Defense Science *Quarterly*

News about the Science Campaign November 2007

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Chris Deeney, Director, Office of Defense Science

Thank you for another exciting quarter in the Science Campaign. We recently visited Los Alamos and Sandia National Laboratories to conduct a technical review, and we were impressed! Technical progress towards predictive capability is moving at a pace; projects are going well (DARHT) or are finished (ZR, see article on page 10); and the staff are enthused. Lawrence Livermore National Laboratory and Nevada will be reviewed in November and I am sure we will see the same great progress. As I mentioned in the first quarterly newsletter, we have two key themes: support of stockpile stewardship and ensuring the highest quality of science. The recent site visits reinforced that the Science Campaign is on course in both areas.

In this issue, we highlight work in proton radiography and nuclear cross-sections that are advancing our understanding and models for stockpile stewardship. Also, Christian Mailhiot, on detail to the Office of Defense Science, has written an article on the Basic Energy Sciences Workshop on Materials Under Extreme Environments. Clearly, NNSA has a great need to understand, model and improve materials for performance in extreme environments. This workshop will lead to some exciting research in material science that is important to our program. Thank you to Basic Energy Sciences for inviting us to the workshop.

We have seen significant activity in our University Programs due to our recent solicitation. The results of the solicitation, as well as the outreach represented by our Stewardship Science Academic Alliances program, are described in this issue. Congratulations to our chosen centers of excellence: Carnegie Institute of Washington, Rutgers University, University of Texas at Austin, and Cornell University! These institutions produced 553 journal articles in the last five years under NNSA funding, and we can look forward to similar or increased contributions in the coming five years. Our University Programs provide competitively-awarded research, high quality science, and a pipeline of future recruits into the program. I am convinced that as we move further beyond nuclear testing, the confidence in stockpile stewardship will be increasingly based on the quality of our science and peer reviews; two themes that were discussed in recent JASON reviews. We also funded one grant and are hoping to add more grants if funds are available. As we will do in every issue, we have highlighted three articles in high impact journals that demonstrate great science is alive and well in our complex.

Now to the photo! I know most of you are thinking: "Deeney has aged quickly at HQ!" Well, last quarter's issue contained a photo that I had on hand, taken before conducting plutonium experiments on Z and other aging events. HQ is actually a fun place to work, so please watch out for a new position we will be advertising soon.

Dr. Robert Hanrahan has seen the advantages of life at HQ and it is our pleasure to welcome him to the team! Robert will continue to bring great material science understanding and broad connections to our team. A recent visit to the Canyon Grill in Los Alamos revealed that we are also gaining a pretty good karaoke singer as well!

Dr. Robert Hanrahan

Dr. Brad Wallin

We also have a new detailee in our office, Dr. Brad Wallin, from Lawrence Livermore National Laboratory. Welcome Brad! Brad will be taking over a number of the activities that Dr. Cris Barnes, from Los Alamos, was stewarding for us. We want to thank Cris for all his significant contributions and wish him the best back at his home laboratory.

Contributions of the Los Alamos Proton Radiography Program to the Nuclear Weapons Program by Victor Gavron

Proton Radiography (pRad) has been studied at the Los Alamos Neutron Science Center (LANSCE) for more than a decade. During this period, pRad results have provided important contributions to the stockpile stewardship including input to specific weapons systems design and testing, impacting weapons assessment and certification decisions.

pRad utilizes the 800 MeV proton beam, to obtain sequential images of dynamic processes, similar to the way one uses X-rays to obtain an image. The advantage of protons is that they lose more energy in light materials, and provide a much better contrast. For example, pRad can obtain sequential images of an explosively driven flyer plate, impacting a static object. One can obtain the density distribution at several different times during the process, and consequently, determine the density and shock propagation velocity as a function of time.

The camera and pulse system are presented schematically in Figure 1 below.

The image of the dynamic object is formed by a series of lenses – protons are charged particles, and they can be focused by magnetic fields similar to the way glass lenses focus light. The typical resolution of these lenses was 0.18 mm, but it has recently been upgraded to 0.065 mm, allowing the study of new dynamic processes on a much smaller scale. The figure to the right (Figure 2) shows the actual system of beam-lines and lenses as it is implemented at LANSCE.

pRad performed 47 dynamic experiments in 2006. The experiments dealt with numerous topics, including

- Hydrotests
- High Explosives Burn Studies
- Equation of State Measurements
- Sub-Critical Development Experiments
- Dynamic Material Failure Studies
- External Users topics

Two examples of pRad capabilities are the determination of the aluminum equation-of-state, and Material Strength at High Strain Rate Experiments.

In the aluminum equation-of-state experiment (Figure 3), an explosion causes an aluminum "flyer" to hit an aluminum target. Using a series of radiographs, one can determine the change in density due to the shock wave at different times, and consequently – the propagation velocity of the shock front.

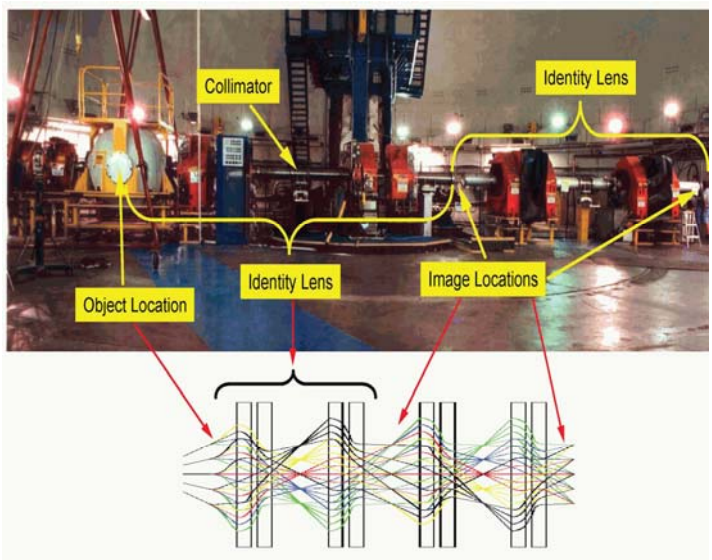


Figure 2. Picture of actual layout of the pRad beam line and lenses at LANSCE.

