

# The National Ignition Facility: An Experimental Facility for High Energy Density Science



**Edward I. Moses**  
Director of the National Ignition Facility  
Presentation to DOE NNSA SSGF Annual Conference  
June 21, 2010

LLNL-PRES-437932



# Fusion powers the cosmos





Albert Einstein – 1905

A black and white portrait of Albert Einstein is centered in the image. He has his characteristic wild, white hair and a mustache. The equation  $E=mc^2$  is superimposed in white, bold, sans-serif font across his forehead. The background is a vibrant, colorful nebula with swirling patterns of orange, red, and blue, interspersed with numerous small, bright stars.
$$E=mc^2$$





# Could we build a miniature sun on earth?

... to provide significant  
carbon-free energy  
for humankind.

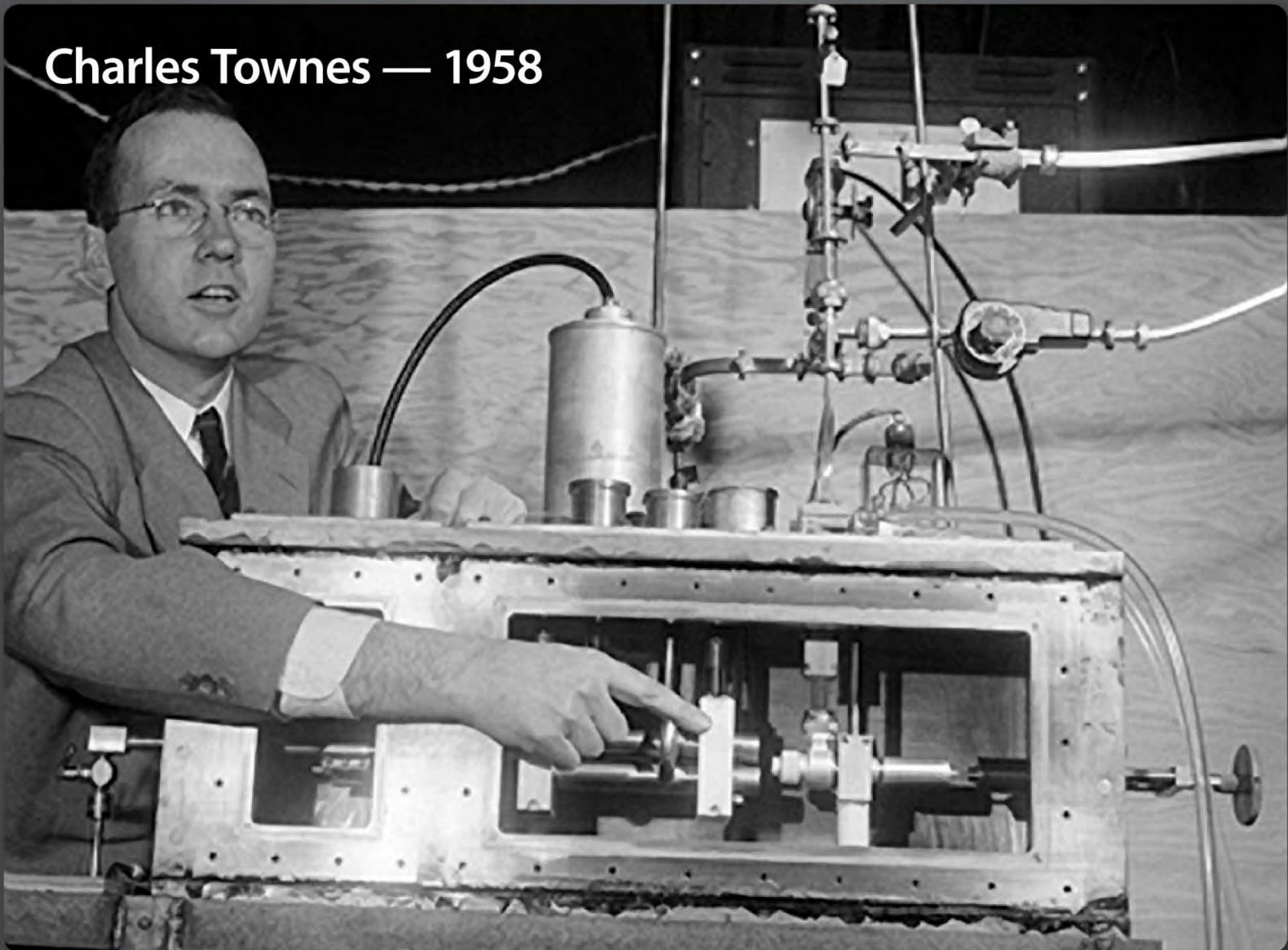


# To demonstrate the route to fusion energy



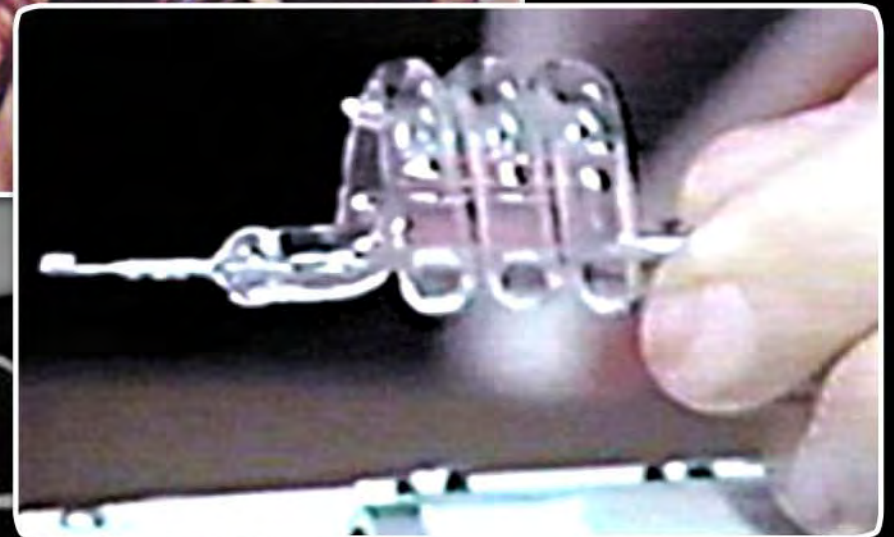


# Charles Townes — 1958



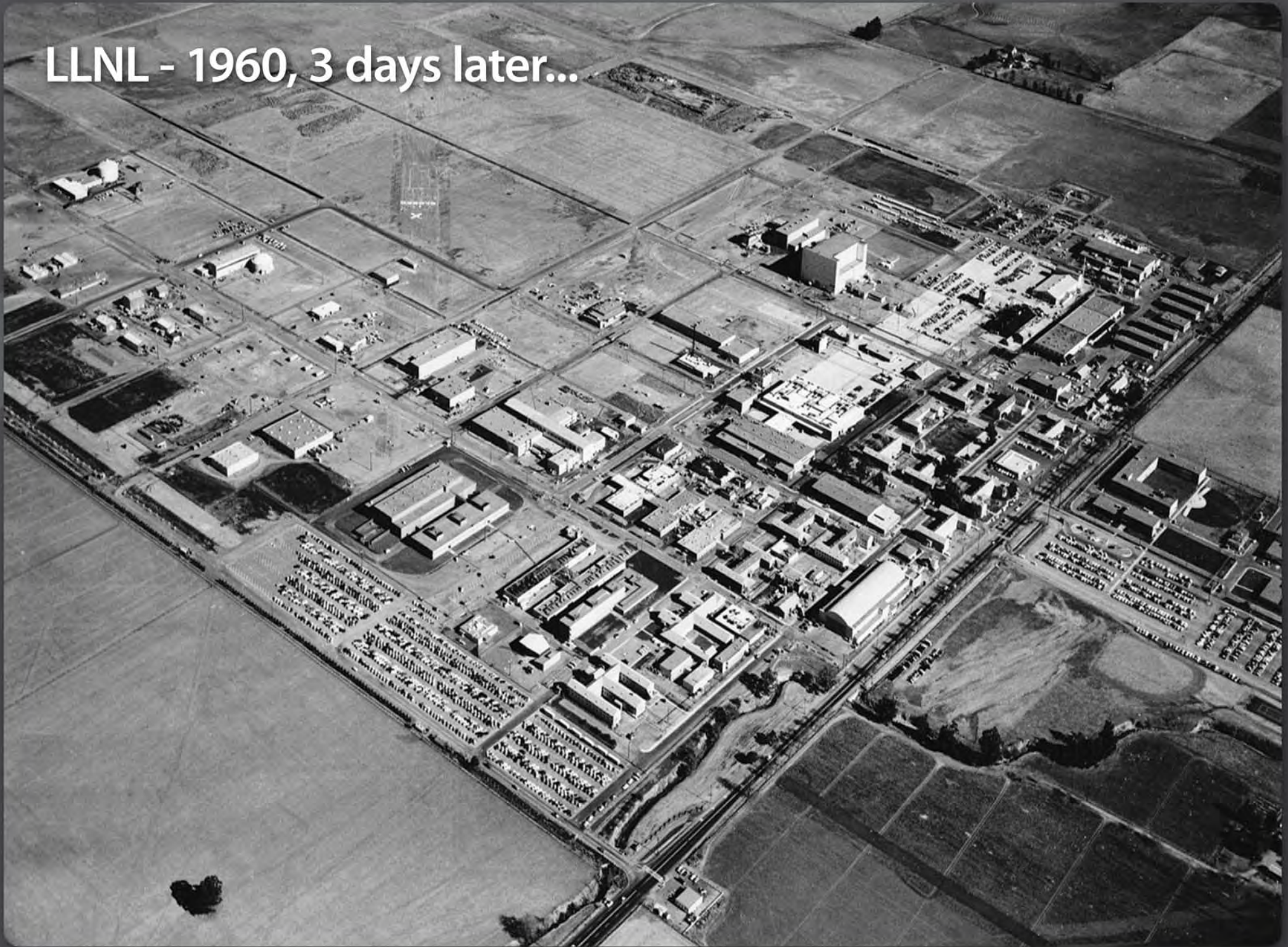


# Ted Maiman    First laser demonstrated on May 16, 1960





LLNL - 1960, 3 days later...





John Nuckolls proposed to use  
lasers for fusion energy

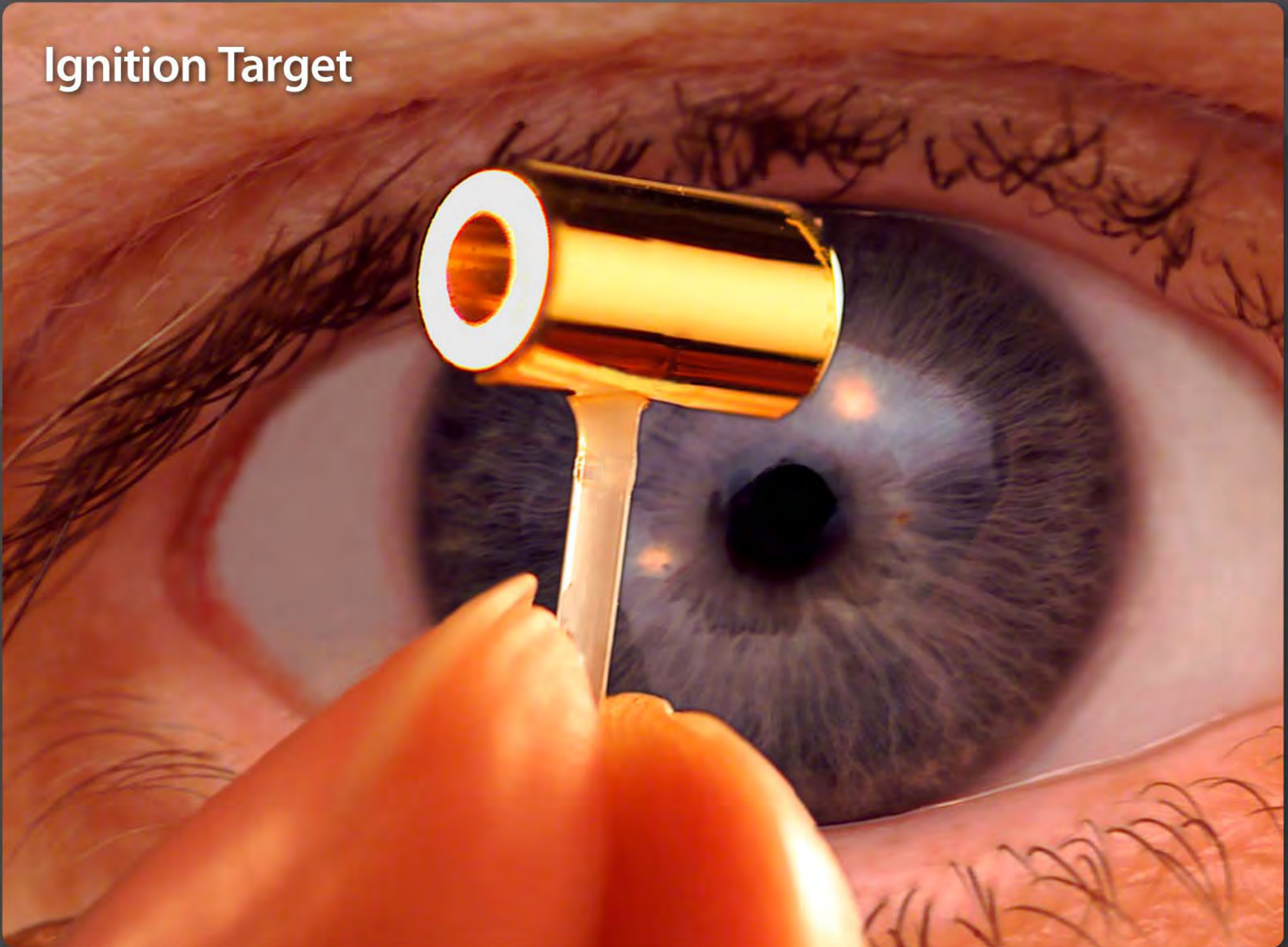








# Ignition Target







**San Francisco  
(45 mi.)**

**LLNL**

**National Ignition Facility**



# National Ignition Facility



- 1 Building, 5 Hectare
- 10 year construction complete
- 30 year operation



# NIF Laser System

- 192 Beams
- Frequency tripled Nd glass
- Energy 1.8 MJ
- Power 500 TW
- Wavelength 351 nm

