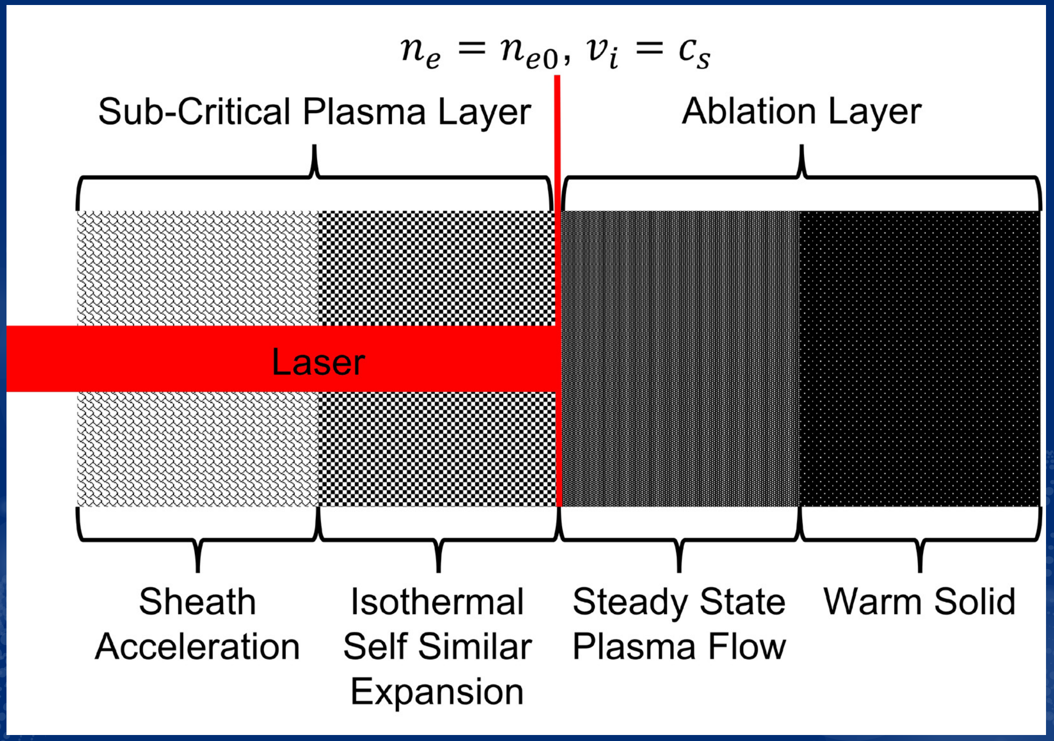
Several other interesting features of the ions were also noted, including free expansion of the ions shortly after plasma formation, off-normal peaking of ultrafast ions, and prompt emission of high-energy photons during the initial plasma expansion. These results were presented at the 2023 International Conference on Plasma Science (ICOPS) and published as a feature publication in the Journal of Applied Physics.

Further studies into high-energy interactions by direct laser impulse are currently ongoing through collaborative efforts between PNNL, University of California San Diego (UCSD), and others. To predict the evolution of materials following high-energy interactions, researchers at UCSD utilize hydrodynamic simulations—computer programs that simulate the behavior of fluids—such as FLASH code, paired with equation of state solvers.

The results of these simulations may then be compared to early time measurements of plasma properties obtained using measurements such as interferometry and shadowgraphy. Through these collaborative efforts, we hope to obtain a more detailed understanding of the physical processes occurring during high-energy interactions.



Density contour plots for Ti obtained at (left to right) 200, 1000, and 3000 ns at a laser intensity of 50 GW cm^{-2}. The red lines are set at 30°.



Summary of laser-material interactions

RESEARCH SPOTLIGHT

USING OPTICAL SPECTROSCOPY TO PROBE INTERACTIONS IN SIMULATED EXTREME ENVIRONMENTS

Dr. Mark C. Phillips, Associate Research Professor, Wyant College of Optical Sciences, University of Arizona

The field of optical spectroscopy, in which scientists use light to characterize materials, has great potential to detect, identify, and quantify atoms and molecules in extreme environments. Every atom and molecule interacts with light in a characteristic way, and by measuring the spectrum of absorbed light with high-precision lasers, these species can be probed from a safe distance.

In Research Area 3 of MSEE, we are developing new tools for high-performance laser spectroscopy and applying these tools for quantitative chemical analysis. Laser spectroscopy is a useful diagnostic tool with a wide range of applications. I often collaborate with researchers throughout MSEE, taking lasers to labs across the country for joint experiments. In November 2022, I helped introduce students and researchers to experimental and analysis methods commonly used in spectroscopy by organizing an MSEE workshop on optical spectroscopy in Tucson, Arizona.

In RA3-FA1, researchers use tunable lasers and frequency combs—laser sources that produce equally-spaced frequency lines and act as a sort of yardstick for other light sources— to probe atoms and molecules in laser-produced plasmas, which act as laboratory-scale surrogates for nuclear fireballs. By measuring the absorption of laser light by the plasmas, we can detect characteristic spectral features of the atoms and molecules with high precision and accuracy. Quantitative spectral fitting, the practice of matching emitted spectra to known models, is then used to determine the atomic and molecular concentrations and how they change in time.

