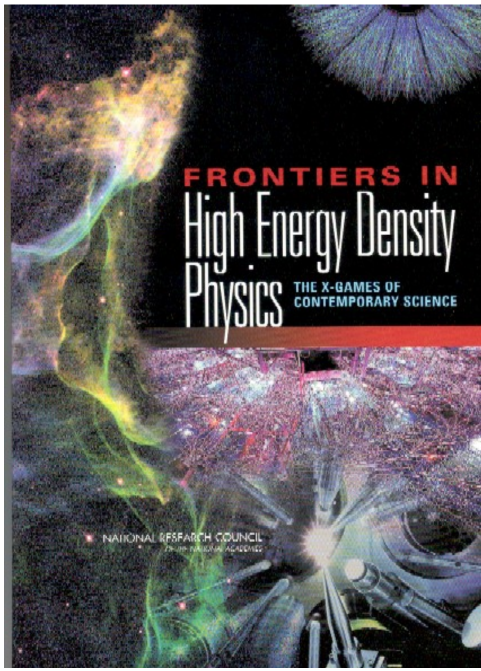
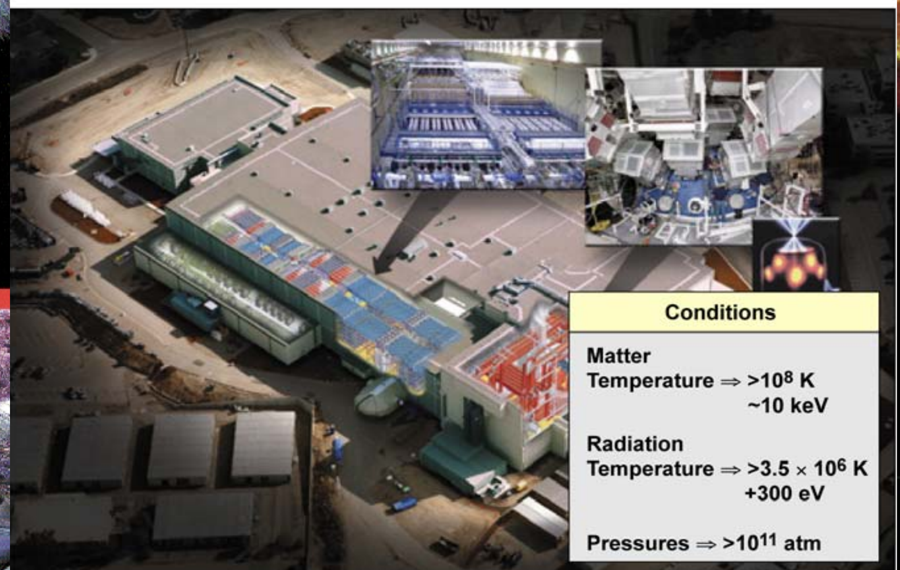
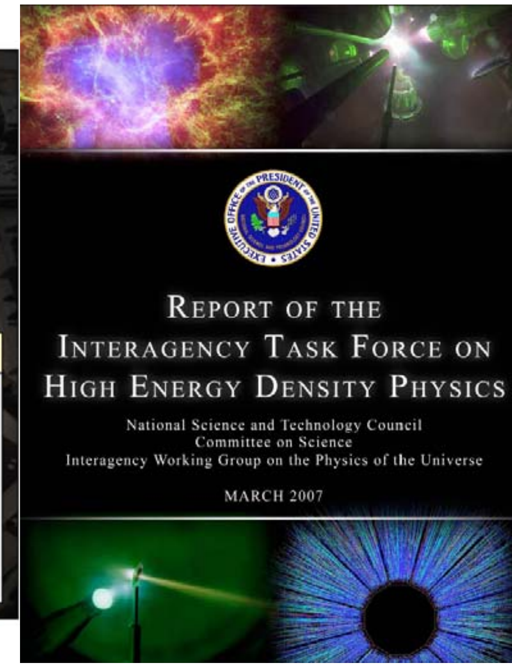
HEDP – A critical discipline in NNSA







Dr. Christopher Deeney

National Nuclear Security Administration/DOE

(202) 586 7416, Chris.Deeney@nnsa.doe.gov

Outline

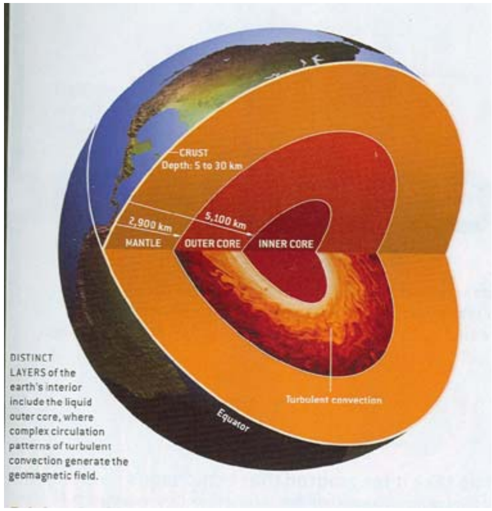
- Motivation for the Stewardship Scientific Academic Alliance Program
- Four Pillars – Dynamic Materials, Low Energy Nuclear, Hydrodynamics and High Energy Density Physics
- Recent solicitation and award of four centers, two in HEDP
  - Our centers have been opening up access e.g. Cornell, UNR
- Where is SSAA going and how will it interface with the new joint program in HED Laboratory Plasmas?
  - HED will remain a topic in SSAA (not all HED is HEDLP)
  - We will collaborate on the Joint Solicitation
  - Due to budget cuts, SSAA will have a smaller solicitation in FY09 and we have had to reduce our contribution to the joint program in FY09

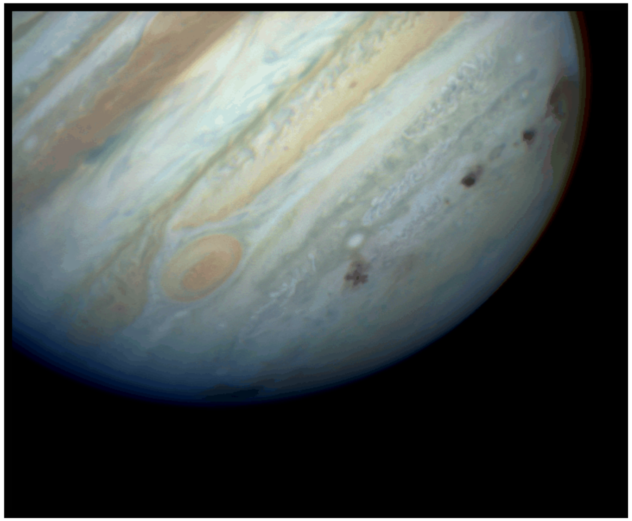
NNSA has a mission to develop improved understanding and predictive models for nuclear weapons in the absence of nuclear testing

- Nuclear weapons are definitely "high energy density physics"
- 100 kilotons in 1 cubic meter is 4.2E8 J/cc, i.e. greater than the 1e5 J/cc definition of high energy density in the NRC report
- Key HEDP areas to support our predictive goals are:
  - Materials at megabar pressures
  - Radiation transport and opacities
  - Thermonuclear burn
  - Electron-ion coupling
  - Warm dense matter – equation of state, viscosity
  - Hydrodynamics, turbulence and material transport

NNSA Mission Needs cover significant HEDP phase space

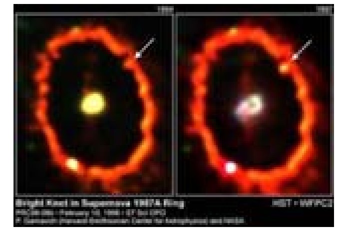
We have to get it right!!!

