ICF Program Status

Presented to:
Fusion Power Associates Annual Meeting

By:
Dr. Christopher J. Keane
Assistant Deputy Administrator for
Inertial Confinement Fusion and the NIF Project
National Nuclear Security Administration

October 12, 2005

Key points

- **The stockpile and the nuclear weapon complex will be transformed**
  - SEAB report on future of the nuclear weapon complex (D. Overskei et al.)
  - Transformation enabled by success of science-based stewardship
- **ICF vision- ignition 2010, possible next steps assessed by 2012-2015**
- **Strong ICF/HEDP technical progress in the past year**
  - NIF Project now 81% complete- positive review (D. Lehman et al.)
  - Indirect drive “phase space” significantly increased
  - Strong progress on direct drive (“polar” and uniform)
  - Weapon physics- diverse application of ICF facilities to stockpile issues
  - Pulsed power fusion- measurements of fuel and symmetry conditions
  - Fast ignition-electron/proton heating physics; key issues identified
  - OMEGA EP and ZR construction on schedule; important new capabilities for ICF and HEDP
  - IFE technologies- Elektra, Mercury, Z-pinch progress

Key points (cont.)

- **Revised plans for NIF Project and NIF ignition submitted to Congress on June 30, 2005**
  - National Ignition Campaign formulated
  - JASON/Lehman reviews support moving forward on planned path
- **High energy density physics is recognized as an important and emerging scientific field**
  - NAS, OSTP reports
- **Budget outlook remains tight**
  - FY2006 appropriation
  - Outyear plans

The nuclear weapon complex will be reconfigured over the next 10-20 years

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Stockpile reductions:
By 2012, the U.S. nuclear weapons stockpile will be the lowest it has been since the Eisenhower administration.

The science-based stewardship program will enable this transformation

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Acting Principal Assistant Deputy Administrator for Military Application
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Timothy G. Evans

Assistant Deputy Administrator for Research, Development and Simulation
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Deputy for Technical Direction
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  Acting Director
  Dr. Kevin C. Greenaugh
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- **Office of Institutional & Joint Programs**
  Director
  Michael E. Long
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- **Office of Facilities Management & ES&H Support**
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- **Office of Planning, Budgeting, and Integration**
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Assistant Deputy Administrator for Inertial Confinement Fusion and National Ignition Facility Project
Dr. Christopher J. Keane
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- **Office of Inertial Confinement Fusion**
  Acting Director
  Dr. Christopher J. Keane
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- **Office of the NIF Project**
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  Scott L. Samuelson
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Office of Defense Programs (NA-10)

ICF Campaign Strategic Goals

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1. Achieve ignition in the laboratory and develop it as a scientific tool for stockpile stewardship

- Provide thermonuclear burn capability for the SSP
- Key *integrated* test for validation of integrated ASC simulations

2. Execute high energy density physics experiments necessary to provide advanced assessment capabilities for stockpile stewardship

- Support stockpile refurbishment and assessment
- Address specific weapon issues, validate advanced ASC simulations

3. Develop advanced technology capabilities that support the long-term needs of stockpile stewardship

- Pursue promising advanced concepts (pulsed power fusion, “fast ignition”, petawatt lasers)

4. Maintain robust national program infrastructure and attract scientific talent to the Stockpile Stewardship Program

- Support university programs and use of NIF, Omega, Z (~15% level)

The National Ignition Facility concentrates the energy in a football stadium-sized facility into a mm^3

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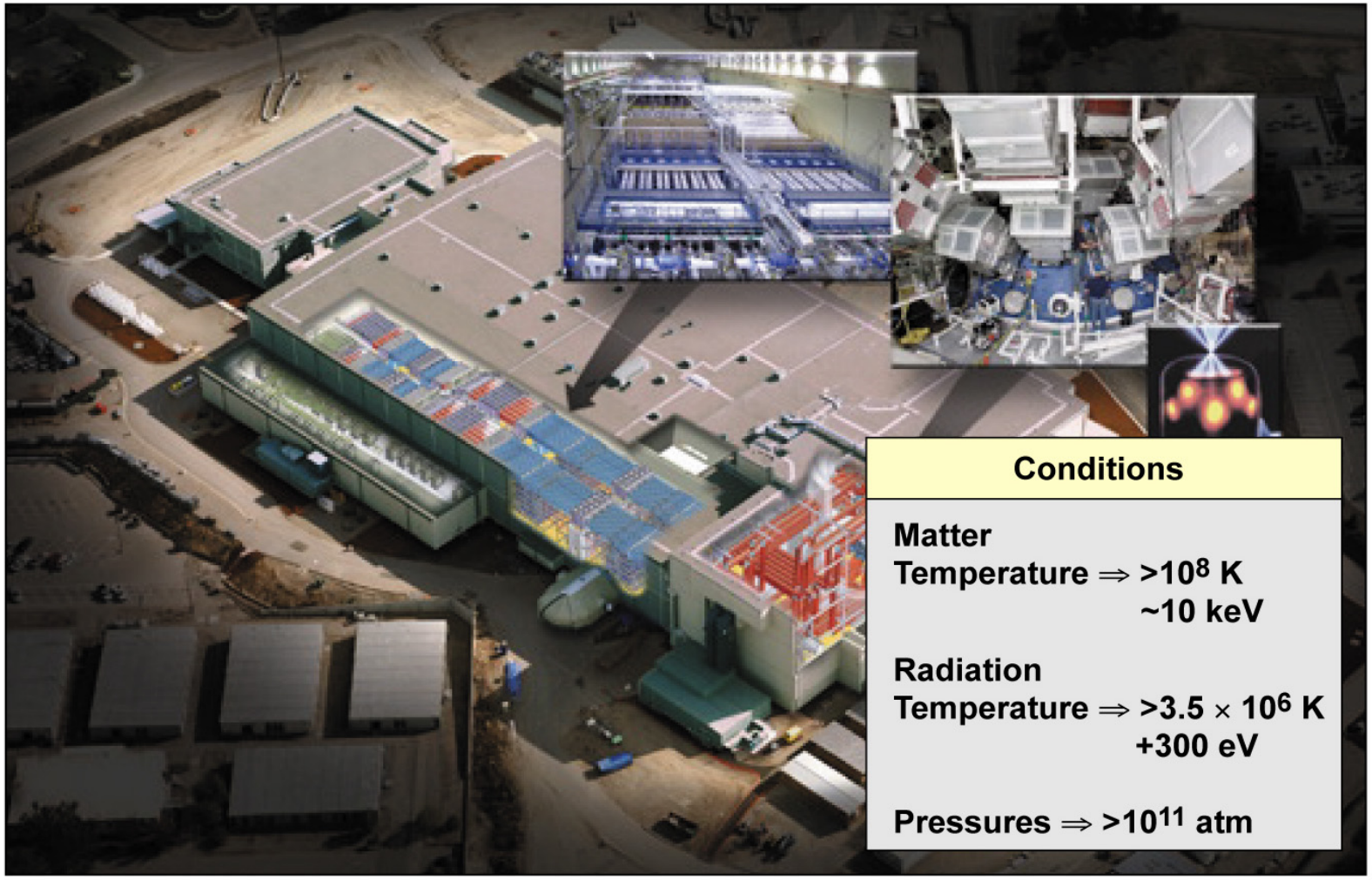

NNSA Deliverables to Congress on June 30, 2005

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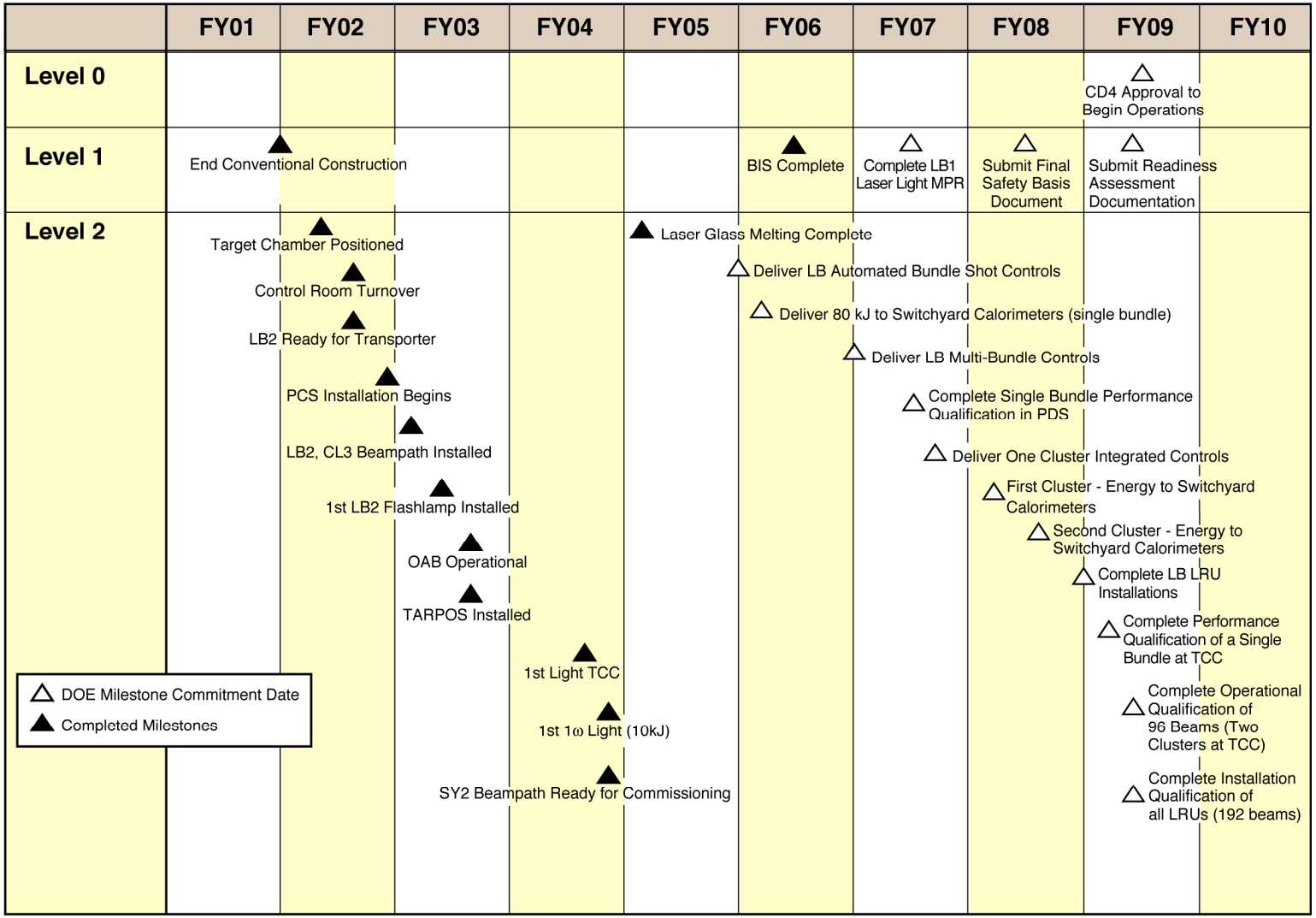
- Requested by Congress in FY 2005 appropriation
  - Updated plan for use of NIF and JASON review of the plan for ignition
  - Review to "… validate the NIF construction baseline"
  - Letter from four Laboratory Directors on the "…promise of this target design to achieve ignition on the original schedule of 2010…."
- Items promised by NNSA in FY2006 submission
  - Revised NIF Activation and Early Use Plan
  - Revisions to NIF Project
  - Update to ICF Campaign Performance Targets

