Department of Energy
United States of America

Progress and vision in the HED Sciences for national security

Presented by:

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Outline

- Some recent major accomplishments
- A strengthened planning basis
- The 2015 ICF/HED program review
- Federal partnerships with OFES and NCT
- Drivers for HED capability modernization

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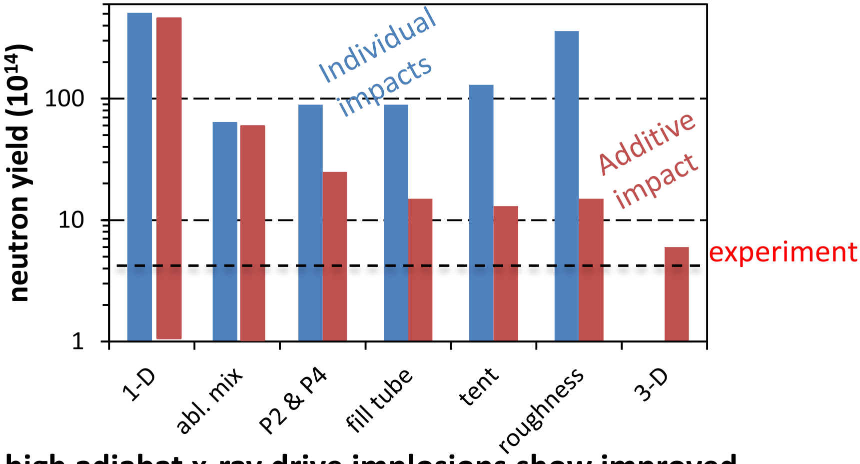
2014 was the most successful year to date at the National Ignition Facility

- Excellent data was obtained on the complex **evolution of hydrodynamic flows**
- New experimental techniques were developed and demonstrated to measure the **properties of materials at very high pressures and strain rates**
- Significant progress in inertial confinement fusion research was made, enabling **access to regimes that have been inaccessible** since the cessation of underground nuclear testing.
- In **support of broader national security** questions, tests exploring System Generated Electromagnetic Pulse (SGEMP) were performed.
- In support of **discovery science**, a team from U.C. Berkeley, Princeton University, and LLNL utilized the NIF to explore the behavior of carbon at fifty million times atmospheric pressure, to better understand the interior of giant planets, like Jupiter.
- NIF executed 191 experiments for users, **significantly exceeding** the 150 experiments outlined in the FY14 NIF Facility Use Plan.
- NIF developed a FY15 shot plan based on the recommendations of the 120-Day Study that calls for a **50+% increase** in experiments to over 300 experiments in FY15 assuming flat funding from FY14.

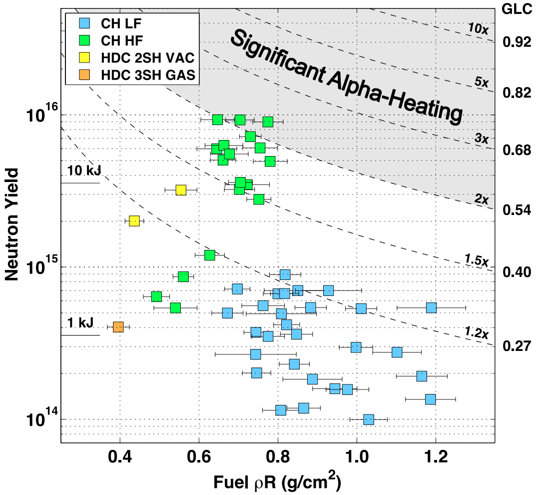
We are bringing our full capabilities to laboratory ignition at NIF

- Focused physics experiments have shown that multiple phenomena were degrading NIC implosion performance.
  - Incorporating these effects into full sphere 3D HYDRA simulations of NIF shot (N120321) reproduces the observed capsule yield to within 50% of the experimental value and matches other key parameters.
- Made progress on understanding ignition conditions with “High-foot”
  - Yield amplified ~ 2X due to alpha heating
  - Drive symmetry remains challenging.
- Ignition will require more demanding, higher convergence implosions further stressing:
  - <u>Symmetry</u>: new directions include diamond capsules in low LPI near vacuum hohlraums that have already exceeded NIC performance – more experiments needed to verify whether this is a viable ignition path
  - <u>Capsule stability</u>: Focused experiments have validated simulations of instability growth on the capsule surface enabling more stable designs to begin to be developed. Beryllium experiments have also begun.

