The NIF Ignition Campaign

Presentation to
Heavy Ion Fusion Science – Virtual National Laboratory
Program Advisory Committee

NIC

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Physics & Systems Engineering
National Ignition Campaign

Aug. 9, 2006

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the University of California, Lawrence Livermore National Laboratory under
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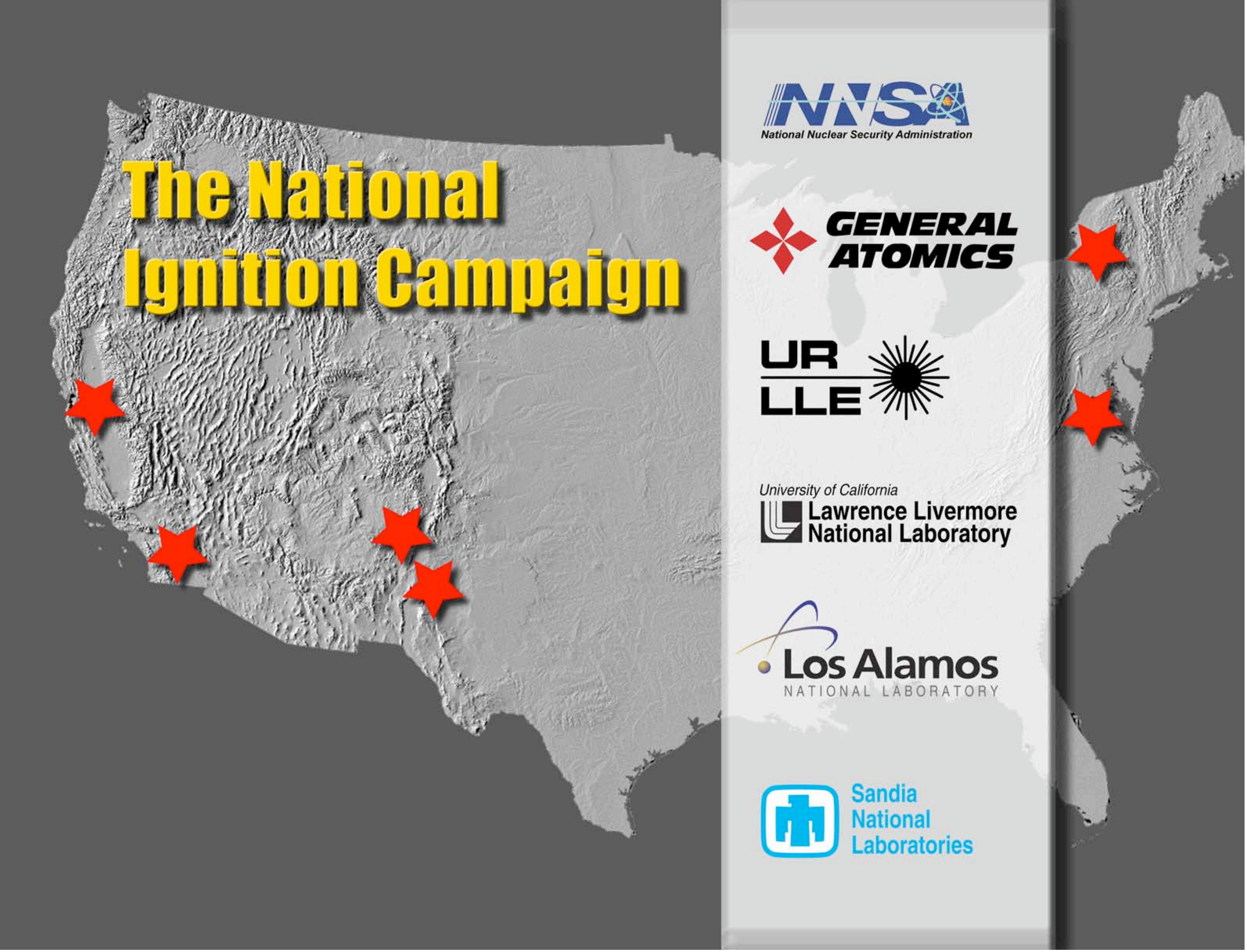
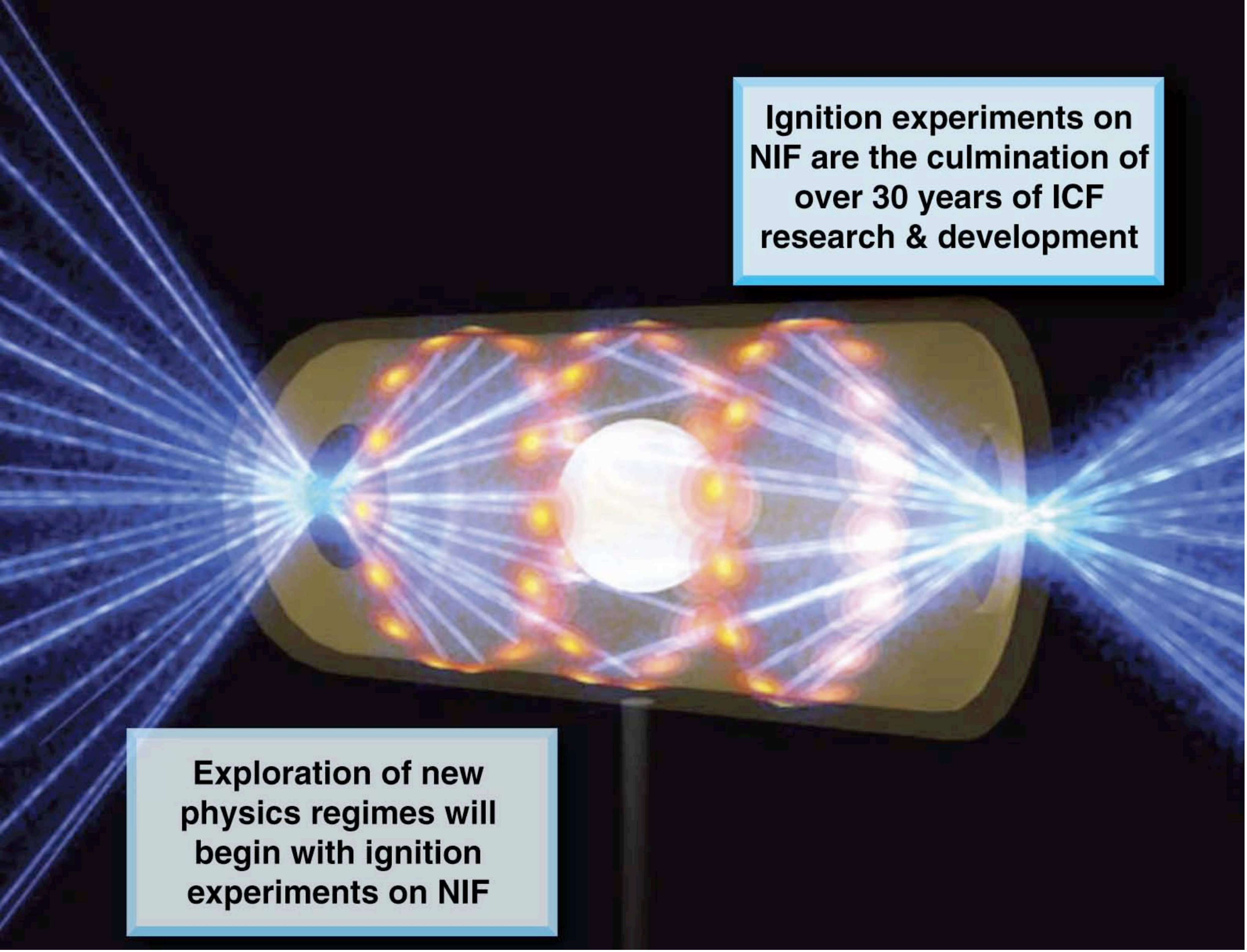
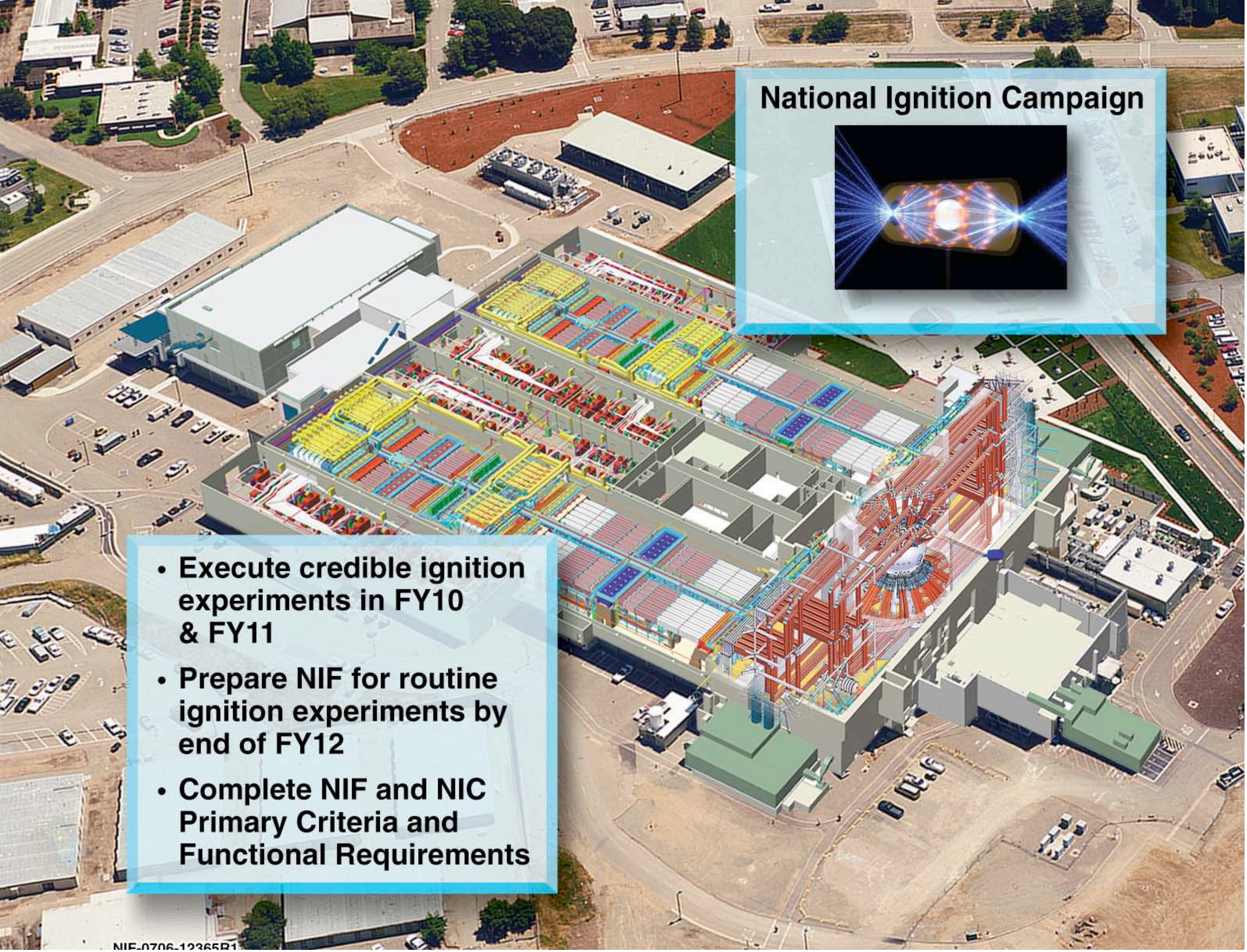
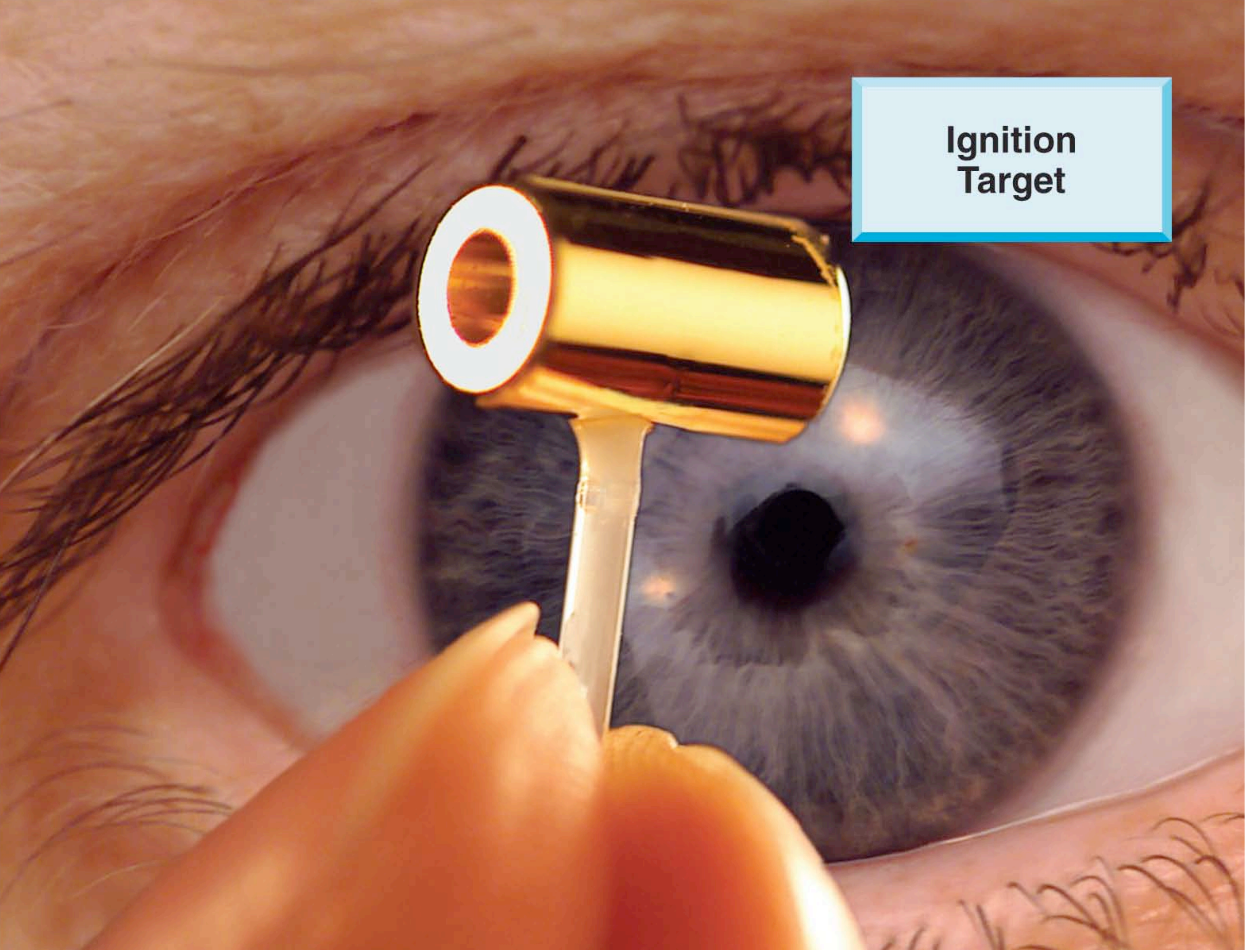
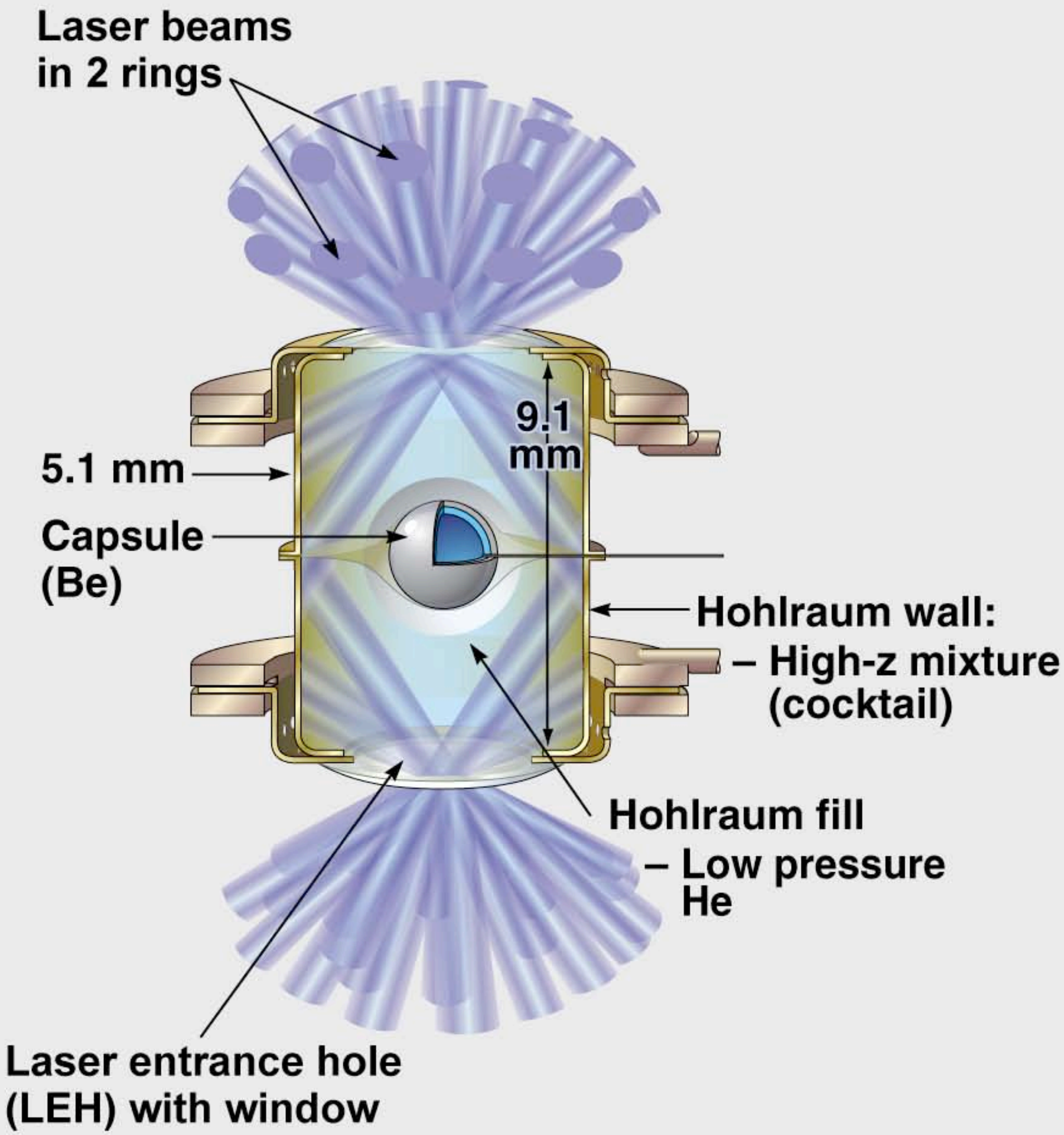

