Review of Advanced Science and Technology
Sponsored by NNSA

Presented to:
The National Academy of Sciences
Board on Physics and Astronomy

Presented by:
Dr. Allan A. Hauer
Chief Scientist, Stockpile Stewardship Office
April 27, 2012
NNSA sponsorship of advanced Science and Technology - Outline

• An impressive tandem increases in experimental and computational power are producing outstanding advances.

• Advances in High Performance Computing continue despite budgetary constraints

• NNSA continues to be an important sponsor of academic research in a number of disciplines
  – High Energy Density Physics
  – Materials in extreme conditions
  – Computational Physics
  – Low Energy Nuclear Physics
  – Astrophysics

• Ignition remains an important if illusive goal
NNSA has been a leader in high performance computing

- NNSA has been a leader in increasing processing power with much needed associated memory
- Our problems are hard: hydro, radiation, multi-dimensional issues, etc.
- ASC will be essential to the upcoming stockpile modernization
- Can we sustain the needed advances in computing? Can we efficiently use future computer technologies? Can we make sure we are computing on US technology?
Advanced Scientific Computing Research

Delivering world leading computational and networking capabilities to extend the frontiers of science and technology

The Scientific Challenges:
- Deliver next-generation scientific and energy applications on multi-petaflop computers.
- Discover, develop and deploy exascale computing and networking capabilities.
- Partner with U.S. industry to develop the next generation computing hardware and tools for science.
- Discover new applied mathematics, computer science, and networking tools for the ultra-low power, multicore-computing future and data-intensive science.
- Provide technological innovations for U.S. leadership in Information Technology to advance competitiveness.

FY 2013 Highlights:
- Co-design centers to deliver next generation scientific applications.
- Investments with U.S. industry to address critical challenges on the path to exascale.
- Operation of a 10 petaflop low-power IBM Blue Gene/Q at the Argonne Leadership Computing Facility and installation and early science access to a hybrid, multi-core computer at the Oak Ridge Leadership Computing Facility.
- Research efforts across the portfolio in support of data-intensive science including the massive data produced by Scientific User Facilities.
Scope of the Plan for High Performance Computing

- Plan tied to 2011 Strategic Plan goal:
  - to maintain “leadership in computational sciences and high-performance computing” with a targeted outcome to continue to develop and deploy high-performance computing hardware and software systems through exascale platforms.

- Plan only covers RD&E for exascale to accelerate access by US scientists by 10 years!

- Platform acquisitions linked to plan but kept separate because:
  - Process to acquire and install large systems well understood and low risk; and
  - System acquisitions are required to support missions
Technical Challenges in the pursuit of exascale computing

• **Energy Challenge:**
  – Achieve energy efficiencies so that, when run at the desired computational rates, the entire system will operate within acceptable power budgets. Achieving the required energy efficiency results in crosscutting challenges for DOE exascale systems because all of the hardware and software components need to be changed dramatically.

• **Parallelism Challenge:**
  – Provide the application developer with a programming model that isolates the developer from the “burden” of unprecedented parallelism and allows the development of energy-efficient applications.

• **Resilience Challenge:**
  – Achieve system-level resilience to both permanent and transient faults and failures so that an application can “work through” these problems.

• **Memory and Storage Challenge:**
  – Develop memory and storage architectures that quickly move large amounts of data to individual compute cores and high storage capacity with minimal power requirements.
SSP requirements are driving advanced physical understanding, which will require Exascale to establish predictive 3D UQ.

SSP Drivers:

- Resolve key remaining simulation unknowns
- Establish predictive UQ and key capabilities

Computer procurements:
- Zia 1PF
- Sequoia 20PF
- Roadrunner

Science simulations:
- Single material Fracture data

Design simulations:
- Initial 3D UQ study
- Pure metal strength data
- 3D Science based models
- 3D IDC ↔ atomistic
- Integrated circuit Radiation damage
- QMD EOS data table
- 3D Predictive UQ study

By 2022, ASC should provide a simulation capability for the SSP to support the Stockpile with confidence using QMU methodologies exploiting predictive UQ capabilities.
Turbulence simulation is an iconic example the need for increased computational power

- **Exaflops**
  - Multi-physics: exothermic reactions, shocks, variable accelerations, radiation.
  - High resolution geophysical flows
  - 50000^3: “Solve” the isotropic turbulence problem?

