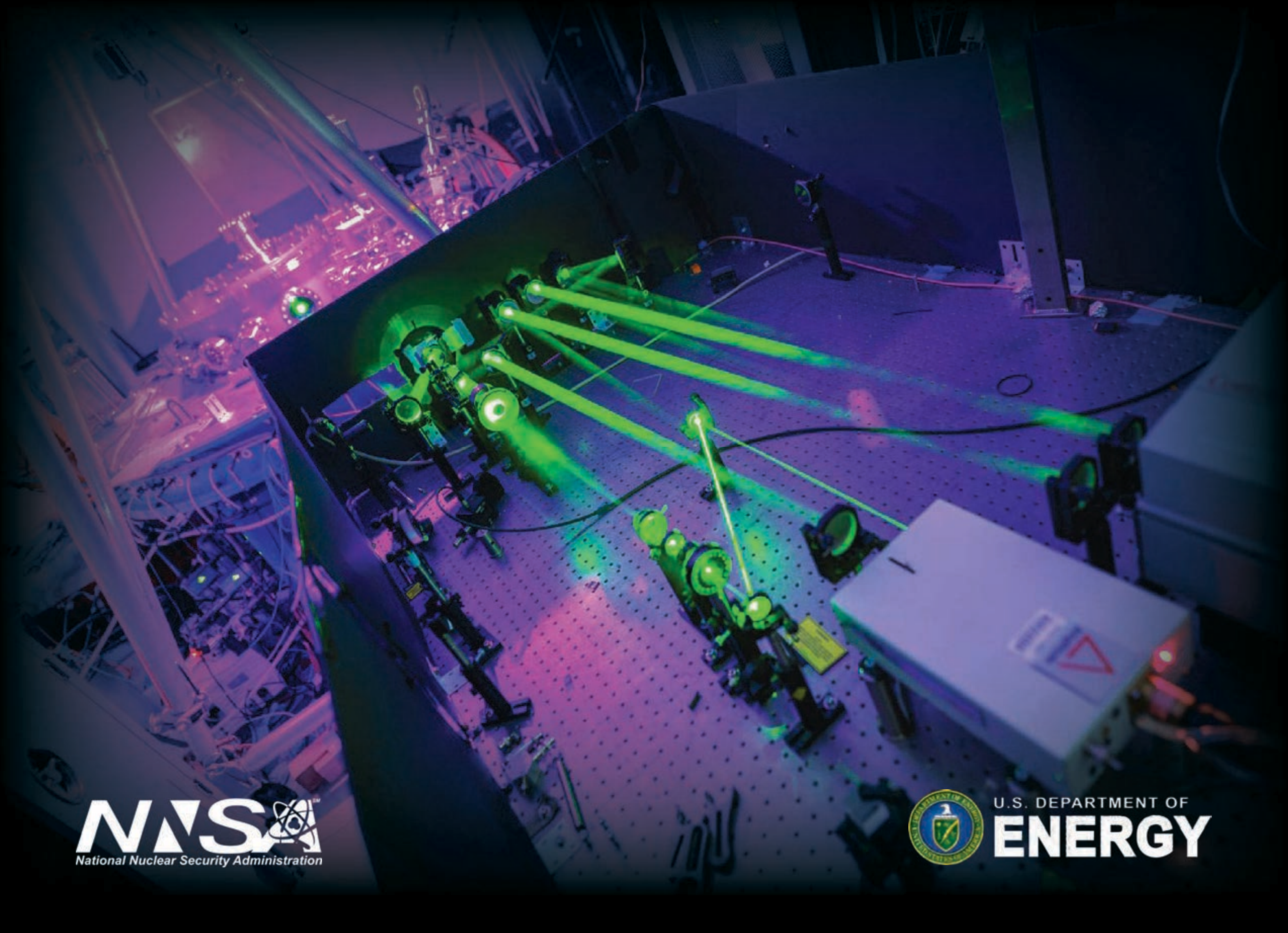
DOE/NA-0164

2025 Academic Programs Annual

NNSA Defense Programs, Technology and Partnerships Office

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



National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY

On the Cover

The image shows a 1 megaampere Linear Transformer Driver in the background with laser beam paths for a multi-channel interferometry system in the foreground. The current generator is used in gas puff Z-pinch experiments to study magneto-Rayleigh-Taylor instability mitigation techniques.

— Image courtesy of Farhat Beg, University of California, San Diego

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National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY

2025 Academic Programs Annual

National Nuclear Security Administration
Office of Defense Programs
Technology and Partnerships Office

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The Academic Programs Annual is produced by NNSA, Defense Programs, Technology and Partnerships Office. 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.

Please submit comments to:

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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

Welcome from the NNSA Defense Programs Technology and Partnerships Office

The National Nuclear Security Administration (NNSA) is tasked with ensuring a safe, secure, and effective nuclear deterrent. Since the end of nuclear testing in 1992, we have accomplished this mission through the expert use of experimental science, engineering, and computational capabilities that are strengthened by NNSA's mission to support the United States' leadership in science and technology. This expertise allows us to model the performance of nuclear weapons and to evaluate changes that may occur to weapon performance as the life of a weapon system is extended beyond its original design lifetime, materials age, or changes are made in material components or manufacturing processes that cause the weapon to differ from its original design. NNSA directs these experimental science, engineering, and computational activities that make it possible to evaluate weapon performance without testing.

To accomplish this mission requires the best minds in the Nation trained in science and engineering disciplines, leading-edge experimental facilities, and world-class, state-of-the-art computing power. The Academic Programs, managed by the Technology and Partnerships Office, allow NNSA to seed the academic pipeline of talent and provide access to world-class computing power and experimental facilities to train the next generation workforce needed to ensure the continued safe stewardship of the existing nuclear weapons' stockpile. The return on investment in the Academic Programs has been significant for NNSA, with much of the best talent choosing to join the NNSA national laboratories as permanent staff or remaining in academia to foster the development of future generations of stewards.

Having such a strong, well-developed base of talent at both the national laboratories and in academia is a key component of the U.S. nuclear deterrent, and expertise in academia provides peer review for the cutting-edge science and technologies that are developed at the national laboratories in support of stockpile stewardship. This work is exciting and ground-breaking. It includes materials under extreme conditions, high energy density science, low energy nuclear science, radiochemistry, hypersonics, high performance computing, modeling, and others. We highlight some of the most recent research results in this issue and feature students and alumni of the Academic Programs who write in their own words about their research and about their perspective on the Academic Programs and the opportunities it has provided to them.

NNSA continues to develop talent from all across America and believes strongly that better science and better solutions to the issues faced in stockpile stewardship come from an interdisciplinary approach applied to the challenges.

I extend my congratulations to you on a job well done in being part of the Academic Programs community. Thank you for sharing your research and perspectives, which contribute to the world-changing science at the core of all we do. I wish you continued future successes.

Jahleel A. Hudson

Jahleel A. Hudson
Director
Technology and Partnerships Office
NNSA Defense Programs

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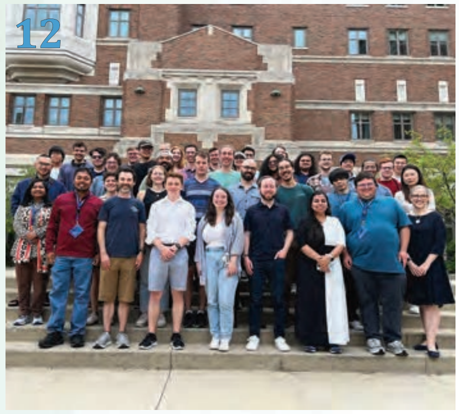


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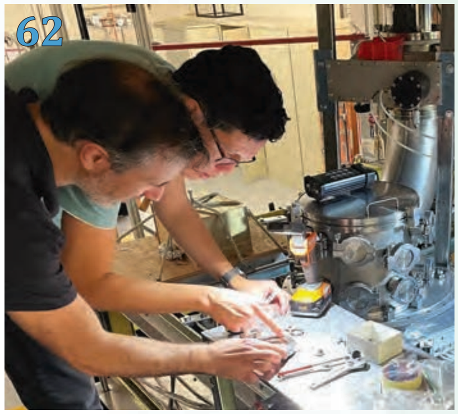
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The challenges of modernizing our nuclear stockpile demand a strong and robust base of national expertise and educational opportunities in specialized technical areas that uniquely contribute to nuclear stockpile stewardship. The Academic Programs 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, hypersonics, high performance computing, modeling, and others.

Overview

Academic Programs

Training the Next Generation of Stockpile Stewards

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, hypersonics, 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
- Maintain 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.

University of Rochester graduate student Nitish Acharya, aligning a mirror in the Janus target chamber at the Jupiter Laser Facility at Lawrence Livermore National Laboratory. The photo was taken by Gaia Righi.

The Academic Programs enable a robust and multi-faceted research and science, technology, engineering, and mathematics (STEM) educational community through various methods of support. Investments in consortia partnerships and centers of excellence provide collaborative groups to tackle large questions through multi-disciplinary approaches and leverage preeminent scientists in the field. Research grants and focused investigatory centers support individual principal investigators to foster a vibrant community responsive to new breakthroughs by providing flexibility for innovations and career growth. Support to minority and tribal serving institutions prepares a talented workforce through strategic partnerships. Fellowships provide graduate students with key opportunities to connect with the DOE/NNSA mission and provides direct experiences at the NSE sites. NNSA user facilities provide opportunities for academic partners to use NNSA's cutting-edge research facilities and to push frontiers of current scientific understanding. Several underlying features of all Academic Programs include the focus on quality science through competitive awards, connections with DOE/NNSA national laboratories, plants, and other site facility work, and a view to future needs and opportunities of the NSE.

The Academic Programs is comprised of six subprograms:

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

Stewardship Science Academic Alliances

The Stewardship Science Academic Alliances (SSAA) Program supports scientific academic research programs to develop the next generation of highly trained, 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 NSE.

The SSAA Program funds both collaborative 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, training 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.

High Energy Density Laboratory Plasmas

High energy density (HED) science is central to many aspects of nuclear weapons, and maintaining a strong HED academic community in this unique field will be 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 stored energy reaches approximately 100 billion joules per cubic meter (i.e., pressures of approximately 1 million atmospheres). The program supports individual investigator research grants, centers of excellence, and the Facility Access and Community Development Program.

Individual Investigator Grants

NNSA's Technology and Partnerships Office partners with the DOE'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.

Centers of Excellence

The HEDLP program provides funding support toward the HED centers of excellence selected under the competitive SSAA centers of excellence process. Centers of excellence are an integrated, multi-institutional, collaborative effort focused on a central problem or theme. These centers work closely with NSE 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 ZNetUS and for student and postdoctoral researchers' travel to attend the High Energy Density Science Summer School and various facility workshops.

Predictive Science Academic Alliance Program

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: multi-disciplinary simulation centers (MSCs), single-discipline centers (SDCs), and focused investigatory centers (FICs). MSCs focus on scalable application simulations, targeting large-scale, integrated, multidisciplinary problems, whereas SDCs focus on scalable application simulation for targeting a broad single science or engineering discipline. FICs are tightly focused on a specific research topic of interest to NNSA's mission in either a science/engineering discipline or an exascale-enabling technology.

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.

Minority Serving Institution Partnership Program and Tribal Education Partnership Program

The Minority Serving Institution Partnership Program (MSIPP) and the Tribal Education Partnership Program (TEPP) align investments in educational research capacities and workforce development through unique partnerships between Institutions of Higher Education (IHEs) and the Nuclear Security Enterprise with the goal to advance the NNSA mission priorities. The Program supports collaborations between IHEs and the national laboratories, plants, and site facilities (LPS) to increase faculty-to-scientist interactions, develop cutting-edge research methods, support technical engagements at the LPS, and provide access to LPS research facilities. Through competitive, merit-based awards, MSIPP and TEPP build educational capacity in research and innovative technologies to support a network of talented students ready to meet the needs of NNSA's STEM workforce.

DOE/NNSA Fellowship Programs

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 https://www.krellinst.org/fellowships.

Outstanding Poster Awards

2024 Stewardship Science Academic Programs Symposium

Ten of the exceptional 132 graduate student posters submitted last year had that something extra that made them stand out. We are pleased to present the 2024 Stewardship Science Academic Programs (SSAP) Symposium Outstanding Posters winners here.

Jahleel A. Hudson, Director, NNSA Technology and Partnerships Office (left) and Stephanie Miller, SSAP Program Manager (right) with the 2024 Stewardship Science Academic Programs Symposium Outstanding Poster Award recipients.

Anirudh Hari | Stanford University
Phase Transformations in Additively Manufactured Eutectic High Entropy Alloys under Laser-Driven Shock Compression and Release

Genevieve Kidman | University of Nevada, Las Vegas
Stress Percolation in Polycrystalline Materials Through Elastic Strain Mapping

Heather Moon | Washington State University
Shock Compression of Silver Single Crystals

Samuel Patzkowsky | Washington University in St. Louis
In-situ Production of ^{130}Xe in Ancient Rocks and Constraints on the Evolution of Noble Gas Isotopes in Earth's Mantle

Jonathan Phillips | Washington University in St. Louis
Invariant-Mass Spectroscopy of Neon Isotopes

Michael Pokornik | University of California, San Diego
Using Deep Learning to Analyze Thomson Scattering Diagnostic Data in Laboratory Astrophysics Experiments

Trevor Johannes Smith | University of Michigan
Power Feed Plasma Formation Studies on the 1-MA Mykonos Facility

Michael Springstead | University of Michigan
Laboratory-Generated Photoionization Fronts Relevant to Cosmology

Afreen Syeda | University of Rochester
Shock-Particle Interaction Experiments to Measure Viscosity in Epoxy

Justin Warren | Ohio University
Active Target Measurement of the ^{35}Cl(n, p) and ^{35}Cl(n, alpha) Cross Sections

Stewardship Science Academic Alliances

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

PI: Dr. Amy Clarke (amyclarke@mines.edu); Authors: Irene Beyerlein, University of California Santa Barbara (beyerlein@ucsb.edu); Pulkit Garg, University of California Santa Barbara (pulkitgarg@ucsb.edu); Emily Pittman, Colorado School of Mines (erpittman@mines.edu); Leslie Lamberson, Colorado School of Mines (les@mines.edu); Amy Clarke, Colorado School of Mines (amyclarke@mines.edu)

The Advanced Characterization of Metals under Extreme Environments ($ACME^2$) is a Stewardship Science Academic Alliances (SSAA) center of excellence focused on understanding the responses of metastable microstructures in metallic alloys with novel experimental and computational approaches and training the Nuclear Security Enterprise's next-generation workforce. Workforce development examples include summer internships for undergraduate students from Fort Lewis College in Durango, Colorado—a Native American-serving, non-tribal college, a graduate research associate summer internship at Lawrence Livermore National Laboratory (LLNL), and the hiring of a Center postdoc by Los Alamos National Laboratory (LANL). The Center was launched in fiscal year 2024 and is comprised of the Colorado School of Mines, University of California Santa Barbara, Baylor University, and Cornell University. It has leveraged the High Explosives Applications Facility at LLNL and the Sigma Facility at LANL. Two project highlights are provided below.

Role of Temperature on Screw Dislocation Dynamics in Ta, W, and TaW

Refractory metals and alloys exhibit superior properties in extreme environments. The effect of temperature on screw dislocation dynamics in Ta, W, and Ta-10W (wt.%) was examined by a three-dimensional phase-field-dislocation dynamics (PFDD) model combined with Langevin dynamics (Figure 1). It uses temperature-dependent elastic moduli and generalized stacking fault energy curves from atomistic calculation. For a broad range of temperatures and in all metals, a critical stress associated with the glide of a long screw dislocation by 1b is predicted. Glide at this critical threshold undergoes two temperature-induced transitions. The critical stress for screw dislocation motion declines with temperature increases in three stages, eventually reaching a plateau where it is insensitive to temperature. These transition temperatures strongly correlate with experimentally-measured transitions in yield strength with increasing temperature. At low temperatures, the classic kink pair mechanism prevails, and the predicted activation enthalpies for kink pair formation agree quantitatively with those reported by atomistic and/or experimental studies. When the material deforming under high temperature and stress is subsequently cooled to room temperature and fully unloaded to examine the dislocation line morphologies "post-mortem", the initial screw orientation is nearly recovered, regardless of the prior deformation temperature and stress. This implies the thermally-activated motion of screw dislocations governs the temperature-dependent strength of body-centered cubic (BCC) metals and alloys over a wider range of temperatures than initially thought.

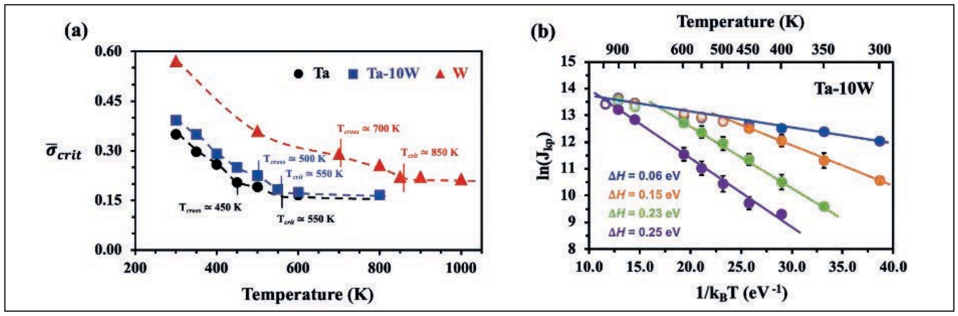

Figure 1.(a) Critical stress for screw dislocation glide by 1b at different temperatures for Ta, Ta-10W, and W. The critical stress for each material is normalized by the corresponding critical stress at 0K. The reduction in critical stress with temperature follows the reduction in yield strength of BCC metals and alloys with temperature. (b) The PFDD-calculated ΔH as a function of the applied stress ratio (R) for Ta-10W are consistent with the experimental data obtained from reference 1.

Microstructure and Dynamic Compressive Response of Ti-15wt.%Mo (Ti-15Mo)

Figures 2a and 2b illustrate the experimental setup and the positioning of the sample relative to the thermal camera. Figures 2c and 2d compare the full-field temperature profiles of Ti-15Mo (wt.%) samples that exhibit twinning with different grain sizes (65 and 200 μm) under dynamic compression at $2.5 \times 10^3\ s^{-1}$. For both grain sizes, the average temperature measured by the thermocouple was approximately 80 °C. However, smaller-grain samples exhibited a more uniform temperature distribution, whereas larger-grain samples showed localized heating up to 185 °C, particularly along planes near 45° to the compression axis. Heating along these planes indicates a likely precursor to the formation of adiabatic shear bands. It was observed that in larger-grain samples, significant adiabatic heating leads to reduced work hardening and enhanced flow softening under dynamic loading conditions, whereas flow softening was not as significant in smaller grained samples.

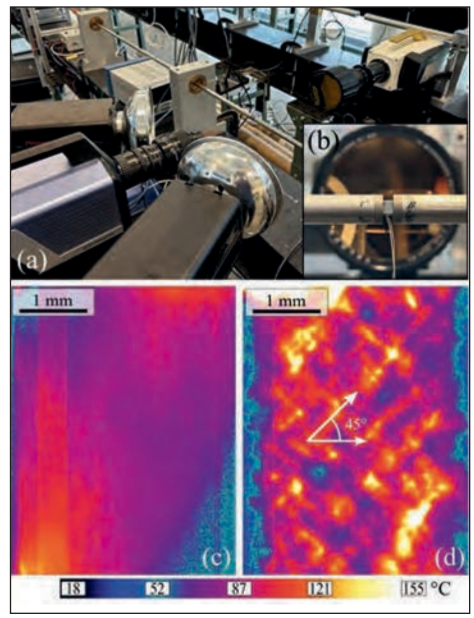

Figure 2.(a) Dynamic compression setup with ultra high-speed optical and infrared (IR) cameras for in-situ monitoring, (b) a close-up of the IR imaging setup, and full-field temperature maps obtained by IR imaging for (c) 65 μm and (d) 200 μm grain size Ti-15Mo samples deformed at 2.5×10^3 per second to 0.22 true strain.

Reference

[1] R.J. Arsenault, "An investigation of the mechanism of thermally activated deformation in tantalum and tantalum-base alloys," Acta Metallurgica 14, 831–8 (1966).

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

PI: Prof. Henry S. La Pierre (la_pierre@chemistry.gatech.edu); Authors: Prof. Scott R. Daly, University of Iowa (scott-daly@uiowa.edu), Prof. Bess Vlaisavljevich, University of Iowa (bess-vlaisavljevich@uiowa.edu), Prof. Ivan A. Popov, Washington State University (ivan.popov@wsu.edu)

The mission of the Transuranic Chemistry Center of Research Excellence (TRU-CoRE) is to advance the fundamental chemistry of the transuranic elements and to develop a vibrant, professional, and transformative workforce to drive nuclear science research that enhances national security. TRU-CoRE's interdisciplinary research is focused on (1) the chemistry and physical properties of actinide hydrides, (2) efficient, safe, and proliferation-resistant americium separations, and (3) predictive computational modeling of chemical bonding, reactivity, and spectroscopic properties. In its second year, TRU-CoRE supports nineteen graduate students, nine undergraduates, and two postdoctoral scholars. One alumnus works at a Department of Energy national laboratory. Studies conducted in the first year have resulted in five articles in refereed journals, three of which are highlighted below.

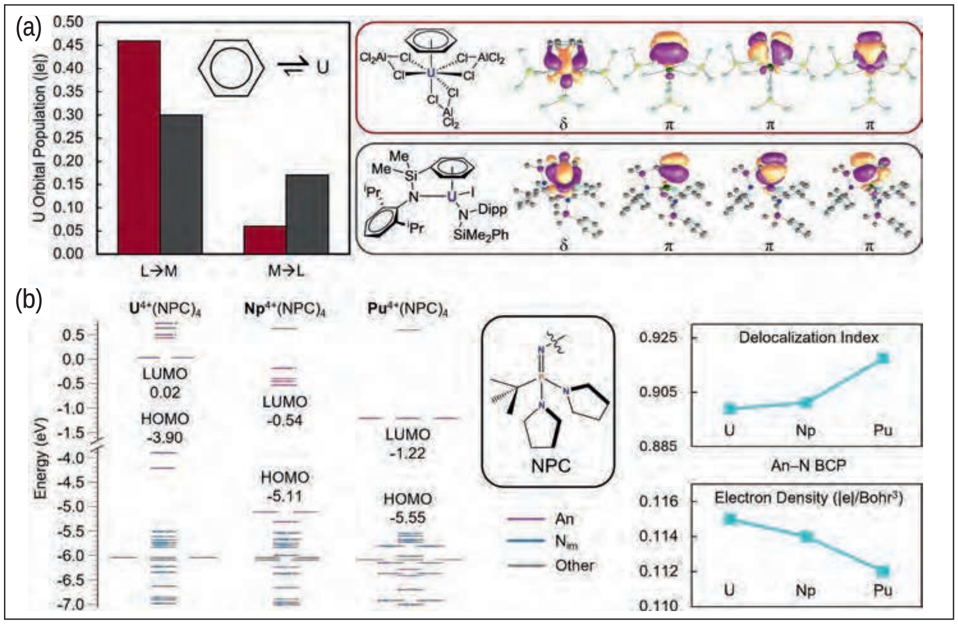

Figure 2.(a) The ligand to metal (L→M) π- and metal to ligand (M→L) δ-charge transfer between uranium and arene in (η^6-C_6H_6)U^{III}(μ^2-Cl,Cl-$AlCl_4$)$_3$ (top, red) and (3,5-$PhMe_2SiNDipp$)$_2$UI (bottom, gray). (b) The orbital energy diagrams (left) and select parameters from topological analysis of the An–N bond critical point (right) for $An^{4+}(NPC)_4$ (An = U–Pu; NPC = $[NP^tBu(pyrr)_2]^-$). The colors of the MO lines represent the percentage of the atomic orbitals of selected fragments in the MOs: actinide, magenta; N^{im} atoms, blue; all other atoms, gray.

Structural Characterization of a Plutonium Borohydride Complex

Actinide borohydrides, metal complexes featuring actinide-hydrogen bonds, were first discovered during the Manhattan Project when volatile $U(BH_4)_4$ was prepared and tested as a candidate for isotopic uranium enrichment. Despite this long historical relevance, only one example of a plutonium (Pu) borohydride complex is known, and none have been structurally characterized in the solid-state—until now.

In a groundbreaking study published in collaboration with Los Alamos National Laboratory,[1] the Daly and Vlaisavljevich Groups reported $Pu_2(H_3BP^tBu_2BH_3)_6$ (Figure 1), the first Pu borohydride complex characterized by single-crystal X-ray diffraction, nuclear magnetic resonance spectroscopy, UV-vis-NIR spectroscopy, and quantum chemical modeling. The structure revealed Pu to be surrounded exclusively by hydrogen, as observed in Pu hydrides, the problematic corrosion products that form when Pu metal is exposed to hydrogen gas. Experimental analysis revealed that borohydride bonding with Pu is highly sensitive to hydrogen positioning around the metal, a finding corroborated by theoretical calculations. These results suggest that well-defined Pu borohydride complexes may serve as useful models to understand how hydrogen positioning influences electronic structure and reactivity in more difficult-to-study Pu hydride materials.

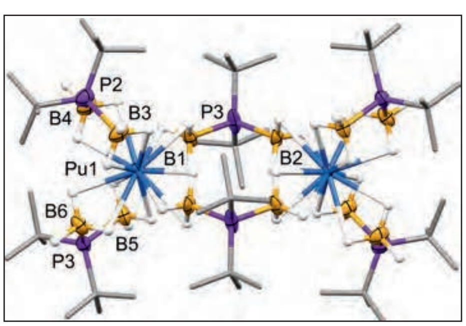

Figure 1.The structure of $Pu_2(H_3BP^tBu_2BH_3)_6$.

Stabilizing Actinide Oxidation States

Separation of heavy elements in nuclear waste is a monumental challenge but is critical to mitigating long-term storage risks. Understanding the nature of actinide ligand interactions in both low and high actinide oxidation states may help in the design of suitable ligands to achieve this goal. However, reaching extreme oxidation states in actinides, especially in transuranics, is a daunting task due to their inherent reactivity. For example, in low-valent systems, the substantial electron density at the actinide center oftentimes leads to decomposition of the desired products or disproportionation reactions.

To address this issue, the Popov Group has been using *in silico* modeling to guide ligand modulation of highly-electron-donating ligands in collaboration with the La Pierre and Boncella Groups.[2,3] These studies show how bonding and reactivity can be tuned by varying a ligand's electron storing capacity, protective steric groups, and/or the presence of intercalated counterions (Figure 2a). The studies also show how actinide oxidation becomes increasingly challenging due to the more core-like nature of 5*f* orbitals which shift to lower energies across the actinides in high-valent systems (Figure 2b). In addition to support of extant synthetic projects, the results provide a computational rationale for ligands that can stabilize actinides in extreme oxidation states, as needed for developing novel actinide separation methods.

References

[1]J.C. Zgrabik et al., J. Am. Chem. Soc. 146, 25943–25948 (2024).

[2]E.D. Reinhart et al., Organometallics 43, 284–298 (2024).

[3]K.S. Otte et al., J. Am. Chem. Soc. 146, 31, 21859–21867 (2024).

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

PI: Dr. Sherry Yennello (yennello@tamu.edu); Co-Author: Lauren McIntosh (lmcintosh@tamu.edu)

The Center for Excellence in Nuclear Training and University-based Research (CENTAUR) coordinates research at seven universities (Texas A&M University (TAMU), Florida State University (FSU), Louisiana State University, University of Massachusetts-Lowell, University of Tennessee-Knoxville, University of Washington (UW), and Washington University in St Louis) and currently supports one undergraduate, 15 graduate students, and one postdoctoral researcher. CENTAUR students work in experimental or theoretical low-energy nuclear science directly related to work at the National Nuclear Security Administration (NNSA) laboratories. The Center has been supported by the Stewardship Science Academic Alliances (SSAA) since 2019 and is in a second, five-year funding cycle. Eight of our graduates have worked post-graduation at either Los Alamos National Laboratory (LANL) or Lawrence Livermore National Laboratory (LLNL). CENTAUR also has influenced other students from our institutions to consider NNSA laboratory careers.

In the past year, CENTAUR has deepened investigations begun in its first five years. All projects involve one or more graduate students. Fission mechanics was investigated theoretically in the first iteration of CENTAUR (Prof. Aurel Bulgac, UW), which indicates the importance of the angular distribution of fission fragments and scission neutrons in more fully understanding fission.[1] CENTAUR now is investigating these observables experimentally, using a combination of reanalyzing older data (Prof. Vandana Tripathi (FSU)) and new experimental techniques (efforts at TAMU, Grisha Rogachev, and FSU, Sergio Almaraz-Calderon). This was the subject of a productive discussion between CENTAUR and LLNL researchers at our recent collaboration meeting in Livermore, California.

Nuclear data is needed to constrain neutron capture cross sections. In the last year CENTAUR has expanded the capabilities of the Detector Array for

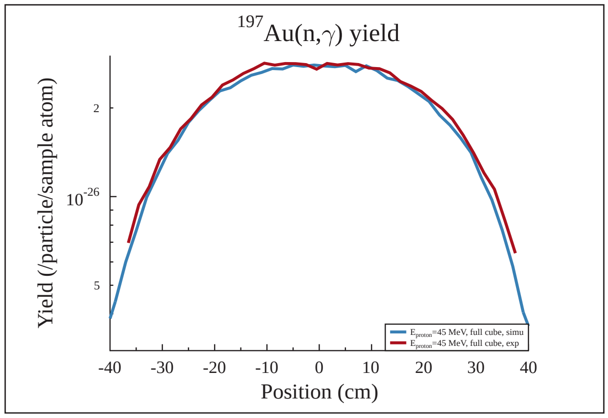

Figure 1.Preliminary simulation (blue) and experimental (red) yields of Au-197 resulting from (n, gamma) reactions at TAMU. Figure courtesy of Rene Reifarth, LANL.

Figure 2. Prof. Ingo Wiedenhoever shows off the FSU Tandem to a group of interested middle school campers. Photo courtesy of Professor Paul Cottle, FSU.

Photons, Protons, and Exotic Residues (DAPPER), made a new photon strength function (PSF) measurement, and the team has made measurements to aid development of a neutron target. Two students have graduated from the group, and a new student has joined. A zero-degree ionization chamber was installed in DAPPER to measure heavy residues event-by-event. This will allow removal of background reactions event-by-event from fusion evaporation and from transfer reactions on contaminants in secondary beams. Reaction products from ^{54}Fe(d,p) reactions were obtained to measure the photon strength function of ^{55}Fe, building out the isotopic chain of iron including the previous measurement of ^{58}Fe and anticipating measurements beyond stability of ^{60}Fe. The calibration for the ^{55}Fe strength function is well underway.

A neutron target is needed to directly measure neutron capture for short-lived nuclei. Moderation of neutrons increases the neutron density, improving the scientific reach. Accurate moderator simulations are needed. In collaboration with CENTAUR-affiliated LANL researchers Rene Reifarth and Aaron Couture, TAMU produced neutrons by spallation with a proton beam on a beryllium target, moderated the neutrons with an 80 cm cube of graphite, and measured the resulting neutron flux via activation of gold samples using high purity germanium detectors. Preliminary analysis indicates good agreement between simulation and measurement (Figure 1).

The youngest scientists impacted by the CENTAUR portfolio are middle school students participating in the nuclear science summer camp. The fifth consecutive summer of three camps in Texas brought the total of young scientists who have participated to over 300. These week-long camps are offered free-of-charge to students in College Station, TX, Lamar Consolidated School District, TX, and Bay County, Florida. One key to the camp's success is recruiting dynamic middle or high school science teachers from the area to engage the students' brains and creativity. The equipment CENTAUR purchased for demonstrations during the camp is available to be used in the teacher's classroom. Many students have learned some basic nuclear science due to this program. A highlight is bringing the students to one of our universities to tour our facilities (Figure 2). CENTAUR plans to expand into Baton Rouge, LA next summer.

Reference

[1] I. Abdurrahman, M. Kafker, A. Bulgac, and I. Stetcu, Neck Rupture and Scission Neutrons in Nuclear Fission, Phys. Rev. Lett. 132, 242501, (12 June 2024) https://doi.org/10.1103/PhysRevLett.132.242501.

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

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The Stewardship Science Academic Alliances (SSAA)-funded Center for Additively Manufactured Complex Systems Under Extremes (CAMCSE) has a scientific goal to advance the fundamental understanding of how additively manufactured, compositionally-complex systems respond to extreme environments of pressure, temperature, and high strain rates. Specifically, we seek to reveal the nature and mechanisms underlying their phase transformation, microstructure evolution, strength, and plasticity. CAMCSE combines the technical expertise of five academic institutions, including the University of Alabama at Birmingham (UAB), the University of Massachusetts Amherst, Stanford University, Tuskegee University, and the University of California Irvine. CAMCSE was launched in September 2023 and currently supports 9 faculty, 3 postdoctoral scholars, and 11 graduate students in various aspects of static high pressures studies, shock compression studies, and computational modeling of three-dimensional (3D), printed materials. CAMCSE offers workshops and training in additive manufacturing, static and shock compression of materials, machine learning and materials modeling, and mechanical properties under high strain rates and will play a leading role in preparing the future workforce of the National Nuclear Security Administration (NNSA) in these areas.[1]

Principal Investigator Vohra states that CAMCSE offers unique opportunities for students to investigate a system's approach to 3D printed materials including fabrication, studying their crystal structures and mechanical behavior under static and shock compression, and applying first principles theory to explain the experimental results. The students' training is strongly complemented by internships at NNSA laboratories and research opportunities at national facilities dedicated to studies on materials under extreme conditions.