The National Ignition Campaign
NNSA
National Nuclear Security Administration
GENERAL ATOMICS
UR LLE
University of California
Lawrence Livermore National Laboratory
Los Alamos
NATIONAL LABORATORY
Sandia National Laboratories


Ignition experiments on NIF are the culmination of over 30 years of ICF research & development
Exploration of new physics regimes will begin with ignition experiments on NIF

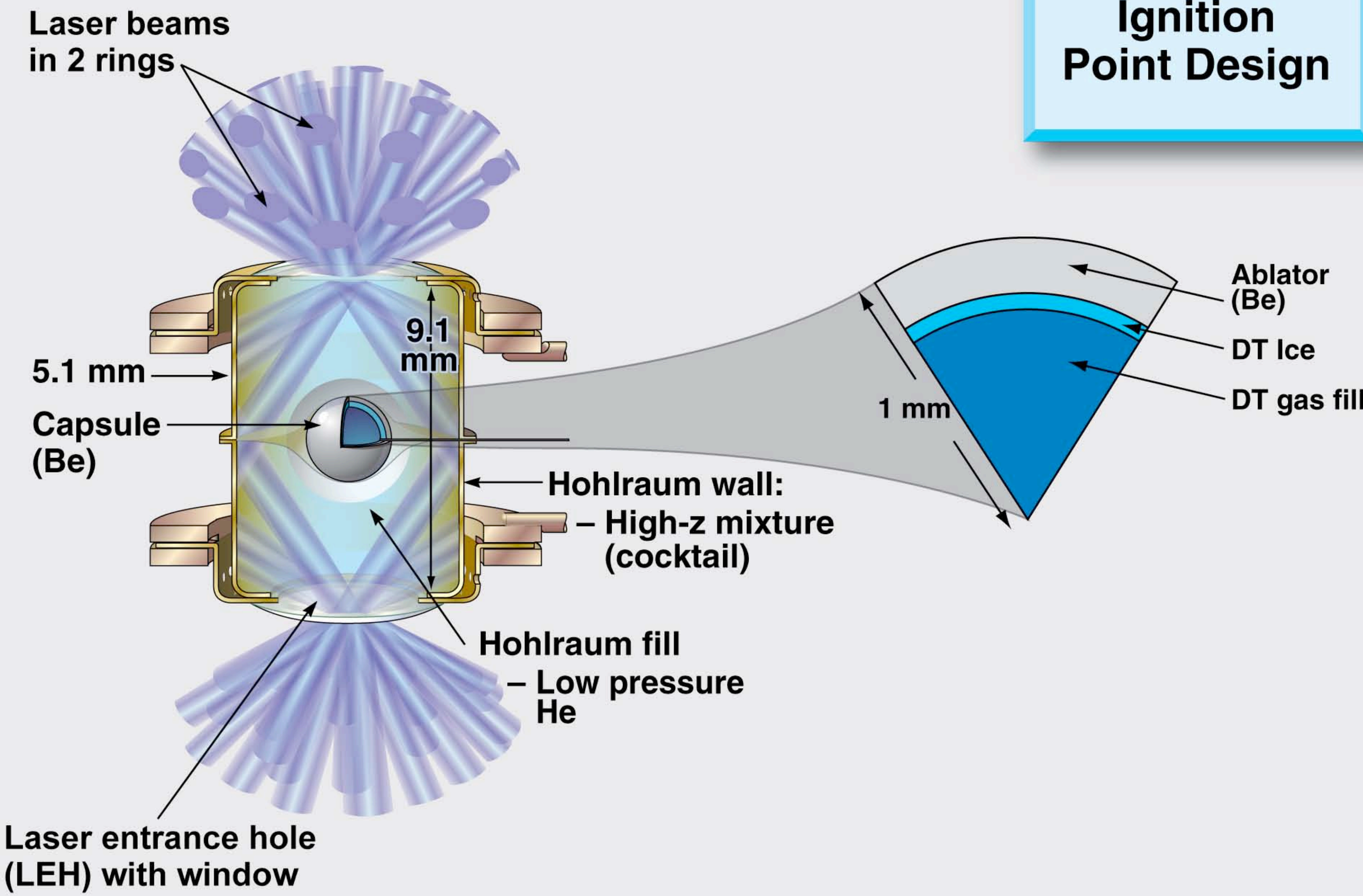

National Ignition Campaign
• Execute credible ignition experiments in FY10 & FY11
• Prepare NIF for routine ignition experiments by end of FY12
• Complete NIF and NIC Primary Criteria and Functional Requirements
NIF-0706-12365R1


