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

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Director of the National Ignition Facility

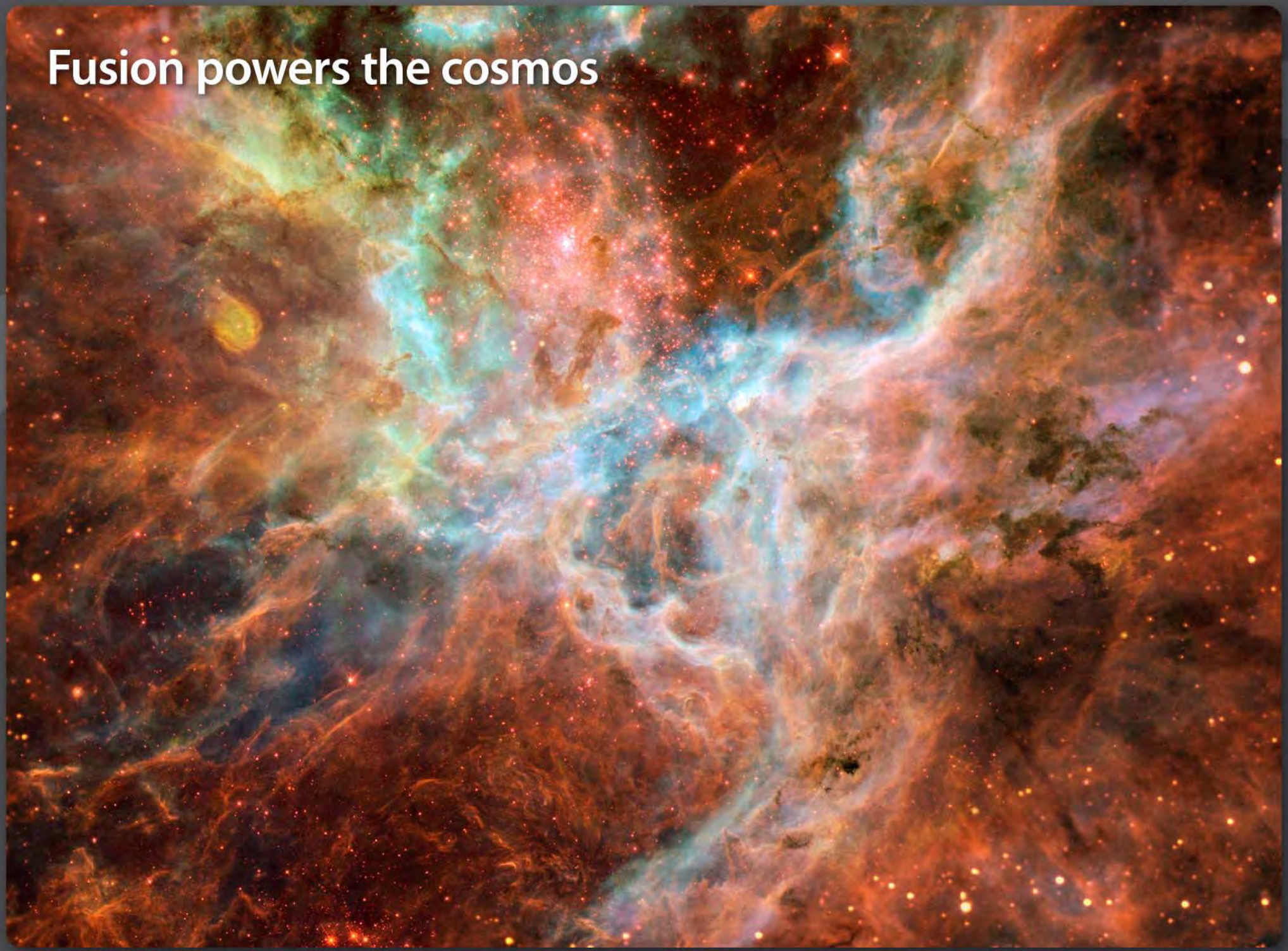
Presentation to DOE NNSA SSGF Annual Conference

