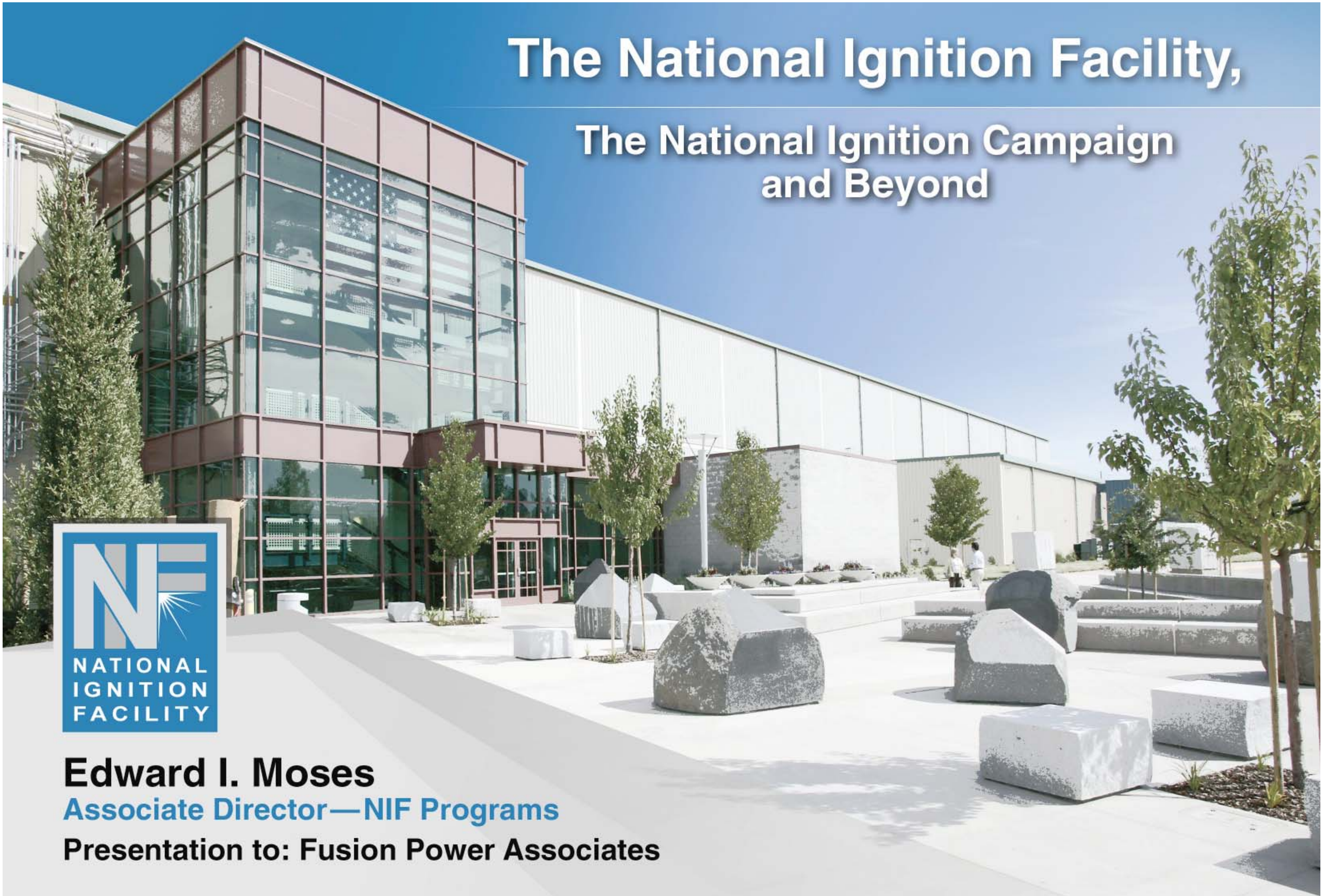
The National Ignition Facility,

The National Ignition Campaign and Beyond



NATIONAL IGNITION FACILITY

Edward I. Moses

Associate Director—NIF Programs

Presentation to: Fusion Power Associates

Lawrence Livermore National Laboratory

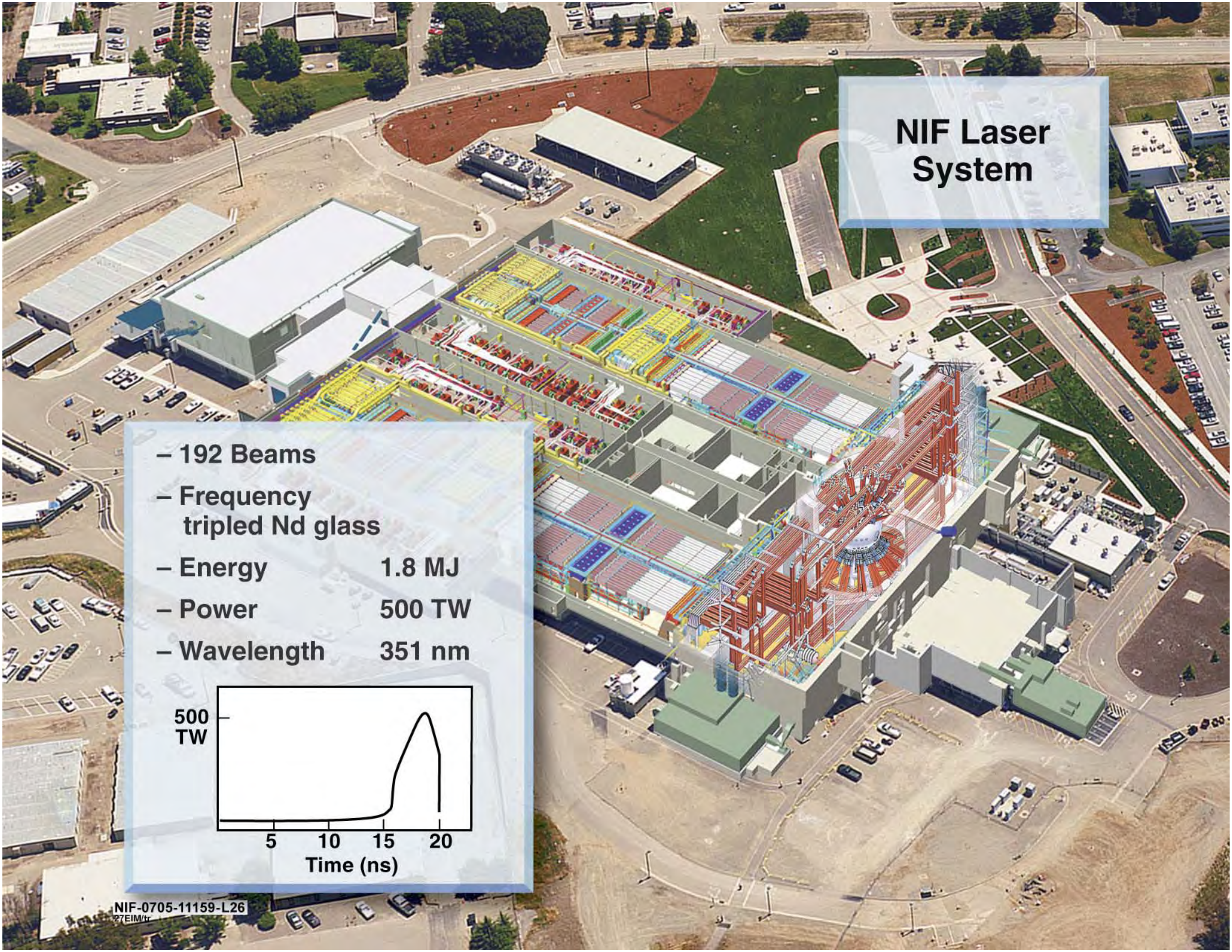
September 27, 2006

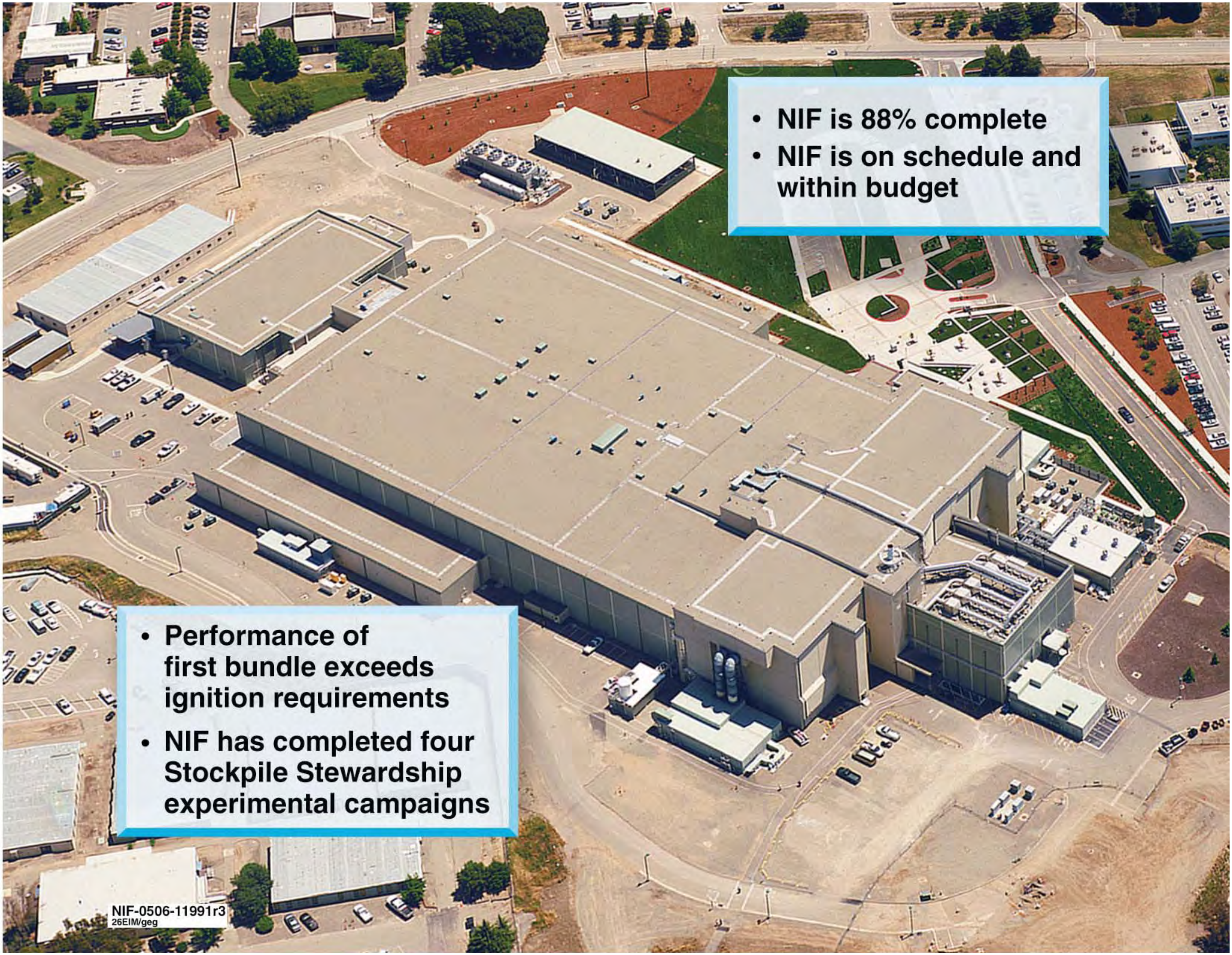
Work performed under the auspices of the U.S. Department of Energy, National Nuclear Security Administration by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

UCRL-PRES-225531

National
Ignition
Facility
NIF-0705-11159-L20
27EIM/tr


NIF is
705,000
square feet
49ers
REDSKINS
RAIDERS
SAN FRANCISCO
WASHINGTON
OAKLAND
NIF-0706-12555 L4
17EIM/doc

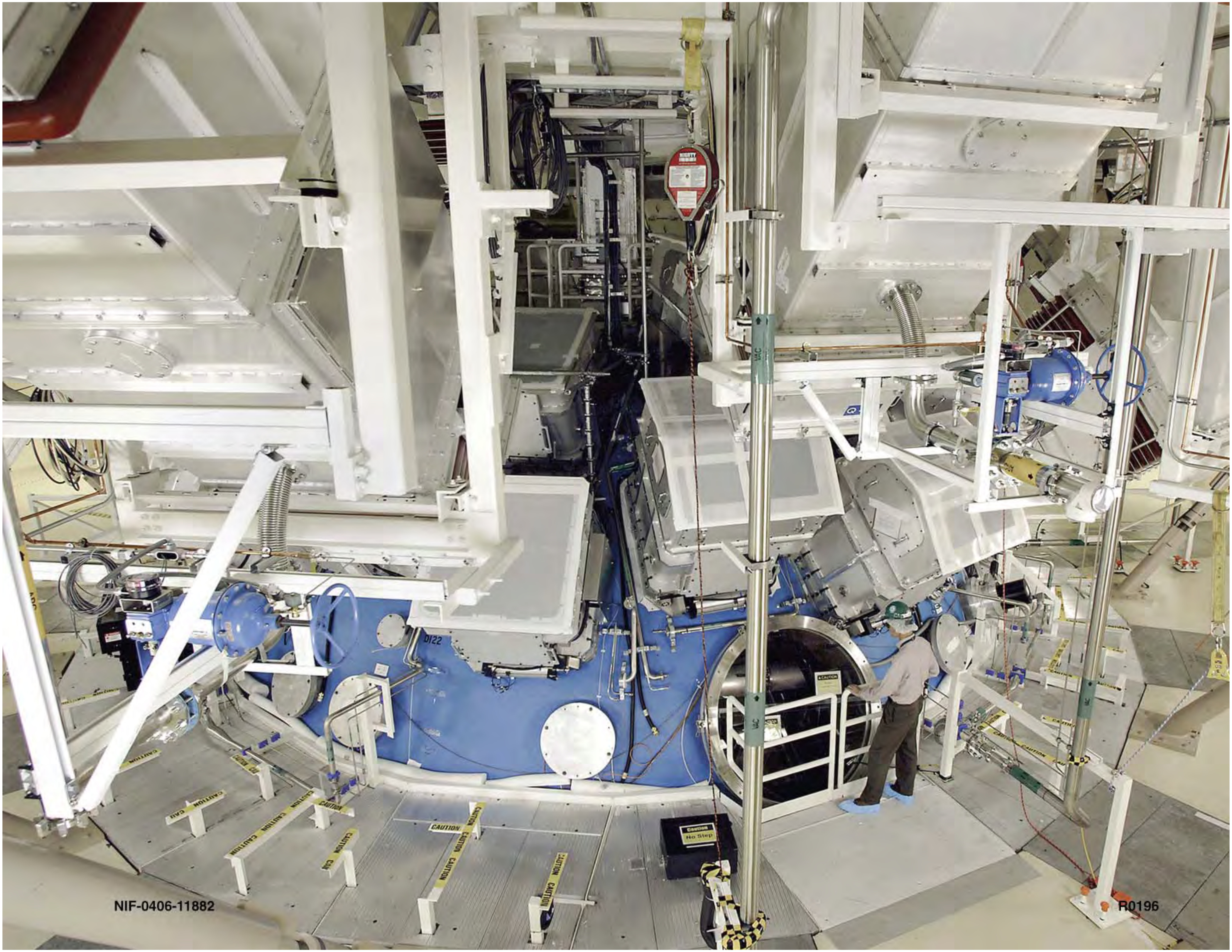

NIF Laser System
– 192 Beams
– Frequency tripled Nd glass
– Energy 1.8 MJ
– Power 500 TW
– Wavelength 351 nm
500 TW
5
10
15
20
Time (ns)
NIF-0705-11159-L26
27EIM/tr