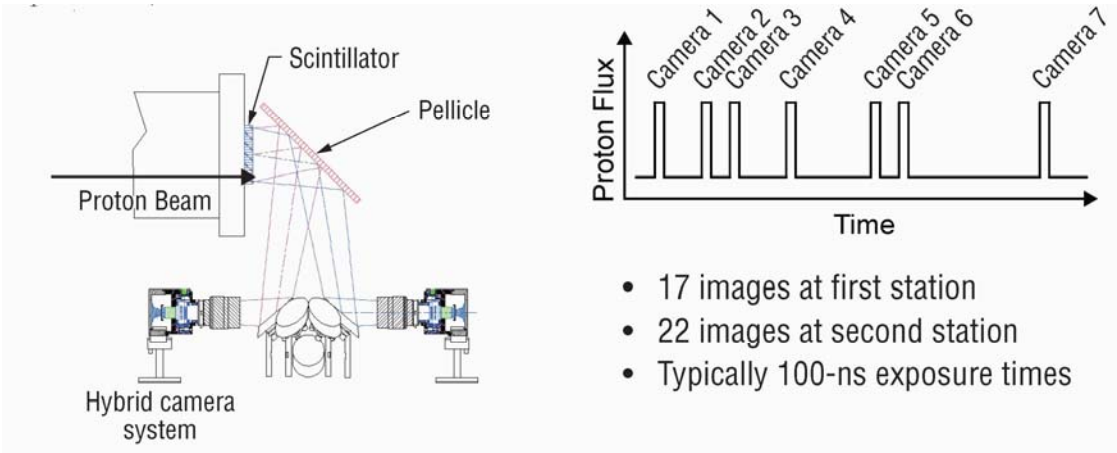


Figure 1. Schematic of camera system. The LANSCE proton pulse is broken up into several 100 nanosecond long pulses, each of which is synchronized with different cameras.

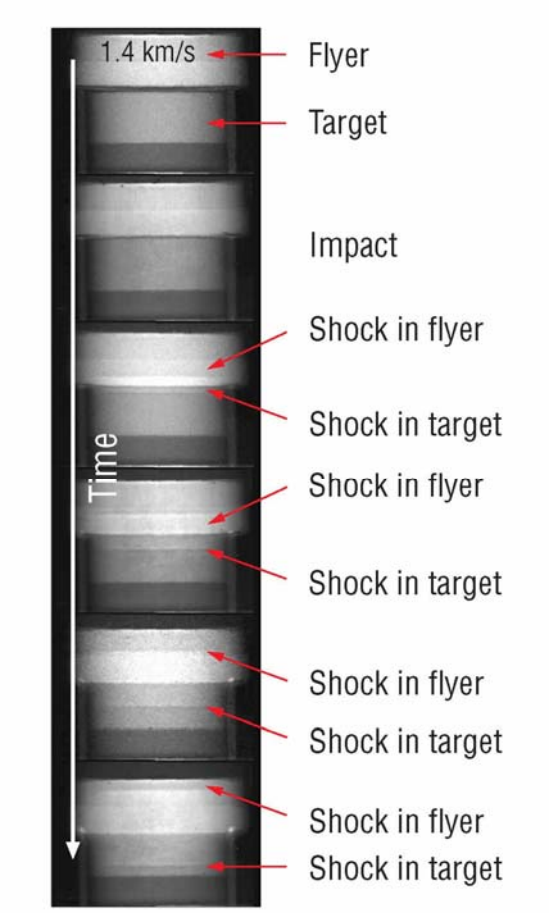


Figure 3. The different shades of gray in the picture are associated with different densities that change as time increases.

These experiments were performed to determine the precision of proton radiographic equation-of-state measurements. Through measurements of density, flyer velocity and shock velocity, a point on the Hugoniot (a property of shock waves) for 6061 Aluminum was measured with 1% accuracy. Aluminum is a well characterized material, and the pRad results were obtained with good agreement to previous measurements.

The Material Strength at High Strain Rate Experiments were performed to test models that are currently implemented in hydrodynamic computer codes used at LANL. The initial set of experiments used proton radiography as the primary diagnostic and Photonic Doppler Velocimetry (PDV) as the secondary diagnostic to study the dynamic strength properties of well-characterized copper samples. Proton radiography was used to obtain multiple radiographs per experiment with the new X3 magnifier. Initial sinusoidal 0.1 mm perturbations were machined into half-annealed copper. The perturbation amplitude is extracted from these images for each radiographic time and provides a metric for easily comparing to the computational results. The velocity at the back side (opposite the perturbations) of the sample was measured as a function of time with PDV. This velocity data provides a direct constraint on the pressure profile the models compute to accelerate the plate.

A plane-wave high explosive lens was detonated to generate a planar cloud of high pressure gas. The expanding gas interacted with the copper coupon, seeded with the sinusoidal surface modulation. The instability growth rate was measured radiographically as a function of pressure by varying the distance between the copper coupon and the high energy plane wave lens (see Figure 4 below).

