

# National Ignition Facility

## A New Age for HED Science



**Fusion Power Associates**  
**Oak Ridge, Tn, December 4, 2007,**  
**Edward I. Moses, NIC Director**

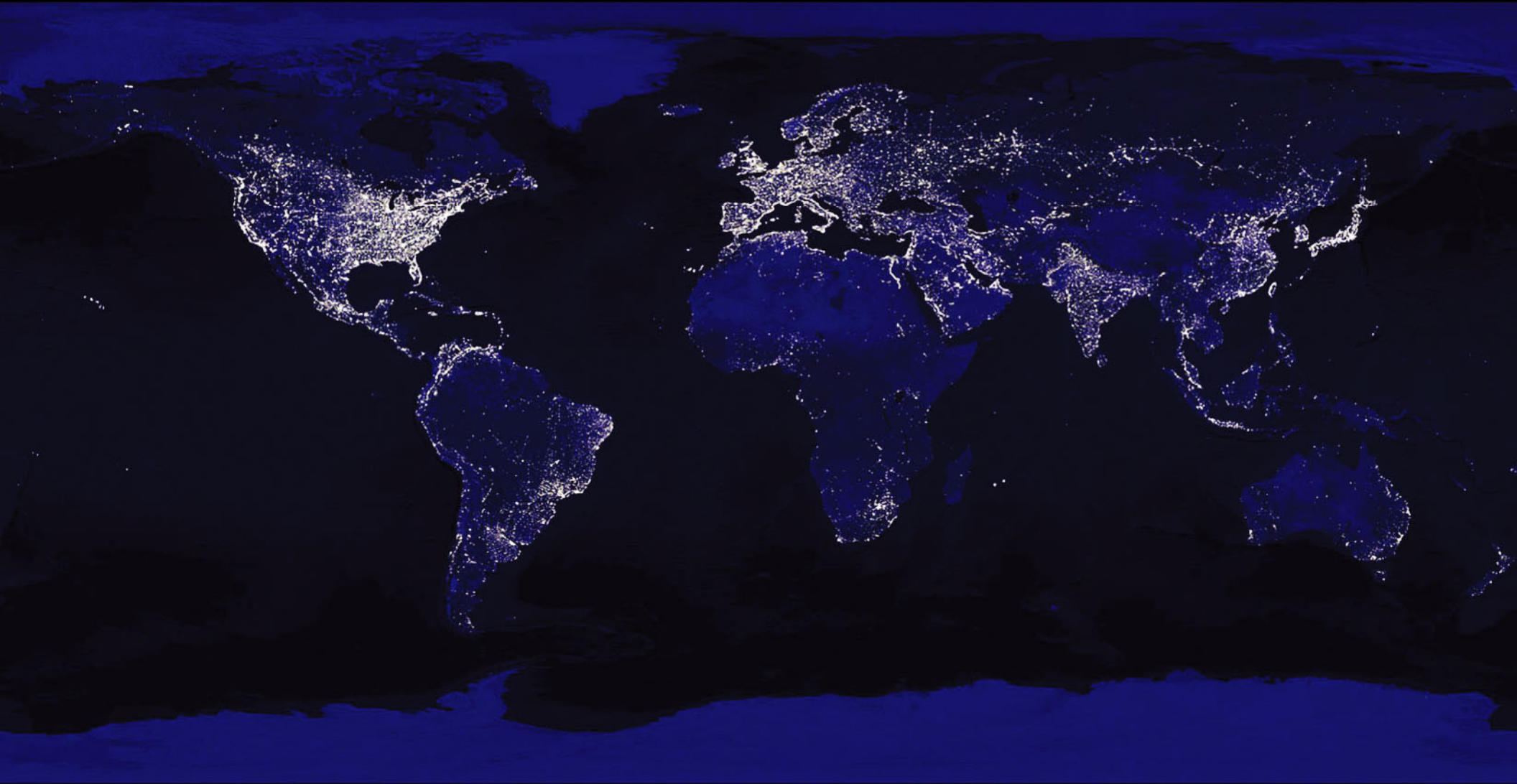


# The National Ignition Facility

Limitless Clean Energy  
Eye on the Cosmos

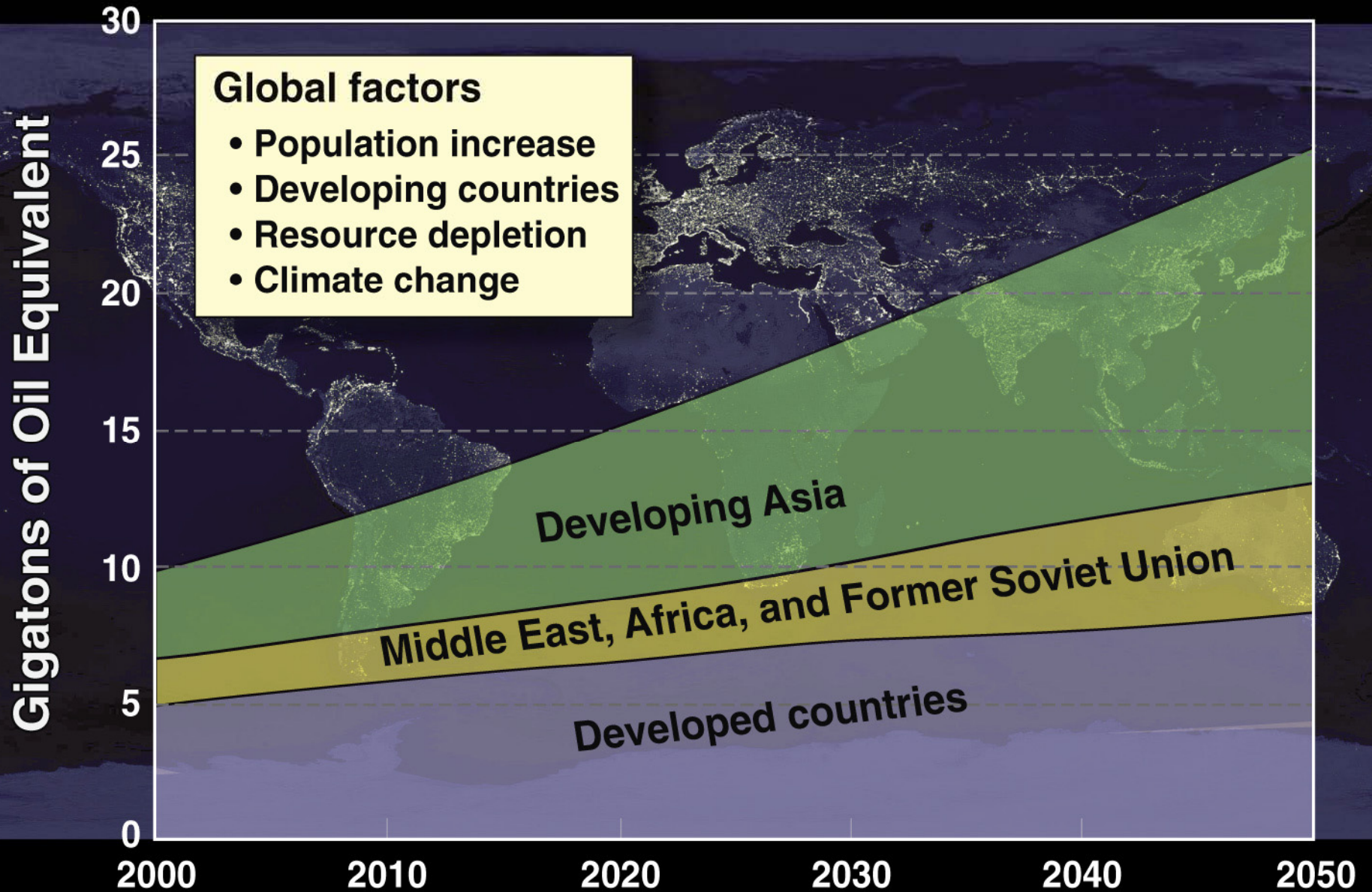


# Clean Energy: Humankind's Challenge





# Clean Energy: Humankind's Challenge





# How Many More Power Plants Do We Need?

10,000 Power Reactors Must Be  
Built This Century

Two New Ones Each Week!



**Fusion Energy:  
70 g of Water  
Carbon Free**

**=**

**Chemical Energy:  
Supertanker Full  
of Carbon Dioxide-Rich Oil**







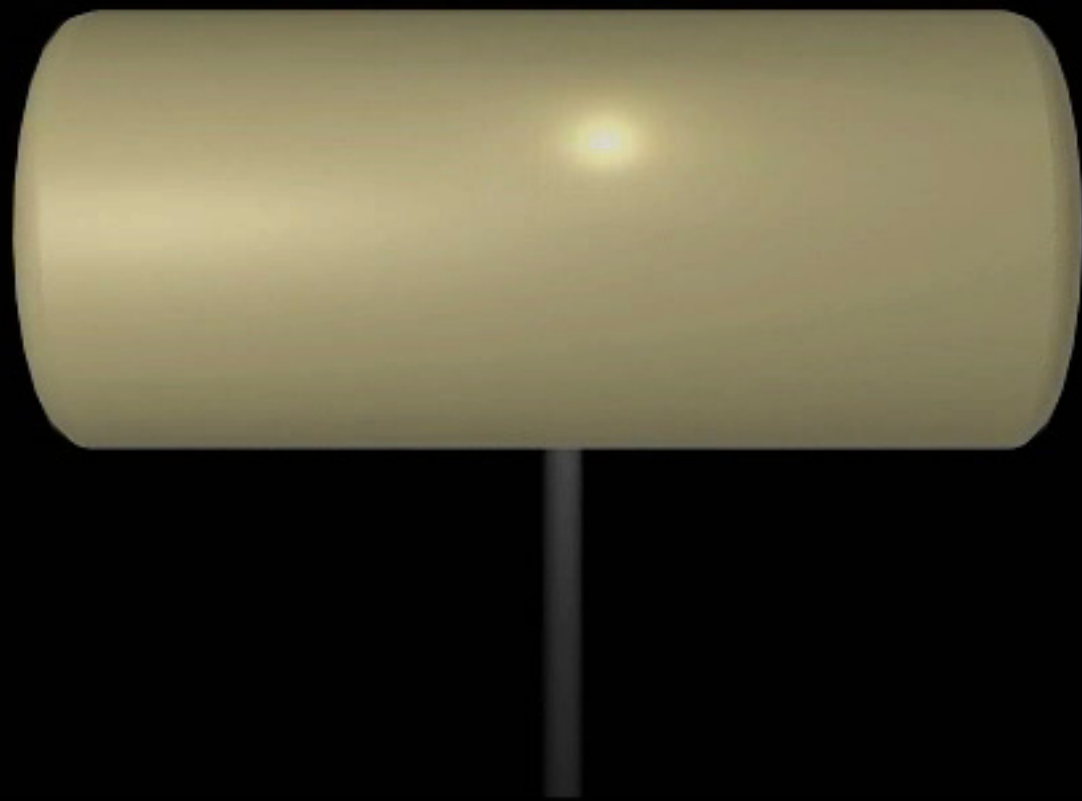
**Could we build a miniature  
sun on earth?**





**Ignition  
Target**







# After 47 years, all of the pieces for ignition are nearly in place

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- **The NIF laser and the equipment needed for ignition experiments, including high quality targets, will be available in 24 months**
- **We have an ignition point design target near 1 MJ with a credible chance for ignition during early NIF operations**
- **We have an Early Opportunity Shots (EOS) system commissioning campaign with 96 beams planned to start in 12 months**
- **The initial ignition experiments will only scratch the surface of NIF's potential, which includes high yields with green light and greatly expanded opportunities for the uses of ignition by decoupling compression and ignition in Fast Ignition (FI)**





**San Francisco  
(45 mi.)**

**Lawrence Livermore National Laboratory**

**National Ignition Facility**





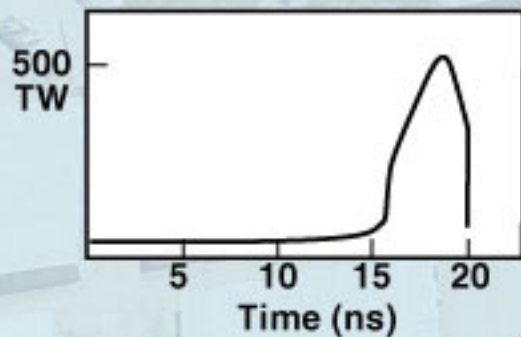
**NIF is  
705,000  
square feet**



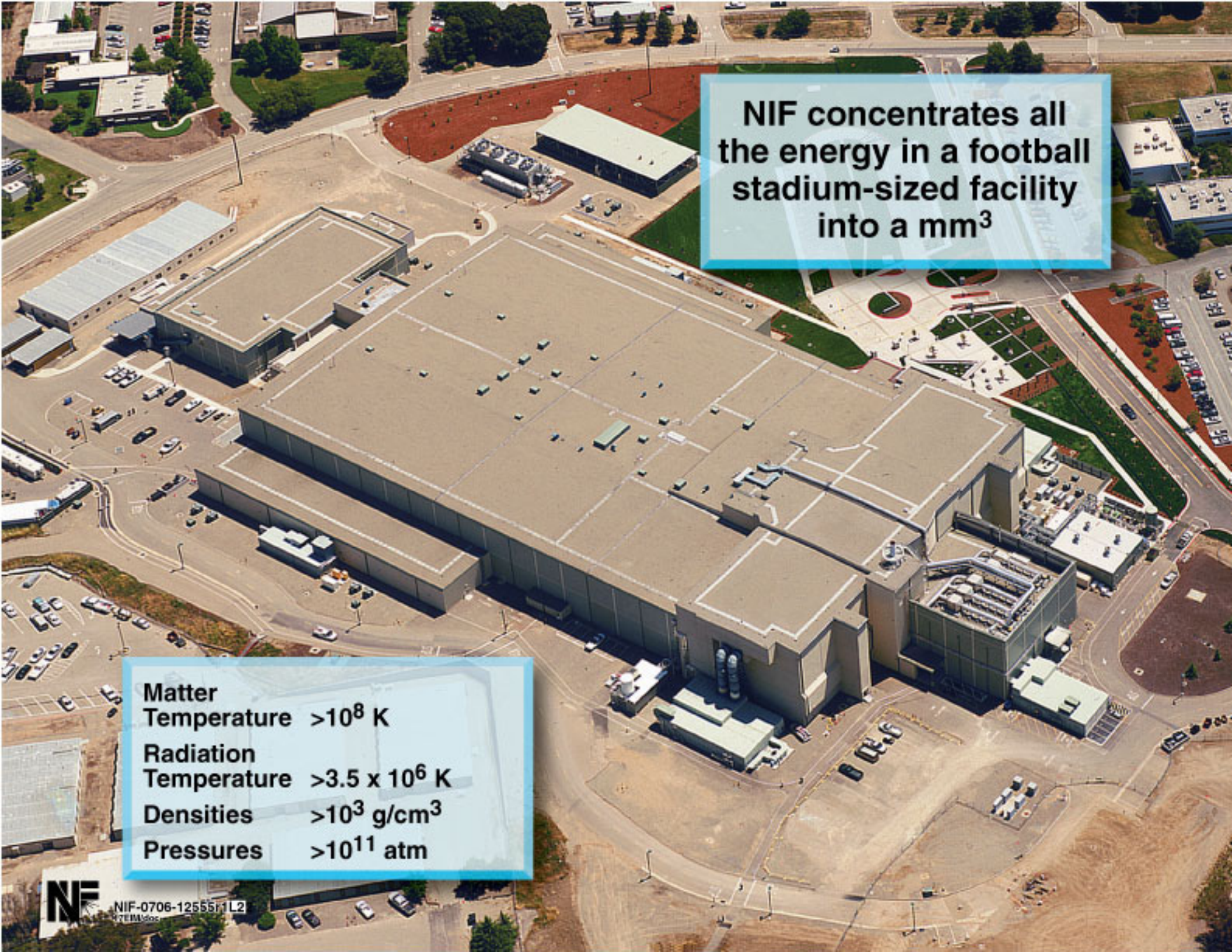


# NIF Laser System

- 192 Beams
- Frequency tripled Nd glass
- Energy 1.8 MJ
- Power 500 TW
- Wavelength 351 nm







**NIF concentrates all  
the energy in a football  
stadium-sized facility  
into a mm<sup>3</sup>**

**Matter**  
**Temperature**  $>10^8$  K  
**Radiation**  
**Temperature**  $>3.5 \times 10^6$  K  
**Densities**  $>10^3$  g/cm<sup>3</sup>  
**Pressures**  $>10^{11}$  atm