June 21, 2010

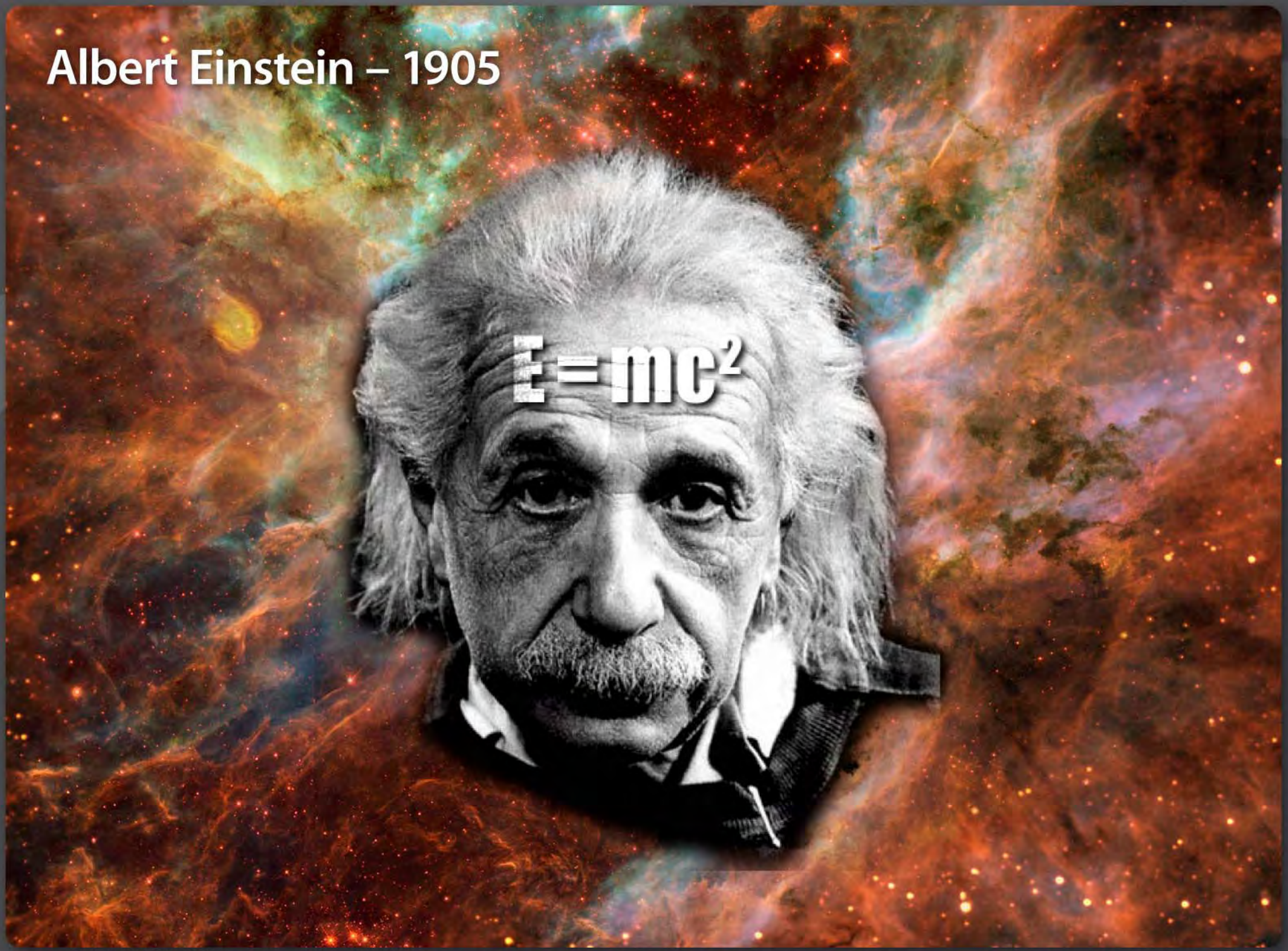
LLNL-PRES-437932

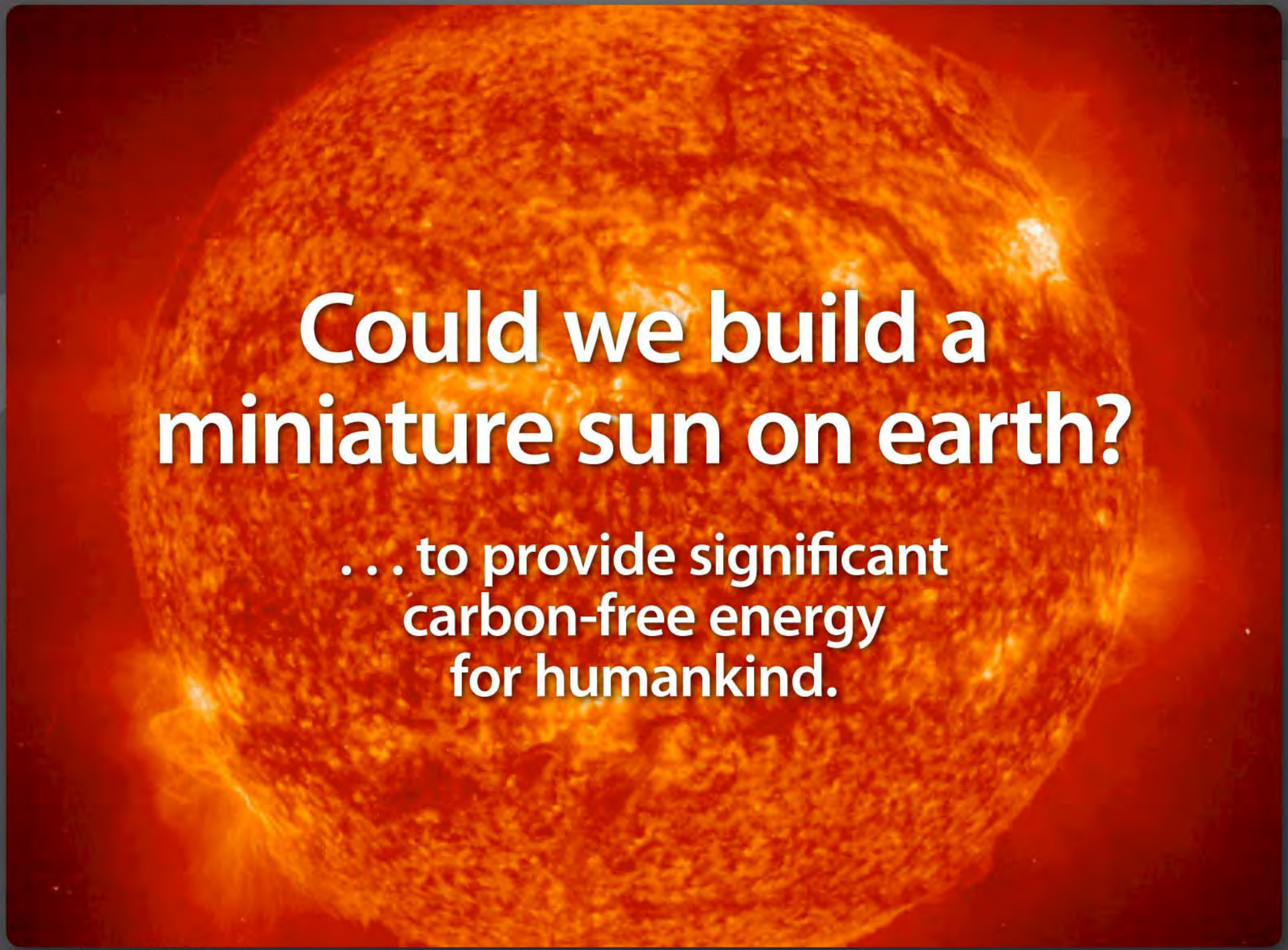
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Fusion powers the cosmos