Completed package delivered to Congress on schedule

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



NIF-0402-04478_r12.ai
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A national ignition plan has been signed by the sites and NNSA

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National Ignition Campaign Execution Plan

June 2005

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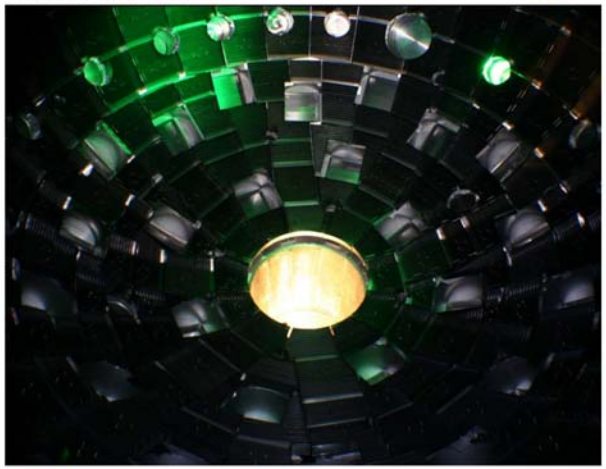


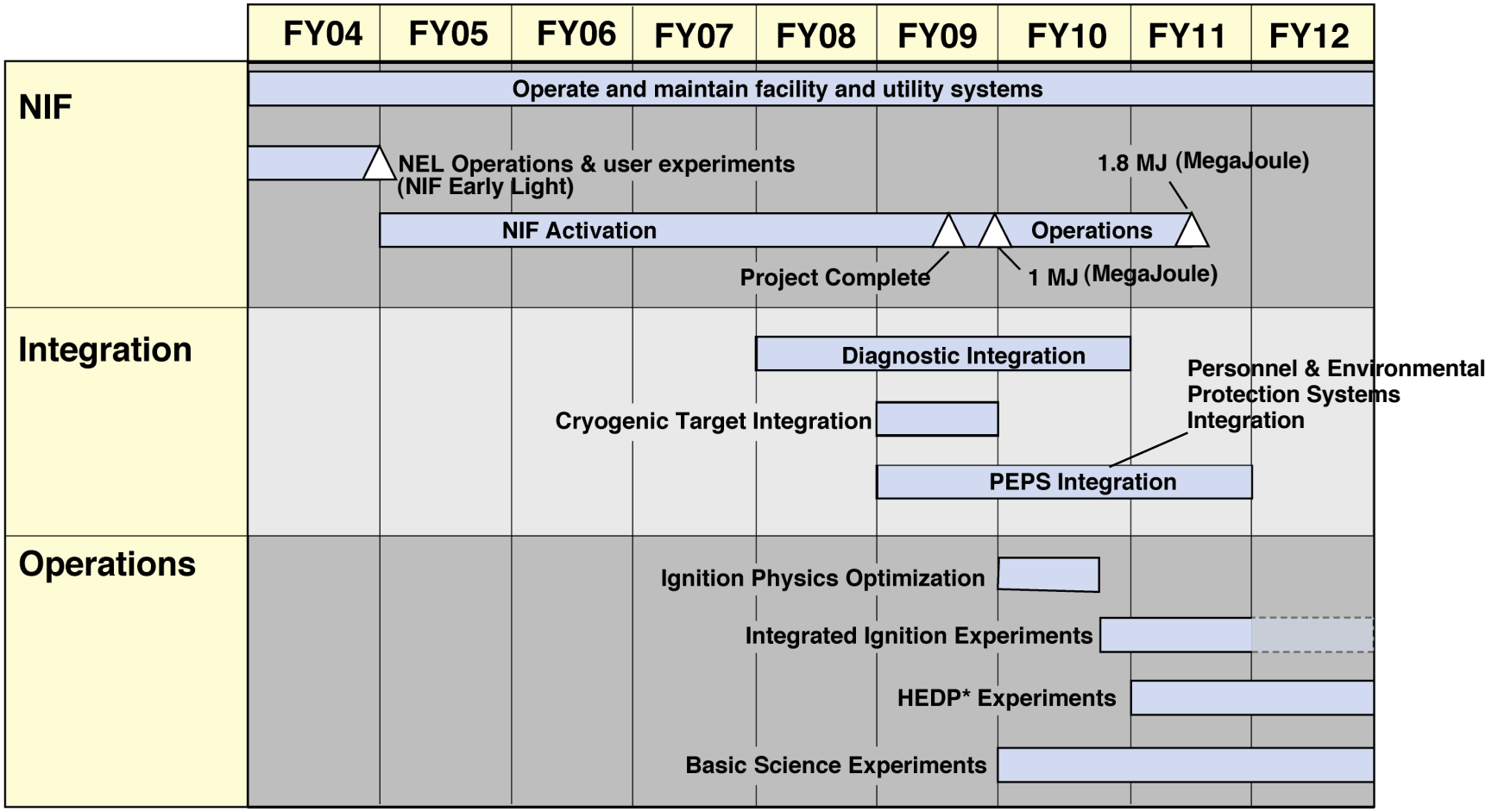
Los Alamos NATIONAL LABORATORY · GENERAL ATOMICS · UR LLE

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

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

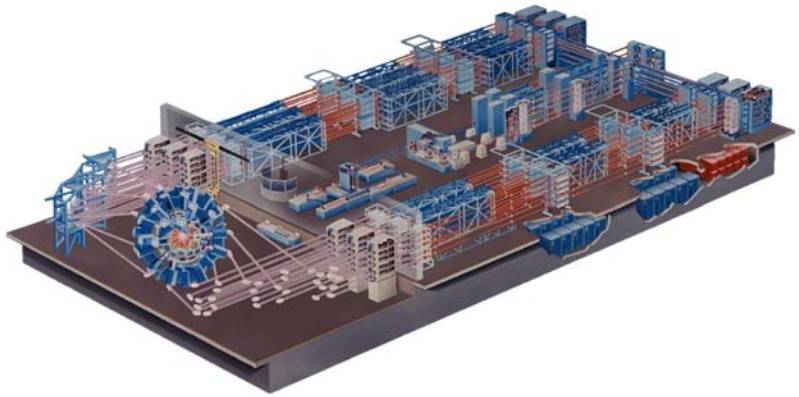
△ DOE Milestone Commitment Date
*Installation Qualification (IQ): Systems are installed, aligned, and under computer control (if required).
Some titles have been abbreviated for this chart, full titles are contained in Appendix E, Table E-1.