For example, when a plasma is formed containing atoms, reactions with oxygen in the surrounding gas often cause molecules to form as the plasma cools. University of Arizona students use frequency comb spectroscopy to probe the decreasing atomic concentrations and increasing molecular oxide concentrations, while also correlating with the temperature of the cooling plasma to obtain thermodynamic information.

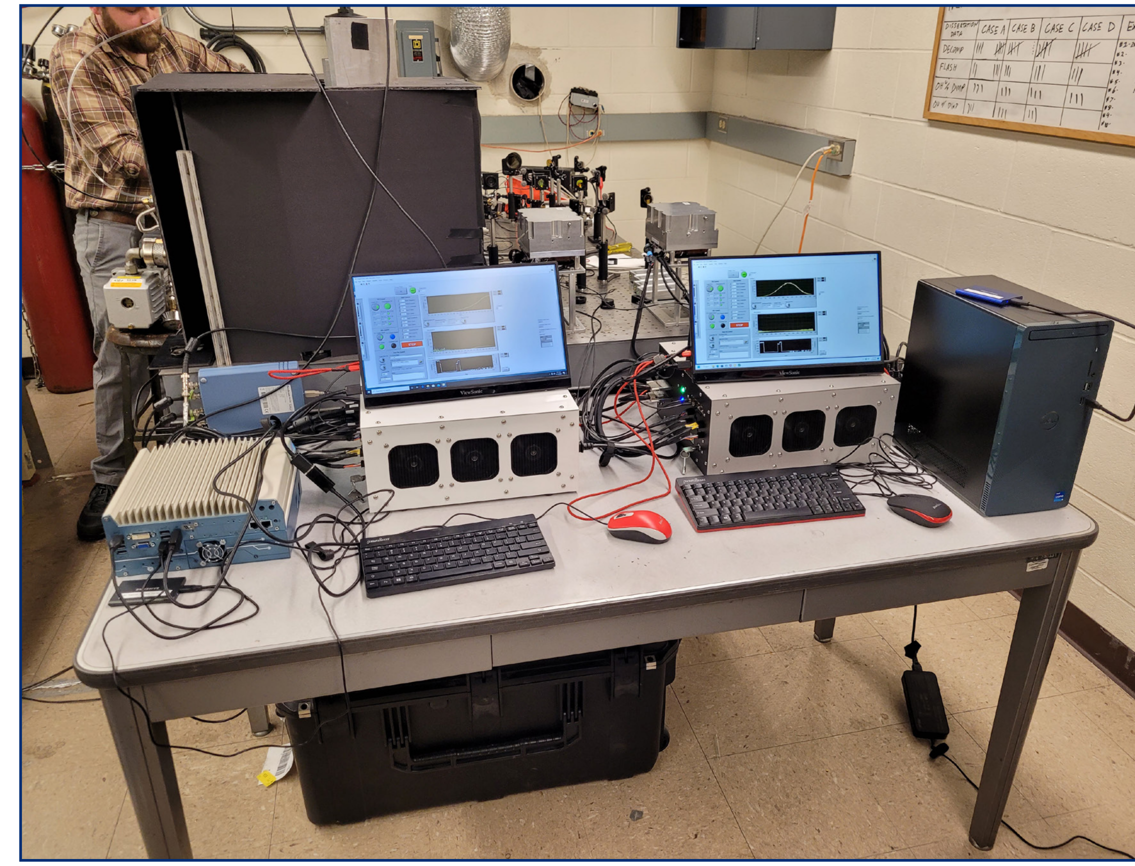
Studies like these yield valuable insight into molecular formation dynamics for species of interest, including uranium oxides. In work with Pacific Northwest National Laboratory (PNNL), tunable laser absorption spectroscopy is used to probe uranium atoms in laser-produced plasmas, and new methods of spectral analysis are being developed to understand thermal equilibrium (or lack thereof) during certain times of the plasma cooling.

In RA3-FA2, custom-built infrared lasers are used to probe molecular reactions that occur when chemical warfare simulants are exposed to high-temperature extreme environments including flames and explosive fireballs. These swept-wavelength external cavity quantum cascade lasers (swept-ECQCLs) provide the unique combination of broad infrared tuning range, high spectral resolution, and high scan speed that is needed to measure dynamics at millisecond time scales.

Recent work in collaboration with the University of Illinois Urbana-Champaign and CRAFT Tech used these swept-ECQCLs to probe simulants when ignited in a combustion chamber (see pg. 14). These experiments simultaneously measured the decrease in simulant concentration along with the increase in multiple molecular decomposition products, confirming the simulant's degradation. Researchers also used the measured spectra to determine the gas temperature.