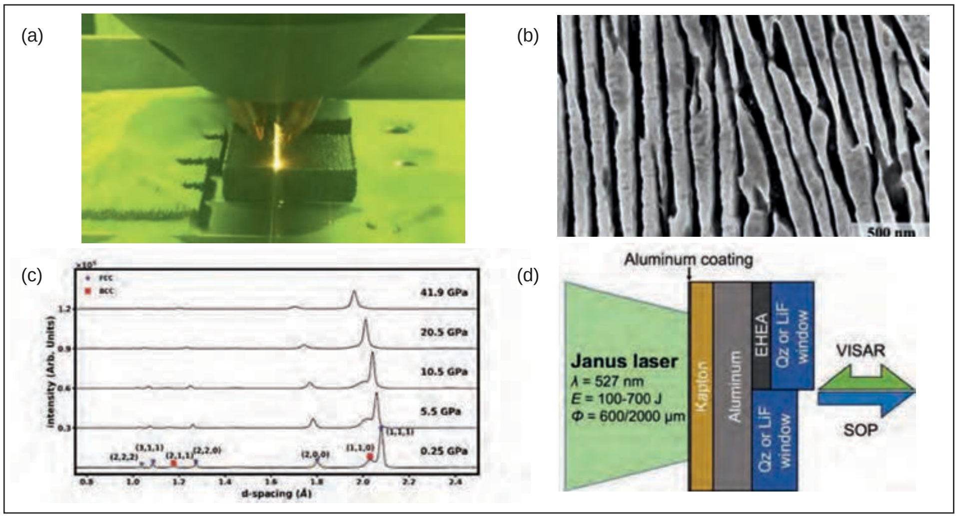

Figure 1. (a) Laser-directed energy deposition additive manufacturing of AlCoCrFeNi2.1 eutectic high-entropy alloy (EHEA) (b) Nanolamellar structure showing alternating layers of FCC (face-centered cubic) (bright region) and body-centered cubic (BCC) (dark region) structures (c) X-ray diffraction under static high pressures at HPCAT facility, Advanced Photon Source indicating BCC to FCC phase transformation completed by 20 GPa (d) Schematic of the pump-probe experiments at the Janus beam of the Jupiter Laser Facility at Lawrence Livermore National Laboratory for Hugoniot measurements of EHEA.

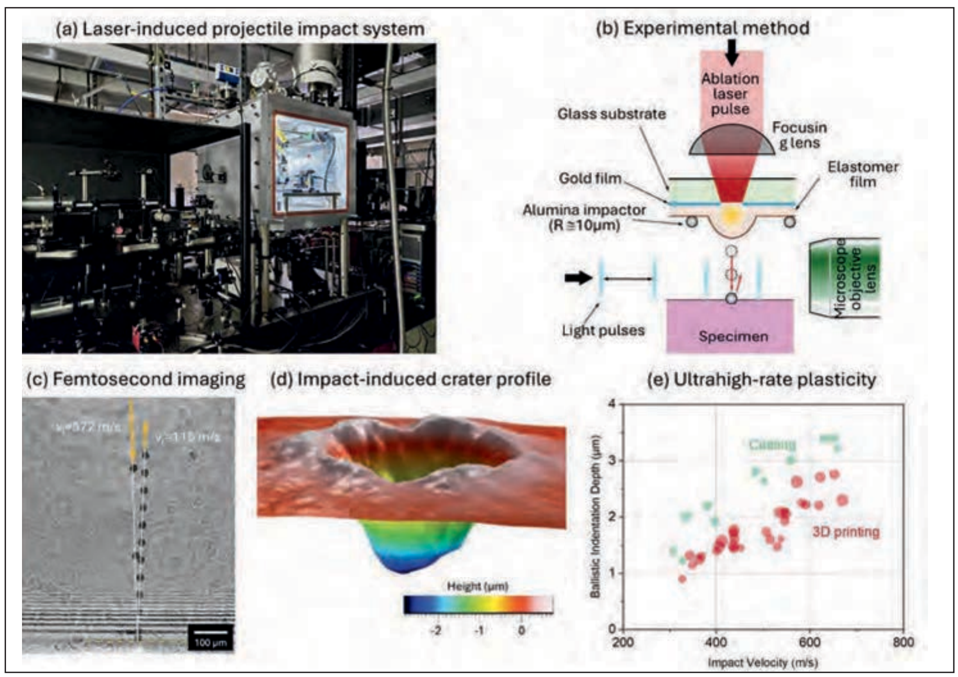

Figure 2. (a) A photo of the laser-induced projectile impact system at the University of Massachusetts Amherst. (b) Schematic of the microscopic ballistic indentation using supersonic microsphere impacts. (c) A 20um-diameter alumina sphere collides on the surface of an EHEA sample at 572 m/s and rebounds off. (d) A surface height profile of a crater on the EHEA surface, created by a 572 m/s impact of a 20um-diameter alumina sphere. (e) The depths of craters created on the surface of 3D printed and as-cast EHEA samples with varying impact velocities.

Figure 1 shows laser-directed energy deposition additive manufacturing of a eutectic high-entropy alloy (EHEA) AlCoCrFeNi2.1. This alloy has exceptionally high yield strength and ductility, a nanolamellar structure, and shows phase transformation under high pressures. This EHEA has been studied under static pressure of 300 GPa and under shock compression to 515 GPa. Figure 2 shows the laser-induced projectile impact studies on EHEA. CAMCSE is also conducting thermal equation of state measurements to connect static data with shock compression data obtained at X-ray Free Electron Laser (XFEL) facilities.

Reference

[1]https://sites.uab.edu/camcse/

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

PI: Dr. Farhat Beg (fbeg@ucsd.edu); Authors: Michael Pokornik (UC San Diego, mpokorni@ucsd.edu) and Brandi Daddario (Arizona State University, bdaddari@asu.edu)

The Center for Matter Under Extreme Conditions (CMEC) is a collaboration among University of California (UC) San Diego, UC Berkeley, UC Los Angeles, the University of Rochester, Arizona State University, and General Atomics. Its main goals are to create and study extreme states of matter, including magnetized and unmagnetized high energy density (HED) physics; train students in all aspects of HED science, including curriculum, theory, experiments, and diagnostics; and develop a strong pipeline of early-career talent for the Stockpile Stewardship Program.

Since its renewal in 2023, CMEC has funded 16 graduate students from a wide variety of backgrounds and has published more than 20 peer-reviewed articles on topics such as (1) Magnetohydrodynamic Compression and Radiation Generation, (2) Shocks and Particle Acceleration, (3) Physics-driven Code Enhancements, (4) Material Strength at Extremes, and (5) Electronic Transitions in the Equation of State of Materials across the HED regime. Here, we present two pieces of work by CMEC graduate students.

Machine Learning in Magnetized Collisionless Shocks

Technological advancements have made higher repetition rate (HRR) experiments more accessible in HEDP and have helped shift the field into a new paradigm. Access to greater ranges of time and length scales in experiments will both help enhance HEDP theory and more rigorously benchmark high fidelity, multi-physics simulations that are important to the mission of the National Nuclear Security Administration. The Thomson scattering (TS) diagnostic provides information on several key plasma parameters and is utilized in many HEDP experiments. Whereas TS is a valuable diagnostic, conventional analysis methods may become challenging for very large and diverse datasets that could be characteristic of HRR experiments. Deep learning models are an excellent candidate to help address these issues.

A CMEC collaboration, primarily tasked in studying magnetized collisionless shocks, recently published work on accelerating TS analysis for experimental campaigns using neural networks (NN).[1]

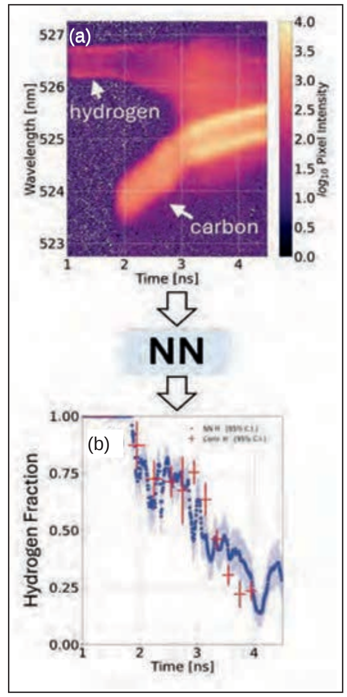

Figure 1. Adapted from Ref. 1. (a) TS ion acoustic wave (IAW) image from experiment. The TS IAW image is passed as inputs to the NN to predict plasma model parameters. The NN predictions (blue) and conventional analysis results (red) for hydrogen fraction are shown in (b).

A UCSD PhD student, Michael Pokornik, served as the deep learning project lead. An appeal of using the NN is its fast prediction rate and that it can predict plasma parameters for thousands of spectra in a fraction of a second. While the NN can be used as a standalone tool as an effective first pass over large datasets, it also can be used to help accelerate conventional methods when more rigorous analysis is needed. Fully kinetic particle-in-cell (PIC) Chicago simulations helped inform dataset curation to train the NN, and the NN was ultimately used on real experimental data. We found the NN predictions to be mostly consistent with conventional analysis (Figure 1). A future improvement to the NN will involve training on theoretical spectra with a realistic noise model added.

Planetary Equation of State Experiments at the Sandia Z Machine

The knowledge of equation of state is extremely important to the understanding of planet formation. Experiments were conducted on the Z Machine for long duration uniaxial shock on large samples. CMEC PhD student, Brandi Daddario and collaborators, studied natural materials, such as bronzite [$(Mg,Fe)SiO_3$] and methane [CH_4], to understand the deep interiors of planets and the outcomes of giant impacts. Shock and free surface release experiments intersect the vapor curve, which are inaccessible in static experiments.

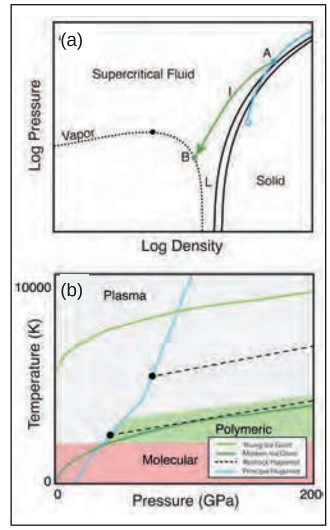

Figure 2. (a) Schematic of the shock and release experiments. (b) Schematic of the shock and re-shock experiments. Samples are shocked to a point on the principal Hugoniot and then reshocked by the downrange window of higher impedance.

In Figure 2a, mineral samples are first shocked to a supercritical state (point A) and then follow a release isentrope to the vapor curve (point B) where the temperature can be observed. In addition, by flow across a gap and stagnation onto a window, the density of the liquid can be inferred. The Z machine has been used to map the vapor curves for planetary materials like $MgSiO_4$ and Fe.[2] Current work on bronzite provides the first measurements of the vapor curve on an iron-bearing silicate. This work will expand the understanding of the accretion and evolution of Earth and Earth-like exoplanets. In Figure 2b, shock and reshock experiments on methane reach pressure-temperature conditions close to the interiors of the ice giant planets. These are the first temperature data in a region of the phase diagram where CH_4 is polymerized.[3]

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

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The mission of the Chicago/DOE Alliance Center (CDAC), now entering its fifth phase, is to enhance the understanding of materials in extreme thermomechanical, chemical, and radiation environments. We seek to integrate and coordinate experimental and theoretical studies of materials in these conditions and to train the next generation of scientists for the National Nuclear Security Administration in this growing field of materials science.

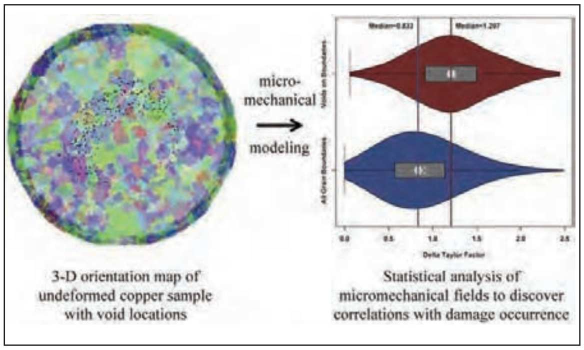

Figure 1. Three-dimensional orientation map and analysis from HEDM for a Cu sample.

In its current phase, CDAC has taken the scientific program in a new direction by addressing problems unique to additively manufactured (AM) materials in extreme environments from two different perspectives. In the first, the Center focuses on the characterization of AM materials in extreme environments to determine the factors affecting performance and lifetimes. The second focus is directed toward understanding, predicting, and controlling the complex, extreme chemistry associated with AM material fabrication.

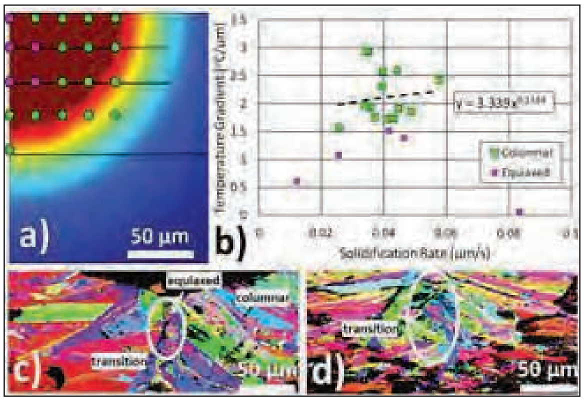

Figure 2. Temperature-grain structure analysis for laser processing of Bi_2Te_3 thermoelectric. a) Finite element modeling results showing the T gradient formed by laser heating and the points where T gradient G and solidification rate R were calculated; b) Computational G-R data; c) Electron backscatter defraction (EBSD) image showing the columnar to equiaxed transition limit used in simulations, d) EBSD image showing a larger columnar to equiaxed transition region.

Understanding the mechanics of polyphase aggregates or materials formed through AM is challenging due to grain heterogeneity and microstructure. For example, strength depends on microstructure and is a nonlinear function of component phases and their volume fractions. This plays an important role during phase transitions, such as the body-centered cubic-hexagonal close-packed transition in Fe where anomalous unit cell dimensions are observed due to differences in the compressibility of the phases. Anisotropy development during deformation also can be complex, with each phase developing a distinct texture.

An approach to this problem is being pursued in CDAC by new academic partners Anthony Rollett and Robert Suter (Carnegie Mellon University), who are collaborating with a Los Alamos National Laboratory (LANL) team on computationally-enabled analysis of shocked Cu. The polycrystalline metal was orientationally mapped with nearfield, high energy diffraction microscopy (nf-HEDM) at the Advanced Photon Source (APS) (Figure 1). The sample then is subjected to a shock designed to induce porosity, followed by analysis at the APS with computed tomography. Further nf-HEDM is required to register the void structure (from computed tomography) with the initial nf-HEDM map and full-field simulations to develop stress and strain fields.[1]

Given the need for improved damage models under high strain-rate shock conditions and the development of process-structure-performance (PSP) relationships for damage and spall, CDAC is pursuing new efforts that focus on non-cubic materials such as Sn and Zr.

Laser-based AM induces repeated cycles of rapid melting, vaporization, and solidification of material, a process that may be considered an example of chemical extremes. The process results in multi-scale interfaces and defects in the final product, and these interfaces impact the mechanical and transport properties of the fabricated material. Moreover, currently there is little insight into the behavior of the interfaces when the laser-processed material subsequently experiences extreme thermomechanical conditions, so the evolution of critical properties, such as thermal diffusivity and elastic moduli, in response to extreme conditions is unknown. The lack of knowledge about interface evolution impacts the ability to fabricate many materials by AM.

New academic partner Saniya LeBlanc (George Washington University) is developing advanced, laser-based AM techniques for the preparation of thermoelectric materials. The CDAC effort in this direction focuses on multi-technique characterization of thermoelectric materials such as Bi_2Te_3 (Figure 2).

CDAC is exploring PSP relationships for these materials as well, particularly on those fabricated with laser-based AM methods such as laser powder bed fusion. Research is directed toward varying the processing parameters as a way of controlling the spatial and temporal temperature gradients in the melt pools and the surrounding heat affected zone, as the laser locally melts layers of powder material. Such effects strongly impact the formation of multi-scale interfaces during solidification.

A second part of this effort focuses on the behavior and performance of these materials at high *P-T* conditions. The work dovetails with ongoing static compression experiments and theoretical studies in CDAC that indicate the ability of these materials to transform to novel superconductors at high pressure.

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

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The Center for High Energy Density Laboratory Astrophysics Research (CHEDAR), a center of excellence, is a renewal and expansion of the Center for Laboratory Astrophysics. Both Centers have been directed by Dr. Carolyn Kuranz, an Associate Professor at the University of Michigan. CHEDAR has many academic partners at the University of Michigan (Profs. Scott Baalrud, Paul Drake, Eric Johnsen, Nick Jordan, Karl Krushelnick, Ryan McBride, Alec Thomas, and Louise Willingale; University of Notre Dame (Prof. Ryan McClarren); University of California, Los Angeles (Prof. Derek Schaeffer); and Rice University (Prof. Pat Hartigan). CHEDAR studies fundamental research in high energy density (HED) science relevant to astrophysical systems and the National Nuclear Security Administration's (NNSA) Stockpile Stewardship Program. "There's overlapping science between science-based stockpile stewardship and astrophysical systems. They both involve very extreme states with high pressures, densities, and temperatures," said Kuranz.

Currently, CHEDAR supports 15 graduate students and postdoctoral researchers. Graduate students work closely with a CHEDAR investigator with expertise in HED experiments, simulation, or theory in one or more of its science areas: Radiation Hydrodynamics, Complex Hydrodynamics, and Magnetized Plasmas. "The majority of the funding at CHEDAR supports graduate students and early career scientists," said Kuranz. In the past year, two CHEDAR students have received their PhD. Dr. Kevin Ma worked with Prof. Eric Johnsen on "Electron Thermal Transport Modeling of Laser-plasmas"[1], and Dr. Stephen DiIorio worked with Prof. Alec Thomas on "The Role of Ionization Physics in Intense Laser-Plasma Interactions".[2] Currently, Dr. Ma is a postdoctoral fellow at Los Alamos National Laboratory, and Dr. DiIorio is a postdoctoral fellow at CHEDAR working with Prof. Eric Johnsen.

Dr. Ma's thesis examined the effects of nonlocal deviations in electron heat flux due to steep temperature gradients when electron distributions can become non-Maxwellian. Figure 1 shows

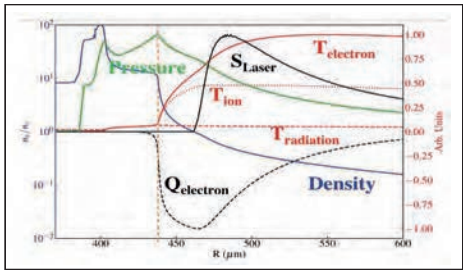

Figure 1.One-dimensional (1D) profile of laser-ablation front from a 1D-spherical HYDRA radiation hydrodynamics simulation. The laser is propagating from right-to-left towards the origin. The dashed-orange vertical demarcates the local thermodynamic equilibrium (LTE) and nLTE portions of the plasma.[1]

Figure 2. 2024 HEDSS cohort with Director Kuranz on University of Michigan Campus.

HYDRA simulation results of a laser-ablated copper sphere and the relevant temperatures, density, pressures, and energy sources, such as laser energy heating and electron heat flux. At laser intensities relevant to inertial confinement fusion (ICF) research, non-Maxwellian electron distributions are produced by the collisional absorption of laser light and by laser-plasma-instabilities (LPI). Current computational approaches of complex, integrated systems often use simplified models with numerical corrections for physical process deficiencies. In electron heat transport, flux-limiters coupled with the Spitzer-Harm conduction model are commonly used in radiation hydrodynamics codes. Dr. Ma used atomic-kinetics simulations and Vlasov-Fokker-Planck theory to study the impact of non-Maxwellian electron distributions on plasma radiative properties. From one-dimensional comparisons, he found the impact of non-Maxwellian electrons from nonlocal transport and from collisional laser absorption on the radiation emissions (<1%) and the K-shell line intensities (<10%) is minimal. These differences may not be experimentally significant, suggesting that current nonlocal models are sufficient for modeling electron transport in laser-irradiated spheres under ICF-relevant conditions. This approach also was used to assess the effect of non-Maxwellian electrons from other physical processes, such as several LPI effects.

In summer of 2024, CHEDAR hosted the High Energy Density Summer School (HEDSS) at the University of Michigan. The summer school was supported by the NNSA, the National Science Foundation ZEUS Laser Facility, and the Center for Magnetic Acceleration, Compression and Heating (MACH), another center of excellence at the University of Michigan led by Prof. Ryan McBride. The summer school has a week-long virtual component followed by a week-long in-person component held in Ann Arbor, MI. The in-person segment at Ann Arbor brought together 40 participants from across the globe for an intensive week of advanced lectures and hands-on group projects. This segment included lectures on HED Laboratory Conditions, HED Diagnostics, Radiation Hydrodynamics, Laboratory Astrophysics, and advanced topics in Shocks and Instabilities. Participants also presented group projects, proposing HED research initiatives at various HED facilities. These projects fostered practical experience in proposal planning and writing, covering experimental goals, motivations, plans, and resource requirements, including targets, diagnostics, and simulations. The High Energy Density Virtual Summer School exemplifies CHEDAR's commitment to educating and training the next generation of scientists in this dynamic field, fostering a deeper understanding of HED physics and its applications in both fundamental research and practical implementations. Figure 2 shows the group on University of Michigan campus with Director Kuranz.

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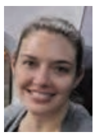
The Wootton Center for Astrophysical Plasma Properties | The University of Texas at Austin

PI: Dr. Donald Winget (dew@astro.as.utexas.edu); Authors: Mike Montgomery, Bart Dunlap, Don Winget, Dan Mayes, and Alisha Clark

The purpose of the Wootton Center for Astrophysical Plasma Properties (WCAPP) is to explore matter under a wide variety of cosmic conditions in the laboratory, transforming astrophysics into experimental science. WCAPP enables graduate students and postdoctoral researchers to work in a national laboratory scientific culture and to gain expertise in theoretical and experimental atomic and materials physics, spectroscopy, and platform development. The Center's experimental work currently makes use of the Z Pulsed Power Facility at Sandia National Laboratories and the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL).



Clark

The Center has expanded with the addition of Assistant Prof. Alisha Clark (University of Colorado (CU) Boulder), who officially joined in the Fall of 2023. Her research focus is on the physical properties of planetary materials at extreme conditions, which she investigates with dynamic compression experiments on the Z machine. She recruited American Geophysical Union Bridge Program student Israel Carrillo to join her research group in the spring of 2024. Israel spent the Summer working with former WCAPP student Zethran Berbel, training on data processing so that he could take over the WCAPP subproject on the accretion of exoplanetary material onto cool white dwarfs.

This work will complement and expand the Center's white dwarf photosphere experiment at the Z machine, which uses optical spectra of plasmas at white dwarf atmospheric conditions to benchmark the line broadening models that underpin inferences of white dwarf fundamental properties from astronomical spectra. In collaboration with Clark and her students, University of Texas at Austin (UT) research associate Bart Dunlap is exploring ways to expand the white dwarf photosphere experiment to measure the neutral broadening of elements (e.g., Ca, Mg, Fe) used to infer the relative abundances of exoplanetary material from white dwarf spectra. As part of this multipronged approach involving materials compression experiments, laboratory plasmas, and astronomical observations, graduate student

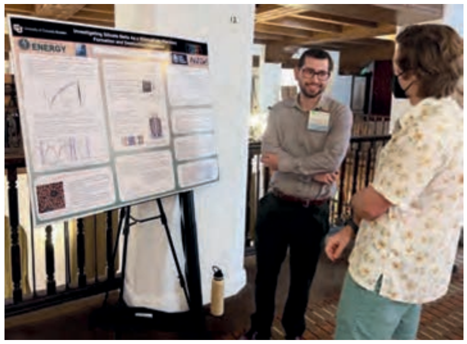


Figure 1. Graduate student Israel Carillo (CU Boulder) discusses his work with graduate student Bryce Hobbs (UT Austin) at the 2024 Z Fundamental Science Workshop in Albuquerque.

Malia Kao (UT) has used machine learning to expand the number of candidate white dwarfs that can be used to derive exoplanetary abundances from a few dozen to a few hundred.[1] She currently is undertaking follow-up observations with the Hobby-Eberly Telescope at McDonald Observatory.

Graduate student Jackson White (UT, currently a Stewardship Science Graduate Fellow at Los Alamos National Laboratory) has been working on line broadening theory related to close ion interactions, which is relevant to both our white dwarf and solar oxygen experiments. He has developed a new method of calculating plasma microfields that accounts for both the quantum atomic structure and N-body effects while being more computationally efficient than density functional theory.[2]

Jackson's theoretical work builds upon the work of former graduate student Thomas Gomez (now Hale Fellow at CU Boulder) who continues to mentor graduate students and lead theory efforts for WCAPP. These have included important diagnostics for the WCAPP experiments, in particular the Fe and O opacity experiments. Gomez has mentored graduate student Bryce Hobbs in expanding the capabilities for the line-shape code Xenomorph, which will allow modeling ionized carbon lines observed in the white dwarf photosphere experiment. Other developments include expanding the Balrog code[3] to include high magnetic fields[4-7] for developing neutron star diagnostics.[8]

In the summer of 2024, UT graduate student Patty Cho defended her dissertation on photoionized plasmas at conditions observed in black hole accretion disks. This work, based on data Patty collected at the Z machine is crucial to benchmark models of these disks. In particular, the measurements show models underpredict Fe L-shell emission intensity. This helps resolve the supersolar Fe abundance problem. In August, Patty began as the 2024 HEDS Postdoctoral Fellow at LLNL, where she will continue to collaborate with WCAPP, working on the NIF Fe and O opacity measurements.

For this O opacity work, postdoctoral researcher Dan Mayes is leading experimental efforts at both Z and NIF. The experiments aim to address the discrepancy between standard solar models and helioseismology by making benchmark measurements of oxygen, the dominant opacity source at the relevant solar interior conditions. The effort at Z is focused on refining measurements of the monochromatic oxygen opacity over the wavelength range of 5-20 Angstroms (at T_e~150 eV and n_e~8e21 e/cc). Preliminary comparisons with models show good agreement in the continuum but significant disagreements in the line features. The team also began measurements at higher temperatures and densities where density effects are likely more important. At NIF, preliminary results, which showed a large model-data discrepancy at higher density (n_e~2e22 e/cc) and similar temperature, have led to an effort by graduate student Bryce Hobbs to improve analysis methods, including an improved method for handling second-order contamination in the crystal spectrometer,[9] and investigate potential sources of systematic uncertainty. So far, systematic uncertainties have not been able to explain the discrepancy observed in the NIF data.[10] Additionally, work is underway to produce experimental data at conditions similar to those on Z for a more direct comparison between the platforms.

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Constraining Neutron-capture Cross Sections via Direct and Indirect Experimental Methods | University of Notre Dame

PI: Dr. Anna Simon-Robertson (anna.simon@nd.edu)

Neutron-capture cross sections are key to many nuclear physics applications, from the modeling of nucleosynthesis processes in stellar objects to new developments for energy and national security applications. This project focuses on constraining neutron-capture cross sections using both direct and indirect experimental approaches. Through direct neutron capture measurements on ^{68}Zn, the project constrains the neutron-capture cross section on a common construction material—information crucial for neutron economy calculations for nuclear physics applications. A new indirect technique is being developed to measure neutron capture cross section on ^{94}Nb, a long-lived, unstable nucleus that might be a branching point in the s-process nucleosynthesis path.

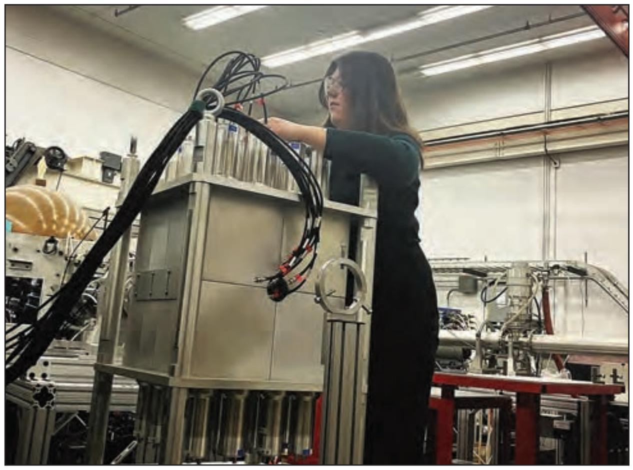

Figure 1.Chloe Jones preparing HECTOR for an upcoming experiment.

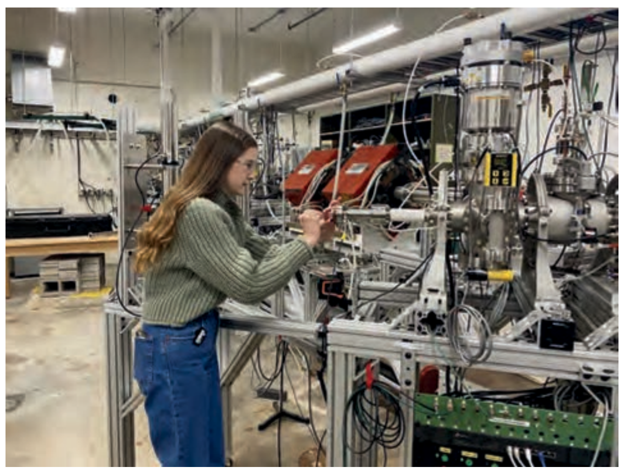

Figure 2. Miriam Matney working on the Neutron Irradiation Station.

Chloe Jones, a third-year graduate student, works on developing a new technique to measure the neutron-capture cross sections indirectly using a NaI(Tl) detector array, HECTOR (Figure 1). HECTOR is a High EfficienCy Total Absorption spectrometeR designed for detecting γ rays following a proton or alpha capture reaction. However, due to its large volume, it also is capable to detect neutrons, thus allowing for a simultaneous measurement of (p,γ) and (p,n) reactions. This opens the possibility to observe the competition between neutron and γ-ray emission from the compound nucleus populated by the proton capture. Such information then can be used to constrain the Hauser-Feshbach theory models describing the properties of the compound nucleus and to calculate the neutron-capture cross section.

While the γ-ray detection efficiency of HECTOR has been well characterized and tested during nearly ten years of experimental work, the response of the detector to neutrons must be determined. Chloe currently is working on Geant4 simulations to determine the efficiency of neutron detection in HECTOR. This is a crucial step to correctly extract the experimental neutron yields. Once the simulations are completed, Chloe will extract the γ-ray and neutron yields to investigate the competition between the (p,γ) and (p,n) channels on ^{94}Zr and will use Talys code to model the experimental data. The results will allow her to constrain the ^{94}Nb(n,γ)^{95}Nb reaction rate. This reaction is a possible branching point in the s-process nucleosynthesis path and may have a direct impact on production of ^{94}Mo, a proton-rich isotope of Mo whose solar abundances cannot be correctly reproduced by any nucleosynthesis models.

The second part of the project focuses on direct measurements of neutron capture. For this purpose, Miriam Matney, a fifth year graduate student, utilizes two facilities: the Detector for Neutron Capture Experiments (DANCE) array at Los Alamos National Laboratory (LANL) and a newly established Neutron Irradiation Station (NIS) (Figure 2) at the University of Notre Dame (UND) to measure neutron capture on ^{68}Zn. This reaction is important for stockpile stewardship applications, as Zn is a common construction material and must be included in any neutron economy calculations. DANCE allows for in-beam measurements of prompt γ-rays following the neutron capture. At NIS, Miriam uses the activation techniques where after the target irradiation, she moves it into a counting station to detect β-radiation and γ-rays following the decay of the reaction product. This is the first measurement of a neuron-capture reaction at NIS after its commissioning. Thus, the measurement at DANCE will serve as an additional benchmark for the work at UND.

The project provides training opportunities for the graduate students who learn about various techniques for detecting γ-rays and neutrons and modeling the response of the detectors using simulations. The students are trained in operating the particle accelerators at UND, learn about beam production and ion optics, and become independent accelerator operators. They also are responsible for all steps of the experimental work, from planning and setting up the experiment, to collecting and analyzing the data, to preparing it for publication. The students work in close collaboration with scientists at LANL and Lawrence Livermore National Laboratory.

Predictive Simulations of Explosive Particulate Dispersal | University of Florida, Gainesville

PI: Dr. S. Balachandar (bala1s@ufl.edu); Authors: Thierry Daoud, Sam Briney, T. L. Jackson, and S. Balachandar

Explosive dispersal of a packed bed of particulate matter is of considerable interest in many national security, energy, and industrial applications. As the particulate matter is rapidly propelled outward, the advancing material front exhibits an amazing variety of spatio-temporal dynamics and instabilities, which can be most vividly observed in volcanic Plinian eruptions. We currently lack the ability to accurately predict the dispersal pattern that can be expected given the input parameters of an application. However, such understanding is of importance in controlling turbulent mixing and chemical reactions.

Due to the extreme conditions of pressure and temperature and their rapid evolution on very short time scales, the problem of explosive dispersal poses a great challenge to experimental investigation and detailed diagnostics. Large-scale simulations using peta- and exascale computing powers offer a unique opportunity to study these problems at an unprecedented level of detail to reveal the complex underlying instability mechanisms that control the space-time dynamics of the particulate fronts. The large-scale simulations, however, face the challenge that complete accounting of all the flow processes, contact mechanics between the interacting particles, and gas-phase/surface chemistry from first-principles is not feasible. Coarse-graining is essential, which leads to closure models that encapsulate particle-gas, particle-particle, and particle-gas-particle interactions. Developing the best possible closure models of these interaction processes is the primary quest of this work, so that the large-scale simulations that employ them become truly predictive so that their results can be trusted.