## National Ignition Facility

- NIF Project is 95% complete
- NIF will be complete in 16 months







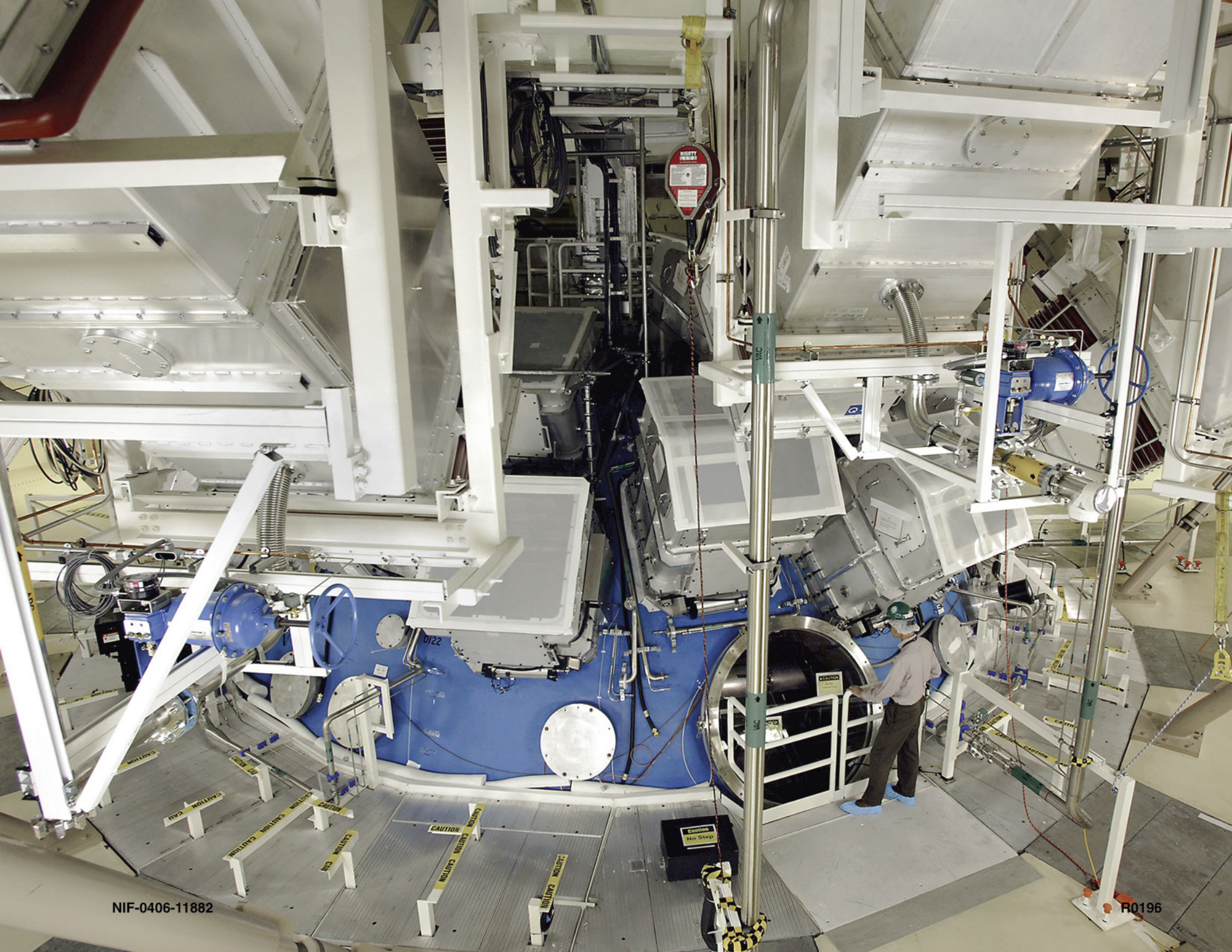
# Laser Bay 2











NIF-0406-11882

R0196

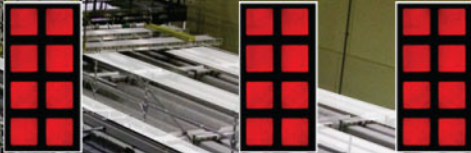
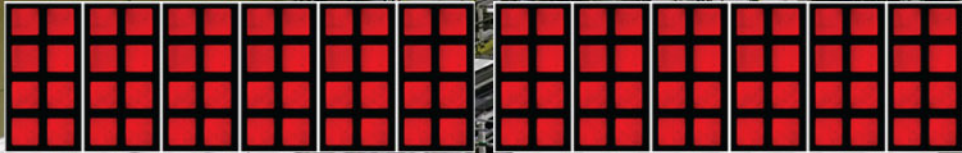


The image shows the interior of a large, cylindrical industrial chamber. The walls are covered in a complex pattern of circular openings of various sizes, some of which are recessed into the metal. A worker in an orange safety vest and green helmet is visible in the center, standing on a platform or scaffolding. The lighting is bright, highlighting the metallic surfaces and the intricate details of the chamber's construction.

## Target Chamber



**15 Main Laser Bundles  
Operationally  
Qualified  
October 31, 2007**

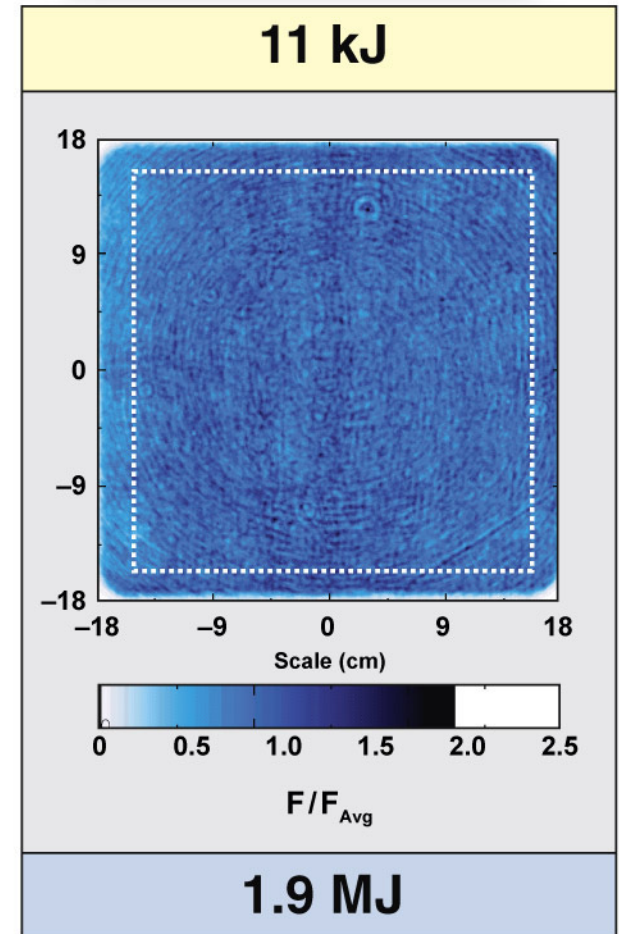
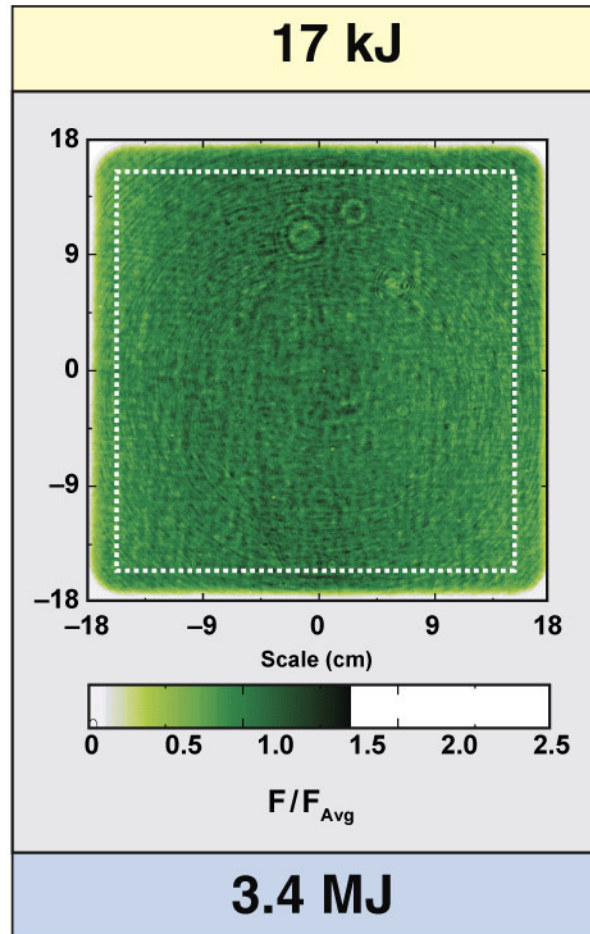
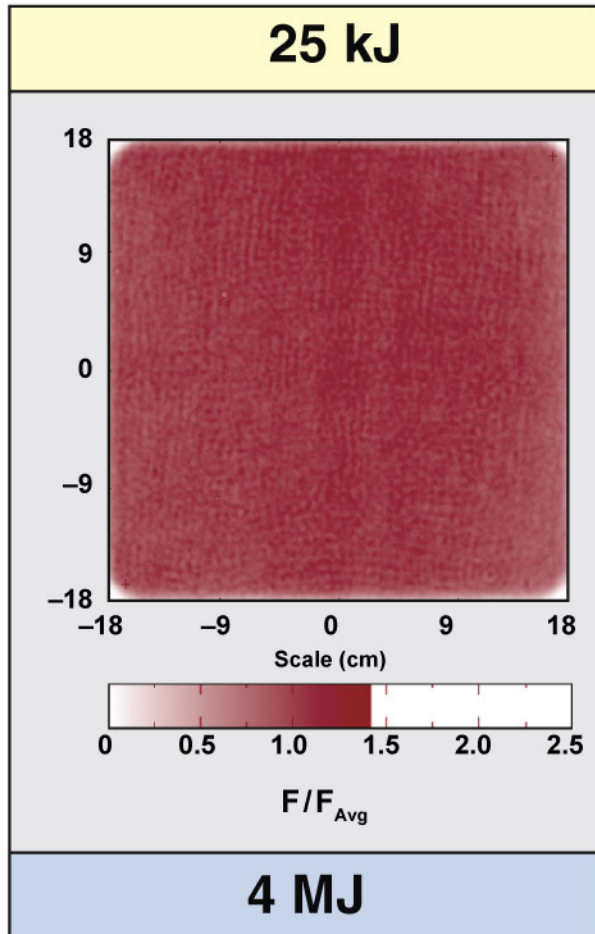


**World's Highest Energy  
Laser – 2.5 MJ  $1\omega$**





# Beamline Performance

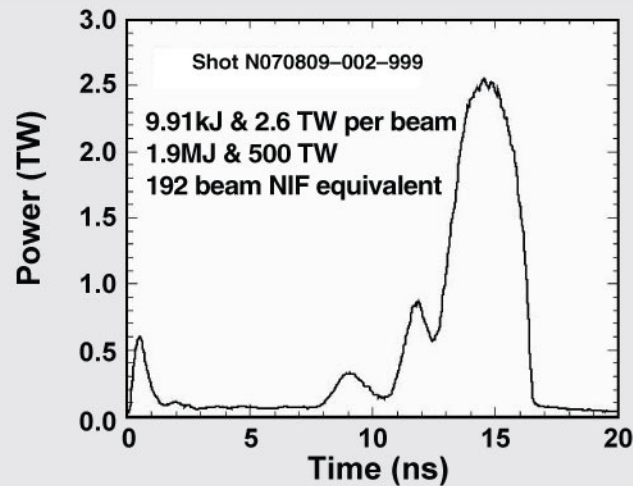


Each beam on NIF, is on its own, the World's most energetic laser

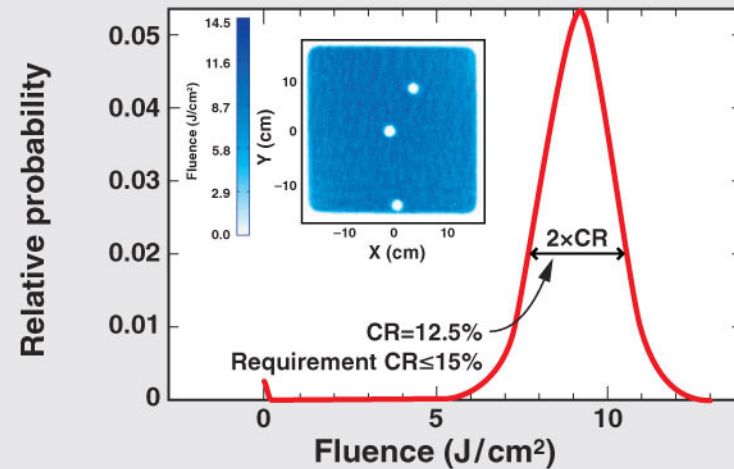


# NIC 1.8 MJ ignition point design, energy, power, pulse shape & smoothing were achieved simultaneously

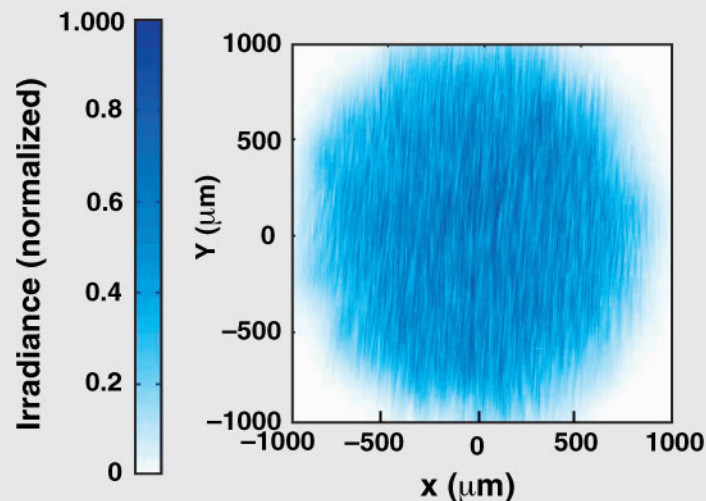
## $3\omega$ Pulse Shape (500 TW)



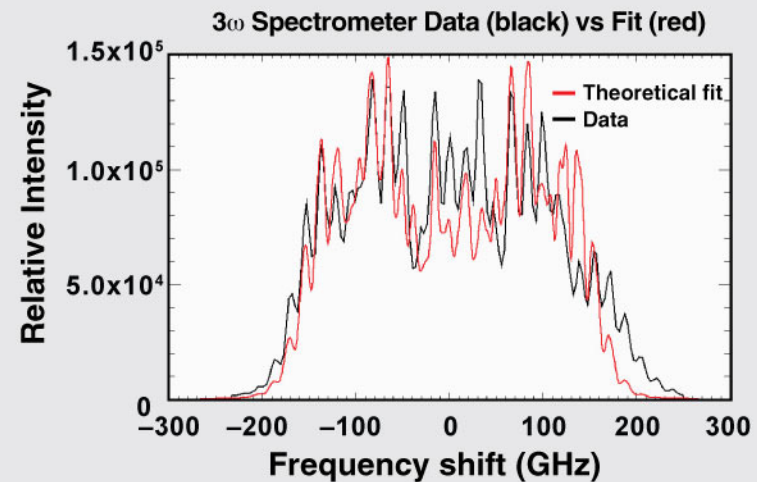
## $3\omega$ Near Field Profile



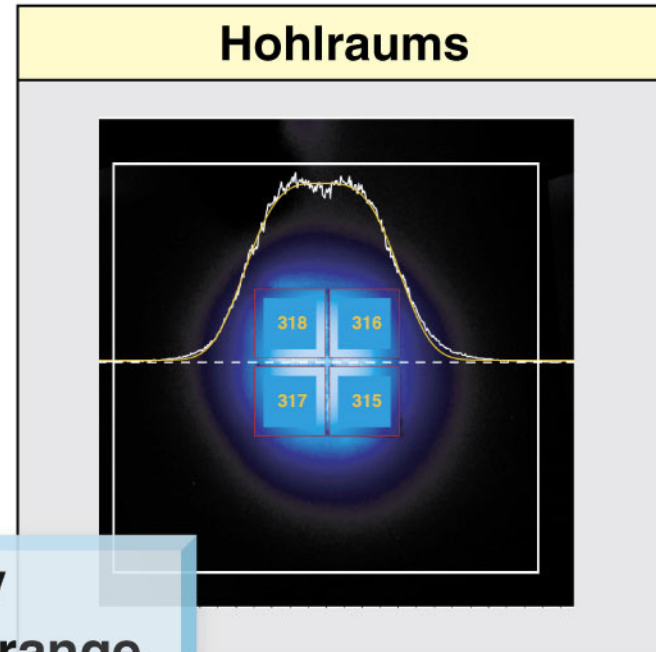
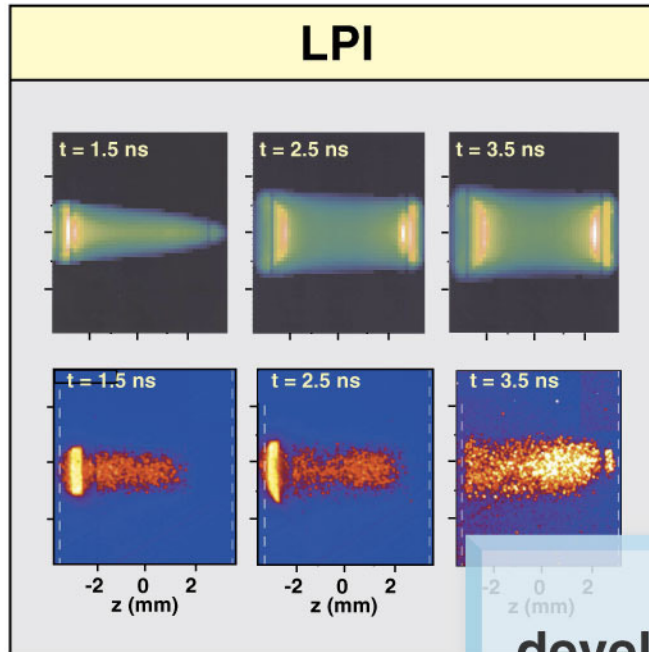
## $3\omega$ Focal Spot ( $1.91 \times 1.64 \text{ mm}^2$ )



