



The National Ignition Facility: Status of Construction

Fusion Power Associates Annual Meeting

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October 11, 2005



SCIENCE IN THE NATIONAL INTEREST



LLNL



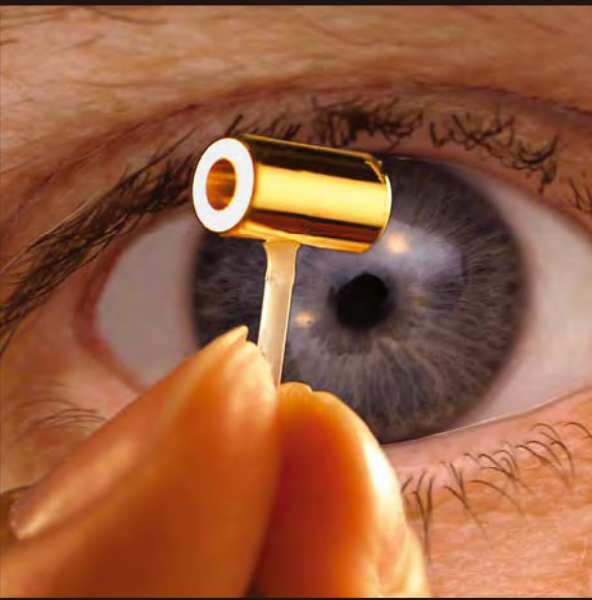
San Francisco

LLNL

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NIF concentrates all the energy in a football stadium-sized facility into a mm³



Conditions

Matter

Temperature $\Rightarrow >10^8$ K
 ~ 10 keV

Radiation

Temperature $\Rightarrow >3.5 \times 10^6$ K
 >300 eV

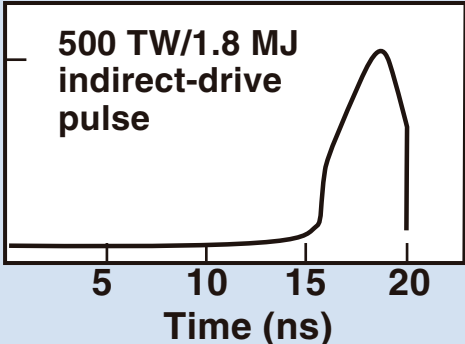
Pressures $\Rightarrow >10^{11}$ atm



Specifications for NIF



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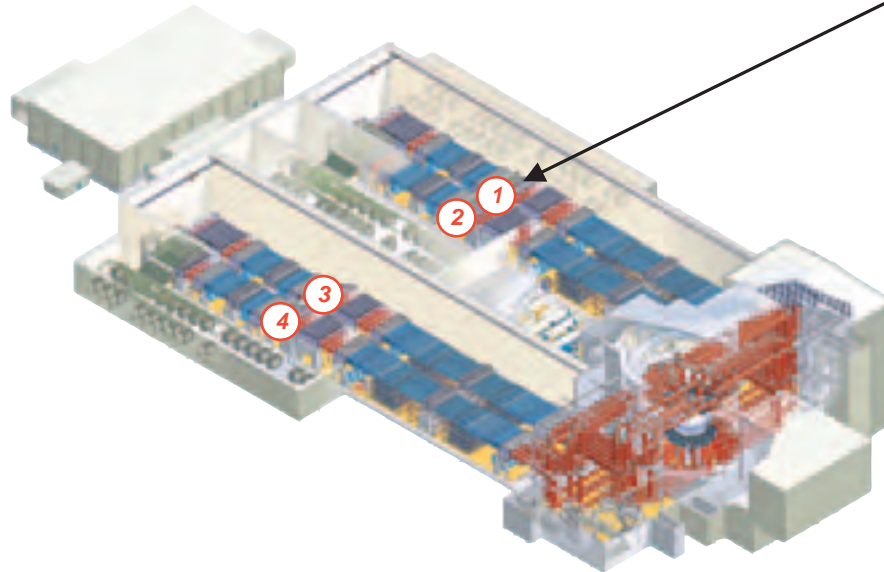
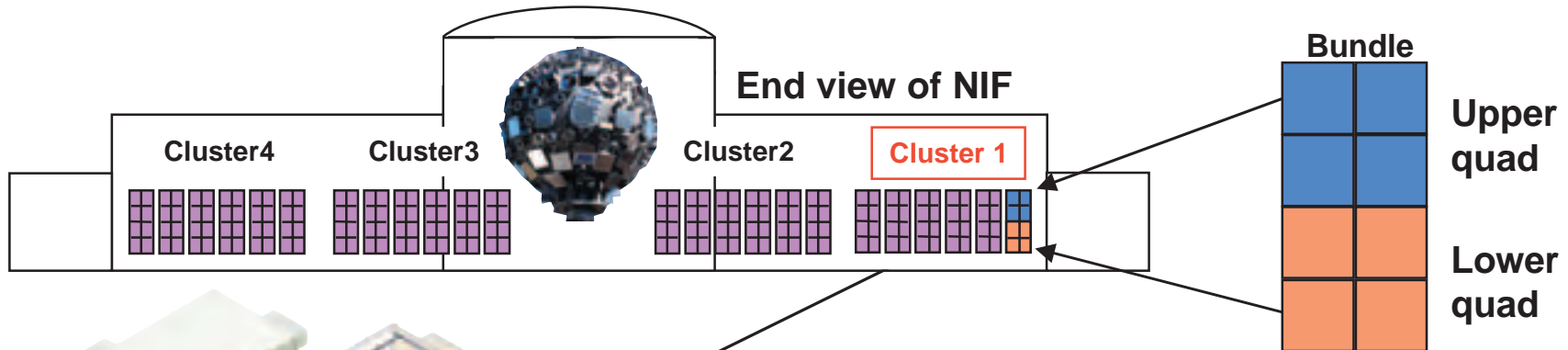
Performance parameter	Value
Energy	1.8 Megajoules
Power	500 Terawatts
Wavelength	351 nm
Pulse length	1 to 21 nsec
Pulse shape	Flexible,  <p>The graph shows a pulse shape that remains at zero until approximately 15 ns, then rises sharply to a peak of 500 TW at about 18 ns, and then falls back to zero by 20 ns. The x-axis is labeled 'Time (ns)' with ticks at 5, 10, 15, and 20. The y-axis is labeled '500 TW'.</p>
Power balance	8% over any 2-nsec interval in 48 beams spots
80% focal spot diameter	250 to 350 microns

**4 Clusters
Beampath
Complete**

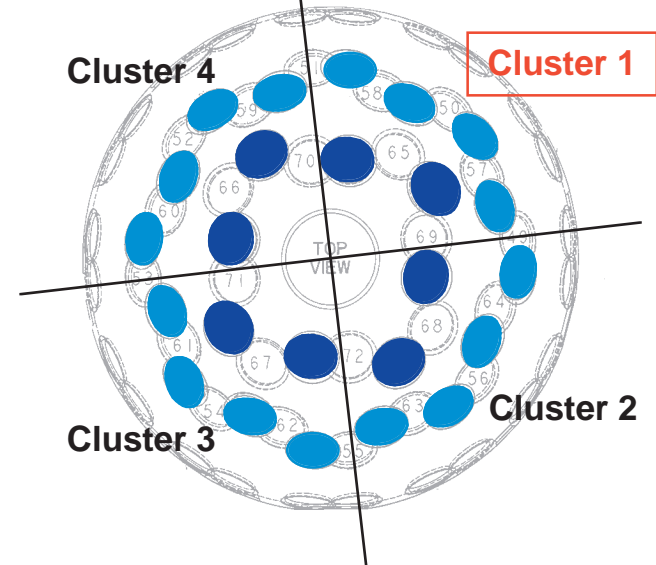
192 beam, 1.8 MJ, laser organized into “bays,” “clusters”, “bundles”, and “quads”



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Top view of target chamber (upper quads)

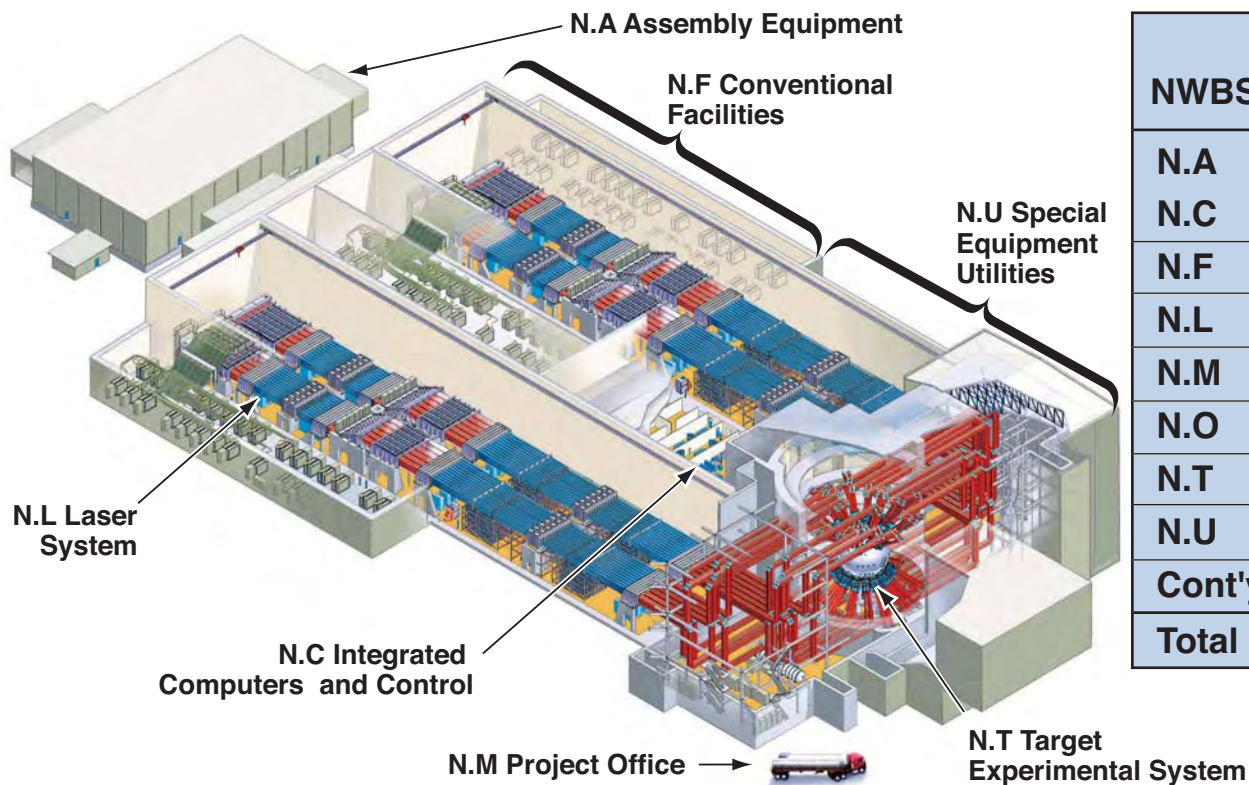


“Quads” are the basic building blocks of a NIF experiment, 4 beams with the same pulse shape and time delay