NIF is 50 times more energetic than any previous laser



# NIF, 2009 4 MJ IR





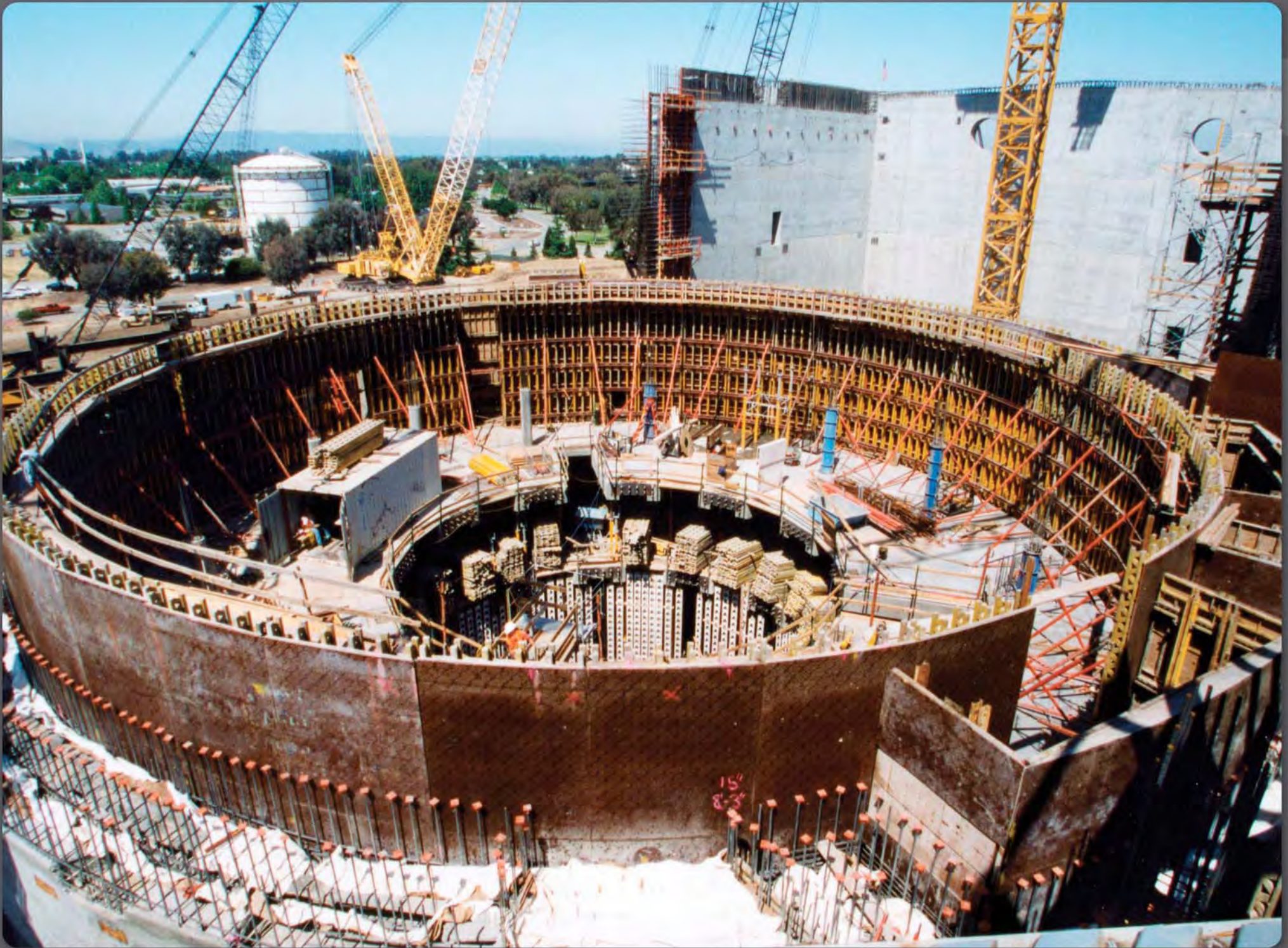




# Target Chamber Dedication June 1999



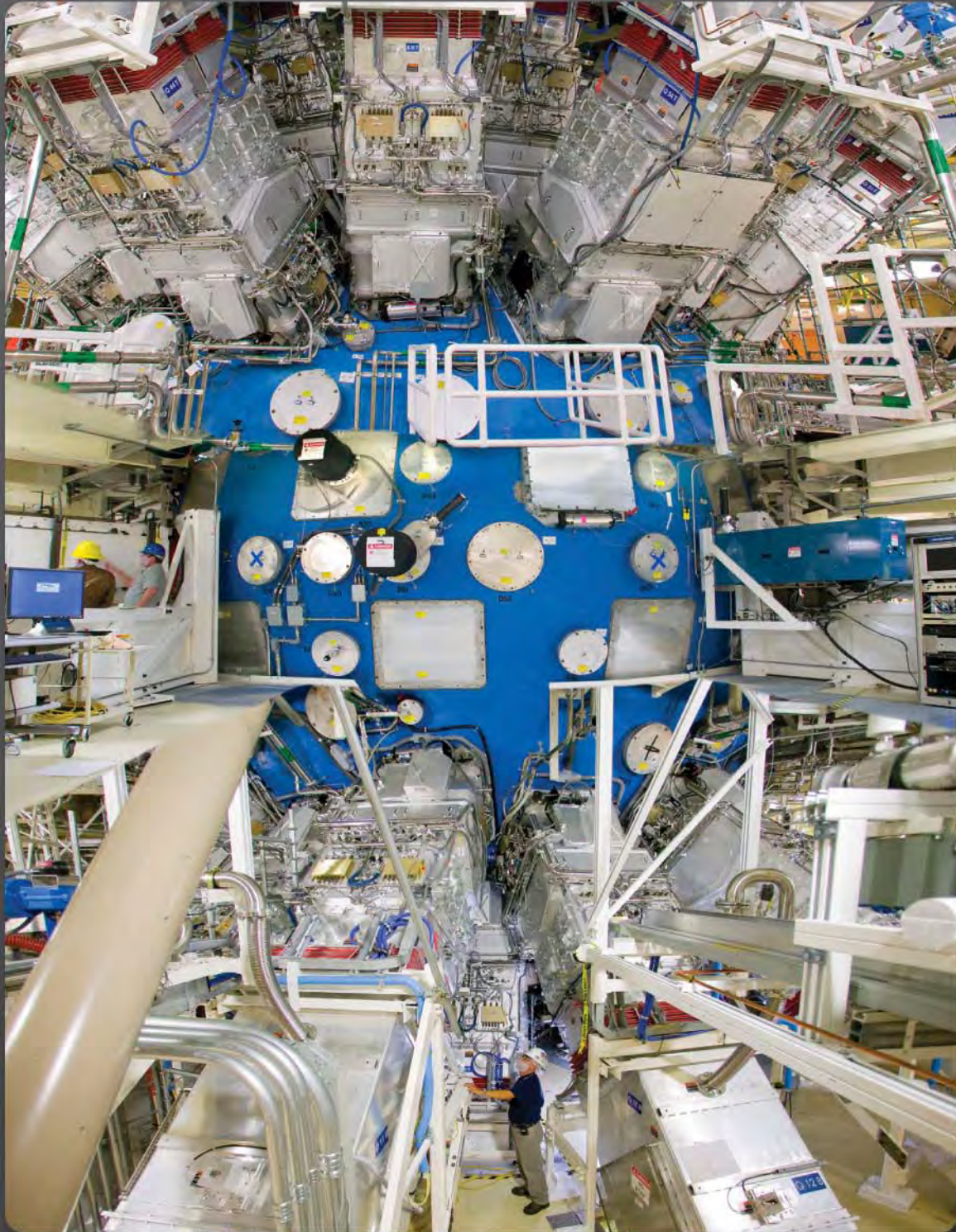










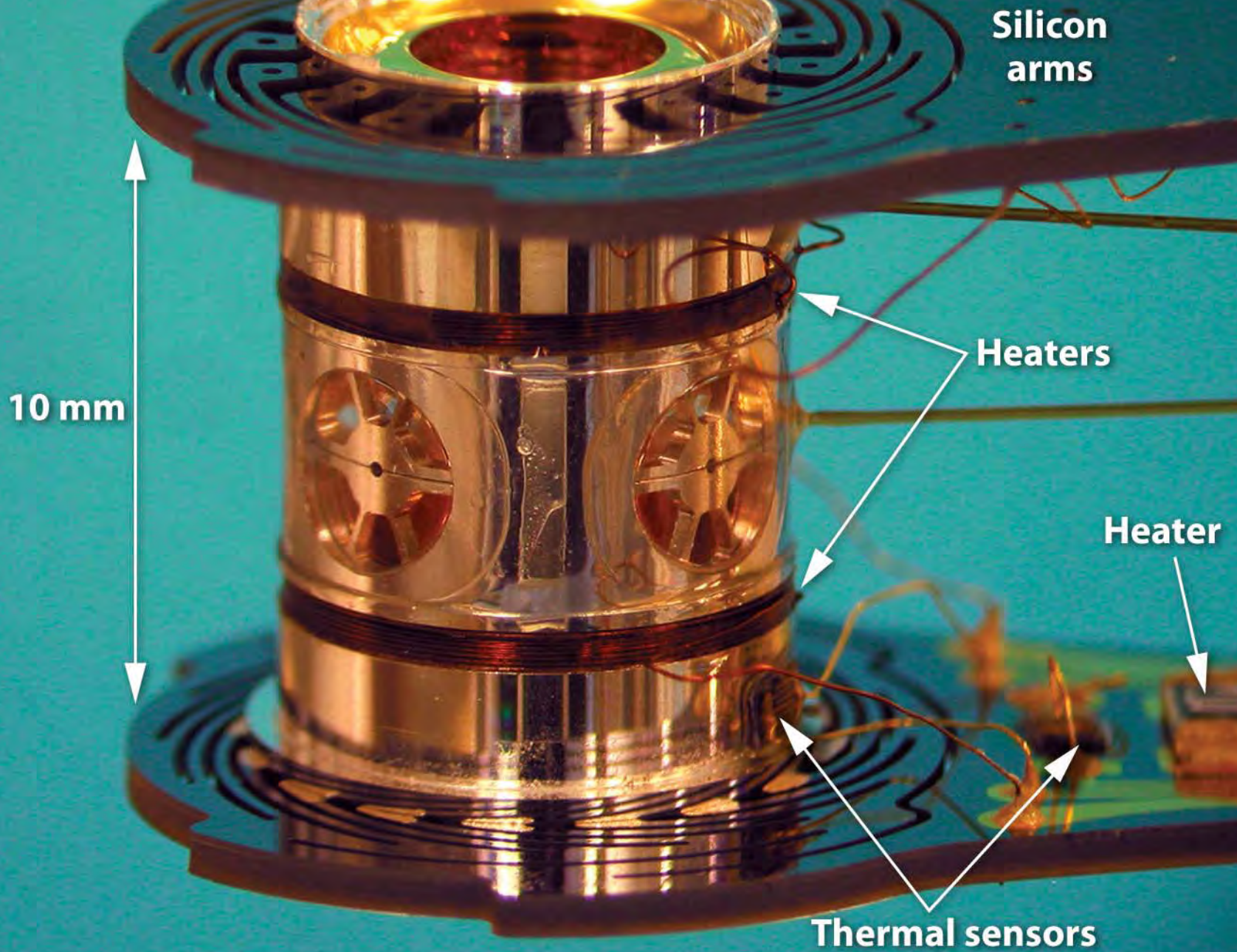




# Inside the Target Chamber







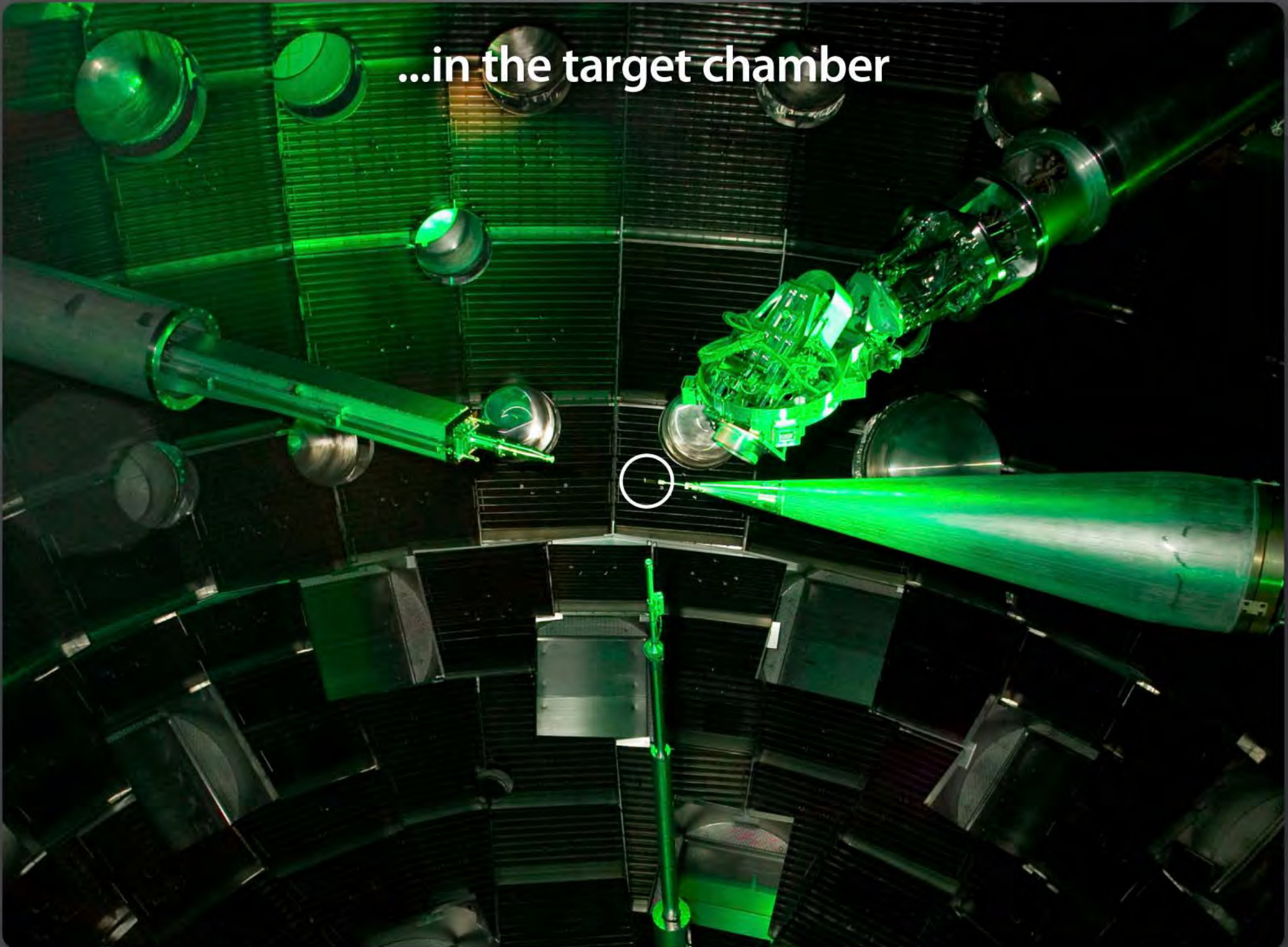


# NIC Target Assembly





...in the target chamber

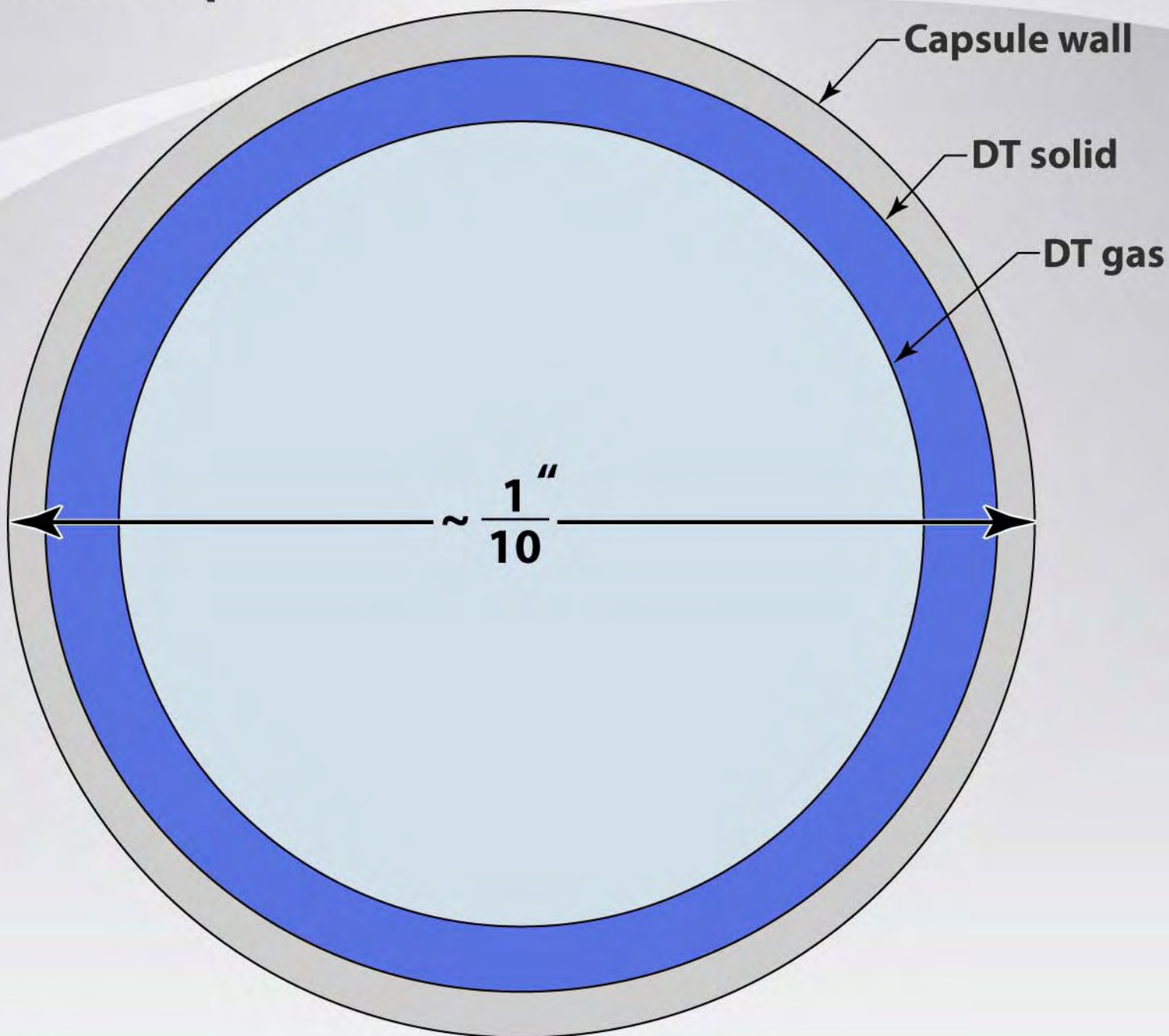








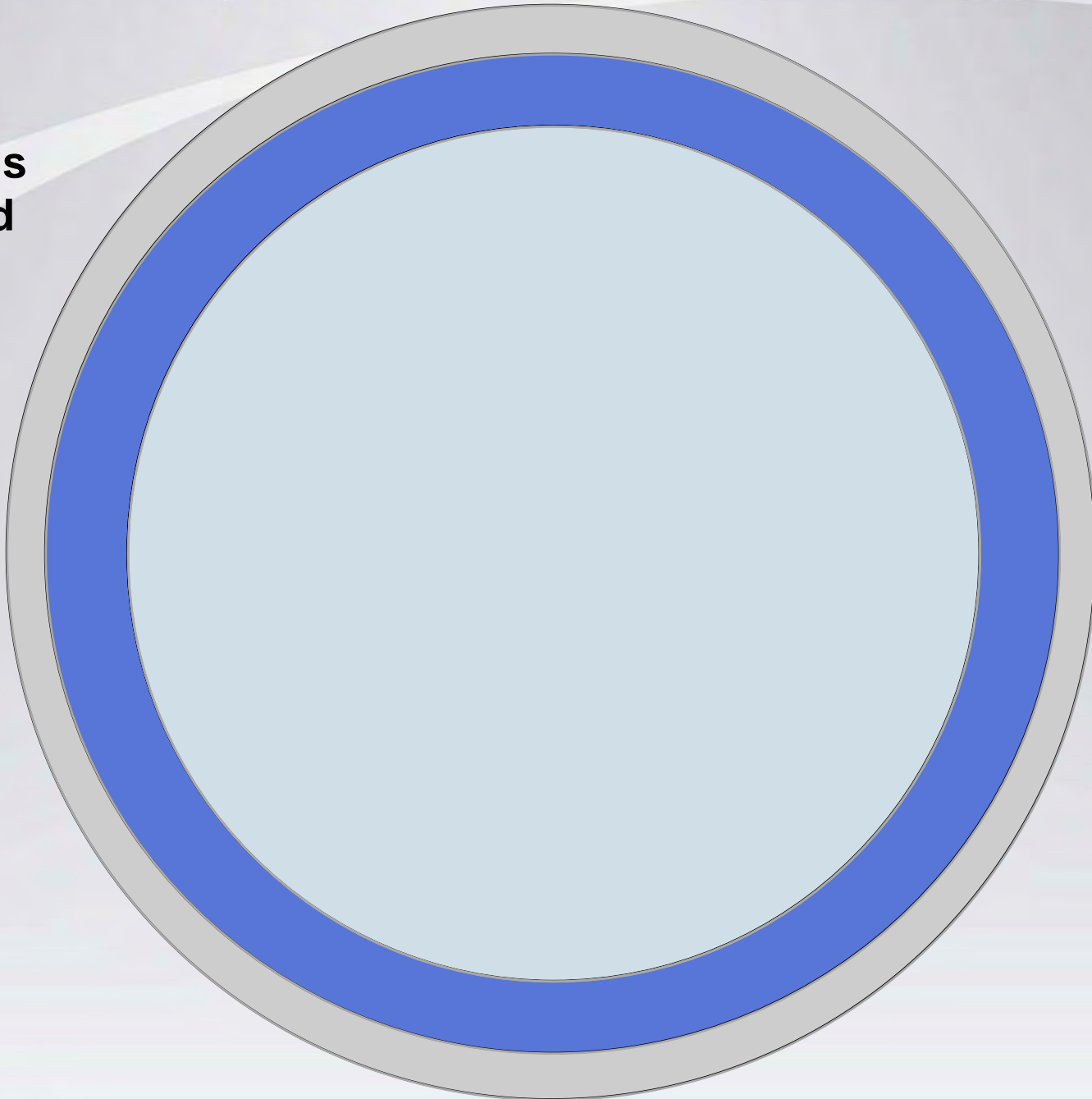
