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Report

20 Years of US/Russian Laboratory Cooperation in Science and Technology 1992-2012 (U)

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Background

Formal cooperation in unclassified, non-sensitive science and technology (S&T) efforts specifically in disciplines related to nuclear weapons science (but distinct from the Joint Verification Experiments of the late 1980's) between the DOE Laboratories (LANL, LLNL and SNL) and the ROSATOM laboratories, Russian Federal Nuclear Centers, (RFNCs), began with a first with an exchange of technical experts in January 1992. The opportunity for these timely discussion grew out of relationships formed in open scientific channels (journals and conferences) during the duration of the Cold War. This discussion, among technical experts, provided the opportunity to extend invitations for exchange visits by Laboratory Directors to both Russian and US Labs in Feb and March 1992. The driver for these first interactions was, of course, the dissolution of the USSR, and US concern about the stability, and even possible emigration, of top Russian weapon scientists during the collapse of the Russian economy in the years following 1992. The first joint, formal, S&T efforts (cutting-edge experiments conducted by joint US/Russian teams involving 20-30 members, first in Sarov, and then in Los Alamos) occurred in the fall of 1993. These earliest efforts were followed, in short order, by expanded, joint S&T projects in pulsed power technology and applications topics, and within a few years by joint projects in material science experiments and modeling, and more recently by joint projects in computational physics and computer science.

Since 1994, Los Alamos has continued to support a portfolio of 10-20 projects, and Livermore and Sandia have supported portfolios of 5-10 projects each year: some small, single PI efforts; some involving large, generally experimental, teams working at either Russian or US facilities. Some projects last less than a year; some take up to 5 years to complete. All projects have involved unclassified, non-sensitive topics and all result in joint scientific publications. All relate to principle Laboratory (US and Russian) national security missions, while carefully respecting classification, export control, critical technology, and economic competitiveness concerns in both countries. Projects that might encroach on the concerns of either nation are dropped from consideration without attribution. The number of projects and the topics in the US/Russian Labs portfolio has evolved and changed over time. Similarly, the level-of-effort varied with evolving each Laboratory's resources, programs, and with the international climate over the 20 year duration of the cooperation. Nevertheless, efforts by individual PIs and first level Program Managers have maintained an intellectually stable, continuous, and well-received exchange with VNIIEF, and VNIITF (LANL and LLNL) and VNIIEF, VNIITF and VNIIA (Sandia), and to a lesser degree with Russian Academy of Sciences (RAS) institutions.

The S&T cooperation has been conducted as Lab-to-Lab activities, authorized by Presidential Decision Directive (NSDD-189, 1995 and PDD-47, 1996) and several implementing protocols signed by the US Secretary of Energy and ROSATOM (Reis/Ryabev, 1998; Moniz/Ryabev, 1999; and Gordon/Rayebev (2002)), and generally adhering to, but never formally a part of, the

WSSX government-to-government agreement. At LANL, S&T cooperation takes the form of research contracts governed by a Statement of Work, with Deliverables and Schedule structured under a Master Task Ordering agreement. All projects involve some level of active participation by LANL scientists ranging from technical consultation and review, to active, hands-on work in the areas of theory, simulation, experiment design, fabrication, diagnostic measurements, and data analysis. To date, all projects involve some funding from the US to the Russian labs, a practice that originated in the financially critical years of 1992–94. It has been clear from the beginning that the effort applied by the Russian laboratories to joint projects far exceeds the amount of funds provided by the US. Funding is frequently directed to the purchase of materials and fabrication of experimental assemblies and other consumables associated with experiments.

Benefits:

The S&T cooperation has provided one means to engage the unique expertise of the US and Russian nuclear weapons laboratories in cooperative support for the shared nuclear security objectives of the two countries, including technical confidence building and advancing mutual trust. These efforts articulate and reinforce the commitment of each laboratory to outstanding, innovative, world-class S&T research in topics underlying the national security missions of each laboratory that is recognized internationally. Through cooperation, the Laboratories and Institutes seek to advance their mutual interests in computational science, material science, and high energy density experimental techniques.

Recent Technical Efforts:

Since 1992 more than 50 individual technical projects have been completed in cooperation with the laboratories of the Russian Federal Nuclear Centers (RFNCs). A few examples of unclassified, non-sensitive joint technical efforts, drawn from the Los Alamos portfolio over the last 20 year of cooperation include:

- Magnetically imploded liners as mechanism to reach extended states of pressure, strain, strain rate in condensed matter including
  - Impact Experiments
  - Controlled Compression Experiments
  - Experiments Producing Large Internal Energy Densities.
- Material Properties Models and Experiments
  - Plutonium Aging
  - Constitutive Properties of reference materials
  - Understanding of “f-electron” metals starting with Cerium
- Lagrangian methods in hydro codes.