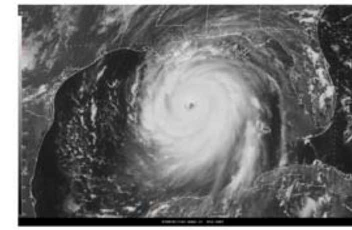




We have to integrate the physics of high pressure dynamic materials, nuclear physics , and high energy density plasmas

We have some major advantages in obtaining predictive capability versus our scientific peers





Extensive integrated observational database

Extensive "controlled" experimental database

Ability to validate physical processes and models

Ability to do controlled experiments to test predictability of the models

Rigorous peer review

Computational capabilities are key to our science program

National Nuclear Security Administration

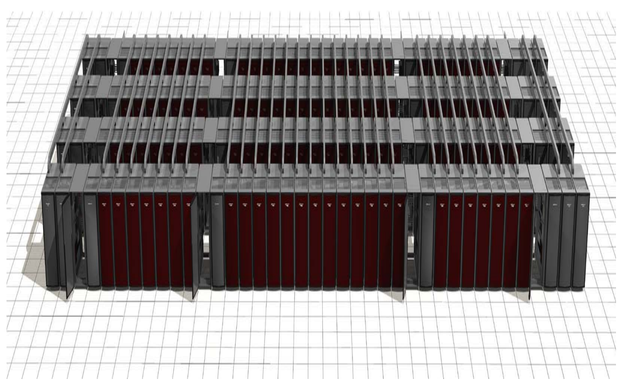
Red – Intel (3TF)
SNL, 1997

Blue Pacific – IBM (3TF)
LLNL, 1998

Blue Mountain – SGI (3TF)
LANL, 1998
RETIRED

White – IBM (12TF)
LLNL, 2000

Q – HP (20TF)
LANL, 2002



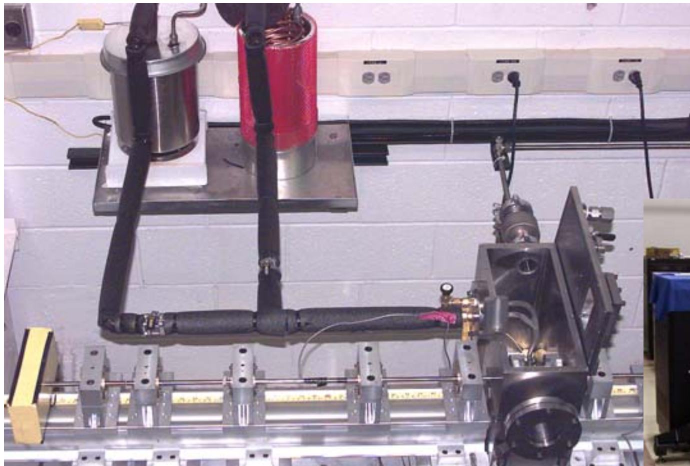
Red Storm – Cray (40TF)
SNL, 2005

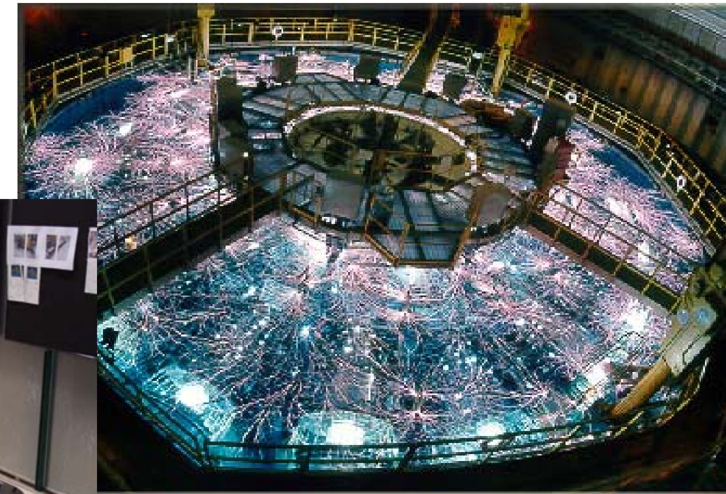
Fifth Generation ASCI Platform

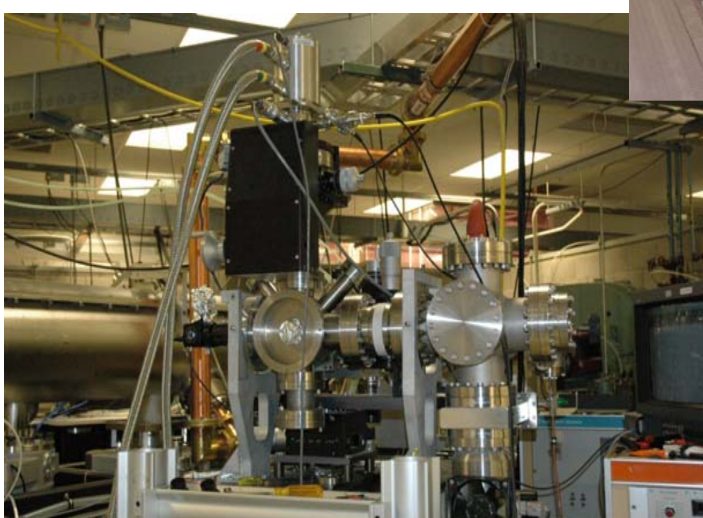
ASCI Purple

Purple - IBM
Purple C (100TF)
Blue Gene/L (180/360TF)
LLNL, 2005

Validation of models and experimental discovery requires experimentation exploring fundamental properties through integrated performance



