National Ignition Facility (NIF) Overview

Presented to: DOE Laser Safety Officer Workshop

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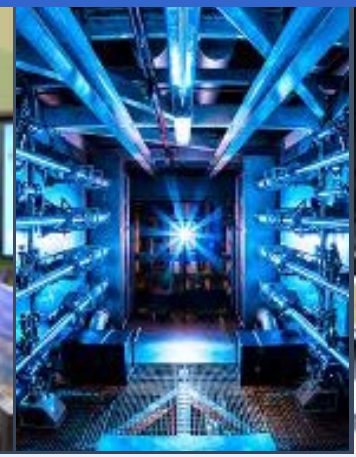
We ensure confidence in the US nuclear deterrent through the NNSA science-based Stockpile Stewardship Program

Expert workforce

THEN
Nuclear Testing

NOW
Science-based stockpile stewardship

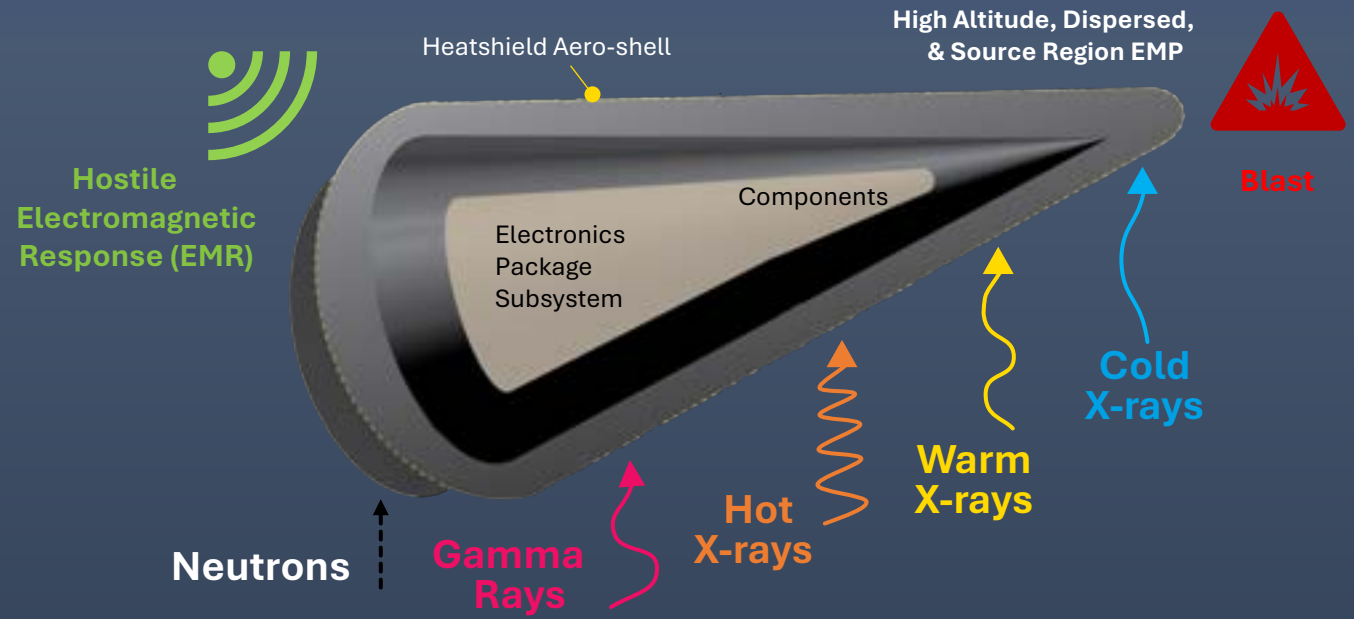
Tools and capabilities



The Challenge

Ensure the nation's stockpile remains an effective deterrent into an uncertain future without additional explosive nuclear tests

Successfully meeting that challenge depends on a detailed scientific understanding of diverse and extreme physical regimes



Moreover, we must understand how weapons respond in a variety of hostile environments

EMP = electromagnetic pulse

High-Energy-Density

NNSA's high-energy-density (HED) program enables constraining experiments in survivability and performance

NNSA HED Facilities

Providing single and multi-physics experimental access across the entire nuclear phase

