National Ignition Facility Update

2025 NIF/JLF User Group Meeting

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National Ignition Facility Director

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LLNL-PRES-2002618

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It has been an outstanding year at NIF with great progress made on near term priorities and future capabilities

- Advanced scientific understanding and control of the fusion process with higher yields
  - Ignition yields now being used for important stockpile stewardship priorities
- New commissioned capabilities continue to increase scientific reach on NIF
- We established a new working group to improve experiment success rate
- We're progressing well on NIF sustainment to address degradation and obsolescence risks affecting users
- A significant milestone was achieved towards a future NIF upgrade to increase performance and expand applications

NIF's Discovery Science program continues to generate new ideas and attracts new talent to the Program

Our priorities over the next decade strive to expand mission value while growing the next generation HED scientists and engineers

- **Execute HED science and ignition applications**
  - Deliver robust NIF operations through 2040s
  - Enable material options for future programs
  - Enhance fundamental physics understanding
  - Execute robust applications of multi-MJ yields

  2.2 MJ laser
  <5MJ yield

  2025

- **Increase ICF performance with improved sensitivity understanding**
  - Enable higher yield performance and facility compatibility
  - Understand performance sensitivities to maximize output of existing capabilities

  2.2 MJ laser
  10+MJ yield

  2025

- **Maximize NIF performance to expand applications at higher yields**
  - Deliver an enhanced yield capability (EYC) on NIF
  - Design and execute applications of EYC
  - Develop and test EYC ignition platforms on NIF

  2.6 MJ laser
  30+MJ yield

  2032

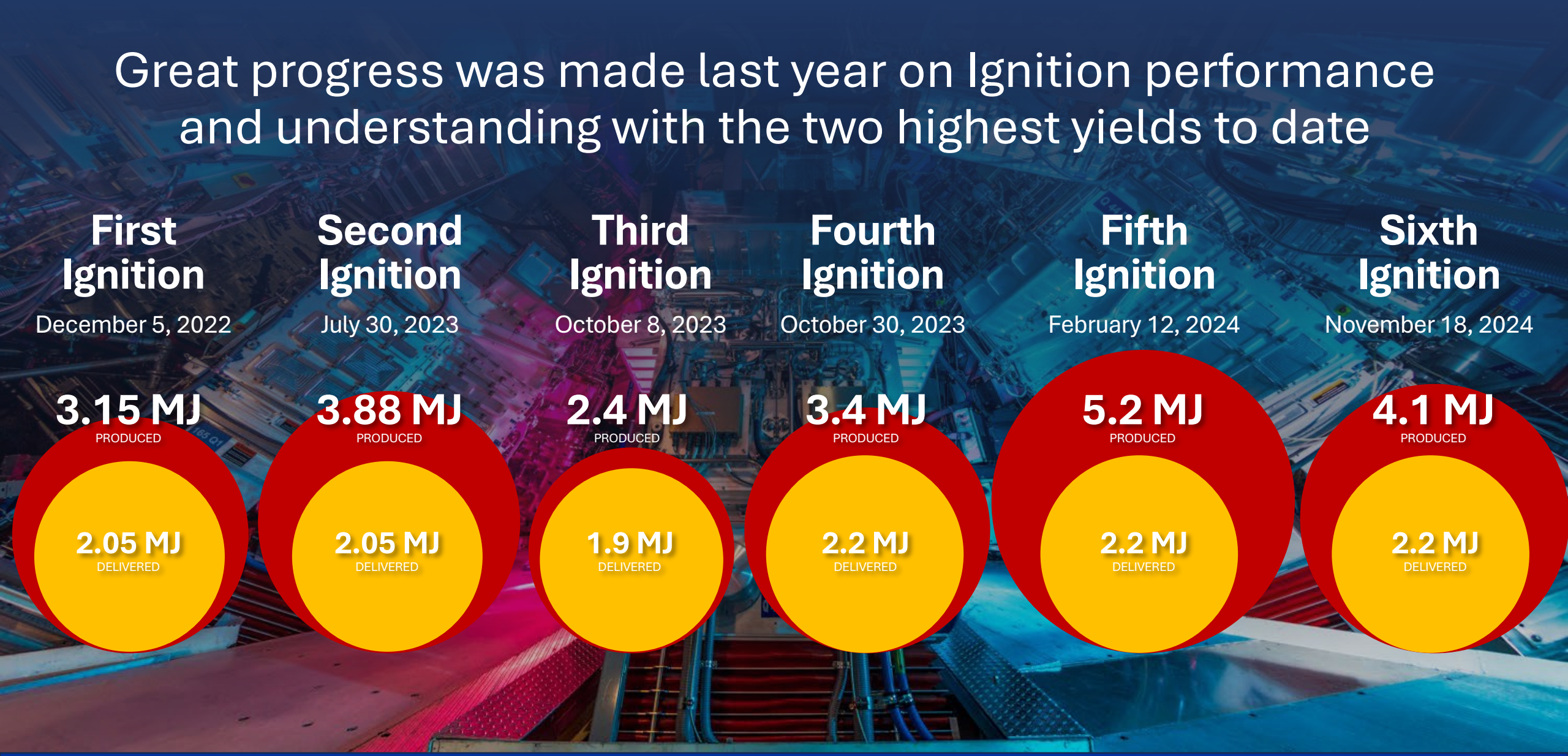
- **Prepare for next-gen laser-indirect-drive high yield facility**
  - Develop high yield applications to close capability gaps lost with UGT cessation
  - Develop laser driven high yield ignition platforms
  - Improve maturity of technology and science supporting high-yield applications

  ? MJ laser
  200+MJ yield

  204x

It is an exciting time for NIF and its users and expanding its performance opens many new opportunities

Great progress was made last year on Ignition performance and understanding with the two highest yields to date



We continue to explore facility, target and experimental designs to further increase the yields and quantify the key degradation factors

The most critical NIF sustainment projects are underway and good progress is being made to address degradations and obsolescence risks

Injection Laser

- Pulse Shaping System Replacement
- Optic Damage Mitigation System Repl.
- Multi-pass Amplifier Replacement
- 3ω Power Sensors Refurbishment

Amplifiers

- Debris Elimination & Refurbishment
- Pulsed Power Replacements
- Transport and Handling Equipment Repl.