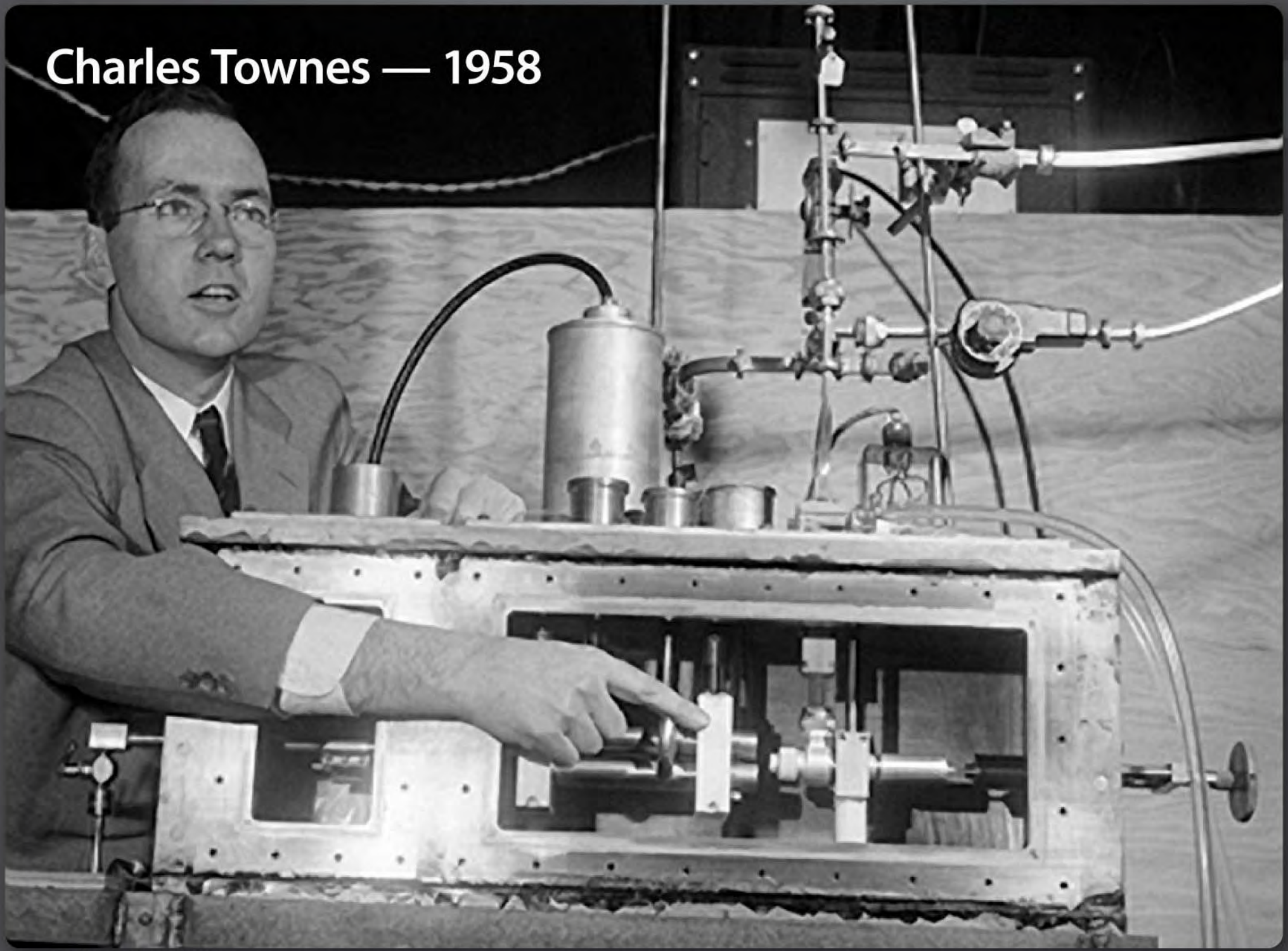


Albert Einstein – 1905

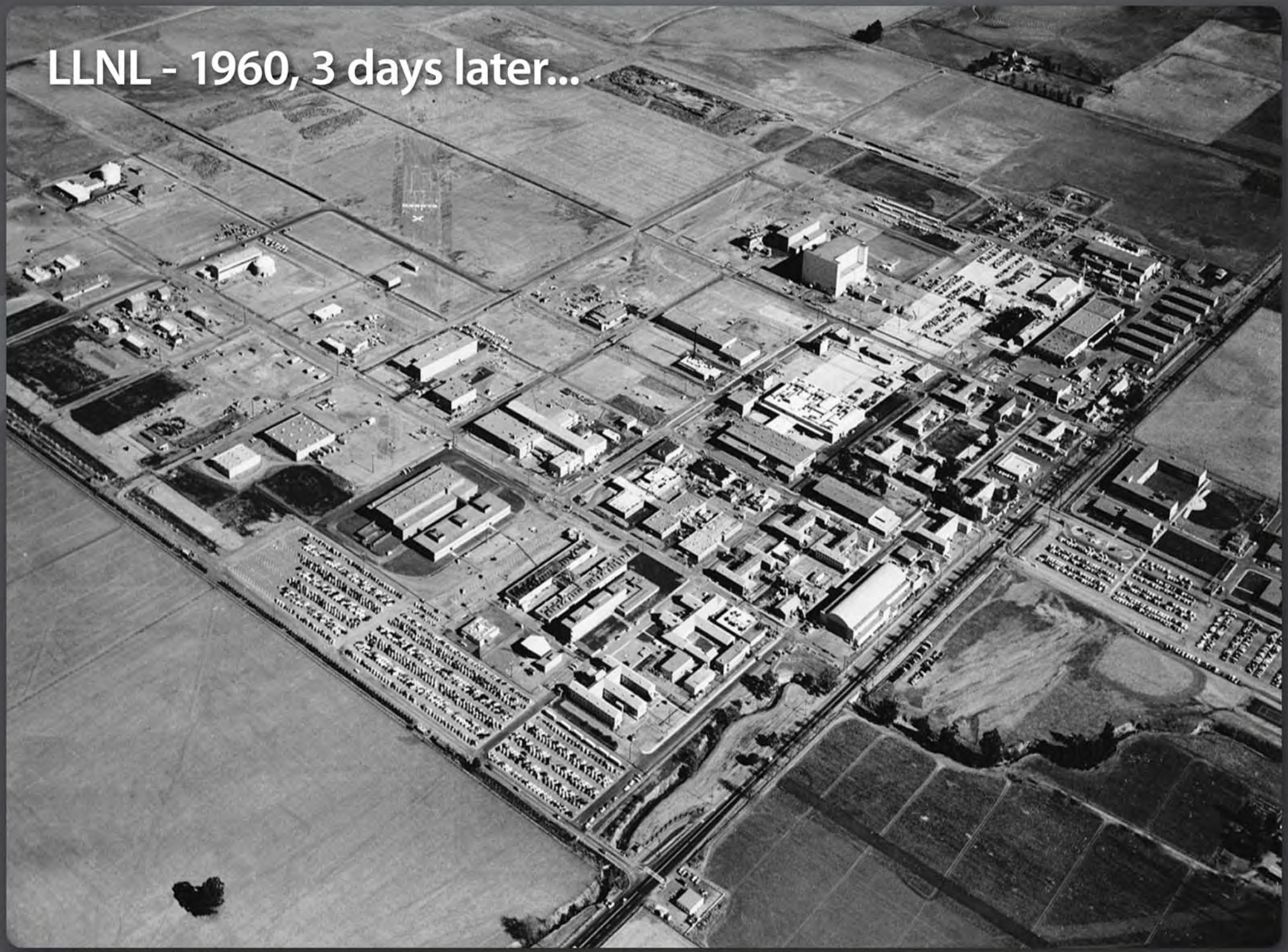



Could we build a miniature sun on earth?
. . . to provide significant carbon-free energy for humankind.