# DT implosion capsule





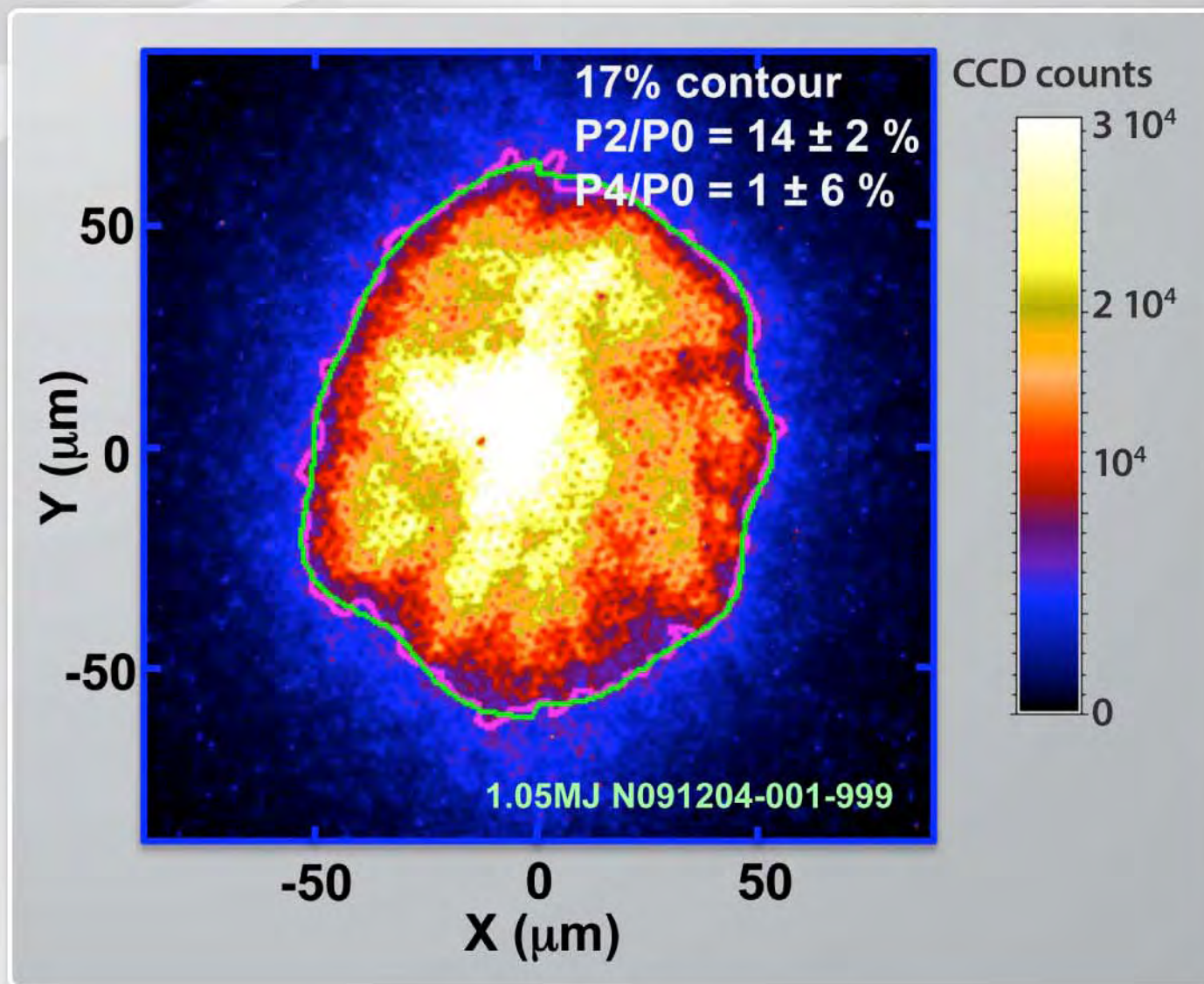
# DT implosion capsule

**10 billionths  
of a second  
later!**



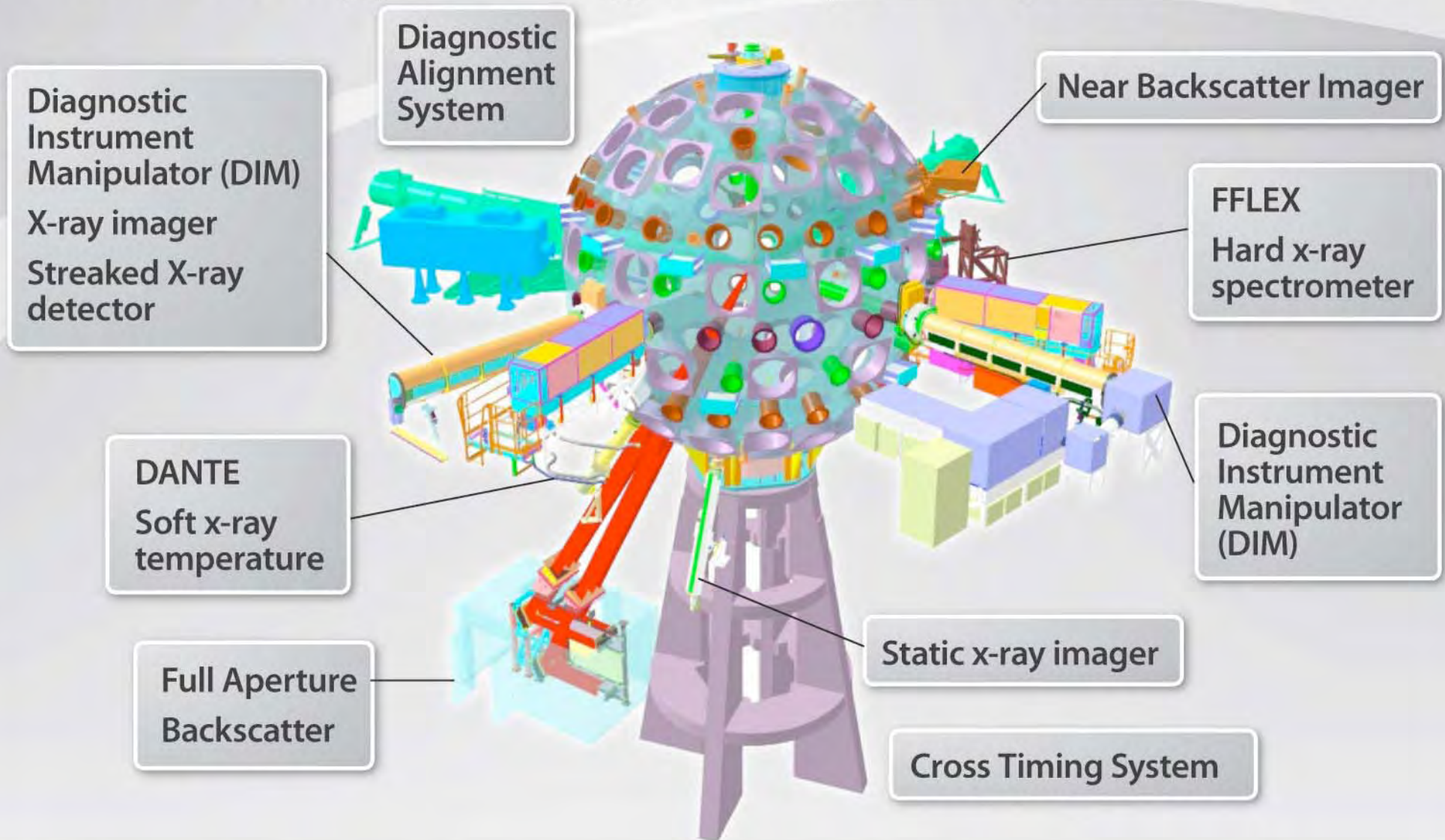


# Capsule implosions in 1 MJ cryogenic gas-filled hohlraum have shown good symmetry at 284 eV





# We have 36 types of diagnostic systems planned for NIC



**We successfully fielded half of all the types of diagnostic systems on NIF with 200 channels taking data on energetics campaign**