NIF

Z Machine

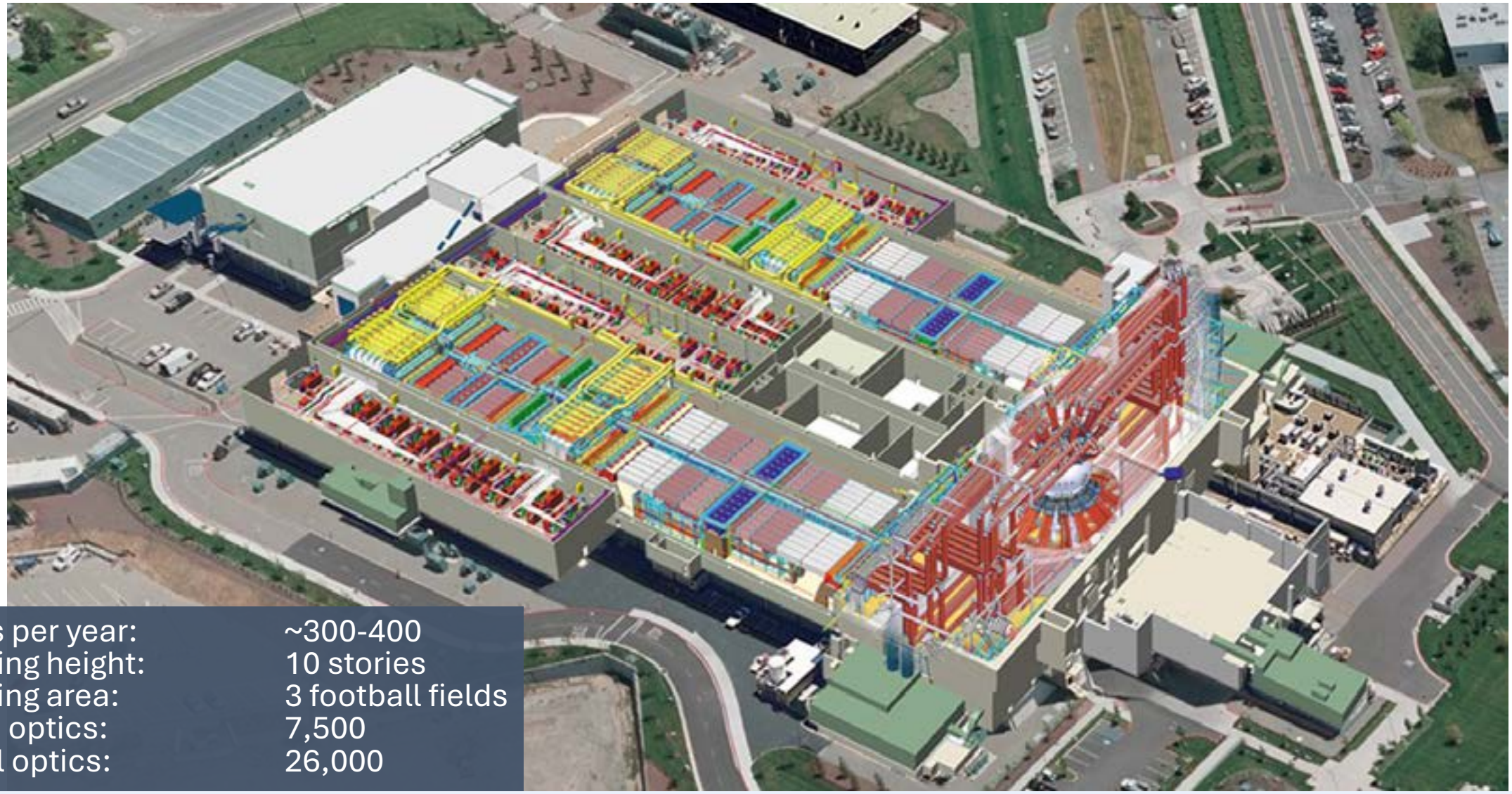
Omega

- Enables assessments of design changes that affect the HED behavior of weapons
- Acquires HED material properties data including aging
- Provides increasingly relevant environments to understand survivability
- Pursuit of fusion ignition and enable a path to high yield (ultimate goal)
- Develops and challenges our workforce