Magnetically Imploded Liners:

Electromagnetically imploded liners are the most widely studied mechanism for converting large amounts of electro-physical energy into the particle kinetic energy needed for a wide variety of experiments, especially experiments in condensed matter; experiments in gas dynamics; and in plasmas. Among the experiments for which electromagnetically imploded liners can be useful are: 1) High-precision, and especially high velocity, impact experiments; 2) controlled compression experiments and 3) experiments aimed at producing large internal energy densities.

1. Shock Physics (Impact) Experiments

Two examples of shock physics experiments whose results can be enhanced by application of liner implosion techniques include: first, experiments exploring the onset, development and, ultimately, recollection and healing of material damage; and, second, exploration of material EOS at shock pressures higher than are available from conventional linear gun techniques. For damage experiments the ability to apply precise shock-wave drive allows exploration of the onset of damage with a degree of control that exceeds that available from other drivers. Spallation damage in aluminum, for example, occurs for matched impacts (identical impactor and target material, densities and sound speeds) at velocities above 180 m/sec. But aluminum displays complete failure for matched impact velocities above 205 km/sec, giving a very narrow range of impact velocities (~185-205 m/sec) over which the evolution of damage can be explored. Therefore, to explore the evolution of spall damage in experiments, impact velocities of 190 m/sec +/- 2 m/s are required, and electromagnetic drive provides just that capability.

To fully understand damage processes, it is also necessary to describe the inverse process when damaged material is recollected, after initial damage, when closing of the damaged areas is expected, and perhaps even healing of the damaged region, might be possible. To perform such experiments requires either the slowing of the free-flying spall layer, allowing the bulk material to catch up, or the ability to dramatically reaccelerate the bulk material overtaking the free-flying spall layer. The first category of experiments can be performed in linear geometry but introduces the possibility of introducing additional damage processes in the process of decelerating the damaged layer. Reapplication of drive is very difficult to accomplish either with linear guns or

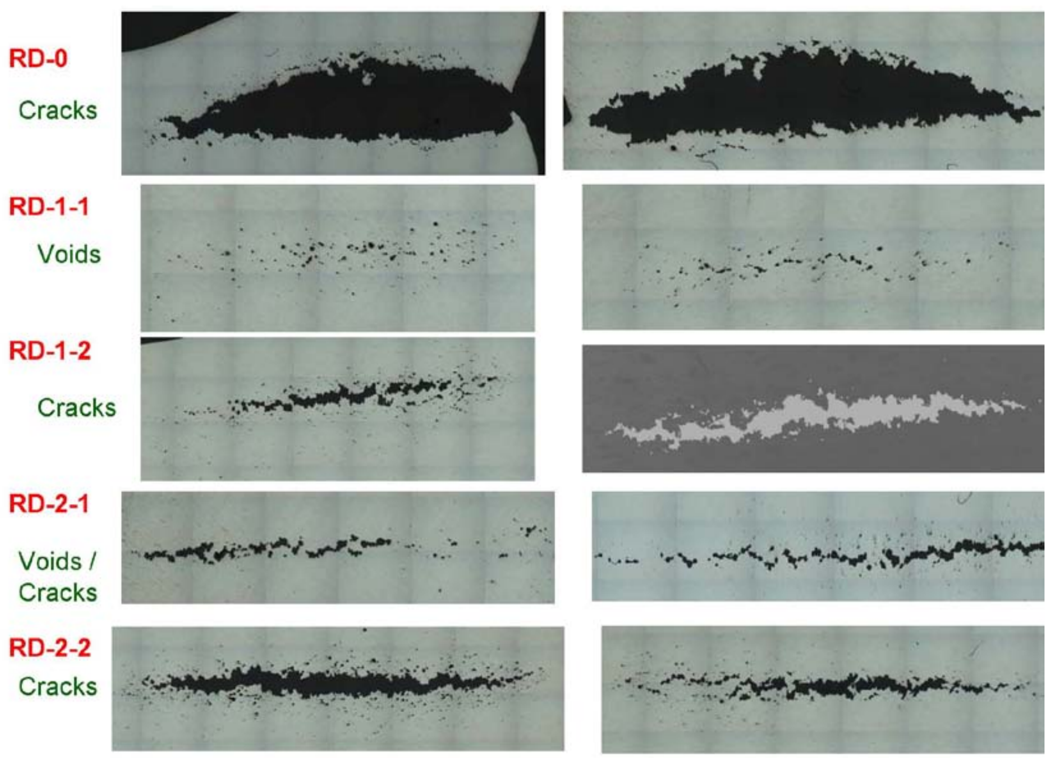

Fig 1. Electromagnetic drive allows control of impact velocity to about +/- 2 m/sec allowing damage and recovery of samples detailing the evolution of damage by spallation.

with high explosive drive but is easily accomplished with current pulsed shaping techniques in electromagnetic drive. Furthermore, to recover the samples, without additional damage, it is frequently necessary to remove the drive from the experiment, immediately following the damage and recollection porcess -- and removing drive is virtually impossible with gun or HE drive techniques. The R-Damage series of experiments conducted jointly by LANL and VNIIEF used magnetic flux compressors, and combinations of opening and closing switches to provide precise drive, and to remove that drive precisely as needed. In a series of ten experiments, damage evolution, and recollection were successfully accomplished.