# MIT and collaborators have provided the Magnetic Recoil Spectrometer (MRS) to the NIC

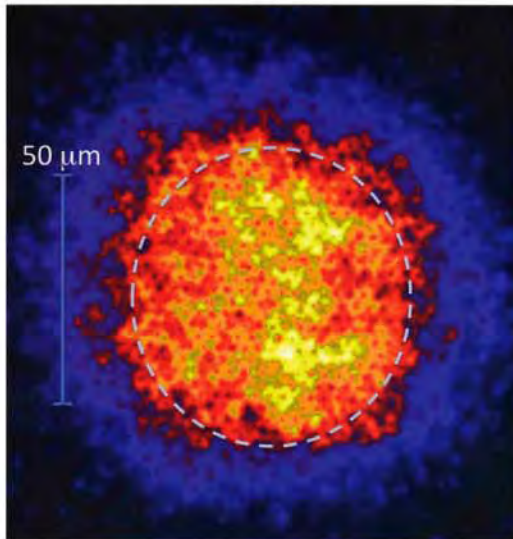




# NIF is ready for fusion demonstration experiments

## BULLETIN OF THE AMERICAN PHYSICAL SOCIETY

51<sup>st</sup> Annual Meeting of the Division of Plasma Physics  
November 2–6, 2009  
Atlanta, Georgia



November 2009  
Volume 54, No. 15



18-22 February San Diego

### NEWSFOCUS



## Fusion's Great Bright Hope

**IN NOVEMBER 2009, GORDON GIBSON, a grad student at Columbia University, joined others in a makeshift news office in here to make a scene a man that he would. Possible news for such a device, he served, included agreement, later the energy, fuel, and nuclear fusion—all 7 years before a laser was actually demonstrated. Gibson's team, various were depicted. He was not included in the 1993 Nobel Prize for the laser, and five 3 decades for thought in the past could be awarded a nomination. For researchers usually searched, and some of the applications he discussed up such as testing and operating materials, monitoring disease, communications, and television, have come from—optical, that is, from nuclear fusion.**

Five years, researchers at the Lawrence Livermore National Laboratory (LLNL) in California hope to mix that form of Gibson's for. Despite his thought, Gibson could not have imagined the lengths to which scientists and engineers would have to go to bring his prediction to reality. LLNL's National Ignition Facility (NIF), which was off its fully completed last month, is a laser on a truly epic scale. The building housing it is 10 stories high and contains an area that is as large as football fields. For a very long time, it

brings delivers a power of 500 megawatts, more than the power-generating capacity of the entire United States.  
If all goes according to plan, some time in 2018 the power of those beams will be delivered as a small but efficient capsule filled with hydrogen isotopes. The resulting implosion will compress the hydrogen to temperatures and pressures a billion times that in the core of the sun. If NIF's scientists get everything right, the hydrogen capsules will do what they do in the sun: fuse together into helium nuclei and release a huge amount of energy. NIF's principal aim is to reach "ignition", a self-sustaining fusion burn that grows off more energy than was put into it to make it happen—something that so far has occurred only in nuclear explosions and stars.

"It only has a few years waiting for this moment for a long time," says NIF Director Dr. Edward Moses. The achievement could have profound implications for our future energy supply. If the fusion gain—the ratio of energy out over energy in—is high enough and is repeatable, the development of a small, safe, quiet, and steady state, low-carbon energy source is almost inevitable. The world will again see a change in the political

climate," says Mike Chase, head of the Central Laser Facility of the Rutherford Appleton Laboratory near Oxford, UK.  
Energy production is not NIF's main aim, however. Its funding comes from the energy or science budgets but from the efforts of the National Nuclear Security Administration (NNSA), the agency tasked with the maintenance and testing of nuclear weapons and control reactors. NIF's main mission is to provide hard data that can be used to improve the design of nuclear weapons, not to the elimination of nuclear weapons, NIF is the best way to ensure



This point, an eye for eye, may not show the end of the participants, with another target.

# NIF fusion in the News



# NIF and advanced computing - 2 key capabilities for national security

NIF

**NIF**

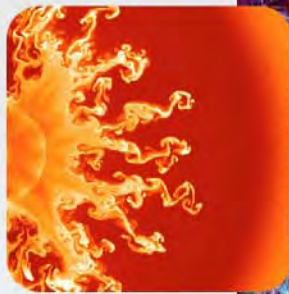
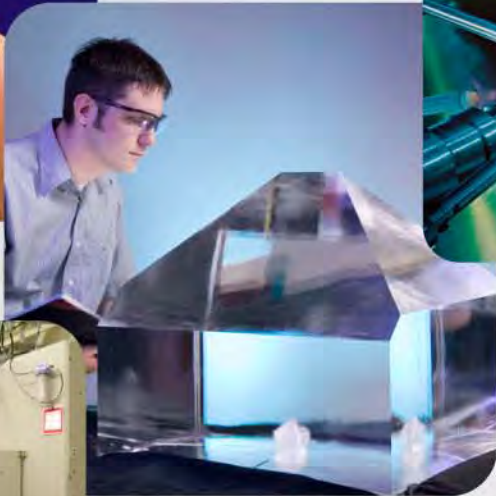
**World's Most  
Energetic Laser**

**ASC**

**World's Most  
Powerful Computers**



# Large and dedicated multi-disciplinary teams from National Laboratories, Academia, Industry and the International Community



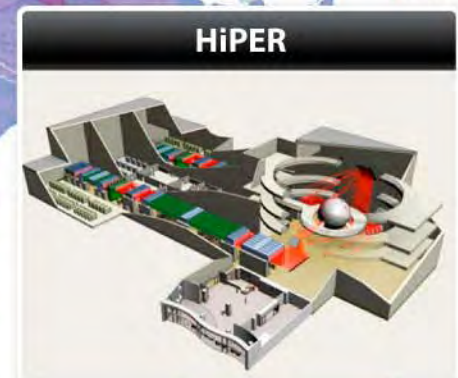
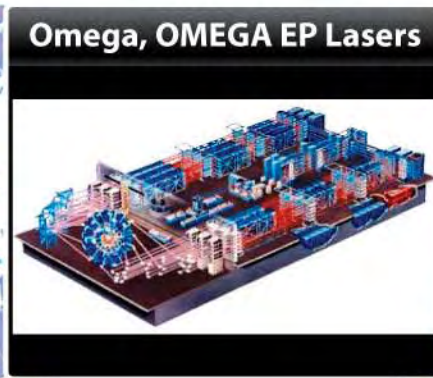
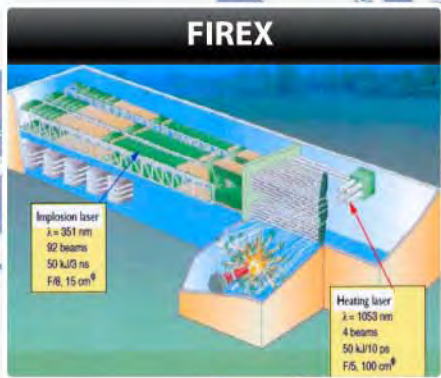


# U.S Partners in NIF Enterprise:





# ...and we have growing international capabilities





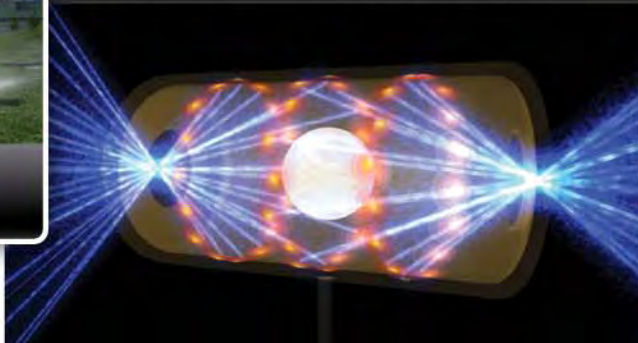
# NIF Master Strategy

## NIF Project



**Operational**

## National Ignition Campaign



**2006–2012**

## National User Facility



**2009–2030  
support all sponsors**



# NIF missions

## Ensuring National Security



## Advancing Frontier Science



## Building Future Generations of HED Scientists



## Enabling Clean Energy





# NIF Master Strategy

**NIF Project**



**Operational**

**National  
Ignition Campaign**



**2006-2012**

**National  
User Facility**

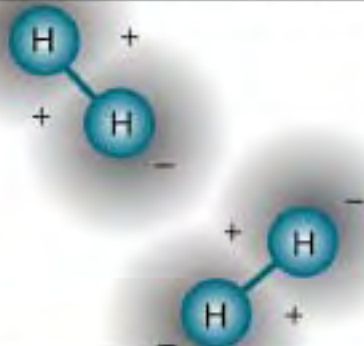


**2009-2030**



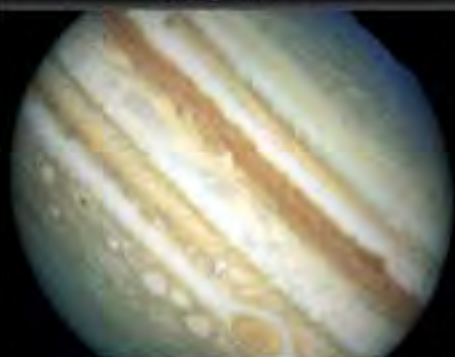
# NIF will provide unprecedented capabilities to study matter at high-energy density conditions

## Hydrogen Molecule



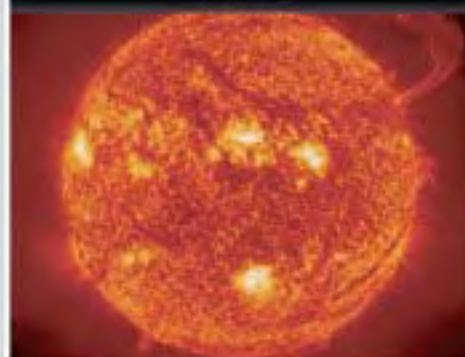
Binding energy  
 $\sim 10^{11}$  J/m<sup>3</sup>

## Jupiter



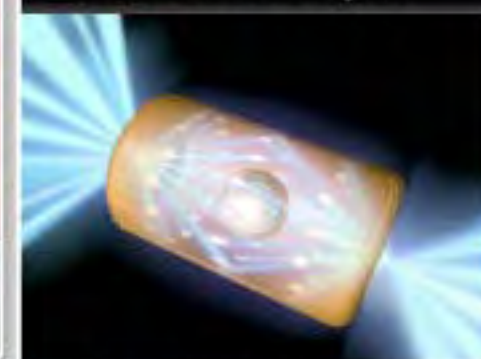
P ~ 80 MBar  
(core)

## Sun



P ~  $3 \times 10^5$  MBar  
(core)

## Fusion Target



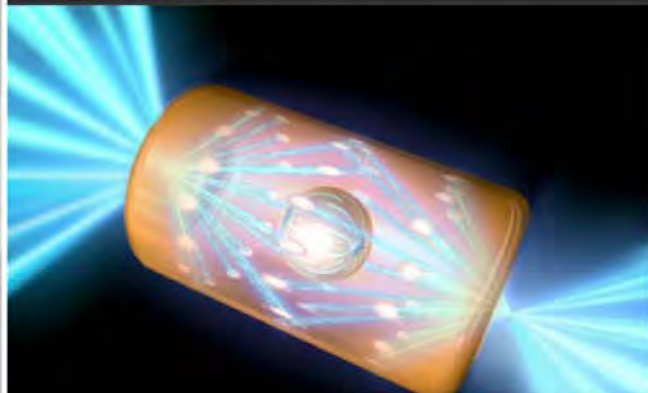
P ~  $2 \times 10^6$  MBar  
(peak burn)

1 atm = .98 Bar

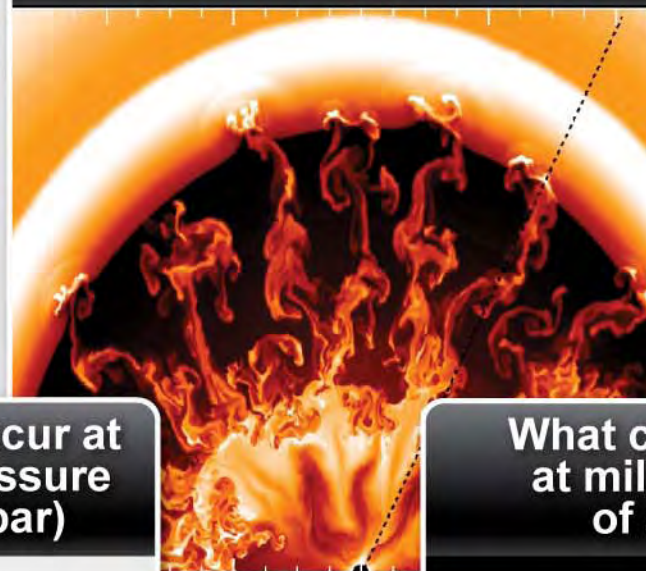


# Compelling scientific questions for NIF

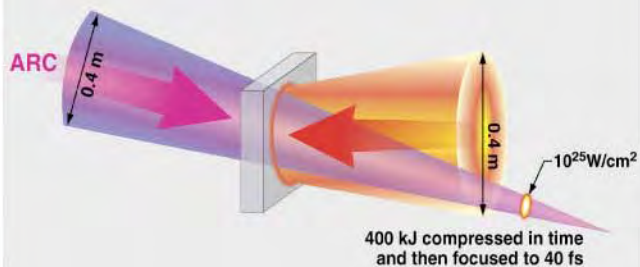
Can we demonstrate laboratory ignition?



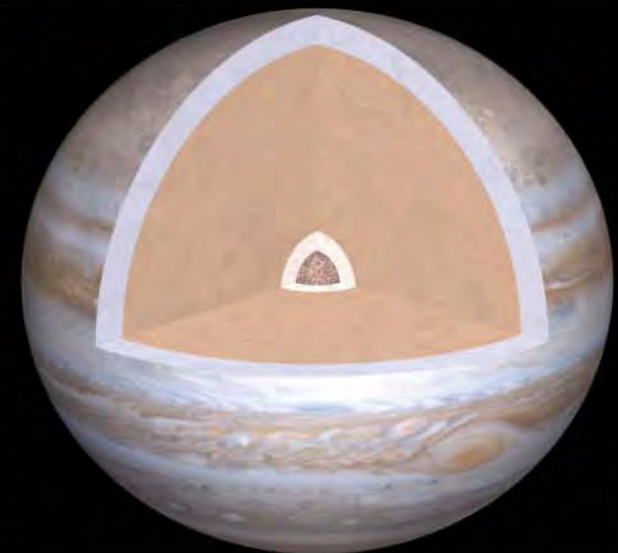
How are elements with  $Z > 26$  created?



