# Overview of ICF Program


**Presented to:**
**Fusion Power Associates**
**Annual Meeting**

**By:**
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**Acting Assistant Deputy Administrator for**
**Inertial Confinement Fusion and the NIF Project**
**National Nuclear Security Administration**

**December 5, 2007**

# Agenda

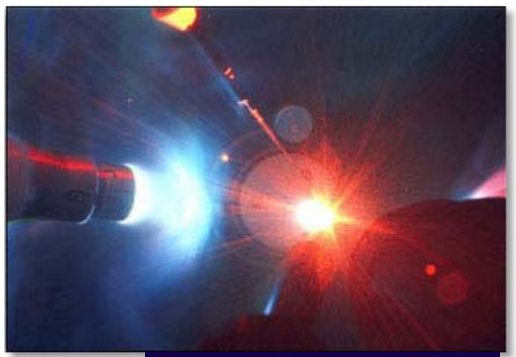
- Mission/Strategic Objectives
- National Ignition Facility (NIF)
- National Ignition Campaign (NIC)
  - A National Partnership
  - Achieving Key Milestones
- Pulsed Power ICF
- High Average Power Laser Program (HAPL)
- Joint Program in High Energy Density Laboratory Plasmas (HEDLP)
- Summary

# The production of ignition in the laboratory is a crucial goal for NNSA Defense Programs

National Nuclear Security Administration

## Mission of NNSA ICF Campaign

**Provide the experimental capabilities and scientific understanding in high energy density physics to maintain a safe, secure, and reliable nuclear weapons stockpile without underground testing**



## Strategic Objectives

- **Achieve thermonuclear ignition in the laboratory and develop it as a scientific tool for stockpile stewardship**
- **Support execution of high energy density physics experiments necessary to provide advanced assessment capabilities for stockpile stewardship**
- **Develop advanced technology capabilities that support the long-term needs of stockpile stewardship**
- **Maintain a robust national program infrastructure and attract scientific talent to the Stockpile Stewardship Program**

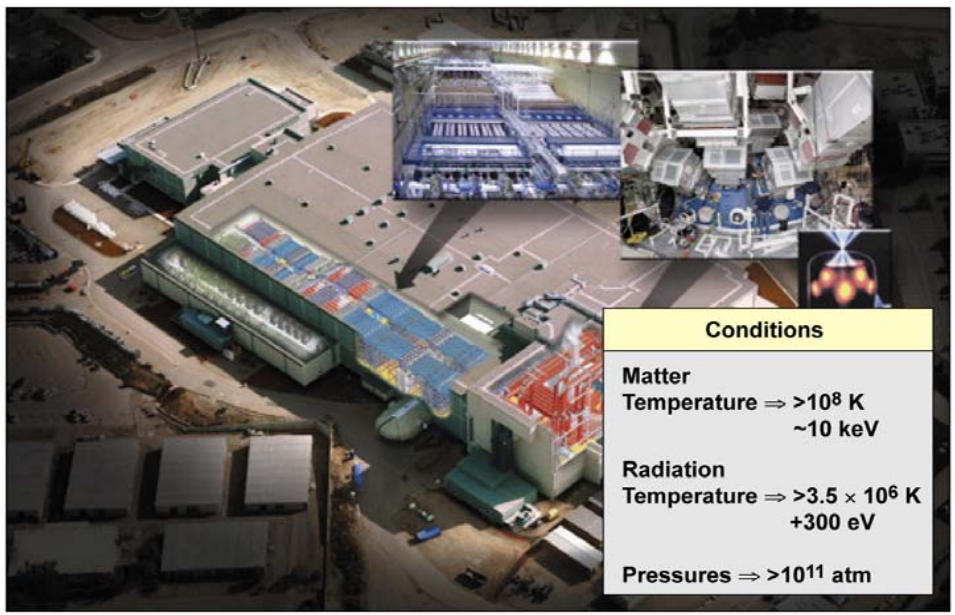
**Progress toward Fusion energy is an important ancillary benefit of the ignition campaign**

# The technological achievement of a generation is less than 3 years away

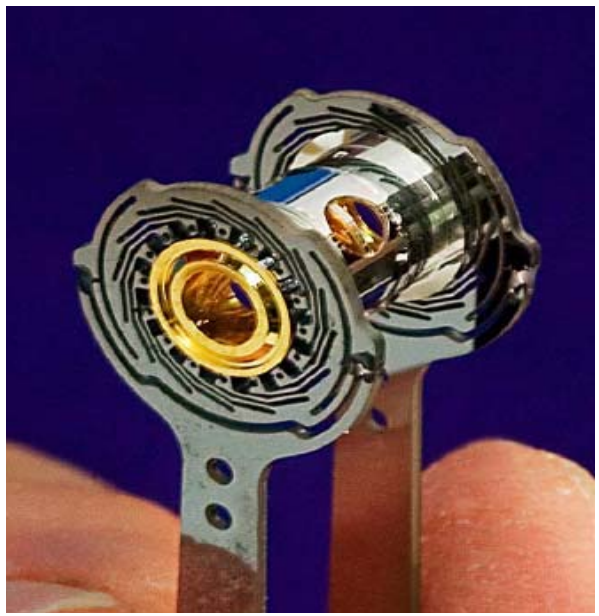
National Nuclear Security Administration

- The National Ignition Facility (NIF) laser is on track for completion in FY09.
- The National Ignition Campaign (NIC) is also on track and producing outstanding results in preparation for the first ignition experiments in FY10.