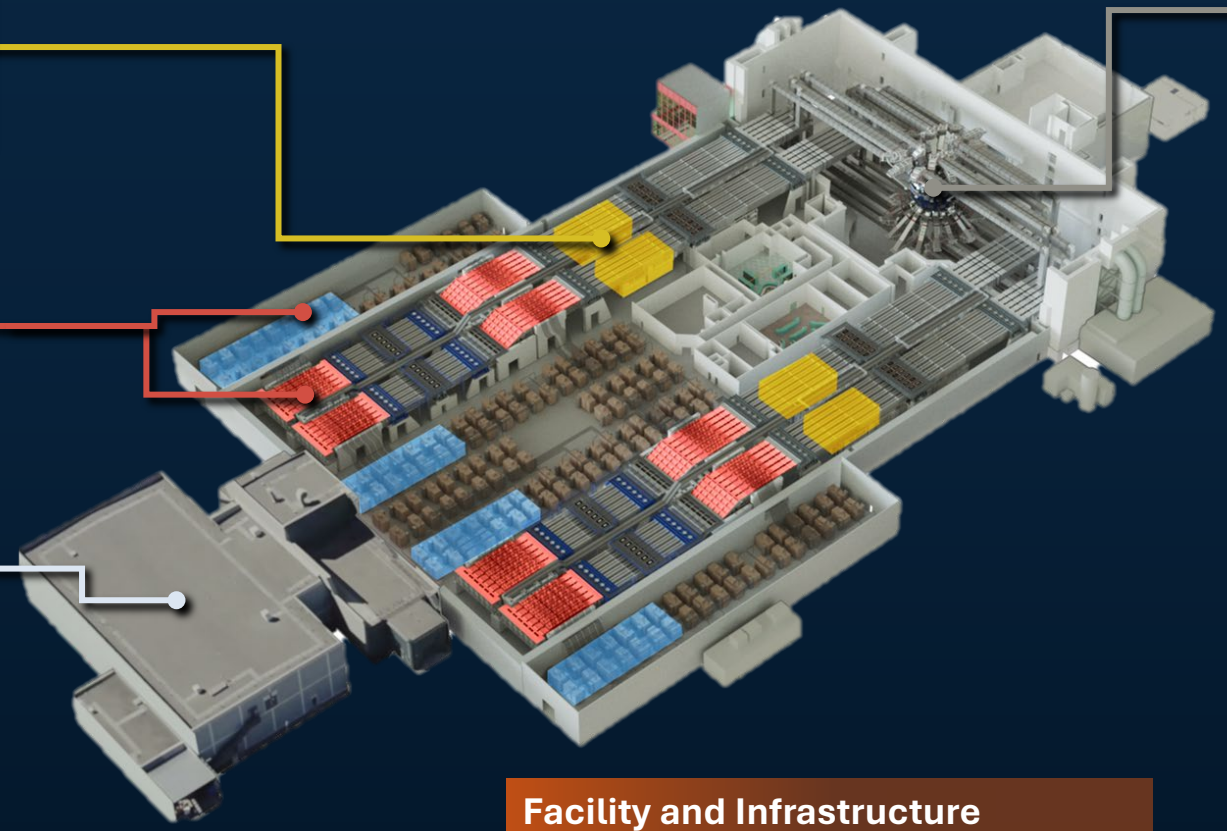
Optics Processing

- Equipment Refurbishments

Target Fabrication

Separate LLNL facility

- Equipment Replacements
- Data/ Processing Equipment Improvement
- General Atomics Equipment Repl.



Target Area

Final Optics

- Final Optics Refurbishment
- Debris Induced Damage Mitigation
- Blue Blockers Damage Mitigation
- Optic Installation Platforms Repl.
- Phase Plate Exchange Improvement

Alignment and Optics Inspection

- Optics Damage Inspection System Repl.
- Chamber Interior Viewing System Repl.
- Target Alignment System Repl.

Other

- Chamber Entry Lift Refurbishment
- Polar Diagnostic Insertion Replacement
- Target Line Replaceable Unit Improvement

Controls and Data Systems

Facility wide effort

- Industrial Controls Replacements
- Facility Controls Replacements
- Embedded Controller Replacements
- Laser System Controls Replacements
- Alignment and Optics Inspection Controls
- Data Archive Replacement

Facility and Infrastructure

Facility wide effort

- Clean Dry Air Compressors Replacements
- Electrical System Replacements
- Chiller Replacements
- HVAC Replacements
- Boiler Replacements
- Elevator Controls Replacements