What phenomenon occur at ultra high photon pressure ( $10^{25} \text{ w/cm}^3$ ,  $10^{10} \text{ M bar}$ )

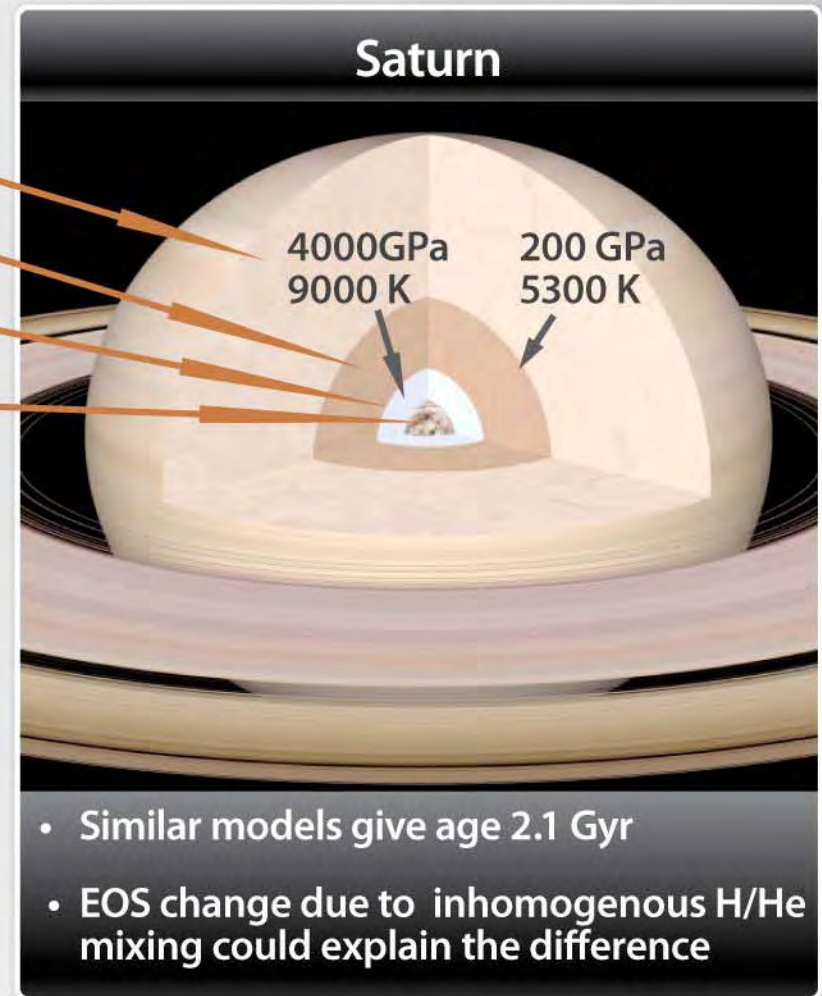
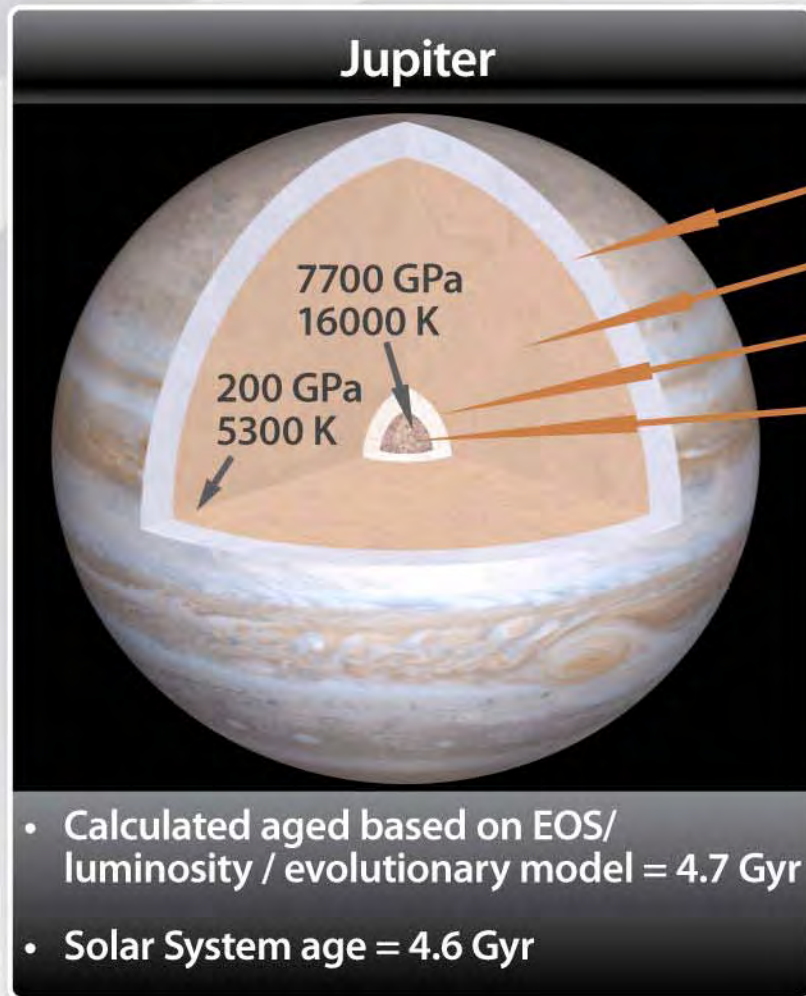


What chemistry occurs at millions to billions of atmospheres?





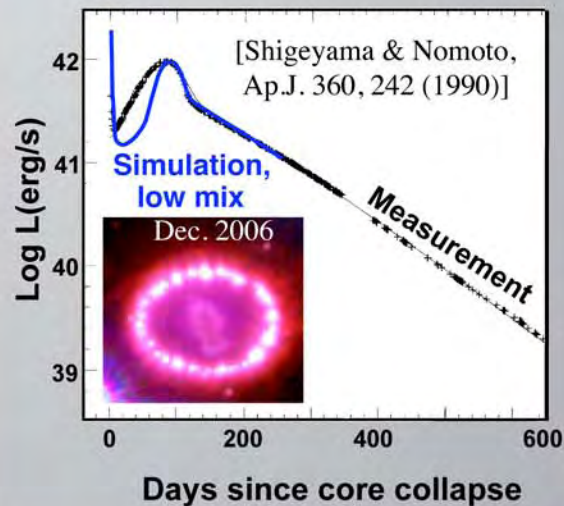
# This capability will allow us to explore fundamental questions in planetary physics



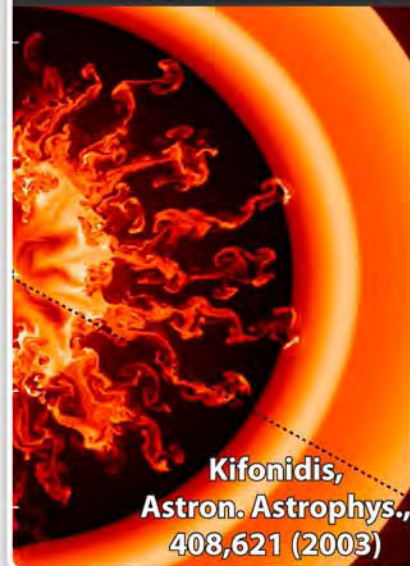


# Simulations with low degree of hydrodynamic mixing do not agree with observations

SN1987A measured light curve does not match low-mix simulation

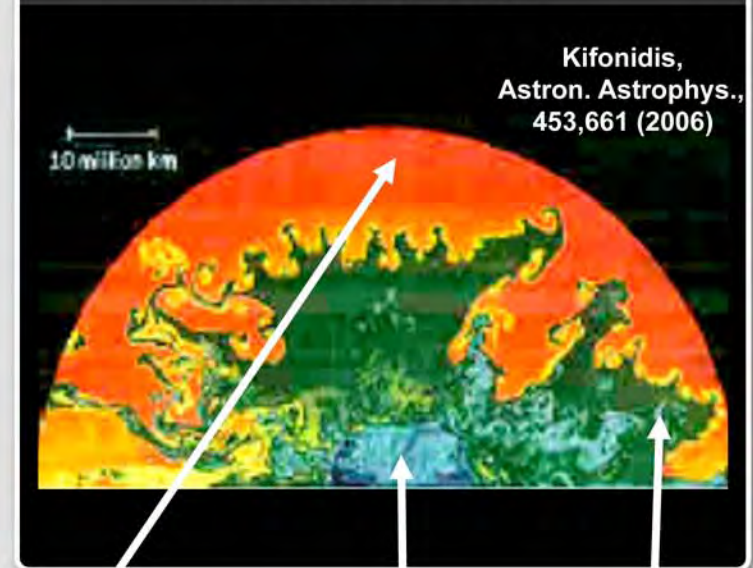


Type II supernova simulation



$5 \times 10^{11}$  cm  
(Prof. A. Burrows, Princeton)

Simulation at t=5 hours, showing mixing of core, mantle, envelope

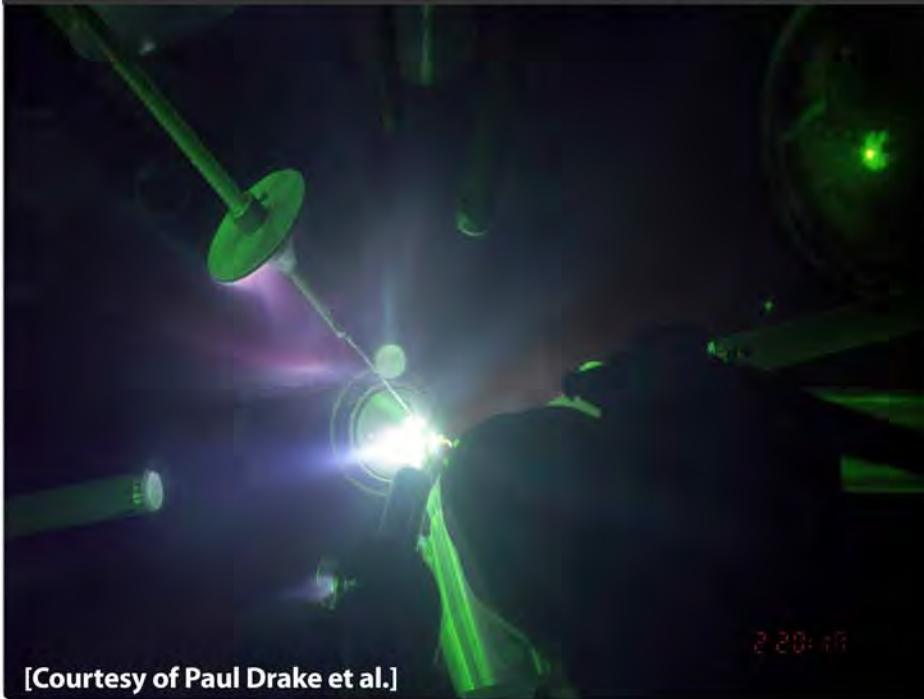


- Does He shell breakup allow core spikes to escape?
- Are differences in 3D vs 2D spike velocities important?
- How do 3D perturbations on multiple interfaces interact?
- How does the initial perturbation spectrum affect the late-time evolution?
- Are the simulations sufficiently turbulent to properly reproduce the supernova?



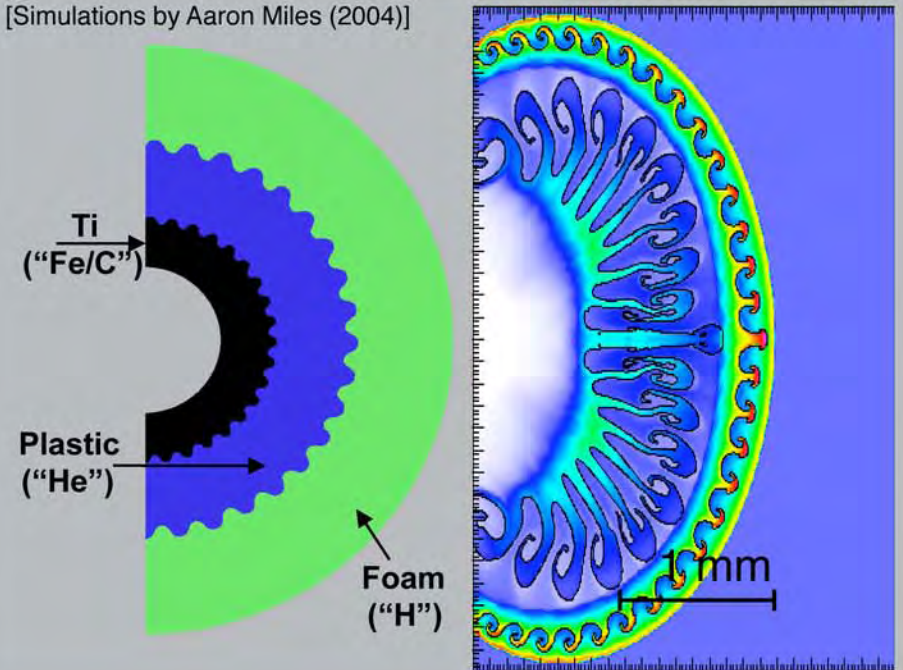
# NIF has sufficient energy to test multi-interface simulations of core-collapse supernovae turbulent hydrodynamics

**OMEGA experiments at University of Rochester Laboratory for Laser Energetics- proof of principle**



**NIF hemisphere target and simulation- sufficient energy for multi-interface, diverging, scaled SN experiment**

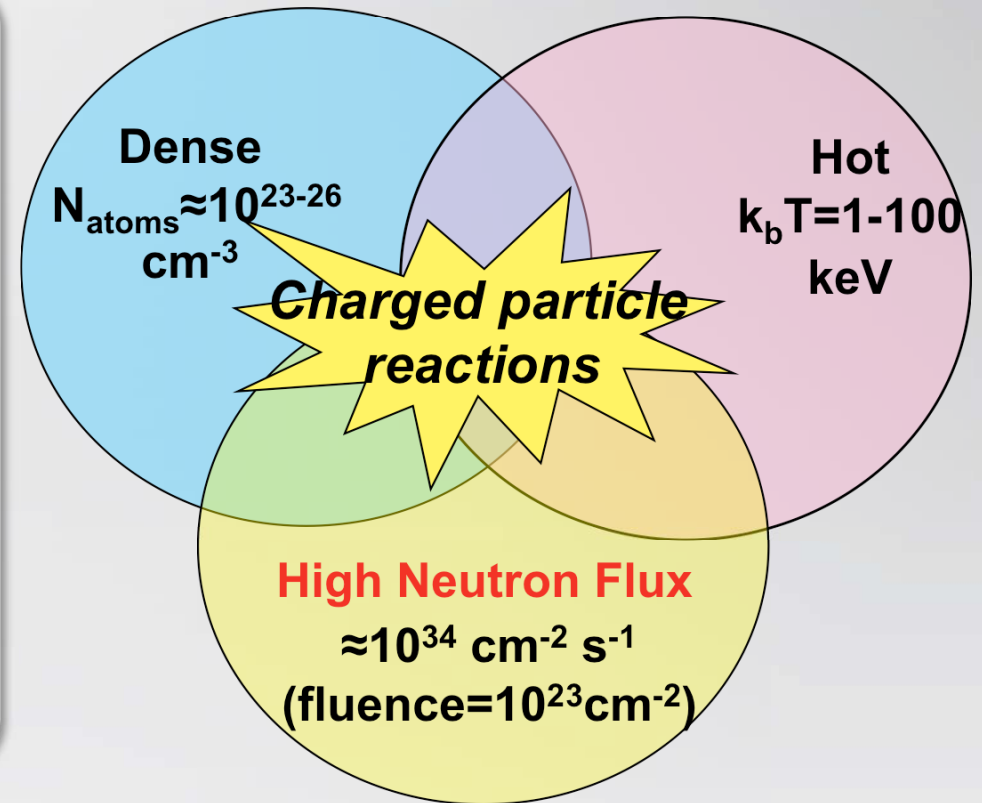
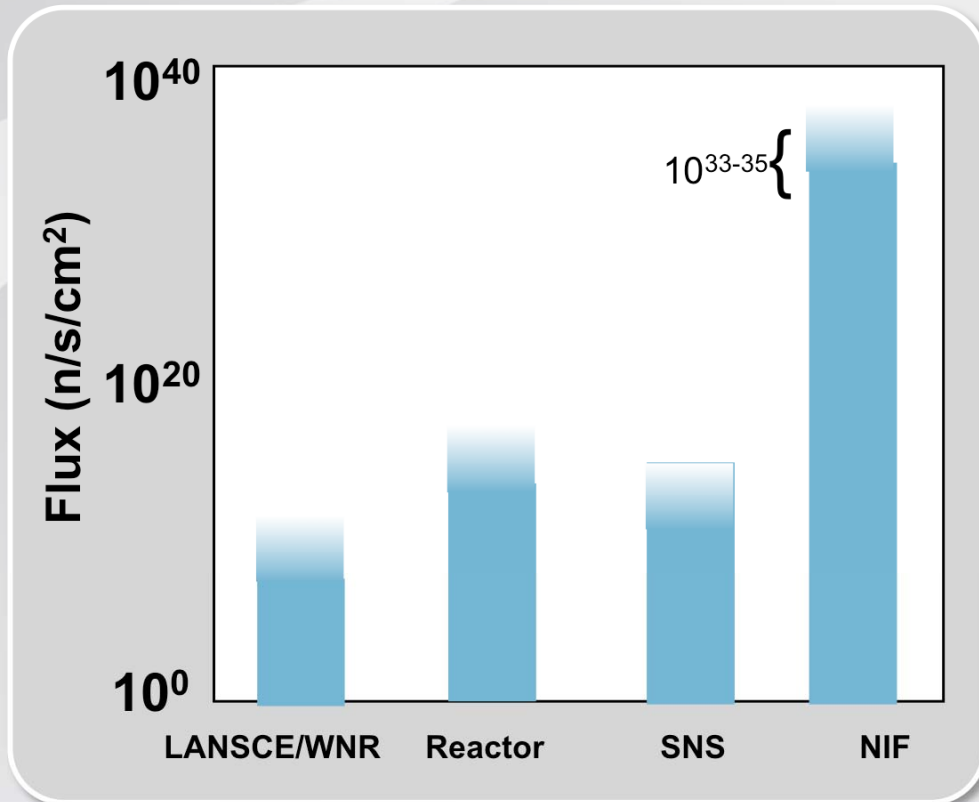
[Simulations by Aaron Miles (2004)]