The NIF Project is now over 80% complete as of July 2005



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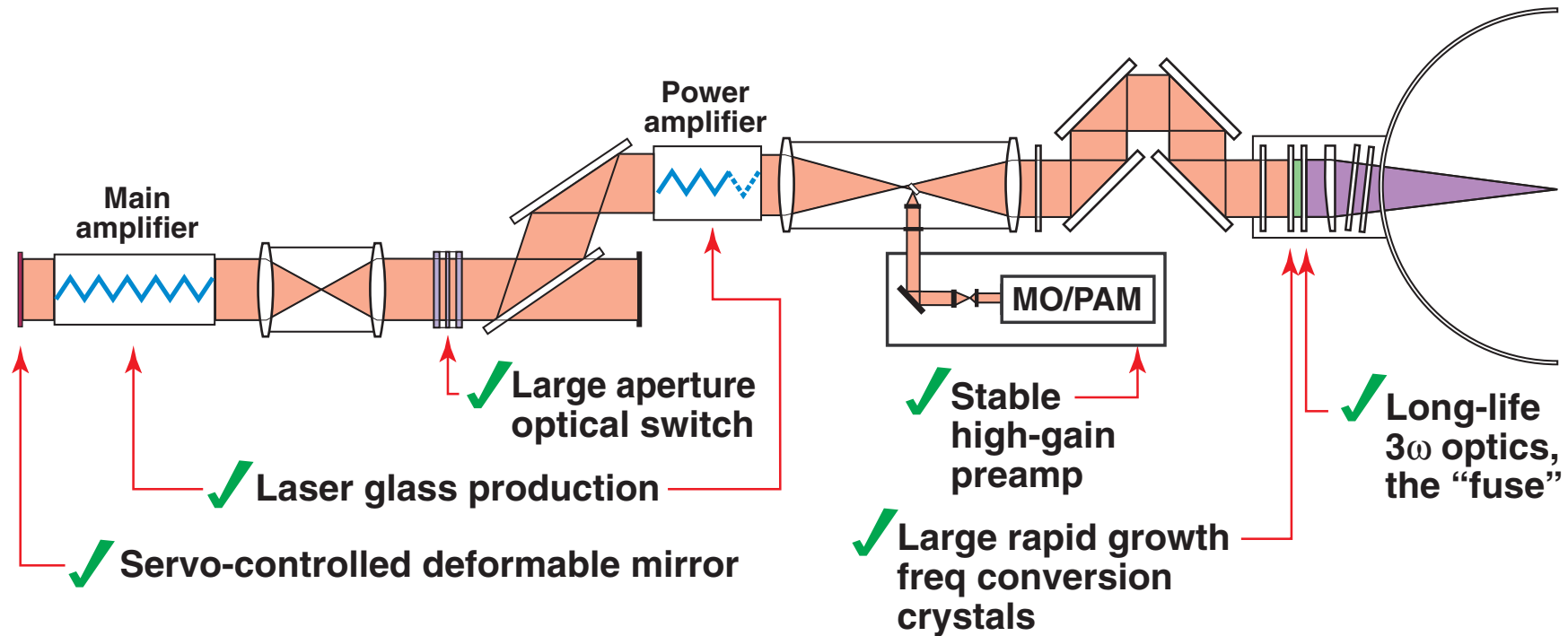


NWBS	BAC (\$M)	Planned % complete	Actual % complete
N.A	137	83%	82%
N.C	176	69%	68%
N.F	290	96%	96%
N.L	1,689	79%	79%
N.M	699	81%	81%
N.O	5	100%	100%
N.T	70	100%	100%
N.U	296	75%	75%
Cont'y	140		
Total	3,502	81%	81%

NIF required solving multiple technical challenges, many on an industrial scale



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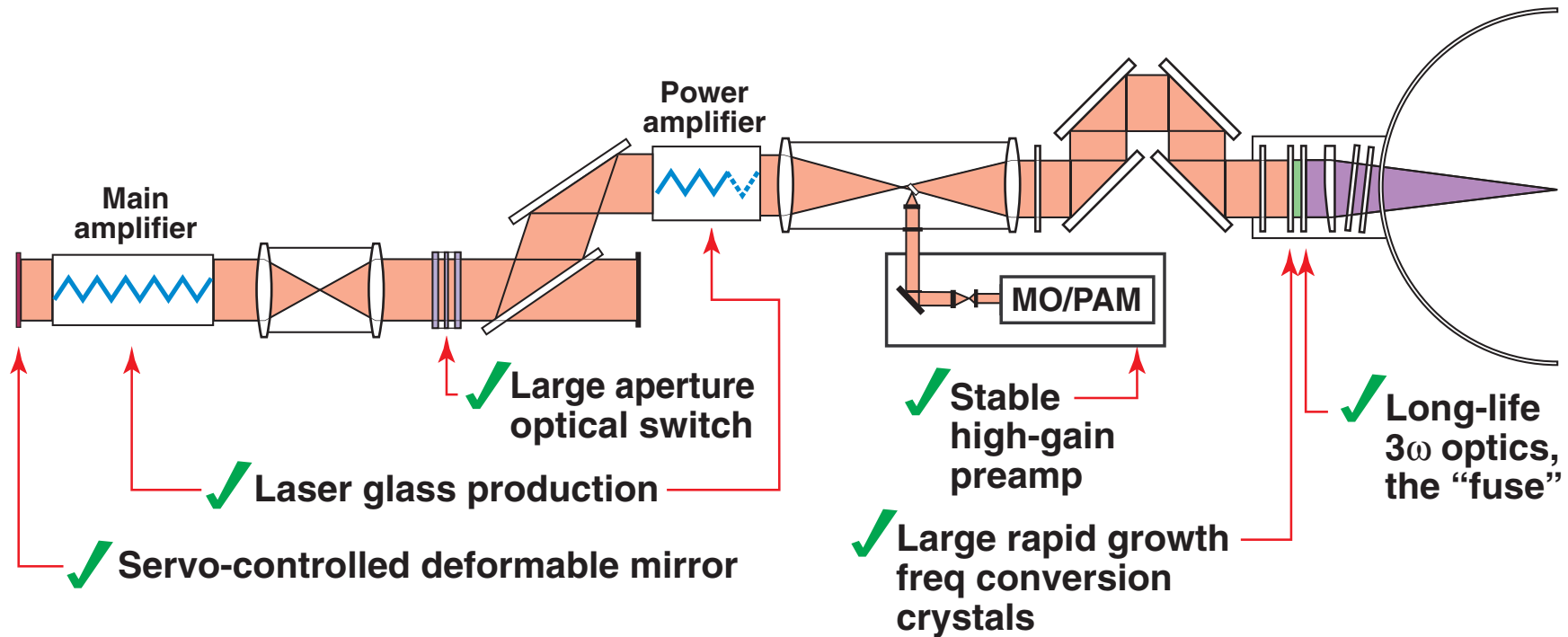
Additional issues:

- ✓ • High packing density of the laser components
- ✓ • Clean assembly of the beampath
- ✓ • Clean fabrication and installation of Line Replaceable Units (LRUs)

NIF required solving multiple technical challenges, many on an industrial scale



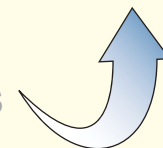
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Additional issues:

- ✓ • High packing density
- ✓ • Clean assembly of the beampath
- ✓ • Clean fabrication and installation components

Line replaceable units (LRUs)



To complete the project we must process, assemble, and install over 5,700 line replaceable units (LRUs)



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**Preamplifier Modules
(48)**