- **Petaflops**
  - Reacting turbulence with supernova microphysics
  - Full supernova explosions

- **Teraflops**
  - 3D hydrodynamic instability at moderate density ratio
  - Accurate hurricane prediction

- **Gigaflops**
  - Buoyancy driven multi-component mixing
  - 3D hydrodynamic instability at high density ratio with gravity inversion

- **Gigaflops**
  - 128^3 isotropic turbulence

- **Gigaflops**
  - Single mode 2D instability, ~1980.
Multi-scale modeling of materials is requires significant increase computational power

- Controlled fabrication
- High fidelity characterization
- Novel in situ diagnostics
- Generation of realistic extreme environments

- Multi-scale approaches to connect fundamental scales to bulk properties
- Defect generation and evolution
- Failure

- Multi-scale, multi-physics simulation tools
- Ab initio methods applied to larger, more complex materials
Molecular Dynamics has been the unifying paradigm for much of the advanced computational work

Large-scale Molecular Dynamics of Dense Plasmas: The Cimarron Project

Frank R. Graziani\textsuperscript{a}, Victor S. Batista\textsuperscript{b}, Lorin X. Benedict\textsuperscript{c}, John I. Castor\textsuperscript{a}, Hui Chen\textsuperscript{a}, Sophia N. Chen\textsuperscript{a}, Chris A. Fichtl\textsuperscript{b}, James N. Glosli\textsuperscript{a}, Paul E. Grabowski\textsuperscript{b}, Alexander T. Graf\textsuperscript{a}, Stefan P. Hau-Riege\textsuperscript{a}, Andrew U. Hazi\textsuperscript{a}, Saad A. Khairallah\textsuperscript{a}, Liam Krauss\textsuperscript{a}, A. Bruce Langdon\textsuperscript{a}, Richard A. London\textsuperscript{a}, Andreas Markmann\textsuperscript{a}, Michael S. Murillo\textsuperscript{b}, David F. Richards\textsuperscript{a}, Howard A. Scott\textsuperscript{a}, Ronnie Shepherd\textsuperscript{a}, Liam G. Stanton\textsuperscript{a}, Michael P. Surh\textsuperscript{a}, Jon C. Weisheit\textsuperscript{d}, Heather D. Whitley\textsuperscript{a}

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Figure 1: The various domains of non-degenerate vs. degenerate matter, and weak vs. strong plasma coupling in $\rho_e, T$ space are compared with the prevalent conditions in ICF, LCLS and JLF plasmas. Abscissa: electron density $\rho_e$ in electrons/cm$^3$; ordinate: temperature $T$ in eV.
The NNSA Academic outreach program has had major successes

- One project was the recipient of the Schawlow Prize
- Several of the sponsored simulation efforts have received the Gordon Bell Awards
- Bridgman Award for High Pressure Science
- Academic participants have contributed major diagnostic and theoretical tools for NNSA programs
NNSA sponsored simulations are coupled with forefront experiments and have received wide recognition

Gordon Bell Award winners

First simulation of Kelvin-Helmholtz instability in molten metals

VPIC simulation of high intensity Laser-matter interaction

- important component of ignition-level experiments
Support for Academic Research

Centers and Cooperative Agreements
- Grants & Fellowships
- National Laser User Group
- ASC Alliances Centers

Map of institutions supported:
- UC Davis
- UC Berkeley
- Polymath Research Stanford
- UNR
- UNLV
- UCLA
- Cal Tech
- UCSD
- Arizona State
- Brigham Young
- U. Colorado
- Colorado School of Mines
- U. New Mexico
- UT Austin
- Texas A&M
- Rice
- Krell Institute
- CSGF & SSGF
- U. Washington
- WSU
- Stanford
- MIT
- Harvard
- RPI
- SUNY
- Rutgers
- Princeton
- Carnegie
- Artep
- Princeton
- Krell Institute
- CSGF & SSGF
- U. Michigan
- U. Illinois
- U. Cincinnati
- U. Kentucky
- U. Richmond
- Duke
- NC State
- U. Alabama
- Florida State
- New Mexico State University
Over 500 faculty and students were involved in the first 5 ASC Alliance Centers (1998-2010)