The second family of shock physics experiments that profit from use of electromagnetic drive are those exploring EOS of materials where higher shock pressures are required than those available using guns or direct HE drive. Two stage gas guns, even with the second stage operating in hydrogen are limited to about 8 Km/sec impact velocity. For matched impacts (impacts using the same target and impactor materials) at 8 Km/sec, gas guns can achieve shock pressures just over 1 Mbar in Aluminum, 1.8 Mbar in iron or 6.6 Mbar in tungsten. To probe higher pressure regimes, higher impact velocities are required. LANL and VNIIEF are collaborating to demonstrate 20 Km/sec high precision cylindrical liner implosions, suitable for making EOS measurements. In the initial demonstration experiment, a matched aluminum impact will produce 10 Mbar pressures, while future experiments will use a composite liner with an aluminum or copper current carrying layer on the outside and a higher density impactor within.

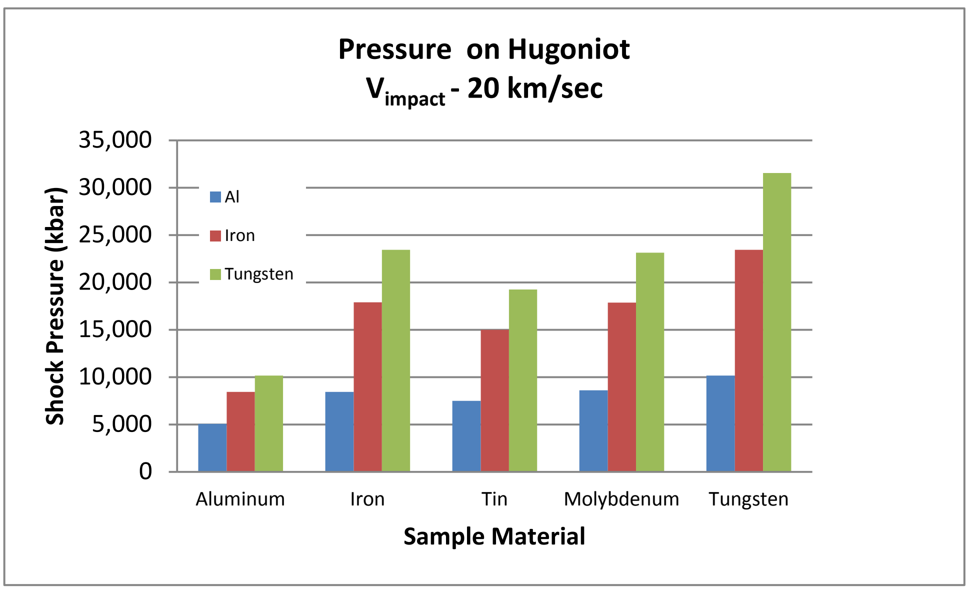

Fig 2 Hugoniot (single) shock pressure (from the Hugoneot relations) for combinations of aluminum (blue), iron (red) and tungsten (green) impactors on aluminum, iron, tin, molybdenum and tungsten targets at impact velocities of 20 Km/sec. Pressures range from 5 MBars (Al/Al) to over 30 Mbar (W/W).

A new Disk Explosive Magnetic Generator (DEMG) specifically designed to be powered by explosive formulations available in either Russia or in the US provides 65-70 MA drive to an aluminum liner, initially 3 mm thick, with 40 mm initial outer radius. The target radius is 5 mm. The EOS measurement consists of measuring shock velocity by recording shock breakout time after the initial shock transits precise thicknesses of target material, generally incremented by about 200 μm and simultaneously measuring the velocity of the free surface (giving particle velocity) immediately after breakout. New photon-doppler (PDV) velocimetry measurements are the primary diagnostic for both shock breakout time and free surface velocity, and for pre-impact assessment of the iiner velocity as well. Multiple (three) independent redundant EOS measurement are planned to assess the overall accuracy of the technique. Precision (azimuthal symmetry and axial uniformity) of liner impact with the target is of major concern in order to obtain the few percent accuracy needed to constrain EOS predictions. And detailed simulations using both Russian and US simulation techniques have been applied to evaluate liner precision upon impact.