These swept-ECQCL lasers are also being ruggedized for industrial and outdoor measurements through small business development efforts.* In the coming years, we plan to use these swept-ECQCL lasers in collaborative experiments with MSEE PIs and their students to enable new scientific discoveries about molecular properties in extreme environments.

**Disclosure: Mark Phillips is also an employee of a small business called Opticslah, LLC.*



Two swept-wavelength external cavity quantum cascade lasers being used for experiments in Professor Nick Glumac's laboratory at UIUC, under RA3-FA2's efforts to study decomposition of chemical warfare simulants in high-explosive and high-temperature environments.

MSEE FACILITIES SPOTLIGHT

MEASURING CHEMICAL AGENT NEUTRALIZATION AT HIGH TEMPERATURES AND SMALL TIME SCALES

Written by Nick Glumac, Shao Lee Soo Professor of Mechanical Science & Engineering, University of Illinois Urbana-Champaign

The Energetic Materials Group at the University of Illinois studies reactive flows, or fluids undergoing chemical reactions in the fluid phase, with an emphasis on spectroscopic diagnostics. Recently, we have tested detailed chemical mechanisms for neutralizing simulants of chemical warfare agents. Our research focuses on conditions relevant to a warhead-based approach, specifically the high temperatures typical of combustion environments.

Developing these mechanisms—a task that is currently being tackled by Raj Sinha, Mike DeMagistris, and Andrea Zambon of CRAFT Tech—involves studying large sets of reactions. While MSEE partners and researchers at other labs measure some of these reactions experimentally, others are estimated using theoretical or computational means. However, due to the complexity of the chemistry and the significant uncertainty associated with these reactions, careful validation experiments are necessary to inform our theoretical and computational models.

Performing these validation experiments required the development of a specialized facility. Working with collaborators at CRAFT Tech and the University of Arizona (Mark Phillips), UIUC post-doctoral researcher Austin Butler and I designed a new chamber system for these validation exercises.

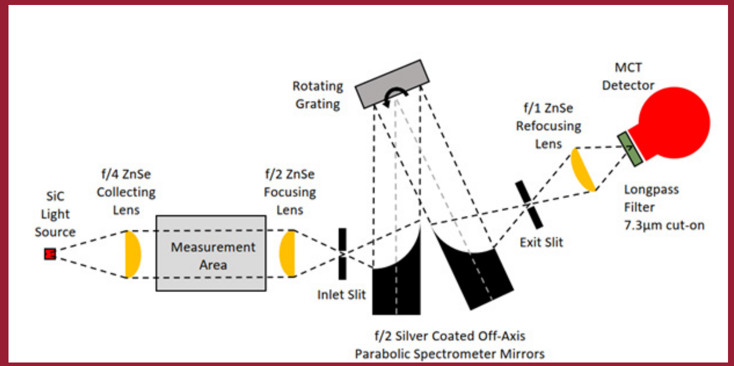
One critical aspect of the design was to reduce the dimensionality so that the problem could be solved computationally in one spatial dimension, allowing for the inclusion of detailed chemistry. This reduction necessitated making a spherical chamber with central ignition. To allow for optical diagnostics to probe the flow while maintaining symmetry, windows were carefully designed to limit deviation from the spherical profile and still allow optical beams in and out of the chamber.

After overcoming many practical challenges, our design was successful. Researchers at UIUC conducted a parametric series of experiments varying critical parameters in a surrogate/fuel/oxidizer mixture that was ignited and burned at temperatures analogous to those in a warhead-based agent defeat scenario. In these tests, we used Diisopropyl Methylphosphonate (DIMP) to simulate chemical warfare agents. However, working with DIMP presents its own unique challenges.

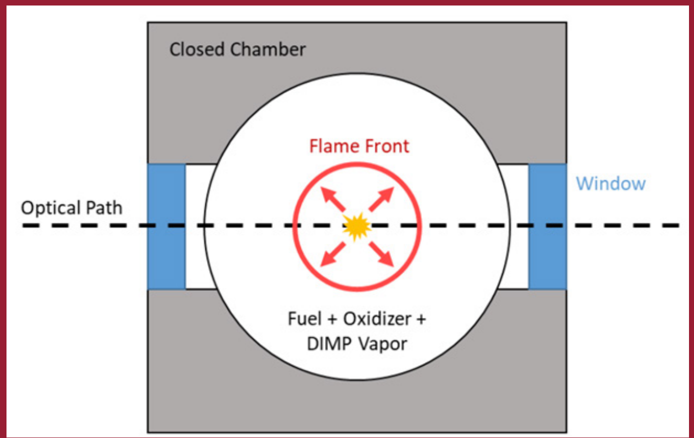
DIMP concentration can be measured by its infrared absorption signature. Because DIMP is neutralized rapidly under combustion conditions, the facilities used for these experiments must be able to gather data on a timescale of one millisecond or better. Broad DIMP absorption features in the infrared are most often measured by Fourier-transform infrared spectroscopy (FTIR), but even fast FTIR systems are ten times too slow. To measure the neutralization of the agent surrogate material, we needed to develop new optical techniques.