**NIF experiments are planned to start in 2011-2012**



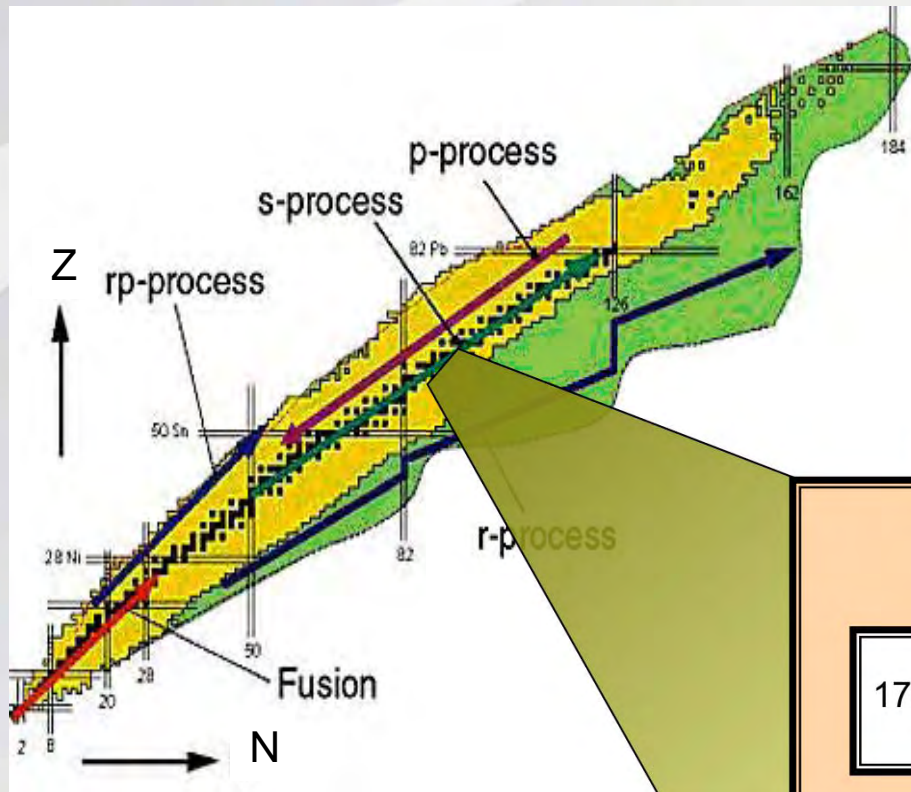
# NIF enables a unique set of Nuclear Physics because NIF is a nuclear facility after all



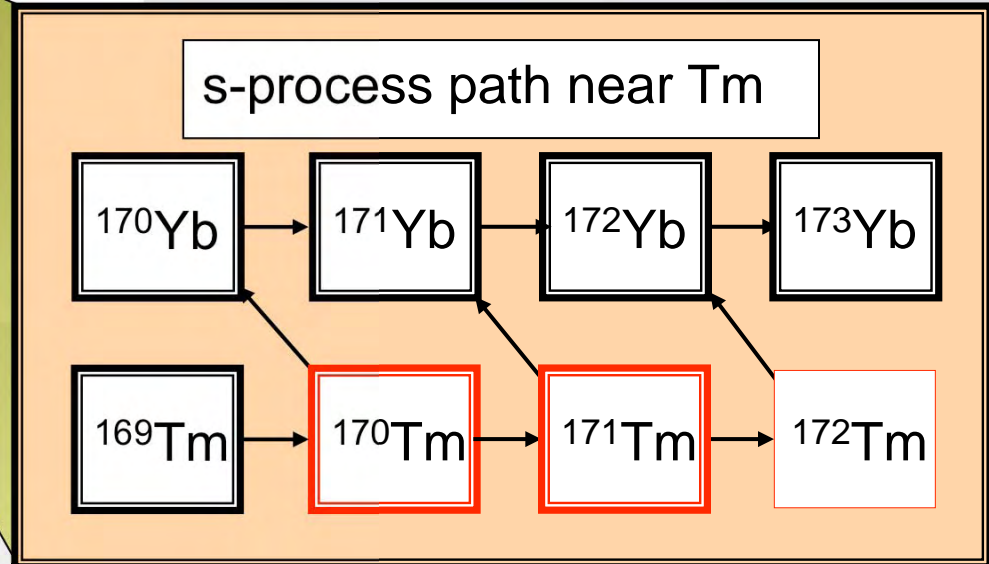
- NIF will enable us to measure nuclear cross sections involving new processes for the first time
- To measure things you need the right diagnostics



# Workshop on Neutron Capture Nucleosynthesis using NIF held at LBNL – March 23-25, 2010



- 32 participants from 3 countries and 5 different institutions



*>1/2 of all nuclei with  $A > 56$  are made via the s-process*



# Call for proposals: Fundamental High Energy Density Science Experiments at the NIF



## Call for Proposals in two major areas:

- **Facility Time - 40 proposals**
- **Concept Development (\$100k maximum 1 year awards) - 40 proposals**



completed on March 27, 2009. NIF is now operational and the most powerful ICF laser facility in the world.

LLNL is issuing a call for proposals for experiments in fundamental high energy density (HED) science experiments at the NIF for the period FY2010-FY2012. The solicitation contains two components:

- **NIF Facility Time Solicitation:** Applicants may apply for NIF facility time in the FY2010-FY2012 timeframe. Direct financial support for NIF experiments via this call is not available at this time, though the facility will provide internal support consistent with available

The National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL) is a 192-beam laser system designed for research in inertial confinement fusion (ICF) and other areas of high energy density (HED) science. NIF was constructed by the US National Nuclear Security Administration (NNSA) in support of the US Stockpile Stewardship Program (SSP). NIF construction was

DRAFT- PREDECISIONAL

## National Ignition Facility Governance Plan



**NIF**  
National Ignition Facility

August 31, 2009

An Equal Opportunity Employer • Lawrence Livermore National Security, LLC •  
Operated for the US Department of Energy • P.O. Box 808, Livermore, CA 94551-0808 •  
(925) 422-4100 • <http://www.llnl.gov>

**Proposed NIF experiments will be reviewed by an advisory committee chaired by Dr. Robert Rosner**

**To learn more visit us on the web at:  
[http://lasers.llnl.gov/for\\_users](http://lasers.llnl.gov/for_users)**



CERN

Chandra x-ray observatory

**NIF will be a premier international center for experimental science**



APS

SLAC

**We look forward to your experiments**





**We are burning up to 10 million years of fossil carbon fuel every year**

**It's not going to last forever**

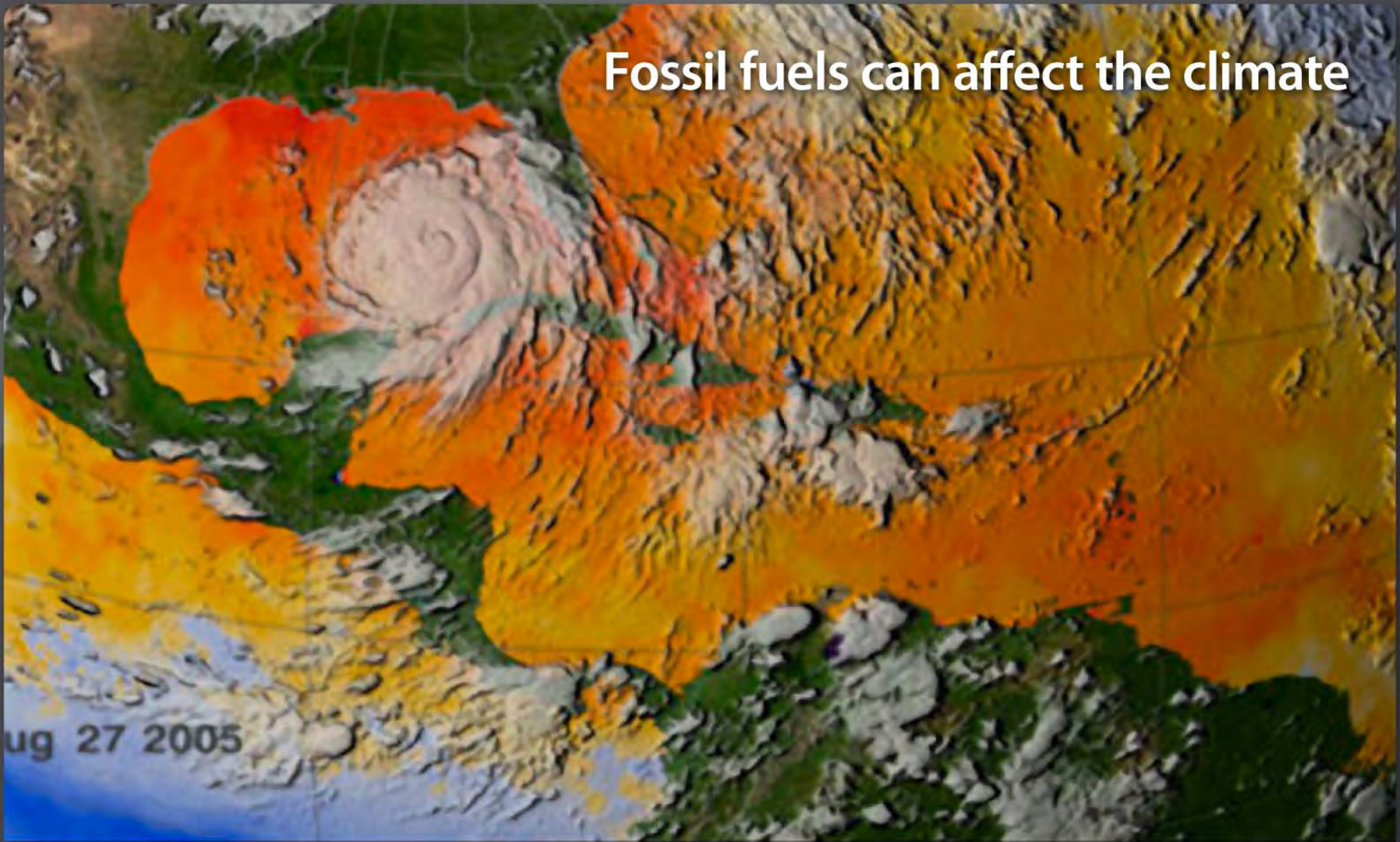


# Fossil fuel can affect quality of life

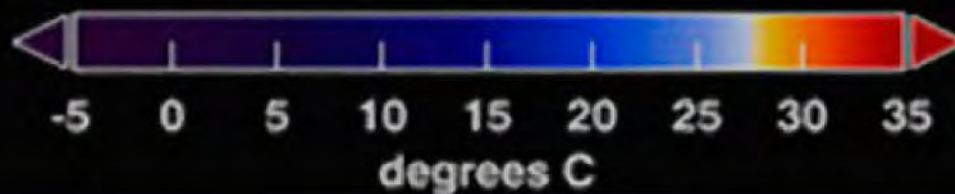




# Fossil fuels can affect the climate



Sea Surface Temperature





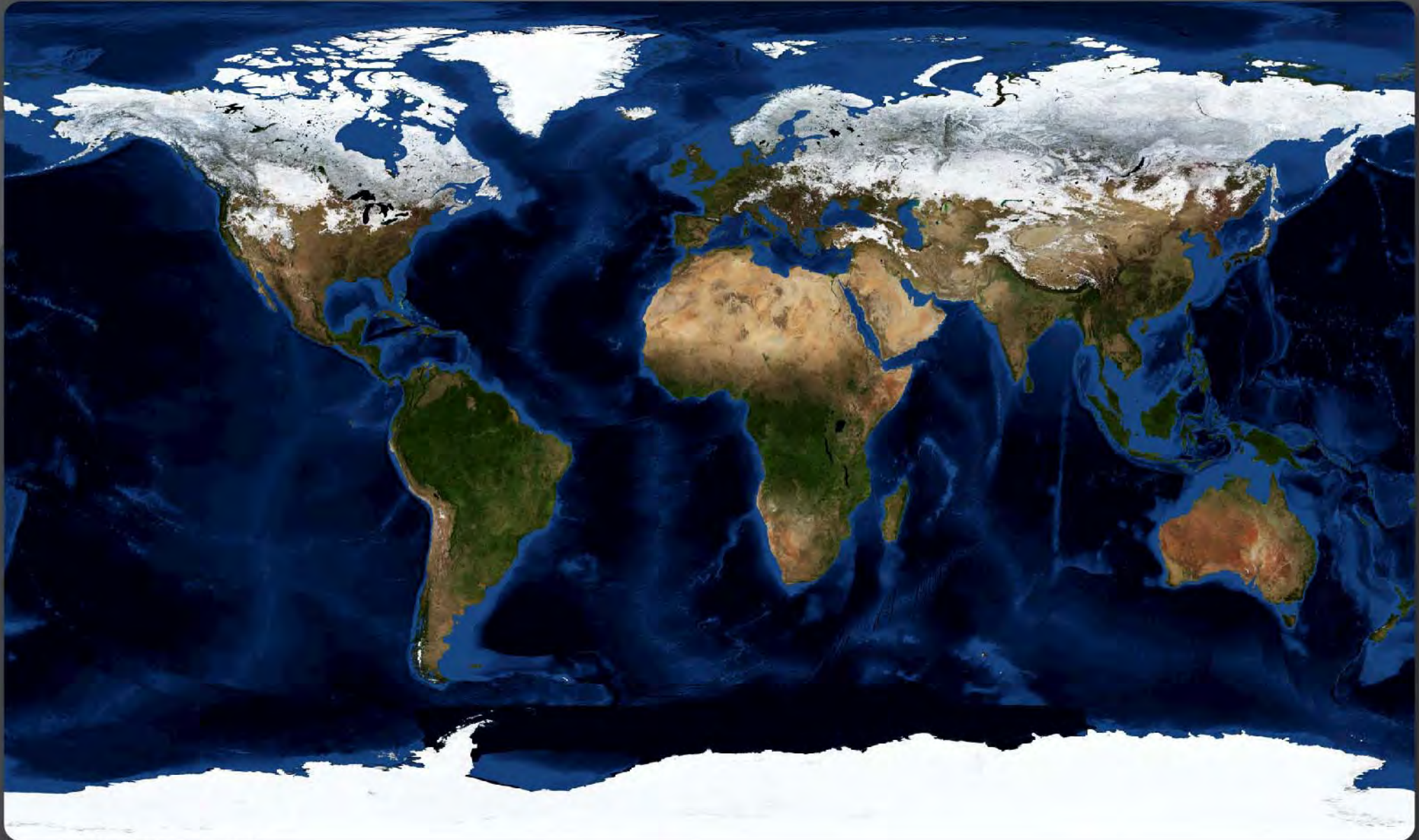
# Fossil fuels can lead to environmental disaster