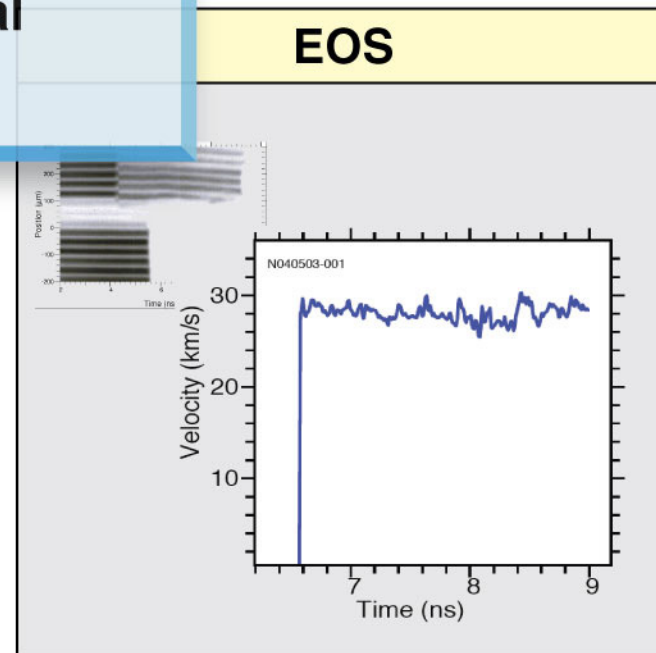
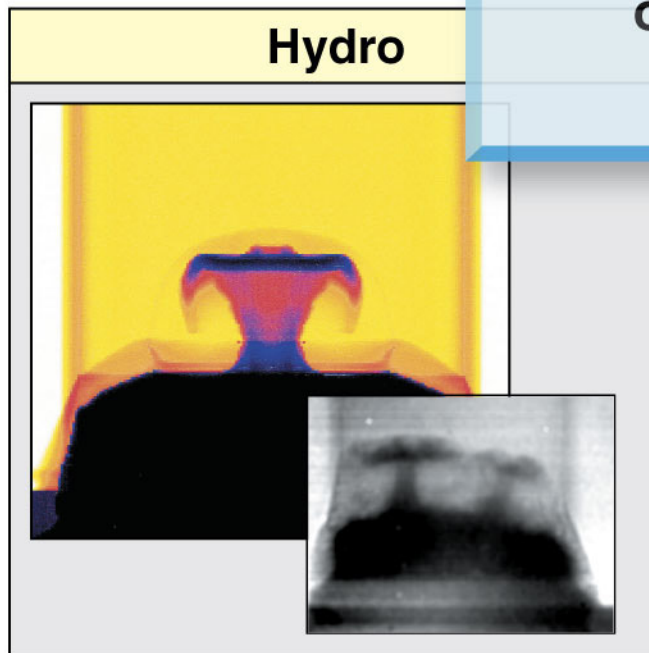
## $3\omega$ SSD Bandwidth (270 GHz)







**NIF is steadily  
 developing a large range  
 of experimental  
 capabilities**





# "External Users" participated in the 2004 NIF Early Light Experiments



## Physical Review Letters

vol ending MARCH 2005

### Experimental Investigation of High-Mach-Number 3D Hydrodynamic Jets at the National Ignition Facility

B. E. Blue,<sup>1</sup> S. V. Weber,<sup>1</sup> S. G. Glendinning,<sup>1</sup> N. E. Lanier,<sup>2</sup> D. T. Woods,<sup>1</sup> M. J. Beno,<sup>1</sup> S. N. Dixit,<sup>1</sup> C. A. Haynam,<sup>1</sup> J. P. Holder,<sup>1</sup> D. H. Kalantar,<sup>1</sup> B. J. MacGowan,<sup>1</sup> A. J. Nikitin,<sup>1</sup> V. V. Rekov,<sup>1</sup> B. M. Van Wenterghem,<sup>1</sup> E. I. Moses,<sup>1</sup> P. E. Stry,<sup>1</sup> B. H. Wilde,<sup>2</sup> W. W. Hsing,<sup>1</sup> and H. F. Robey<sup>1</sup>

<sup>1</sup>Lawrence Livermore National Laboratory, Livermore, California 94550, USA  
<sup>2</sup>Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

The first hydrodynamic experiments were performed on the National Ignition Facility. A supersonic jet was formed via the interaction of a laser disk (400 μm) with 2D and 3D density perturbations. The temporal evolution of the jet's spatial scales and ejected mass were measured with point-projection x-ray radiography. Measurements of the large-scale features and mass are in good agreement with 2D and 3D numerical simulations. These experiments provide quantitative data on the evolution of 3D supersonic jets and provide insight into their 3D behavior.

DOI: 10.1103/PhysRevLett.94.095005

PACS numbers: 52.35.Tc, 52.50.Jn, 52.57.-z

The interaction of a shock wave with a density perturbation is a problem of basic scientific interest [1] with specific application to astrophysics [2] and inertial confinement fusion (ICF) [3]. For instance, high-Mach number hydrodynamic jets, which can result from a shock-perturbation interaction, are ubiquitous features of supernovae in astrophysics [4–7] and may result from the presence of capsule joints or cryogenic fill tubes in ICF [8]. Although the spatial scales of these systems vary over 16 orders of magnitude from supernovae jets (~10<sup>6</sup> m) to micron scale jets inside ICF capsules, they are unified by the physics of a high-Mach number shock interacting with a perturbation at a two fluid interface. In both systems the shock-perturbation interaction results in a jet of plasma being ejected ahead of the shocked material interface. In the case of supernovae, a jet provides a possible mechanism for explaining the observation of the early appearance of core high-Z elements (nickel, iron, etc.) [9] in the helium and hydrogen envelope. In the case of ICF-capsules, fabrication joints or fill tubes can mix cooler shell material into the fuel before optimal compression, possibly affecting ignition [8]. Previous work has studied the spatial evolution of 2D jets [6]. This Letter describes quantitative measurement of the evolution of 3D supersonic jets and provides insight into their 3D behavior. To validate the simulations of these phenomena, there are several parameters of critical importance. They are the spatial dimensions, the characteristic velocities, the total mass of material and the spatial mass distribution of the jet material.

An experiment was conducted to investigate jet formation in 2D and 3D shocked systems using the first four beams of the National Ignition Facility (NIF) [11] located at Lawrence Livermore National Laboratory. A 1.5 ns, 6 kJ (2 × 3 kJ beams), 3σ (351 nm wavelength), 1000 μm diameter laser pulse (4 × 10<sup>14</sup> W/cm<sup>2</sup>) was used to drive a 40 Mbar shock wave into aluminum targets

backed by 100 mg/cc carbon aerogel foam. The experimental package consisted of a 101 ± 2 μm thickness aluminum disk placed in direct contact with a central, 162 ± 2 μm diameter hole. The hole was drilled either 0° for the case of a two-dimensional cylindrical symmetric target [Fig. 1(a)] or 45° for the case of a three-dimensional target [Fig. 1(b)]. The two 800 diameter aluminum disks were inserted into a 2000 diameter, 250 μm thick gold washer that delays propagation of shocks around the exterior of the package. The front surface of the target was coated a 57 ± 2 μm thick polystyrene ablator. The carbon was encased in a polystyrene shock tube with a thickness of 40 μm.

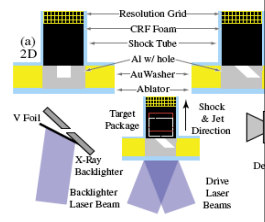


FIG. 1 (color). Schematic of a 2D target (a), a 3D target (b), and the radiographic configuration used on NIF (c) (not to scale).

0031-9007/05/94(9)/095005(4)\$23.00

095005-1

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## Nuclear Fusion

INSTITUTE OF PHYSICS PUBLISHING  
Nuc. Fusion 44 (2004) S185-S190

NUCLEAR FUSION  
PII: S0029-5515(04)06276-8

### Progress in long scale length laser-plasma interactions

S.H. Glenzer, P. Arnold, G. Bardsley, R.L. Berger, G. Bonanno, T. Borger, D.E. Bower, M. Bowers, R. Bryant, S. Buckman, S.C. Burkhardt, K. Campbell, M.P. Chrisp, B.L. Cohen, C. Constantin, F. Cooper, J. Cox, E. Dewald, L. Divol, S. Dixit, J. Duncan, D. Eder, J. Edwards, G. Erbert, B. Felker, J. Fomes, G. Frieders, D.H. Froula, S.D. Gardner, C. Gates, M. Gonzalez, S. Grace, G. Gregori, A. Lee, D. Lund, B. MacGowan, S. Marshall, C. Haynam, G. Heestand, M. Hennesian, G. Hermes, D. Hinkel, J. Holder, E. Holdner, G. Holmeier, W. Hsing, S. Huber, T. James, S. Johnson, O.S. Jones, D. Kalantar, J.H. Kamperschroer, R. Kaufman, T. Kelleher, J. Knight, R.K. Kirkwood, W.L. Krauter, W. Labiak, O.L. Landen, A.B. Langdon, S. Langer, D. Latray, A. Lee, E.D. Lee, D. Lund, B. MacGowan, S. Marshall, J. McBride, T. McCarville, L. McGrew, A.J. Mackinnon, S. Mahavadi, K. Manes, C. Marshall, J. Menapace, E. Mertens, N. Mezzan, G. Miller, S. Montelongo, J.D. Moody, E. Moses, D. Munro, J. Murray, J. Neumann, M. Newton, E. Ng, C. Niemann, A. Nikitin, P. Opsahl, E. Padilla, T. Parham, G. Parrish, C. Petty, M. Polk, C. Powell, L. Reinbachs, V. Rekov, R. Rinnert, B. Riordan, M. Rhodes, V. Roberts, H. Robey, G. Ross, S. Saitors, R. Saunders, M. Schmitt, M.B. Schneider, S. Shiromizu, M. Spaeth, A. Stephens, B. Still, L.L. Suter, G. Tietbohl, M. Tobin, J. Tuck, B.M. Van Wenterghem, R. Vidal, D. Voloshin, R. Wallace, P. Wegner, P. Whitman, E.A. Williams, K. Williams, K. Winward, K. Work, B. Young, P.E. Young, P. Zapata, R.E. Bahr<sup>1</sup>, W. Seka<sup>1</sup>, J. Fernandez<sup>2</sup>, D. Montgomery<sup>3</sup> and H. Rose<sup>2</sup>

<sup>1</sup>Lawrence Livermore National Laboratory, Livermore, CA 94550, USA  
<sup>2</sup>University of Rochester, Laboratory for Laser Energetics, Rochester, NY, USA  
<sup>3</sup>Los Alamos National Laboratory, NM, USA

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#### Abstract

The first experiments on the National Ignition Facility (NIF) have employed the first four beams to measure propagation and laser backscattering losses in long scale length laser-plasma interactions. Gas-filled targets between 2 and 7 mm length have been heated from one side by overlapping the focal spots of the four beams from one quad operated at 351 nm (3σ) with a total intensity of 2 × 10<sup>15</sup> W/cm<sup>2</sup>. The targets were filled with 1 atm of CO<sub>2</sub> producing up to densities of n<sub>e</sub> = 6 × 10<sup>20</sup> cm<sup>-3</sup> and temperatures of T<sub>e</sub> = 2 keV. The high energy in an NIF quad of beams of 6 kJ, illuminating the target from one direction, creates unique conditions for the study of laser-plasma interaction through the large-scale plasma was measured with a gated x-ray imager that was filtered for 3.5 keV x-rays. These data indicate that the beams interact with the plasma during the large-scale plasma during the last ~1 ns of the experiment. During that time, the full aperture measurements of the stimulated Brillouin scattering and stimulated Raman scattering show scattering into the four quadrants using lenses of 3% for the smallest length (~2 mm), increasing to 10–12% for ~7 mm. These results demonstrate a three-dimensional modelling of the laser-plasma interactions at ignition-size scale lengths.

PACS numbers: 52.38.-r, 52.25.-b, 52.35.-g

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Printed in the UK

S185

## Physics of Plasmas

PHYSICS OF PLASMAS 13, 032703 (2006)

### Hard x-ray and hot electron environment in vacuum hohlraums at the National Ignition Facility

J. W. McDonald, L. J. Suter, O. L. Landen, J. M. Foster,<sup>1</sup> J. R. Celeste, J. P. Holder, E. L. Dewald, M. B. Schneider, D. E. Hinkel, R. L. Kaufman, L. J. Atherton, R. E. Bonanno, S. N. Dixit, D. C. Eder, C. A. Haynam, D. H. Kalantar, A. E. Koenigs, F. D. Isaacs, B. J. MacGowan, K. R. Manes, D. H. Munro, J. R. Murray, M. J. Shaw, R. M. Stevenson,<sup>2</sup> T. G. Parham, B. M. Van Wenterghem, R. J. Wallace, P. J. Wegner, P. K. Whitman, B. K. Young, B. A. Hammel, and E. I. Moses

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(Received 25 October 2005; accepted 23 February 2006; published online 31 March 2006)

Time resolved hard x-ray images ( $h\nu > 9$  keV) and time integrated hard x-ray spectra ( $h\nu = 18$ –150 keV) from vacuum hohlraums irradiated with four 351 nm wavelength National Ignition Facility [J. A. Paisner, E. M. Campbell, and W. J. Hogan, *Fusion Technol.* 26, 755 (1994)] laser beams are presented as a function of hohlraum size, laser power, and duration. The hard x-ray images and spectra provide insight into the time evolution of the hohlraum plasma filling and the production of hot electrons. The fraction of laser energy detected as hot electrons ( $F_{\text{hd}}$ ) shows a correlation with laser intensity and with an empirical hohlraum plasma filling model. In addition, the significance of Au K-alpha emission and Au K-shell reabsorption observed in some of the bremsstrahlung dominated spectra is discussed. © 2006 American Institute of Physics.  
[DOI: 10.1063/1.2186927]

#### I. INTRODUCTION

High-Z cavities or hohlraums are an essential part of the indirect drive approach to internal confinement fusion (ICF).<sup>1</sup> These hohlraums convert intense laser light into soft x rays that can symmetrically implode fuel capsules or can be used for a wide variety of other high-energy density experiments. The physics of laser absorption in the hohlraum must be understood in order to predict the hohlraum symmetry, radiation temperatures achievable within the hohlraums, and the efficiency of coupling of the driver energy to the capsule. Several studies of the interaction of lasers with cavities and their associated plasmas have been conducted over the past decades.<sup>2–5</sup> Parametric instability growth leading to reflection of laser light by the plasma<sup>6</sup> can present a limit to the achievable radiation temperature in laser-heated hohlraums.<sup>7</sup> However, in this paper we focus on the effect of hohlraum plasma filling on hot electron production that results from the laser-hohlraum plasma interactions as evidenced by hard x-ray photos.

Single-ended cylindrical hohlraums ("halfraum") were used in this study, as illustrated with a computer-generated image in Fig. 1(a). The laser beams enter the halfraum along its axis through a laser entrance hole (LEH) (bottom), striking the back wall (top), rapidly heating the Au producing laser ablated plasma and x rays. The x rays in turn interact with and heat the unilluminated walls, producing x-ray ablated plasma and reemitted x rays. In contrast to laser-disk experiments,<sup>8</sup> where the ablated plasma is free to expand, the hohlraum confines and accumulates the plasma.<sup>9</sup> As the plasma moves into the path of the incident laser beam, hot electrons (>10 keV) are produced by laser plasma instabil-

ties such as the stimulated Raman instability.<sup>10</sup> Quantifying the hot electron production is important for ignition experiments because the hot electrons can penetrate the fuel capsule, preheating the fuel and thereby making it harder to compress. Hot electrons can be important for other experiments, for example, by preheating hydrodynamic packages or by driving the plasma out of equilibrium. Hard x-ray electron bremsstrahlung emission is produced when the fast electrons interact with the surrounding plasma or the cold dense matter. Bremsstrahlung production is on the order of a few percent of the fast electron energy for high-Z materials such as Au and is proportional to Z. For very hot plasmas, hard x rays can be produced by the thermal electron distribution through bremsstrahlung or by free-bound transitions. In previous laser-plasma experiments in indirect drive targets, the hard x-ray levels have been correlated with Raman scattered laser light signals.<sup>11</sup> Often the spectrum had a harder, super-hot component thought to be produced by forward Raman scattering.<sup>11</sup>

This paper describes measurements of hot electrons produced in laser heated cavities. The scaling with hohlraum size and laser power and duration are presented. The fraction of laser energy detected as hot electrons ( $F_{\text{hd}}$ ) shows a correlation with laser intensity and with an empirical hohlraum plasma filling model. In addition, evidence of Au K-alpha emission and Au K-shell reabsorption in some of the bremsstrahlung dominated spectra is discussed.

