National Nuclear Security Administration

Stewardship Science Today

Office of Research, Development, Test, and Evaluation (RDT&E)

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Stewardship Science Today (SST) highlights the stewardship science and academic programs supported by the Department of Energy/National Nuclear Security Administration (DOE/NNSA). It is published quarterly by the NNSA Office of Research, Development, Test, and Evaluation. Questions and comments regarding this publication should be directed to Terri Stone via email at terri.stone@nnsa.doe.gov.

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Calendar

4/24-26
Omega Laser Facility Users Group (OLUG) Workshop, Rochester, NY

6/5-7
2019 General/Working Meeting for the International Agreement on Fundamental Science, Bordeaux, France (includes the NNSA/CEA postdoctoral exchange program)

6/25-27
SSGF/LRGF Annual Symposium, Capitol Hilton, Washington, DC

Inside

*Contractor Support

Welcome to the inaugural issue of the *Stewardship Science Today* (SST) newsletter which replaces the *Stockpile Stewardship Quarterly*. The SST will present science-based stockpile stewardship efforts with an emphasis on academic partnership programs and cutting-edge research being conducted by National Nuclear Security Administration (NNSA) national laboratory professionals, academicians, postdoctoral researchers, and students. The first article in this issue showcases the development, by scientists at the University of Rochester, of an advanced diagnostic known as x-ray particle image velocimetry (xPIV). xPIV will provide information on the fluid mechanics of flowing plasmas, addressing the fundamental physics of turbulent flow. Developments such as this are expected to provide informative data for high energy density (HED) physics experiments, leading to new insights. The second article features a collaborative effort to gather and evaluate fundamental nuclear data and to make the data available to end users, including various programs within the Department of Energy (DOE). As part of this collaboration, current efforts are underway to produce new evaluations of fission product yield data, which are fundamental data on which many nuclear programs depend. As can be expected, both of these efforts involve solid collaborations reaching beyond NNSA RDT&E (e.g., DOE Office of Science, other NNSA organizations, etc.). Once again, the annual Stewardship Science Academic Program Symposium was a great success. Details about the 2019 symposium and a recognition of the poster session award winners can be found inside. I'd like to take this opportunity to thank all of those who make this event exceptional and to congratulate all of the students on their hard work. We wish you every success.

Dr. Kathleen B. Alexander
Assistant Deputy Administrator
for Research, Development Test, and Administration

Friends and Former LANL Postdocs Reunite at the 2019 SSAP Symposium

Left to right: Nenad Velisavljevic, Devesh Ranjan, and Michael Demkowicz

Nenad Velisavljevic, Devesh Ranjan, and Michael Demkowicz met as postdoctoral researchers at Los Alamos National Laboratory (LANL) in 2006 and were the original members of the group that established the Los Alamos Postdoc Association (LAPA). At the recent 2019 Stewardship Science Academic Programs (SSAP) Symposium, the trio had time to catch up but also used the opportunity to discuss future collaborations that are vital in helping strengthen the effort between the national laboratories, NNSA university partners, and NNSA-funded external experimental facilities, such as the High Pressure Collaborative Access Team (HPCAT).

Nenad Velisavljevic is now a staff member at Lawrence Livermore National Laboratory and Director for the NNSA-funded HPCAT facility at the Advanced Photon Source at Argonne National Laboratory.

Devesh Ranjan is the Associate Chair for Research and an Associate Professor at the George W. Woodruff School of Mechanical Engineering at Georgia Institute of Technology and the Principal Investigator (PI) for NNSA Stewardship Science Academic Alliances (SSAA) grant "Measurements of Turbulent Rayleigh-Taylor Mixing at Large Atwood Numbers."