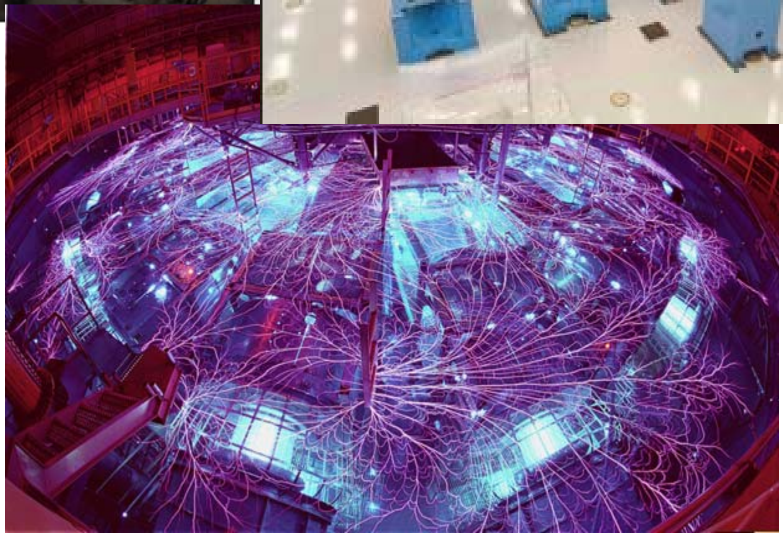




By 2012, we will have an outstanding array of unique facilities to advance high energy density physics

NIF

Omega EP



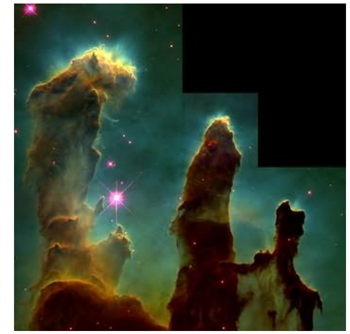
Upgraded Z

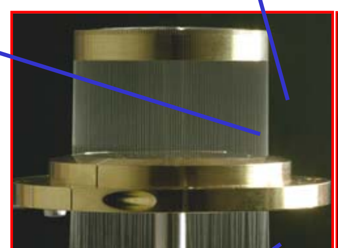
NNSA mission needs have driven the creation of HEDP environments that are ideal to study complex HED plasmas and materials