3-D HYDRA simulation of NIC implosion



NIF high adiabat x-ray drive implosions show improved performance



“Low-foot” implosions

“High-foot” implosions

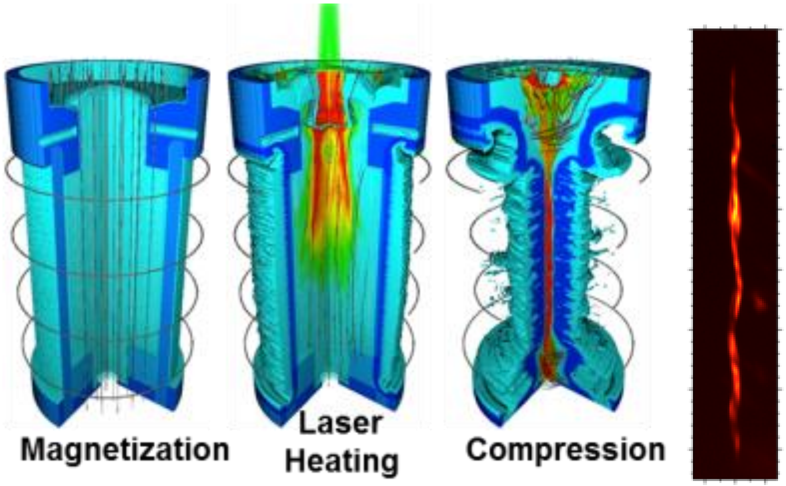
Diamond implosions

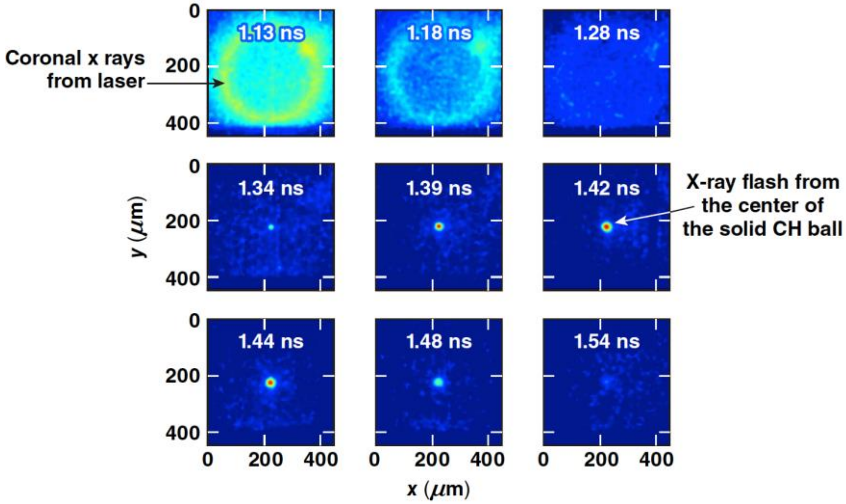
GLC: Generalized Lawson Criteria

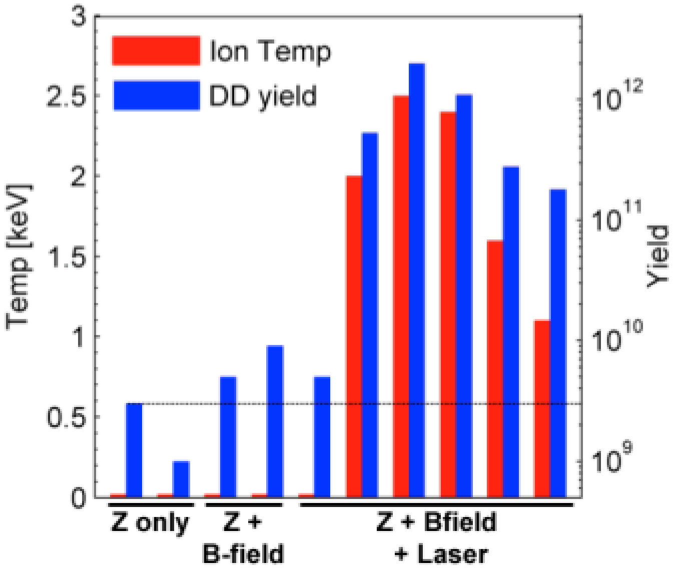
BLACK Text: NIF Shot Identifier, with date as YYMMDD

