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

September 28, 2006
Key points

• A new vision (Complex 2030) for the nuclear weapon complex and stockpile is being implemented
  • High energy density physics- essential piece of Defense Programs long term science and technology base
  • Logic: increase margin/uncertainty

• The next 10 years will offer extraordinary new opportunities for inertial fusion and high energy density physics
  • OMEGA EP; Z/ZR; NIF and ignition; petawatt capabilities;…
  • Ignition and applications planned for NIF; integrated program of “non-ignition” experiments to be conducted at OMEGA/ZR/NIF

• Federal government vision for high energy density physics under development- response to NAS reports and Senate mark (HEDP Office)
  • External use program at “intermediate scale” facilities
The nuclear weapon stockpile and complex will be transformed

Increased confidence in warhead designs and demonstration of a responsive infrastructure will enable a reduction in total stockpile size
NNSA short term commitments:

- Continue to deliver products to DoD.
- Eliminate backlog of surveillance units in FY 2007.
- Accelerate dismantlement of retired weapons by 49% from FY 2006 to FY 2007.
- Deliver B61-ALT357 First Production Unit (FPU) in FY 2006.
- Deliver W76 FPU in FY 2007.
- Certify the W88 with a new pit and manufacture 10 pits in FY 2007.
- Extract Tritium in FY2007.
- Support an RRW decision by the Nuclear Weapons Council in Nov 2006.
- Implement starting actions to achieve Complex 2030 infrastructure vision.
The plan for use of NIF calls for first ignition experiments in FY2010

<table>
<thead>
<tr>
<th></th>
<th>FY04</th>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operate and maintain facility and utility systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NEL Operations &amp; user experiments (NIF Early Light)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NIF Activation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project Complete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.8 MJ (MegaJoule)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 MJ (MegaJoule)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cryogenic Target Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diagnostic Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personnel &amp; Environmental Protection Systems Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ignition Physics Optimization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrated Ignition Experiments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HEDP* Experiments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Basic Science Experiments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Weapons physics experiments in support of Stockpile Stewardship
Both Bundles Meet All Performance Requirements

- Over 2 MJ equivalent in the ultraviolet
- 2 Bundles produce 300kJ @ 1\(\omega\)

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 Line-Replaceable-Unit installation progress through Sept. 26, 2006

Cumulative Planned Units Installed
Cumulative Actual Units Installed

FY05 FY06 FY07 FY08 FY09
NIF and ignition is a major Departmental commitment

The Secretary of Energy
Washington, DC 20585
November 18, 2005

The Honorable Pete V. Domenici
United States Senate
Washington, D.C. 20510-6050

Dear Senator Domenici:

I want to follow up our recent phone conversation regarding the Department of Energy’s (DOE) national security programs and the role that the National Ignition Facility (NIF) and the Dual-Axis Radiographic Hydrotest (DARHT) play in these programs. The DOE Stockpile Stewardship Program, including our scientific tools, is vital to the continued certification and assessment of the nuclear weapons stockpile without the need for underground nuclear testing. There are two projects in particular that I would like to highlight.

Proceeding with the National Ignition Facility is essential to the success of the Stockpile Stewardship Program. NIF is the only facility capable of creating the extreme conditions of temperature and pressure required for fusion ignition and other experiments that support stockpile stewardship. I visited the NIF site at Lawrence Livermore National Laboratory, and I have concluded that NIF ignition and the experimental campaigns planned for NIF will yield vital data necessary to maintain our nuclear deterrent. NIF remains a top priority for the Department.

The DARHT Facility at Los Alamos National Laboratory is another project that has my attention and support. I know DARHT is already producing results important to stockpile stewardship and that its capabilities will increase significantly when the two-axis hydrodynamic capability is established in Fiscal Year 2008. While there have been cost and schedule concerns at DARHT in the past, the Department is resolved to complete the project on the revised baseline.

Thank you for your continued support for these vital national security programs. I look forward to working with you to complete these important facilities. If you have any questions on these important DOE initiatives, please contact me or Ms. Jill Sigal, Assistant Secretary for Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Samuel W. Bodman
The OMEGA EP laser beams will be located next to the existing OMEGA facility.

### Short-pulse performance

<table>
<thead>
<tr>
<th>Short-pulse performance</th>
<th>Short-pulse Beam 1</th>
<th>Short-pulse Beam 2</th>
</tr>
</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>
</tr>
</tbody>
</table>
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 hv 9 - 25 keV
  - integrated FI experiments on ZR

- The ZR and Z-Petawatt facilities will begin operations in 2007.
The last Z shot was July 26, 2006; refurbishment is in progress.

- Remove existing hardware (7/27/06 – 8/23/06)
- Remove existing oil/water wall (8/24/06 – 9/18/06)
- Install new hardware (start expected late October)
- Construct new oil/water wall and reinforce floor structures (9/19/06 – present)

<table>
<thead>
<tr>
<th>Feb-02</th>
<th>Aug-02</th>
<th>Sep-04</th>
<th>May-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD0</td>
<td>CD1</td>
<td>CD2/3a</td>
<td>CD3b</td>
</tr>
</tbody>
</table>

- plan and develop architecture
- design and fabricate Z20 module
- operate Z20 & develop project baseline
- design and fabricate components
- install and test

MAS: 9/26/06
High Average Power Laser Program is a Congressionally funded program within NNSA

Review report from OFES/NNSA review of NRL FTF program to be available shortly
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.
## ICF Program FY2007 Budget Status