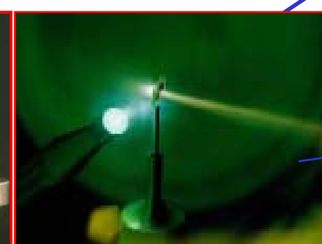
High Mach Number unstable flows

Jets

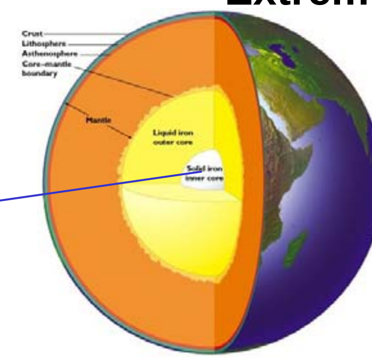
Rayleigh Taylor Instabilities

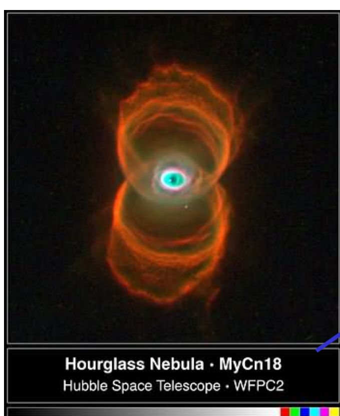




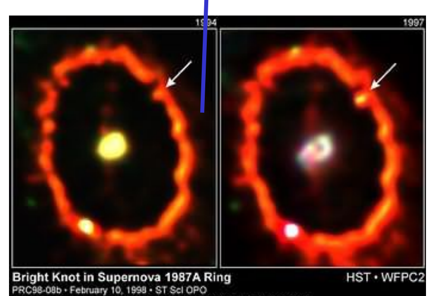


Materials in the Extreme





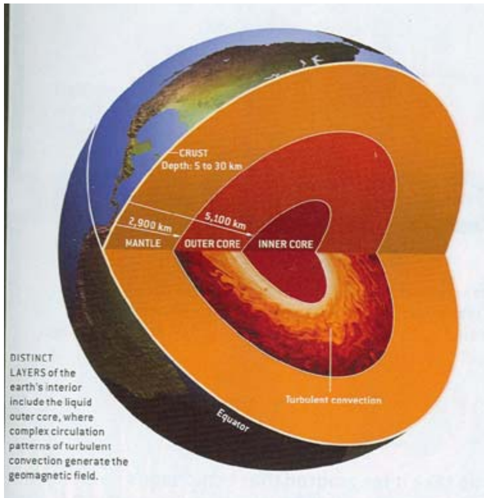
Mass Outflow

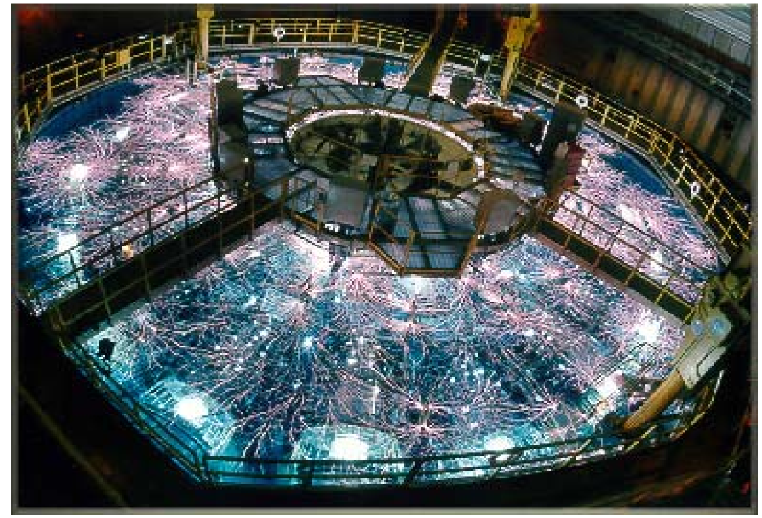


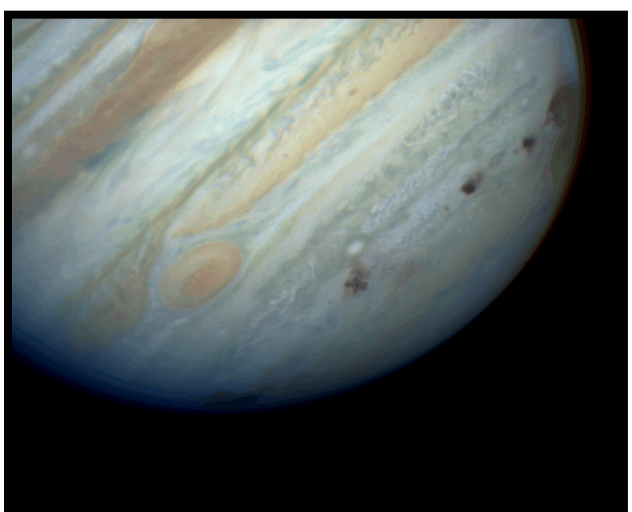
Shocks and radiation transport

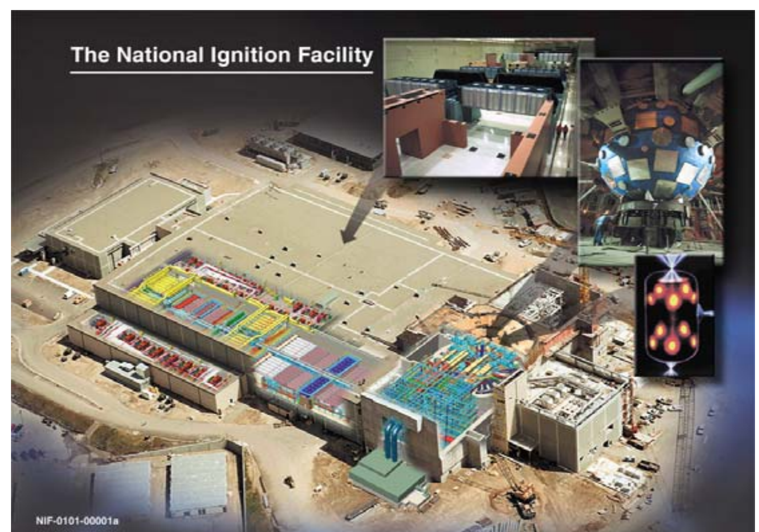
MHD, thermo-electric, and “anomalous” heating

NNSA pulsed power and laser facilities are allowing material properties to be measured at many Mbar pressures