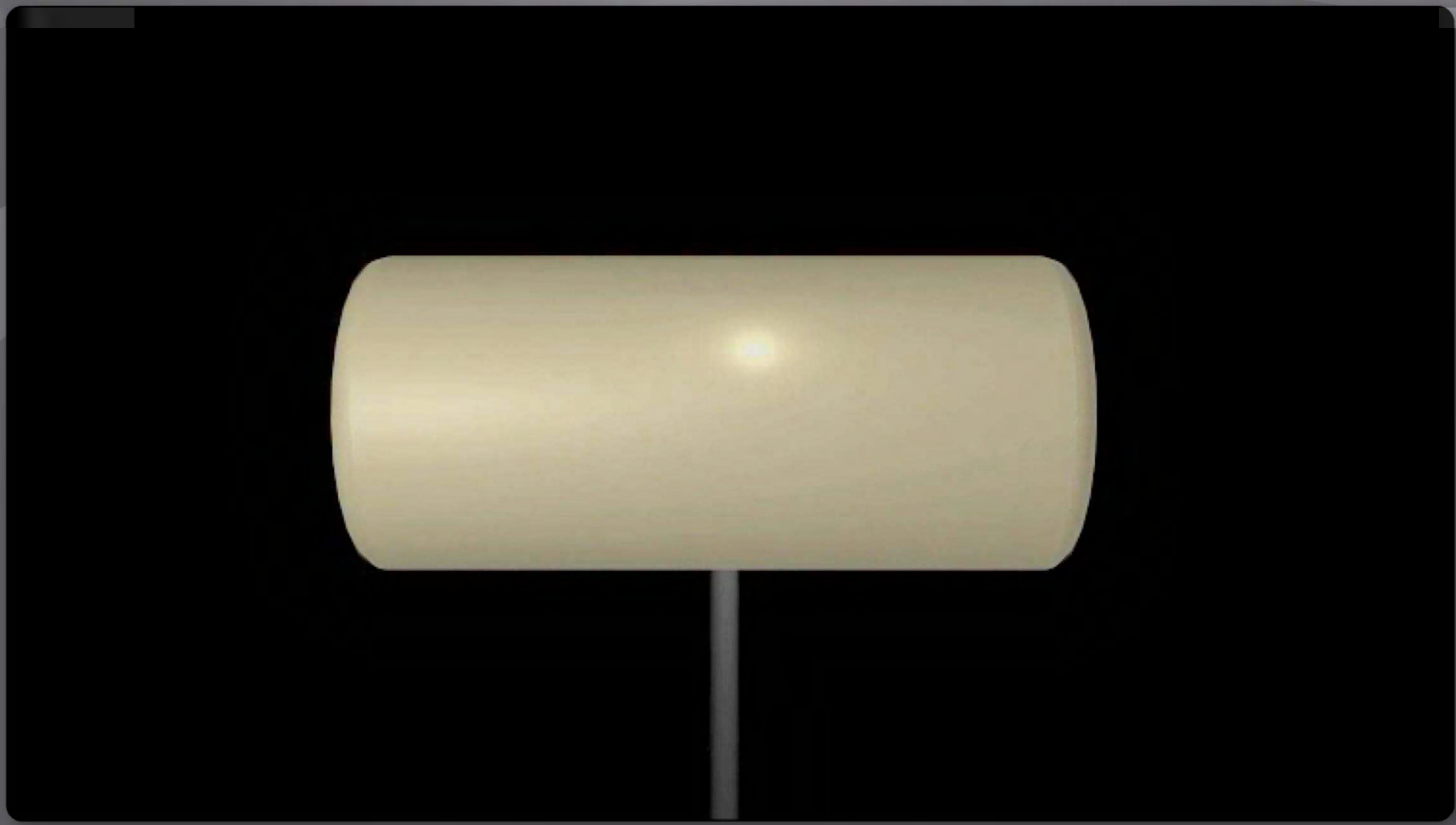
To demonstrate the route to fusion energy


Charles Townes — 1958

Ted Maiman First laser demonstrated on May 16, 1960

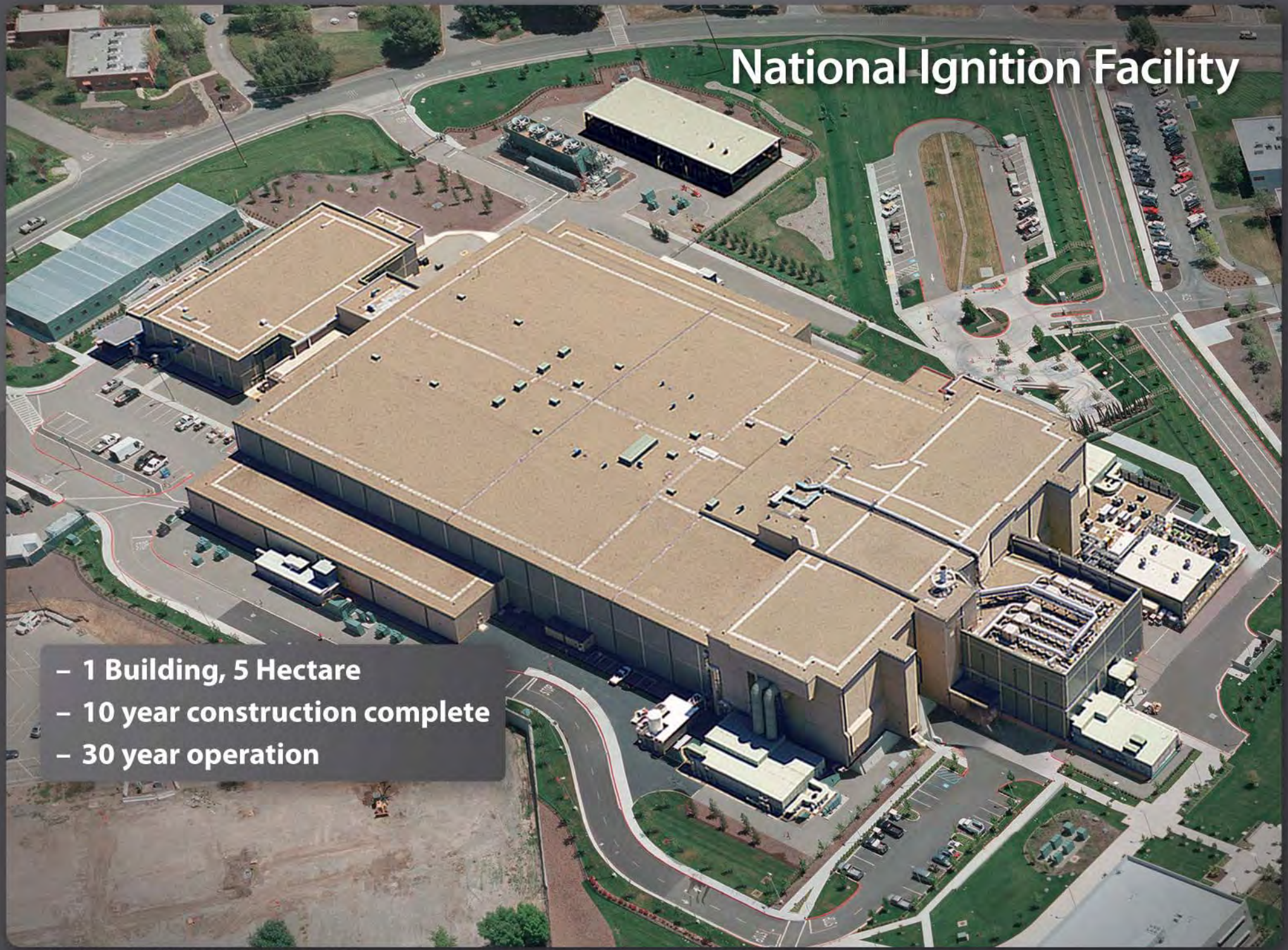

LLNL - 1960, 3 days later...

