The National Ignition Facility,

The National Ignition Campaign
and Beyond

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NIF is 705,000 square feet
- 192 Beams
- Frequency tripled Nd glass
- Energy 1.8 MJ
- Power 500 TW
- Wavelength 351 nm
- 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
- 10,400 slabs melted
- 430 tonnes of ultra-high purity glass

Partners: Hoya, Schott
- 16 glass slabs with 54 equivalent passes
- Output energy/beam 
  ~25 kJ
- Aperture size ~35 cm
Design goals for 1(ω) energy and power exceeded with high overall beam quality.
Completed 2 Bundles of 8 Beams each that Combined Produced 300 kJ at $1\omega$

NIF is now the most energetic pulsed laser
$2(\omega)$ and $3(\omega)$ beamline energies are highest ever achieved

11.4 kJ $2(\omega)$, 5 ns

Contrast = 0.13

Scale (cm)

$F/F_{\text{Avg}}$

10.4 kJ $3(\omega)$, 3.5 ns

Contrast = 0.17

Scale (cm)

$F/F_{\text{Avg}}$

NIF functional requirements and primary criteria have been demonstrated on a single beamline at $3(\omega)$
1.8 MJ NIC ignition point design, energy, power, pulse shape & beam smoothing were achieved simultaneously.
The first LPI experiments on NIF have demonstrated propagation in NIF ignition scale plasmas

- Target
  - CO₂ filled gas pipe
  - 7 mm
  - 2.5x10^{15} W/cm²
  - 16 kJ in 3.5 ns
  - 3(0)

- 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 $3\omega$ pulse shape (N060302-001-999)
NIC ignition mission requires precise adjustment of features in the laser pulse

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

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
Both Bundles Meet All Performance Requirements
• Over 2 MJ equivalent in the ultraviolet
• 2 Bundles produce 300kJ @ 1ω

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

The goal of NIC is thermonuclear burn in the laboratory with a credible campaign in 2010.
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
National Ignition Campaign 2006

Edward I. Moses
Director, National Ignition Campaign
Major elements of the National Ignition Campaign

- User Optics
- Cryogenic Refrigerator
- The NIF Laser
- Operations
- Diagnostics
- Personnel and Environmental Protection System
- Target Fab
- Physics

NIF

NIC
NIF Indirect Drive target point design

- Laser beams in 2 rings
- Capsule (Be)
- LEH shield
- Laser entrance hole (LEH) with window
- Hohlraum wall:
  - High-z mixture (cocktail)
- Hohlraum fill
  - Low pressure He
- 1.0 mm
- Ablator (Be)
- DT Ice
- DT gas fill

Typical Pulse Shape $T_R$ (eV)

- Power (per beam TW)
- Time (ns)
Low Yield Diagnostics
($>10^{12}$ DD neutrons)
Magnetic Recoil Spectroscopy (MRS), $T_{\text{ion}}$ and $\rho_r$, 6 m (no vulnerable components)

10-20 keV core imaging, 20 m

$\gamma$-ray bangtime, 20 m

PROTEX, yield 20 m

Neutron Time of Flight $T_{\text{ion}}$ and $\rho_r$, 20 m

Neutron imaging hot spot and fuel asymmetry, 40 m

Activation, yield and $\rho_r$, ~30 m

NIC High Yield Diagnostics ($>10^{19}$ DT neutrons)
NIF/NIC Integration Schedule

30 Months Until The Beginning of Ignition Experiments on NIF
High-energy high-intensity missions define the laser requirements.
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

Laser 100 kJ, 5 ps
2 × 10^20 W cm^-2
50 kJ electrons
kT = 2 MeV
20 kJ protons
kT = MeV

Proton source foil protects rear surface from pre-pulse
Thickness limits conversion efficiency
High energy petawatts require minor beamline modification
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.
Omega EP will support both FI science (EP chamber) and integrated FI experiments (Omega chamber) – in FY09

<table>
<thead>
<tr>
<th>Short-pulse performance</th>
<th>Short-pulse Beam1</th>
<th>Short-pulse Beam 2</th>
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</thead>
<tbody>
<tr>
<td>Short pulse (IR)</td>
<td>1 to 100 ps</td>
<td>35 to 100 ps</td>
</tr>
<tr>
<td>IR energy on-target (kJ)</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Intensity (W/cm²)</td>
<td>$6 \times 10^{20}$</td>
<td>$\sim 4 \times 10^{18}$</td>
</tr>
<tr>
<td>Focusing</td>
<td>&gt;80% in 20 µm</td>
<td>&gt;80% in 40 µm</td>
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Is NIF a precursor to an Inertial Fusion Energy plant?

- **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

- 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

- 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

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

- 2025
  - IFE

- 2020
  - Direct Drive Ignition
  - Fast Ignition R&D
  - Diode pumped NIF beam line
  - IRE beam line demonstration

- 2015
- NIF Ignition Campaign

- 2005
  - Mercury – 100 J/10Hz

- 2000
  - NIF Early Light
NIF: Visions of yesterday become reality of today

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