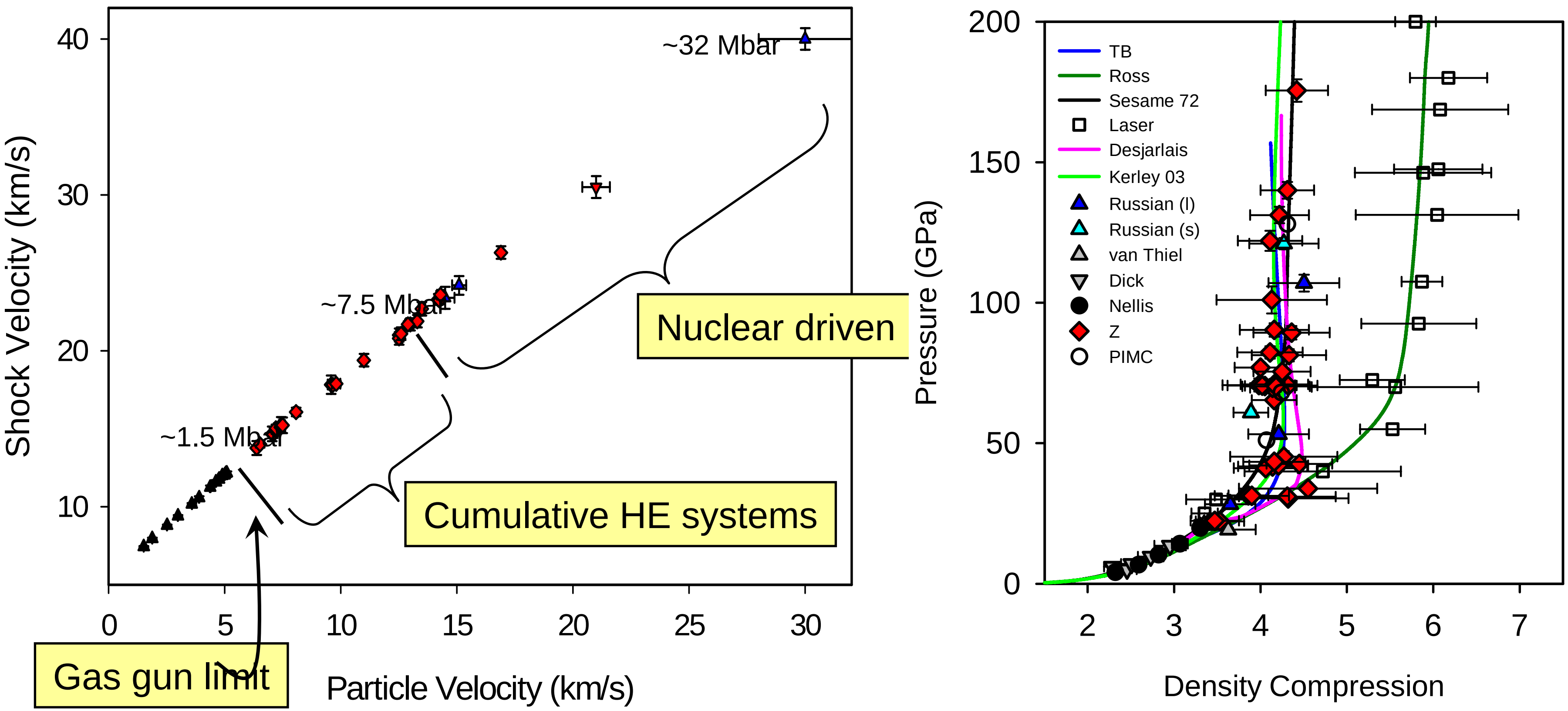








NNSA mission needs have driven phenomenal basic science in the HEDP arena

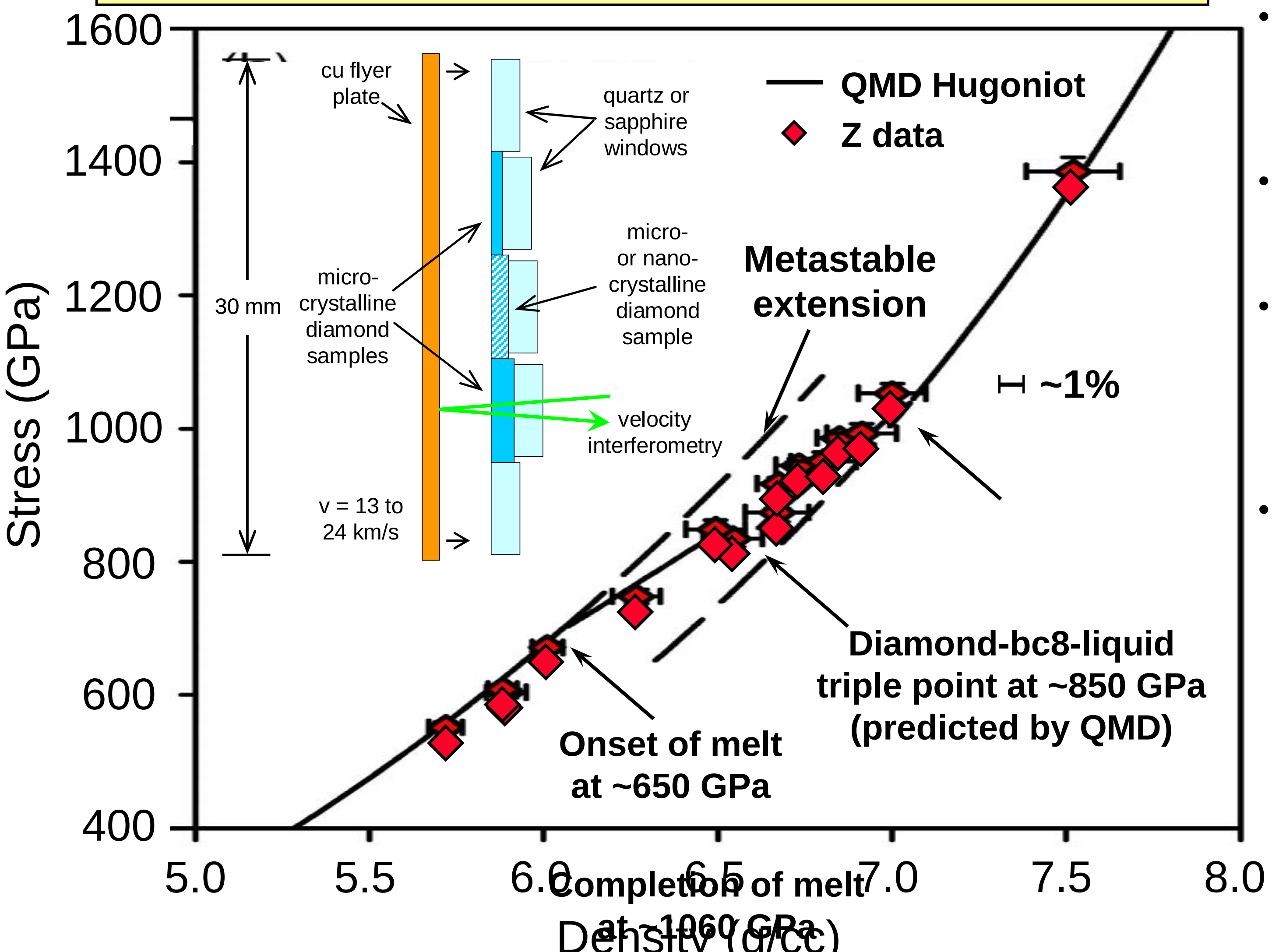


The deuterium equation of state produced multiple PRL and Physical Review papers

Diamond experiments on Z have provided unprecedented accuracy at multi-Mbar stresses

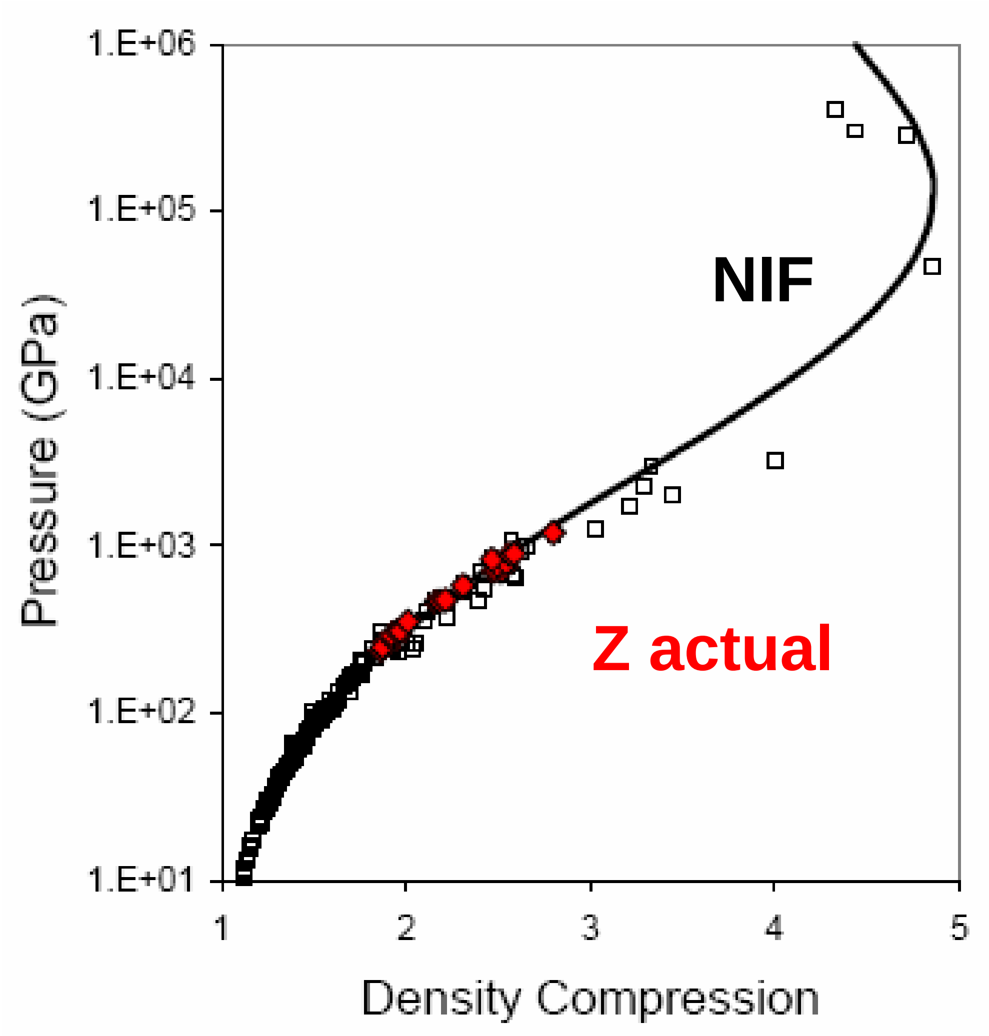
National Nuclear Security Administration

σ – ρ Hugoniot for microcrystalline diamond

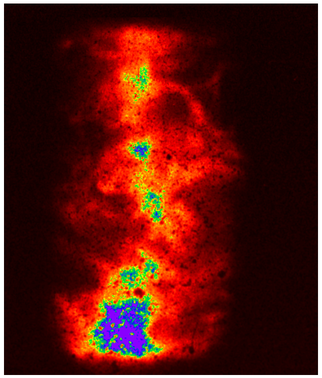


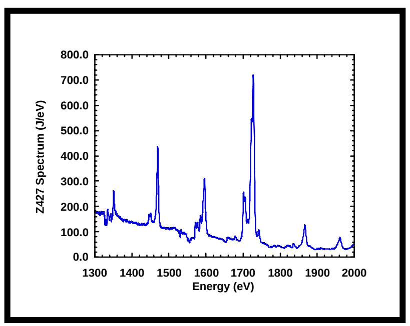
- Multiple, large samples enable high precision measurements
- Density uncertainty of ~1% on average, as low as 0.67%
- High precision allows for quantitative comparison with theory
- These are by far the most accurate Hugoniot measurements of diamond in the multi-Mbar stress regime

