

# **Status of the US National Inertial Fusion Program**



**Presentation to the Fusion Energy Sciences  
Advisory Committee Meeting**

**by:**

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**Director, Office of Inertial Confinement Fusion**

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## The US Inertial Fusion Program has 3 principal components



- The first ignition experiment on the National Ignition Facility in 2010
- Pulsed Power fusion experiments with the goal of high yield
- High energy density experiments related to the “Fast Ignition” concept for ICF



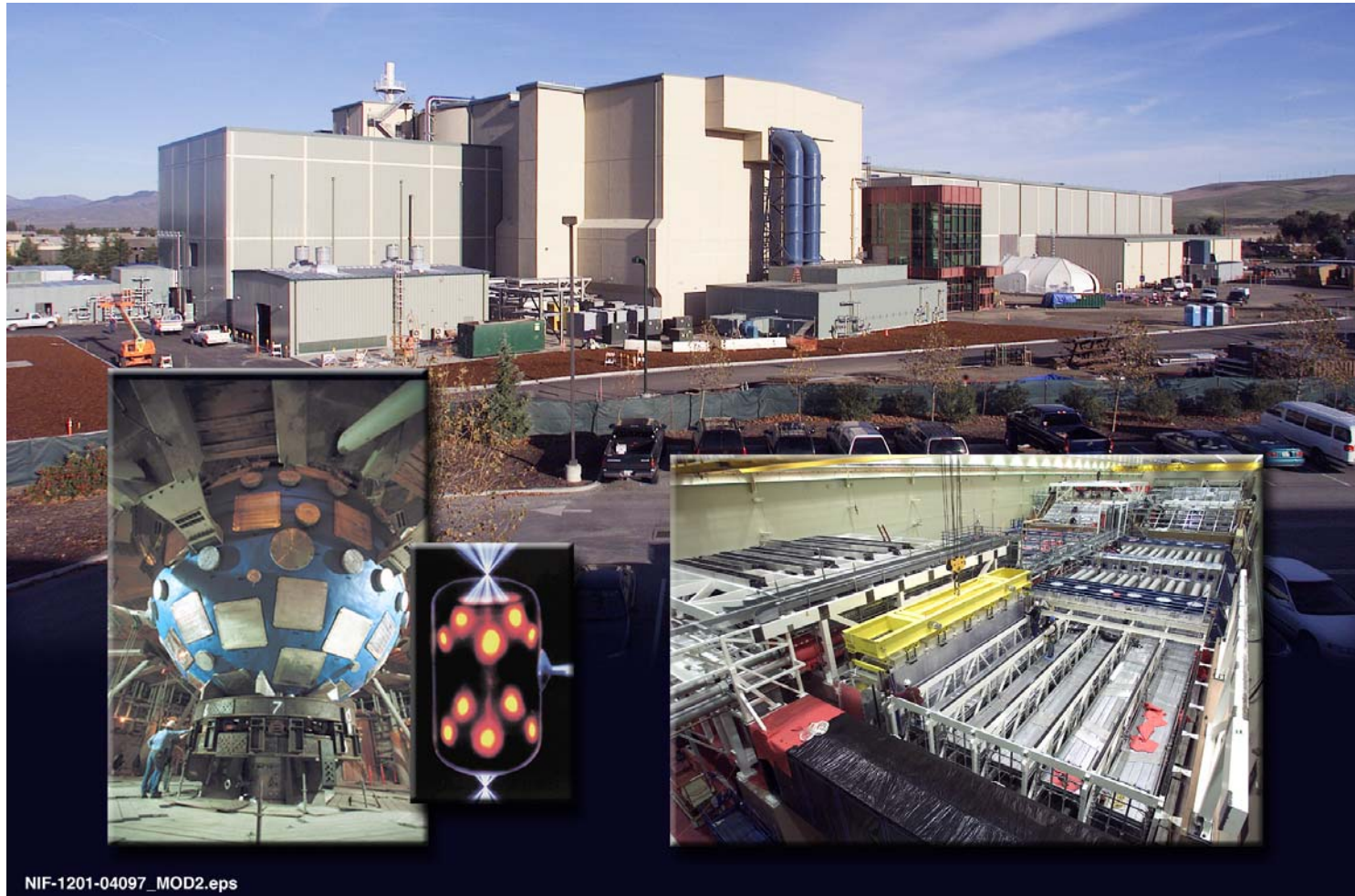
# NNSA has a vigorous program of Activity in ICF



- **The next 10 years will offer major new opportunities for inertial fusion and high energy density physics**
  - NIF 81% complete, first ignition experiments planned for 2010
  - Ignition confidence increasing (direct and indirect drive)
  - Strong progress in pulsed power fusion- fuel and symmetry conditions
  - Petawatt lasers open new programmatic and scientific opportunities
  - Important new scientific capabilities coming in FY2007- OMEGA EP, refurbished Z, Z-Beamlet PW
- **High energy density physics is recognized as an important and emerging scientific field**
  - NAS, OSTP reports
  - Interagency working group
- **University activities continue to play an important role**
  - Recent SSAA solicitation- awards nearly complete
  - User group for high energy density physics (HEDSUP)



# The National Ignition Facility is 85 % complete

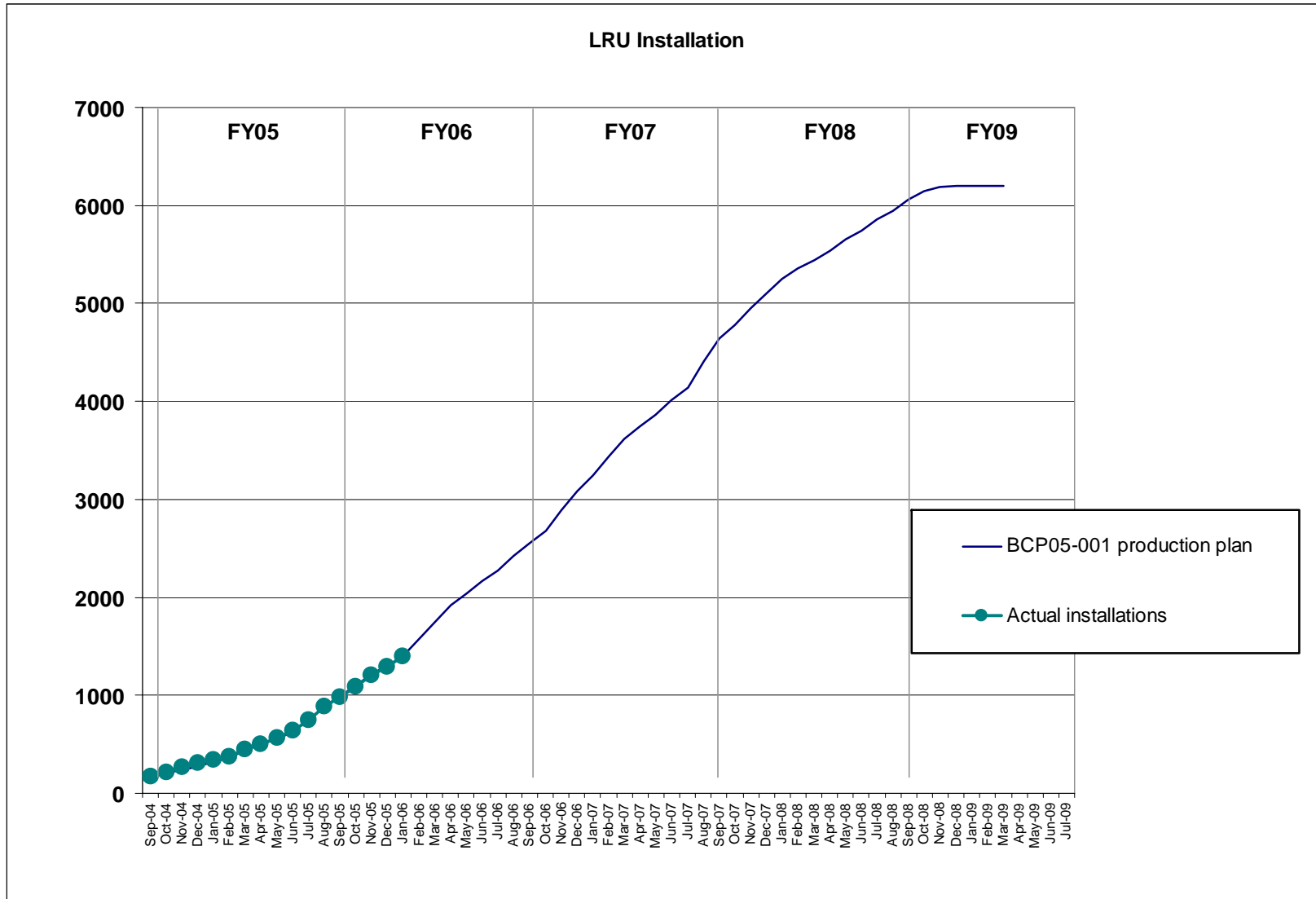


NIF-1201-04097\_MOD2.eps

**NIF concentrates 1.8 Mega Joules of energy into a  $\text{mm}^3$  size target through the use of advanced laser technology**