Michael Demkowicz is Associate Professor and Graduate Program Director in the Materials Science and Engineering Department at Texas A&M University and the PI for NNSA SSAA grant "Center for Research Excellence on Dynamically Deformed Solids." ◆

The Probing of High-Energy Density Flows with X-Ray Particle Image Velocimetry

by J.K. Shang (UR[1]), H. Aluie (UR[1]), J.R. Rygg (UR[1,2,3]), R. Betti (UR[1,2,3]), A.E. Gleason (Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory), D.N. Polsin (UR[3]), D.H. Kelley (UR[1]), and G.W. Collins (UR[1,2,3])*

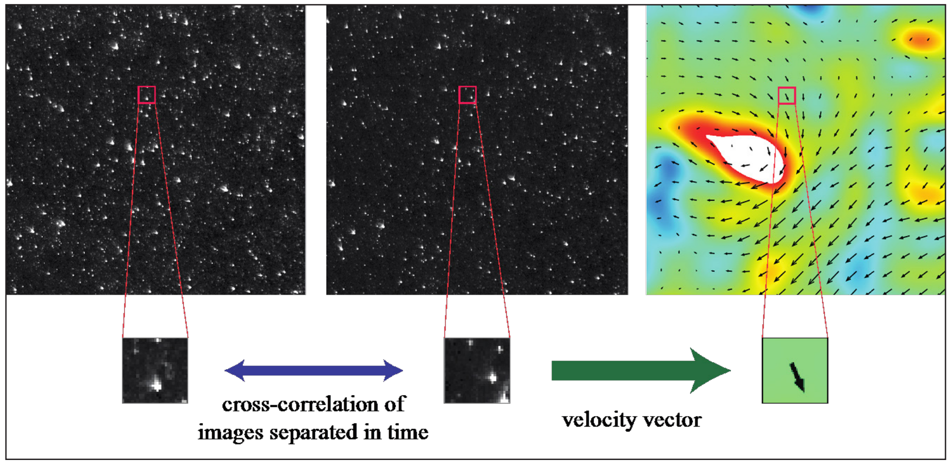

Figure 1. Images obtained with optical PIV, taken a short time apart (left, middle), can be subdivided into smaller images and cross-correlated to yield a velocity vector field from which quantities such as vorticity can be calculated (right).

The description of complex, high-energy density (HED) flows, including instabilities, nonlinear evolution, and turbulence, has broad connections to stockpile stewardship and to scientific disciplines ranging from astrophysics to planetary and fusion sciences. Many unsolved problems in the fundamental physics of fluids and plasmas are related to the properties of turbulence and the complex manner in which it couples the large-scale "bulk" flow with the microphysics via the cascade process. Whereas HED science has directed computational initiatives for some time, multi-physics models are limited in their ability to predict experimental observations. These discrepancies may be partially attributable to missing models for physical processes such as microscopic kinetic effects, small-scale hydrodynamic instabilities, and turbulence that occur at scales smaller than hundreds of microns.

If the discrepancy is at the small scales, validation of the models against detailed, quantitative flow measurements is critical. However, flow characterization has been macroscopic and global in nature, such as growth rates of Rayleigh-Taylor instabilities, and local velocity measurements are lacking. To address this problem, our team from the University of Rochester, the Laboratory for Laser Energetics, and the SLAC National Accelerator Laboratory looks towards a parallel diagnostic development in engineering fluid dynamics. Particle image velocimetry (PIV) revolutionized the field beginning in the late 1980s by measuring the displacement of small, brightly illuminated tracer particles that follow local streamlines. Whereas flow measurement methods previously were restricted to point-wise measurements with probes, PIV permitted a minimally invasive, quantitative visualization of the velocity field (see Figure 1). The global velocity field allows calculations of vorticity, strain rates, and Reynolds stresses but also gives instantaneous flow structure which provides insight into the evolution of a flow. Its applicability extends from small-scale, slow-speed flows, as you might find in lab-on-a-chip devices, to supersonic gas-dynamics. With advances in high-speed imaging and laser technology, PIV has enabled highly resolved measurements of 3D velocity components used to benchmark computational models.