Much attention has been devoted to improving modeling of particle-gas interactions in terms of force and heat transfer models that specifically account for compressibility effects in the presence of shocks and density interfaces.[1,2] Similar advances have been made in the simulation of particle-particle contact interactions using soft-sphere collision models. The focus of the recent work has been to build upon these earlier modeling efforts to systematically account for particle-gas-particle interactions during which the particles, as they disperse, continue to influence each other mediated by the surrounding gas flow. Though traditionally such interactions have been ignored, there is growing recognition of their importance. For example, it has been shown that only with the inclusion of these gas-mediated interactions, the coarse-grained governing equations become well-posed.[3,4] Furthermore, only with particle-gas-particle interactions properly accounted for, the simulations predict the correct level of force fluctuation and capture longitudinal and lateral dispersion.

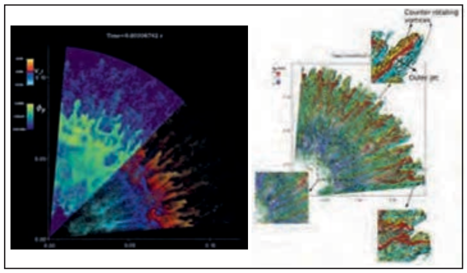

Figure 1. Color plots of projected particle volume fraction (top left sector) and particle radial velocities (bottom right sector) while the axes show the particles x- and y-positions, for Ms = 1.8, at 3 ms (left) and the isosurfaces of vorticity in the z-direction with particles colored by their radial velocities, for Ms = 2.2, at 3 ms, with close-up views shown at the inner and outer edges (right). Figures are courtesy of reference 5.

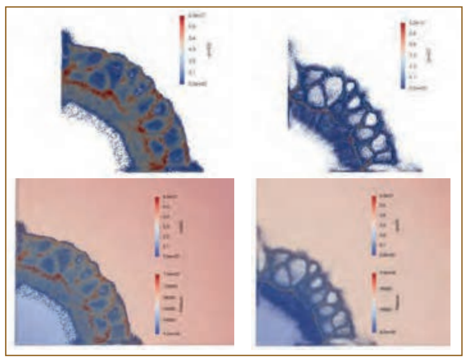

Figure 2. Color plots showing particles' volume fraction at (a) 0.47 ms and (b) 1.33 ms and both fluid pressure and particle volume fraction plots at (c) 0.47 ms and (d) 1.33 ms, respectively. Results are taken from the on-going work of our group.

An example of high-fidelity simulations of explosive dispersal is shown in Figure 1, which has been designed to mimic the experiments of Rodriguez, et al.,[6] where we can clearly identify fingering instability resulting in the formation of long particulate fingers that penetrate far-out into the gas phase. A careful analysis of the flow and particulate phases has revealed that the back effect of particles results in the formation of longitudinal vortices that play a central role in the formation of streaky structures.[5] Although the above experiment was performed in a Hele-Shaw cell, another explosive dispersal example where the instability takes on a different character of clusters and voids is shown in Figure 2, depicting three-dimensional, four-way-coupled, quarter-cylindrical mesoscale runs of a very high-pressure region with a dense particle bed. The formation of particle agglomeration starts as early as 0.47 ms (Figure 2 (a) and (c)), as these clustered regions develop into voids as the leading particle front propagates further out in time, while the trailing side slows down and starts to propagate radially inward (Figure 2 (b) and (d)). The gas-particle-gas interaction has a primary influence on the various instabilities observed, as the expansion fans and reflected shocks drive the upstream particle front radially inward, while the leading shock propels the outer particle front. Interestingly, the radially-expanding shock decelerates over time but is subsequently accelerated by the advancing dense particle front that will exhibit fingering instabilities when simulated further in time.

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Virtual-Slit Cycloidal Mass Spectrometer for Portable, Rapid Ultra-trace Isotope Ratio Analysis of Actinides | Duke University

PI: Dr. Jason J. Amsden (jason.amsden@duke.edu); Authors: Jason J. Amsden and Rafael Bento Serpa (rafael.bento.serpa@duke.edu)

The virtual-slit cycloidal mass spectrometer (VS-CMS) is a revolutionary concept for a portable, high-resolution, high-sensitivity mass spectrometer for analyzing the elemental and isotopic composition of trace actinides in environmental particulate matter. VS-CMS incorporates the unique perfect focusing properties of the cycloidal mass analyzer with recently developed capacitive trans-impedance amplifier (CTIA) ion array detectors. The focusing properties of the cycloidal mass analyzer, when coupled with a suitable array detector, allow the use of a micron-sized particle ionized by a laser as a "virtual-slit" resulting in a high-resolution, relatively small instrument.[1] Funded through the National Nuclear Security Administration's Stockpile Stewardship Academic Alliances (SSAA) program, a team of researchers at Duke University and the University of Arizona have been working on developing a better understanding of the laser ionization process, including measuring the energy distribution of ions generated by laser ionization and improving the sensitivity and resolution of a proof-of-concept virtual slit, cycloidal mass analyzer (POC-VS-CMS) instrument. During the first year of the program, Research Scientist Dr. Rafael Bento Serpa, along with graduate student Tanouir Aloui and high school student Kevin Lee, designed, modeled, and built an apparatus to measure the ion energy distribution from laser ionization. In the second year of the program, the team made the laser ion energy measurements described below. In the program's final year, Dr. Serpa is working with undergraduate student, Daniel Ross, on ways to improve the sensitivity and resolution of POC-VS-CMS.

Measurement of the ion energy distribution from laser ionization is a critical parameter needed for the optical design of a VS-CMS instrument. A cycloidal mass analyzer employs perpendicularly-oriented electric and magnetic fields. Ions generated by the laser undergo cycloidal trajectories and are focused on a detector placed on the mass analyzer focal plane independent of their initial speed and direction (Figure 1). However, the size of the trajectories are proportional to the ion energy.[2] Therefore, for optimal design of a cycloidal mass analyzer, an accurate measurement of the ion energy is needed. A wide range of values are reported in the literature for the ion energy distribution from laser ionization, indicating that it is essential to measure the distribution for a specific laser system.[3] Figure 2 shows a diagram of the apparatus designed, modeled, and built by the team and initial data. The apparatus consists of an array of electrodes with a cavity in which ions and electrons travel after ionization by a Nd:YAG laser. The ion energy is measured by measuring the time between the laser pulse and arrival at the electrodes. Results indicate that the ion energy is proportional to laser fluence and relatively independent of laser wavelength. In addition, results show that the ion energy changes as a function of distance from the source, indicating that ions are being generated in the plume above the laser focal spot. The generation of ions in the plume above the laser focal spot helps explain a broad background signal in the mass spectrum from the POC-VS-CMS instrument (Figure 1).

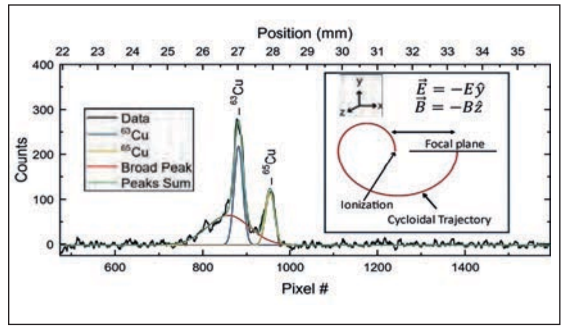

Figure 1.Mass spectrum of copper taken with the POC-VS-CMS instrument. The inset shows a cycloidal mass analyzer schematic.

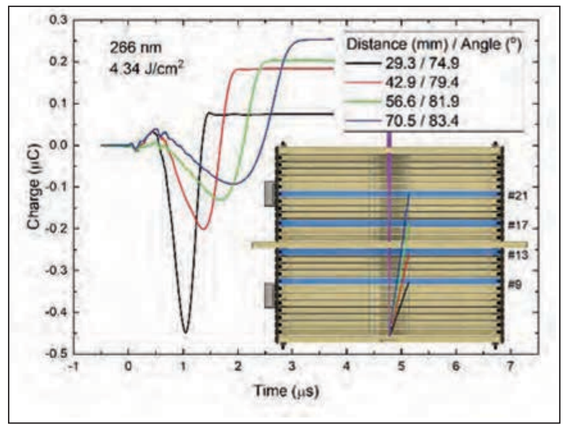

Figure 2. Signal on different electrodes as a function of time in the ion energy measurement apparatus. Negative signals represent electrons and positive signals represent ions. The inset shows a CAD model of the apparatus.

Based on the improved understanding of the laser ionization process and to help mitigate the broad background signal, Dr. Serpa and undergraduate student Daniel Ross are working to implement a "double-pulse" ionization technique to improve the sensitivity of the POC-VS-CMS instrument. In a "double-pulse" configuration, an initial laser pulse is used to generate a plume of neutral molecules, ions, and electrons. A subsequent laser pulse delayed by several microseconds is used to ionize neutral atoms on the plume. It is expected that this double-pulse configuration will result in a smaller plume and a reduced broad background signal.

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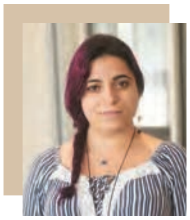
Stefania Dede (sdede@lanl.gov) | Los Alamos National Laboratory, 2024 - Present
Degree: PhD, Nuclear Physics ✦ **SSAA:** 2019 - 2023, Texas A&M University, University of Notre Dame



I am a postdoctoral researcher at Los Alamos National Laboratory (LANL) in the Nuclear Engineering and Nonproliferation Division, working within the Safeguards Science & Technology group. Our mission is to safeguard nuclear materials by developing advanced techniques and systems for the nondestructive assay of nuclear and hazardous materials.

My team specializes in low temperature detectors and their application to international nuclear safeguards. One of the cutting-edge projects I am currently involved in is the development of the Spectrometer Optimized for Facility Integrated Applications (SOFIA). SOFIA is a breakthrough in nondestructive nuclear material analysis, nuclear data measurements, and actinide science. It is the first ultra-high-resolution gamma spectrometer based on low-temperature microcalorimeter technology. By precisely measuring the gamma rays passively emitted from radioactive and nuclear materials, SOFIA provides rapid, completely nondestructive analysis, significantly improving the efficiency and timeliness of nuclear material evaluation. This reduces reliance on costly sampling and destructive analysis. The development of this compact instrument aims to bring this groundbreaking technology into practical use in nuclear facilities and analytical laboratories worldwide. It is designed to complement existing spectroscopic methods by offering enhanced sensitivity and precision for a wide range of applications, from nuclear safeguards to basic science research.

My research focuses on utilizing this advanced detection system to measure nuclear materials. These measurements are being used to improve nuclear data and characterize nuclear materials by uncovering signatures that were previously undetectable, advancing both the science and practical applications of nuclear material analysis. For instance, Figure 1 illustrates a comparison of a high-burnup light water reactor fuel measurement using three different detection systems: a High-Purity Germanium (HPGe) detector, a cadmium zinc telluride (CZT) detector, and our microcalorimeter detector. The superior resolution of our microcalorimeter, particularly at low energies, reveals features that are entirely obscured when using the other detection systems. This highlights the transformative potential of microcalorimeter technology in uncovering previously undetectable nuclear material signatures.

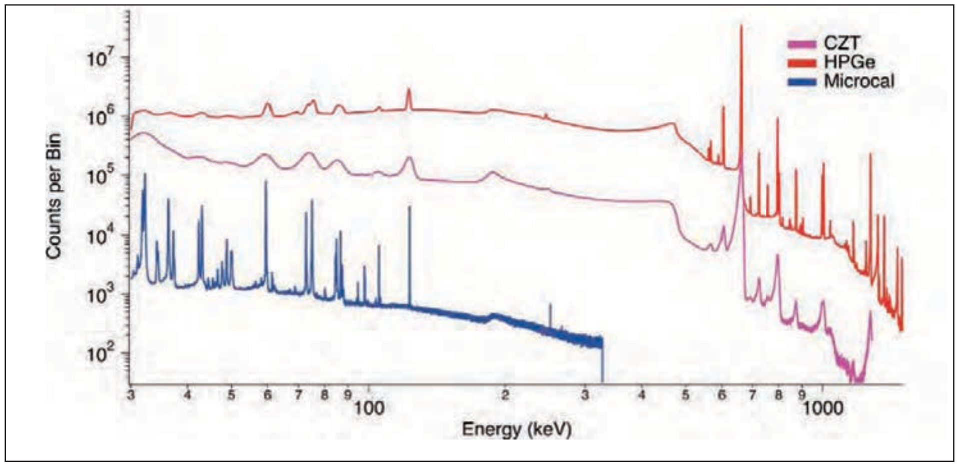


Figure 1. Comparison of a high-burnup light water reactor fuel measurement using three different detection systems.

I completed my PhD in December 2023, having the privilege of working at two centers of excellence: the Center of Excellence in Nuclear Training and University-based Research (CENTAUR) at Texas A&M University and the Actinide Center of Excellence (ACE) at the University of Notre Dame. Shortly after graduation, I began my career as a postdoctoral researcher at LANL in late January 2024.

During my graduate studies at the University of Notre Dame, I explored multiple subfields of nuclear physics, including nuclear astrophysics and actinide target fabrication. My Stewardship Science Academic Alliances (SSAA)-supported research focused on developing innovative approaches for preparing actinide targets that are isotopically pure, cost-effective, reliable, robust, and highly uniform, with precisely controlled thicknesses and dimensions to support advanced nuclear measurements. At Texas A&M University, I participated in several measurement campaigns and contributed to subsequent data analysis, gaining valuable experience in programming and simulation using various coding languages and software tools.

I was fortunate to have multiple opportunities to connect with scientists from national laboratories through conferences, laboratory visits, and sponsored talks at my university. These experiences were invaluable, as they enabled me to network with scientists at LANL, ultimately leading to summer internships, further connections, and job offers. The SSAA-funded symposia, particularly, provided dedicated networking sessions between students and national laboratory staff. These interactions played a crucial role in building the relationships necessary for pursuing a career at a national laboratory.

Many factors influenced my desire to work at LANL, but the exposure I gained during my graduate education through the SSAA was instrumental in shaping my career path. The experiences and knowledge enabled by the SSAA were invaluable, offering unique opportunities to build connections and gain insight into the field. Being part of an SSAA-supported university was a significant advantage for me, as it helped establish the relationships necessary to pursue my career at a national laboratory. [LA-UR-24-32915]

Shree Krishna Neupane (neupane1@llnl.gov) | Lawrence Livermore National Laboratory, 2023 - Present
Degree: PhD, Nuclear Physics ✦ **SSAA:** 2018 - 2019, University of Tennessee, Knoxville

As a postdoctoral researcher at Lawrence Livermore National Laboratory (LLNL) in the Nuclear and Chemical Sciences Division, I conduct precision nuclear decay spectroscopy experiments, develop advanced radiation detectors, and utilize simulations to characterize isotopes critical to national security and fundamental nuclear science.

My research focuses on long-lived fission products, such as ^{161}Tb and ^{115m}Cd, which provide crucial insights into stockpile stewardship, nuclear forensics, and nonproliferation efforts. Located in distinct regions of the fission product distribution, these isotopes exhibit significant sensitivity to the original fission source conditions. Their reliable characterization is therefore essential for identifying the actinides and neutron energies that produced them, thereby improving our understanding of post-detonation fallout and strengthening global security initiatives.

These isotopes are produced by neutron irradiation of high-purity target materials at the McClellan Nuclear Reactor Center and are then chemically separated at LLNL. The resulting radiopure samples are deposited on thin carbon foils for decay measurements. By combining a 4π–β-counter with a precisely calibrated Broad Energy Germanium (BEGe) detector, we achieve ~1% precision in the γ-ray intensities of these isotopes. Such precision measurements of decay properties are vital for applications ranging from stockpile stewardship and nuclear security to medical isotope production and cancer therapy.

Monte Carlo simulations, particularly those implemented with the GEANT4 toolkit, play a crucial role in my work. These simulations inform the optimization of detector configurations, enhance our understanding of detector responses, and refine analytical methods. For instance, at LLNL, I model complex β–γ coincidence systems to support precision decay measurements of fission product and medical isotopes. I also simulate state-of-the-art neutron detectors, including highly segmented plastic and organic glass scintillators, which provide improved energy resolution, timing, and pulse-shape discrimination capabilities.

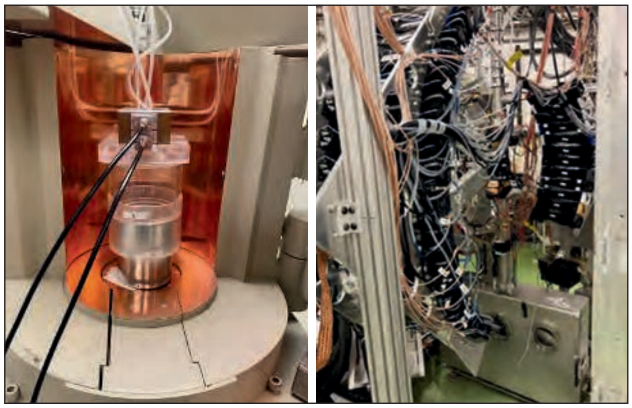


Figure 1. A β–γ coincidence detection system at LLNL for precision decay measurements of long-lived fission products (left) and the NEXT array at ISOLDE decay station for β-delayed neutron emission studies.

In addition, I study the β-decay of neutron-rich nuclei near the regions of ^{24}O and ^{54}Ca at the Facility for Rare Isotope Beams (FRIB), formerly known as the National Superconducting Cyclotron Laboratory (NSCL). By employing cutting-edge detection systems, these studies aim to uncover fundamental nuclear properties relevant to both basic science and security applications.

I completed my PhD in Physics at the University of Tennessee, Knoxville, in December 2022. My doctoral work focused on developing a segmented neutron time-of-flight (TOF) detector, a project funded by the National Nuclear Security Administration. This detector, known as the Neutron Detector with Xn Tracking (NEXT) array, is designed for high-resolution measurements of beta-delayed neutron emission of neutron-rich nuclei critical to basic science, stockpile stewardship, and nuclear energy. By incorporating optical segmentation of a neutron–gamma (n–γ)-discriminating plastic scintillator along the neutron flight path, the NEXT array enables precise localization of neutron interactions. This segmentation significantly reduces systematic uncertainties in time-of-flight measurements, improving energy resolution while maintaining high neutron detection efficiency. This work established new methodologies in detector development and digital signal processing, providing me with the technical expertise required for advanced experiments. The detector array has been commissioned at various radioactive ion beam facilities, including the NSCL (now FRIB), Argonne National Laboratory, and the On-Line Isotope Mass Separator (ISOLDE), and is now producing exciting results. Through this project, I was introduced to the Stewardship Science Academic Alliances (SSAA) and the diverse range of research it supports at universities across the United States.

Programs like SSAA have offered invaluable experiences, enabling me to contribute to cutting-edge, multidisciplinary research efforts. At LLNL, I have the opportunity to collaborate with leading experts and leverage unique resources, including high-performance supercomputers and advanced experimental facilities—an ideal environment for pushing the boundaries of nuclear science. Additionally, working at various radioactive ion beam facilities has provided hands-on experience in experimental design, data analysis, and detector characterization. Combined with my background in simulations, these experiences have prepared me for the challenges and opportunities I now face at LLNL. My journey through academia and the national laboratories has deepened my interest in nuclear physics research, and SSAA has played a crucial role.

Will Bassett (wpbasse@sandia.gov) | Sandia National Laboratories, 2021 - Present
Degree: PhD, Chemistry ✦ SSAA: 2013 - 2018, University of Illinois at Urbana Champaign

I am an experimental scientist with the Explosives Technology Group (ETG) at Sandia National Laboratories. Scientist is an intentionally vague title, because of how much multidisciplinary work is done at the labs broadly and the ETG more specifically. On some days, I'm a chemist, others an engineer, and still others a data scientist or even project manager. The pathway to such multidisciplinary work is through a wide variety of experiences, enabled by graduate school projects and notably the Stewardship Science Academic Alliances (SSAA) program's Chicago/DOE Alliance Center (CDAC).

In graduate school, supported by the SSAA, I worked on developing high-throughput methods and the associated diagnostics for exploring short-pulse shock compression events on explosive targets. The high-throughput techniques were adopted by groups working with the Army and all three National Nuclear Security Administration (NNSA) labs mainly for looking at explosive initiation and shock physics. Most significantly, the development of a pyrometry diagnostic for measuring *in-situ* temperatures during explosive shock initiation was regarded well-enough that I was hired to recreate it into a different experimental platform as a post-doctoral researcher at Lawrence Livermore National Laboratory (LLNL). The connections with the NNSA labs made during the annual Stewardship Science Academic Programs (SSAP) Symposium enabled this broadly by introducing me to key personnel at those labs. These connections again came in handy during COVID, when my wife and I decided to relocate closer to family. I was able to call on some colleagues at Sandia National Laboratories (SNL) and move to a staff position in Albuquerque, New Mexico. This professional network that enabled the move necessary for my career was not all established through the SSAP, but it certainly began there early on in my graduate school career. The support and opportunities provided by the program were invaluable in establishing and maintaining a career with the NNSA labs.

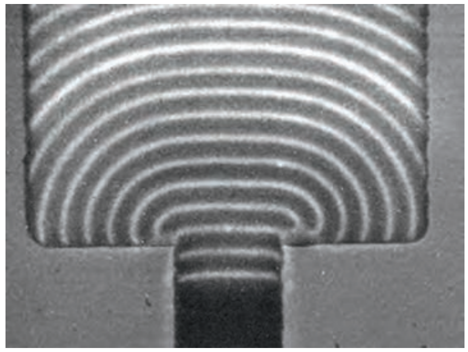


Figure 1. Composite framing camera images of detonation corner turning in an explosive micromushroom experiment. Original images were recorded at 25 MHz (1/40 ns) with an exposure time of 10 ns. Bright bands are the detonation front at each frame time, overlaid on a still pre-shot image of the explosive geometry.

My current work at the ETG involves furthering our understanding of explosives at the micron-scale. Through micro-scale sample fabrication techniques such as laser-machining and vapor-deposition, we create explosive samples in otherwise inaccessible geometries and then test those materials for their fundamental properties such as detonation velocity, corner-turning, and critical dimension for sustaining a detonation (Figure 1). Some of this work leverages advances our group made during my time in graduate school for high-throughput techniques, utilizing the advanced sample fabrication and metrology techniques which are unique to SNL. The bulk of my work is at the microscale, with samples from less than 1 mg up to a few grams of explosive. However, within the ETG, the range of problems to tackle is enormous and has enough variety to ensure work is always interesting. As I worked on more applied projects at both LLNL and SNL, I found that although in graduate school I focused on the fundamental research of explosives, I greatly enjoyed seeing those fundamentals transition to real-world applications. Due to the wide range of experiences that the SSAP enabled me to explore, I was able to find various ways in which I could contribute and push forward research in more applied subjects.

“As I worked on more applied projects at both LLNL and SNL, I found that although in graduate school I focused on the fundamental research of explosives, I greatly enjoyed seeing those fundamentals transition to real-world applications. Due to the wide range of experiences that the SSAP enabled me to explore, I was able to find various ways in which I could contribute and push forward research in more applied subjects.”

The national laboratories offer access to an unparalleled community of scientists and engineers with wide-ranging backgrounds as well as facilities for pursuing both team-based big science questions and more individual research. The closeness of the research teams and sense of unified purpose enable collaboration between experiments and theory and modeling to advance the understanding of both basic physics and more applied work. The opportunities for mentorship and guidance are invaluable to new staff and postdocs, and the ability to take a path between fundamental and applied work as your interest's dictate are some of the biggest advantages of a job at the NNSA labs.

Andre Archer (a.archer@ufl.edu) | University of Florida

Degree in Progress: PhD, Mechanical Engineering ✦ **Advisor:** Dr. Douglas Spearot ✦ **SSAA:** 2022 - Present

Research Topic

Characterization of Shock-Induced Plasticity via Molecular Dynamics Simulations

Research Responsibilities

My research goal is to understand how metallic materials respond on the nanoscale to shock loading conditions. Shock impacts are frequent events in spacecraft and nuclear applications, but the mechanisms that drive the plastic deformation leading to shock-induced failure are not sufficiently understood. Through computer modeling, I can capture the details of plasticity on the nanoscale and build a framework for understanding mechanical responses typically seen in shock experiments.

My responsibilities are to create non-equilibrium molecular dynamics simulations to generate a shockwave in a metal, such as aluminum, and to use the resulting atomistic data to spatially characterize the nucleation and growth of dislocations that result in plastic deformation. These large-scale simulations, consisting of tens-of-millions of atoms, are performed utilizing the computational resources of HiPerGator at the University of Florida. By developing a computer-vision based framework, I identify length scales associated with dislocation activity that can then be fed into higher length simulations such as discrete dislocation dynamics (DDD) to comprehensively characterize shock induced plasticity.

Benefits of SSAA

In my first two years under the support of the Stewardship Science Academic Alliances (SSAA) program, I attended the 2023 Dynamic Compression Workshop at Argonne National Laboratory and presented a poster at the 2024 SSAA Symposium. In spring of 2025, I will be a guest student researcher at Los Alamos National Laboratory to expand my research skills alongside collaborators. Through these experiences, I have not only expanded my technical skills as a scientist and engineer but also have grown my confidence in being able to tackle complex problems as they arise in research. Additionally, I have been able to grow an expanding network of peers that will undoubtedly be beneficial to my career as a graduate student and beyond.

What Students Considering SSAA Should Know

The SSAA offers experiences that I did not know existed previously but have now resulted in incredible opportunities for collaboration and networking. Through presenting research and receiving expert feedback, you are enabled to grow as a scientist and a professional. The connections and events from this program open career paths you may not have even been aware of and can be one of the most influential experiences available during graduate school.

Miriam Matney (mmatney@nd.edu) | University of Notre Dame

Degree in Progress: PhD, Nuclear Physics ✦ **Advisor:** Dr. Anna Simon-Robertson ✦ **SSAA:** 2022 - Present

Research Topic

Direct Measurements of Neutron Capture Reactions

Research Responsibilities

Neutron capture reactions are the driving force in heavy element nucleosynthesis and important in nuclear energy and stockpile stewardship applications. Direct measurements of these reaction cross sections are needed for a better understanding of these systems. My work focuses on neutron instrumentation and measurements of neutron capture cross sections. I commissioned the Neutron Irradiation Station (NIS) at the University of Notre Dame Nuclear Science Laboratory, which produces high fluxes of neutrons via the $^{7}Li(p,n)^{7}Be$ reaction for neutron-induced reaction measurements.

I use NIS to study neutron capture on the naturally occurring zinc isotope, ^{68}Zn. Zinc is a component in common construction materials present in nuclear reactors. The $^{68}Zn(n,\gamma)$ reaction cross section is important for isotopic abundance predictions with nucleosynthesis models. To find the reaction cross section, I expose targets containing ^{68}Zn to neutrons from NIS and then measure their activity due to the neutron capture product. Simultaneously, I work with data on the same reaction measured with the Detector for Advanced Neutron Capture Experiments (DANCE) located at Los Alamos National Laboratory (LANL). Multiple measurements of the same reaction are beneficial in constraining cross section uncertainties.

Benefits of SSAA

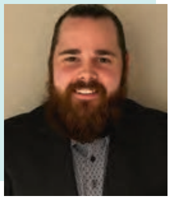
The Stewardship Science Academic Alliances (SSAA) program has enabled me to develop technical skills and scientific knowledge as I conduct research in experimental nuclear physics. It also has connected me with scientists outside my institution. The annual Stewardship Science Academic Programs Symposium has been a great opportunity to present my work and learn about research and opportunities at the National Nuclear Security Administration labs.

What Students Considering SSAA Should Know

Because of the SSAA, I had the opportunity to spend the summer of 2023 at LANL working with Dr. Aaron Couture on DANCE data on the $^{68}Zn(n,\gamma)$ reaction, the same reaction I study at Notre Dame. This experience has been one of the highlights of my graduate career. I was able to collaborate with other nuclear physicists, learn more about neutron-induced reactions and the instrumentation involved, and work with a data set directly applicable to my thesis research. This helped me with my DANCE analysis work as well as my project at Notre Dame. I have a much better understanding of what a national laboratory career can look like, and I am better equipped to work toward my career goals as a result.

Andrew Pope (adpope@uab.edu) | University of Alabama at Birmingham
Degree in Progress: PhD, Physics ✦ **Advisor:** Dr. Yogesh K. Vohra ✦ **SSAA:** 2021 - Present

Research Topic



Additively Manufactured Alloys under Extremes of Pressure and Temperature

Research Responsibilities

My research explores the relatively new and ever-expanding frontier of additively manufactured alloys that exhibit a desirable combination of high strength and high ductility due to unique nanostructures that are achieved by rapid cooling in three-dimensional (3D) printing. I study pressure- and temperature-induced phase transformations in 3D printed alloys that have a bearing on their exceptional mechanical properties.

Benefits of SSAA

The Stewardship Science Academic Alliances (SSAA) program has provided me with an incredible foundation to pursue a career as an experimental physicist in a collaborative research environment involving multiple academic institutions under the SSAA-funded center of excellence, the Center for Additively Manufactured Systems under Extremes (CAMCSE). The SSAA program hosts superb annual symposiums that allow the research community to discuss cutting-edge and novel results and point to future research directions in materials under extreme conditions. These symposiums have provided me the opportunity to present my research and develop vital presentation skills and to network with fellow graduate students and other research scientists.

What Students Considering SSAA Should Know

The SSAA has provided me with hundreds of hours of beam-time at the High-Pressure Collaborative Access Team, Advanced Photon Source at Argonne National Laboratory to conduct high-pressure, high-temperature studies on 3D printed alloys. The phase diagrams and thermal equations of state data generated on 3D printed alloys provide an opportunity to validate computational models of these complex materials. SSAA also opened the door to an internship at Sandia National Laboratories allowing me to get a day-in-the-life view of those working there and demonstrate my abilities to potential future employers. These experiences have given me a direct path to the best possible opportunity at working at both a place I want to work and where I can have the most impact using my developed expertise. Before the SSAA, I was unsure of what I wanted to do and where I wanted to apply myself. Now I am confident in answering both of those questions.

Chirag Rathi (cr850419@ohio.edu) | Ohio University
Degree in Progress: PhD, Nuclear Astrophysics ✦ **Advisor:** Dr. Alexander Voinov ✦ **SSAA:** 2022 - Present

Research Topic

Development of New Nuclear-Level Density Database & Investigating the Role of Neutron Optical Potential in Neutron-rich ^{55}V

Research Responsibilities

My research focuses on statistical nuclear physics, encompassing two main projects. The first involves creating a nuclear level density (NLD) database to address uncertainties in nuclear reaction rates for astrophysics and other applications. Unlike available databases, which rely on limited neutron resonance data, this database will integrate diverse experimental techniques across broad excitation energies. My research responsibilities are to collect datasets from literature and to build a website to host this database. I have added functionalities to explore data by proton and mass number, extraction method, and reaction type. I am working on improving tools for visualizing NLD trends, comparing datasets, and fitting models to data. The website will enable users to download datasets, advancing nuclear data initiatives and making future evaluations more accessible.

The second project examines the neutron optical potential in neutron-rich ^{55}V to better understand neutron capture reactions, which are responsible for element formation in the universe. Using a ^{7}Li beam on a ^{48}Ca target, we estimated optical model (OM) parameters, critical for Hauser-Feshbach cross section calculations. I was involved in the measurements of the reaction cross sections and in performing model calculations. Our preliminary findings indicate that existing models fail to reproduce experimental results, requiring reductions in level densities and the imaginary part of neutron OM. These results could provide new insights into nucleosynthesis processes and neutron-induced reactions relevant for applications.

Benefits of SSAA

My affiliation with the Stewardship Science Academic Alliances (SSAA) has enriched my academic and professional growth. Presenting my research to the scientific community has honed my communication skills and boosted my confidence. The platform also enabled me to network extensively with peers and experts, exchanging ideas with graduate students and scientists from the national laboratories.

Participating in the Stewardship Science Academic Programs (SSAP) symposium has been particularly impactful, exposing me to advancements in nuclear physics and keeping me abreast of emerging methodologies. This experience has broadened my perspective and prepared me for future scientific endeavors.

Trevor Johannes Smith (tjsmith@sandia.gov) | **University of Michigan**

Degree: PhD, Nuclear Engineering and Radiological Studies ✦ **Advisor:** Dr. Ryan McBride ✦ **SSAA:** 2019 - 2025

Research Topic

Characterizing Desorbed Surface Contaminants Leading to Plasma Formation in Power Feeds of Pulsed Power Accelerators

Research Responsibilities

As a graduate student researcher, my role was to conduct research on the formation of plasmas in power feeds of pulsed power accelerators. I developed spectroscopic diagnostics to characterize neutral species and ions, before and after breakdown to better understand the processes at play. The main tool I used to investigate the formation of plasmas in power feeds was a vacuum ultraviolet spectrometer, which was a tool I developed for use on the Mykonos Facility at Sandia National Laboratories (SNL).

Benefits of SSAA

The National Nuclear Security Administration (NNSA) Stewardship Science Academic Alliances program was a large contributor to my funding as a graduate student. From things as small as laboratory supplies to, most recently, a ZNetUS campaign on the Mykonos Facility, I would not have had the success I've had in my graduate career without NNSA Academic Programs.

National Laboratory Experience

As a graduate student intern, I spent the last two and a half years on-site at SNL working at the Mykonos Facility in support of advanced diagnostics and power flow research for the Z machine. I was able to work and collaborate with the top researchers in their fields, work on state-of-the-art facilities, like the Mykonos Facility, and, in general, get to know what life is like at a national lab level. I was able to lead three research campaigns on the Mykonos Facility and develop a vacuum ultraviolet spectrometer diagnostic. This diagnostic paired with a suite of other imaging, spectroscopic, and electric and magnetic field diagnostics were necessary to conduct the experiments. This was only possible on the Mykonos Facility. Our ZNetUS campaign utilized cross-center collaborations at SNL by having another organization help create our targets. Now, a postdoctoral appointee at SNL, these connections will be extremely helpful to have in the future.

