DOE/NA-0172

2026
Academic Programs Annual

NNSA Defense Programs, Office of Research, Development, Test, and Evaluation

- Stewardship Science Academic Alliances
- High Energy Density Laboratory Plasmas Program
- Predictive Science Academic Alliance Program
- Minority Serving Institution Partnership Program
- Fellowship Programs

National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY

On the Cover

Michigan State University (MSU) graduate student Emily Gordon (left) shows Alyssa Gaiser, assistant professor of chemistry at the Facility for Rare Isotope Beams and in MSU's Department of Chemistry (right), the synthetic method to grow crystals of f-element tris pyrazolyl borate crystals.
— Image courtesy of Dr. Alyssa Gaiser, Michigan State University

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National Nuclear Security Administration
Office of Defense Programs
Office of Research, Development, Test, and Evaluation

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The Academic Programs Annual is produced by NNSA, Defense Programs, Office of Research, Development, Test, and Evaluation. It features select research conducted by the following NNSA-supported research programs: Stewardship Science Academic Alliances, High Energy Density Laboratory Plasmas, Predictive Science Academic Alliance Program, Minority Serving Institution Partnership Program, and fellowship programs.

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> *No less critical to the reliability of the stockpile is the workforce of the Nuclear Security Enterprise—the cadre of scientists, engineers, machinists, craft and trade workers, and program managers whose technical skill is matched only by their dedication to our national security. DOE/NNSA is taking aggressive steps to attract and retain a workforce qualified to maintain today's deterrent and design the systems of tomorrow.*
>
> FY 2025 Stockpile Stewardship and Management Plan

OFFICE OF RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

The National Nuclear Security Administration's (NNSA) primary mission is to ensure a safe, secure, and reliable nuclear stockpile. We accomplish this national security mission through the application of unparalleled science, technology, engineering, and manufacturing. We partner with our world-class, state of the art NNSA laboratories, plants, and sites to continually develop and strengthen the nuclear deterrent.

The leading-edge science and technology necessary for this mission are made possible by the brilliant scientists, engineers, and technicians that work tirelessly to safeguard the nation. They are essential in maintaining the effectiveness of our nuclear deterrent, and our Academic Programs develop and educate this critical workforce and serve as a pipeline of talent for the Nuclear Security Enterprise. The NNSA partners with academia to provide real-time, hands-on, on-site education to the next generation of nuclear security experts ready to meet the future needs of the enterprise.

In addition to developing the next generation of highly skilled workers, Academic Programs also works to ensure U.S. preeminence in critical technical areas and enables scientific innovation that enhances the NNSA's mission and strengthens relevant fundamental fields of research.

In this year's Academic Programs Annual, you'll read about the research and work of some of the academic partners who are contributing to our national security. We feature select students pursuing relevant degrees and alumni of NNSA's Academic Programs who provide their own perspectives of the Academic Programs and the opportunities that the programs have afforded them. We are honored to have helped support and shape their educational growth and career choices.

As we look to the future, advances in science, technology, engineering, and manufacturing will continue to be core to NNSA's successful mission execution with Academic Programs playing a pivotal role in shaping that future. To all of you participating in the Academic Programs, I congratulate you on a job well done.

Dr. David A. LaGraffe
Principal Assistant Deputy Administrator
Office of Research, Development, Test, and Evaluation
NNSA Defense Programs

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Feature Article & Financial Assistance Awards

The challenges of modernizing our nuclear stockpile demand a strong and robust base of national expertise and educational opportunities in specialized technical areas that uniquely contribute to nuclear stockpile stewardship. The Academic Programs of the Department of Energy/National Nuclear Security Administration (DOE/NNSA) are designed to support academic programs in science and engineering disciplines of critical importance to the Nuclear Security Enterprise (NSE), including materials under extreme conditions, high energy density science, low energy nuclear science, radiochemistry, high performance computing, modeling, and others.

In addition, building a highly skilled workforce will strengthen the stewardship of the future. The role of the Academic Programs is three-fold:

- Develop the next generation of highly trained, technical workers ready to support NNSA's core mission and priorities
- Ensure technical peer expertise external to the NSE for providing valuable oversight, cross-check, and review
- Enable scientific innovation to enhance the NSE missions, strengthening the basic fields of research relevant to the NNSA mission.

2025 Stewardship Science Academic Programs Symposium

Outstanding Poster Awards

Several excellent posters were presented at the 2025 Stewardship Science Academic Programs (SSAP) Symposium, held June 10-11, 2025 in Chicago, Illinois. Seven of the 115 posters received the 2025 SSAP Symposium Outstanding Poster Award. Many thanks to the esteemed judges and congratulations to the recipients.

Lucas Babati
University of Michigan
Mean Force Kinetic Theory of Warm Dense Matter

Sumner Gubisch
The George Washington University
Manipulating the Seebeck Coefficient by Engineering Point Defects through Laser Processing

Hannah M. Hansen
University of Iowa
X-ray Absorption Spectroscopy Investigations of Actinide-(boro) hydride Bonding

Chloe Jones
University of Notre Dame
Modeling Neutron Interactions in HECTOR Using GEANT4

Matthew Kafker
University of Washington
Time-Dependent Density Functional Theory Description of 238U(n,f), 240,242Pu(n,f) and 237Np(n,f) Reactions

Victor Perez-Ramirez
Stanford University
Optical Properties of Plasma Diffraction Gratings for High-Power Lasers

Thomas Varnish
Massachusetts Institute of Technology
Two-Fluid Effects in Pulsed-Power-Driven Reconnection

The annual SSAP symposium highlights accomplishments from awards in the Stewardship Science Academic Alliances and High Energy Density Laboratory Plasmas programs. Also, it provides opportunities to learn about the National Nuclear Security Administration (NNSA) and NNSA labs, plants, and sites, and partners, as well as make professional contacts from fields vital to national security.

Academic Programs Coordinator and Federal Program Manager for Stewardship Science Academic Alliances and High Energy Density Laboratory Plasmas Stephanie Miller (right) with six of the 2025 Stewardship Science Academic Programs (SSAP) Symposium Outstanding Poster Award recipients. (L-R): Gubisch, Jones, Hansen, Varnish, Babati, and Perez-Ramirez.

Left: Dr. Kim Budil, Director, Lawrence Livermore National Laboratory, delivered the key note address at the 2025 Stewardship Science Academic Programs Symposium. Middle and Right: Students present their posters and discuss their research with 2025 SSAP Symposium attendees.

The Stewardship Science Academic Alliances (SSAA) Program supports scientific academic research programs to develop the next generation of highly skilled technical workers able to support its core mission and to ensure there is a strong community of technical peers, external to the NNSA national laboratories, capable of providing peer review and scientific competition to strengthen the basic fields of research relevant to the Nuclear Security Enterprise(NSE).

The SSAA Program funds both collaborative, multi-university Centers of Excellence and smaller individual investigator research projects to conduct fundamental science and technology research of relevance to stockpile stewardship. Current technical areas include properties of materials under extreme conditions; low-energy nuclear science; high energy density physics; and radiochemistry. SSAA funding supports research at U.S. universities, educating hundreds of undergraduate students, graduate students, and postdoctoral researchers each year. A key element of both centers of excellence and individual investigator awards is the connection of students with the NSE. These opportunities are focused in technical fields critical to stewardship science and build a field of talented researchers and committed doctoral students sharing a common desire to advance science while impacting national security.

Centers of Excellence

SSAA Centers of Excellence benefit the NNSA mission by enabling scientific innovation and developing the next generation of highly skilled technical workforce. The Centers cover scientific research areas that support the missions of the National Nuclear Security Administration (NNSA) and NSE. These are large-scale university partnerships that promote cross-university collaboration in areas of relevance to the NNSA and its core missions. Following are summaries of recent accomplishments from each of the nine SSAA Centers of Excellence.

Advanced Characterization of Metals under Extreme Environments | Colorado School of Mines

PI: Dr. Amy Clarke (amyclarke@mines.edu); Authors: Julia Puerstl and Dan Gianola, University of California Santa Barbara

The Advanced Characterization of Metals under Extreme Environments (ACME^2) explores the responses of metastable microstructures in metallic alloys with novel experimental and computational approaches and educates the Nuclear Security Enterprise's next-generation workforce. The development of refractory high-performance alloys has traditionally required strict oxygen-free processing, as oxygen has long been associated with embrittlement and the formation of detrimental secondary phases. However, recent observations in Ti-containing refractory alloys indicate that controlled oxygen incorporation can enhance both strength and ductility, suggesting new opportunities for designing cost-effective, high-performance alloys.

Here we investigate the influence of oxygen on phase transformations in the model Ti–50Nb system, focusing on whether oxygen can induce a martensitic α'' transformation within the body centered cubic (bcc) matrix. To probe subtle effects, we employ advanced, in-situ μ-Laue synchrotron X-ray diffraction and 4D-STEM (Scanning Transmission Electron Microscopy). The transformations, if present, occur at the nanoscale and resemble a strain-glass-like state, rather than the formation of large martensitic laths. Using a combination of the above techniques, we examined the evolution of local strain and structure under external stimuli. Preliminary μ-Laue measurements reveal reversible spot spreading, consistent with nanoscale strain evolution associated with a reversible α''-type transformation. Such reversible martensitic behaviour provides a mechanism for mechanical damping, allowing the alloy to absorb and release strain energy efficiently under cyclic or dynamic loading. ✦

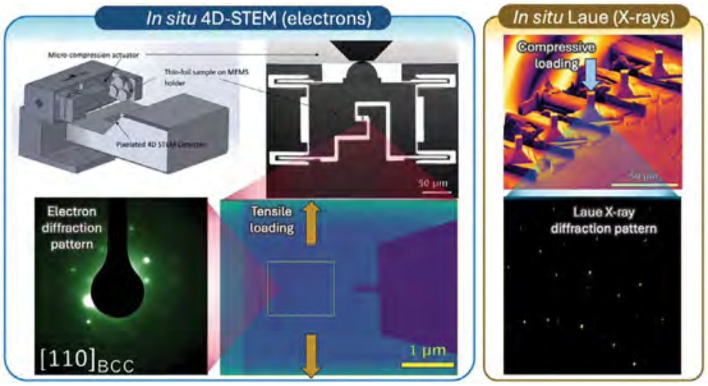

Figure 1.Advanced in situ materials characterization applied to the study of stress-induced phase transformations in refractory alloys with the incorporation of intentional oxygen interstitials.

The Transuranic Chemistry Center of Research Excellence | Georgia Institute of Technology

PI: Prof. Henry S. La Pierre (la_pierre@chemistry.gatech.edu)

Borohydrides are a class of chemicals that contain boron-hydrogen bonds. They have long fascinated chemists because of their penchant for forming metal complexes with remarkable properties and structures. A prominent example is the actinide borohydride complex U(BH$_4$)$_4$ discovered during the Manhattan Project. An unusual feature of borohydrides in complexes like U(BH$_4$)$_4$ is that they bind to metals via boron-hydrogen-metal (B-H-M) bonds. This chemical bonding is delocalized over all three atoms. The extent of this delocalization is thought to govern the molecular properties and reactivity of borohydride complexes, but experimentally assessing the degree of B-H-M bonding for different metals has remained a challenge. This includes recent uranium and plutonium borohydride complexes reported by the Transuranic Chemistry Center of Research Excellence (TRUCoRE) members Daly and Vlaisavljevich with collaborators at Los Alamos National Laboratory.

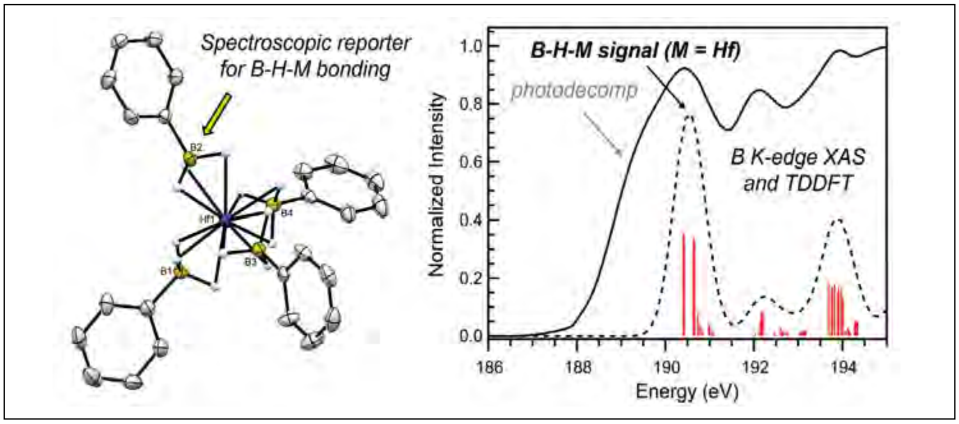

Figure 1. Left: molecular structure of Hf(PhBH$_3$)$_4$. Right: B K-edge X-ray absorption spectrum (black line) and time-dependent density functional theory (TDDFT) data (dashed line and red bars) for Hf(PhBH$_3$).

Now, the Daly Research Group at the University of Iowa (as part of the SSAA TRU-CoRE Center) has taken the first step towards experimentally quantifying metal-dependent variations in B-H-M bonding (*Chem. Sci.* 2025, 16, 22333-22347). Led by SSAA-funded graduate student Hannah Hansen, they demonstrated how a technique called B K-edge X-ray absorption spectroscopy can reveal signatures of B-H-M bonding in borohydride complexes using boron as a spectroscopic reporter (Figure 1). Though further optimization is needed to quantify variations in B-H-M delocalization, these proof-of-principle studies open the door for assessing metal-borohydride bonding in actinide complexes similar to U(BH$_4$)$_4$. ✦

Center for Excellence in Nuclear Training and University-based Research | Texas A&M University

PI: Dr. Sherry Yennello (yennello@tamu.edu); Authors: A. Bulgac, I. Abdurrahman, M. Kafker, and I. Stetcu

Nuclei with an odd number of neutrons and/or protons have much higher level densities at the same excitation energy than those with even numbers of both nucleon types. This includes navigation through the critical barrier regions and onto ultimate scission. The time from saddle-to-scission is often significantly longer in odd-odd or odd-mass nuclei than for even-even nuclei, since systems with unpaired nucleons are easier to excite and the potential energy surfaces of these nuclei have more structure, often resembling a very complicated obstacle course, rather than a more direct evolution of the nuclear shape from the top of the outer fission barrier to the scission configuration. The importance of the oddness issue was manifest when the first reactor produced plutonium for the Manhattan Project. While the microscopic amounts of pure ^{239}Pu were produced with a cyclotron, which has negligible spontaneous fission, the reactor produced also ^{240}Pu, which has sufficient spontaneous fission that predetonation became a concern, that required implosion to circumvent. ✦

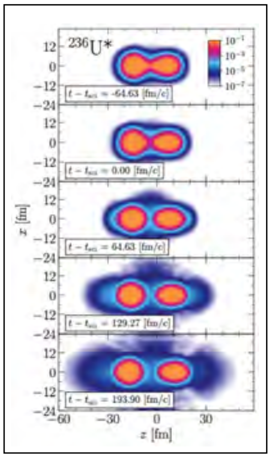

Figure 1. Time series of the neutron number density in fm^{-3} for a typical fission trajectory.

Center for Additively Manufactured Complex Systems Under Extremes | The University of Alabama at Birmingham

PI: Dr. Yogesh K. Vohra (ykvohra@uab.edu)

The Center for Additively Manufactured Complex Systems Under Extremes (CAMSCE) conducted a multi-institutional study on an Additively Manufactured Eutectic High Entropy Alloy (AM-EHEA) $AlCoCrFeNi_{2.1}$ under extreme conditions including static high pressures and temperatures, laser shock compression, micro-ballistic impact, and molecular dynamics simulations. This AM-EHEA fabricated by University of Southern California and Tuskegee University have a dual-phase body-centered cubic (BCC)/ Face Centered Cubic (FCC) nano lamellar morphology and have high yield strength and high ductility for impact resistant applications. The static high-pressure experiments conducted by The University of Alabama at Birmingham (UAB) and shock compression experiments conducted by Stanford University show BCC to FCC transformation under a variety of strain rate conditions. In addition, X-ray diffraction under high-pressure high-temperature conditions achieved in both static and shock experiments reveal occurrence of a high temperature BCC phase before melting. The static nanoindentation hardness conducted by UAB and dynamic strength measurements by University of Massachusetts Amherst show higher highness for non-equilibrium nanostructures in additively manufactured as compared to alloys fabricated by conventional suction casting. The molecular dynamics simulations conducted by the University of California Irvine predict lower transition pressure for phase transformations in suction cast alloys as compared to additively manufactured alloys. The Transmission Electron Microscopy conducted on samples recovered after high pressure compression reveals that nano lamellar morphology is maintained after phase transformation indicating spontaneous transformation without any long-range diffusion. These studies have resulted in several joint publications and cross-institutional training of graduate students involving all academic partners in CAMCSE (https://sites.uab.edu/camcse/publications/). ✦

Figure 1. UAB graduate student Andrew Pope conducting high-pressure high temperature studies on additively manufactured high-entropy alloys at the HPCAT facility, Advanced Photon Source, Argonne National Laboratory.

Center for Matter Under Extreme Conditions | University of California San Diego

PI: Dr. Farhat Beg (fbeg@ucsd.edu)

Simon Bolaños, Center for Matter Under Extreme Conditions (CMEC) postdoctoral researcher at University of California San Diego, led a team of researchers to study the effects of a moderate magnetic field on backward Stimulated Raman Scattering (SRS). The work was recently published and featured on the cover of Physics of Plasmas (Figure 1). The experiment conducted at the OMEGA-EP laser

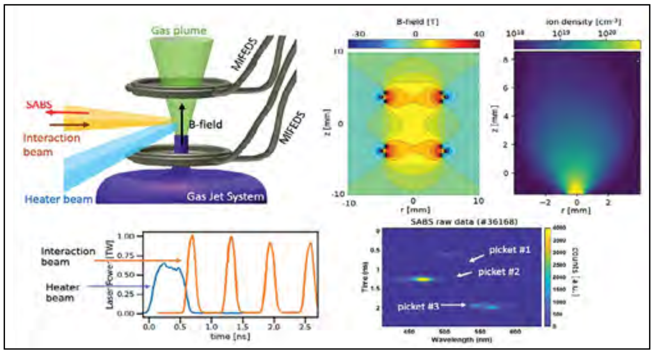

Figure 1. Cover of the Physics of Plasmas featuring the publication of S. Bolaños et al., "Direct evidence of the effect of a moderate external magnetic field on stimulated Raman scattering in the kinetic regime." Figure presents the experimental setup at OMEGA-EP and raw SRS data. [S. Bolanos et al., Phys. Plasmas 32, 092102 (2025)]

facility demonstrated that a moderate magnetic field (13 Tesla) can significantly alter the growth and behavior of SRS. The findings show that when plasma conditions favor wave-particle interactions, the applied magnetic field mitigates SRS activity. Conversely, in a dilute plasma, the same magnetic field enhances SRS growth. This research was carried out in collaboration with scientists from the University of California Los Angeles, Lawrence Livermore National Laboratory, Laboratory for Laser Energetics, and General Atomics. The experimental results were discussed in the context of magneto-hydrodynamic simulations performed with the GORGON code and particle-in-cell simulations performed with the OSIRIS code. While the experimental evidence of SRS mitigation validates prior work on the kinetic simulation of SRS in an external magnetic field, we also find that other mechanisms such as SRS rescatter can lead to an enhancement of measured SRS reflectivity in simulations of parameters relevant to this experiment. ✦

Chicago/DOE Alliance Center (CDAC): A Center of Excellence for Materials at Extremes | University of Illinois Chicago

PIs: Dr. Russell J. Hemley (rhemley@uic.edu) and Dr. Stephen Gramsch (sgramsch@uic.edu)

With its significantly increased brightness, the recent upgrade at the Advanced Photon Source (APS-U) has improved the quality of data available from a wide range of X-ray diffraction, scattering, and spectroscopy measurements, and enabled new classes of experiments important for the NNSA. Among the techniques that have benefitted the most from APS-U have been X-ray imaging methods, which rely on the sub-micron beam now available.

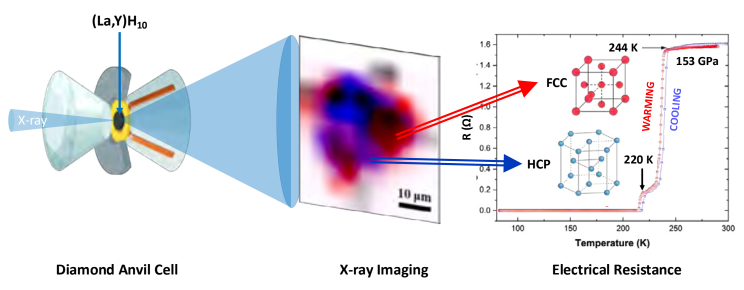

Figure 1.(Left) XDI data show coexistence of different structures of (La,Y)H_{10} under pressure as recorded with a 1 micron synchrotron X-ray beam. Red features, cubic (FCC) phase; blue features, hexagonal (HCP) phase; grey features, platinum electrical leads. (Right) Convolved electrical resistivity measurement in which x-ray imaging allowed identification of the signal from the cubic versus the hexagonal phase at 153 GPa.

This breakthrough is particularly important for samples under extreme conditions, at which multiple phases may coexist at micron to submicron length scales. A recent collaborative effort led by the CDAC group at the University of Illinois Chicago and including Lawrence Livermore National Laboratory, along with APS groups at HPCAT (Sector 16) and GSECARS (Sector 13), has utilized newly-enabled X-ray diffraction imaging (XDI) methods, combined with 4-probe resistivity measurements, to study the superhydride (La,Y)H_{10} in the superconducting state at high pressure. An open question in understanding the near-room temperature superconducting behavior observed in the rare earth superhydrides, a new class of materials discovered by CDAC, is the extent to which sample heterogeneity affects the bulk measured superconducting transition temperatures. These new imaging techniques are the ideal tools for resolving such local effects.

Imaging results (Figure 1) show clear coexistence of cubic and hexagonal phases of (La,Y)H_{10} between 136 and 168 GPa, spatially resolved at the micron scale, and illustrate structural inhomogeneity in the sample. Resistivity measurements of the superconducting transitions at 244 K for the cubic phase and 220 K for the hexagonal phase correspond directly with structures observed by X-ray imaging. [Marathamkottil, A. H. M. et al., Nature Communications 16, 11222 (2025). ✦

Center for High Energy Density Laboratory Astrophysics Research | University of Michigan

PI: Dr. Carolyn Kuranz (ckuranz@umich.edu)

The Center for High Energy Density Laboratory Astrophysics Research (CHEDAR), an SSAA Center of Excellence led by Professor Carolyn Kuranz of the University of Michigan investigates fundamental high-energy-density (HED) science relevant to astrophysics and NNSA stockpile stewardship by integrating HED experiments, theory, and simulations. This work is done in partnership with students and faculty at the University of California Los Angeles, University of Notre Dame, and Rice University. We use NNSA experimental facilities (e.g., the Omega Laser Facility, the Z facility, National Ignition Facility, and the Jupiter Laser Facility) to create and observe HED systems in conjunction with modeling and theoretical efforts using radiation hydrodynamics, magneto hydrodynamics, kinetic, and molecular dynamic simulation codes. CHEDAR has supported over 24 students since the project began in 2023. CHEDAR's most recent graduate, Dr. William White, completed his thesis in the Fall of 2025 which was entitled, "Discontinuous Galerkin Methods and Phase-Field Models for Numerical Simulations of Compressible Interfacial Flows with Shocks and Vortices". This body of work included the development of an open-source simulation framework that implements consistent and conservative interface regularization techniques with an adaptive mesh grid. This framework was used to study compressible interfacial flows, including systems that were Richtmyer-Meshkov unstable (Figure 1). Dr. White is currently a postdoc at the University of Michigan as part of our new Predictive Science Academic Alliance Program (PSAAP) Center led by Dr. Venkat Raman. Overall, CHEDAR has graduated three PhD students and one MS student. ✦

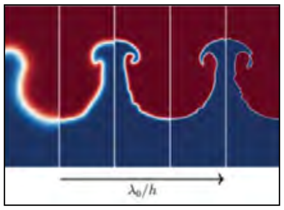

Figure 1. Example of two-dimensional Richtmyer-Meshkov instability.