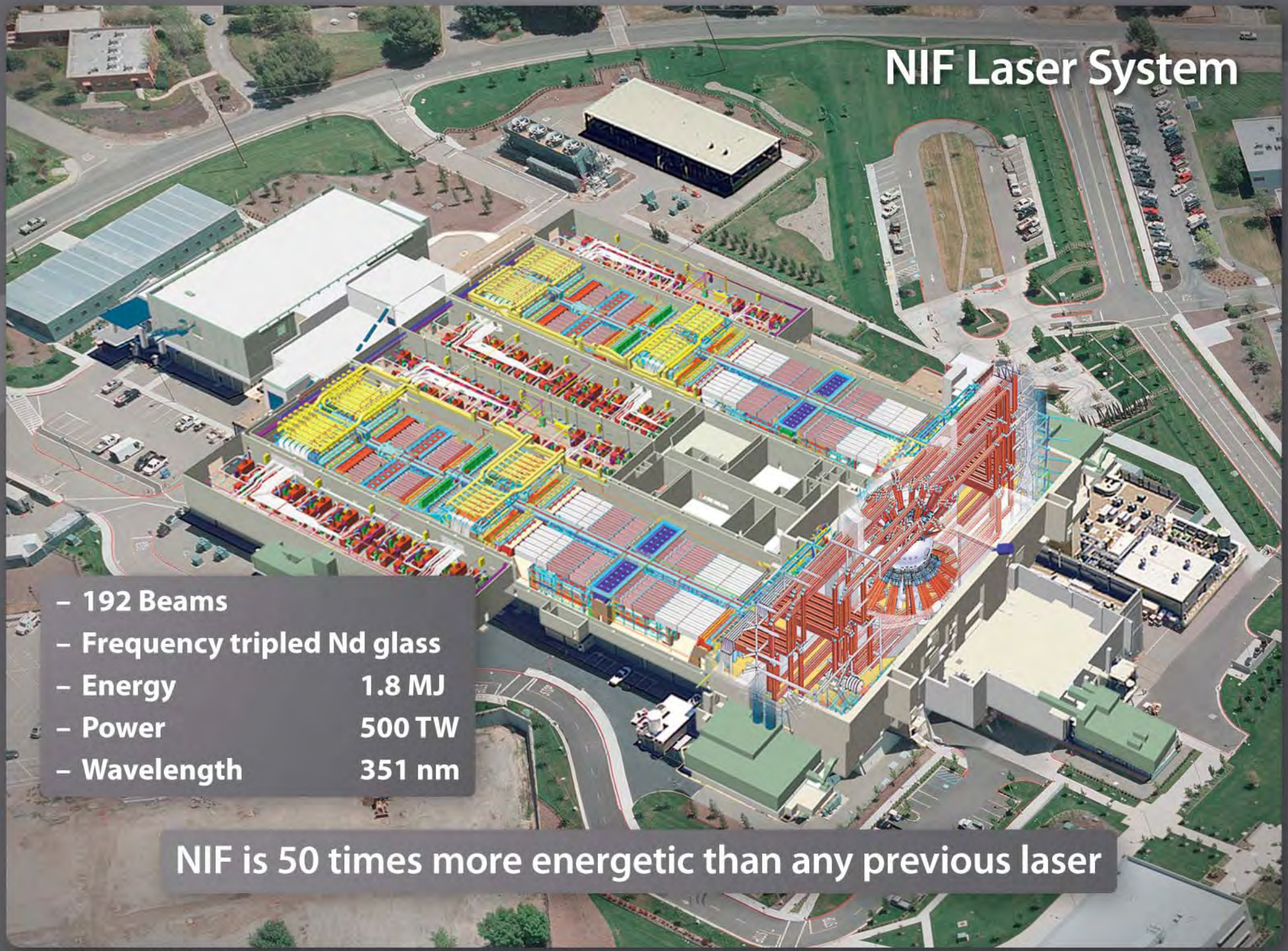
John Nuckolls proposed to use lasers for fusion energy