We are pursuing alternative approaches to indirectly-driven laboratory ignition

- First fully-integrated Magnetized Liner Inertial Fusion (MagLIF) experiments on Z successfully integrated target implosions, pre-magnetization, and laser pre-heating. Continuing to refine two-dimensional simulation designs for MagLIF to understand today's results on Z.
- Double and triple pickets were used to implode direct-drive cryogenic deuterium-tritium targets and had opacity consistent with no ablator mix. The inferred ablation pressures from Omega spherical strong- shock experiments exceed the 300 Mbar required for shock ignition.

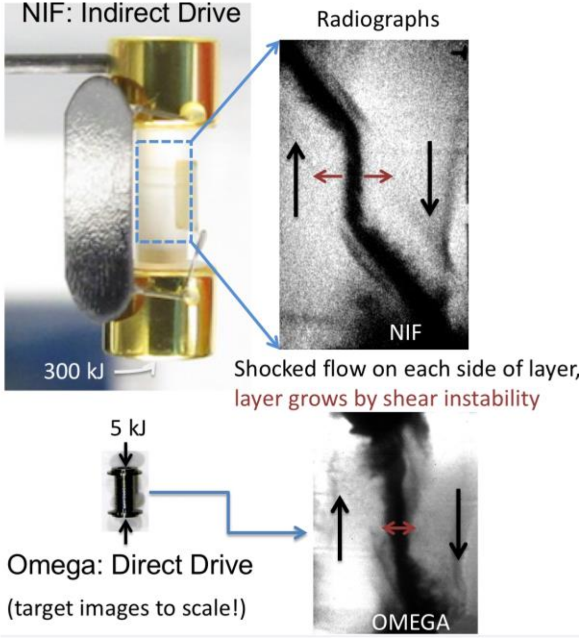






We are using the full compliment of our HED capabilities to address stockpile stewardship issues

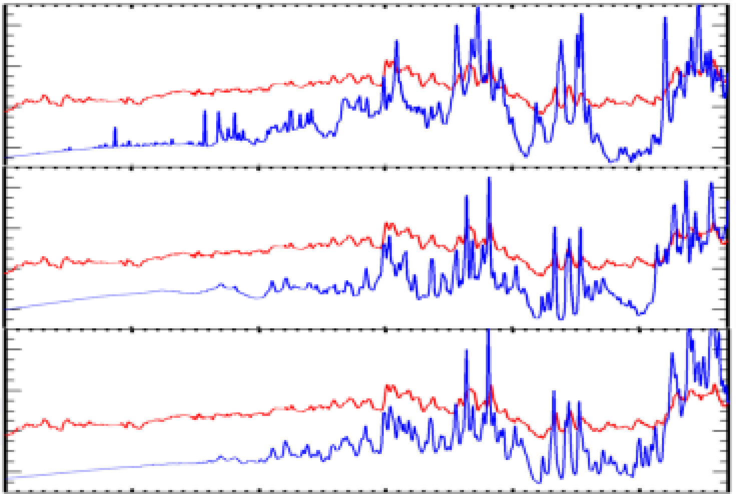
- Data on the effect of shear is needed to validate computational mix models in HED regimes.
- **OMEGA confirmed a subset of the physics, NIF has access to much wider parameter space.**
- Dynamically scaled shots in the regime of overlap are used to explain data and develop techniques.
- Iron opacity data from Z show significant discrepancies with all theoretical models. These discrepancies may help resolve questions long standing mysteries in solar modeling.(bottom right)
- Cylindrical targets on the Z facility enabled shockless EOS measurements above 1000 GPa in several materials
- **A cross platform (NIF/Z) study of tantalum strength is helping identify which mechanisms are important at different strain rates**



Shocked flow on each side of layer, layer grows by shear instability

(target images to scale!)