#### II. EXPERIMENTAL SETUP

The National Ignition Facility (NIF), currently under construction,<sup>12</sup> is a 192-beam laser system that is designed to deliver up to 9.4 kJ (3 TW) of laser energy (power) per beam at 351 nm wavelength. The laser system will be used

<sup>1</sup>Atomic Weapons Establishment, Aldermaston, United Kingdom.

1070-664X/06/13032703/\$23.00

13, 032703-1

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## Los Alamos National Lab

## University of Rochester, LLE

## Atomic Weapons Establishment



NIF-0607-13692.ptt

NIF Town Hall Meeting, June 16, 2007



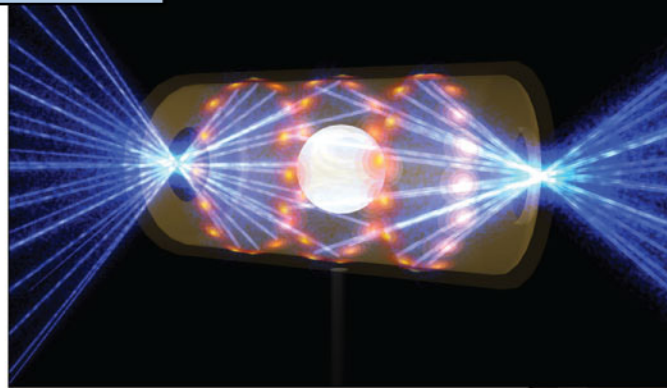
## NIF Project



Completion in 2009

The goal of NIC is  
thermonuclear burn in  
the laboratory with a  
credible campaign  
in 2010

## National Ignition Campaign



2006—2012

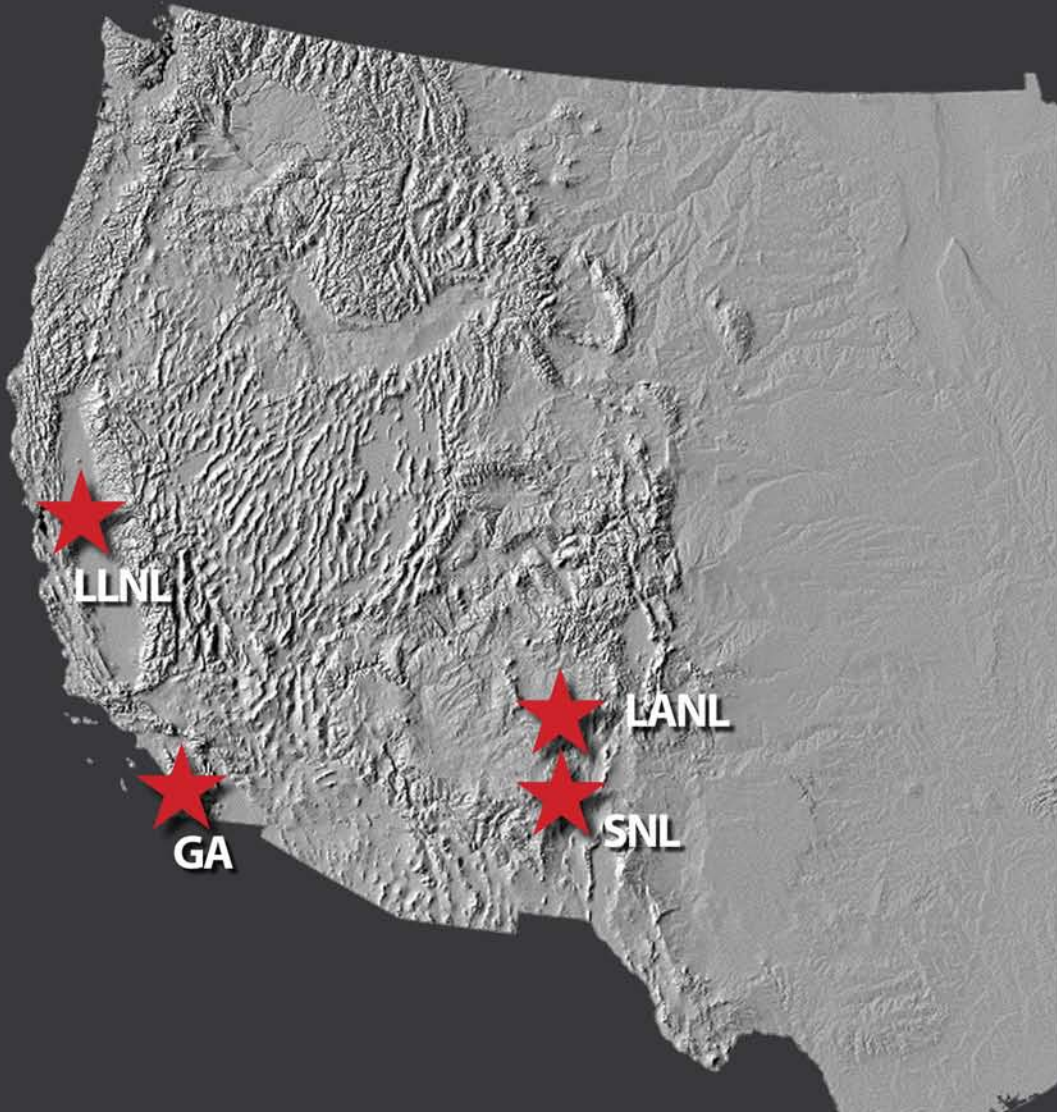
NIC is the bridge from  
NIF to routine operations  
of a highly flexible HED  
science facility

## National User Facility



2009—2030





# 2010

## NATIONAL IGNITION CAMPAIGN

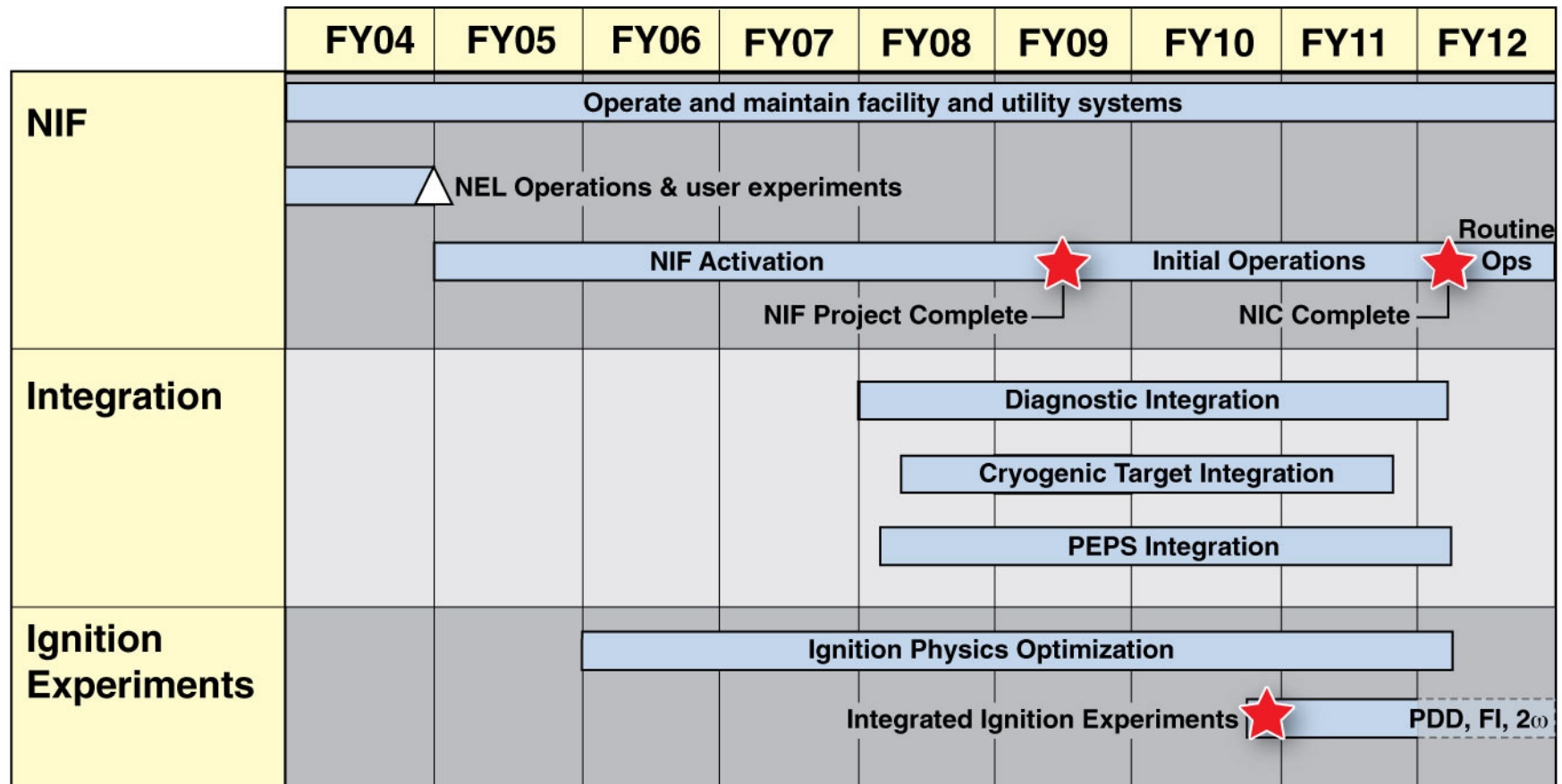




# NIF/NIC Schedule



The National Ignition Campaign



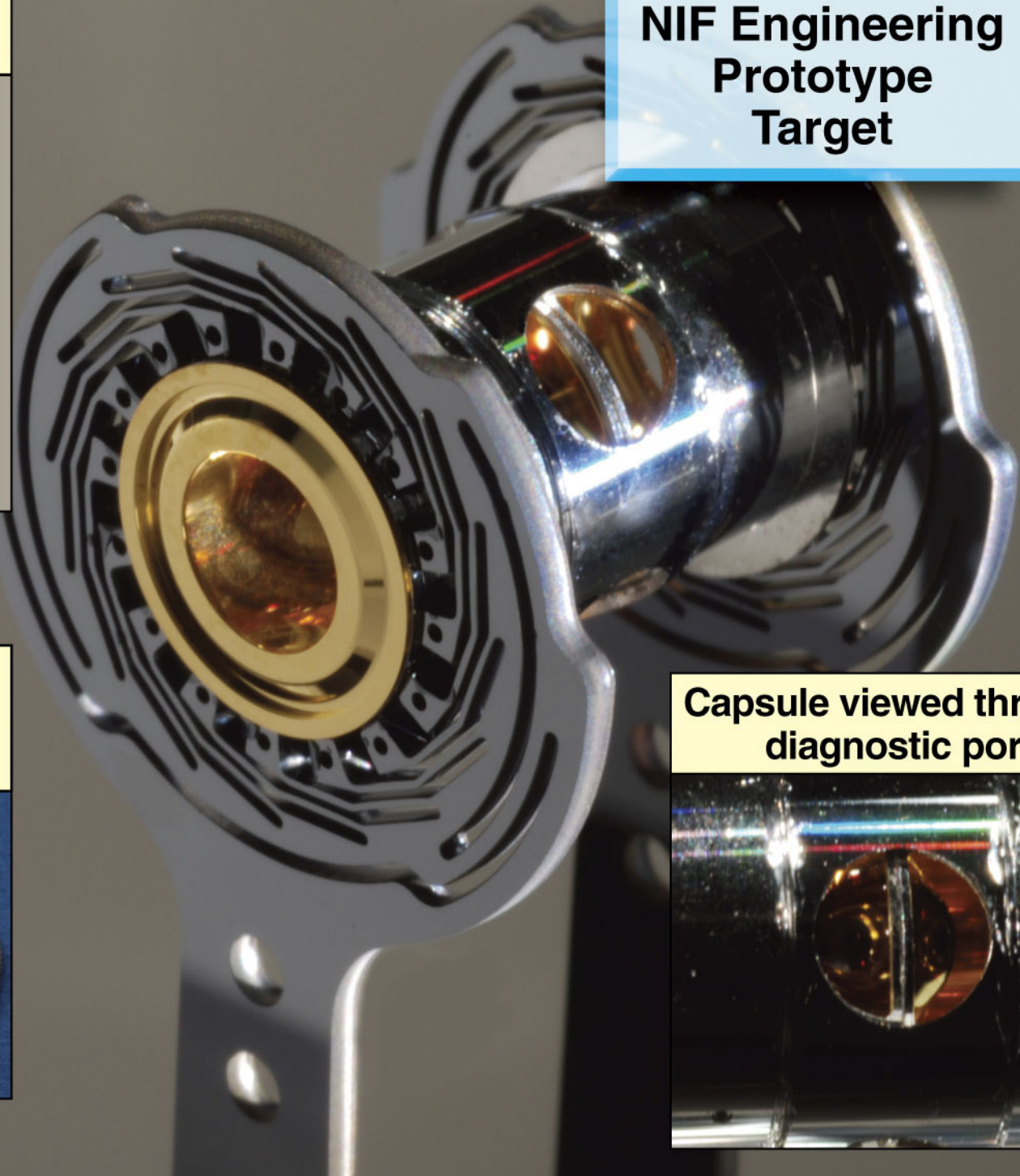
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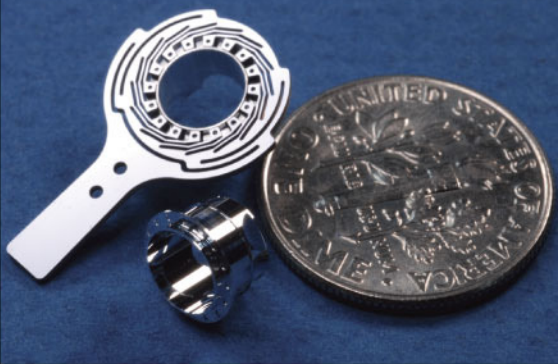
**Aluminum Thermal Can  
and Cocktail Hohlräum**



**NIF Engineering  
Prototype  
Target**



**Silicon Cooling Ring  
and Thermal Package  
Component**



**Capsule viewed through  
diagnostic port**





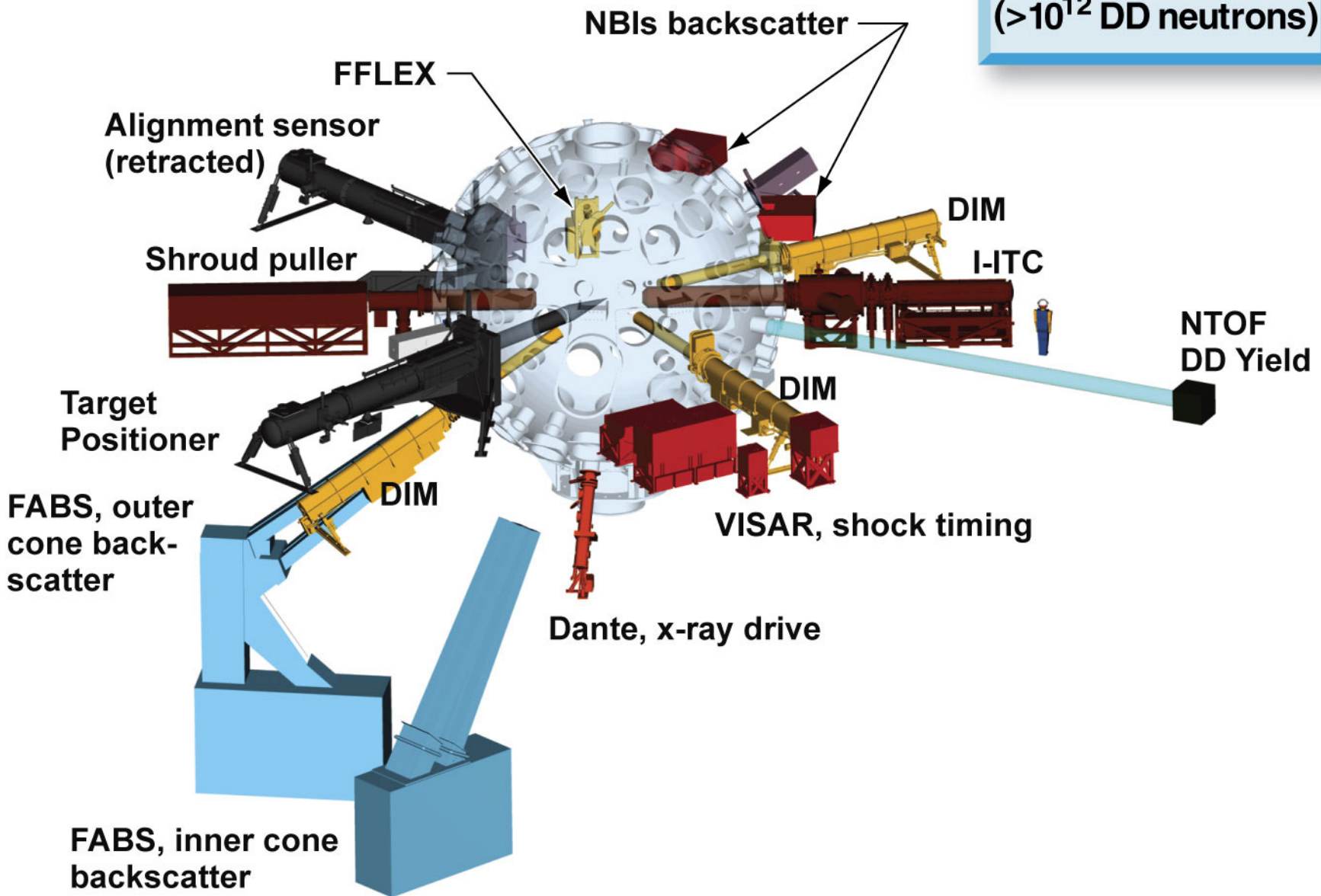


**Ignition Plan has 35  
distinct diagnostic  
requirements**

- 13 requirements were met by systems fielded on NEL
- 98% channel reliability in NEL experiments