# A tangible demonstration of progress is the insertion rate of modular units - LRUs

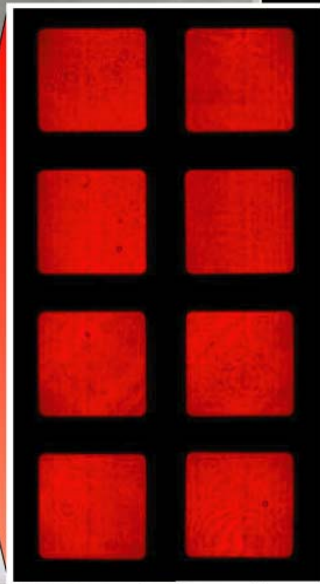
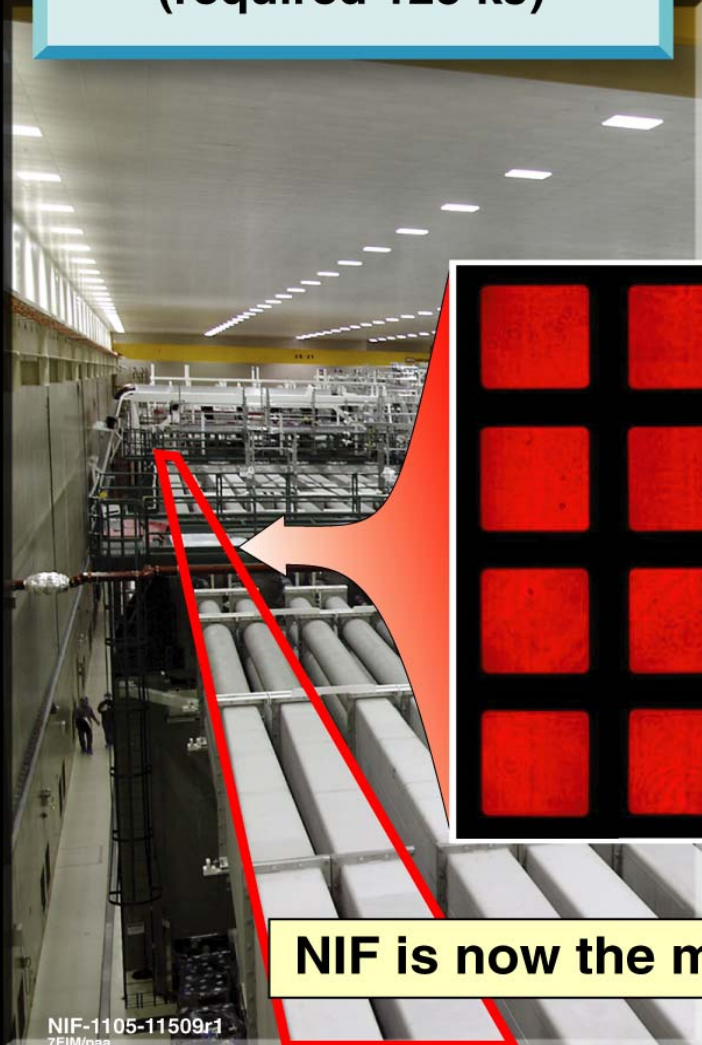




**1st Bundle  
Operated at  
152 kJ  
(required 125 kJ)**



**1,600 of 6200 LRUs  
Installed on schedule**



**NIF is now the most energetic pulsed laser**



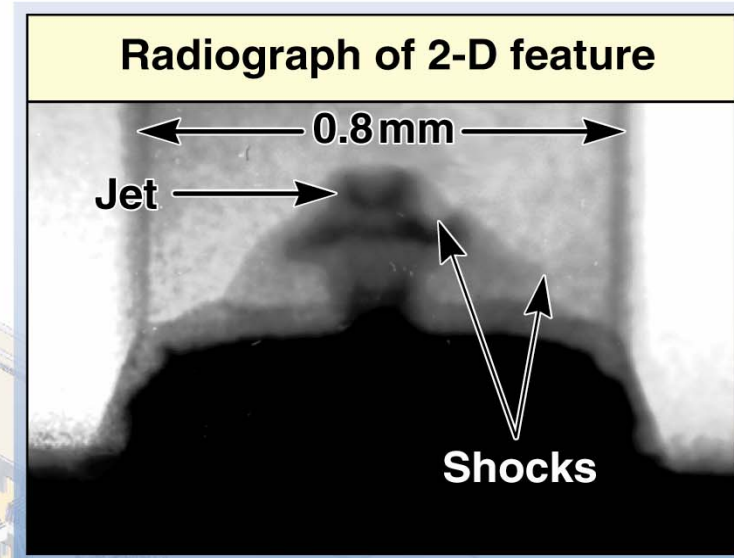


# NIF has executed over 400 experiments



## Hydrodynamic experiment: (FY 2004)

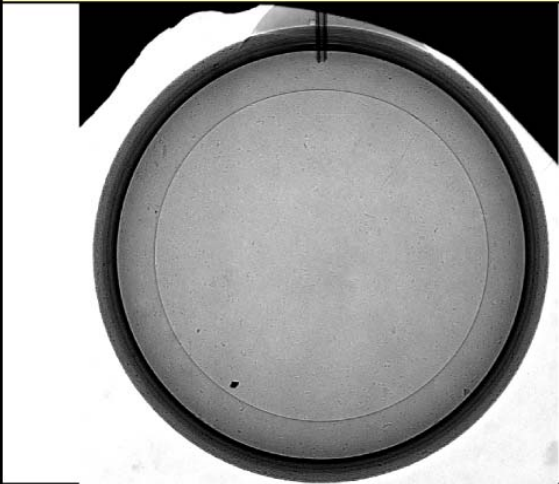
- Challenges our 2- and 3-D code capabilities
- Demonstrates our ability to do complex experiments on NIF
- Uses sophisticated target, diagnostic, and laser alignment providing great accuracy and reproducibility