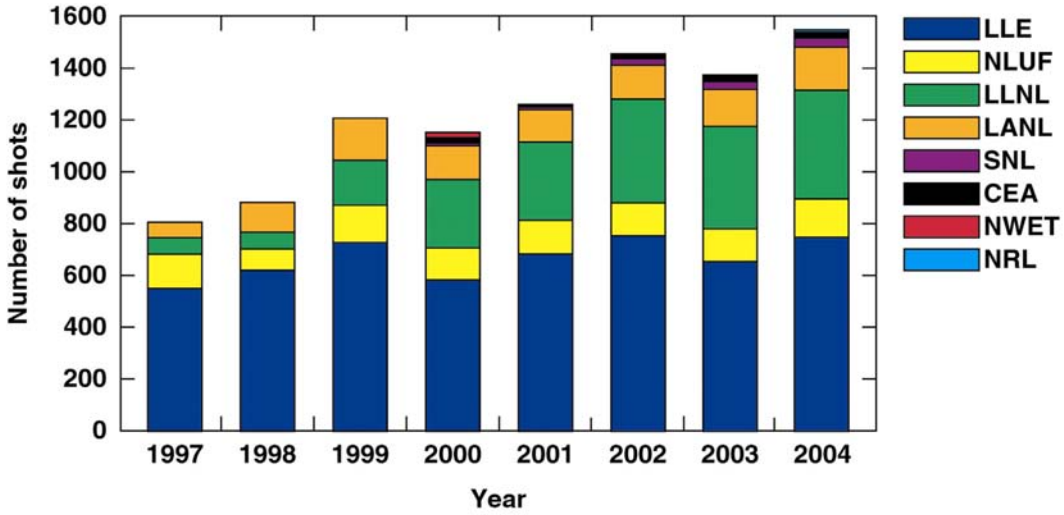
The plan for use of NIF calls for first ignition experiments in FY2010



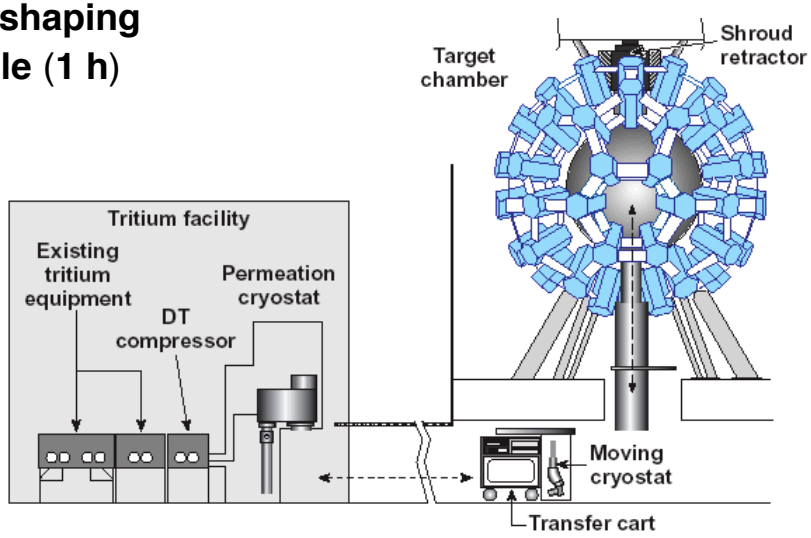
* Weapons physics experiments in support of Stockpile Stewardship

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



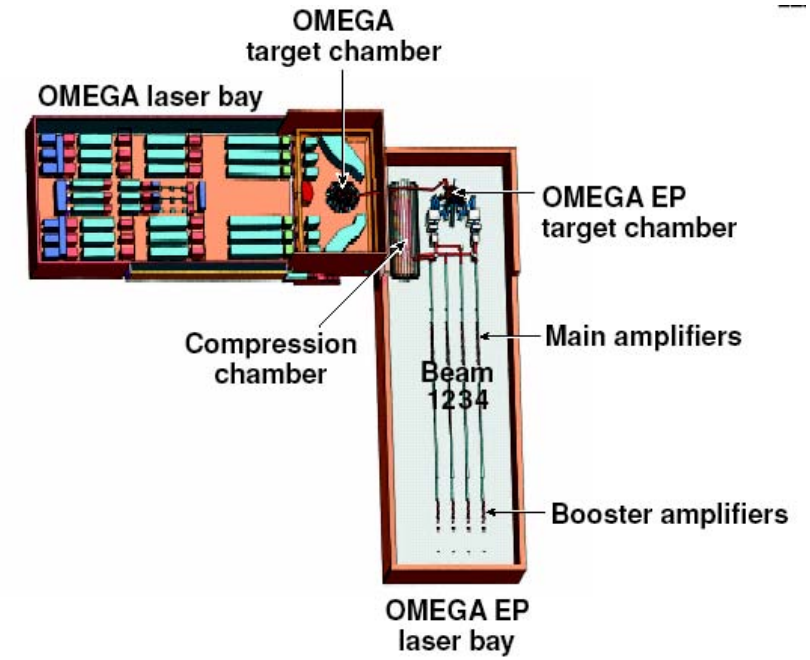


- 60 beams
- >30 kJ UV on target
- 1%-2% irradiation nonuniformity
- Flexible pulse shaping
- Short shot cycle (1 h)



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

OMEGA Extended Performance (EP) Project



- Add two high-energy petawatt lasers for advanced backlighting and fast-ignition experiments
- $45-55M total estimated cost, 4-5 year schedule ($15M appropriated through FY03)
- University of Rochester to provide new $20M building, State of New York to fund $2M target chamber
- Construction started in May 2004

	Pulse duration	Pulse Energy	Power
Petawatt beams	**10^{-10}-10^{-12} sec**	**2500 joules**	**25 Terawatt-2.5 Petawatt**
Long pulse beams	**10^{-8}-10^{-9} sec**	**6000 joules**	**0.6 Terawatt-6 Terawatt**

OMEGA EP construction

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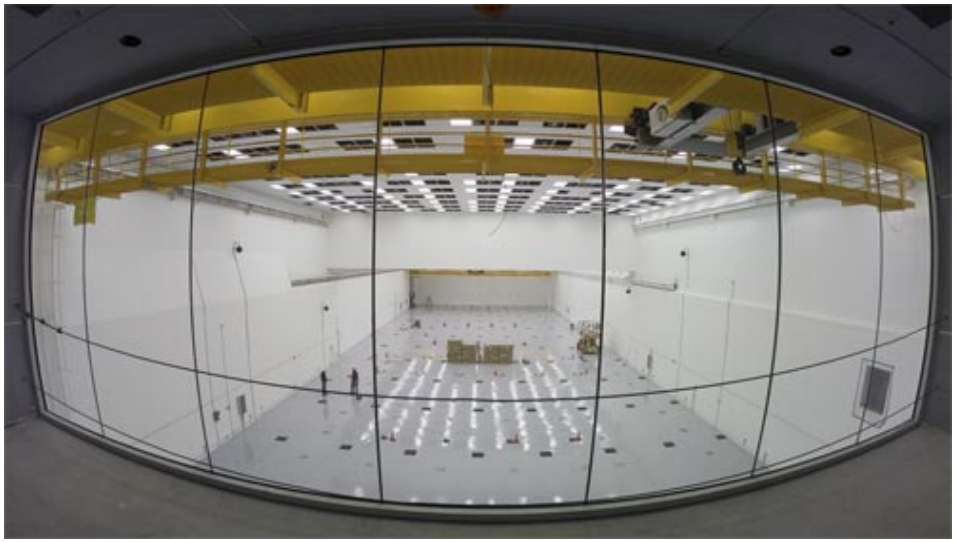
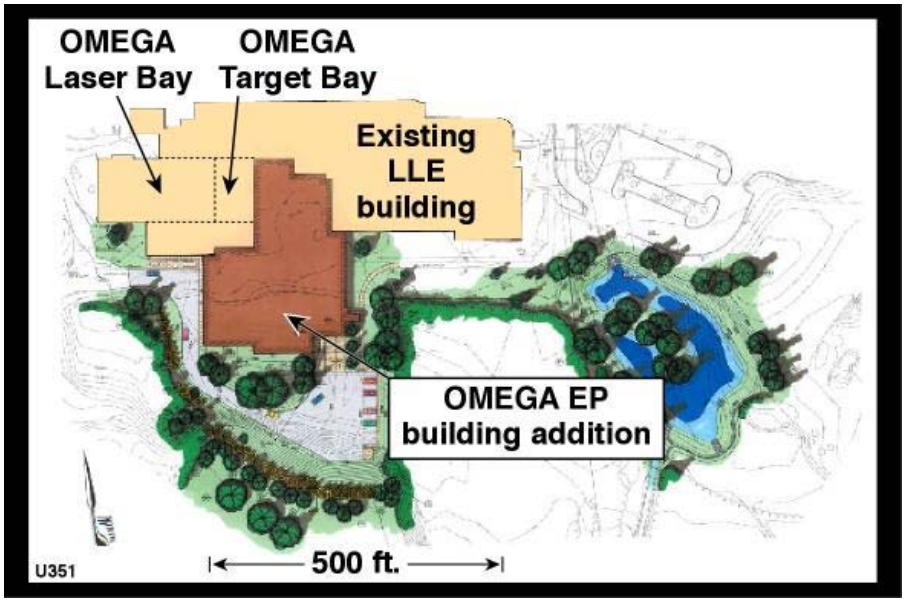
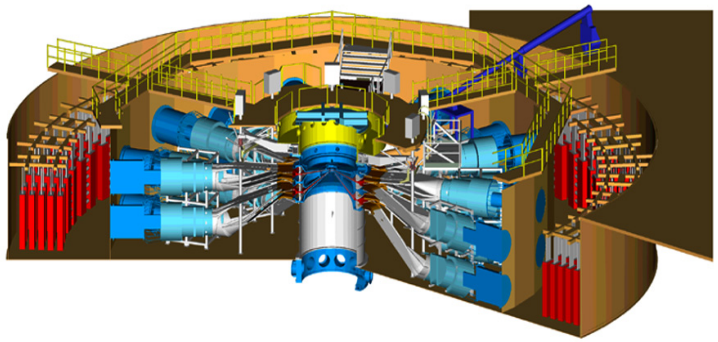




ZR and Z Beamlet- petawatt are important additions to program capability



- 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 hν 9 - 25 keV
  - integrated FI experiments on ZR

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

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ZR- Refurbishment of the Z Pulsed Power Accelerator