The NIF is the world's most energetic laser

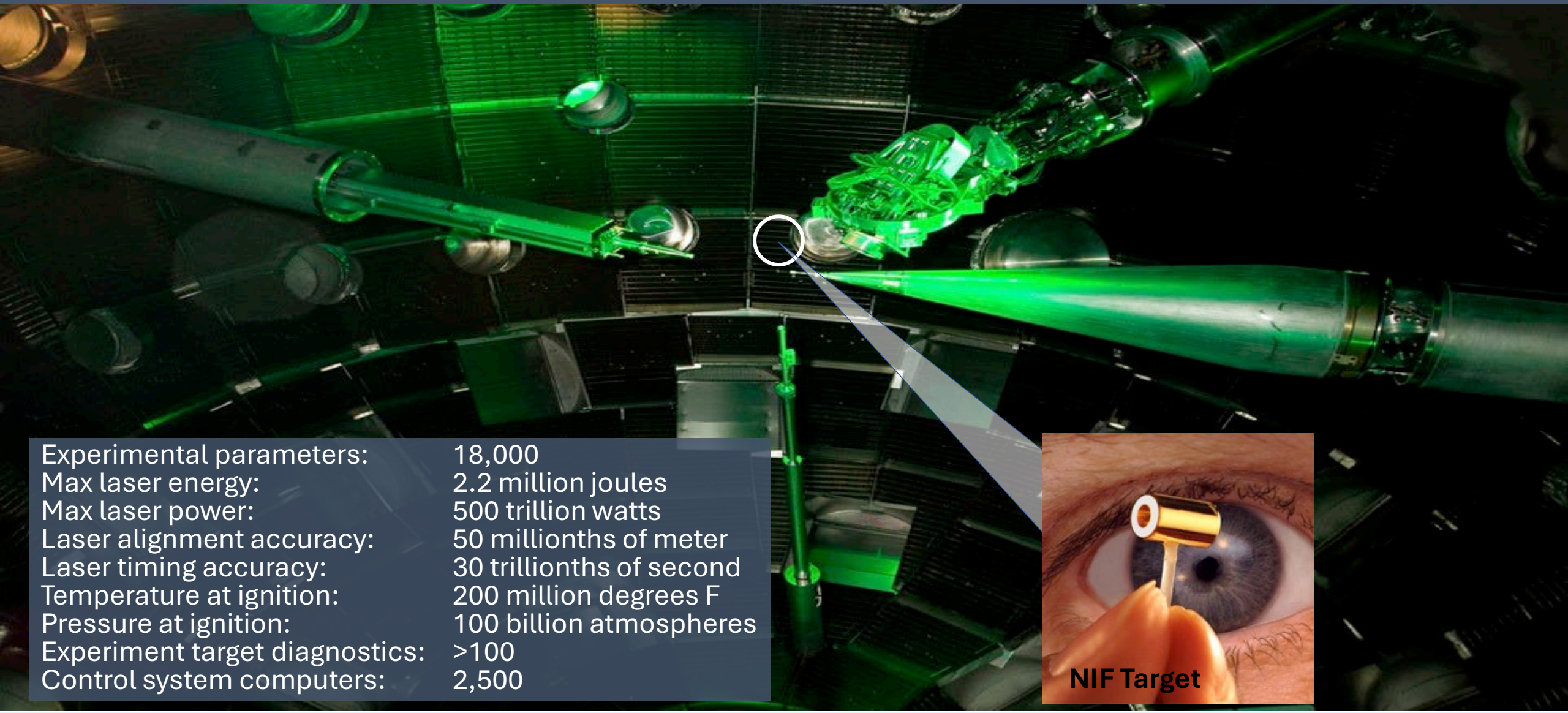
Construction began in 1997 and 24x7 operations commenced in 2009

The NIF concentrates energy from 192 laser beams into a few mm^3 in a few billionths of a second



Shots per year:	~300-400
Building height:	10 stories
Building area:	3 football fields
Large optics:	7,500
Small optics:	26,000

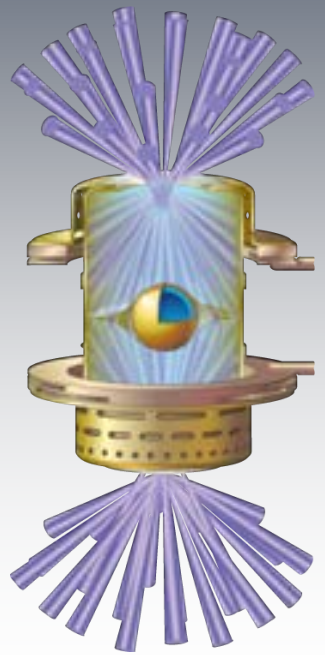
The unprecedented physical conditions generated on NIF enable and advance the NNSA Stockpile Stewardship Program (SSP) missions



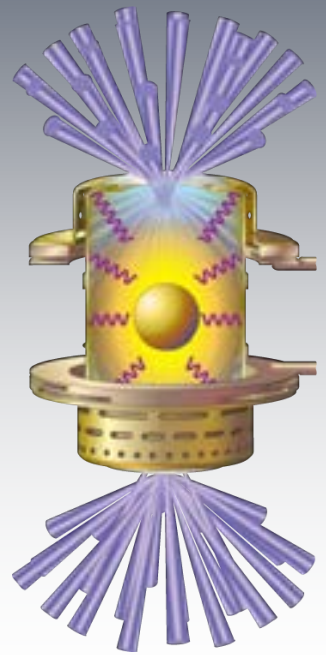
Experimental parameters:	18,000
Max laser energy:	2.2 million joules
Max laser power:	500 trillion watts
Laser alignment accuracy:	50 millionths of meter
Laser timing accuracy:	30 trillionths of second
Temperature at ignition:	200 million degrees F
Pressure at ignition:	100 billion atmospheres
Experiment target diagnostics:	>100
Control system computers:	2,500

These extreme experimental conditions enabled the pursuit of achieving fusion ignition, a major goal of NIF (it's in the name!)