Mark Phillips of the University of Arizona brought a swept-wavelength external cavity quantum cascade laser (swept-ECQCL) to UIUC, allowing researchers to make high-resolution measurements at several hundred Hertz during testing. To obtain the highest temporal resolution measurements, albeit at significantly reduced spectral resolution, Glumac and Butler developed a rapid-scanning grating spectrometer, similar to those employed prior to the widespread use of FTIR, that was capable of measurements at 2 kHz, allowing 0.5 ms temporal resolution.

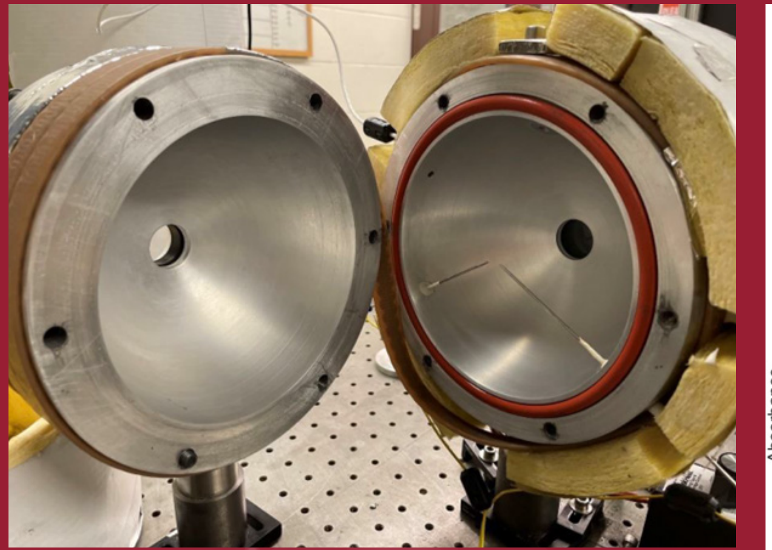
The combination of the swept-ECQCL and rapid-scanning spectrometer measurements allowed for excellent characterization of the decomposition of DIMP under combustion conditions for a wide array of environments. These results in turn provide a sensitive test of the explicit chemistry being developed at CRAFT Tech.



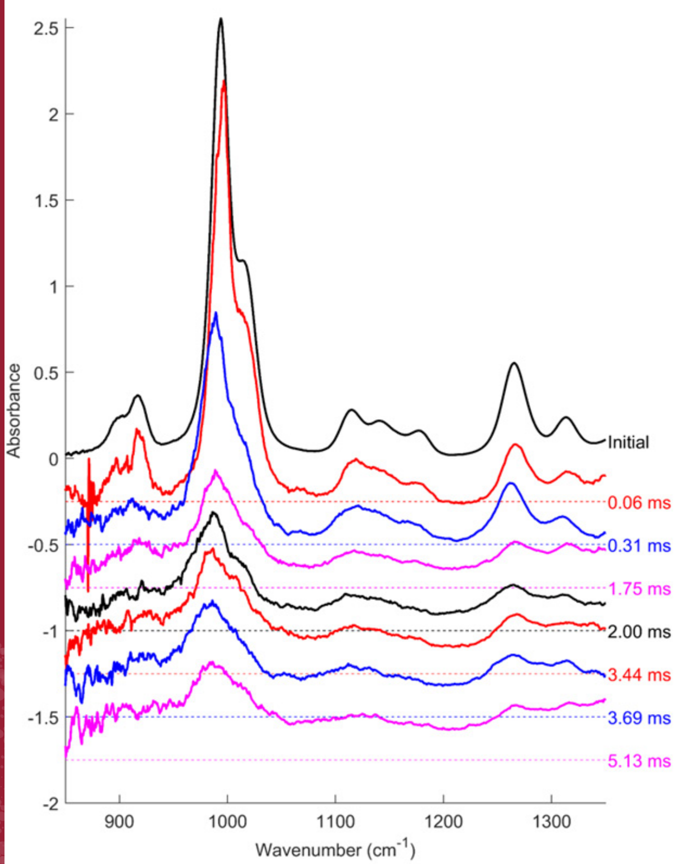
Design of the custom infrared spectrometer allowing for better than 1 kHz temporal resolution of DIMP absorption



Overview of the spherical chamber approach.



The spherical chamber developed for this study.



DIMP decomposition is demonstrated by the reduction in the peak near 980 wavenumbers. Note that kHz resolution is required here to accurately quantify neutralization.

MSEE FACILITIES SPOTLIGHT

HIGH-SPEED IN-OPERANDO HYPERSPECTRAL MICROSCOPY: JHU AND UCR RESEARCHERS COLLABORATE ON EXTERNALLY FUNDED DIAGNOSTIC INSTRUMENT

Written by Sarah Preis
Contributions from Mark Foster, Associate Professor of Electrical and Computer Engineering, Whiting School of Engineering, Johns Hopkins University

At Johns Hopkins University, Mark Foster and his team use a tool called "Snapshot Hyperspectral imager for Emission And Reactions," or "SHEAR," to gather time-based data on combusting particles. Foster, an associate professor of electrical and computer engineering and coordinator of MSEE's Cross-Cutting Research Initiative (CCRI), collaborates with other researchers in the area of chemical agent defeat.