At the most fundamental level, the facilities for experiments of extreme HED flows have the components to execute x-ray PIV (XPIV) in optically opaque, seeded materials: a dynamic compression driver to induce flow, an x-ray illumination source, and imagers. Whereas XPIV has been used in other environments (e.g., cavitation, biophysics), we see an opportunity to develop the working principles for XPIV in parallel with our objective to measure velocity in extreme flows. After all, confidence in the accuracy of PIV was built after years of parallel experimentation, diagnostics development, and theory and modeling to generate the diagnostics, particles, and algorithms used today. Development and modification of current PIV theory will be necessary in order to satisfy the fluid physics in the regime of interest considering differences in compressibility, constitutive relations, and body forces, to name a few.

Measuring local velocities with XPIV may prove crucial to guiding theoretical and modeling developments in hydrodynamics. XPIV would unravel a wealth of information about the flow, including vorticity, shocks and small-scale shocklets, rarefactions, and viscosity, all of which can be subsequently tied to density and temperature measurements. Bright, coherent x-ray sources have the potential to interrogate HED flows at finer temporal and spatial resolutions than ever obtained with PIV, down to the smallest of turbulent eddies. Investigators inside and outside the stewardship community who are limited by current velocimetry methods will be able to adapt XPIV to their needs, building an experimental database that will continuously refine the method. The development and implementation of the diagnostics and algorithms needed for XPIV will herald a new phase in the broad field of HED hydrodynamics, turbulence, and mixing. ◆

This work was performed under the auspices of the U.S. Department of Energy under Grant DE-SC0019329 within the joint HEDLP program, and is supported by the Laboratory Basic Sciences program administered by UR/LLE for DOE/NNSA.

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Five Decades of Collaboration on Nuclear Data

by T. Bailey (Lawrence Livermore National Laboratory) and D.A. Brown (Brookhaven National Laboratory)

Nuclear data describes the fundamental physical processes that drive nuclear systems and has been essential since the Manhattan Project. In the decades following the Manhattan Project, collections of nuclear data evolved into the "Barn Book" (Hughes, 1955) first sponsored by the United States Atomic Energy Commission. By 1963, there were many nuclear data libraries being developed independently at multiple national laboratories, universities, and industrial companies. In many cases this data was hard-wired into simulation codes. As a result, data users could not easily update their cross-section data or share it among groups, even though sometimes the fundamental data were available for several years (Goldstein, 1968). Furthermore, dissimilarities in the formats adopted by each lab kept data users from reconciling differences in calculated values for the same reactor configurations. The community identified a clear need for a systematic way to intercompare data and simulations using this data. The Atomic Energy Commission asked the American Nuclear Society to organize a series of meetings, culminating in the formation of the Cross Section Evaluation Working Group (CSEWG). This group provided a forum to discuss national nuclear data needs, track progress, and define the Evaluated Nuclear Data Files (ENDF) format. CSEWG is thriving today. It is chaired by the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory (BNL) and is composed of members from other U.S. national laboratories, industry, and academia. The CSEWG collaboration has most recently produced the ENDF/B-VIII.0 data library in the ENDF format, and the Generalized Nuclear Data Structure, GNDS, which is the new international standard.

Over the decades, CSEWG has been a key support mechanism for establishing a national "nuclear data pipeline." This pipeline takes experimental or theoretical results and prepares them for use in applications. This process is illustrated in Figure 1 and can be divided into four steps:

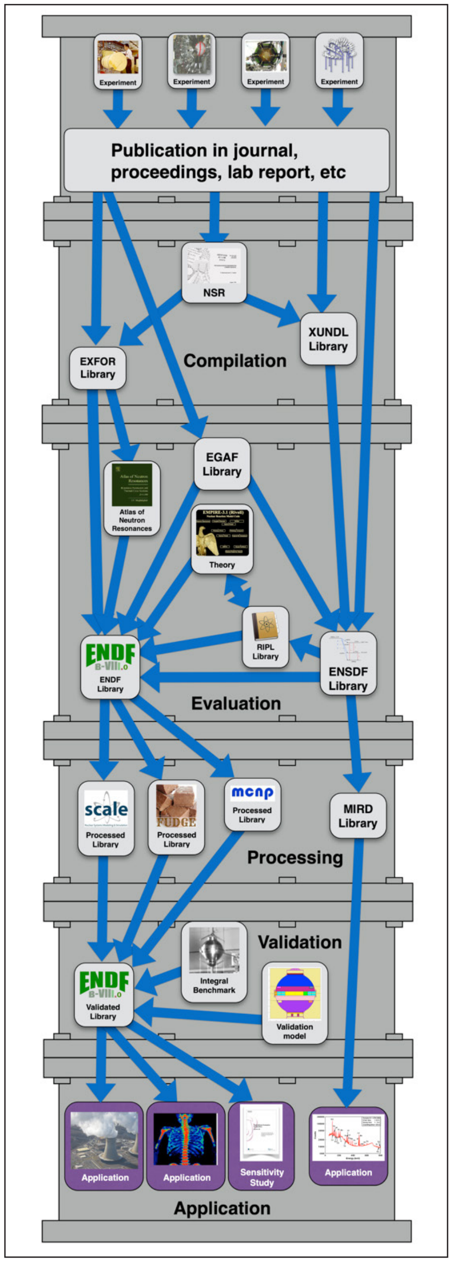


Figure 1. The nuclear data pipeline. This is the process by which a nuclear reaction or structure measurements are converted into data tables for use in applications.

- compilation into the bibliographic database, NSR, the experimental reaction data library, EXFOR, or the experimental structure data library, XUNDL
- evaluation, into the ENDF reaction data library or the ENSDF structure data library
- processing into a form usable for applications
- validation testing to ensure the data is acceptable in applications.

Interest among different programs, including Department of Energy National Nuclear Security Administration (DOE NNSA) and Office of Science programs, has led to a new collaborative goal: produce a new evaluation of fission product yields. This goal was identified as cross-cutting for multiple programs throughout DOE at the 2018 Nuclear Data Roadmapping Enhancement Workshop (NDREW) organized by the Office of Defense Nuclear Nonproliferation Research and Development. As a result of this meeting, multiple programs are sharing our expertise and resources to deliver a comprehensive, national solution. NNSA programs anticipate using this new fission product data in multiple applications ranging from forensics to supporting the stockpile. The Office of Science is interested in this to understand the reactor antineutrino anomaly–namely the shortage of anti-neutrinos emitted from power reactors at short distances (<100 meters). This shortage may indicate another family of (anti) neutrinos as the emitted anti-neutrinos oscillate into these unobserved anti-neutrinos. The source of the anti-neutrinos of interest clearly is those from the decay of fission products. A 2019 interagency meeting, Workshop for Applied Nuclear Data Activities (WANDA), was held January 22-24, 2019. DOE labs and Department of Defense partners again came together as a community to discuss cross-cutting interests and to track progress on the collaborations built during the NDREW in 2018. These interagency meetings have provided an excellent forum for the community to continue to build its collaborative culture and to work towards delivering a next generation nuclear data capability for the nation. ◆

The work was performed under the auspices of the U.S. Department of Energy at Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and Brookhaven National Laboratory under Contract DE-AC02-98CH10886.

2019 Stewardship Science Academic Programs Symposium

The 2019 Stewardship Science Academic Programs (SSAP) Annual Review Symposium was held in Albuquerque, New Mexico on February 19-20, 2019. The Symposium, which hosted more than 300 attendees, featured overviews of work to date from ongoing grants and cooperative agreements from the following programs: Stewardship Science Academic Alliances, High Energy Density Laboratory Plasmas, and the National Laser Users' Facility.