Full single beam performance has been demonstrated

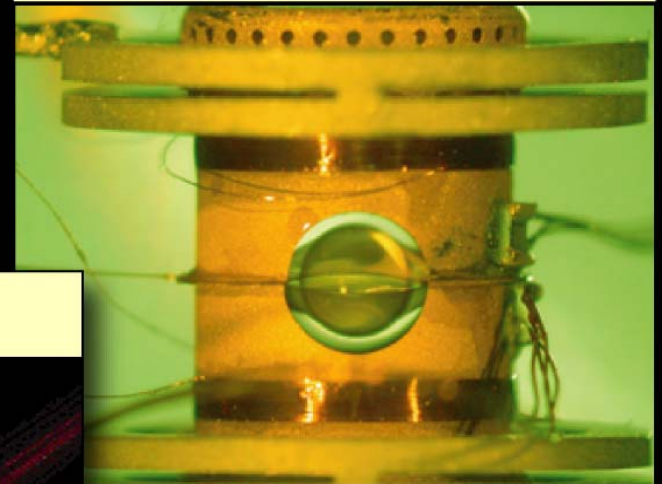


## Cryogenic System

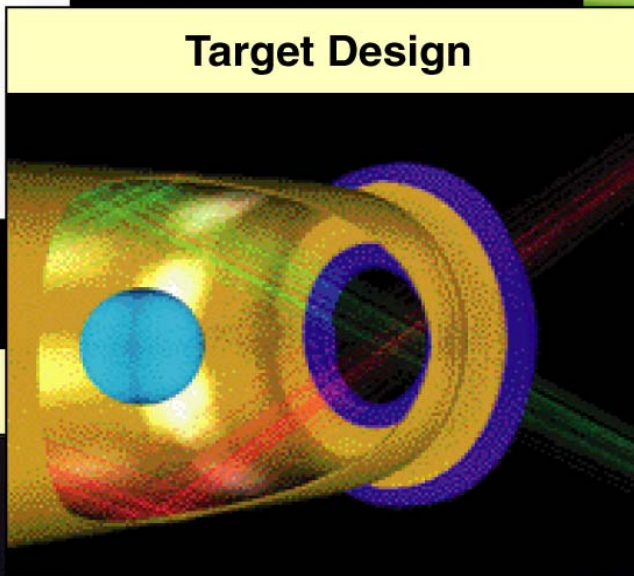


# NIC

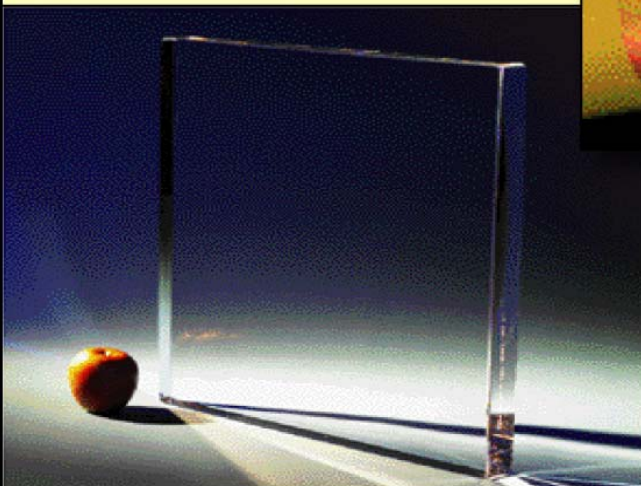
## Target Fabrication



## Target Design



## User Optics



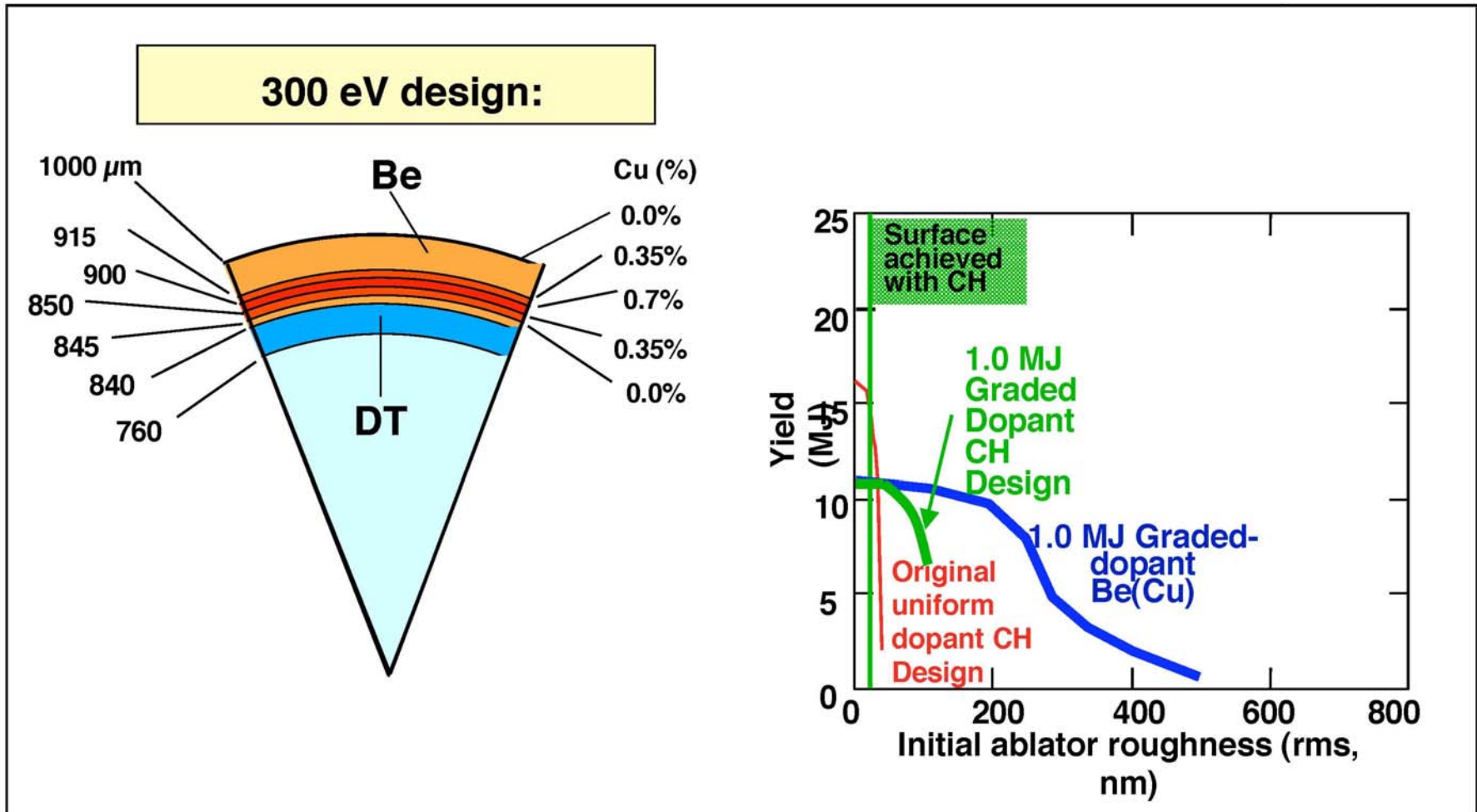
## Diagnostics







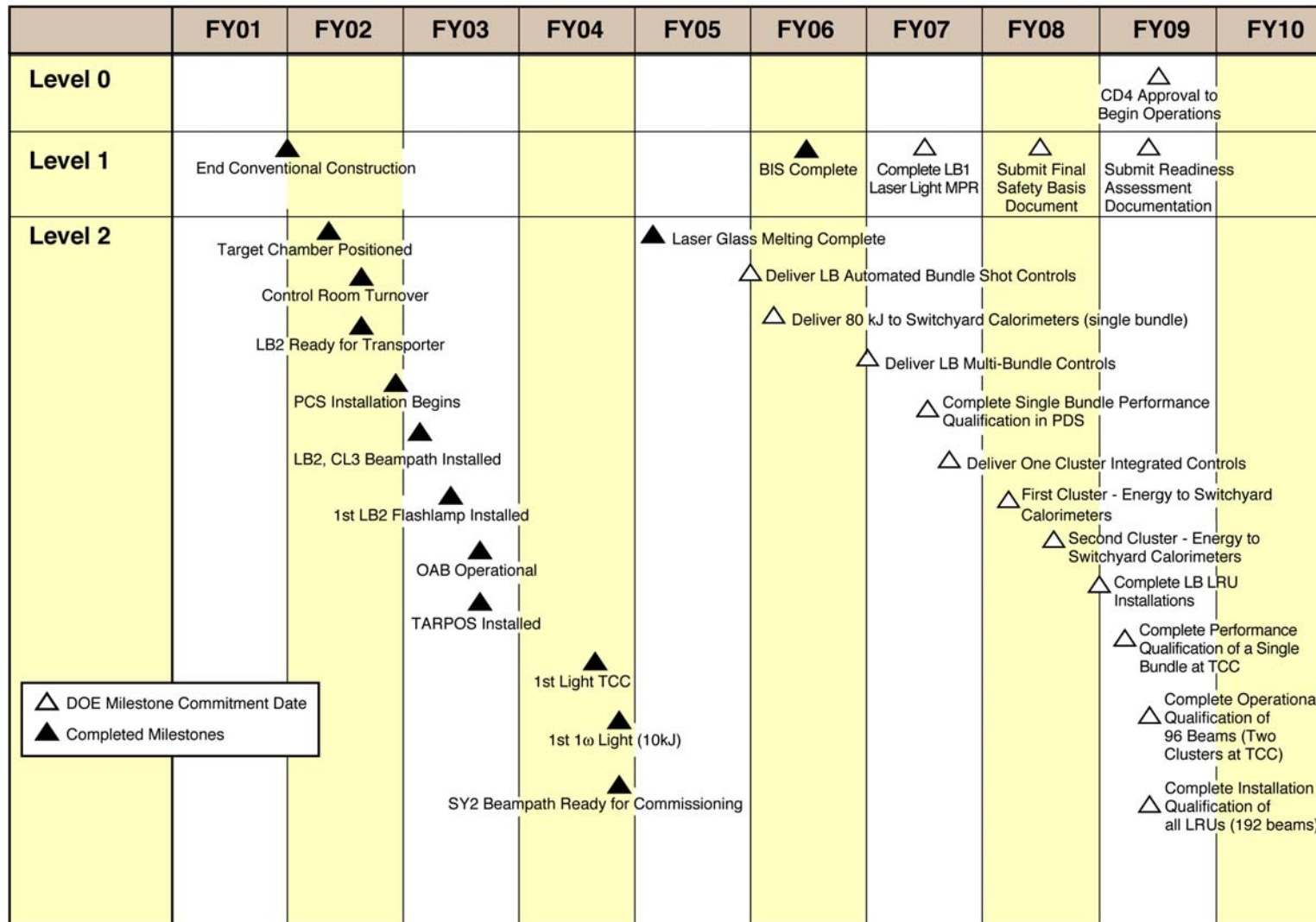
# The “phase space” over which NIF targets are expected to ignite has expanded