SHEAR is crucial to researchers in multiple MSEE research areas, including RA2–FA2 and the CCRI. By combining spatially resolved optical spectroscopy with high-speed video, SHEAR allows experimentalists to obtain highly accurate, high-resolution data on chemical reactions involved in combustion. Two imaging arms capture simultaneous measurements of burning composite samples: one takes a high-speed RGB video of the experiment, while the other gathers data on emitted spectra and temperature fields.

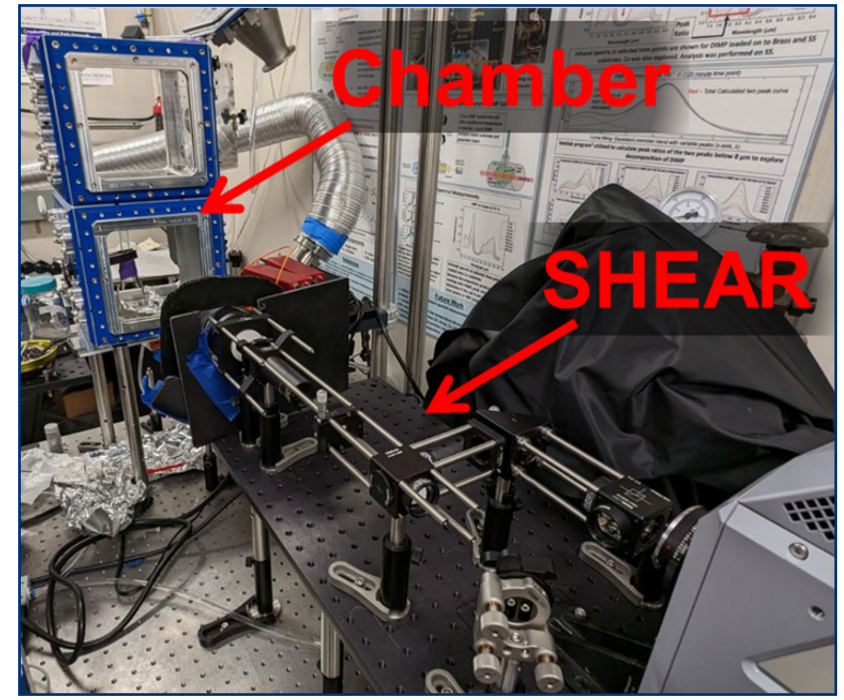
Thanks to SHEAR, collaborators can gain insight into the thermodynamics of these complex chemical reactions at a microscopic level, assisting them in their quest to develop new materials that can neutralize chemical warfare agents effectively.

Earlier this year, Foster and RA2 Lead Michael Zachariah were awarded a Defense University Research Instrumentation Program (DURIP) award that funds a novel SHEAR microscope at the University of California Riverside, where Zachariah is a professor of chemical engineering and material science. The award was granted in December of 2022, and the new instrument is currently under construction. Zachariah and Foster plan to use this new instrument for the in-operando study of combusting materials, and they aim to understand structure-function relationships by characterizing reacting materials in real time.

The original SHEAR imager was tailored to the study of particulate combustion, focused on capturing data on sparsely distributed, freely moving particles undergoing combustion. The new SHEAR microscope will incorporate a hyperspectral imaging strategy known as integral field spectroscopy, allowing it to capture the spectral properties of more diffuse reactions such as those studied by the Zachariah group. The ability to capture these diffuse reactions is crucial for researchers studying the reaction fronts of reactive composite films undergoing combustion.

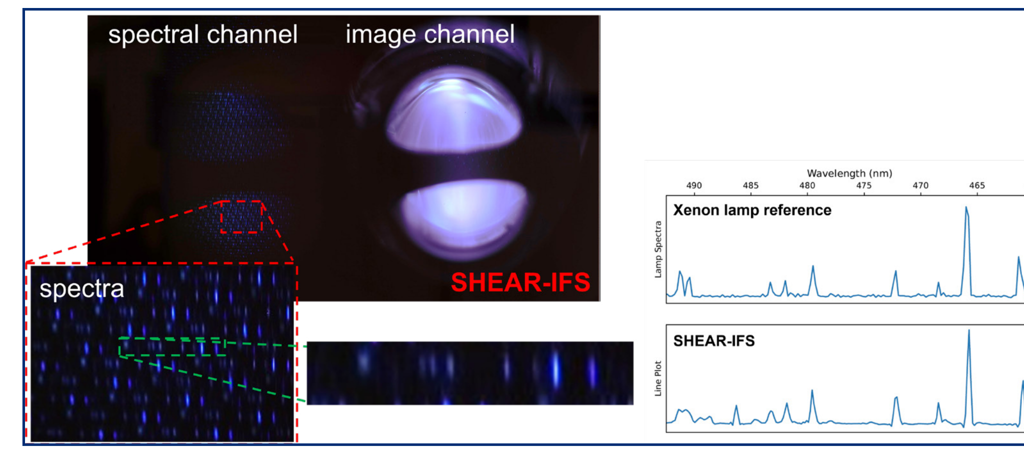
The impact of this new instrument extends beyond its potential research implications. Not only does this award showcase the URA's collaborative nature, but it also represents a step by researchers toward externally funded efforts.