Ignition
Target

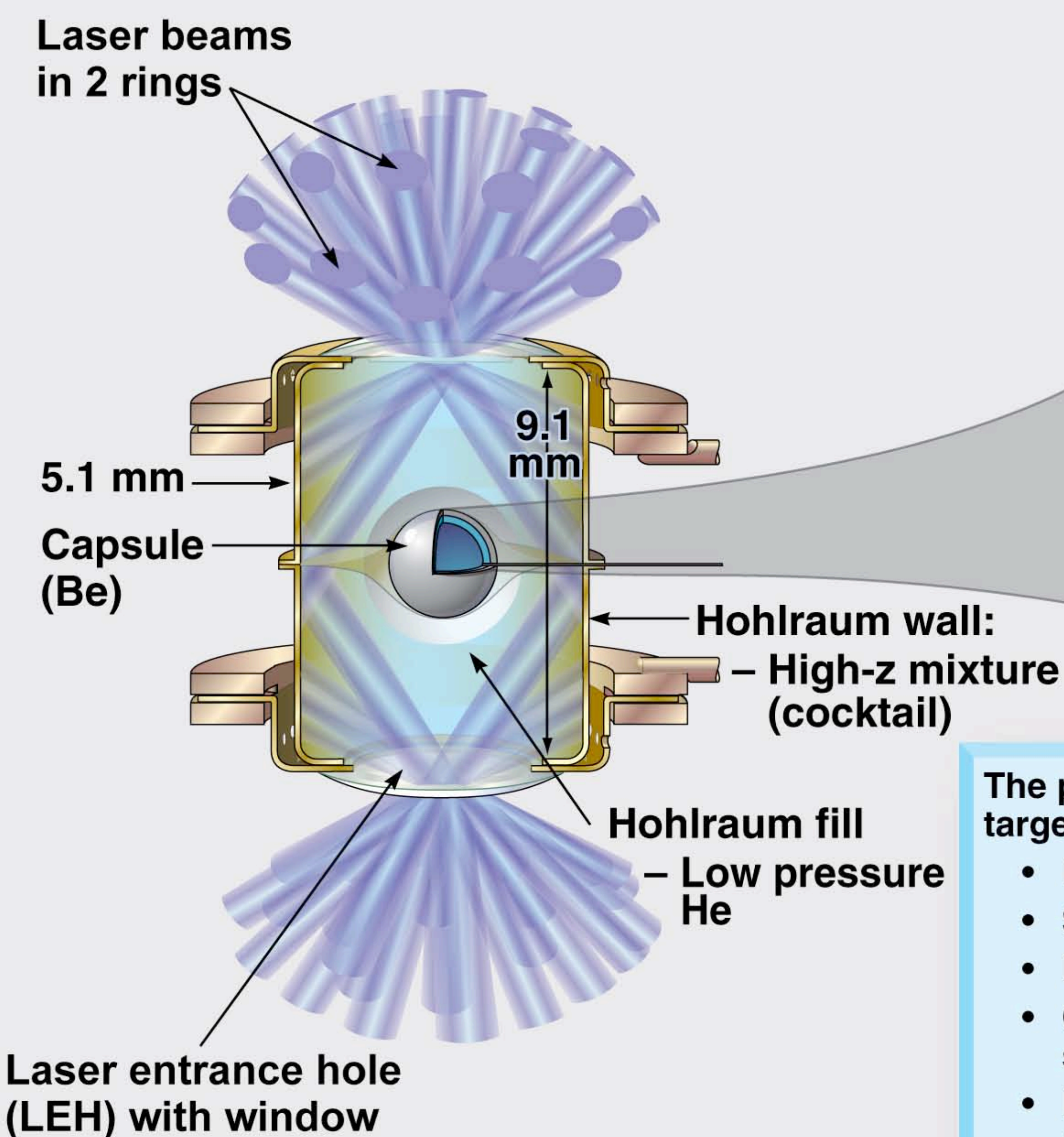
Ignition Point Design

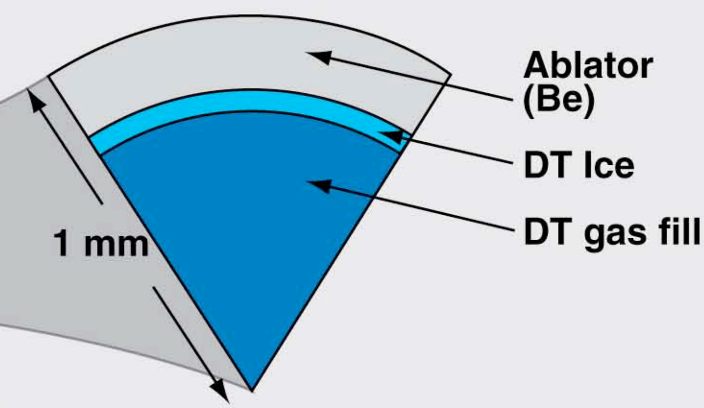


Ignition Point Design



Ignition Point Design





The point design fully specifies the laser-target system

- Pulse shape, energy
- Spot size, uniformity
- DT ice layer roughness
- Capsule dimensions and surface roughness
- Hohlraum dimensions, materials, and efficiency
- Target thermal and position stability
- Diagnostics

Extract from the point design requirements document

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Number	Rev	Component	Title	short req't	Requirement Text
1	0	Target	Requirements apply at shot temperature	Requirements apply at shot temperature	All requirements on targets shall apply at the temperature of the subject component at the time of the shot
2	0	Target	Tolerances are specified as hard limits	Tolerances are hard limits	Unless specifically stated otherwise, all requirements on targets shall be hard limits (as opposed to statistical values such as 1 sigma, 3 sigma, or RMS). If targets are produced that do not meet hard-limit requirements, they shall be dispositioned on a case-by-case basis by an MRB.
3	0	Capsule	Capsule outer radius, range of possible requested values and point-design value	900-1100 µm	Capsules shall be producable with outer radii within the range 900 - 1100 µm. The outer radius of each capsule will be specified within this range. The point design value shall be 1.0 mm.
4	1	Capsule	Capsule outer radius, tolerance	± 5µm	The outer radius of the capsule shall be within +/- 5µm of the specified value. On each shot the outer radius shall be measured to within +/- 1 µm.
5	0	Capsule	Ablator – Low level impurities	sum(atomic fraction)*Z^2 < 0.1	Except for allowed ingredients as listed in the ablator composition entries, the ablator material in all layers shall contain suffieciently low impurity levels that the sum over all impurities of atom fraction * Z^2 shall be less than or equal to 0.20, i.e. 20%. For example, a barely allowed impurity set would be [C,Al,Si,Mn,Fe,Ni] with atomic fractions 0.01*[.015,.007,.006,.0005,.021,.0031] giving Fe-dominated weighted sum 0.01*(.54+1.18+1.18+0.31+14.20+2.43)=0.20
6	0	Capsule	Ablator – High level impurities with known acceptable presence		Ablators may contain specified materials as described in individual albator composition requirments.
7	0	Capsule	Ablator – measurement of x-ray optical depth variations	accuracy <0.01%	Lateral variations in optical depth through the ablator shall be measured with accuracy better than 0.01%, at lateral scales between 120 and 3000 µm (modes 2–25), at 5.4 keV x-ray energy. Entire capsule shall be measured down to 120 µm lateral scale (mode 25). These measurements will constrain porosity, density variations, isolated defects, and variations in thickness of the internal layers. It will be very valuable to have scans of representative patches of representative capsules at lateral scans down to 20 µm (mode 150).

- **The current version (rev 1) has 81 lines with supporting tables and drawings**
- **There are additional requirements for the campaigns leading up to ignition**

Four Integrated Experiment Teams are developing the requirements for the campaigns leading up to ignition

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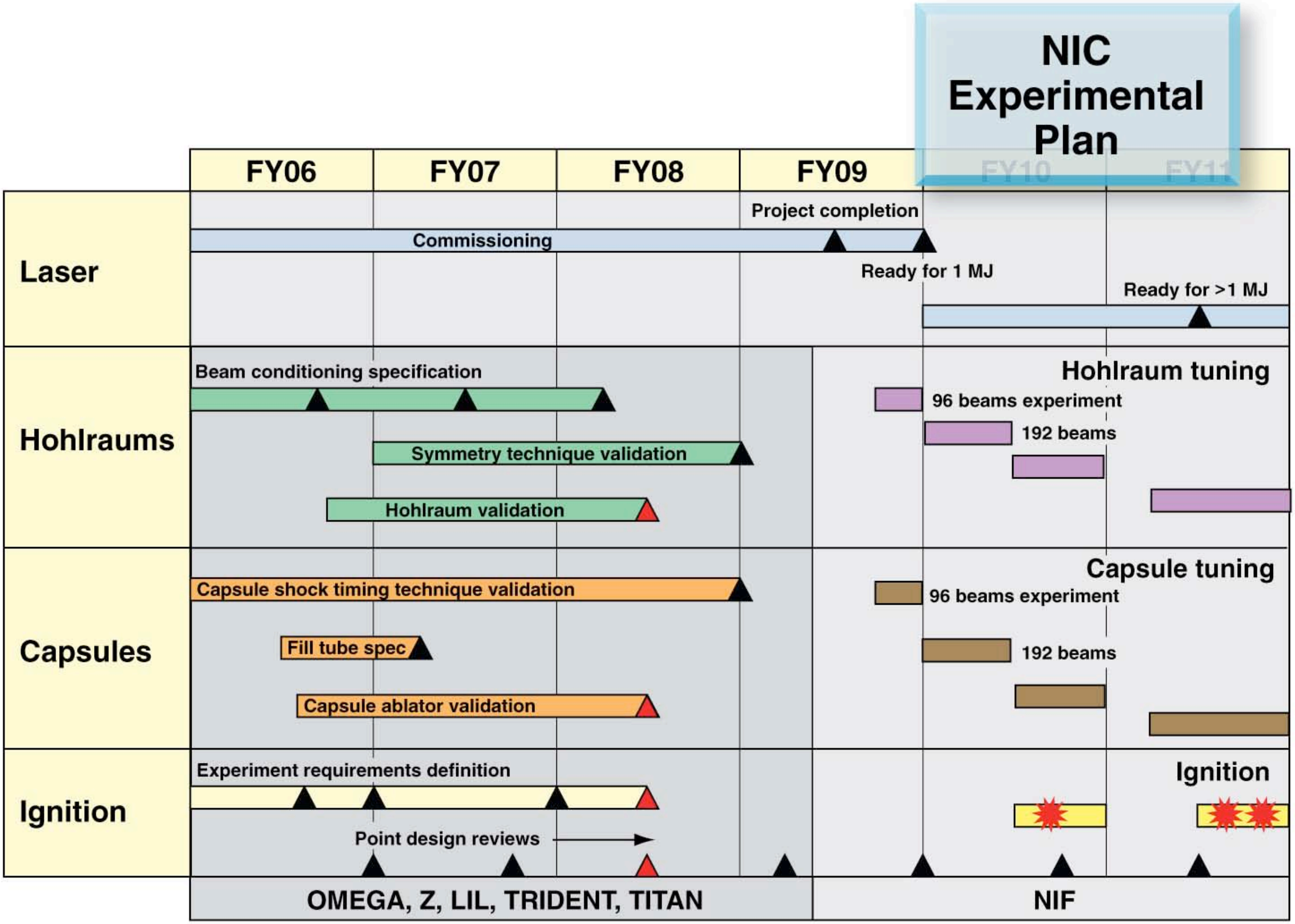
- **Laser Performance** — Pulse shaping, power balance, pointing, beam conditioning
- **Hohlraum Performance** — Energy coupling, radiation characteristics, radiation symmetry
- **Capsule Performance** — Shock timing, material ablation and state, hydrodynamic stability
- **Ignition Performance** — Point design
  Overall ignition campaign plan Integrated implosions, ignition failure diagnostics


NIC Experimental Plan
FY06
FY07
FY08
FY09
FY10
FY11
Laser
Project completion
Commissioning
Ready for 1 MJ
Ready for >1 MJ
Hohlraums
Beam conditioning specification
Symmetry technique validation
Hohlraum validation
Hohlraum tuning
96 beams experiment
192 beams
Capsules
Capsule shock timing technique validation
Fill tube spec
Capsule ablator validation
Capsule tuning
96 beams experiment
192 beams
Ignition
Experiment requirements definition
Point design reviews
Ignition
OMEGA, Z, LIL, TRIDENT, TITAN
NIF