California Institute of Technology  
*Center for Simulating Dynamic Response of Materials*

Stanford University  
*Center for Integrated Turbulence Simulations*

The University of Chicago  
*Center for Astrophysical Thermonuclear Flashes*

Flow through a Pratt & Whitney 6000 engine

University of Utah  
*Center for Simulation of Accidental Fires and Explosions*

Simulation of a heptane pool fire

HMX detonation in a tantalum canister

University of Illinois  
*Center for Simulation of Advanced Rockets*

Thermonuclear burn in a Type Ia supernova

3D joint effects in Titan IV SRMU booster
ASC Predictive Science Academic Alliance Program (PSAAP) (2008-2013)

- Focuses on a multi-scale, multi-disciplinary, unclassified application of NNSA interest
- Demonstrates validated simulation capability for prediction
- Supports more than 200 faculty and students
- Benefits: Interdisciplinary teaming focused on solving an overarching problem; cross-fertilization of academic ideas with labs

**PARTNERS:**
- **PURDUE – Center for Prediction of Reliability, Integrity, Survivability of Microsystems (PRISM)**
  - Partners: U of New Mexico, U of Illinois
- **STANFORD – Center for Predictive Simulations of Multi-Physics Flow Phenomena with Application to Integrated Hypersonic Systems**
  - Partners: U of Michigan, SUNY
- **CALTECH – Center for the Predictive Modeling and Simulation of High-Energy Density Dynamic Response of Materials**
- **U of TEXAS, Austin - Center for Predictive Engineering and Computational Sciences (PECOS)**
- **U of MICHIGAN - Center for Radiative Shock Hydrodynamics (CRASH)**
  - Partner: Texas A&M
Workforce Investments

Stewardship Science Academic Alliance (SSAA) trains students in key areas for stewardship not supported by other agencies

- Offers the highest caliber of education and hands-on training and experience to the next generation of scientist and physicists
- Recruiting for NNSA Labs
  - More than 90 SSAA-supported students have taken positions at the NNSA labs since 2002
- Publications Awards
  - Over 1,300 peer reviewed articles published since 2005
- Currently 7 Centers of Excellence and 45 research grants; approx. $30M per year

We must maintain weapons design, engineering, and key manufacturing capabilities yet also create modern era nuclear scientists to sustain the stockpile for decades beyond the last nuclear test.
Graduate Fellowship Programs

These fellowship programs provide outstanding benefits and opportunities to students pursuing a Ph.D. in areas of interest to stewardship science

Computational Science Graduate Fellowship Program
• Started in 1992 by DOE SC and NNSA ASC joined in 1998
• Nearly 350 fellows and alumni have been supported by the program
• Approximately 30% have or are working at the DOE
• Fellows have been attended over 65 universities
• There have been approximately 320 practicum at 13 DOE labs

Stewardship Science Graduate Fellowship (SSGF) Program
• Started in 2006
• Currently 19 students are supported at 14 Universities
• Of the 5 alumni 3 are employed by the National Labs
NIF was used to “quasi-isentropically” compress carbon to 50 Million atmospheres pressure

Gas-filled, room-temperature, stepped target mounted on side of Hohlraum with VISAR cone.

<= flux history for 2 NIF Diamond ramp experiments. 1\textsuperscript{st} experiment (blue) shocked up due to physics understanding. Models and pulseshape were adjusted, NIF delivered ~ exactly what was asked for=> Diamond was ramp compressed to 30-40 Mbar

Raymond Jeanloz UCB, Tom Duffy Princeton, Ray Smith, Jon Eggert, Peter Celliers, Matt Cowan, Gilbert Collins
Precision measurements on Z quantified properties of Be & diamond for the National Ignition Campaign

\begin{itemize}
\item Z data obtained in 1 week
\item Measurements on Z have an accuracy of ≤ 1%
\end{itemize}

\textbf{Stress versus density for diamond}

![Graph showing stress versus density for diamond with QMD predicted region of melt highlighted.]