NNSA National Nuclear Security Administration

Lawrence Livermore National Laboratory

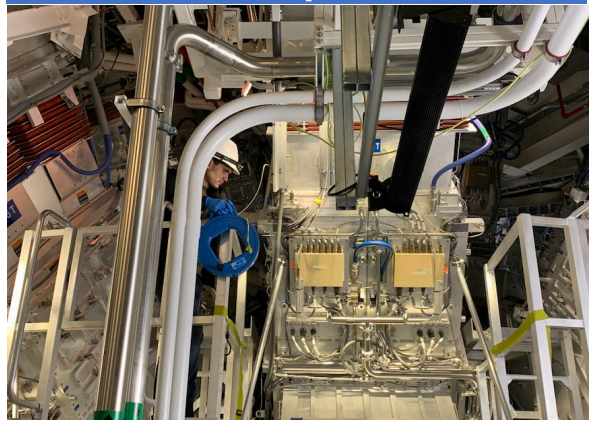
Many sustainment activities have benefits to users as each project completes

- Completed replacement of obsolete pulse shaping system
  - Improved accuracy and repeatability on every shot
- Replaced all neutron degraded 3w power sensor fibers
  - Restored laser energy measurement accuracy of every shot
- Replaced 3 (of 192) integrated optic modules, first time in a decade
  - First debris assessments insights may point to cause of increased optic damage that limits NIF power limit

Replaced Pulse Shaping System

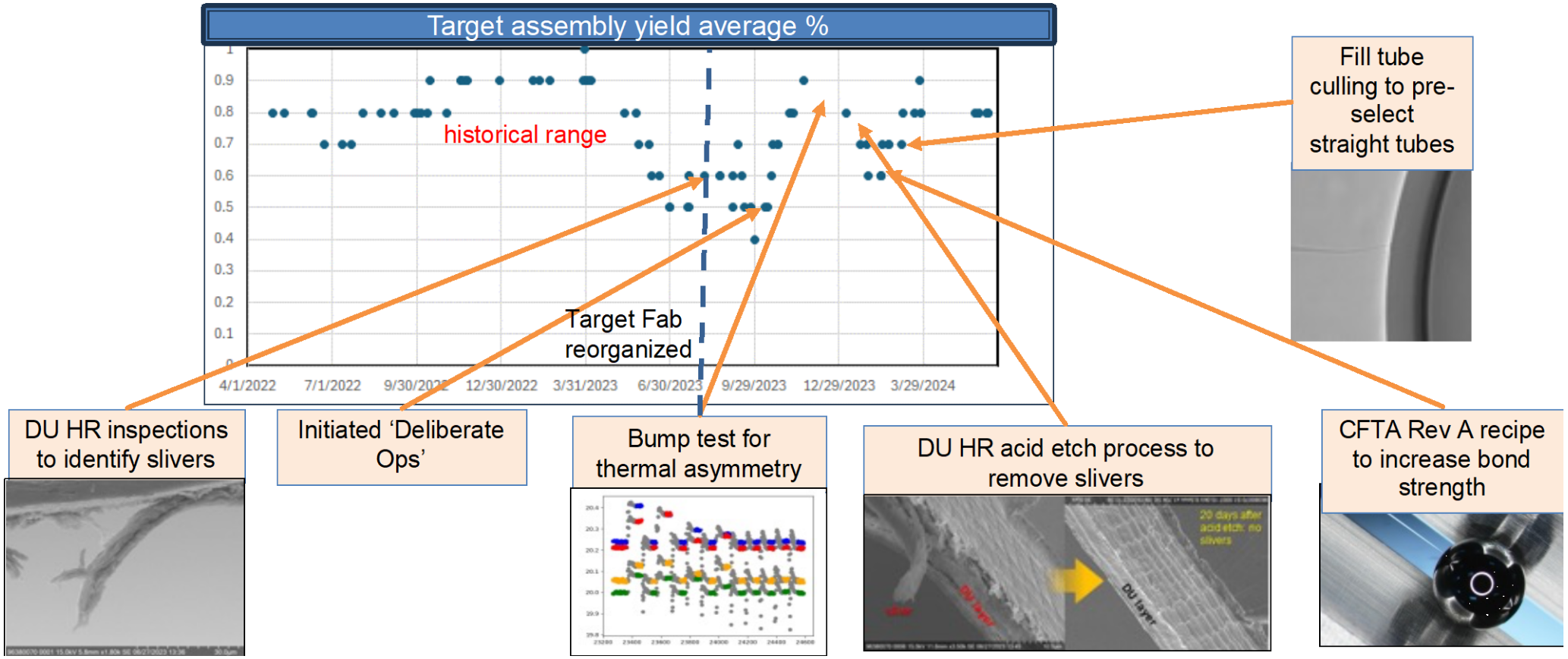
Replaced Optic Modules

3w Fiber Replacement



Talks later this week will describe additional user benefits of several other sustainment projects

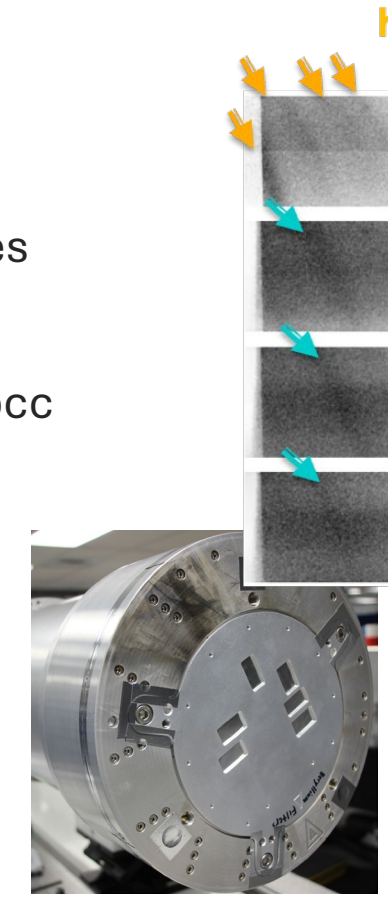
Process and procedure improvements have robustly restored ICF target assembly yield levels without reliance on heroics