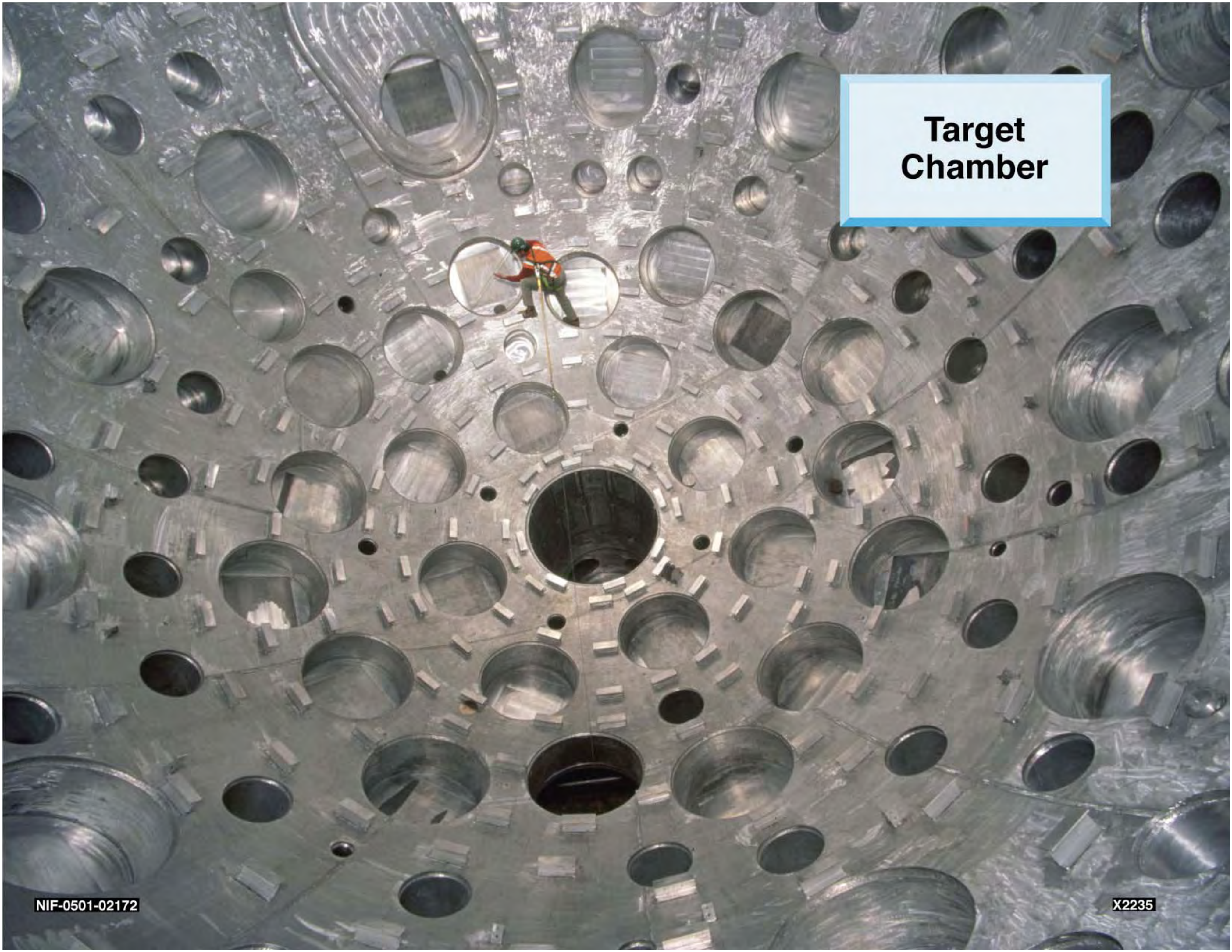

• NIF is 88% complete
• NIF is on schedule and within budget
• Performance of first bundle exceeds ignition requirements
• NIF has completed four Stockpile Stewardship experimental campaigns
NIF-0506-11991r3
26EIM/geg

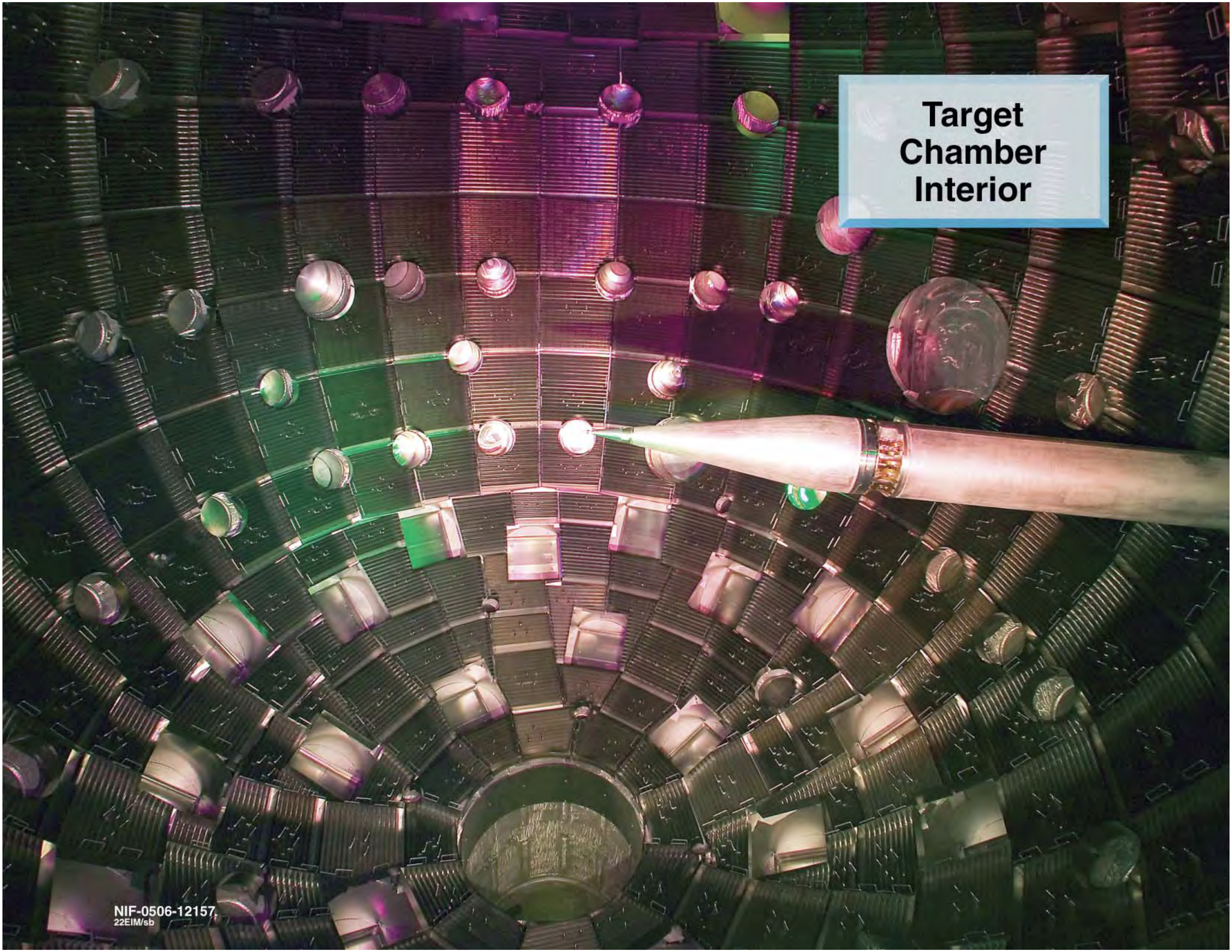

NIF-0506-11956


Switchyard 2
NIF-0105-10119r1
21EIM/paa

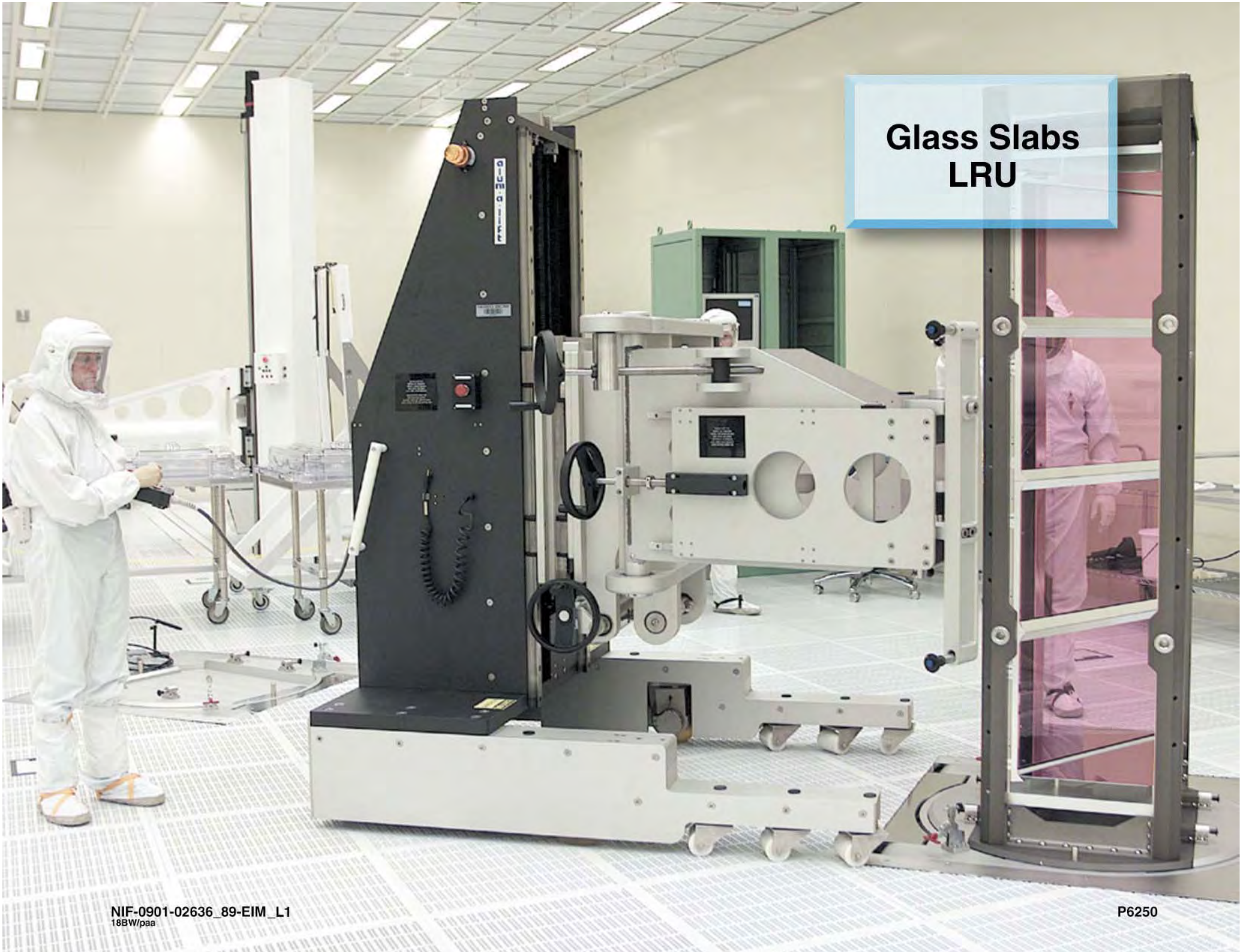

Target
Chamber
NIF-0105-10124
31EIM/dj
P8136


D122
Caution
No Step
NIF-0406-11882
R0196


Target
Chamber
NIF-0501-02172
X2235


Target
Chamber
Interior
NIF-0506-12157
22EIM/sb


NIF/LMJ
Laser Glass
• 10,400 slabs melted
• 430 tonnes of ultra-high purity glass
Partners: Hoya, Schott
NIF-0101-00025L1DP#53.ai
16EM/cbf



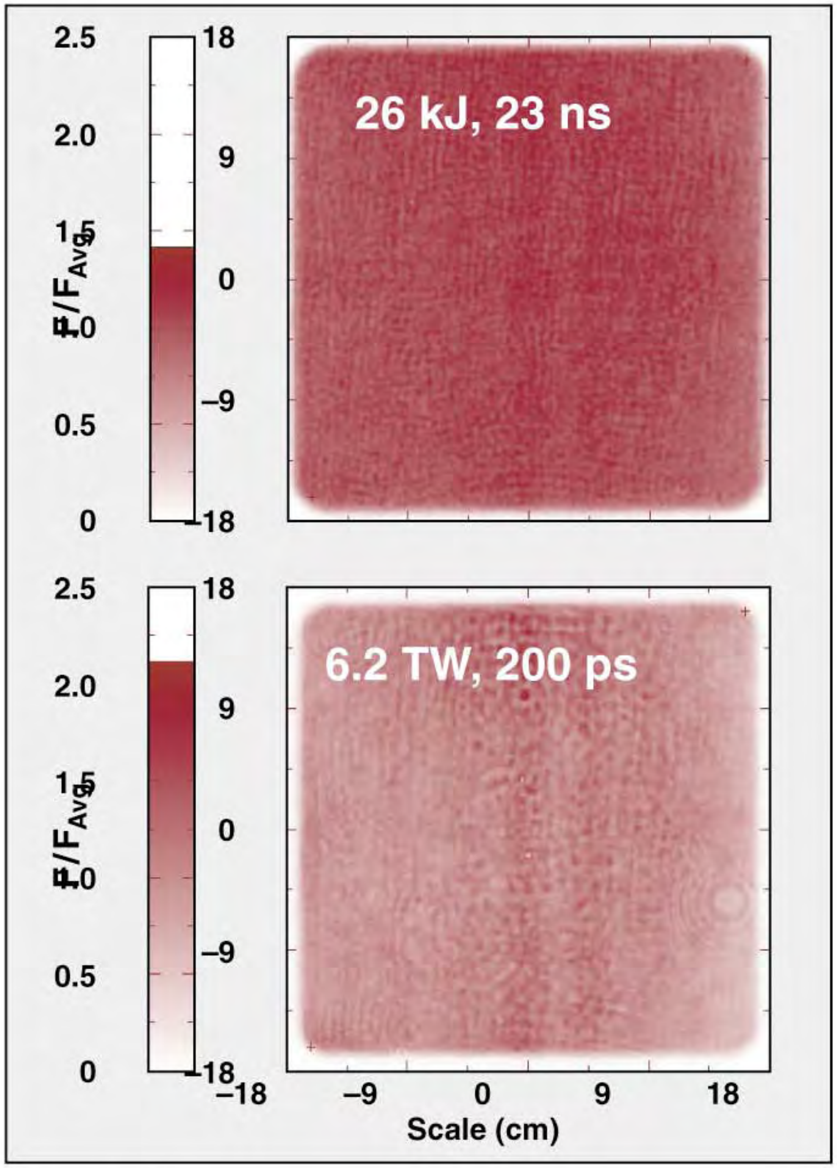
NIF-0901-02636_89-EIM_L1
18BW/paa

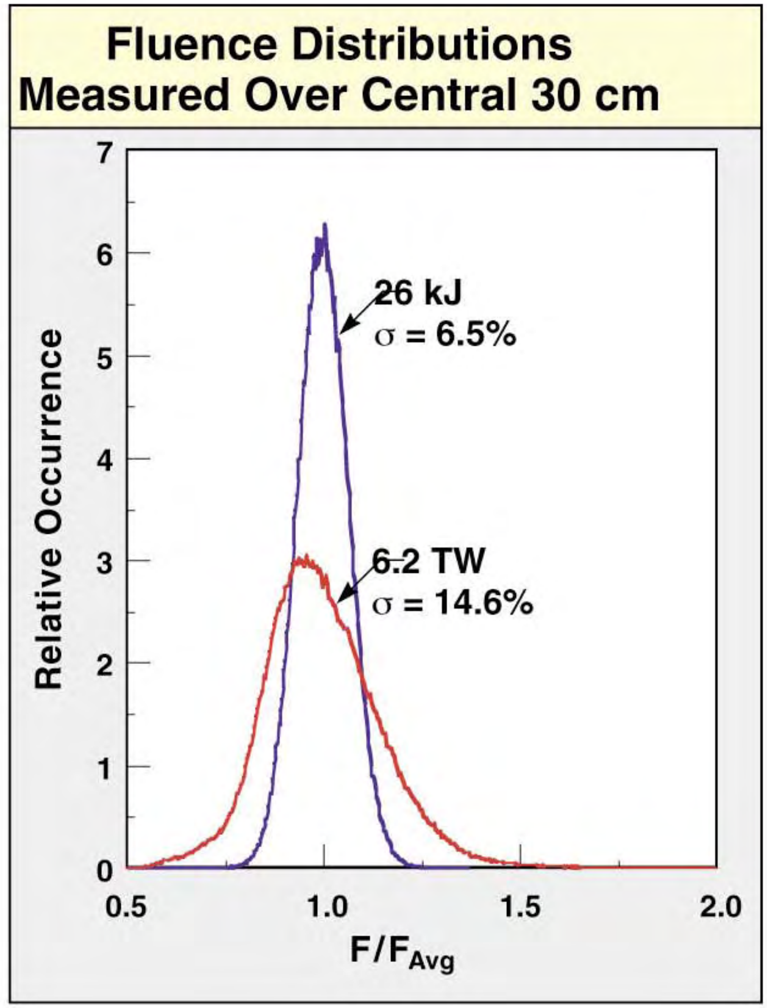
P6250

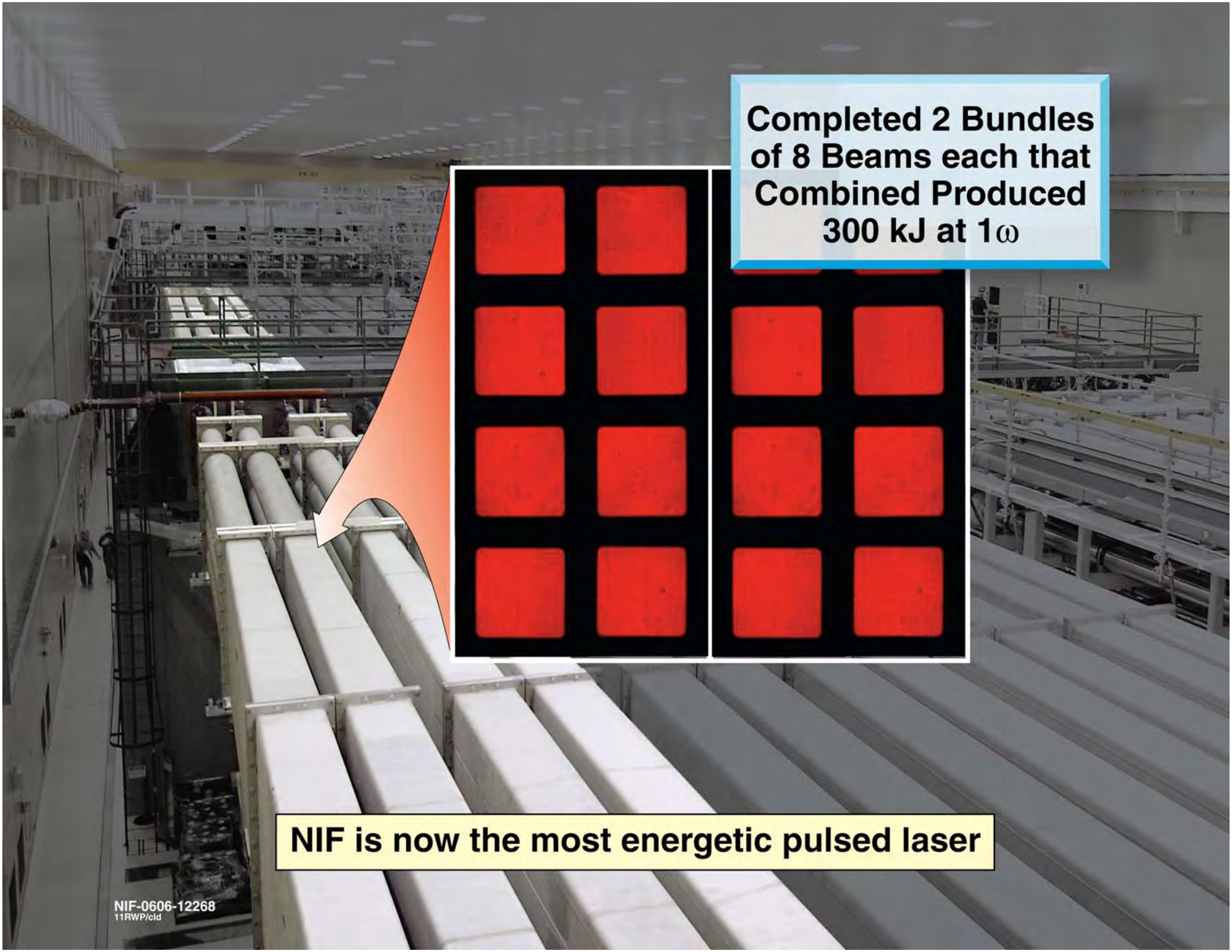
- 16 glass slabs with 54 equivalent passes
- Output energy/beam ~25 kJ
- Aperture size ~35 cm