<table>
<thead>
<tr>
<th>MTE</th>
<th>FY06 Approp</th>
<th>FY07 Presid</th>
<th>FY07 House</th>
<th>FY07 Senate</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1 Ignition</td>
<td>74,859</td>
<td>79,763</td>
<td>79,763</td>
<td>69,763</td>
</tr>
<tr>
<td>10.2 Stock Sup</td>
<td>19,673</td>
<td>5,872</td>
<td>5,872</td>
<td>25,872</td>
</tr>
<tr>
<td>10.3 Diagnostics</td>
<td>42,578</td>
<td>45,959</td>
<td>55,959</td>
<td>42,578</td>
</tr>
<tr>
<td>10.4 Pulse Power</td>
<td>10,902</td>
<td>10,603</td>
<td>10,603</td>
<td>10,603</td>
</tr>
<tr>
<td>10.5 Universities</td>
<td>7,623</td>
<td>8,903</td>
<td>8,903</td>
<td>0</td>
</tr>
<tr>
<td>10.7 Targets &amp; Ops</td>
<td>63,977</td>
<td>43,021</td>
<td>58,021</td>
<td>53,021</td>
</tr>
<tr>
<td>10.8 Inertial Fusion</td>
<td>47,520</td>
<td>0</td>
<td>40,000</td>
<td>0</td>
</tr>
<tr>
<td>10.10 Petawatt</td>
<td>34,650</td>
<td>2,213</td>
<td>14,213</td>
<td>0</td>
</tr>
<tr>
<td>10.9 Demo</td>
<td>101,307</td>
<td>143,438</td>
<td>143,438</td>
<td>129,000</td>
</tr>
<tr>
<td>NIF Construction</td>
<td>140,494</td>
<td>111,419</td>
<td>111,419</td>
<td>81,419</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>543,583</strong></td>
<td><strong>451,191</strong></td>
<td><strong>528,191</strong></td>
<td><strong>412,256</strong></td>
</tr>
</tbody>
</table>
Federal vision for basic HEDP is under development

OSTP chartered interagency task force (C. Keane, D. Kovar, chairs) will produce report by end of CY2006
Key points

• A new vision (Complex 2030) for the nuclear weapon complex and stockpile is being implemented
  • High energy density physics- essential piece of Defense Programs long term science and technology base
  • Logic: increase margin/uncertainty

• The next 10 years will offer extraordinary new opportunities for inertial fusion and high energy density physics
  • OMEGA EP; Z/ZR; NIF and ignition; petawatt capabilities;…
  • Ignition and applications planned for NIF; integrated program of “non-ignition” experiments to be conducted at OMEGA/ZR/NIF

• Federal government vision for high energy density physics under development- response to NAS reports and Senate mark (HEDP Office)
  • External use program at “intermediate scale” facilities
Backups
The objectives of the ZR Project are to extend Z’s life in a balanced way and to exercise SNL’s pulsed power research and engineering capabilities for future endeavors.
The major ICF facilities provide unique capabilities

- **NIF (2010)**
  - Ignition and burn
  - Highest temperatures
  - Highest pressures

- **OMEGA EP (2007)**
  - Direct-drive ICF target physics
  - Fast ignition proof-of-principle

- **Z (2007)**
  - Magnetically-driven implosions
  - Highest precision equations of state
  - Weapons effects tests

Cost, availability, diagnostics, reproducibility, precision, and flexibility ultimately determine which facilities are used for specific experiments.
The revised NIF Project baseline completes in Q2FY2009 and supports Ignition 2010

<table>
<thead>
<tr>
<th>Level 0</th>
<th>FY01</th>
<th>FY02</th>
<th>FY03</th>
<th>FY04</th>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Target Chamber Positioned
- Control Room Turnover
- LB2 Ready for Transporter
- PCS Installation Begins
- LB2, CL3 Beampath Installed
- 1st LB2 Flashlamp Installed
- OAB Operational
- TARPOS Installed
- 1st Light TCC
- 1st 100 Light (100kJ)
- SY2 Beampath Ready for Commissioning
- BiS Complete
- Complete LB1 Laser Light MPR
- Submit Final Safety Basis Document
- Submit Readiness Assessment Documentation
- Laser Glass Melting Complete
- Deliver LB Automated Bundle Shot Controls
- Deliver 80 kJ to Switchyard Calorimeters (single bundle)
- Deliver LD Multi-Dandle Controls
- Complete Single Bundle Performance Qualification in PRR
- Deliver One Cluster Integrated Controls
- First Cluster - Energy to Switchyard Calorimeters
- Second Cluster - Energy to Switchyard Calorimeters
- Complete LB LRU Installations
- Complete Performance Qualification of a Single Bundle at TCC
- Complete Operational Qualification of 90 Beams (Two Clusters at TCC)
- Complete Installation Qualification of all LRU's (192 beams)

- DOE Milestone Commitment Date
- Complotted Milestonea
High resolution x-ray backlighting is an important new diagnostic now in routine use on Z.

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
ICF FY 2005 Budget by Element

Total Budget = $536.7 M

- NIC: 42%
- Weapons Physics: 29%
- Pulsed Power: 7%
- University Grants: 7%
- Inertial Fusion Technology: 6%
- Petawatt Laser Development: 8%
- NIF Project: 1%

RTBF Z Operations – 11.8M
RTBF Z-backlighter laser – 13M
NIF Funding Profile

Dollars in Millions

FY01 FY02 FY03 FY04 FY05 FY06 FY07 FY08 FY09 FY10

TEC OPC MOD NDP O&M