**Laser Amplifiers
(672)**



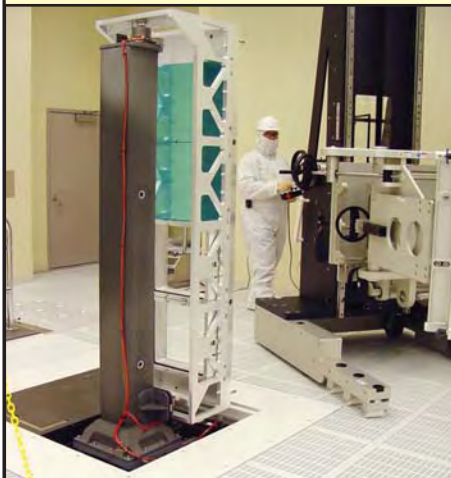
**Final Optics Assemblies
(960)**



**Laser Mirrors
(656)**



**Spatial Filter Lenses
(960)**



**Spatial Filter Towers
(72)**



**Plasma Electrode
Pockels Cell (192)**



**Flashlamps
(1008)**

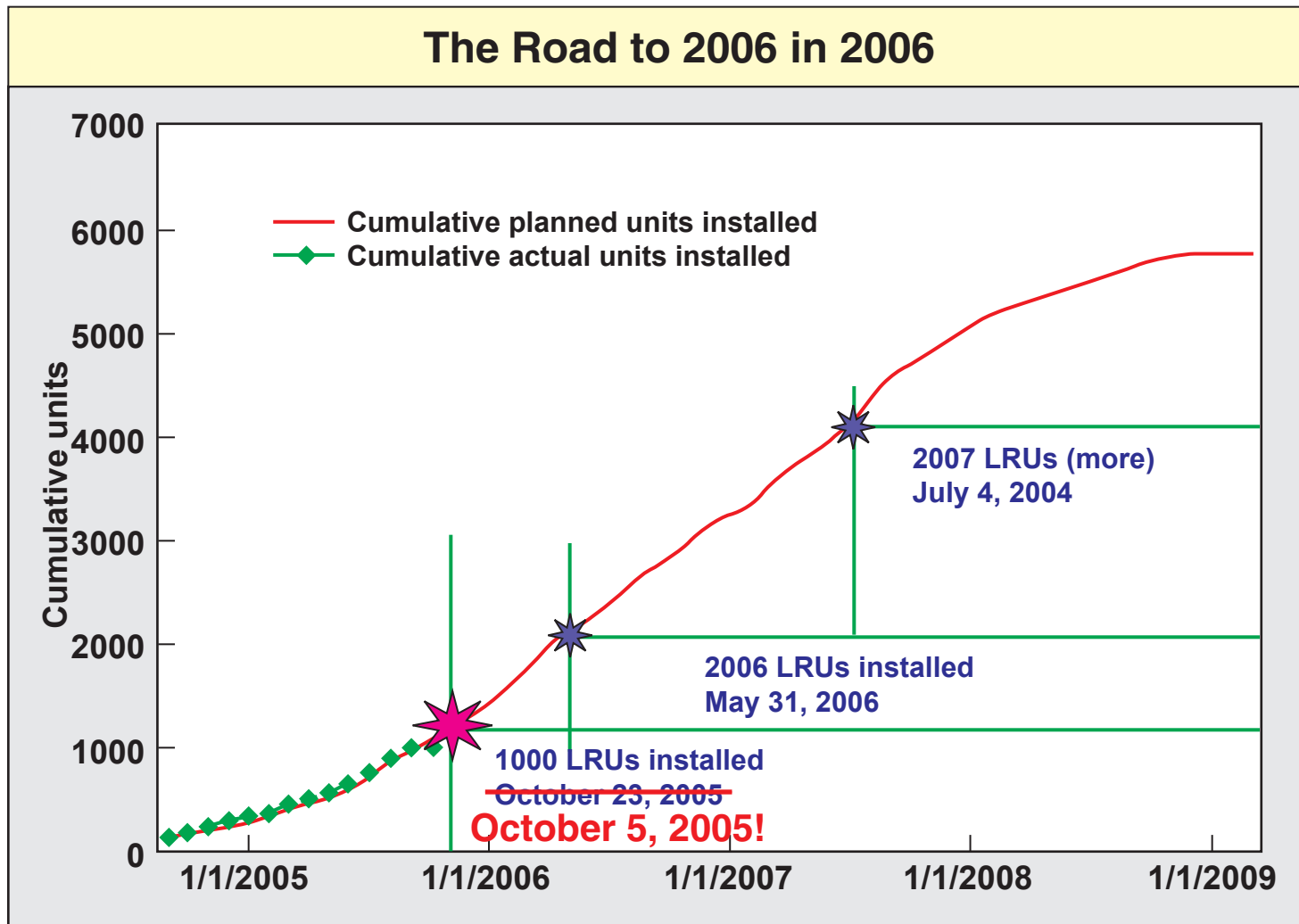


~900 LRUs installed to date

Major part of project completion is building, installing, and commissioning LRUs



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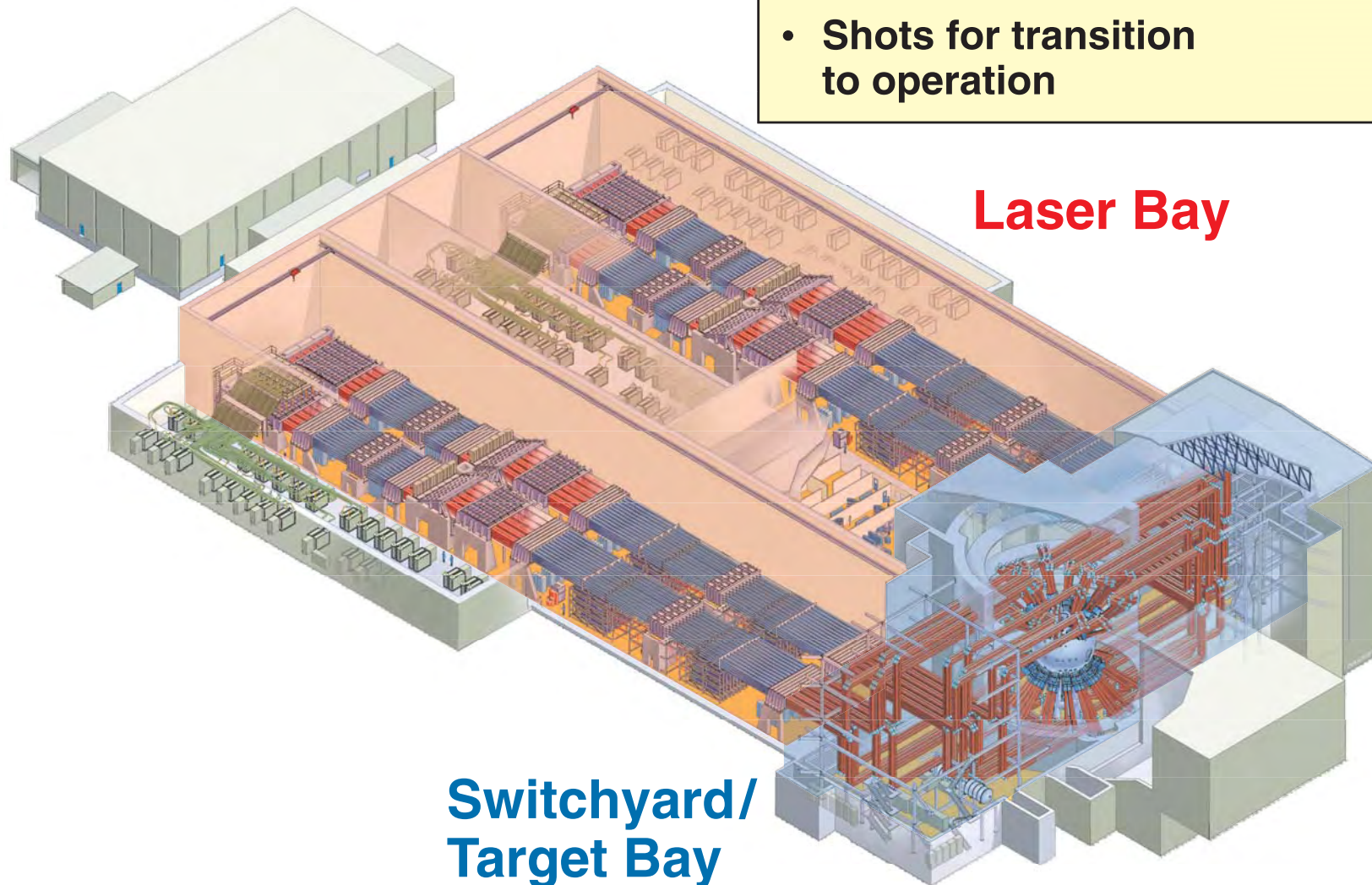
1,000 LRUs were installed by October 5, 2005

Present NIF Project completion approach



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- Laser and then SY/TB project
- Shots for transition to operation



Project rebaselining was driven by FY05 Budget Process & Congressional Language



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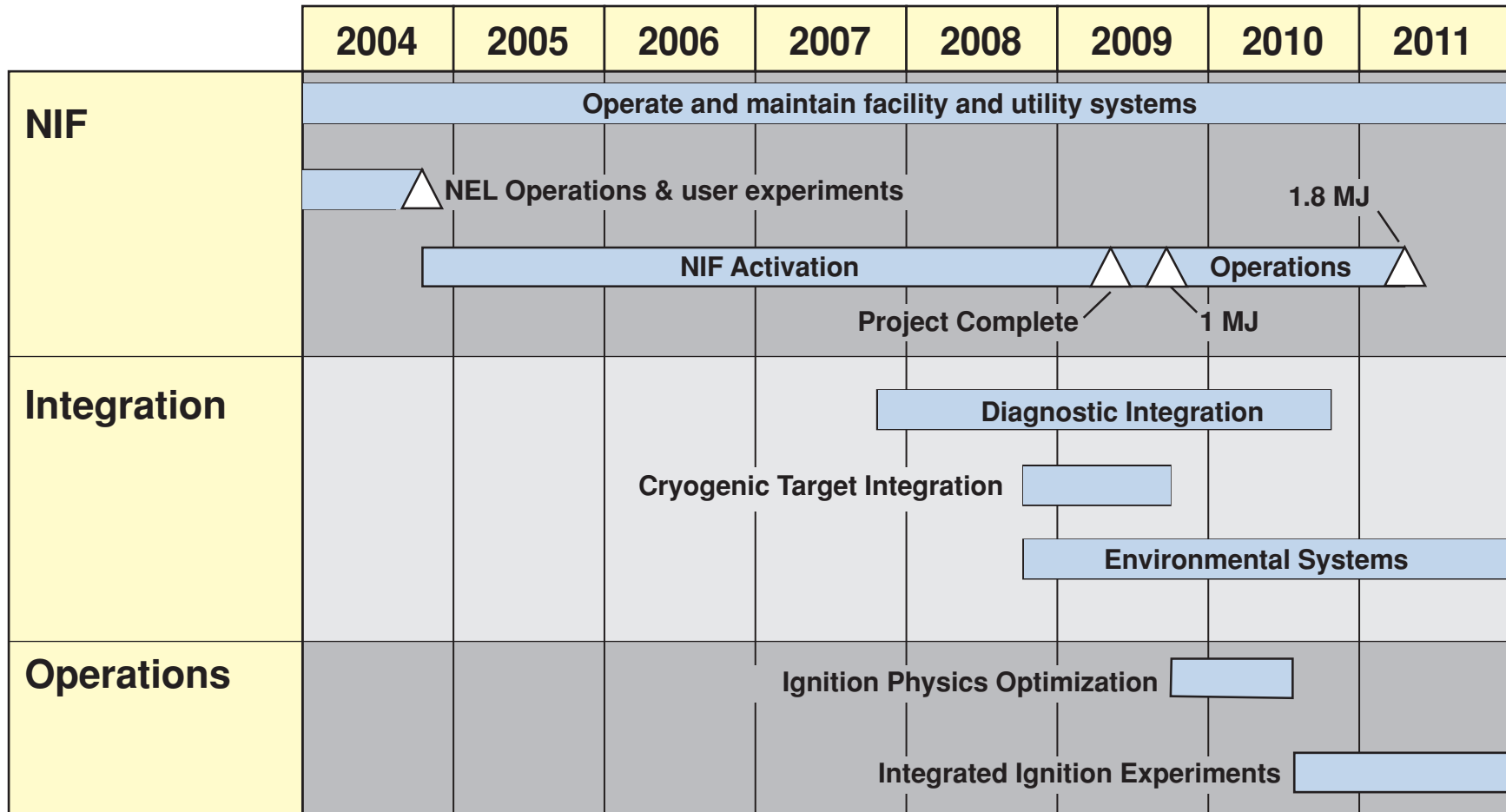
- **Pre FY05 Strategy**
 - **Complete First Cluster**
 - **Continue with experiments w/First Cluster, while building out the rest of machine**

- **Current Strategy**
 - **Head toward Ignition in 2010 ASAP**
 - **Complete build out of Laser**
 - **Fill 92 1ω beamlines**
 - **Final Optics and Target Bay**