In summary, the pRad program continues to have a major impact on our ability to benchmark and update computational tools to predict nuclear weapons performance. LANL/pRad continues to provide these data in collaboration with weapons designers, to assure the predictability of the United States stockpile.

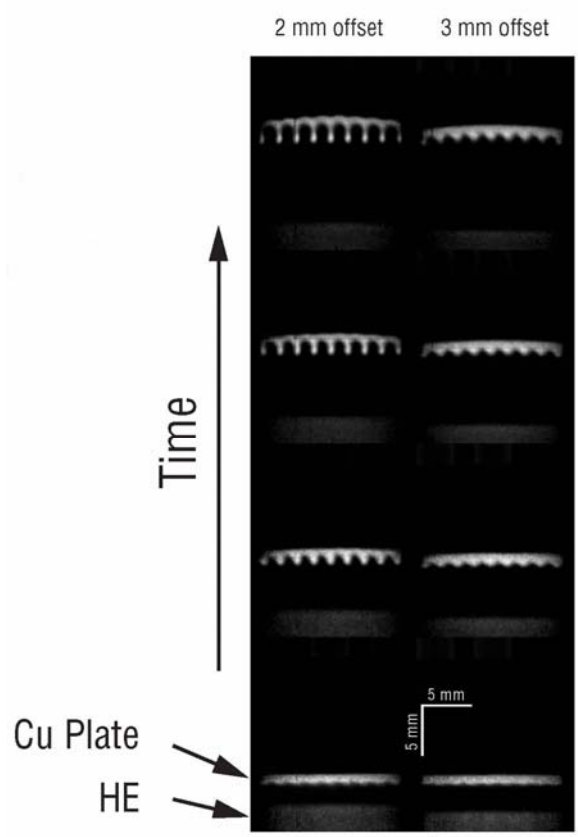


Figure 4. Radiographs of the increasing sinusoidal perturbation with increasing time.

Contributions of the Los Alamos Weapons Neutron Research Facility Programs to the Nuclear Weapons Program by Victor Gavron

A decade has passed since the Los Alamos Meson Physics Facility (LAMPF) was transferred to Defense Programs, and renamed the Los Alamos Neutron Science Center (LANSCE). Throughout this period, the Weapons Neutron Research (WNR) facility at LANSCE has provided important contributions to the stockpile stewardship methodology—especially input to Quantification of Margins and Uncertainties (QMU). These capabilities have impacted weapons assessment and certifications decisions, and are an essential part of existing milestones.

The WNR facility utilizes 800 MeV protons from the linear accelerator to produce neutrons with energies between 100 keV and hundreds of MeV. WNR is used for basic, applied, and weapons-related nuclear-physics research, neutron radiography, and neutron resonance spectroscopy. WNR experiments have a direct impact on understanding the physics in a nuclear device – both weapons performance calculations and weapons diagnostics calculations are impacted by the data provided. Experimental data generated by the Science Campaign are evaluated and then incorporated into the Advanced Simulation and Computing (ASC) codes for device design and are then used in analyzing data from previous nuclear tests for the Stockpile Stewardship Program. During operations in 2006, LANSCE provided a consistent beam for nuclear physics and materials science, operating at a reliability of 85% beam delivery to all facilities. The accelerator reliability enabled WNR to host 84 experiments.

Concerning weapons performance, WNR research provides direct physics input to the two fundamental processes that drive a nuclear weapon: 1) fission of uranium and plutonium, and 2) the thermonuclear fusion process. The calculation of neutron multiplication in the fission trigger requires three distinct pieces of nuclear information: 1) the number of neutrons emitted by each fissioning nucleus, 2) the energy spectrum of these neutrons, and 3) the probabilities that these neutrons cause further fission, or will be scattered or captured without causing fission.

Extensive neutron spectrum measurements are performed at WNR, using the Fast Neutron-Induced Gamma-Ray Observer (FIGARO) detector system. This system contains an array of 20 neutron detectors that can distinguish between neutrons and gamma-rays using pulse-shape discrimination. The energy of the produced neutron is determined by the time difference between the fission event and the detection in the FIGARO array. Results indicate that there is generally good agreement between measured spectra, and those generated by the Los Alamos model. Modifications to the model are needed around 6 to 8 MeV, and above 14 MeV.

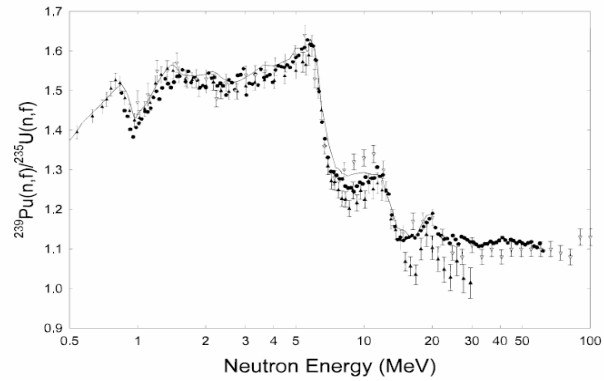


Figure 1. Measured ^{239}Pu fission cross-section, relative to the ^{235}U cross section that serves as a standard. The full points are from data taken at WNR. The line is an evaluation (ENDF/B-VI).

WNR has performed numerous measurements of fission cross-sections of fissile materials, for example, a detailed measurement of the ^{239}Pu fission cross-section, in ratio to the ^{235}U cross-section that serves as a standard (Figure 1).

The differences between the evaluation (line) and the data measured at WNR (full points) are small, but they have a definite impact in calculating the performance of a fission weapon.