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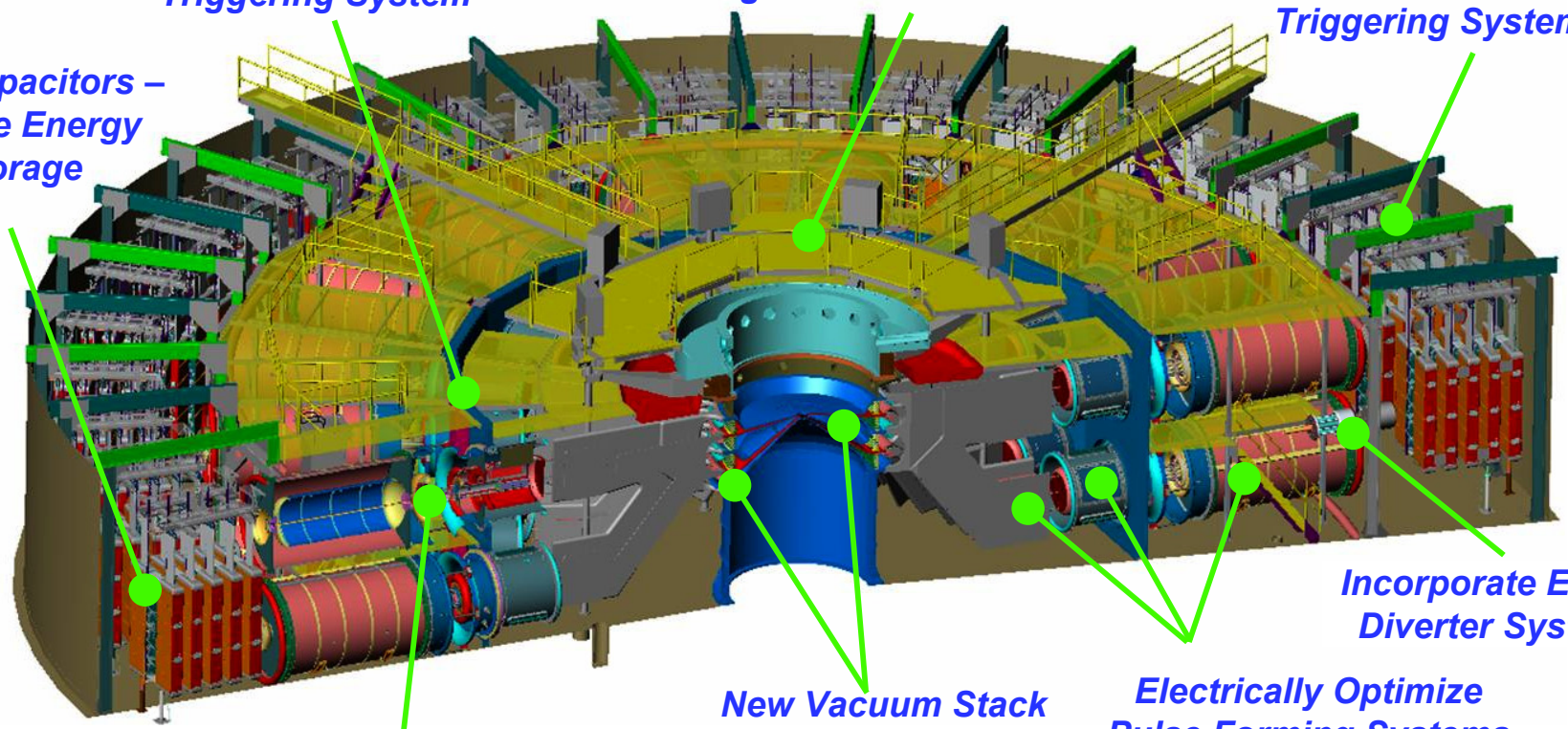

Improve Overall Reliability/Maintainability of Z's Components

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

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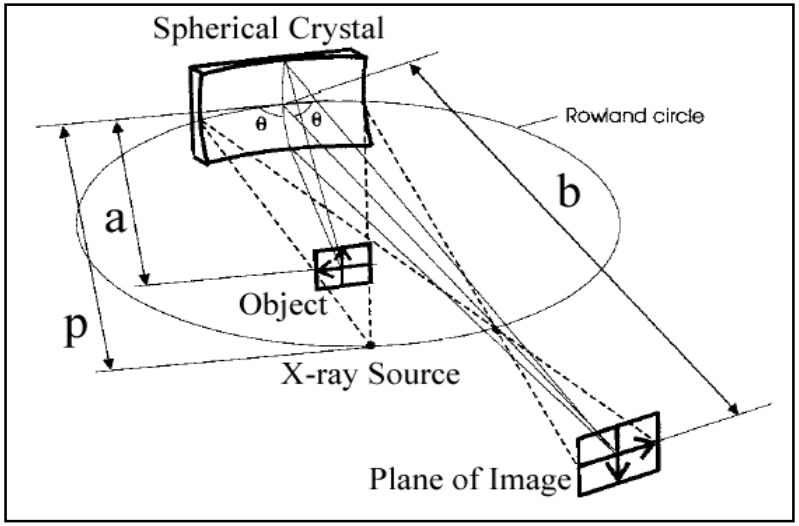
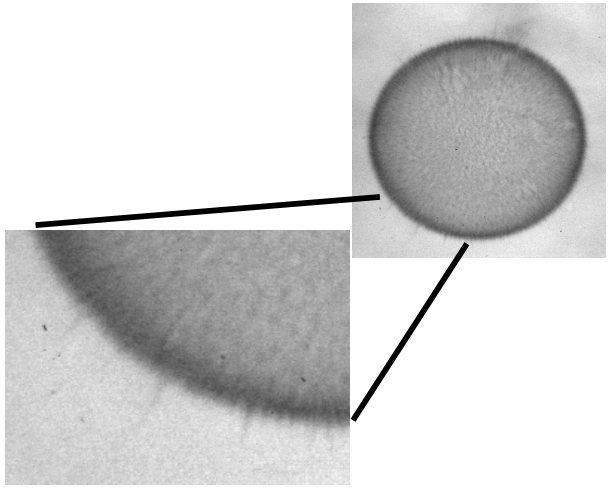
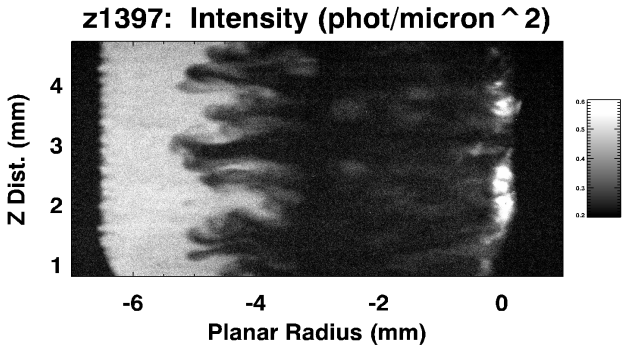
X-ray backlighting using a bent crystal imaging detector system



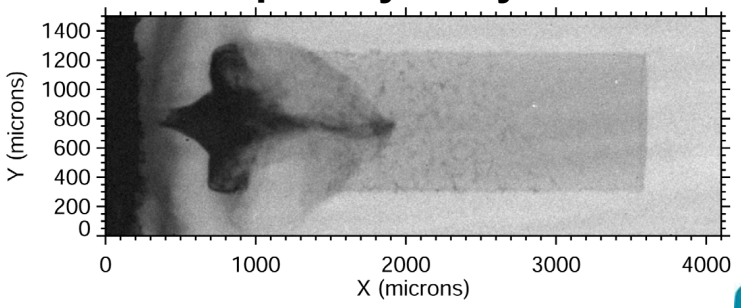
3.2 mm dia. capsule radiograph (C_r = 1.7)



Z-pinch implosion

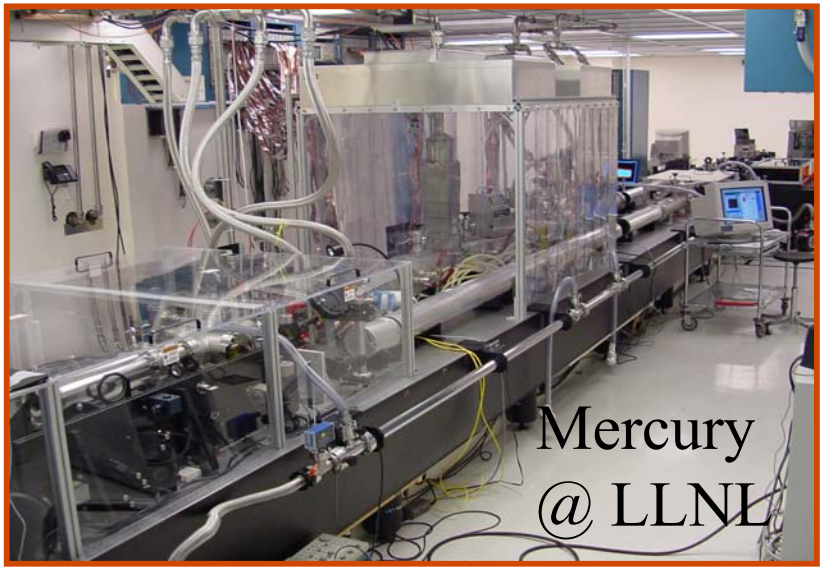


Complex hydrodynamics



Sandia National Laboratories

High Average Power Laser Program is a Congressionally funded program within NNSA



Phase 1 - $25M/year – thru 2006

Lasers
- Electra KrF
- Mercury DPPSL

Other technologies
- target fabrication
- target injection
- final optics
- Chamber & materials