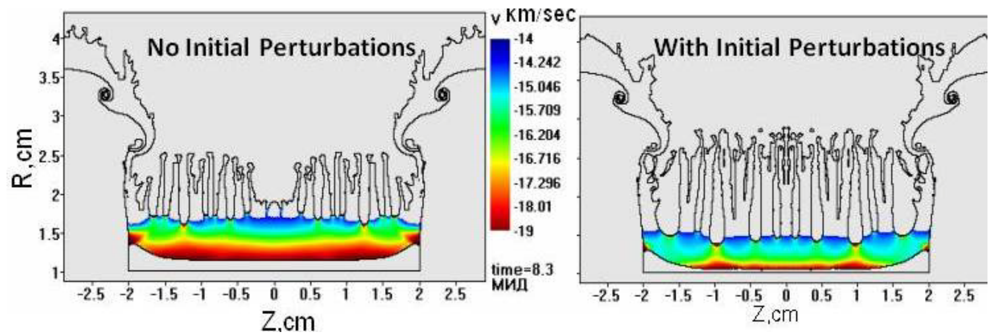

Figure 3, VNIIEF 2-D combined Lagrangian/Eulerian calculation of ALT-3 liner implosion showing precision of the liner inner surface just before impact on the target. Calculation with (a) and without (b) explicitly imposed perturbations are shown.

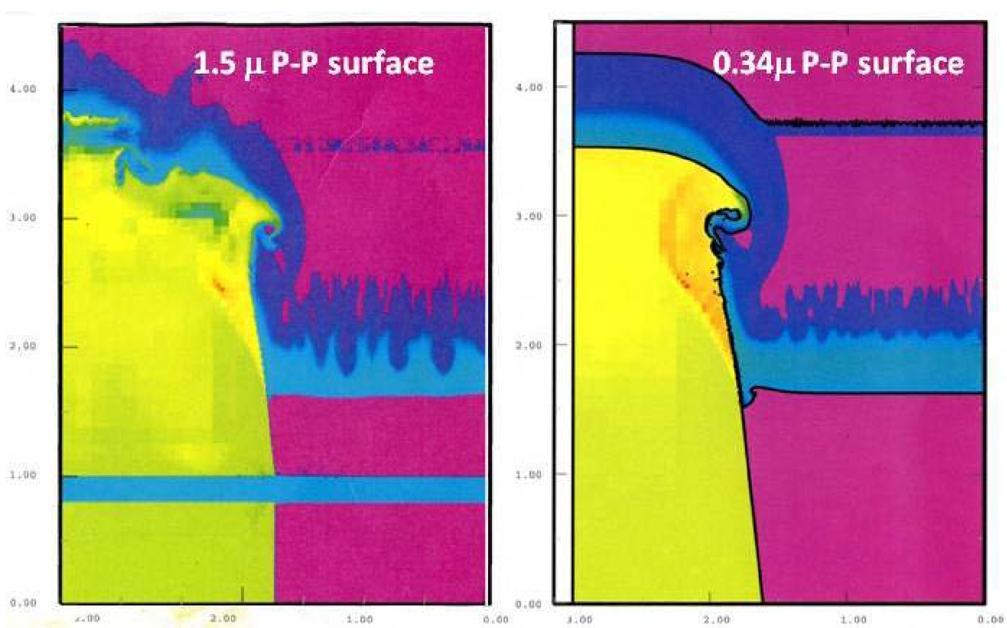

Figure 4, LANL 2-D Eulerian calculation of ALT-3 liner implosion showing condition of the liner inner surface a few mm before impact on the target. Calculation with 1.5 m initial perturbations (a) and with 0.34 m explicitly imposed perturbations are shown .

2.. Controlled Compression experiments

Exploring the effect on material strength that is imposed by large deformation, at high rates of strain is another current question in modern material science. In 1974 Barnes in Los Alamos and shortly thereafter, and continuing, Rayevski in Sarov, applied the perturbation growth method to the assessment of material strength at high rates of strain. In this method a metal surface, with initially imposed single mode, multi mode, or random perturbations is subjected to acceleration by a light fluid, such as HE detonation products in a geometry that is Rayleigh-Taylor unstable. Time resolved imaging techniques (typically x-ray imaging) is used to evaluate the subsequent amplitude and rate of growth of the initially imposed perturbations, and strength parameters are inferred from simulations, using the bulk motion of the sample is used as a check on the experimental drive pressure (which for HE can vary significantly.) Because relatively short wavelength peruturbations can be used, high strain rates can be obtained, and relatively high growth rates of the perturbations observed.

To improve the controllability of the drive and to remove some of the uncertainty in driving pressure, the HE product drive can be replaced with magnetic drive. To eliminate ohmic heating effects, resulting from the drive current, a well understood working fluid can be introduced between the perturbed surface of the sample material and the inner surface of the electromagnetically driven liner. VNIIEF and LANL cooperated in designing and executing a series of experiments utilizing a multi-layer configuration, driven by a flux compression generator, and diagnosed with imaging x-ray recording.