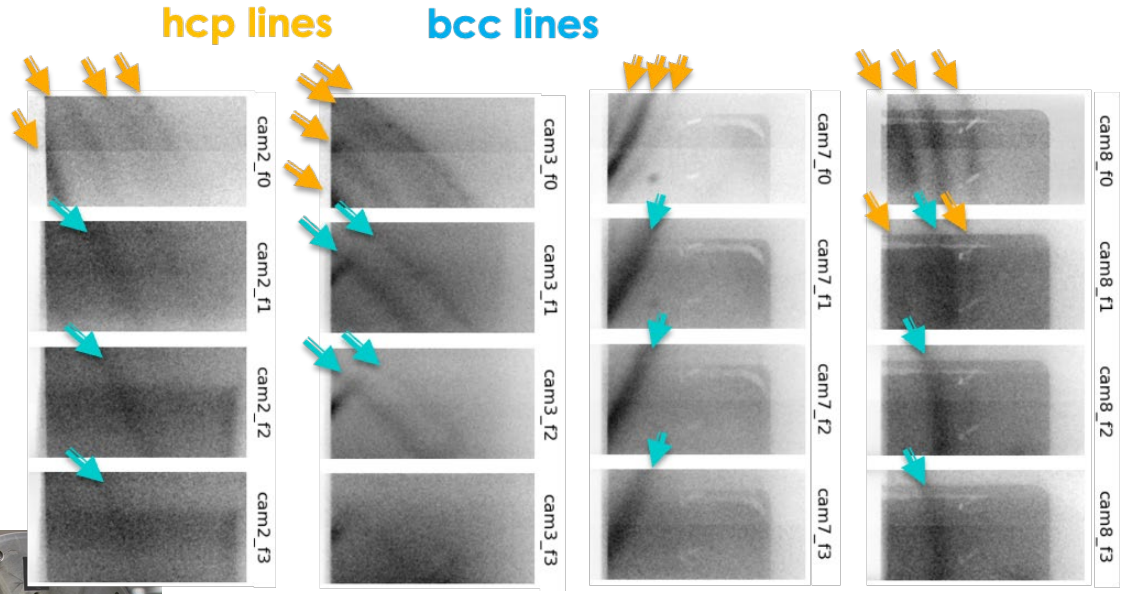


Although primary focus is on ICF targets, many organization improvements have benefited all users

New time resolved x-ray diffraction (FIDDLE) diagnostic progressing well to a mainstream user capability

- A novel self-shielding target design substantially reduced the x-ray background
- First time all sensors recorded diffraction lines
- Four frames timed at different delays clearly show the phase transition of Pb from hcp to bcc
- An accompanying timing shot was also successful to pin down timing uncertainties



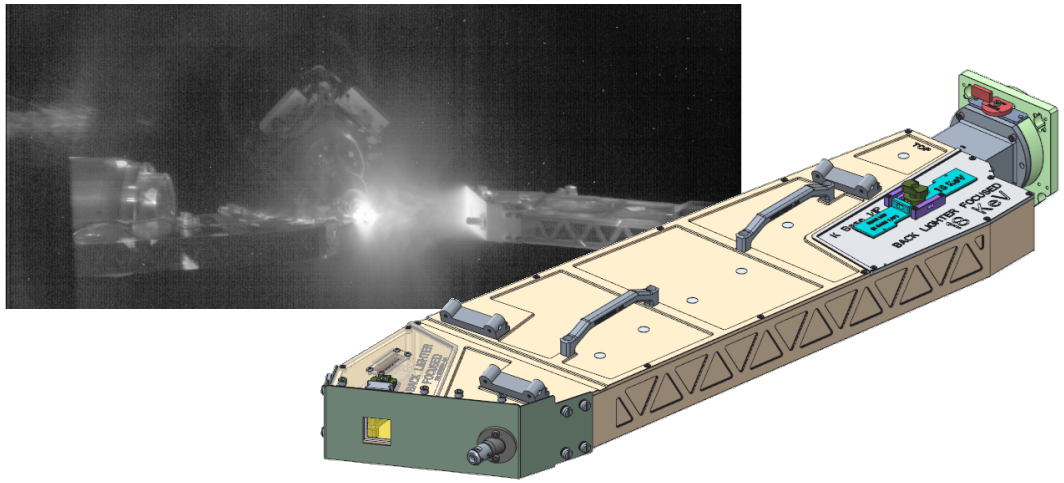


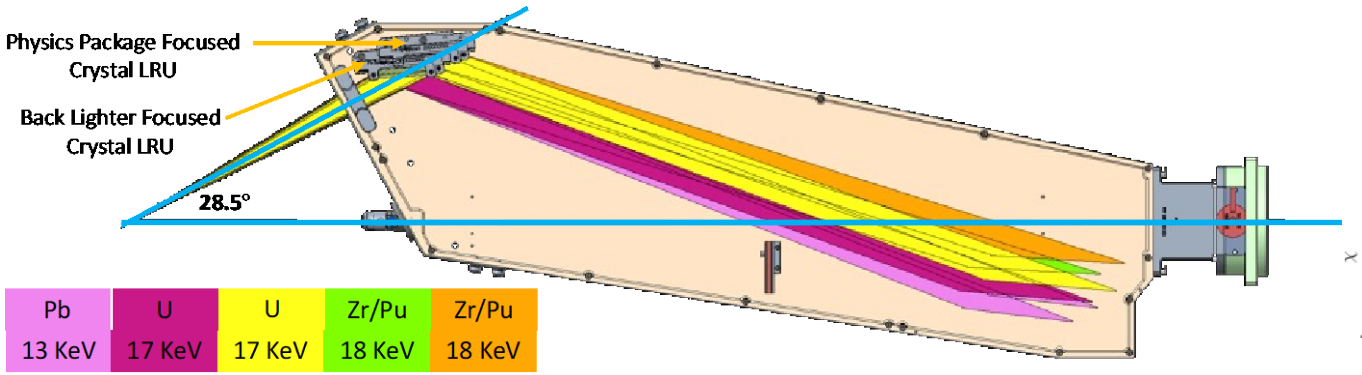
Raw images showing diffraction lines in four frames of different sensors from NIF shot N241126-001.