Design goals for 1ω energy and power exceeded with high overall beam quality

The National Ignition Facility






Completed 2 Bundles of 8 Beams each that Combined Produced 300 kJ at 1ω
NIF is now the most energetic pulsed laser
NIF-0606-12268
11RWP/cld


NIF-0104-07906
25PJW/sk
G5429

2ω and 3ω beamline energies are highest ever achieved

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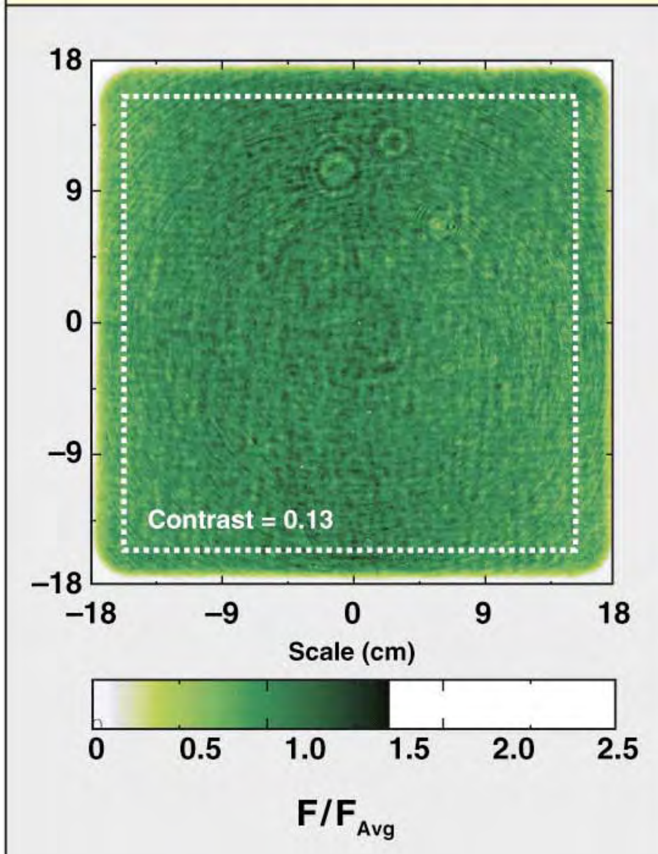
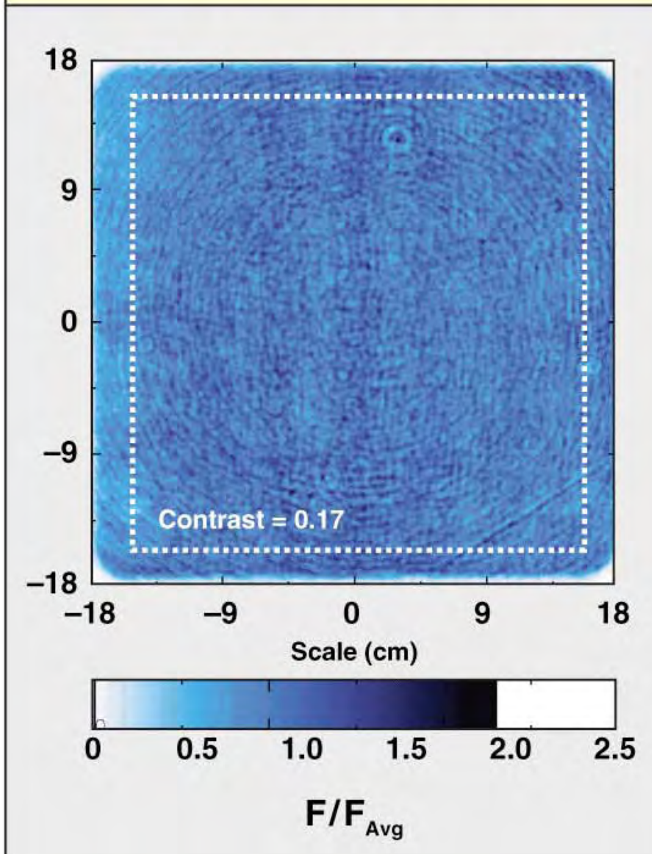
11.4 kJ 2ω, 5 ns



10.4 kJ 3ω, 3.5 ns



NIF functional requirements and primary criteria have been demonstrated on a single beamline at 3ω

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

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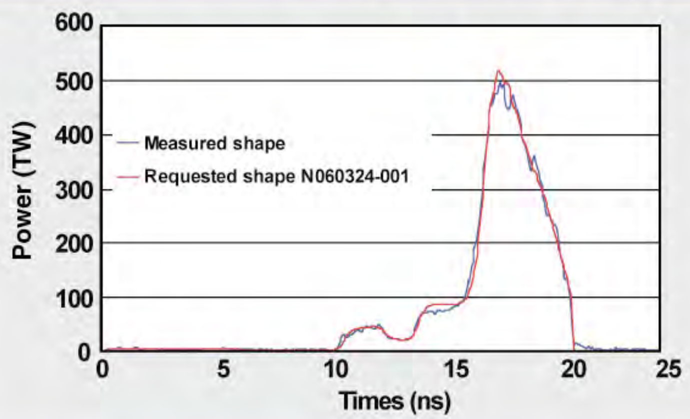
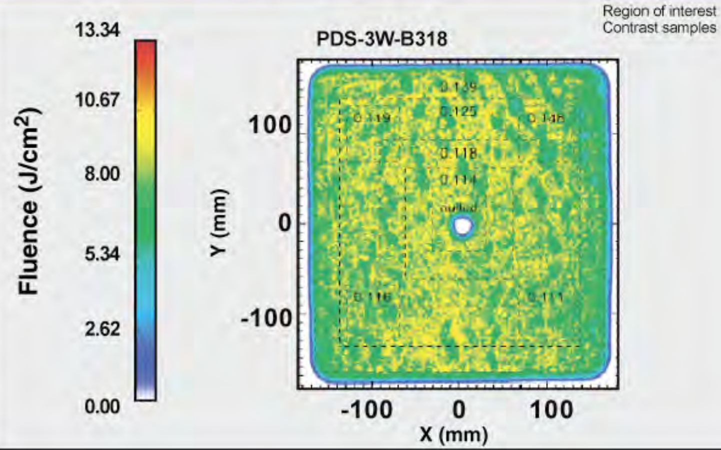
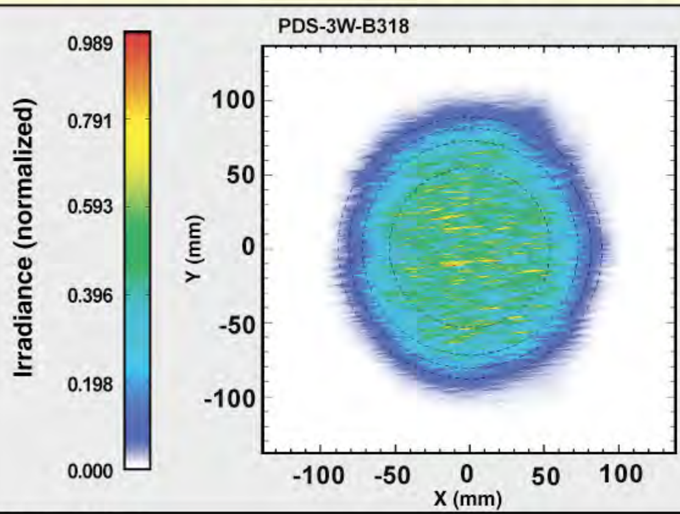
3ω Pulse Shape (500 TW)



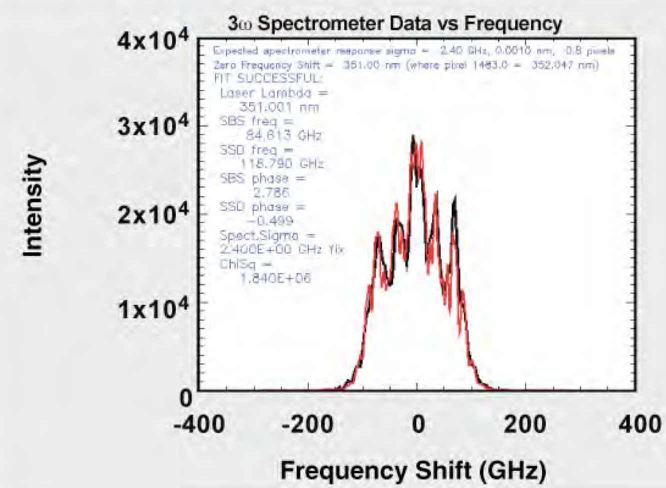
3ω Field Profile (CR = 12.5%)



3ω Focal Spot (1.3 × 1.2 mm²)



3ω SSD Bandwidth (100GHz)



The first LPI experiments on NIF have demonstrated propagation in NIF ignition scale plasmas

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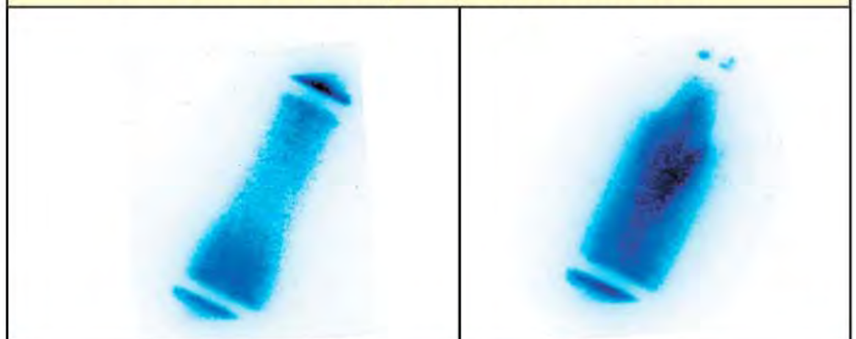
Target

- $2.5x10^{15}$ W/cm^2
- 16 kJ in 3.5 ns
- 3ω

Polarization Smoothing

3 - 5 keV x-ray images at 3 ns



Phaseplate, SSD, and Polarization wedges	Phase-plate only (filaments)

Propagation improvement consistent with modeling and increase in filamentation threshold with improved beam smoothing (i.e. less power/speckle)

S. Glenzer (10186)
E. Dewald (This Session)

1 MJ shaping results: Comparison of requested vs measured 3ω pulse shape (N060302-001-999)

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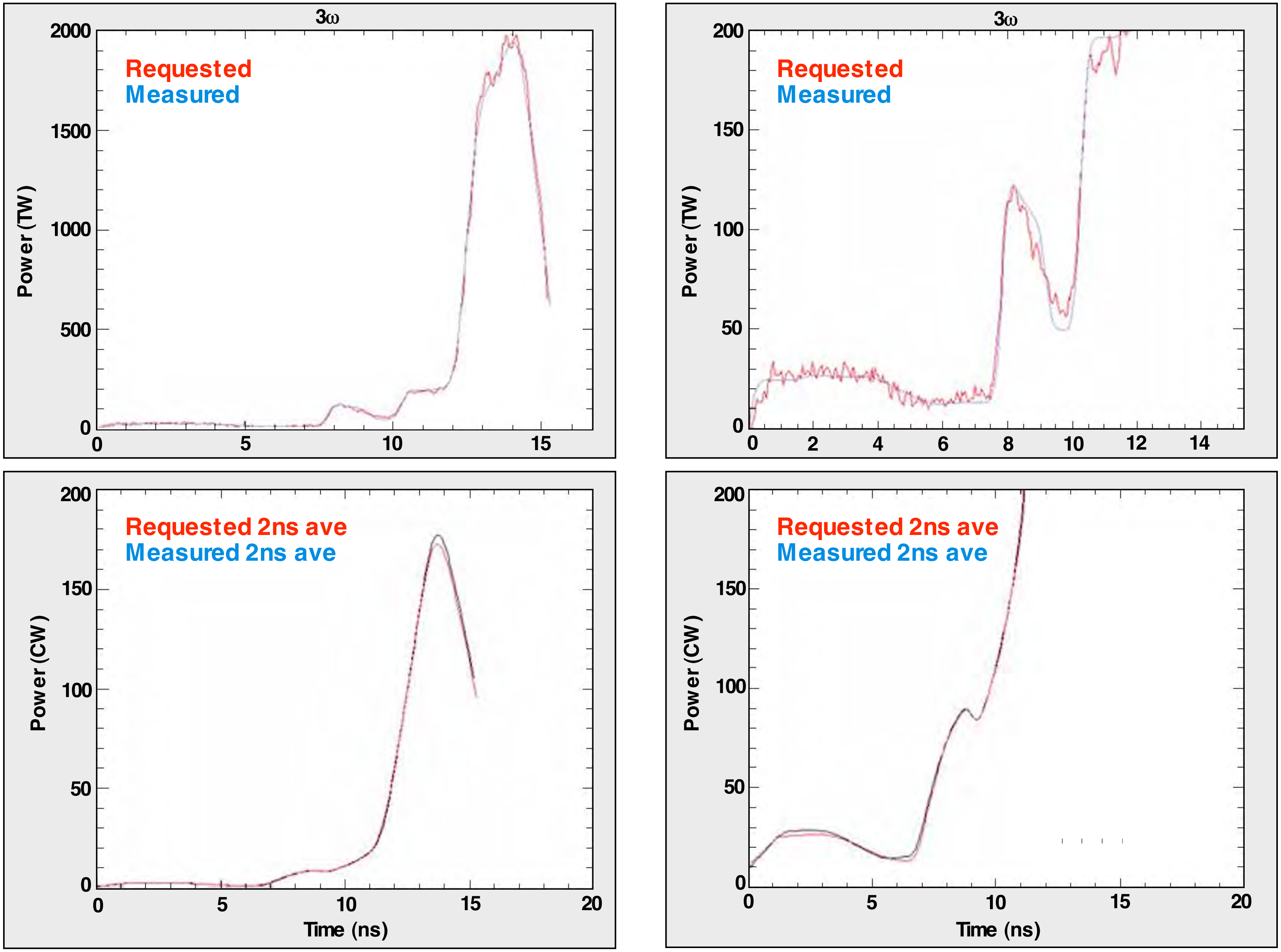