**Z data**

**QMD**

\begin{align*}
\text{Density (g/cc)} & : 4.75, 5.25, 5.75, 6.25, 6.75, 7.25, 7.75, 8.25, 8.75 \\
\text{Stress (GPa)} & : 400, 600, 800, 1000, 1200, 1400, 1600
\end{align*}

\begin{figure}
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\includegraphics[width=\textwidth]{stress_density_graph.png}
\caption{Stress versus density for diamond with QMD predicted region of melt.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{pressure_density_graph.png}
\caption{Pressure versus density graph with melt onset and melt completion points.}
\end{figure}

\textbf{Z data obtained in 1 week}

\textbf{Measurements on Z have an accuracy of ≤ 1%}

\textbf{Shock-Wave Exploration of the High-Pressure Phases of Carbon}

M. D. Knudson, et al. Science 322, 1022 (2008); DOI: 10.1126/science.1165273
Magnetically-driven isentropic compression (ICE) on Z provides high quality dynamic material property data

- **Quasi-Isentropic Compression (ICE) on Z**
  - Multi-megabar
  - Centimeter sized samples millimeters thick
  - Ramp durations that are reasonable to approximate isentropic compression based on theoretical investigations

ICE measurements can be done in a containment system
Emerging capabilities address fundamental questions in planetary and condensed matter physics

**NIF allows access most of these states for the first time**

- **FOR EXAMPLE:**
  - Jupiter: luminosity data + EOS models + evolutionary $\Rightarrow$ calculated age = 4.7 GYr
  - Age of our solar system = 4.6 Gyr
  - Saturn: Using the same models + luminosity data from Saturn, it “looks” to be only 2.1 GYr old!
    - The difference may be due to inhomogeneous mixing of He/H!
Links between HED laboratory expts. and astrophysics are becoming stronger

Figure 1. Artist’s conception of a cataclysmic binary system. Infalling matter from the companion star falls onto the accretion disk surrounding a white dwarf star, producing a radiative reverse shock and complex interactions.

Figure 2. Radiative reverse shock produced at Omega by impacting a supersonic tin plasma on a tilted aluminum wall. Image at 34 ns.

Work performed by the CLEAR Center at U. Michigan
Lead by Prof. Paul Drake
NNSA sponsors a broad spectrum of High Energy Density Plasma Activities

• The pursuit of ignition at the National Ignition Facility remains the largest experimental activity in NNSA Defense Programs.
  – A major effort in diagnostic development is part of this effort

• Other High Energy Density Plasma experiments are also a major emphasis
  – Materials under extreme conditions
  – Atomic physics in dense plasma conditions

• The NNSA Academic outreach program has had major successes.
  – One project was the recipient of the Schawlow Prize
  – 2 of the sponsored simulation efforts have received the Gordon Bell Award
  – Bridgman Award for High Pressure Science
  – Academic participants have contributed major diagnostic and theoretical tools for NNSA programs
In addition to increasing computational power, NNSA is also considering major new experimental capabilities

• Measurements of materials in extreme conditions
  – The MARIE concept at Los Alamos is one suggestion in this area

• Enhanced laser capabilities for HED research
Materials research is on the brink of a new era – from observation of performance to control of properties.

The confluence of unprecedented experimental capabilities (e.g. 4th generation light sources, controlled synthesis and characterization, …) and simulation advances are providing remarkable insights at length and time scales previously inaccessible.

New capabilities will be needed to realize this vision:

- In situ, dynamic measurements
- simultaneous scattering & imaging
- of well-controlled and characterized materials
- advanced synthesis and characterization
- in extreme environments
- dynamic loading, irradiation
- coupled with predictive modeling and simulation
- materials design & discovery

MaRIE 1.0, building on LANSCE success, is a key first step towards this vision.
The challenge is to observe the dynamic evolution of polycrystalline materials including Pu at the granular and sub-granular level.