The Center for Magnetic Acceleration, Compression, and Heating | University of Michigan

PI: Dr. Ryan McBride (mcbrider@umich.edu)

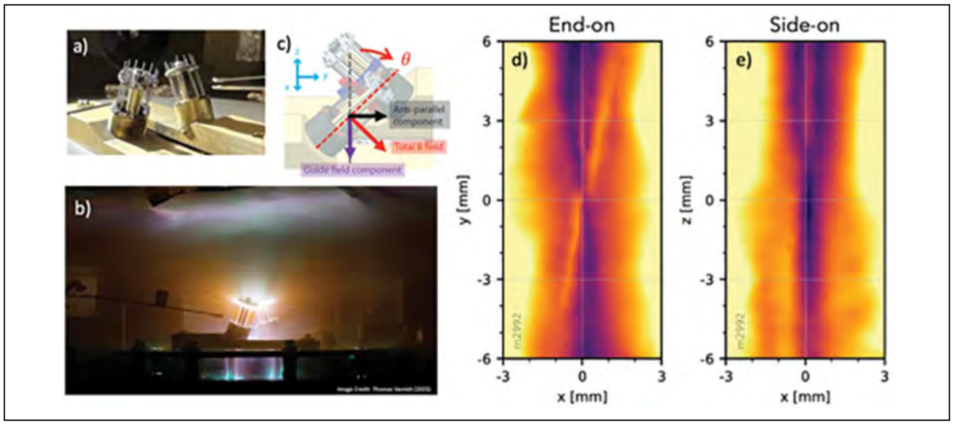

Figure 1. Description of the MIT/Cornell guide-field magnetic reconnection experiment on the MAIZE facility at UM. (a) Pre-shot photograph of the two tilted exploding wire arrays installed in MAIZE. (b) Open-shutter photograph of the experiment. (c) Description of how the guide field is generated. (d,e) Laser interferometry data from the experiments. The quadrupolar density structure can be seen in (d).

Within the Center for Magnetic Acceleration, Compression, and Heating (MACH), researchers from Cornell University and Massachusetts Institute of Technology (MIT) used the MAIZE pulsed power facility at the University of Michigan (UM) to study magnetic reconnection with a guide field at scales much larger than in previous laboratory studies. To create the guide field, MIT PhD student Thomas Varnish developed a new experimental platform that consisted of two tilted exploding wire arrays, where mechanical pencil refills were used as the "wires" – see Figure 1(a-c). The presence of the guide field resulted in a complex quadrupolar density structure within the reconnection layer – see Figure 1(d). This work was published in *Physics of Plasmas* and was featured in AIP Scilight. Thomas and his advisor, Prof. Jack Hare of Cornell University, were then invited to present their work as part of the *Physics of Plasmas* webinar series on April 25, 2025 (a recording of the webinar is available here: https://mediacentral.princeton.edu/id/1_37p76g7s). Even more recently, this work was featured as part of Prof. Hare's invited talk at the 67th Annual Meeting of the American Physical Society Division of Plasma Physics. This invited talk was part of Prof. Hare's recent Thomas H. Stix Award for Outstanding Early Career Contributions to Plasma Physics Research. The reconnection team, led by Hare, is now using the tilted wire-array platform on the COBRA facility at Cornell to take temperature measurements via Thomson scattering to help answer some outstanding questions about the newly observed quadrupolar density structure. ✦

The Wootton Center for Astrophysical Plasma Properties | University of Texas at Austin

PI: Dr. Michael Montgomery (mikemon@astro.as.utexas.edu)

This past summer, Wootton Center for Astrophysical Plasma Properties (WCAPP) graduate student Bryce Hobbs interned at Lawrence Livermore National Laboratory (LLNL), working closely with LLNL scientists Bob Heeter, Kathy Opachich, and WCAPP alumna Patty Cho on the National Ignition Facility (NIF) Opacity Campaign. The focus of this work is on the opacity of oxygen at the conditions near the base of the Sun's convection zone, i.e., T_e~150-180 eV and n_e~8e21 e/cc. This work complements a similar investigation of oxygen opacity on the Z machine at Sandia, led by current WCAPP postdoc Dan Mayes. While at LLNL, Bryce analyzed data from the DANTE, VIRGIL, and GXD diagnostics on the NIF to characterize a source of uncertainty in a background correction for the opacity measurements. Bryce says, "a major highlight of the experience was learning how to assemble the Opacity Spectrometers before experiments. It gave me a better appreciation for the level of detail needed to make these measurements." The internship culminated in two research poster presentations and an oral presentation to the LLNL Physics Division. On his return to The University of Texas at Austin in Fall 2025, Bryce has been able to involve undergraduate students in different aspects of his work at LLNL. ✦

Figure 1. From left to right: Patty Cho (HEDP postdoc, former WCAPP student), Bryce Hobbs (current WCAPP UT-Austin student), Matt Wallace (NNSS), and Annabelle Peterson (current WCAPP UNR student) make preparations for using the OpSpec spectrometer. Laser interferometry data from the experiments.

Stewardship Science Academic Alliances and LANL Scientists Recreate First Possible Observation of DT Fusion | Duke University

PI: Dr. Sean W. Finch (sean.finch@duke.edu); Authors: Sean W. Finch and Werner Tornow (werner.tornow@duke.edu)

Fusion of the two heavy hydrogen isotopes, deuterium and tritium, is the reaction at the center of the National Ignition Facility (NIF) and a cornerstone of stockpile stewardship and future clean energy production. The first application of deuterium-tritium (DT) fusion was proposed by Emil Konopinski during early Manhattan Project discussions. Konopinski's proposal predated any known laboratory measurements of DT fusion, which raised the interests of Los Alamos National Laboratory (LANL) scientists M.W. Paris and M.B. Chadwick. They uncovered a previously uncited 1938 paper by A.J. Ruhlig,[1] published in Physical Review Letters, that indicated Ruhlig observed high-energy neutrons, which he hypothesized could only result from DT fusion. Konopinski and Ruhlig were contemporaries at the University of Michigan, and both were in contact with Hans Bethe at the time, making it likely that Konopinski knew of Ruhlig's findings.

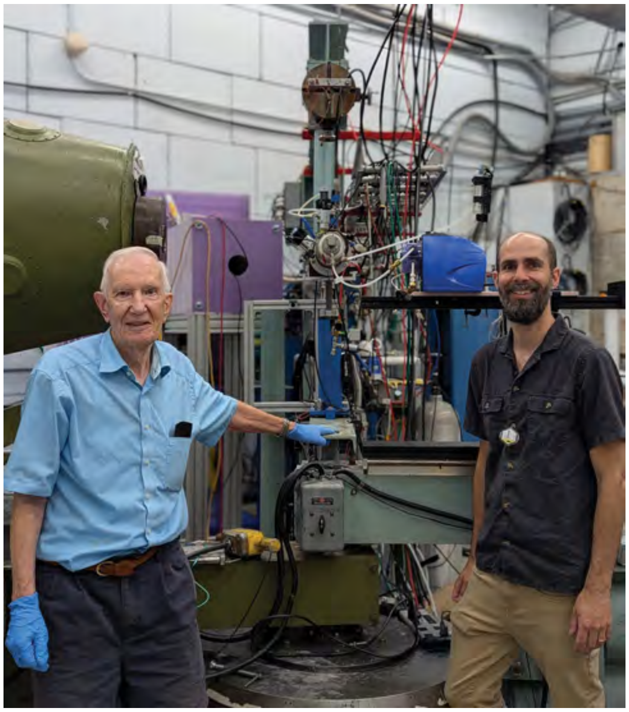

Figure 1. W. Tornow (left) and S.W. Finch (right) with the setup they used to recreate the 1938 DT fusion experiment.

Ruhlig realized that the deuterium-deuterium (DD) fusion he was studying would, roughly 50% of the time, produce a high-energy tritium ion. The recoiling tritium ion could then react with another deuterium ion in the target, resulting in DT fusion. This mechanism is referred to as a reaction in flight (RIF) and is an active area of research at the NIF. DT fusion produces higher energy neutrons, allowing it to be distinguished from DD fusion. As DT fusion would represent a second-order reaction in Ruhlig's experiment, he asserted that the DT reaction must be "exceedingly probable." To confirm Ruhlig's claimed observation of DT fusion, experimental verification is needed. For this experimental verification, the LANL scientists turned to their Stewardship Science Academic Alliances collaborators at Duke University.

The first test was to search for DT fusion RIF neutrons using a pure deuterium target. A deuterium beam was accelerated at Triangle Universities Nuclear Laboratory tandem accelerator laboratory, located on the campus of Duke University. The neutron time-of-flight technique was used to measure the neutron energy and distinguish DD and DT fusion neutrons. DT RIF neutrons were indeed observed, and the results were published.[2] This work included contributions from Duke graduate student Ethan Mancil, who is included as a coauthor.

Ruhlig used a more complicated deuterated phosphoric acid target in his experiment. Once the feasibility of DT fusion by the RIF mechanism was proven, the 1938 experiment would need to be replicated using Ruhlig's exact target. The experiment was performed, as shown in Figure 1. The modern values were found to be ≈25 times smaller than those reported by Ruhlig; although, firm conclusions are difficult given the lack of detail in the 1938 publication. Nonetheless, Ruhlig's instincts were correct when he claimed the DT reaction must be "exceedingly probable." Werner Tornow presented these results at the Fusion History Workshop, hosted by Los Alamos National Laboratory, October 1-2, 2024. These results are published in Physical Review C[3] and have been covered by many news outlets, including the Research Highlights section of Nature.[4] This work was done in collaboration with LANL scientists J.B. Wilhelmy, M.B. Chadwick, G.M. Hale, J.P. Lestone, and M.W. Paris.

These results are not solely of historical interest, as the RIF technique has found application in modern-day research. Measurements of DT fusion by the RIF mechanism, as have been conducted by the Duke University team, could be used to verify tritium stopping powers in a variety of different deuterium-containing materials. These stopping powers have important applications in DT fusion facilities such as NIF.

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Novel *d*- & *f*-Electron Materials Under Extreme Conditions of Pressure, Temperature, and Magnetic Field | University of California San Diego | PI: Dr. M. Brian Maple (mbmaple@ucsd.edu)

The objectives of this Stewardship Science Academic Alliances (SSAA) project are to investigate the behavior of matter under extreme conditions of pressure, temperature, and magnetic field, obtain a greater understanding of the physics of transition metal-, lanthanide- and actinide-based *d*- and *f*-electron materials, and educate the next generation of scientists in static high-pressure experimental techniques in support of stockpile stewardship. During the past year, three postdoctoral researchers and two PhD graduate students received support from the SSAA grant. Two master's graduate students and twelve undergraduate students contributed to the research as volunteer interns. Since the beginning of this program in 2003, nine former group members have held postdoctoral appointments and five are currently staff members at Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory. Several members of the group have performed research at the High-Pressure Collaborative Access Team at Argonne National Laboratory, the Pulsed Field Facility (PFF) at LANL, and the Center for Integrated Nanotechnology at Sandia National Laboratories. Numerous students and postdocs in this program have gained experience in materials synthesis and high-pressure techniques using piston-cylinder, Bridgman anvil and diamond anvil cells for performing electrical transport and magnetic measurements at pressures up to ~100 GPa.

During the past year, experiments were performed at high pressure and in high magnetic fields on various correlated electron materials, including the *f*-electron systems $U_{1\text{-}x}Th_xTe_2$ and $URu_{2\text{-}x}Os_xSi_2$, the *d*-electron compound FeSi, and the lanthanide (*Ln*)-substituted La-based nickelates $La_{3\text{-}x}Ln_xNi_2O_7$. Recent experiments on the correlated electron materials FeSi and $U_{1\text{-}x}Th_xTe_2$ are summarized below. These two systems may exhibit topological phenomena with future applications in technology such as spintronics and quantum computing.

The discovery of a conducting surface state (CSS) in the small gap semiconductor FeSi in 2018[1] led to the conjecture that FeSi may be a correlated *d*-electron version of a "topological Kondo insulator".[2] Electrical resistance R measurements[3] on single crystalline FeSi under pressure P and magnetic field B revealed that the energy gap Δ associated with the semiconducting bulk phase begins to close abruptly at a critical pressure P_{cr} of ~10 GPa above which the bulk material becomes metallic (Figure 1(a)). Under increasing pressure, hysteresis in the $R(B)$ curves associated with the magnetically ordered CSS decreases and vanishes at P_{cr}, while the slope of the $R(B)$ curve, dR/dB, decreases in magnitude and changes sign from negative to positive at P_{cr} (Figure 1 (b)). These experiments show the CSS and the corresponding two-dimensional magnetic order collapse at P_{cr} where Δ of the bulk material starts to close abruptly, revealing the connection between the CSS and the semiconducting bulk state in FeSi.

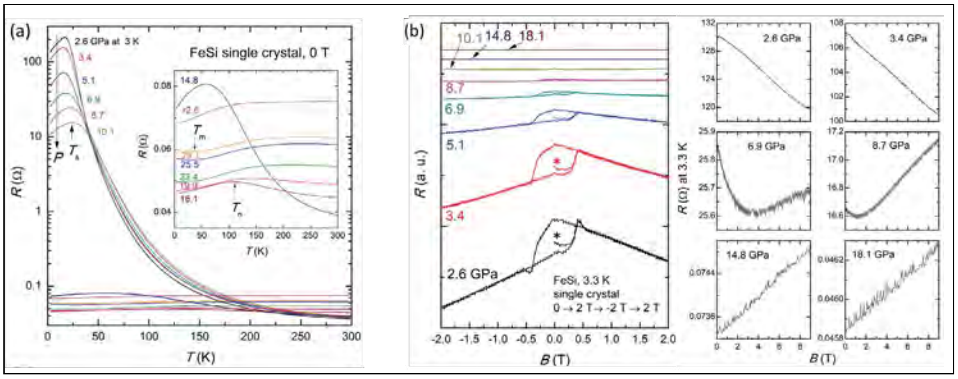

Figure 1. Electrical resistance (a) and magnetoresistance (b) of FeSi under high pressure

The correlated *f*-electron compound UTe_2 is widely believed to be a candidate for a spin-triplet superconductor in which the superconducting electron pairs have parallel spins.[4] At temperatures well below its superconducting critical temperature (T_c) of 2.1 K, UTe_2 has a unique high field phase diagram of H vs the orientation of H (θ) in the orthorhombic unit cell which contains three superconducting phases, SC_1 for $H \leq 15$ T, SC_2 for 15 T $\leq H \leq$ 35 T, and SC_{FP} that extends from 40 T to 60 T and resides within a field polarized FP phase.[5] Experiments were performed at the LANL PFF[6] on $U_{1\text{-}x}Th_xTe_2$ single crystals in magnetic fields H up to 60 T to determine how the high field H vs θ phase diagram of UTe_2 is modified by Th substitution. The experiments suggest that the three superconducting phases are distinct from one another and may have different types of electron-pairing symmetries or mechanisms. The SC_{FP} phase appears to be consistent with spin-triplet superconductivity.

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Exploring Varied Oxidation States of Plutonium, Americium, and Curium Tris Pyrazolyl Borate Complexation for Separations |

Michigan State University | PI: Dr. Alyssa Gaiser (alyssa@msu.edu)

This research has been supported by the Stewardship Science Academic Alliances (SSAA) program since March 2025. The aim is to discover fundamental, exploitable differences between plutonium (Pu), americium (Am), and curium (Cm) with organic molecules, specifically tris pyrazolyl borates (Tp), that may be used to separate Pu, Am, and Cm from one another. Pu, Am, and Cm are often generated together in settings like spent nuclear fuel and weapons fallout found in the environment. Of critical importance, Am-241 appears in aged Pu stockpiles as a pesky ingrowth, removed during reprocessing via a metal chlorination process, but not without bringing along some Pu with the Am. The need for a routine and efficient separation methodology for Pu, Am, and Cm—particularly from one another—is critical to stewardship science. Graduate student Emily Gordon has optimized Tp experiments for milligram quantities of Pu, Am, and Cm and is gaining expertise in handling open-source radiological materials.

The Tp ligand may be substituted on the pyrazolyl rings to adjust ligand and complex solubility and properties. For example, substituting at the R2 position, as seen in Figure 1b with three 4-bromo-tris pyrazolyl borate (TpBr) ligands bound to a neodymium (Nd) cation, significantly increases solubility options for both the ligand and resultant metal complex. Emily Gordon grew crystals of Nd TpBr out of acetone overnight on the 0.5 milligram Nd scale (an analog for Am), showing a great improvement and flexibility from traditional synthetic methods for f-element unsubstituted Tp syntheses, which generally require weeks of sublimation or extraction into benzene on the 100's of milligram scale.[1] The f-element TpBr procedure expands synthetic capabilities for more expeditious and safe actinide syntheses. The electron-withdrawing effect of the bromo group in the TpBr derivative contracts the TpBr bond to each lanthanide, allowing for 9-coordinate lanthanide complexes to be made through holmium (filled in circles, Figure 1a), while the unsubstituted Tp,(reference 1) only through terbium (X's in Figure 1a). These differences imply that a careful choice of Tp substitution can create a precise break from 9 to 8 coordinate in the trivalent lanthanide or actinide series, exploitable for separations. Further, three TpBr bound to Pu(IV), Am(III), and Cm(III) would result in a positively charged Pu TpBr complex and neutral Am and Cm TpBr complexes. Here, the Pu complex would have a vastly different solubility from the Am and Cm complexes, allowing for facile separation. The Pu work will be performed at Los Alamos National Laboratory with Dr. Melissa Fairley Rier.

Further, substitution at the R1 position, as seen in Figure 1c with the two 3-trifluoromethyl-tris pyrazolyl borate (TpCF3) ligands bound to divalent Am, can significantly stabilize divalent f-element cations through both an advantageous steric and electronic environment. The trifluoromethyl group (CF3) sterically protects the metal center in that it physically hinders interaction from other molecules, allowing unstable oxidation states to be stabilized longer than in the absence of that protection. Additionally, the CF3 group is electron withdrawing. This feature stabilizes divalent states of metals that are traditionally trivalent by drawing away some of the extra electron density. Am is most stable in its trivalent state and has a more accessible reduction to Am(0) than Am(II). With the Tp ligand system, the Am(II) state may become more accessible than the Am(0) state when reduced, allowing Am(II) to be isolated and avoid accessing high valent Am that disproportionates between Am(IV), Am(V), and Am(VI) for a straightforward separation from Cm(III). The f-element Tp complexes often fluoresce allowing them to be tracked in real time with UV light. Figure 2 shows Emily Gordon collecting fluorescence data on a f-element Tp crystal.

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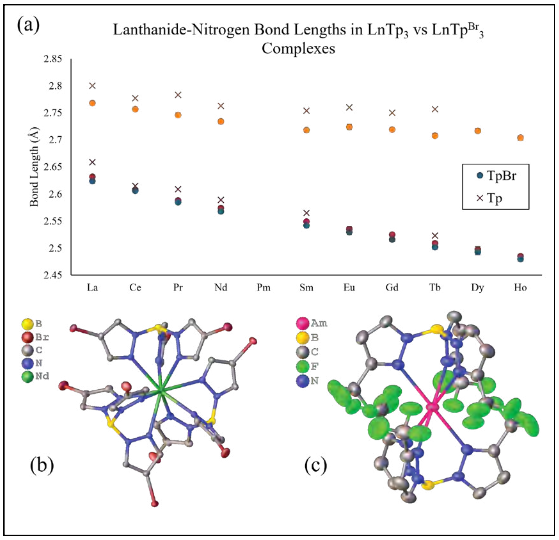


Figure 1.1a. Plot of the bond lengths from each 9-coordinate lanthanide to tris pyrazolyl borate (Tp) X's (reference 1) and 4-bromo-tris pyrazolyl borate (TpBr) filled in circles, highlighting the shortening of the bond lengths induced from the electron withdrawing bromine group on the pyrazolyl rings and the ability to extend the 9-coordinate system from terbium in the Tp system to holmium in the TpBr system. 1b. Structure of neodymium TpBr. 1c. Proposed structure of divalent americium with 3-trifluoromethyl-tris pyrazolyl borate (TpCF3). For 1b and 1c, hydrogen atoms and outer sphere solvent molecules are omitted for clarity.

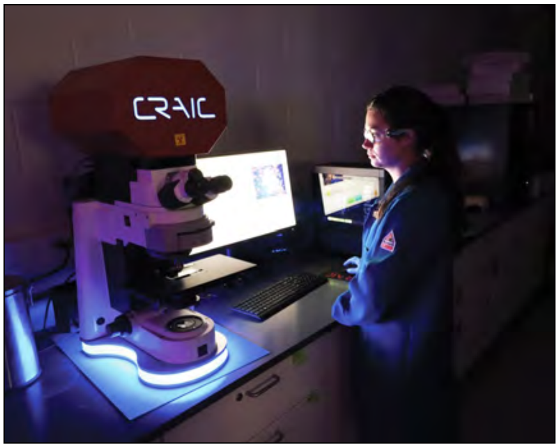


Figure 2. Emily Gordon, graduate student funded on the SSAA project, collecting solid state fluorescence data on f-element TpBr crystals.

Michael Pokornik (pokornik1@llnl.gov) | Lawrence Livermore National Laboratory, 2023 - Present
Degree: PhD, Engineering Sciences Physics ✦ **SSAA:** 2021 - 2025, University of California, San Diego

I recently joined Lawrence Livermore National Laboratory (LLNL) as a postdoc in the Design Physics Division where I work on using cognitive simulation techniques, combining experimental measurements and physics-based simulations with machine learning (ML) methods for applications in inertial confinement fusion.

SSAA Experience and Benefits

Sometime within the first couple years of my PhD program I joined the Center for Matter Under Extreme Conditions (CMEC) to conduct research in modeling the formation of magnetized collisionless shocks in the laboratory. Unlike common shocks we find on Earth that mostly rely on dissipating energy via binary particle collisions, collisionless shocks form on scales much shorter than the particle mean free path and must dissipate energy through complex collective interactions between the particles and fields. These shocks are ubiquitous in astrophysics and are an active area of research in the laboratory astrophysics field. I used both hybrid-kinetic and fully kinetic particle-in-cell simulations to study how these shocks form and dissipate energy and compared results with measurements made in experimental campaigns.

I have benefitted from CMEC and the Stewardship Science Academic Alliances (SSAA) program immensely. Being an academic collaborator with LLNL through the program gave me access to advanced plasma simulation codes and high-performance computing platforms that allowed me to identify interesting features in shock development and conduct studies that could only be done using resources like those made available to users at the national laboratories. I made several connections with highly talented scientists not just through direct research collaboration but also conferences (Stewardship Science Academic Programs Symposium), seminars, and monthly meetings. My interactions spanned new PhD students to world leading experts and within my area of discipline to outside it. This multi-disciplinary experience has given me a new perspective on problem solving and an appreciation for team science. One aspect of my research I believe underscores this is getting to combine my interest in ML, that had been fostered through LLNL summer internships, with shock simulations I had been running and experimental diagnostics. While I am not an experimentalist, I was able to work with those who were and learn how they analyze Thomson scattering (TS) diagnostic data, a key source of information for non-invasively measuring plasma conditions. From there I set out to train machine learning models to analyze this data, using the simulations to guide the creation of a physics motivated dataset for the models to train on Figure 1 a) shows a time resolved ion acoustic wave feature measurement from an unmagnetized shot as part of the magnetized shock campaign. A carbon target ablates and expands into ambient hydrogen gas sweeping up hydrogen in the process. The TS diagnostic probes a location far from the target and at initial times only undisturbed ambient hydrogen is detected until later times when the carbon and swept up hydrogen are detected. Figure 1 b) shows one component of many plasma conditions predictions made by a neural network (NN), here the fraction of only the fast moving swept up hydrogen. The NN predictions are in blue and conventional analysis is shown in red. This work contributed to multiple poster awards, a publication, and an invited talk and was a culmination of the diverse experiences I gained from being in CMEC and the SSAA program.

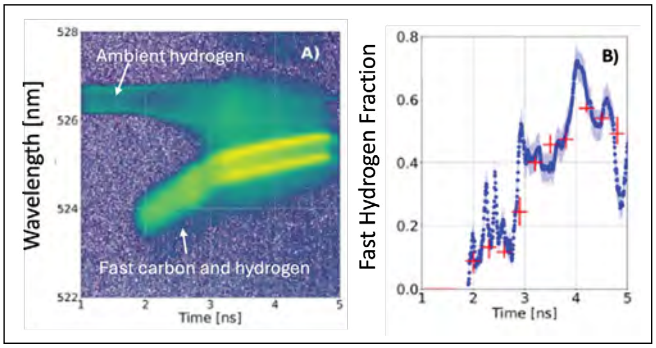


Figure 1.

NNSA National Laboratory

I sought employment with a NNSA national laboratory because of the personal experiences I had through SSAA. The mentorship, research topics, and access to resources all contributed to great experiences for me both interning and working as a collaborator for LLNL, and it made me want to seek out a career there to continue my intellectual and professional growth. I feel privileged to be able to support the stockpile stewardship program and national security science at a world class institution like one you'll find at a national laboratory.