Each of the 192 laser beams are focused onto the inner wall of the hohlraum



Laser beams rapidly heat the inside surface of the hohlraum creating x-rays



The x-rays blow off the fuel capsule wall, accelerating the fuel inward to ~500 km/s

The fuel core reaches 100 times the density of lead and ignites at 100,000,000°C

Fusion burn spreads rapidly through the compressed fuel, yielding many times the input energy

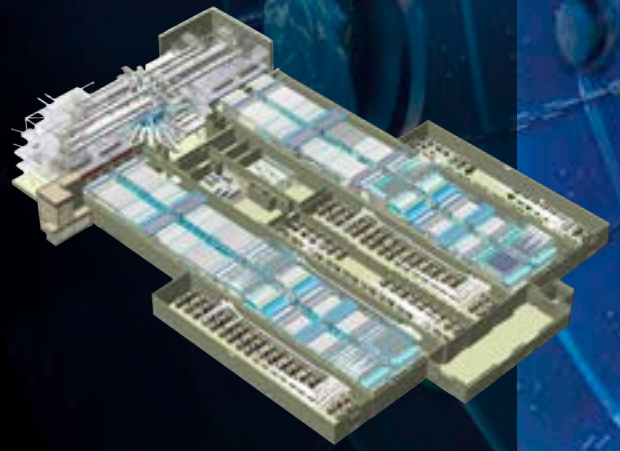
Achieving ignition in the laboratory was a Scientific Grand Challenge nearly 60 years in the making

J. Lindl, *PoP*, 1995; S. Haan, *et al*., *PoP,* 2011
J. Nuckolls et al., *Nature*, 1972

After many years, on Dec. 5, 2022, we demonstrated for the first time an igniting fusion* reaction in the laboratory

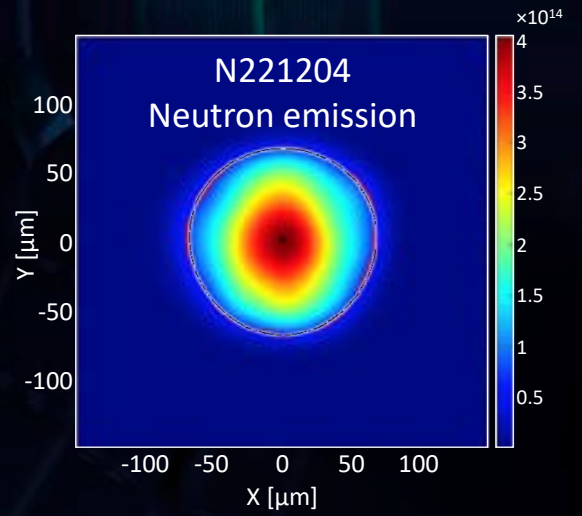
NIF Laser on 12/5/2022

2.05MJ UV
440 TW



Energy Output

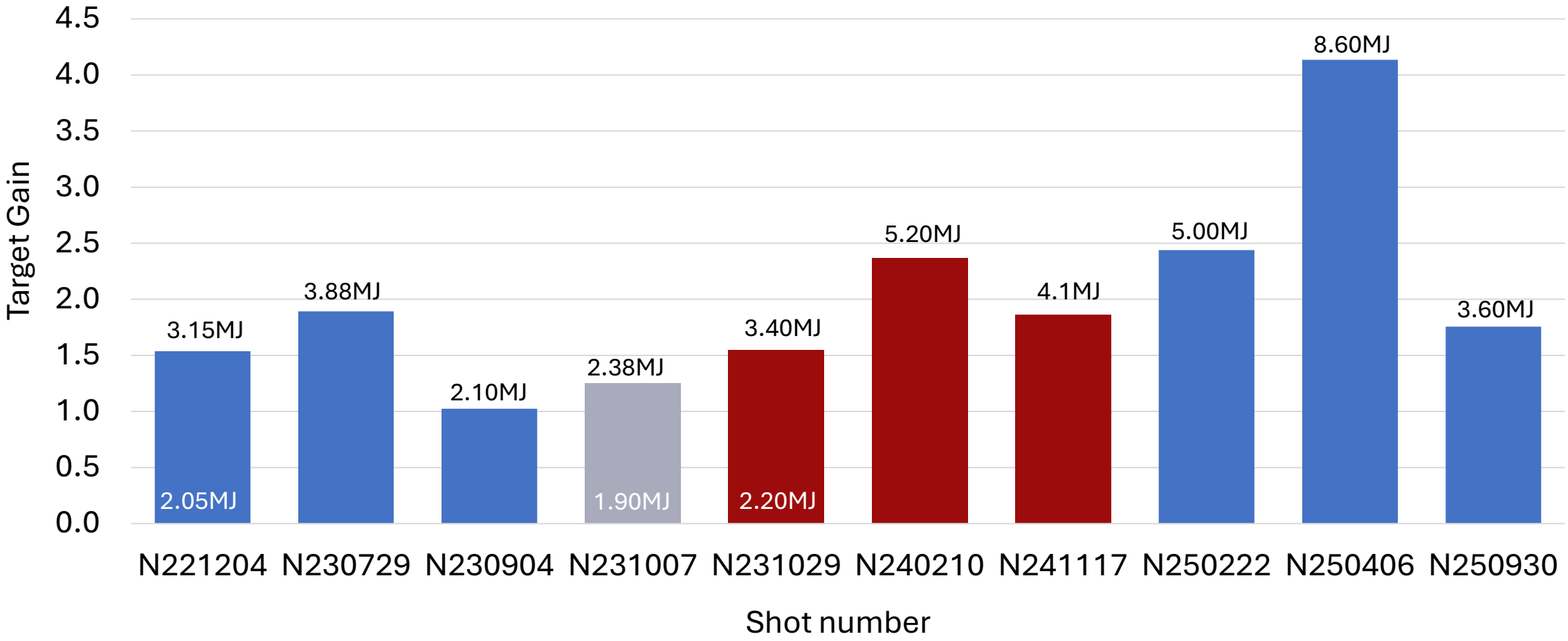
>30,000 trillion watts (30 PW)
~3.15 MJ with G_{target} ~ 1.5*
for ~100 ps