Iron Opacity data highlight need for improved theory



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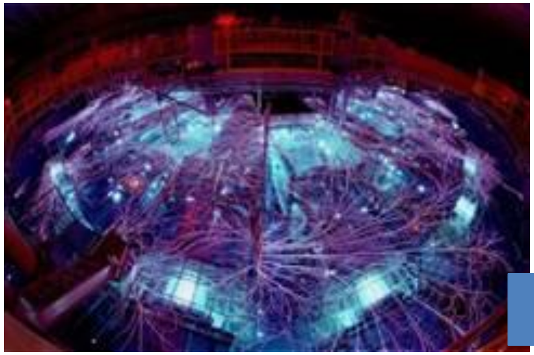
We have established a unified National Program in the applied HED Sciences

- In June 2014, we held the first annual working group meeting on the applied HED sciences
  - 150 participants, 12 institutions divided into subgroups
- The product was a physics-based (vice facility-based) 10-year HED Scientific Strategic Vision in four areas:
  - Nuclear (materials properties, hydrodynamics, and nuclear physics),
  - Thermonuclear (mix, burn, ignition, plasma properties, and application of capsule output)
  - Radiation (radiation transport and opacities)
  - Output & Effects (weapon output, weapon effects, and forensics)
- We are prioritizing these areas against programmatic needs in the near, medium and long term and developing a Strategic Plan.
- **Next step:** develop unclassified document to enhance external partnerships
- **Revision: Mid 2016**