**Be is also about 2x more tolerant to ice roughness**



# The revised NIF Project baseline completes in Q2FY2009 and supports Ignition 2010



NIF-0402-04478\_r12.ai  
052605/cc









# A national ignition plan has been signed by the sites and NNSA



## National Ignition Campaign Execution Plan

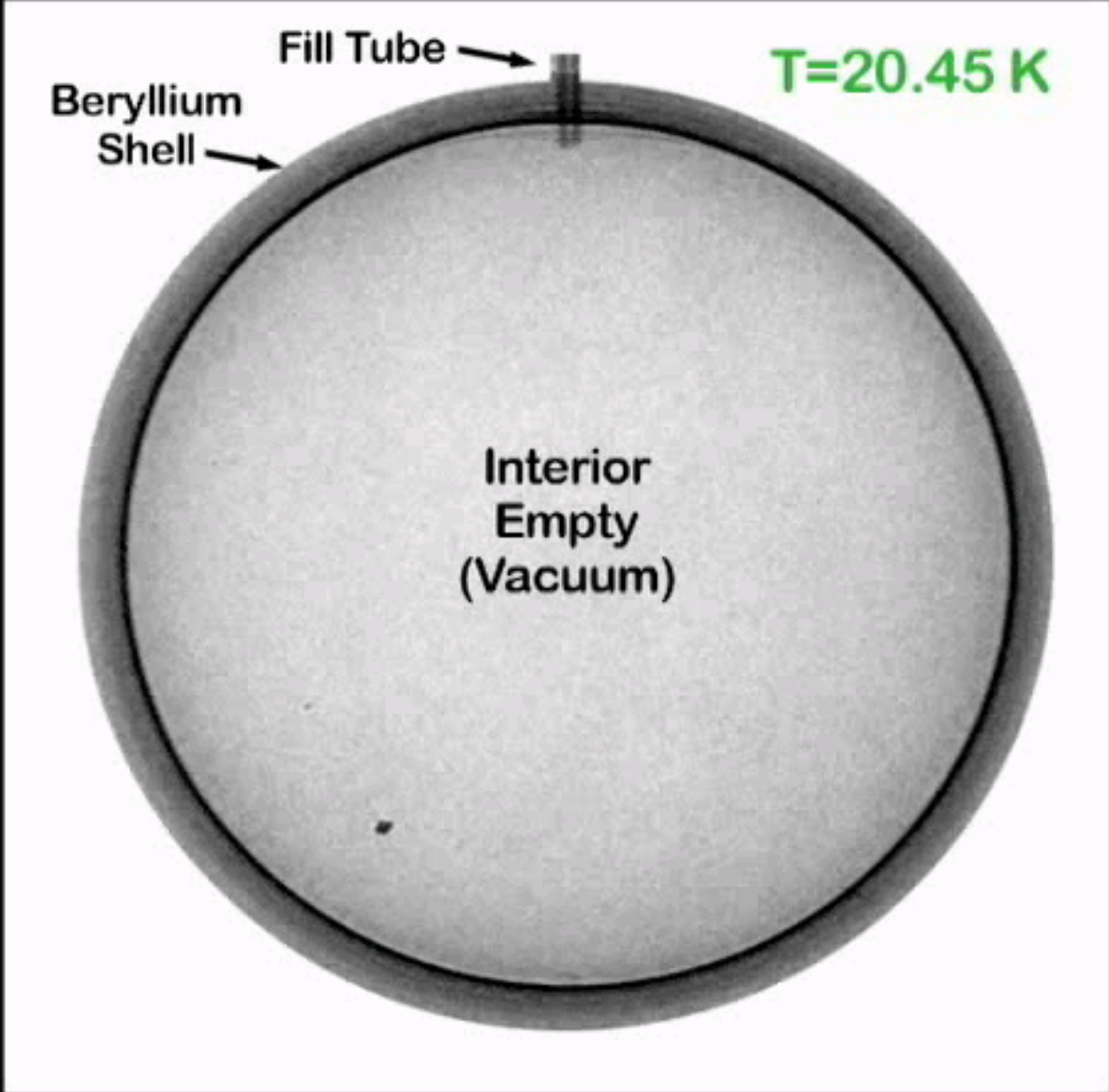
June 2005

	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Level 0	<b>National Ignition Campaign</b>			Begin first integrated ignition experiments $\Delta$			
Level 1	<b>National Ignition Campaign</b>			Ready for 1 MJ operations $\Delta$ Begin FY10 target performance experiments $\Delta$ Ready for 1.8 MJ operations $\Delta$			
Level 2	<b>National Ignition Campaign</b>			Complete hazardous materials MPR $\Delta$ Complete tritium/neutron production MPR $\Delta$ Complete first ignition experiments MPR $\Delta$			
	<b>Systems Engineering</b>			$\Delta$ Facility requirements for FY10 ignition experiments under CM Complete laser performance and facility impacts review $\Delta$ Complete LPOM power balance calibration $\Delta$			
	<b>Target Physics</b>			$\Delta$ Place ignition point design under CM $\Delta$ Begin hohlraum energetics experiments with smoothed beams on OMEGA $\Delta$ Specify laser irradiance requirements $\Delta$ Complete Title II design review for FY10 ignition target $\Delta$ Validate convergent shock timing on OMEGA Complete FY10 target performance experiments $\Delta$			

	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Level 2	<b>Integrated Target Systems</b>			$\Delta$ Complete cryogenic Title I design $\Delta$ Demonstrate scientific prototype capsules $\Delta$ Demonstrate scientific prototype capsules with fill tubes $\Delta$ Complete cryogenic Title II design $\Delta$ Demonstrate engineering prototype ignition target $\Delta$ Demonstrate engineering prototype target layering $\Delta$ Quality cryogenic target production $\Delta$ Complete IQ of cryogenic sys*			
	<b>Diagnostics</b>			$\Delta$ Place ignition diagnostics requirements under CM $\Delta$ Complete initial target illumination characterization diagnostics Complete full target illumination characterization diagnostics $\Delta$ Complete diagnostics for FY10 target performance experiments $\Delta$ Complete ignition implosion diagnostics $\Delta$			
	<b>User Optics</b>			$\Delta$ Begin PS crystal growth $\Delta$ Begin CPP imprinting $\Delta$ Begin DDS production $\Delta$ Comp. user optics for FY10 exps.			
	<b>Personnel and Environmental Protection Systems</b>			$\Delta$ Complete PEPS Title I design $\Delta$ Complete PEPS Title II design Complete PEPS IQ for tritium operations* $\Delta$ Complete PEPS IQ for first ignition experiments* $\Delta$			

$\Delta$  DOE Milestone Commitment Date  
 \*Installation Qualification (IQ): Systems are installed, aligned, and under computer control (if required).  
 Some titles have been abbreviated for this chart, full titles are contained in Appendix E, Table E-1.