©2010 HollywoodBackstage.com



For the first time humankind is acting as  
a force of nature





# Energy fingerprint of humankind



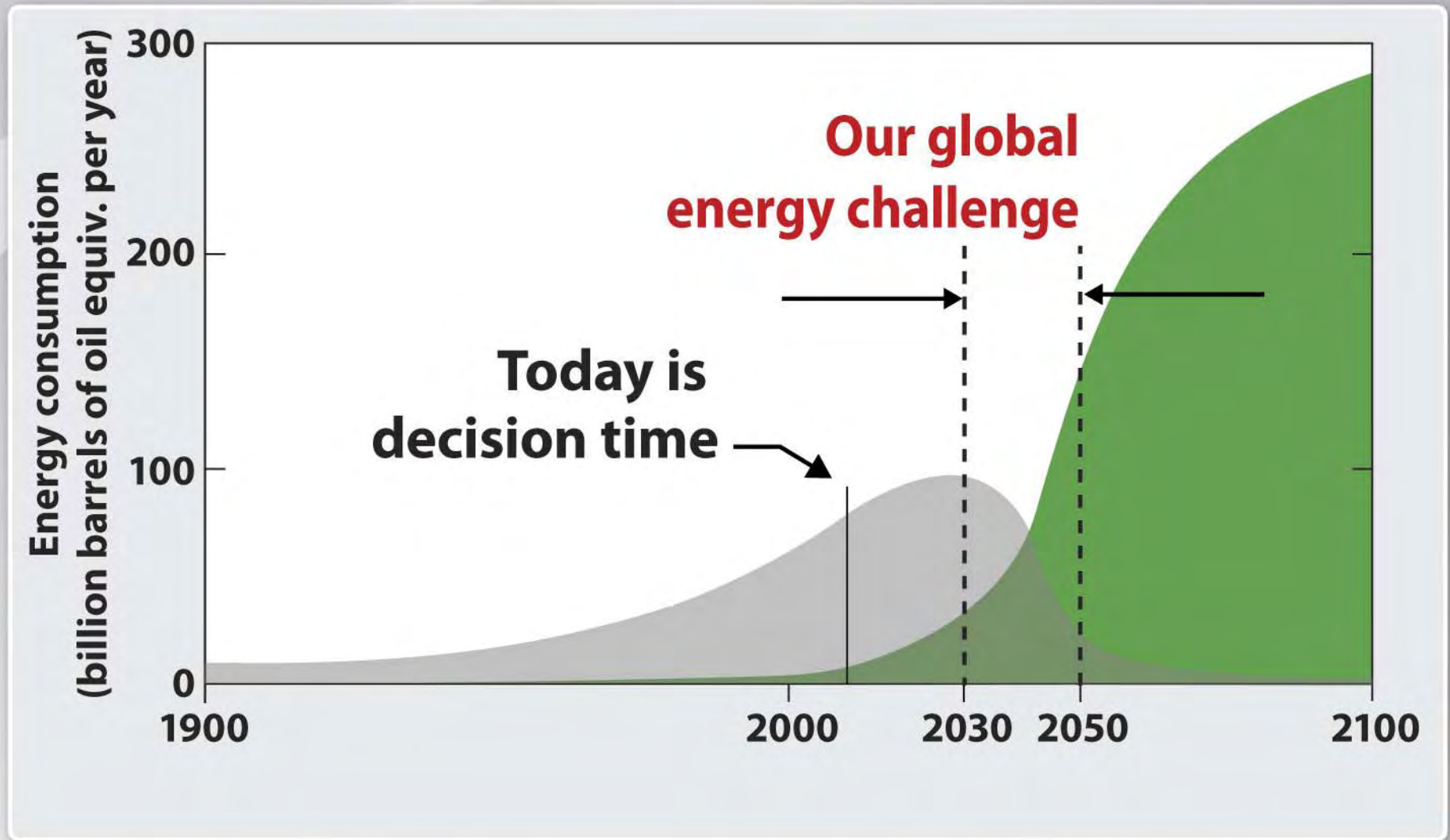


# Clean energy: Humankind's challenge

We are at a tipping point



# Time to act!



Assumes world population stabilizes at 10 billion, consuming at 2/3 U.S. 1985 rate



# The way forward to clean energy

**“The National Ignition Facility is a marvel, and while the Laboratory will achieve ignition, we need to think about what we should be doing in a year or two from today.**

**... DOE should assume ignition success in that planning, and not wait for NIF ignition to start such planning.”**

**- Steven Chu U.S. Secretary of Energy**

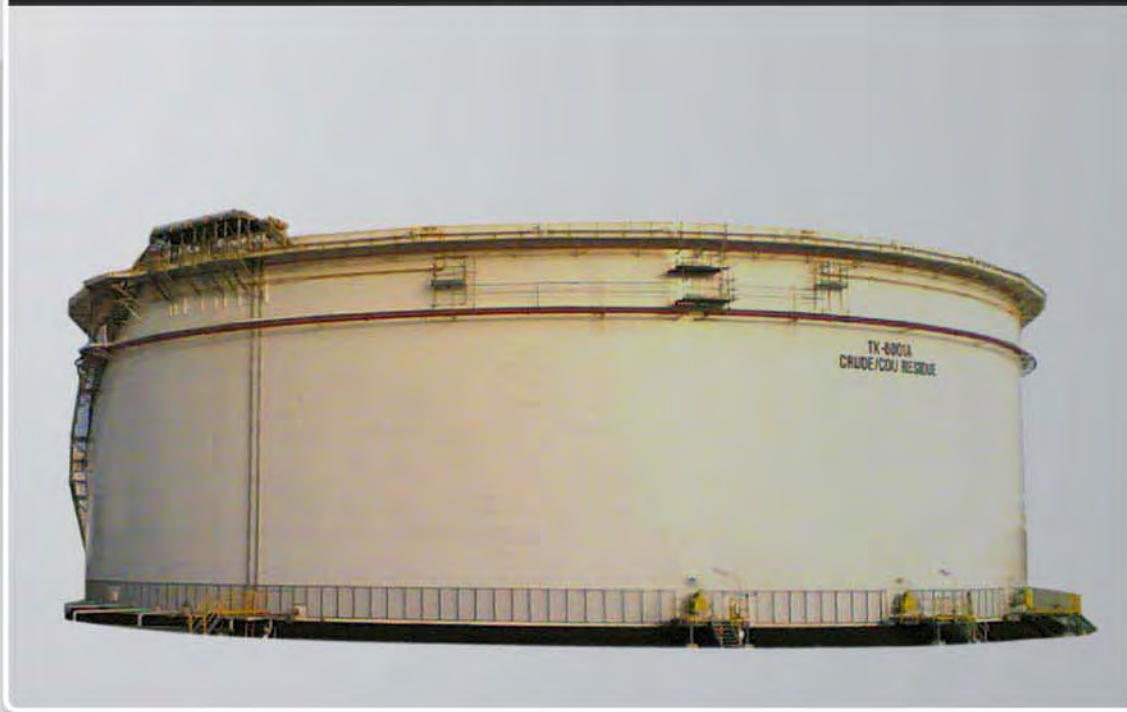
**Steven Chu**





One liter of heavy water has the energy of more than 2 million gallons of gasoline