This new diagnostic FIDDLE will be adopted for plutonium diffraction measurements in FY26-27

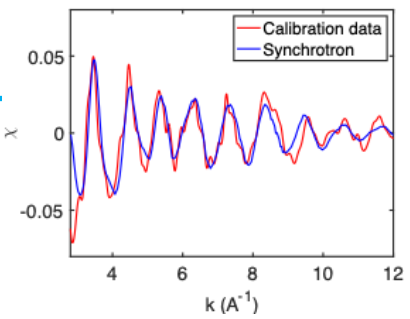
New EXAFS spectrometer fielded with18keV crystal and recorded K shell Zr data on NIF

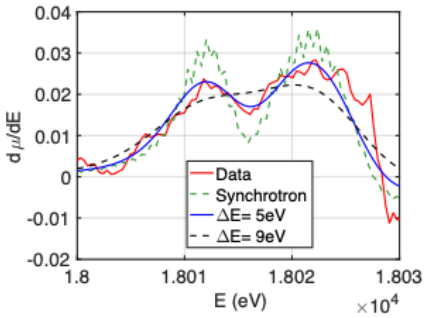
- Experiments in FY24 showed 18keV crystal system meets resolution and throughput requirements for high Z experiments in FY25
- Work Authorization ongoing to prepare for high Z experiments on NIF in Mid-late FY25





Offline Calibration data

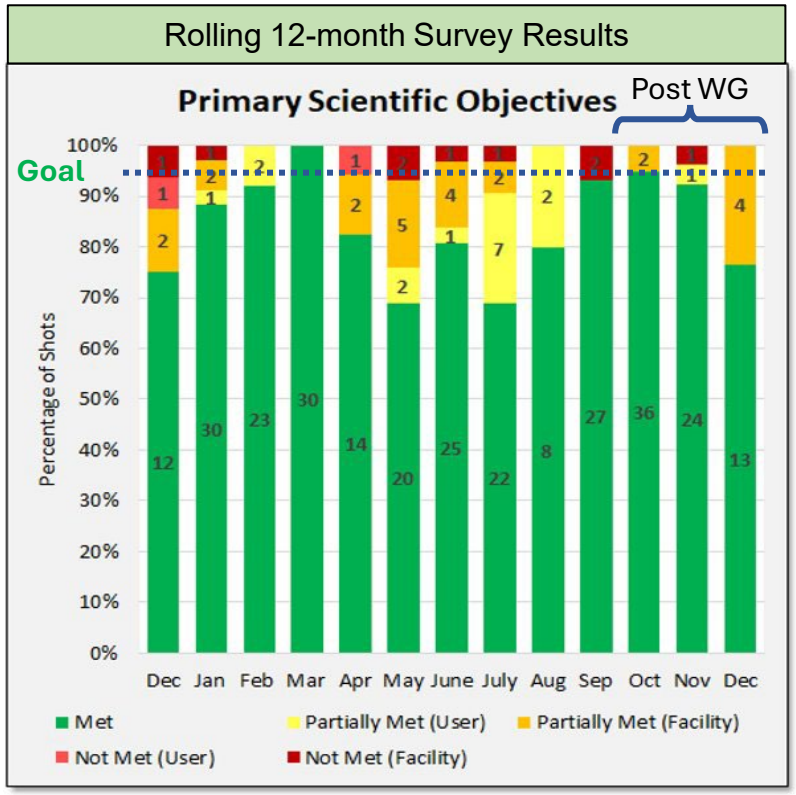




EXAFS is a great example of Discovery Science proposals that have enabled a new stewardship capability

We established a new Experiment Execution working group to improve experiment success rate

- NIF shot rate has declined due to impacts of aging hardware and reduction in staff experience levels
  - We recognize the need to improve the success rate of the shots we conduct
- WG has broad representation from physics and facility and assessed impediments to achieving primary scientific goals
  - Analyzed process feedback and provided recommendations for improvement
  - Feedback collected through broad survey from significant number of RIs
  - Focus on reducing experiment setup, review and execution errors
- WG recommendations address areas to restore success rate to 95% goal:
  - ✓ Improve data collection and communication of data
    - Deferred shots, Near Misses as well as Shot Survey data
  - ✓ Establish monthly joint review meeting of the shot survey data and shot deferrals facility/physics leads and RIs and make results widely available
  - ✓ Reinforce culture to achieve <5% failure – ongoing
  - ✓ Improve user training – NIF User forum restart - ongoing
  - ✓ Add redundancy to shot set tool (SST checker) - imminent
  - ✓ Facility dashboard to advertise capability issues and availability
  - ✓ Incorporate continuous feedback and improvement in our processes



Good progress has been made and we continue to monitor data regularly and reinforce as needed

HED scientists are exploiting NIF's capabilities to push the scientific boundaries