## National Ignition Facility




## Ignition Target

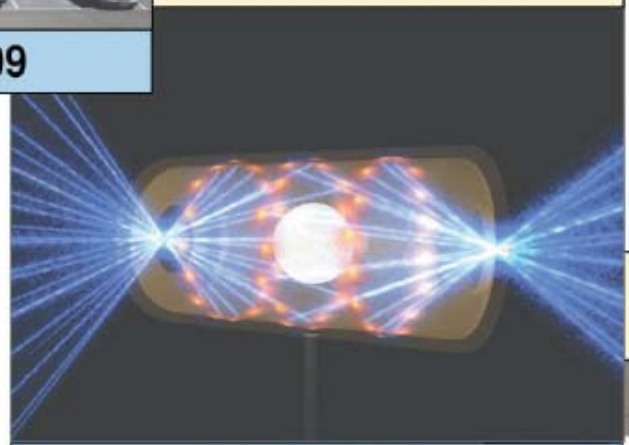


# NIF Master Strategy

## NIF Project

Completion in 2009

## National Ignition Campaign

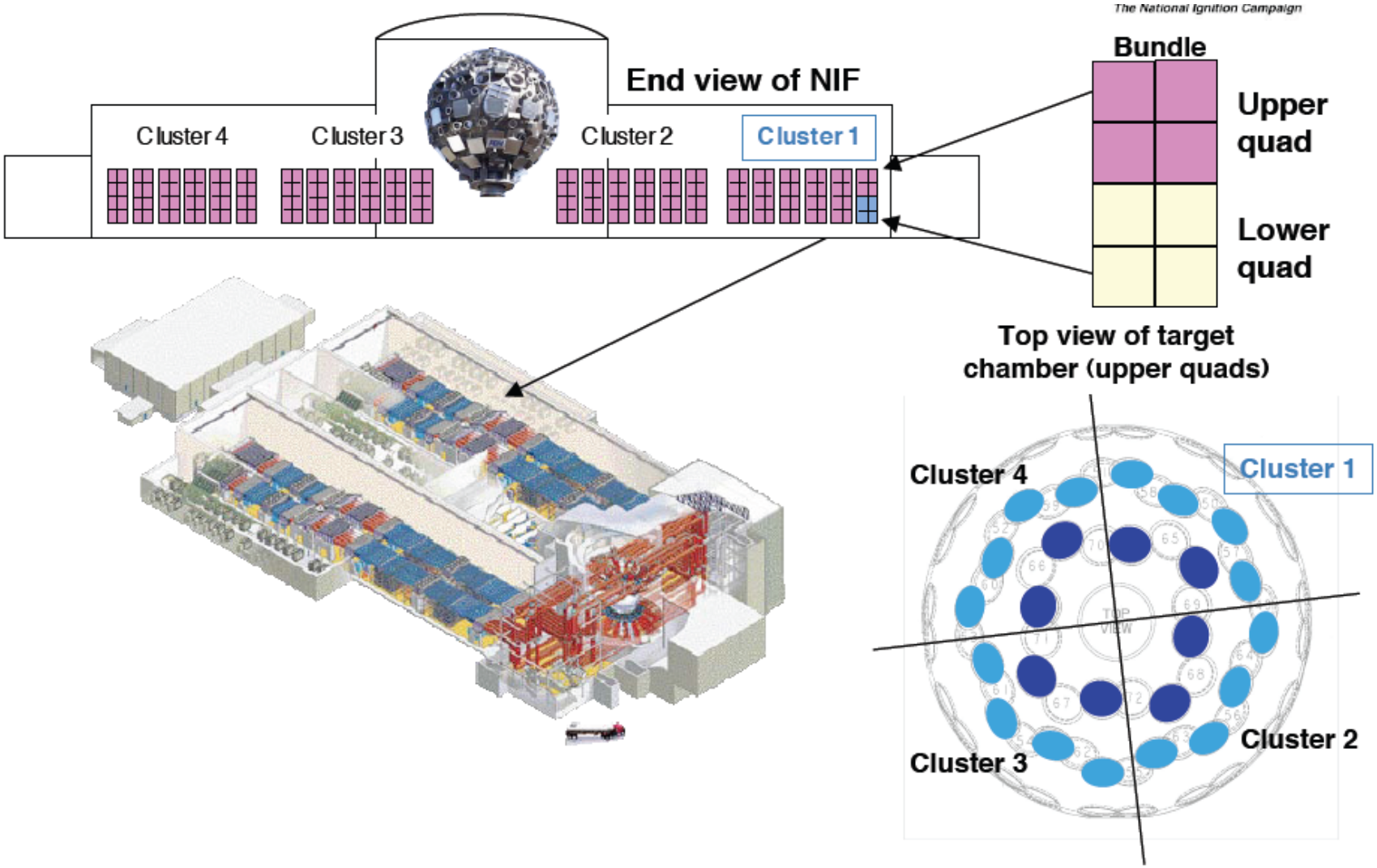


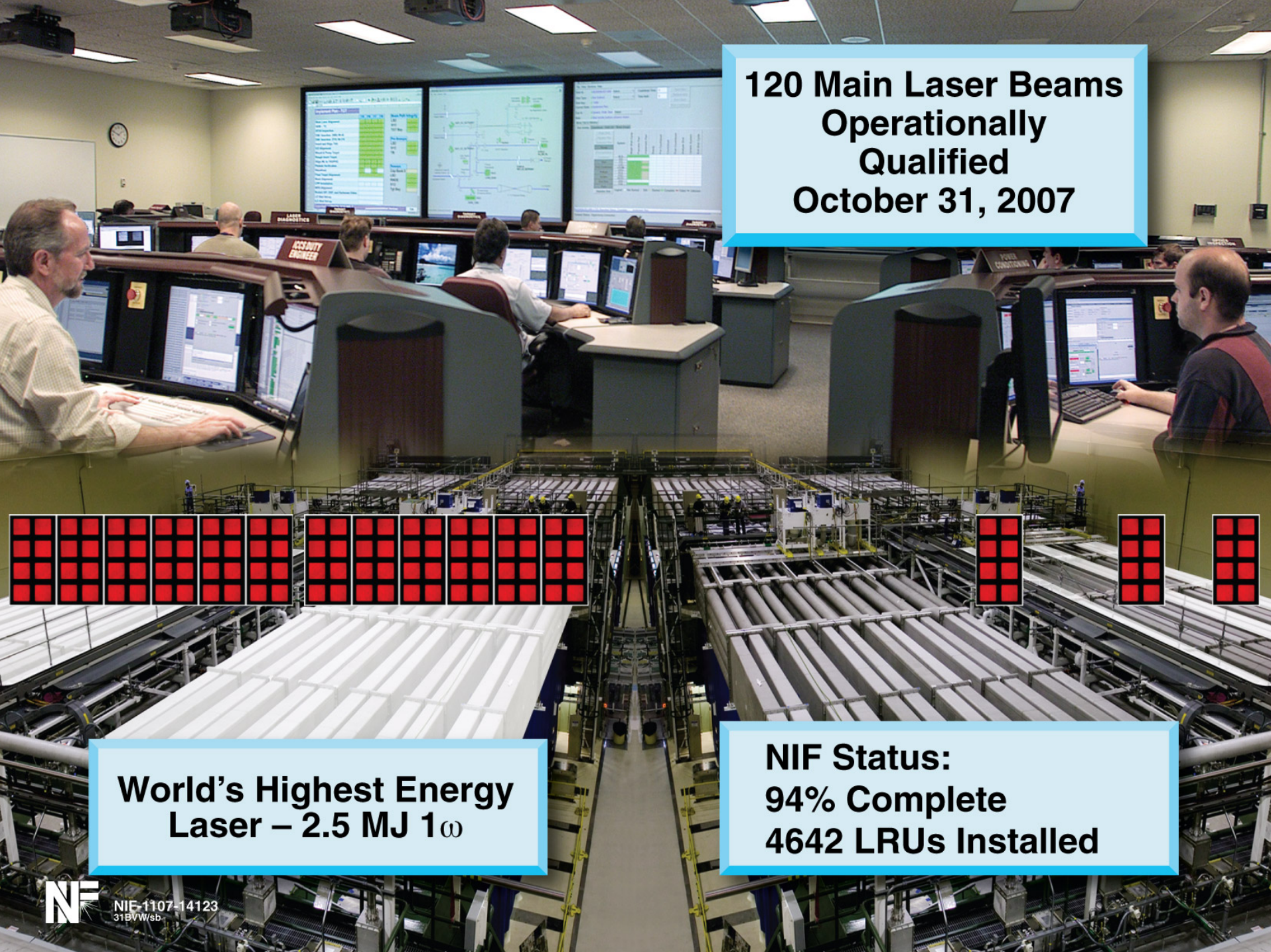
2006—2012

## National User Facility

2009—2030

# NIF is a 192-beam laser organized into "clusters," "bundles," and "quads"



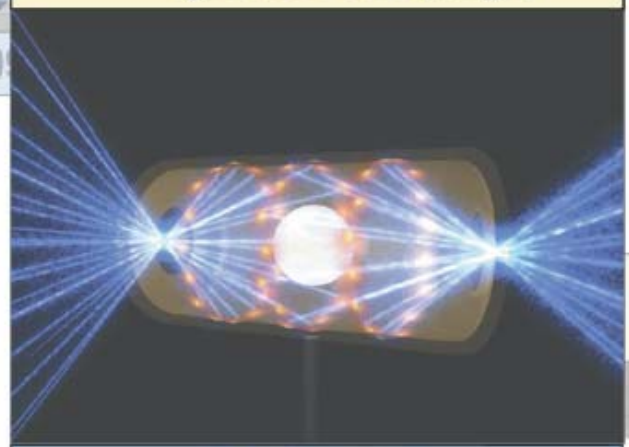

120 Main Laser Beams
Operationally
Qualified
October 31, 2007
World's Highest Energy
Laser – 2.5 MJ 1ω
NIF Status:
94% Complete
4642 LRUs Installed
NIF-1107-14123
31BVW/sb