**The goal**

Predict dynamic microstructure and damage evolution

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**Sub-μm resolution**

100’s – 1000’s μm samples

Sub-ns resolution,

~30 frames in 1 μs duration

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**The first experiment:** Multiple, simultaneous dynamic in situ diagnostics with resolution at the scale of nucleation sites (< 1 μm; ps – ns)

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**The model:** Accurate sub-grain models of microstructure evolution coupled to molecular dynamics.
The achievement of igniting conditions will open new frontiers in plasma research

- Plasma temperatures > 20 keV; compressed densities > 1000 gm/cm$^2$; pressures ~ 1 Tbar
- Performing detailed measurements under igniting conditions will present a considerable diagnostic challenge.
- The high performance implosions and high temperature hohlraums needed for ignition can also be employed in a variety of non-ignition basic science investigations.
  - Planetary and astro-physics
  - Materials under extreme conditions

The extraordinary capabilities at NIF are also being applied to variety of non-ignition experiments
NIF is operational and performing a wide variety of Experiments in addition to those focused on ignition.
### NIC Experimental Plan for remainder of FY12

#### Cryo and layered shots

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- **Hohlraum characterization**
- **Platform Commissioning**
- **First Pass CHSi Tuning**
- **Shape**
- **Pressure**
- **Mix evaluation**
- **Alpha heating**
- **Precision tuning**
- **Ignition**

**Gain** = DT Yield/Laser Energy into Hohlraum

**Ignition** \( \equiv \) **Gain** = 1

\*ITFX = 0.3 – 0.5

\*ITFX \( \geq \) 1.0

![Diagram showing experimental plan with stages and ITFX values]
Code predictions lead to following theoretical expression for ignition margin

\[
\text{ITF} = I_0 \left( \frac{M_{DT}}{M_0} \right) \left( \frac{v}{v_0} \right)^8 \left( \frac{\alpha}{\alpha_0} \right)^{-4} \left( 1 - 1.2 \frac{\Delta R^{K-wtd}}{R_{hotspot}} \right)^4 \\
\times \left( \frac{M_{clean}}{M_{DT}} \right)^{0.5} (1 - P_{HS}).
\]

Haan et. al, Phys. Plasmas 18, 051001 (2011)

This is compared to experimental results:

\[
\text{ITFX} = \left( \frac{Y}{Y_0} \right) \left( \text{dsf}/0.07 \right)^{2.3}
\]

We are making progress, but slowly
January 2012 NIC Review - Gaps in Understanding

- **SYMMETRY**
  - Laser energy deposition and LPI effects remain uncertain for cases in which the laser drive is changed from proven tunes
  - Changes in applied laser power sometimes result in implosion shape different than expected
  - Needed: improvements in understanding of laser-hohlraum interactions

- **ABLATOR BEHAVIOR**
  - Improved non-local thermodynamic equilibrium (NLTE) models & correction for laser entrance hole (LEH) size partly explain low velocity & increased thickening of ablator in-flight
  - NLTE models predict formation of double ablation front (leads to additional shocks & increased ablator entropy) which leads to increase in ablator width & decrease in density
  - Models suggest that replacing Ge-doped CH with Si-doped will result in lessened NLTE effects
  - No clear path for testing Be ablators even though these may be less susceptible to NLTE effects
  - Needed: experimental data to confirm or further elucidate model results
January 2012 NIC
Review Gaps in Understanding

• MIX
  – Recent results indicate that ability to control mix will be key to obtaining ignition
  – At high velocities ablator shell can be unstable, can break apart, and can introduce cold DT into hot DT core
  – Surface irregularities (ablator, DT ice, or material interfaces) can result in growth of instabilities
  – Needed: well-designed program of deliberate variation in these factors (e.g., Remington plan)
Workshop on the science of Fusion ignition on NIF
The path to predictive capability for icf ignition physics

Bill Goldstein
April 2, 2012
Goals

- Engage and expand the community of scientists interested in exploring science of ignition on NIF
- Form the basis for future efforts to explore underlying physics needed to understand ignition designs for a range of applications
- Identify paths leading to improved integrated design capabilities
- Maximize the utility of NIC results for broader ICF/IFE community
Panel structure