I feel fully integrated into the culture and workplace at SNL. I successfully defended my dissertation in March of 2025. I am a postdoctoral appointee in the Pulsed Power Sciences Center at SNL.

Chad Studvick (cms457@uakron.edu) | **University of Akron / Washington State University**

Degree in Progress: PhD, Chemistry ✦ **Advisor:** Dr. Ivan Popov ✦ **SSAA:** 2023 - Present

Research Topic

Computational Analysis of Actinides in Extreme Oxidation States

Research Responsibilities

My research focuses on modeling redox properties, metal–ligand covalency, and spectroscopic signatures of actinide-containing complexes through density functional theory (DFT) and multireference calculations. The driving force of covalency in actinide systems is thought to arise from the combination of actinide–ligand orbital overlap and orbital energy degeneracy, which also may elucidate diverging reactivity between certain complexes. A variety of tools are employed in our lab to analyze covalency, including orbital-based and electron density-based approaches. Through studying non-aqueous actinide systems in which the actinide is in an unusually high or low oxidation state, we can uncover novel bonding properties, evaluate the role of the 5*f* electrons across multiple oxidation states, and predict reactivity. This is integral to improving techniques commonly used in the nuclear fuel cycle to separate minor actinide and lanthanide fission byproducts in spent nuclear fuel. The insight I provide with my calculations gives invaluable information to experimentalists who use the data to guide the synthesis of new ligands. In the same manner, with experimental validation supporting our models, the methods we leverage can be extrapolated to make predictions on currently-experimentally-unavailable systems and to spearhead research on elusive oxidation states in non-aqueous transuranic species.

Benefits of SSAA

The Transuranic Chemistry Center of Research Excellence (TRU-CoRE) has provided me with opportunities to publish in high-impact journals, present and explain my research at various conferences across the country, and has allowed me to connect with several nationally-renowned scientists. The close ties I have with my collaborators have greatly helped me as I perform my research; providing me with excellent feedback, encouragement, and networking opportunities, as my group continues to advance our research on fundamental aspects of nuclear chemistry.

What Students Considering SSAA Should Know

The Stewardship Science Academic Alliances (SSAA) provide a platform for students to enhance their academic career through tight-knit collaborations with a variety of scientists. Students will develop a robust toolkit of problem-solving skills which will help them in tackling significant problems that our country faces today. Their research will have a resounding impact on the greater good, which can propel them forward to a worthwhile future career.

High Energy Density Laboratory Plasmas Program

Density Functional Theory at Extreme Conditions—Warm Dense Matter from First Principles | Georgia Institute of Technology

PI: Dr. Phanish Suryanarayana (phanish.suryanarayana@ce.gatech.edu)

The overall objective of this project is to develop an open-source computational framework that enables the study of warm dense matter (WDM) from the first principles of quantum mechanics, without the need for any empirical or ad hoc parameters. This National Nuclear Security Administration (NNSA)-funded project, which has been ongoing for two years and has supported two graduate students, is part of the High Energy Density Laboratory Plasmas Program.

WDM can be found in diverse physical settings, from giant planets and stars to inertial confinement fusion (ICF) and other high energy density (HED) experiments. Accurately modeling WDM is essential for understanding and designing HED experiments like ICF, as well as for studying the formation, characteristics, and evolution of planetary and stellar systems. However, the extreme temperature and pressure conditions involved present substantial experimental and theoretical challenges. As illustrated in Figure 1, both classical and quantum mechanical effects (including degeneracy) influence the properties and behavior of WDM, with the relative significance of each varying depending on the specific temperature and density conditions.

Kohn-Sham density functional theory (DFT) is a widely used quantum mechanical approach for studying material systems. However, applying Kohn–Sham calculations to WDM presents unique challenges. One key issue is the increase in the number of partially occupied states with temperature, which exacerbates the cubic scaling bottleneck of DFT calculations, even for smaller system sizes. This bottleneck becomes particularly limiting in *ab initio* molecular dynamics, where the Kohn–Sham equations may need to be solved hundreds of thousands of times to access the timescales necessary for capturing relevant phenomena. As a result, the range of WDM systems that can be subject to a rigorous quantum mechanical investigation using DFT has been severely restricted.

In this project, a highly optimized parallel implementation of the Spectral Quadrature (SQ) method has been developed within the state-of-the-art electronic structure code SPARC (https:// github.com/ SPARC-X/SPARC). The SQ method is particularly well-suited for high-temperature calculations, as its scaling is independent of the number of occupied states, its prefactor decreases rapidly with temperature, and it exhibits excellent parallel scalability. As a result, it has already found a number of applications in the study of WDM, many of which were impractical before. It also has been used in equation of state (EOS) calculations to verify the accuracy of Kohn-Sham DFT for the study of WDM.[1]

In spite of the significant advances provided by the SQ method, the computational cost associated with DFT calculations is still significant, particularly when compared to classical force fields/interatomic potentials. In this project, an on-the-fly machine learned force field scheme for molecular dynamics (MD) simulations has been developed in the SPARC code. In this scheme, the MD simulation begins with a series of SQ-DFT calculations to generate the initial training data. Machine learning models are then used to predict the quantities of interest, e.g., internal energy, forces, and stresses, in the subsequent MD steps. However, if the Bayesian uncertainty or error in the computed forces exceeds a specified threshold, a new SQ-DFT calculation is performed, and the resulting values are added to the training dataset. In so doing, EOS and transport property calculations can be accelerated by up to three orders-of-magnitude, while retaining *ab initio* accuracy.[2,3,4]

Overall, the developed framework has enabled the calculation of highly accurate thermodynamic and transport properties for WDM from first principles, which has applications in ICF and other HED systems.

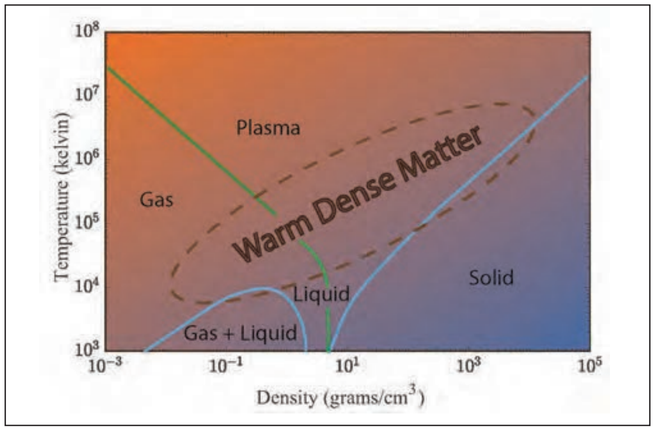


Figure 1. Illustration of the WDM regime. The shading of blue/orange indicates the relative importance of quantum mechanical/classical effects. (Adapted from Report of the Workshop on High Energy Density Laboratory Physics Research Needs, November 2019.)

References

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[2] S. Kumar, X. Jing, J.E. Pask, and P. Suryanarayana, On-the-fly machine learned force fields for the study of warm dense matter: Application to diffusion and viscosity of CH, Physics of Plasmas 31, 4 (2024).

[3] S. Kumar, J.E. Pask, and P. Suryanarayana, Shock Hugoniot calculations using on-the-fly machine learned force fields with *ab initio* accuracy, Physics of Plasmas 31, 10 (2024).

[4] L.J. Stanek et al., Review of the second charged-particle transport coefficient code comparison workshop, Physics of Plasmas 31, 5 (2024).

Direct Laser Acceleration for Bright Directional Radiation Sources | University of Michigan

PI: Dr. Louise Willingale (wlouise@umich.edu); Co-PI: Alexey Arefiev (aarefiev@ucsd.edu)

The Direct Laser Acceleration (DLA) mechanism can drive high-charge, superponderomotive energy electron beams during relativistically intense laser-plasma interactions. The ponderomotive force of the laser pulse acts on the low-density plasma to form a channel containing transverse electric and azimuthal magnetic fields that enable energy exchange from the laser to the electrons. Electrons undergo oscillations within the channel, meaning they will emit X-rays as they are accelerated. DLA may create high-charge, short-duration, high-energy electron beams, bright directional sources of X-rays, or could create Bremsstrahlung-photons or positrons through secondary interactions. One application of these sources may be to probe High Energy Density Laboratory Plasmas (HEDLP) experiments.

This HEDLP-supported project continues from a prior National Laser User Facility (NLUF) grant and uses the OMEGA EP laser facility to perform experiments accessed through the NLUF Program as well as simulation and theory support to study DLA. The project is a collaboration between the University of Michigan (experimental lead), the University of California San Diego (simulation and theory lead), and partners at the Laboratory for Laser Energetics, Lawrence Livermore National Laboratory, and from Instituto Superior Técnico in Portugal. This project has supported three PhD students, including Dr. Hongmei Tang (now a postdoctoral researcher at Lawrence Berkley National Laboratory), Veronica Contreras, and I-Lin Yeh. Dr. Tang's PhD thesis (2023) was mainly based on this project, and she gave an invited talk at the 2024 American Physical Society, Division of Plasma Physics annual meeting on this topic.

Principal Investigator (PI) Professor Willingale says, "The National Nuclear Security Administration support has allowed us to form a strong collaboration to provide a broad training in HEDP for graduate students. This includes PI training to conduct experiments on large-facilities and how to perform theoretical high energy density science, while we study basic plasma physics and pursue bright directional radiation sources for backlighting applications."

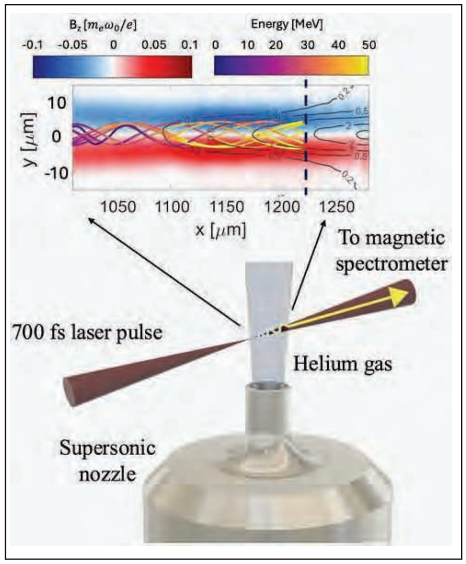

Figure 1.The OMEGA EP experimental configuration. Inset shows the result of a PIC simulation with the magnetic field within the channel and typical electron trajectories as they gain energy via DLA.

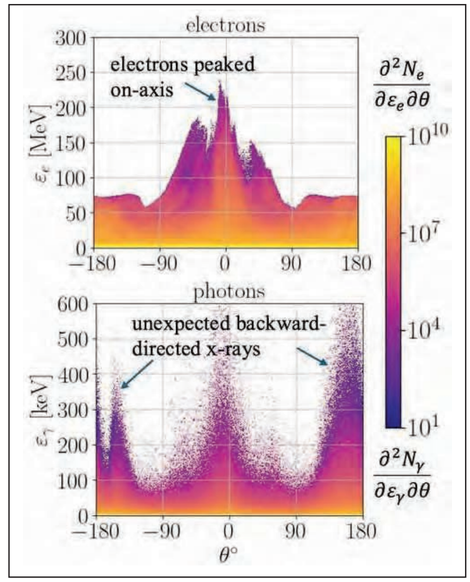

Figure 2. Simulations of a laser pulse with a_0=10 and electron density n_e=0.04 n_c, showing (top) the electron and (bottom) X-ray energy spectra in different directions.

OMEGA EP experiments (set-up shown in Figure 1) and OSIRIS 4.0 particle-in-cell (PIC) simulations investigated how variables including the plasma density and profile, the laser pulse focusing, energy, and pulse duration affect DLA. Matching the focal spot to the transverse extent of the oscillations the electrons perform within the channel is most favorable for achieving the highest energy electrons.[1] Therefore, an optimum focal spot size was found to be a function of density and laser pulse power. This has implications for the focusing geometry of future facilities.

An aspect studied theoretically was how the modulation of the effective laser frequency affects the energy exchange process.[2] An electron can gain energy from the laser field when its transverse momentum is anti-parallel to the transverse electric field of the laser. The channel fields confine the electrons making them perform betatron oscillations as they travel forward. Matching the betatron oscillation frequency to the laser frequency allows the oscillations to remain in phase to promote efficient energy exchange between the laser field and electrons, i.e., the betatron resonance. The relativistic motion of the electrons means the laser electric field experienced by the electrons is modulated from a simple sinusoidal oscillation. One implication of this finding is it allows for higher odd-order resonances beyond the betatron resonance.

While investigating the X-ray generation using PIC simulations with a set-up like the OMEGA EP experiments, PhD student, I-Lin Yeh, found an unexpected source. Figure 2 shows the forward going electrons, but the X-rays have a forward-directed and backward-directed source. The DLA accelerated electrons set up a large sheath field at the rear plasma-vacuum interface. This acted to turn and reaccelerate the electrons backwards into the oncoming laser pulse, with this collision being an efficient source of X-rays in the backwards direction.[3]

References

[1]H. Tang et al., New Journal of Physics 26, 053010 (2024).

[2]A. V. Arefiev et al., Physics of Plasmas 31, 023106 (2024).

[3]I-L. Yeh et al., Physics of Plasmas 31, 113108 (2024).

High Energy Density Laboratory Plasmas **Students**

The HEDLP program opens doors for meaningful collaborations with Department of Energy labs, renowned as some of the world's leading research institutions. These partnerships not only enrich students' understanding by working alongside top researchers but also create pathways to connect with professionals who can offer significant career opportunities and internships after graduation.

Nitish Acharya
University of Rochester

The HEDLP program has been an important part of my growth as a researcher. It has given me the opportunity to work on large-scale experiments and develop technical skills that I would not have gained otherwise. Through the program, I also have been able to collaborate with researchers from different institutions. Having experts on my team has brought valuable insights and perspectives, often sparking ideas and approaches I had not before considered.

Jesse Griff-McMahon
Princeton University

The residency, spread across two summers, benefited my research by giving me easier access to LLNL scientists ... This was especially useful for the part of my project where I used machine learning, as LLNL has a lot of machine learning experts. I did not have very much experience with machine learning prior to this, so access to these experts was especially helpful. The collaborative and accommodating spirit of the scientists made it easy to learn the relevant information.

Justin Kunimune
Massachusetts Institute of Technology

I am a Stewardship Science Graduate Fellow, and the Academic Programs have benefitted me by providing me financial support to study incredibly interesting problems in my practicum that greatly enhanced my knowledge of computational tools in plasma physics. Additionally, it has given me access to a very expansive and knowledgeable network of scientists and other graduate students in the Department of Energy (DOE) ecosystem.

Benjamin Reichelt
Massachusetts Institute of Technology

Nitish Acharya (nachary2@ur.rochester.edu) | University of Rochester

Degree in Progress: PhD, Mechanical Engineering ✦ **Advisors:** Dr. Jessica. K. Shang and Dr. Hussein Aluie ✦ **HEDLP:** 2018 - Present

Research Topic

Viscosity Measurements of Materials at High Pressures and Temperatures

Research Responsibilities

Measuring transport properties like viscosity is vital for accurately modeling the mixing and instabilities inherent in processes such as inertial confinement fusion, as well as for understanding the composition of planetary interiors and their dynamic evolution. Whereas theoretical and computational approaches provide viscosity estimates, these values often differ by several orders of magnitude. To address this, we are developing an experimental platform to measure viscosity in materials under warm dense matter conditions. This approach leverages the influence of viscosity on the evolution of a sinusoidal shock front traveling through a planar material sample.

My responsibilities are to design and conduct experiments at the OMEGA EP laser facility at the Laboratory for Laser Energetics, University of Rochester (UR). These experiments generate sinusoidally-rippled shock fronts in fused silica samples and probe the dynamics using optical velocimetry and pyrometry diagnostics. I was able to collect some fascinating shock emission and velocity interferometry data, which revealed an oscillatory damped evolution of the rippled fronts at pressures of 300–600 GPa. In addition to designing and performing these experiments and analyzing the experimental data, I am responsible for conducting hydrodynamic simulations to generate synthetic diagnostics and gain deeper insights into the physics of experiments.

Benefits of HEDLP

The HEDLP program has been pivotal in my transition to high energy density physics, providing opportunities to lead experimental campaigns as a principal investigator at large-scale laser facilities like OMEGA EP and collaborate on experiments at other labs, such as Janus at Lawrence Livermore National Laboratory. This experience, coupled with access to supercomputing resources for simulating experiments, has been invaluable. Starting at UR as a Mechanical Engineering graduate, shifting to high energy density physics was a significant learning curve. Attending summer schools and participating in conferences such as the American Physical Society, Division of Plasma Physics and the Stewardship Science Academic Programs symposium helped me build a good foundation in this field and connect with national lab scientists, expanding my network and fostering collaborations.

What Students Considering HEDLP Should Know

The HEDLP program opens doors for meaningful collaborations with Department of Energy labs, renowned as some of the world's leading research institutions. These partnerships not only enrich students' understanding by working alongside top researchers but also create pathways to connect with professionals who can offer significant career opportunities and internships after graduation.

Jesse Griff-McMahon (jgriffmc@pppl.gov) | Princeton University

Degree in Progress: PhD, Astrophysical Sciences ✦ **Advisor:** Dr. Will Fox ✦ **HEDLP:** 2022 - Present

Research Topic

Magnetic Field Generation and Reconnection in Laser-Driven Plasmas

Research Responsibilities

Over the last two years, I have designed and conducted two experiments at the Omega Laser Facility to investigate magnetic field generation and magnetic reconnection in laser-driven plasmas. These studies are important because magnetic fields can self-generate in inertial confinement fusion conditions and can modify the heat transport, for example. In these experiments, a laser irradiates a thin plastic foil and generates an expanding plasma plume with embedded Biermann-battery magnetic fields. The fields are then imaged with proton radiography as the primary diagnostic tool.

One of my primary responsibilities has been improving the proton radiography diagnostic and analysis techniques. We used an X-ray reference image to increase the fidelity of the radiograph, revealing that magnetic fields extend much farther away from the laser than previously observed. I also developed an improved analysis pipeline to invert proton fluence images into magnetic field maps by incorporating boundary conditions and constraining the proton source profile. Additionally, I designed the experiments for tomographic proton radiography to constrain the three-dimensional field geometry, breaking the degeneracy of the path-integrated measurement. To complement the experimental findings, I conducted particle-in-cell simulations to explore kinetic effects within the plasma. These simulations were compared with experimental data and extended magnetohydrodynamic simulations to help explain the physics of the experiment.

Benefits of HEDLP

The HEDLP program has been an important part of my growth as a researcher. It has given me the opportunity to work on large-scale experiments and develop technical skills that I would not have gained otherwise. Through the program, I also have been able to collaborate with researchers from different institutions. Having experts on my team has brought valuable insights and perspectives, often sparking ideas and approaches I had not before considered.

I have had the chance to present my work at conferences, where feedback from other scientists has helped refine my research and helped me see new ways my research could be applied.

What Students Considering HEDLP Should Know

This program connects national and university-scale research, which gives you the big picture of what problems are important and where you can fit into solving them. The support for conferences also has helped me learn from experts and build connections.

Justin Kunimune (kunimune@mit.edu) | Massachusetts Institute of Technology

Degree in Progress: PhD, Nuclear Fusion Diagnostics ✦ **Advisor:** Dr. Johan Frenje ✦ **HEDLP:** 2022 - Present

Research Topic

Implementation and Use of Novel Nuclear Diagnostics and Neural Networks to Diagnose Three-Dimensional Morphology and Power Balance in Inertial Fusion Experiments at OMEGA and the National Ignition Facility

Research Responsibilities

Maintaining the software that runs our lab's ion accelerator, analyzing wedge range filter spectra, and developing diagnostic techniques for nuclear diagnostics at OMEGA and the National Ignition Facility (NIF).

Benefits of HEDLP

I was given the opportunity to live at Lawrence Livermore National Laboratory (LLNL) and work directly with LLNL scientists on my main thesis project.

National Laboratory Experience

I spent 24 weeks at LLNL in Livermore, California, working on three-dimensional reconstructions of fusion implosions at the NIF, using a suite of heterogeneous neutron data. The project provides a novel way to combine existing diagnostic information at NIF to extract new insights about degradation mechanisms and their sources. A key aspect of my project was the integration of machine learning techniques to reduce the computational intensity of the reconstructions. This made it possible to explore the complex solution space more quickly than is possible with conventional programming techniques.

The residency, spread across two summers, benefited my research by giving me easier access to LLNL scientists than I would have had living in Cambridge, Massachusetts, where my home university is. This was especially useful for the part of my project where I used machine learning, as LLNL has a lot of machine learning experts. I did not have very much experience with machine learning prior to this, so access to these experts was especially helpful. The collaborative and accommodating spirit of the scientists made it easy to learn the relevant information. My machine learning also benefitted from the unparalleled computational resources of LLNL.

Spending time at a national lab also provided critical insights into how large-scale, interdisciplinary institutions are managed—something that is rare in traditional academic settings.

For students considering a residency like this, I want to emphasize the unique environment at national laboratories like LLNL. The collaborative culture is unparalleled, bringing together experts from diverse fields such as nuclear physics, computational science, and engineering. The people of the lab were truly the best part of the residency and made my project quickly come together in a publishable fashion.

Benjamin Reichelt (bir@mit.edu) | Massachusetts Institute of Technology

Degree in Progress: PhD, Physics ✦ **Advisor:** Dr. Chikang Li ✦ **HEDLP:** 2021 - Present

Research Topic

Kinetic Effects in Inertial Confinement Fusion Experiments

Research Responsibilities

I study the impacts of kinetic, non-Maxwellian effects in inertial confinement fusion. This includes the impact of self-generated magnetic fields on hot electron transport in hohlraums, enhancement of mix into the hot spot of shock-driven implosions, and how alpha energy from fusion reactions is deposited into the hot spot. The mix work has involved several campaigns at the OMEGA laser facility, and I have utilized national-laboratory-developed simulation tools to help analyze the data. I also am the responsible scientist for the Particle Time-of-Flight (PTOF) diagnostic, which measures nuclear emission histories at the National Ignition Facility (NIF). This has entailed communicating with shot research investigators to determine optimal diagnostic setup for campaigns, performing data analysis, doing research of detector physics, and designing diagnostic upgrades.

Benefits of HEDLP

I am a Stewardship Science Graduate Fellow, and the Academic Programs have benefitted me by providing me financial support to study incredibly interesting problems in my practicum that greatly enhanced my knowledge of computational tools in plasma physics. Additionally, it has given me access to a very expansive and knowledgeable network of scientists and other graduate students in the Department of Energy (DOE) ecosystem.

National Laboratory Experience

Over the years, I have spent a lot of time at different DOE/NNSA labs. I went to high school in Los Alamos, New Mexico and completed internships at Los Alamos National Laboratory from my junior year of high school through the end of my undergraduate degree, studying materials shocked by high explosives. During graduate school, I completed a practicum and internship at LANL where I worked with the kinetic ion code iFP. This has been incredibly useful for my overall research, as I am very interested in kinetic effects. The ability to complete simulations with a cutting-edge tool like iFP has been instrumental to other research projects. Additionally, I have been to Lawrence Livermore National Laboratory twice to use the MegaRay linear electron accelerator facility for measuring the impulse response function of PTOF detectors. This led us to large improvements in temporal response and accuracy with the discovery of some diamonds with an ultra-fast response, and these detectors have enabled new measurements not previously possible at the NIF. These connections have provided me with many valuable contacts and interactions at both national labs, and I am planning on pursuing a postdoctoral research position or fellowship at one of them.

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 at the University of Rochester Laboratory for Laser Energetics (LLE) and other National Nuclear Security Administration (NNSA) user facilities. This provides hands-on research experience to academic researchers using NNSA user facilities as tools for conducting basic research experiments. In the pursuit of fundamental science advances, the innovative development of diagnostics and platforms by user facility partners have often proven to benefit NNSA experimental needs.

The High Energy Density Laboratory Plasmas Facility Access Program supported travel for executing Massachusetts Institute of Technology (MIT)-led National Laser User Facility experiments on the OMEGA laser. This enabled in-person participation of graduate student principal investigators (PIs) and a team to support them for the execution and outcome of their experiments. Senior graduate students, Ben Reichelt and Justin Kunimune, led experiments to study kinetic and stalk-induced mix using buried-layer

Figure 1. Members of the team executing the August 2024 OnionMix Campaign on OMEGA-60 (from left): Arnold Schwemmlein (LLE), Enac Gallardo-Diaz (University of Nevada Reno), Justin Kunimune (MIT), Ben Reichelt (MIT), Melody Scott (LLE), Maria Gatu Johnson (MIT), Tim Filkins (LLE) and Johan Frenje (MIT). The facility access program supported the travel of graduate students and experiment PIs, Justin Kunimune and Ben Reichelt, and project PI, Maria Gatu Johnson. Photo credit: Jake Deats, LLE.

implosions in the August 2024 OnionMix Campaign (Figure 1). The data from these experiments will form part of their PhD theses. Second year graduate student, Bryan Foo, conducted his first OMEGA experiment in November 2024, investigating prevalence of non-Maxwellian ion velocity distributions in inertial confinement fusion-relevant plasmas in the FoilGasDist Campaign (Figure 2). The opportunity for in-person execution of OMEGA experiments is a key piece of

Figure 2. MIT graduate student, Bryan Foo, characterizing targets for his November 2024 FoilGasDist OMEGA-60 Campaign. The facility access program supported the travel of graduate student experiment PI Bryan Foo, postdoc Graeme Sutcliffe, and project PI, Maria Gatu Johnson. Photo credit: Jake Deats, LLE.

the training for these graduate students. This helps students understand how to optimize shot setups and provides them the opportunity to interact and build connections with platform and diagnostic experts at the Laboratory for Laser Energetics (LLE), allowing them to get the best possible data for their theses.

— Maria Gatu Johnson
Massachusetts Institute of Technology

Experiments on the OMEGA Laser Facility at the University of Rochester Laboratory for Laser Energetics (LLE) investigated magnetic reconnection (Figure 3), one of the driving mechanisms behind solar flares. This work, led by Dr. Will Fox and funded through the High Energy Density Laboratory Plasmas program, gained insights into the three-dimensional nature of the magnetic field geometry and magnetic instabilities through tomographic proton radiography. The Facility Access Program enabled two graduate students and a staff scientist to participate in the experiments on-site at LLE, which played a key role in the experiment's success and provided important exposure to high energy density physics experiments for the students (Figure 4).

— Jesse Griff-McMahon
Princeton University

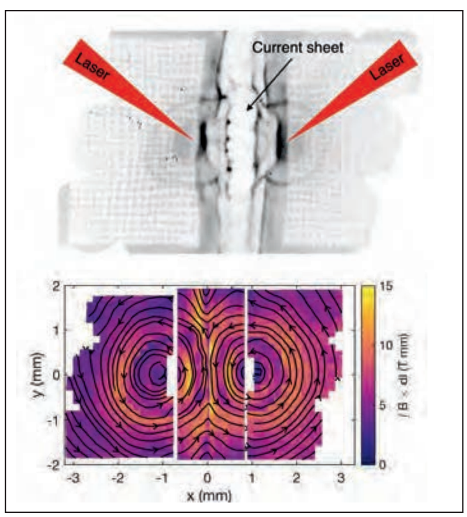

Figure 3. (Top) Proton radiograph of the magnetic reconnection experiment with instabilities in the central current sheet. (Bottom) Inverted magnetic field profile showing the reconnection geometry. The inversion combines information from mesh deflectometry and high-resolution radiography.

Figure 4. On-site experimental team: (left to right) Sophia Malko, Jesse Griff-McMahon, Brendan McCluskey, Will Fox, Mike Rosenberg, and Tim Filkins. Sophia, Jesse, and Brendan were supported through the NNSA Facility Access Program.

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 summer school and various facility workshops.

High Energy Density Science Summer School

The High Energy Density Science Summer School (HEDSS) is held annually at either the University of California San Diego or the University of Michigan (UM). In June 2024, HEDSS was structured into two components over two weeks: a high-level virtual segment and an in-depth, in-person session at the UM. The virtual component attracted over 100 registrants and included a series of ten, two-hour lectures that provided foundational knowledge in high energy density physics. The in-person segment brought together 40 participants from across the globe for an intensive week of advanced lectures and hands-on group projects. Lectures were delivered by faculty that are part of the Center for High Energy Density Laboratory Astrophysics Research led by Professor Carolyn Kuranz. The National Nuclear Security Administration generously supported travel and related fees for 35 students.

— Carolyn Kuranz
University of Michigan

HEDSS students taking a campus tour courtesy of the University of Michigan Blue Bus.

The National Ignition Facility & Jupiter Laser Facility User Groups Meeting

The National Ignition Facility (NIF) & Jupiter Laser Facility (JLF) User Groups Meeting took place in Livermore, CA on February 11-13, 2025. As in previous years, approximately 200 attendees gathered to hear presentations on big questions in high energy density (HED) science, on-going and recently awarded NIF Discovery Science experimental campaigns, recent JLF results, the status of capability development and refurbishment at both the NIF and the JLF, and updates on the Nation's basic research needs for inertial fusion energy. The meeting's success is in part due to Academic Programs' continued support for student and postdoc travel. Each year, 30-40 students are supported to travel to the meeting and present a poster on their research. This continued support has resulted in the development of a strong pipeline for early career HED scientists to find positions at the national laboratories.

— Kevin Fournier
Lawrence Livermore National Laboratory

Winners of the Best Poster awards at the 2024 NIF & JLF User Groups Meeting – from left to right: Kevin Fournier, Vicente Valenzuela-Villaseca, Skylar Dannhoff, Sonya Dick, Maria Gatu-Johnson, and Félicie Albert.

2024 Z Fundamental Science Workshop

The 15th Z Fundamental Science Workshop was held in downtown Albuquerque on August 7-9, 2024. This workshop, which has been held annually since 2010, is a key aspect of the Z Fundamental Science Program and consists of both plenary and breakout sessions. The plenary sessions are meant for the external Z user community to learn about the Z accelerator facility status and future plans, receive an update on Z diagnostics capabilities, and for collaborative users to present the status of their research. The breakout sessions provide opportunities for current and prospective future collaborators to discuss research directions and ideas for new work on Z. Many of these discussions are the genesis of Z Fundamental Science Proposals. The 15th Z Fundamental Science Workshop was a great success with 134 in-person attendees (73 external to Sandia National Laboratories) from 29 institutions and 4 countries, including 32 students and 12 postdoctoral fellows (postdocs). Many of the students and postdocs (20 total) were able to attend through the generous support of the High Energy Density Laboratory Plasmas Community Development effort. This group was very engaged during the workshop, and many enthusiastically participated in the poster session. Student and postdoc involvement in the workshop are critical to growing the user base for Z and attracting the next generation of talent to the Pulsed Power Sciences Center at Sandia.

— Marcus Knudson
Sandia National Laboratories

Sandia National Laboratories postdoctoral fellow Amanda Dumi presenting during the Planetary Physics and Materials breakout session during the 15th Z Fundamental Science Workshop.

Predictive Science Academic Alliance Program III

The Center for Exascale Monte Carlo Neutron Transport | Oregon State University

PI: Dr. Todd Palmer (todd.palmer@oregonstate.edu); Author: Dr. Kyle Niemeyer (kyle.niemeyer@oregonstate.edu)

The Center for Exascale Monte Carlo Neutron Transport (CEMeNT) is a Predictive Science Academic Alliance Program (PSAAP)-III Focused Investigatory Center with the dual missions of enabling accurate, efficient simulation of dynamic neutron transport using exascale computing systems and educating the next-generation of leaders in this field. Launched in 2020, CEMeNT is led by Oregon State University with partner institutions North Carolina State University, Notre Dame University, and Seattle University. The project has supported 10 MS and PhD students, all of whom have previously interned or plan to intern at National Nuclear Security Administration (NNSA) laboratories.

The PSAAP III program funding has provided a unique opportunity to train graduate students on challenging, NNSA-relevant problems, allowing these students to explore career pathways in the national laboratories.

CEMeNT's work is motivated by the need to simulate highly dynamic problems, including nuclear criticality experiments and pulsed neutron sources. Unfortunately, the computational complexity required to simulate time-dependent neutron transport can be substantially more complex to model than conventional steady-state systems. Recently deployed and planned NNSA exascale high-performance computing systems offer the raw number-crunching performance necessary to tackle such problems, but we need to make advances in both Monte Carlo algorithms and software engineering techniques to fully exploit the potential power of these computing systems.

To rapidly investigate new Monte Carlo algorithms and parallel computing strategies, CEMeNT has developed Monte Carlo/Dynamic Code (MC/DC), an openly available Python-based software package that relies on the Numba just-in-time (JIT) compiler to achieve exascale performance on diverse computing architectures. Being written primarily in Python, even novice researchers can use MC/DC to quickly study new algorithms, while expert users can investigate challenging problems with high computational performance.