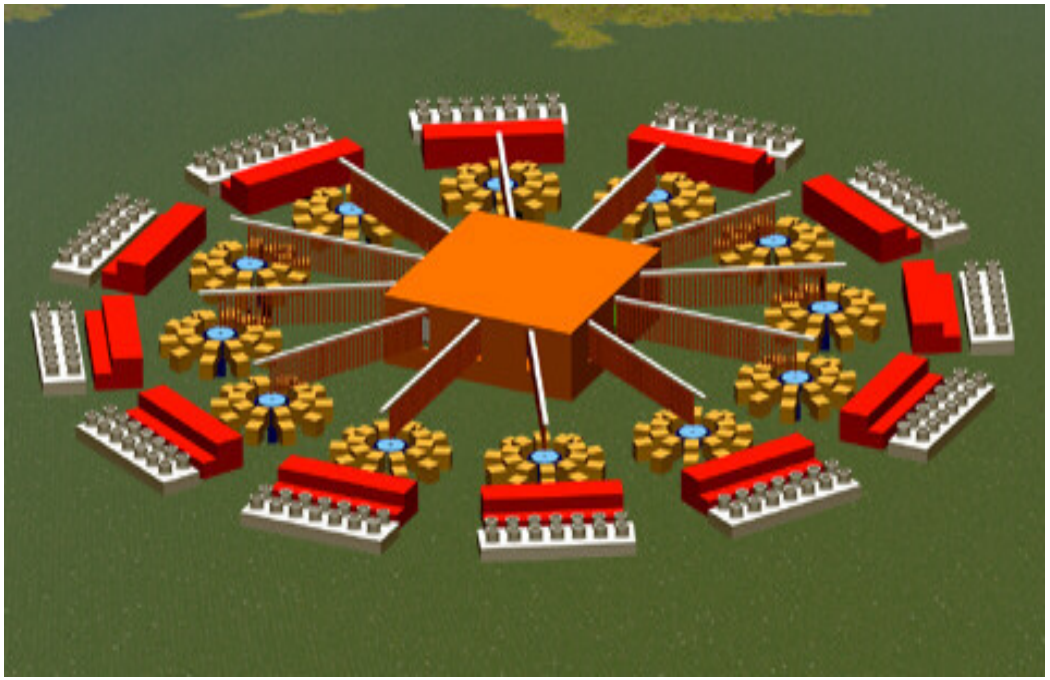
Phase 2 - thru 2012

- **1 Laser facility** –modular reactor beam hits injected targets @ 5hz
- **Target Fab/injection facility** - inject cryo pellets into heated chamber
- **Power Plant Design**

Phase 3 (ETF)

Engineering Test Facility (ETF)
- 2-3 MJ laser-driven implosions @ 5-10 Hz
- Optimize high-gain target implosions
- Optimize chamber materials & components.
- Generate ~ 300 MW electricity from fusion

The *long-term* goal of Z-Pinch IFE is to produce an economically attractive power plant using high-yield z-pinch-driven targets (~3 GJ) at low rep-rate per chamber (~0.1 Hz)



Z-Pinch IFE DEMO (ZP-3, the first study) used 12 chambers, each with 3 GJ at 0.1 Hz, to produce 1000 MWe

The *near-term* goal of Z-Pinch IFE is to address the science issues of repetitive pulsed power drivers, recyclable transmission lines, high-yield targets, and thick-liquid wall chamber power plants

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

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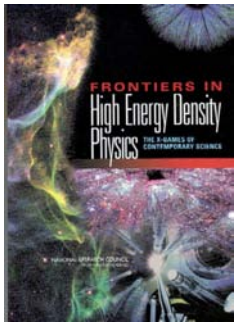
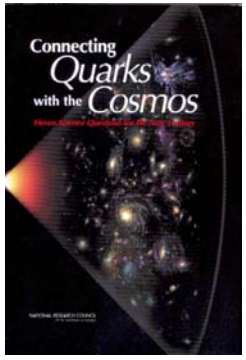
- **"Frontiers in High Energy Density Physics" (R. Davidson et al.)**



"..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)

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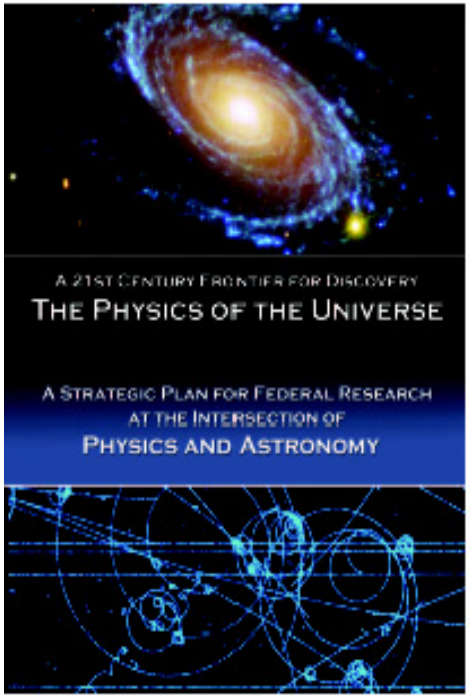
"HEDP is an emerging field that provides crucial measurements that are relevant to interpreting astrophysical observations of the universe. The field has great promise that should be better coordinated across the various Federal agencies to capitalize on the emerging opportunities."