NIF Project and Ignition Campaign Integration Schedule



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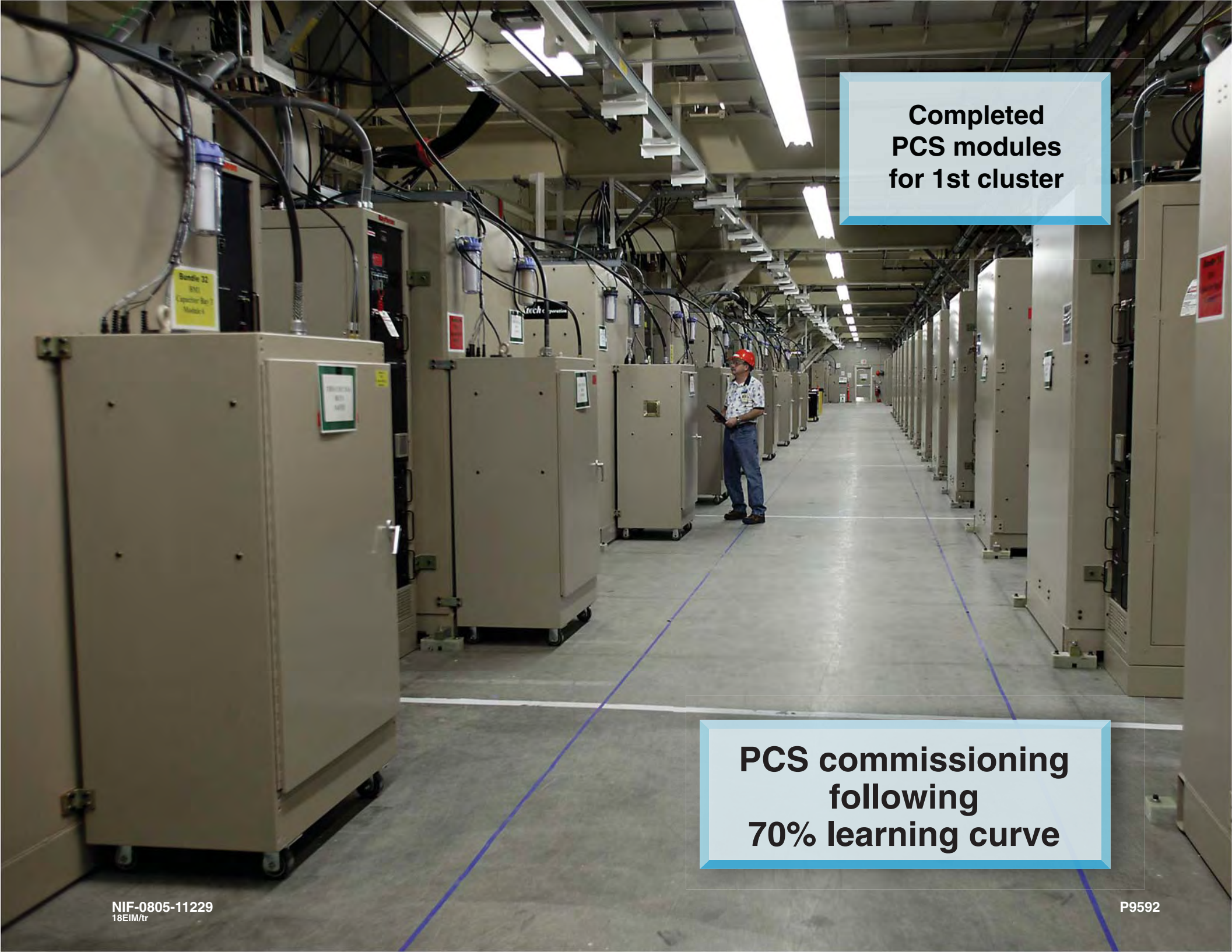
PAM Factory
9th and 10th
PAMs in factory
now

**~85% of
Crystals have
been grown**

PEPC Discharge



**Laser Glass
Melting
Complete**



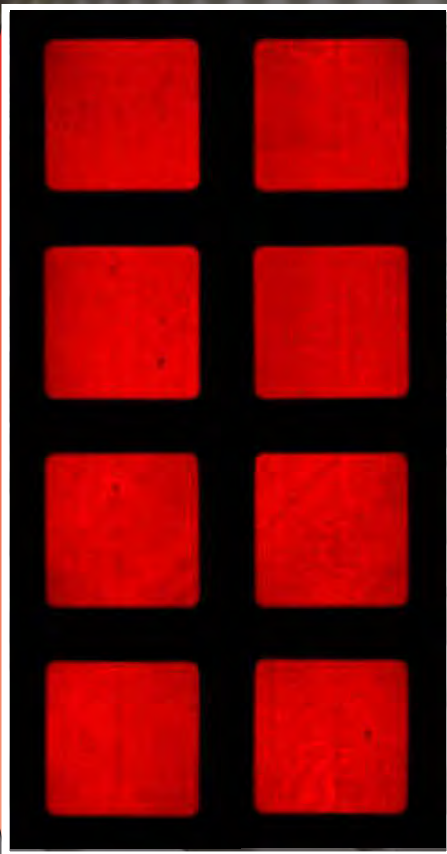
**Completed
PCS modules
for 1st cluster**