NIC ignition mission requires precise adjustment of features in the laser pulse

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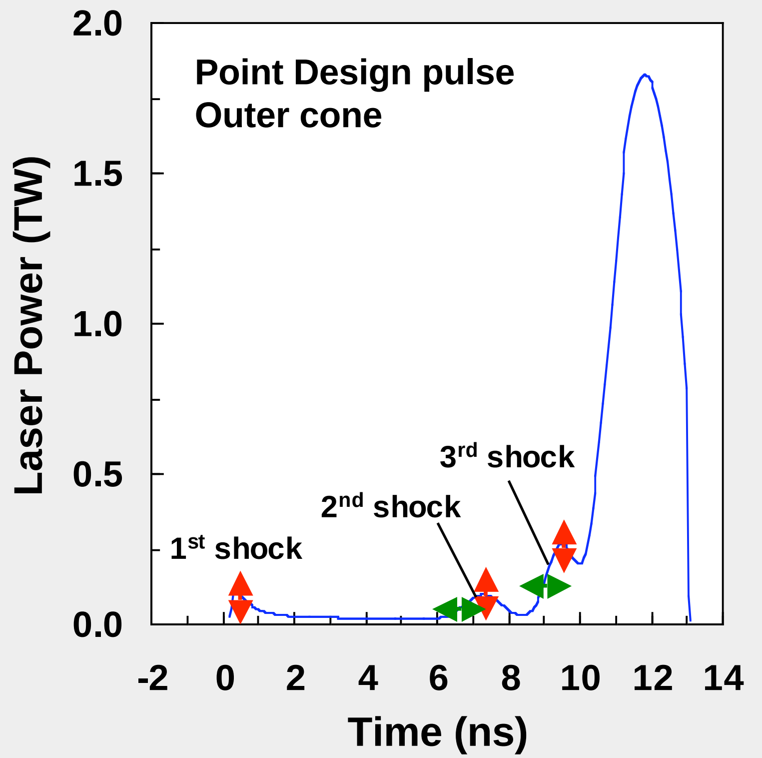
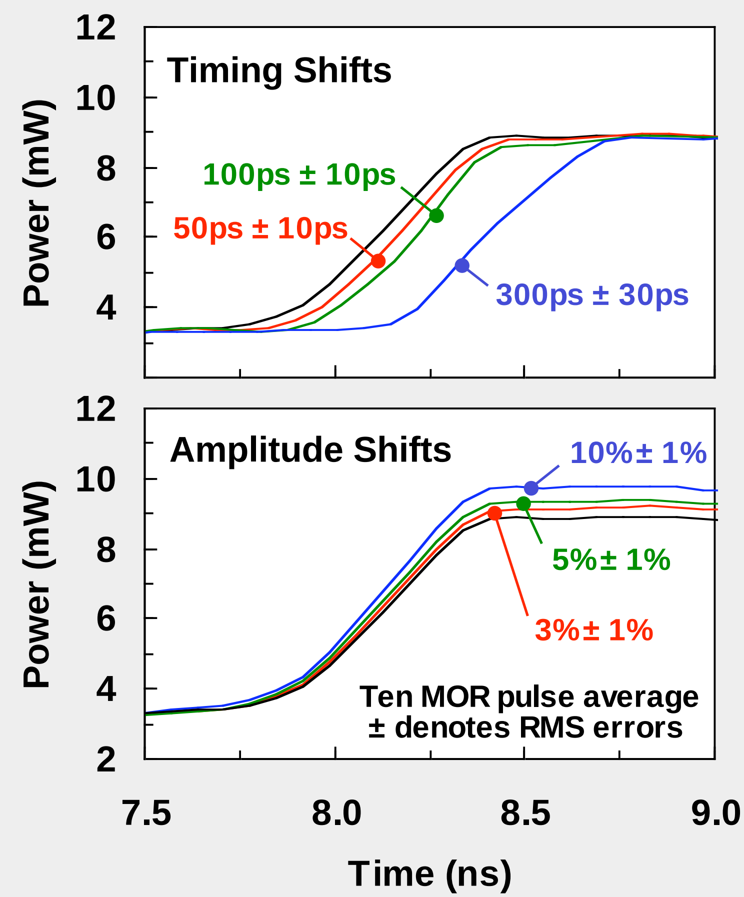
Shock timing and amplitude will be adjusted for implosion efficiency

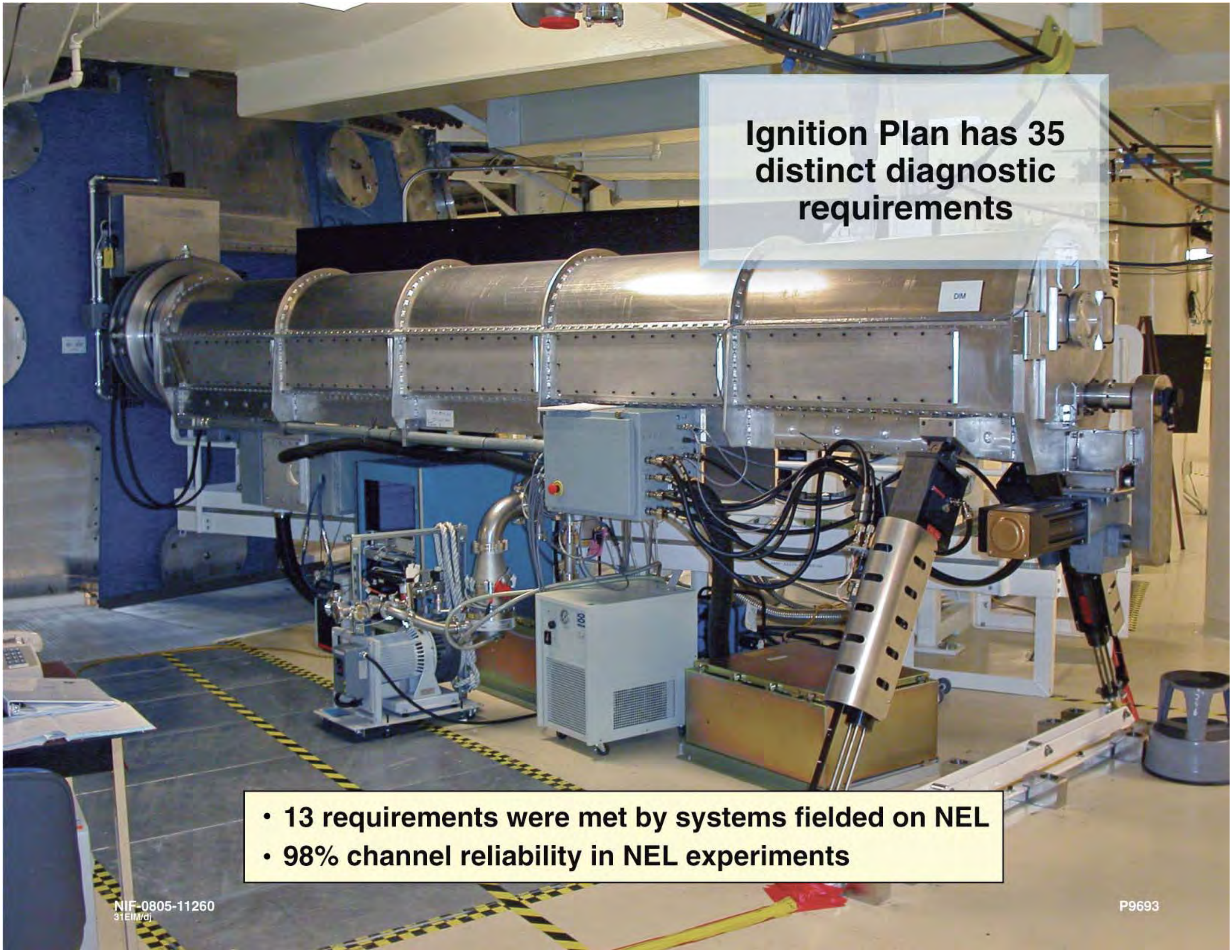


- Minimum timing adjustment: ± 50 ps
- Minimum amplitude adjustment: ± 3%

Measurements demonstrate that required adjustments are achievable



This level of capability is unique to NIF

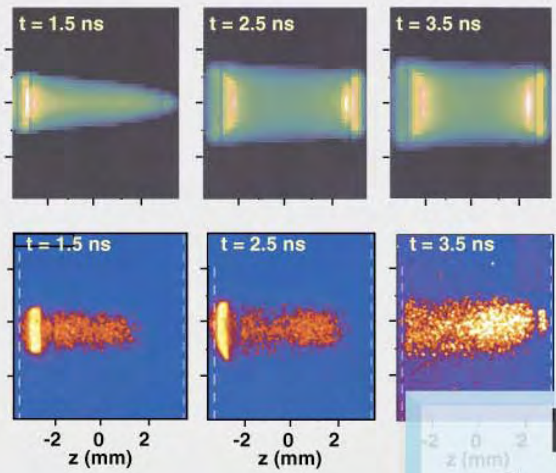


Ignition Plan has 35 distinct diagnostic requirements

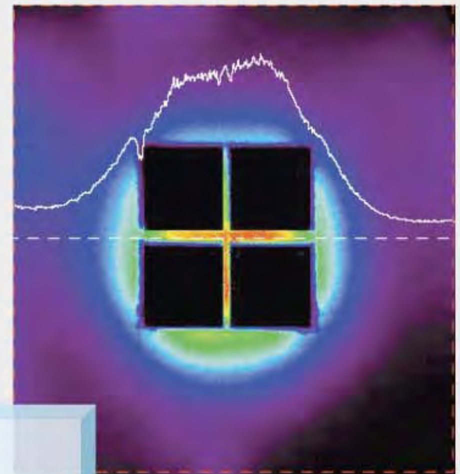
- 13 requirements were met by systems fielded on NEL
- 98% channel reliability in NEL experiments

NIF is steadily developing a large range of experimental capabilities

LPI

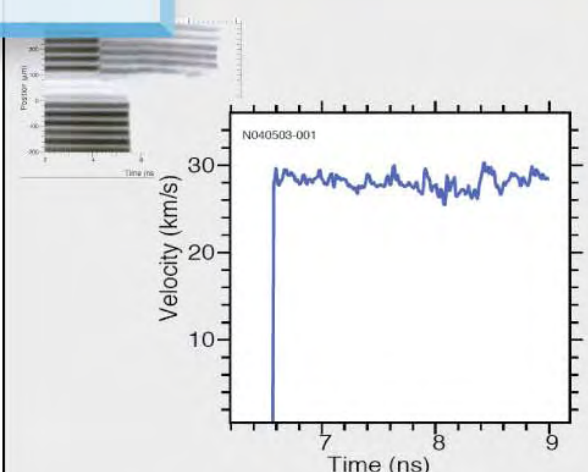


Hohlraums



Hydro

EOS



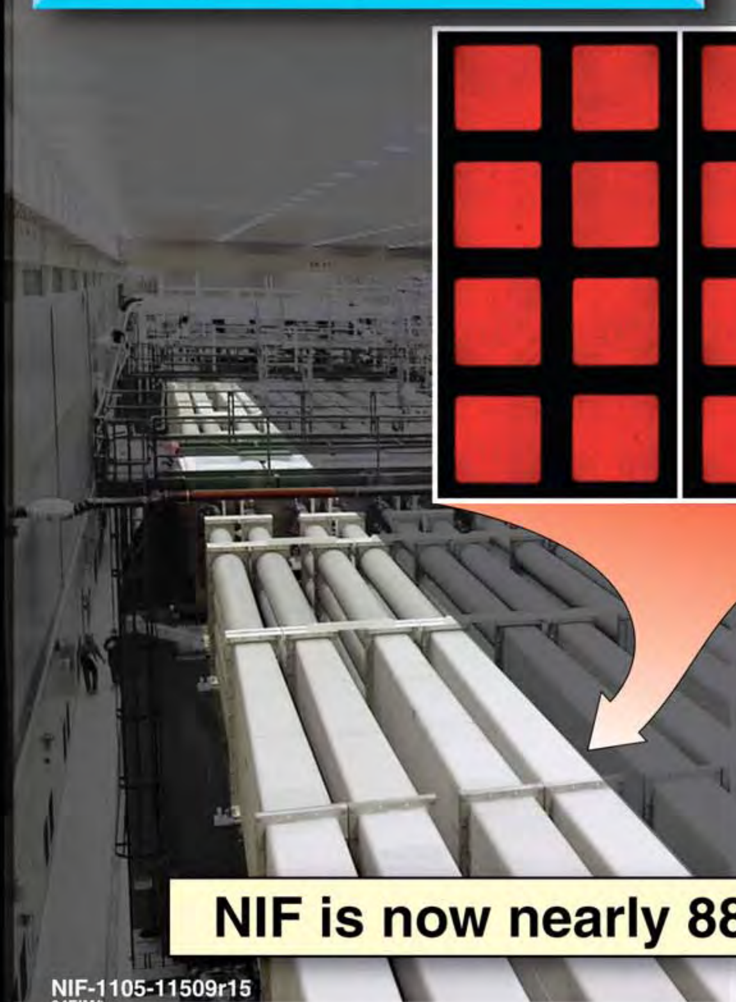
Both Bundles Meet All Performance Requirements