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

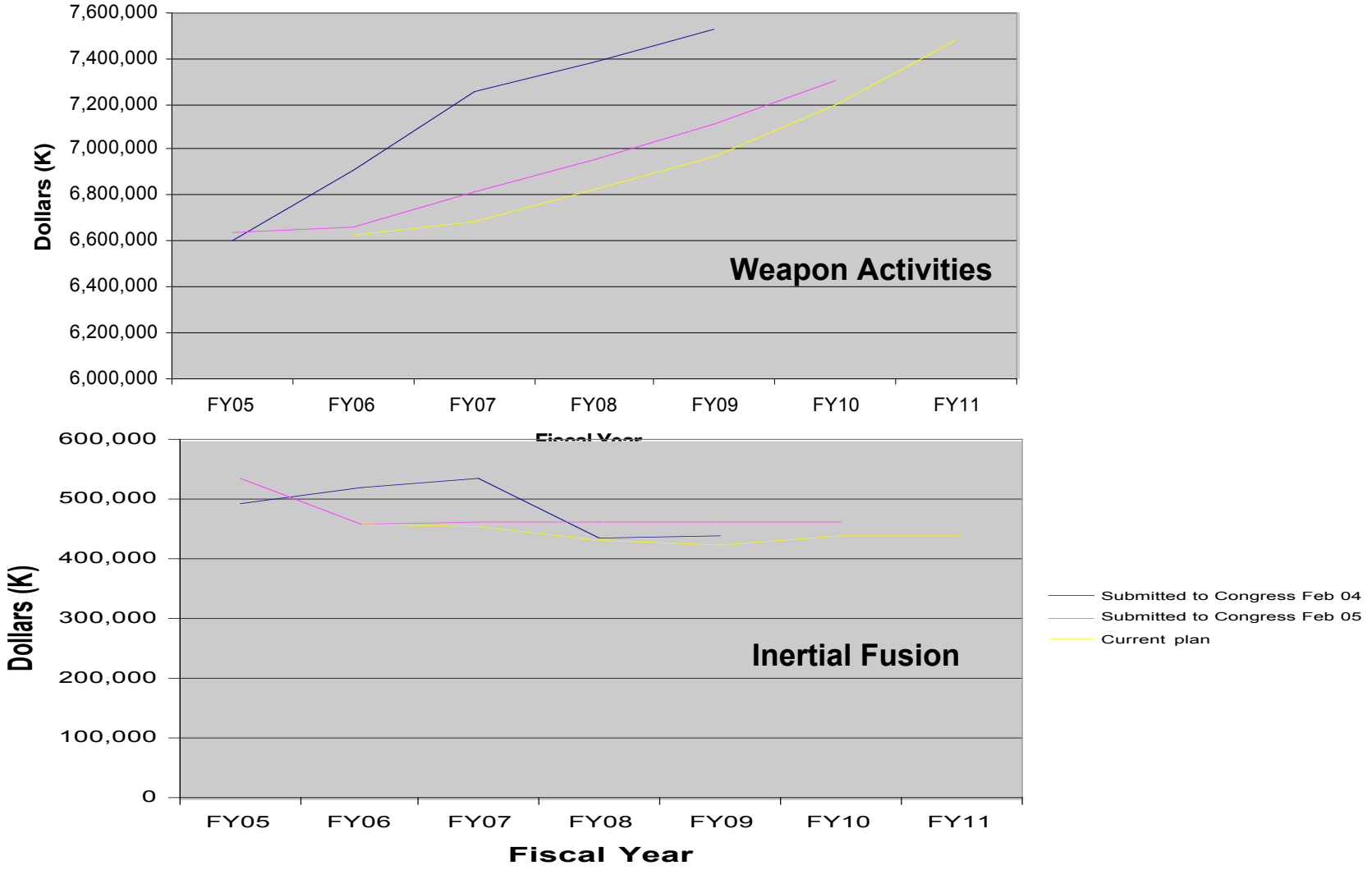
Prepared by

National Task Force

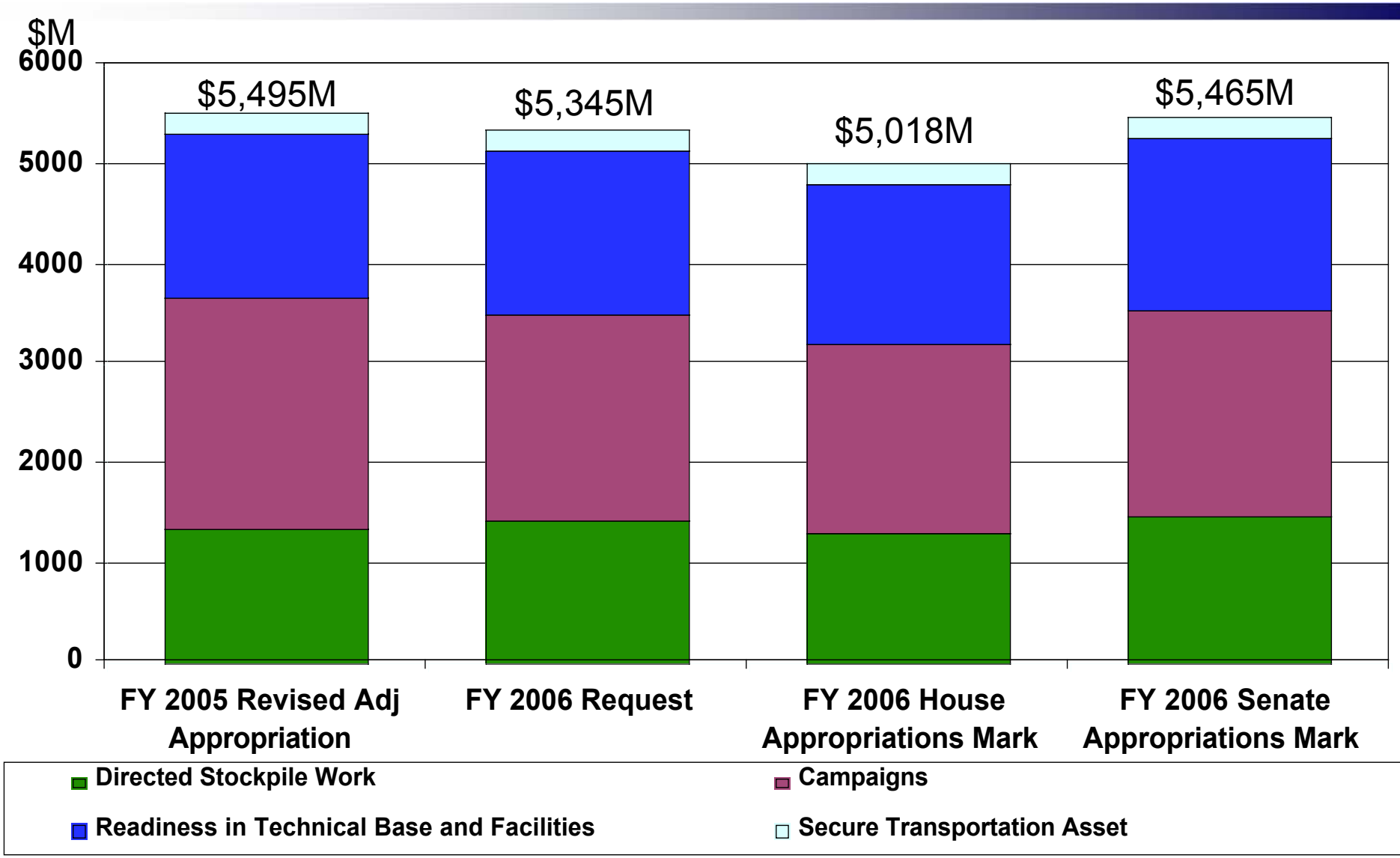
on High Energy Density Physics

July 20, 2004

Five year budgets are constrained



FY 2006 Appropriations for Defense Programs



FY06 funding status- NIF activities

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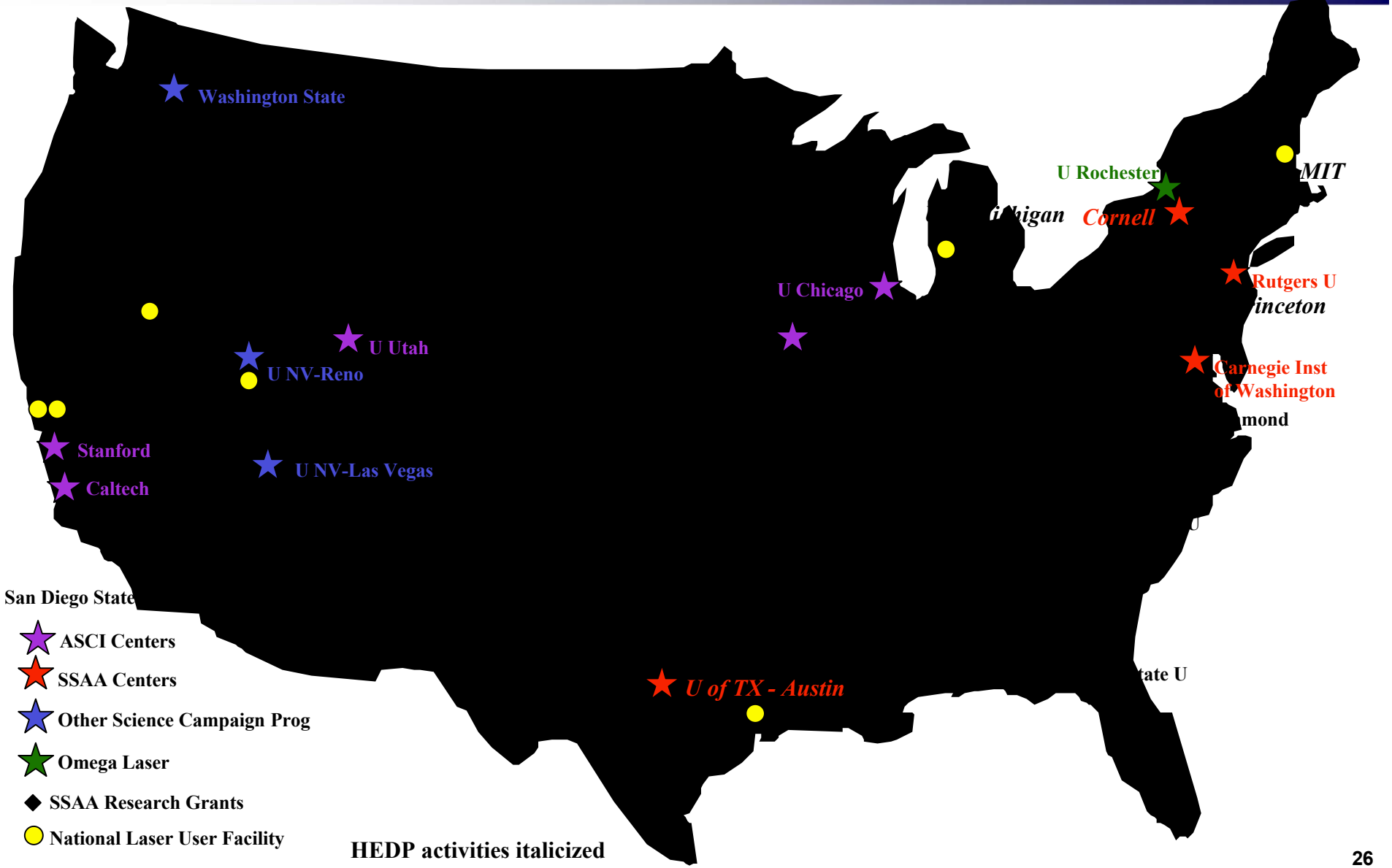
Appropriation / Activity	FY 2006 President's Budget	FY 2006 House Bill	FY 2006 Senate Bill
96-D-111-NIF Project Construction	141,913	141,913	0.0
NIF Demonstration Program	112,330	112,330	50,000
Ignition	75,615	75,615	68,000
NIF Diagnostics, Cryogenics & Exp Sup	43,549	43,008	30,000
University Grants/ Other Support	9,946	9,946	7,700

Differences must be worked out in conference committee

Academic Alliances



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  - Strong progress on direct drive (“polar” and uniform)
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  - Pulsed power fusion- measurements of fuel and symmetry conditions
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- **High energy density physics is recognized as an important and emerging scientific field**
  - NAS, OSTP reports
- **Budget outlook remains tight**
  - FY2006 appropriation
  - Outyear plans

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Backup

Key quotes- JASON review

- "In our judgment the technologies necessary to support the ignition campaign are likely to be ready by 2010"
- "First attempts to achieve ignition are likely to take place in 2010 – this is an important and valuable goal that has strongly focused the efforts of the NIF Program."
- "The scientific and technical challenges in such a complex activity suggest that success in the early attempts at ignition in 2010, while possible, is unlikely. …The program has identified a series of tests of the key physical processes and diagnostic instruments that provides a reasonable roadmap for progress toward ignition after the initial attempts."
- "The NIF laser has clearly been a major engineering achievement so far, for which LLNL and its staff can be proud."
- "The NIF ignition program has scientific and technical risks that demand involvement by experienced personnel to the greatest extent possible…We would like to see greater inclusion of the expertise that exists in ICF and related fields at other institutions."

Key quotes from the independent NIF Project review team

- "The project's performance is tracking the baseline plan."
- "The project has made appropriate planning adjustments to address the funding reduction in the FY 2005 congressional appropriation."
- "…the new project completion strategy minimizes potential disruptions to project installation and integration activities, and provides opportunity to leverage technology improvements and lessons learned…"
- "…the project is being managed appropriately for successful completion. The project team has established sound management processes and procedures and effectively uses project management tools to appropriately plan, monitor, and control project activities."
- "The project was able to respond to the FY 2005 budget reduction with less than proportionate response in out-year impacts…However,…**it is clear that a greater than proportional impact would occur if the practice of "nominal" budget cuts were to be repeated."**