I sought employment with a NNSA national lab because of the personal experiences I had through SSAA. The mentorship, research topics, and access to resources all contributed to great experiences for me both interning and working as a collaborator for LLNL, and it made me want to seek out a career there to continue my intellectual and professional growth.

Eloisa Zepeda-Alarcon (zepedae@nv.doe.gov) | **Nevada National Security Sites, 2020 - Present**
Degree: PhD, Engineering Sciences Physics ✦ SSAA: 2011 - 2017, University of California, Berkeley

As part of the Stewardship Science Academic Alliances (SSAA) program that supported my PhD research at University of California, Berkeley, I was exposed, through symposia, to the multitude of research relevant to the program, and how my work contributed to that. It was always encouraging to see how my research was connected to a larger community and purpose.

As I moved deeper into the stewardship science program, the perspective gained through my PhD with SSAA became more valuable and provided an advantage in understanding the bigger picture of how all our work is connected and relevant to our mission. . . . The big picture perspective I have developed through the years, and through my involvement in the SSAA program in my PhD, is an important aspect of my contributions and skill set in my current role today.

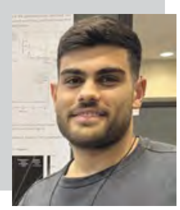
In my PhD, I investigated plastic deformation of polycrystalline minerals at high pressures up to about 80 GPa. I achieved the high pressures by using a diamond anvil cell technique, and I assessed deformation of the polycrystalline materials by using a 2D diffraction technique at synchrotron X-ray facilities. The SSAA program supported my PhD, specifically the Chicago/DOE Alliance Center for high pressure science and technology was instrumental in the accessibility to the synchrotron X-ray facilities and also with the support of my travel to the Advanced Photon Source where I performed most of my experiments. The experience I obtained and skills I developed performing experiments in large synchrotron facilities, became one of the pillars of my career. In my postdoc, I continued performing diffraction experiments at the Lujan Center of the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory. As I moved deeper into the stewardship science program, the perspective gained through my PhD with SSAA became more valuable and provided an advantage in understanding the bigger picture of how all our work is connected and relevant to our mission.

I currently work at the Nevada National Security Site. I design, assemble, and field custom radiographic imaging systems for experiments on materials at extreme dynamic conditions, at pulsed power X-ray sources. As the radiography team lead, I coordinate work across different disciplines like opto-mechanical engineers, optical engineers, electrical engineers and technical subject matter experts that all contribute to the design, assembly and ultimately fielding of the radiographic imaging systems. The big picture perspective I have developed through the years, and through my involvement in the SSAA program in my PhD, is an important aspect of my contributions and skill set in my current role today.

Working in the NNSA complex is extremely rewarding, I work in large collaborations to perform materials experiments at extreme conditions, utilizing state-of-the-art equipment and techniques that we develop through a careful R&D process that never forgets the goals and requirements of the experiment at hand. I enjoy collaborating with scientist and engineers across the NNSA complex to perform these large scale experiments, we all work together towards a common goal, and as the experiments are performed and successful they become milestones in my life achievements and my career.

Thierry Daoud (t.daoudl@ufl.edu) | University of Florida

Degree in Progress: PhD, Mechanical Engineering, Compressible Multiphase Flows ✦ Advisor: Dr. S. Balachandar ✦ SSAA: 2023 - Present



Research Topic

Key Mechanisms Behind the Formation of Multiphase Instabilities in Diverging Shock Tube Geometries

Research Responsibilities

Closure models for Euler–Lagrange (EL) compressible multiphase flow simulations are well represented in the literature, yet important components—such as a fully consistent Reynolds stress tensor closure—are still lacking. A central part of my role is to evaluate, enhance, and implement these models within a state-of-the-art hydrocode framework coupled to a Lagrangian particle solver. This capability enables the investigation of the key physical mechanisms driving instability development in diverging shock-tube geometries, including cylindrical and conical configurations. The resulting findings are disseminated through detailed technical reports, peer-reviewed journal publications, and conference presentations.

Benefits of SSAA

The Stewardship Science Academic Alliances (SSAA) placed me in an exceptional research environment, surrounded by leading experts whose guidance has helped me grow both technically and professionally. Through the SSAA program, I gained access to advanced computational resources that allowed me to run large-scale, high-fidelity simulations critical to my research. The program also exposed me to a network of scholars and collaborators, opening doors to new ideas, mentorship, and future opportunities.

What Students Considering SSAA Should Know

Dr. Balachandar's expertise in explosive dispersal of particles was a defining factor in my decision to pursue graduate studies. The opportunity to work on a SSAA-funded project was not to be missed and ultimately reshaped my academic trajectory in profound ways. The research introduced me to critical national security challenges and enabled me to investigate complex multiphase flow phenomena central to high-consequence defense applications. This experience not only strengthened my interest in defense-relevant science but also guided my decision to attend a university where I could continue advancing this line of inquiry with leading researchers in the field. The SSAA provided a rare environment where my work directly contributes to the nation's scientific and strategic capabilities, and that sense of purpose was instrumental in selecting both my research focus and institution. Moreover, this funding opportunity enabled invaluable interactions with scientists at national laboratories, enabling pathways to mentorship, collaboration, and potential internship opportunities this upcoming summer that will further enhance my professional development.

Peter Dyszel (pdyszel@vols.utk.edu) | University of Tennessee, Knoxville

Degree in Progress: PhD, Nuclear Physics ✦ Advisor: Dr. Robert Grzywacz ✦ SSAA: 2022 - Present

Research Topic

Development of Low-Energy Neutron Detectors and Beta-Delayed Neutron Spectroscopy

Research Responsibilities

Beta-delayed neutron (βn) spectroscopy is a method to probe low-energy nuclear structure in neutron-rich isotopes, such as those generated in fission. Fission fragments can be produced with high yields in radioactive beam facilities by bombarding a uranium-carbide target directly with protons or indirectly with spallation neutrons, and many of these fragments are delayed single- and multi-neutron emitters (βxn). Improved understanding of uranium fission fragments and subsequent decay channels plays a critical role in supporting stockpile stewardship efforts, such as the evolution and degradation of fissile material over extended periods of time.

My research responsibilities include the development and use of low-energy neutron detectors for βn measurements. The ability to measure low-energy neutrons is essential for probing near-threshold neutron-unbound states in exotic nuclei. Specifically, I investigate the nuclear structure of ^{133,134}In which help shape the final pattern of elemental abundances in the r process. Experimental neutron-branching ratios and lifetimes for these isotopes constrain astrophysical models, and are also used to improve the predictive power of fissile material simulations to assess the performance, security, and safety of aging nuclear weapons. My work includes the first β2n spectroscopy of an r-process nucleus ^{134}In using energy correlations in two-neutron emission, providing insight towards single- versus two-neutron competition from neutron-unbound states.

Benefits of SSAA

Stewardship Science Academic Alliances (SSAA) has provided opportunities in professional development through the numerous conferences and workshops that I am able to attend through the program. These experiences helped build the capacity to present research topic in a professional setting, which was further supported by healthy discussion with experts in the field.

What Students Considering SSAA Should Know

A highlight of SSAA is the annual Stewardship Science Academic Programs Symposium, that are designed to support professional development and provide insight into career pathways within the national laboratories. In addition to discussing research, the symposia include presentations from representatives about life at the national laboratories, ongoing initiatives, and future opportunities. Open postdoc or staff positions are relayed, and students are encouraged to speak with representatives in both one-on-one and group settings.

Richard Gumbel (gumbel@frib.msu.edu) | Michigan State University

Degree in Progress: PhD, Physics ✦ Advisor: Dr. Witold Nazarewicz ✦ SSAA: 2023 - Present

Research Topic

Heavy-Ion Collision Dynamics and Superheavy Element Synthesis

Research Responsibilities

I'm a nuclear physicist who uses time-dependent density functional theory (TD-DFT) to explore the dynamics of heavy-ion collisions. My home institution is the site of a Department of Energy (DOE) user facility, the Facility for Rare Isotope Beams, where I work as part of the low-energy nuclear theory community. My graduate research spans several phenomena: from investigating how neutron richness impacts quantum tunneling probabilities, to examining hurdles to the synthesis of superheavy elements (SHE). In the latter, I seek to understand how shell structure influences reaction outcomes, and how the competing process of quasi-fission suppresses compound nucleus formation. Part of this work explores the utility of alternate candidate projectiles for the hot fusion experiments used to create SHE. The study of which is vital for extending our models at the limits of nuclear stability, probing the interplay between quantum shell effects and coulombic repulsion, and exploring the boundaries of nuclear existence. Beyond questions of basis science, principled models of nuclear structure and dynamics provide a foundation for applied nuclear science, with potential impacts in nuclear astrophysics, nuclear energy, and stockpile stewardship.

Benefits of SSAA

The biggest benefit by far is mentorship. The impact of this is difficult to overstate, as it's been key in expanding my sense of what projects are possible. The guidance I've received has connected me with a network of theorists and experimentalists within the DOE/National Nuclear Security Administration national laboratory system, creating collaborative opportunities and providing access to computational resources essential for advancing theoretical methods. After I complete my PhD, my hope is to work at a national laboratory, so this has been an excellent opportunity.

New Contacts, New Opportunities

I'm currently a visiting researcher at the Laboratoire des deux infinis in Toulouse, France. Where I'm participating in an international collaboration to expand TD-DFT models for heavy to superheavy nuclei. We're implementing pairing correlations into collision dynamics—addressing key limitations of previous time-dependent studies. Opportunities such as this, working with experts from around the world, would not have been possible without the program's support.

This experience has demonstrated how critical communication is in research. Regular discussion can reveal connections between problems that then spark new insights, leading to new approaches.

Jacob Minnette (jminnet1@vols.utk.edu) | University of Tennessee, Knoxville

Degree in Progress: PhD, Nuclear Engineering (completed December 2025) ✦ Advisor: Dr. Maik Lang ✦ SSAA: 2021 - 2025

Research Topic

Characterization of High Temperature Ceramics under Intensive Radiation Conditions

Research Responsibilities

As a graduate student, I designed and executed a comprehensive research plan involving experimental work at large-user facilities both foreign and domestic (e.g., Advanced Photon Source (APS), High-pressure collaborative access team (HPCAT)). Some responsibilities and skills that I have acquired in pursuit of my goals include laboratory safety management, student mentorship, technical writing and communication, and work as a liaison between the University of Tennessee, Knoxville, and fellow Chicago/Department of Energy Alliance Center (CDAC) partner institutions. Stewardship Science Academic Alliances (SSAA) provided instrumental support, not only through funding, but critical access to large-user facilities and intra-center research collaborations.

New Contacts, New Opportunities

The focus for my research is on high-temperature ceramics, evaluated after exposure to intensive dense electronic excitations. Analyzing these materials required the unique capabilities available at the High-pressure collaborative access team (HPCAT) suite of beamline endstations, a facility with support of the Chicago DOE Alliance Center (CDAC). Through CDAC, the affiliated institutions are granted consistent access, not only to the facilities, but also scientific personnel at HPCAT. This enables high-throughput research with microdiffraction, X-ray absorption, and high-pressure X-ray diffraction analysis techniques, all of which were conducted during my time as a graduate student.

National Laboratory Experience

SSAA enables great opportunities for research collaboration and access to unique facilities across the national laboratory system. Working with the talented scientists at the national laboratories and supported academic institutions helped hone my scientific skill set and lead to more comprehensive, robust scientific output. During my time as a SSAA-supported graduate student, I engaged in work with several national laboratories, including Argonne (ANL), Oak Ridge (ORNL), Brookhaven (BNL), Los Alamos (LANL), and Lawrence Livermore (LLNL). I was fortunate enough to work on experiments directly at ANL, BNL and ORNL. While working at the national laboratories, I garnered experience with accelerator particle sources at various material characterization beamlines. Also, I learned a wide variety of data analysis techniques leveraged to improve understanding of materials in far-from equilibrium conditions. All of these acquired skills were essential, not only for my thesis work, but going forward with my career working in nuclear radiological material management and shielding design field.

High energy density (HED) science is central to many aspects of nuclear weapons and maintaining a strong HED academic community in this unique field is critical for the future needs of a modern nuclear stockpile. The High Energy Density Laboratory Plasmas (HEDLP) program is designed to steward the study of laboratory HED plasma physics by funding academic research of ionized matter in laboratory experiments where the conditions are extreme. The program supports individual investigator research grants, centers of excellence, and the Facility Access and Community Development Programs.

Individual Investigator Grants

The National Nuclear Security Administration's (NNSA) Office of Research, Development, Test & Evaluation, partners with the Department of Energy's Office of Fusion Energy Sciences to issue an annual joint solicitation for high energy density laboratory plasmas research. The coordination across agencies enables the support of a strong and broad academic presence in HED science, leveraging common interests and assuring NNSA-specific interests in this area remain vibrant. Competitively awarded research grants are selected through the joint solicitation conducted in coordination with the Office of Science Fusion Energy Sciences.

Centers of Excellence

The HEDLP program provides funding support toward the HED Centers of Excellence selected under the competitive SSAA Centers process. Centers of Excellence are an integrated, multi-institutional, collaborative effort focused on a central problem or theme. These Centers work closely with Nuclear Security Enterprise scientists and maintain a core set of academic expertise in key technical areas.

Facility Access and Community Development Program

The Facility Access and Community Development Program provides travel support for researchers who have been granted experimental time at NNSA user facilities. The HEDLP program’s community development effort provides funding for student and postdoctoral researchers’ travel to attend the High Energy Density Science summer school and various facility workshops.

ZNetUS

The HEDLP program provides funding to ZNetUS. ZNetUS is a consortium of researchers from academia and the national laboratories, dedicated to advancing pulsed magnetic science, technology, and high energy density physics for energy and national security applications, and creating the much needed pipeline of next-generation scientific leaders. These efforts enable user access to a network of university-scale pulsed power machines.

Driving Plasmas to Extreme Magnetizations Using Strong Laser Compression and High Initial Magnetic Field | University of California, San Diego | PI: Dr. Mathieu Bailly-Grandvaux (mbaillygrandvaux@ucsd.edu)

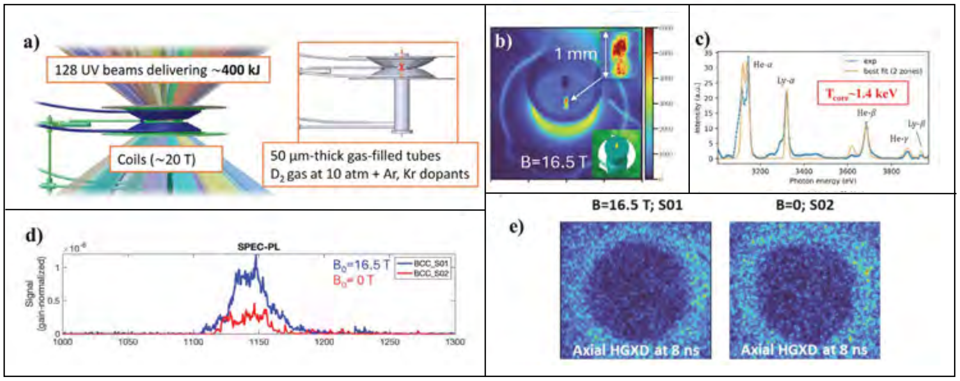


Figure 1. (a) Setup of the 2024 NIF experiment. (b) Target and core self-emission images. (c) Spectral analysis of argon K-shell emission and inferred average core temperature. (d) neutron time-of-flight spectra for magnetized (blue) and unmagnetized (red) implosions. (e) Gated X-ray images of the magnetized (left) and unmagnetized (right) experiments at t=8 ns.

The B-Coil Compressed group is a large collaboration among several US (University of California San Diego, University of California Los Angeles, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Laboratory for Laser Energetics at the University of Rochester) and European institutions (University of Bordeaux, University of Valladolid, and University of Gran Canaria) whose mission is to investigate the effects of strong magnetic fields on laser-driven compressed targets. At the Center for Energy Research, University of California San Diego, supported by a DOE/NNSA grant, our team leads experimental campaigns at the OMEGA and National Ignition Facility (NIF) laser facilities, conducts supporting simulations, and trains new researchers in all aspects of magnetized implosions, encompassing theory, experimentation, and modeling.

The compression of a target with a seeded magnetic field leads to a highly magnetized core plasma in which alpha particles can be confined, while reducing heat losses perpendicular to the magnetic field. These effects can relax ignition constraints and increase the efficiency of inertial confinement fusion (ICF) targets.

The group employs a novel diagnostic technique based on detailed spectroscopic analysis of dopant gases mixed into the fusion fuel to characterize the core plasma at stagnation. This method proved highly reliable during the group's 2021 OMEGA experimental campaign,[1] which compared magnetized (applying a 30 T axial magnetic field) and unmagnetized implosions of cylindrical targets filled with argon-doped deuterium fuel.

A follow-up to this experiment was carried out during the 2024 Discovery Science campaign at the NIF facility, introducing krypton as an additional dopant to the deuterium–argon fuel mixture to diagnose the inner regions of the imploding core. The experimental setup, shown in Figure 1a, used a cylindrical target imploded by 128 ultra-violet beams, with a custom-designed coil generating an axial magnetic field of approximately 20 T. Core assembly was clearly observed (Figure 1b); however, hydrodynamic instabilities at the target surface led to premature shell breakup and mixing with the fuel, preventing the core from reaching the required temperature at stagnation for sufficient krypton emission (Figure 1c). Consequently, the neutron yields (Figure 1d), on the order of several 10^9, were also too low to use secondary neutron measurements to diagnose magnetic confinement properties of the core plasma. Nevertheless, a marked improvement in implosion performance was observed, with neutron yield increasing by roughly a factor of three for the magnetized case, likely due to stabilization of the implosion by the magnetic field (Figure 1e). In the upcoming 2026 NIF campaign, we will double the shell thickness (from 50 µm to 100 µm) and fuel pressure (from 10 atm to 20 atm) to reduce implosion velocities and mitigate shell instability growth.

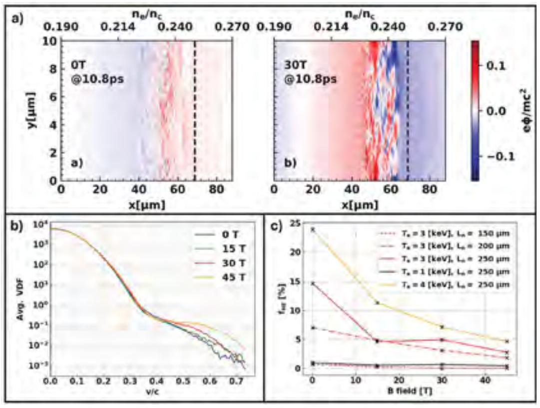


Figure 2. (a) LPSE simulations of the electron plasma wave potential in real two-dimensional space, (b) average velocity distribution function (with hot electron tail at higher normalized velocities) and (c) hot electron conversion fraction leaving the simulation boundaries in the direction of laser propagation for the entire simulation dataset.

In parallel, we conducted a complementary study to model the target's magnetized plasma corona and investigate hot-electron generation driven by laser–plasma instabilities at subcritical densities. Building on previous work,[2] two-dimensional simulations using the Laser Plasma Simulation Environment (LPSE) hybrid code were carried out over an extended range of plasma conditions, incorporating the effects of plasma turbulence. In the presence of an applied magnetic field, the transition from ballistic to gyrating electron trajectories enhances energy transfer from electron plasma waves to the electrons, leading to strong damping of modes located away from quarter-critical density (Figure 2a). Furthermore, although stronger magnetic fields increase hot-electron production (Figure 2b), these energetic electrons remain largely confined near the quarter-critical region (Figure 2c). These findings have implications for controlling target preheat in ICF experiments. A paper detailing these results has recently been submitted.

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Generation of Light with Dynamically Controllable Orbital Angular Momentum | The Ohio State University

PI: Dr. Douglass Schumacher (schumacher.60@osu.edu); Author: Dr. Brady Unzicker

One of the most exciting avenues of research in high energy density physics is the use of structured light to modify and control laser-plasma interactions. One such example is vortex beams of light that have orbital angular momentum (OAM), like a spinning top. OAM arises due to an angular dependence in the phase distribution and it can have arbitrarily small or large values (characterized by index number ℓ_z, $-\infty \le \ell_z \le \infty$), unlike the usual spin angular momentum which is determined by the light's polarization and must be between $-1 \le s_z \le 1$. Thus far, vortex light has been used for rotation control in optical tweezers, to create entangled states with extremely high quantum numbers, and has even been suggested to modify the quantum selection rules in atoms, enabling so-called forbidden transitions. Recently there has been much excitement over the advent of large spiral phase mirrors and spiral phase plates, suitable for high power lasers, that create high quality relativistic vortex beams. Denoeud, et al. used these optics to reflect a high intensity vortex beam from a fused silica mirror to produce extreme ultraviolet light (XUV) with OAM.[1] This experiment remains one of the few attempts to study the role of OAM in relativistic laser plasma interactions in the lab, largely due to the current high cost of spiral phase optics.

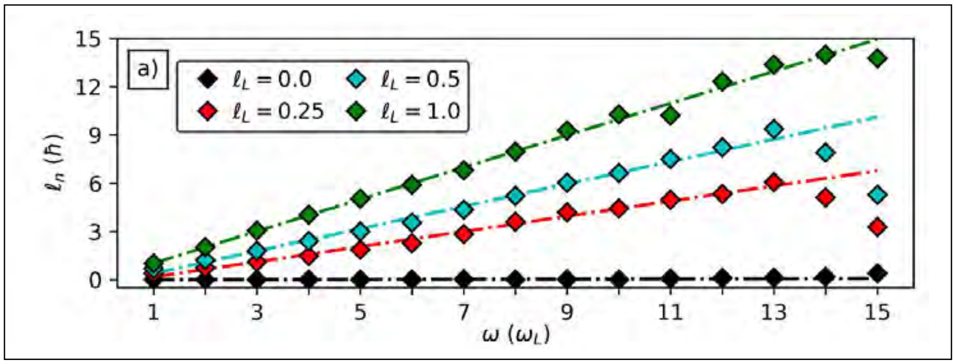

Figure 1.The OAM of the XUV light produced when a drive beam with different average OAM values is incident onto solid density plasmas.

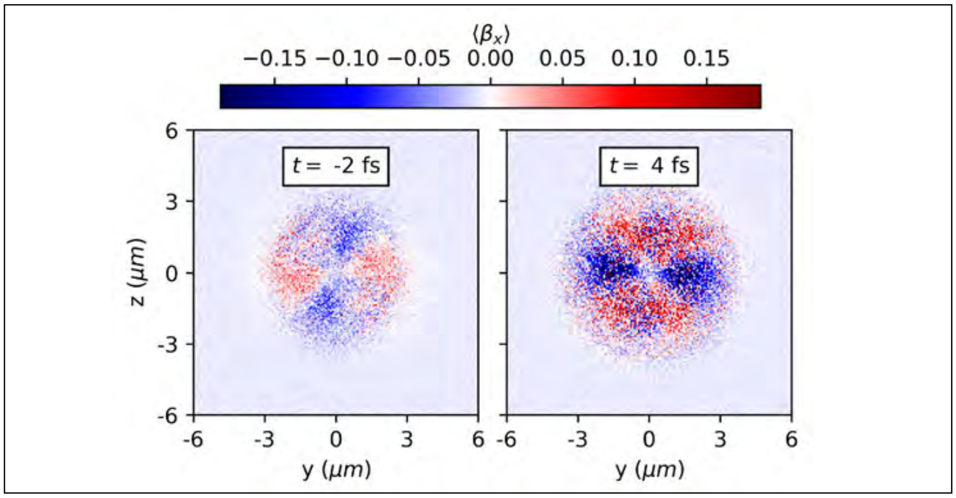

Figure 2. The average velocity of the plasma's critical surface (indicated by color) driven by an intense drive beam with OAM. The azimuthal variation in the critical surface can produce a reflected beam with tunable OAM.

To remedy this, we proposed a method to extend the scheme shown by Denoeud, et al. that generates light with a nearly arbitrary amount of OAM at a chosen frequency.[2] Our scheme starts with overlapping Gaussian ($\ell = 0$) and vortex beams ($\ell = 1$) to produce a composite drive beam with average OAM anywhere between $0 \le \ell_L \le 1$. We used a 3D particle-in-cell code to perform simulations that show that reflecting this composite beam off a solid density plasma produces OAM XUV light, and that changing the relative intensity of the Gaussian and vortex beams allows us to tune the amount of OAM at a specific frequency, as shown in Figure 1. The origin of this behavior lies in the relativistically oscillating mirror effect. When infrared light is incident onto a solid density plasma, it is reflected at the plasma critical surface. At high intensities the laser's electric field is strong enough to drive oscillations in the electron population, giving rise to a time-dependent phase shift in the reflected beam that results in high harmonics of the fundamental. When this process is driven by light with OAM, the spatiotemporal structure of the drive beam results in vortex plasma waves, leading to an azimuthally varying phase shift that encodes OAM into the reflected XUV light. Examples of the vortex plasma waves are shown Figure 2.