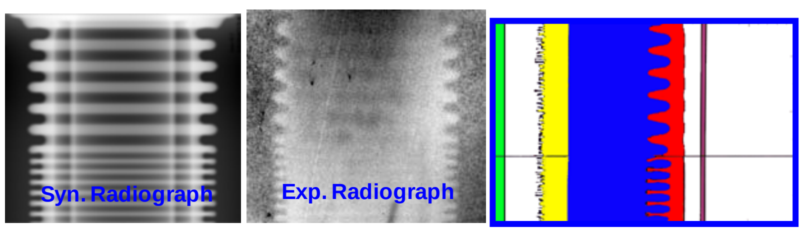

Fig 5 The three layer liner provides a highly controllable platform for perturbation growth experiments

Experiments evaluating the behavior of material strength in copper at high rates of strain demonstrated that while time independent strength models were adequate at for strain rates of a few 10^5/second (resulting from imposition of longer, 4mm wavelength perturbation), such rate independent models were inadequate to describe copper behavior as strain rates approach 10^6/second (resulting from imposition of shorter 2 mm wavelength perturbations). Data also indicated that polymer working fluids (polyethylene) displayed material strength 16-20 times larger than static when strained at rates above 10^5/second.

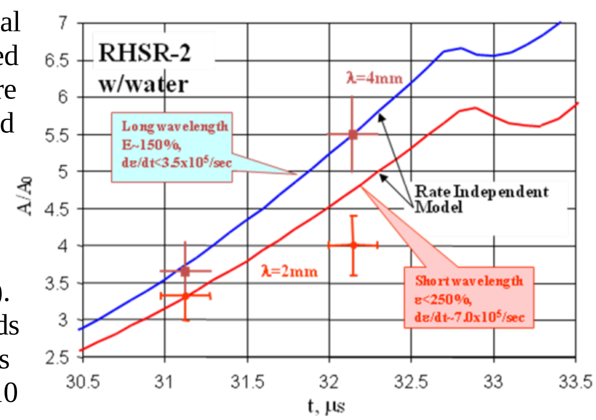

Fig 6 Perturbation growth results for copper

3. Production of Very Large Internal Energy in Dense Matter

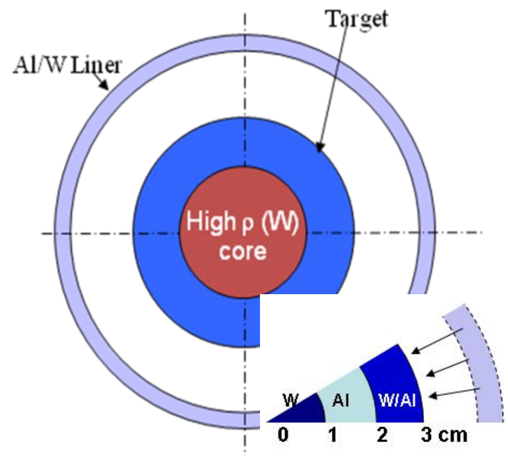

Figure 7. WDM conditions can be created using liner impact.

"Warm Dense Matter" is a state intermediate between condensed matter that is the subject of most traditional shock-physics work and traditional plasmas. Typically described as material at densities between half normal densities and two to three times normal densities and temperature from a fraction to a few electron volts, the conditions for warm dense matter are notoriously hard to create, maintain or access for measurements. Experimental difficulties in studying these states is matched only by theoretical complexity of describing their behavior. Liner implosion techniques, compressing an initially solid target, can convert many megajoules of liner kinetic energy into internal energy producing WDM while requiring only modest precision from the liner impactor. In hydrodynamic design calculations, an aluminum liner imploding at 10 km/sec (2 MJ/cm of height) compresses a matched aluminum target to 8 gr/cc (3X normal density) and energy densities approaching 140 kJ /gram (<1MJ/cc) at a few eV, and maintains these conditions for several hundred nanoseconds. Compressing the aluminum sample between a tungsten liner imploding at 10 km/sec and a tungsten anvil in coaxial geometry reach densities of 10gr/cc (>4X normal) and 150 kJ/gr (1.5 MJ/cc) in design calculations. Techniques producing 20-30 MJ of liner kinetic energy at 5-8 MJ/cm of height with velocities approaching 10 Km.sec have been demonstrated. Systems such as ALT-3 can be designed to achieve very high liner velocities with large kinetic energies. Since the precision requirements are substantially lower than those needed for EOS measurements, application of liners to producing warm dense matter should be practical.