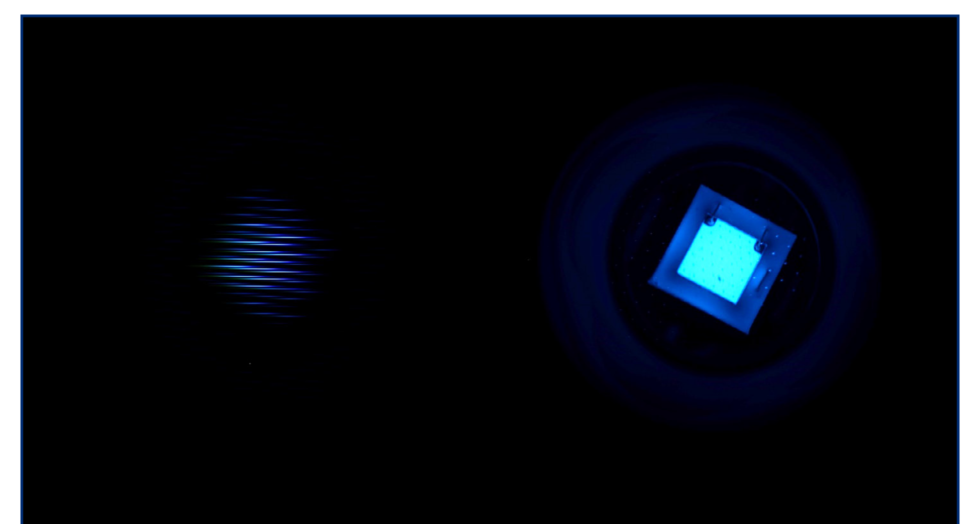
The joint proposal for this new instrument, "High-Speed In-Operando Hyperspectral Microscopy," represents a collaborative effort between Foster and Zachariah, and is a particularly good example of the teamwork present in every corner of the URA. "Professors Zachariah and Foster were able to leverage techniques developed as part of MSEE's CCRI into an externally funded effort, which we'd like to see more of," said MSEE Program Manager Andrew Proulx. "This DURIP award highlights MSEE's collaborative nature and how it expands beyond the URA to other DoD agencies."



The original SHEAR imager, used in collaboration with the Weihs Group, aided researchers in capturing data on burn times and temperatures during the test combustion of plasma-ignited powders.

As with the original SHEAR imager, SHEAR-IFS captures information through two channels. Seen here observing a Xenon calibration lamp, SHEAR-IFS utilizes integral field spectroscopy, allowing MSEE collaborators to observe spectra emitted during more diffuse reactions.





ANNUAL TECHNICAL REVIEW

Collaboration is a fundamental part of MSEE throughout the year, but the cross-institutional teamwork that makes this alliance so exceptional was on full display at this year's Annual Technical Review (ATR).

MSEE collaborators convened in Baltimore, Maryland from June 13–15 to share their progress and learn about the work being done by other members of the alliance. There were 120 in-person participants, as well as 25 virtual participants. Research area leads, principal investigators, postdoctoral researchers, and graduate students presented the year's successes and challenges in each of MSEE's focus areas.

After each of the 43 technical presentations, attendees (both virtually and in-person) were encouraged to engage with the presenters. These dialogues consisted of questions, suggestions, and potential avenues for collaboration and further study. Many attendees followed up with presenters throughout the multi-day event; it was not uncommon to see researchers discussing the finer points of their work over meals, during coffee breaks, or at poster sessions.

The first two days of the ATR concluded with poster sessions during which postdocs and graduate students presented posters, discussed their research with peers, and socialized over appetizers and drinks. Of the 52 posters entered, four best poster winners were decided by popular vote. The winners—Jesse Grant (JHU), Ella Ivanova (NJIT), Brett Kuwik (JHU), and Ryland Wala (UArizona)–were each awarded a $500 prize, presented to them at the ATR Banquet by U.S. Air Force Colonel Cory Lane.

The 2023 Annual Technical Review featured a star-studded list of guest speakers. Rhys M. Williams, Executive Director of the Defense Threat Reduction Agency (DTRA), and Denis Wirtz, vice provost of research at Johns Hopkins University, gave opening remarks. The ATR Banquet featured guest speaker Sarah Nelson, the acting office director of the National Nuclear Security Administration's (NNSA) Office of Experimental Sciences.

Throughout each day's events, MSEE collaborators received input from technical points of contact, members of MSEE's science advisory board and research management board, and other key figures. Many noted the progression of MSEE's research compared to years prior, as well as MSEE's workforce development activities and sizeable population of graduate students.