Fill Tube

Beryllium  
Shell

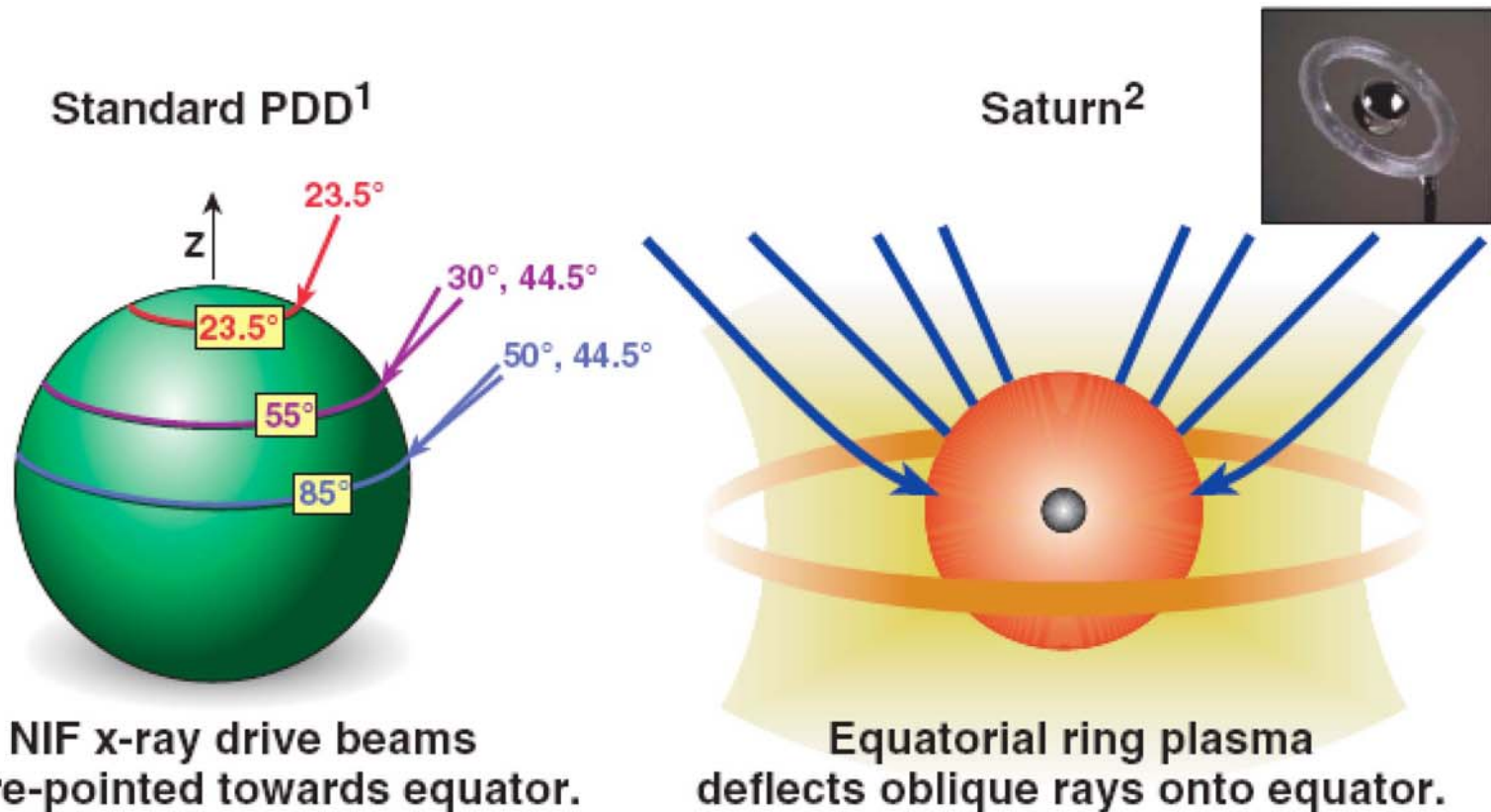
T=20.45 K

Interior  
Empty  
(Vacuum)





# Direct drive (uniform and “polar”) is also being developed for NIF



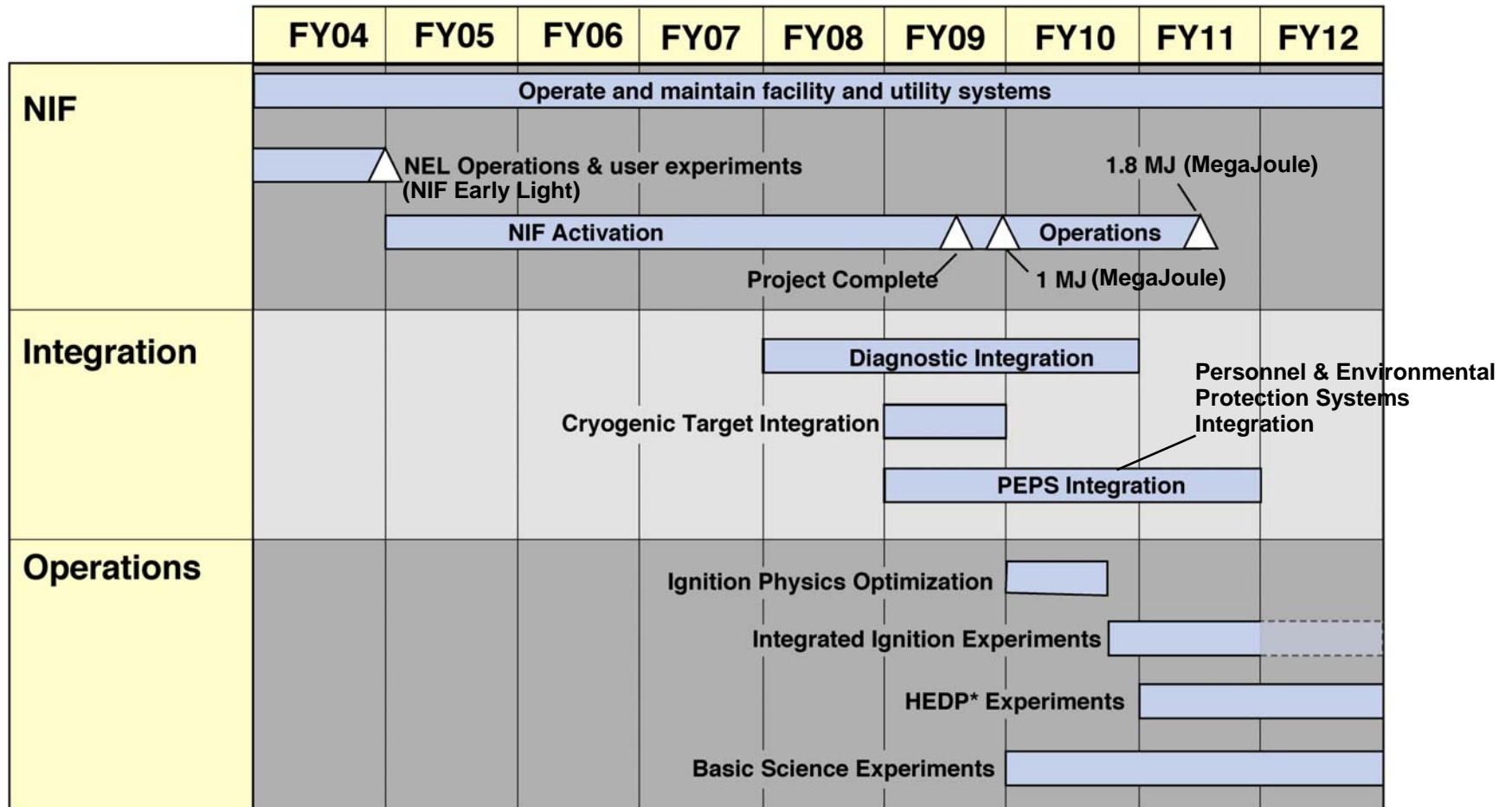
**PDD target performance is being validated on OMEGA.**

<sup>1</sup>S. Skupsky *et al.*, *Phys. Plasmas* **11**, 2763 (2004).

<sup>2</sup>R. S. Craxton *et al.*, *Phys. Plasmas* to be published (2005).