In conclusion, this scheme offers a way to generate ultrahigh intensity vortex beams with tunable amounts of OAM that can be rapidly controlled during an experiment. It opens the door to a variety of experiments to study the role of OAM in laser plasma interactions and can be used as a time-dependent probe of the resulting plasma waves. It shows the significant impact that structured light can have on laser-driven plasmas, and this approach can be implemented on any high power laser with adequate pre-pulse control.

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Michael Weller (wellerme@nv.doe.gov) | Nevada National Security Sites, 2020 - Present
Degree: PhD, Physics ✦ HEDLP: 2007 - 2015, University of Nevada, Reno

Research Responsibilities

The ASD Scorpius Project will deliver a next generation linear induction accelerator. It is currently being designed by multiple national laboratories (Los Alamos National Laboratory (LANL), Sandia National Laboratories (Sandia), and Lawrence Livermore National Laboratory (LLNL)) and will be installed at PULSE (formerly U1a), which is operated by the Nevada National Security Sites (NNSS). Scorpius is planned to deliver a 22.4 MeV, 1.4 kA electron beam up to four pulses at various pulse spacing and pulse widths.

A few years ago, I was named Technical Lead of the Downstream Transport (DST) subsystem of the Scorpius Accelerator. The DST is where the accelerated electron pulses are converted to the short X-ray pulses needed for dynamic radiography of subcritical experiments, while at the same time protecting the accelerator from damage, and securing personnel from radiation. As Technical Lead, I am responsible for ensuring the design meets high level and subsystem requirements. The DST is LANL scope to perform, so this is an example of a collaboration within the project, having an NNSS employee responsible for LANL scope, working with LANL employees.

Before on the project I performed beam transport simulations that helped confirm the design was meeting requirements during the technical maturation phase. I had used multiple codes to achieve this, including particle-in-cell transport codes. My work helped bring the project through Final Design Review.

Recently I have been named Accelerator Physics Manager at the NNSS to lead the ongoing efforts of the Scorpius Accelerator. Working for the NNSS is an amazing experience. I chose this over other opportunities due to the Scorpius Accelerator and the stability of the project and future program. It is the best professional decision I have ever made.

> *I was able to work in an advanced laboratory at the Nevada Terawatt Facility at the University of Nevada, Reno where I worked in both theoretical and experimental physics. I had collaborated with scientists at multiple national laboratories which prepared me for my postdoctoral experience at LLNL. The skills I learned back then I still use today in my position at the NNSS.*

Benefits of the High Energy Density Laboratory Plasmas (HEDLP) Program

I benefitted greatly from the HEDLP program. I was able to work in an advanced laboratory at the Nevada Terawatt Facility at the University of Nevada, Reno (UNR) where I worked in both theoretical and experimental physics. I had collaborated with scientists at multiple national laboratories which prepared me for my postdoctoral experience at LLNL. The skills I learned back then I still use today in my position at the NNSS.

National Laboratory Experience

While at UNR I had collaborations with scientists at LLNL, Sandia, and at the Naval Research Laboratory (NRL). I even had a scientist from LLNL on my PhD Committee. I learned a great deal about plasma spectroscopy and everything that one can learn from the subject matter. One interaction with a scientist at NRL about the potential of lasing from a z-pinch experiment involving Ag prompted experiments and a published paper, which became a chapter in my dissertation.

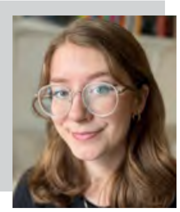
Figure 1. Weller working at the Princeton Plasma Physics Laboratory, fielding three spectrometers on the NSTX-U, circa 2017.

All of this led to me accepting a Postdoctoral position at LLNL, where I was put on assignment at the Princeton Plasma Physics Laboratory working on an upgrade of a tokamak. My assignment was to field three spectrometers which covered a range from X-ray to extreme ultraviolet that tracked impurities in the plasma. With this project I had further sharpened my plasma physics tools, and I made countless more connections in the plasma physics community and national laboratories. One unique paper that came from this work was comparing the spectroscopic data of Fe that came from the tokamak to Fe spectra collected from space. The tokamak data came from known temperature and density, and this knowledge is important to compare with that collected from space, which do not have readily known temperature and density measurements.

All this work prepared me for my work now at the NNSS. I owe a great deal of my success to the opportunities the HEDLP program provided.

Mara Klebonas (maraklebonas@utexas.edu) | The University of Texas at Austin

Degree in Progress: PhD, Physics ✦ Advisor: Dr. Bjorn Manuel Hegelich ✦ HEDLP: 2025 - Present



Research Topic

Relativistic Laser-Plasma Interactions, γ-ray Generation, and Radiation Signatures from Ultrafast High-Intensity Laser Pulses in Low-Density Solid Targets

Research Responsibilities

My graduate work examines MeV γ-ray emission generated via ultra-intense laser-plasma interactions, focusing on near-critical, low-density solid targets fielded at large-scale laser facilities. I support the design and execution of high-energy-density experiments, with responsibilities including diagnostic development and deployment, target alignment, and operation of ultrafast laser systems. A central focus of my research is understanding how pre-pulses drive pre-plasma formation and their influences on the onset of relativistic transparency in microstructured targets and resulting photon emission. A major motivation for my work is to advance the development of stable, collimated MeV photon sources and using the emission signatures to probe relativistic transparency and electron-acceleration dynamics in near-critical plasmas.

Benefits of HEDLP

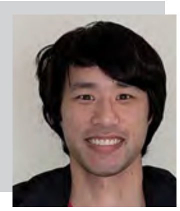
The HEDLP Program has been crucial in expanding my involvement in high-energy-density physics and strengthening my development as an experimentalist. With the support of the HEDLP Program, I am able to refine my skills in experimental design, diagnostic integration, and working with high-intensity laser systems. The Program has enabled me to travel for experiments, participate in extended research efforts, and gain the hands-on experience needed to accelerate both my technical training and dissertation progress. The opportunity to take on greater responsibility in experiment planning, manage technical tasks independently, and contribute to proposal preparation has increased my confidence in the skills required for a future career in scientific research.

New Contacts, New Opportunities

The HEDLP Program has enabled my participation in collaborative research efforts that would not have been possible without the program's support. It allowed me to work at ELI Beamlines, where I collaborated with scientists from multiple institutions on high-intensity laser-plasma experiments. Through this experience, I developed a strong understanding of how large HEDLP campaigns are successfully organized and executed at the facility scale and how individual contributions fit into broader scientific goals. Engaging in these coordinated research activities has significantly shaped my development as an experimentalist and prepared me for the collaborative environment of national laboratory research.

Kavin Tangtartharakul (ktangtar@ucsd.edu) | University of California San Diego

Degree in Progress: PhD, Engineering Physics ✦ Advisor: Dr. Alexey Arefiev ✦ HEDLP: 2023 - Present



Research Topic

High Intensity Laser Plasma Physics

Research Responsibilities

My research focuses on the theoretical and computational modeling of ultra-high-intensity laser–plasma interactions, with particular emphasis on direct laser acceleration (DLA) of charged particles.

Benefits of HEDLP

Participation in the Academic Program has been beneficial in shaping both my research trajectory and professional development. The program has provided sustained support, exposure to a broader scientific community, and access to national laboratory collaborations that would otherwise be difficult to establish as a graduate student. Through workshops, meetings, and interactions with other AP students and researchers, I have gained a deeper appreciation for the interdisciplinary and mission-driven nature of this research.

National Laboratory Experience

I have spent significant time working with and in collaboration with Department of Energy/National Nuclear Security Administration national laboratories, and these experiences have played a central role in shaping both my research direction and long-term career goals. Early in my graduate studies, I completed a Parallel Computing Summer Internship at Los Alamos National Laboratory (LANL), where I worked within the Theoretical Division on high-performance computing and scientific software development. During this internship, I contributed to the modernization of a GPU-accelerated neutron transport code by porting it from CUDA to Kokkos, enabling performance portability across multiple supercomputing architectures. This experience provided first-hand exposure to mission-driven science and the development and maintenance of large, collaborative HPC codebases typical of national-laboratory research.

My PhD research has also been closely connected to national laboratory experiments and collaborations. My work provides theoretical and computational support for high-intensity laser experiments at facilities such as OMEGA-EP, BELLA, and the ELI Beamlines, where national laboratory and international teams investigate extreme laser–plasma interactions. Through these collaborations, I have learned how large-scale simulations, theory, and diagnostics are integrated to inform experimental design and interpret results.

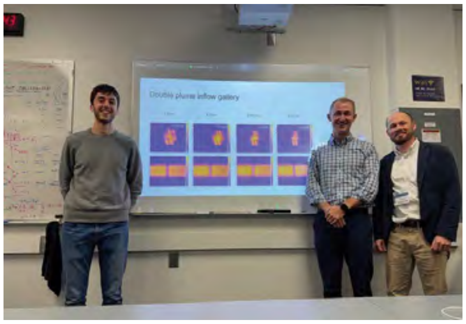
New Contacts, New Opportunities

I have presented my research at NNSA-affiliated meetings, including the Stewardship Science Academic Programs Symposium, where I engaged with researchers, program managers, and fellow students working on stewardship-relevant science. Participation in these meetings has helped me better understand how fundamental plasma physics research aligns with broader NNSA mission objectives and has provided valuable opportunities for feedback and professional networking.

Facility Access and Community Development Programs

Facility Access

The Facility Access Program supports travel for researchers who are granted shot time at the Omega Laser Facility and other NNSA user facilities. This provides hands-on research experience to academic researchers. In the pursuit of fundamental science advances, the innovative development of diagnostics and platforms by user facility partners have proven to benefit NNSA experimental needs. In fiscal year 2025 the Facility Access Program supported travel for 14 groups of researchers granted experimental time at the Omega Laser Facility and one group to the National Ignition Facility Discovery Science Program.



Left to right: Jesse Griff-McMahon (graduate student, Princeton University), Brendan McCluskey (graduate student, Princeton University), and Will Fox (professor, University of Maryland, College Park) showcasing fresh data from their shot day at the OMEGA Laser Facility in November 2025.

✦ ✦ ✦

Our OMEGA experiment went extremely well! We were able to complete 13 shots during the day, which is 3 more than we expected. Our high pace enabled us to measure three complete data sets. We plan to start analyzing the data soon, and while we expect it to answer many questions, it has already got us asking new questions.

The goal of our experiments was to study how self-generated magnetic fields alter the heat transport and temperature evolution in high-energy-density plasmas. To this end, we measured plasma density and temperature in two different geometries: single plasma plumes and double (colliding) plasma plumes. These experiments are directly applicable to indirect-drive inertial confinement fusion research, since self-generated magnetic fields can alter the laser-hohlraum interaction and influence implosion symmetry.

The travel support from NNSA was essential for ensuring that this experiment was a success. By being in person at OMEGA, we were able to quickly mitigate issues as they arose by talking through solutions with the OMEGA operations team. Additionally, data quality was improved thanks to on-the-fly diagnostic changes that were suggested via face-to-face discussions with OMEGA staff. Finally, travel support for multiple individuals allowed our team to 'divide and conquer' tasks, making us more efficient and effective.

— Brendan McCluskey
Princeton University

Community Development

Community Development provides specialized educational opportunities that both train and attract students to high energy density science. The High Energy Density Laboratory Plasmas program provides travel support for students and postdocs to attend the High Energy Density Science (HEDS) Summer School and various facility workshops. In fiscal year 2025, 215 students and postdocs were supported for travel to the HEDS Summer School or various facility workshops, such as the Omega Laser Users Group Workshop, NIF & JLF User Group Meeting, and the Z Fundamental Science Workshop.

Student presentation awards presented by the chair of the 2025 HEDS summer school, Prof. P. Tzeferacos (University of Rochester, right).

✦ ✦ ✦

In July 2025, approximately 90 graduate students and postdoctoral scholars traveled to the La Jolla campus of the University of California San Diego to participate in the biannual HEDS Summer School. Early-career scientists were presented with a unique opportunity to learn about the fundamentals of and cutting-edge research in HEDS. This intense two-week, lecture-workshop bootcamp covered several subjects in fundamental plasma physics, radiation and atomic physics, laser-driven hydrodynamics and shocks, laser-plasma interactions, diagnostic techniques, and target manufacturing. Four parallel hands-on workshops in computational physics were offered, introducing students in radiation (magneto) hydrodynamic modeling, particle in cell simulations, machine learning methods, and molecular dynamics. The summer school agenda included applications of HEDS in industry—from extreme ultraviolet lithography to demos of fusion reactors, student posters and oral presentations, and a no-questions-barred career panel discussion with representatives from academia, the Department of Energy/National Nuclear Security Administration (DOE/NNSA) national laboratories, and private partners. A total of 32 university professors and world-class researchers from the national laboratories volunteered their summer to work shoulder to shoulder with the 2025 cohort of students, which originated from 30 institutions and 14 countries.

The HEDS Summer School was organized by the Center for Matter under Extreme Conditions, a Stewardship Science Academic Alliances Center of Excellence (Organizing Committee Chair, Professor P. Tzeferacos, University of Rochester), under the auspices of DOE/NNSA, including the DOE Office of Science (SC) Fusion Energy Sciences (FES), and with support from the FES-supported Inertial Fusion Energy ecosystem (IFE-STAR) and its hub at the Laboratory for Laser Energetics at the University of Rochester, IFE-COLoR.

— Professor Farhat Beg
University of California, San Diego

ZNETUS— Expanding Capability and Training the Next Generation

Authors: Jens Schwarz, Farhat Beg, Clement Goyon, Bruce Kusse, Roberto Mancini, and Ryan McBride

Over the past year, the Z-pinch Network US (ZNetUS) has successfully executed experiments that were awarded during the program's inaugural call for proposals. These National Nuclear Security Administration (NNSA)-funded experimental campaigns have resulted in facility improvements for the host institutions and provided unique research opportunities that directly benefit students.

CESZAR (University of California, San Diego, PI: Farhat Beg)

The NNSA's Academic Programs supported two experimental campaigns on the CESZAR Linear Transformer Driver (LTD), which delivers roughly 0.8 MA of current with a 200 ns rise time into a low-inductance load (Figure 1). The generator is fully equipped for both gas-puff and wire-array experiments. The gas-puff injector can operate in three configurations, liner-only, liner-on-target, and double-liner-on-target, while allowing independent control of each gas-injection timing. A comprehensive suite of diagnostics includes two four-frame XUV cameras, a laser interferometer, and high-resolution optical, EUV, and X-ray spectrometers. These capabilities enable detailed studies of high-energy-density plasma dynamics under precisely controlled conditions.

Figure 1. PhD student Robert Beattie-Rossberg is aligning the laser for the interferometry diagnostic. The CESZAR machine is shown in the foreground.

COBRA and PUFFIN (Cornell University, PI: Bruce Kusse)

There have been some recent additions to the COBRA hardware and modifications to the Thomson Scattering system. A new large bore magnetic field coil, constructed by our colleagues at Imperial College, and a large capacitor bank driver are available for experiments on COBRA. It can produce 0.2-3 T, 7 ms rise time fields over a cylindrical volume 18 cm in diameter and 18 cm long. The Thomson Scattering system has a modification available that splits the laser pulse into four paths with independent time delays to make measurements at four different spatial locations resulting in unprecedented temporal and spatial resolution. PUFFIN (the Pulser for Fundamental Investigations) is a new pulsed-power facility that provides a long-pulse (2 µs) capacitive (16 µF) driver, designed to deliver a 700 kA peak current pulse. It uses two of the LTD5 modules developed at CEA Gramat for the SPHINX machine. This long rise-time makes PUFFIN ideal for studying slowly developing plasma processes, such as instabilities, plasma turbulence and magnetic reconnection. Led by Professor Jack Hare, construction and commissioning (Figure 2) were completed at the Massachusetts Institute of Technology (MIT) in November 2024. With Jack's move to Cornell, PUFFIN should be available to ZNetUS users in late 2026.

Figure 2 The PUFFIN facility during commissioning at MIT.

MAIZE (University of Michigan, PI: Ryan McBride)

The MAIZE facility at the University of Michigan recently expanded its diagnostics suite to include several new instruments for characterizing neutron-producing experiments. These instruments include a neutron time-of-flight (nTOF) system with one axial line of sight and two radial lines of sight (Figure 3); a Be activation detector; multiple bubble detectors; a slit step wedge X-ray spectrometer; an ion beam spectrometer; an ion beam pinhole camera; an X-ray pinhole camera; ion deflectometers; and CR-39 detectors. These instruments on MAIZE were developed in collaboration with Prof. Daniel Klir and his team from the Czech Technical University in Prague. These instruments complement MAIZE's preexisting diagnostic suite, which includes a fast 12-frame visible-light camera for self-emission imaging; a four-frame XUV self-emission imaging pinhole camera; a diagnostic laser probe (for schlieren imaging, shadowgraphy, interferometric imaging, and Faraday rotation imaging); photo-conducting diamond X-ray detectors (PCDs); silicon diode X-ray detectors (SiDs); a fiber-coupled visible-light spectrometer; B-dot probes; Rogowski coils; and more. The expanded diagnostic suite has enabled neutron, X-ray, and ion-beam measurements from deuterated fiber X-pinch loads and deuterium gas-puff z-pinch loads on MAIZE, as described in the references.

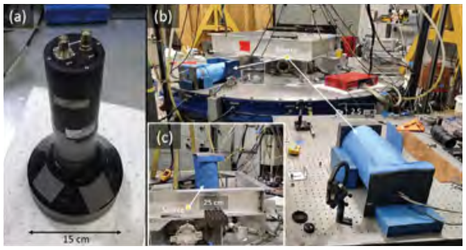


Figure 3. (a) One of the two nTOF detectors composed of a Hamamatsu H2431-50 PMT assembly and a Ø15 cm x 2.5 cm EJ-204 scintillator with a light guide. (b) Near and far positions of the nTOF detectors for radial lines of sight, roughly 1 and 2.5 m from the source, respectively. (c) Detector placement for the near-axial line of sight on the top lid of the vacuum chamber, roughly 0.25 m from the source.

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MJOLNIR
(Lawrence Livermore National Laboratory; PI: Clement Goyon)

In FY2025, the LLNL team leveraged internal funding to develop a user-facility pilot program, selecting four proposals from seven applicants. This work enabled us to create a robust user model for non-programmatic applications and raised MJOLNIR's visibility within the ZNetUS scientific community. The team is building on this early success, as multiple proposals involving MJOLNIR were submitted to the most recent ZNetUS call for proposals, and additional internal funding has been obtained to support experiments in collaboration with Cornell and Stanford Universities. New capabilities installed to support these experiments include an on-axis gas jet and the ability to add radial wires (Figure 4).

Figure 4. On-axis gas jet at MJOLNIR.

Mykonos (Sandia National Laboratories; Author: Jens Schwarz)

Academic Programs fully or partially supported a variety of key improvements to the facility: 10 T axial external B-field capability, clean room for target preparation (Figure 5), commercial laser safety control system (Figure 6), and a control room upgrade. The 10 T field has been applied to thick-rod z-pinch targets, enabling studies of ETI physics under conditions relevant to the surface of MagLIF liners. In addition, these upgrades improved experiment and shot operation and laid the groundwork for integrating a powerful pump-probe laser (532 nm, 0.3-5 ns, 1-50 J) from the adjacent Z-Beamlet facility. Furthermore, we were able to mentor and partially fund graduate students from three universities across the country that were able to perform "hands on" experiments on the pulsed power driver.

Figure 5. (Left) New clean room. (Right) Small optics table in the clean room that will serve as the user station for setting up hardware or diagnostics.

Figure 6. New laser interlock system. Image on the screen shows whether any of the lasers are interlocked and whether the room is safe to enter.

ZEBRA (University of Nevada, Reno; PI: Roberto Mancini)

The Zebra Pulsed Power Laboratory houses the 1 MA Zebra pulsed power generator and the high-power Leopard laser; the laser has two modes of operation delivering 30 J in 1 ns or 15 J in 350 fs.

Here we highlight the ZNetUS flyer plate campaign led by Dr. S. Bott-Suzuki (University of California, San Diego) in collaboration with First Light Fusion (United Kingdom) that successfully performed a radiography of an aluminum flyer plate launched by Zebra with the 22 keV X-ray photons from a Kα silver backlit source driven by the Leopard laser operating in short pulse mode. Figure 7 displays three 22 keV X-ray radiographs performed at three different times that track the time evolution of the flyer plate, including initial acceleration and later motion.

In a different campaign, the ZNetUS X-pinch experiment led by Dr. F. Kraus (Princeton University) fielded a high-spectral resolving power imaging X-ray spectrometer equipped with three spherically bent Quartz crystals to record the He-like titanium Heβ line spectrum with a spectral resolving power $\lambda/\Delta\lambda \approx 5000$. The goal was to employ the titanium X-pinch plasma as a testbed to produce and record titanium K-shell X-ray spectra from dense plasmas where the Stark effect dominates the line broadening of the atomic transition. Figure 8 shows a sample of the data recorded in the Zebra X-pinch experiments. The high spectral resolving power enabled the observation of the Stark broadening of the Heβ line shape with an unprecedented level of detail.

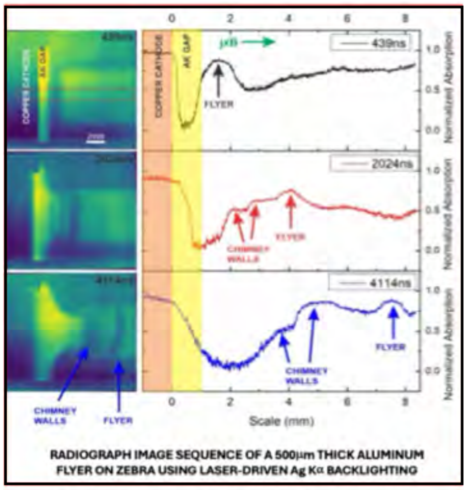


Figure 7: Time-evolution of flyer plate recorded with 22 keV silver Kα X-rays, needed to penetrate aluminum.

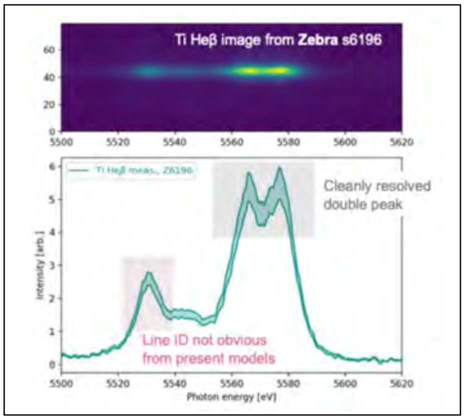


Figure 8. He-like titanium Heβ line spectrum recorded high-spectral resolving power ($\lambda/\Delta\lambda \approx 5000$) in Zebra experiment.

The Predictive Science Academic Alliance Program (PSAAP) consists of participation by leading U.S. universities, focusing on the development and demonstration of technologies and methodologies to support effective, high-performance computing in the context of science and engineering applications. The research performed by the universities in this program is discipline-focused to further predictive science and is enabled by effective, extreme-scale computing. The predictive science that is a highlight of this program is based on verification and validation and uncertainty quantification for large-scale simulations.

PSAAP currently consists of the following types of centers: Predictive Simulation Centers (PSCs), and Focused Investigatory Centers (FICs). PSCs focus on scalable application simulations, targeting large-scale, integrated multidisciplinary problems. PSCs develop and demonstrate computational science technologies and methodologies that advance exascale computing, and demonstrate integrated, verified, validated predictive simulation with uncertainty quantification. FICs are tightly focused on a specific research topic of interest to National Nuclear Security Administration's mission in either a science/engineering discipline or an exascale-enabling technology. FICs demonstrate compelling and significant scientific advances that represent a qualitative step up in the respective disciplines or technologies.

PSAAP has a long-term goal to cultivate the next generation of scientists and engineers to support the Advanced Simulation and Computing and Stockpile Modernization missions. These efforts establish academic programs for multidisciplinary simulation science and provide students the relevant experience for weapons code development through open science applications.

Predictive Science Academic Alliance Program III | Centers of Excellence Summary

The PSAAP III Centers began in September 2020 and are now finishing work on their cooperative agreement awards. PSAAP III consisted of the following types of Centers: Multidisciplinary Simulation Centers (MSCs), Single Discipline Centers (SDCs), and Focused Investigatory Centers (FICs). MSCs focused on scalable application simulations, targeting large-scale, integrated multidisciplinary problems, whereas SDCs focused on scalable application simulation for targeting a broad single science or engineering discipline. The PSAAP III FICs were tightly focused on specific research topics of interest to NNSA's mission in either a science/engineering discipline or an exascale enabling technology. Outlined below are some recent accomplishments from the PSAAP III Centers.