Material Properties

Both the empirical measurement and the modeling of the fundamental properties of materials emerged, early, as an area in which LANL had common interests with both VNIIEF and VNIITF. With the exception of the dynamic properties of some materials under the most extreme conditions and most dynamic properties of a few materials such as plutonium, fundamental material properties are unclassified, non-sensitive, and fertile ground for scientific cooperation. Several specific areas emerged as leading candidates for cooperative investigation. 1) Aging of Pu, especially modern modeling techniques such as Molecular Dynamics Simulations, 2) Constitutive properties including damage mechanics of widely studied "reference" materials (eg. aluminum, copper, tantalum) for which there is much relevant date in the literature for comparison and 3) Measurement and modeling of the unique properties including phase transition and kinetics of the challenging "f-electron" materials, using cerium as a first example

1. Molecular Dynamics Studies of Pu Aging

The development of physical models of the time evolution of the material properties of plutonium resulting from self-irradiation requires an understanding of physical mechanisms at microscopic (atomistic) scales. The only technique for direct theoretical investigation into the processes arising from self irradiation and their effect upon macroscopic properties of the material is the molecular dynamics (MD) simulation. LANL and VNIIEF have cooperated in MD investigations into the mechanisms of defects formation and the accumulation of decay products in plutonium due to self-irradiation. Preliminary models have been develop describing the accumulation and saturation of point-like defects within single-crystals, based on MD simulation of point-like defects mobility and damage region annealing. The effect of decay product accumulation on the thermodynamic and mechanical properties was evaluated through comparison of perfect and defect-containing (single) crystals in MD simulations. Models developed for the behavior of single crystals are being expanded to explore the behavior at grain boundaries -- allowing assessment of the impact of point-like defects and decay product accumulation on the behavior of real (multi-crystal) samples. In addition, the metastability of the fcc phase is also being explored with MD simulations.

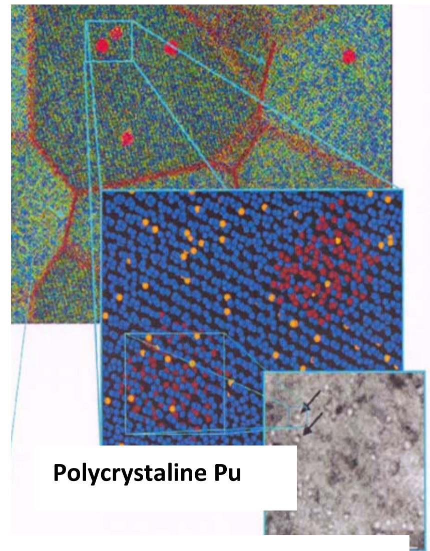

Fig 8. MD simulations of mult-crystaline Pu under aging.

B. Constitutive Behavior and Damage Mechanisms

The formulation of mathematical models, especially continuum models, for predicting the response of materials when they are subjected to thermo-mechanical loading is also an active area of research in Russia and in the US, included the development of models for predicting the constitutive response, and the initiation and evolution of damage. Successful development of such predictive models frequently relies on experimental data obtained from laboratory tests carefully designed to evaluate particular thermo-mechanical responses or mechanisms. The physical measurements motivate and support the development of theoretical models -- models which can be implemented into a variety of numerical methods, thereby providing general-purpose predictive tools. The suite of experimental techniques includes: split Hopkinson pressure bar (SHPB), Taylor cylinder, flyer plate impact, quasi-isentropic and shock loading by the expansion of HE detonation products. Metallographic analysis is used to assess micro-structural morphologies.

Models of well studied, reference materials such as aluminum, copper, tantalum, are the starting point, leading subsequently to models of more complicated materials, such as discussed below. Issues under investigation include, the effect of grain size on constitutive behavior and the mechanics of damage; the effect of deformation localization on constitutive behavior and the mechanics of damage; the evolution in both the time and space of grain morphology and deformation localization; time-scale effects related to transient thermal softening associated with deformation localization—both as it affects constitutive behavior and as it affects damage initiation and evolution; the mechanisms involved in damage compaction and the apparent ”healing” of previously damaged materials; the effects of such “healing” on subsequent constitutive behavior and sequel damage evolution; the convergence of cylindrical channels under