A complementary, but no less important, factor that determines the performance of a fission weapon is the capture cross-section — the probability that a neutron will undergo capture in the nucleus without producing fission and its associated energy. This is done at the Detector for Advanced Neutron Capture Experiments (DANCE) (Figure 2). DANCE has an array that surrounds the target and detects almost all of the gamma-rays emitted when a neutron hits the target nucleus. These gamma-rays are different when a nucleus undergoes fission, compared to when a nucleus captures the neutron, and this difference enables measuring the capture cross-section. Numerous measurements on fissile materials have resulted in significant improvements to the nuclear data libraries that are utilized in weapons calculations.

The thermonuclear yield of a weapon is produced by the fusion of deuterium and tritium. In the weapon, tritium is produced by a reaction between a neutron and ^{6}Li (one of the stable isotopes of lithium). The tritium production rate is not well known; in the few MeV incident-neutron-energy range relevant to weapons physics, this cross section is considered to be uncertain by as much as 30%. The production rate is being measured at WNR using a "sandwich" of silicon detectors used to detect both reaction products (tritium particle + alpha

particle), as a function of the incident neutron energy. These data are currently being analyzed, and are expected to be complete by the end of FY 2008.

Relating to weapons diagnostics, many past nuclear tests incorporated isotopes of various elements (radiochemical, "radchem," diagnostics) located in different sites within the nuclear weapons to determine the performance parameters at those sites. When we know the cross sections of reactions of these isotopes, we can benchmark weapons calculations by comparing the calculated ratios of produced isotopes to the isotopes measured. In the past, if calculations did not agree with experimental data, it was difficult to determine whether this discrepancy was due to a problem in the weapons code, or due to the poor quality of the nuclear data. To correctly interpret the radchem activation results, we need to know cross sections (both capture and reaction) of several adjacent isotopes.

Measurements were performed at the GEANIE (Germanium Array for Neutron-Induced Excitations) detector system at WNR. This is an array of 26 high-resolution gamma- and x-ray detectors that view a sample bombarded with neutrons (see Figure 3 below). It was constructed by a collaboration of researchers from Los Alamos National Laboratory and Lawrence Livermore National Laboratory specifically to investigate neutron reactions at the center of radchem diagnostics, reactions that were tantalizingly difficult to study by any other means. Results of numerous isotopes are being incorporated into weapons calculations, resulting in a much improved agreement between test results and calculations.

In summary, the current and future availability of accurate nuclear data for use in weapons calculations continues to have a dramatic impact on our ability to utilize computational tools to predict nuclear weapons performance. LANL-WNR continues to provide this data in collaboration with weapons designers, to assure the predictability of the U.S. stockpile.

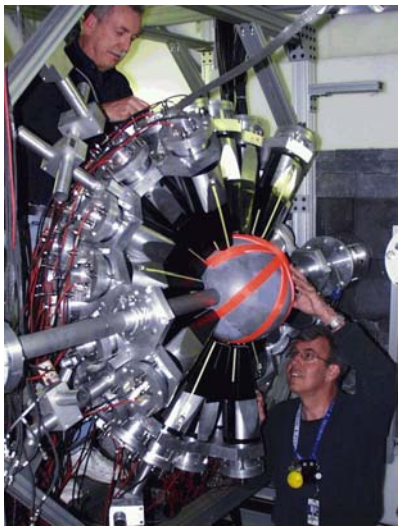


Figure 2. The DANCE detector system.

Figure 3. The GEANIE Detector. GEANIE is composed of 26 high-purity germanium detectors. The photo shows them viewing gamma rays from an encapsulated ^{239}Pu sample bombarded with neutrons from the WNR source.

Cross-cutting Science: Materials in Extreme Environments by Christian Mailhiot

I. Background:

The development of new materials that can perform at the theoretical limit in extreme environments, and the ability to predict the properties and response of materials over a wide range of extreme conditions are at the heart of the Department of Energy's (DOE) ability to execute its national missions in nuclear weapons science, national security, energy security, environmental management and fundamental science. Extreme conditions of interest include regimes of high pressure and temperature, high strain and strain rates, extreme electric and magnetic fields, and conditions produced by extreme radiation and chemical environments, as well as combinations of these environments. Materials responses under these conditions encompass, but are not limited to: structural phase transformations, including melting and solidification; elastic and plastic deformation; fracture and failure; and corrosion and radiation effects.

In addition, it is widely recognized that today's materials will not meet the demands of tomorrow's application, particularly in the area of energy generation, transport, and storage. Developing an entirely new generation of materials that can meet the requirements derived from DOE's broad-range mission needs will be achieved by sustained investments in fundamental research to

unravel the complex effects that occur when materials are exposed to extreme conditions. This fundamental knowledge will enable the design of new materials that will exhibit optimum performance in extreme environments. Moreover, this knowledge may enable the use of these same extreme environments – of temperature, pressure, chemical composition, and external fields — to tune the intrinsic properties of materials to realize their ultimate performance and even to create altogether new materials with optimized properties for future applications. Consequently, transformational materials science and technology will be needed to achieve orders of magnitude improvement in properties and realize the fundamental, theoretical performance limit of materials in extreme environments (see Figure 1 below).