NIF Project

Completion in 200

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

National Ignition Campaign



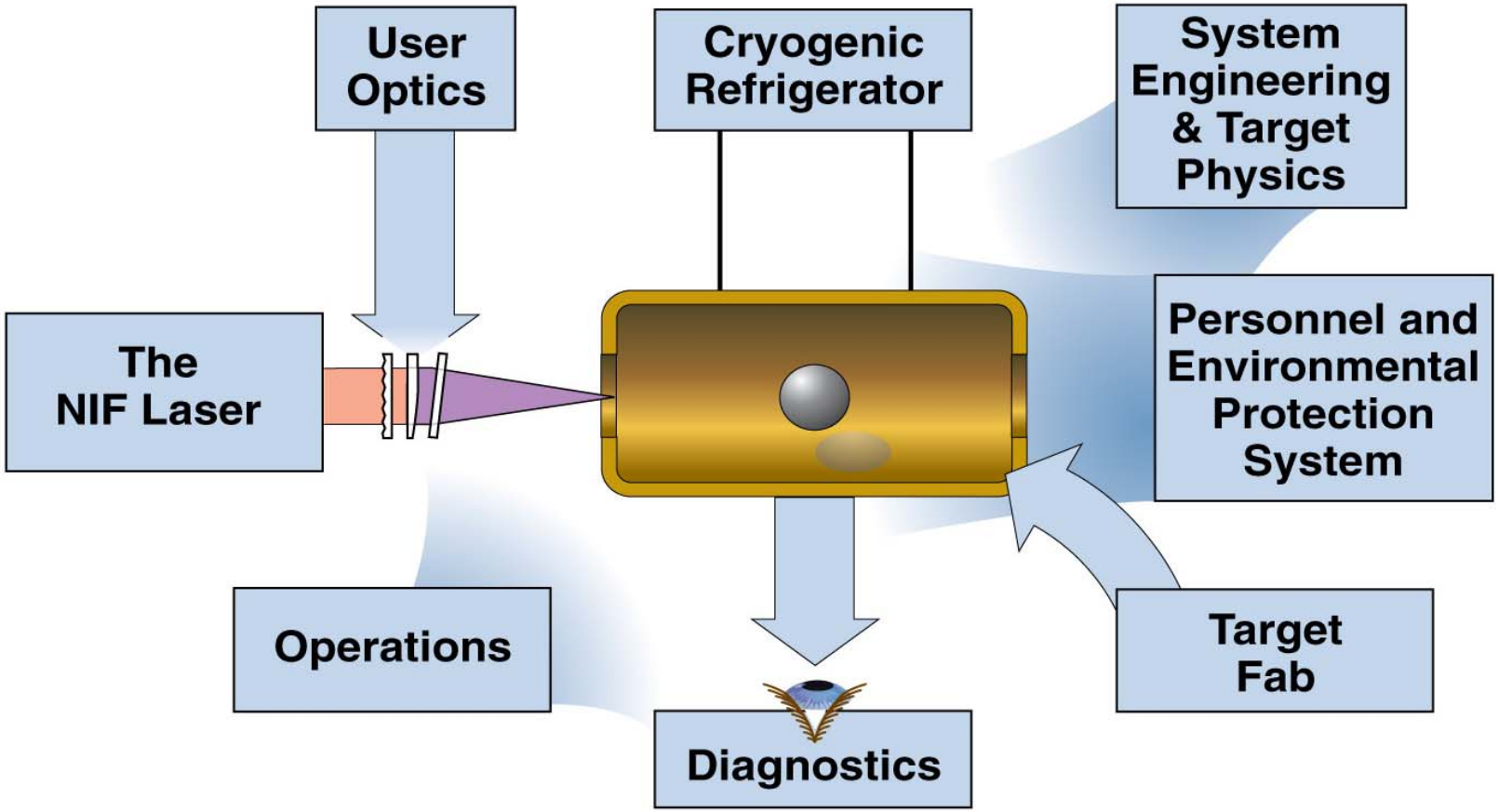
2006—2012

National User Facility

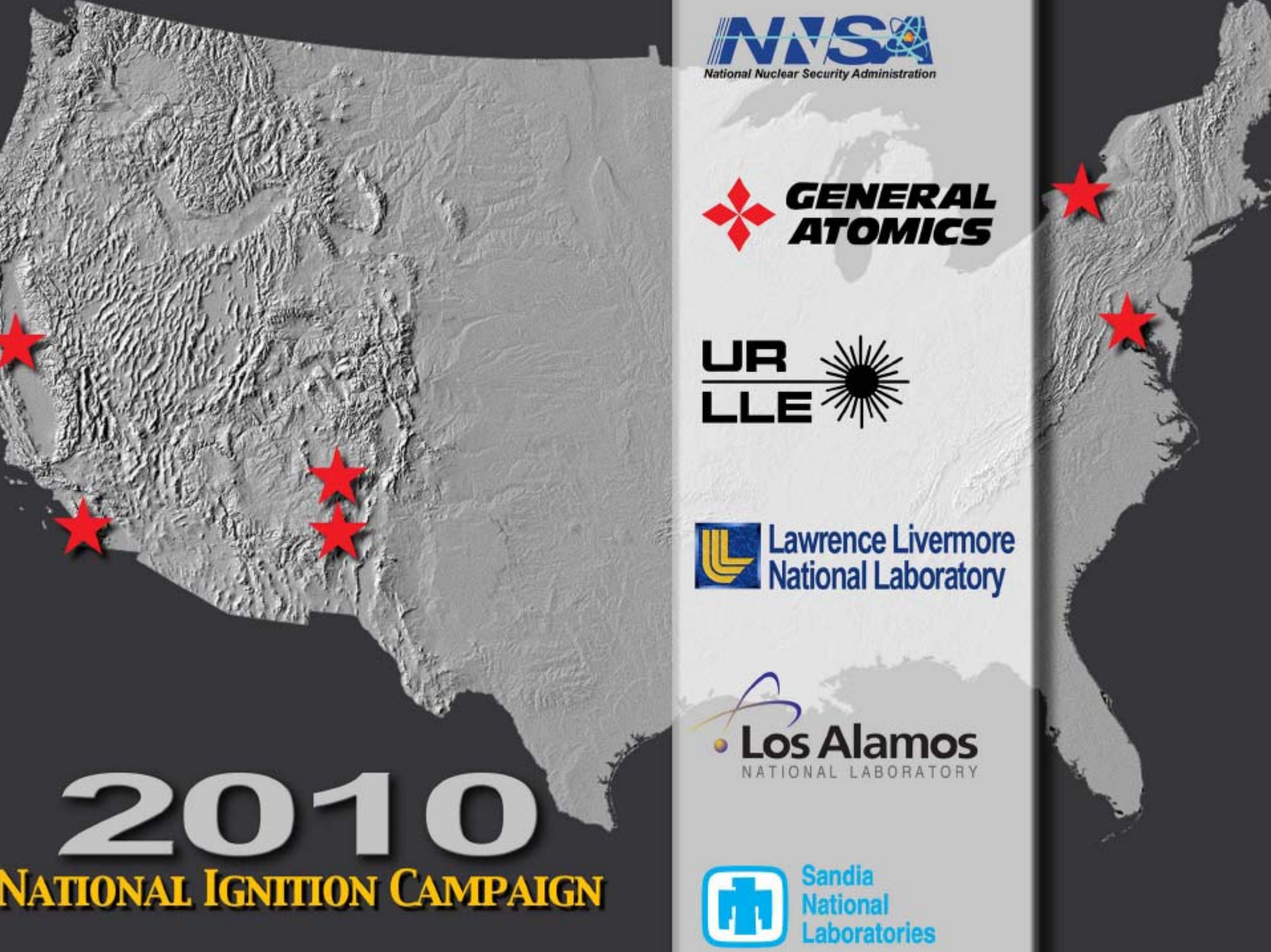
2009—2030

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

# Major elements of the National Ignition Campaign are nearing completion




**For a credible ignition campaign, all these elements must be in place, each with stringent specifications.**


NNSA
National Nuclear Security Administration
GENERAL ATOMICS
UR
LLE
Lawrence Livermore National Laboratory
Los Alamos
NATIONAL LABORATORY
Sandia National Laboratories
2010
NATIONAL IGNITION CAMPAIGN

# NIC is a *National* Partnership

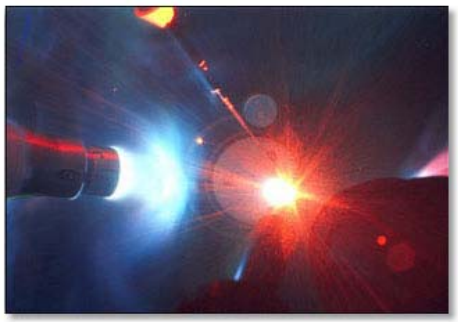
National Nuclear Security Administration

| Participant | Scope |
|---|---|
| General Atomics (GA) | Ignition capsule fabrication, hohlraum development and assembly |