Multidisciplinary Simulation Centers (MSCs)

Center for Micromorphic Multiphysics Porous and Particulate Materials Simulations with Exascale Computing Workflows | University of Colorado at Boulder

PI: Dr. Richard Regueiro (richard.regueiro@colorado.edu)

The Center has performed grain-resolving simulations of quasi-static, uniaxial strain pressing of IDOX-nitroplasticized-Estane mock high explosive (HE) at 50 degrees Celsius resulting in 5mm diameter 5mm tall cylinders were run with LAMMPS (explicit dynamic quasi-static approximation) and quasi-static Ratel implicit Material Point Method (iMPM). Quantities of Interest (QoI) included force-displacement and force-time curves, and grain statistics. Grain-resolving simulations of quasi-static, room temperature, unconfined compression of pressed IDOX-nitroplasticized-Estane mock HE 5mm diameter 5mm tall cylinders were run with the quasi-static Ratel implicit Finite Element Method (FEM). These grain-resolving simulation results were upscaled through the Tardigrade micromorphic filter enabling calibration of micromorphic constitutive material parameters, and separate Tardigrade-MOOSE finite element simulations including gradient-enhanced damage (additional parameters calibrated to macroscale data) with same QoI (force-displacement curves, and localized deformation patterns obtained via Digital Image Correlation (DIC) and Digital Volume Correlation (DVC)). ✦

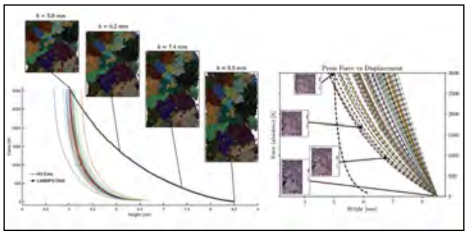


Figure 1. (Left) Grain-resolving DEM (bonded-"particle"-method (BPM) https://github.com/slamont1/lammps) press sims of IDOX grains in "dirty" nitro-Estane binder (9M atoms, 23M bonds) from CT scanned images IP-01 (Peterson, Lamont, White, Jensen, Clemmer, Bolintineanu). (Right) Grain-resolving iMPM IP-01 preliminary press sims, 3M points, ~4-6 hours/run on 4 nodes of Tuolumne (Atkins, Ratel team https://ratel.micromorph.org/)

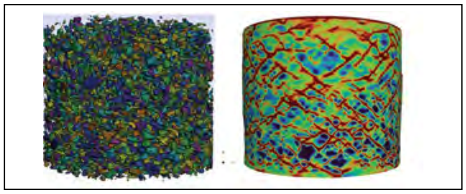


Figure 2. Full (5 x 5 mm) puck under quasi-static unconfined compression (143.09) IDOX-nitro-Estane: 100M DoFs on Tioga with 4 nodes, 32 GPUs, 12h runtime (Javadzadeh, Peterson, Di Gioacchino, Jensen, Ratel team https://ratel.micromorph.org/).

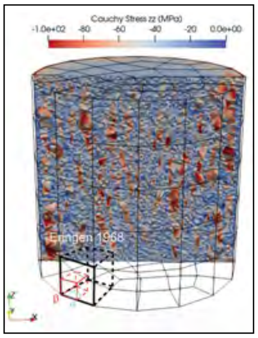


Figure 3. Micromorphic continuum mechanics upscaling with ML in Tardigrade https://github.com/UCBoulder/tardigrade (Miller, Allard, Regueiro).

The Center for Exascale-enabled Scramjet Design (CEESD) | University of Illinois at Urbana-Champaign

PI: Dr. Jonathan Freund (jbfreund@illinois.edu)

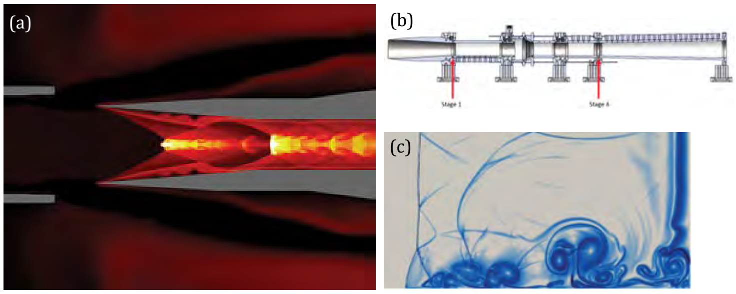


Figure 1. Integrated simulations using MIRGE: (a) a scramjet model inlet visualizing temperature, (b) CAD of the scramjet model, (c) shock-tube model for co-verification and assessing resolution.

The CEESD PSAAP III center demonstrated a new paradigm for multi-physics high-performance computing called MIRGE. A Python control layer expresses the mathematics [the M in MIRGE] of the physics models. The Center used a discontinuous Galerkin (DG) discretization of the compressible reacting Navier-Stokes equations, with coupled thermal, species transport, and material degradation models of the wall material in a scramjet combustion. The computation expressed in the control layer, represented as a graph, is used to reconstruct the operations in an intermediate representation [IR]. This allows platform portable optimizations and efficiencies such as lazy evaluation to be identified, leading to generation [G] of OpenCL code for execution [E]. MIRGE has demonstrated performance on both CPUs and GPUs on many NNSA systems, while also facilitating rapid adoption of new models by non-experts, showing that usability and portable performance concerns were successfully separated. The Center has contributed to the training of over 20 PhD students, most of whom completed at least one 10-week internship at an NNSA lab. Several hope to find positions at labs upon graduation. ✦

Integrated Simulations Using Exascale Multiphysics Ensembles | Stanford University

PI: Dr. Gianluca Iaccarino (jops@stanford.edu)

Achieving reliable laser-induced ignition in rocket combustors is hard. The tight coupling among turbulent mixing of fuel and oxidizer, laser energy deposition, and high-speed flame growth drives run-to-run variability, which makes data acquisition in experiments and predictive simulations both a grand challenge and extremely time consuming. This motivates the development of next generation digital enhancement of experimental pipelines for better understanding and better predictive capability.

Figure 1. Time series of the neutron number density in fm-3 for a typical fission trajectory.

Exascale computing has enabled advances in CFD and machine learning that were unimaginable even ten years ago. Using ensembles of simulations, Stanford has leveraged this computer power to repair and extend partially observed measurements and to recreate diagnostics that are mutually incompatible during acquisition. In ongoing work, they computationally model shadowgraphy, the formation of Schlieren images, and chemiluminescence to provide enlarged optical access as well as combined modalities. ✦

Exascale Predictive Simulation of Inductively Coupled Plasma Torches | University of Texas at Austin

PI: Dr. Robert Moser (rmoser@oden.utexas.edu)

The PSAAP III Center at The University of Texas at Austin has been pursuing predictive simulation of an inductively-coupled plasma torch (Torch). This effort required modeling plasma kinetics, turbulent flow, electrodynamics, radiative heat transfer and the driving electronic circuit. Major accomplishments include: a novel GPU-accelerated solver for the electron Boltzmann equation; a multifidelity, domain-decomposed solver that eliminates the need to simulate the high-speed highly turbulent jets that feed gas into the torch; and the integration of these models in a low-Mach-number variable density Torch simulator implemented in MFEM. The models underwent detailed validation based on experiments using advanced diagnostics on the Torch device. In support of the plasma torch simulations, there have been developments in uncertainty quantification (UQ) methods, and in exascale computing. In UQ, a novel representation of uncertainty in impact cross sections was developed, and a state-of-the-art multifidelity uncertainty algorithm (MLBlue) was extended to improve generality, performance and robustness. ✦

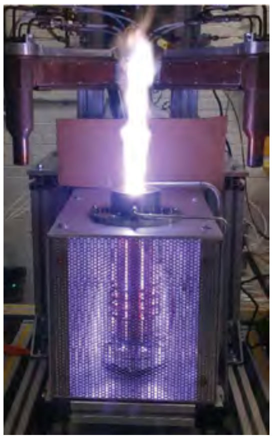


Figure 1. Inductively-coupled plasma torch (Torch).

Single Discipline Centers (SDCs)

Center for Hybrid Rocket Exascale Simulation Technology | University at Buffalo

PI: Dr. Paul DesJardin (ped3@buffalo.edu)

The Center for Hybrid Rocket Exascale Simulation Technology (CHREST) was formed to explore the physics of turbulent reacting flows in hybrid rocket motors using exascale computing and employing model reduction strategies based on machine learning for design optimization and uncertainty quantification. Faculty and students from the University at Buffalo (UB) and Tufts University who specialize in engineering, computer science, and mathematics, combine new mathematical models with first principles' simulation of rocket motors to enable a next-generation of low-cost space flight. The primary effort of the Center involved simulating sounding hybrid rocket motors using pure oxygen with an atomizing wax fuel and validating the simulation with experimental data from motor tests performed at UB. An image from one of the sounding rocket experiments developed by past and present CHREST graduate students, is shown on the top of Figure 1, showing the post nozzle

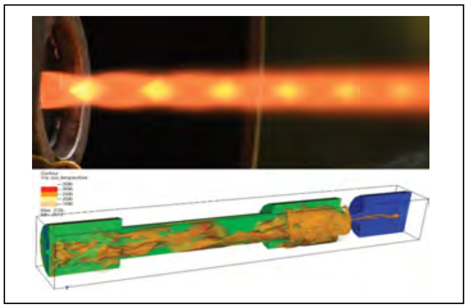


Figure 1. Post-nozzle exhaust showing shock diamonds from experiments (top) and numerical simulation of the ignition (bottom).

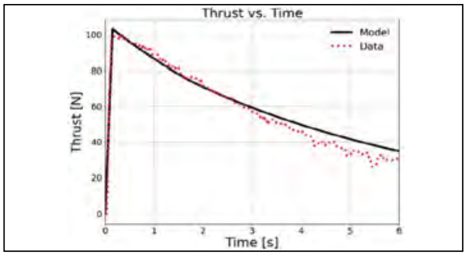


Figure 2 Comparison between experimental thrust measurements and model predictions over the experimental burn time..

exhaust region of the hybrid rocket (top). A snapshot from a simulation of the hybrid rocket motor during ignition in Figure 1 (bottom) shows temperature contours from the turbulent flame spanning throughout the internal rocket motor and into the exhaust. This simulation is performed with the Center's open source exascale framework ABLATE (Ablative Boundary Layers At The Exascale) and is the culmination of Center's 5-year effort. Comparisons of the thrust data between the model and experiments show reasonable agreement for the experimental burn time and are shown in Figure 2 . ✦

Center for Exascale Simulation of Material Interfaces in Extreme Environments | Massachusetts Institute of Technology

PI: Dr. Youssef Marzouk (ymarz@mit.edu)

The overarching goal of Center for Exascale Simulation of Material Interfaces in Extreme Environments (CESMIX) is to predictively simulate the degradation of complex materials in extreme environments, from first principles. As an exemplar, we study thermal protection materials for hypersonic vehicles, exposed to extreme temperatures, heat fluxes, and oxidative atmospheres. CESMIX has developed an automated multiscale simulation capability to predict materials degradation with chemical accuracy, and a composable exascale software framework that makes central use of the Julia language.

Key accomplishments this year include large-scale predictive simulations of hafnium oxidation, focusing on mechanisms tied to microstructural features of the material. These simulations were enabled by improved environment-adaptive machine learning interatomic potentials, extending the proper orthogonal descriptor (ML-POD) potentials previously developed by the Center, and by a new accelerated off-lattice parallel replica kinetic Monte Carlo scheme reaching long time scales. ✦

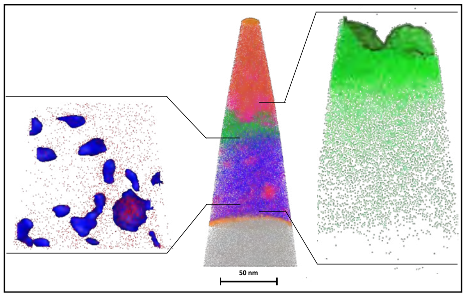
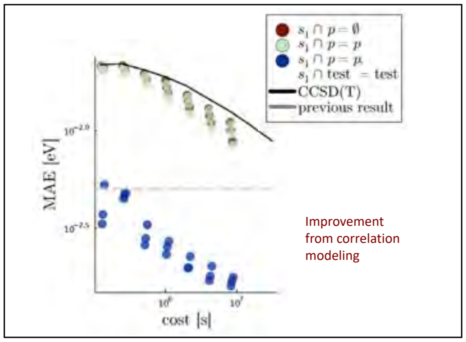


Figure 1.



Improvement from correlation modeling

Figure 2.

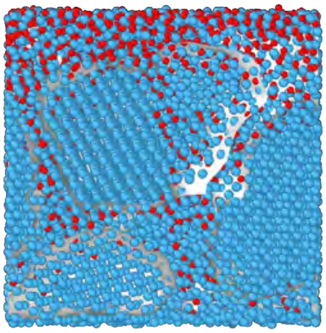


Figure 3.

Focused Investigatory Centers (FICs)

Solution-Verification, Grid-Adaptation and Uncertainty Quantification for Chaotic Turbulent Flow Problems | University of Maryland

PI: Dr. Johan Larsson (jola@umd.edu)

This Center has been focused on the problem of how to estimate errors and uncertainties in simulations of turbulent flows. These types of simulations are chaotic in nature and produce solutions with broadband spectra, two characteristics that make error estimation, error attribution, and ultimately uncertainty estimation particularly challenging. The Center is a collaboration between research groups at the University of Maryland, the University of Southern California, and Massachusetts Institute of Technology. A large thrust of the Center has been the development of three different novel methods for sensitivity estimation for turbulent flow problems: the so-called "space-split sensitivity" (S3) method which is based on mathematical linear response theory, and the "multi-fidelity sensitivity analysis" (MFSA) method which is based on turbulence modeling ideas, and a method based on information theory (IT-SA). These methods were essentially created from scratch during the project and have been developed to the point that they were applied to a turbulent channel flow problem (Figure 1). Figure 2 shows the sensitivity of the mean velocity profile as computed by all 3 methods, compared to a (very computationally expensive) surrogate truth. ✦

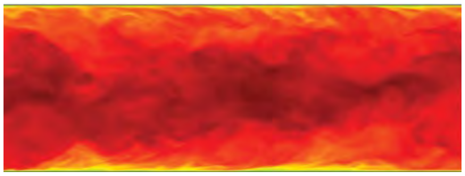


Figure 1. Instantaneous snapshot of a turbulent channel flow.

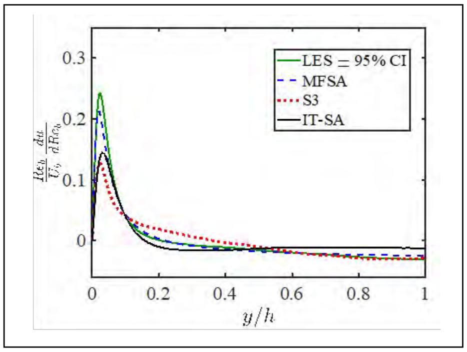


Figure 2. Sensitivity (= change) of the entire mean velocity profile of a turbulent channel flow to changes in the Reynolds number, comparing the 3 different methods developed in this PSAAP-3 Center (MFSA, S3, IT-SA) against a surrogate truth (LES) with estimated confidence interval.

Center for Understandable, Performant Exascale Communication Systems | University of New Mexico

PI: Dr. Patrick Bridges (patrickb@unm.edu))

The overall mission of the Center for Understandable, Performant Exascale Communication Systems (CUP-ECS) is to meet the challenges of providing optimized, performance-transparent communication systems for emerging NNSA exascale applications. Center research has focused on designing new techniques to assess communication in NNSA applications and new primitives for irregular communication and communication on GPU systems. Figure 1 shows the communication patterns and intensity from multiple levels of the hypre sparse solver on test problems; this data provides essential information for guiding communication optimization in applications. Using insights gleaned from these and similar tools, Center researchers have developed new performant communication primitives available in the open source MPI Advance software system. For example, Figure 2 shows how different communication algorithms developed by Center researchers improve the performance of sparse matrix solves in the coarse levels of hypre AMG solves. Center researchers also created new GPU-triggered communication primitives for the AMD GPUs and Slingshot network cards used in NNSA supercomputing systems. These primitives, designed for later integration into the MPI standard, reduce communication latency and increase the scalability of halo exchanges, which Figure 3 shows from test executions on up to 256 nodes on the LLNL Tuolumne system. ✦

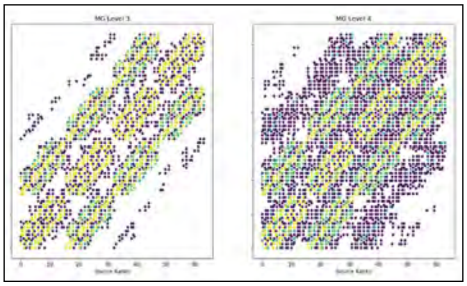


Figure 1. Combined AMG2023 Communication Intensity per AMG Level measured using center-developed Caliper extensions. (Nansamba et al, "Leveraging Caliper and Benchpark to Analyze MPI Communication Patterns: Insights from AMG2023, Kripke, and Laghos", HPEC 2025)

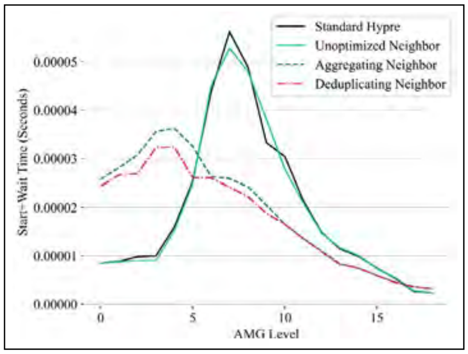


Figure 2. AMG2023 communication performance by multi-grid level with different center-developed communication optimizations on the LLNL Quartz system. (G. Collom et al, "Optimizing Irregular Communication with Neighborhood Collectives and Locality-Aware Parallelism", ExaMPI 2023.)

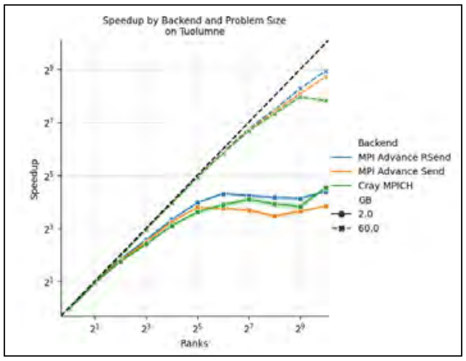


Figure 3. Comparison between halo exchange strong scaling performance of center-developed stream-triggering communication abstractions versus Cray MPICH performance on up to 1024 ranks/256 nodes of the LLNL Tuolumne system.

Center for Exascale Monte Carlo Neutron Transport | Oregon State University

PI: Dr. Todd S. Palmer (todd.palmer@oregonstate.edu)

As we work toward the conclusion of the Center for Exascale Monte Carlo Neutron Transport, we have undertaken a significant code refactoring. This refactor improves usability (as a prototyping tool), maintainability and extensibility, and specifically enables the use of more continuous energy neutron cross section information from ENDF and ACE libraries. A more comprehensive set of nuclear data yields higher fidelity MC/DC calculations. The restructuring of the code into more modular components also anticipates future modifications of the code to a wider variety of particle types; this work is planned (and underway) as a part of the new PSAAP-IV Center for Advancing the Radiation Resilience of Electronics (CARRE).

During the past year, members of CEMeNT have been performing MC/DC simulations of variations of our challenge problem: a multi-stage transient occurring in a high-fidelity 3D model of a small modular pressurized water nuclear reactor. Working with colleagues from LLNL, we intend to generate results from these challenge problems on Tuolumne and then utilize El Capitan to investigate performance nearer to exascale. ✦

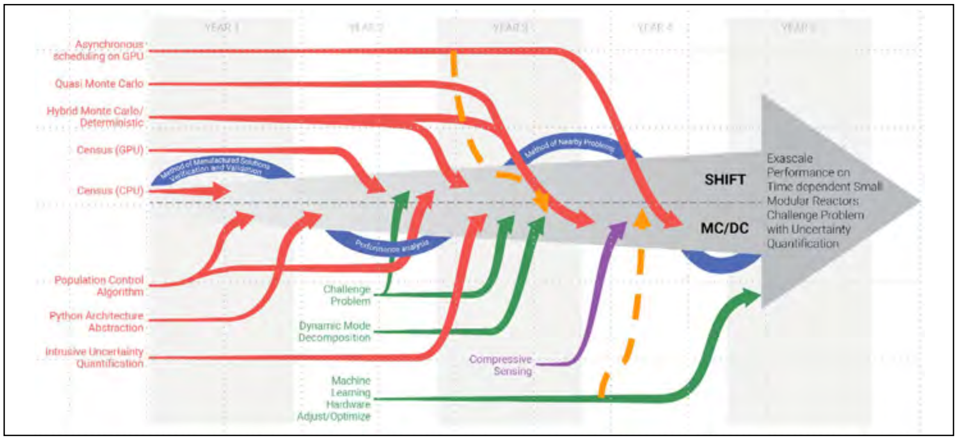


Figure 1. Roadmap and Milestones from Year 1 to Year 5 for Center for Exascale Monte Carlo Neutron Transport (CEMENT).

Predictive Science Academic Alliance Program IV | Centers of Excellence Overview

The PSAAP IV Centers were selected during Fiscal Year 2025 and began performance in September 2025. The Centers' primary focus is on the following major technical areas:

- Discipline-focused research needed to further predictive science and enabled by effective Exascale computing technologies;
- Developing and demonstrating technologies and methodologies to support effective Exascale computing in the context of science/engineering applications;
- State-of-the-art machine learning and data science technologies for predictive science and engineering;
- Predictive Science based on verification and validation and uncertainty quantification (V&V/UQ) for large-scale simulations; and
- Workforce development of the next-generation computational scientists and engineers.

Nine universities have been selected in PSAAP IV to lead either a Predictive Simulation Center (PSC), or a Focused Investigatory Center (FIC). PSCs will focus their research on scalable application simulations, targeting either large-scale, integrated multidisciplinary problems or a broad single science/engineering discipline like multi-disciplinary simulation centers and single-discipline centers in PSAAP III. FICs will maintain similar focus as well on specific research topics either in one of the disciplines or one or more of the exascale-enabling computational science, machine learning, or verification and validation/uncertainty quantification (VVUQ) technologies.

Predictive Simulation Centers

- University of Florida: Center for Multiscale Modeling of Multiphase Combustion
- Massachusetts Institute of Technology: Center for the Exascale Simulation of Coupled High Enthalpy Fluid-Solid Interactions (CHEF-SI)
- University of Michigan: Center for Prediction, Reasoning and Intelligence for Multiphysics Exploration (C-PRIME)
- Oregon State University: Center for Advancing the Radiation Resilience of Electronics (CARRE)
- University of Virginia: Center for Stochastic Simulations of Ablative Geometries with Error-Learning in Space and Time

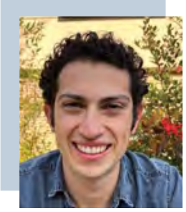
Focused Investigatory Centers

- Brown University: Center for Information Geometric Mechanics and Optimization (CIGMO)
- University of California at San Diego: Center for Simulation and design of Heterogeneous Architectures for Performance and Energy absorption ((SHAPE)
- Michigan State University: High Order Plasma Turbulence Modeling for Z-Pinch
- University of New Mexico: Center for Optimized Modern Parallel Adaptive System Software (COMPASS).

PSAAP IV Kickoff Meeting held on 8/26-27, 2025, at the Hilton Arlington National Landing in Arlington, Virginia.

Q&A with Keynote Speaker: Dr. Kimberly Budil, Director, Lawrence Livermore National Laboratory.

Caetano Melone (cmelone@llnl.gov) | **Lawrence Livermore National Laboratory, 2025 - Present**
Degree: MS, Public Policy ✦ PSAAP: 2020 - 2024, Stanford University



I worked in the Integrated Simulations using Exascale Multiphysics Ensembles (INSIEME) Center at Stanford University as both a master's student and support staff. The Center's goal was to study laser-induced rocket combustion through modeling and simulation. Our data-driven methods were built around the Hypersonic Task-based Research (HTR) solver, a computational fluid dynamics application used to simulate hydrodynamic turbulence. HTR is built on Legion, a parallel programming model developed at Stanford and was designed to run at scale on the National Nuclear Security Administration (NNSA) computing resources provided through the PSAAP program.