Self-heating plasmas offer hope for energy from fusion

Article | Open access | Published: 26 January 2022

Burning plasma achieved in inertial fusion

A. B. Zylstra, O. A. Hurricane, D. A. Callahan, A. L. Kritcher, J. E. Ralph, H. F. Robey, J. S. Ross, C. V. Young, K. L. Baker, D. Casey, C. Choate, M. J. Edwards, S. J. Ali, P. Tommasini, S. J. Ali, P. Hopkins, ... G. B. Zimm

PHYSICAL REVIEW LETTERS 129, 075001 (2022)

Suggestion | Featured in Physics

Lawson Criterion for Ignition Exceeded in an Inertial Fusion Experiment

H. Abu-Shawareb et al.*

(Indirect Drive ICF Collaboration)

THE ASTROPHYSICAL JOURNAL LETTERS

Electron Injection via Modified Diffusive Shock Acceleration in High-Mach-number Collisionless Shocks

A. Grassi, H. G. Rinderknecht, G. F. Swadling, D. P. Higginson, H.-S. Park, A. Spitkovsky, and F. Fiuza

Society.

Science

Measuring the melting curve of iron at super-Earth core conditions

RICHARD G. KRAUS, [illegible]

GILBERT W. COLLINS, [illegible]

SCIENCE · 13 Jan 2022 · Vol 375, Issue

PERSPECTIVE | PLANETARY SCIENCE

Molten iron in Earth-like exoplanet cores

Iron crystallization in super-Earth interiors plays a key role in their habitability

Article | Published: 24 May 2023

Observing the onset of pressure-driven K-shell delocalization

T. Döppner, M. Bethkenha

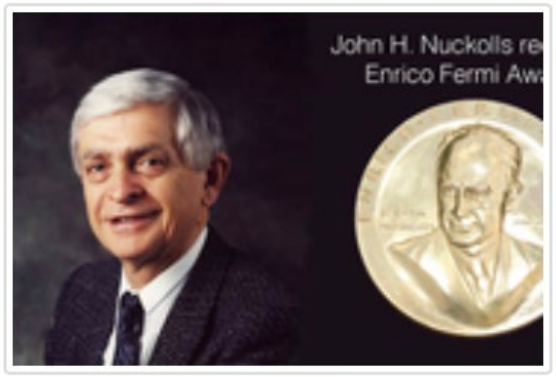
Böhme, L. Divol, R. W.

nature

RESEARCH BRIEFINGS | 24 May 2023

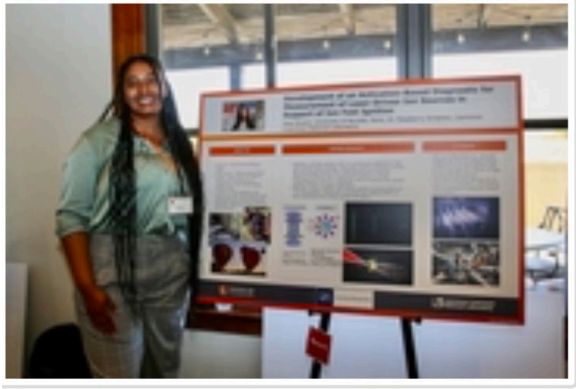
World's strongest laser enables pressure-driven ionization

Livermore scientific staff have had a highly productive year and received many high profile awards and honors



Former LLNL Director John Nuckolls
Enrico Fermi Award for
"seminal leadership in ICF and HEDP

Daniel Casey, Daniel Clark, and Raymond Smith 2024
American Physical Society (APS) Fellows



Two LLNL student interns honored as 2024 Fusion
Fellows by Livermore Lab Foundation

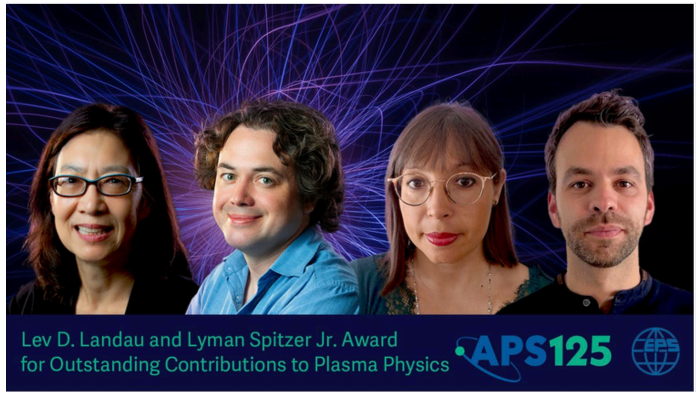
Annie Kritcher
2024 David J. Rose Excellence in Fusion Engineering
Award by Fusion Power Associates

Zhi Liao
Elected senior member of SPIE, the international
society for optics and phonics.

Brent Stuart and Paul Armstrong
Named senior members of Optica

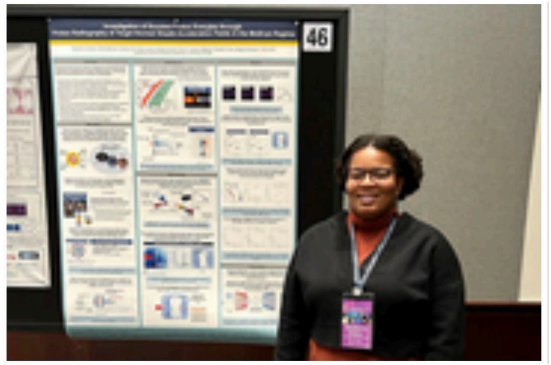
Further examples include winning the Landau–Spitzer award for plasma physics, and the “Genius Award” from the Liberty Science Center of NJ for ICF science.

Bruno Van Wonterghem
2024 Distinguished Career Award by Fusion Power Associates



Hye-Sook Park and George Swadling, Anna Grassi and Frederico Fiuza
2024 Lev Landau and Lyman Spitzer Jr. award for outstanding contributions to plasma physics.