NIF/NIC integrated summary schedule

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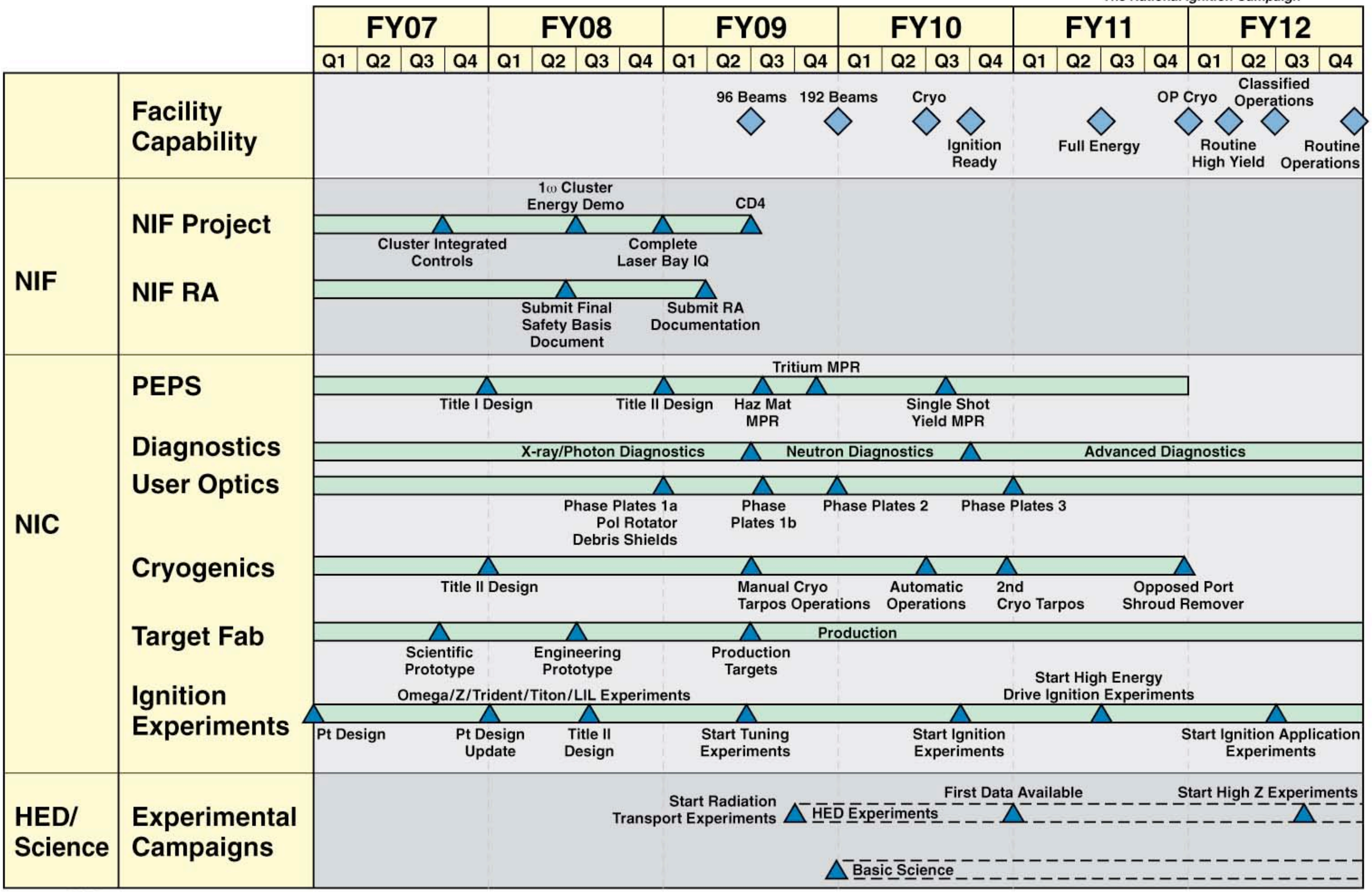

NIF-0706-12472

Major elements of the National Ignition Campaign

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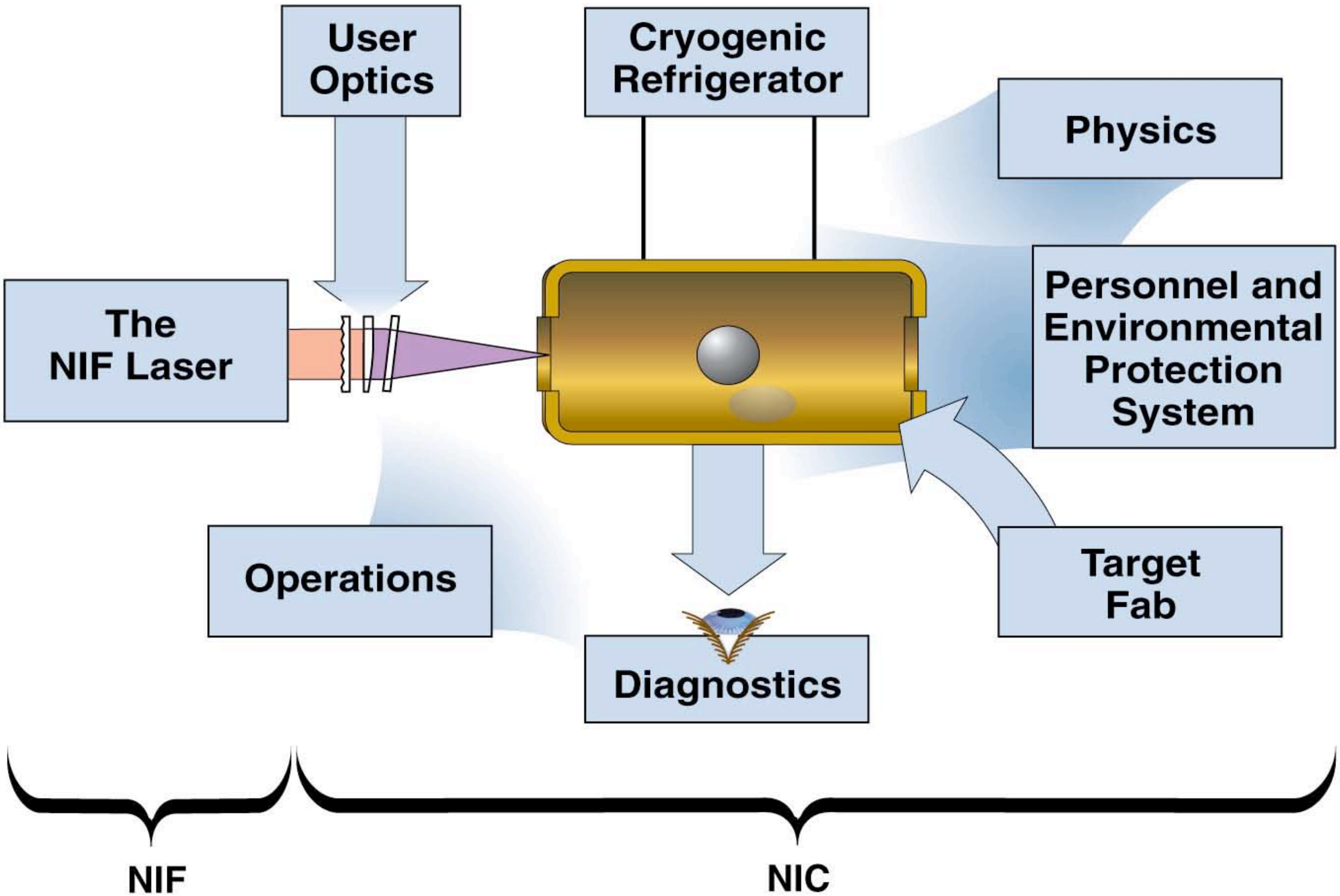


NIF-0606-12269r1

Process, assemble, and install 6,206 line replaceable units (LRUs)

The National Ignition Facility

Preamplifier Modules (48)

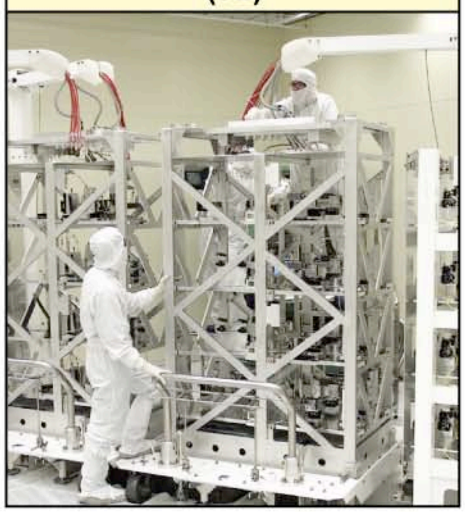
Laser Amplifiers (672)

Final Optics Assemblies (960)

Laser Mirrors (656)

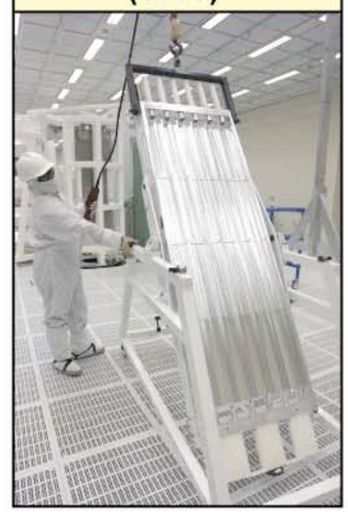
Spatial Filter Lenses (960)

Spatial Filter Towers (72)



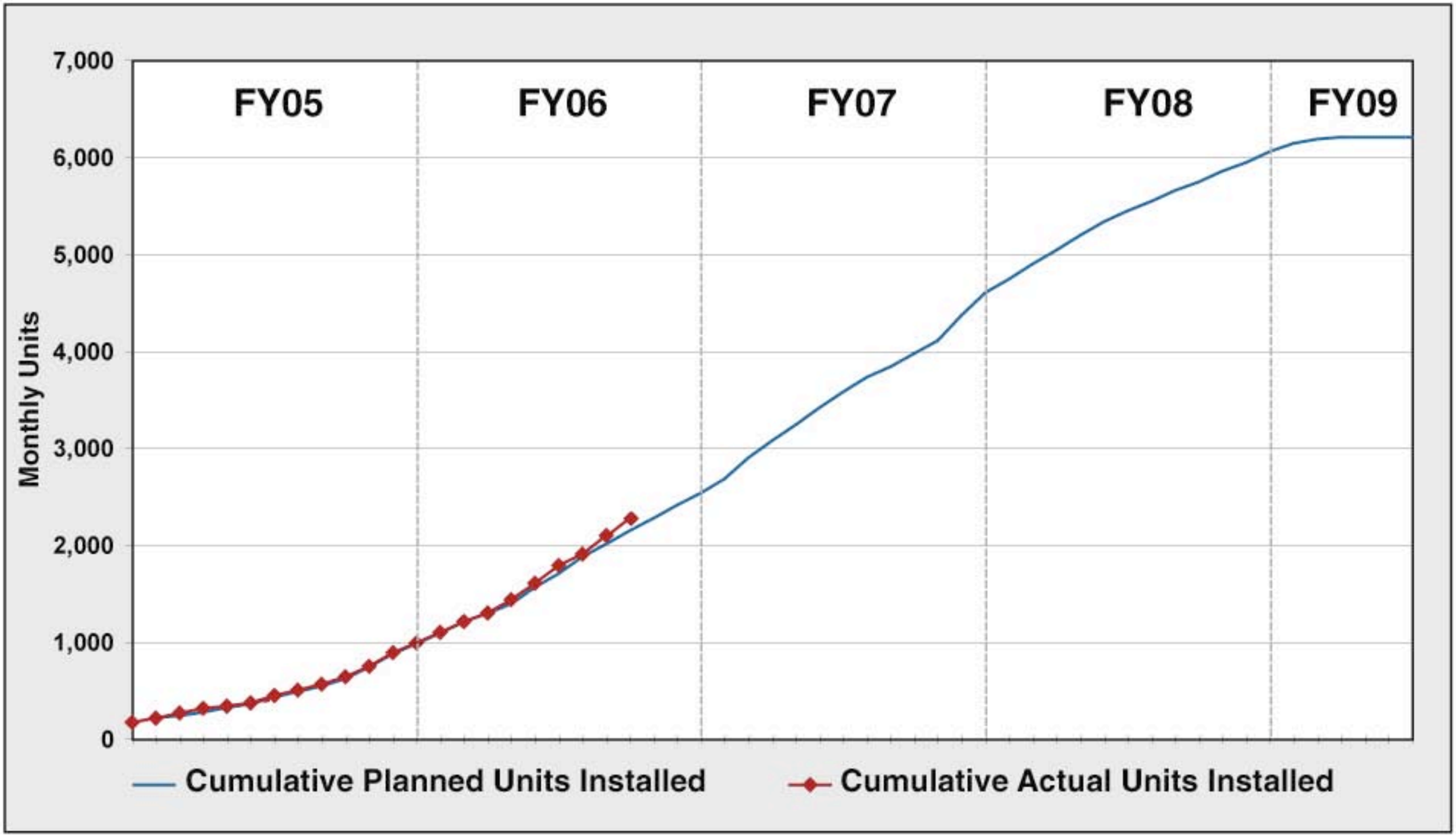
Plasma Electrode Pockels Cell (192)

Flashlamps (1008)