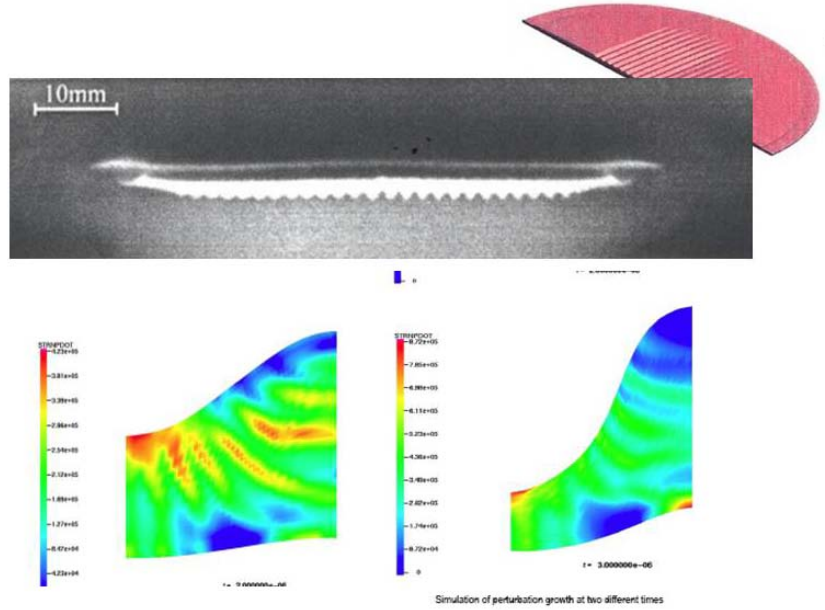

Fig 9. Application of perturbation growth techniques for assessing material strength at high rates of strain

shock loading; and the time dependent formation of heterogeneous structures on damage nucleation

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C. Theoretical and Experimental Exploration of Phase Transition, Transition Kinetics, and Damage, in "f-electron" Metals (Cerium)

The development of methods for calculating the properties of strongly correlated electron systems is currently an area of very active research in the US, Russia and around the world. In strongly correlated materials the electrons occupy incompletely filled 3d (transition metals), 4f (lanthanides), or 5f (actinides) orbitals. Such materials, for example, cerium and plutonium, have electronic structures that are neither ionic nor free-electron-like, but a mixture of both. There is competition between delocalization, leading to band formation, and a tendency toward localization and atomic-like behavior. Density functional theory (DFT), which is a very successful ab-initio approach for predicting the ground-state properties of weakly correlated solid state systems, metals in particular, fails in strongly correlated materials. The strong correlations preclude a description in terms of well-defined quasi particles; hence, band structure methods are not sufficient and a genuine many-body approach is necessary. One of the most successful approaches for incorporating many-body physics is the powerful, but yet practical, dynamical mean field theory (DMFT), in which the solid-state many-body problem is mapped onto a quantum impurity model. Recently, DMFT was combined with LDA (local density approximation) This LDA+DMFT approach combines the advantages of LDA, a successful method in the weak-correlation limit, with a correct description of the correlations within DMFT.

In a joint LANL/VNIITF project, the LDA+DMFT was used to calculate the spectral and magnetic properties of cerium to validate the method. The relative stabilities of the α,γ and ε phases of cerium is being determined by calculating the total energy as a function of volume at zero temperature. Finally a method for calculating inter-atomic forces will be developed. This is an essential step toward the long-term goal of writing a molecular dynamics code based on LDA+DMFT.

VNIITF and LANL have conducted a series of experiments to measure the time-resolved kinetics of the α-ε phase transition in pure iron and 30 CGSA steel, and to investigate the influence of the phase transformation on spallation as a prelude to exploring similar behavior in "f-electron" materials such as cerium. In experiments conducted primarily at VNIITF, the effects of shock-induced solid-solid phase transition and melting on the high-rate stress-strain response of pure cerium is being investigated by mean of Hopkinson bar tests. Phase transformation kinetics have been measured in wedge experiments and wedge experiments with sample recovery for metallographic analysis are planned. Several planar shock wave experiments are also planned to measure stress wave profiles (kinetics) and sound velocities in shock-compressed Ce, and to determine where Ce melts on the shock Hugoniot. The cooperation includes development of preliminary multi-phase equation-of-state (EOS) for Ce by VNIITF, and Los Alamos and VNIITF modelers will jointly develop a theoretical description of the phase transformation kinetics and a preliminary deviatoric constitutive model for Ce.

In addition the LANL/VNIIEF team have explored, experimentally, the mechanisms of porosity and crack formation, spallation, and fracture in Cerium along with work in phase transformation. Experiments include provisions for sample recovery, pre- and post-shot metallography to explore changes in morphology. In conjunction with the metallographic analysis, the shock wave loading structure is recorded to evaluate sound velocities for the higher pressure phases and Hugoniot data. For cerium, Hugoniot data will be obtained in pressures less than 10 GPa where only a few Hugoniot data points to date.

Modeling, Simulation and Computer Science

While computational physics (computer modeling, simulation techniques) and computer science (hardware and system architecture) are obvious areas of common interest among NNSA labs and the RFNCs, and while these topics were identified early as areas for possible cooperation, it was not until the last few years that active collaborations were established.

One recent project, conducted by LANL and VNIIEF, involves the development of mathematically exact solutions for shell structures as benchmarks for large computational analysis codes. Exact solutions to the governing differential equations for shell structures are important for verifying the accuracy of large scale simulations. Thus, the development of such solutions represents an important area of research because large computational analysis codes play an integral role in fulfilling the core missions of both LANL and VNIIEF.