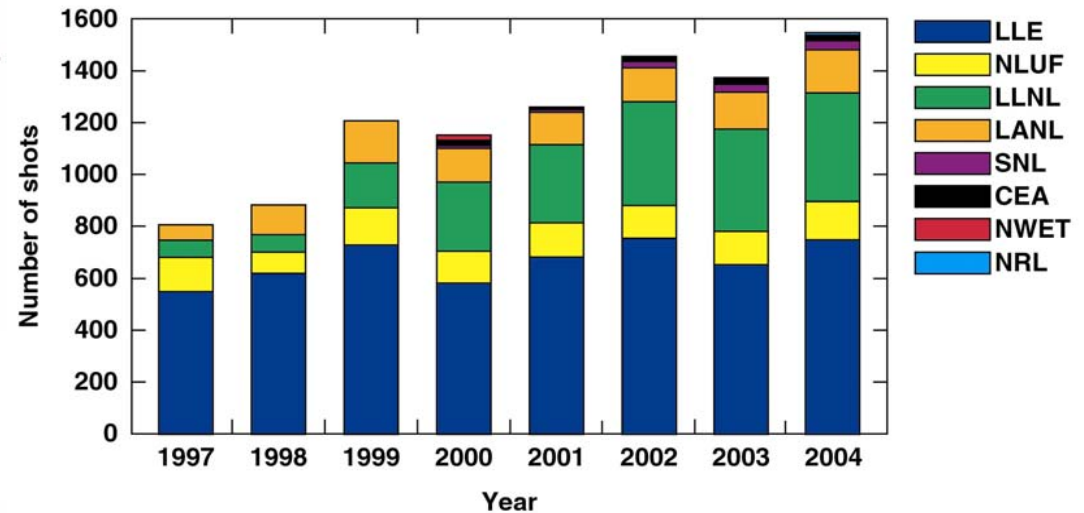
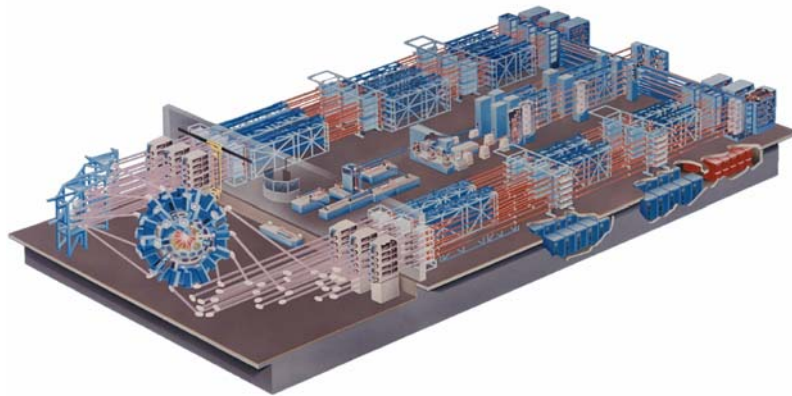
# The plan for use of NIF calls for first ignition experiments in FY2010



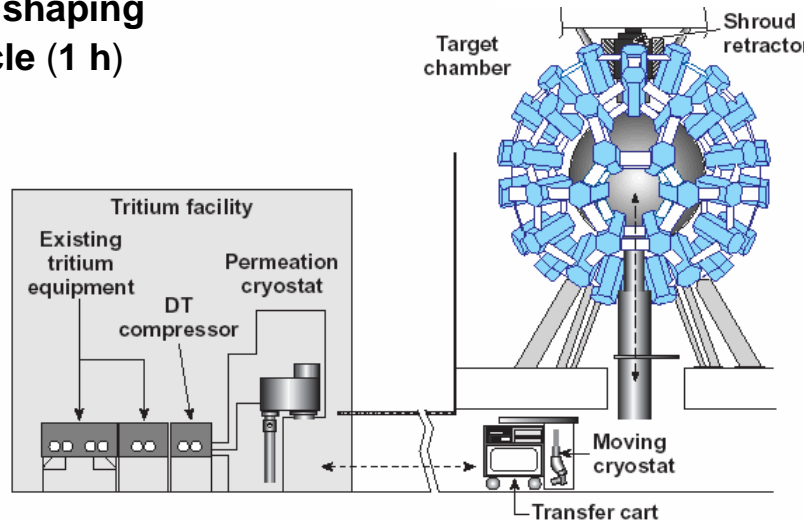
\* Weapons physics experiments in support of Stockpile Stewardship



# OMEGA continues to be the principal experimental laser facility in the United States (World)



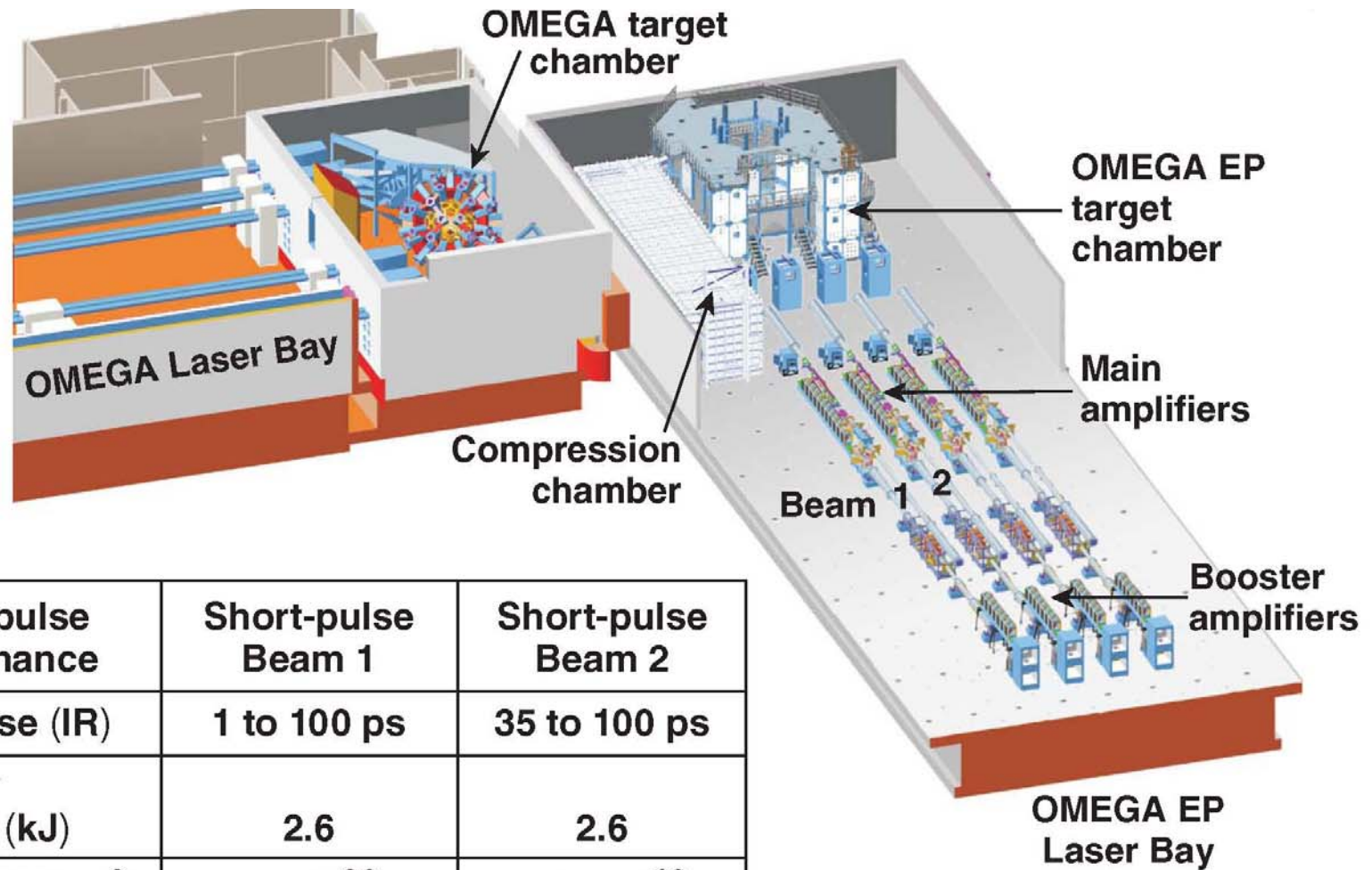
- 60 beams
- >30 kJ UV on target
- 1%-2% irradiation nonuniformity
- Flexible pulse shaping
- Short shot cycle (1 h)