**PCS commissioning
following
70% learning curve**

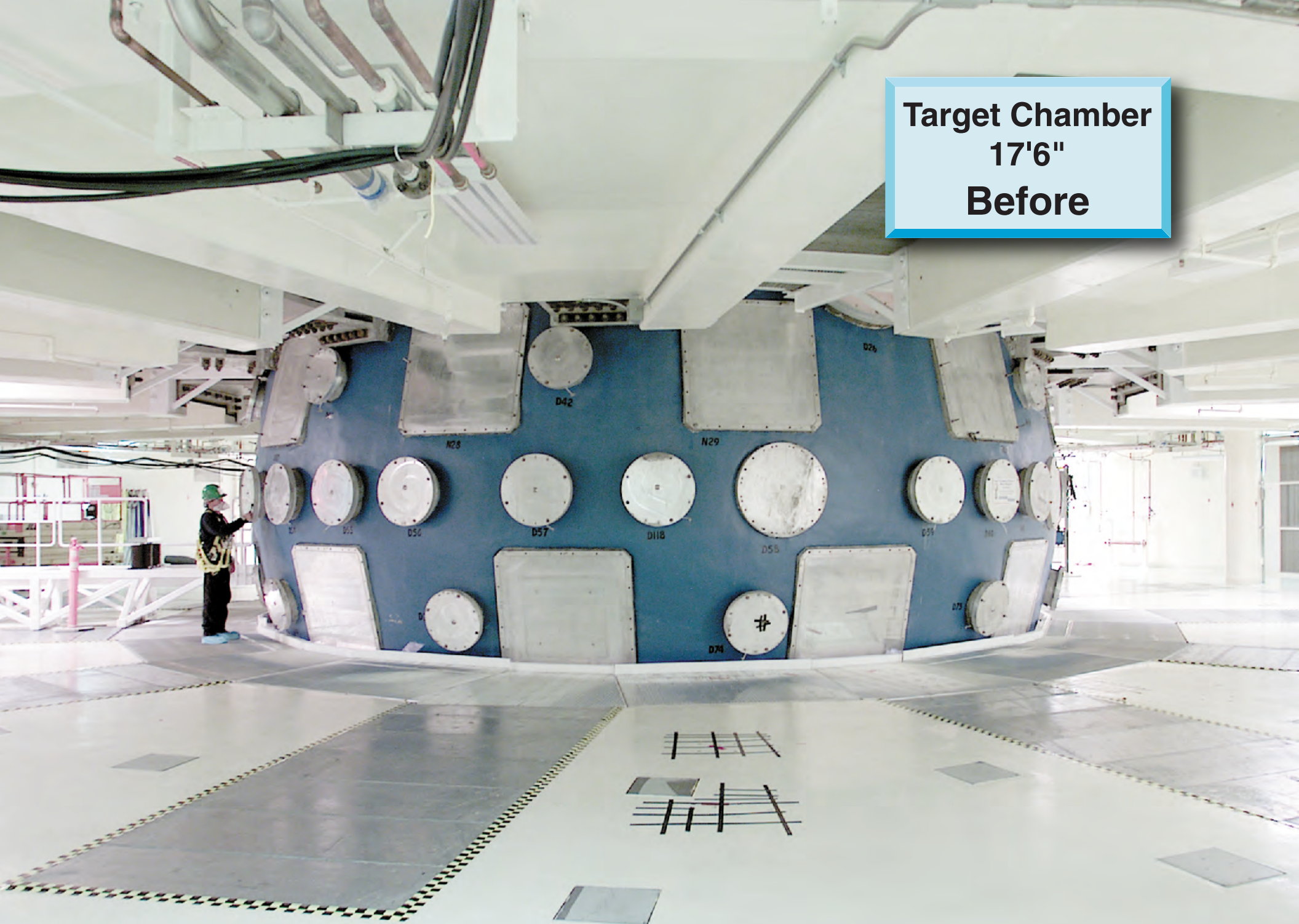
NIF Control Room Controls Metrics



Completed One
Bundle of Eight
Beams that
Produced 152 kJ

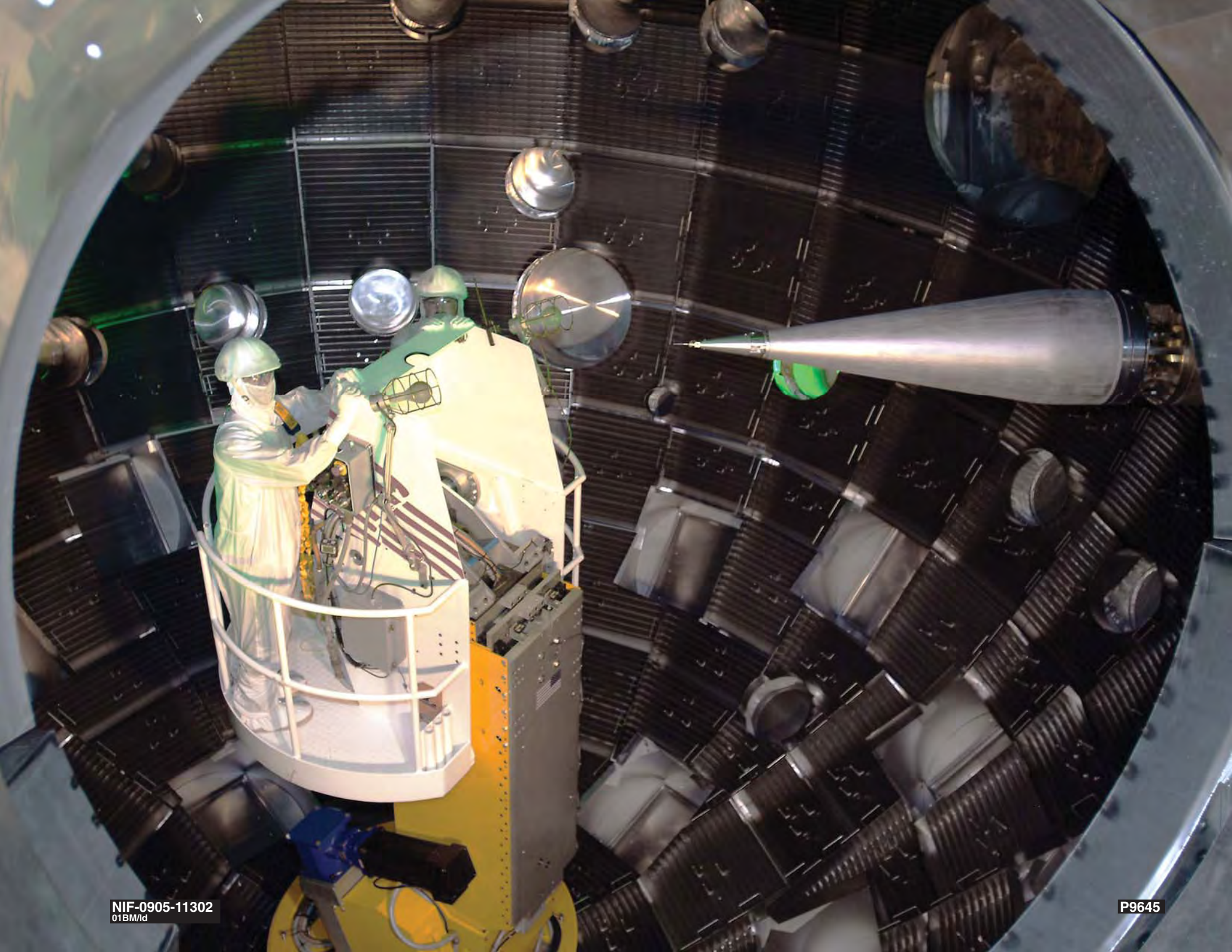


**Target Chamber
17'6"
Before**



**Target Chamber
17'6"
After**



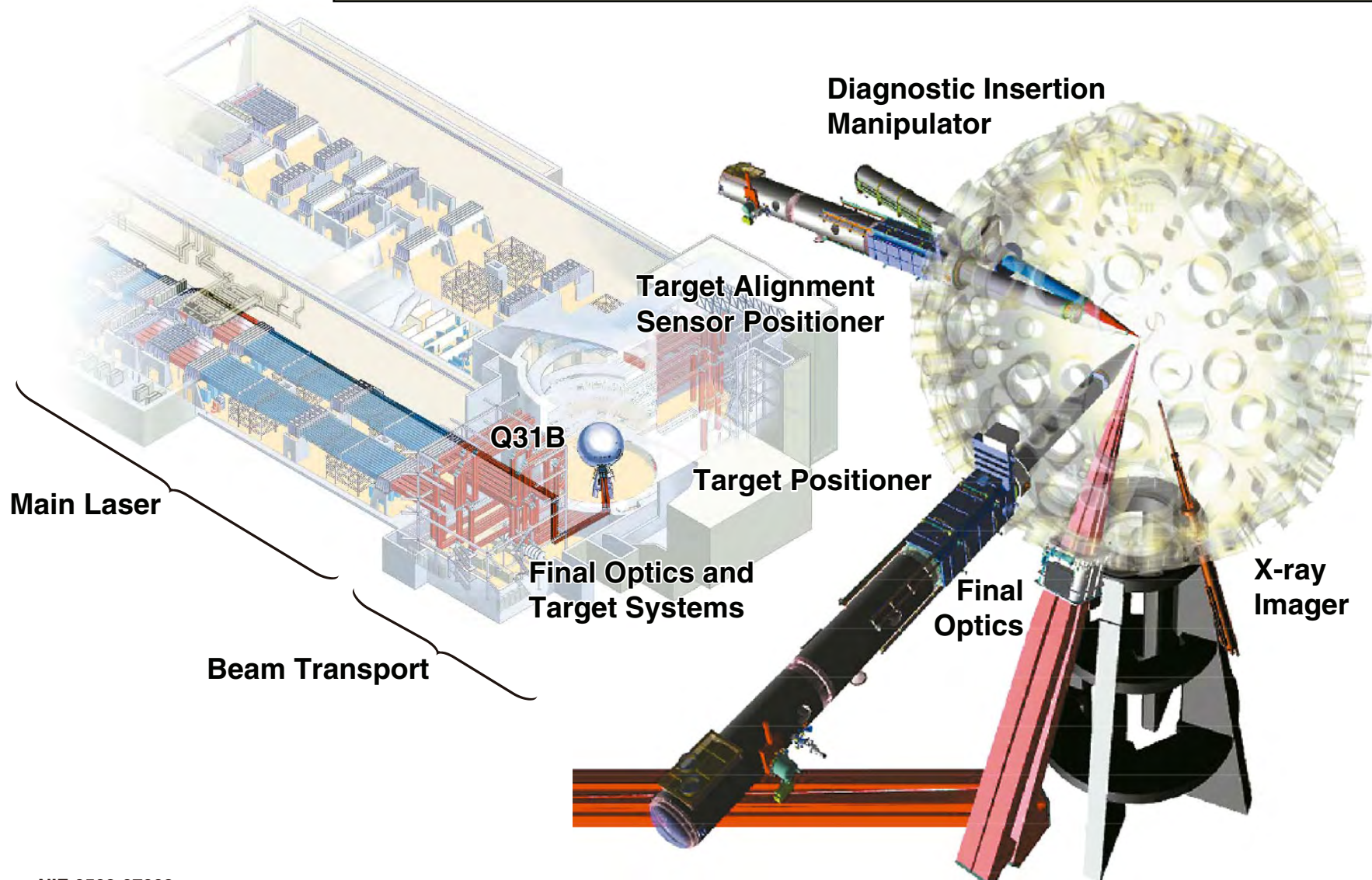


NIF-0905-11302
01BM/ld

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The first four NIF beamlines have been commissioned to the center of the target chamber

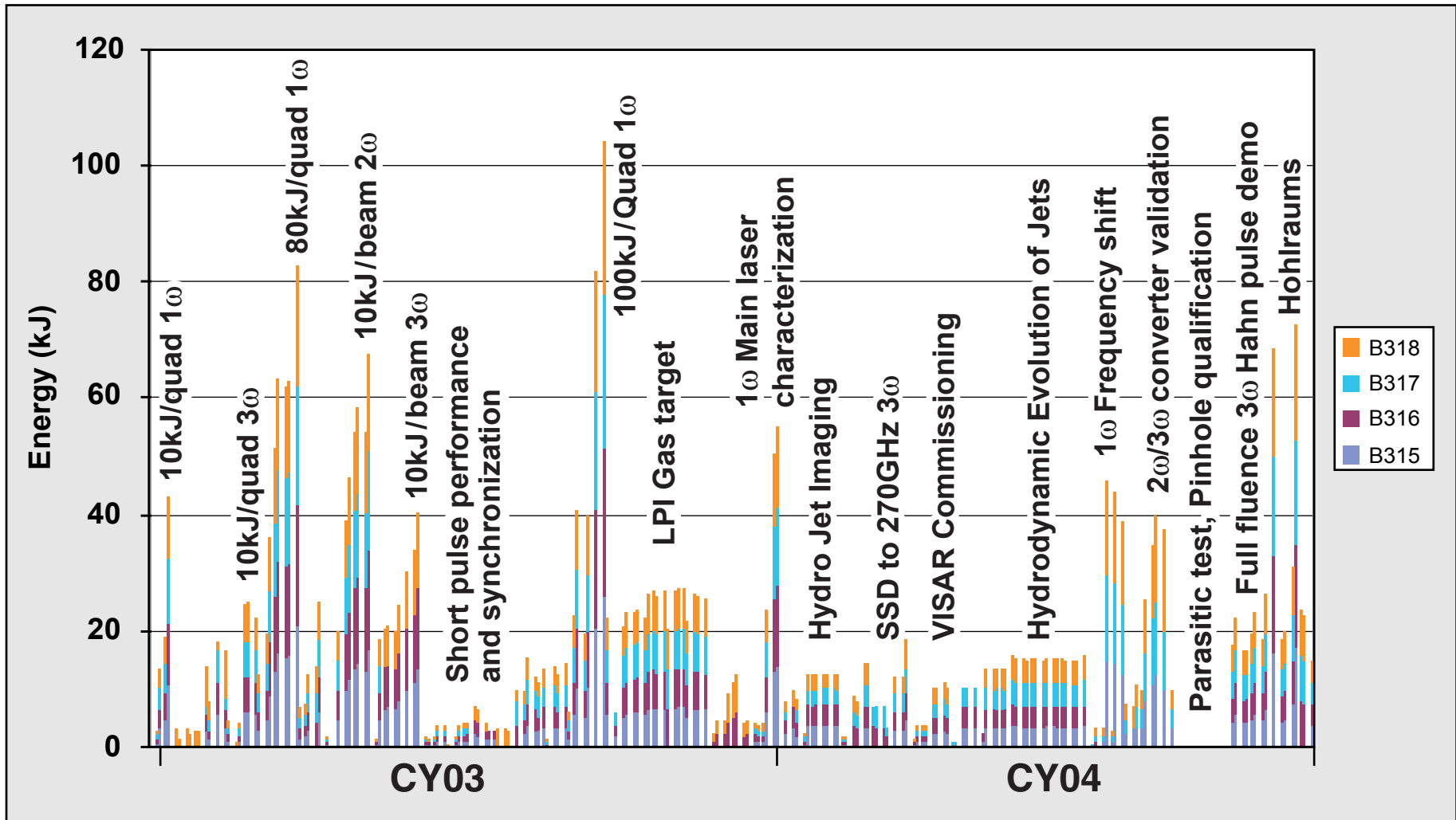
End-to-end functionality of all major subsystems demonstrated



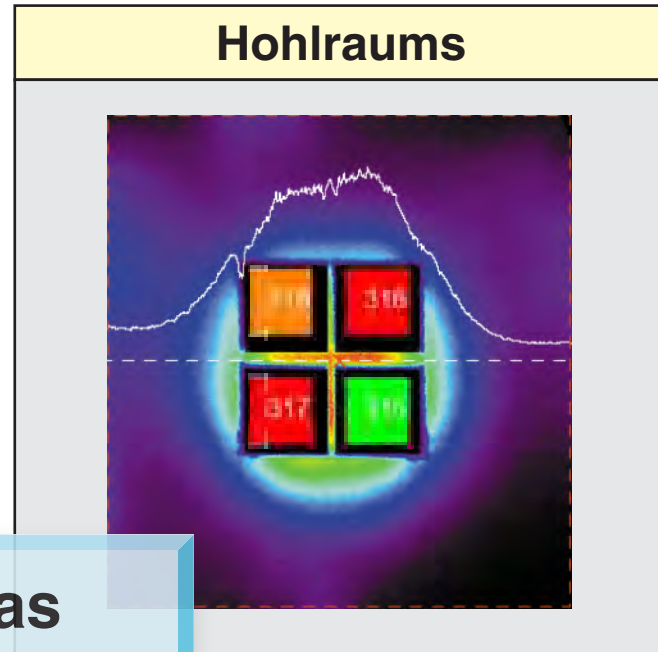
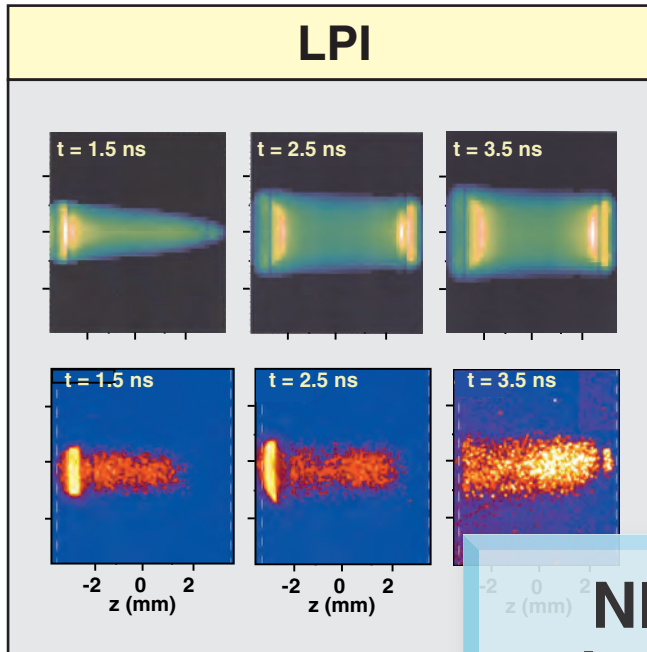
We have taken data on over 400 shots on NIF's first quad