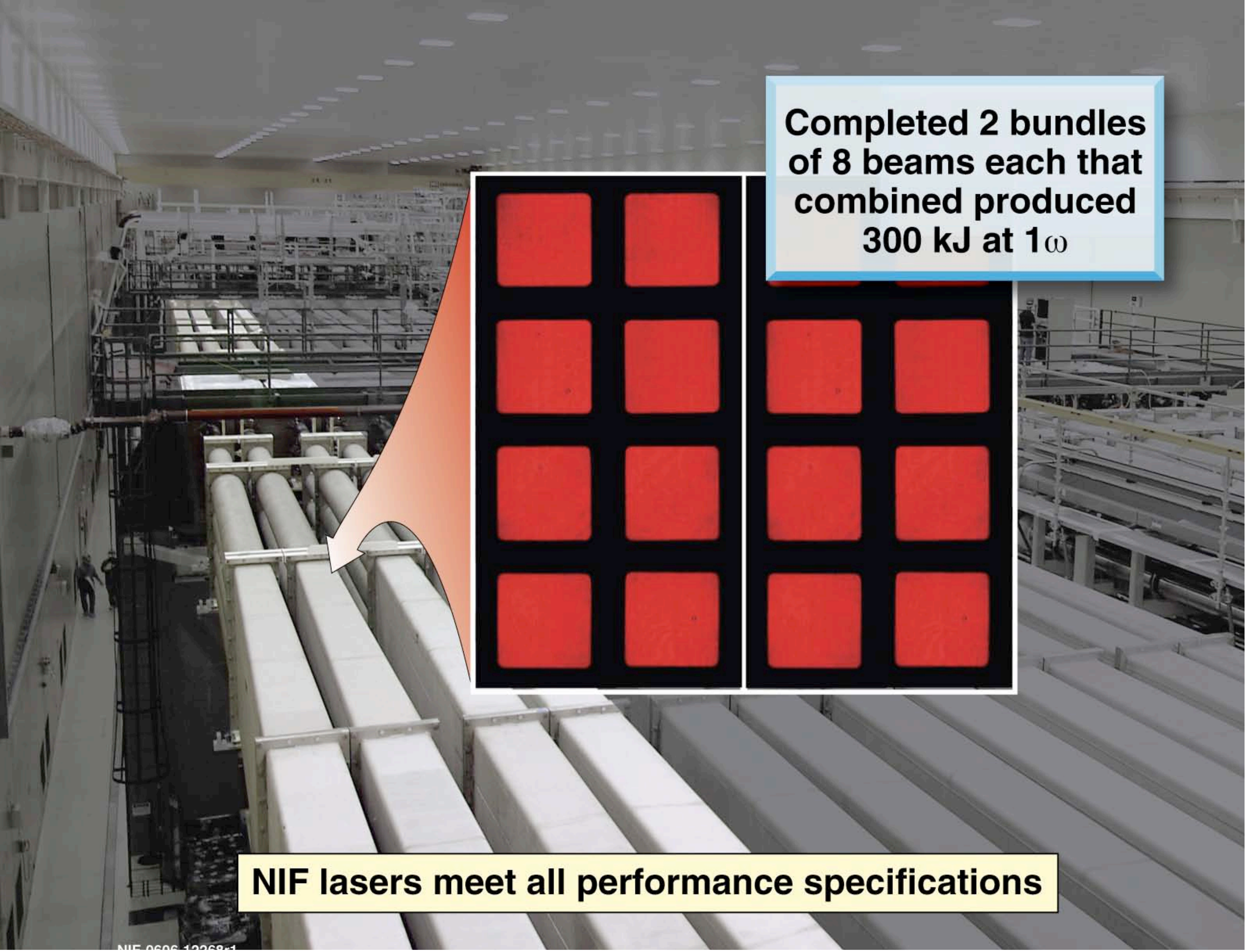


>2,300 LRUs installed to date

LRU Installation status – June 2006



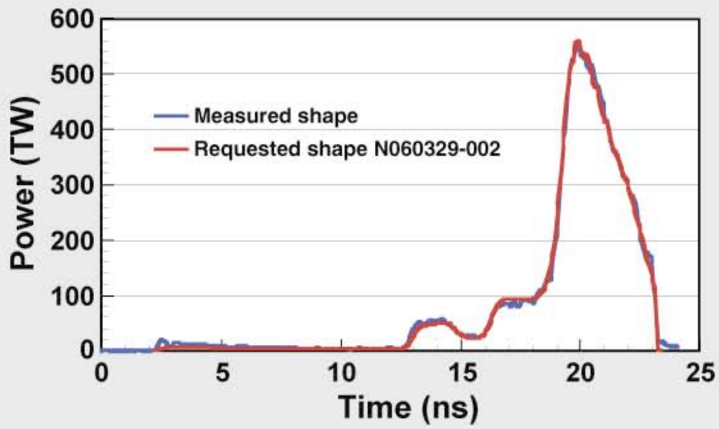
LRU installations are now >36% complete


Completed 2 bundles of 8 beams each that combined produced 300 kJ at 1ω
NIF lasers meet all performance specifications
NIF-0606-12268r1

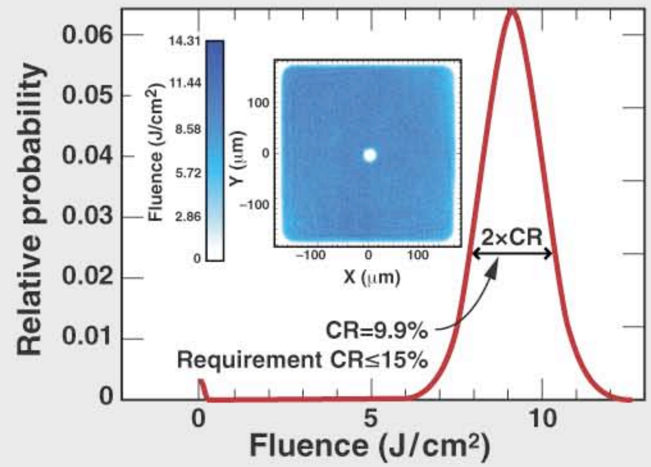
PQ shot energy, power, pulse shape and beam smoothing were achieved simultaneously

Single Bundle Performance Qualification Achieved (will be formally claimed when published)

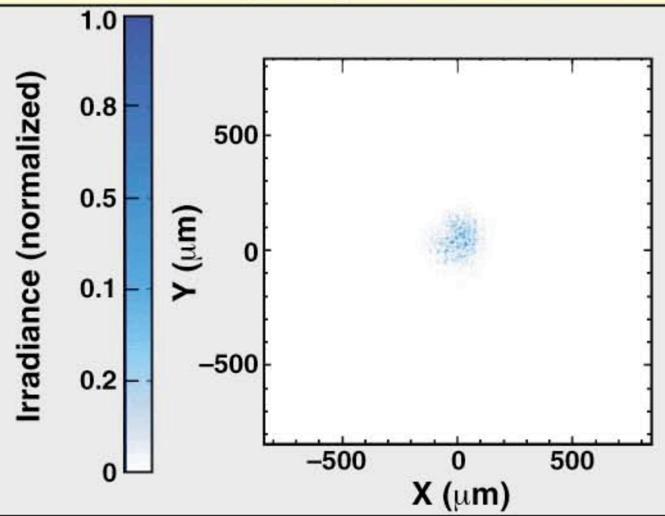
3ω Pulse Shape (355 TW)



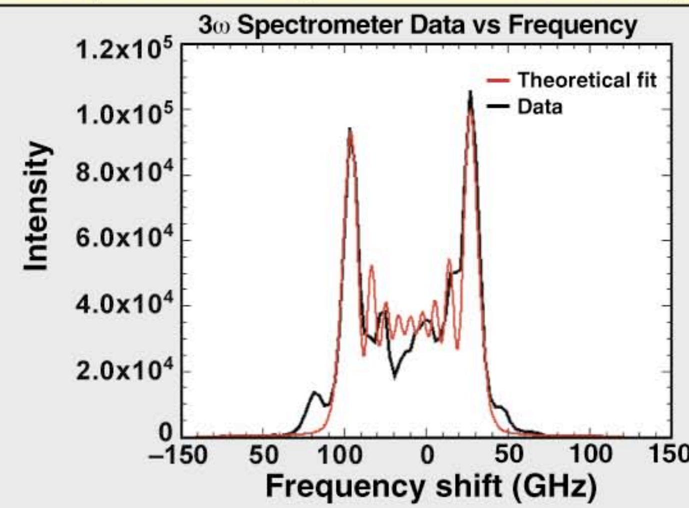
3ω Near Field Profile

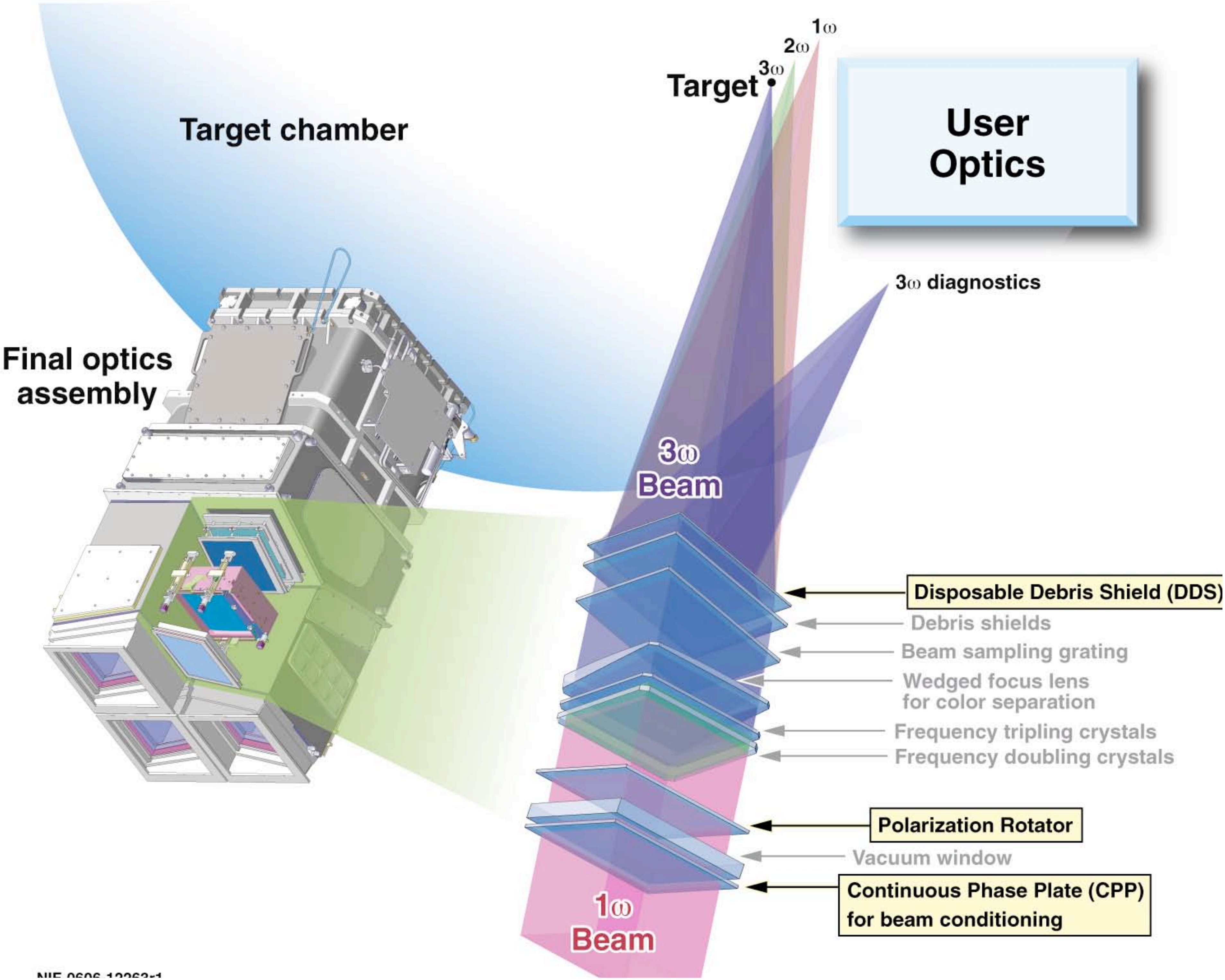


3ω Focal Spot (0.145 mm FWHM)



3ω Spectrum (90 GHz SBS only)