| Los Alamos National Laboratory (LANL) | Ignition target design, LPI, Be ablator physics, neutron imaging |
| Laboratory for Laser Energetics (LLE) | Target exps. at OMEGA (energetics and shock timing), target diagnostics (yield, NTOF, activation), cryogenic system design support |
| Lawrence Livermore National Laboratory (LLNL) | National Ignition Campaign Director, NIF operations and infrastructure, target cryogenic system, target diagnostics, user optics, PEPS, ICF design and experimental program |
| Sandia National Laboratory (SNL) | Cryogenic Target System x-ray shield design and manufacturing plan, collaborate on strategy for radiation neutron and EMP shielding of NIF diagnostics, Be shocked melt experiments on Z |

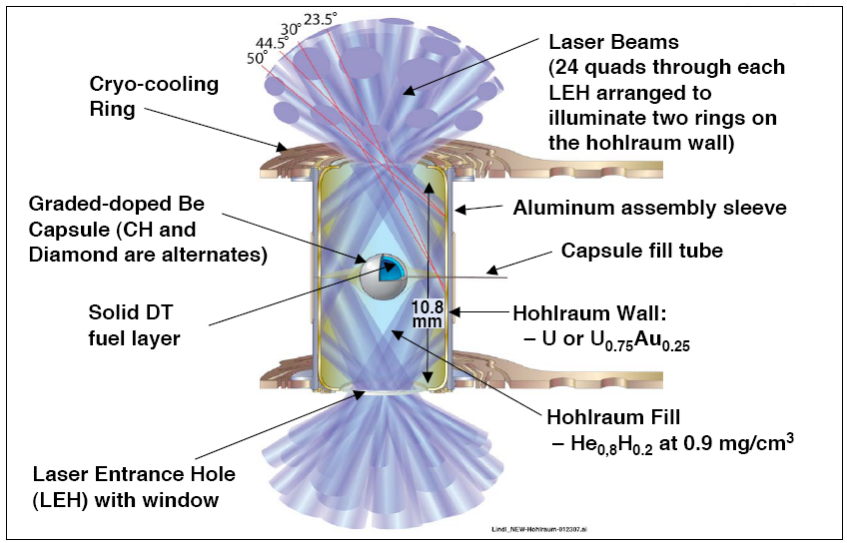
Be – beryllium, LPI – Laser Plasma Instabilities, NTOF – Neutron Time-of-flight, PEPS – Personnel Environmental Protection System, EMP – Electromagnetic Pulse