FY 2006 Defense Programs congressional budget submission

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Weapons Activities	FY 2005 President's Request Comp'd to FY 2006	FY 2006 President's Request	FY 2005 to FY 2006 Change Dollar	Percent
Directed Stockpile Work	1,277.2	1,421.1	143.9	11.3%
Science Campaign	276.0	261.9	(14.1)	-5.1%
Engineering Campaign	175.6	164.2	(11.4)	-6.5%
Engineering Campaign Const. (TEC)	85.8	65.6	(20.3)	-23.6%
Inertial Confinement Fusion and High Yield Campaign	535.9	460.4	(75.5)	-14.1%
Advanced Simulation and Computing Campaign	696.7	660.8	(35.9)	-5.2%
Pit Manufacturing and Certification Campaign	263.0	248.8	(14.3)	-5.4%
Readiness Campaign	261.4	218.8	(42.7)	-16.3%
Readiness in Technical Base and Facilities	1,786.5	1,631.4	(155.1)	-8.7%
Secure Transportation Asset	199.7	212.1	12.4	6.2%
Deputy Administrator Defense Programs	5,557.9	5,345.0	(212.8)	-3.8%
Defense Programs O&M	5,043.9	4,869.6	(174.3)	-3.5%
Defense Programs Construction	514.0	475.4	(38.6)	-7.5%
Deputy Administrator Defense Programs	5,557.9	5,345.0	(212.8)	-3.8%
Nuclear Weapons Incident Response	108.4	118.8	10.4	9.6%
Facilities and Infrastructure Recapitalization Program	313.7	283.5	(30.2)	-9.6%
Environmental Projects and Operations	192.2	174.4	(17.8)	-9.3%
Safeguards & Security	751.9	740.5	(11.5)	-1.5%
Subtotal, Weapons Activities	6,924.1	6,662.2	(261.9)	-3.8%
Use of Prior Year Balances	(13.1)	-	13.1	-100.0%
Transfer of DoD Appropriations	(297.6)	-	297.6	-100.0%
Grand Total	6,583.4	6,630.2	46.8	0.7%

Resources are focused on extending service life of key weapons (SLBM, others)

ICF Campaign includes 6 major contractors and university participants

National Nuclear Security Administration

- Lawrence Livermore National Laboratory
  - National Ignition Facility
  - Glass laser technology development
  - Indirect drive ignition
  - High energy density physics
  - Diode Pumped Solid State Laser
- Sandia National Laboratory
  - Z/ZR pulsed power accelerator
  - Physics of z-pinches and applications
  - Pulsed power technology development
  - High yield assessment
- Los Alamos National Laboratory
  - Trident glass laser
  - Indirect drive ignition
  - High energy density physics
- University of Rochester / Laboratory for Laser Energetics
  - Omega/Omega EP glass lasers
  - High energy density physics
  - Laser technology development
  - Direct drive physics assessment
- Naval Research Laboratory (not funded in FY06)
  - Nike KrF laser
  - Use of smooth beams for physics
  - Direct drive target design
  - KrF laser technology development
- General Atomics
  - Target fabrication
  - Cryogenic technology target handling
- Academic Alliances Program

Laboratory Director's letter to Senate Subcommittee on Energy and Water, June 30, 2005

National Nuclear Security Administration

- "NIF will open up a whole new frontier that will transform ignition and nuclear weapons physics for the subsequent two decades."
- "We believe that the probability of success on NIF and the potential for the post-ignition, multi-megajoule thermonuclear capability is worthy of the combined efforts of our laboratories; the long-term value to our country is very great."
- "…we are confident that the NIF Project and the required target diagnostics, user optics, cryogenics, and ignition targets will be integrated and available for ignition physics experiments by the end of FY2009."
- "The reviews have confirmed the significant progress that has been made at NIF and with the ICF Program; they have contributed to our confidence in the reasonable and realistic schedule for the first attempt at ignition in 2010 and for increasing the probability of success in the subsequent years."

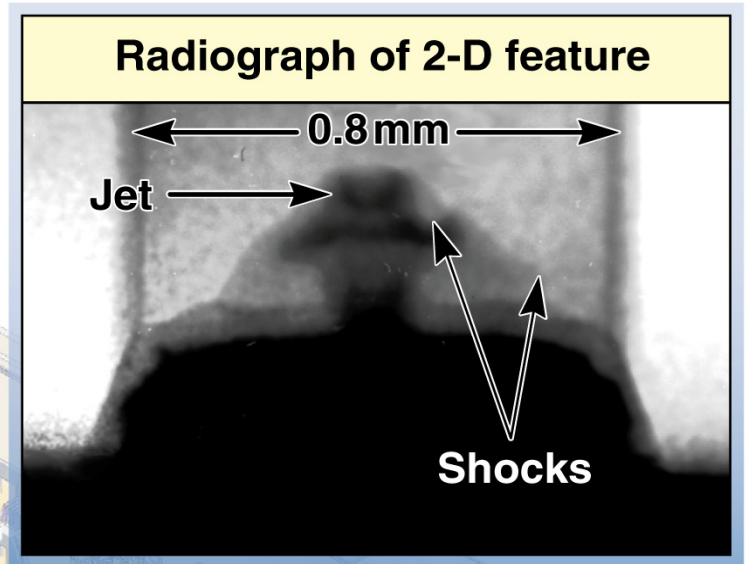
"Furthermore, we jointly developed and do endorse the National Ignition Campaign Plan for June 28, 2005."

NIF has acquired data for Stockpile Stewardship

National Nuclear Security Administration

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

NIC Level 0-2 Milestones

National Nuclear Security Administration

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

NIC Level 0-2 Milestones (continued)

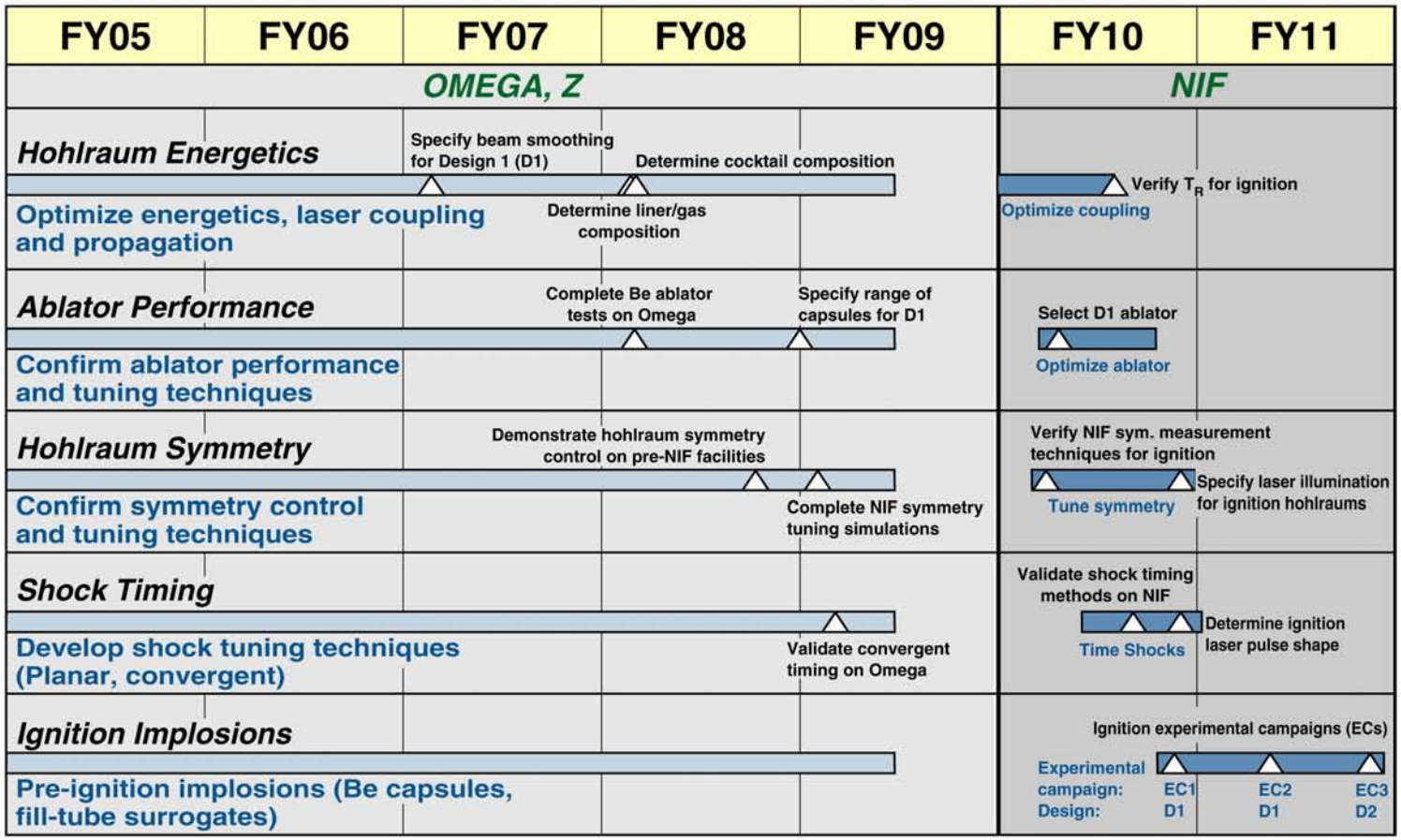
National Nuclear Security Administration

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

△ 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.