Target chamber
Final optics
assembly
Target
3ω
2ω
1ω
User
Optics
3ω diagnostics
3ω
Beam
Disposable Debris Shield (DDS)
Debris shields
Beam sampling grating
Wedged focus lens
for color separation
Frequency tripling crystals
Frequency doubling crystals
Polarization Rotator
Vacuum window
Continuous Phase Plate (CPP)
for beam conditioning
1ω
Beam

User optics condition and size the beams as required by the point design

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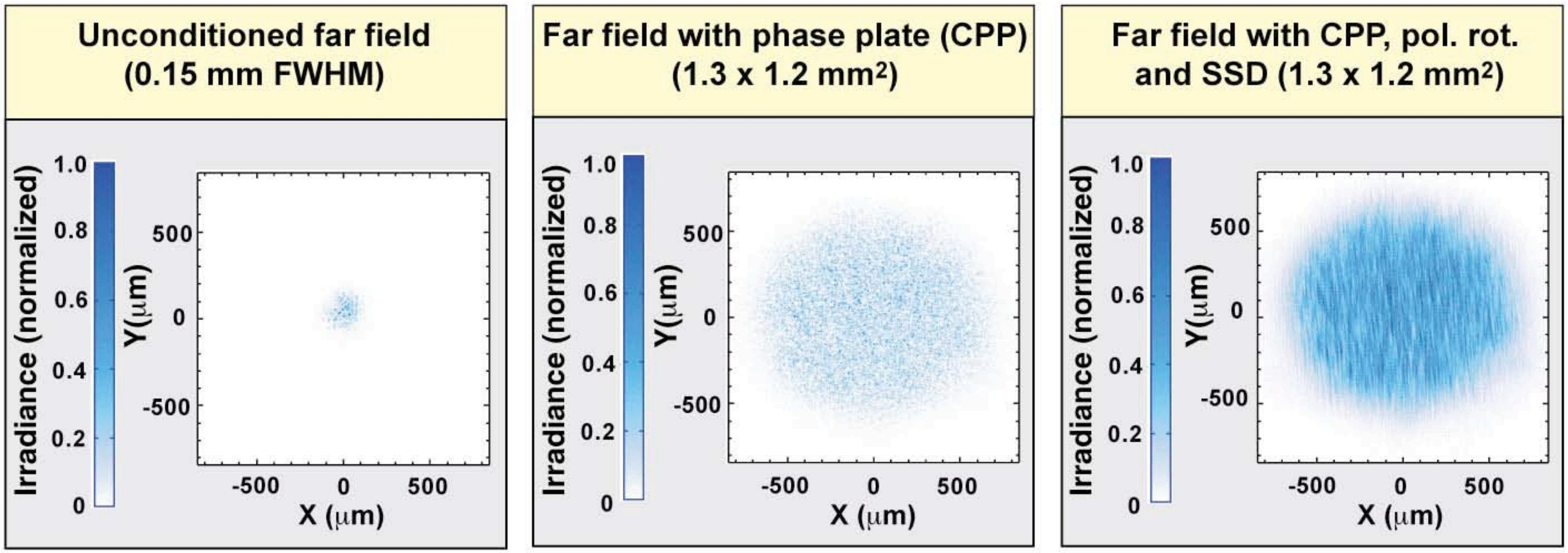

- All users optics have been demonstrated
- All meet ignition point design requirements

Multiple diagnostic and cryogenics systems will be commissioned for the FY10 ignition campaign

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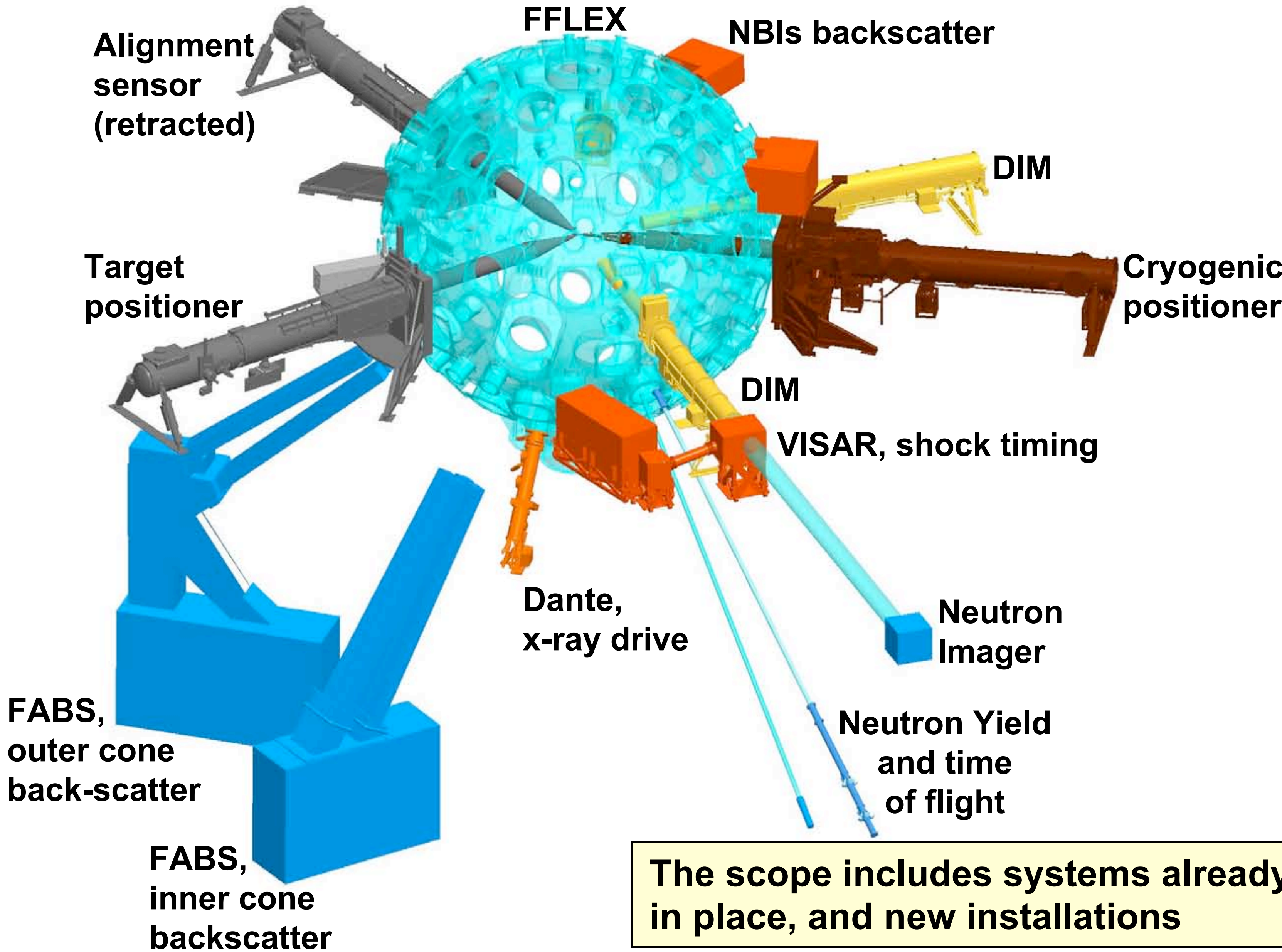
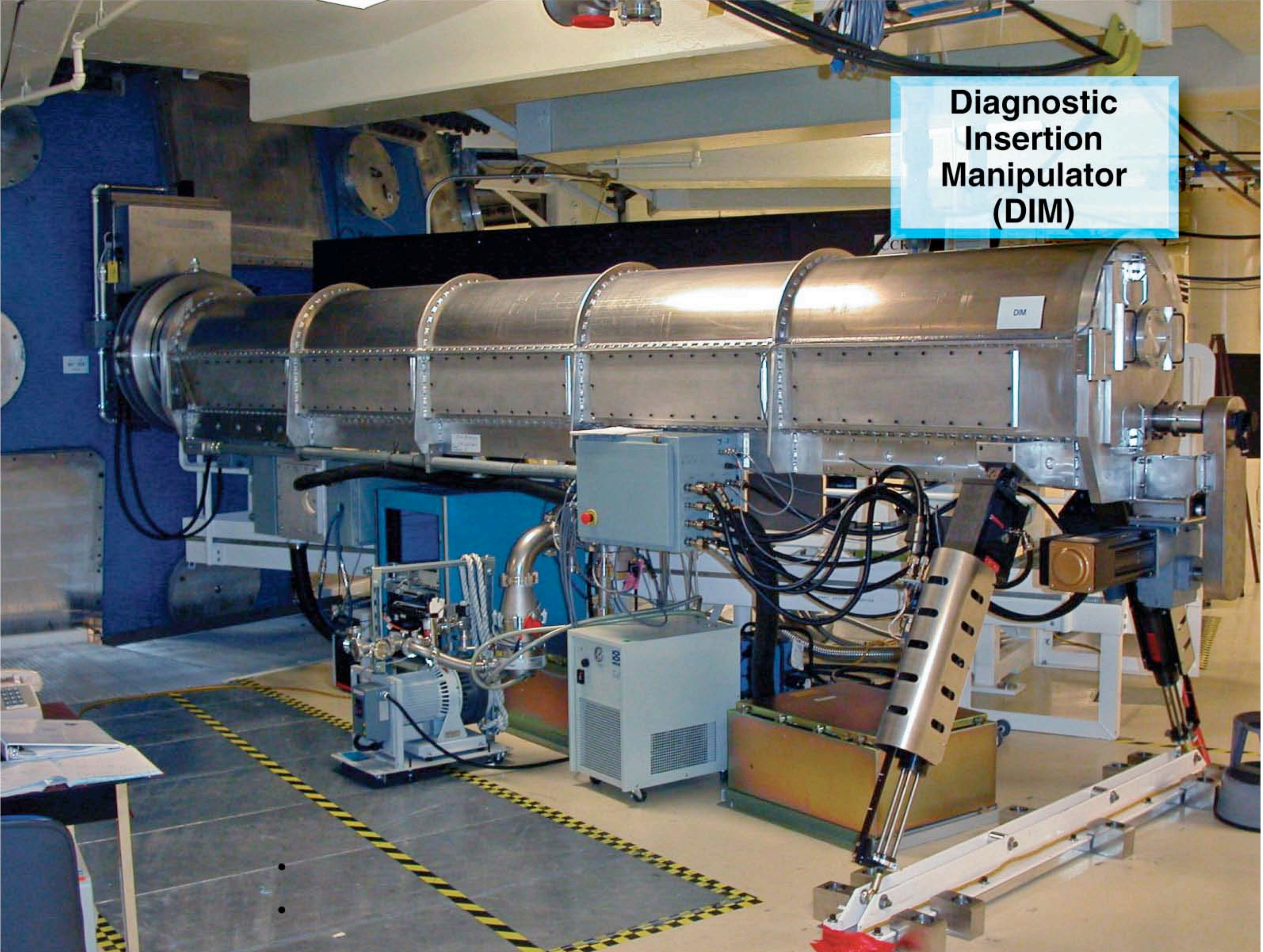


The scope includes systems already in place, and new installations



NIF-0706-12370

Energetics diagnostics installed and working include Dante and FFLEX detector arrays