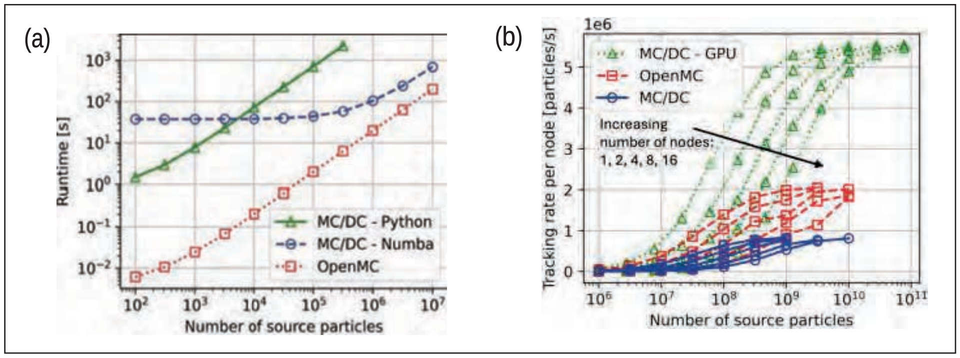

Figure 1. (a) Serial runtime and (b) parallel performance of MC/DC JIT-compiled CPU and GPU modes compared with OpenMC on the transient Kobayashi dog-leg vacuum pipe benchmark problem.

When initially exploring a novel Monte Carlo transport method, a developer can work in a pure Python environment where functions are entirely executed in the Python interpreter. In this mode, any package can be brought into any function, typing can be done dynamically, and any Python data structure can be used. This gives developers incredible flexibility when exploring new methods at any location in the transport workflow. Whereas a full Python development environment is great for initial proofs of concept, it often proves too slow for problems of interest.

When more performance is required, MC/DC can use Numba to compile transport functions to approach C-like speeds on central processing units (CPUs), and even Nvidia and AMD graphics processing units (GPUs) for even higher performance—often using the same Python script that was originally written to explore a method.

However, for optimal performance on GPUs, algorithms usually need to be altered, because GPUs use a different parallelism paradigm than CPUs. This often leads to significant difficulty in porting from CPUs to GPUs. To avoid this issue when targeting GPUs, MC/DC can compile with the Harmonize GPU runtime scheduler to efficiently manage memory and threads in a way that increases performance. This abstraction technique has the added benefit of not requiring developers of numerical methods to know on which hardware their methods will execute.

This makes MC/DC a single source, portable code that can run performantly on phones, laptops, and supercomputers alike. Figure 1 shows the performance of MC/DC on CPUs and GPUs, compared with the production code OpenMC (part of the ExaSMR project) in running a fine-grained (36 million phase-space quantities of interest), pulse-driven transient version of the Kobayashi dog-leg vacuum pipe benchmark problem with increasing numbers of source particles.

CEMeNT's ongoing research focuses on embedding uncertainty quantification into MC/DC, implicit quasi-Monte Carlo iterative hybrid methods, and variance reduction techniques, as well as continuing to improve performance on a small modular reactor challenge problem.

Laser-based Ignition of Rocket Engines | Stanford University

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The Predictive Science Academic Alliance Program Center at Stanford University, with companion efforts at the University of Colorado Boulder and Purdue University, investigates laser-induced rocket combustion. For the past four years, this work has supported graduate and postdoctoral work for approximately 20 researchers and has facilitated ongoing collaboration and internships between the Center and Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratories (SNL). This research expands many frontiers including current, state-of-the-art computational physics, campaign designs for data ensembles in laboratory rocket-testing, data-driven methodologies for physics modeling, and large-scale computational parallelism, with the overarching aim of constructing ignition reliability maps.

Figure 1. Visualization of the temperature field during a later stage of ignition. Bright colors indicate higher temperatures, whereas darker colors represent lower temperatures.

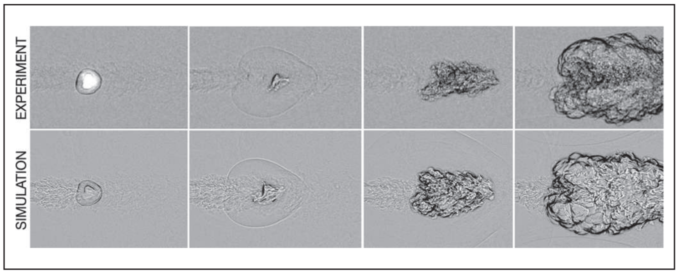


Figure 2. Experimental Schlieren images of direct ignition (top) and their in-silico counterpart (bottom), illustrating the transition from a laser-induced plasma spark to a fully developed flame

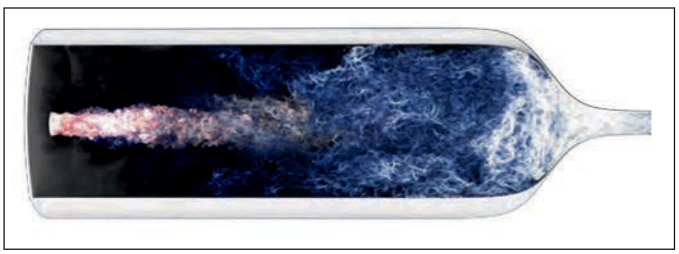


Figure 3. Visualization of the magnitude of the vorticity field in the rocket combustor during pre-ignition. Bright colors depict high vorticity values, whereas darker colors represent lower values.

When ignition success is of primary interest, many challenges exist in rocket combustors because of the fluctuating fuel and oxidizer streams, numerous parameters associated with a laser spark that is fired to trigger combustion, and flame growth in a rocket nozzle geometry (Figure 1). Due to this multi-physics setting, ensembles of simulations are required to represent the system for a nominal ignition target in response to unavoidable physical uncertainties. The goal of this research, therefore, is to quantify factors that lead to ignition success and to determine their contribution to system reliability. However, because of the challenging computational physics simulation environment, significant resources are dedicated to building accurate computational representations and then representing the physics faithfully at cheaper computational cost. As an added extension of the model development process, several co-aligned fundamental investigations have taken place into hypersonics and multiphase flows. Success of this project would deepen the real-world applicability of rocket research, providing confidence in the predictive capabilities of academic studies.

Several technical aspects of this Center have paradigm-changing aims. Growth in computational facilities is accelerating each decade, but the hardware is increasingly heterogeneous. Currently, at the core of our simulations on Exascale-class machines is a runtime system called Legion which allows the user to write code agnostic to the architecture that executes the program. This approach facilitates a new era of computational discovery, as data science and traditional numerical computations are increasingly co-deployed and interfaced, but each have their own programming and deployment strategies. Accordingly, a technical breakthrough in the Center has been unprecedented levels of alignment between computations and laboratory experiments. These two modes are traditionally compared using few quantities of interest. Here we focus on numerically modeling the signal acquisition and processing techniques used in the laboratory (Figure 2). The result is exciting, as the parallel data streams output results are so similar that even experts cannot successfully discern the source. This is a pivotal development towards digital twins and scientific discovery in unified data stream frameworks.

Current work is further extending the rocket combustor to the case of in-space ignition with cryogenic propellants (gaseous methane and liquid oxygen) for which further increases in physical complexity now includes liquid-gas interface motion, spray droplets, flash vaporization, and primary and secondary atomization (Figure 3). Interactions with SNL and LLNL personnel during program reviews have offered guidance and technical feedback in the areas of solver development, structured verification efforts, and the importance of specific multiphase technical challenges. Success would enable faithful-to-reality computations of multiphase flows that incorporate a high number of distinct physical phenomena that push the boundaries of multiphysics capabilities.

The Center for Hybrid Rocket Exascale Simulation Technology | University of Buffalo

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

The primary effort of the Center over recent years involved validating the numerical analysis using experimental data of a well characterized, smallscale slab burner. The insights from the slab burner experimental work, along with uncertainty analysis of the measurements and numerical models, has driven the development of the CHREST's collaborative software framework, Ablative Boundary Layers At The Exascale (ABLATE). The open-source exascale framework, ABLATE (ablate.dev) consists of low- and high-Mach computational fluid dynamics solvers, detailed chemical kinetic and radiation solvers, prediction assessment modules, flows, and several subgrid-scale models to account for shear-driven atomization and turbulent combustion phenomena.

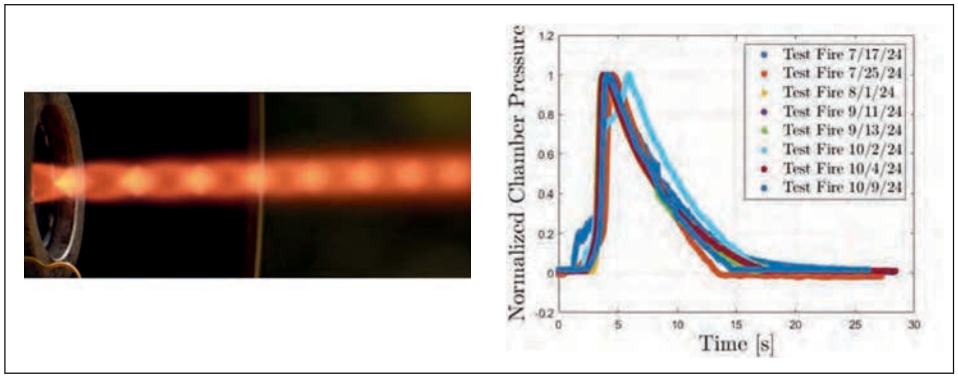


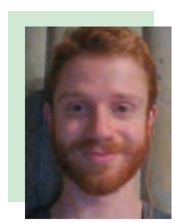
Figure 1.Post-nozzle exhaust region showing shock diamond structure and repeatability of experimentally-obtained data using chamber pressure of PMMA experimental test fires of the sounding rocket designed by CHREST graduate students.

The Center has been shifting its efforts to applying the insights and software developed to real world rocket applications. Current CHREST graduate students, Jasper Stedman and Joseph Cygan, have further developed the sounding rocket experiment started by previous students to aid in the validation of ABLATE predictions of key rocket quantities of interest such as the thrust, specific impulse, and shock geometry. Figure 1 shows the experimental and post-nozzle exhaust region and chamber pressure of the sounding rocket. These tests have shown adequate replicability and have been used to provide valuable insight and data to guide uncertainty quantification and rocket design using ABLATE.

Education has been a primary focus at CHREST with emphasis in areas ranging from undergraduate education to National Nuclear Security Administration (NNSA) laboratory internships. One highlight is the open-source, new researcher ABLATE boot camp (coding.ablate.dev). This day-by-day guide is tailored to help onboard individuals with little to no programming experience using a 20-day online course. This course is designed to take a few hours every day and includes selected book chapters, online tutorials, and videos.

CHREST graduate researchers Dwyer Deighan and Kolos Retfalvi recently have completed NNSA laboratory internships at Sandia National Laboratories (SNL) and Lawrence Livermore National Laboratory (LLNL), respectively.

Dwyer Deighan



At his internship this past summer at SNL, Dwyer and his advisors, Dr. Ravi Patel and Dr. Jonas Actor, worked on a project that uses an ensemble of neural operators to better understand boundary conditions and to facilitate uncertainty quantification. The method they developed is being applied to Turbulent Channel flow direct numerical simulation data from the Johns Hopkins Turbulent Dataset.

Kolos Retfalvi

Kolos's internship last spring at LLNL involved the area of chemical kinetic modeling. He implemented and interfaced LLNL's Zero-RK reaction kinetics integrator into the ABLATE framework used by CHREST. The Zero-RK interface enables ABLATE's chemistry solver easy integration onto GPU architectures, and its effective reactor load-balancing paradigm helps obtain 3-10x speedup in ABLATE's chemistry solver.

Their knowledge and insights gained during the NNSA internships have proven invaluable to the continued research efforts at CHREST.

More details can be found at: https://buffalo.edu/chrest.

Center for Micromorphic, Multiphysics, Porous and Particulate Materials' Simulations within Exascale Computing Workflows |

University of Colorado Boulder | PI: Dr. Richard Regueiro (richard.regueiro@colorado.edu) | Webpage: micromorph.gitlab.io

Scientific Question

Is the change in mechanical behavior (i.e., force-displacement, force-time, and failure pattern) of Plastic-Bonded eXplosive (PBX) materials related to grain-size distribution or something else? Answering the scientific question will lead to improved understanding of the manufacturing-to-physical-behavior relationship that will allow more precise design, manufacturing, and mechanical behavior prediction of PBX materials and other plastic-bonded composite granular materials.

State-of-the-Art

We cannot currently change manufacturing parameters prior to pressing and track the effects through a tightly-integrated, grain-resolving, experimental-computational modeling (spatially in three dimensions) framework upscaled to a micromorphic, continuum-scale, computational simulation accounting for grain-scale features in a computationally-more-tractable manner (than the grain-resolving DNS [direct numerical simulation] itself) without spatial-discretization-dependence. Exascale computing is needed to simulate these more sophisticated micromorphic-multiphysics-bridged-DNS simulations. Furthermore, Validation and Uncertainty Quantification (UQ) require multiple instances of these simulations over statistical distributions of inputs (such as grain size distribution and grain contact network connectivity, material parameter distributions, and boundary condition variability) with high and low fidelity.

Integrated Task Team (ITT) efforts involve the three ITTs within the Center: (1) ITT09 (renamed ITT-5.1 in Year 5) simulates the die-press manufacturing process of the 5 mm diameter cylinders using LAMMPS-granular DNS (Figure 1) (and preliminary results for Ratel implicit MPM; not shown), specifically quasi-static uniaxial strain in compression pressing of IDOX-Estane prills in 5 mm diameter steel dies at 50° and 90° C conditions at Mines with QoI (force vs displ, force vs time, post-press CT grain statistics); (2) ITT07 (renamed ITT-5.2 in Year 5) uses Ratel DNS to simulate quasi-static unconfined compression (Figure 2) of 5 mm diameter by 5 mm tall cylinders of IDOX-Estane at UT Dallas with QoI (force vs displ, DIC), upscaled through micromorphic filter, calibration of micromorphic parameters, and separate Tardigrade-MOOSE simulation including gradient-enhanced damage with same QoI; and (3) ITT08 (renamed ITT-5.3 in Year 5) uses GEOS-MPM DNS to simulate dynamic SHPB unconfined compression of 5 mm diameter by 5 mm tall cylinders of IDOX-Estane at UT Dallas and ARL APG with QoI (force vs displ, DIC; no DIC for ARL data).

Other significant updates include implicit MPM in Ratel for which progress has been made on hyperelastic simulations, demonstrating large deformations through the "sinker" problem and convergence rates with respect to spatial discretization refinement on order of that observed for linear hexahedral finite elements.

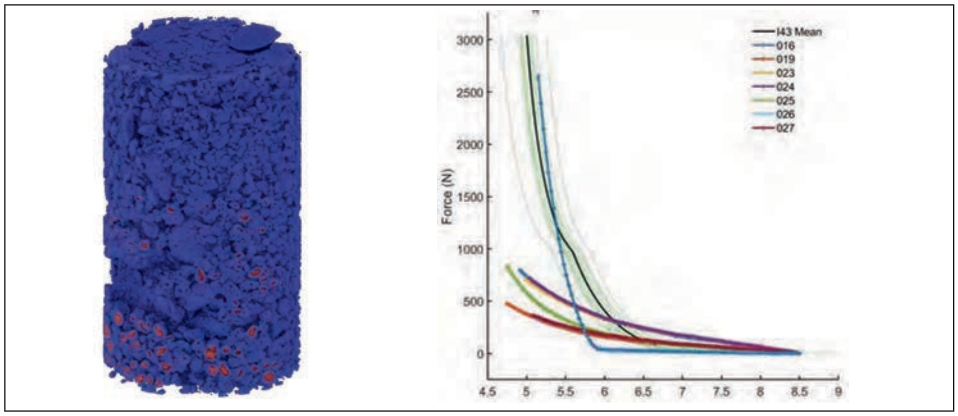


Figure 1. (a) Initial configuration of pressing simulation in LAMMPS using Bonded Particle Method (BPM). Geometry created from CT images taken from pour series in acrylic 5 mm die (but no pressing), while actual pressing is in steel die. (b) Force (N) versus height (mm) of cylinders as compared to experimental data.

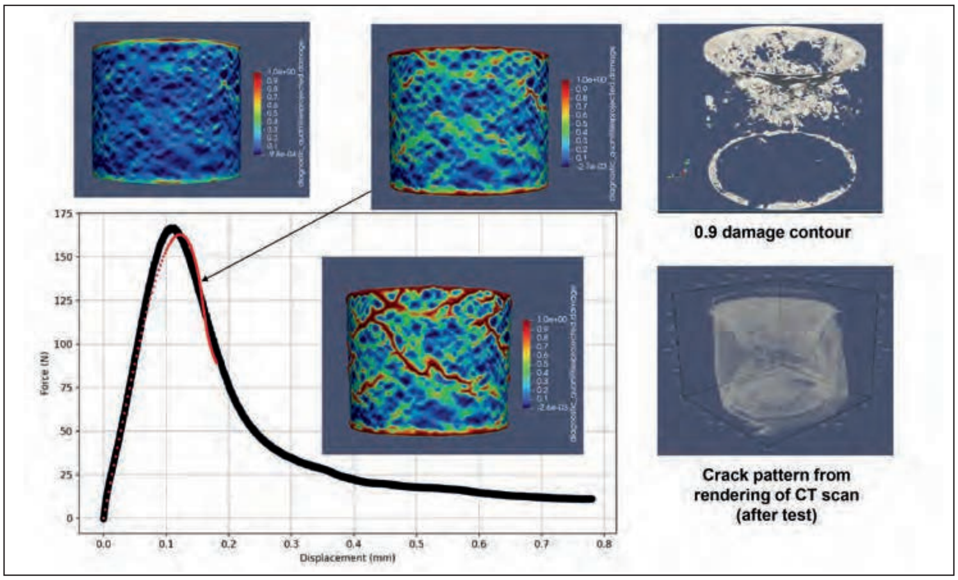


Figure 2. Ratel FEM simulation of quasi-static unconfined compression of 5 mm diameter mock HE IDOX-Estane composite cylinder. Calibration of matrix binder (mix of nitroplasticized Estane binder and small (< 40 micrometer) IDOX grains) to force versus displacement curve and comparison to localized deformation pattern measured by CT.

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The Center for Exascale-enabled Scramjet Design | University of Illinois Urbana-Champaign

PI: Dr. Jonathan Freund (jbfreund@illinois.edu); Co-Director: Dr. William Gropp (wgropp@illinois.edu)

Predictive science methods are being developed and integrated to advance scramjet propulsion technology by evaluating how to introduce light-weight, fiber composite, thermal protective combustor materials. How these materials strategically ablate in the supersonic combustor is the key concern for improving designs with them. To reliably include this within relatively empirical end-to-end scramjet models, physics-based models are integrated for gas-phase turbulent combustion, the carbon oxidation, degrading material, pyrolysis and outgassing from the phenolic fiber coatings, radiation cooling, and thermal transport into the materials. This requires massive-scale simulations. Physics-targeted experiments are being designed and used for sub-model validation. The Center's end-to-end uncertainty quantification workflow leverages these same physics-targeted configurations for reduction of the uncertainty space by sensitivity analysis.

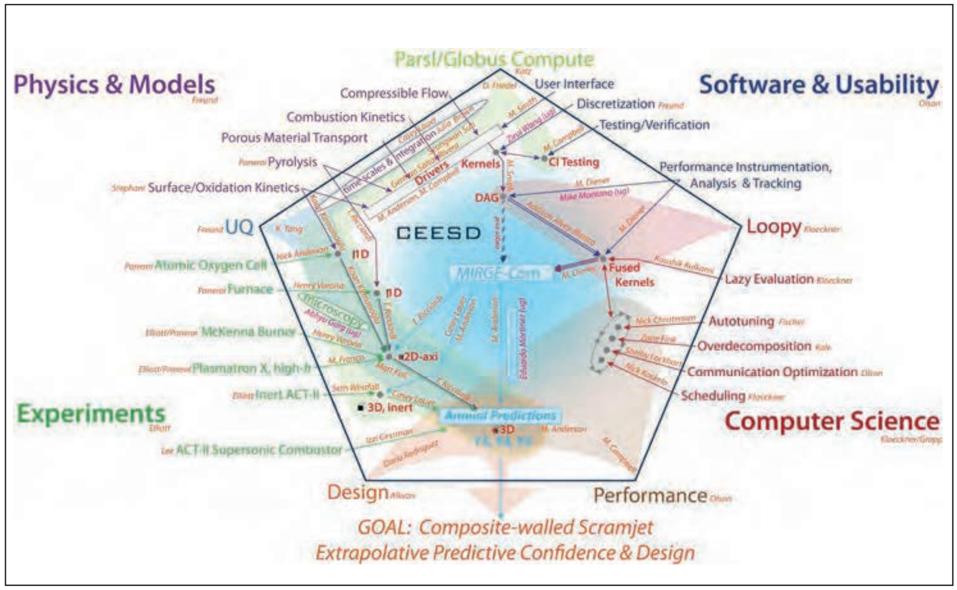


Figure 1. The integrated predictive science effort, as mapped out in this schematic, has demonstrated the MIRGE framework for the new MIRGE-Com simulation tool for scramjets. PhD students research in computer science, computational science, and experimental validation is within this integrated Center.

A centerpiece accomplishment has been a successful demonstration of the new Mathematics, Intermediate Representation, Generation, and Execution (MIRGE) approach for high-performance computing. Its goal is to separate concerns: the concern of model implementation from the concerns of optimization and hardware implementation. A Python control layer provides an expressive representation of the mathematics [M] of the physics models. Specifically, the Center has implemented a discontinuous Galerkin (DG) discretization of the compressible reacting Navier-Stokes equations, which are coupled thermal, species transport, and material degradation models of the wall material. We have demonstrated both rapid addition of new physics models (e.g., new transport equations) and the use and modification of these models by new users. The computational kernels are similar to traditional code with annotations to guide polyhedral decomposition in an intermediate representation [IR]. This is the key for the optimization: the intermediate representation facilitates design of a lazy evaluation path that also exploits opportunities to fuse the basic computational operations into macro kernels. The result is a directed acyclic graph of macro kernels, which enables generation [G] of OpenCL code for execution [E] on available computing hardware. MIRGE has demonstrated performance on both central processing units (CPUs) and graphics processing units (GPUs), and it will provide flexibility for future architectures.

Of course, any new approach has challenges. Foremost has been that the opportunities exposed for lazy evaluation optimization can explode in number, which leads to long compile times that hinder the development of integrated simulation models. We now have demonstrated a function abstraction within the intermediate discretization that upon generalization will ameliorate this. Another more subtle challenge is a performance floor associated with the launch of the computation kernels. This has no consequence for any simulation that actually needs high performance computing resources, but it can slow the code for small problems with many time steps, such as for debugging or extensive sampling of uncertainty spaces with one-dimensional multi-million-time-step models. An eager evaluation approach that better fuses computational kernels would fix this but has not been a top priority. Importantly, neither of these challenges have hindered demonstration of MIRGE for integrated multiphysics simulation nor are they fundamental problems with the approach.

The code MIRGE-Com, developed using MIRGE, has been used effectively on local laptops and workstations, LLNL Quartz and Dane CPU clusters, and Lassen and Tioga GPU clusters. For making predictions, a meshing and simulation workflow has been established, and the Python-based workflow management tool Parsl has been extended for orchestrating multi-stage simulations and uncertainty quantification, including a new framework for tracking simulation provenance.

The Center currently supports 16 PhD students. To date, 15 Predictive Science Academic Alliance Program-III PhD students have completed at least one, 10-week internship at a National Nuclear Security Administration laboratory, and 2 more have specific internship plans. Several internships have led to ongoing collaborations with lab personnel, including 5 students who have returned for additional internships. Several of these hope to find positions at the labs upon graduation.

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

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

This Focused Investigatory Center is 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 the Massachusetts Institute of Technology.

The high computational cost of turbulence simulations implies that sampling-based methods for uncertainty quantification (UQ) often are not feasible. A useful alternative is the sensitivity of the problem, defined as the infinitesimal change in a Quantity-of-Interest (QoI) due to infinitesimal changes in the uncertain problem parameters. Existing methods for sensitivity computation generally fail for chaotic problems due to the butterfly effect which amplifies infinitesimal disturbances beyond bound.

A large thrust of the Center has been the development of two novel methods for sensitivity estimation for turbulent flow problems: the 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. At the start of the Predictive Science Academic Alliance Program III (PSAAP III) project, the S3 method had been used only on simple chaotic maps (i.e., not even differential equations). The method was developed for ordinary and then partial differential equations during the first 3 years of the project and eventually was applied to a turbulent channel flow problem (illustrated in Figure 1) during Year 4. In parallel, the MFSA method was developed essentially from scratch during the project, with successive incremental

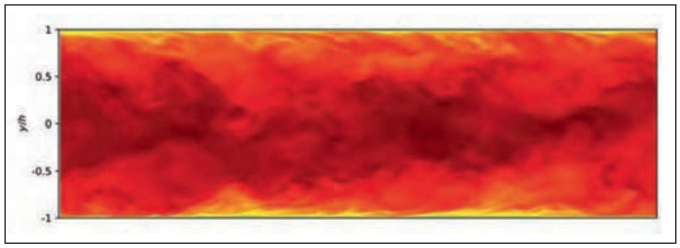


Figure 1. Instantaneous snapshot of a turbulent channel flow.

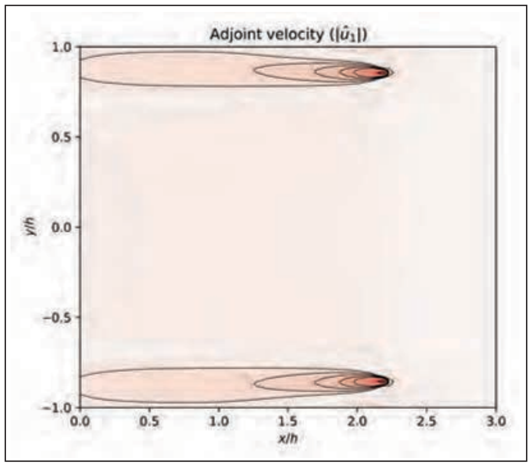


Figure 2. Approximate adjoint field for a QoI measuring the mean velocity at two locations, computed using the MFSA method.

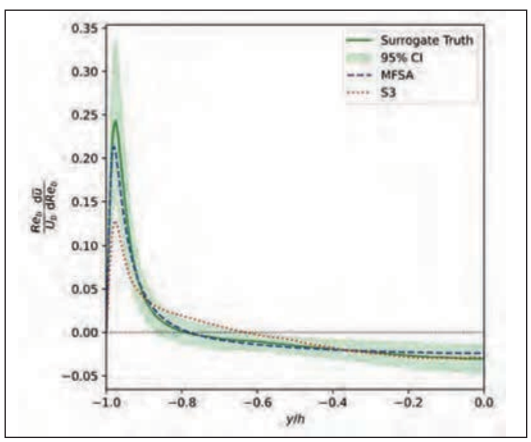


Figure 3. Sensitivity (= change) of the entire mean velocity profile of a turbulent channel flow to changes in the Reynolds number, comparing the two main methods developed in this PSAAP III Center against a surrogate truth (from multiple high-fidelity simulations) with estimated confidence interval.

improvements to improve the accuracy of the method. The essence of the method is to compute a high-fidelity prediction at the nominal condition and then to define a regularized (non-chaotic), lower-fidelity problem around the high-fidelity average. The accuracy of the method then depends directly on the closure models used for the lower-fidelity problem. Having a non-chaotic problem then allows for the computation of a non-diverging sensitivity or adjoint problem. The adjoint for a specific QoI (the mean velocity at a point close to the wall) for the turbulent channel flow is shown in Figure 2.

One core objective of the Center was to develop these different sensitivity estimation methods in parallel and to then apply them to the same turbulent flow problem during the final two years of the project. From that perspective, Figure 3 represents a proud achievement of the Center. It shows the result of applying both methods to the turbulent channel flow problem, in this case, to estimate the sensitivity in the mean velocity profile across the channel. The results are compared to “truth” data computed from several high-fidelity simulations with perturbed problem parameters, with the 95% confidence interval from these high-fidelity simulations included in the figure. Both methods do a rather good job of estimating the sensitivity, particularly the MFSA method which is everywhere inside the 95% confidence interval. In addition, the computational cost of the MFSA method is less than a single high-fidelity forward prediction, making it applicable in practice. The cost of the current incarnation of the S3 method is many times higher than the forward prediction (in fact, higher than the “truth” estimate for this problem).

Both methods need additional work before being ready for engineering use. The S3 method requires additional innovations to bring down the computational cost without sacrificing accuracy. The MFSA method needs to be applied to problems with more challenging physics; in truth, the test used here represents a rather benign scenario for the method. This work is ongoing in the Center.

Boltzsim: A Fast Eulerian Solver for the Collisional Electron Boltzmann Transport Equation | The University of Texas at Austin

PI: Dr. Robert Moser (rmoser@oden.utexas.edu); Author: Milinda Fernando (milinda@oden.utexas.edu)

The Center for Predictive Engineering and Computational Science (PECOS) is a research center at the Oden Institute for Computational Engineering and Sciences at The University of Texas at Austin. It is a multidisciplinary simulation center primarily funded by the Predictive Science Academic Alliance Program III. The major research effort at the center is to develop high-fidelity simulations of inductively coupled plasma (ICP) torches. This project started in 2020 and currently involves fifteen senior investigators, seven postdoctoral researchers, and eleven graduate students.

ICP torch plasmas are low temperature plasmas (LTPs). LTPs occur in many science and engineering applications, including hypersonics, material science, semiconductors, and energy. One of the many challenges in simulating LTPs is that electron kinetics often deviate from the Maxwell-Boltzmann distribution. The electron Boltzmann transport equation (BTE) governs the evolution of the electron distribution function (EDF) in a non-equilibrium system. One major research thrust at PECOS is to develop scalable algorithms for solving the electron BTE for LTPs. Two major solver approaches were explored by the PECOS kinetic transport team; Lagrangian and Eulerian. In the Lagrangian approach, a particle-in-cell (PIC) scheme is used for phase space advection, and particle collisions are modeled using the direct simulation Monte Carlo (DSMC) method. In contrast, the Eulerian approach uses numerical discretization of the electron BTE in a fixed coordinate frame. The developed Eulerian electron BTE solver (named Boltzsim) supports portable graphics processing unit (GPU) execution and is openly available at https://github.com/ut-padas/boltzmann.

Compared to existing state-of-the-art electron BTE solvers, Boltzsim offers several contributions to the field. These contributions include an EDF representation that goes beyond the traditional two-term approximation in angles, support for Coulomb electron-electron interactions, novel GPU accelerated numerical algorithms for fast steady-state and transient solutions, algorithms for solving a spatially-decoupled, batched system of electron BTEs, and algorithms for solving spatially-inhomogeneous Boltzmann transport. In addition to these features, Boltzsim solutions are cross-verified with the developed PIC-DSMC code and the state-of-the-art Bolsig+ framework. The Boltzsim framework is being used for ICP torch and one-dimensional radio frequency glow discharge plasmas (RF-GDPs) simulations.

ICP torch simulations with Boltzsim: The Boltzsim solver is coupled to a subsonic, inductively-coupled argon plasma flow with six species: electrons, ground state atoms, ions, and three excited metastable species. The flow/species transport solver is implemented using the Lawrence Livermore National Laboratory MFEM library using a standard discontinuous Galerkin formulation. The flow solver with heavy species is named the torch plasma simulator (TPS). We observed significant differences between the TPS coupled with the electron BTE (TPS + BTE) and the baseline TPS model with the tabulated electron kinetic coefficients (Figure 1).

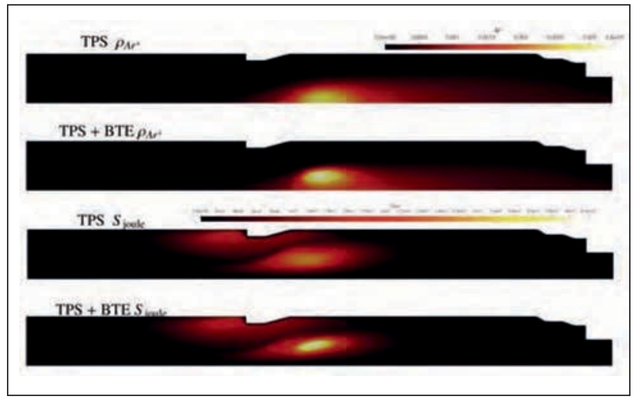


Figure 1.Comparison between steady-state solutions for the TPS with tabulated rate coefficients (i.e., baseline model) vs. strongly coupled BTE TPS solver. The first and second figures (from the top) show the normalized Ar+ density profiles, computed using the baseline and coupled BTE TPS solver. For the same problem figures three and four (from the top) show Joule heating profile differences between the two modeling approaches.

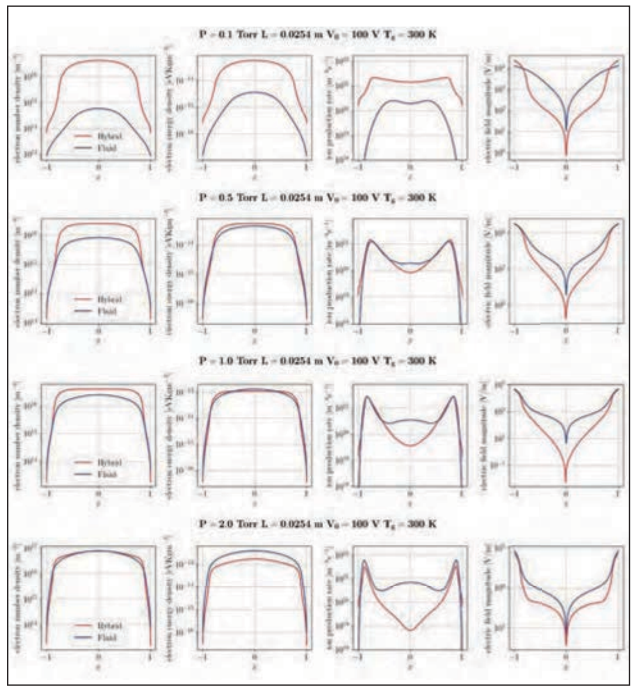


Figure 2. Cycle-averaged time-periodic steady-state profiles computed by the hybrid and the fluid approximation of RF-GDPs under varying pressure values from 0.1 Torr to 2 Torr.