The formulation of mathematically exact solutions for the response of electronic shell structures when subjected to different thermo-mechanical loading states is an area of active research. Current work at LANL has developed solutions for the geometrically linear and nonlinear elastic behavior of shell structures as well as the geometrically linear, history-dependent behavior of such structures for spherically symmetric loading states. Possible areas for extended cooperation include the development of thermo-mechanically coupled physics, i.e., solving both the equations of motion and the energy equation simultaneously, as well as incorporating equation-of-state (EOS) behaviors into the analysis.

Another effort involving LANL and VNIIEF is in the area of multi-material pressure relaxation methods for Lagrangian hydrodynamics and arbitrary Lagrangian-Eulerian hydrodynamics. The numerical simulation of multi-material compressible flows presents numerous modeling challenges. In particular, there are several competing approaches to modeling multi-material cells in the Lagrangian frame under the assumption of pressure relaxation with a single velocity. The main challenge is to accurately assign the thermodynamic states of the individual material components, despite a lack of detailed information about the velocity distribution within such multi-material cells. The relations among these different approaches remain largely unexplored. The objective of understanding these models is to develop new algorithms that are both more accurate and more robust than existing numerical schemes. This activity involves the motivation, description, and quantitative evaluation of algorithms. The quantitative comparison of these algorithms on well-codified test problems forms the rigorous basis by which to evaluate these models.

Prospective:

Since 1992, the directors of the US and Russian laboratories have met occasionally, but the last two years has seen increased encouragement from NNSA and positive reaction from the Labs to extension and even possible expansion of the cooperation. The reaction of the Russian laboratory leaders to cooperative activities has been generally very positive, especially from the leadership of VNIIEF (Sarov) and, in Sandia's experience, from the leadership of VNIIA (Moscow). In June 2011 directors of six laboratories meeting in LLNL identified four high level areas of cooperation including: 1) the traditional S&T cooperations in areas supporting the labs main nuclear security missions; 2) non-proliferation topics; 3) civilian nuclear power and 4) broader energy and environmental topics. In October 2011, US/Russian technical experts meeting in Barcelona explored expanded S&T topics, ultimately identifying a family of 10, relatively detailed, areas of continued or expanded scientific cooperation growing from the Labs core national security missions. From October to March similar portfolios of potential collaboration in non-proliferation and energy topics emerged from the other communities. In June 2012 the Directors met again in Sarov to evaluate progress and to further articulate directions for future research.

In Sarov, in June 2012, each Laboratory Director discussed some of their specific interests. In the S&T arena Los Alamos has named several focus areas for future cooperation.

- The physics of "f-electron" metals starting with Cerium in the Lanthanide series, where physical properties are complex, experimental data is limited or non-existent, theory is complex and difficult; and simulations techniques in their infancy. The breadth and complexity of the topic makes it appropriately described as a Grand Challenge well suited to the capabilities of these Laboratories.
- Nuclear physics data and modeling have played a small part in collaborative projects in the past, but additional work comparing simulations of well documented criticality experiments, and perhaps even new experiments at US and Russian experimental facilities should be considered
- Energetic material physics including explosive initiation, detonation kinetics and failure (including diagnostics, codes and models)formulation, measurements and simulations of excited state properties in common materials (TATB, DAAF).comparison of safety performance characterizations and high explosive–metal interactions. In addition to high performance energetic materials, home-made explosives, their sensitivity, properties and detection are of interest

Several additional S&T topics are also under discussion:

- Expanding the venue of hydrodynamic experiments to include joint work with proton radiography using both US and Russian facilities where high resolution and penetration might allow the recording of unprecedented data sets describing dynamic experiments.
- There is an on-going dialogue on some aspects of Plutonium Science including metallurgy and the physics of aging along with modeling efforts (using atomistic

simulation techniques). Joint experimental projects, such as conducting identical experiments and exchanging data sets – or conducting complementary measurements on similar samples, within controlled topical area and conditions would be valuable.

- Plasma Physics and High Energy Density Physics, has been a topic of some joint theoretical and some simulation work. Except for some fusion-related experiments in the early1990's and some recent analysis of experimental work done by a US graduate student at a US university, plasma topics and HED topics, despite current interest in the community such as the properties of warm-dense-matter, have not been vigorously pursed, and are of interest in the future.

Summary:

Unclassified, non-sensitive technical projects, conducted jointly with the Russian Federal Nuclear Centers provide unique scientific insights in the fundamental physics areas that underpin the principle nuclear defense missions of both NNSA and RFNC. The S&T cooperation has, for the last 20 years, provided a unique opportunity for maintain a level of trust and transparency in basic science with the RFNCs