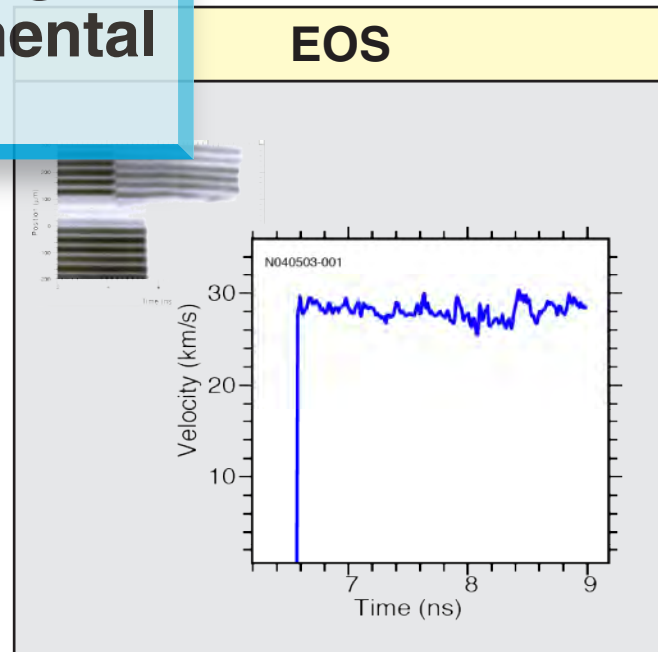
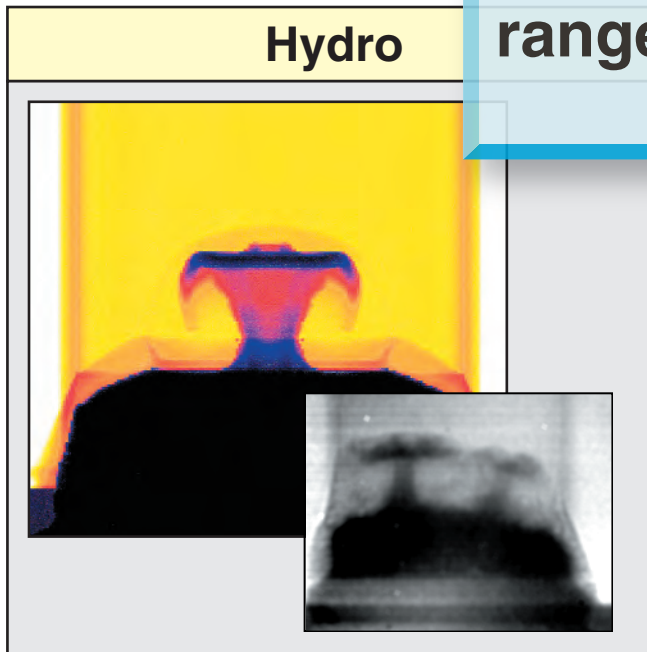
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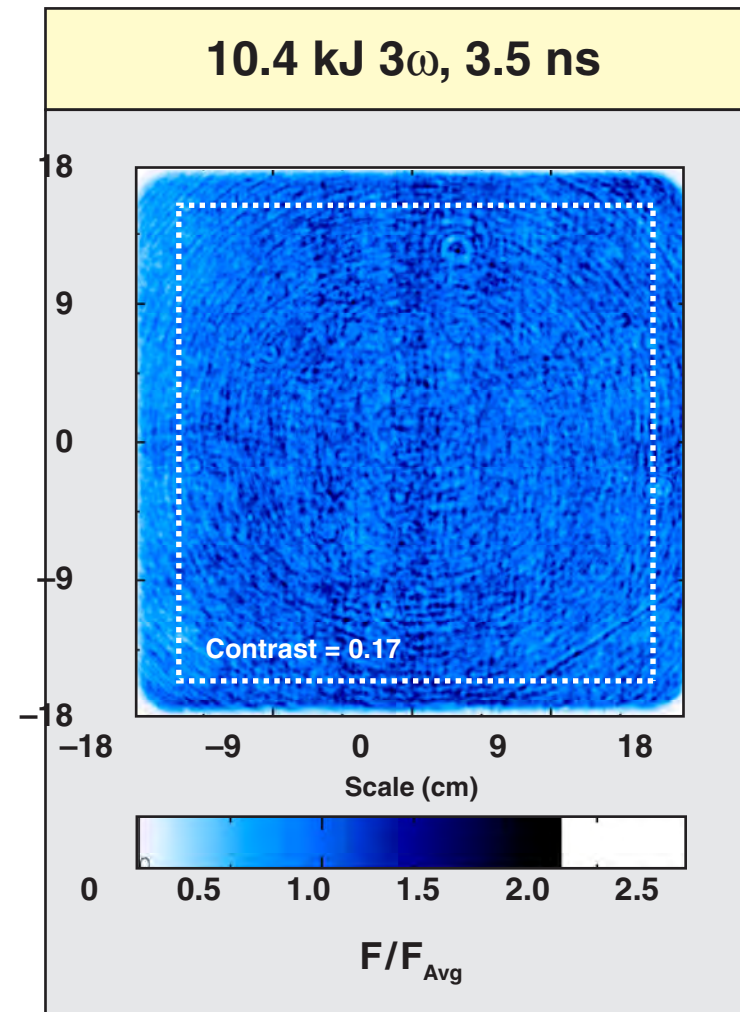
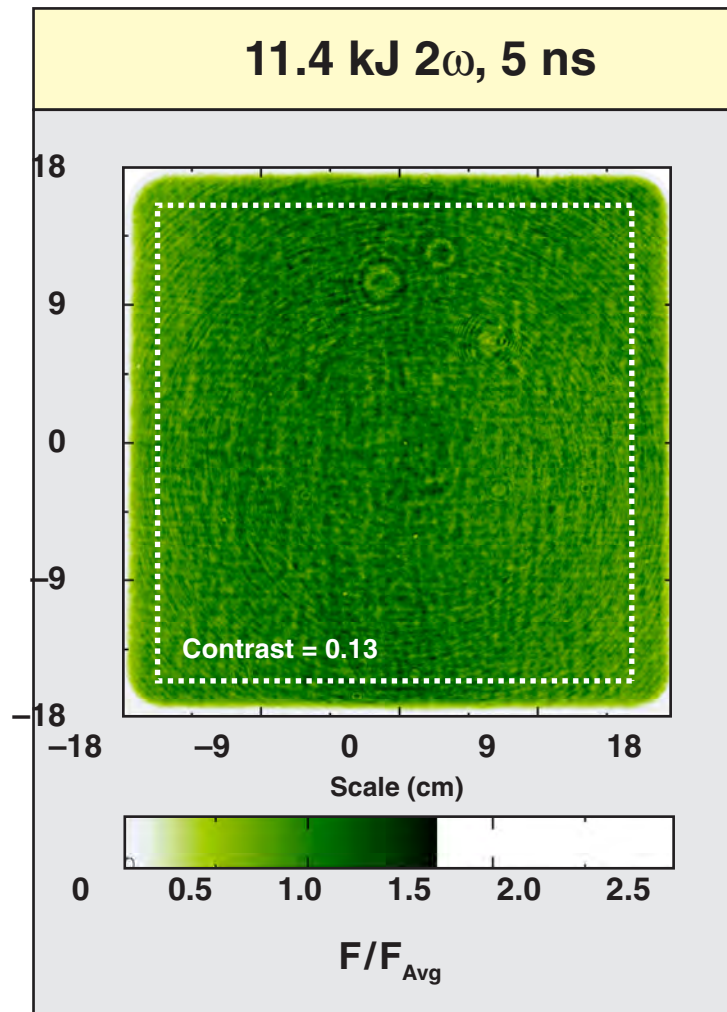
NIF operations have supported a variety of users and covered a wide operational range



NIF already has developed a large range of experimental capabilities



2ω and 3ω beamline energies are highest ever achieved

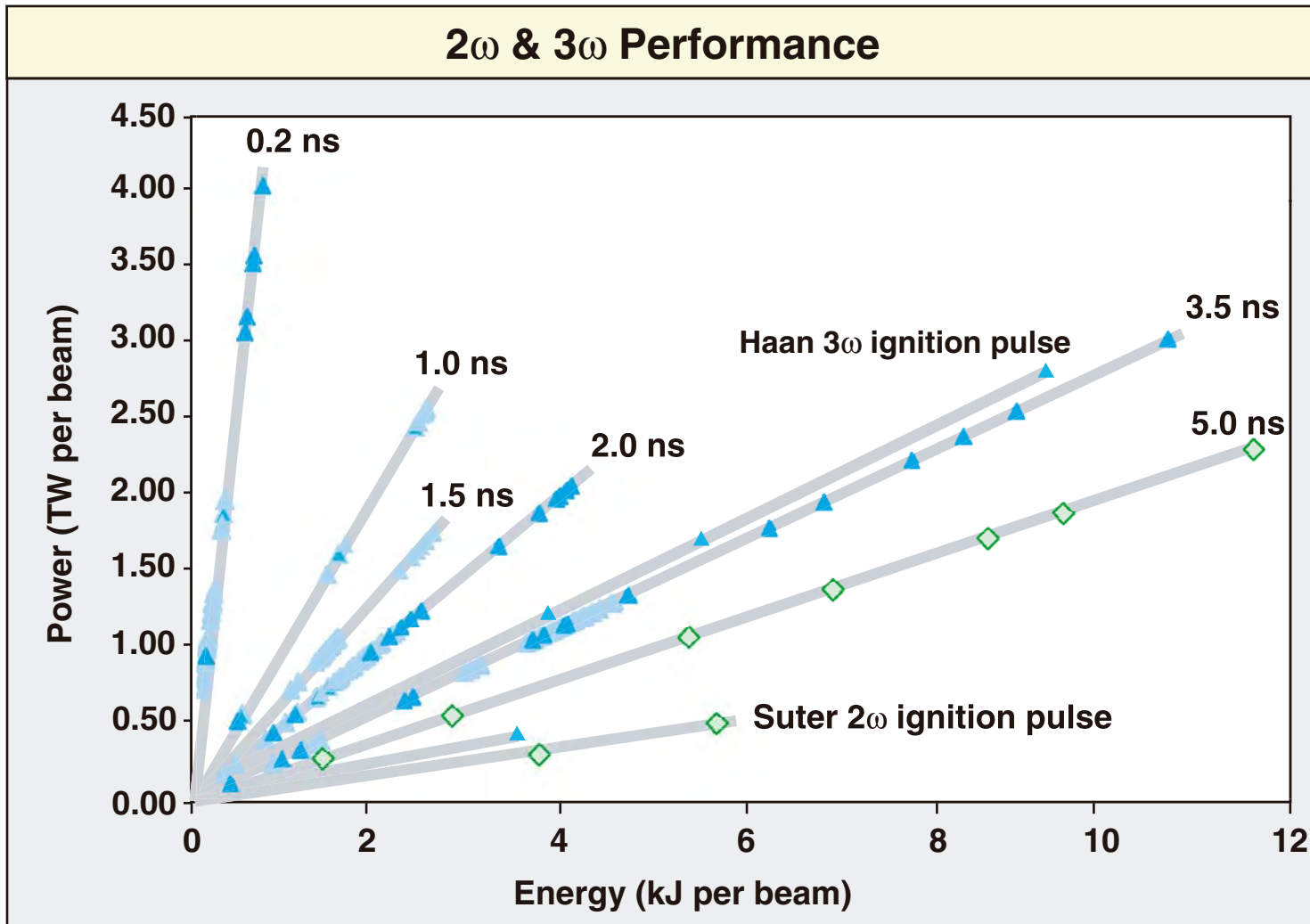


NIF Completion Criteria as well as Functional Requirements and Primary Criteria have been demonstrated on a single beamline at 3ω