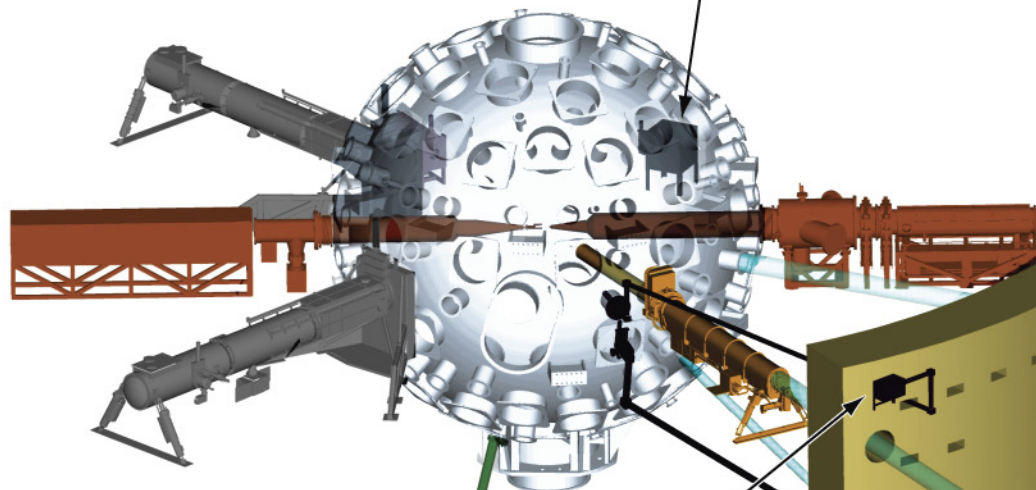
**Low Yield  
Diagnostics  
( $>10^{12}$  DD neutrons)**





**NIC High Yield  
Diagnostics  
( $>10^{19}$  DT neutrons)**

**Magnetic Recoil Spectroscopy  
(MRS),  $T_{ion}$  and  $\rho_r$ , 6 m  
(no vulnerable components)**



**Neutron Time  
of Flight  
 $T_{ion}$  and  $\rho_r$ , 20 m**

**10-20 keV core  
imaging, 20 m**

**$\gamma$ -ray bangtime,  
20 m**

**PROTEX,  
yield 20 m**

**Neutron imaging  
hot spot and fuel  
asymmetry, 40 m**

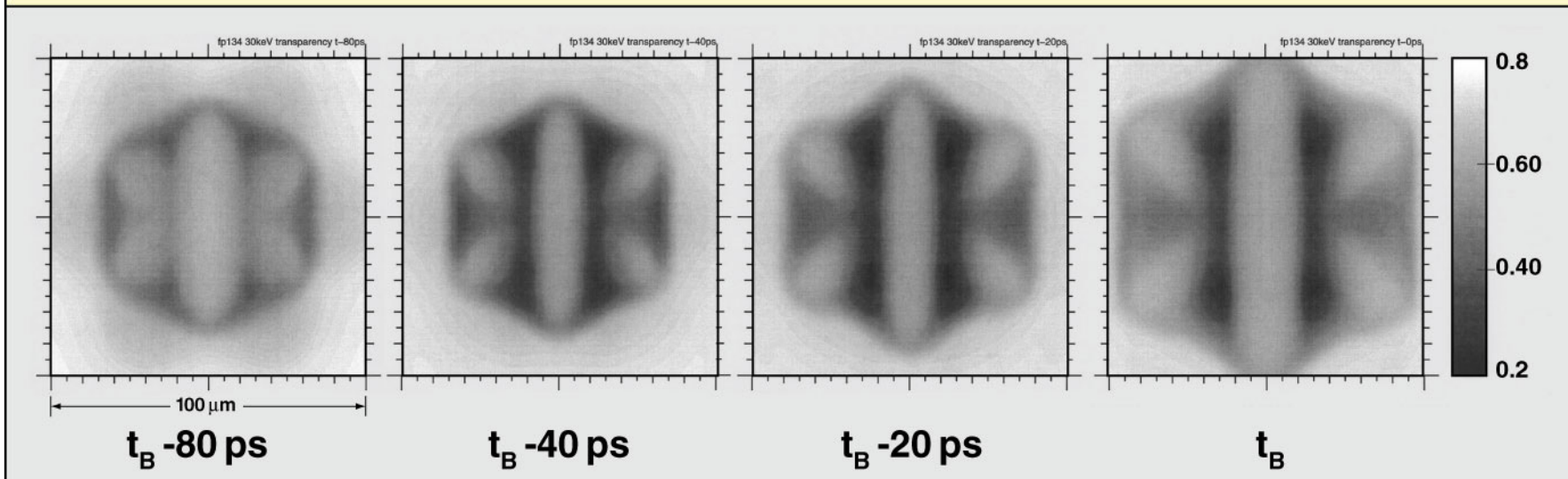
**Activation,  
yield and  $\rho_r$ ,  
~30 m**





**Multiple ARC radiographs at intervals ~20 – 80 ps with ~10 ps exposure times would produce valuable time-history data (Phys. Rev. Lett. worthy)**

**ARC Radiographs (same gray scale at all times)**



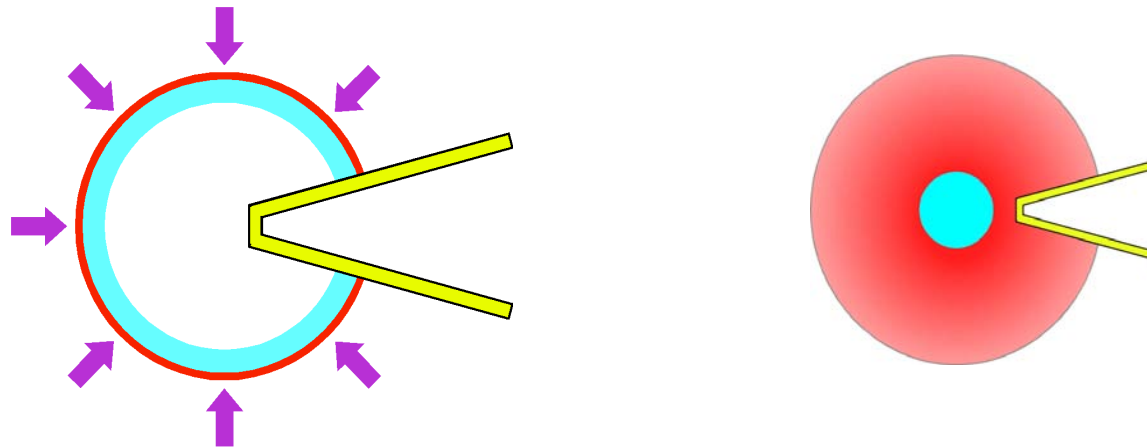
**Multiple ARC images combined with reaction history and primary neutron imaging provide detailed core diagnostics**



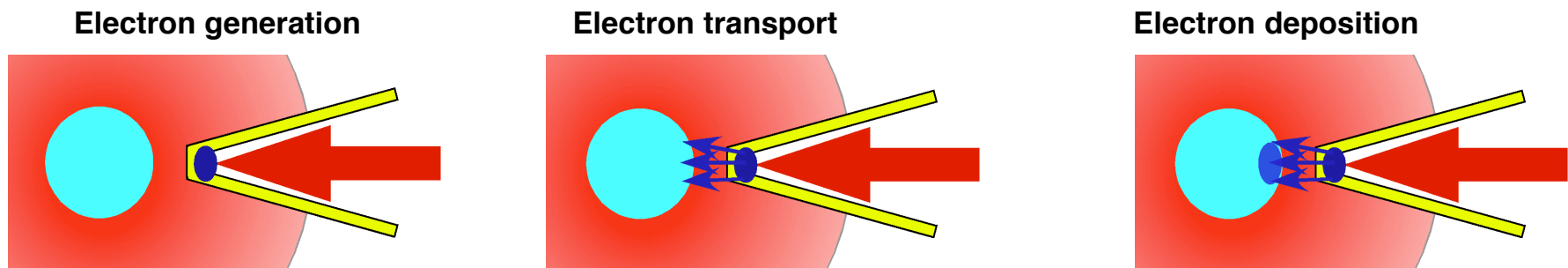
# Fast ignition, which separates the fuel compression and ignition, will be tested on NIF



- The compression laser assembles the fuel to uniform, high density:



- The ignition laser generates hot electrons that propagate through to the dense fuel and deposit their energy initiating a burn wave:

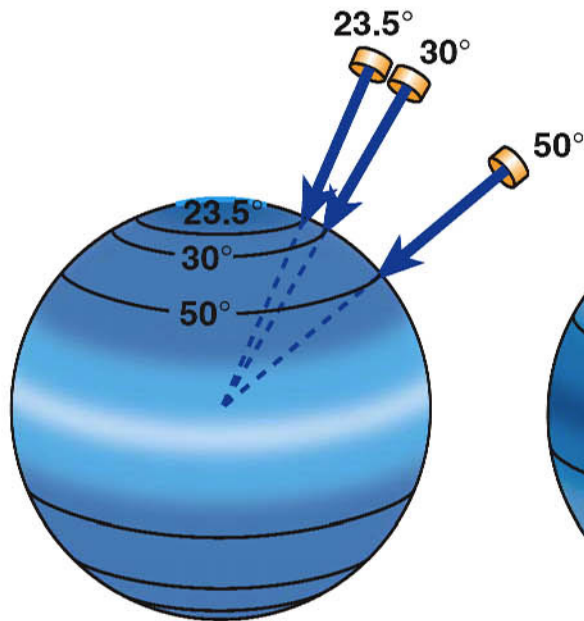




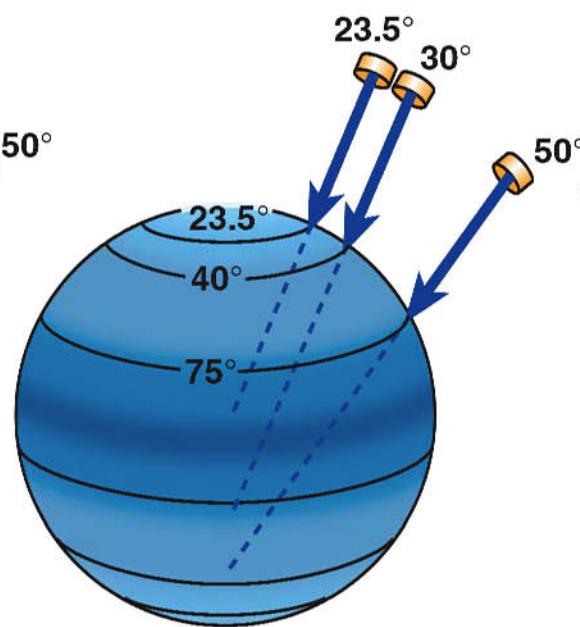
# Direct drive can achieve ignition conditions while NIF is in the x-ray-drive configuration



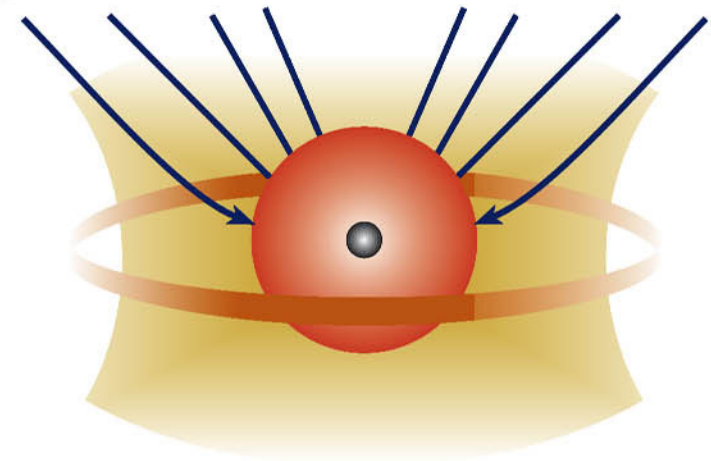
Standard pointing with x-ray-drive configuration



Repointing for polar direct drive (PDD)



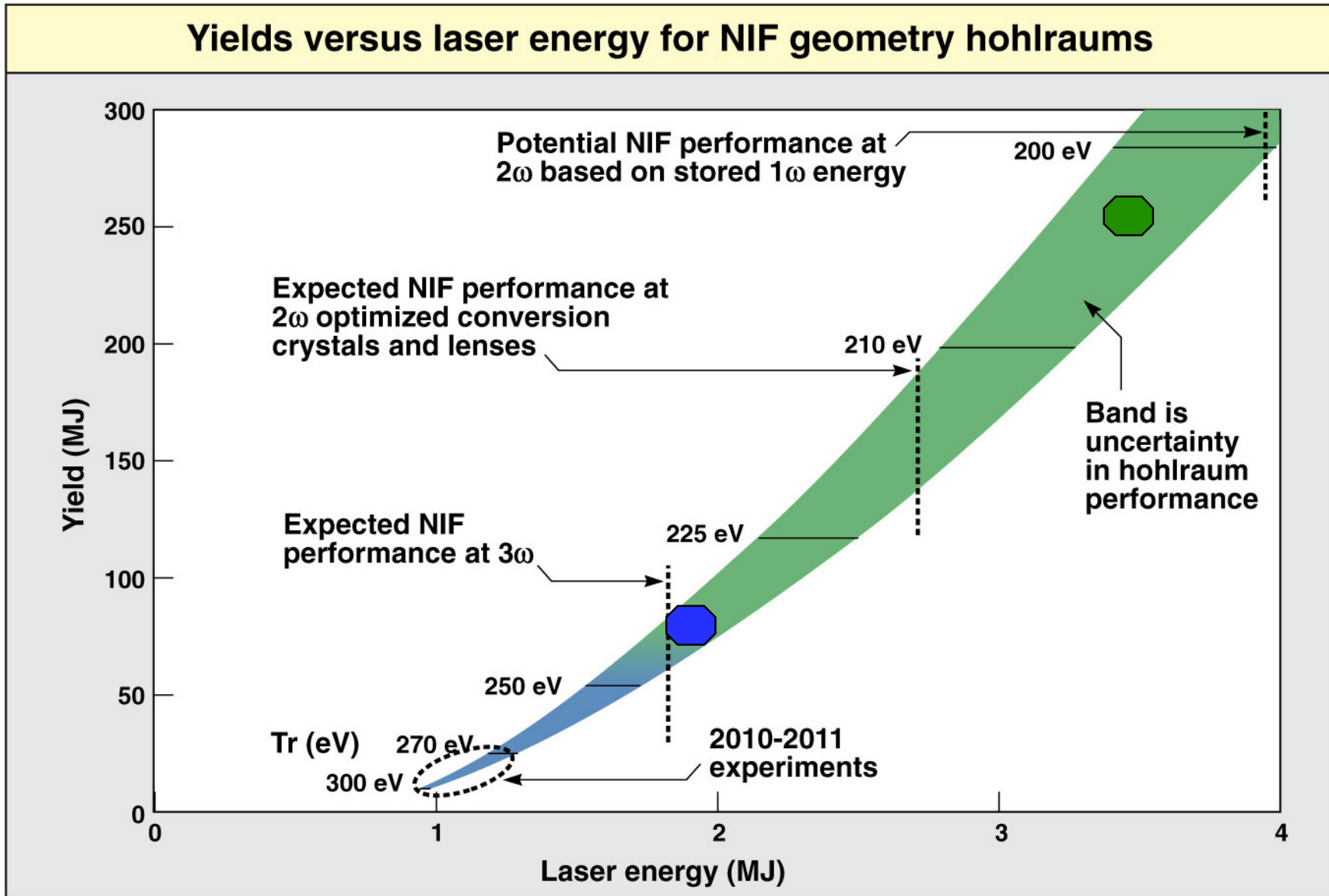
Saturn concept



Experimental and theoretical progress gives increasing confidence in achieving PDD ignition.