- Over 2 MJ equivalent in the ultraviolet
- 2 Bundles produce 300kJ @ 1ω

NATIONAL IGNITION FACILITY

LRU Installation Count >2600

- Over 43% complete and ahead of schedule
- Learning curves at 80% or better



NIF is now nearly 88% complete and on schedule

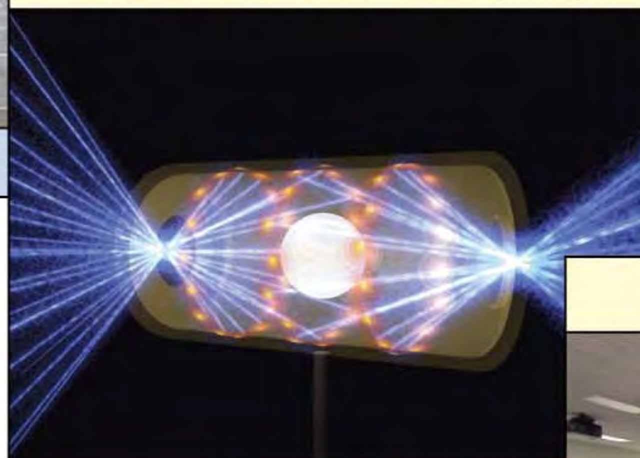
NIF-1105-11509r15
04EIM/tr

NIF Master Strategy

NIF Project

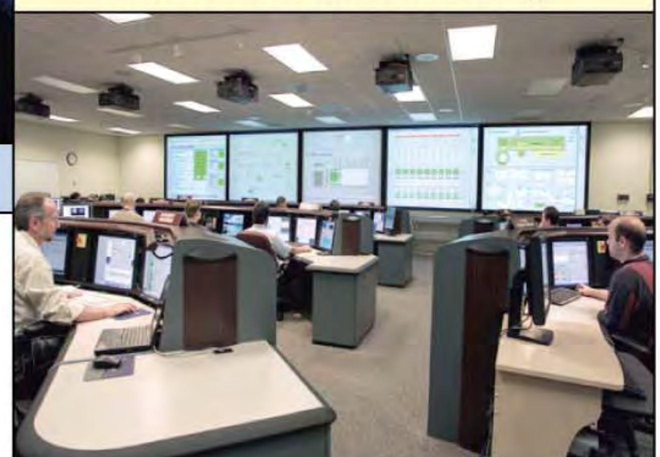
2009

National Ignition Campaign



2006–2012

National User Facility



2009–2030

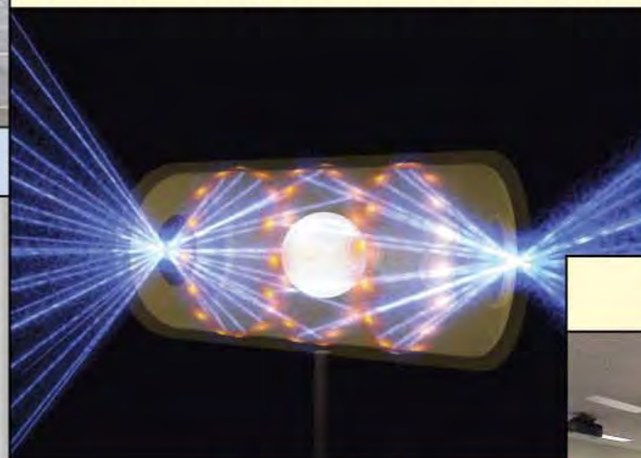
NIF-0906-12712
25EIM/dj

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

NIF Project

2009

National Ignition Campaign



2006–2012

National User Facility

2009–2030

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

NIF-0706-12508r2
25EIM/dj

- 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

NIC
NATIONAL IGNITION CAMPAIGN

National Ignition Campaign

2006

Edward I. Moses
Director, National Ignition Campaign

NNSA
National Nuclear Security Administration

GENERAL ATOMICS

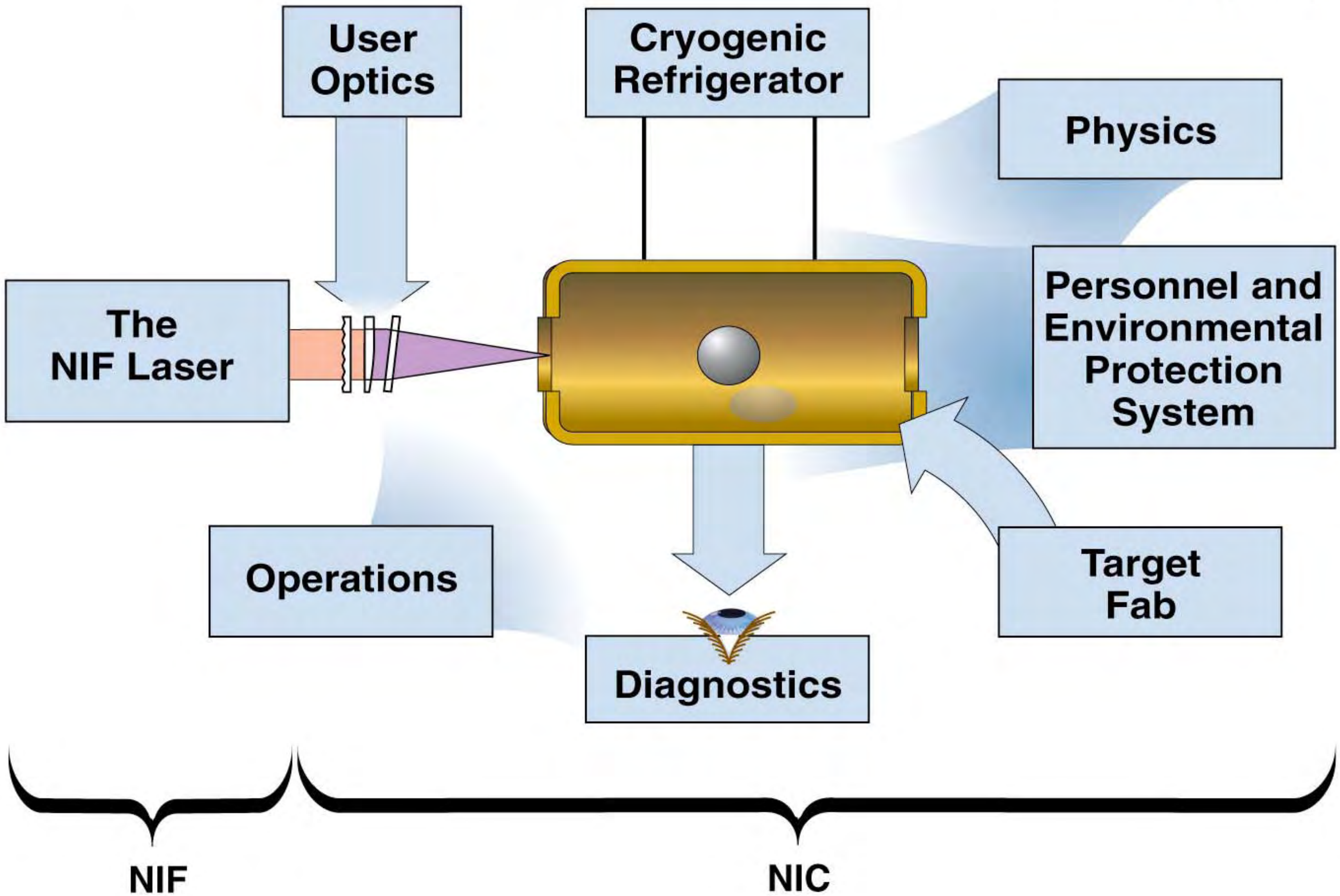
UR LLE

University of California
Lawrence Livermore National Laboratory

Los Alamos
NATIONAL LABORATORY

Sandia National Laboratories

Major elements of the National Ignition Campaign



NIF-0606-12269r1
11EIM/fm

NIF Indirect Drive target point design

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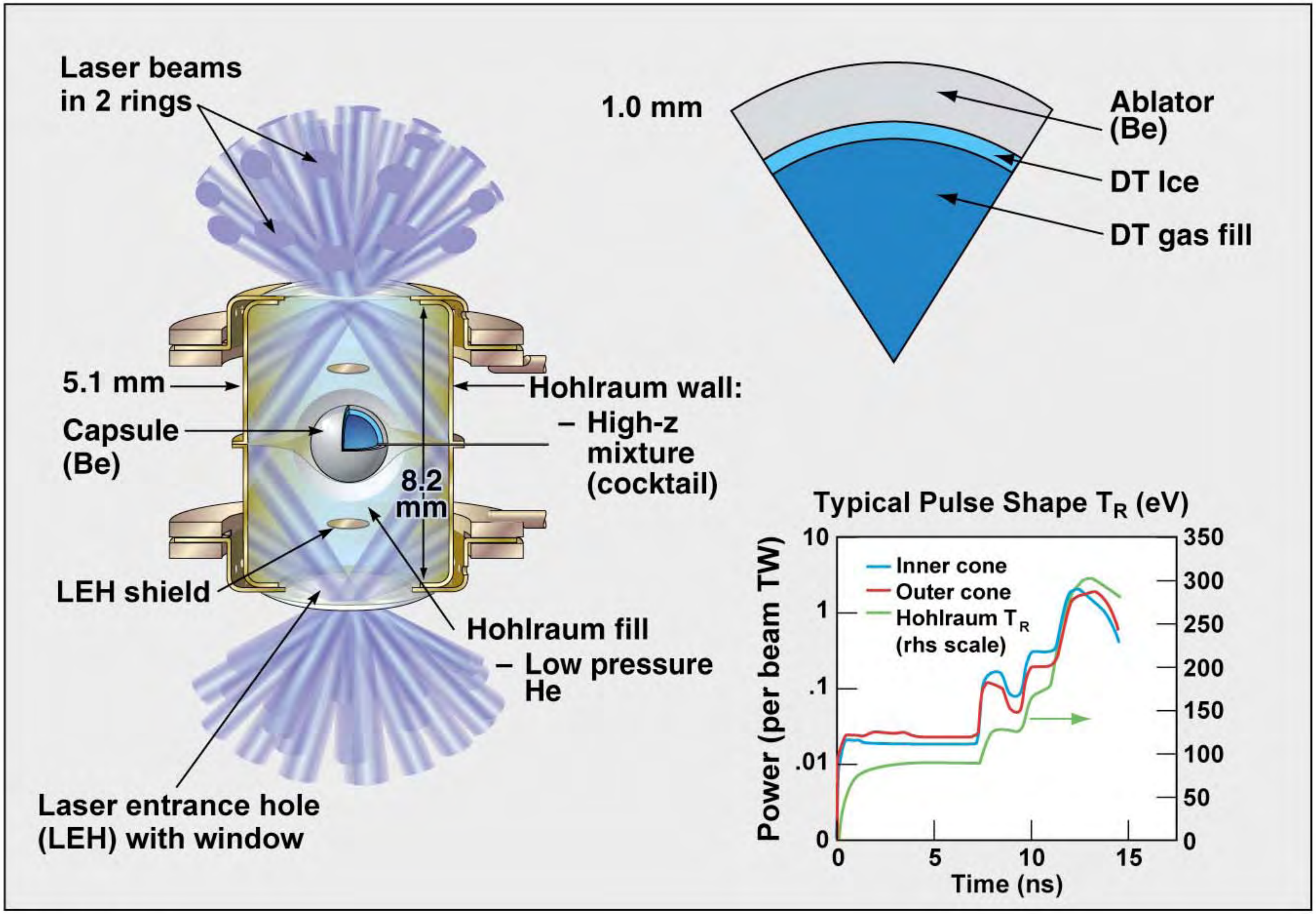
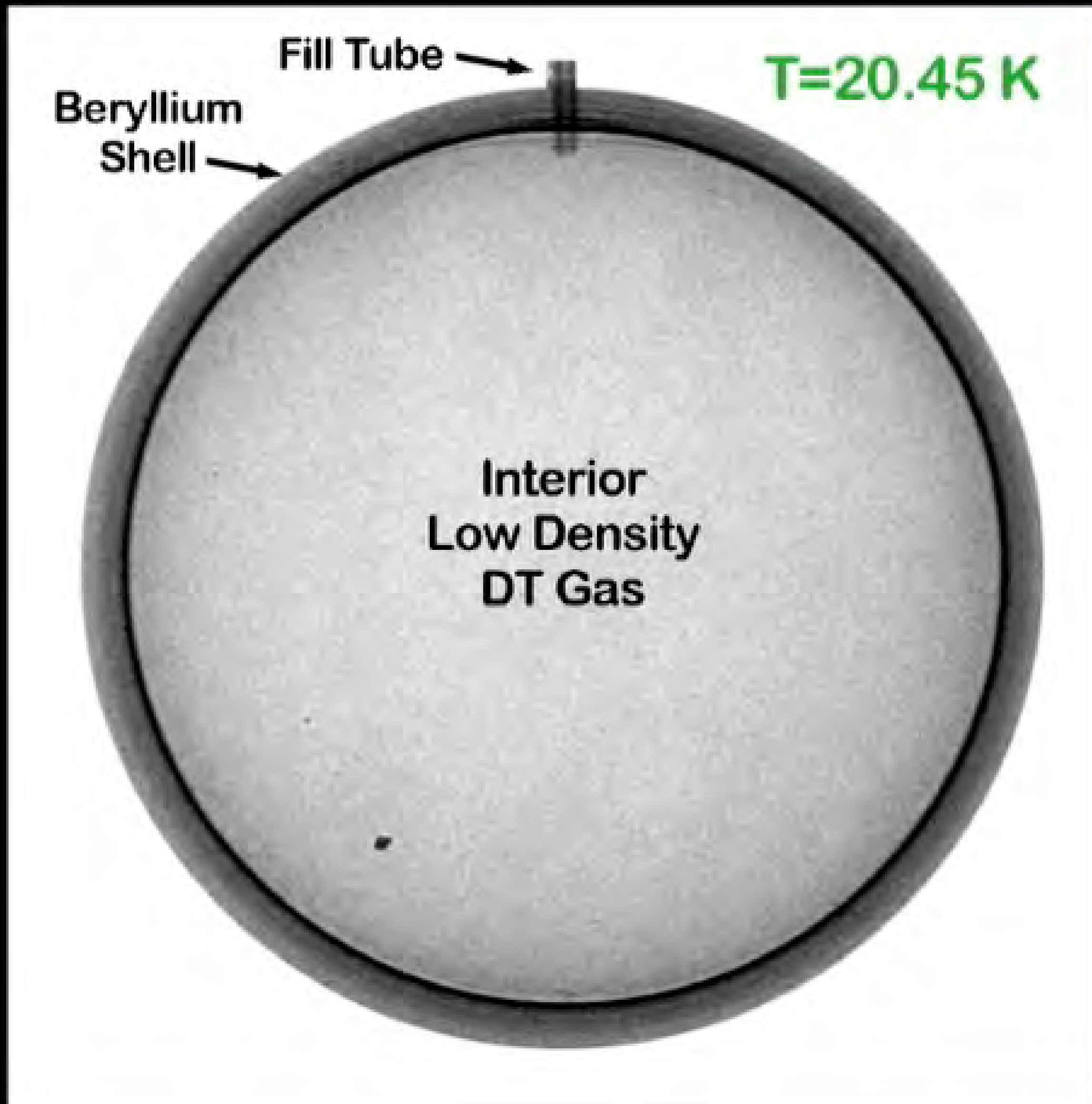
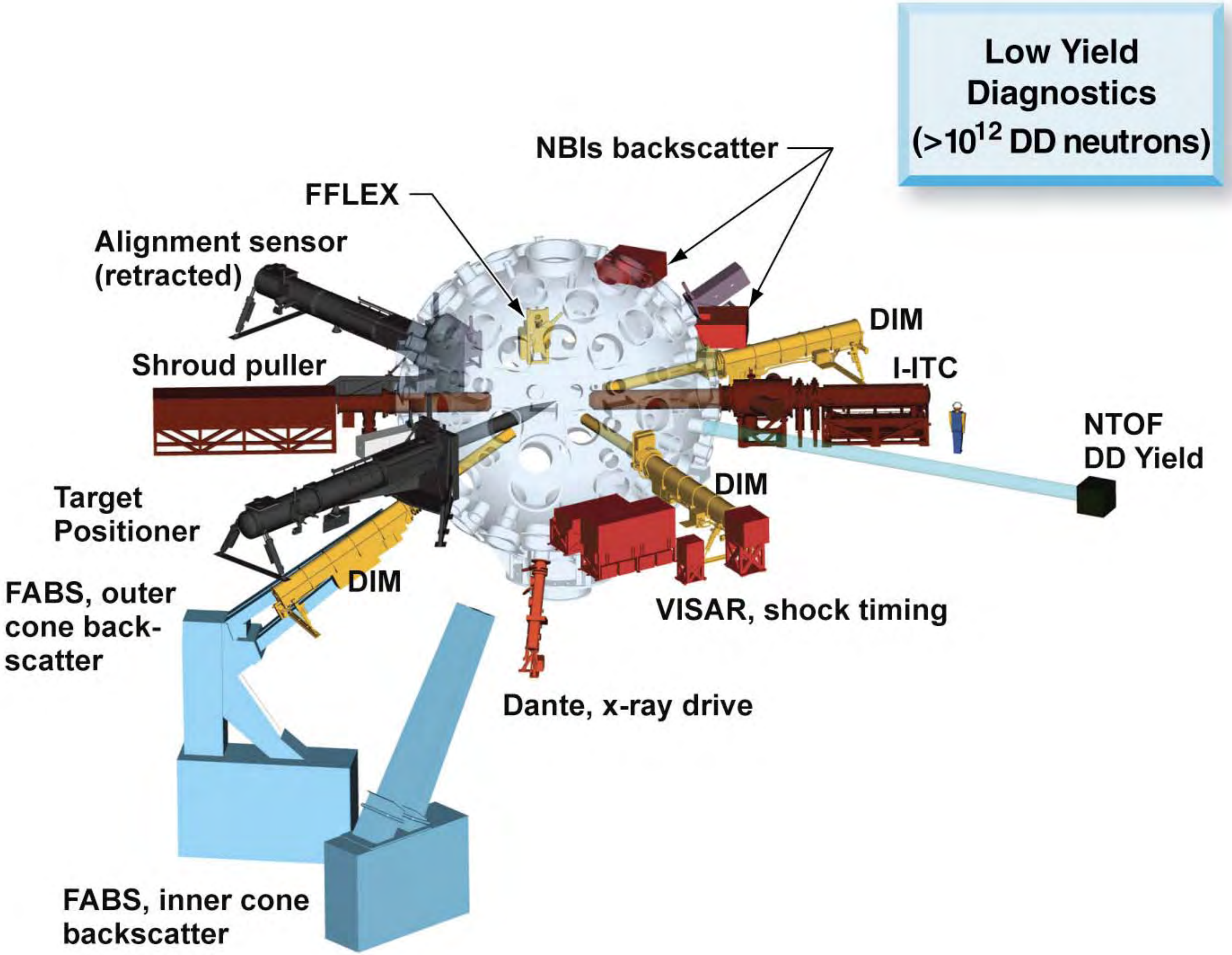
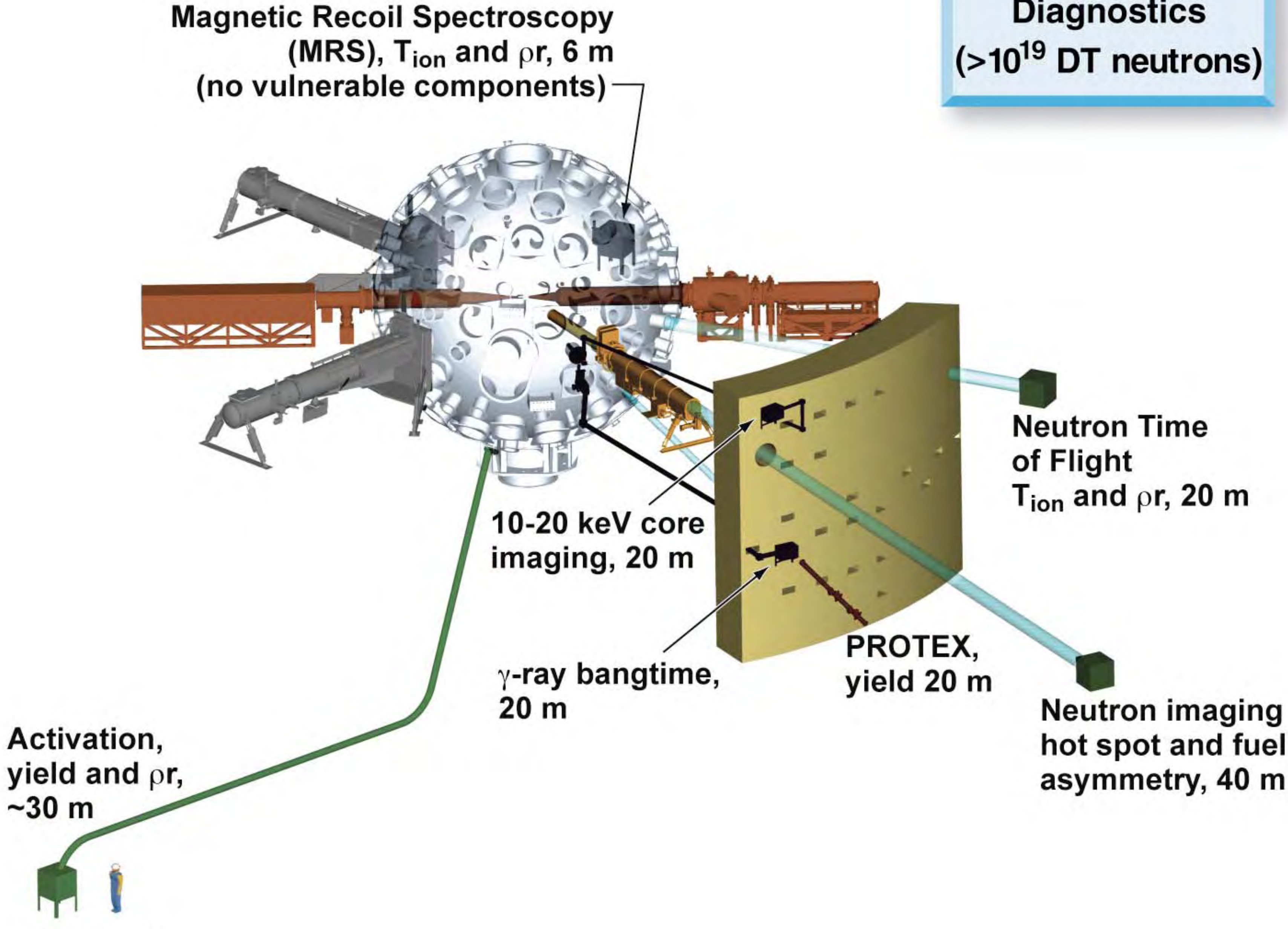