- Laser propagation and X-ray generation
- X-ray transport and ablation physics
- Implosion hydrodynamics
- Stagnation properties and burn
- HED Materials cross-cut: opacity, EOS
- Integrated modeling
Deliverables

• Each panel provide, in a presentation and report section:
  – What underlying physics is important in understanding and modeling this process
  – How is the process currently modeled; what approximations are made; what improvements could be made in the short term?
  – What have we learned experimentally about the process?
  – What are the important current unknowns or uncertainties, and why (sensitivity)?
  – How can/should they be addressed or further investigated, through experiment, diagnostic development, theory and modeling?
  – What new diagnostics are required in this area?
  – Identify at least one high priority research activity with a champion and a set of near term actions

• Organizers to produce final integrated report identifying themes, guidance and requirements for future research programs, with multi-year research directions prioritized based on the workshop goals.
Conclusions

• NNSA remains committed to a strong computational and experimental research agenda
• Interaction with the broader scientific community is increasing.
• NNSA continues a strong program of academic outreach
• The pursuit of ignition will continue but other HED priorities will receive increased priority
Backups
NNSA sponsors a variety of academic outreach programs spanning both experiment and computation

- **Graduate Fellowships**
  - 35 Students in experimental and theoretical pursuits

- **Competitively awarded individual and small group grants**
  - 57 Awards

- **Competitive awards to moderate size centers ($750K -$3.0M)**
  - 14 Centers ranging from materials science, plasma diagnostics, computational science and other activities
NNSA sponsors a variety of academic outreach programs spanning both experiment and computation

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Measuring the astrophysically-relevant low energy neutron spectrum using GRH in NIF capsules

PI : L. Bernstein (LLNL)

Scientific Objective: Develop a capability to measure the low-energy ($E_n<200$ keV) neutron spectrum responsible for the formation of most of the elements above Fe ($Z=26$).

Experiment Description: We will use GRH to observe “late-time” (≥ 250 ps) gamma-rays from neutron capture on the gold in the hohlraum and an additional external diagnostic band. This information is needed to allow for the measurement of the “stellar thermal” component of the NIF neutron spectrum needed for astrophysical nucleosynthesis studies.
Recent graduates from NNSA Academic Programs are now staff members at various national laboratories

Dr. Eric Harding
Sandia Nat. Labs.

Dr. Seth Root
Sandia Nat. Labs.

Dr. Nenad Velisavljevi
Los Alamos Nat. Lab.

Dr. Amy Cooper
Lawrence Livermore Nat. Lab.
Important advances in experimental and computational power have occurred.

• **National Ignition Facility (NIF)**
  - Only access to burning plasma conditions
  - Important mission experiments have already been performed

• **Omega EP**
  - Sophisticated high irradiance capabilities
  - Important venue for advanced fusion research

• **Z Machine**
  - Key venue for materials science measurements
  - Outstanding new results at 4 Mbar.

• **Enormous increase in computational power**
  - Peta-flop performance utilized for important developments in plasma science
  - 20 PF in 2012
Recent advances in laser-plasma interaction science required Petaflop-scale simulations

- Laser-plasma interaction (LPI) is a source of uncertainty in inertial confinement fusion experiments – LPI scatters laser beams & makes hot e\(^{-}\) that preheat capsule
- With Petaflop/s supercomputing and the best-in-class VPIC simulation code, ab initio “at scale” kinetic modeling offers insight into*:  
  - Electron trapping - lowers onset threshold for stimulated Raman scattering (SRS)  
  - The nonlinear physics that saturates SRS

* Yin et al. PRL 2007; PoP 2009
Generation of characterization of highly compressed matter

PI: P. Neumayer (GSI), R. Falcone (UC Berkeley)
Collaborators: R. Redmer (Rostock); E. Forster (Jena); P. Davis (UC Berkeley); H. Lee, G. Hays (SLAC/LCLS); R. Hemley (Carnegie Institution); S. Rose (Imperial College); S. Glenzer, P. Celliers, J. Eggert, D. Milathianaki, S. LePape, T. Doppner, C. Fortmann, A. Kritcher, J. Hawreliak (LLNL)