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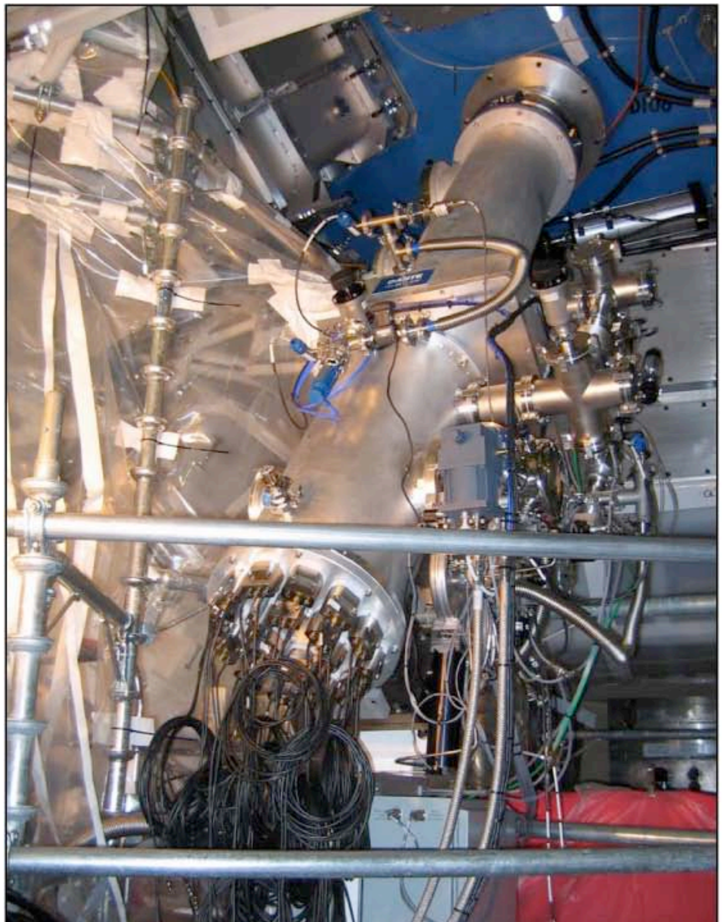
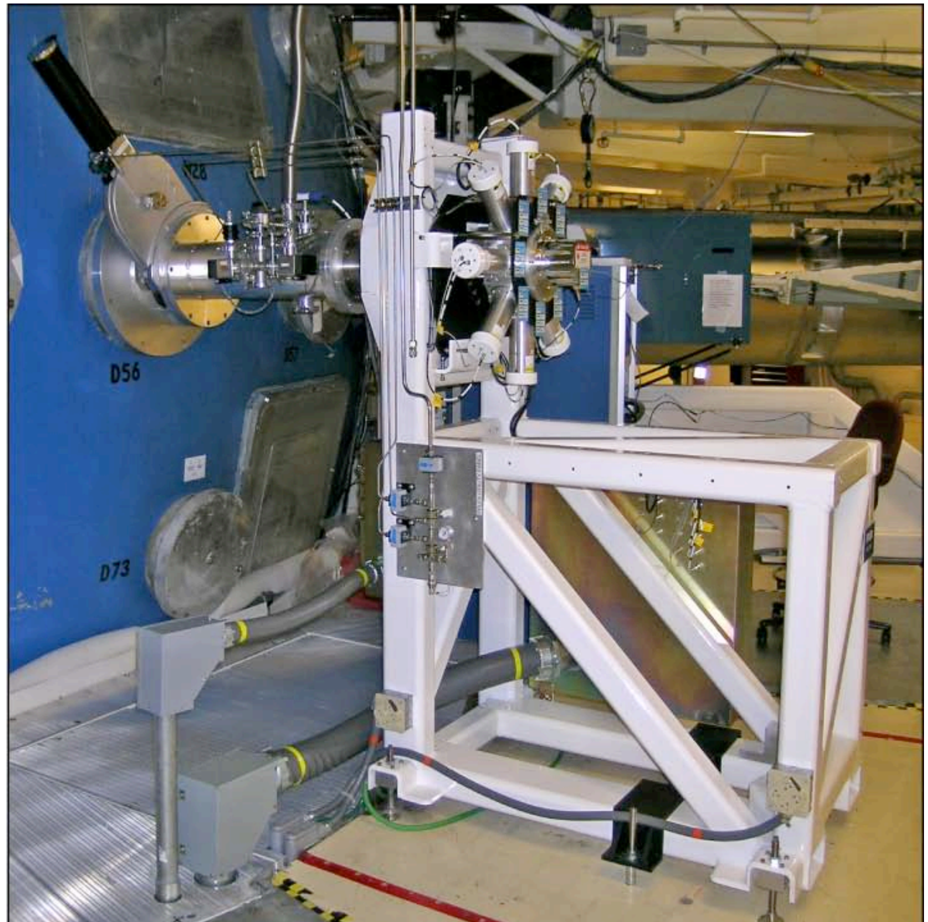
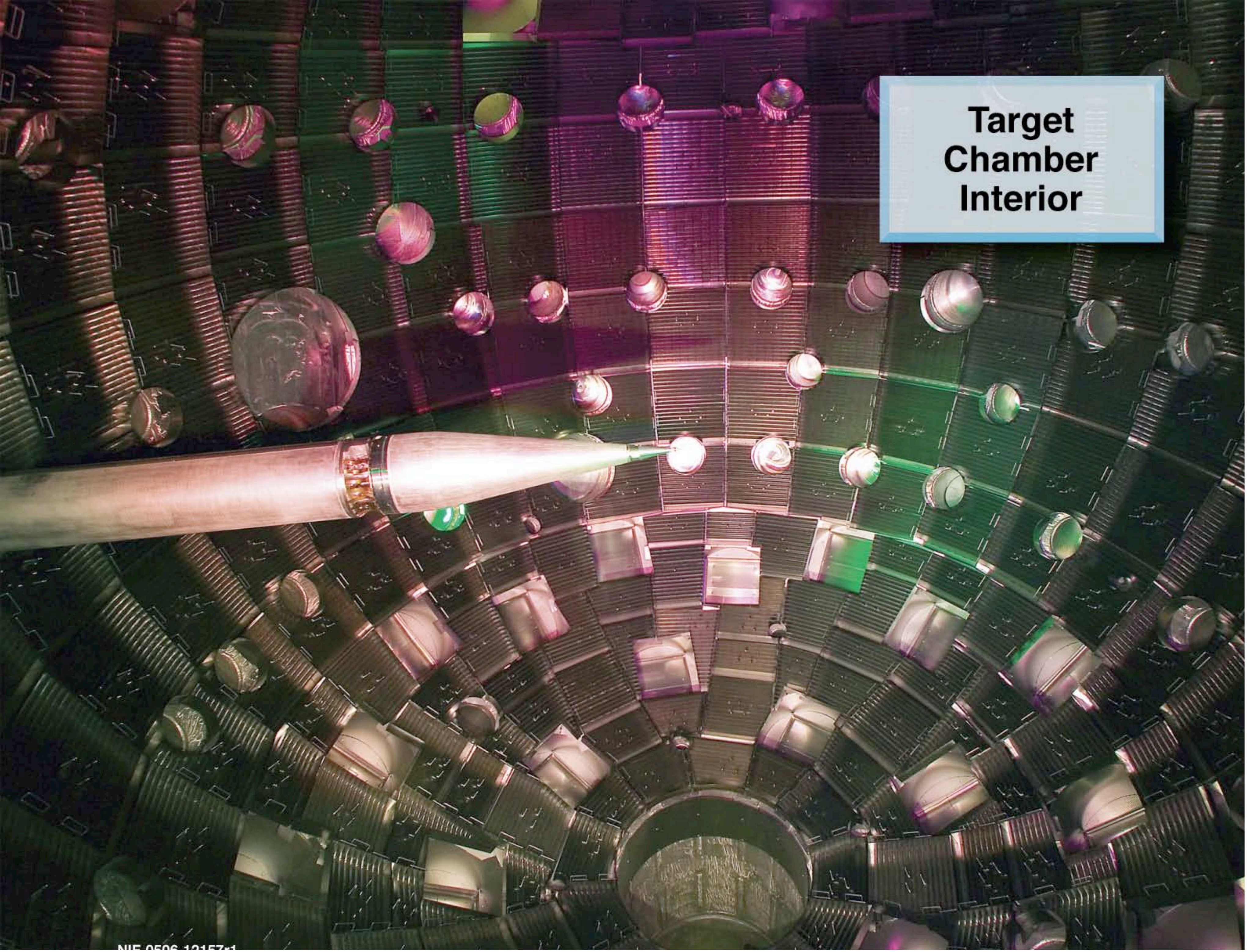
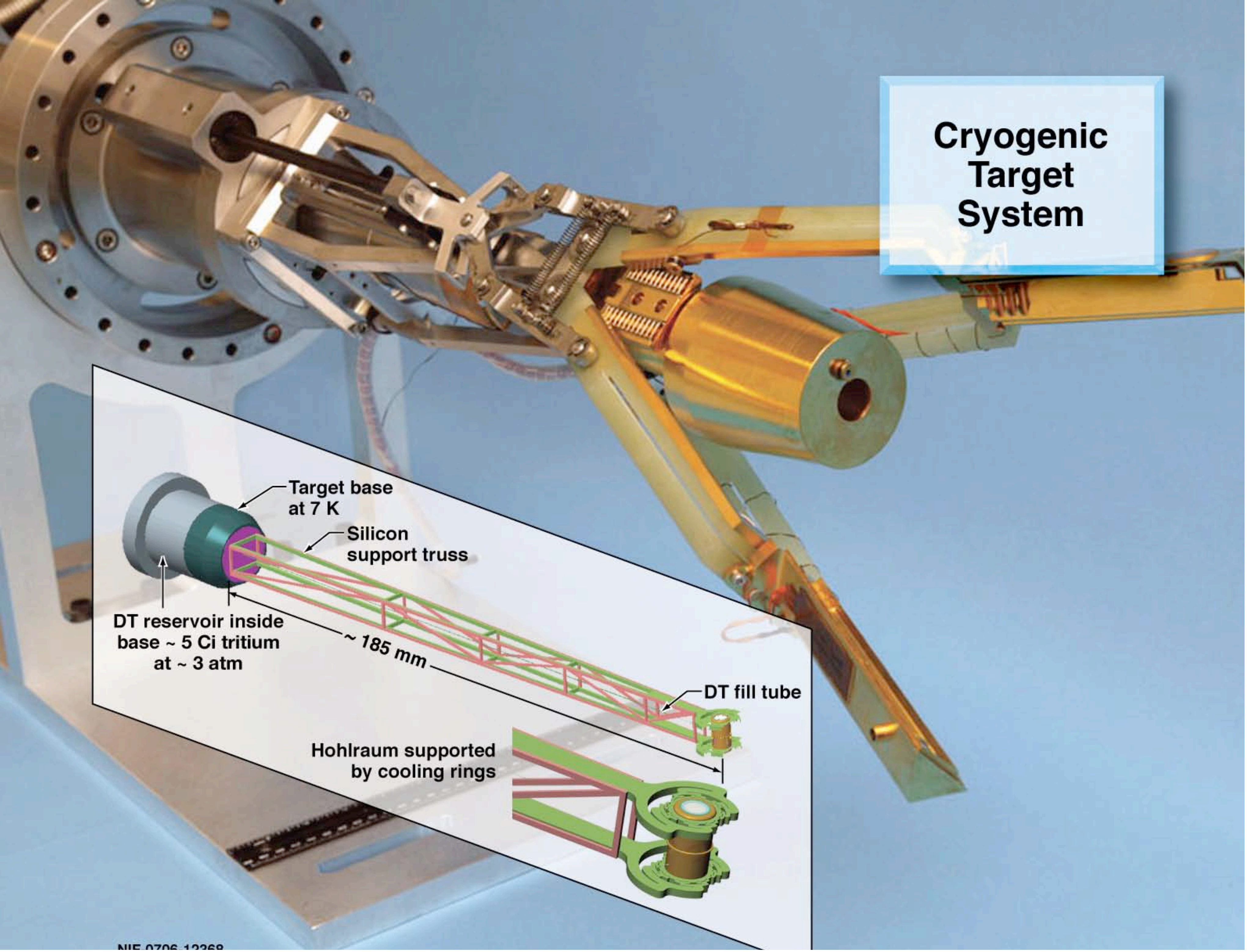