2 ω and 3 ω performance



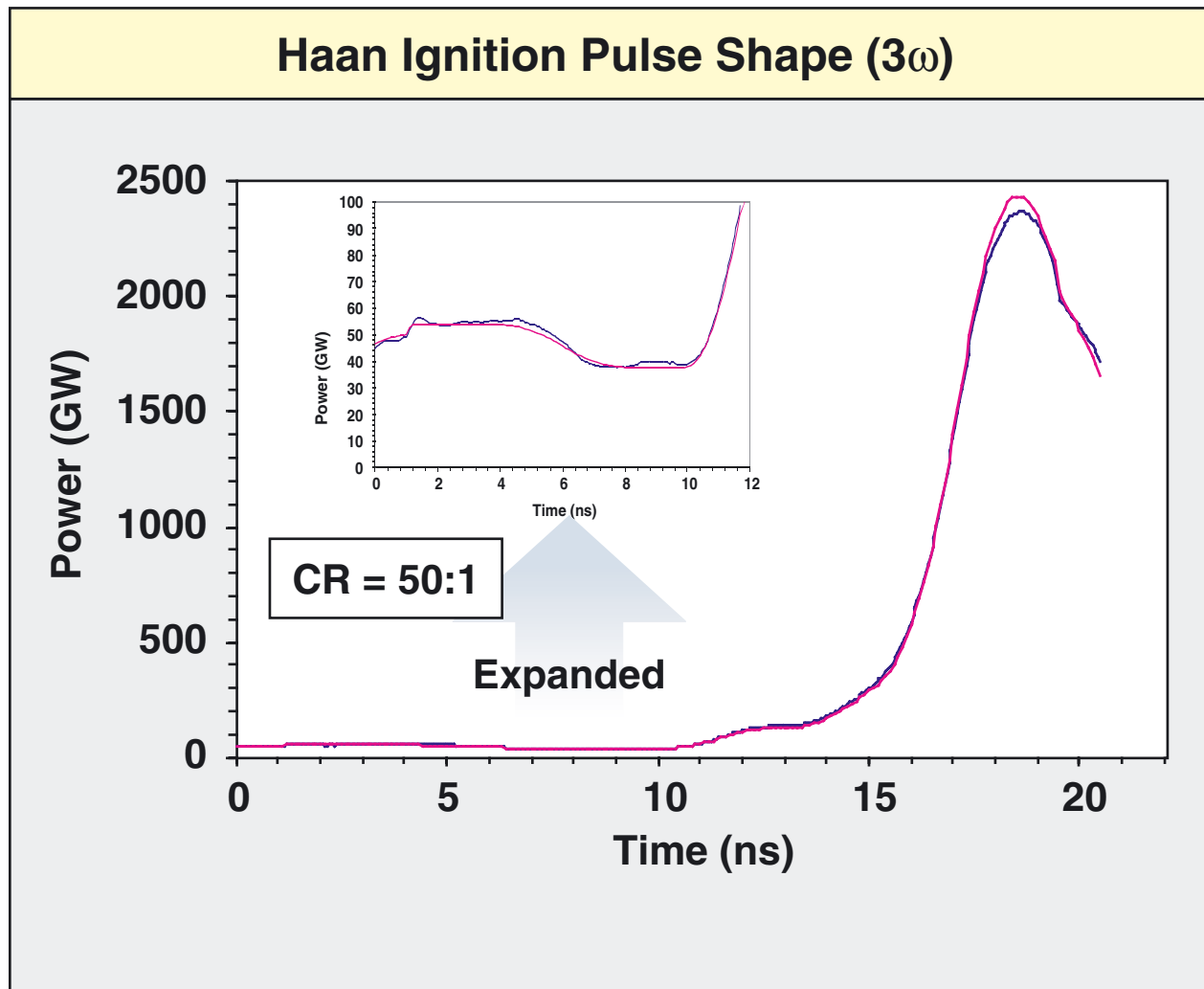
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A wide range of pulse shapes have been produced: Haan Ignition Pulse

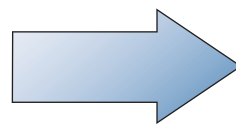
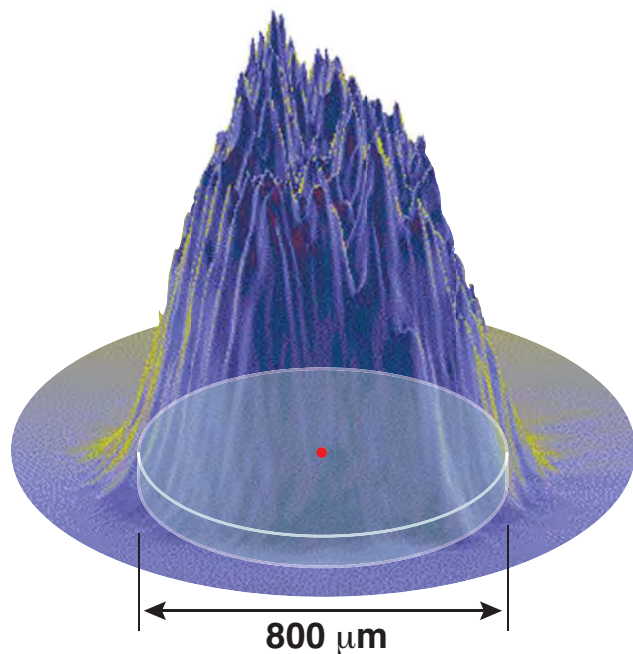


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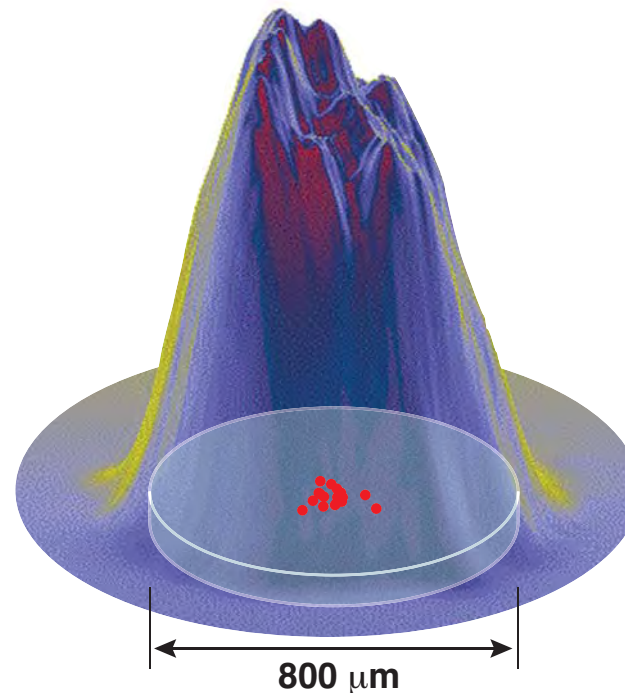


NIF pointing requirement ($<50 \mu\text{m}$ RMS) was demonstrated in June '04 Hydro Campaign

Single Shot



17 Shot Average

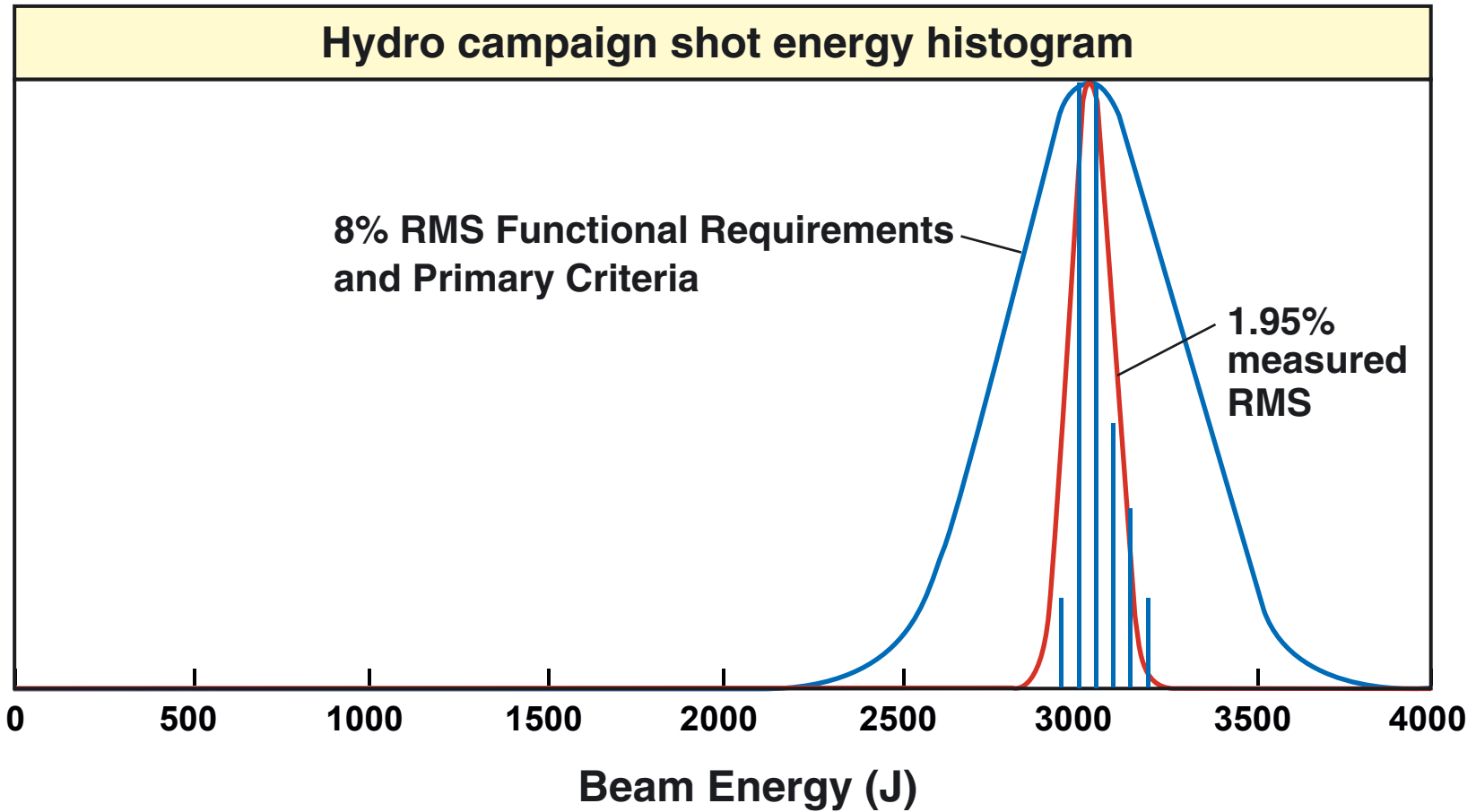


- 17 shot pointing deviation is 30 μm RMS
 - Better than NIF FR & PC pointing requirement of 50 μm RMS