Temperature ~130,000,000 K

* Exceeding 1997 NAS definition of Fusion Ignition

Since then ignition has been demonstrated ten times and last year we set a record target gain > 4 with a yield of 8.6MJ

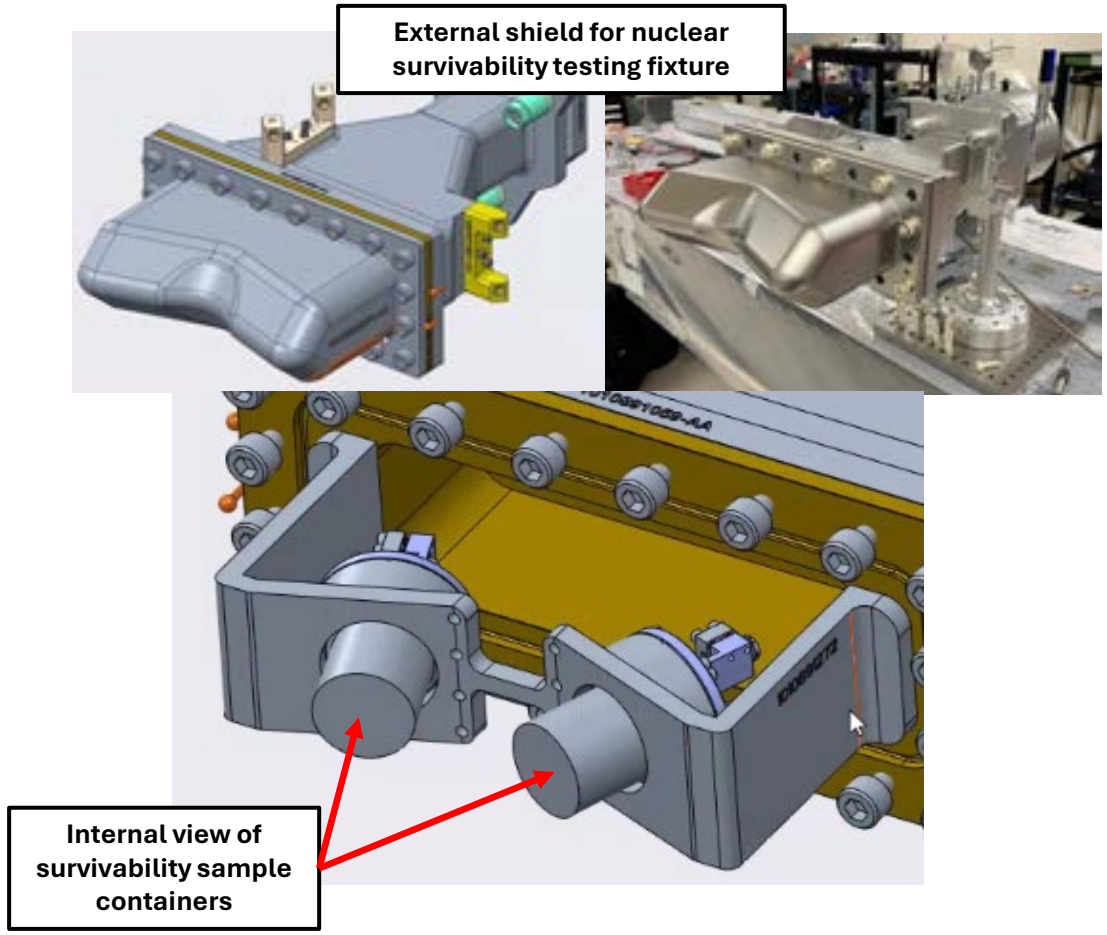


We continue to learn from each experiment and optimize designs to push the performance even higher

Fusion yields are now being used routinely at NIF to provide crucial nuclear survivability data

- Neutrons generated from ignition experiments are now being used to evaluate response of weapons materials to hostile nuclear environments