Fill Tube
T=20.45 K
Beryllium
Shell
Interior
Low Density
DT Gas



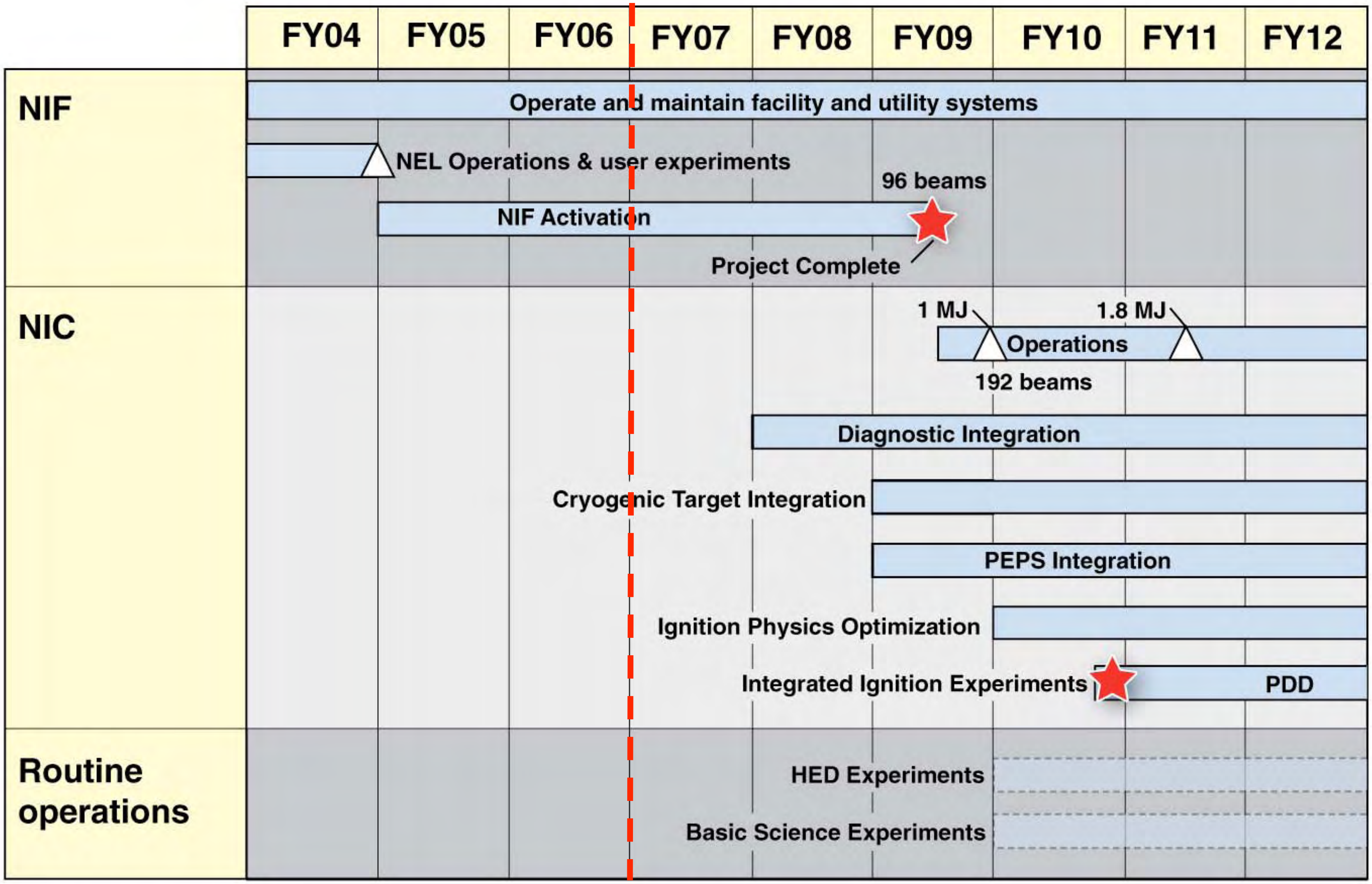
NIF-0506-12000
14EIM/dj

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



NIF-0506-12001
14EIM/dj

NIF/NIC Integration Schedule



NIF-0805-11232r5
16EIM/rjs

NIF/NIC Integration Schedule

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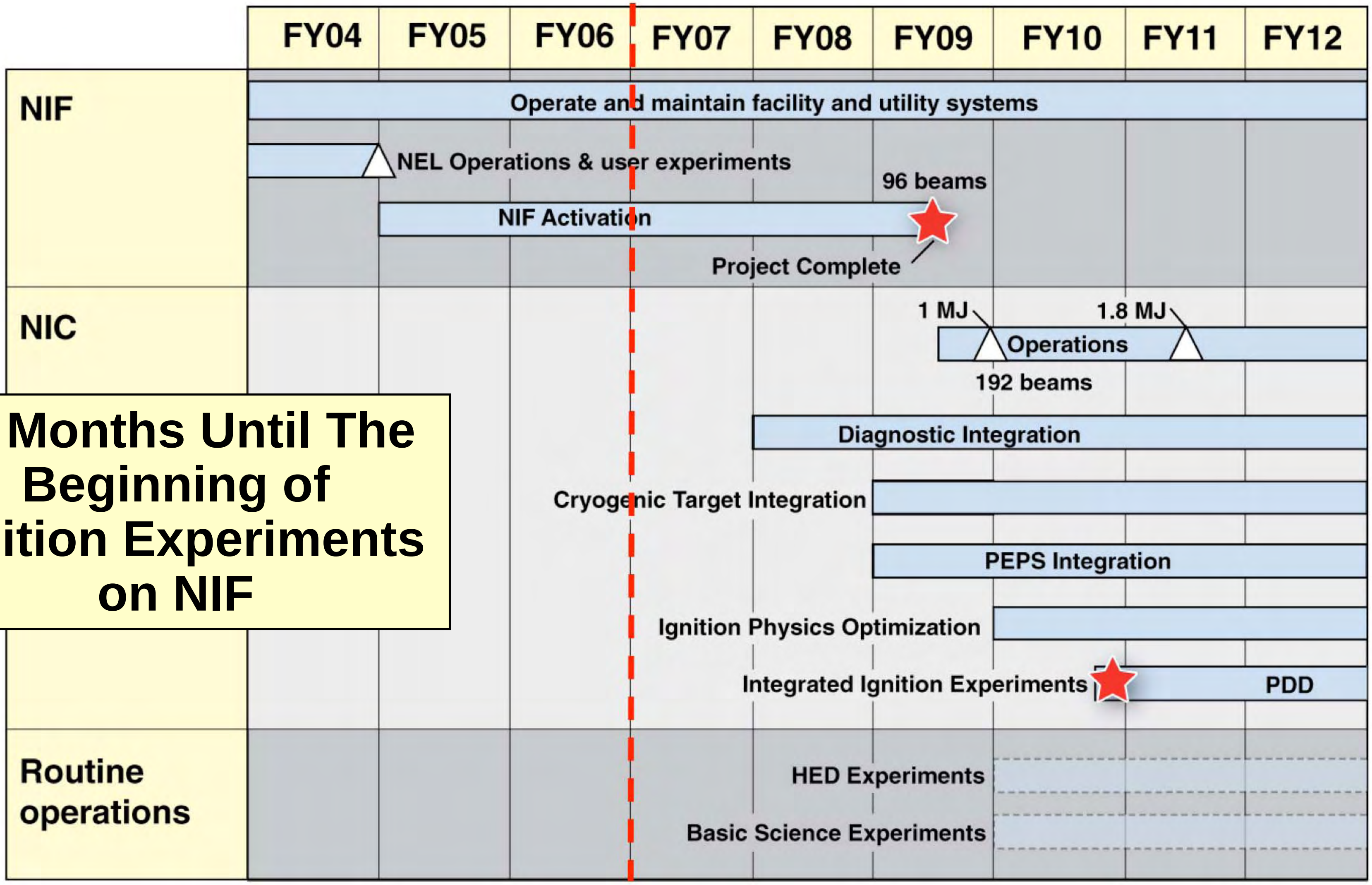

30 Months Until The Beginning of Ignition Experiments on NIF

NIF-0805-11232r5
16EIM/rjs

High-energy high-intensity missions define the laser requirements

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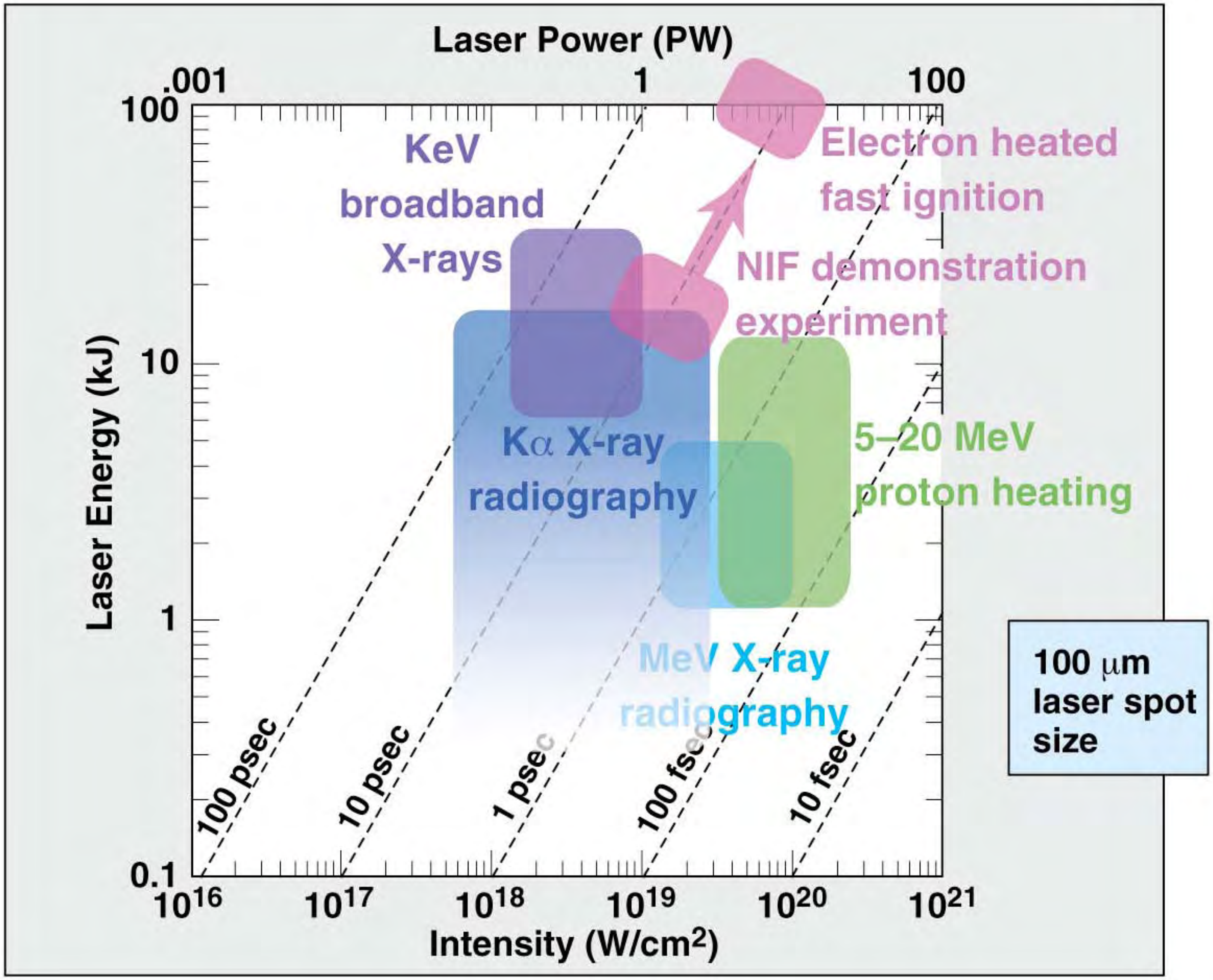
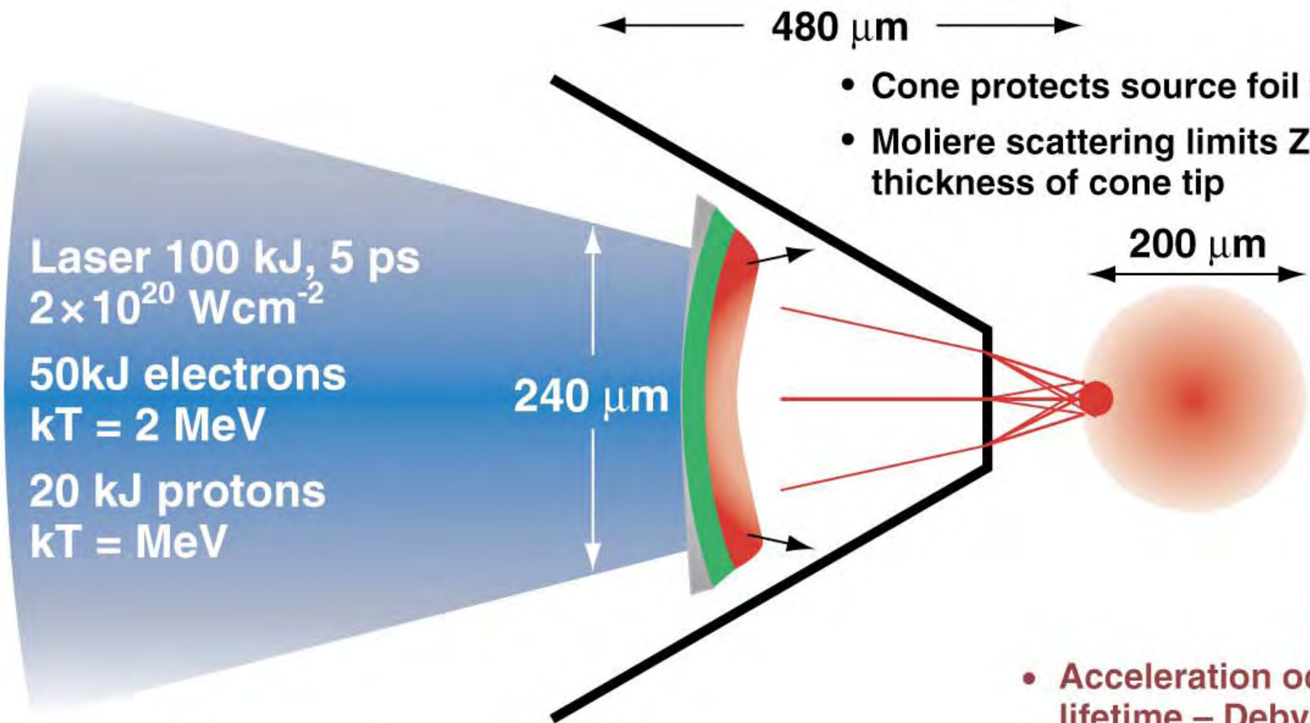


Conceptual full scale proton fast ignition must satisfy many criteria – design is evolving



- Cone protects source foil from shock and x-rays
- Moliere scattering limits Z, distance and thickness of cone tip

- DT fuel at 300 g/cc
- 33 μm ignition spot

- Acceleration occurs during hot electron lifetime – Debye sheath moves forward
- Edge effects limit focal spot quality

- Proton source foil protects rear surface from pre-pulse
- Thickness limits conversion efficiency