# Recent progress: We continue to attain key milestones on the path to ignition

National Nuclear Security Administration

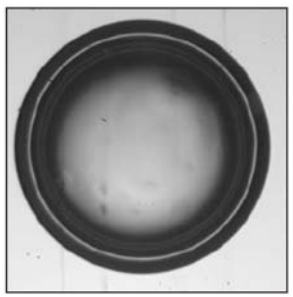


**Fuel density reaches ~ 100 g/cc (500x liquid density, more than adequate for NIF)**

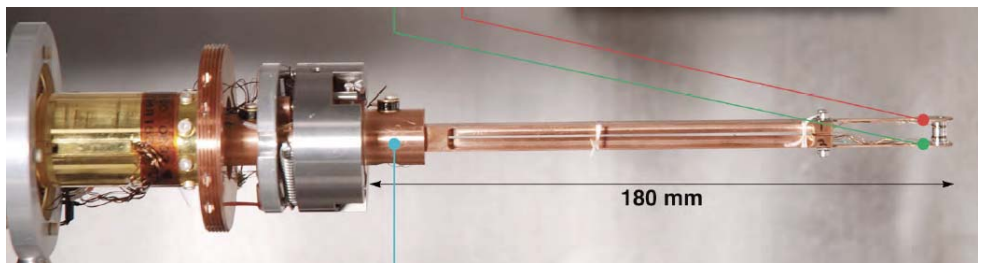



**Demonstrated prototype Be ignition capsule with fill tubes**

**Ignition point design target near 1 MJ that has a credible chance for ignition in early NIF operations**



**Demonstrated 1μm rms inner surface roughness DT ice layer**



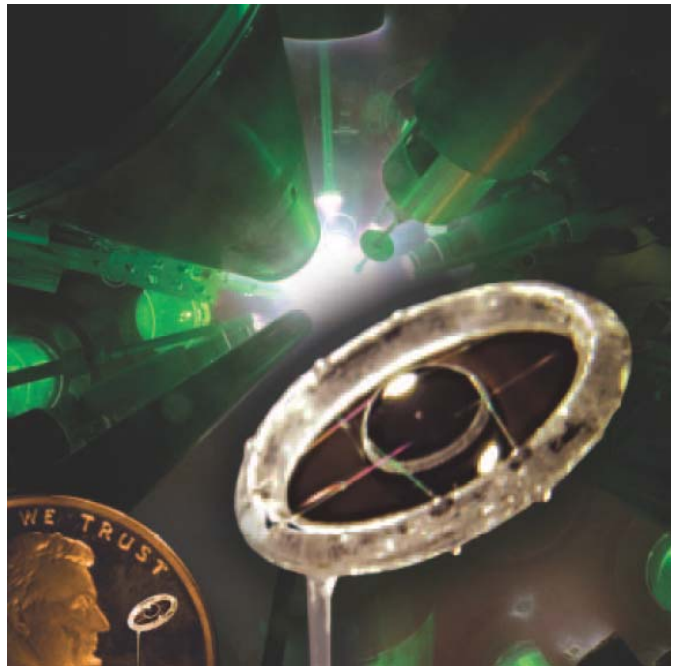

**NIF cryo-system demo - 27 days of continuous operation with 1 mK target base stability**

**The Z machine has been used to test key ignition ablator issues**

# Direct Drive is an important part of the NNSA ignition program

LLE is the lead laboratory for direct-drive ignition

- Direct drive is a credible alternative to indirect-drive ignition
- Direct drive offers the possibility of higher/more robust gain
- Direct-drive targets produce significantly less debris than indirect-drive targets, potentially allowing greater numbers of ignition shots
- Direct-drive ignition experiments on the NIF will be possible with the current (indirect drive) beam configuration via Polar Direct Drive (PDD)




***A Saturn target comprising a fusion-fuel containing capsule surrounded by a ring for achieving highly symmetric PDD implosions.***

**Direct drive may provide advantages for Inertial Fusion Energy**

# Pulsed Power ICF: Important New Facilities Are Coming Online

## Program

- The Pulsed Power ICF Program uses science and technology to create and measure extreme conditions of temperature, pressure, and radiation that approach those in nuclear weapons
- The ZR project was completed on October 2, 2007; the related Z-Petawatt diagnostic project will be completed in December 2007

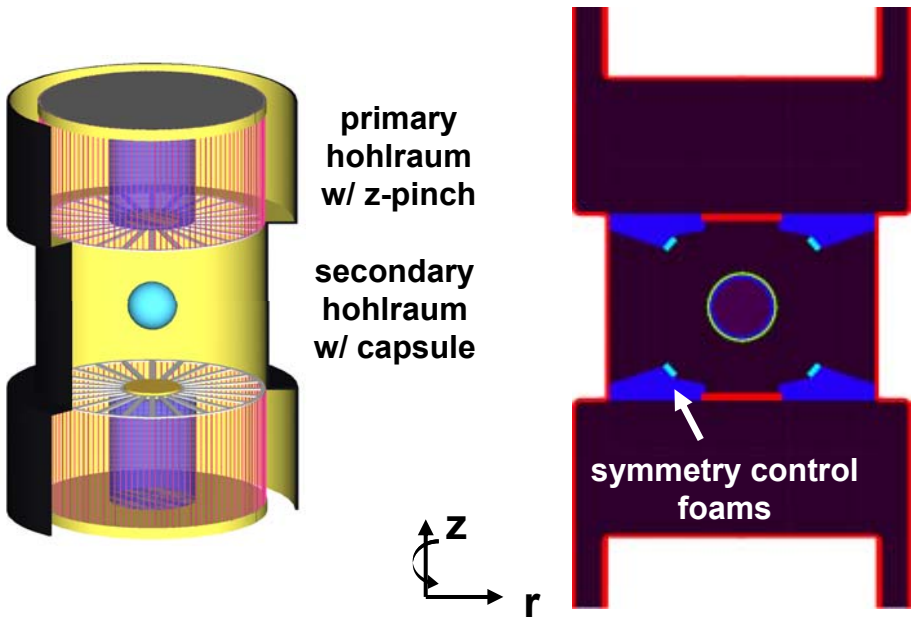
SNL has just completed a major upgrade of the Z Machine

- The ZR project is upgrading the performance of Sandia's z-pinch facility
  - current increased from 19 MA to 26 MA
  - 2x increase in diagnostic access
  - 2x increase in shot rate capability
  - 100 to 300 nsec pulses for Equation-Of-State experiments
- The Z-Petawatt project is upgrading the capability of Sandia's Z-Beamlet laser facility
  - power increased from 1 TW to 1 PW
  - backlighter x-ray probe energies up to 40 keV