Ignition Target

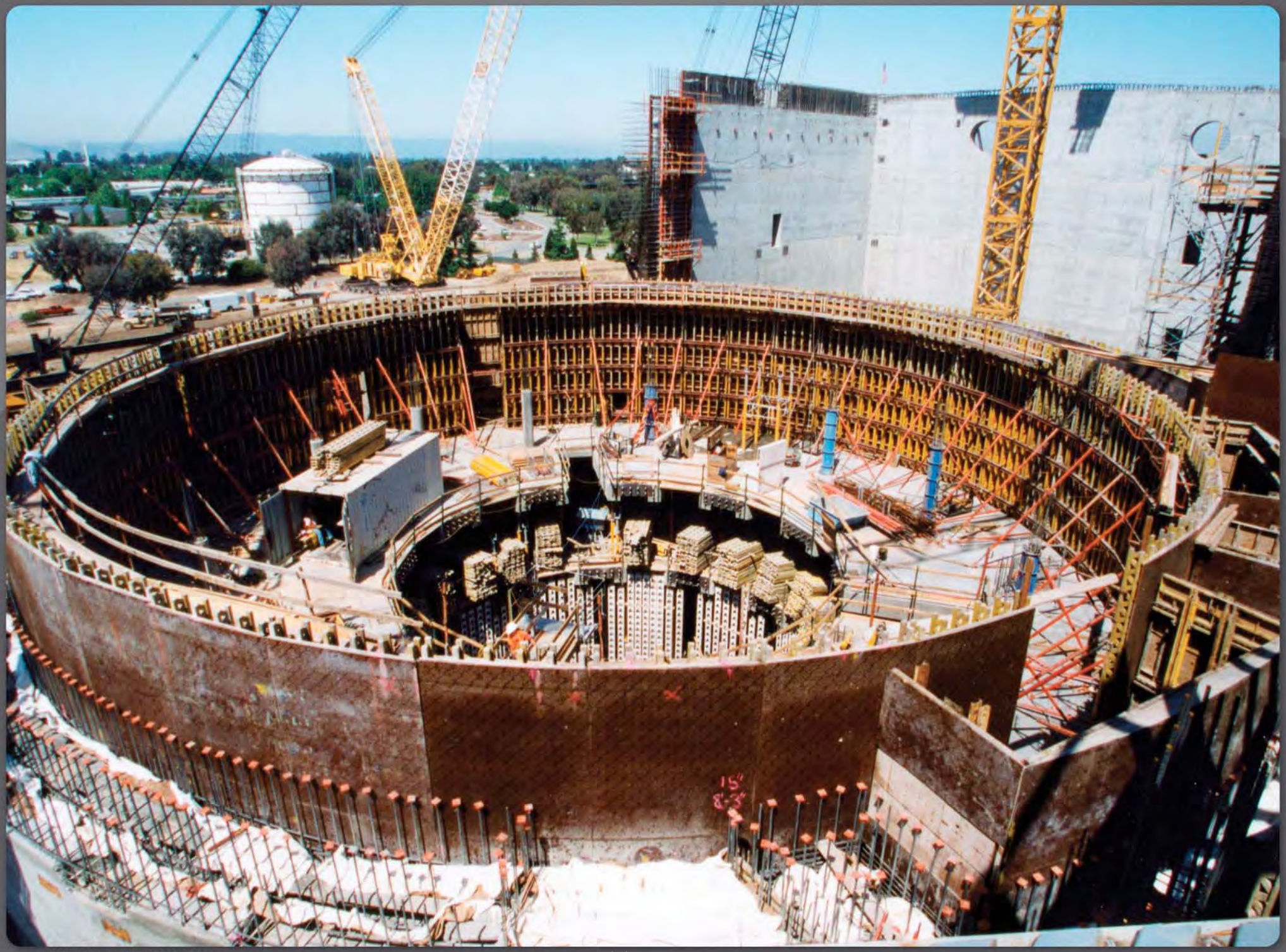

San Francisco
(45 mi.)
LLNL
National Ignition Facility

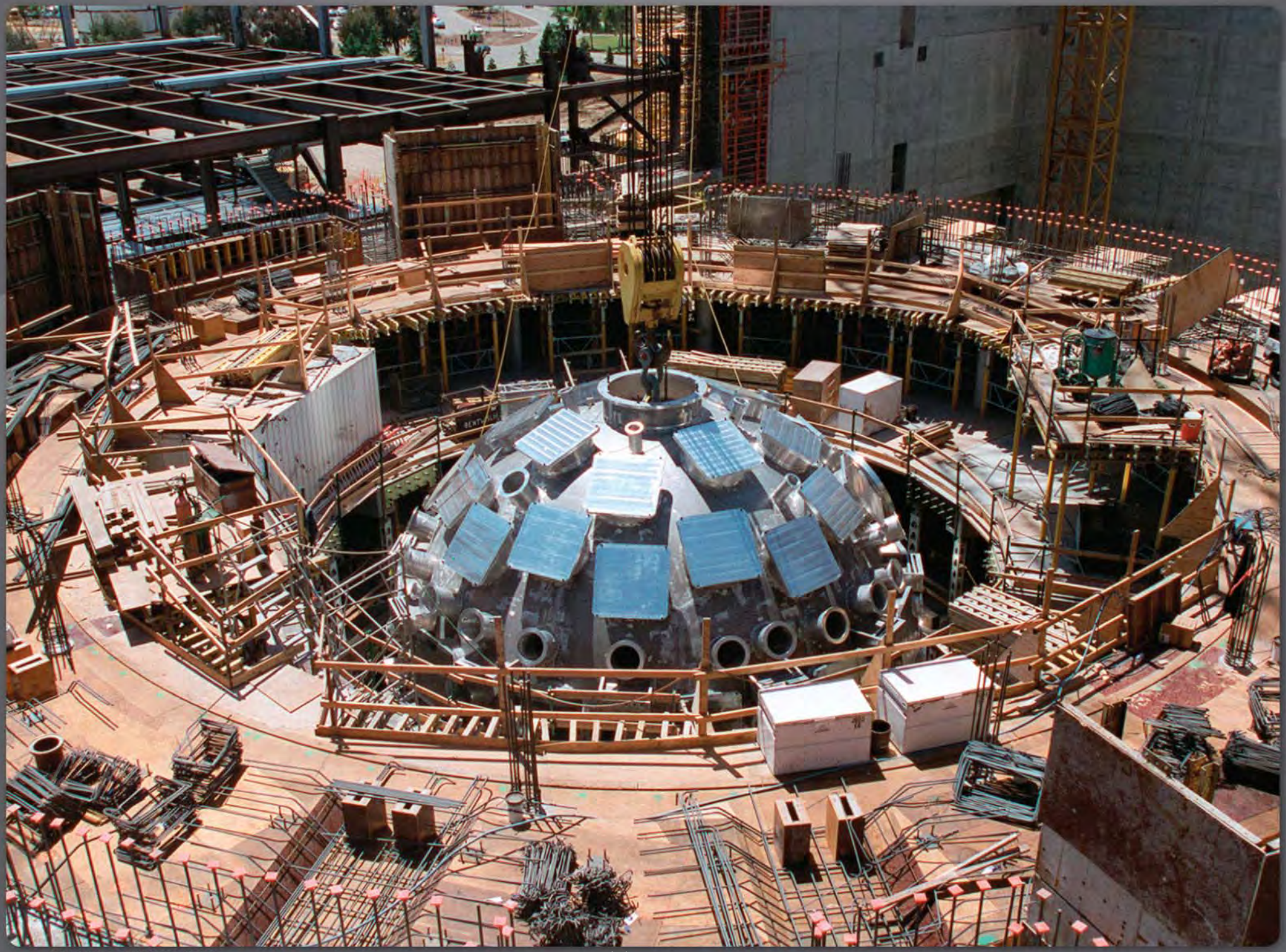

National Ignition Facility
– 1 Building, 5 Hectare
– 10 year construction complete
– 30 year operation