NIF energy repeatability (<2% rms) supports power balance primary criteria



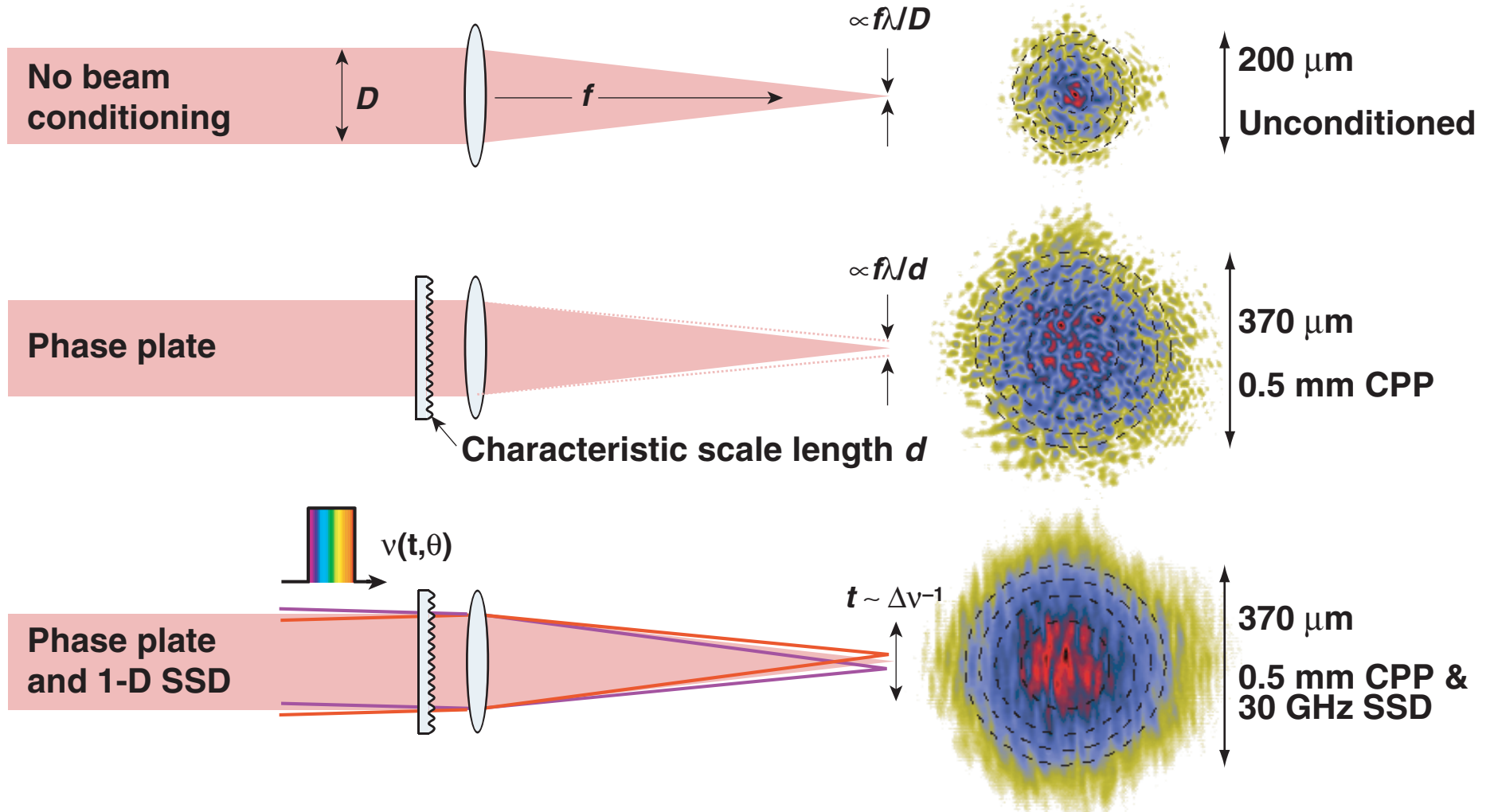
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Measured RMS deviation of 1.95% is a small fraction of 8% power balance requirement

Beam conditioning concepts were also tested using NIF's first 4 beams

Measured 3ω focal spot



In addition Polarization Smoothing was demonstrated

NIF Project Completion Criteria: Laser Performance

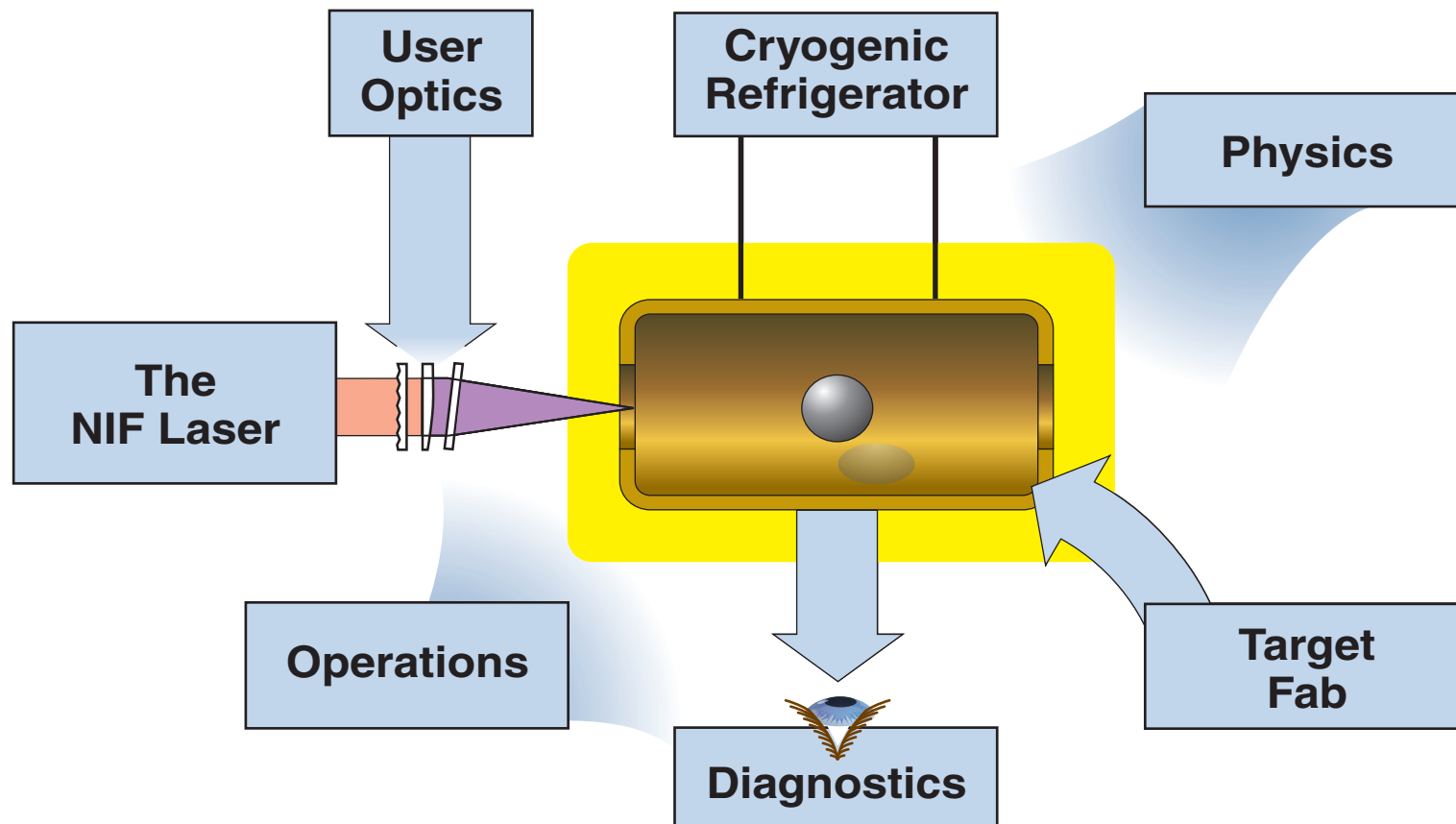


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Specification	Single Bundle Performance	96 Beam Performance	Current Beamline Status
Pulse Energy	75 kJ (83 kJ)	500 kJ (1000 kJ)	✓
Peak Power	21 TW (32 TW)	200 TW (400 TW)	✓
Wavelength	.35 μm (.35 & .53 μm)	.35 μm (.35 & .53 μm)	✓
Positioning Accuracy	100 μm RMS (30 μm)	100 μm RMS (30 μm)	✓
Pulse Duration	20 ns (0.2 – 23 ns)	20 ns (0.2 – 23 ns)	✓
Pulse Dynamic Range	50:1 (108:1)	>25:1 (108:1)	✓
Pulse Spot Size	600 μm (140 – 750 μm)	600 μm (140 μm – 750 μm)	✓
Pre-pulse power	$<4 \times 10^6$ W/cm ² ($<<4 \times 10^6$)	$<10^8$ W/cm ² ($<<10^8$ W/cm ²)	✓
Cycle Time	8 hours max between full system shots (<4 h)	8 hours max between full system shots (<4 h)	✓

- NIF has fired over 400 full system shots
- On a beamline basis, NIF has demonstrated operation at:
 - All Project Completion Criteria
 - Long-term Functional Requirements and Primary Criteria

The next experimental challenge is a demonstration of ignition on NIF



Our plan for 2009–2010 concentrates on systems integration and executing a credible ignition campaign

NIF Status



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- NIF has demonstrated its performance specifications on early beams
- The facility will be completed in 2009
- Ignition baseline innovations make it significantly more robust
- The systems to support ignition including cryogenic targets, high reliability diagnostics, and user optics have been demonstrated and will be deployed for a 2010 campaign

NIF will be a high class experiment facility capable of supporting precision High Energy Density Experiments