# Integrated LASNEX simulations predict 400+ MJ fusion yield in a pulsed-power z-pinch driven hohlraum

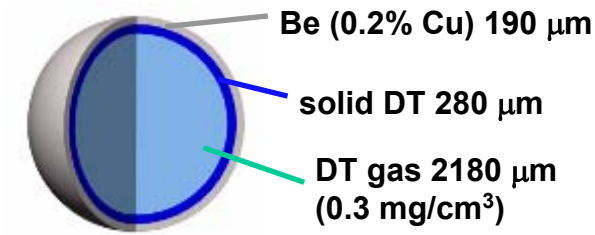
## Double z-pinch hohlraum fusion concept

R. A. Vesey, M. C. Herrmann, R. W. Lemke *et al.*,
to appear *Phys. Plasmas* (2007)

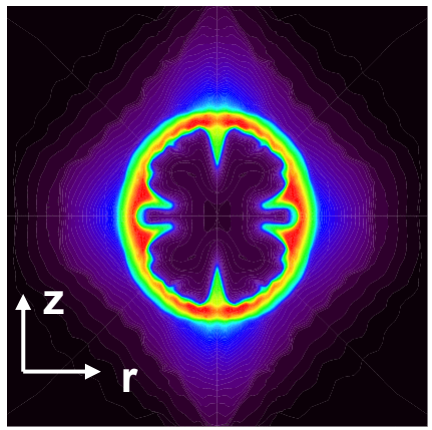



- Two z-pinches, each with 9 MJ x-ray output
- Symmetry control to 1% via geometry, shields
- Capsule absorbs 1.2 MJ, yields 400-500 MJ

## High yield capsule design

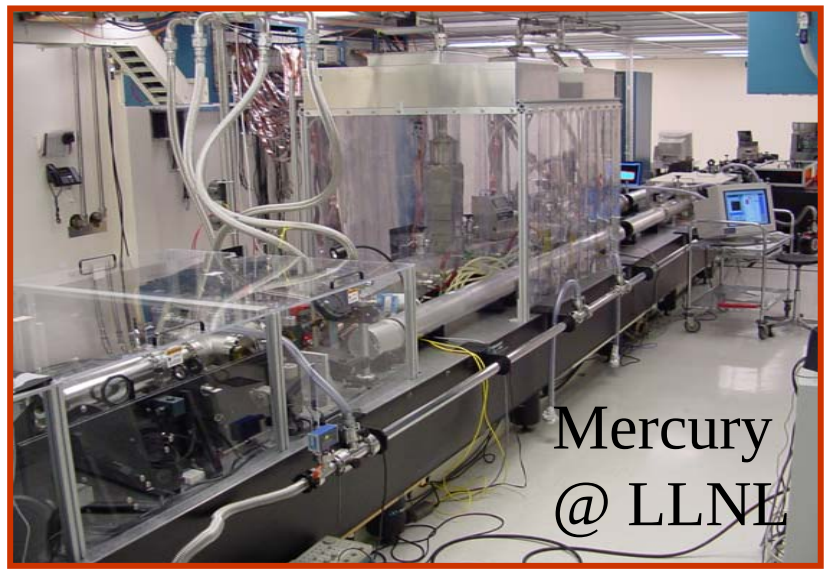



## Fuel density at ignition




**1D capsule yield 520 MJ**
**2D integrated yield 470 MJ**

# High Average Power Laser Program Continued Progress in 2007

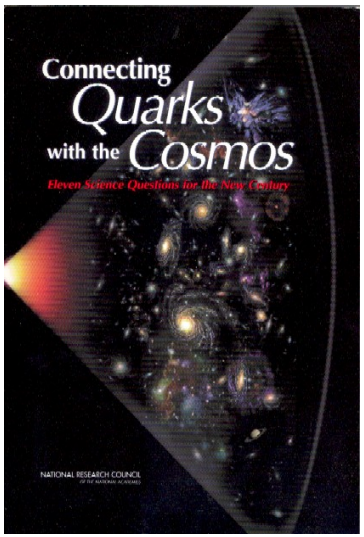

- 5 Hz operation has been demonstrated by the NRL Electra system
- Marx demo: $10^6$ shots @ 5 Hz, Efficiency > 82%

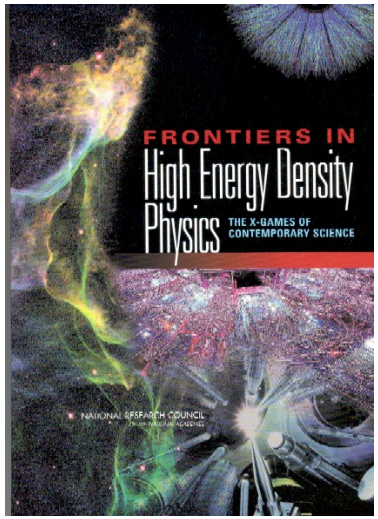
- Complete activation and commissioning of the new front end of the Mercury laser system

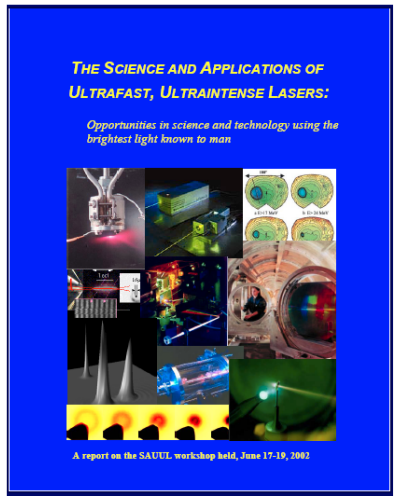
# The new Joint Program in High Energy Density Science is an important vehicle for collaboration between NNSA and the Office of Science