# Ultimately, yields well in excess of 100 MJ may be possible on NIF

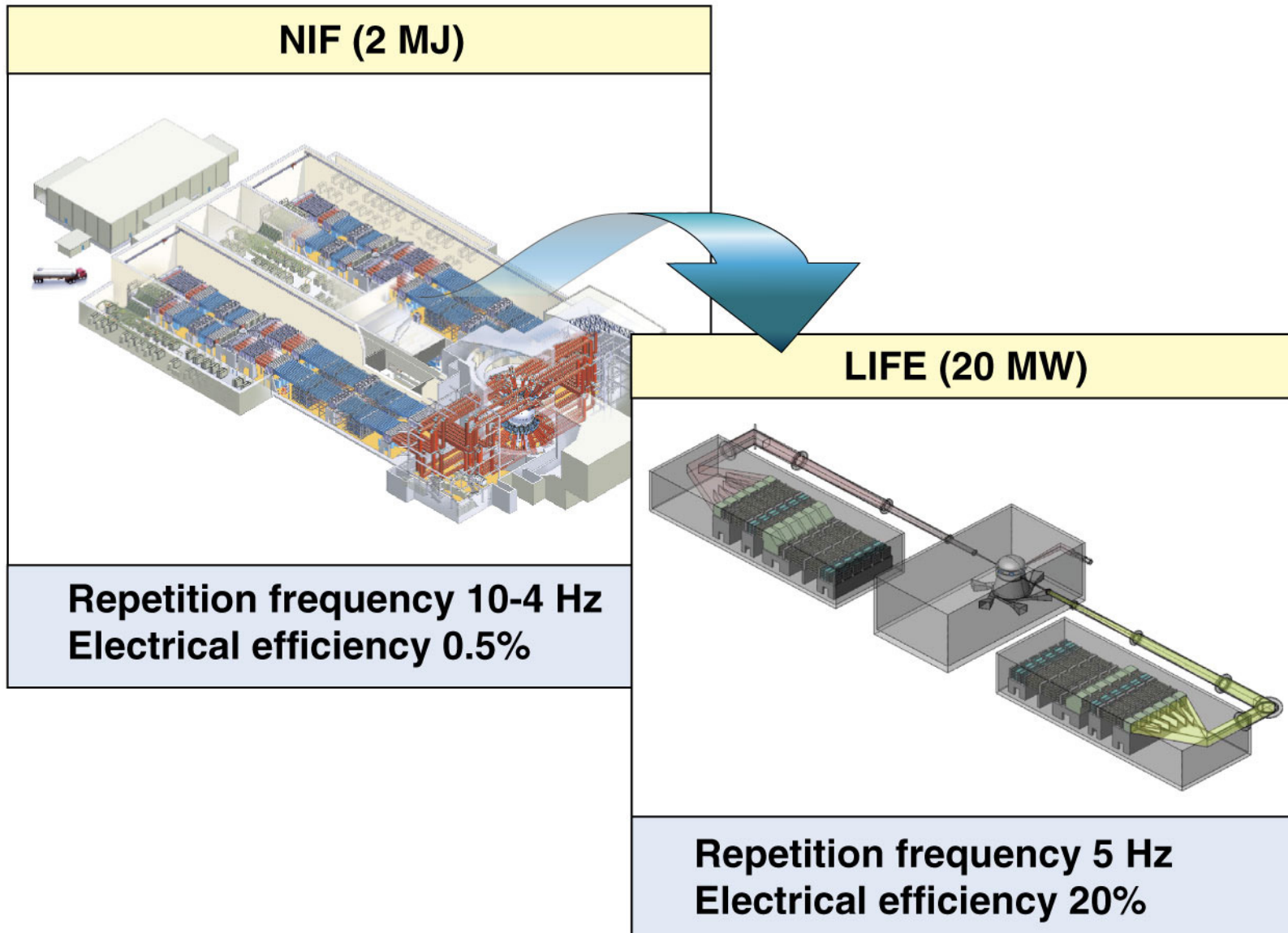




# Is NIF a precursor to an Inertial Fusion Energy plant?

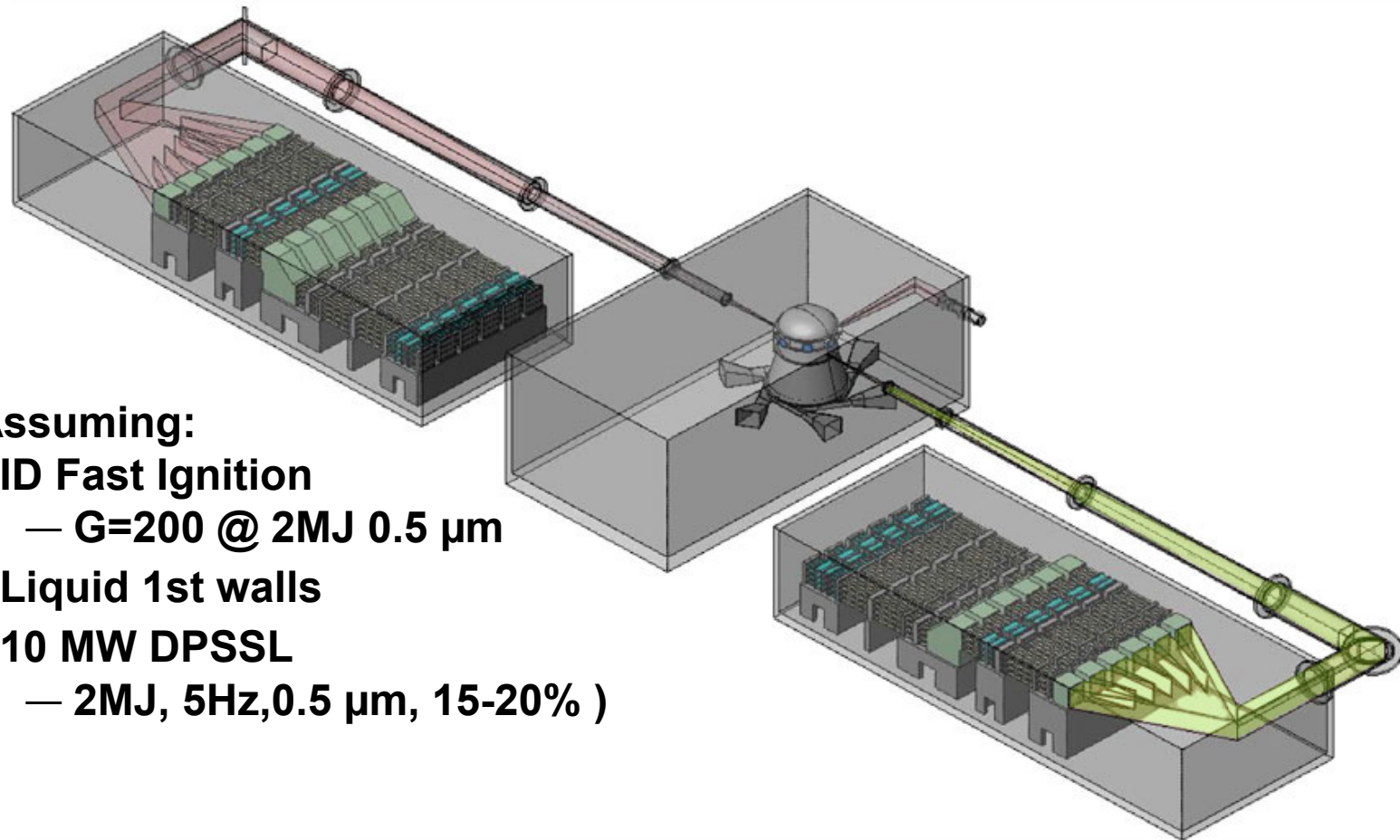


The National Ignition Facility





# We have performed a systems study of a 1 GWe IFE power plant



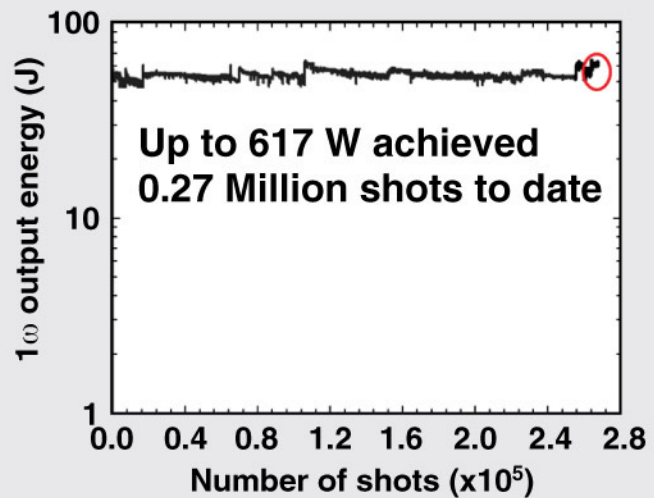
## Assuming:

- ID Fast Ignition
  - $G=200$  @ 2MJ 0.5  $\mu\text{m}$
- Liquid 1st walls
- 10 MW DPSSL
  - 2MJ, 5Hz, 0.5  $\mu\text{m}$ , 15-20% )