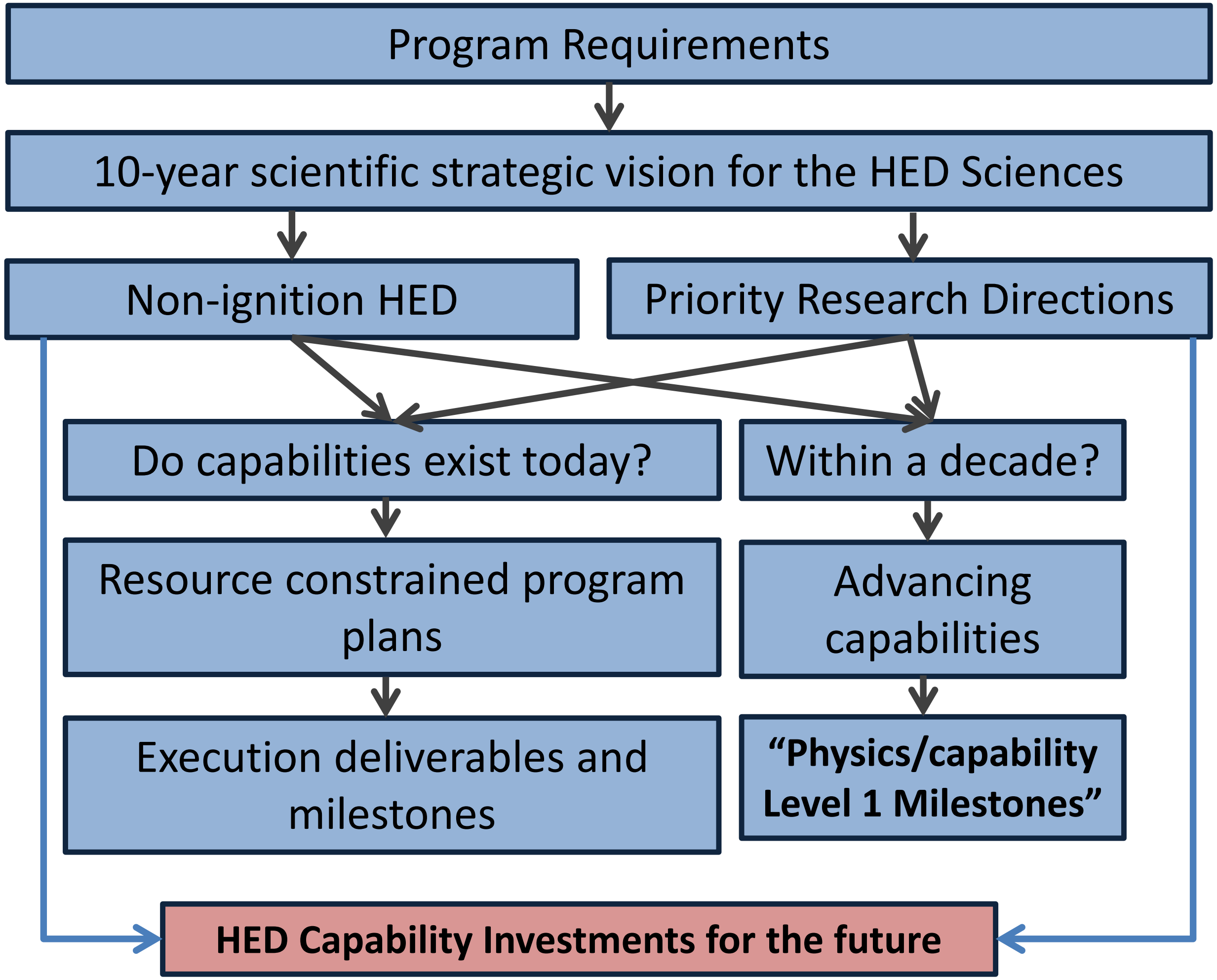


We have developed a unified national diagnostics strategy

- **Multi-frame** x-ray detectors from nsec down to 10 psec
- **Localized** density and temperature in hohlraums and foams
- Burn as a function of **time and space**
- T_e, T_{ion} and areal density as a **function of time** in burn and boost
- **Time resolved** phase change
- Other longer term diagnostics

We will rebalance existing resources and assess multiple investment strategies

We continue to review and refine the planning basis to ensure alignment with requirements



Program Requirements

10-year scientific strategic vision for the HED Sciences

Non-ignition HED

Priority Research Directions

Do capabilities exist today?

Within a decade?

Resource constrained program plans

Advancing capabilities

Execution deliverables and milestones

“Physics/capability Level 1 Milestones”

HED Capability Investments for the future

- Program requirements
  - RPD, SSMP, NWC
- 10-year vision
  - Resource informed prioritization of requirements
  - 5-year national diagnostics strategy
- Priority Research Directions
  - Scientific hypotheses that guide the ICF program of work

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We have commissioned a Federal Advisory Subcommittee on ICF

- In 2012, the ICF program committed to conducting a comprehensive review in 2015 on the "progress toward ignition"

- We have established a FACA compliant subcommittee to conduct the 2015 ICF/HED program review that will:
  - Assess the scientific hypotheses that guide today’s ICF program of work.
  - Assess the prospects of achieving ignition with existing scientific capabilities and facilities, or, if indicated, by specifying what would be required to do so, based on quantitative physics analysis.
  - Evaluate program balance among ICF / HED approaches.
  - Assess the contribution and balance of efforts in the non-ignition HED sciences in the near, medium, and long term.
  - Assess the effectiveness of the ICF Program’s cross-platform and cross-laboratory collaboration.

Timeline (subject to change)

- June 2014: Set date and rough scope for 2015 ICF/HED review
- August 2014: Decision to have review conducted by FACA subcommittee
- October 2014: Develop subcommittee charge
- December 2014: Notify nominees and populate committee
- January 2015: Establish subcommittee chair
- February (and April, June) 2015: Program meetings to coordinate review
- March 2015: subcommittee vector check with DPAC
- July 2015: Review
- September 2015: Report

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We are enhancing partnerships at the federal level

- OFES
  - JHEDLP panel reviews early next year
  - Engagement in upcoming workshops (“Science Frontiers”)
  - Common future technologies and science

- NCT
  - Developing new platforms on Z
  - Developing new platforms for the Dynamic Compression Sector
  - Developing a long term vision for future investments

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We need to continue evolving our capabilities to support our mission