Scientific Objective:
(1) Test first principle DFT-MD calculations of EOS and other properties of warm dense matter via shock compressed matter expts. diagnosed with x-ray Thomson scattering
(2) Determine absolute equation of state and pressure-induced ionization for 10-1000 TPa regimes to understand and model material under shock loading

Experiment Description:
(1) Planar geometry experiments will use multi-shock compression
(2) High pressures to be obtained in convergent geometries
Measurements of properties of hydrogen and methane at ultra-high pressures

PI: R. Jeanloz (UC Berkeley)/P. Loubeyre (CEA); R. Hemley (Carnegie Institution)
Collaborators: S. Bryggo (CEA); A. Goncharov, A. Dalton, S. McWilliams (Carnegie); D. Fratanduono (UR/LLE); J. Eggert, R. Rygg, R. Smith, R. Collins (LLNL)

Scientific Objective:
(1) Provide data used to test planetary evolution models relevant to extrasolar planets
(2) Determine absolute equation of state and pressure-induced ionization for 10-1000 TPa regimes to understand and model material under shock loading

Experiment Description:
(1) Using mini-DAC and indirect drive configurations, test predictions for plasma phase transitions; provide highest pressure H shock data ever collected; ultra-high pressure melt curve; look for Wigner crystal state
(2) Using ramp compression platform under development at NIF, determine optical-electronic properties and phase diagrams of hydrogen and methane at high densities and low temperatures
The pursuit of ignition will dominate the agenda at NIF through 2012

• 3 major series of ignition experiments are planned for 2010-2012.
  – The plan is to transition to development of an “ignition weapons physics platform”
  – This “platform” development shares many common goals with energy research
    • Robust operation, moderate to high gain

• The diagnostic suite will be rapidly evolving during this period.
  – Installation of Neutron imaging began in 2010
  – Several beam lines of the ARC backlighting system will be available in 2012.
  – Detailed burn history measurements were begun in 2010
  – Diagnostics that may be unique to the energy mission should be under consideration now.

The schedule for the first ignition attempts is somewhat behind the projection presented at the ‘09 FPA meeting
NNSA relies on intermediate scale plasma science facilities for basic science support

Examples of intermediate size plasma facilities:

- Jupiter at LLNL (lasers): support of NIC and NIF; mission; users
- Trident at LANL (laser): support of NIF and NIC; mission; users
- Texas Petawatt at UTX (laser): discovery-driven research; users
- Z-Beamlet / Z Petawatt at SNL (laser): diagnostic for ZR; users
- Nevada Terawatt at UNR: pulsed power

Intermediate-size plasma facilities provide both direct and indirect mission support, and we are encouraging user access at our intermediate facilities
NIF will provide unprecedented capabilities to study matter at high-energy density conditions.
The unique laser capabilities and extensive diagnostic suite enable cutting edge research at Trident.

Scope of Research on Trident:
- Relativistic Laser-Matter Interactions
- Fast Ignition Science
- Novel Laser-driven accelerators
- Novel X-ray source development
- Inertial Fusion Science & HEDP
- Fundamental laser-plasma research
- High-strain-rate Dynamic Materials
Jupiter is a unique multi-platform user facility for high energy-density physics

- Fusion Research
- Material Science
- HED Laser Plasma Physics
The expansion of HED Laboratory Plasma Science continues

• **There has been active work in Laboratory astrophysical experiments**
  - One experiment contributed to Hubble planning
  - A center for Lab Astrophysics has been established as part of the Joint HEDLP Program.

• **Discovery driven, high energy density plasma science**
  This is specifically supported by NNSA through: the HEDLP joint program, User Facilities (including NLUF), LDRD, University programs, workshops and individual contracts.

• **Intermediate –scale plasma science**
  NNSA continues to develop its intermediate scale User Facilities, where peer-reviewed academic use for discovery-driven science is growing

• **Cross-cutting research**
  NNSA is growing its collaborative partnerships with other agencies, institutions, and individuals through WFO, LDRD, User Facilities, and University programs. This is an effective method to optimize cross-cutting research