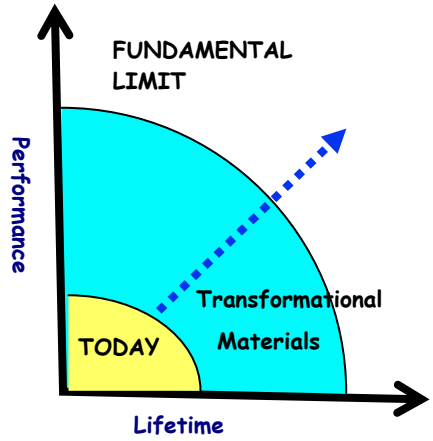


Figure 1. Transformational materials will be needed to achieve orders of magnitude improvement in properties and to achieve the fundamental performance limit.

From the perspective of the National Nuclear Security Administration (NNSA), there exist unprecedented challenges and opportunities in the development of scientific capabilities needed to predict the properties of materials in the range of conditions germane to its national security mission needs. An important characteristic of these mission-derived needs and requirements is that they drive the NNSA scientific enterprise towards areas which are inherently at the overlapping intersection of traditional scientific disciplines. Consequently, the scientific challenges and opportunities offered by the investigation of materials under extreme conditions within NNSA cut across scientific discipline boundaries, for example, materials science and plasma physics, chemistry in radiation environments and shock physics, etc.

As an overall scientific strategy to address these challenges and capture these opportunities, NNSA has established a comprehensive set of large- and laboratory-scale experimental facilities, and advanced experimental diagnostics; as well as high-performance computational facilities and scaleable coupled-physics simulation tools. This scientific strategy is underpinned by broad-based fundamental research in the area of materials behavior.

II. Workshop on Basic Research Needs for Materials under Extreme Environments:

On June 11 – 14, 2007, the Office of Basic Energy Sciences (BES) sponsored a workshop on Basic Research Needs for Materials under Extreme Environments (MuEE). This is a topic of significant interest to NNSA since the ability to predict the properties and response of materials over a wide range of extreme conditions cuts across NNSA's ability to execute its national security missions.

The purpose of the BES workshop was to identify basic research needs and opportunities in materials under extreme environments encountered in energy generation, conversion and utilization processes, with a focus on new, emerging and scientifically challenging areas that have the potential to significantly impact science and technology. Examples of extreme environments and energy-relevant applications are indicated in Figure 2.

The chair of the BES workshop was Jeff Wadsworth of Oak Ridge National Laboratory (ORNL). Associate chairs were Russell Hemley of the Carnegie Institution of Washington and George Crabtree of Argonne National Laboratory (ANL). The workshop was attended by approximately 160 participants from academia, industry, national laboratories, and basic and applied DOE offices. A report summarizing the findings of the workshop will be issued in December 2007. It is hoped that this report will provide the groundwork for future funding opportunities in fundamental research.

The workshop was organized along the following topical panels:

- Materials under extreme energetic photon and particle fluxes
- Materials under chemical extremes
- Materials under thermomechanical extremes
- Materials under electromagnetic extremes
- Cross-cutting science

The panels identified a number of priority research directions in the area of Materials under Extreme Environments including:

- Control and synthesize materials with new properties using photon and particle beams
- Design of materials with revolutionary tolerance to extreme photon and particle fluxes
- Toward ideal surface stability
- Fundamental reaction dynamics at extremes
- Novel materials by Design
- Chemical and materials dynamics in complex systems
- Disordered materials in the extreme
- High performance electric and magnetic materials
- Electromagnetic extremes

- Theoretical and simulation framework for predicting and extrapolating performance
- Experiments on the scale of the underlying fundamental interactions

A briefing to NNSA senior leadership was held on August 29, 2007. The purpose of the briefing was to put the findings of the workshop within the context of NNSA mission-inspired research needs and to identify areas of synergy between NNSA and BES in the area of materials under extreme conditions.

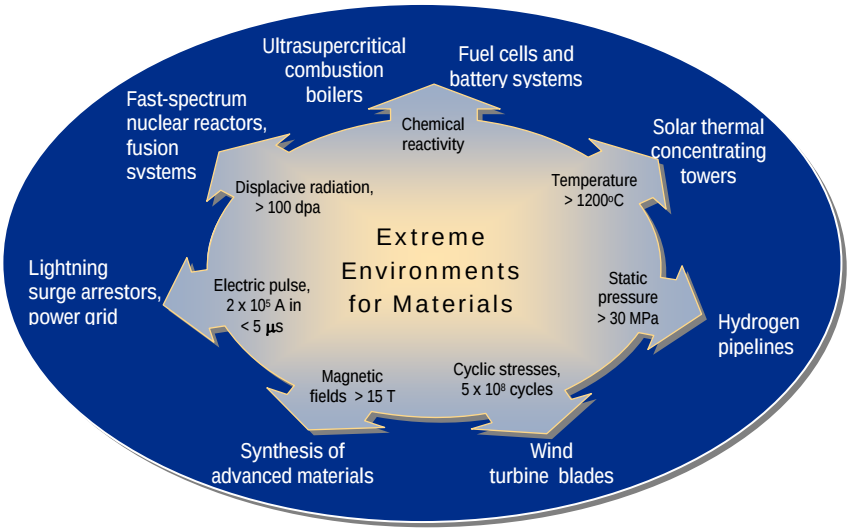


Figure 2. Improving the properties of materials in extreme environments to achieve the fundamental, theoretical performance limit would benefit several energy-relevant applications.

Academic Outreach: The Stewardship Science Academic Alliances Program

by Christian Mailhiot

The Stockpile Stewardship Program (SSP) is a comprehensive scientific approach to ensuring the safety, reliability, and performance of the nuclear stockpile in the absence of nuclear testing. The stewardship mission requires significantly increased fundamental understanding of all physical phenomena associated with nuclear weapons performance, safety, and reliability, as well as the preservation and enhancement of core science, technology and engineering (ST&E) competencies within the Department of Energy's (DOE) National Nuclear Security Administration Defense Programs (NNSA/DP). Consequently, SSP mission needs drive work that spans multiple traditional scientific disciplines. An important element of the strategy necessary to successfully accomplish this cross-disciplinary work is the establishment of a robust and sustained academic outreach program to seek fresh ideas and approaches and to develop a leadership-class workforce in those ST&E areas underpinning the SSP.