- In 2032, 17 years from now, *it will be 40 years since the last U.S. nuclear test*
  - 17 years ago construction started on the NIF
- **Drivers for Science Based Stockpile Stewardship**
  - Sustaining and modernizing the stockpile
  - Qualifying systems and components for new threat environments
  - Avoiding technological surprise
  - Recruiting, training, and retaining technical staff
  - Providing expert technical judgment to the President
  - Assessing nuclear designs without a return to nuclear testing
- **These mission drivers require sustained HED capability modernization to:**
  - Test nuclear designers in high energy density (HED) implosion design.
  - Probe alpha-deposition dominated thermonuclear burning plasmas.
  - Develop commensurate high-fidelity diagnostics and experimental platforms that assure our weapons are safe, secure, and effective.
  - Create and apply multi-megajoule fusion yields to enable enduring stockpile stewardship.

As we look out to 2032, HED/ICF science is critical to sustained nuclear deterrence

Questions?

- We are putting our tools to work to solve challenging problems

- We must continue to be creative and do more.

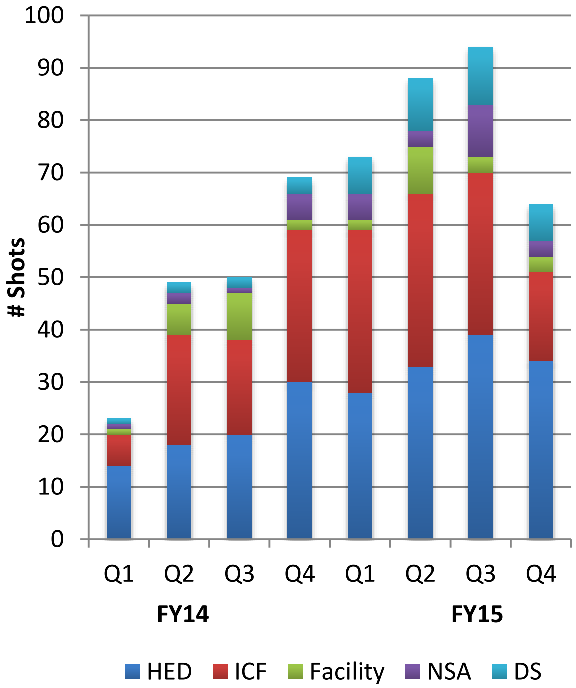
- Reality is a forcing function on our future.

Backup

There are opportunities for increasing <u>partnerships</u> on our HED facilities

- In many ways, Z and NIF are like some Office of Science high-energy physics facilities:
  - Single end-station
  - Heroic efforts to execute experiments
  - Multimillion dollar diagnostics with ~100 contributors
- However, we have a unique challenge not constraining for most Office of Science facilities – *an applied mission!*
- We have a vibrant existing program in non-laboratory funded work in HED science
  - SSAA, SSGF, NLUF, various summer schools
- We are increasing partnerships with nuclear threat science communities and we are pursuing an agreement with OFES
- We are interested in supporting a partnership vice ownership model
  - Do our interests align?
- Deployment of "ownership" user-models are commensurate with our other priorities. We recognize a need to:
  - Develop target design-constrained catalog of arbitrary sources
  - Improve access to facilities (efficient operations)
  - Establish an NLUF-like program to fund non-laboratory PIs

- The "120-Day Study" forms the backbone of our shot-rate improvement effort
  - Includes ~ 80 specific actions
    - About half completed in FY14
    - Remainder planned for FY15 and FY16



The key to enabling partnerships is increased operational efficiency at NIF and pursuit of dedicated materials science platforms

We have developed mission drivers for HED capability modernization

- Support stockpile maintenance and modernization through qualifying component reuse or replacement, improving surety, understanding the aging of plutonium, and understanding boost.
- Ensure stockpile component qualification for hostile, normal and abnormal environments as threats evolve.
- Facilitate the science-based assessment of intelligence-based nuclear threats from state and non-state actors, and anticipate technological surprise.
- Provide credible technical judgment to the President regarding the effectiveness of a state's nuclear weapons program capabilities.
- Recruit and train technical staff, the foundation of nuclear deterrence, and maintain a credible nuclear test-readiness capability.
- Enable the potential for assessing nuclear designs without a return to nuclear testing, should that one day be deemed necessary to ensure the deterrent remains effective.