High Energy Density Physics in the NNSA

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NNSA’s ICF program is undergoing a transition

- End of the National Ignition Campaign marks the end of construction and commissioning of major facilities.
- Transition of NIF and other ICF facilities to routine operations under new governance models.
- Increased focus of the NNSA ICF program on its Stockpile Stewardship Mission
- Sequestration and the FY 2014 President’s Budget Request
- NAS report on Inertial Fusion Energy
- Implementation of the 2012 Path Forward Report to Congress
- Basic science research to be concentrated at Omega as are direct drive ignition approaches
- Advancements in diagnostics and experimental techniques are producing stunning results
ICF facilities provide unprecedented environments for national security and fundamental science

60% of the ICF Program budget is applied to facility operations at NIF, Z, and Omega

- Research on indirect drive ignition
- Laser plasma instabilities
- Hydrodynamic instabilities
- Radiation hydrodynamics
- Materials at extreme conditions

- Research on polar drive ignition
- Diagnostics development
- Open science platform
- Focused experiments on scientific issues for ICF
- Platform development for NIF experiments

- Research on magnetically-driven ICF
- Dynamic material properties – including Pu
- Radiation effects
- Radiation hydrodynamics
- Radiation transport
The ICF Program is a critically important element of NNSA’s Stockpile Stewardship Program (SSP)

Ensure that the Nation’s nuclear weapon stockpile remains safe, secure, and effective without nuclear testing

- Last underground test occurred more than 20 years ago (9/23/1992)
- Our confidence relies in part on computer models validated against experimental data
- ICF Program provides unique and extreme High Energy Density (HED) environments for model validation
ICF Program has 5 principal elements

• Develop a robust burning plasma platform for the Predictive Capability Framework (PCF) of the SSP (Ignition is the first major step)

• Obtain fundamental physical properties of materials and plasmas in HED environments (in collaboration with Science Campaigns)

• Provide experimental data for computer model validation in the HED regime (in collaboration with the Advanced Scientific Computing Campaign)

• Develop and advance capabilities in HED Science

• Strengthen the HED community and grow the next generation of stewards
Path Forward planning led by “ICF Executives” comprised of 1 lead member from each ICF organization (LLNL, LANL, SNL, LLE, NRL, GA)

Working Groups responsible for detailed planning and implementation:
- Indirect Drive
- Polar Drive
- Magnetically-Driven ICF
- Diagnostics
- Targets
The NRC 2013 Report on Inertial Fusion Energy is consistent with the NNSA program

- “The appropriate time for the establishment of a national, coordinated, broad-based inertial fusion energy program within DOE is when ignition is achieved [Conclusion 4-13].”

The Target subcommittee report:

- “[t]he national program to achieve ignition using indirect laser drive has several physics issues that must be resolved if it is to achieve ignition [Conclusion 4-1].”

- “Based on its analysis of the gaps in current understanding of target physics and the remaining disparities between simulations and experimental results, the panel assesses that ignition using laser indirect drive is not likely in the next several years [Conclusion 4-2].”
## Budget Trends for the NNSA ICF Program

<table>
<thead>
<tr>
<th>Campaign</th>
<th>FY 2012</th>
<th>FY 2013 Annualized CR</th>
<th>FY 2014 Request</th>
<th>FY 2015 Request</th>
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</thead>
<tbody>
<tr>
<td>Ignition</td>
<td>109,888</td>
<td>84,172</td>
<td>80,245</td>
<td>73,638</td>
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<tr>
<td>Support of Other Stockpile Programs</td>
<td>0</td>
<td>14,817</td>
<td>15,001</td>
<td>17,358</td>
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<td>Diagnostics, Cryogenics and Experimental Support</td>
<td>85,654</td>
<td>81,942</td>
<td>59,897</td>
<td>56,835</td>
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<td>Pulsed Power Inertial Confinement Fusion</td>
<td>4,997</td>
<td>6,044</td>
<td>5,024</td>
<td>5,676</td>
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<tr>
<td>Joint Program in High Energy Density Laboratory Plasmas</td>
<td>9,100</td>
<td>8,334</td>
<td>8,198</td>
<td>9,498</td>
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<tr>
<td>Facility Operations and Target Production</td>
<td>264,845</td>
<td>269,691</td>
<td>232,678</td>
<td>204,836</td>
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<tr>
<td><strong>Campaign</strong></td>
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<td><strong>465,000</strong></td>
<td><strong>401,043</strong></td>
<td><strong>367,841</strong></td>
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The NIF Indirect Drive Ignition approach is shifting focus to experiments on the illumination of underlying physics issues

- Primary focus in FY 2013 has been on understanding and controlling capsule implosion symmetry.
- New x-ray sources developed for radiographic measurements demonstrate that implosion symmetry does not meet ignition requirements.
- Lower convergence higher adiabat implosions being pursued to establish “known knowns.”
  - A single shock exploding pusher (indirect drive) experiment demonstrated nearly 1D performance
  - Platforms (diagnostics, targets, operating protocols) to support a campaign of experiments using three shocks are being qualified
- Mix experiments are being developed
  - E.g. C (n,γ) reaction produces 4.1 Mev gamma that can provide a measure of ρho-R of ablator material mixed into dense fuel regions.

~120 scientists from around the world met to identify key missing understanding & path to resolve
Polar Drive experiments being pursued at LLE

- Polar Drive is an alternative for NIF ignition that would have a significant but manageable impact on NIF facilitization.
- Advantage is laser energy coupled to hot-spot.
- Disadvantage – uncertainties about LPI (preheat from two plasmon decay, and energy loss from cross beam energy transfer)
- Omega experimental effort vital to providing alternative views and peer review of NIF approaches and results.
MagLIF program being pursued at SNL Z-facility

By 2015 put capabilities in place for:

• applied magnetic fields of $>$20 Tesla,
• laser pre-heat energies $>$4 kJ,
• liner peak drive currents of $>$22 MA.
Workshop Report on Basic Research Directions at the NIF

Science of Fusion Ignition on NIF

NIF/Jupiter Users Group meeting – Feb 10-13, 2013

Omega Laser Users Group meeting – Apr 24-26, 2013

5th Fundamental Science with Pulsed Power: Research Opportunities & User Meeting – Aug 11-14, 2013

Selections made from the FY 2011 solicitations for the JPHEDLP and SSAA centers & contracts let

Proposals for the FY 2012 JPHEDLP solicitation under review

Selections for FY 2013-2014 NLUF solicitation completed
ICF budget justification relies on demonstrated relevance to current & future stockpile needs and continuous progress

• ICF facilities are providing data today that address long standing questions in the weapons program
• ICF provides the only path to a laboratory burning plasma platform and, when achieved, will add a significant new tool for SSP
• Significant progress continues to be made in understanding the physics and technology limiting the indirect drive approach to ignition
• Alternate approaches to ignition are advancing and provide robustness to single point failure
• The Path Forward describes a consensus plan for future activity

In NNSA’s opinion, ignition is the sine qua non for any Inertial Fusion Energy program
Summary

• Support of the stockpile stewardship program is highest priority
• Ignition not achieved but remains a principal goal of the ICF Program, and our understanding is increasing rapidly
• Alternate concepts to the mainline indirect drive approach are advancing
• HED facilities are operating well and are oversubscribed (by a lot)
• Vibrant HED community is recognized to be critical to the success of SSP
• ICF is an exciting grand challenge endeavor and remains a leading attractor for talent and the next generation of stewards