Recent studies — such as the National Academies' report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Produced by the National Academies Press, 2006) — conclude that the U.S. must prepare with great urgency to preserve its strategic and economic security by increasing the number of engineers and scientists. This will require a vigorous and sustained government-supported university outreach program. NNSA/DP identified a similar urgent need to support future capabilities within the U.S. in the areas of fundamental science essential to support the SSP, such as materials science and technology, high-energy-density physics, and nuclear sciences. Consequently, NNSA/DP Office of Defense Science launched the competitive Stewardship Science Academic Alliances Program (SSAAP) in 2000. Other NNSAS/DP university outreach programs include the Predictive Simulation Academic Alliances Program (PSAAP) established in 1996 by the Office of Advanced Simulation and Computing (ASC). A central motivation to establish the SSAAP was to launch a university outreach program that focuses primarily on experimental investigations and complements the PSAAP, which focuses on high-performance scientific computing.

The SSAAP supports both single-investigator research grants and comprehensive, multi-disciplinary and multi-investigator Centers of Excellence. Four Centers of Excellence and 40 grants are currently being supported by the SSAAP. The geographical distribution of all NNSA-supported academic alliances is indicated in Figure 1 at the end of this article.

The objectives of the Stewardship Science Academic Alliances Program are:

1. Supporting the U.S. scientific community by funding research projects at universities in the areas of fundamental science and technology critical to stockpile stewardship, with a focus on those areas not supported by other federal agencies, and for which there is a recruiting need within the NNSA/DP laboratories;

2. Providing advanced experimental measurement techniques in selected areas of Condensed Matter Physics and Materials Science, Hydrodynamics, Plasma and High-Energy-Density Physics, Fluid Dynamics, and Low-Energy Nuclear Science;

3. Providing opportunities for intellectual challenge and collaboration by promoting scientific interactions and personnel exchanges between the academic community and scientists at the NNSA/DP laboratories;

4. Increasing the availability of unique experimental facilities sited at the NNSA/DP laboratories to the academic community, particularly for collaborations in areas of relevance to Stockpile Stewardship; and

5. Developing and maintaining a long-term recruiting pipeline to the NNSA/DP laboratories by increasing the visibility of the NNSA/DP scientific activities to the U.S. faculty and student communities.

The specific technical areas supported by the SSAAP include:

Properties of Materials Under Extreme Conditions and Hydrodynamics

In this area, the topics of interest include:

1. Static and dynamic (i.e., shock-compressed) properties of materials under conditions of high-pressure, high-temperature (1–10 eV regime), high-strain and high-strain-rate; including thermodynamic properties (equation-of-state, high-pressure phase diagram, pressure-induced phase transformation, etc.) and mechanical constitutive properties (plasticity and strength, failure, fracture, etc.);

2. Hydrodynamic experiments in low-energy-density physics regimes where materials properties (strength, etc.) dominate;

3. Advanced diagnostics and measurement techniques leading to the observation of physical phenomena at appropriate length and time scales with particular emphasis on in-situ techniques; and

4. Validation of physics-based multi-scale models of the dynamic response of materials.

High-Energy-Density Physics

In this area, the topics of interest include:

1. Properties of matter in high-energy-density regimes, e.g. as those produced by lasers and/or pulsed power (this includes investigations in related areas of hydrodynamics, plasma physics, properties of materials under high-energy-density conditions, inertial fusion, atomic physics, radiation generation, and the interaction of radiation with matter);

2. Astrophysical phenomena;

3. Physics of turbulence and fluid interfaces; and

4. Diagnostics and measurement techniques for the observation of physical phenomena under high-energy-density conditions.

Low-Energy Nuclear Science

In this area, the topics of interest include:

1. Investigations leading to greater accuracy in the knowledge of low-energy cross sections of stable and unstable nuclei and corresponding reaction rates for neutron-, γ- and ion-induced reactions for both simulation and radiochemistry diagnosis;

2. Advanced simulations and measurement techniques leading to improved radiation and particle detection methods, in terms of energy and spatial resolution;

3. Physics of the fission process, including division of mass and charge as a function of excitation, production of energy, and the reaction properties of prompt fission products;

4. Particle production and advanced diagnostic techniques relevant to high-energy proton radiography and advanced diagnostic techniques relevant to X-ray radiography; and

5. Experimental diagnostic techniques for laser or pulsed-power implosion systems.

Congratulations:

- LANL, LLNL, and SNL for their 2007 R&D 100 Awards.
- SNL for its 2007 Interagency Partnership Award by the Federal Laboratory Consortium.
- Ward Sigmond for his Certificate of Service for 40 years of service to the federal government.