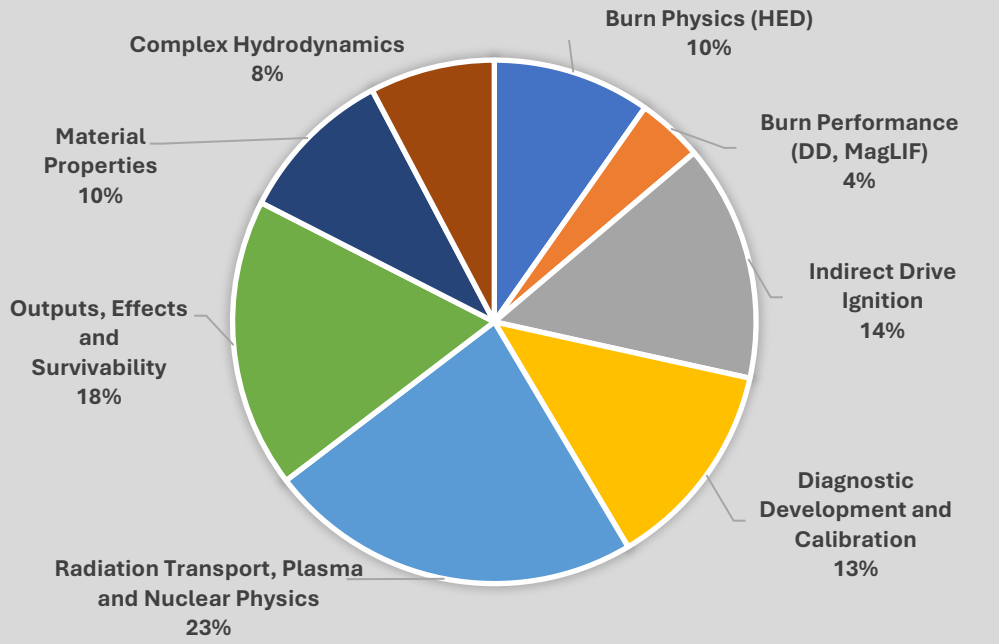
- As yields increase experiments can become increasingly sophisticated and even more relevant to nuclear weapon functions and design options

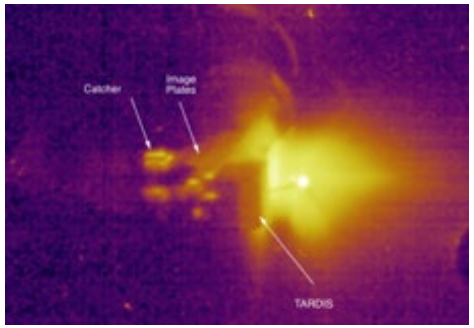


A recent experiment performed critical testing on Pu in support of W87-1 certification

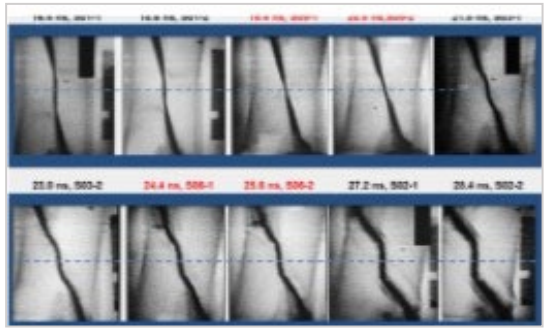
Last year NIF conducted 277 experiments contributing to the weapons program and scientific advancement of U.S. nuclear security

NIF Experimental Physics Areas (FY25)

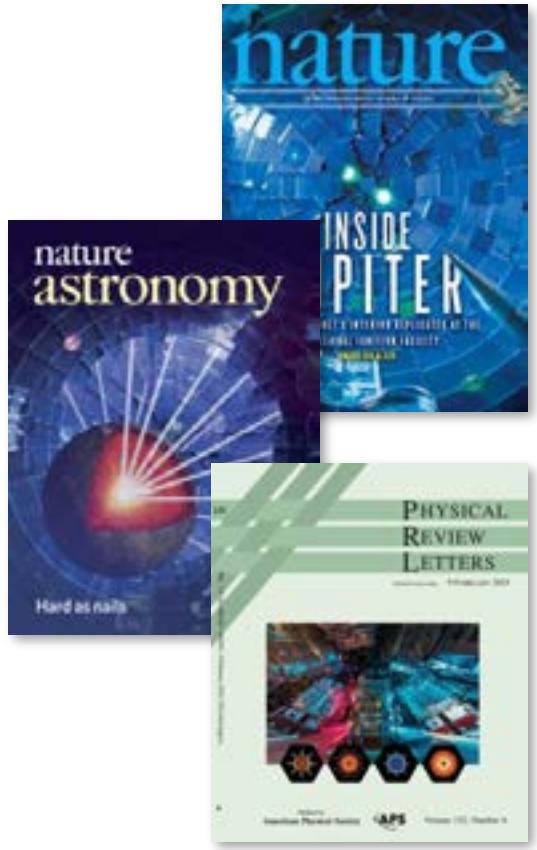




First WG Plutonium experiment on NIF



Hydrodynamic mixing with shear flow



Scientific leadership, proven through peer-reviewed research, is integral to our deterrent

Over the next decade, our priorities are the long-term sustainment of NIF while also expanding capabilities to enhance yield