**Gasoline**



**Heavy water**





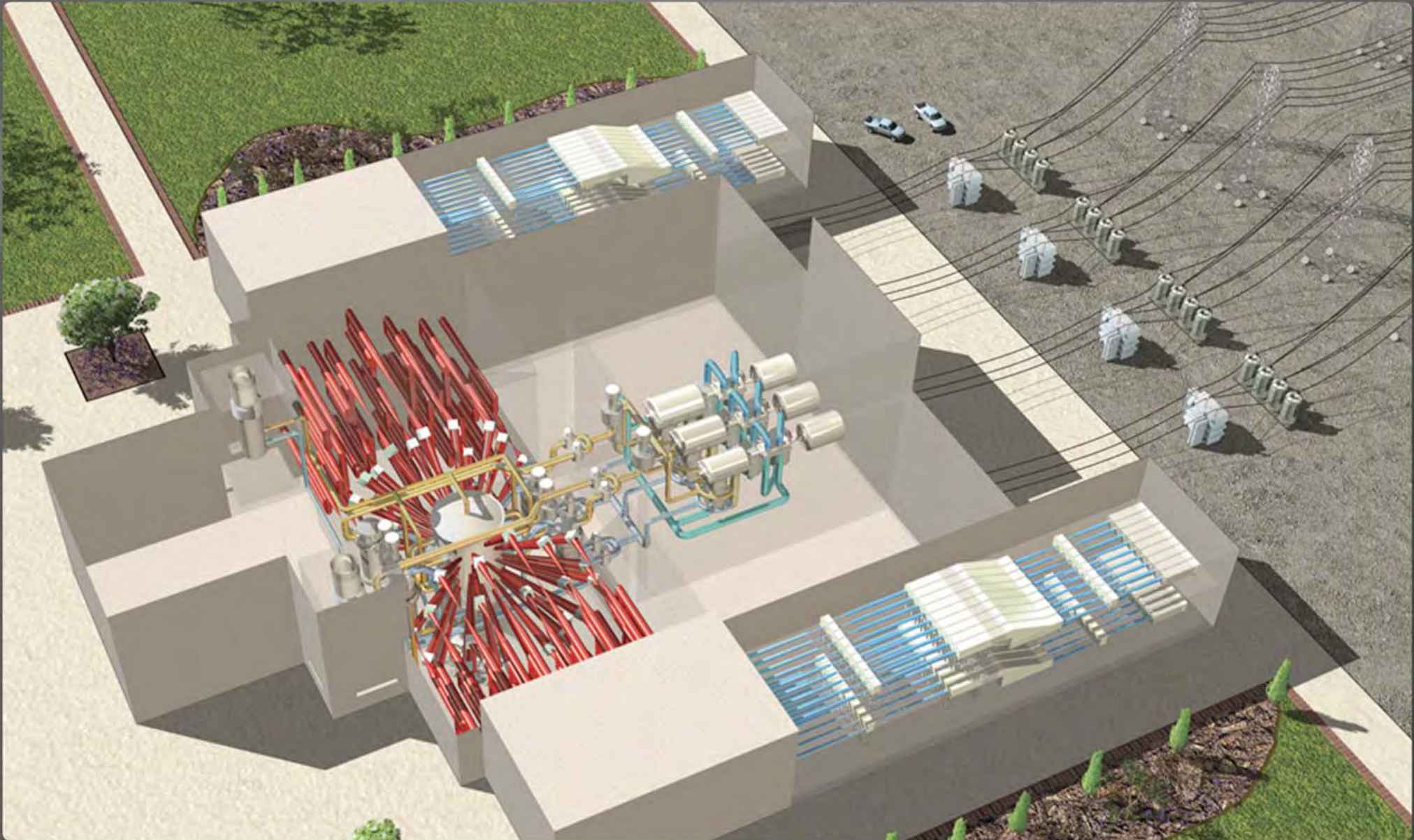
Think about the alternative



**LIFE avoids 7 million tons of CO<sub>2</sub>/year for a GW plant**

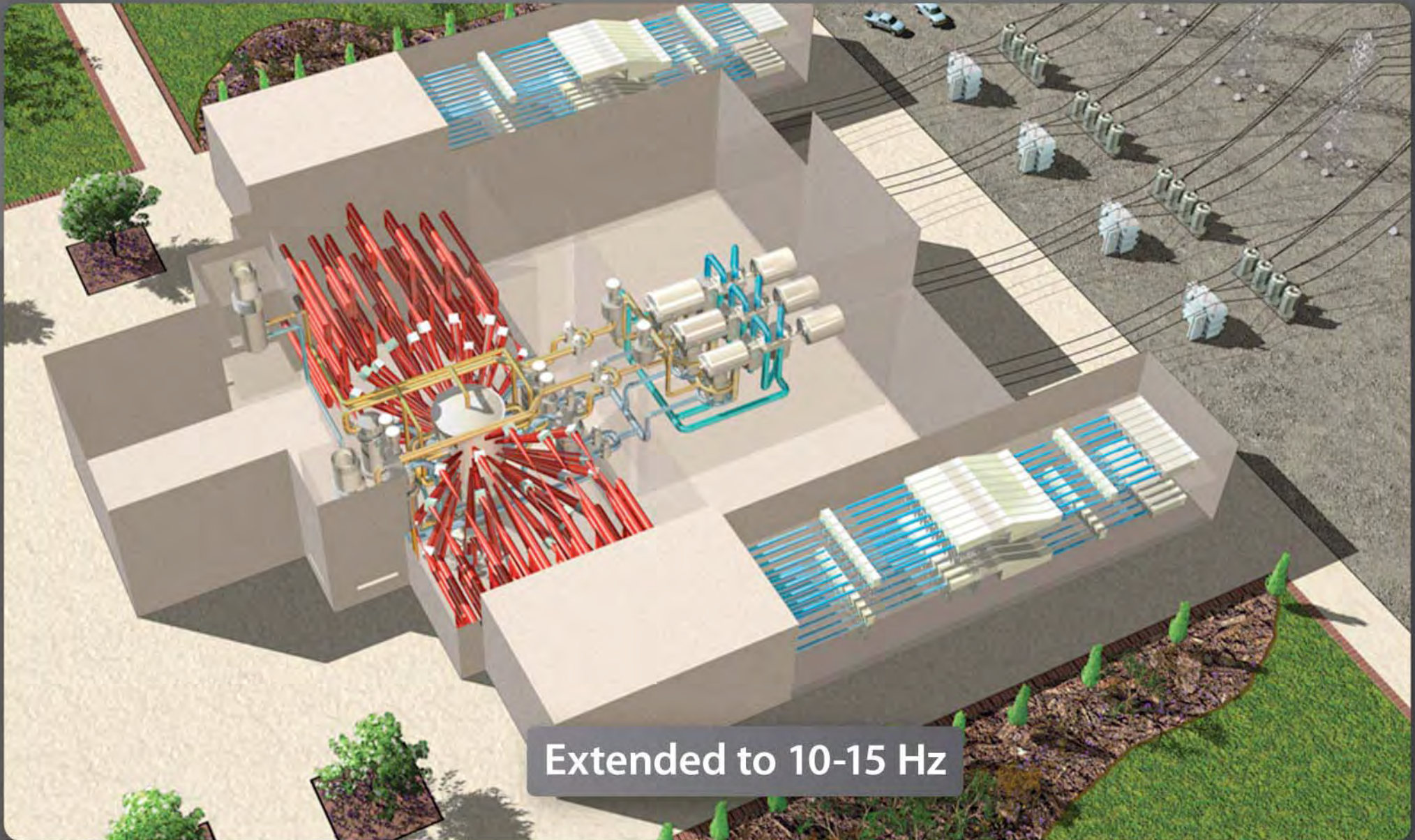


# NIF's demonstration of fusion could be leveraged to build a Laser Inertial Fusion Engine = LIFE



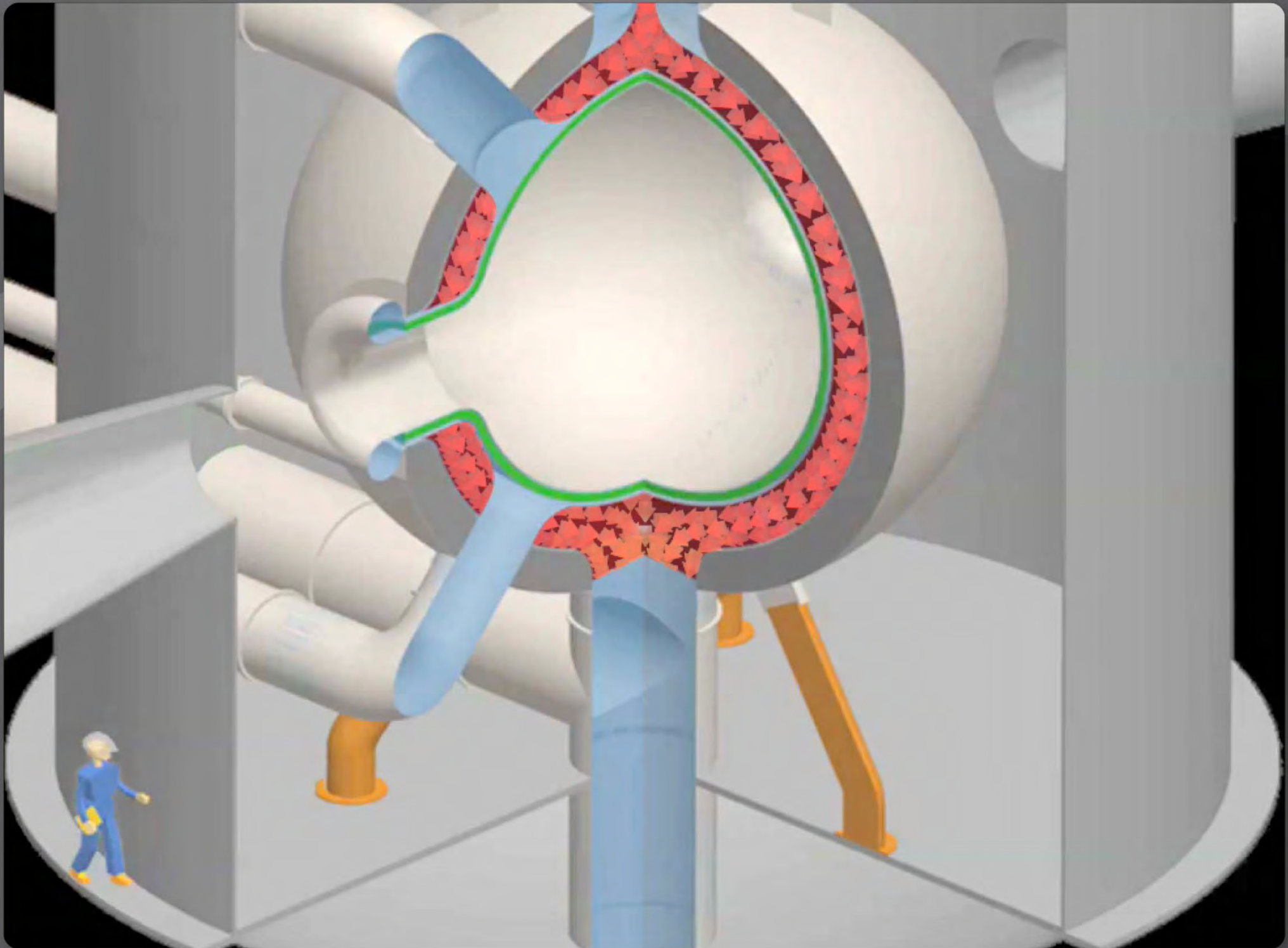


# LIFE builds on NIF technology

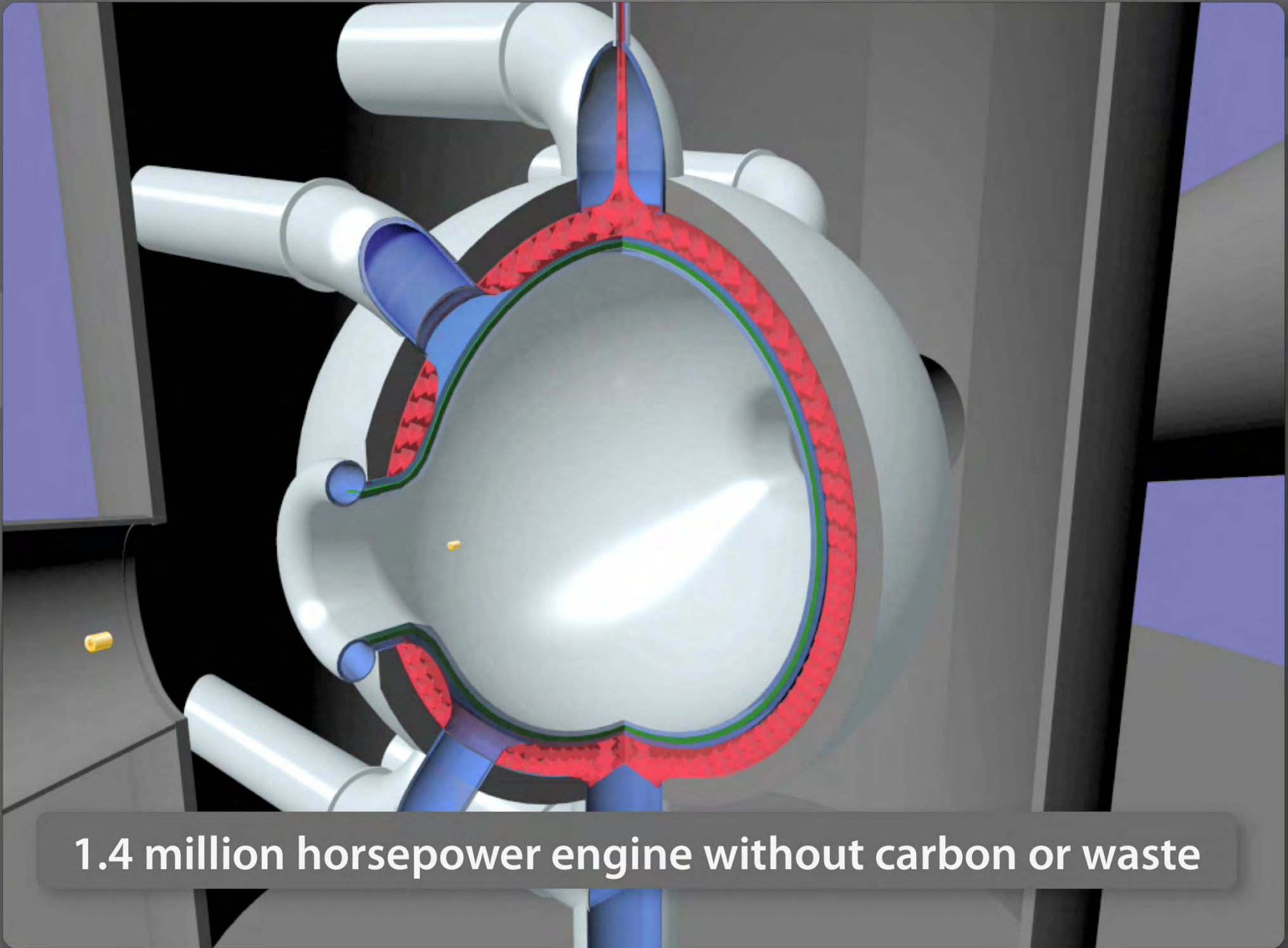


Extended to 10-15 Hz





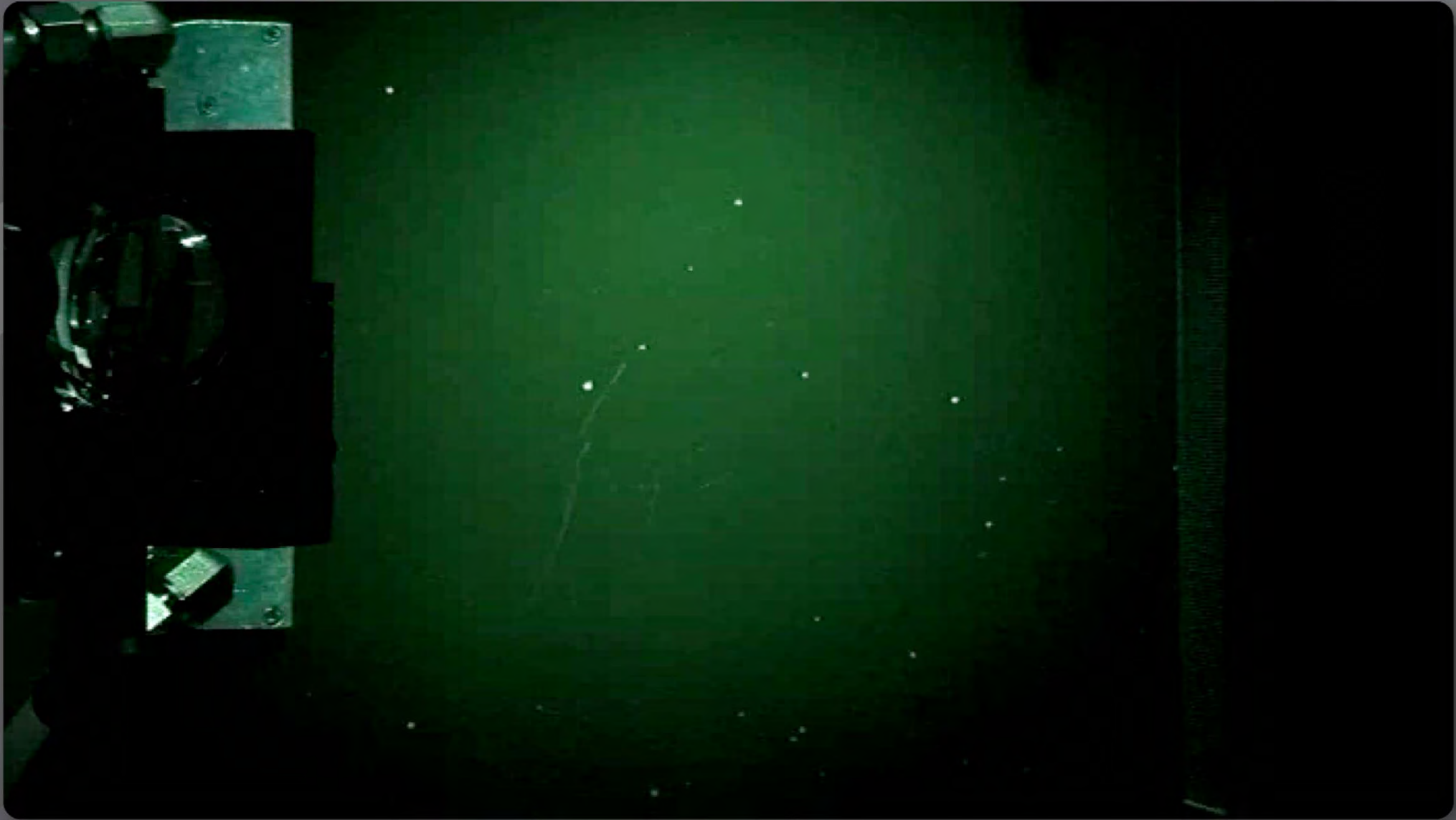




1.4 million horsepower engine without carbon or waste



# 50 kWatt laser burning through steel





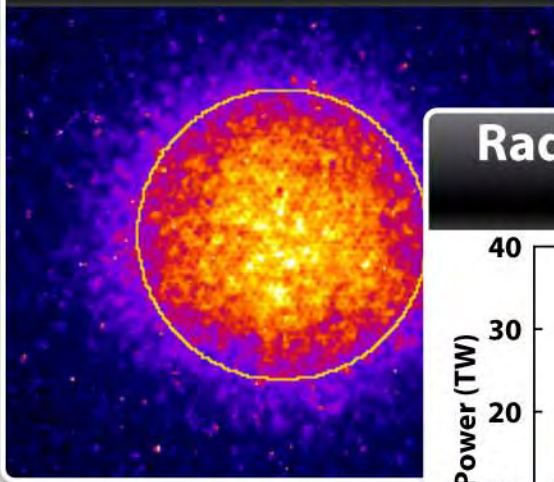
# This is the Story of the National Ignition Facility and Our Energy Future!



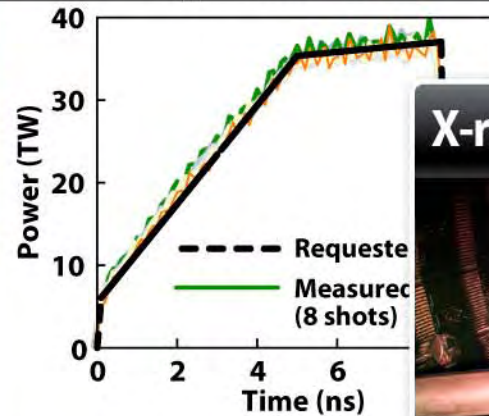


# NIF's experimental potential is already being realized

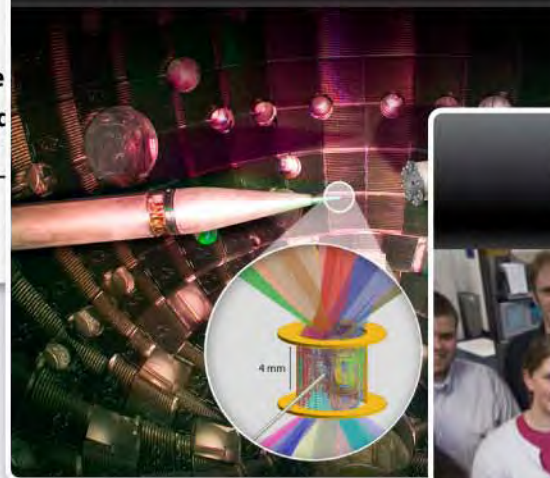
## Ignition experiments



## Radiation Transport experiments



## X-ray Source Applications



## Basic science experiments