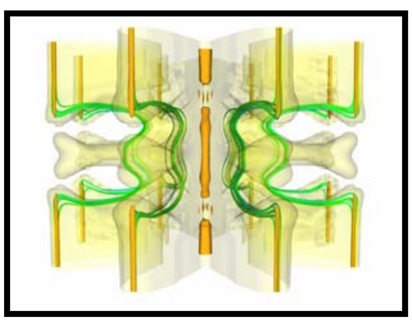
Pulsed Power is providing very accurate high pressure materials data: Laser should get us into regions where ionization dominates



Z-pinches have exciting HEDP plasma issues





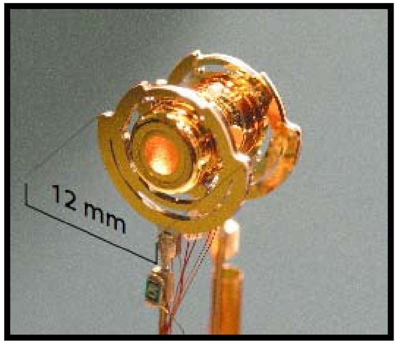


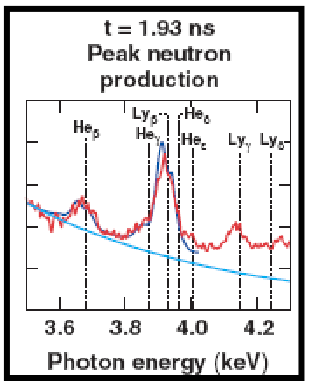
- **Plasma Physics**
  - **Electron-ion coupling**
  - **MHD instabilities and turbulence**
  - **Rayleigh-Taylor and other instabilities**

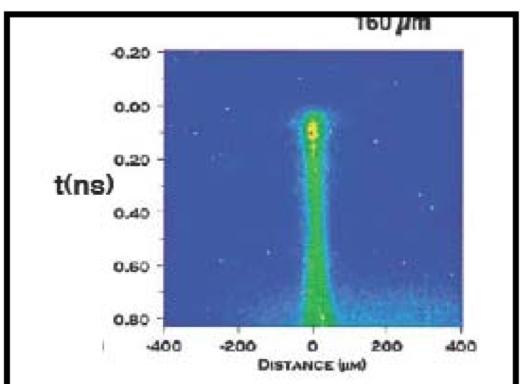
- **Radiation Physics**
  - **Collisional-radiative atomic physics**
  - **High opacities**
  - **Significant radiation transport**
  - **Coupled MHD and radiation**

- **Other plasma physics**
  - **Electron and ion acceleration**
  - **Plasma closing switches and electrical breakdown**
  - **High current electron flow and electrode losses**

Laser-plasma physics and ICF are very rich in HEDP science to explore







- Plasma Physics
  - Laser-plasma interactions and instabilities
  - Beam propagation with intense currents
  - High pressure shocks and hydrodynamics
  - Thermo-nuclear burn
  - Rayleigh-Taylor and other instabilities
- Radiation Physics
  - High density effects
  - High temperature opacities
  - Ultra-intense field interactions
- Other plasma physics
  - Electron and ion acceleration
  - Plasma pockels cells

NNSA created the Stewardship Scientific Academic Alliance and Graduate Fellowships (SSAA and SSGF) to encourage excellent research