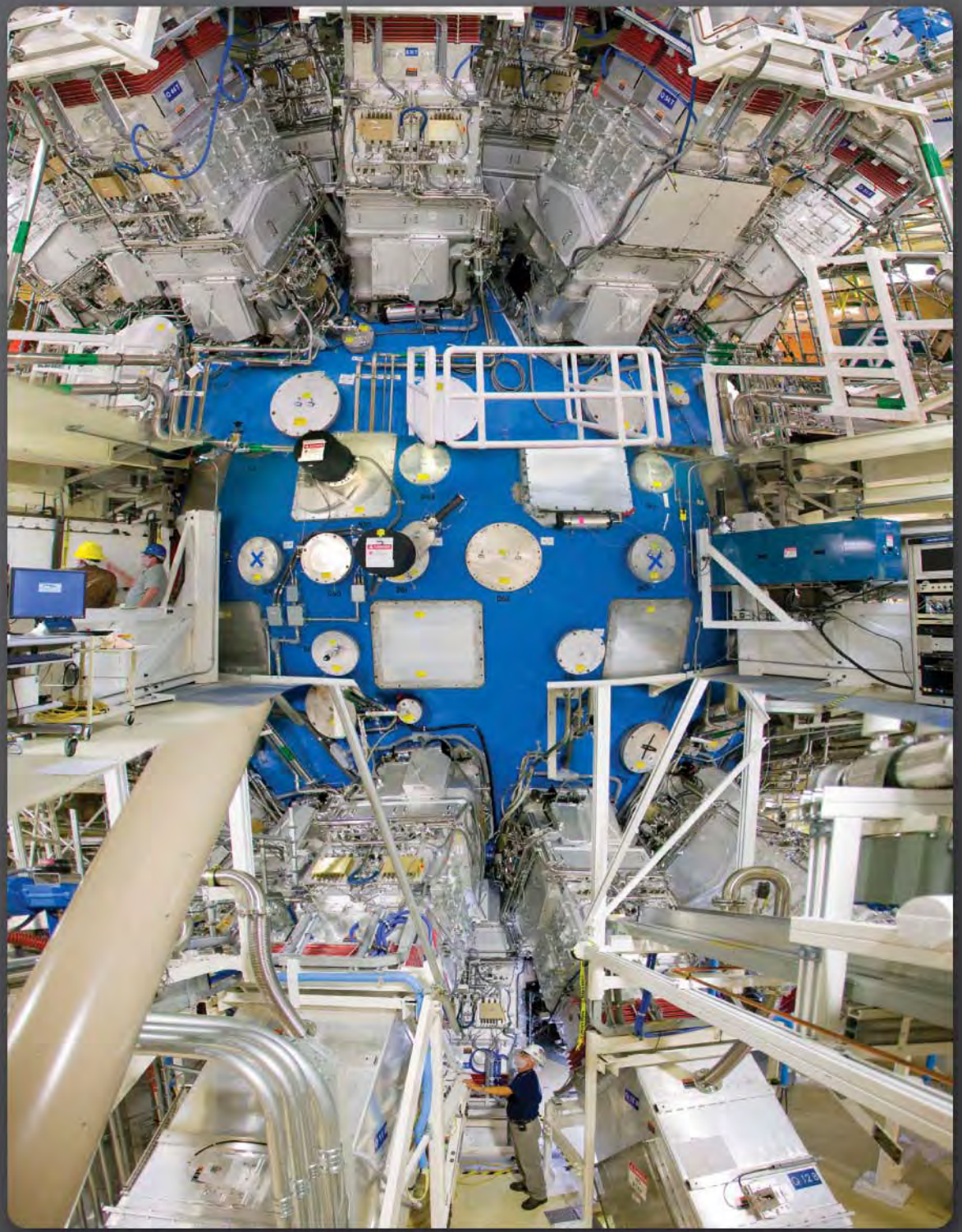

NIF Laser System
– 192 Beams
– Frequency tripled Nd glass
– Energy 1.8 MJ
– Power 500 TW
– Wavelength 351 nm
NIF is 50 times more energetic than any previous laser