NIF has not yet reached its full potential

Yield

Few MJ

10s of MJ

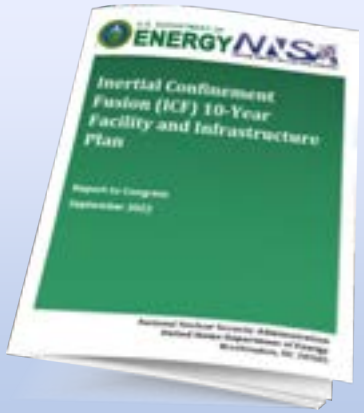
100+ MJ

2023

Routine MJ-yield operations and ignition

2023–2033

Long-term sustainment



NIF Enhanced Yield Capability (EYC)

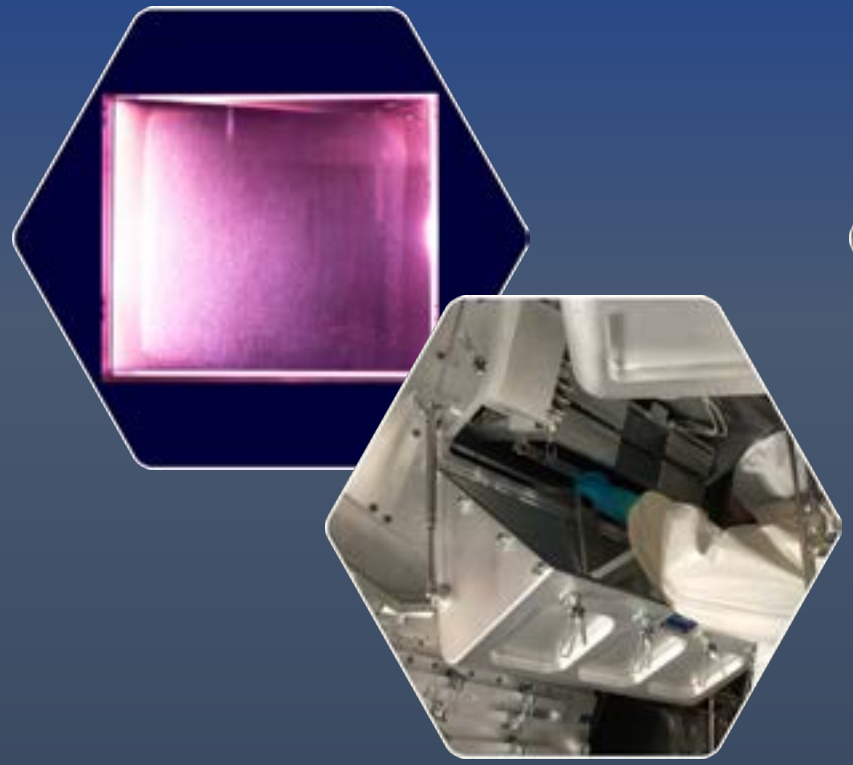
2032+

Explore high-yield, high-gain regime

NIF sustainment will address both capability degradations and restore lost workforce experience

Over the next ~6 years, we are refurbishing high risk degraded systems at NIF to sustain experimental operations through 2040s

Laser Aging

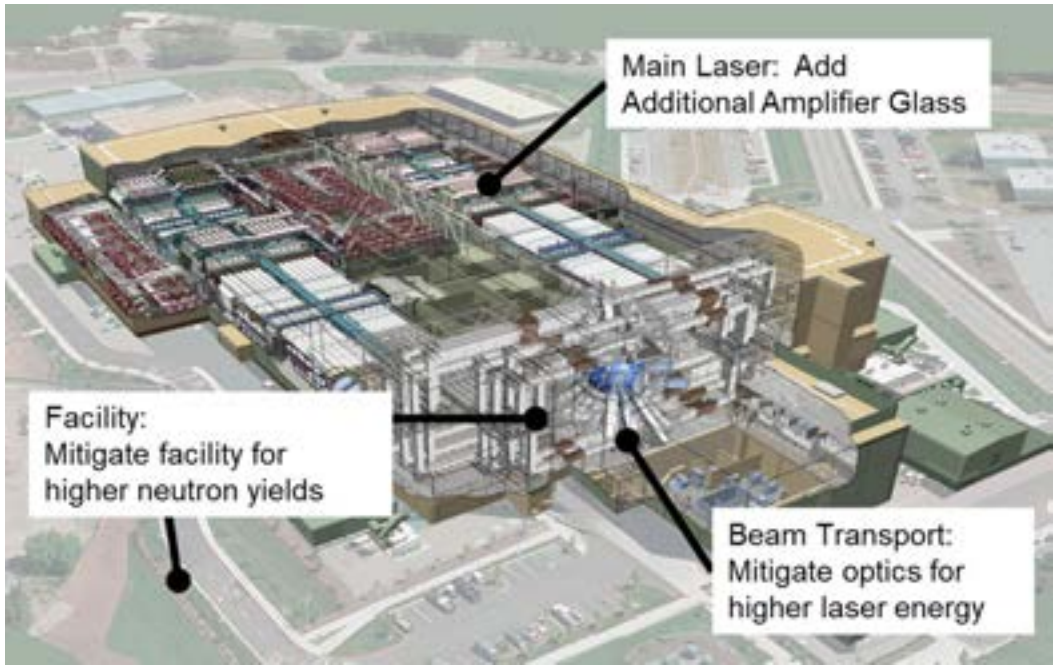


Obsolescence

Deferred Maintenance

All refurbishment activities are performed largely in parallel with continued operations