SSAA

DYNAMIC MATERIALS

HYDRODYNAMICS

HIGH ENERGY DENSITY PHYSICS

LOW ENERGY NUCLEAR PHYSICS

New Round for centers and grants was completed in FY08

Some still pending funding decisions

New Grant Solicitation in March 2008

SSGF

New Round is Posted
Deadline January 2008
http://www2.krellinst.org/ssgf/

NNSA Support for Academic Research

February, 2007

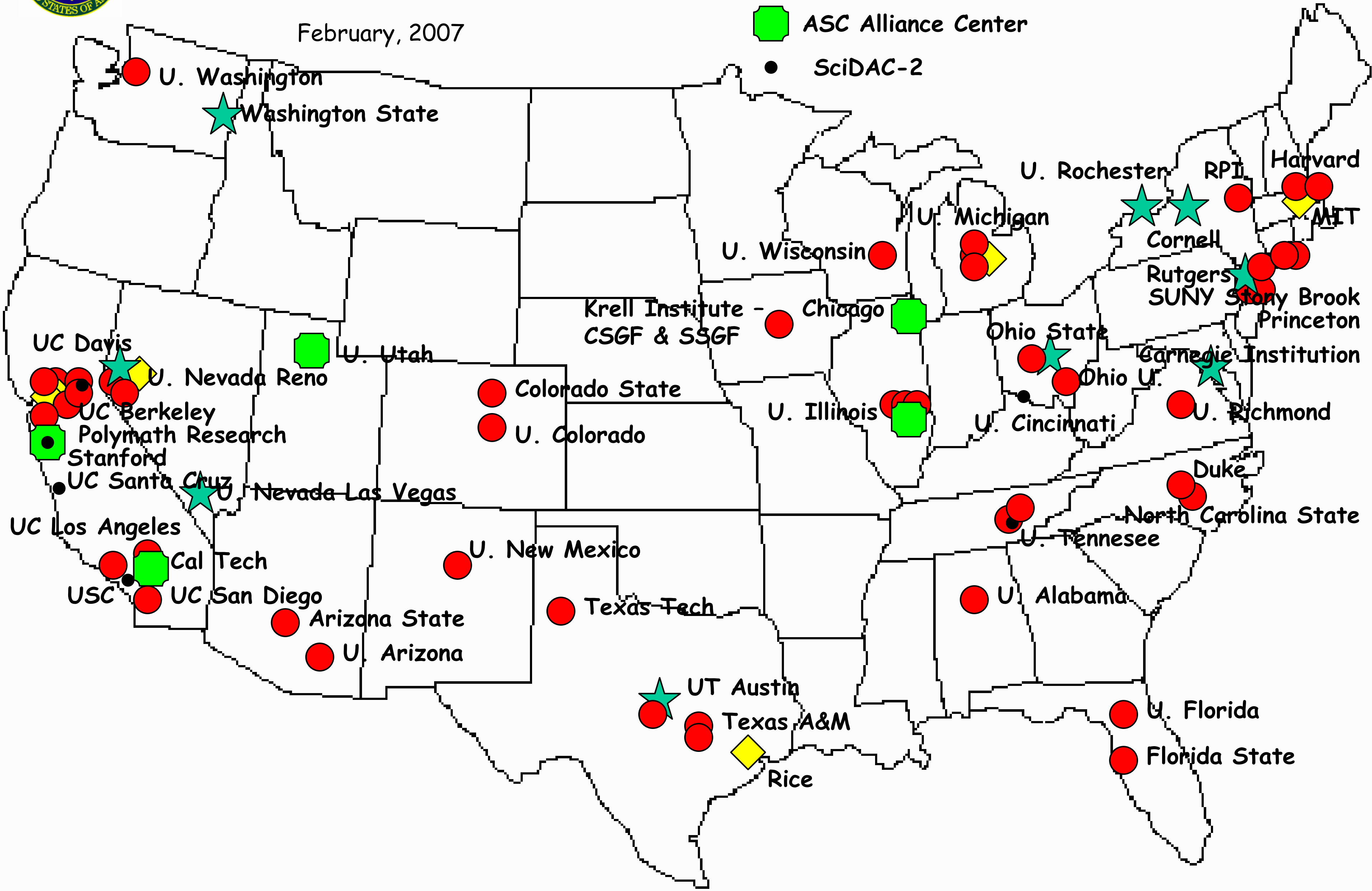
Centers and Cooperative Agreements

National Laser User Facility U

Grants & Fellowships

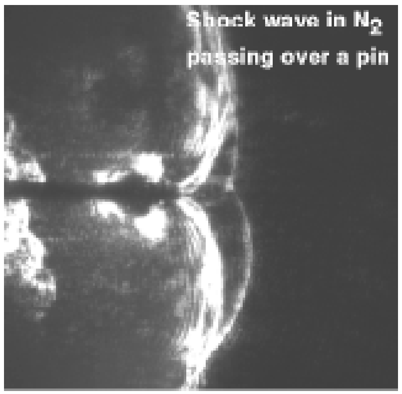
ASC Alliance Center

SciDAC-2

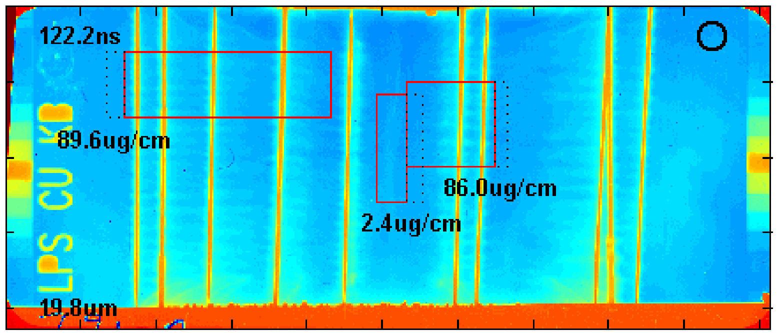


University Centers

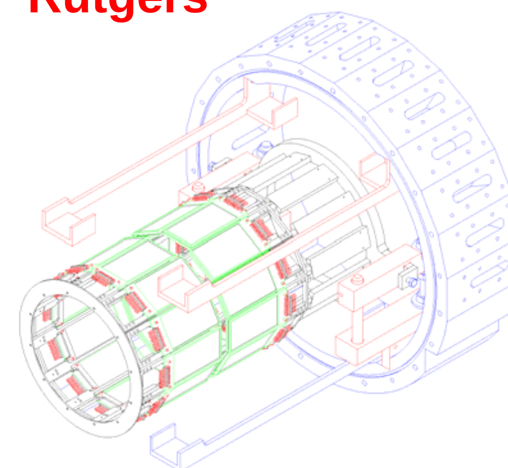
U.T. Austin

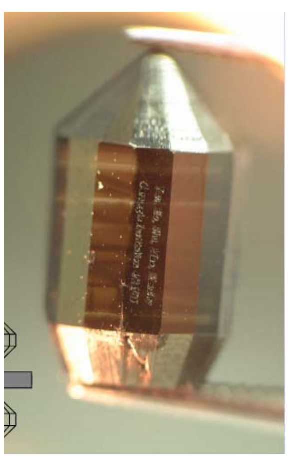


Cornell

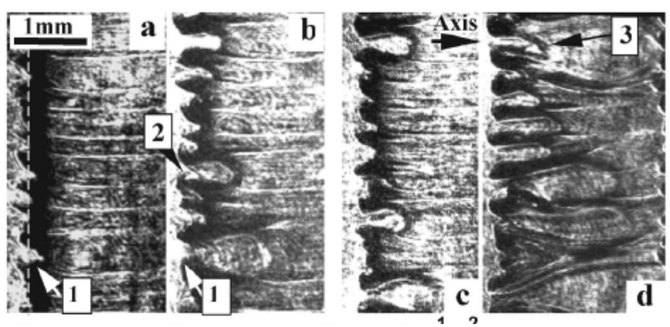


Rutgers

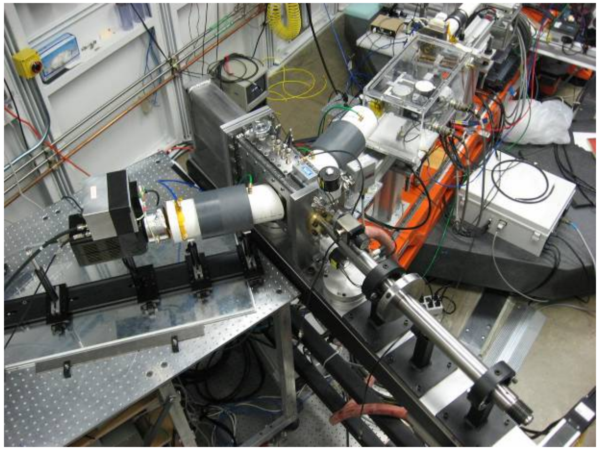




CDAC - Carnegie



Reno



ISP – Washington State

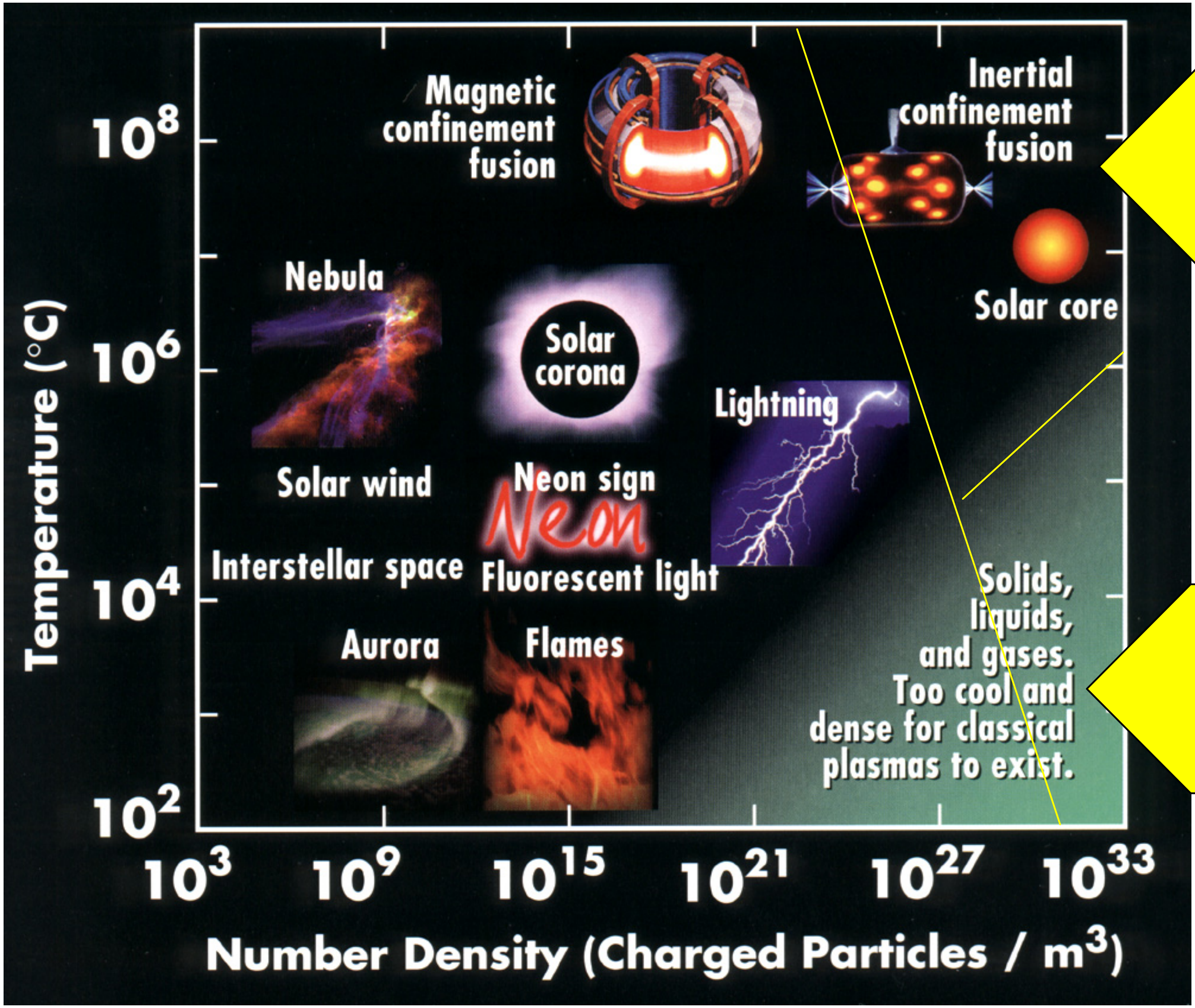
HEDLP and the FESAC charter

- NNSA started the SSAA program mainly for workforce development
- NNSA welcomes the joint program, more stewardship beyond SSAA, but we will not be executing our program through the joint program
  - We are transitioning our HEDP grants and centers from the SSAA