Dante diode array – time resolved radiation drive

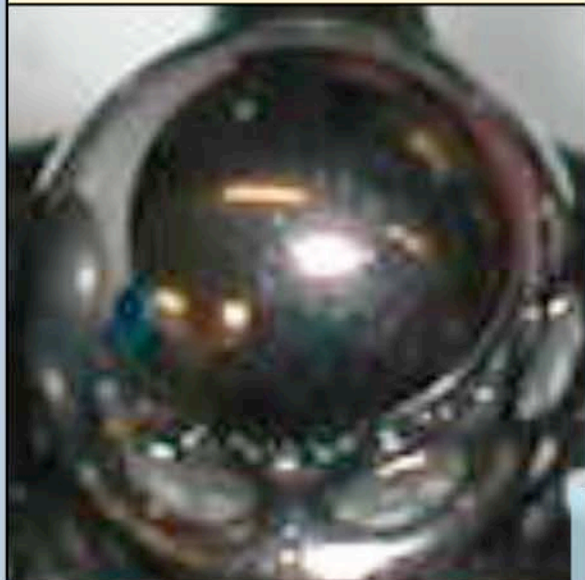


FFLEX fluorescer array – hard x-ray spectrum

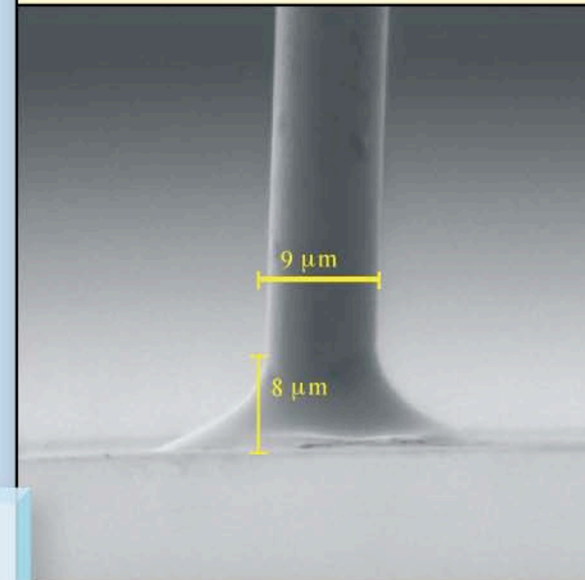

Target
Chamber
Interior


Cryogenic Target System
Target base at 7 K
Silicon support truss
DT reservoir inside base ~ 5 Ci tritium at ~ 3 atm
~ 185 mm
DT fill tube
Hohlraum supported by cooling rings
NIF-0706-12368

Polished Be Capsule

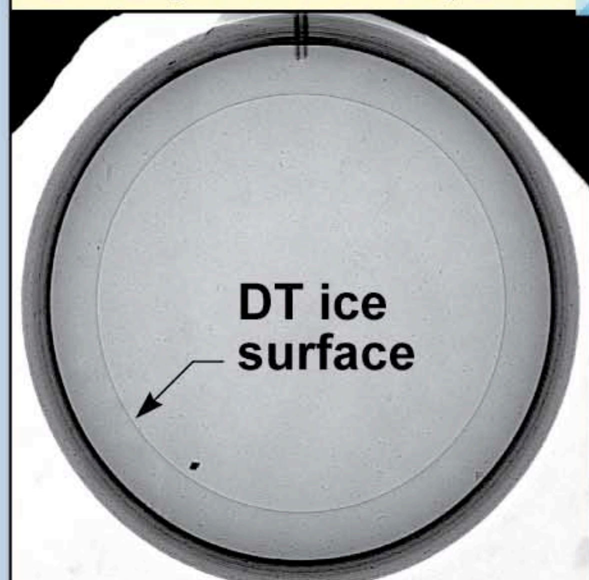


Fill Tube

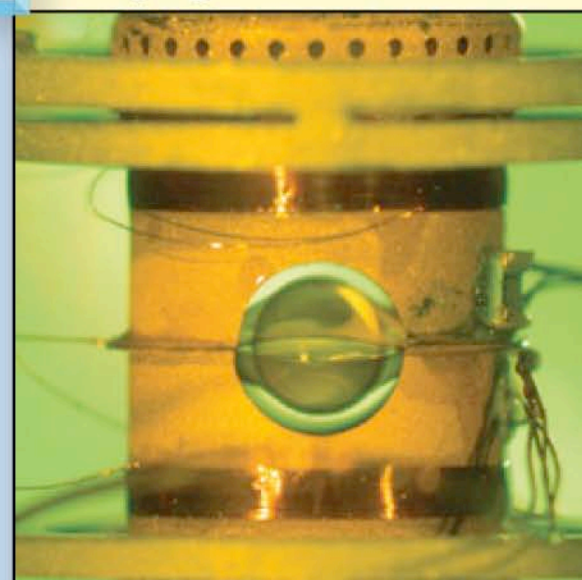


Target Fabrication

DT Layer in Be Capsule



Cryogenic Hohlraum



NIF-0706-12389

DT ice layers in a carbon shell at 1.5 K below the melt meet the NIF roughness spec

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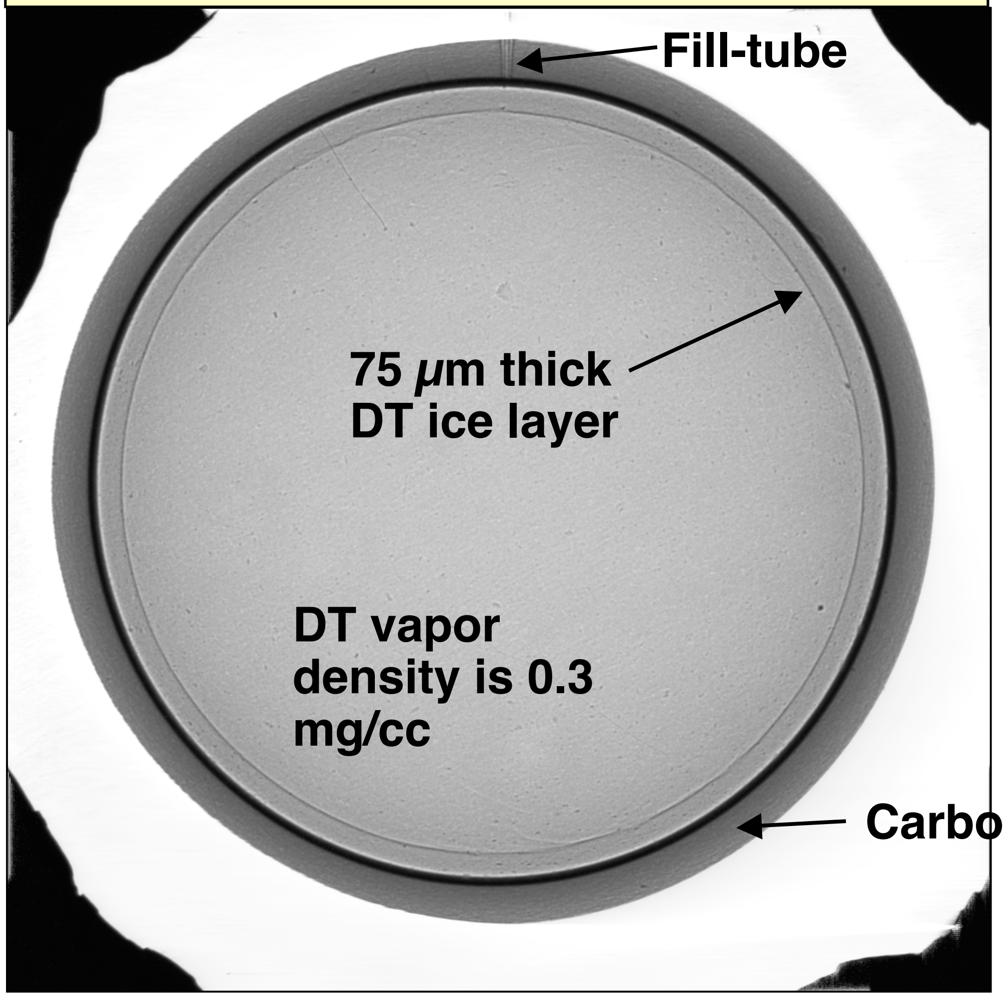
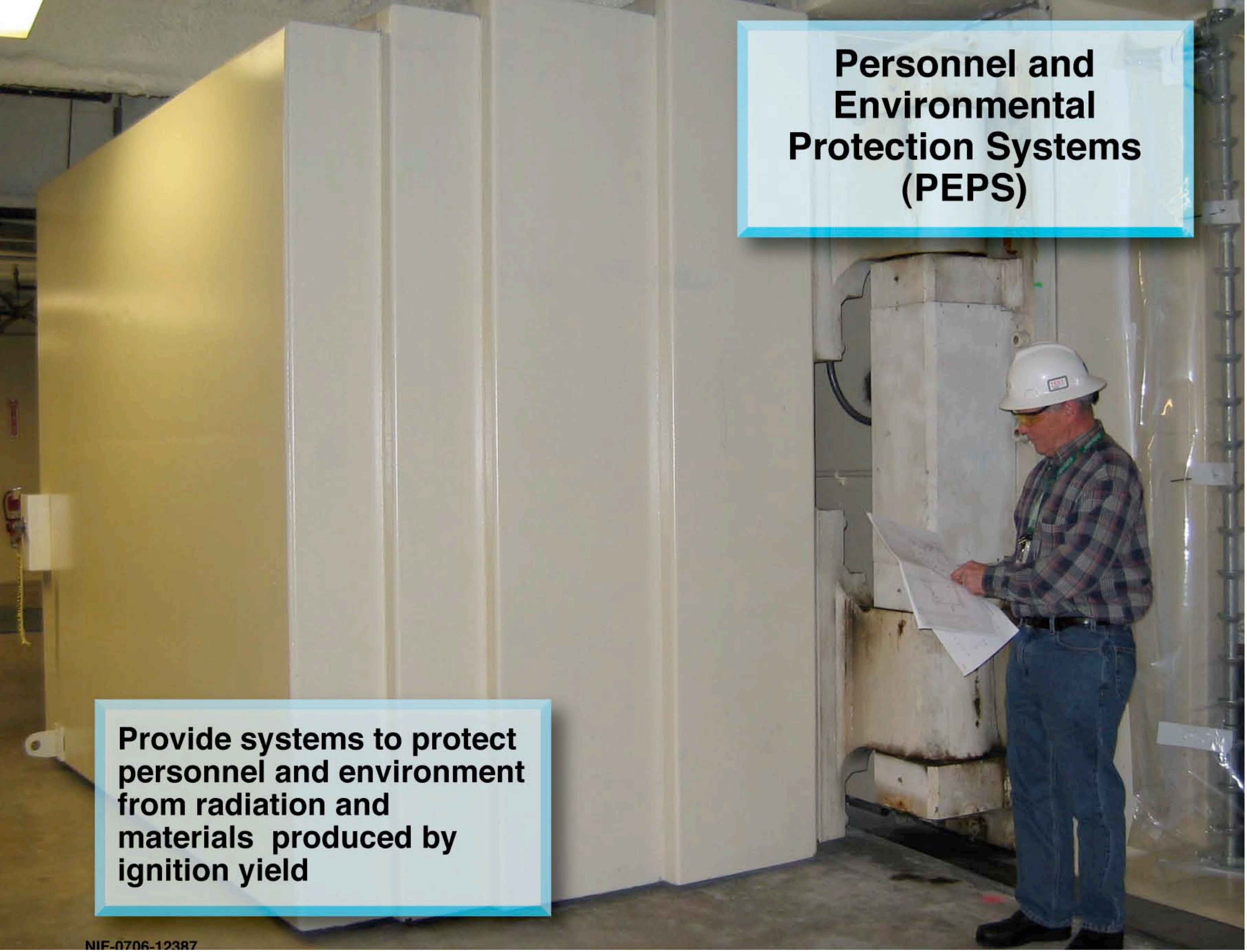
X-ray phase contrast image



- NIF roughness spec for modes 7 and above is an RMS of 0.93 μm
- DT ice layers have been grown with an RMS of ≤ 0.9 μm for modes 7 and above


Personnel and Environmental Protection Systems (PEPS)
Provide systems to protect personnel and environment from radiation and materials produced by ignition yield
NIF-0706-12387

The NIC has brought together NNSA's ICF programs

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- NIC is an enhanced managed program and is operated within a project framework and with project-like rigor
- Formation of the NIC "enterprise" has many benefits
  - Integrated budget and earned value management system
  - Integrated schedule and milestones
  - Integrated risk management across all activities at all sites
  - Integrated work breakdown structure
  - Improved and increased communications
    - Daily interactions, weekly VTCs, monthly and quarterly reviews

We have a unified and focused goal of ignition on NIF

This is a national effort with important contributions from all participants

NIC
The National Ignition Campaign

Inst.	Scope
GA	Ignition capsule development, facilitization and production, hohlraum development and assembly
LANL	Ignition target design, LPI, Be ablator physics, neutron imaging, machined Be
LLE	Target exps. at OMEGA , target diagnostics cryogenic system design support, 4th shock timing campaign lead
LLNL	National Ignition Campaign Director, NIF operation and capability and infrastructure, target cryogenic system, target diagnostics, user optics, PEPS, ICF design and experimental program
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

• Over the past year we have stood up the National Ignition Campaign
• We now have a unified and focused effort for ignition on NIF including a credible ignition experiment in 2010
NIF-0706-12365

NATIONAL
IGNITION
FACILITY