National Nuclear Security Administration

## National Academy/workshop reports

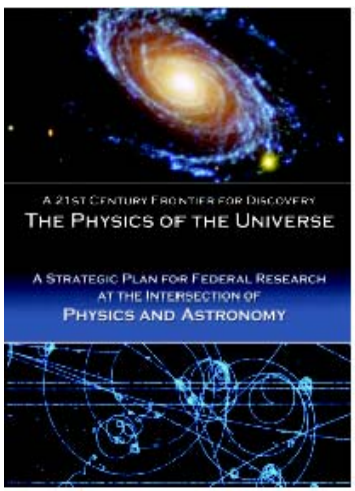


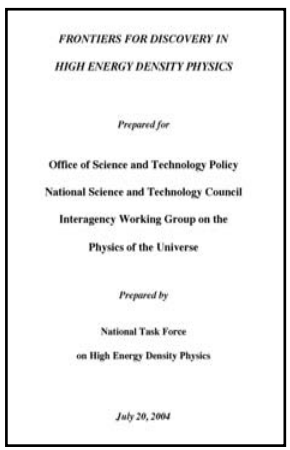



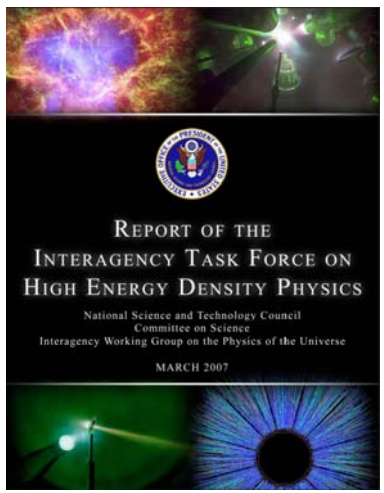




**Plasma Science: Advancing Knowledge in the National Interest**

May 2007




**Office of Science / NNSA Joint Program In HEDLP**

Federal response

# Joint Program in High Energy Density Laboratory Plasmas (HEDLP)

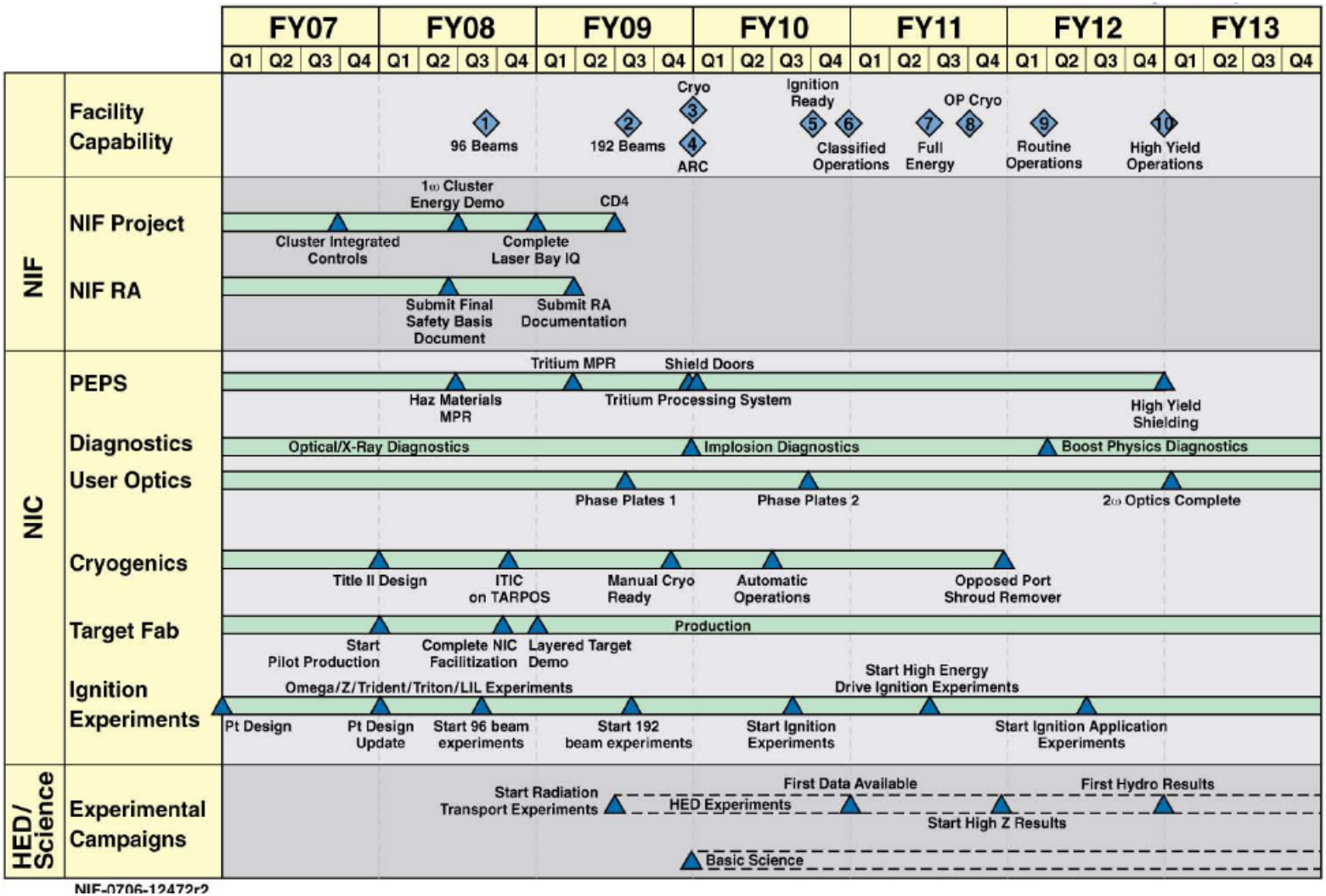
- NNSA and the Office of Science (OFES) have established a joint program in high energy density laboratory plasmas
- Purpose is to steward effectively this emerging field within DOE while maintaining the interdisciplinary nature of this area of science
- Program includes individual investigators, research centers activities, and user programs (National Laser User Facility program)
- Other agencies may join in the future (NSF, NASA)

# Summary

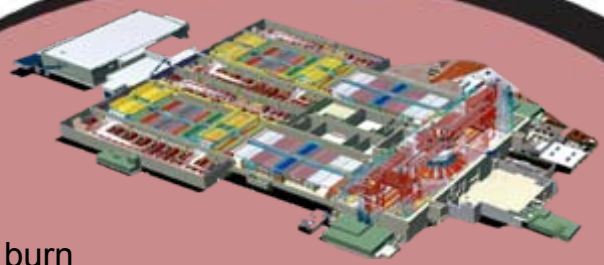
- NNSA is pursuing ignition as a crucial component of its Stockpile Stewardship mission
- NNSA welcomes the spin-offs of its technology for energy applications
- Inertial Fusion Energy Sciences are managed by the DOE Office of Science
- The new HEDLP Joint Program is an important vehicle for collaboration between NNSA and the Office of Science.