  - We will keep our SSAA program in materials and low energy nuclear
- NNSA sees benefit in:
  - Laboratory astrophysics – strong technical overlap
  - Basic HEDP sciences – enabling to our missions
  - IFES – strong technical overlap with ICF
- NNSA supports having FESAC inputs to HEDLP to help steward the program
- We support the inclusion of IFES in the mission space for the joint program, as long as the program is driven by strong technical workshops to ensure the highest quality of work

Summary

- NNSA mission needs drive significant investments that are critical to HEDP – Z, Omega, NIF and >100 TFlop computing
- NNSA does world class science, especially in HEDP!
- NNSA has supported a vibrant university program – mainly for future staff development – but this program has helped NNSA's mission
- We welcome the joint program in HEDLP to better steward HEDP

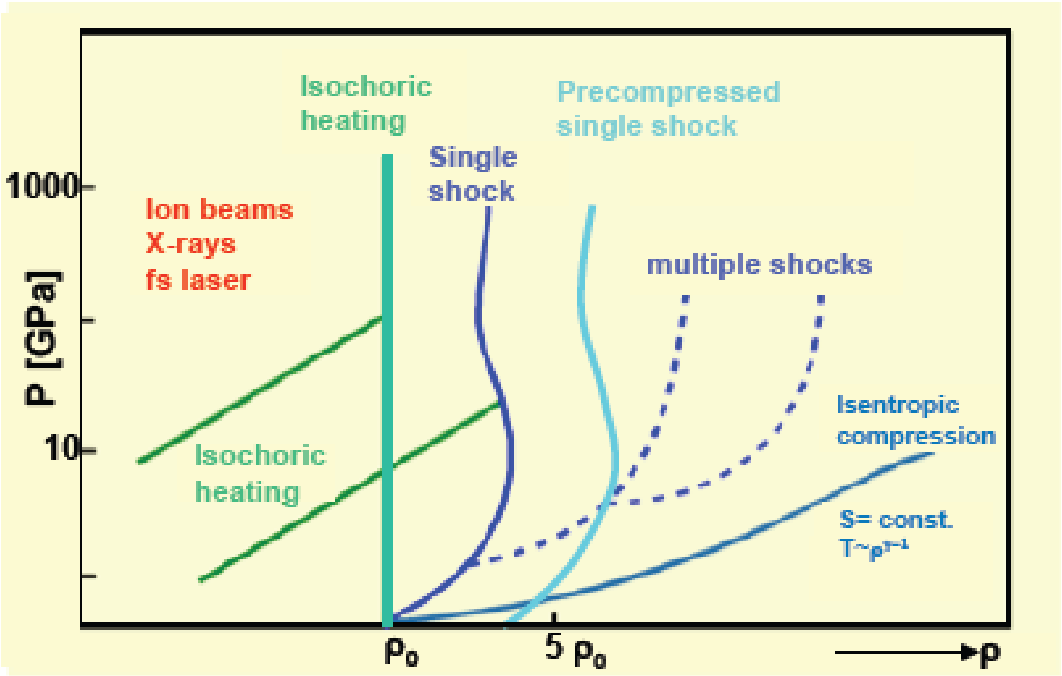
High Energy Density Physics extends from solids (SCCM) to plasmas (DPP)



Joint HEDLP Program

Donovan/Thio

SSAA Program


Isochoric heating
Precompressed single shock
Single shock
1000
Ion beams
X-rays
fs laser
multiple shocks
P [GPa]
Isentropic compression
10
Isochoric heating
S= const.
T~ρ^{γ-1}
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