**OMEGA is being upgraded with "petawatt" capabilities (OMEGA EP)**



# The OMEGA EP laser beams will be located next to the existing OMEGA facility

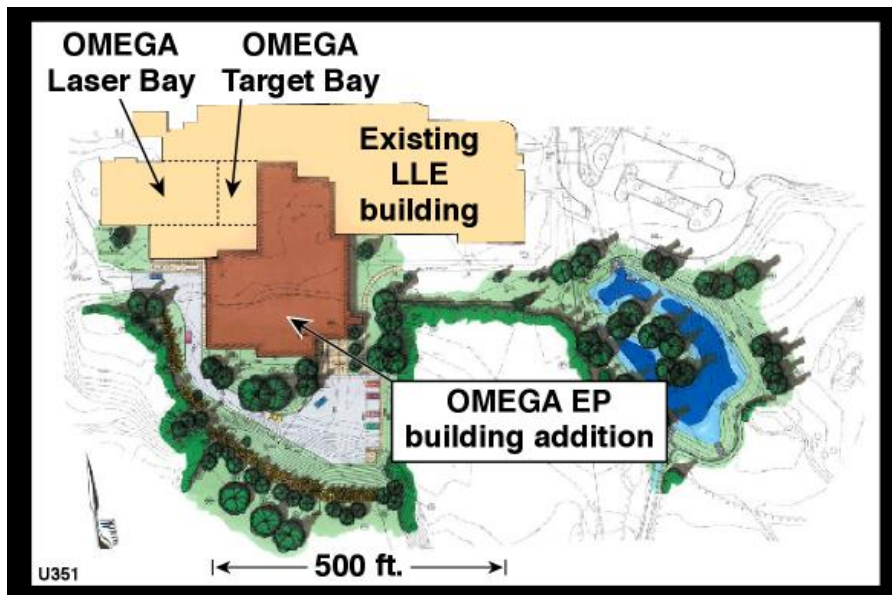
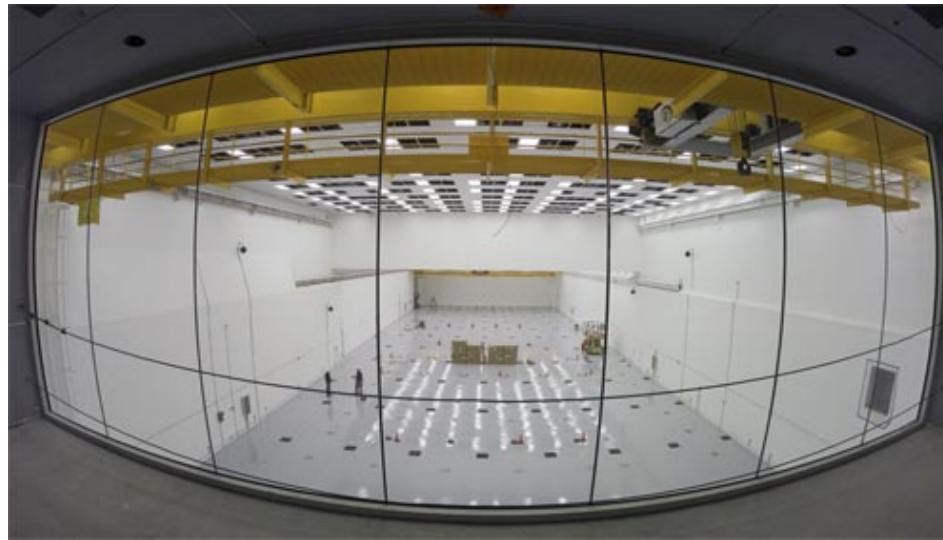


Short-pulse performance	Short-pulse Beam 1	Short-pulse Beam 2
Short pulse (IR)	1 to 100 ps	35 to 100 ps
IR energy on-target (kJ)	2.6	2.6
Intensity (W/cm <sup>2</sup> )	$6 \times 10^{20}$	$\sim 4 \times 10^{18}$
Focusing	> 80% in 20 $\mu\text{m}$	> 80% in 40 $\mu\text{m}$



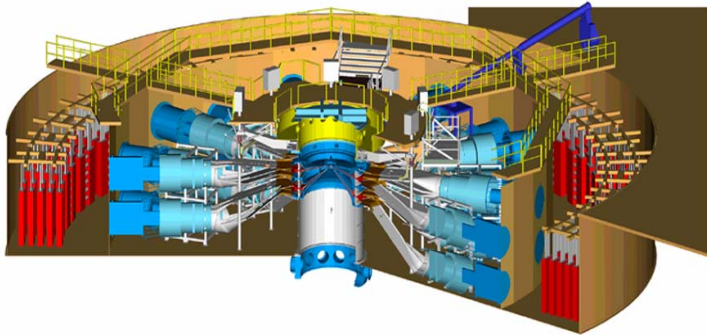


# OMEGA EP construction





# ZR and Z Beamlet- petawatt are important additions to program capability



- The ZR project is upgrading the performance of Z
  - 18 MA to 26 MA
  - 2x increase in diagnostic access
  - 2x shot rate capability



- The Z-Petawatt project is upgrading the capability of Z-Beamlet
  - 2 TW to 1 PW
  - backlighter  $h\nu$  9 - 25 keV
  - integrated FI experiments on ZR

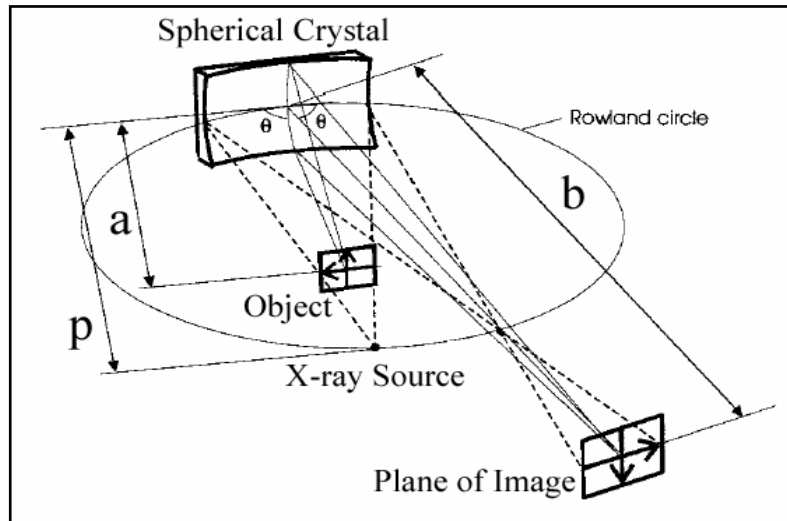
• The ZR and Z-Petawatt facilities will begin operations in 2007.



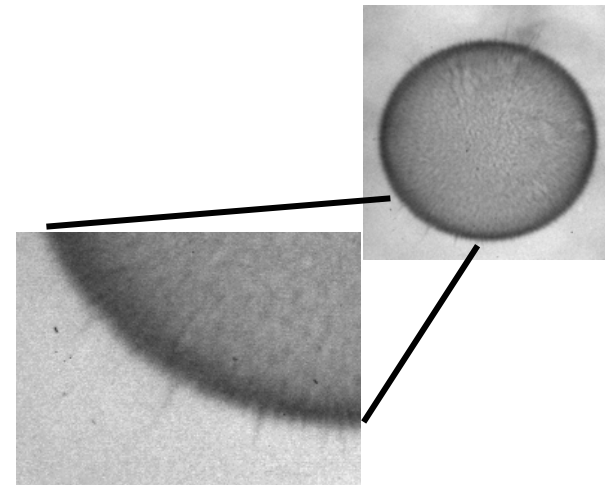
# High resolution x-ray backlighting is an important new diagnostic now in routine use on Z