DTRA Executive Director Rhys M. Williams giving opening remarks. (image: Darnell Gardner)

Himanshu Sharma (right) of JHU discusses his poster with AFIT's Adib Samin. MSEE's ATR gives collaborators a venue to exchange ideas and discuss their research with collaborators from other institutions and research areas.

Col. Cory Lane, left, with MSEE ATR poster award winners. From left to right: Jesse Grant, Ella Ivanova, Ryland Wala, Brett Kuwik

STUDENT SYMPOSIUM & UQ SHORT COURSE

MSEE features collaborators from a variety of backgrounds. Because the MSEE URA is a basic research consortium, workforce development is a key driver of its activities. Many MSEE participants are students or postdoctoral researchers.

In the first week of September, MSEE held two events for their graduate students and postdocs in support of the alliance's workforce development goals. Both events took place at Eglin Air Force Base (AFB) in Florida, where attendees were able to network and explore the facilities and career opportunities available at an Air Force Research Laboratory (AFRL).

The first of these events was the second annual Student Symposium. On September 5 and 6, attendees of the student-organized symposium participated in a full slate of networking, mentorship, and educational opportunities.

The symposium's first day featured a discussion with Kyle Overdeep, an AFRL Technical Program Manager. Overdeep, a former DTRA-funded graduate student, discussed his journey from PhD student to technical program manager. After hearing from Overdeep, students presented their MSEE research through oral talks and a poster session, followed by tours of some of the facilities within the Advanced Munitions Technology Complex at Eglin AFB.

Day two of the symposium continued with a networking session and tours of the Terminal Engagement Research Facility and the McKinley Climatic Laboratory. Throughout the symposium, MSEE students and postdocs were able to engage with AFRL researchers and scientists, including the Branch Chief of the Energetics Materials Branch, Jacob Morris.

Following the student symposium, AFRL researchers and MSEE students and postdocs participated in a two-day short course on uncertainty quantification (UQ) in physics-based modeling using Python. The UQ Short Course, led by Dimitris Giovanis and Dimitrios Tsapetis of Johns Hopkins University, was held at AFRL's off-site facility, the Doolittle Institute.

Participants in the short course were introduced to uncertainty quantification (UQ) in computational modeling using the Python programming language and a variety of UQ methods, including forward propagation of uncertainty, surrogate modelling, and Bayesian inference using the UQpy toolbox.

IMPACT RESEARCH WORKSHOP & SHORT COURSE

Impact research experiments are an important tool for materials scientists, geologists, engineers, and physicists working in planetary science, materials synthesis, and defense applications. Researchers today use a plethora of cutting-edge tools and methods to observe and analyze the effects of impacts on materials. However, learning how to use these tools is a critical first step for researchers hoping to utilize and understand the latest technology.

In July, faculty and staff from the Hopkins Extreme Materials Institute (HEMI) and the Materials Science in Extreme Environments University Research Alliance (MSEE URA) hosted a five-day event exploring the theory and application of impact experiments utilizing gas guns, a type of instrument used to generate high-velocity impact conditions. The Impact Research Workshop and Short Course consisted of a three-day workshop and a two-day short course. The event, which took place at the Johns Hopkins Homewood campus, culminated in the opportunity for short course participants to set up and execute a gas gun experiment in HEMI's Hypervelocity Facility for Impact Research Experiments (HyFIRE).

The first three days featured numerous lecture-style presentations, poster sessions, and tours of the HyFIRE facility. Participants, including students, postdocs, national laboratory staff, and DoD program managers, had ample opportunities for networking between lectures.

Throughout the workshop, participants were treated to lectures and speeches from eight speakers, each with extensive experience in the field of impact research. Topics included design of gas gun experiments, elastic and shock wave propagation, material-specific response to impact and shock loading, equations of state, and constitutive modeling.

The two-day short course emphasized a hands-on approach to learning. Participants, presented with a research objective, drew upon the knowledge they'd gained during the workshop to design two experiments using HyFIRE. They learned how to set up and synchronize diagnostics such as high-speed imaging and photon doppler velocimetry (PDV), execute an experiment, and analyze the data they collected.

Having access to tools like HyFIRE is of significant value for researchers, but these tools mean little if scientists do not know how to use them effectively. "With proper training, researchers can use impact research experiments to improve our understanding of material response to dynamic loading events in applications ranging from planetary science to defense," said Ryan Hurley, Research Area 1—Focus Area 2 Coordinator.

Hurley, a lead organizer of the event and assistant professor of mechanical engineering at Johns Hopkins University, highlighted the importance of programs like this one. "Workshops and short courses like this support a critical need to educate and train the next generation of scientists and engineers," he said.