## Mercury Laser at LLNL

- 40 W/cm<sup>2</sup>
- Scalable architecture
- 0.27 M shots to date

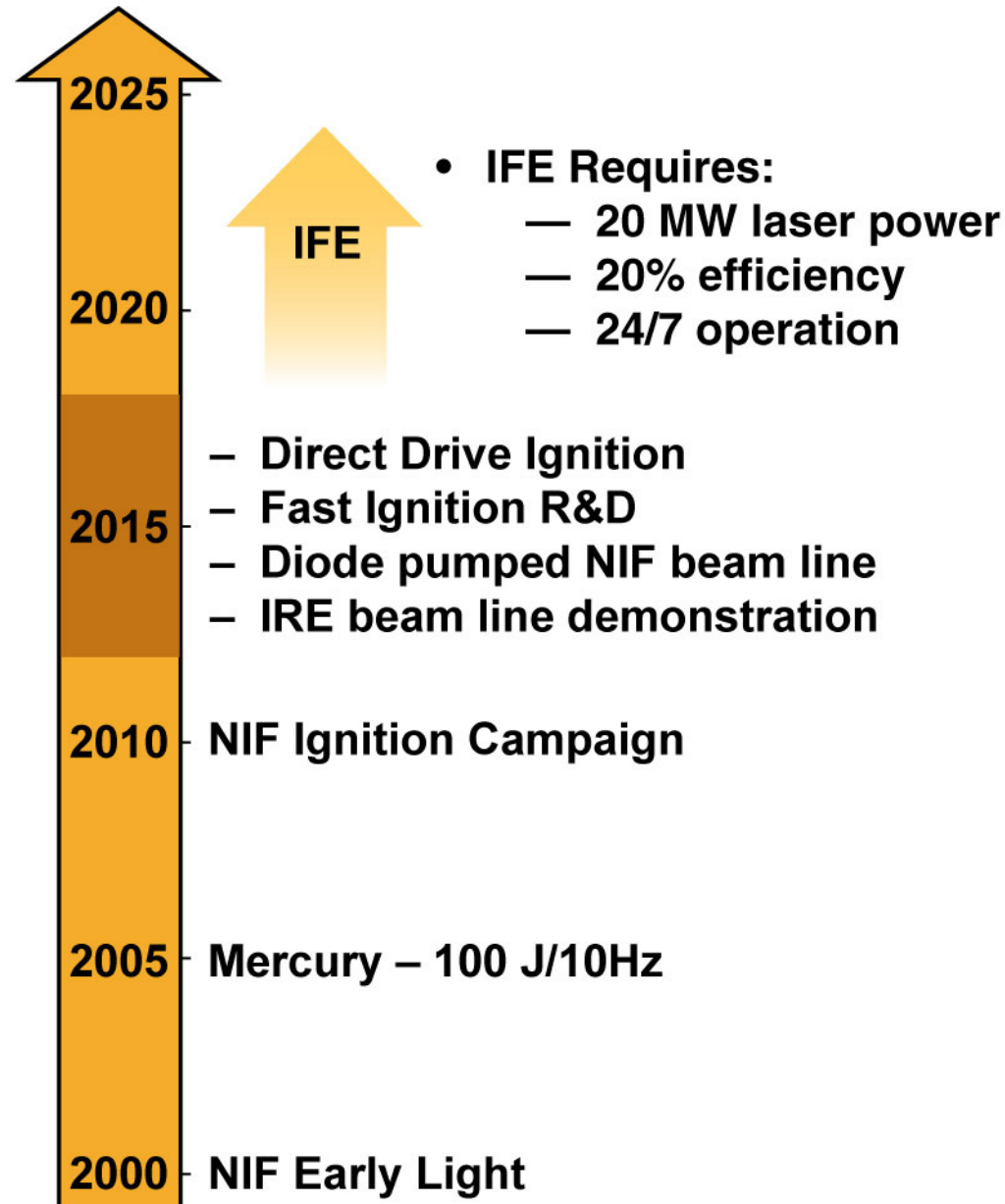




# Leveraging the NIF provides a near-term pathway for fusion energy



The National Ignition Facility



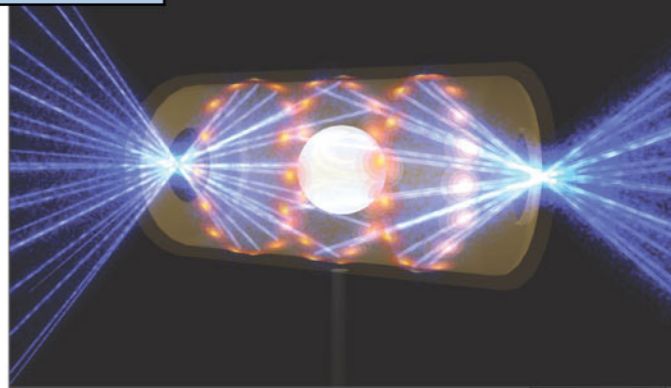


## NIF Project



Completion in 2009

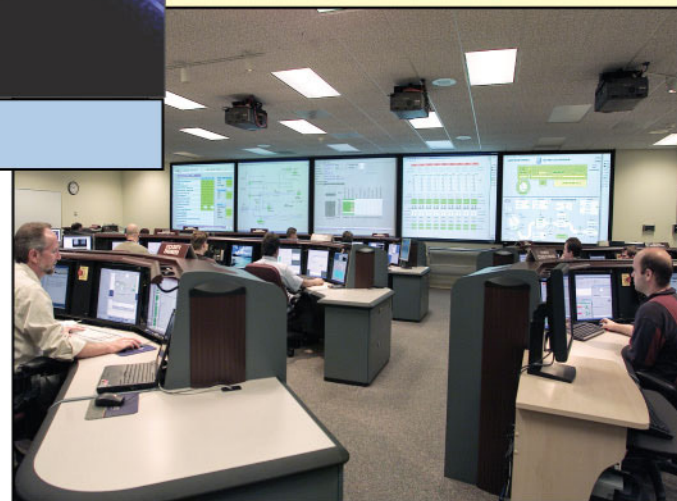
## National Ignition Campaign



2006—2012

## NIF Master Strategy

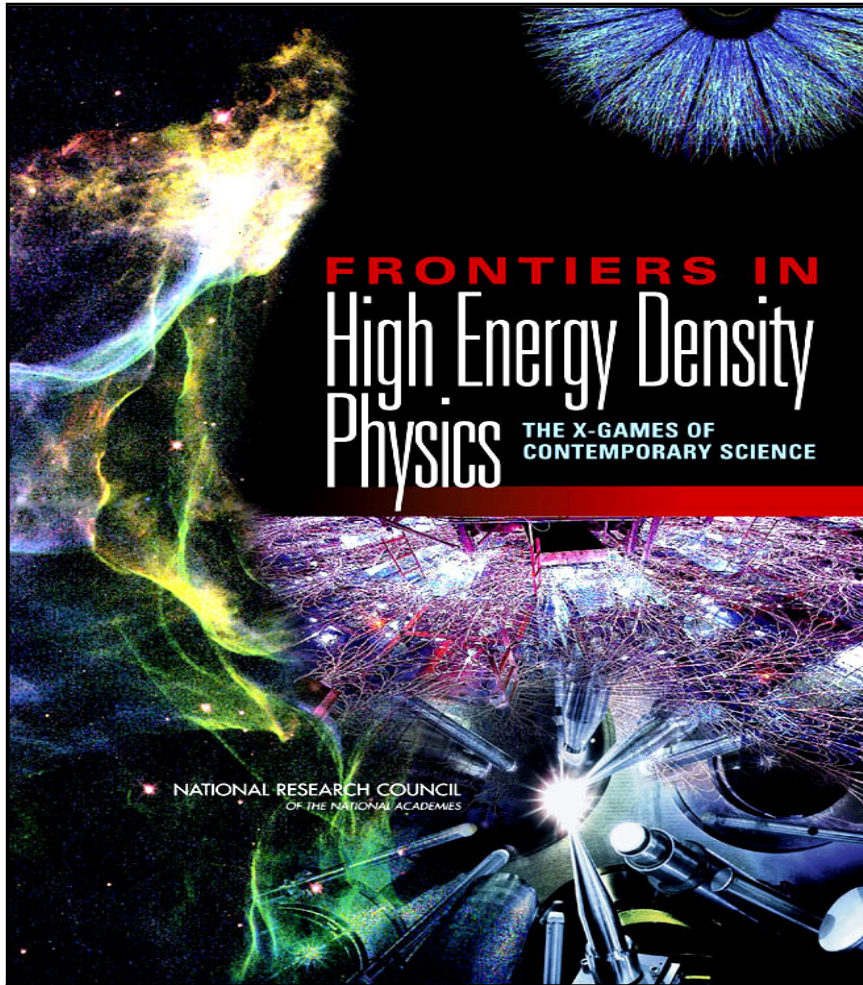
## National User Facility



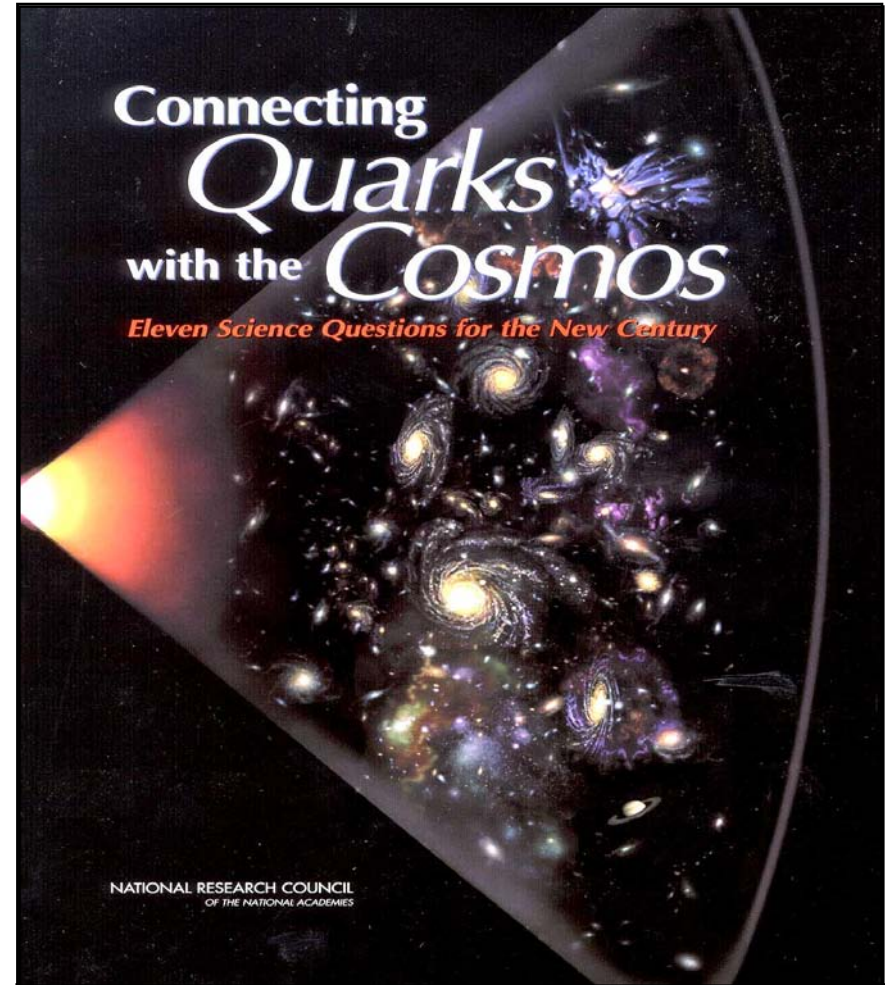
2009—2030



# NIF can play a key role in international science vision



**NRC committee on HEDP:  
X-Games of Contemporary Science**

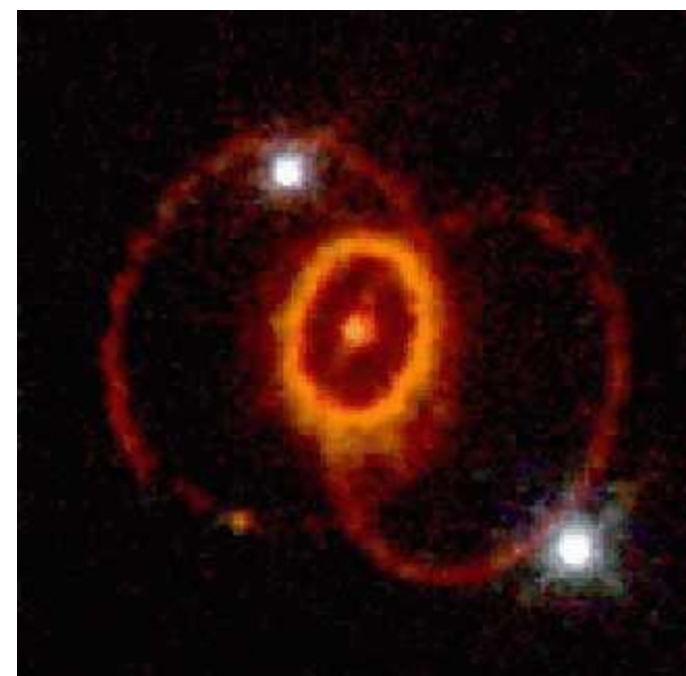


**NRC committee on the  
Physics of the Universe**



# NIF's Scientific Environments

- **These are the conditions of Extreme Laboratory Astrophysics**
  - $T > 10^8$  K matter temperature
  - $\rho > 10^3$  g/cc density
  - Those are both 7x what the Sun does!  
Helium burning, stage 2 in stellar evolution, occurs at  $2 \times 10^8$  K!
  
- **Core-collapse Supernovae, colliding neutron stars, operate at  $\sim 10^{20}$  n's/cc**
  - NIF:  $\rho_n = 10^{26}$  neutrons/cc
  
- **These apply to Type Ia Supernovae!**
  - Electron Degenerate conditions
  - Rayleigh-Taylor instabilities for (continued) laboratory study.
  
- **Only need  $\sim$ Mbar in shocked hydrogen to study the EOS in Jupiter & Saturn**
  - **These certainly qualify as "unprecedented."**  
— **Pressure  $> 10^{11}$  bar**



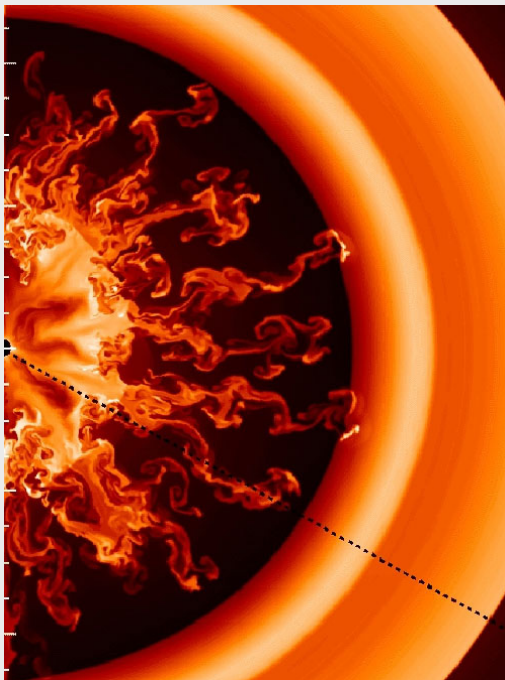


# Three university teams are starting to prepare for NIF shots in unique regimes of HED physics



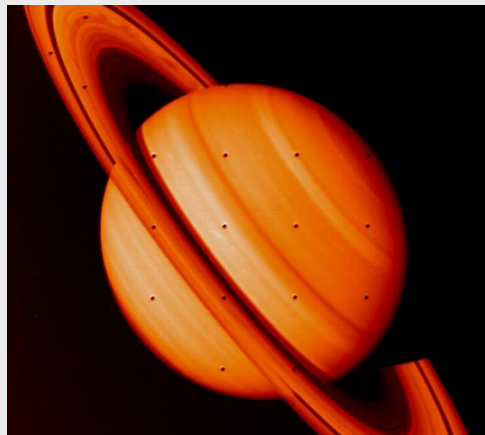
The National Ignition Facility

## Astrophysics - hydrodynamics



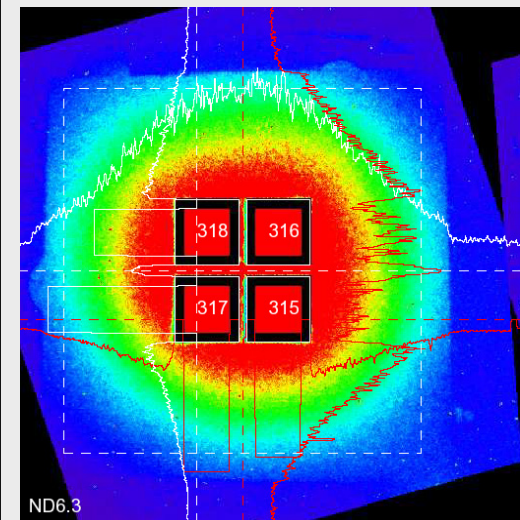
Paul Drake, PI, U. of Mich.  
David Arnett, U. of Arizona,  
Adam Frank, U. of Rochester,  
Tomek Plewa, U. of Chicago,  
Todd Ditmire, U. Texas-Austin  
LLNL hydrodynamics team

## Planetary physics - EOS



Raymond Jeanloz, PI,  
UC Berkeley  
Thomas Duffy, Princeton U.  
Russell Hemley, Carnegie Inst.  
Yogendra Gupta, Wash. State U.  
Paul Loubeyre, U. Pierre & Marie  
Curie, and CEA  
LLNL EOS team

## Nonlinear optical physics - LPI

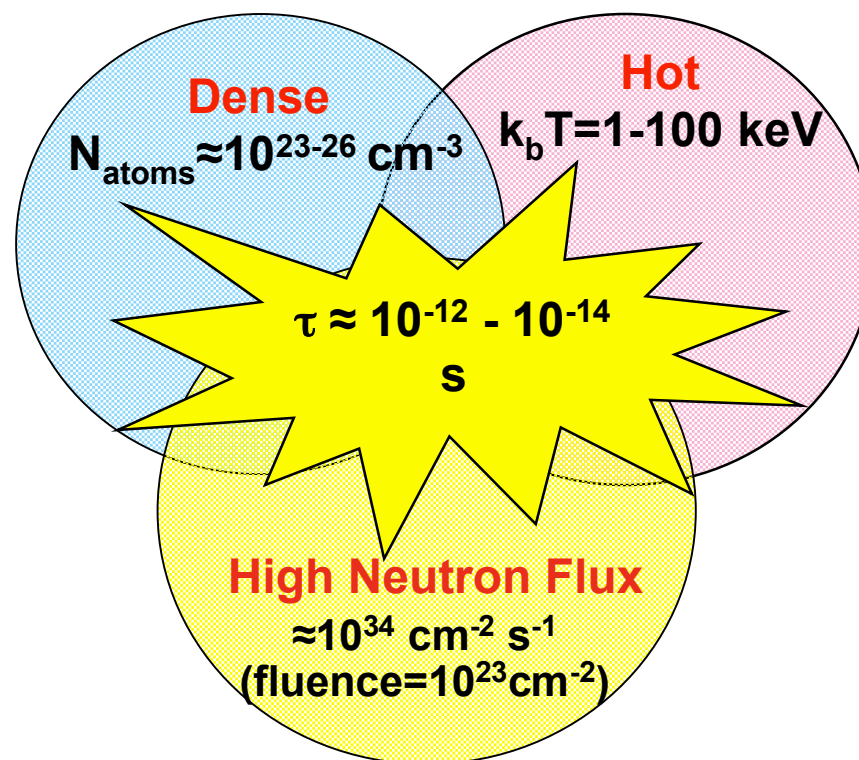


Christoph Niemann, PI,  
UCLA NIF Professor  
Chan Joshi, UCLA  
Warren Mori, UCLA  
Bedros Afeyan, Polymath  
David Montgomery, LANL  
Andrew Schmitt, NRL  
LLNL LPI team



# Nuclear science on NIF

- Unique conditions on NIF will enable studying:
  - Dynamics of nuclei in excited states
  - Charged particle reactions relevant to nucleosynthesis
  - Solar neutrino physics



A working group has been formed including: LLNL (Schneider), LBNL (Phair), UCB (Moretto), Univ. Notre Dame (Wischer), Colorado School of Mines (Greife), GSI, University of Oslo



# NIF's planning supports DOE's goals for "civilian research" and NNSA-SC partnering



Science Sept 29 Issue, p1874

NEWSFOCUS

## Ray Orbach Asks Science to Serve Society

For a decade, chemist Radoslav Adzic has explored the basic structure of metal-electrolyte interfaces at Brookhaven National Laboratory in Upton, New York. His employer, the U.S. Department of Energy (DOE), has long sponsored fundamental science on catalysis in such systems in hopes of making hydrogen fuel cells efficient enough to one day replace fossil fuels as an energy source. But it wasn't until 2004 that Adzic decided to tackle a research question with more direct applications: how to use monolayers of platinum to build cheaper fuel cells, focusing on hydrogen.

It wasn't a random decision. The year before, President George W. Bush had proposed an 8-year, \$1.2 billion hydrogen fuels program that would begin with applied engineering studies. After attending a DOE-sponsored workshop to discuss the basic research needed to turn hydrogen into a commercially viable fuel, Adzic won a \$700,000 grant to study

Los Alamos National Laboratory in New Mexico.

Another barrier to developing new technologies, says Badman, is DOE's current compartmentalized bureaucracy. In July, he sent out a memo giving Orbach "detailed access" to DOE's vast empire, hoping that regular meetings among disparate programs will break through that mentality. It's not a new concept, Orbach says, but "what's new is the intensity and importance" of those meetings.

Money greases the wheels of cooperation. In addition to the hydrogen initiative and a similar effort in solar energy, Orbach has called for \$250 million for biofuel start-ups involving industrial scientists, technologists, and genomicists (*Science*, 11 August, p. 746). Sharlene Weatherwax, a DOE program manager, says a previous partnership with DOE's technology program might have consisted of a single grant.

Orbach knows that change doesn't come easily for areas, such as nuclear weapons development, that have traditionally been walled off from civilian research. In initial meetings with applied-research managers, he admits, "people don't quite know what to make of us." But Edward Moses, director of the National Ignition Facility, a superlaser at Lawrence Livermore National Laboratory in California, says Orbach is helping him grow a civilian research community to utilize an instrument designed to maintain the nation's nuclear arsenal.

Some fear that such cross-fertilizing could weaken basic science at DOE. "There is a danger of letting the basic program become a technical-



Teammates. Ray Orbach (left) hopes researchers can help his boss, Energy Secretary Samuel Bodman, (right) do his job, too.

support enterprise for the applied programs," says energy expert Robert Fri, a former Environmental Protection Agency official who believes unfettered basic work can "cook up" whole new energy ideas. Materials scientist Ward Plummer of the University of Tennessee, Knoxville, decries a 20% decline in funding core, unsolicited research within DOE's Office of Basic Energy Sciences in the last 3 years at the same time that solar energy, nanotechnology, and hydrogen programs have grown.

Plummer and others hope that DOE's new effort to define so-called grand challenges will stop that erosion. And although Orbach says he has no plans to "fuzz the boundaries" between basic and applied work, he is looking for greater cooperation between the two camps. A recent discussion with managers studying how fluids flow in dry soil at DOE's planned nuclear waste fuel repository at Yucca Mountain, Nevada, proves its value, he says. "When we met with Fossil Energy and learned more about carbon dioxide sequestration," Orbach recalls, "it suddenly popped out that that's the same problem."

Whatever happens, Orbach says DOE is determined to squeeze more impact out of its science. That's good news for Adzic, who relishes taking on challenges "directly important to society." It's also a good deal for academics. "If you publish something relevant" to a problem, says Adzic, "your paper is more [often] cited."

—ELI KINTISCH

CREDIT: DOE

Orbach knows that change doesn't come easily for areas, such as nuclear weapons development, that have traditionally been walled off from civilian research. In initial meetings with applied-research managers, he admits, "people don't quite know what to make of us." But Edward Moses, director of the National Ignition Facility, a superlaser at Lawrence Livermore National Laboratory in California, says Orbach is helping him grow a civilian research community to utilize an instrument designed to maintain the nation's nuclear arsenal.

research could better fulfill energy needs. A 1997 report by the President's Council of Advisors on Science and Technology, for example, called for "better coordination" between basic and applied energy research. "Everyone knows it's a problem, but nothing's happened," says physicist George Crabtree, a manager at DOE's Argonne National Laboratory in Illinois.