RF-GDPs with Boltzsim: Existing state-of-the-art RF-GDP formulations rely on the fluid approximation for the species (e.g., electrons, ions) transport. These fluid approximations are derived based on the first three moments of the BTE with additional approximations. The PECOS kinetic team has used Boltzsim to replace the fluid-based electron transport with the BTE. The developed hybrid model combines fluid approximation for heavy species and the BTE for electrons. This study showed that the discrepancy between the fluid and the BTE-based electron transport is significant, especially for low-pressure discharge plasmas (Figure 2).

Tarun Prabhu (tarun@lanl.gov) | Los Alamos National Laboratory, 2022 - Present
Degree: PhD, Computer Science ✦ PSAAP: 2014 - 2019, University of Illinois, Urbana-Champaign

My PhD research involved exploring the use of Just In Time (JIT) compilation of Fortran, C, and C++ applications. This was a somewhat counter-intuitive idea since it involved re-compiling part of the application at run-time. After all, why would one want to introduce run-time overhead into high-performance, low-overhead, languages like C or Fortran that are already compiled? I am immensely grateful that the Predictive Science Academic Alliance Program (PSAAP) allowed me to explore a risky idea that went against conventional wisdom.

We eventually showed that simple programmer annotations paired with sophisticated static analyses could be used to build a JIT compiler that improved overall application performance. This would not have been possible without PSAAP. The program led me to work with computational scientists whose experience and input led me to a design that was intuitive for the users while also providing enough information for the static analyses to be effective.

As part of the PSAAP center, I was exposed to the full breadth of the scientific process, from theoretical modeling to computer simulation and experimental validation. It was instructive to see how scientists from different backgrounds approached the same problem. This experience has stood me in good stead over the years.

Building a JIT compiler as a PhD student required me to learn a lot about the design and implementation of multiple compilers. I realized then that I enjoyed both finding solutions to fundamentally difficult problems in program analysis and optimization and making those solutions work in practice and at scale. The national laboratories were an obvious professional destination since they straddle academia and industry. I joined the programming models team at Los Alamos National Laboratory (LANL) where we continue to rethink the fundamental design of compilers, while also building new ones for production use.

My production engineering efforts are focused on flang—a brand new, start-of-the-art Fortran compiler that is part of the LLVM project. I am part of a multi-national team that spans other national laboratories, academia, and industry. While the current emphasis is on enabling functionality, we clearly can see the potential to perform very sophisticated optimizations with it, including some that raise interesting research questions.

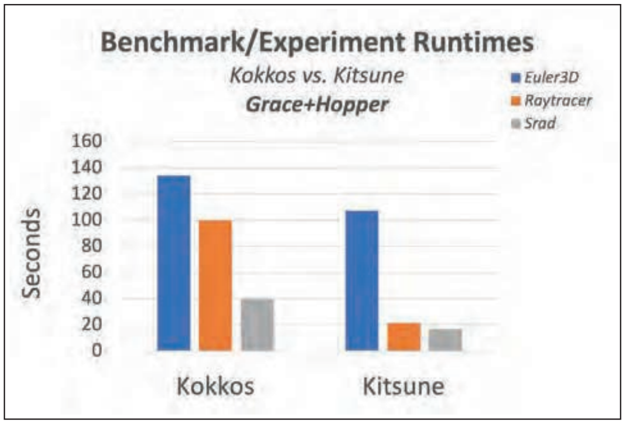


Figure 1. Performance of three simple benchmarks compiled by Kitsune compared to a similar implementation using Kokkos parallel_for. The benchmarks are a three-dimensional Euler-like benchmark, a simple ray tracer, and a Speckle Reducing Anisotropic Diffusion (SRAD) stencil. These were run on an NVIDIA H100 GPU.

> *"As part of the PSAAP center, I was exposed to the full breadth of the scientific process, from theoretical modeling to computer simulation and experimental validation. It was instructive to see how scientists from different backgrounds approached the same problem. This experience has stood me in good stead over the years."*

Kitsune is our research-focused compiler, the product of a long-running collaboration that builds on the foundational work of colleagues at the Massachusetts Institute of Technology. Kitsune can reason about parallelism in a principled manner. When combined with some programmer-provided hints about their parallelizability, Kitsune can compile serial loops to run on both NVIDIA and AMD graphics processing units (GPUs). It can also parallelize the loops on the central processing unit (CPU) by targeting parallel runtimes such as OpenCilk and Qthreads.

Through Kitsune, we explore both compile-time (static) and run-time (dynamic) analyses and optimizations, as well as programming language and application programming interface design that can improve scientists' productivity while simultaneously delivering high performance and the flexibility to target a range of computing devices and runtime systems.

Perhaps the best part about my experience at LANL, though, has been my continued involvement in the PSAAP program. I have served as a reviewer for a PSAAP center and mentored PSAAP students pursuing an internship at LANL. It is immensely rewarding to be part of the program that has shaped my own career and to work with the talented students, and future colleagues, at the PSAAP centers.

Joseph J. Marziale (jjmarzia@buffalo.edu) | **University at Buffalo**
Degree in Progress: PhD, Aerospace Engineering ✦ **Advisor:** Dr. David Salac and Dr. James Chen ✦ **PSAAP:** 2023 - Present

Research Topic

Parallelized Volume of Fluid (VOF)-based Interface Sharpening Method for Compressible Multiphase Flows with Surface Tension on Unstructured Meshes

Research Responsibilities

Since joining the Center for Hybrid Rocket Exascale Simulation Technology (CHREST) team in September 2023, my research has centered on developing an interface sharpening scheme (used to mitigate numerical diffusion in finite discretizations of a compressible, multiphase Euler system) which is generalizable to an arbitrary distribution of cell centers. Resolving interfacial dynamics is crucial towards CHREST's broader goal of characterizing paraffin droplet pinchoff induced by shearing oxidizer flow in a hybrid rocket motor during combustion. As I work on this, my day-to-day is a wide-ranging mix of theoretical, computational, and communicative tasks. Recent efforts include integrating PETSc's MPI-based parallel communication capabilities into the sharpening calculation; deriving truncation errors from finite volume (FV) approximations of Euler conserved variables at cells; designing and executing numerical simulations of flows that elicit Weber number-specific droplet pinchoff; comparing postprocessed droplet results to the surrounding literature; and organizing my research output into upcoming publications, conferences, and monthly CHREST meetings.

Benefits of PSAAP

I am looking forward to learning from the great people at Los Alamos National Laboratory (LANL) in 2025 during a summer internship. Of course, this opportunity was made accessible to me because of CHREST's close relationship to the National Nuclear Security Administration laboratories, for which I am grateful. It will be nice to see familiar faces from the Tri-Lab Support Team meetings and the 2024 Fluid Engineering Division Summer Meeting.

What Students Considering PSAAP Should Know

My sincere impression is that the entire enterprise is set up to equip students like me with the guidance and muscle to be competent professionals who will do good in the world. I've worked with CHREST for a little over a year, and already the input I've received from experts who comprise the research meetings has significantly improved the quality of my research. So, if a student was on the fence about where to do their graduate studies, I'd encourage them to consider the benefit of joining a program that collaborates with NNSA as opposed to studying in a vacuum. For example, if you can imagine that having a PhD advisor is useful, then you can imagine the multiplicative benefits of having several more advocates in the national lab space.

Ruairi O'Connor (ruairioconnor@utexas.edu) | **The University of Texas at Austin**
Degree in Progress: PhD, Aerospace Engineering ✦ **Advisor:** Dr. Philip Varghese ✦ **PSAAP:** 2020 - Present

Research Topic

Experimental Study of Electron Kinetics in Low-temperature Radiofrequency Plasmas

Research Responsibilities

My responsibilities are to conduct experiments in a glow discharge plasma facility using optical and probe-based measurement techniques to study kinetic plasma processes. This aids in the validation of an advanced chemistry model to be used in exascale simulations of an inductively coupled plasma torch. A key element of my work is incorporating advanced uncertainty quantification (UQ) techniques into the data analysis process. I work with experts in the Predictive Science Academic Alliance Program III (PSAAP III) Center to develop new UQ frameworks for evaluating optical emission and laser absorption spectroscopy as well as Langmuir probe data. I generate databases of electron density and excited species populations in argon and nitrogen plasmas at a range of conditions, with uncertainty, which allows for rigorous model validation. This component validation study in an isolated plasma kinetics experiment feeds into the larger PSAAP Center simulations and allows the group to gain confidence in our predictive science targets.

Benefits of PSAAP

I believe the PSAAP III program has benefitted me hugely throughout my studies by connecting me with an incredible and immensely talented network of multi-disciplinary scientists, researchers, and engineers. The discussions and mentorship I have experienced while working with PSAAP III have changed my approach to science and have given me a new lens through which to understand not only my research but also the world-at-large. I have felt that the unique benefit of the program has been the exposure to so many difference branches of science while still being connected to one problem. That really highlights, for me, how much can be gained by stepping outside your area of expertise and seeing how others tackle their difficult questions.

New Contacts, New Opportunities

PSAAP III has provided me with the opportunity to work extremely closely with faculty and other students from a wide array of disciplines that are usually disconnected from my area of work. I perform experiments, but I meet regularly with modeling and simulation experts to discuss comparisons between our results. I also have exposure to researchers working on advanced algorithms and other areas of computer science that I would never otherwise have interacted with in my graduate studies. In addition, PSAAP III has connected me with many scientists from the national lab system through our regular review meetings and an internship at Los Alamos National Laboratory.

Ayush Parajuli (ayushp11@umd.edu) | **University of Maryland**

Degree in Progress: PhD, Mechanical Engineering ✦ **Advisor:** Dr. Johan Larsson ✦ **PSAAP:** 2023 - Present

Research Topic

Multi-fidelity Sensitivity Analysis

Research Responsibilities

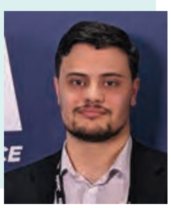
Our project focuses on developing algorithms for solution verification and uncertainty quantification (UQ) in chaotic turbulent flow problems. A central aspect of my work is quantifying the uncertainty of a Quantity of Interest (QoI) using Multi-Fidelity Sensitivity Analysis (MFSA). This approach combines high-fidelity models as references with low-fidelity models to improve uncertainty estimation while reducing computational cost. Additionally, I am involved in developing a turbulent adjoint flow solver, which is crucial for efficiently calculating sensitivities of the QoI to flow parameters. Together, these efforts aim to enhance the accuracy and efficiency of uncertainty quantification in turbulent flow simulations.

Benefits of PSAAP

The Predictive Science Academic Alliance Program III (PSAAP III) project has provided me with a valuable opportunity to bridge the gap between my knowledge of fundamental fluid mechanics and the critical issues of solution verification, validation, and uncertainty quantification (VVUQ). I also learned that these vital aspects often are overlooked in our research community, even though they are essential for reliable engineering simulations. Through PSAAP III, I have been able to compare results from various models and solvers, gaining a deeper understanding of the importance of VVUQ in ensuring the accuracy and reliability of numerical predictions. Additionally, being part of a diverse team of PhD students, postdocs, and professors from different universities has expanded my knowledge and improved my collaborative skills. This multidisciplinary environment has been invaluable, helping me communicate complex ideas and work more effectively in teams. Moreover, the PSAAP III project has introduced me to large-scale research project management, providing insights into the organizational and financial aspects of coordinating such efforts. Overall, my experience with PSAAP III has significantly broadened my perspective, equipping me with the skills to address both fundamental fluid mechanics and practical engineering challenges, ensuring that our research solutions are reliable in real-world scenarios.

Kolos Retfalvi (kolosret@buffalo.edu) | **University at Buffalo**

Degree in Progress: PhD, Aerospace Engineering ✦ **Advisor:** Dr. Paul DesJardin ✦ **PSAAP:** 2020 - Present



Research Topic

Direct Numerical Simulation of Hybrid Rocket Engines

Research Responsibilities

The primary research goal of our Predictive Science Academic Alliance Program III (PSAAP III) Center at the University at Buffalo is to study hybrid rocket engines through direct numerical simulations (DNS). My research focuses on the development and scaling of our DNS framework, ABLATE, to better understand turbulent mixing and fuel entrainment in hybrid rocket motors. A fundamental challenge in these simulations is the immense computational power requirement, which makes maximizing computational efficiency a critical priority. My responsibilities include developing performance models to evaluate the scalability and performance of ABLATE, with a special focus on reactive thermochemistry. These models enable us to identify and eliminate bottlenecks, improving overall solver efficiency and reducing the time to solution in large-scale hybrid rocket simulations.

Benefits of PSAAP

The most significant benefit of PSAAP III has been the access to state-of-the-art computational platforms. These resources have enabled me to conduct high-fidelity simulations and scalability studies on the ABLATE framework to tackle complex problems in hybrid rocket combustion. The combination of advanced computational tools and a collaborative research environment has not only enriched my academic experience but also significantly enhanced my professional growth and technical expertise. Being part of a PSAAP III project has given me the opportunity to work in a large, multidisciplinary research group, providing exposure to a range of diverse perspectives and approaches. Collaborating with multiple National Nuclear Security Administration partners has offered invaluable networking opportunities, allowing me to connect with experts across various fields and to develop critical teamwork and communication skills.

National Laboratory Experience

I concluded my PSAAP III internship in the Computational Engineering Division at Lawrence Livermore National Laboratory (LLNL) in the Spring of 2024 under the mentorship of Russell Whitesides. During this internship, my work was directly connected to my research, and my main responsibility was to further optimize the chemistry solver by integrating Zero-RK, a chemistry solver developed at LLNL, into our software framework. My work during the internship has significantly benefited our entire PSAAP III Center by enabling us to run the simulations more efficiently. Overall, the internship provided me with invaluable experience in computational performance analysis and GPU computing, greatly advancing my professional development.

Robert Loek Van Heyningen (rloekvh@mit.edu) | **Massachusetts Institute of Technology**
Degree in Progress: PhD, Aeronautics and Astronautics ✦ **Advisor:** Prof. Jaime Peraire and Ngoc Cuong Nguyen ✦ **PSAAP:** 2021 - 2024

Research Topic

High-order Methods and Reduced-order Modeling for High-speed Flows

Research Responsibilities

I conduct research in numerical methods for the simulation of hypersonic flows using high-order finite element methods when high accuracy is needed and reduced-order modeling techniques for many-query workflows such as uncertainty quantification.

Benefits of PSAAP

I have completed two summer internships with Sandia National Laboratories (SNL) and have stayed on as a year-round intern following the second internship. The collaboration between my group and the lab has resulted in conference presentations and publications, and a large part of my thesis is built off of work completed during these internships. Academic Programs has shaped my graduate and professional career, and I encourage any graduate students interested in a research or national lab career to participate. My first summer internship at SNL concerned a topic that was related to my research but did not have a role in the research trajectory I had planned. I grew to appreciate the usefulness and rigor of the data-driven methods studied in my internship, and I felt that my internship project was well-scoped while still being a useful contribution to the group. I was encouraged as a researcher that some of the methods I implemented as an intern are still being used on projects at the lab. The internship provided a refreshing mental break from my PhD projects and provided an experience that was faster-paced and more collaborative than some of my prior work. After that internship, the lab team, my advisors, and I stayed in touch and looked for ways to combine my planned research with the work begun at the lab. This led to a second internship, during which we developed new methods that incorporated my original and newfound interests. Since then, we have continued collaborating on projects for my own research and efforts at the lab.

The internship has introduced me to new research communities and to the community of experts at the national labs. I also believe it has augmented my PhD research. This is perhaps obvious in the sections added to my thesis related to my internship work, but it also has provided my original research topic with a new, more holistic perspective on the problems at hand. I think this has helped me become a more flexible and versatile researcher, which is invaluable in a field as inherently interdisciplinary as computational science. As I enter the late stages of my PhD, I think this has left me with more options for my career. Finally, the people I have worked with and met through the internship have all been professional, friendly, and supportive.

Christopher Williams (ctwilliams@stanford.edu) | **Stanford University**
Degree in Progress: PhD, Mechanical Engineering ✦ **Advisor:** Prof. Parviz Moin ✦ **PSAAP:** 2020 - Present

Research Topic

Compressible Reacting Turbulence

Research Responsibilities

As part of the Predictive Science Academic Alliance Program III (PSAAP III) Center at Stanford, I am developing novel dynamic subgrid-scale (SGS) models for chemical-kinetic processes and hydrodynamic mixing in the context of large-eddy simulation for the compressible reacting Navier-Stokes equations. In conjunction with SGS modeling, my research at the Stanford PSAAP III Center likewise focuses on numerical simulation of non-equilibrium effects in compressible turbulence, particularly as it pertains to laser-induced ignition within rocket combustors. In representing the effect of small-scale turbulence fluctuations on thermochemical processes, these subgrid models under development extend the large-eddy-simulation paradigm to non-equilibrium reacting flows, relevant for both hypersonic flight and plasma-kernel ignition. As only the large-scale dynamics are directly resolved in this framework, the number of degrees of freedom required to predict engineering quantities of interest is reduced significantly. My ongoing work, therefore, is focused on a posteriori assessment of the subgrid closure models I have developed for compressible reacting turbulence with finite-rate thermochemical processes, utilizing the Hypersonic Task-based Research (HTR) solver.

Benefits of PSAAP

Being engaged in the Integrated Simulations using Exascale Multiphysics Ensembles (INSIEME) PSAAP III Center has been the highlight of my graduate program at Stanford. Collaborating with exceptional researchers at the Center and beyond has introduced me not only to broad topics in fluid mechanics, to include chemical reactivity and ignition, multi-phase flow, plasma physics, and fluid turbulence, but also data-driven science, uncertainty quantification, and high-performance computing. In addition to these enriching interactions, the PSAAP III has enabled my own research in reacting turbulence by providing access to the unparalleled computational resources at the labs, allowing for detailed numerical investigations.

National Laboratory Experience

I spent the Summer of 2022 working as an intern at Sandia National Laboratories in Albuquerque, focusing on the comparison of molecular-level and continuum simulations of fluid physics. With my thesis research at Stanford largely focusing on efficient numerical solutions of the Navier-Stokes equations, this internship provided an excellent complement, expanding my understanding of both molecular gas dynamics and the direct simulation Monte Carlo method. Following my summer internship, I have continued to work as a year-round research fellow, which has proven to be an invaluable opportunity to engage in fundamental research at Sandia.

Minority Serving Institution Partnership Program

Minority Serving Institution Partnership Program | Overview

Program Manager: Betsy Snell; Authors: Betsy Snell and Suraya Bair (msippinfo@nnsa.doe.gov)

The Minority Serving Institution Partnership Program (MSIPP) operates under the National Nuclear Security Administration (NNSA) with the mission to establish a sustainable career pathway that prepares a talented workforce of students to make immediate contributions to the national laboratories, plants, and sites (LPS) that form the Nuclear Security Enterprise (NSE). The MSIPP develops and enhances workforce and educational capacities in Institutions of Higher Education (IHEs) through partnerships, aligning investments to support a career pathway for science, technology, engineering, and mathematics (STEM) talent committed to advancing the nation's nuclear security.

Figure 1. MSIPP at Florida A&M University during the 2024 Technical Meeting.

The MSIPP currently supports 38 projects across 57 IHEs nationwide, cultivating student talent, progressing collaborative research and experiential learning opportunities, and supporting collaborations with NSE facilities. Across these partnerships, students and faculty gain hands-on experience through research activities, internship opportunities, and mentoring sessions, preparing participants to make immediate contributions to the Nation's nuclear security efforts.

In 2024, MSIPP expanded program and financial support to four new projects under the Consortia Grant Program. These new consortia collaborations support critical innovation in the fields of nuclear security, cybersecurity, advanced manufacturing, and engineering. Each project connects IHEs with the LPS, providing students and faculty with multiple opportunities in capability and capacity building. These awarded projects include:

- PARTNERS: The PARTNERShip and Training for NNSA Engineering and Relevant Sciences consortia is led by the University of Central Florida in partnership with the University of California at Irvine and Florida A&M University. The NNSA collaborators are Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories.
- QUICKSTART: The QUantum Integrated Cyber Knowledge Simulation, Training, Advanced Research, and Technology consortia is led by the University of Central Florida in partnership with Florida A&M University, and Seminole State College of Florida. The NNSA collaborator is Y-12 National Security Complex.
- SPINE: The Scholarly Partnership in Nuclear Engineering consortia is led by Morgan State University in partnership with Navajo Technical University and the University of Puerto Rico – Rio Piedras Campus. The Department of Energy (DOE)/NNSA collaborators are Idaho National Laboratory and Savannah River National Laboratory.
- TRACS: The Tri-State Consortium for Resilient Automation and Cybersecurity System consortia is led by North Carolina A&T State University in partnership with Tennessee State University and South Carolina State University. The DOE/NNSA collaborators are Oak Ridge National Laboratory and Savannah River National Laboratory.

By expanding access to STEM resources and nurturing academic talent at IHEs, MSIPP plays a pivotal role in advancing key priorities in support of NNSA. The program addresses critical workforce needs at the LPS by supporting an educational and career pathway for talented students ready to tackle the challenges of modern nuclear security. MSIPP collaborations and funded projects contribute to the Nation's national security efforts through scientific excellence and technological innovation.

The program's portfolio of projects reinforces NNSA's commitment to educational advancement, excellence, and economic opportunity, building the next generation of STEM professionals dedicated to protecting the Nation.

Learn more about NNSA's Minority Serving Institution Partnership Program here.

Community and Junior College Trade Occupation Program | Developing Next-Generation Radiation Safety Professionals

Lead: City University of New York Queensborough Community College | NSE Collaborator: Brookhaven National Laboratory
Authors: Dr. Sharon Lall-Ramnarin and Dr. Paul Sideris

The Developing Next Generation Radiation Safety Professionals (DNGRSP) Program addresses future radiation safety workforce needs by recruiting and training students to support the missions of the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA) by advancing nuclear security, nonproliferation, and radiation protection. The main project objectives are to (1) create a Radiation Safety Certificate embedded in an existing associate's degree pathway that includes specialized courses in radiation safety, in collaboration with technicians and scientists at Brookhaven National Laboratory (BNL) and (2) incorporate internships in the certificate experience, building lasting collaborations with personnel at BNL and other DOE/NNSA facilities that support the Nuclear Security Enterprise initiatives.

Figure 1. Professors Paul Sideris and Sharon Lall-Ramnarine demonstrate the use of a "Pancake" Geiger Muller counter to their first cohort of Radiation Safety students.

Students in the program participate in a week-long, mini-semester focusing on radiation safety and a 10-week summer internship at BNL. During the mini-semester, students participate in guided tours of facilities at BNL, attend specialized workshops by radiological control professionals, and are introduced to potential summer internship mentors.

Since the program's inception in 2023, two courses in radiation safety have been created and approved. The courses have lecture and laboratory components that were co-developed with the guidance of BNL staff and radiological control experts to include relevant topics on the detection and identification of radioactive materials and hands-on activities using instrumentation commonly found in the workforce. Some labs are co-taught by BNL scientists and technicians in-person at Queensborough Community College (QCC), BNL, or remotely. High-impact practices, such as undergraduate research, also are embedded in the radiation safety coursework or as optional independent study courses. A Radiation Safety Certificate has been formally approved by the New York State Education Department and is awarded after students earn approximately 30 credits in English Composition, General Chemistry, College Physics, and Radiation Safety.

Six students from the first cohort who participated in the BNL mini-semester and summer internships presented their research at the 2024 International Nuclear Materials Management (INMM) meeting in Portland, Oregon, capturing the favorite poster award! This is the first time QCC students have attended and presented at an INMM meeting.

Mentorship from BNL professionals continues beyond summer programs. To facilitate continued partnership with BNL, QCC revived and modified an existing cooperative education course in chemistry that allows for mentor-led undergraduate research internships, either in-person or remote, at external partner sites throughout the academic year. This is the first time BNL has partnered with QCC for these courses.

The collaboration strengthens DNGRSP's objectives to build pathways between students at QCC and DOE/NNSA facilities.

Figure 2. DNGRSP program students determine the radiation counts per minute from a lantern mantle sample.

Figure 3. DGRSP program student determines the radiation counts per minute from a granite sample.

Consortium on Nuclear Security Technologies | CONNECT 2.0 Advances Nobel Worthy Nuclear Detection Research

Lead: University of Texas at San Antonio | NSE Collaborators: Argonne National Laboratory, Los Alamos National Laboratory, and Pacific Northwest National Laboratory | Authors: Betsy Snell and Suraya Bair

Funded by the National Nuclear Security Administration's (NNSA) Minority Serving Institution Partnership Program (MSIPP), research from the University of Texas San Antonio (UTSA) and Argonne National Laboratory (ANL) is advancing innovative techniques for detecting radioactive materials using Hopfield Neural Network – an area highlighted in this year's Nobel Prize in Physics. The project, titled the Consortium on Nuclear Security Technologies (CONNECT 2.0) and led by UTSA in partnership with the University of Nevada Las Vegas, St. Mary's University, Los Alamos National Laboratory, ANL, and Pacific Northwest National Laboratory, tackles a major challenge for nuclear security: detecting and identifying radioisotopes from low-quality gamma spectra.

The CONNECT 2.0 research team includes Luis Valdez, a graduate student from UTSA and current intern at ANL, Dr. Miltos Alamaniotis, a professor at UTSA, and Dr. Alexander Heifetz, principle engineer at ANL. Together, the team has applied the concept of auto-associative memory implemented with Hopfield Neural Networks (HNN) to recognize orphan isotopes from challenging gamma spectra gathered in real-world conditions. The HNN model, which mimics human memory's ability to recognize partially obstructed objects, was the focus of this year's Nobel-winning physics research and represents a pioneering shift in data processing for nuclear detection.

"Detection and identification of radioisotopes in poor-quality, low-level gamma spectra remain a pressing issue," explains Heifetz. "Using the principles behind HNN, we trained this model on high-quality gamma spectra in controlled lab conditions. This allows the HNN to recognize the target radioisotopes from lower-quality spectra captured by mobile detectors in field trails, like our urban campaign drive-through in Chicago."

Figure 1. Students and national lab collaborators from CONNECT 2.0 advancing HNN-based techniques for detection of radioactive materials.

CONNECT 2.0's research holds immense potential across multiple sectors. Nuclear security, border checkpoints, and cargo screening can benefit from these enhanced capabilities, enabling federal and local authorities to more accurately and efficiently identify radioactive sources. Industries in nuclear energy and nuclear medicine can apply this technology to monitor weak sources of radioactivity, promoting safer practices and regulatory compliance.

This project already has garnered attention within the nuclear research community, as the team's findings have been published in *Nuclear Technology*. Emphasizing the efforts of CONNECT 2.0's research, Heifetz adds, "the potential of HNN networks for nuclear security is still underexplored. CONNECT 2.0's success has shown that there is a wealth of opportunity to further integrate HNN in the field, and we hope it encourages others to see its value and application."

Figure 2. Students and faculty from CONNECT 2.0 working on nuclear detection using auto-associative memory implemented with a HNN.

The CONNECT 2.0 consortia exemplifies how MSIPP fosters science, technology, engineering, and mathematics innovation within Institutions of Higher Education, contributing to national security and scientific progress. This Nobel-prize-connected research advances the field of nuclear detection and aligns CONNECT 2.0 with NNSA as a driving force in future technological breakthroughs.

Colt Cagle (cagle@lanl.gov) | **Princeton University**
Degree: PhD, Mechanical Engineering, Texas Tech University ✦ **Advisor:** Dr. Michelle Pantoya ✦ **MSIPP:** 2020 - 2024

Focus Area

I originally joined Sandia National Laboratories (SNL) running shock physics simulations and learning Sandia code. My focus for my PhD work was advanced diagnostics. However, it is important nowadays for diagnostics to be geared towards simulations due to the increasing importance simulations play for stockpile stewardship and other aspects of engineering development. Sandia gave me a great opportunity to learn this skillset and learn how national labs function. I ended up accepting a job at Los Alamos National Laboratory (LANL) in Group Q-6 (Detonation Sciences), maintaining my focus on diagnostics but continuing to leverage my modeling and simulation experience.

Benefits of MSIPP

Skills and Knowledge

I immersed myself in an entirely new field of engineering (modeling and simulation) that would have been impossible to gain experience in without MSIPP. The program gave me the opportunity to collaborate with the national laboratories, including SNL, Pacific Northwest National Laboratory (PNNL), and Los Alamos National Laboratory.

Academic and Career Path Impact

MSIPP has greatly helped my career and resulted in my becoming employed at LANL. The program allowed me to understand how national labs function, ultimately leading me to choose a career at LANL over other industry offers.

STEM, Nuclear Security, or Related Fields

This experience helped me jump into the world of nuclear security in an important way. Before MSIPP, I had a notion that the nuclear enterprise and national labs were veiled in some mysterious force that only physics and nuclear engineers could possibly understand. After joining Sandia through MSIPP, I realized how vast and varied the work is and how open and interesting the culture is. This ultimately drew me into working for the enterprise full time.

What Students Considering MSIPP Should Know

Getting to work at PNNL was a great opportunity with truly amazing people in a beautiful region. National labs have a great work-life balance, so being at PNNL and working on incredible cutting-edge manufacturing technology while spending every weekend exploring the surrounding national parks, coastal cities, volcanic washes, etc. was a truly unique experience.

Make use of the time you spend! MSIPP allowed me to explore all over the nation, not just for job opportunities, but for job opportunities that I truly loved and was interested in. There is no use spending great deals of time and money on college only to come away with a job you don't enjoy. Leverage the programs available and find work you love with a purpose you find meaningful.

Jasmine Charley (becentij@unm.edu) | **University of New Mexico**
Degree in Progress: PhD, Biomedical Engineering ✦ **Advisors:** Dr. Tommy Rockward ✦ **MSIPP:** 2023 - Present

Focus Area

Electrochemistry

Benefits of MSIPP

Skills and Knowledge

I gained knowledge and experience with different analytical methods, how to handle the equipment, and how to prepare test experiments. Most importantly, I gained an understanding of the purpose of the research. I also received some useful information about graduate school from the other students who trained me on the project.

Academic and Career Path Impact

MSIPP influenced my academic goals and career plans tremendously. Tommy Rockward and the students with whom I have worked gave me the courage to apply to graduate school. My career dream as a child was to become a scientist, and working at a national laboratory gave me the push I needed to pursue that dream. I am a first-generation student, which means I did not have knowledge nor anyone around me who had experienced the college environment, let alone working with a national laboratory. I'm thankful to MSIPP for this great opportunity and for helping me along the way, as I am currently attending graduate school.

STEM, Nuclear Security, or Related Fields

The program helped me see more clearly what I want to pursue in graduate school. I always loved conducting research and helping with projects, and because of this I have had the opportunity to be involved in several projects. This made me unsure of what direction I wanted to pursue. Although it provided me with great experiences, the range of projects contributed to my being unsure of what I truly love doing and what my specialty should be. The work that I did at LANL and at Navajo Technical University helped point me to Biomedical Engineering.

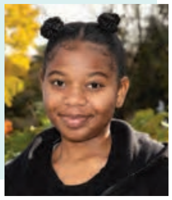
What Students Considering MSIPP Should Know

The program has impacted my professional growth by allowing me the opportunity to 1) work well with others to achieve goals, 2) improve my public speaking when presenting research, and 3) better stay on task, manage my time, and stay organized. All of this has improved my professional skillset as a research intern and as a student.

My most memorable experience occurred when I attended a symposium for graduate students at Arizona State University. As an undergraduate, I felt nervous about presenting my poster about the fundamentals of electrochemistry in front of graduate students. After my presentation, several students said that they did not fully understand the concept before reading my poster. This made me feel proud.

Pedrocia De-Sosoo (pedrocia.desosoo02@student.qcc.cuny.edu) | **City University of New York Queensborough Community College**
Degree in Progress: B.S., Computer Science and Information Security ✦ Advisors: Dr. Sharon Lall-Ramnari and Dr. Paul Sideris ✦ MSIPP: 2023 - Present

Focus Area



I participated in the Developing Next-Generation Radiation Safety Professionals (DNGRSP) program. As part of the student cohort, I attended courses, workshops, and seminars that prepared me for a career as a Radiological Control Technician (RCT).

Benefits of MSIPP

Skills and Knowledge

The MSIPP program has profoundly influenced my academic and career path. It has deepened my understanding of radiation safety and its practical applications. The hands-on experience and mentorship I've received have been invaluable. The program has opened many doors for me, including an internship at a national lab, which was an incredible opportunity. After the internship, I secured a continuing mentored research position through a cooperative education course at my college that allows me to continue my project with my Brookhaven National Laboratory (BNL) mentor while still in school. These experiences equipped me with numerous practical skills and professional connections that are essential for my future career.

Academic and Career Path Impact

My career aspirations involve specializing in software development with a focus on nuclear security. MSIPP has been instrumental in preparing me for this path by providing internships that offered hands-on experience directly related to my major. Additionally, I had the opportunity to attend conferences like the annual meeting of the Institute of Nuclear Materials Management, which was incredibly beneficial for my professional growth.

What Students Considering MSIPP Should Know

One of my most memorable experiences was visiting BNL with my cohort this past summer. This was the first time I visited a national laboratory. I was in awe of all the instruments and the scientific work that occurs there.

My advice to future students would be to stay curious and open-minded. Don't turn down opportunities just because they don't seem directly related to your major. You never know what doors these opportunities may open. I wasn't sure if the radiation safety technician program was right for me, but I gave it a try. The opportunities, connections, and supportive environment I've experienced since joining have been incredible and well worth it. Also, I would advise students to not just focus on completing a degree; ask questions, engage in research, participate in programs, and take advantage of any opportunities that come your way.