# Backups

# NIF/NIC Integrated Work Schedule



# The major ICF facilities provide unique capabilities



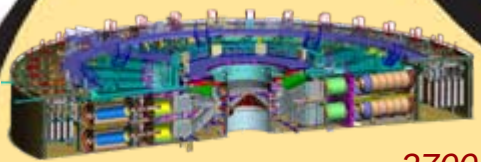
- ignition and burn
- highest temperatures
- highest pressures

1800 kJ

NIF
(2010)

complementary capabilities

radiation flow
radiation hydrodynamics
instability and mix
opacity
equations of state
ICF target physics
alternative fusion concepts



2700 kJ

- magnetically-driven implosions
- highest precision equations of state
- weapons effects tests

Z

30 kJ

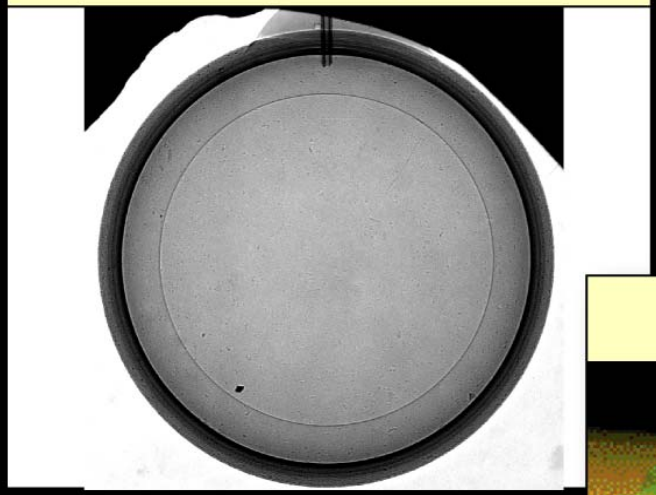
- direct-drive ICF target physics
- fast ignition proof-of-principle

OMEGA
OMEGA EP (2008)

Cost, availability, diagnostics, reproducibility, precision, and flexibility ultimately determine which facilities are used for specific experiments.

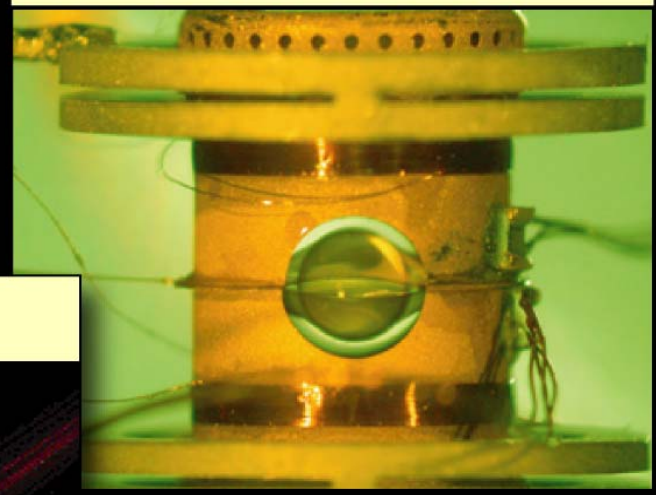
Sandia National Laboratories

## Cryogenic System

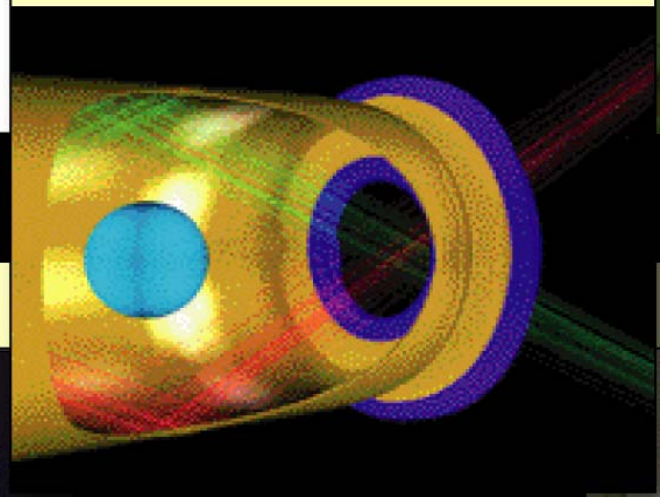


# NIC

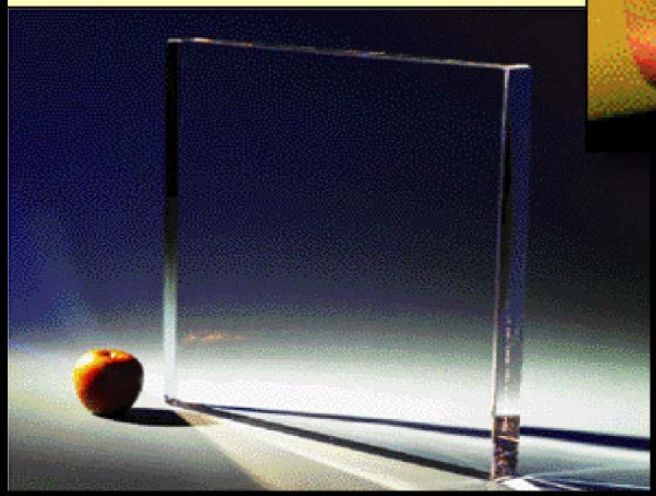
## Target Fabrication



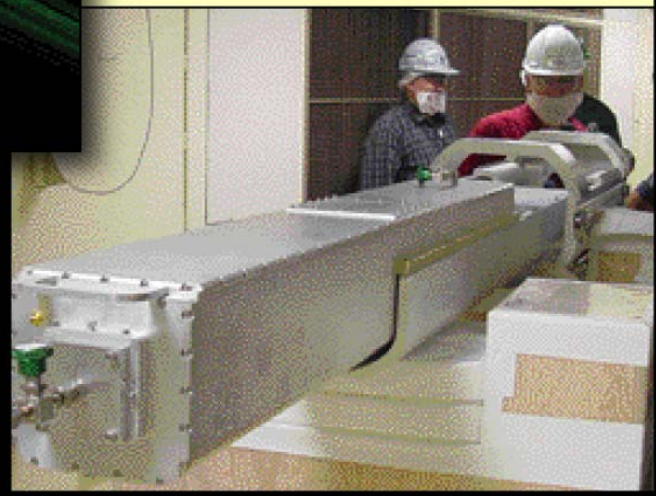
## Target Design



## User Optics



## Diagnostics



NIF-1105-11560
15EIM/cds

P9895

# We are actively exploring the post-ignition path forward

The ICF Program, in collaboration with its major program sites, has developed several potential high level goals for the 2012-2020 time period, including, but not limited to,

- Demonstrate 50 MJ to 100 MJ yield on the NIF (via enhanced point design, polar direct drive, 2ω, double shell, etc.)
- Gain > 0.1 with alpha particle heating on OMEGA
- NIF Polar Direct Drive (PDD) demo
- Linear Transformer Driver (LTD) module installation on Z
- Definitive FI energy transport experiment on NIF supported by experiments done on OMEGA EP
- An IFE-relevant ignition target design tested on NIF in coordination with Office of Science.

We currently in the process of down-selecting and formalizing the ICF Program's long term strategic goals.

# Budget

## ICF FY 2008 Budget (%) by Element