Annie Kritcher
The Liberty Science Center of New Jersey “Genius Award” for her work on the Lab ICF team.



Raspberry Simpson
Named a National Academy of Sciences Kavli Fellow

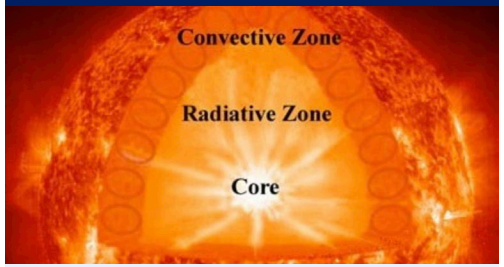
Jamie King
Named fellow of the Laser Institute, the organization’s highest level of membership.

Kelli Humbird
Presidential Early Career Award for scientists and engineers

Jeff Wisoff
Named Optica fellow “for outstanding technical and program leadership in lasers and inertial confinement fusion in achieving fusion ignition in a laboratory setting.

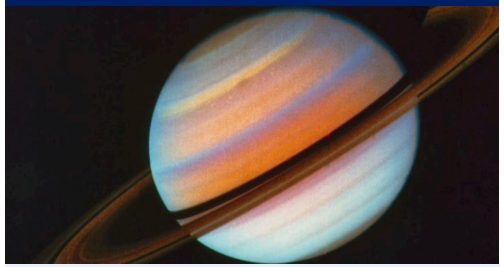
7 Discovery Science Campaigns were awarded in 2024