Highlights of the Symposium included keynote speaker Dr. Susan Seestrom, Advanced Science and Technology Associate Labs Director and Chief Research Officer, along with presentations on recent accomplishments from grantees, presentations from the NNSA national laboratories, and a poster session reception. This year, attendees were able to take a post-symposium tour of Z Machine, the Dynamic Integrated Compression Experimental facility, Thor, and the additive manufacturing facility at Sandia National Laboratories. The winners of the Poster Session follow.

Camille Bernal, California Institute of Technology, *Non-harmonic Interactions in BCC Chromium*

David Bernstein, The University of Iowa, *Effects of Coulomb Coupling on Stopping Power and Thermalization Rates*

Abraham Chien, Princeton Plasma Physics Laboratory, *Proton Radiography of Magnetic Reconnection Using Laser-Powered Capacitor Coils*

William Cureton, University of Tennessee, Knoxville, *Probing the Defect Structure in* UO_2 *Induced by Dense Electronic Excitation*

Daniel Felton, University of Notre Dame, *Radiation Induced Assembly of Uranium Peroxide Nanoclusters*

Kevin Ferguson, The University of Arizona, *Experiments in the Dual Shock Vertical Shock Tube*

Theodore Lane, West Virginia University, *Self-Consistency of Stark Broadening Predictions in a Multi-Element HEDP Plasma*

Rebecca Lewis, National Superconducting Cyclotron Laboratory / Michigan State University, *Experimentally Constrained Neutron-Rich Nickel Cross Sections*

Stephanie Miller, University of Michigan, *Laser Gate Experiment for Reducing Energy Coupling Losses in Magnetized Liner Inertial Fusion (MagLIF)*

Jesus F. Perello, Florida State University, *The CATRiNA Deuterated Neutron Detector Array*

Lawrence Salvati III, University of Illinois, *Probing Shock-Initiation of Plastic Explosives with a Tabletop Microscope*

Brittany Thiessen, Washington State University, *Phase Transformations in Paraformaldehyde at High Pressures and High Temperatures* ◆

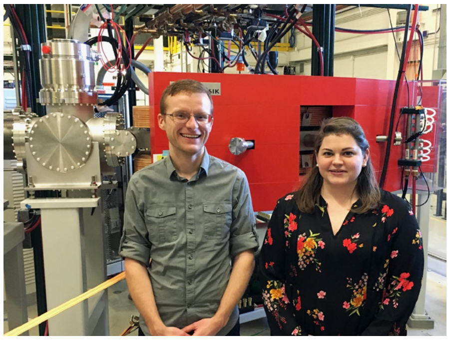
The Outstanding Poster Award Winners of the 2019 Stewardship Science Academic Programs Symposium

From the Stewardship Science Academic Alliances Program to the NNSA Graduate Fellowship Program

National Superconducting Cyclotron Laboratory (NSCL) graduate students Rebecca Lewis and Zachary Matheson have been selected as fellows in the NNSA Graduate Fellowship Program (NGFP) beginning in June 2019. Both are working on research funded by the NNSA's Stewardship Science Academic Alliances Program.

Lewis is investigating techniques to indirectly constrain neutron capture reaction rates with Sean Liddick at Michigan State University (MSU). The goal of the program is to provide neutron capture reaction rates for exotic neutron-rich nuclei that cannot be directly measured due to the lack of a suitable target of short-lived nuclei or neutrons. The experimentally constrained reaction rates are compared to theoretical predictions used in a wide range of applications. Rebecca will be working in Defense Nuclear Nonproliferation Research and Development.

Matheson studies theory of nuclear fission with Witold Nazarewicz at MSU. The goal of their research is in the delivery of high-fidelity fission models capable of providing high-quality nuclear data with quantified uncertainties. For many NNSA applications, the required data on fission cross sections or fission products cannot be obtained via experiment, because very neutron-rich nuclei with short half-lives are required. Matheson will be working in the Office of Research, Development, Test, and Evaluation's Office of Advanced Simulation and Computing and Institutional Programs. ◆



New NGFP fellows Matheson and Lewis