I joined the Center as an undergraduate through Stanford's High Performance Computing Center, where I learned to manage high performance computing (HPC) clusters and worked with scientists to improve their software. At INSIEME, I collaborated with mechanical engineers and computer scientists to ensure that HTR ran correctly and efficiently on platforms such as Lawrence Livermore National Laboratory's (LLNL) Lassen system. My focus was on integrating modern software development practices into our code review process to improve the portability, correctness, and performance of HTR. Due to the complexity of the solver and its dependencies, automated testing during development was essential for identifying bugs early and lowering barriers for users building and running the code.

Through my participation in the PSAAP program, I presented talks and posters at the bi-annual grant reviews, where I met representatives from the NNSA tri-labs and learned about their mission and scope. Attending meetings with other PSAAP Centers also gave me a broader view of how different institutions were approaching similar challenges in the development of their simulation codes. These discussions helped strengthen our own strategies for testing and performance portability, and they led to connections with researchers who later became collaborators.

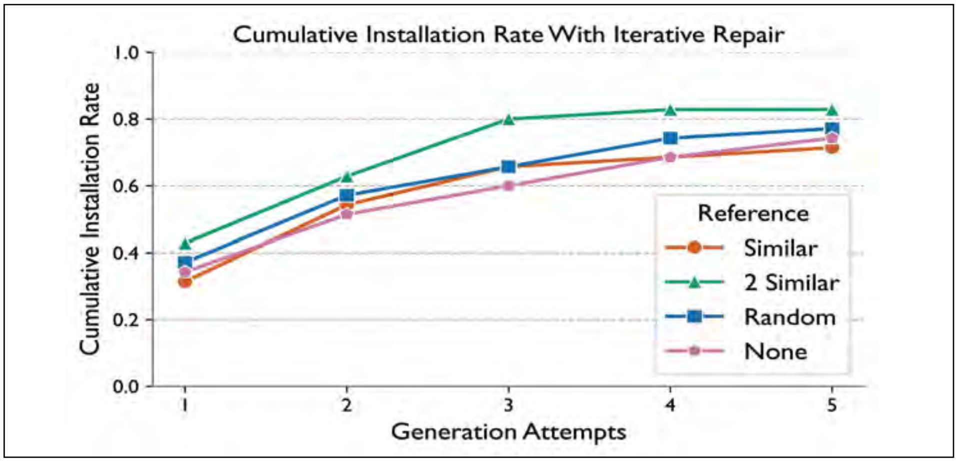


Figure 1. Performance of large language models (GPT-5) at generating valid Spack packages. Providing relevant exemplars as references and structured feedback after failure improves success rates from 20%-80%, showing that LLM-based tools can be used to increase productivity for developers in HPC environments.

My work with HTR centered on applying continuous integration to automate testing and improve software reliability, which led me to connect with members of the Spack package management project at LLNL. I began collaborating with them on a project to optimize resource usage in Spack's testing infrastructure. What started as a summer internship continued through the remainder of my time with INSIEME, and working closely with the team gave me firsthand experience with production-scale software workflows in an HPC environment.

After completing my degree, I joined Livermore Computing, LLNL's HPC center, as a software developer. My work spans a range of efforts across HPC software and scientific computing, with an emphasis on improving developer productivity and software sustainability. I work on projects to improve the performance of large language models in HPC environments, build secure continuous integration systems for development teams, and support community engagement through Spack tutorials and presentations.

Working at a national laboratory has provided a unique environment that combines cutting-edge research with an applied mission. The collaborative culture, interdisciplinary teams, and driven colleagues have been major highlights of my experience. The opportunity to work on problems that support national security and scientific discovery has made the work intellectually challenging and meaningful.

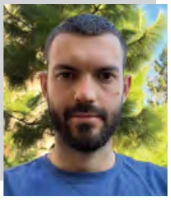
The PSAAP program was an integral step in my career progression. It exposed me early to the intersection of academic research and mission-driven science and provided direct access to world-class computing resources and collaborators. I gained valuable insights into how large research efforts are organized, developed the skills needed to succeed at an NNSA lab, and built relationships that later shaped my career. I chose to work at LLNL because it brings together many of the things I value: challenging technical work, cross-disciplinary collaboration, and real-world impact, making it an ideal place to grow as a developer and researcher.

Alboreno Voci (albovoci@stanford.edu) | Stanford University

Degree in Progress: PhD, Aeronautics & Astronautics, Compressible Multiphase Flows ✦ Advisor: Dr. Sanjiva Lele ✦ PSAAP: 2021 - Present

Research Topic

Multiblock Grids, Task-Based Parallel Computing



Research Responsibilities

My primary focus of research is algorithmic development of multiblock structured grids and its integration to a task-based parallel solver for general purpose compressible fluid dynamics. In addition, my responsibilities include combining the efforts with parallel numerical development in the Stanford PSAAP III Center to make possible computational simulations of laser-induced combustion in a rocket chamber. Our work was part of a joined effort involving both numerical and experimental studies of reliable ignition mechanisms for space propulsion. Fortunately for me, the beginning of my graduate studies aligned with the start of the project. The goal of the PSAAP III Center at Stanford has helped to steer my PhD research and become a part of a large team of researchers. Due to the inherent multidisciplinary nature of the research problem, the Center offers a unique environment which promotes teamwork. This is one of the key advantages of being part of a larger group, leading to new ideas and cumulative growth of knowledge where everyone contributes in different dimensions.

> *Another unique opportunity which the PSAAP Center offered me was an internship at the Los Alamos National Laboratory (LANL) for the duration of a summer quarter.*

Benefits of PSAAP

Another unique opportunity which the PSAAP Center offered me was an internship at the Los Alamos National Laboratory (LANL) for the duration of a summer quarter. The internship has been incredibly valuable to my academic path, since I was able to investigate in-depth problems related to turbulent mixing. Furthermore, my summer in the Lab gave me a perspective of how research and a career in a national laboratory might look like. I feel incredibly fortunate to have had the chance to be part of the PSAAP III Center; I believe I would not have the chance to work with such a big, dedicated team otherwise. It has given me insight into the internals of how an ambitious project comes together and all the gears necessary for progress. Reflecting back, I would urge incoming students to consider joining a PSAAP Center; I believe it offers one of the best pathways in the course of graduate studies.

Joseph Farmer (jfarmer4@nd.edu) | University of Notre Dame

Degree in Progress: PhD, Aerospace and Mechanical Engineering ✦ Advisor: Dr. Ryan McClarren ✦ PSAAP: 2025 - Present

Research Topic

Scientific Machine Learning for Radiation Transport

Research Responsibilities

My research focuses on developing machine learning-based methods for computational radiation transport. I design and train surrogate models that emulate high-fidelity radiation transport simulations, with the goal of improving both efficiency and scalability. In addition, I communicate findings through publications and collaborations, and I mentor students on scientific computing and model development.

Benefits of PSAAP

PSAAP has provided invaluable support through mentorship, collaboration, and community engagement. It has connected me with peers across related disciplines, leading to cross-disciplinary insights that have informed my modeling and helped to broaden the scope and impact of my research.

National Laboratory Experience

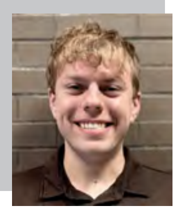
I spent time at Los Alamos National Laboratory as part of a summer internship, where I explored central processing units and graphics processing units performance optimizations for large-scale computational radiation transport simulations. This experience was formative, both technically and professionally. It offered a firsthand view of how research in nuclear science and high-performance computing comes together to address complex, real-world problems. During the internship, I worked on developing algorithms for Monte Carlo particle transport simulations aimed at improving the computational throughput of the solver. We implemented an event-based Monte Carlo approach that leveraged low-level programming to address memory bottlenecks and improve occupancy of modern computer architectures, enabling faster and more scalable simulations.

Collaborating closely with domain experts in nuclear physics and computational science helped me to understand how my work could contribute to accelerating simulation workflows that are central to energy and safety applications. The collaborative, interdisciplinary nature of the lab also helped me gain insight into how and when new methods are evaluated, validated, and deployed in production environments—knowledge that continues to inform my approach to research today.

Overall, the internship was a great experience that has influenced my current research and career trajectory. It solidified my interest in computational physics and has helped to reinforce my goal of pursuing a career where computing methods can be applied to accelerate discovery in physical sciences.

Joseph Marziale (jjmarzia@buffalo.edu) | University at Buffalo

Degree in Progress: PhD, Aerospace Engineering ✦ Advisor: Dr. David Salac and Dr. James Chenz ✦ PSAAP: 2023 - Present



Research Topic

Interfacial Surface Capturing and Dynamics in Immiscible N-Phase Flow Models

Research Responsibilities

My primary technical responsibility has been capturing sharp interfaces of numerical multiphase flow simulations. This starts with deriving both new and legacy interface sharpening source terms and discretizing them on an arbitrary computational grid. To assess robustness, unit tests are written and simulated to quantify the extent of artificial interface smearing under advection, changes in grid topology or spatial distribution of gridpoints, rigid body rotation, and velocity shear. These source terms are integrated into physics-conserving flow models with constituent flux calculation schemes and slope limiters that I am involved in writing and testing. Lastly, after a flow model is validated in convergence and accuracy, case setups of physical problems involving high-curvature interface topologies, e.g., ligament pinchoff, surface instabilities, and droplet entrainment are simulated. The characterization of this phenomenological space is informative of the physics of pre-combustion fuel-oxidizer interactions inside a hybrid rocket motor, the understanding of which is a key objective of the National Nuclear Security Administration-supported Center for Hybrid Rocket Exascale Simulation Technology (CHREST), the group of which I'm a member. On the nontechnical side, I write journal and conference articles; prepare conference, seminar, and in-group presentations; and give research-adjacent lectures to talk about my work, all hopefully to invite interest and improvement.

Benefits of PSAAP

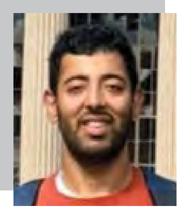
Connecting with NNSA laboratories at meetings held between CHREST and Trilab Sponsor Team liaisons has directly contributed to my growth as a researcher and professional. Thanks to NNSA support, I was granted the opportunity to conduct research at Los Alamos National Laboratory (LANL) this past summer. It was under mentorship by LANL scientists that I came to appreciate the genealogy of interface capturing methods, N-phase generalizations, and slope limiting (some of which originates out of LANL directly); implementation of some of these methods have since directly appeared in my research. I'm sincerely grateful for the experience and I look forward to connecting with LANL scientists in future capacities.

What Students Considering PSAAP Should Know

If the adage that you're the average of the five people you spend the most time around is at least directionally true, then it's a good bet to surround yourself with as many of the most capable researchers on the planet. Joining a PSAAP Center is your opportunity to get on that right away.

Namit Juneja (namitjun@buffalo.edu) | University at Buffalo

Degree in Progress: PhD, Computer Science ✦ Advisor: Dr. Varun Chandola ✦ PSAAP: 2024 - Present



Research Topic

Deep-Learning-Based Surrogate Modeling of Boundary-Layer Dynamics in Hybrid Fuel Combustion

Research Responsibilities

My primary research focus centers on developing deep learning–based surrogate models to approximate the combustion processes in hybrid rocket systems. Specifically, I model boundary-layer phenomena, heat flux, shear stress, and species transport by training neural networks on sparse simulation data derived from high-fidelity simulations. Traditional Partial Differential Equation--based simulations of such quantities are computationally expensive and often limited in temporal and spatial resolution. My work seeks to reduce this burden by constructing surrogate models capable of accurately predicting boundary-layer conditions across a wide range of operating regimes. The methodology involves encoding the governing physics into the network architecture and optimizing the model to respect known conservation laws while preserving generalization to unseen flow conditions. These models are validated against direct numerical simulations to ensure both accuracy and physical fidelity. This approach contributes to advancing hybrid propulsion modeling by enabling faster, data-efficient analysis that can inform system-level simulations and design optimization.

Benefits of PSAAP

Participation in the PSAAP has been instrumental in expanding both my technical and professional capabilities. The program's structure, particularly its emphasis on interdisciplinary collaboration, has provided exposure to advanced simulation frameworks, uncertainty quantification methods, and high-performance computing environments. During my internship at Lawrence Livermore National Laboratory (LLNL), I worked on multi-fidelity Bayesian optimization techniques for computationally intensive models. This experience directly complemented my research by introducing strategies for efficient exploration of high-dimensional design spaces and adaptive data acquisition. The mentorship and collaboration with LLNL scientists have profoundly shaped my approach to research, reinforcing the importance of balancing mathematical rigor with computational efficiency.

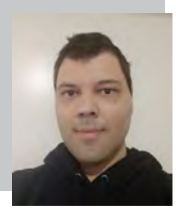
What Students Considering PSAAP Should Know

PSAAP offers a rare environment where computational science, applied mathematics, and physical modeling intersect seamlessly. For students eager to tackle complex problems with real-world impact, it provides not only resources and mentorship but also a community of researchers committed to pushing the boundaries of predictive science.

Dionysios Sema (dsema@mit.edu) | Massachusetts Institute of Technology

Degree in Progress: PhD, Mechanical Engineering and Computation ✦ Advisor: Dr. Nicolas Hadjiconstantinou ✦PSAAP: 2021 - Present

Research Topic



Environment-Adaptive Machine Learned Interatomic Potentials for Materials from Ambient to Extreme Conditions

Research Responsibilities

My research area lies at the interface between machine learning (ML) and materials science. As part of the PSAAP III Center for Extreme Scale Science and Engineering Modeling & Simulation (CESMIX) at the Massachusetts Institute of Technology, my research focuses on developing methods for generating specialized datasets and creating novel architectures for machine-learned interatomic potentials (MLIPs). The aim is to enable the prediction of complex material dynamics under extreme conditions with the overarching goal of advancing predictive multiscale simulation capabilities. These predictions become fundamental inputs for continuum simulations required to develop gas-surface interaction models for hypersonic vehicles.

Benefits of PSAAP

My participation in a PSAAP-funded internship program at one of the NNSA laboratories has significantly shaped my research trajectory and career development. During my summer internship at Sandia National Laboratories in 2022, I was introduced to a research community of experts at the national laboratories. It provided me with a holistic perspective of the key components in my research field and grew my appreciation of how computation can be used most effectively to advance scientific discovery. It also inspired a novel architecture I subsequently incorporated into my PhD thesis. This initial collaboration led to a continued partnership with scientific groups at the national labs which resulted in a second internship at Lawrence Livermore National Laboratory in 2024, where I have stayed on as a collaborator. The focus revolved around leveraging MLIPs to uncover physical phenomena inaccessible through traditional computational and experimental methods. The work conducted during both internships resulted in conference presentations, publications, and contributed to open-source projects that are maintained by the national labs.

These internships provided invaluable hands-on experience and led to novel research topics that also contributed to chapters of my thesis. Furthermore, the exposure to different research communities and the supportive environment at the labs broadened my perspective, making me a more versatile researcher suited for the interdisciplinary challenges of computational science. The collaborations continue to be productive, have significantly enhanced my research capabilities and given me more options for my future career.

Zachary Ryan Atkins (jet1@vols.utk.edu) | University of Colorado Boulder

Degree in Progress: PhD, Computer Science ✦ Advisor: Dr. Jed Brown ✦ PSAAP: 2022 - Present

Research Topic

Grain-Resolving Simulation of Bonded Granular Materials via the Implicit Material Point Method

Research Responsibilities

My research applies the implicit material point method (iMPM) to simulate consolidation experiments used to manufacture mock polymer-bonded explosives. The experiments involve die-pressing heterogeneous prills: clumps of mock high-explosive grains, at a scale of 5-100 micrometers, coated with a polymer binder. Traditional finite-element approaches must resolve those fine grains with meshes, causing mesh distortion and numerical difficulties. MPM avoids those issues by storing material properties on material points which can move through the domain while using a semi-uniform background mesh. Implicit time stepping adds difficulty because each nonlinear step requires solving a linear system assembled from these material points; optimizing memory and compute bottlenecks is critical to reach grain-resolving scales. I lead the development of iMPM in Ratel, the open-source, matrix-free solid-mechanics library our group developed for the University of Colorado (CU) Boulder PSAAP Center. I have implemented material models, designed and optimized algorithms for Compute Unified Device Architecture and Heterogenous-computing Interface for Portability Graphics Processing Units (GPUs), and built workflows to initialize material properties from processed experimental data for simulations with billions of material points across hundreds of GPUs. I have also developed matrix-free contact methods for finite elements that are used in other predictive simulations within the Center.

Benefits of PSAAP

The PSAAP Center provided computational resources, mentorship, and continual feedback from peers, faculty, and laboratory researchers. Before joining the Center, my research was primarily theoretical; the Center's structured goals taught me to engage with the real-world complexities of experimentally driven research. The relationships I built with other researchers across CU Boulder, our collaborating universities, and the NNSA national laboratories will enable me to continue to do high-impact research even after the end of our PSAAP Center.

National Laboratory Experience

I worked with work with leading computational engineering researchers at Lawrence Livermore National Laboratory (LLNL). I learned new simulation tools and software practices and contributed to the Serac project by enabling 2-3× performance improvements through solver optimization. I continue to communicate with my LLNL mentor and plan to work at a national laboratory after graduating.

The Minority Serving Institution Partnership Program (MSIPP) and the Tribal Education Partnership Program (TEPP) develop and enhance educational, research, and workforce capacities, developing a talented network of students prepared for career pathways into the Department of Energy/National Nuclear Security Administration (DOE/NNSA) national laboratories, plants, and sites (NLPS). Through MSI-NLPS partnerships, the programs align investments in educational and research capacities and workforce development, providing opportunities for students and faculty to participate in research activities and internships, strengthening skills and talents in their relevant fields to make immediate contributions to the Nuclear Security Enterprise (NSE).

MSIPP and TEPP support MSIs across the nation, including Historically Black Colleges and Universities and Tribal Colleges and Universities, investing in a portfolio of student enrichment programs, curriculum development, and STEM outreach programs. The mission of the programs to enhance educational and research capabilities while building a robust workforce is met through four main objectives:

1. Strengthen and expand the capacities of institutions of higher education.
2. Target collaborations and increase interactions between institutions of higher education and DOE/NNSA laboratories, plants, and sites.
3. Increase the number of students who graduate with STEM degrees relevant to NNSA mission areas.
4. Increase the number of students hired into the NSE's technical and scientific workforce.

Investing in the Future of the Nuclear Security Enterprise | Minority Serving Institution Partnership Program

Program Office: Betsy Snell, Federal Program Manager; Suraya Bair, Communications Specialist (Contractor)

The National Nuclear Security Administration's (NNSA) partnership programs, the Minority Serving Institution Partnership Program (MSIPP) and the Tribal Education Partnership Program (TEPP), play a vital role in advancing the agency's priorities and developing a mission-ready workforce. Through strategic collaborations with institutions of higher education (IHE), these projects strengthen educational capacities, expand access to technical research opportunities, and build lasting pathways between academia and the national laboratories, plants, and site (NLPS) facilities.

MSIPP and TEPP share a unified goal: to develop partnerships that enhance research capabilities, challenge students with real-world experiences, and prepare talented students to address the evolving challenges of national security. Guided by four core objectives—building capacities at IHEs, developing collaborations with NLPS facilities, growing graduates in STEM disciplines aligned with the NNSA needs, and increasing the number of qualified hires—the partnership programs ensure that every investment yields measurable outcomes in workforce readiness, institutional growth, and sustained collaborations across the Nuclear Security Enterprise (NSE).

Measuring Impact: Partnerships, Pathways, and Progress

The partnership programs have demonstrated measurable growth in collaborative research and workforce outcomes. Currently, 32 active awards support projects across 50 IHEs, including Minority Serving Institutions and Tribal Colleges and Universities. These collaborations have expanded research capacities and strengthened technical education while establishing enduring relationships between academic partners and national (LPS) facilities.

Engagements show strong returns through internship and employment outcomes. In 2025, national LPS partners reported the highest number of interns to date, reflecting a growing interest in careers within the NSE. Among these, Kansas City National Security Campus achieved a remarkable 95% intern-to-full-time hire conversion rate, underscoring the success of experiential learning as a direct pathway to meeting workforce needs and advancing careers within the NSE.

The projects also served as catalysts for innovation, with new technologies emerging from joint research initiatives. For example, Argonne National Laboratory (ANL) in collaboration with the Consortium on Sensing, Energy-efficient Electronics, Photonics with 2D Materials and Integrated-Technologies (SEEP-IT) advanced technical methods culminating in multiple registered copyrights on novel techniques in applied physics. Technology developed through SEEP-IT involves a machine-learning (ML) based image processing technique that improves the quality of Pulse Infrared Thermography (PIT) images, enabling the detection of microscopic material flaws for Pulse Infrared Thermography (PIT) nondestructive evaluation of materials.

Dr. Alexander Heifetz, Principle Electrical Engineer at ANL states, "With support from MSIPP and in collaboration with university consortia, Argonne scientists have developed ML algorithms detecting and segmenting material defects in PIT images. Through software licensing process, this enables Argonne to support domestic private industry and U.S. government agencies." These outcomes illustrate the tangible achievements when academic ingenuity aligns with NNSA's mission-driven research and development priorities.

National LPS facility partners also leverage collaborations with IHEs to expand academic inquiry at institutional research facilities. This generates new data and insights, with results and findings subsequently brought back to the facilities. As an example, the Consortium for Education and Research in Electronics for Extreme Environments (E3C), involving Sandia National Laboratories, University of Texas El Paso, University of New Mexico, and North Carolina Agricultural & Technical State University, provides a research-based ecosystem. Each are fabricated at the IHE and then used for fabricating electronic devices and tested for electrical characteristics after irradiation. Samples and test results were shared with at the partnering NLPS facility, where additional characterization tests were performed. Ultimately, utilizing multiple research facilities streamlines research outcomes and provides valuable practical experience for student researchers.

Partnership Programs: Fostering Workforce and Innovation

Strategic partnerships between NLPS facilities and IHEs are vital, fostering academic growth, generating critical research, and providing experiential learning for students, resulting in high-quality outcomes. The NNSA's MSIPP and TEPP programs are crucial for developing a skilled, innovative workforce. These partnerships provide technical opportunities and build career pathways, preparing students for national security challenges.

These examples represent a portion of the strategic value and national impact from collaborations within the partnership programs. For further insight into ongoing projects visit the website.

Boosting National Security: Partnership Success in Radiation Control Workforce Development | Nuclear Security Enterprise Workforce Pipeline | Program Office: Betsy Snell, Federal Program Manager; Suraya Bair, Communications Specialist (Contractor)

The National Nuclear Security Administration (NNSA) faces a complex landscape of evolving global challenges and advancing nuclear threats. Meeting these demands requires a new generation of skilled technical workforce, which includes radiation professionals. To build this talent pathway, the Enhancing the National Security Enterprise Workforce Pipeline (ENSEWP) project—a collaboration between Augusta Technical College (ATC) and the Savannah River National Laboratory (SRNL)—creates hands-on training pathways, preparing students to strengthen the nation's security infrastructure.

ENSEWP is funded by the NNSA's Minority Serving Institution Partnership Program through the Community and Junior College Trade Occupation Program. The Program's goal is to build sustainable relationship between national laboratory, plants, and site facilities and community colleges. ENSEWP meets this goal by increasing student and faculty awareness of SRNL's mission and workforce needs, fosters opportunities for technical staff to contribute to research, and strengthens connections between academic communities and SRNL staff. Through this partnership, ATC, a unit of the Technical College System of Georgia, builds a skilled workforce through career-advancing credentialing.

Over the last two years, ENSEWP expanded ATC's curriculum and training capacity, preparing students to enter SRNL's process operator apprentice program. In addition to supporting five student internship opportunities at SRNL, ATC now serves as an official offsite training center for the program and has successfully graduated three cohorts of students.

Figure 1. Two Augusta Tech and 2 College of Southern Nevada students are interns at SRNL working on NNSA missions (mobile melt consolidate and mobile plutonium facility).

Figure 2. Seven students and two staff from Augusta Technical College toured SRNL in early June.

"This project bridges critical needs and skill gaps," says John Tucciarone, principal investigator for ENSEWP. "Through Augusta Technical College's School of Engineering Technology, the project provides an academically sound, industry-based curriculum that meet the needs of both industry and government for operations and maintenance personnel. By utilizing a school-to-work environment, we are preparing for the next generation of nuclear professionals to address the anticipated shift in the technical workforce."

Through the implementation of ENSEWP, SATC executes recruitment, planning, and student placement aligning with internship needs while mentors and experts from SRNL guide the students in applied goals. This shared leadership drives a 68% student retention rate and fosters relationships with other government agencies and industry partners.