Jhaell Jimenez (jhaell.jimenez@unlv.edu) | **University of Nevada, Las Vegas**
Degree in Progress: PhD, Computer Science ✦ Advisor: Dr. Yoohwan Kim ✦ MSIPP: 2021 - 2023

Focus Area

Cybersecurity

Benefits of MSIPP

Skills and Knowledge

Through the Cyber Range/Labs project (August to December 2021), I gained deep insights into cybersecurity education. I learned that effective cybersecurity training goes far beyond traditional lectures or slideshows. It requires hands-on, practical experience in realistic environments.

My work with the MiniNDN project (January 2022 to January 2023) was essentially a crash course in becoming a technical specialist. I learned that mastering a specific technology requires a multi-faceted approach: diving deep into technical documentation, experimenting with hands-on implementations, and sometimes even dealing with frustrating debugging sessions. Working with Raspberry Pis and NDN protocols taught me the value of persistence in technical work.

Influence on Academic Goals and Career Path

Through MSIPP, I discovered that pursuing a PhD wasn't just a dream but an achievable goal, and now I'm truly thrilled to be part of the program. The experience also has sparked my interest in becoming an educator myself. I have countless examples of being inspired by mentors like Dr. Kim and Dr. Jo of the University of Nevada, Las Vegas (UNLV) who have been instrumental in my cybersecurity journey. Their guidance and support have shown me the profound impact that dedicated mentors can have on a student's growth, and I hope to provide that same level of mentorship to future students in cybersecurity.

After graduation, I'm considering two career paths that have been shaped by my MSIPP experience. My primary goal is to become either a professor at UNLV teaching cybersecurity to undergraduate and graduate students or to work full-time as a researcher at a national laboratory. My internship at the Sandia Center for Cyber Defenders during summer 2024 has reinforced my interest in national laboratory work, and I'm particularly interested in continuing with their team.

MSIPP has been instrumental in preparing me for either path I choose by providing research experience, teaching opportunities, and exposure to national laboratory operations. All of these experiences have given me the confidence and skills needed to pursue either academia or national laboratory research with the utmost confidence knowing that I can make meaningful contributions to the cybersecurity field.

Christopher Mason (christopher.mason@nsc.doe.gov) | University of Central Florida

Degree in Progress: PhD, Astrophysical Sciences ✦ **Advisor:** Dr. David Metcalf ✦ **MSIPP:** 2021 - 2023

Introduction to MSIPP

I heard about the MSIPP through Dr. Shonda Bernadin of the Advanced Sensor Technologies for Applications in Electrical Engineering – Research and Innovation Excellence (ASTERIX) group at Florida A&M University. I am grateful to MSIPP, Dr. David Metcalf, the University of Central Florida (UCF) Mixed Emerging Technology Integration Laboratory (METIL) team, along with Dr. Ashley Stowe and Dr. Mary Lin at Y-12 for providing me the opportunity to work and inspire others to pursue an engaging STEM-related career path.

Focus Area

My focus area for my internship involved bringing real-world tools and machinery into virtual and augmented reality so that our team could develop training on those virtual assets to eventually deploy to the workers at Y-12. My goal for the internship involved bolstering our knowledge around virtual production by using Unreal Engine and our Vive Pro Eye VR Headset along with our Vive tracking system to create a virtual production environment.

Benefits of MSIPP

MSIPP greatly affected my career trajectory and opened the door to the world of modeling and simulation jobs during my senior year at UCF. Working at a lab while getting my bachelor's degree in Game Design, helped me actively apply the skills I was learning in class into a real-world project.

I collaborated with the Y-12 National Security Complex, Knowledge Acquisition and Performance Studies (KAPS) Group under Mary Lin and the UCF METIL under David Metcalf. Currently, I work full-time as an Extended Reality (XR) Developer and three-dimensional (3D) Tech Artist at Y-12, and I hope to grow even more into my role here at KAPS under Mary Lin and Ashley Stowe. MSIPP gave me a taste of what my full-time job here at Y-12 would be, and the experience was invaluable.

What Students Considering MSIPP Should Know

Focus on what you can do and keep moving forward. In many different fields, being a student means it's expected of you to not know things or have experience. Ask questions, and don't be too afraid of failure. It's better to fail and learn how to better complete a task for the next time than it is to be too scared of failure to even open up or try.

My most memorable experience definitely came from working on the exciting demos at Y-12 and at UCF METIL. Being a part of a cutting-edge industry and getting a chance to preview the newest technologies before they become commercially released has really been memorable to me. Seeing the articles of what our teams have done across various websites is rewarding!

Lyra S. Troy (ltroy@lanl.gov) | University of Arizona

Degree: M.S., Chemical Engineering ✦ **Advisors:** Dr. Tommy Rockward ✦ **MSIPP:** 2022 -2024

Introduction to MSIPP

Tommy Rockward and Joseph Dumont from Los Alamos National Laboratory (LANL) visited the University of Arizona and presented a talk on student opportunities at LANL. I followed up and sent Tommy and Joseph an email expressing my interest in joining LANL for their fuel cell and hydrogen technologies research

Focus Area

I focused on proton exchange membrane (PEM) fuel cell component durability, namely membrane lifetime prediction and bipolar plate durability efforts. In addition, I was focused on fusion energy research and hydrogen storage technologies.

Benefits of MSIPP

Academic and Career Path Impact

MSIPP had a strong influence on my career. It encouraged me to continue pursuing cutting-edge hydrogen technologies, namely fuel cells and fusion energy. Through MSIPP, I found that I wanted to permanently dedicate myself to these fields of research. MSIPP achieved this by connecting me with leaders and projects in these research areas, and I was able to develop my technical skills through available expertise all around me. Tommy introduced me to and tasked me with cutting-edge General Motors projects. Joseph introduced me and tasked me with projects in fusion energy research. Once I had these opportunities in front of me, I became a helpful researcher and eventual leader in these areas. Without MSIPP, I would not have had these opportunities. No one in my graduating class had ever heard about LANL (this was before the Oppenheimer movie), nor is there much fuel cell or fusion research at my university.

STEM, Nuclear Security, or Related Fields

Coming from my university, I mostly wanted hands-on experience. Now, I went from wanting to try out a new experience in hydrogen fuel cells and fusion energy to becoming an on-the-rise leader in these fields, something I would have never anticipated during my M.S. at my university.

What Students Considering MSIPP Should Know

I encourage all future students to join national labs to help work on hydrogen energy. I believe we need our generation to become involved so that the experts from previous generations may pass down their knowledge before they leave. I would also encourage future students to take the leap to move states and try something new.

Minority Serving Institutions Internship Program

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

The Minority Serving Institutions Internship Program (MSIIP) develops the next generation of scientists and professionals to support the missions of the National Nuclear Security Administration (NNSA). MSIIP 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 (ORISE) and is managed by the NNSA Office of Management and Budget, Learning and Career Management (NA-MB-40).

On June 5, 2024, NNSA-MSIIP welcomed 151 students (10 Associate, 107 Bachelors, 22 Masters, 12 PhDs) to the Class of 2024-2025. Following the completion of the summer internship, 96 interns continued their projects for year-long appointments. The cohort included students from 50 minority serving institutions (MSIs), with 79% supporting projects at national laboratories, plants, and sites, while the others supported projects at Headquarters in Washington, DC (Figure 1).

Figure 1. MSIIP 2024-2025 cohort at the NNSA-MSIPP Orientation with Principal Deputy Administrator Corey Hinderstein, Associate Administrator and Chief for the Office of Defense Nuclear Security Lew Monroe, and Senior Advisor to the Office of Defense Programs Chuck Kosak.

For the Class of 2025-2026, MSIIP saw a significant increase in applicants from across the country, and from mentors within the NSE. Applications opened on August 1, 2024, and closed on October 27, 2024, attracting 551 eligible candidates—a 34% increase from the previous year. Approximately 200 interns will begin their appointments in June 2025, supporting 14 national laboratories and NNSA Headquarters and Field Offices. 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. They will develop technical and professional skills in real-world settings, receiving professional development, training, and one-on-one mentorship to guide them towards becoming experts in their fields.

NNSA-MSIIP remains a highly competitive program, attracting and retaining the nation's top talent. Learn more about the NNSA Minority Serving Institutions Internship Program at https://orise.orau.gov/NNSA-MSIIP/.

Fellowship Programs

Miriam Kreher (mkreher@lanl.gov) | Los Alamos National Laboratory, 2023 - Present
Degree: PhD, Nuclear Engineering ✦ CSGF: 2017 - 2021, Massachusetts Institute of Technology

From the Manhattan Project to the Human Genome Project, Los Alamos National Laboratory (LANL) has been famous for decades for technical advancement. The town, being so full of history, science, and nature, has been an absolutely wonderful place to land as an early career scientist. Throughout my time as a Computational Science Graduate Fellow, I completed several internships at LANL, each time seeing a new facet of the lab. First, I worked on criticality experiments, later on Monte Carlo code development, then in reactor analysis, and now, I am a Metropolis Postdoctoral Fellow in the nuclear data team. As someone whose PhD was focused on Monte Carlo methods, there is no greater honor than the namesake of Metropolis who, with Ulam, is credited for the invention of the Monte Carlo method.

My postdoctoral research has taken a turn from Monte Carlo methods to focus on multi-group methods. Whereas a Monte Carlo algorithm can sample neutron cross sections at any point along the energy grid, a multi-group method uses a number of bins along the energy grid in which to sample a constant cross section. Multi-group methods can be very accurate, if the bins are chosen wisely. My project has explored optimizations of these energy bins and different loss functions that could find improvements in the existing group structures.

I have been contributing to an additional project that seeks to analyze a new fission product yield evaluation. Fission products are all the elements that result from the initial fission of an actinide and the subsequent decay products of those fission products. This new evaluation is the first truly energy-dependent fission product yield evaluation, enabled by new measurements and advancements in theory modeling. Past efforts have used a coarse binning for incident neutron energy, and this new approach offers much richer information. As part of a validation effort for this new evaluation, I am using decay heat calculations to compare it against other evaluations and the decay heat standard. Figure 1 shows the performance of several evaluations against this standard.

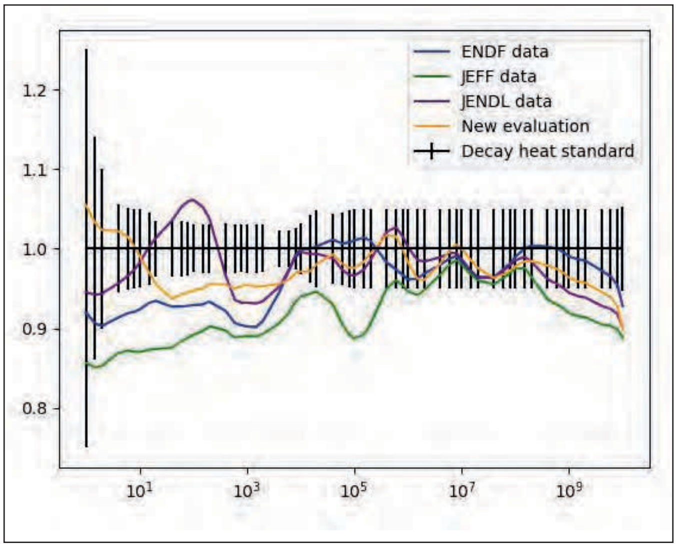


Figure 1. Comparing decay heat calculations using four different fission product yield evaluations to the decay heat stand for a single fission event on Pu-239. The x-axis shows time in seconds, and the y-axis is the ratio of the evaluation's results to the decay heat standard.

Figure 2. Volunteer appreciation event with Frances Chadwick, Laboratory Staff Director, Miriam Kreher, and Thomas Mason, Laboratory Director.

Besides neutronics simulations, my other passion is mentorship and educational outreach. Throughout graduate school, I stayed active in science outreach, teaching nuclear engineering topics to students as young as elementary school. My time at LANL has allowed me to continue pursuing this interest as the Chair of the Trinity Local Section of the American Nuclear Society. Through this organization, we perform science outreach activities at the Santa Fe Indian School, local Girl Scout and Boy Scout troops, and our regional science fairs. LANL values the positive impact their employees have on the surrounding community and recently honored the hundreds of volunteers across the lab who spend their personal time giving back. The photo in Figure 2 is from that event.

I greatly credit the Computational Science Graduate Fellowship for providing four years of excellent support and programing along with a life-long community of alumni that never cease to amaze me with their enthusiasm, passion, and scientific output. The freedom I experienced during my PhD allowed me to complete a number of side projects, many of which contributed to my thesis in some way, but that would have been difficult to pursue otherwise. I am thankful for the breadth of experience I've gained in the past 7 years which will be helpful throughout my career for understanding the collaborative opportunities throughout the national lab complex.

Elizabeth Benewitz (ebennew@umd.edu) | **University of Maryland, College Park**
Degree in Progress: PhD, Physics ✦ **Advisor:** Dr. Alexander V. Gorshkov ✦ **CSGF:** 2022 - Present

Research Topic

Simulating Many-Body Quantum Systems

Research Responsibilities

I utilize classical and quantum computational tools to study quantum systems in high energy and condensed matter physics. I am particularly interested in exploring quantum systems that can contribute to the development of quantum computers, as well as designing protocols that leverage quantum technology to reveal new properties and dynamics of quantum many-body systems. Just as classical computing offered scientists a new way of studying physical systems, quantum technologies provide an exciting new probe, hopefully leading to future discoveries.

Benefits of CSGF

The Computational Sciences Graduate Fellowship (CSGF) has allowed me to choose my research directions and experience different research settings, ultimately helping me take ownership of my research and grow my confidence. The freedom of having a fellowship has allowed me to carefully choose the specific types of projects I work on, adding to my sense of ownership over my work. Additionally, the practicum helped me recognize my strengths as a researcher. By leaving my home research setting, I saw how my skills and knowledge could be adapted effectively to a new project with new collaborators. This experience occurred as I transitioned from an early to a later-year graduate student. Combined with the freedom to choose my research directions, the CSGF has greatly contributed to my growth as a researcher.

What Students Considering CSGF Should Know

Doctoral degrees are long processes with many stages of personal and academic growth. Something I have grown to appreciate about the CSGF is the additional structure it provides to help guide and shape each fellow into a strong researcher and computational scientist. I am grateful that the CSGF program of study pushed me outside my academic comfort zone, because it allowed me to formalize my computer science knowledge, which I may not have done on my own. Additionally, through my practicum at Lawrence Berkeley National Laboratory (LBNL) and the CSGF fellow community, I have access to a network of researchers at national labs and in different fields of science. Exposure to these groups gives me a perspective on how my work fits into the larger scientific research landscape. Not only is this an amazing resource for graduate students, but it will be an amazing resource to take into the future when I am an early career researcher.

Alexander Johnson (ajohnson3@g.harvard.edu) | **Harvard University**
Degree in Progress: PhD, Physics, Cosmology ✦ **Advisor:** Dr. Daniel Eisenstein ✦ **CSGF:** 2022 - Present

Research Topic

Large Scale Structure of the Universe

Research Responsibilities

The large-scale structure of the universe (LSS), characterized by the spatial distribution of dark matter halos and the galaxies that form within them, provides a fundamental framework for understanding cosmic formation and evolution. My current research focuses on studying the LSS by creating large cosmological simulations with resolutions and volumes sufficient to bridge the gap between theoretical models and high precision observations. In my current project, we are introducing a concept called massless aggregation particles (MAPs) to generate realistic galaxy distributions in gravity-only dark matter simulations. In the real universe, galaxies form as baryonic matter falls into the gravitational potential wells of dark matter halos and undergoes hydrodynamic processes dominated by radiative cooling. Simulating these processes in full detail is computationally challenging for volumes large enough to match current observational datasets. MAPs address this challenge by approximating radiative cooling using in-elastic collisions. By allowing MAPs to in-elastically collide under a set of properly constructed phase-space criteria, they can approximate the effects of radiative cooling and generate distributions that correspond to observed galaxy populations. This approach offers a practical method for creating mock galaxy catalogs.

Benefits of CSGF

The CSGF has profoundly shaped my graduate experience by equipping me with advanced skills in computer science and applied mathematics, while also placing me in a network of researchers working at the intersection of science and high-performance computing. The fellowship has provided unique opportunities, such as conducting research at a national laboratory and attending annual supercomputing conferences, which have expanded my expertise and exposed me to cutting-edge developments in the field.

National Laboratory Experience

In the summer of 2023, I had the privilege of working at the Computational Cosmology Center at Lawrence Berkeley National Laboratory under Zarija Lukic. This experience broadened my expertise in computational cosmology and offered first-hand exposure to the national laboratory environment. During my time there, I developed a load-balancing algorithm for the Nyx cosmological code, a high-accuracy hydrodynamics code originally used to simulate the Lyman-alpha forest. The algorithm enabled Nyx to perform higher-resolution simulations without exhausting memory. This project deepened my understanding of hydrodynamics and computational challenges in cosmology while providing insight into the collaborative and innovative culture of Berkeley Lab—a place I would consider working long term.

Raspberry Simpson (simpson56@llnl.gov) | Lawrence Livermore National Laboratory, 2022 - Present
Degree: PhD, Plasma Physics ✦ LRGF: 2018 - 2022, Massachusetts Institute of Technology

I had the opportunity to join the Laboratory Residency Graduate Fellowship (LRGF) in 2018 with the first class of LRGF fellows. While I remember being so excited and almost in shock that I would have the chance to be a part of this prestigious fellowship, I didn't realize at the time how impactful this program would be to my career and to helping me create a network of people who have been important mentors, colleagues, and friends.

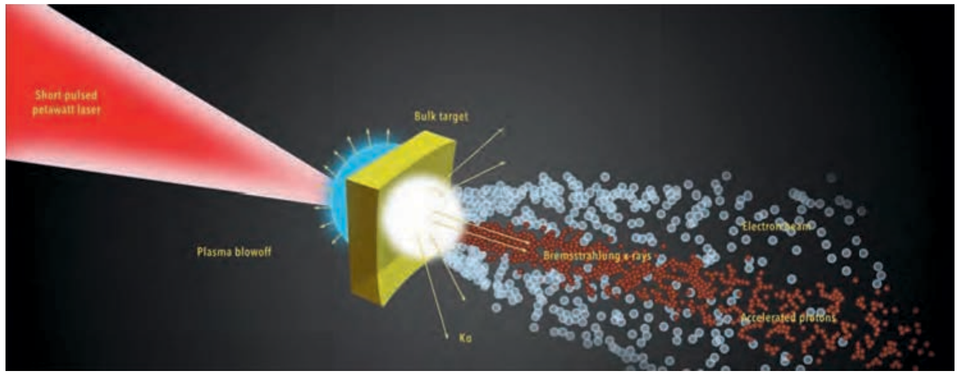


Figure 1. Illustration of the Target Normal Sheath Acceleration Process.

I'm currently a Lawrence Postdoctoral Fellow at Lawrence Livermore National Laboratory (LLNL), where I work in the Short Pulse Laser Science & Applications Team led by Dr. Matthew Hill, which is a part of the Advanced Photon Technologies Program. Working collaboratively with our team, I study the science of laser-driven particle acceleration and its applications to inertial fusion energy, high energy density physics, and stockpile stewardship. In this work, we use high-intensity lasers to irradiate thin solid foils which creates a plasma that contains very strong electric fields. These fields are strong enough to pull ions off the surface of the foil and accelerate them to high energies. This process is called Target Normal Sheath Acceleration (TNSA) (Figure 1) and was first explored at LLNL. The intensities of lasers used in this process typically exceed 10^{18} W/cm^2 or, in other words, a quintillion times the intensity of a typical laser pointer!

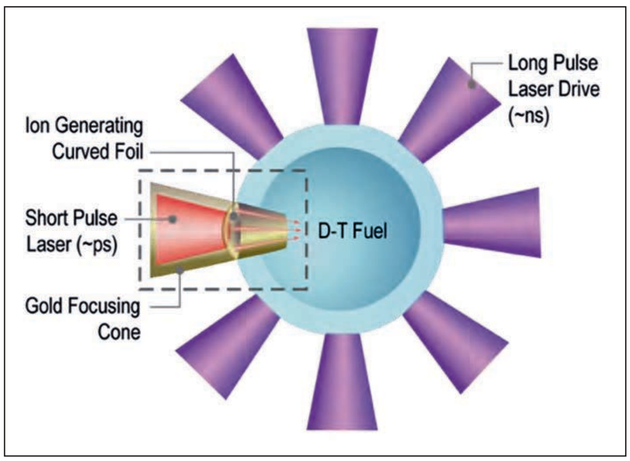


Figure 2. Illustration of the Ion Fast Ignition Process.

At LLNL, we're very lucky to have access to cutting-edge laser systems like the Jupiter Laser Facility (JLF) and National Ignition Facility (NIF) that enable us to study TNSA and other laser-plasma interactions in detail. In fact, my first LRGF laboratory residency was working on the Titan laser at the JLF studying laser-driven proton acceleration. I had never had any prior experience with hands-on experiments using high-intensity lasers, and I credit this first LRGF experience and my laboratory residency mentor, Dr. Tammy Ma, with setting me on this course for my future career in this field. During this first residency, having the opportunity to learn from experts in laser-plasma interactions in a collaborative, supportive, technically challenging, and fun environment was very impactful, since it allowed me the unique opportunity to gain the experimental and technical skills that I still use in my work today.

One of my current projects is studying the alternative inertial confinement fusion (ICF) scheme called ion fast ignition (IFI). IFI is one promising pathway to the high gain and high-repetition rate fusion concepts needed for a future inertial fusion energy scheme by potentially reducing driver energy and symmetry requirements compared with current central hot spot ignition schemes through separating the compression and heating phases in inertial confinement fusion. The fast ignition scheme was first invented by Max Tabak at LLNL. In IFI, a spherical capsule of deuterium-tritium fuel is compressed to high densities using a long-pulse (ns-scale) laser drive and then heated to fusion-relevant temperatures by short-pulse (ps-scale) generated ions. One prevailing IFI design (Figure 2) involves using a cone to direct the laser-driven ions into the core of the compressed fuel, where they are stopped by the dense fuel and couple energy. Understanding ion stopping and energy coupling in warm dense plasma is a key fundamental physics topic in high energy density physics more broadly.

Towards this goal, in my research, I've been leading experiments with our team to study how to efficiently focus laser-driven ions beams and the implosion dynamics of cone-in-shell fast ignition implosions. These experiments have been conducted at several laser facilities including the Orion laser facility at the Atomic Weapons Establishment in the United Kingdom and the OMEGA laser facilities at the Laboratory for Laser Energetics. Despite these laser systems existing in a different laser parameter space as Titan, I still use the foundational experimental skills developed during my first LRGF residency and subsequent LRGF residencies. I continue to be thankful to the LRGF program and the Krell Institute (who manages the LRGF program for the National Nuclear Security Administration (NNSA)) for allowing me the opportunity to build a community of scientists and program leaders and for demonstrating a path where I can contribute to the important missions of NNSA and NNSA laboratories.

Jazmin Ley (jley3@huskers.unl.edu) | **University of Nebraska-Lincoln**
Degree in Progress: PhD, Mechanical Engineering and Applied Mechanics ✦ **Advisor:** Dr. Joseph Turner ✦ **LRGF:** 2022 - Present

Research Topic

Resonant Ultrasound Spectroscopy of Hybrid Additive Manufacturing

Research Responsibilities

I am part of the Quantitative Ultrasonics for Inspection and Structural Prognosis (QUISP) Research Group at the University of Nebraska-Lincoln, which focuses on quantitative methods for ultrasonic inspection. Specifically, I focus on conducting experiments and finite element modeling of resonant ultrasound spectroscopy and traditional ultrasonic techniques of hybrid, additively-manufactured components. The hybrid process typically involves the addition of secondary energy sources or manufacturing processes to specific layers in metal, three-dimensional printing. My work aims to understand how the resonant modes and ultrasonic signals of hybrid components change based on the residual stresses added by the hybrid processes.

Benefits of LRGF

The obvious advantage of LRGF has been funding and research freedom. However, the most beneficial resource has been the colleagues and collaborators I've gained through my experiences at Los Alamos National Laboratory (LANL) and the LRGF program reviews. I have gained mentors and a support base for not only my research and education, but also for my professional development and my life. I have made long-lasting friendships and gained collaboration opportunities through the fellowship.

National Laboratory Experience

The opportunities gained from being part of LRGF are abundant and transformative. Perhaps the most invaluable aspect of the program is the opportunity to collaborate with some of the brightest minds in a specific field of work—engineers and scientists who have laid the foundation for an entire area of study. The residency experience is unequivocal. Whereas most fellowships merely offer you financial support, LRGF offers you a full journey that can lead you to success in a multitude of ways.

Engaging with individuals whose work has shaped my understanding and guided my research brings a new dimension to my academic journey. For example, without the LRGF program, I would never have delved into resonant ultrasound spectroscopy. My university lacks the necessary tools to perform experiments. With the aid of my mentor at LANL and my university advisor, I have collaborated with multiple universities, tapped into funding for testing on the High-Pressure-Preferred Orientation defractometer at the Los Alamos Neutron Science Center, and used high-performance computing to solve finite element models to understand nondestructive evaluation for hybrid additive manufacturing.

Christopher D. Roper (croper3@gatech.edu) | **Georgia Institute of Technology**
Degree in Progress: PhD, Physics ✦ **Advisor:** Dr. Feryal Özel ✦ **LRGF:** 2023 - Present

Research Topic

Wave Generation Using a Space-Based Accelerator System

Research Responsibilities

My research responsibilities focus on advancing accelerator technology and plasma interactions to address critical challenges in national security and space science. A central aspect of my work is contributing to the Beam Plasma Interaction Experiment (Beam-PIE), a groundbreaking National Aeronautics and Space Administration-sounding rocket experiment designed to investigate wave generation from modulated electron beams in space. This research focuses on developing cutting-edge solutions for mitigating possible threats posed by energetic electrons produced by high-altitude nuclear explosions or natural space weather phenomenon. My goal is to explore methods for radiation belt remediation by studying beam-plasma interactions and wave-particle dynamics harnessing plasma waves for targeted radiation mitigation. I supported modeling, simulation, and experimental design, which culminated in a demonstrated rocket launch in November 2023 in Fairbanks, Alaska. Building on this foundation, I now am leading efforts on Beam2PIE (Beam-PIE 2.0), focusing on the design of a new and improved accelerator technology, a modular anode electron gun to enhance wave generation efficiency to advance our understanding of beam-plasma interactions.

Benefits of LRGF

The Laboratory Residency Graduate Fellowship (LRGF) program has been instrumental in aligning my doctoral research with the Department of Energy's mission priorities. Through immersive residencies at Los Alamos National Laboratory (LANL), I have gained access to world-class resources and mentorship, allowing me to apply advanced computational and experimental techniques to high-impact projects. The program has fostered interdisciplinary collaboration and expanded my technical training immensely. Furthermore, the fellowship has provided opportunities to enhance both my professional growth and my ability to contribute meaningful solutions to national security challenges.

New Connections, New Opportunities

The LRGF program has been instrumental in facilitating collaborations that would not have been possible otherwise. Through my residency at LANL, I have had the privilege to work alongside experts from numerous disciplines, including accelerator physics, plasma diagnostics, computational modeling, and materials science. These interdisciplinary collaborations not only have advanced the scope and impact of my research but also have taught me the importance of effective teamwork and communication when addressing multifaceted scientific challenges. The program's emphasis on fostering connections between fellows, mentors, and laboratory researchers creates an invaluable ecosystem for idea exchange and innovation.

Erin Nissen (enissen@sandia.gov) | Sandia National Laboratories, 2021 - Present
Degree: PhD, Physical Chemistry ✦ SSGF: 2017 - 2021, University of Illinois at Urbana Champaign

I was a Stewardship Science Graduate Fellow from 2017-2021. During that time, I studied an explosive liquid, nitromethane, using a tabletop, laser-driven, flyer plate system under the guidance of Dr. Dana Dlott at the University of Illinois at Urbana Champaign. The tabletop system consisted of a high-power laser that was focused to a small (500-micron) diameter on a piece of aluminum glued to glass. The energy is absorbed at this interface and propels the small aluminum disk over a short distance until reaching a maximum velocity at which it impacts the sample and imparts a shock wave into the sample. I probed the shock-to-detonation evolution in nitromethane with velocimetry, pyrometry, and high-speed imaging of samples that were roughly 125 nanoliters in size. Since I was not a part of any national laboratory, the SSGF program was an invaluable experience for me. It exposed me to the enormous facilities and world-renowned capabilities at each of the individual labs and allowed me to conduct research at Sandia National Laboratories (Sandia) in Albuquerque under the supervision of Dr. Dan Dolan.

During my practicum, I was able to utilize some facilities at Sandia and gain knowledge in an area to which I would otherwise not have been exposed during graduate school. I conducted experiments on both a gas gun and a pulsed power machine called Thor. A gas gun compresses the sample by reverberating shock waves in between two windows of high impedance (Figure 1a); whereas Thor uses a tunable current pulse (80 kV) to generate a magnetic drive that continuously compresses a sample. These experiments allowed me to study how ramp rate and initial temperature affected the phase transition of dynamically-compressed liquid water into the ice VII phase region.[1] This collaboration helped me to secure a postdoctoral position in 2021 after finishing my dissertation, and a year later I was promoted to staff scientist at Sandia.

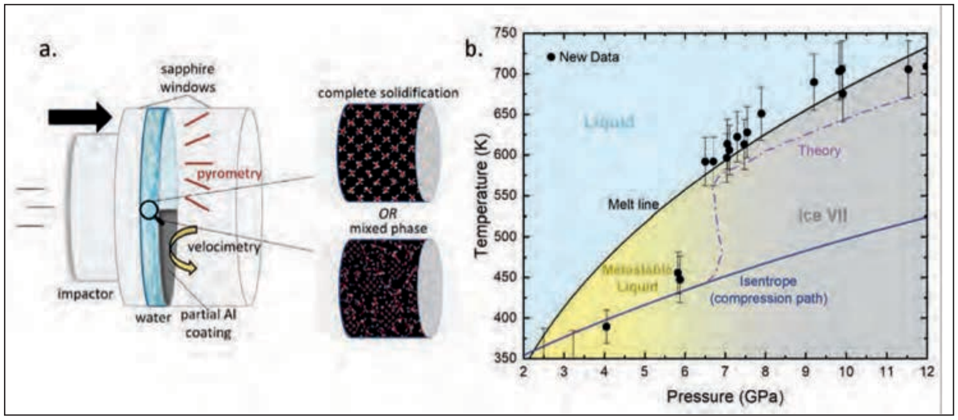


Figure 1.(a) Experimental schematic: the projectile impacts from the left-hand side imparting a shock wave into the sample containing a thin liquid layer. The shock wave reverberates between the optical windows, while the PDV and radiance are collected from the back side. (b) The phase diagram of water showing the meltline (black) between liquid water and ice VII. The compression path follows the calculated liquid isentrope (blue) until solidification at which theory (pink) predicts the latent heat to increase toward the meltline but stay within the ice VII phase region. Steady pressure temperature states (black circles) were extracted from recently published experiments.[2]

In my current position at Sandia, I use both techniques to study phase transitions in liquids and shock dissipation mechanisms in polymers. Figure 1 details a recent set of experiments in collaboration with the Special Technology Laboratory in Santa Barbara, where we successfully probed the temperature, for the first time, of dynamically-compressed water as it transitions to the solid phase. Photon Doppler velocimetry (PDV) probed pressure, while a mid-infrared pyrometer (specifically designed for this project) measured temperature. We found that when solidification happens there is a pullback in the pressure signal due to a volume collapse to the body-centered cubic phase of ice and a large increase in temperature from latent heating. However, instead of increasing in temperature and then remaining in the ice VII phase—as has been the longstanding theory—the temperature and pressure instead track along the meltline. This indicates the water must be in a mixed phase instead of completely solid.[2] To study the shock dissipation in polymers, I have been working with collaborators at Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and the Naval Air Warfare Center Weapons Division to both develop and print new materials and structures in those materials that are beneficial for dissipating a shock wave.[3]

References

[1]E.J. Nissen and D.H. Dolan, Temperature and rate effects in ramp-wave compression freezing of liquid water, J. Appl. Phys. 126, 015903 (2019).

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Isabel Hernandez (isabelhz@berkeley.edu) | **University of California, Berkeley**
Degree in Progress: PhD, Nuclear Engineering ✦ **Advisor:** Dr. Lee Bernstein ✦ **SSGF:** 2024 - Present

Research Topic

Precision β-Decay Measurements of Long-Lived Fission Products

Research Responsibilities

A precise database of the observables following fission is critical to the accurate attribution of nuclear events. The characteristic γ-rays emitted following the decay of cumulative fission products provide reliable and detectable signatures needed to better understand the environment in which fission occurred, provided that the intensity of these γ-rays and their attendant uncertainties are accurately known. Many long-lived fission products have large (5-35%) uncertainties associated with these intensities, which then propagate to valuable fission product yield measurements. My research is centered on reducing uncertainties in γ-ray intensities from the decay of fission products that span the "valley" and "wing" in thermal fission product yield curves, specifically along the A=111, 115, and 161 mass decay chains. My responsibilities involve experimentation at Argonne National Laboratory for fission fragment generation and collection, Texas A&M University for precision γ-β coincidence spectroscopy, and Lawrence Livermore National Laboratory to maintain and optimize a local detector array for continuing precision decay measurements.

Benefits of SSGF

The Stewardship Science Graduate Fellowship (SSGF) has granted me the ability to perform valuable research that I find interesting and impactful, notably in the context of the National Nuclear Security Administration's (NNSA) Stockpile Stewardship mission. Not only does the Krell Institute provide financial support through NNSA, it also consistently encourages collaboration between student fellows and established laboratory scientists. The SSGF allows me to be in a position where I can work directly with the scientists who developed the technology and techniques I am using in my post-experimental analysis. This has been invaluable to my technical and professional development. The opportunity to execute my dissertation research, which is integrally tied to constituents at Lawrence Livermore National Laboratory, would not be possible without the SSGF program.