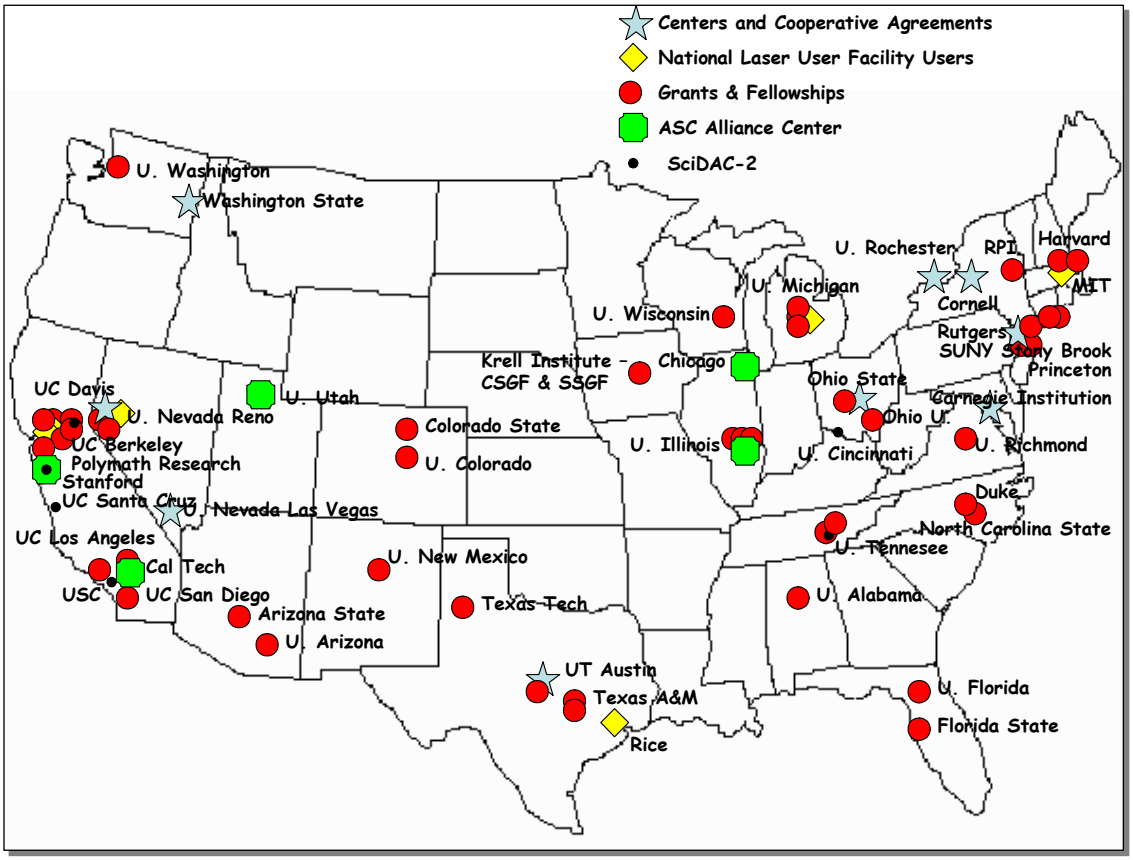


Figure 1. Geographical distribution of the NNSA-supported academic alliances.

Stewardship Science Academic Alliances Solicitation Process Completed

by Cris Barnes

NNSA recently completed evaluation and selection of proposals for financial assistance from academic institutions in its Stewardship Science Academic Alliance Program (SSAAP). Fifty separate proposals were received on www.grants.gov to solicitation DE-PS52-07NA28065 by May 15, 2007 for grants and cooperative agreements in the topical research areas of high-energy-density physics, low-energy nuclear science, and properties of materials under extreme conditions and hydrodynamics. Using the Oak Ridge Institute for Science and Engineering (ORISE) web-based PeerNet system for electronic review, eventually 172 reviews by 62 different people were done to provide technical merit review of all the proposals. An executive committee of DOE or DoD federal employees and contractors on assignment to DOE/NNSA with appropriate backgrounds in the technical and programmatic interests of the SSAA met and developed a merit selection report. Based on this input, the Selection Official, Dr. David Crandall, Assistant Deputy Administrator for Research, Development, and Simulation, NNSA, (NA-11) officially selected five proposals:

- Carnegie/DOE Alliance Center: A Center of Excellence for High Pressure Science and Technology by Carnegie Institute of Washington.
- Center of Excellence for Radioactive Ion Beam Studies for Stewardship Science by Rutgers University.
- The Texas Center for High Intensity Laser Science: A Renewal Proposal for the SSAA Program by University of Texas at Austin.
- The Center for Pulsed Power Driven High Energy Density Plasma Studies by Cornell University.
- Fundamental Issues in the Interaction of Intense Lasers with Plasma by Princeton University.

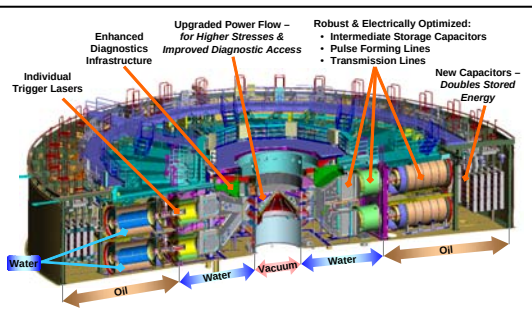
Twelve other proposals were identified as "selectable" within the next year if additional funding beyond present plans is available. The Science Campaign wishes to thank the many principal investigators and their collaborators for the excellent set of proposals, and the many reviewers who provided their time to do the merit review.

Z Refurbishment Project (ZR) Wraps Up by Ed Weinbrecht, Doug Bloomquist, Guy Donovan, Woody Weed, & Mark Savage, SNL

On September 17th, Sandia's Z Pulsed Power Accelerator Z Shot #1766 shook the ground for the first time since July of 2006, when the facility was taken off line for a comprehensive upgrade. The Marx generators were charged to 60 kV for a total stored energy of 10 MJ, approximately the same energy as the old Z machine at routine operating conditions. The refurbished Z is capable of 22 MJ stored energy. The 36 module ensemble charged, triggered, and delivered approximately 17.5 million amps into a standard isentropic compression geometry load with aluminum panels. Material properties will allow independent current verification from the Velocity Interferometry System for Any Reflector (VISAR) measurements.