Oxygen opacities in stellar interiors



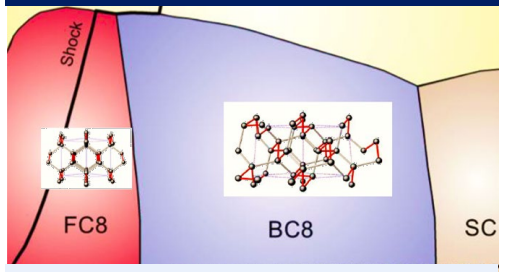
Dan Mayes
Univ. of Texas at Austin

Metallic hydrogen in planetary interiors



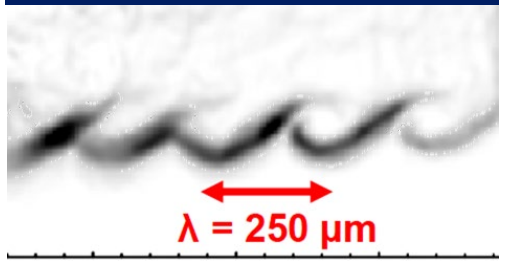
Raymond Jeanloz,
UC Berkeley

Carbon BC8 via C-H phase separation



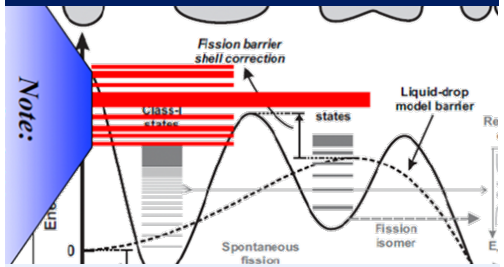
Dominik Kraus,
Univ. Rostock

Highly magnetized KH instability on NIF



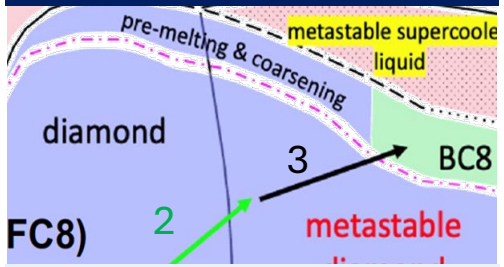
Alexis Casner,
CEA

Nuclear fission from excited states



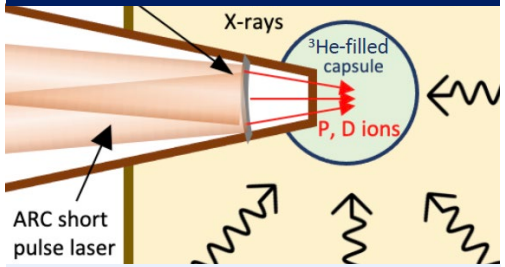
Lee Bernstein,
UC Berkeley

3-shock path to carbon BC8



Ivan Oleynik,
Univ. South Florida

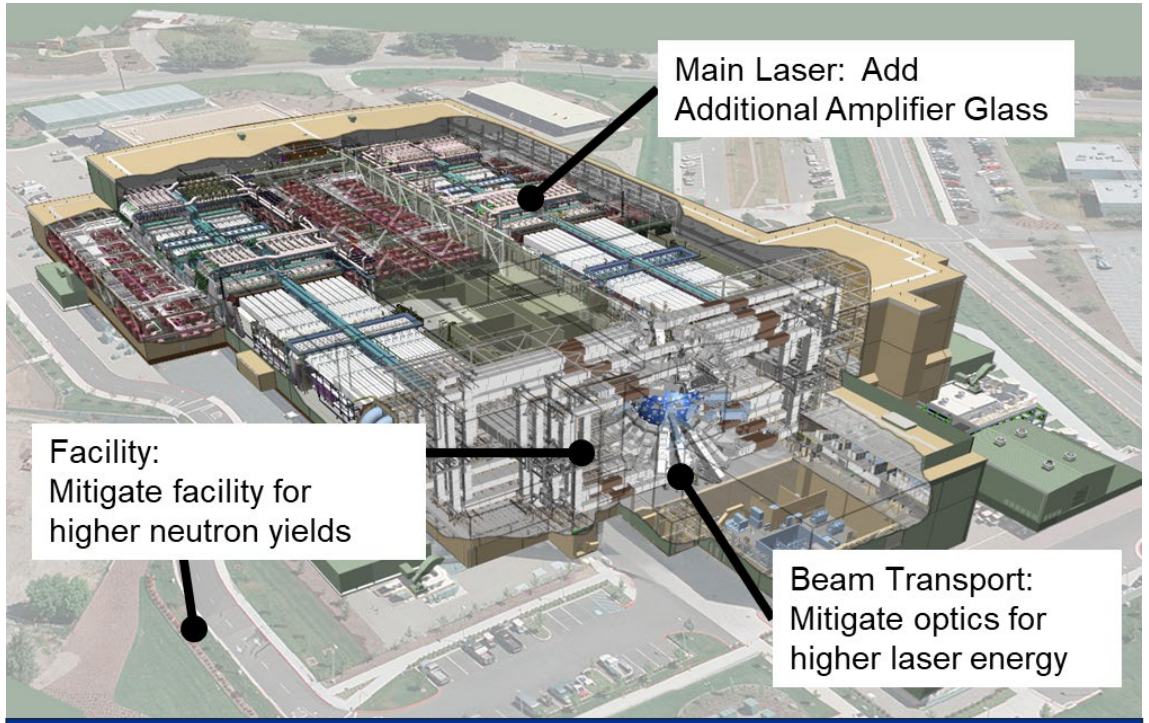
ARC TNSA heating of dense ^{3}He plasma



Drew Higginson,
LLNL

We continue to be impressed by the quality of DS proposals covering a wide range of fundamental science

Beyond sustainment, we are actively pursuing a proposal to upgrade the NIF to its maximal performance



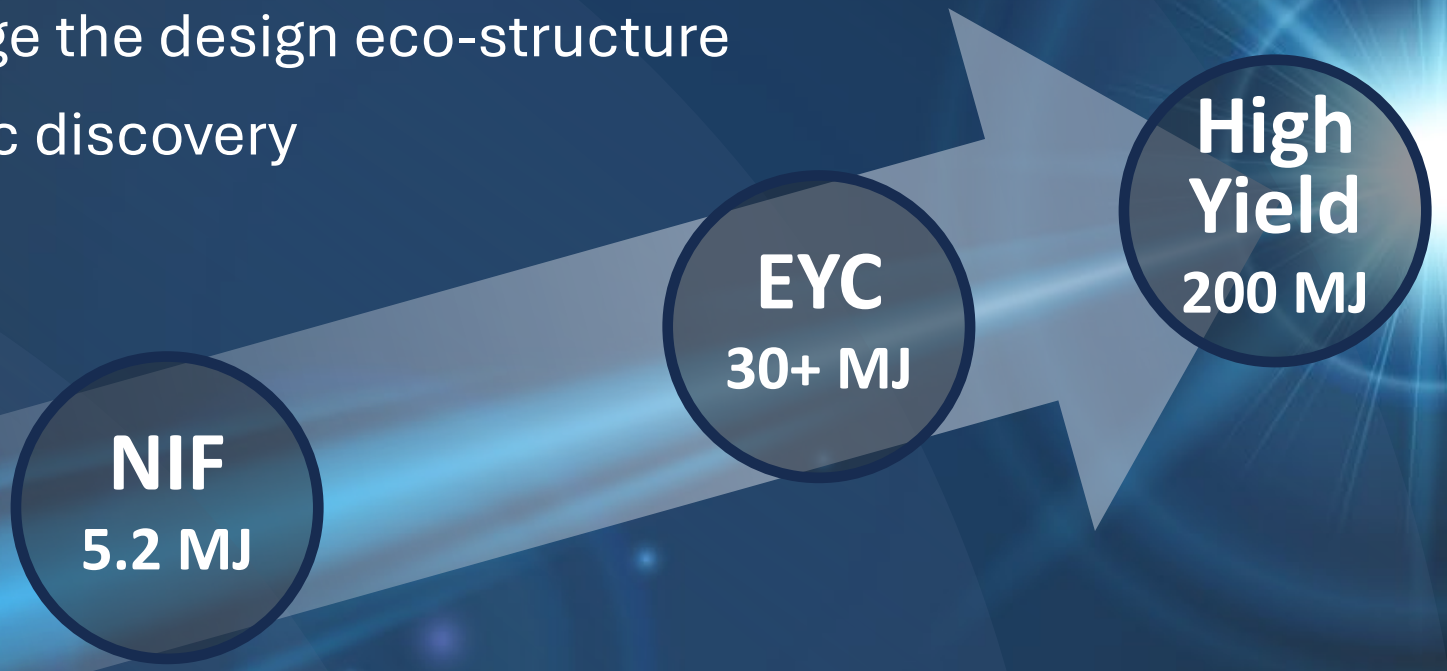
NIF Enhanced Yield Capability (EYC)

- Requires modest upgrades to amplifiers and final optics using existing designs and established supply chains
- Modifications will increase NIF laser energy from 2.2MJ to 2.6MJ
- Experimental design simulations estimate yields of 30+MJ possible
- Enables important new applications for NNSA
- The first project critical decision gate was approved by NNSA and DOE in September 2024

Depending on funding the EYC upgrade could be completed by 2032

EYC will expand the yield frontier

- Unique secondary physics capability
- End to end tests of our people
- Challenge the design eco-structure
- Scientific discovery



EYC is the next logical step towards a future high yield capability for NNSA

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