Internships provide students with valuable hands-on experience, exposing them to real-world challenges on nuclear security projects. "Students are able to fill roles on programs through a structured selection process and places them in challenging assignments," says Mr. Tucciarone. "They get a 'look behind the curtain' at the opportunities available within the site, often within a semester of graduation."

ATC students have applied their skills to real-world projects and tested new techniques in plutonium disposal and data analysis. This work strengthens technical proficiency and positions students competitively for full-time roles across the enterprise. ATC student Jonathan White interned at Savannah River National Laboratory, where he leveraged his specialized radiation expertise contributing directly to critical research, demonstrating both technical mastery and meaningful impact.

"During my time as an intern, I earned my associate's degree from Augusta Technical College," Jonathan shares. "After being exposed to projects at Savannah River National Laboratory, I decided to continue my education to pursue a bachelor's degree. Learning about physics, chemistry, and metallurgy sparks a deeper interest in the nuclear industry and inspires me to learn more about the field."

Jonathan participated in research at SRNL's Modular Facilities Complex, working on the Mobile Plutonium Facility and the Mobile Melt-Consolidate (MMC). During his internship, Jonathan collected and analyzed data from a melt test conducted by MMC. The findings from Jonathan's internship directly contributed to NNSA's mission and were streamlined for broader use across the National Security Enterprise with aligned research goals.

The ENSEWP project ultimately opens clear pathways to student success within the Nuclear Security Enterprise, providing students with a seamless transition from the classroom to the workforce.

Javier Moscoso Cabrera (javier.moscoso1@upr.edu) | University of Puerto Rico at Mayagüez

Degree in Progress: BS, Electrical Engineering ✦ Advisor: Dr. Eduardo Ortiz Rivera ✦ MSIPP: 2024 - Present

Research Topic

Cybersecurity in Utility Scale Storage and Cybersecurity with Distributed Energy Resource

Research Responsibilities

My focus during the summer at the National Renewable Energy Laboratory (NREL) centered around two projects related to cybersecurity in utility scale storage and cybersecurity with distributed energy resource implementation in disadvantaged communities.

Benefits of MSIPP

Through the internship, I familiarized myself with cybersecurity because it was not part of my field of study. It motivated me to pursue a master's degree in electrical engineering. It also motivated me to be mindful of the opportunities that are in the world of research and energy industry and to grow my network. The experience gave me the opportunity to test myself within a national laboratory environment. I am motivated to continue my professional and academic career and look forward to contributing in the path towards energy transformation.

Research and Career Influence

This program gave me the opportunity to make a dream come true: work at NREL (Figure 1). I have been using tools developed at NREL and it was an honor to have the opportunity to meet and work alongside part of the teams responsible for developing such tools. To be among leaders in the energy research and industry world was unforgettable and an experience I will always cherish and never forget. My time at NREL filled me with motivation to face and overcome the greatest challenges. Being able to meet and test myself among some of the world's best in the energy field was amazing, and I will always treasure having the opportunity to represent Puerto Rico and highlight Puerto Rico's capabilities contributing to the future of energy.

Figure 1. Cabrera at the National Renewable Energy Laboratory in Golden Colorado.

Luis Garza (lgarzagarc@miners.utep.edu) | The University of Texas Rio Grande Valley

Degree in Progress: MS, Electrical Engineering ✦ Advisor: Dr. Paras Mandal ✦ MSIPP: 2022 - Present

Research Topic

Enhance the Cybersecurity, Reliability, and Resilience of Cyber-Physical Systems Through the Integration of Artificial Intelligence and Other Innovative Technologies

Benefits of MSIPP

During my experience in the program, I have gained highly relevant skills that have been instrumental in carrying out research. These include analytical skills, the ability to formulate and solve complex problems, presenting research findings effectively, conducting experiments, and analyzing results. Additionally, I have acquired technical tools and techniques for simulating power systems and network communication. I have also deepened my understanding of how the future energy landscape is evolving and the key challenges we need to address to ensure a smooth transition to the smart grid.

Research and Career Influence

Before joining the MSIPP, I didn't have a clear goal for what I wanted to achieve with my degree in electrical engineering. However, after joining the program, I discovered a career path I am truly passionate about. The program not only helped me uncover this passion but also provided the guidance and tools to pursue my newly discovered academic and professional goals. The experience shaped my interest in the fields of cybersecurity, cyber-physical systems, and critical infrastructure resilience. The discovery of this career path greatly motivated me to learn as much as possible and prepare myself to achieve my goals. All the experiences I've had through the program have helped me grow in various ways, and today, I wouldn't have achieved what I have or become the person I am without them.

What Students Considering MSIPP Should Know

My advice is to take every opportunity to learn something new and step outside your comfort zone. Each time you do, you'll discover something new about yourself.

National Laboratory Experience

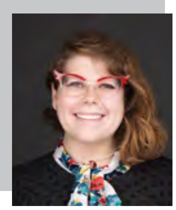
I have conducted research with Sandia National Laboratories over the past two years, both during the summer and as part of year-round projects. Additionally, during some of my projects at Sandia, I had the privilege of collaborating with engineers from other national laboratories, including Pacific Northwest National Laboratory, Idaho National Laboratory, and Oak Ridge National Laboratory, as well as working with a project manager from the Department of Energy, from whom I have learned a lot.

Kristen Hallas (Kristen.hallas01@utrgv.edu) | The University of Texas Rio Grande Valley

Degree in Progress: PhD, Mathematics and Statistics with Interdisciplinary Applications ✦ Advisor: Dr. Jianzhi James Li ✦ MSIPP: 2022 - Present

Research Topic

Manufacturing with Material Extrusion, Laser Powder Bed Fusion, and CNC Machining for Surface Treatments



Research Responsibilities

I have focused on projects ranging from supercomputing system analysis to applying machine learning to materials science applications. I've gained hands-on experience developing technology for self-driving labs; utilizing robot arm technology.

Benefits of MSIPP

My consortia has helped me gain proficiency in programming languages like Python, R, and MATLAB, which are critical for leveraging artificial intelligence and machine learning in any domain. The models I'm designing in these languages will inform the autonomy of our robotic researchers. I'm also well-versed in C++, supporting efficient robotics engineering; G-code, and slicer software like Cura for three-dimensional printing. To handle the massive data generated in research, I've deployed many machine learning models at scale on high-performance computing (HPC) systems, most recently at Lawrence Livermore National Laboratory (LLNL), which is home to El Capitan, the first NNSA exascale system and the fastest supercomputer in the world.

New Contacts, New Opportunities

I've had the honor to collaborate with three prestigious national laboratories. At the start of my MSIPP experience, I joined Oak Ridge National Lab as a Security & Information Engineering Intern through the Department of Energy Omni Technology Alliance. It was my first exposure to HPC, which was amazing, given that Frontier at Oak Ridge was the fastest supercomputer in the world at that time. There, I designed an interactive Python visualization that explores the power and cooling trends of the HPC system nodes of Summit, in relation to their physical location in the data center. I was also invited to Argonne National Lab, working as a Technical Research Aide in the Mathematics and Computer Science Division. I learned more about HPC and software development, improving a Node.js app that renders visual analytics about the performance of simulated HPC networks.

At LLNL I developed a machine learning model for quickly generating equation-of-state tables for mixtures of materials at new mixture compositions. I also contributed to two Laboratory Directed Research and Development projects: developing algorithms for machine vision and robotics control for ARMOR (Advanced Robotics for Materials and Manufacturing Optimization and Research) and applying these algorithms to accelerate discovery for Autonomous Alloy Prediction and EXperimentation.

Jonathan White (jonathan.white@srnl.doe.gov) | Augusta Technical College

Degree in Progress: AAS, Nuclear Engineering Technology ✦ Advisor: Dr. John Tucciarone ✦ MSIPP: 2025

Research Topic

Modular Facilities Complex: MPF and MMC

Research Responsibilities

My responsibilities were multi-disciplinary in nature. My work ranged from assistance with Electrical and Instrumentation (E&I) technicians, to facility and program operations with management personnel. Each employee at the Savannah River National Laboratory's Modular Facilities Complex proved to be a wealth of information with their countless years of experience.

New Contacts, New Opportunities

During my internship, I executed independent temperature data analysis and rapid data processing, constructed several graphs and figures compiling the data, and presented my findings to the project's design authority engineer, senior scientist, and program manager. These findings and this presentation were shared with NNSA's Office of Material Management and Minimization, and international transition partners.

National Laboratory Experience

MSIPP has benefited me greatly by exposing me to the exceptional work performed daily at the Modular Facilities Complex and at the Savannah River Site (SRS). The SRS is well equipped to receive the talented graduates of Augusta Technical College and other area technical schools, and said schools are well equipped to educate students in preparation for entry-level technical careers at SRS. The MSIPP internship program serves as a bridge between the academic world and the workforce, allowing students to gain invaluable experience in numerous technical fields while still pursuing their education.

What Students Considering MSIPP Should Know

Students considering the MSIPP should know that the internship provides an experience that is both highly attractive to future employers and immeasurably valuable to the student. Because of my internship experience with MSIPP, I was able to receive fair compensation for my time and research, experience the work of Department of Energy contractors at SRS, and make various professional connections through multiple networking opportunities. MSIPP has undoubtedly influenced me to continue my education within the nuclear industry while also laying the groundwork for a rewarding career.

NNSA Impact Internship Program | Federal Program Manager: Alexander Godinez-Robinson, Office of Management and Budget, Learning and Career Management

Figure 1. Interns from the Class of 2025-2026 at a Leadership Luncheon with Former Acting Administrator Teresa Robbins and Principal Deputy Administrator Jim McConnell.

Figure 2. Class of 2025-2026 Orientation Group Photo

The NNSA Impact Internship Program (IMPACT) (formerly MSIIP) develops the next generation of scientists and professionals to support the missions of the National Nuclear Security Administration (NNSA). NNSA-IMPACT offers hands-on training through internships and professional development opportunities, exposing participants to challenges unique to the Nuclear Security Enterprise (NSE). The program is administered by the Oak Ridge Institute for Science and Education and is managed by the NNSA Office of Management Budget, Learning and Career Management.

For the Class of 2025-2026, NNSA-IMPACT welcomed 201 participants on June 5, 2025. The cohort is comprised of 5 associates, 125 undergraduates, 40 graduate level, and 31 PhD level participants. The cohort included students representing 83 minority serving institutions across 22 states nationwide. Interns supported mission-aligned projects at national laboratories, plants and sites and at NNSA Headquarters in Washington D.C. Following the completion of the summer internship, 151 interns continued their projects through year-long appointments.

The program saw a significant increase in applicants for the Class of 2026-2027, as well as increased interest from mentors within the NSE. Applications opened on August 1, 2025, and closed on October 26, 2025. This cycle attracted 794 eligible candidates - a 46% increase in candidates from the previous year. Interns selected for this cohort will begin their appointments in June 2026. The selected participants pursue a variety of majors, including cyber security, engineering, social sciences, law, and computer science.

The interns will gain professional experience unique to the NSE by working alongside leading scientists, engineers, and subject matter experts. Through hands-on assignments, they will develop both technical and professional skills in real-world settings, supported by structured professional development, training opportunities, and mentorship. These experiences help guide interns towards becoming future experts in their respective fields.

NNSA-IMPACT remains a highly competitive program, attracting and retaining the nation's top talent.

You can learn more about the program at https://orise.orau.gov/NNSA-IMPACT/.

The Academic Programs also include the Stewardship Science Graduate Fellowship (SSGF), Laboratory Residency Graduate Fellowship (LRGF), and Computational Science Graduate Fellowship (CSGF) programs (jointly sponsored with the DOE's Office of Science). These three programs support PhD students in areas of interest to stockpile stewardship. SSGF and CSGF provide a yearly stipend, tuition, fees, lab practicums, and an academic allowance. The LRGF program extends those benefits to at least two longer practicums and encourages fellows to pursue their thesis research in collaboration with laboratory scientists. This Annual highlights a select few alumni and students from each fellowship. For more information about these programs, please visit http://www.krellinst.org/fellowships.

Alicia Magann (abmagan@sandia.gov) | Sandia National Laboratories, 2019 - Present
Degree: PhD, Chemical Engineering ✦ **CSGF:** 2017 - 2021, Princeton University

My PhD advisor, Herschel Rabitz, often told me that research is about "following your scientific instincts." The Department of Energy Computational Science Graduate Fellowship (CSGF) gave me the independence, confidence, and flexibility to do exactly that. I was able to go after high-risk ideas, fail often, and succeed sometimes too.

Midway through my PhD, I became interested in quantum computing, which was something new to me. Following my advisor's philosophy, I embraced my curiosity and pursued a CSGF program summer practicum at Sandia National Laboratories (Sandia) in 2019 on the subject. I never looked back. After a fantastic summer, I stayed on at Sandia until I completed my PhD in 2021, and then I joined Sandia as a Truman Postdoctoral Fellow. Today, I am a Senior Member of the Technical Staff in Sandia's Quantum Computer Science department.

Without the CSGF program, I doubt I would have come to work at a national lab. I had only previously imagined career opportunities in academia or industry. I also would not have had the opportunity to try out quantum computing research for a summer, an experience that ended up transforming my entire technical focus.

Throughout my six years at Sandia, I have been motivated and fulfilled by the collaborative research environment at the lab, the high caliber of the researchers I get to work with here, and the focus on making sure our work stays targeted towards real-world and mission impacts. It is always inspiring to see the way Sandia scientists and engineers step up and come together to take on big, challenging problems—like the many we face today in quantum computing.

Quantum computing is an emerging technology with the potential to impact multiple Department of Energy and National Nuclear Security Administration mission areas, e.g., by enabling otherwise-intractable simulations of molecules and materials.

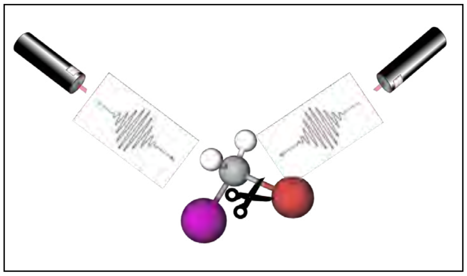


Figure 1. Cartoon depicting the premise of controlling molecular transformations with lasers. Here, two lasers are utilized to drive dynamics in a polyatomic molecule such that a selected chemical bond is broken. At Sandia, we are laying the groundwork for future quantum computer simulations of these types of controlled molecular processes, which could significantly advance our capabilities for discovery science in this domain.

Without the CSGF program, I doubt I would have come to work at a national lab. I had only previously imagined career opportunities in academia or industry. I also would not have had the opportunity to try out quantum computing research for a summer, an experience that ended up transforming my entire technical focus.

For example: it is notoriously difficult to simulate the behavior of molecules and materials that are acted on by strong lasers because of the rapid, complicated transformations that lasers can induce (e.g., chemical reactions, phase transitions). The transformations that occur can depend on precise coordination between the laser and the quantum-mechanical degrees of freedom it acts on. Accurately capturing this coordinated quantum dance in simulation is only possible for very simple systems.

If we could understand and control these transformations, this could yield new insights about nature and inspire new technological possibilities. To this end, quantum computers could extend the reach of our simulation capabilities towards molecular and materials systems of greater scientific interest and engineering relevance.

In line with this prospect, I work with colleagues in Sandia's Quantum Algorithms and Applications Collaboratory (QuAAC) to lay the groundwork for performing quantum computer simulations to study the control of molecular dynamics using lasers, as depicted in Figure 1. Although current quantum computers are too small to execute these simulations today, we are working through the algorithm details and analyzing the resource requirements for performing these simulations in the future.

My work with Sandia's Quantum Performance Laboratory (QPL), meanwhile, is focused on the development of frameworks for controlling and calibrating quantum logic gates, the building blocks of quantum computations. If we can't calibrate quantum logic gates in a way that scales, we won't be able to scale up quantum computers to eventually simulate molecules and materials!

Quantum logic gates typically involve just one or two quantum bits, or "qubits". In principle, this is tractable to simulate or even study analytically. But challenges arise as quantum computers scale up: we simultaneously have more control tasks to manage, more sources of noise, and less confidence in our intuition and our models. At Sandia, our work focuses on utilizing optimization and machine learning to develop adaptive, lightweight, and sample-efficient methods for calibrating quantum computers, targeting solutions that are both performant and scalable into the future.

Tom Gade (gadex007@umn.edu) | **University of Minnesota**

Degree in Progress: PhD, Plasma Physics ✦ Advisor: Dr. Robert Hager ✦ CSGF: 2022 - Present

Research Topic

Gyrokinetic Modeling of Plasma Turbulence and Its Self-Consistent Interaction with Magnetic Islands in Toroidal Geometry

Research Responsibilities

Within the field of magnetic confined fusion, how magnetic islands and turbulence mutually influence one another's development in a self-consistent way remains an open question. Answering this question requires solving stiff numerical systems over long-time scales, and as such it requires state-of-the-art stable numerical methods and efficient, scalable computing algorithms. My current research leverages the X-Point Gyrokinetic Code (XGC), a powerful tool for investigating this phenomenon, on NERSC's Perlmutter to simulate toroidal fusion plasmas, including fully electromagnetic non-linear physics throughout the whole plasma volume to study how turbulence evolves alongside magnetic islands and how they mutually influence one another's development. XGC is highly scalable and able to leverage a large portion of Perlmutter. My simulations have used up to 256 compute nodes and, in total, 10,000 graphics processing unit node hours and 35,000 computer processing unit node hours this year alone.

Benefits of CSGF

The Computational Science Graduate Fellowship (CSGF) program has pushed me to pursue areas of study I might not have explored otherwise and has provided the resources to do so. Through CSGF, I have been encouraged to pursue education in computer science, formal mathematics, and numerical methods, in addition to my major in plasma physics. By attending supercomputing conferences, funded by the CSGF, I have stayed connected with emerging technologies in high-performance computing and further developed hands-on skills with frameworks such as OpenMP, MPI, CUDA, and NVSHMEM. Moreover, through the professional network and connections provided by the program, I established a relationship with my current advisor at the Princeton Plasma Physics Laboratory (PPPL).

National Laboratory Experience

In 2021, prior to my involvement with CSGF, I participated remotely in the PCSRI internship at Los Alamos National Laboratory, where I developed an MPI- and CUDA-accelerated system of equations solver. This exposed me to numerical methods in linear algebra and provided an opportunity to apply my recently learned High Performance Computing skills in a real-world context. In 2023, I completed a practicum at PPPL, where I gained experience working with a high-performing interdisciplinary team of scientists and developers. It was deeply impactful and broadened my perspective to include the possibility of working at a DOE laboratory.

Miruna Oprescu (amo78@cornell.edu) | Cornell University

Degree in Progress: PhD, Computer Science, Machine Learning ✦ Advisor: Dr. Nathan Kallus ✦ CSGF: 2021 - Present

Research Topic

Reliable Machine Learning for Causal Inference

Research Responsibilities

My research focuses on developing reliable machine learning methods for understanding cause-and-effect relationships in complex, real-world systems. These questions are central to fields such as medicine, environmental science, scientific research, and Artificial Intelligence-assisted decision-making, which are high-stakes settings where randomized experiments are often infeasible. I design algorithms that can disentangle causation from correlation in large, noisy datasets by combining tools from statistics, optimization, and reinforcement learning. Much of my recent work focuses on two key settings: spatiotemporal data, where interventions evolve across space and time, and weakly identified systems, where causal effects must be inferred from incomplete information. This involves building mathematical models, deriving theoretical guarantees, and validating them through both simulations and real-world analyses.

Benefits of CSGF

The Computational Science Graduate Fellowship (CSGF) has given me the freedom and support to pursue interdisciplinary work combining computer science, statistics, and domain science. Through the program's introduction to high-performance computing, I gained the tools to scale my methods to large, noisy datasets, accelerating my research and broadening its impact. Beyond funding, the CSGF community has been an invaluable source of mentorship and collaboration. Interacting with fellows and alumni from diverse disciplines has helped me frame my work within a broader scientific context and communicate effectively across fields. The fellowship's flexibility has also allowed me to pursue projects that align with my long-term goal of building trustworthy and robust machine learning systems.

National Laboratory Experience

During my practicum at Brookhaven National Laboratory, I worked with the Computational Science Initiative on developing methods to estimate the causal effects of interventions in spatiotemporal settings. Our research examined how events such as wildfires influence air quality and health outcomes over time and across regions. Collaborating with atmospheric and computational scientists helped bridge machine learning and domain expertise, producing models that were both rigorous and scientifically grounded. The experience deepened my understanding of how causal inference supports large-scale environmental and public health research and strengthened my commitment to applying reliable machine learning methods to real-world challenges.

Ryan Childers (ryan.r.childers2.civ@us.navy.mil) | U.S. Naval Research Laboratory, 2023 - Present
Degree: PhD, Theoretical Plasma Physics ✦ **LRGF:** 2019 - 2023, University of Nevada Reno

I received the Laboratory Residency Graduate Fellowship (LRGF) in 2019 as a PhD candidate in theoretical plasma physics at the University of Nevada, Reno under Dr. Alla Safronova. At the time I couldn't comprehend just how significantly this prestigious fellowship would alter the course of my career. Not only would it support me through the academic gauntlet of graduate school, but it would provide me with the best resources to cultivate the scientific acumen and develop the technical skill set necessary for a career in world-class scientific facilities.

I am currently a Research Physicist in the Plasma Physics Division at the U.S. Naval Research Laboratory (NRL). My research focuses on the theoretical study of matter under extreme conditions, with a specialization in computational modeling of atomic processes in mid-to-high-temperature plasmas. As part of the NRL Karle Fellowship, named after distinguished NRL scientists Isabella and Jerome Karle, my research comprised the development of "hybrid" atomic models to advance diagnostic and simulation capabilities critical to Navy fleet readiness and national security missions. These models treat highly-detailed atomic physics with statistical techniques to predict and describe the interaction of complex plasma systems in a computationally tractable fashion. Such dynamic atomic systems give rise to radiative signatures (Figure 1) with a wealth of information on the micro- and macro-level mechanisms critical for understanding atmospheric, space-based, and high-energy-density (HED) plasmas, directed energy, and fusion sciences.

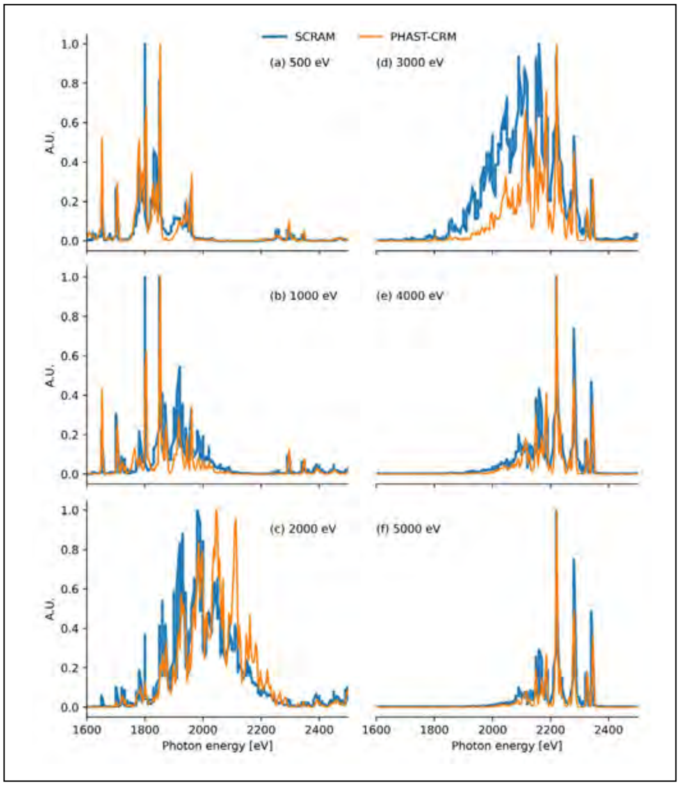


Figure 1. Comparison of synthetic krypton spectra produced by the NRL PHAST-CRM code (orange) and SCRAM[1] (blue) for a range of bulk plasma electron temperatures. PHAST-CRM is a hybrid atomic collisional-radiative model under development at NRL.

At NRL, I provide theoretical and computational support on multiple projects related to hypersonics and laser-driven shock physics. I am the principal investigator of a third-year project investigating the air plasma chemistry of hypersonic flight environments, where I collaborate on theoretical and experimental efforts to model and benchmark the plasma chemistry around high-altitude, hypersonic re-entry vehicles. My duties also include running large-scale multi-physics simulations on the Department of Defense high-performance computing systems. These simulations support cross-agency collaboration investigating laser-driven shock physics in aerospace material to enhance the X-ray survivability of space-based assets and strategic flight missions.