High energy petawatts require minor beamline modification

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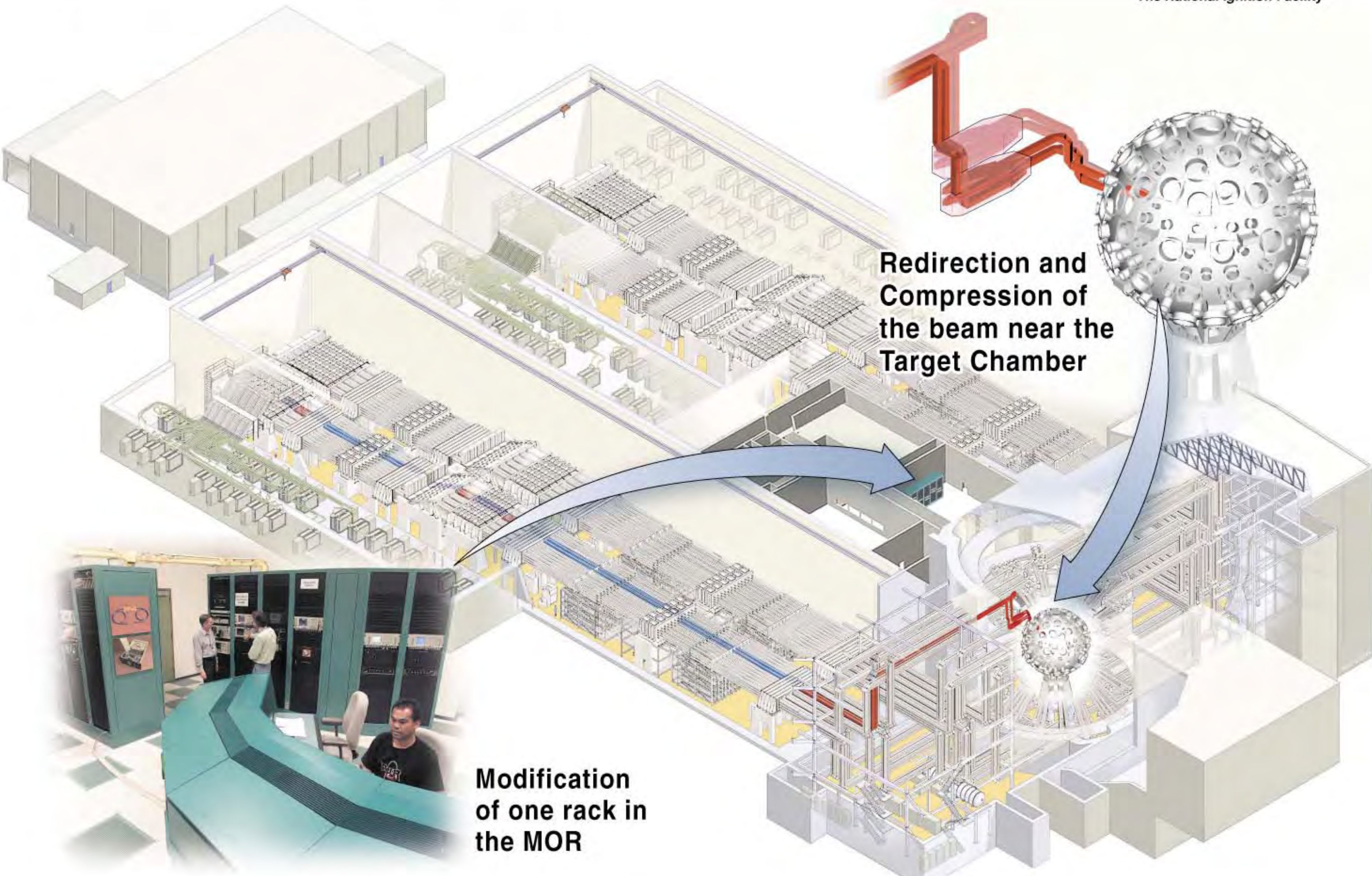
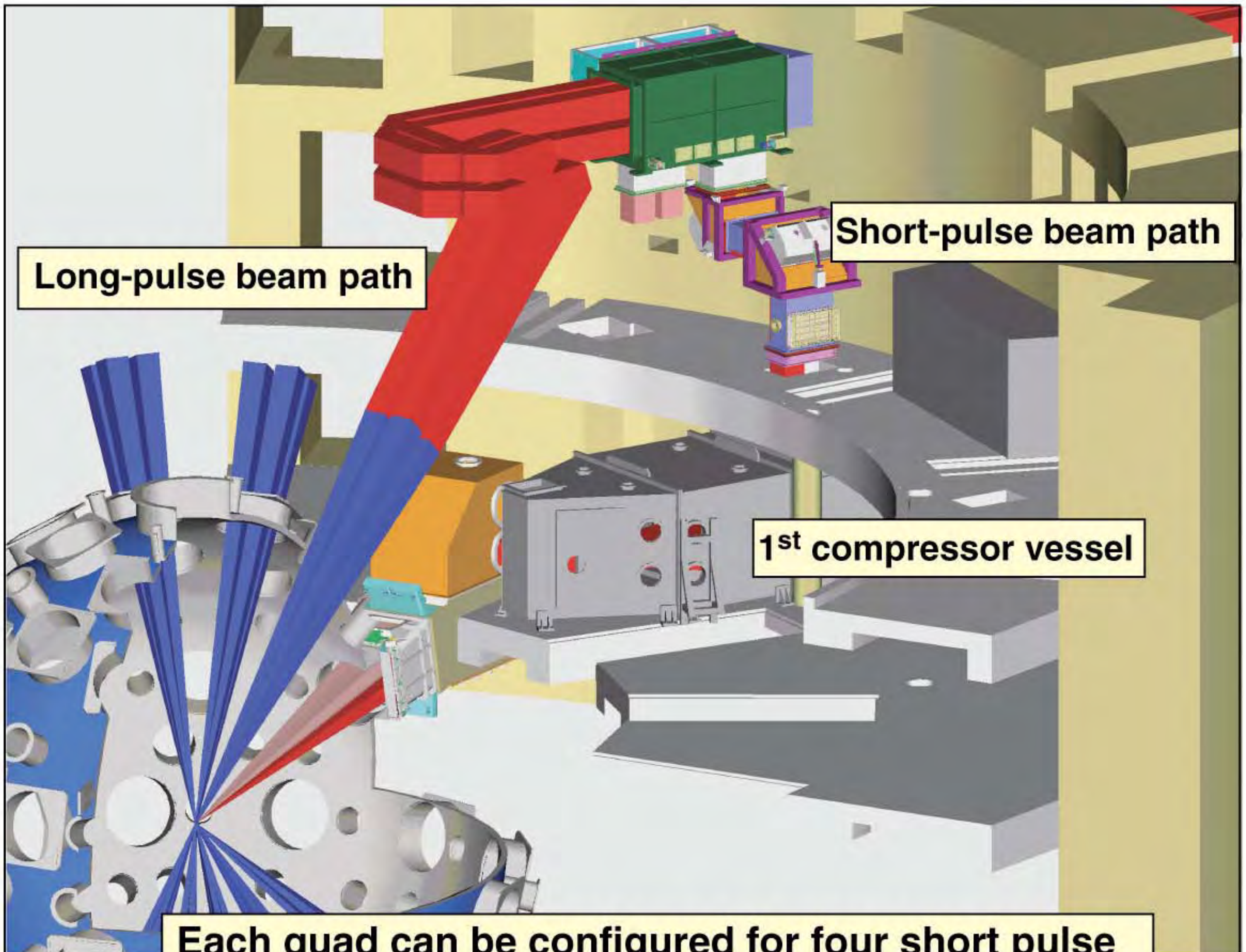
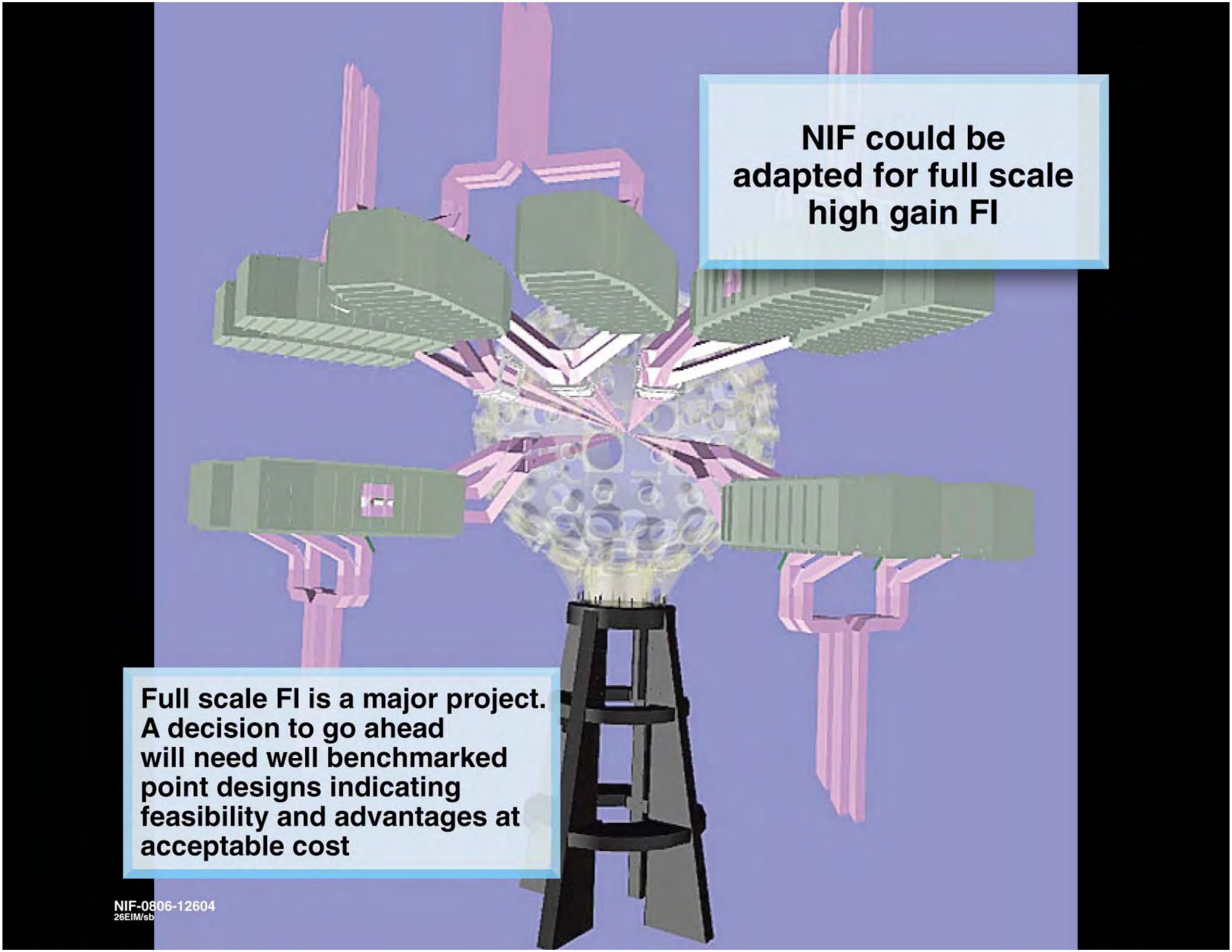


The petawatt beam path in the target bay will be easily switched from the long-pulse beam path



Each quad can be configured for four short pulse multi-kJ beams delivered to target chamber center


NIF could be adapted for full scale high gain FI
Full scale FI is a major project. A decision to go ahead will need well benchmarked point designs indicating feasibility and advantages at acceptable cost
NIF-0806-12604
26EIM/sb

Omega EP will support both FI science (EP chamber) and integrated FI experiments (Omega chamber) – in FY09

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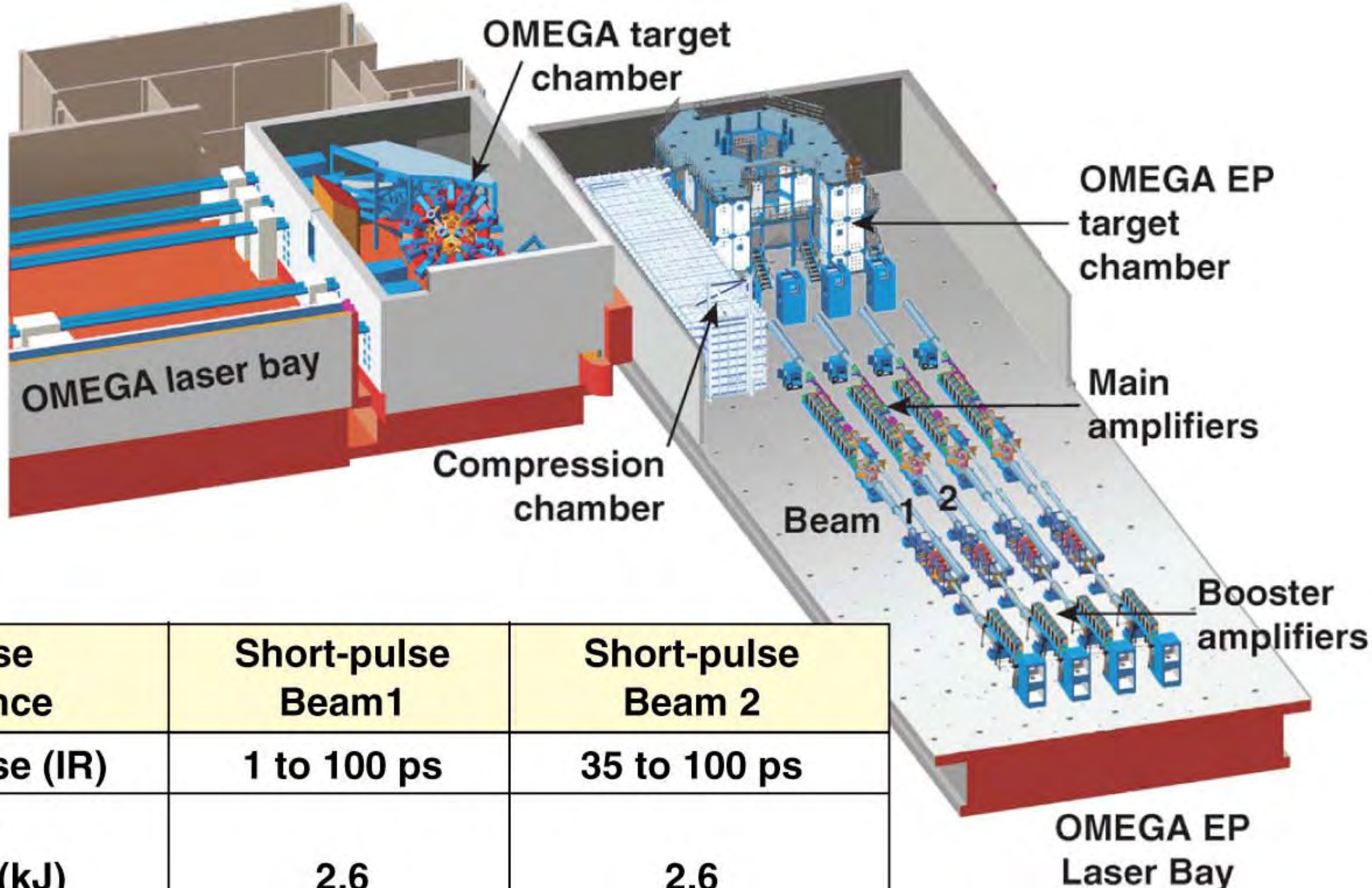
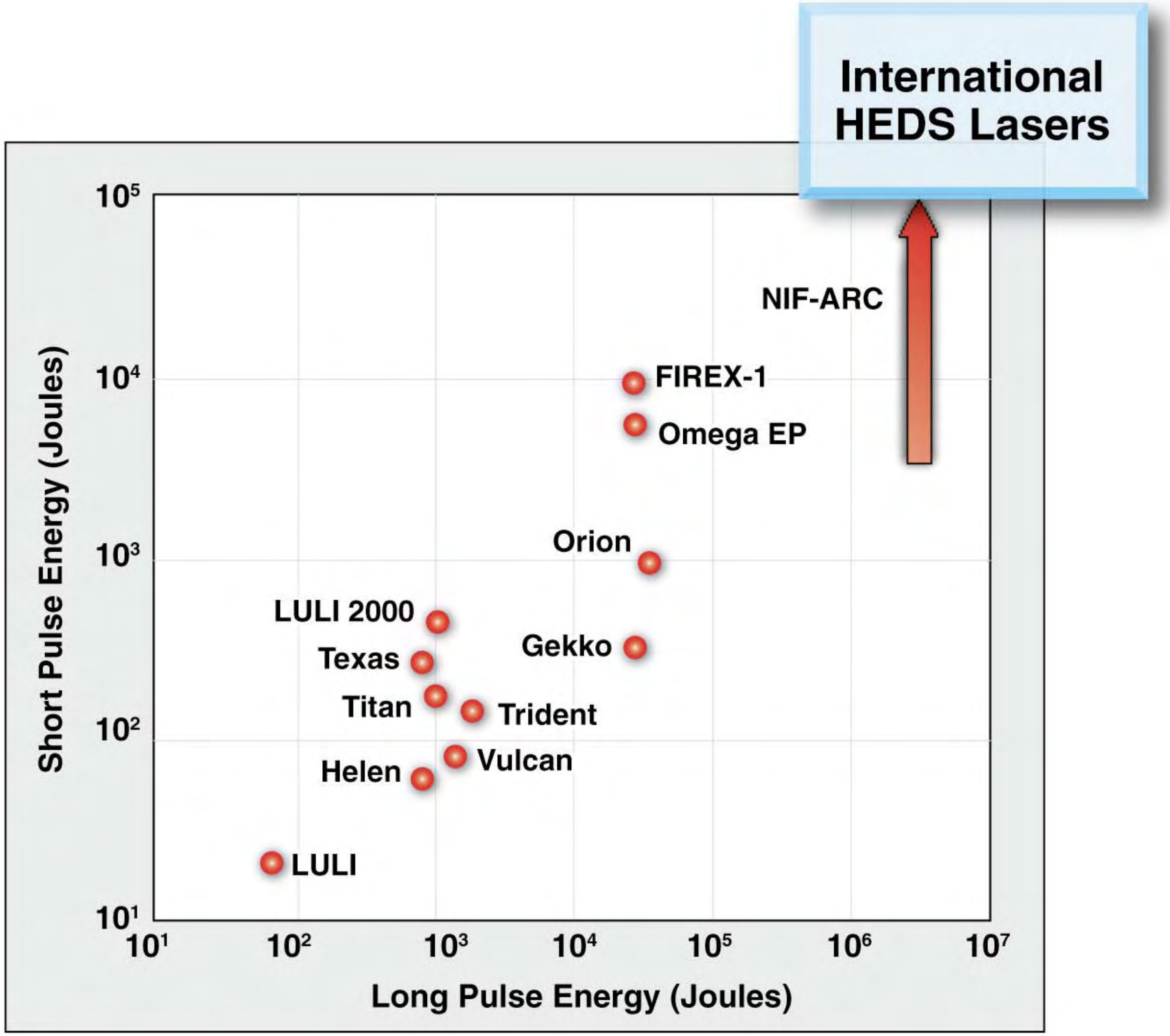


Short-pulse performance	Short-pulse Beam1	Short-pulse Beam 2
Short pulse (IR)	1 to 100 ps	35 to 100 ps
IR energy on-target (kJ)	2.6	2.6
Intensity (W/cm^2)	6×10^{20}	$\sim 4 \times 10^{18}$
Focusing	>80% in 20 μm	>80% in 40μm



NIF-0906-12654r2
25EIM/dj

Is NIF a precursor to an Inertial Fusion Energy plant?