Beyond sustainment, we are beginning a project to upgrade the NIF to its maximal performance

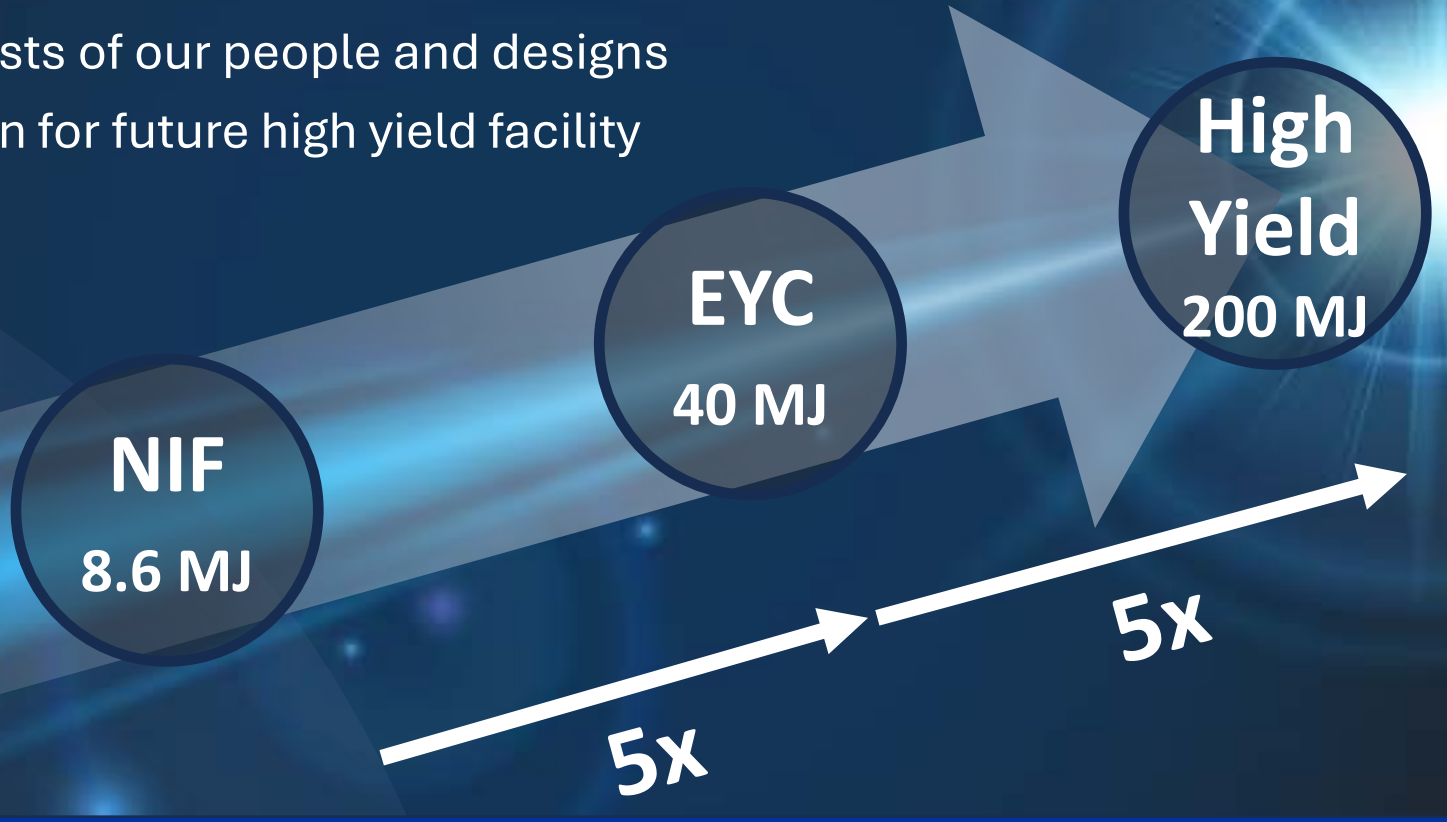


- The NIF Enhanced Yield Capability (EYC) project requires modest upgrades to facility using existing designs and established supply chains
- EYC increases laser energy from 2.2 MJ to 2.6 MJ to expand applications of yield for stockpile missions
- The CD-1 project phase was recently approved
- With necessary funding, EYC will begin operating in 2032

With EYC performance we anticipate achieving fusion yields >30MJ

A high-yield (200+MJ) capability remains a major goal for the NNSA, and an upgraded NIF is the next logical step

- Access unique secondary physics capability
- Challenge the design eco-structure
- End to end tests of our people and designs
- Risk reduction for future high yield facility



Enhanced Yield Capability (EYC) on NIF brings us a major step closer to full weapons conditions

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