Thanks to the LRGF, I had the pleasure of performing two research residencies at Sandia National Laboratories under the supervision and mentorship of Drs. David Ampleford and Stephanie Hansen.[1] My residency research focused on the development of a Monte Carlo radiation transport code to model the production and transport of x-ray radiation in a Magnetized Liner Inertial Fusion plasma on the Sandia Z-machine.[2] The LRGF afforded me the otherwise inaccessible opportunity to work closely with the world-class experimental and theoretical expertise of the Sandia pulsed power and HED plasma personnel. This inimitable experience enriched my knowledge of atomic plasma theory and nurtured the development of cutting-edge skills in numerical modeling of atomic plasma processes.

The professional relationships established during my LRGF residencies granted me unparalleled insight into the community of world-leading scientific research and, along with the advanced technical skills, better prepared me for collaborative research on a professional level. Most importantly, though, the relationships fostered in the community of wonderfully driven and delightfully brilliant individuals of the National Nuclear Security Administration graduate fellowships, managed by the Krell Institute, are lifelong connections that strengthen the national security professional networks. I will be forever grateful for the LRGF, its staff, and my various mentors for these opportunities and for what they have done for me in my early career.

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[1] S.B. Hansen et al., "Hybrid Atomic Models for Spectroscopic Plasma Diagnostics," HEDP 3, pp. 109-114 (2007).

[2] R.R. Childers et al., "Implementation of a Novel Monte Carlo Radiation Transport Code for Modeling Nonthermal Fe Kα Line Generation in a Dense MagLIF Plasma," IEEE Trans Plasma Sci. 52, 10, pp. 4886-4894 (2024).

Raimi Clark (raimi.clark@ttu.edu) | Texas Tech University

Degree: PhD, Electrical Engineering (December 2025) ✦ Advisor: Dr. Andreas Neuber ✦ LRGF: 2023 - 2025

Research Topic

Electron Field Emission from Vacuum Insulation

Research Responsibilities

Pulsed power is an enabling technology for the study of extreme states of matter and inertial confinement fusion. My research focuses on advancing pulsed power technology so that future accelerators can access new experimental regimes in these areas. Most of my work has been directed towards understanding anode-initiated vacuum surface flashover, which is an interface breakdown problem that presents a significant obstacle to the delivery of high-power pulses from a liquid-immersed generator to a vacuum load. I have developed experimental platforms to probe the initial conditions of a developing flashover, enabling the first direct measurements of electron field emission from a bulk insulator, as well as confirmation of the involvement of insulator species in the nascent plasma. I have also contributed to the development of advanced diagnostics, like a 4 GHz multi-pixel fiber-array framing camera, which will see ongoing use by other researchers at the labs. My day-to-day responsibilities include anything from computer-assisted design (CAD) modeling, troubleshooting high voltage systems, developing post-processing codes, performing electromagnetic simulations, digging into the literature, or whatever else is needed to tackle problems at the cutting-edge of pulsed power.

Benefits of LRGF

The fellowship provides financial support, but more so a scientific and professional journey. The program review, for instance, is a rewarding experience that also serves as great practice for tailoring scientific communication to a technically diverse audience. Through residencies and the program review, the fellowship has introduced me to an incredible network within the national laboratories and at universities across the country. I gained relationships with mentors and colleagues—current and future leaders and innovators in their respective fields—that I will carry throughout my career.

What Students Considering LRGF Should Know

The residencies were tremendous research experiences, which enabled access to top-notch facilities and brilliant researchers in my field. What I enjoyed even more, though, was the opportunities for learning outside of my specialization. During my residencies, many times a week I participated in interesting seminars and facility tours that really helped contextualize my work within the broader scope of interests in the National Nuclear Security Administration complex. Experiencing that culture of shared exploration and learning was a unique and valuable experience, and it has provided me with a much better understanding of the “big picture” than I think the average PhD student has a chance to develop.

Josh Luoma (jjl364@cornell.edu) | Cornell University

Degree in Progress: PhD, Applied Physics, Laser-Plasma Physics ✦ Advisor: Dr. Gennady Shvets ✦ LRGF: 2023 - Present

Research Topic

Relativistic and Quantum Effects in Laser-plasma Interactions

Research Responsibilities

My research explores how foam targets can be used to convert laser energy into radiation sources like high-energy ions, gamma rays, and antimatter. Foams are interesting targets because at high laser intensity the opaque, solid-density structures of the material transition into a transparent plasma due to relativistic phenomena. This process takes place on timescales similar to the laser pulse duration, meaning the physical properties of the foam play a large role in the overall efficiency of the radiation source. I make extensive use of computational simulations to address how the properties of foams impact radiation source efficiency. I can use simulations to explore new target concepts, and I also provide support for existing experiments conducted on the OMEGA-EP facility.

Benefits of LRGF

The Laboratory Residency Graduate Fellowship (LRGF) provides an incredible opportunity to blend the vast experimental and computational capabilities of NNSA laboratories with the academic flexibility of universities. As part of LRGF’s residency program, I have been able to work on-site at Lawrence Livermore National Laboratory (LLNL) which has accelerated my ability to study and understand complex laser-target interactions. LLNL has multiple on-going experiments related to my research, enabling crucial validation of my simulations. Additionally, I have acquired an extensive simulation dataset by utilizing the supercomputing resources at LLNL to probe a wide range of target designs.

National Laboratory Experience

I have participated in two residencies at LLNL that have enriched my thesis research. While computational simulations encompass the bulk of my thesis, the residency program has provided avenues to directly contribute to experiments. My first opportunity started with a hands-on experiment on the Titan laser at LLNL’s Jupiter Laser Facility, where I learned several diagnostic techniques widely used to study high-intensity laser-plasma environments. Months later, I shadowed an experiment on OMEGA-EP investigating 3D-printed foam targets. These experiences ultimately resulted in an opportunity to lead a new experimental campaign in FY2026, where I will run laser shots aimed at validating the theories developed out of my simulations. LRGF has enabled me to leverage computational and experimental tools through the residency program, helping me develop a comprehensive understanding of laser-target interactions.

Thomas Saller (tgsaller@lanl.gov) | Los Alamos National Laboratory, 2015 - Present
Degree: PhD, Nuclear Engineering ✦ **SSGF:** 2010 - 2014, University of Michigan

I was a Stewardship Science Graduate Fellowship (SSGF) fellow from 2010 to 2014 while getting a PhD from the University of Michigan. I was lucky enough to study nuclear engineering under Professors Ed Larsen and Tom Downar, both well respected in the field of neutron transport. In my program, most graduate research assistants spent a substantial amount of time working on projects that funded their separate dissertation research. The SSGF gave me the freedom to spend more time on my own research, a privilege I am deeply grateful for. This gave me the freedom to struggle, meaning I could attempt more ambitious research without worrying about a two-year research project deadline. A month spent on a dead-end was tolerable, and those "wasted" months often led to an unrelated breakthrough. During all of this, my knowledge of the mathematical basis of neutron transport grew, which has helped me significantly in my current role.

The SSGF helped me in many other ways. It funded a visit to Japan to attend an American Nuclear Society conference. It encouraged me to take a breadth of classes, including linear algebra, materials science, and plasma physics. It brought me into contact, and friendship, with brilliant graduate students studying an array of stockpile-focused research. It also opened doors for me when I graduated; one prospective employer watched the recording of my final fellowship presentation and liked it well enough to offer me a job. My summer internship at Sandia National Laboratories (California) was a great introduction to both the National Nuclear Security Administration laboratory culture and to California in general. My work over the summer was also an interesting application of my field—simulating fission rates in theoretical nuclear reactors with different concentrations of transuranics to obtain theoretical neutrino outputs. The thought here was that a reactor fueled with plutonium-239 would present a different signature compared to one fueled with uranium-235, something important in nuclear deterrence.

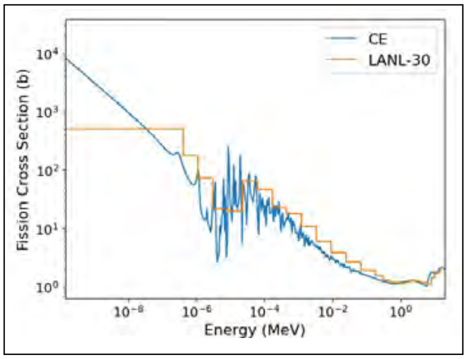

Figure 1. Fine-group (near continuous energy) versus coarse-group U-235 fission cross section.

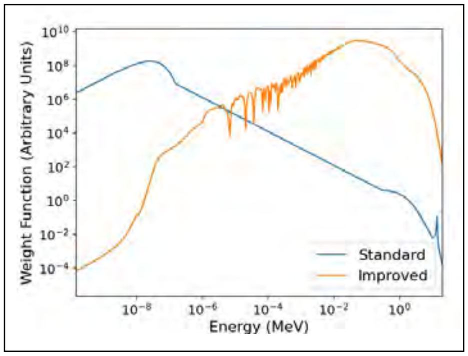

Figure 2. Weight Function Comparison for U-238.

My PhD research on developing a rigorous, asymptotic-based derivation of the Simplified P2 neutron transport equations prepared me well for my work at Los Alamos National Laboratory (LANL). In the desert, I work on LANL's deterministic neutron/gamma transport code, PARTSIN.[1] Neutron transport simulations are critical for many aspects of the lab's mission, from criticality safety to radiation protection to nonproliferation. Uncertainty quantification, which provides confidence levels on simulation outputs, has become increasingly important in decision making. Uncertainty quantification typically requires many simulations with perturbed input parameters, which can translate to hundreds of thousands of PARTISN runs. This makes speed incredibly important. While increasing computing power can alleviate some of this, we are investigating other means of speeding up simulations.

To this end, I study the impact of multigroup neutron cross sections on simulations of fissile systems. Neutron cross sections can be seen as the probability of a neutron interacting with an atom. They are highly dependent on the energy of the incoming neutron. Once we have this nuclear data, we can solve the neutron transport equation to calculate the average distribution of neutrons in a volume. This requires massive numbers of neutrons to avoid the stochastic nature of neutron-atom interactions. PARTISN, as a deterministic code, requires energy-binned neutron cross sections, which are weighted averages of continuous-energy cross sections. Figure 1 shows both the continuous-energy and 30-group uranium-238 fission cross section. Fewer energy groups mean faster simulations, but less accurate results. I am investigating whether both better energy-group boundaries[2] and improved weight functions (Figure 2) that more accurately represents the simulation[3] can increase simulation accuracy without increasing simulation runtime.

References

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[2] T. Saller, V. Nair, A. Till, and N. Gibson, "Using a Random Forest Model to Choose Optimized Group Structures," Nuclear Science and Engineering, 197, pgs 2117-2135 (2023).

[3] T. G. Saller, "Self-Shielding in PARTISN," M&C 2019, Portland, Oregon, August 25-29 (2019).

LA-UR-25-30762

Derek Kuldinow (derek.a.kuldinow@gmail.com) | **Stanford University**

Degree in Progress: PhD, Aeronautics and Astronautics ✦ Advisor: Dr. Kentaro Hara ✦ SSGF: 2022 - Present

Research Topic

Non-equilibrium Hydrodynamic Modeling of Plasmas

Research Responsibilities

Current state-of-the-art device-scale plasma codes utilize hydrodynamic (fluid) models, which assume that the plasma is near thermal equilibrium. This allows for a computational advantage over kinetic simulations which need to simulate myriad individual particles. However, the assumption of thermal equilibrium means that fluid models cannot capture certain physical effects like anisotropy, nonlocality and high-energy tails. These effects can be important in high-temperature plasmas, especially those with magnetic fields. My research focus is on expanding the capabilities of fluid models so that they can capture finite kinetic effects. My main interest is the "10-moment model" that can capture temperature anisotropy, which modifies transport, reaction rates and magnetic field generation. My responsibilities include code development, verification against existing codes and validation against experiment. Our work has been applied to low-temperature plasma experiments as well as experiments on the OMEGA and National Ignition Facility experimental facilities.

Benefits of SSGF

The Stewardship Science Graduate Fellowship (SSGF) has been instrumental to my PhD program in two ways. Firstly, it gave me the freedom to study the topics that I am most interested in. Without external funding, many students are tied to the funded projects within the lab, which may be limiting, especially as the timeline of that grant may not line up with the PhD program. Having the SSGF gave me guaranteed funding for the majority of the PhD to work on the topics that I was interested in and most passionate about. Secondly, the SSGF gave me the chance to complete practicums at national laboratories, which was very helpful for my career.

National Laboratory Experience

Through the SSGF, you're expected to complete a practicum at a national laboratory. I performed two, one at Lawrence Livermore National Laboratory and one at Los Alamos National Laboratory. This experience connected me with collaborators and colleagues that I probably never would have met with otherwise. It exposed me to the mentality and state-of-the-art research of people outside my lab and community. I will also most likely perform a postdoc at one of my practicum locations that is an extension of the work I was able to start through my practicum.

Veera Panova (vpanova@mit.edu) | **Massachusetts Institute of Technology**

Degree in Progress: PhD, Materials Science and Engineering ✦ Advisor: Dr. Christopher Schuh ✦ SSGF: 2023 - Present

Research Topic

Bonding and Microstructure of Supersonic Microparticle Impacts

Research Responsibilities

Cold spray is a manufacturing method that utilizes fine powders (typically metallic) which are accelerated to supersonic velocities by a carrier gas to produce coatings on various substrates in the solid state. Bonding is achieved by plastic deformation of the particles and the substrate upon impact above a threshold velocity. This process enables on-vehicle component repair, manufacturing of oxidation-sensitive components, and production of parts from high melting point metals (like refractories). I study the fundamentals of cold spray by performing experiments using the Laser Induced Particle Impact Test (LIPIT) which enables controlled launch of single microparticles. Since particle histories are known, we can gain mechanistic understanding of various aspects of cold spray (e.g., microstructural and bonding evolution) and study materials' behavior at high strain rates ($\sim 10^7\ s^{-1}$). I also perform tomographic characterization of the embedded particles using Focused Ion Beam Scanning Electron Microscopy to get a 3D view of the impacted surface and directly quantify bonding. This work provides guidance for optimization of bonding throughout the deposition process and helps inform cold spray process parameters for full-scale manufacturing.

Benefits of SSGF

The Stewardship Science Graduate Fellowship (SSGF) has expanded the scope of my thesis work by supporting the collaboration with research scientists at Sandia National Laboratories. During my practicum, I worked with two research groups there. This experience expanded my skill set, introduced me to a new field, and provided access to equipment unavailable at my home university. This work resulted in an additional publication for my thesis. The fellowship also has been beneficial for my professional development: presenting research at the annual program reviews, learning from other scientists in the field, and exchanging ideas with other fellows.

What Students Considering SSGF Should Know

The Fellowship gives an invaluable opportunity to complete a practicum at one of the Department of Energy/National Nuclear Security Administration (DOE/NNSA) national laboratories. This experience has been very helpful to shape my post-PhD career plans and explore a new research direction as a part of my PhD work. The program also emphasizes the connections between fellows, alumni, NNSA headquarters, and staff at DOE/NNSA labs, creating a vibrant community that fosters mentorship, collaboration, and innovation. I highly recommend this fellowship to motivated individuals who want to meaningfully contribute to their field of choice within stewardship science.

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Semantic Data Management for AI-Ready Data: Synchrotron X-ray Diffraction | Case Western Reserve University

PI: Dr. Roger H. French (roger.french@case.edu); Co-authors: Jonah Bachman (jab433@case.edu) and Dr. Ozan Dernek (oxd37@case.edu)

The mission of the Materials Data Science for Stockpile Stewardship Center of Excellence (MDS^3-COE), which is supported by the National Nuclear Security Administration's Office of Production Modernization, is to develop data science tools and deploy novel data-driven, open-source packages, for materials research in the National Security Enterprise (NSE). Students at MDS^3-COE have the opportunity to work at the intersection of data science and a broad range of theoretical and experimental applications, including synchrotron X-ray diffraction.

MDS^3-COE currently employs 4 post-doctoral researchers, 25 doctoral students, 18 master's students, 42 undergraduate students, and 4 high school students, and collaborates with more than 100 scientists across the NSE. A non-exhaustive list of research areas in MDS^3-COE includes: developing data science tooling for Advanced Manufacturing (e.g., laser powder bed fusion, direct ink writing), Aging and Lifetime (polymer formulation and degradation), and Data Governance and Stewardship (digital transformation, cybersecurity, linked data, semantic reasoning).

AI-ready Data for Materials Data Science

Many scientists recognize the critical importance of "Artificial Intelligence (AI)-ready Data" in the current data-centric AI world. Materials science data is complex and there are large amounts of unused/inaccessible historical data. Semantic Data Management (SDM), makes the (meta)data fully understandable using ontology, thereby addressing the fundamental challenges of volume and complexity.

Materials Data Science Ontology (MDS-Onto)

Data needs to be FAIR (Findable, Actionable, Interoperable, and Reusable) in order for it to be AI-ready and to enable machine learning and reasoning capabilities. Figure 1 illustrates data FAIRification using the MDS-Onto Ontology[1] and its tools and documentation.[2] The FAIRified data is transformed with Resource Description Framework (RDF) linked-data syntax and saved. This ensures AI-ready data for automated analysis, scientific workflows, knowledge discovery, and semantic reasoning.

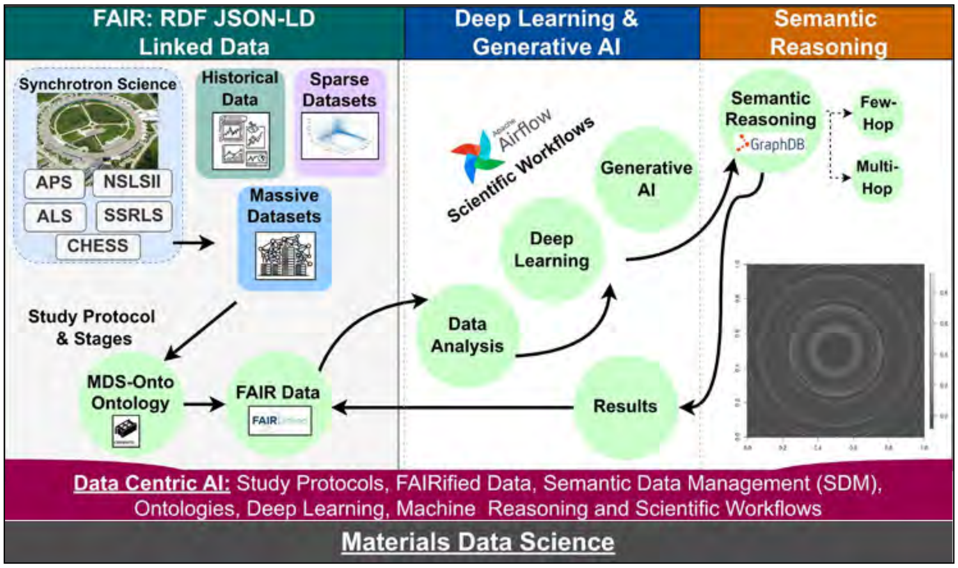

Figure 1. Datasets that are machine-readable and FAIR achieve greater opportunities for data-centric AI. The Materials Data Science Ontology (MDS-Onto) enables the production of RDF-linked data files. As more historical datasets, sparse datasets, and massive datasets produced by synchrotrons become FAIR-linked, researchers can easily move into deep learning, generative AI, and semantic reasoning domains.

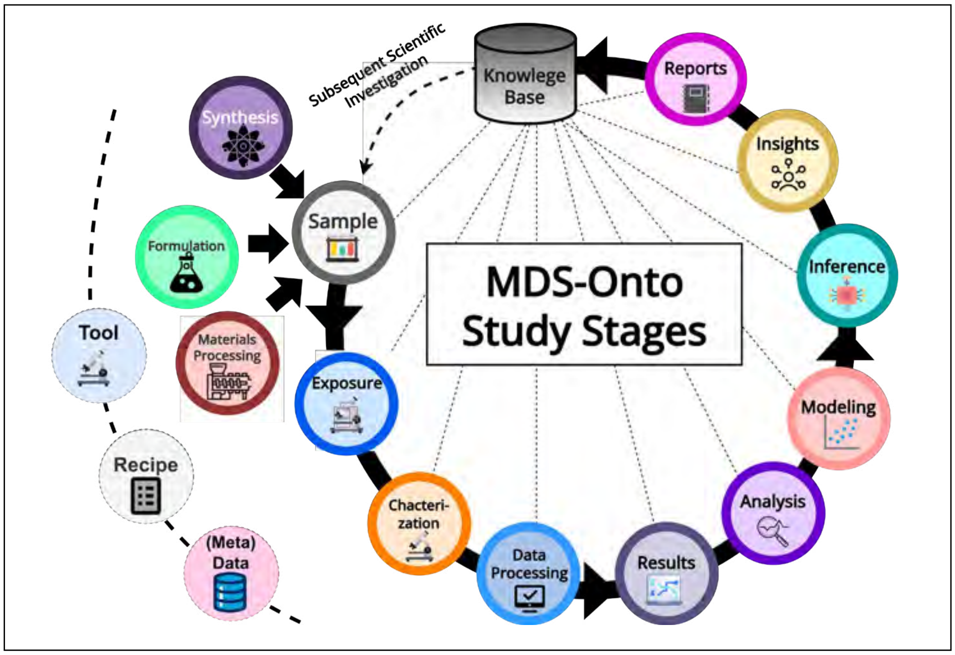

Figure 2. Scientific studies can be summarized by a study protocol that captures the details of each study stage of sample preparation, measurement tools, and the subsequent analysis, modeling, and reasoning.

SDM Exemplar: Synchrotron X-ray Diffraction Studies

Synchrotron science data is a good example of how SDM produces AI-ready data and opens up machine learning and reasoning. For instance, an X-ray beamline experiment at the Advanced Photon Source (APS-U) at Argonne National Lab can produce a massive dataset of 50 terabytes of materials data; AI/ML models can analyze data of this size.

The Synchrotron Science X-ray diffraction team within MDS^3-COE has created a FAIR and semantically enriched framework that can capture variables and (meta)data from X-ray scattering and diffraction data sets, independent of the synchrotron facility from which it was collected. This "source-agnostic" framework provides a standardized and generalizable way to ingest data and perform data pre-processing, analysis, and reasoning across multiple studies and datasets.

The first step is the development of an X-ray Diffraction (XRD) domain ontology in MDS-Onto, an axiomatic representation of relationships between objects and the data they produce within a given domain, thereby providing a machine-understandable context.

This is achieved by first considering the essential aspects of an X-ray diffraction scientific study, such as the sample, the beam, and the detector. Using predefined terms from already established high-level ontologies such as the Common Core Ontologies and Basic Formal Ontology, as well as the open source MDS-Onto study protocol of the XRD experiment, with the appropriate, distinct, and sequential study stages can be defined, as shown in Figure 2. Then data and metadata at each study stage is made into RDF linked data, using the FAIRlinked package, and the resulting JSON-LD files stored for analysis, learning, and reasoning. For instance, one may collect thermocouple data alongside diffraction images to evaluate the effect of heat treatment on lattice spacings. And for this heat treatment study stage, not only is the thermocouple temperature recorded and stored, but also the metadata about the relative locations of the thermocouple and sample, so as to determine any temperature offset, as part of the study's metadata.

Representing XRD experiments and their data in this manner offers the benefit of interoperability between different data sources, like Argonne's APS and National Science Foundation's CHESS synchrotron, while streamlining and standardizing scientific workflows across different synchrotron facilities and beamlines, and enabling semantic reasoning tasks. This reasoning can uncover experimental aberrations in standardized experiments, suggest beamline configurations for a desired measurement, or draw comparisons and conclusions from seemingly different datasets. The standardized linked data format ensures compatibility among all users, enabling high-throughput XRD measurements to occur without the concern of inconsistency across datasets and sites.

References

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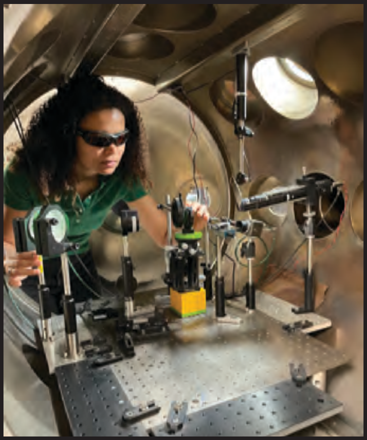
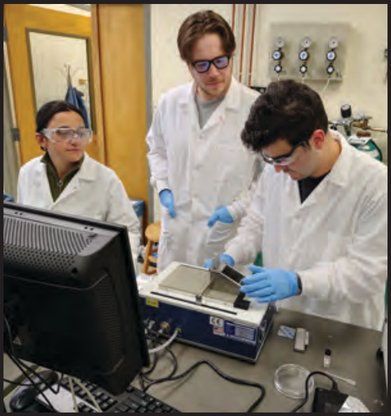

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