One obstacle is the current rewards system in academia. Take the science behind superconductivity, which holds the promise of low-resistance power lines or incredibly efficient transformers. The kind of discovery that earns a scientist a paper in a top journal—learning why a material changes phase at a certain temperature—is too theoretical to help a company trying to make superconducting materials. But a commercially valuable yet incremental improvement in that technology wouldn't interest those top-tier journals. So a scientist might not even bother to record such an advance. "If the currency is just *PRL* [*Physics Review Letters*], *Nature*, and *Science*, you'll just move on," says materials scientist John Sarrao of

1874

29 SEPTEMBER 2006 VOL 313 SCIENCE www.sciencemag.org

Published by AAAS



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NIF Town Hall Meeting, June 16, 2007



# U.S. Academic Alliance

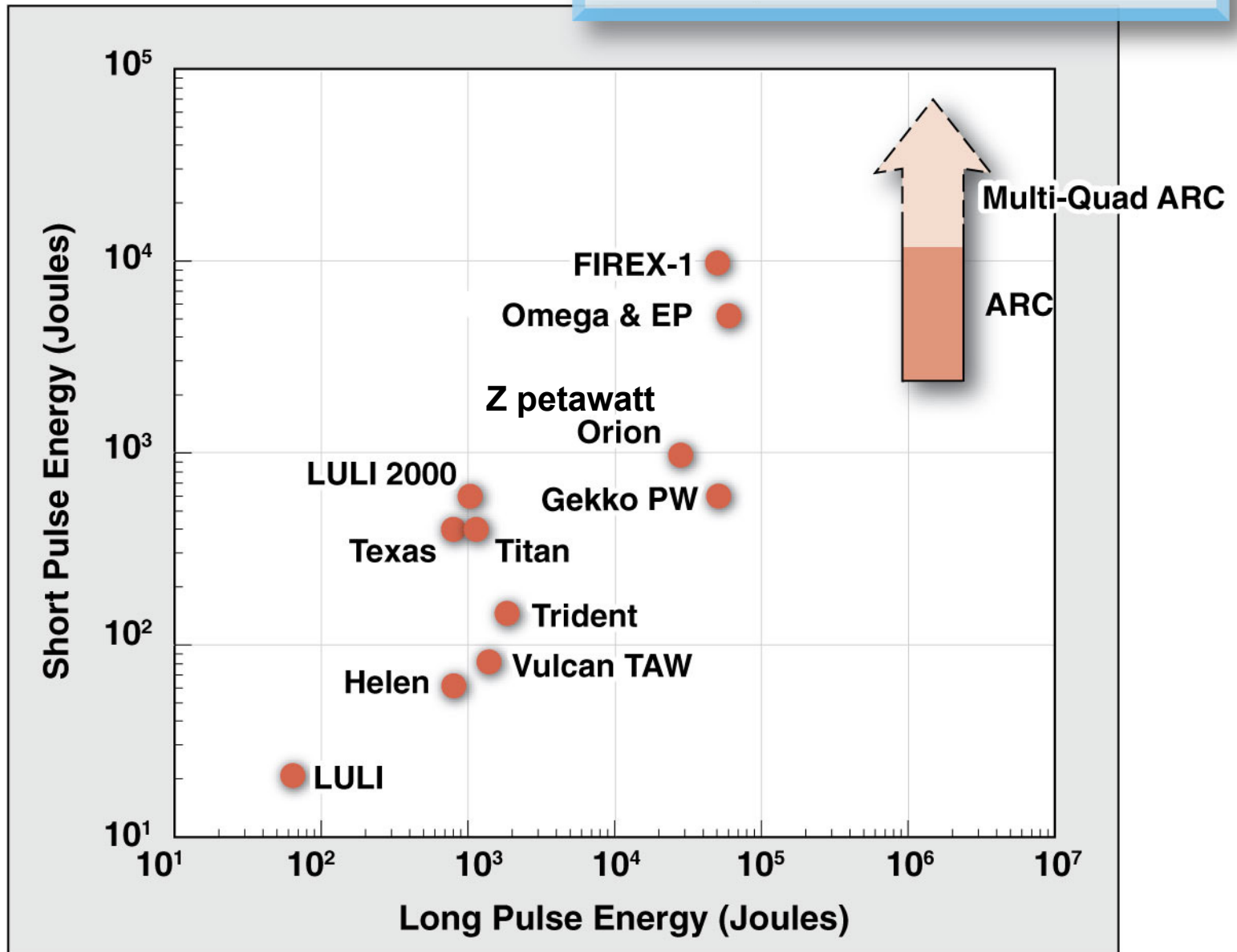


- ★ ASCI Centers
  - ★ SSAA Centers
  - ★ Other Science Campaign Program
  - ★ Omega Laser
  - ◆ Research Grants
  - National Laser User Facility
- HEDP activities Italicized*

**“The NIF will be a unique center of R&D that will assure the U.S. will achieve goals of SSP and HEDP not possible with any other facility”**



NIF will be an integral member of the HED community





# Our goal: turn NIF into the premier international center for HED experimental science



The National Ignition Facility

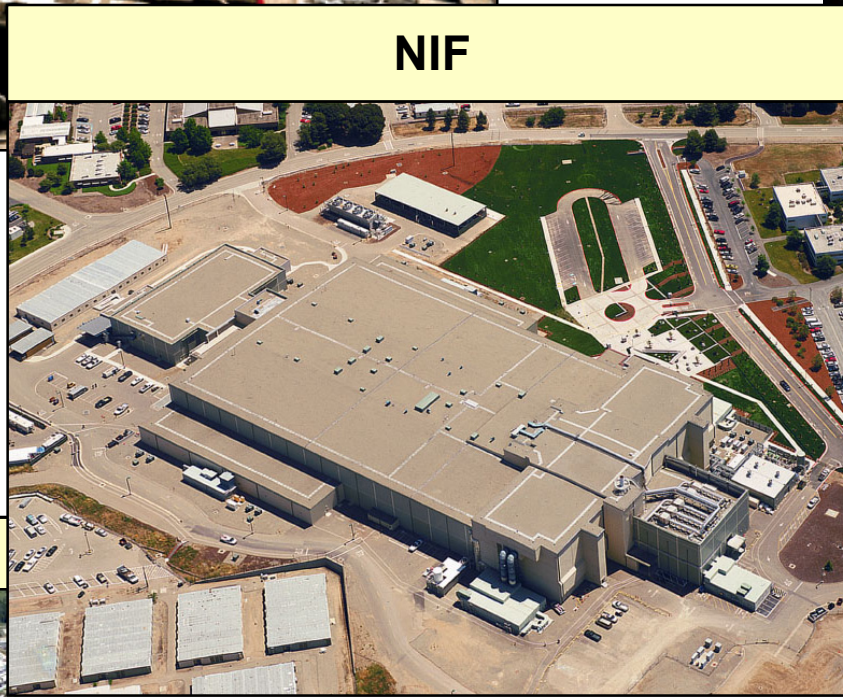
## CERN



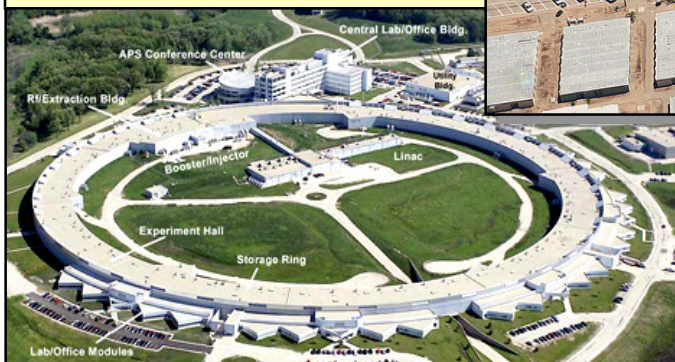
## Chandra X-ray Observatory



## NIF



## APS



## SLAC





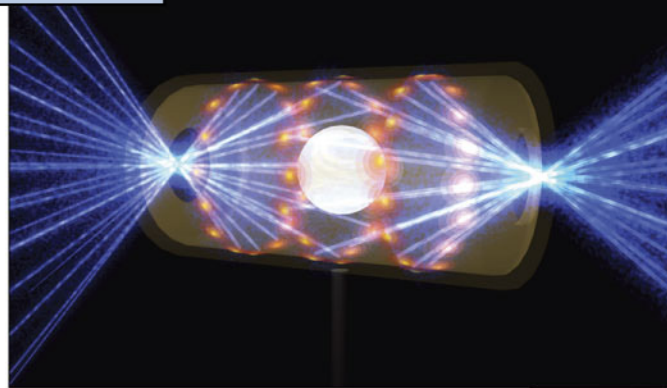
## NIF Project



Completion in 2009

**NIF is a  
National User  
Facility**

## National Ignition Campaign



2006—2012

## National User Facility



2009—2030

- A “Governance Model” is under development
- User friendly environment is being designed



# NIF: Visions of yesterday become reality of today



The National Ignition Facility

## 1960's–Invention of Laser



## 2010–Goal of Ignition



**Ignition by 2010**  
**Golden Anniversary of the Invention of the Laser**  
**and the ICF Concept**



# The National Ignition Facility

Limitless Clean Energy  
Eye on the Cosmos











Oct '03







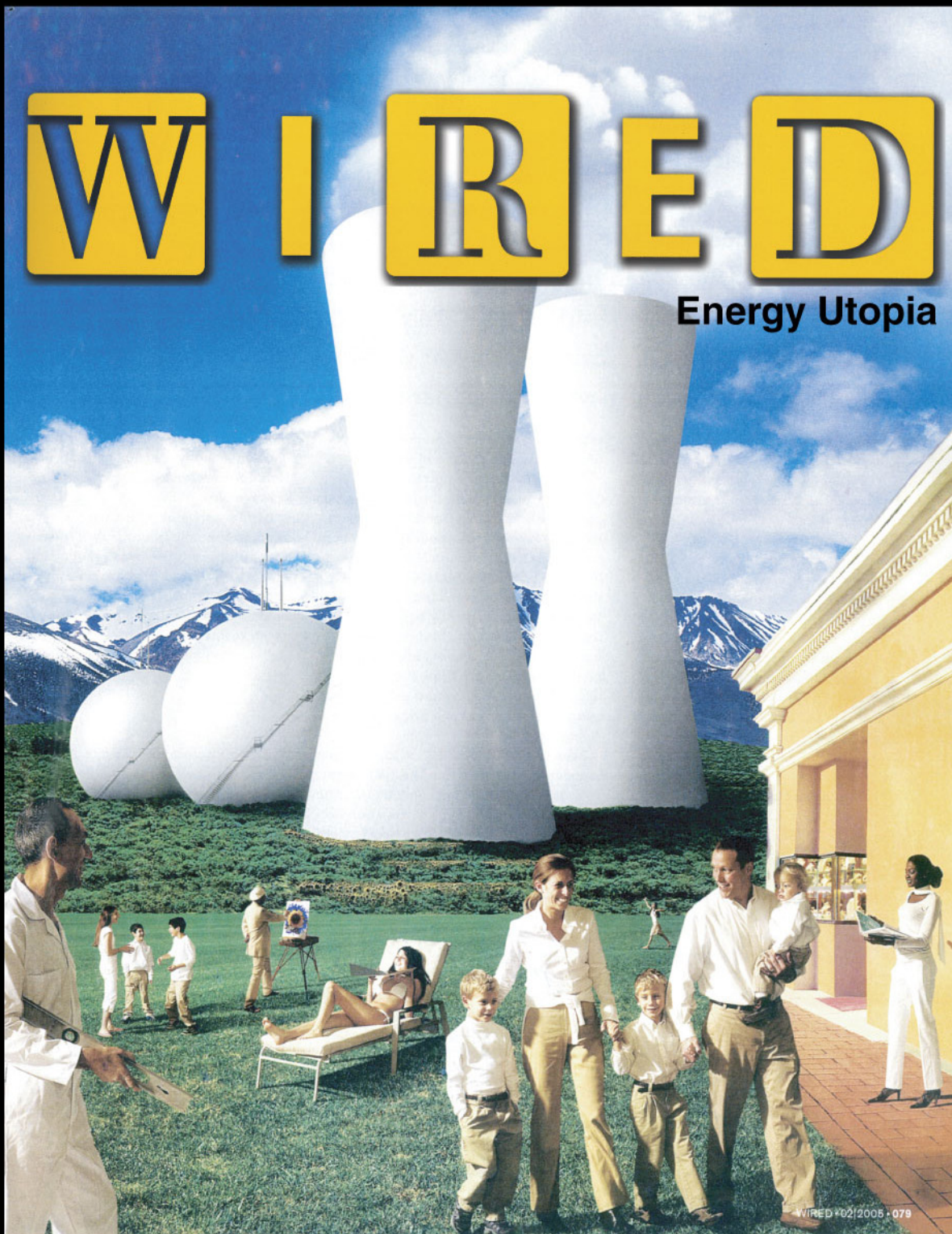
**Fossil Fuels Can't Keep  
Up and their Climatic  
Effects Could be  
Devastating**





# WIRED

Energy Utopia



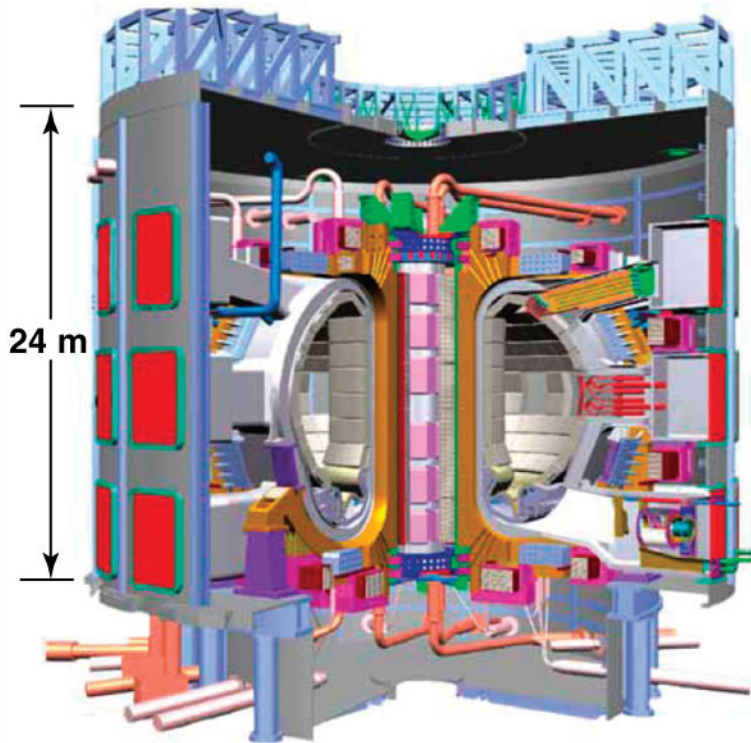


# There are two major possibilities for fusion energy



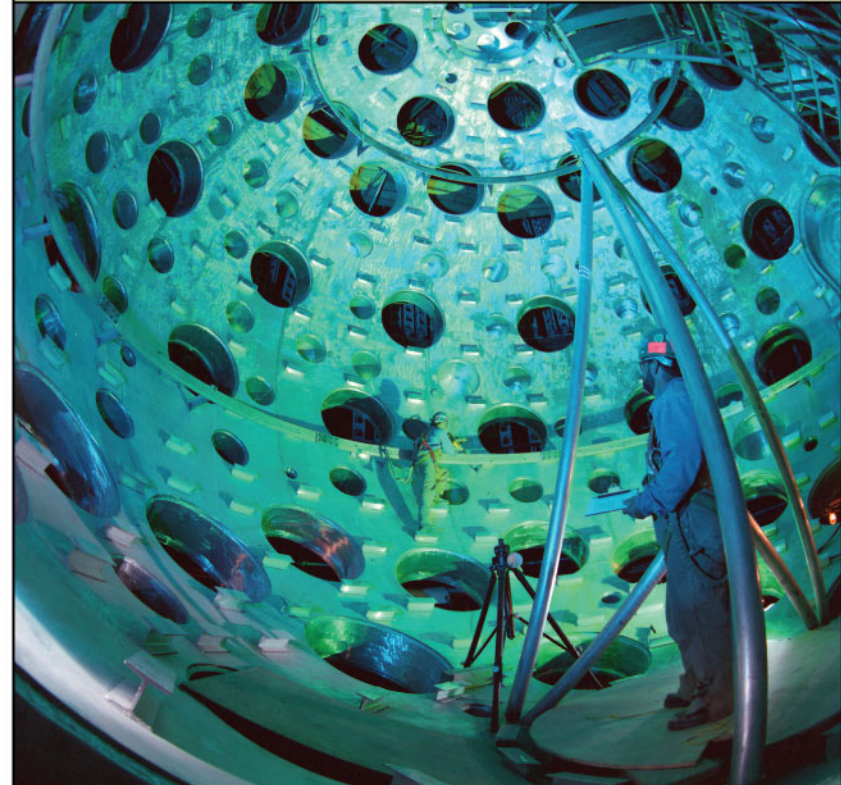
The National Ignition Facility

## Magnetic Fusion Energy (1951)



DOE Office of Science

## Inertial Fusion Energy (1960)



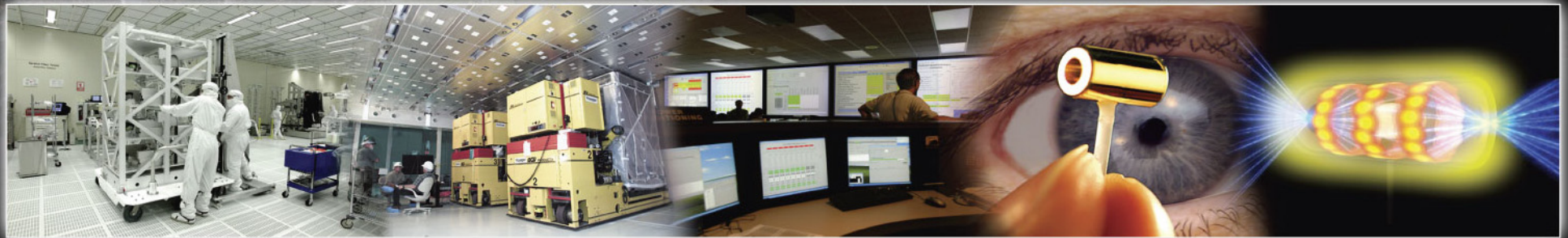
DOE NNSA

Challenges include making it safe, reliable, and cost effective



# National Ignition Facility

## Three Years to a New Age for Science





# NIF provides unique environment for science



The National Ignition Facility