Ignition 2010 Experimental Plan

National Nuclear Security Administration



NIF-0505-10832
05GB/cld

P9090

Experiments on facilities other than NIF are essential to the National Ignition Campaign

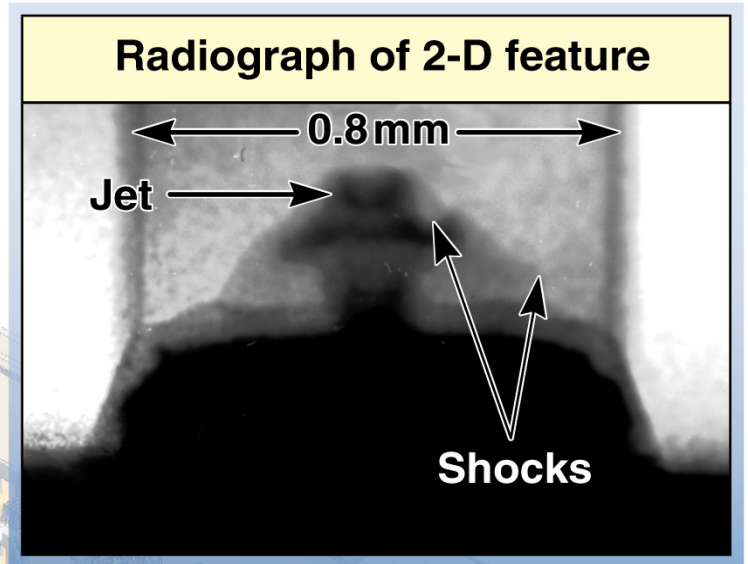
	Energetics	Laser Plasma Interactions	Symmetry	Ablator Physics	Shock Timing	Implosions
OMEGA	✓	✓	✓	✓	✓	✓
Z/ZR			✓	✓		
Trident (LANL)		✓		✓		
LIL (France)	✓	✓				

NIF has acquired data for Stockpile Stewardship

National Nuclear Security Administration

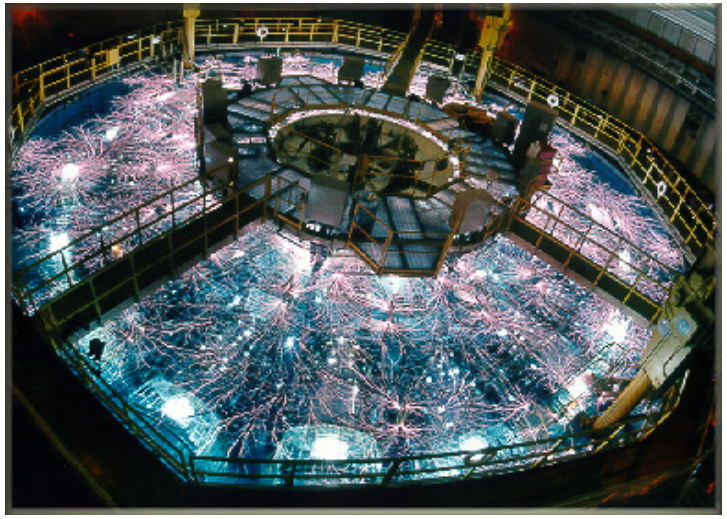
Hydrodynamic experiment: (FY 2004)

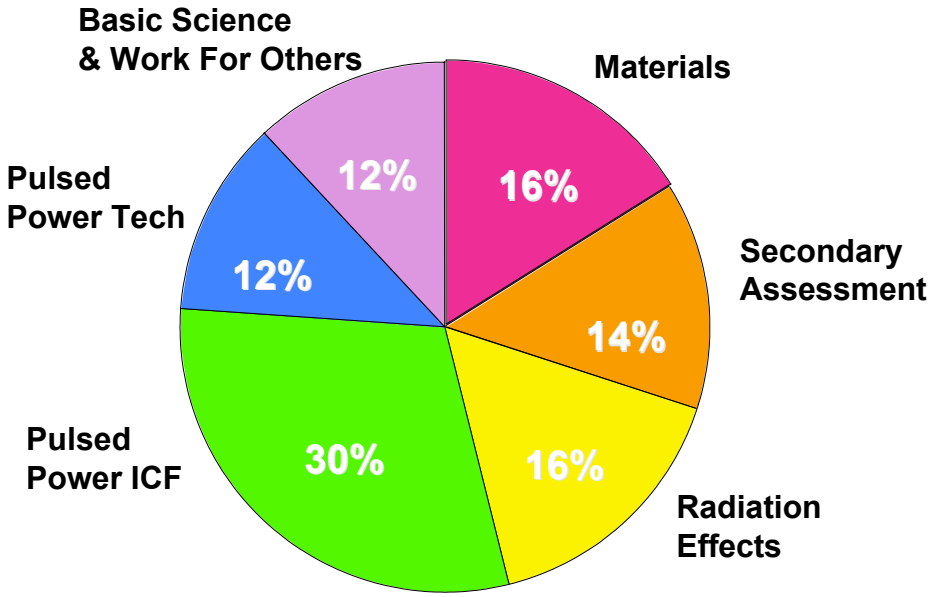
- Challenges our 2- and 3-D code capabilities
- Demonstrates our ability to do complex experiments on NIF
- Uses sophisticated target, diagnostic, and laser alignment providing great accuracy and reproducibility



Full single beam performance has been demonstrated

The Z machine at SNL provides critical capabilities for the SSP



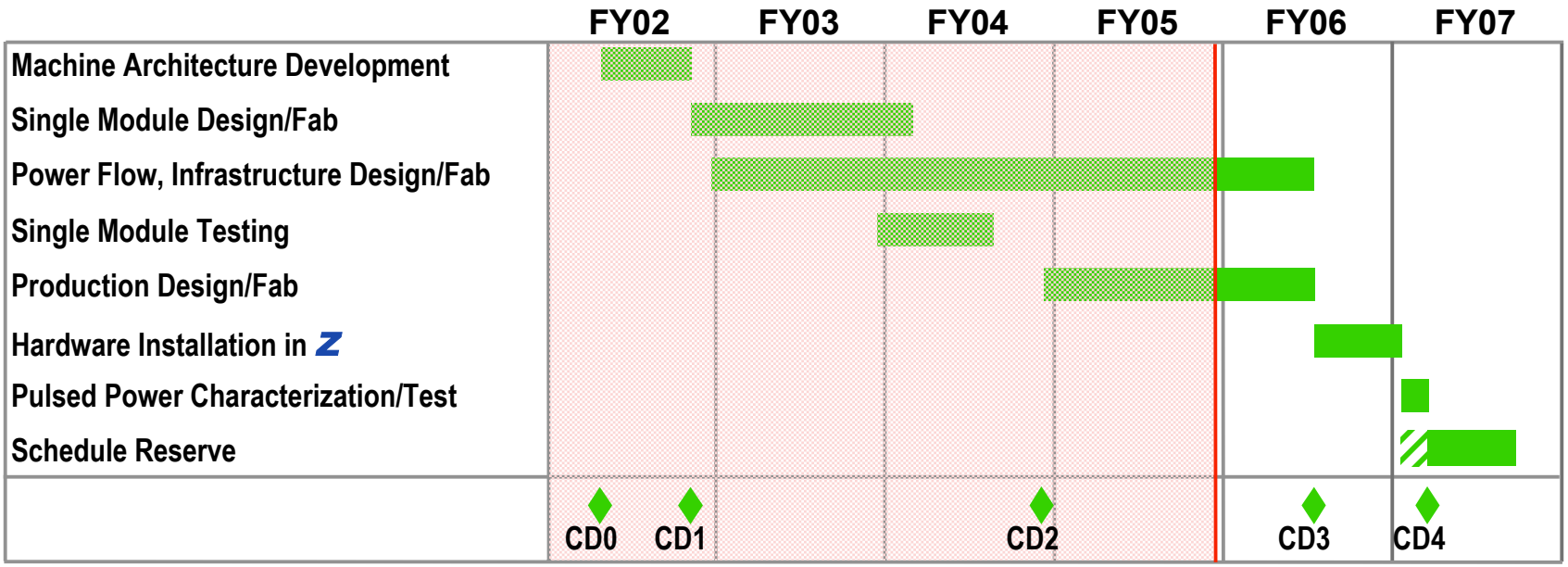


Z is undergoing refurbishment (ZR Project)

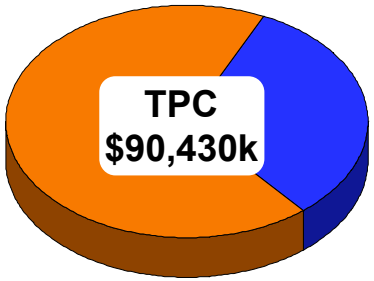
	Energy	Power
Z	1.6 MJ	230 TW
Z-R	2.7 MJ	350 TW

Distribution of Z Experiments (FY03)
Approximately 200 shot-days/year

ZR-Project Summary

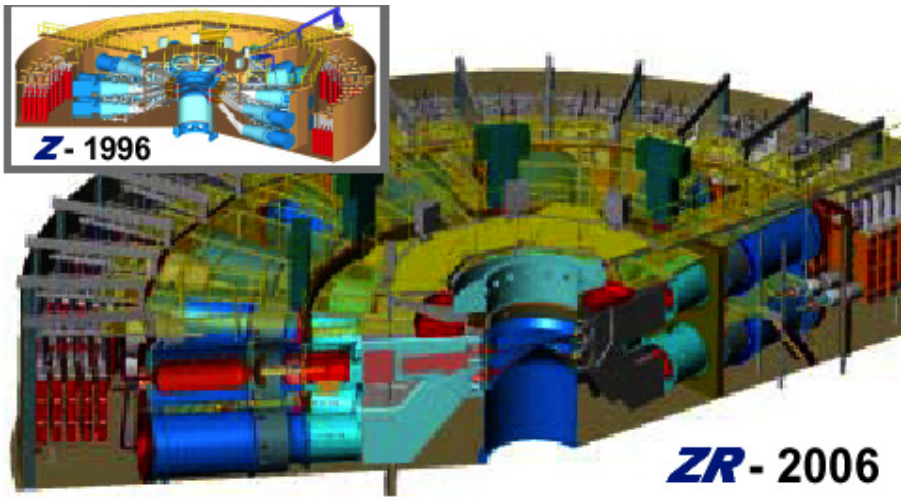


TEC
Engineering, Design, Hardware
$61,710k



OPC
R&D, Installation, Testing
$28,720k

The Z Refurbishment Project will enable z-pinch implosions to produce over 2.5 MJ and 300 TW of x rays



- ZR facility refurbishment in progress
- $61.7M total estimated cost, 4-5 year schedule
- Funded through Readiness in Technical Base and Facilities (RTBF)
- CD-3 approved 9/04