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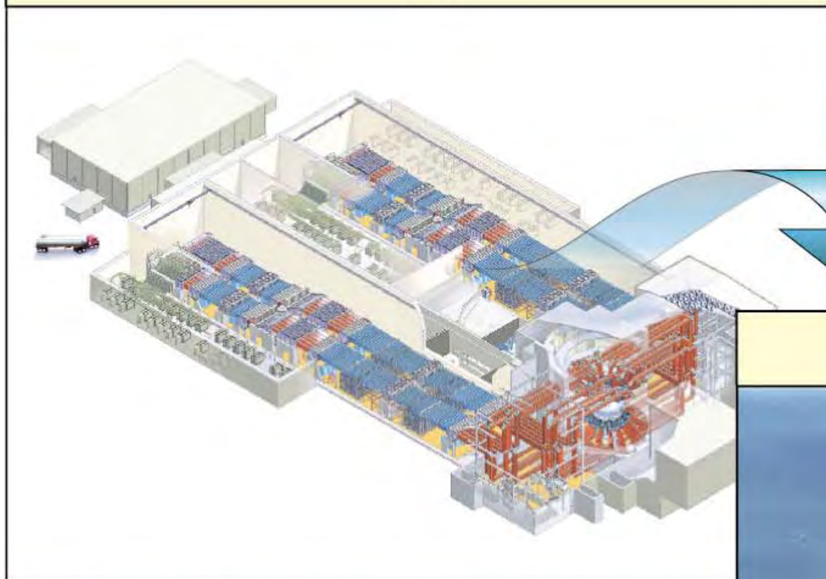
NIF



Repetition frequency 10^{-4} Hz
Electrical efficiency 0.5%

Fusion Reactor

Repetition frequency 10 Hz
Electrical efficiency 10%

NIF is based on 1960's — 1990's laser technology

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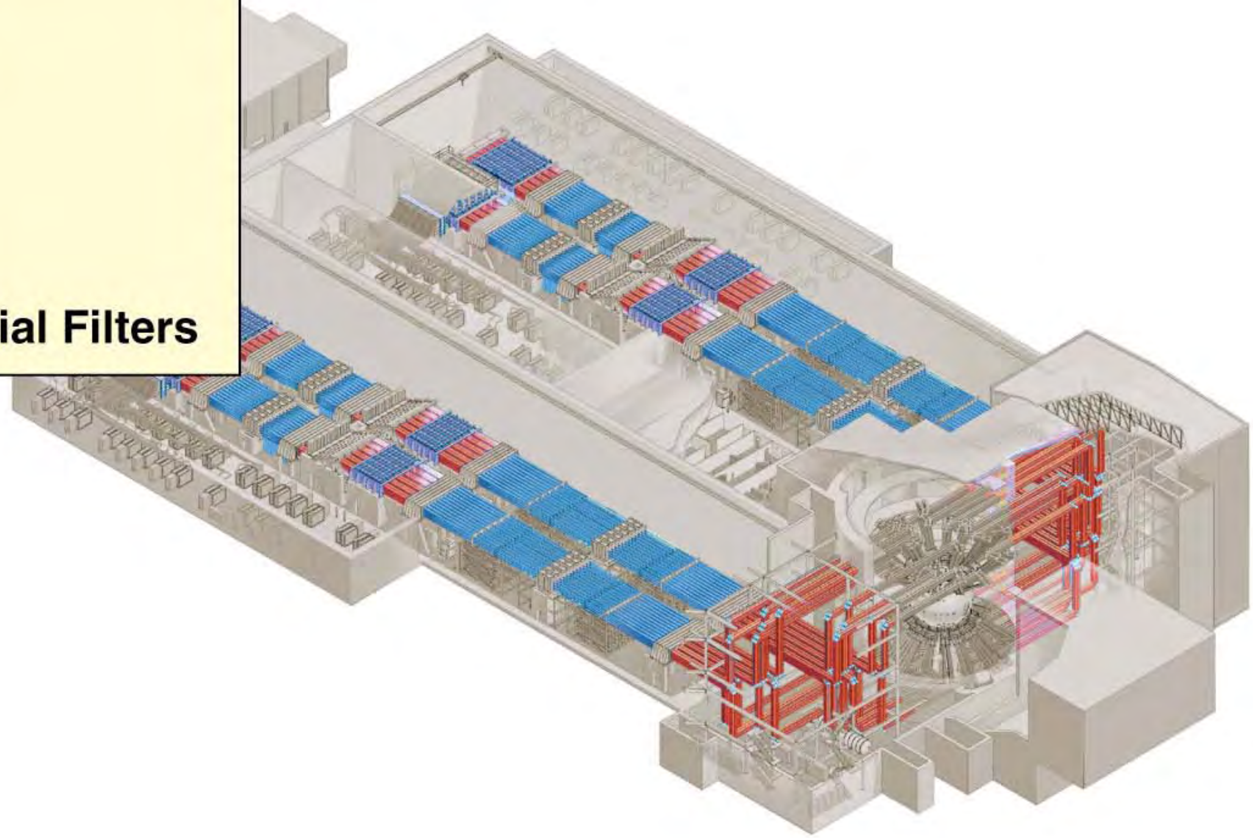
- Glass
- Flashlamps
- KDP
- Air cooling
- Discrete Spatial Filters



These technologies result in a low rep rate, low efficiency laser fusion driver

IFE laser will be based on 1960's — 2020's technology

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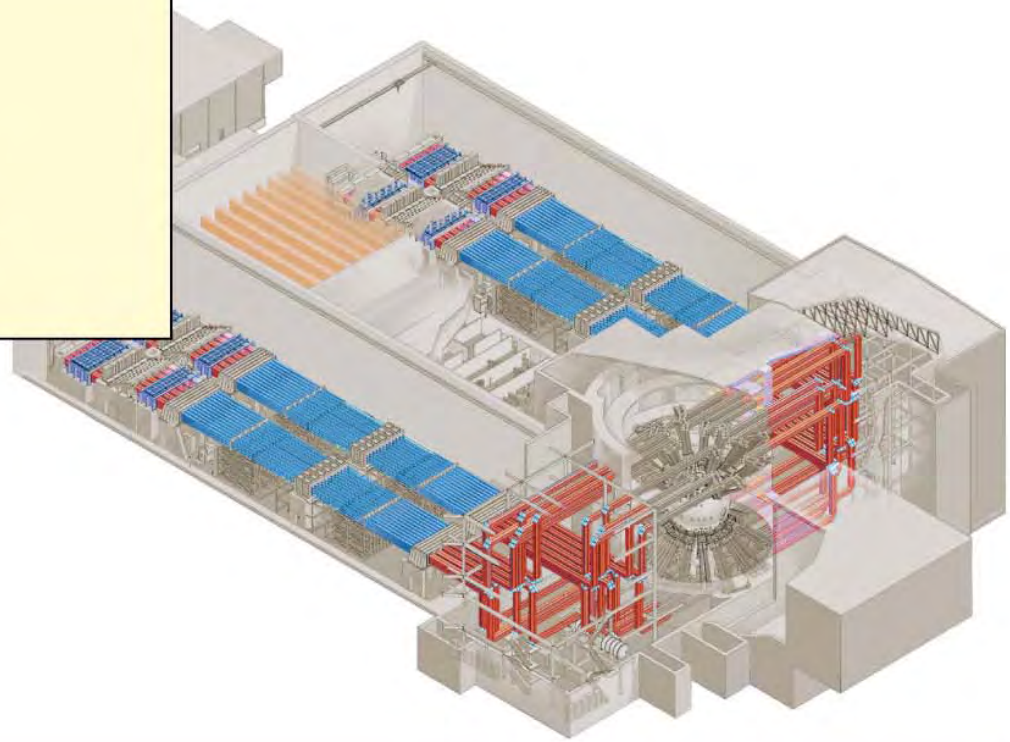
- ~~Glass~~ Glass/Ceramics/Crystals
- ~~Flashlamps~~ Diodes
- ~~KDP~~ DKDP
- ~~Air cooling~~ He cooling
- ~~Discrete Spatial Filters~~
  Rugate reflectors



- These "plug and play" modifications to NIF architecture could increase rep rate by 100,000x and efficiency by 40x

We are embarking on a cost analysis of candidate DPSSL systems for IFE

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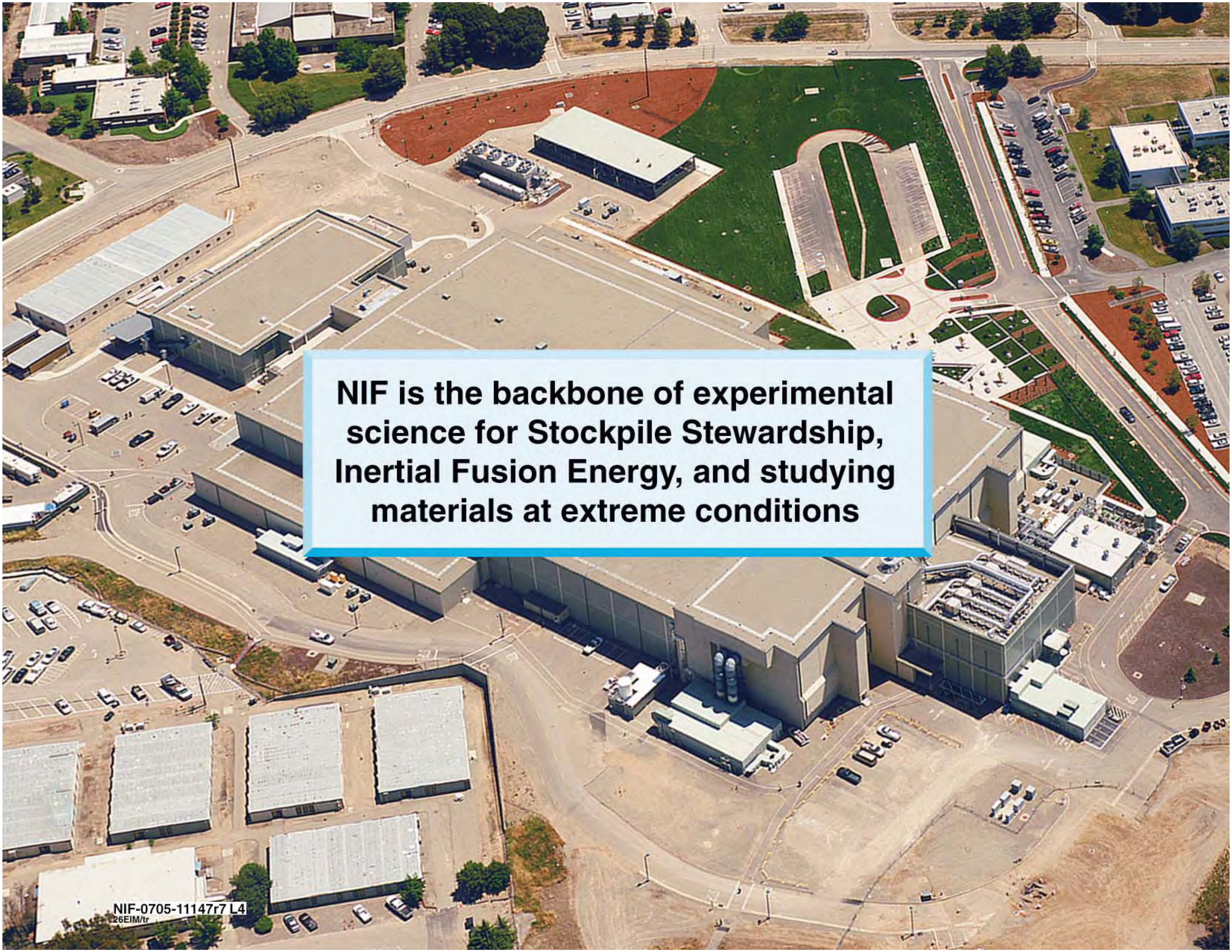
- Comparison of Yb:S-FAP, Nd:Glass, and Yb:YAG (ceramic) based IFE drive lasers
  - Nd:Glass based system
    - Traceable to NIF beam line
    - Leverages technology base developed for NIF: large optic finishing, beam line bundling, switchyard, and LRUs
  - Yb-S-FAP based system
    - Traceable to Mercury architecture, but using a NIF-like configuration
    - Leverages design of Mercury amplifiers
  - Yb doped optical ceramics
    - Scales like glass but has long storage time
    - Replace NIF glass slabs with Yb:YAG ceramic
    - Requires large scale cryo-cooling


NIF is the backbone of experimental science for Stockpile Stewardship, Inertial Fusion Energy, and studying materials at extreme conditions
NIF-0705-11147r7 L4
26EIM/tr

Leveraging the NIF provides a near-term pathway to the demonstration of an IRE beam line

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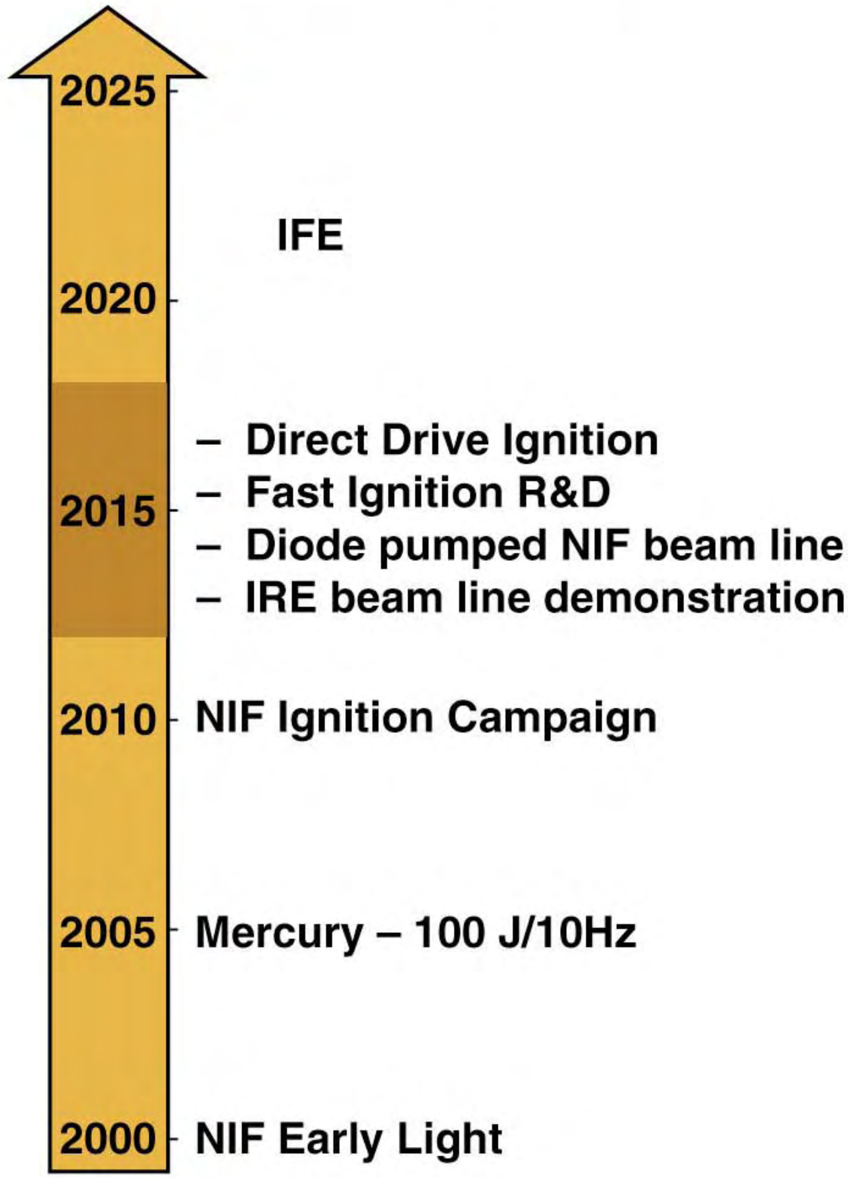

NIF: Visions of yesterday become reality of today

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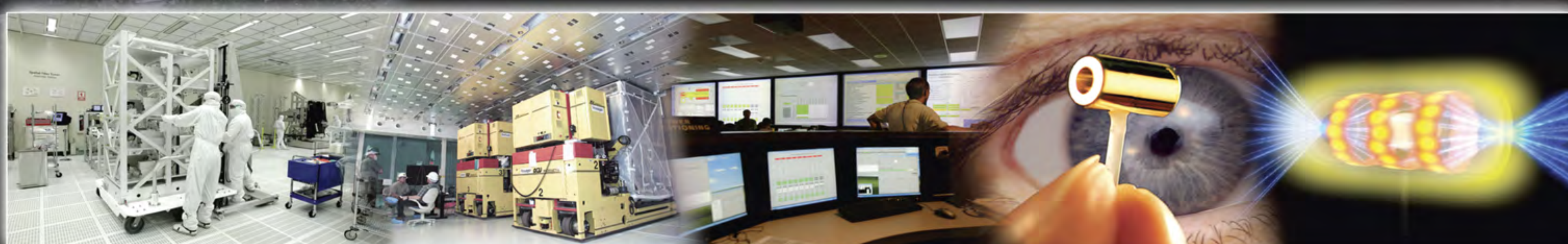
1960's–Invention of Laser	2010–Goal of Ignition
	

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

National Ignition Facility

Three Years to a New Age for Fusion Energy



NIF-0906-12711
25EIM/dj

NATIONAL
IGNITION
FACILITY