What Students Considering SSGF Should Know

The unique opportunity to work in-person with established staff scientists at NNSA laboratories cannot be disregarded. The SSGF program is tuned to the needs of graduate students who not only want to understand, but also contribute to experimental and theoretical developments in their field of choice. The practicum/residency system has allowed me to do exactly this in the national laboratory environment. The program's design helped me to expand my technical skills and to understand how my research serves the needs of other applications not communicated in a traditional academic setting.

Lansing S. Horan, IV (lansing@mit.edu) | **Massachusetts Institute of Technology**
Degree in Progress: PhD, Nuclear Science and Engineering ✦ **Advisor:** Dr. Jack D. Hare ✦ **SSGF:** 2022 - Present

Research Topic

Radiatively-Cooled Magnetic Reconnection for Astrophysics

Research Responsibilities

My research is through the Magnetic Reconnection on Z (MARZ) collaboration with Sandia National Laboratories in New Mexico. MARZ is the laboratory study of magnetic reconnection, a fundamental energizing process in magnetized plasmas throughout the universe. My advisor and I conduct experiments on Sandia's Z Machine, the world's most powerful pulsed-power facility. The Z Machine drives millions of amps of electrical current through our two small metal targets in less than a microsecond, generating plasma flows moving at 10s-100s km/s, many times faster than a bullet. Both streams of plasma carry strong magnetic fields. Where these two flows collide, the field lines are anti-parallel, forming a reconnection layer. Here, the plasma is hot (hundreds of thousands of degrees) and dense (~10^{19} electrons per cm^3), resulting in intense X-ray emission. This makes MARZ relevant to extreme astrophysical environments where such radiative cooling is pervasive. Our efforts on MARZ span the full development cycle: designing the target, choosing plasma diagnostics, executing the shot, analyzing collected data, comparing to physics theory, and iterating and repeating. Thus far, my work has focused on a new shadowgraphy diagnostic, Laser Imaging On Z (LIONZ), which shines a laser beam through the reconnection layer to probe how its structure evolves with time.

Benefits of SSGF

The SSGF tightened the link between my current graduate research at MIT and my future prospective career at the national labs. Because I started my PhD with this fellowship funding, I had the opportunity to join the PUFFIN (PUlser For Fundamental INvestigations) research group. Working with Prof. Hare on his MARZ project has been a great match between my interests and the interests of NNSA. Without the SSGF, I may not have had the full opportunity to choose the right advisor and find the best-fit research topic.

What Students Considering SSGF Should Know

I spent a summer at Sandia to fulfill the research practicum required by the SSGF. There is no better way to see what it means to work at a national lab than to actually do it. This was a great experience, and a nice break from academia to work on a project outside my thesis. The SSGF network has given me numerous connections, both personal and professional, throughout the nuclear complex. I value this very much as I look towards a future research career at the national labs.

User Facilities

User Facility Summaries

Dynamic Integrated Compression Experimental Facility

The Dynamic Integrated Compression Experimental (DICE) facility at Sandia National Laboratories provides multiple platforms for materials property studies utilizing both gun-launched projectiles and pulsed power accelerators with pulse shaping abilities. Unique to DICE is the ability to perform not only shock, or isotropic, compression but also ramped, or isentropic, compression of materials. This allows direct comparison of sample response under different loading conditions. Primary diagnostics include laser-based velocimetry (PDV, VISAR) and high-speed videography. For more information visit https://www.sandia.gov/pulsed-power/research-facilities/dice/. Interested users may contact Scott Alexander (calexa@sandia.gov) for more information.

Dynamic Compression Sector

The DOE/NNSA-sponsored Dynamic Compression Sector (DCS) is a first-of-its-kind experimental capability dedicated to understanding the dynamic compression/deformation response of materials through real-time, multiscale measurements. Managed and operated by Washington State University and located at the Advanced Photon Source (APS) at Argonne National Laboratory, the DCS uniquely integrates state-of-the-art dynamic compression facilities and high energy, synchrotron X-ray capabilities to provide *in-situ* time-resolved, microscopic measurements under high stress impulsive loading. User experiments utilizing X-ray (diffraction, phase contrast imaging, absorption, and scattering) and continuum (laser interferometry) measurements are conducted in each of the experimental stations (Impact Facilities, Laser-Shock, and Special Purpose). Significant enhancements during the APS-Upgrade have resulted in a unique, world-leading experimental capability for the DCS to make measurements using X-ray energies to 70 plus keV. This ability to routinely obtain high energy X-ray measurements under dynamic compression will provide unprecedented opportunities for novel scientific studies. For more details, visit https://dcs-aps.wsu.edu or contact Dr. Paulo Rigg (dcs.admin@wsu.edu).

High Pressure Collaborative Access Team

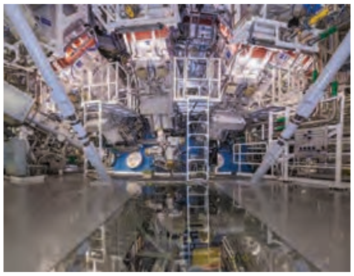
The NNSA-sponsored High Pressure Collaborative Access Team (HPCAT) at sector 16 of the Advanced Photon Source (APS), Argonne National Laboratory, is a synchrotron X-ray facility dedicated for experimental research on materials under extreme pressure-temperature (P-T) and strain rate conditions. The primary experimental focus at HPCAT is on research and development of synchrotron X-ray techniques and coupling these with diamond anvil cell and large volume press, P-T platforms. With four, simultaneously operational, experimental beamline stations, our users are provided X-ray experimental probes, covering an array of diffraction, imaging, and spectroscopy techniques. For more information, visit https://hpcat.aps.anl.gov/ or contact Nenad Velisavljevic (HPCAT-Director@anl.gov). The operational schedule at HPCAT, along with the host APS facility, is divided into three cycles per year – the calendar time-frame of each cycle and any updates can be found on the APS home website. For those interested in performing work at HPCAT the experimental time can be obtained via the General User Proposal (GUP) peer review system or internal partner time allocation request. If interested in GUP, additional information can be found at https://www.aps.anl.gov/Users-Information/About-Proposals/Proposal-Types/General-User-Proposals. For partners (including LLNL/ LANL/SNL and NNSA-SSAA PIs) please email HPCAT-Director@anl.gov to discuss dedicated beamtime allocation, experimental scope/requirements, etc.

Los Alamos Neutron Science Center

For more than 50 years, the Los Alamos Neutron Science Center (LANSCE) has provided the nuclear physics and materials science data needed to ensure the safety and surety of the nuclear stockpile. User time is available at the proton radiography (pRad) facility for dynamic radiography; the Lujan Center for neutron scattering, neutron radiography, and radiography nuclear physics; and the Weapons Neutron Research Facility for nuclear physics, neutron radiography, and electronics testing. In addition to national security research, LANSCE provides the scientific community with intense sources of neutrons and protons for experiments supporting the production of medical and research isotopes, neutron irradiation for industrial application, and research in fundamental physics.

Proposal call dates for the various LANSCE experimental areas vary, but they generally open in December/January and run through January/March. For more information, visit https://lansce.lanl.gov or contact lansce-user-office@lanl.gov.

National Ignition Facility



The National Ignition Facility (NIF) is the world's most energetic laser and is available for user experiments investigating the properties of high energy density matter. The NIF provides up to 2.05 MJ of laser energy to targets, with pulse durations that range from sub-ns to 10s of ns. The NIF main laser can be used in conjunction with the kJ-class, ps-pulse ARC laser. The NIF's 10-meter-diameter target chamber has multiple lines of sight for optical, X-ray, gamma and neutron, and charged-particle diagnostics. Proposals for user experiments are solicited several times each year. A call for proposals for Discovery Science users is issued annually. For details, visit https://lasers.llnl.gov/for-users/call-for-proposals and https://lasers.llnl.gov or contact Kevin Fournier, NIF User Office Director, nifuseroffice@llnl.gov.

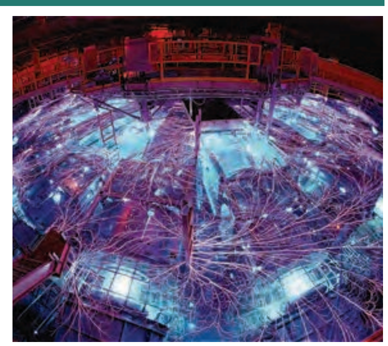
Omega Laser Facility

The Omega Laser Facility at the University of Rochester's Laboratory for Laser Energetics (LLE) includes the 60-beam OMEGA and the 4-beam high-energy, high-intensity OMEGA EP Laser Systems. The OMEGA EP short pulse beam (up to 2) or the tunable-wavelength long-pulse beam can also be transported to the OMEGA chamber for joint operations. The two lasers share over 100 facility-supported diagnostics and perform approximately 1800 highly diagnosed experiments annually. LLE staff work closely with the User Community via the Omega Laser Facility Users Group (OLUG) to improve and add new capabilities every year. Nearly one-third of the experiments at the Omega Laser Facility support basic high energy density science. Three programs provide general user access with beam time granted through a peer-reviewed proposal process (National Laser Users' Facility and Laboratory Basic Science (NBS) funded by NNSA, and LaserNetUS funded by DOE's Office of Fusion Energy Sciences). Application details are available on the LLE website for the NLUF and LBS programs, on the LaserNetUS website for additional beamtime on OMEGA EP. For more information, visit https://www.lle.rochester.edu/ or contact Dr. Mingsheng Wei, NLUF Manager, mingsheng@lle.rochester.edu

Shock Thermodynamic Applied Research

The Shock Thermodynamics Applied Research (STAR) Facility at Sandia National Laboratories is specifically designed, staffed, and used by professionals in the technical disciplines of High Temperature/High Pressure Condensed Matter Physics, Shock Physics, and Dynamic Material Properties. STAR houses a collection of five laboratory test launchers (guns) used for dynamic material property and ballistic impact studies. It is unique in the world in that the collection of launchers can achieve a wide range of sample pressure (bars to multi-Mbar) for material property study. The facility is also equipped to perform ballistics studies with a diverse range of projectile shapes, sizes, and materials. Primary diagnostics include laser-based velocimetry (PDV, VISAR), high-speed videography, and flash X-radiography. For more information visit https://www.sandia.gov/pulsed-power/research-facilities/star/. Interested users may contact Scott Alexander (calexa@sandia.gov) for more information.

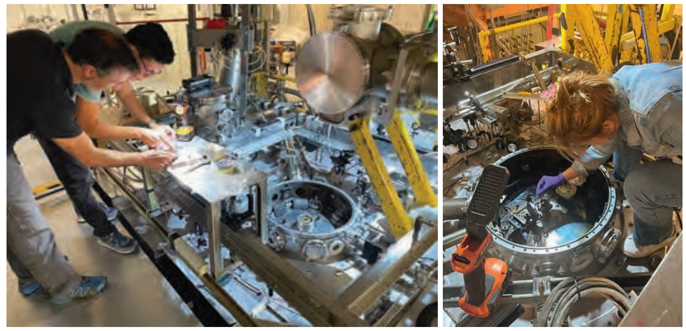
Z Pulsed Power Facility



The Z Pulsed Power Facility (Z) is a megajoule-class pulsed power accelerator and multifaceted experimental resource at Sandia National Laboratories that produces intense X-rays and magnetic fields useful for experiments in fundamental high energy density (HED) science. Approximately 10% of the Z shots allocated—around 14 shots/year— are designated for the Z Fundamental Science Program. These shots are competitively-awarded to academic, industrial, and national laboratory research interests through a yearly proposal process for state-of-the-art fundamental research in HED physics, including hydrodynamics, properties of materials under extreme conditions, laboratory astrophysics, advanced ignition concepts, fundamental HED physics, biology, and chemistry. The Call for Proposals is typically issued in mid-June and closes in mid-September. The Z Fundamental Science Workshop is held in early August. Award notifications are provided in mid-December for a two-year award period that begins the following July. For more information, visit https://www.sandia.gov/pulsed-power/ or contact Marcus Knudson, mdknuds@sandia.gov.

ZNetUS: The First Year of Experimental Campaigns | Author: Jens Schwarz, Sandia National Laboratories

The goal of the ZNetUS organization is to serve as the premier, community-driven entity in the United States dedicated to advancing pulsed magnetic science, technology, and high energy density physics for energy and national security applications. In 2024, ZNetUS successfully launched its first User Facilities program, awarding 11 research groups experimental time on pulsed power user facilities. This report briefly summarizes the experimental campaigns at each facility. For more informaiton, visit https://ZNetUS.org.



ZnetUS users preparing the ZEBRA pulsed-power generator for their experiments.

ZEBRA (University of Nevada, Reno)

Studying Magnetized Shock Physics with Inverse Wire Arrays on ZEBRA: This project used an inverse wire array of graphite rods on the ZEBRA pulsed-power generator to create a magnetized shock by directing a supersonic plasma flow against a conducting surface. The experiment utilized optical and proton probing to gather data that will enhance the understanding of magnetized shocks, which are significant in magneto-inertial fusion.

Principal Investigator
J. Davies, University of Rochester

Probing the Conditions of Electromagnetically-driven Flyer Plates on ZEBRA with X-ray Diagnostics: The research focused on launching flyer plates on the ZEBRA pulsed-power generator and conducting optical diagnostics and X-ray backlighting. This study provided new data on the fundamental physics of flyer plates and validated numerical codes by examining the effects of plasma ablation on the flyer.

Principal Investigators
S.C. Bott-Suzuki, University of California, San Diego and F. Suzuki-Vidal, First Light Fusion, UK

ZEBRA Experiments to Study the Stability of Liner-on-target Gas-puff Z-pinches and Validate the FLASH Code: This campaign investigated the stability of gas-puff Z-pinches at ZEBRA, utilizing the facility's diagnostics to analyze implosion dynamics and growth rates. The collected data will be used to validate the FLASH code's two-dimensional modeling of these experiments.

Research Team
Oren Yang, University of California, San Diego, and Petros Tzeferacos, University of Rochester

Imaging of Ti X-Pinch Plasmas with High-Resolution X-ray Crystal Spectrometers: The experiment aims to utilize Ti X-pinch loads at the ZEBRA pulsed power generator, diagnosed with high-resolution crystal spectrometers to observe Ti K-shell X-ray emissions. This research will enhance the understanding of hot, dense plasmas by combining high spectral resolution with one-dimensional imaging techniques.

Principal Investigators
P. Efthimion and F. Kraus, Princeton University

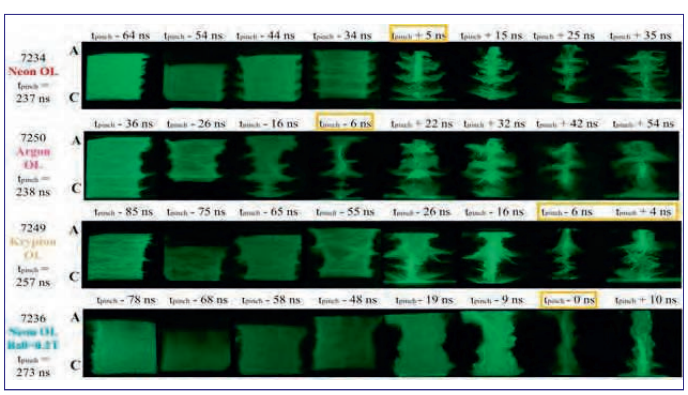
Experimental and Simulation Studies of MagLIF and Laboratory Astrophysics Dynamics through High-resolution, Phase-contrast Diagnostics: This experiment will establish a diagnostic platform for characterizing laboratory astrophysics and magnetized liner inertial fusion (MagLIF) plasmas with high spatial resolution using a Talbot-Lau X-ray phase contrast system on ZEBRA. The experiment involves testing different backlit sources to enhance the imaging capabilities of the ZEBRA facility, including coupling shots with the Leopard laser.

Principal Investigator
Maria Pia Valdivia, University of California, San Diego

COBRA (Cornell University)

Experiments on the COBRA Generator

Experiments conducted on the COBRA generator aimed to investigate the implosion dynamics and Magneto Rayleigh Taylor Instability (MRTI) growth using various gases in the liners and a xenon-doped H2 target, both with and without a magnetic field. Plasma dynamics were analyzed using multiple diagnostic tools, including extreme ultraviolet (XUV) framing cameras, soft X-ray photodiodes, a Mach-Zehnder interferometer, a Thomson scattering laser, and a short-mica crystal X-ray spectrometer. In the absence of a magnetic field, different gases in the outer liners were employed to mitigate MRTI growth, with the outer liner merging with the inner liner slowing the instability's growth rate. The experiments revealed that neon outer liners exhibited longer pinch times and slower MRTI growth, whereas argon outer liners were the most unstable, failing to collimate effectively. In contrast, the magnetized case with neon outer liners demonstrated improved stability, characterized by the smallest instability amplitude among the configurations tested.



XUV images showing evolution of pinch of triple gas puff Z-pinch. .

Reasearch Team
Kimberly Inzunza, Oren Yang, Robert Beattie-Rossberg, and Farhat Beg, University of California San Diego and Dalton Lund, Cornell University

Supersonic, Magnetized Plasma Flows

In July 2024, a group from the Massachusetts Institute of Technology, led by graduate student Rishabh Datta conducted two weeks of experiments on the COBRA facility at Cornell. These experiments used the supersonic, magnetized plasma flows from an exploding wire array to study oblique shocks.

Principal Investigator
Jack Hare
Massachusetts Institute of Technology

Quantitative Examination of Radiative Pre-heat in High-Mach-number Shocks

The UCSD project aimed to examine the interaction of shocks around closely-spaced targets in high Mach number plasma outflows. This is motivated by astrophysical observations of luminous structures in complex shock systems, which may be a result of Mach stem formation. Imaging and Thomson scattering data from COBRA experiments show shock interaction varies with shock target spacing and that a quantitative study of such features is feasible.

Principal Investigator
Simon Bott-Suzuki
University of California, San Diego

Emily Neill and Rishabh Datta loading wires for their experiment on COBRA.

Long-time lab employee Harry Wilhelm, lead technician,checks the alignment of o-rings as he reassembles one of COBRA's self-break main switches.

CESZAR (University of California, San Diego)

The California Institute of Technology (CalTech) team led by graduate student Joshua Moran used a two-dimensional X-ray camera capable of imaging high energy photons (> 5 keV) on the CESZAR generator. The multiframe system has an interframe time of 18 ns. This unique capability facilitated observation of hard X-ray emitting regions in a variety of gas puff configurations. This diagnostic will help to understand the role of electron beam energy deposition in gas puff Z-pinches.

Principal Investigator
Paul Bellan
California Institute of Technology

Robert Beattie-Rossberg, a PhD student at the University of California, San Diego, tweaking the Schlieren diagnostic.

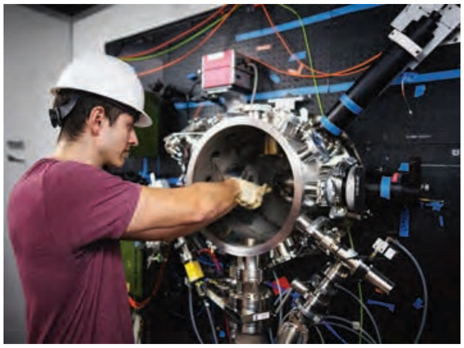
The image shows CESZAR, a 1 megaampere Linear Transformer Driver in the background with laser beam paths for a multi-channel interferometry system in the foreground.

Mykonos (Sandia National Laboratories)

Dielectric Coatings for the Mitigation of Electrode Plasma Formation: The ZNetUS campaign on Mykonos aimed to characterize the effects of parylene-N coatings of thicknesses 1, 5, 10, 20, and 50 μm on 200-μm SAE 304 stainless steel planar magnetically insulated transmission line (MITL) targets for the mitigation of neutral contaminant desorption into anode-cathode gaps. Vacuum ultraviolet (VUV) spectroscopy showed lower density and temperature molecular hydrogen in the gap before plasma breakdown. From one-dimensional gated visible spectroscopy and iCCD imaging, once plasma formed, the parylene-N coating began to ablate and move into the gap adding more plasma in the gap compared to uncoated foils.

Principal Investigators
Trevor Smith and Ryan McBride
University of Michigan

Mykonos Pulsed Power Facility



Ian Kern loading a target into the Mykonos target chamber.

Funded Grants and Cooperative Agreements

Fellowships

Krell Institute
Computational Science Graduate Fellowship
Laboratory Residency Graduate Fellowship
Stewardship Science Graduate Fellowship

High Energy Density Laboratory Plasmas

Cornell University
David Hammer
X-ray Spectroscopic Studies of Radiative Collapse in X-Pinch Plasmas

Cornell University
Gennady Shvets
Super-Ponderomotive Effects in Ultra-Intense Laser-Plasma Interactions: Towards Novel X-ray and Current Sources

Georgia Tech Research Corporation
Phanish Suryanarayana
Density Functional Theory at Extreme Conditions—Warm Dense Matter from First Principles

Massachusetts Institute of Technology
Johan Frenje
Development of New Advanced X-ray and γ-ray Diagnostics for Inertial-Confinement-Fusion and Discovery-Science Programs at OMEGA and the NIF

Massachusetts Institute of Technology
Chikang Li
Study of Magnetized, High-Energy-Density Hydrodynamics at OMEGA

Princeton University
Nathaniel Fisch
Fundamental Issues in the Interaction of Intense Lasers with Plasma

Princeton University
Amitava Bhattacharjee
Particle Heating by High-Mach-Number Collisionless Shocks in Magnetized Laboratory Plasmas

Princeton University
William Fox
Magnetic Reconnection in High-Energy-Density Plasmas

Stanford University
Matthew Edwards
High-Power Photonics Using Adaptively Controlled Plasmas as Diffractive Optical Elements

The Ohio State University
Douglass Schumacher
Novel Plasma Optics for Relativistic Plasma Physics and New Experiments using Novel Polarization

University of California, Los Angeles
Warren Mori
Controlling the Nonlinear Optics of Plasmas Using Spatially and Temporally Structured Light

University of California, San Diego
Maria Pia Valdivia Leiva
Development of Talbot-Lau Phase-Contrast X-ray Diagnostics for High Energy Density Laboratory Plasmas

University of California, San Diego
Mathieu Bailly-Grandvaux
Driving Plasmas to Extreme Magnetizations using Strong Laser Compression and High Initial Magnetic Field

University of California, San Diego
Farhat Beg
Magnetic Field Distribution in Multi Liner Gas Puff Z-pinches Using 700 kA Linear Transformer Driver

University of Michigan
Louise Willingale
Direct Laser Acceleration of Electrons for Bright, Directional Radiation Sources

University of Nevada, Reno
Alla Safronova
Understanding Atomic Properties in HED Plasmas by Studying Line and Continuum Emission from High Z Ions

University of Nevada, Reno
Bruno Bauer
Exploring the Connection of Magnetohydrodynamic Instabilities to Earlier Electrothermal Instability from Controlled Surface Perturbations on Metal Driven by Intense Current

University of Nevada, Reno
Thomas White
Electron-Ion Equilibration in Dense and Quantum Plasmas

University of New Mexico
Mark Gilmore
Exploring the Connection of Magnetohydrodynamic Instabilities to Earlier Electrothermal Instability from Controlled Surface Perturbations on Metal Driven by Intense Current

University of Rochester
Jessica Shang
Probing Transport Mechanisms in HED Flows

The University of Texas at Austin
Sandra Bruce
Observing Quantum Effects in Hole-Boring and Photon Jet Production in Petawatt Laser-Solid Target Interaction

Minority Serving Institutions Partnership Program

Advanced Sensors Technologies for Applications in Electrical Engineering – Research and Innovation Excellence Consortium (ASTERIX)
Florida International University, Lead Recipient
Shekhar Bhansali

Advanced Synergistic Program for Indigenous Research in Engineering (ASPIRE)
Turtle Mountain Community College, Lead Recipient
Austin Allard

Application of Artificial Intelligence to Cybersecurity for Protecting National Critical Infrastructure (CONCISE)
University of Texas at San Antonio, Lead Recipient
Guen Chen

Attract, Educate, Train, and Retain Native American and Minority Students in Nuclear & Related Sciences (AETRNAMS)
Nueta Hidatsa Sahnish College, Lead Recipient
Kerry Hartman

Consortium of Advanced Additive Manufacturing Research and Education for Energy Related Systems (CA2REERs)
The University of Texas – Rio Grande Valley, Lead Recipient
Jianzhi (James) Li

Consortium enabling In- and Ex-Situ-Quality Control of Additive Manufacturing (QCAM)
New Mexico State University, Lead Recipient
Borys Drach

Consortium for High Energy Density Science 2.0 (CfHEDS-2)
Florida A&M University, Lead Recipient
Charles Weatherford

Consortium for Laser-based Analysis of Nuclear and Environmental Materials (LANEM)
Florida A&M University, Lead Recipient
Lewis Johnson

Consortium for Research and Education in Materials Science and Photonics Engineering (NoVel)
Norfolk State University, Lead Recipient
Mikhail A. Noginov

Consortium for Research And Education in Power and Energy Systems (CREPES)
Florida International University, Lead Recipient
Sumit Paudyal

Consortium for Nuclear Security Advanced Manufacturing Enhanced by Machine Learning (NSAM-ML-2)
Elizabeth City State University, Lead Recipient
Abdennaceur Karoui

Consortium Hybrid Resilient Energy Systems (CHRES)
Universidad Ana G. Méndez-Gurabo, Lead Recipient
Amaury Malavé

Consortium on Nuclear Security Technologies (CONNECT 2.0)
University of Texas at San Antonio, Lead Recipient
Elizabeth Sooby

Consortium on Sensing, Energy-Efficient Electronics and Photonics with 2D Materials and Integrated Systems for Training the Next-Generation DOE-NNSA STEM Workforce (SEEP-IT)
University of North Texas, Lead Recipient
Anupama Kaul

Consortium for Education and Research in Electronics for Extreme Environments (E3C)
University of Texas at El Paso, Lead Recipient
Miguel Velez-Reyes

Consortium for Research and Education in Cyber Manufacturing (CMA-MNuR)
Florida International University, Lead Recipient
Ibrahim Tansel

Developing Next Generation Radiation Safety Professionals (DNGRSP)
Queensborough Community College
Sharon Lall-Ramnarine

Enabling Native Researchers and Graduate Engineering (ENRGE)
Navajo Technical University, Lead Recipient
Peter Romine

Enhancing the National Security Enterprise Workforce Pipeline (ENSEWP)
Augusta Technical College
John Tucciarone

Growing STEMs Consortium: Training the Next Generation of Engineers for the DOE/NNSA Workforce (GSC)
Texas Tech University, Lead Recipient
Michelle Pantoya

Integrated Additive Manufacturing – Establishing Minority Pathways: Opportunities for Workforce-development in Energy Research and Education (IAM-EMPOWEREd)
Florida A&M University, Lead Recipient
Charles Weatherford

Indigenous Mutual Partnership to Advance Cybersecurity Technology (IMPACT)
Turtle Mountain Community College, Lead Recipient
Chad Davis

Microelectronics & Materials Engineering Education for Nuclear and Cyber Security (MEMENCYS)
University of California, Riverside, Lead Recipient
Shane Cybart

MSIPP Gulf Coast A&M Consortium: Materials-at-the-Extreme (MATE) – Material Science for Extreme Environments
Florida A&M University, Lead Recipient
Charles Weatherford

Native Education Excellence in Trades (NEXT)
Turtle Mountain Community College
Sheila Trottier

Nevada National Security Site (NNSS) FastStart Program (FastStart)
The College of Southern Nevada
Margaret Taylor

Nuclear Security Science and Technology Consortium (NSSTC)
University of Nevada, Las Vegas, Lead Recipient
Alexander Barzilov

Partnership and Training for NNSA Engineering and Relevant Sciences (PARTNERS)
University of Central Florida, Lead Recipient
Subith Vasu

Partnership for Advanced Manufacturing Education and Research (PAMER)
Navajo Technical University, Lead Recipient
Olanrewaju Johnson

Partnership for Radiation Studies (PaRS)
Alabama A&M University, Lead Recipient
Stephen Babalola

Partnership for Research and Education Consortium in Ceramics and Polymers 2.0 (PRE-CCAP-2)
University of Texas at El Paso, Lead Recipient
Jack Chessa

QUantum Integrated Cyber Knowledge Simulation, Training, Advantage Research, and Technology (QUICKSTART)
University of Central Florida, Lead Recipient
David Mecalf

The Rio Grande Consortium for Advanced Research on Exascale Simulation (Grande CARES)
University of New Mexico, Lead Recipient
Peter Vorobieff

Rapid Education and Placement (REAP)
Las Positas College
Jennifer Decker

Scholarly Partnership in Nuclear Engineering (SPINE)
Morgan State University, Lead Recipient
Stephen Egarievwe

Scholarly Partnership in Nuclear Security (SPINS)
Alabama A&M University, Lead Recipient
Mebougna Drabo

Tri-State Consortium for Resilient Automation and Cybersecurity System (TRACS)
North Carolina A&T State University, Lead Recipient
Sun Yi

Predictive Science Academic Alliance Program III

Massachusetts Institute of Technology
Youssef Marzouk
Center for the Exascale Simulation of Material Interfaces in Extreme Environments

Oregon State University
Todd Palmer
Center for Exascale Monte Carlo Neutron Transport

Stanford University
Gianluca Iaccarino
Integrated Simulations Using Exascale Multiphysics Ensembles

University of Buffalo
Paul DesJardin
Center for Exascale Simulation of Hybrid Rocket Motors

University of Colorado
Richard Regueiro
Center for Micromorphic Multiphysics Porous and Particulate Materials Simulations with Exascale Computing Workflows

University of Illinois
Jonathan Freund
Center for Exascale-Enabled Scramjet Design

University of Maryland
Johan Larsson
Solution-Verification, Grid-Adaption and Uncertainty Quantification for Chaotic Turbulent Flow Problems

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

University of Texas
Robert Moser
Exascale Predictive Simulation of Inductively Coupled Plasma Torches

Stewardship Science Academic Alliances

High Energy Density Physics

Massachusetts Institute of Technology
Chikang Li
Center for Advanced Nuclear Diagnostics and Platforms for ICF and HED Physics at OMEGA, NIF, and Z

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Hydrodynamics, Instabilities, and Hypersonics

Georgia Institute of Technology
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Detailed Measurements of Turbulent Rayleigh-Taylor and Richtmyer-Meshkov Mixing at Extreme Conditions

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Jeffrey Jacobs
An Experimental Study of Rayleigh-Taylor and Richtmyer-Meshkov Instabilities at Large Reynolds Numbers

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Computational Modeling of Hypersonic Flow and Material Response in a Free-jet Test Facility

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S. Balachandar
Understanding Hydrodynamic Instabilities of Explosively-Driven Multiphase Fronts for Accurate Prediction of Their Complex Structures

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Radiation Transport in Strongly Coupled Plasmas

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Experimental Investigation of the Richtmyer-Meshkov Instability Coupled with a Chemical Reaction

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Measurements of Prompt Neutron Differential Multiplicity in Photofission of ^{235}U, ^{238}U and ^{239}Pu

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Measurement and Analysis of Selected Neutron-induced Fission Product Yields for ^{235}U, ^{238}U and ^{239}Pu

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Sean Liddick
Neutron Capture Cross Section Measurements on Short-Lived Isotopes

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Witold Nazarewicz
Microscopic Description of the Fission Process

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Carl Brune
Nuclear Reactions and Scattering

Ohio University
Alexander Voinov
Statistical Nuclear Physics and (a,n) Reactions for Applications

Rutgers University
Jolie Cizewski
Nuclear Reaction Studies with Rare Isotope Beams for Stewardship Science

San Diego State University
Kenneth Nollett
Scattering and Direct Reactions in a Shell Model Framework

Texas A&M University
Sherry Yennello
CENTAUR: Nuclear Science in Service to the Nation

University of California, Berkeley
Lee Bernstein
Correlated Neutron-Gamma Data for Stewardship Science

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Anna Simon-Robertson
Constraining Neutron-Capture Cross Sections via Direct and Indirect Experimental Methods

University of Tennessee, Knoxville
Robert Gryzwacz
Beta-Delayed Neutron Spectroscopy of Exotic Nuclei

Properties of Materials under Extreme Conditions and Energetic Environments

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Sally Tracy
Dynamic Compression of Iron Carbide at Exoplanetary Core Conditions

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Amy Clarke
Advanced Characterization of Metals under Extreme Environments

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Baosheng Li
Thermodynamic and Mechanical Properties of SSP Materials from Simultaneous Ultrasonic and X-ray Studies at High Pressure and Temperature

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Novel d- & f- Electron Materials Under Extreme Conditions of Pressure, Temperature, and Magnetic Field

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Chicago/DOE Alliance Center – A Center of Excellence for High Pressure Science and Technology

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Pamela Burnley
Deformation of Polycrystalline Materials under Extreme Conditions: Stress Percolation, Shear Localization and Grain Boundary Rheology

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Real-time Monitoring of Chemical Reactions at Subsurface Locations in Optically Opaque and Highly Scattering Samples

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Virtual-Slit Cycloidal Mass Spectrometer for Portable Rapid Ultra-Trace Isotope Ratio Analysis of Actinides

Georgia Institute of Technology
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Transuranic Chemistry Center of Excellence

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Ani Aprahamian
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Washington University in St. Louis
Rita Parai
Seeing Through the Fission Phase 2: Multi-Modal Analysis of Actinides and Noble Gas Isotopes in Geological Samples

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