This functional demonstration shot wrapped up an extensive facility outage during which the old pulsed power systems were removed, the tank structure that houses Z was extensively modified, new, more robust pulsed power components and subsystems were installed, technical utility infrastructure modifications were accomplished, and accelerator subsystems were commissioned. A second demonstration shot was successfully conducted on September 21, meeting the Z Refurbishment (ZR) project completion criteria and concluding the 7 year, $90.6M project effort.

Z's roots go back to 1985 when the facility was originally constructed as the Particle Beam Fusion Accelerator II (PBFA II), designed and utilized for light-ion fusion research. Z-pinch technology breakthroughs lead to modifying the center portion of the machine in 1996. Renamed "Z" at that time, the accelerator became a workhorse for the scientific community. As the majority of hardware was old and not specifically designed for z-pinch applications, the ZR project sought to upgrade the accelerator with systems optimized for z-pinch physics technology, support the program's overall capability to perform more shots, improve precision and pulse shape variability, and increase the current delivered to targets. Project enhancements include new capacitors with double the capacitance and electrically optimized



New Architecture and Upgrades

Dismantlement Phase

Old Oil/Water Separation Wall Removal

New Pulsed Power Systems Being Installed

Refurbished Facility

stainless steel pulsed power components for durability. The top of Z is now covered in work platforms for maximum utilization of diagnostics and data recorders towards achieving the highest quality data output from the machine. Operational transition experiments will take place over the next several months to verify, validate, and optimize the performance and predictive models for the accelerator and determine reliable operating points for near-term science programs.

Publication Highlights by Brad Wallin

In this section we highlight recent publications in high-impact scientific journals of research supported by the NNSA Science Campaigns.

"Phonon Density of States of Metallic Sn at High Pressure" by Hubertus Giefers et. al., PHYSICAL REVIEW LETTERS, JUNE 15 2007, v.98, no.24, p.245502

Lattice vibrations give the dominant contribution to the entropy as well as to the thermal pressure in solids, and thus figure very prominently in the study of high-pressure phase stability and equation of state. Only in a very few cases have the phonon spectra of materials at high pressure been measured. Recent increases in performance at the European Synchrotron Radiation Facility and at the Advanced Photon Source have enabled experiments at very high pressures on metallic Sn. Nuclear resonant inelastic x-ray scattering experiments on Sn have extracted phonon density of states up to 64GPa. Density functional theory calculations applying the direct force method give results in excellent agreement with the measured data. Based on the obtained phonon density of states, we have derived several thermodynamic quantities important to understanding the lattice dynamics and construction of the phase diagram of Sn. This combined experimental and theoretical investigation establishes a reliable description of the lattice dynamics of Sn at high pressure. It also validates the theoretical methods employed here for use in further studies of the thermodynamic properties of Sn and its compounds at high pressure.

"Wire Initiation Critical for Radiation Symmetry in Z-Pinch Driven Dynamic Hohlraums" by T.W.L Sanford et. al., PHYSICAL REVIEW LETTERS, FEB 9 2007, v.98, no.6, p.065003

Dynamic hohlraums (DH) driven by a z-pinch are being developed and used as intense blackbody x-ray sources for inertial confinement fusion and high temperature (>200 eV) radiation transport experiments. Central to the utility of the DH is the assumption that the radiation is axially symmetric about the target center, however in experiments there is always an asymmetry in power radiated from the top and bottom exit holes. Here we present new data that clearly show a strong correlation between the axial x-ray asymmetry and the structure of the negative radial electric field between the surface of the wires in the outer array and the current-return can. This field controls the axial energy deposition to the individual wires during the wire-initiation phase, when current first flows through the outer array. Hence, we establish for the first time a connection between wire initiation and x-ray production symmetry in wire-array z-pinches. In studies performed on the 20-MA Z generator at Sandia National Laboratory we observed that in order to minimize the asymmetry it is necessary to keep the relative radial electric field below 0.8.

"The impact of peak shock stress on the microstructure and shear behavior of 1018 steel" by Lisa M. Dougherty et. al., ACTA MATERIALIA, SEPT 20 2007, v.55, p.6356

Shock-loading 1018 steel significantly alters both the microstructure and the shear behavior of the alloy. During shock-loading, a high density of lattice dislocations, twins and microbands were introduced, which significantly increased compressive yield strength over the as-received, commercial 1018 steel. Work-hardening behavior during compression was found to be similar in the as-received and shock-prestrained steel, although the degree of hardening was higher in the shocked steel and increased with peak shock stress. Higher peak shock stresses produced a higher degree of deformation, evidenced by greater dislocation activity in and around twins as well as increased microbanding. No other microstructural differences were observed. As-received 1018 steel resisted shear banding at the strain rate and throughout the strain range tested due to a high capacity for defect storage, unlike the shocked specimens that were prestrained during the shock-loading process. The lower capacity for defect storage in the shocked steel resulted in the failure of the material under shear by the formation of adiabatic shear bands. The greater number of stored defects and the greater density of dislocation tangles at the twin and microband boundaries in the 1018 steel subjected to the higher peak shock stress resulted in a less stable microstructure that saturated with defects more rapidly during shear deformation than the 1018 steel subjected to the lower peak shock stress. Consequently, the steel subjected to the higher peak shock stress exhibited a higher degree of shear localization and a narrower adiabatic shear band.