WORKFORCE DEVELOPMENT

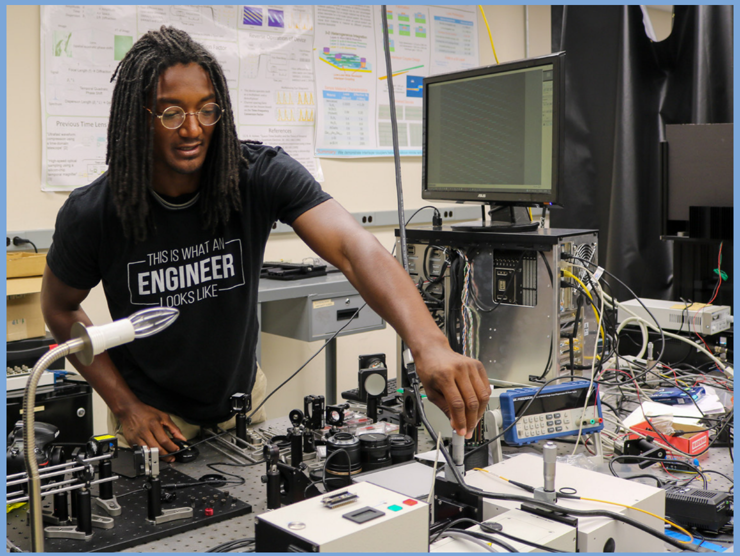
The MSEE URA continues to commit to workforce development and diversity, holding fast to the belief that diversity and professional development are integral to the program's success. MSEE takes a comprehensive approach to professional development and STEM enrichment programs, initiating programs and partnering with others to engage and support individuals ranging from high school students to professionals and faculty.

CDT Evelyn Ayers worked with researchers in Ed Dreizin's lab at NJIT as part of an NSERC summer internship.

ROTC RESEARCH AWARDS

Eligible ROTC cadets and midshipmen can receive compensation to participate in research with MSEE URA principal investigators, either during the academic year or during the summer. This year, MSEE coordinated with the Nuclear Science and Engineering Research Center at West Point to place ROTC cadets in the labs of MSEE PIs.

Name	University Attending	MSEE URA PI
Evelyn Ayers	Georgia Institute of Technology	Ed Dreizin
Kyle Fisher	Johns Hopkins University	Tim Weihs
Thane Gesite	University of Illinois Urbana–Champaign	Gena Miloshevsky
Naoki Heginbotham	Worcester Polytechnic Institute	Gena Miloshevsky
Kyle Miller	Idaho State University	Ed Dreizin
Suttipat Muangna	Virginia Military Institute	Gena Miloshevsky
Trevor Sumlin	University of North Carolina at Chapel Hill	Ryan Hurley



Extreme Science Intern Alexander Aybar worked with researchers in Mark Foster's lab at JHU.

TRAVEL RESEARCH FELLOWSHIPS FOR GRADUATE STUDENTS AND POSTDOCTORAL SCHOLARS

In order to foster collaboration between university researchers and our partners at national and defense laboratories, MSEE awards Travel Research Fellowships. These fellowships provide funds for graduate students and post-doctoral scholars to make extended visits of one month or more to work with collaborators at national (DOE/NNSA) and defense (DoD) laboratories. Fellowship funds can be used to cover travel, housing, and incidental expenses associated with these visits.

AWARDEES

Youssef Abouhussien, PhD candidate at Virginia Commonwealth University, traveling to Pacific Northwest National Laboratory

Jonathan McNanna, PhD candidate at New Jersey Institute of Technology, traveling to Army Research Laboratory

UNDERGRADUATE RESEARCH AWARDS

MSEE provides opportunities for undergraduate students to participate in research through these awards. Students work under the mentorship of a MSEE principal investigator within the technical areas of nuclear blast and chemical and biological agent defeat. These are conducted during the semester and the summer, and the students earn a stipend. Through this program, undergraduates develop research skills and gain professional experience to prepare them for the next steps in their career development.

Name	University Attending	PI
Caleb Cyr	Johns Hopkins University	Mark Foster

AEOP HIGH SCHOOL APPRENTICESHIPS

Supported by the Army Educational Outreach Program (AEOP), this summer program allows talented high school students from groups historically under-represented and underserved in STEM to work on a hands-on research project, exposing them to the world of research and encouraging them to learn about education and career opportunities in STEM.

Name	Attending	Internship Site
Joanne Li	Thomas S. Wootton High School	JHU
Karthik Muthukkumar	Urbana High School	JHU
Radhati Srisukwattananan	Aberdeen High School	JHU

EXTREME SCIENCE INTERNSHIP WITH MORGAN STATE UNIVERSITY

The Extreme Science Internship program enables Morgan State University (MSU) students to participate in research internships associated with the MSEE URA. Students conduct internal internships during the academic year at MSU. During the summer, these students participate in an external internship at one of the many universities within the URA. ESI is focused on developing each student's research skills and providing a broadening experience. Graduates of the ESI program have pursued doctorates and positions in industry. The program is administered by Prof. Birol Ozturk at MSU.

10 TOTAL

8 INTERNAL

2 EXTERNAL

Group photo from the 2023 MSEE URA Annual Technical Review

JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

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