## X-ray backlighting using a bent crystal imaging detector system

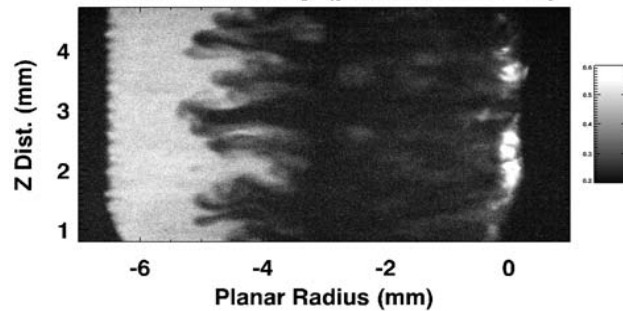


## 3.2 mm dia. capsule radiograph ( $C_r = 1.7$ )

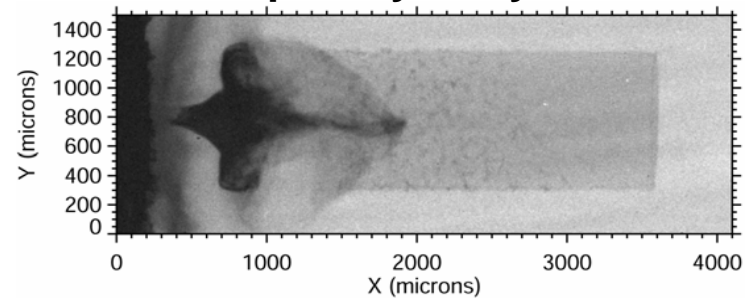


## Z-pinch implosion

z1397: Intensity (phot/micron<sup>2</sup>)



## Complex hydrodynamics



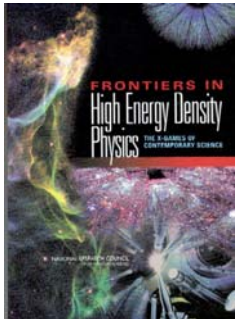




# Recent National Academy of Sciences reports have stressed importance of high energy density physics

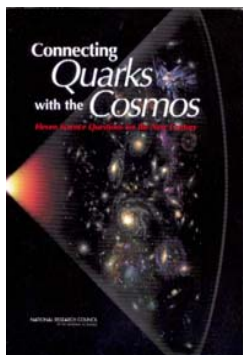


- “Frontiers in High Energy Density Physics” (R. Davidson et al.)



*“..research opportunities in this crosscutting area of physics are of the highest intellectual caliber and are fully deserving of the consideration of support by the leading funding agencies of the physical sciences.”*

- “Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century” (M. Turner et al.)



*“Discern the physical principles that govern extreme astrophysical environments through the laboratory study of high energy density physics. The Committee recommends that the agencies cooperate in bringing together the different scientific communities that can foster this rapidly developing field.”*



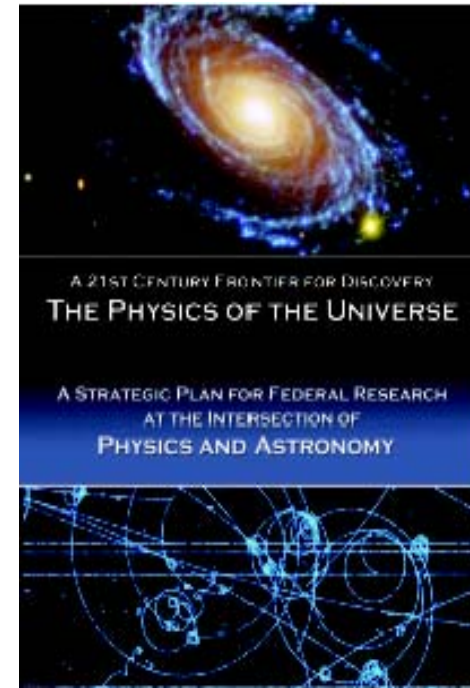


# Interagency Working Group on the Physics of the Universe

(OSTP, DOE/SC, DOE/NNSA, NSF, NASA)



**“HEDP is an emerging field that provides crucial measurements that are relevant to interpreting astrophysical observations of the universe. The field has great promise that should be better coordinated across the various Federal agencies to capitalize on the emerging opportunities.”**





# Interagency group chartered a team to develop an HEDP “roadmap”



*FRONTIERS FOR DISCOVERY IN  
HIGH ENERGY DENSITY PHYSICS*

*Prepared for*

**Office of Science and Technology Policy  
National Science and Technology Council  
Interagency Working Group on the  
Physics of the Universe**

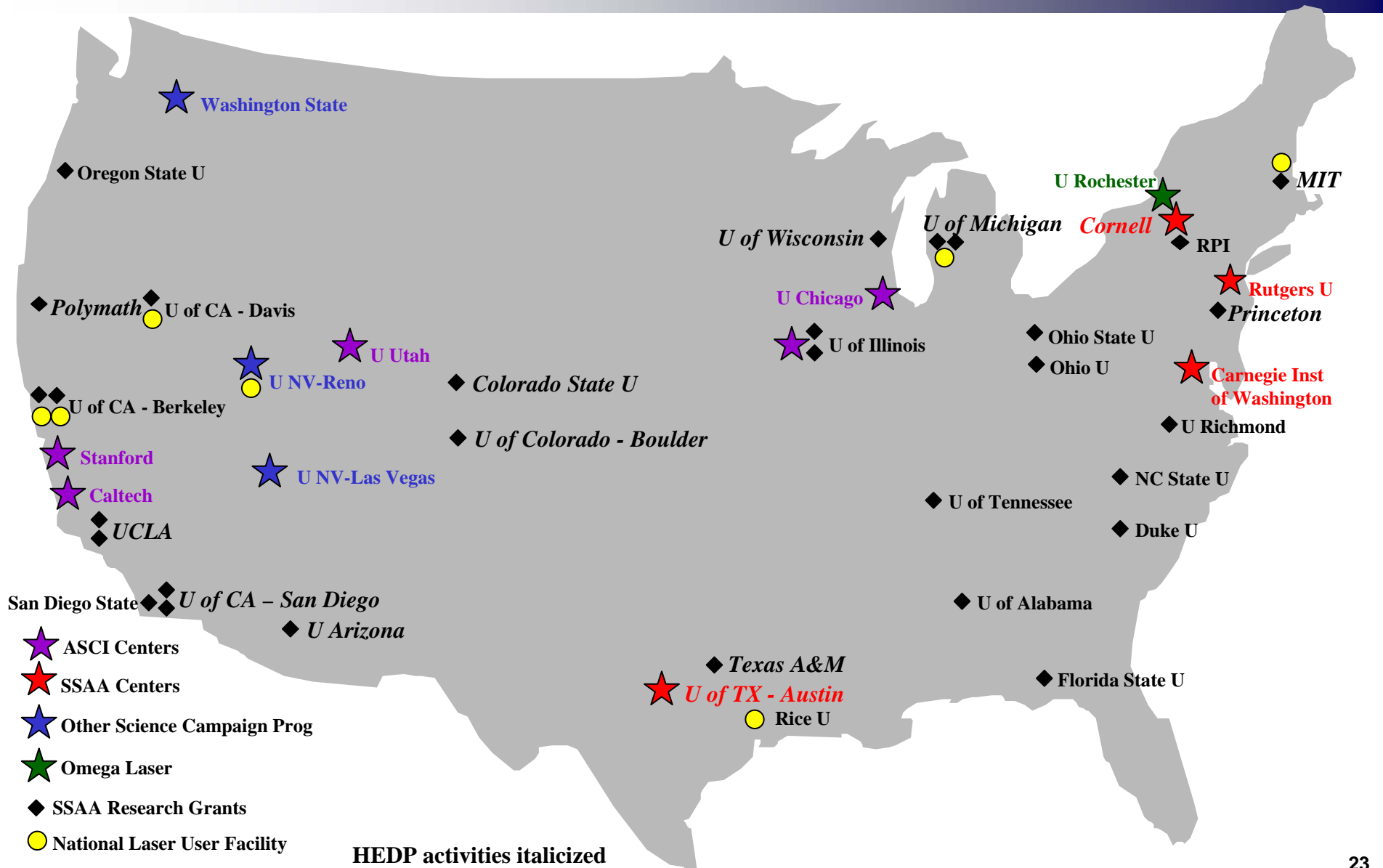
*Prepared by*

**National Task Force  
on High Energy Density Physics**

*July 20, 2004*



# Academic Alliances





# Conclusions



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  - Increased confidence in ignition (direct and indirect drive)
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