NIF, 2009
4 MJ IR


Target Chamber
Dedication June 1999

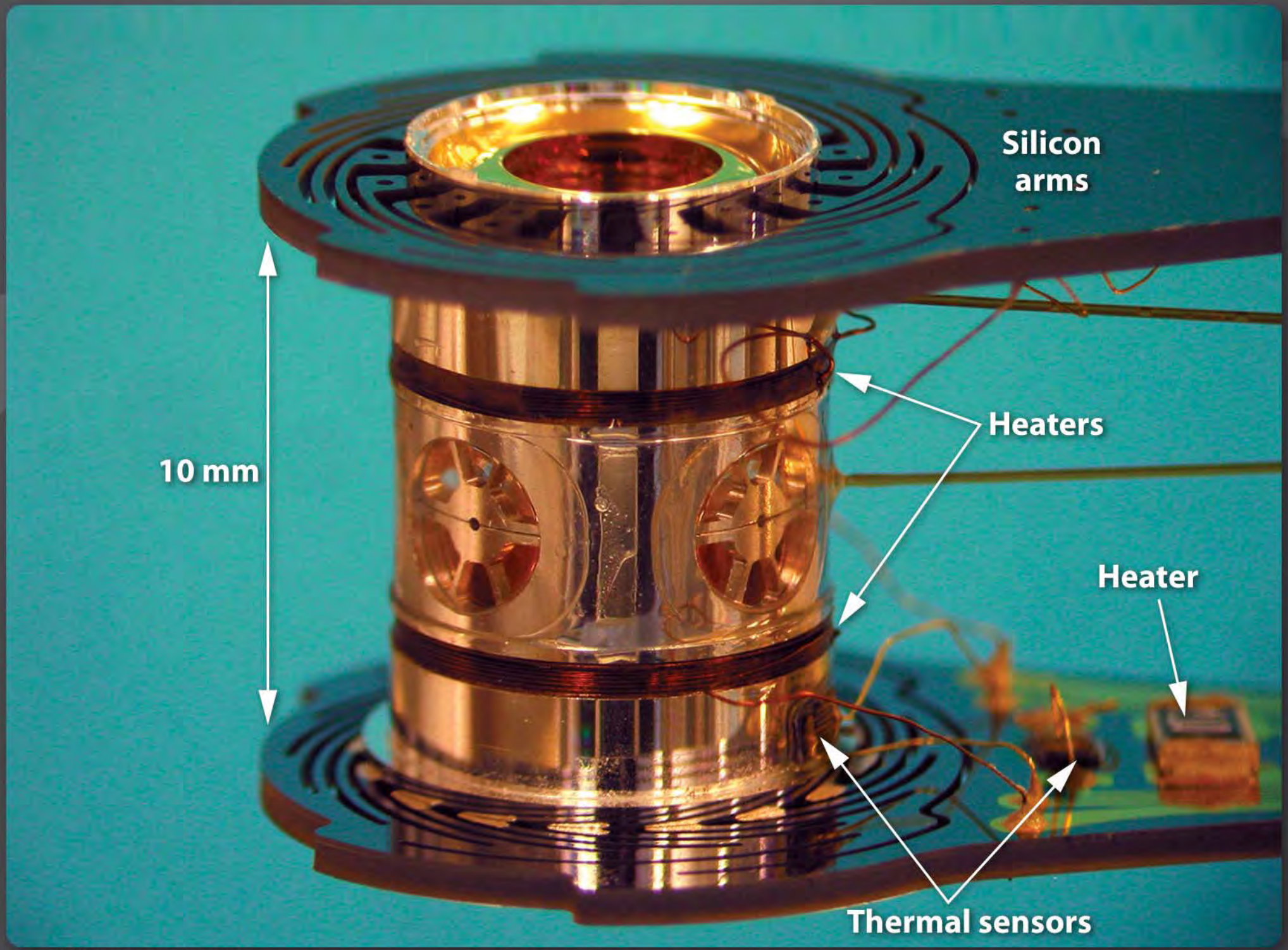




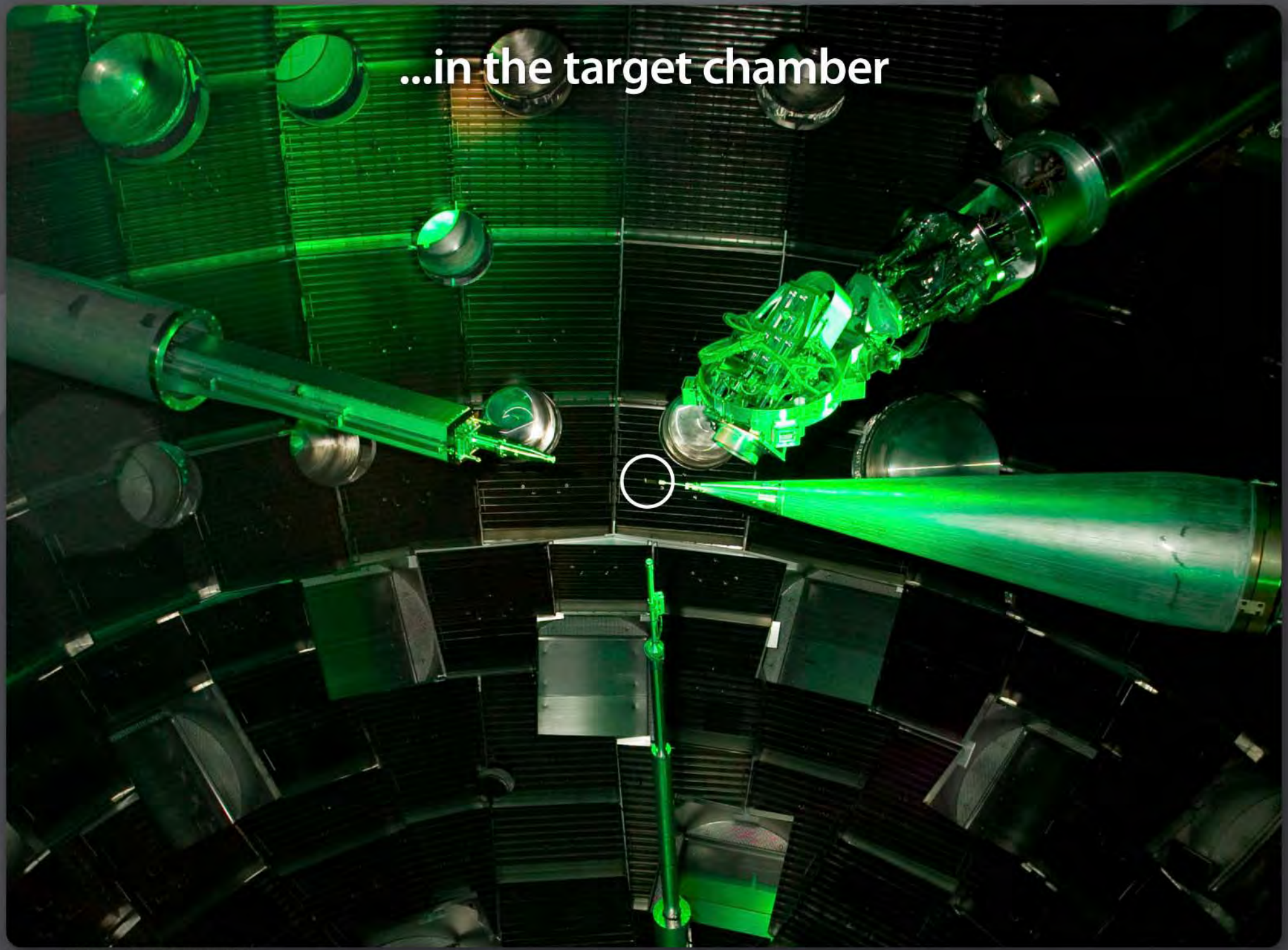


15EIM/dj • NIF-0609-16541s1

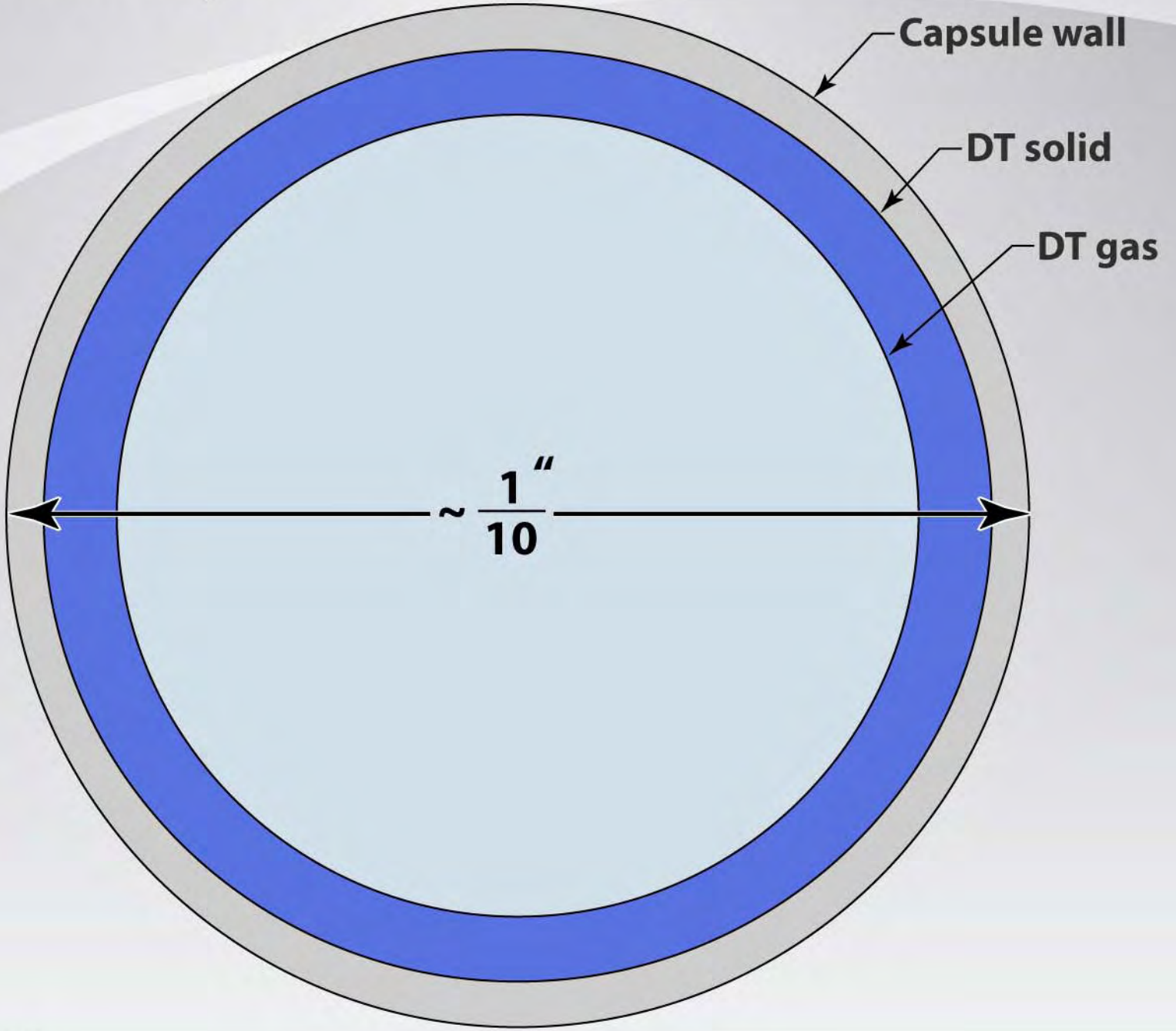

Inside the Target Chamber


Silicon arms
10 mm
Heaters
Heater
Thermal sensors

NIC Target Assembly

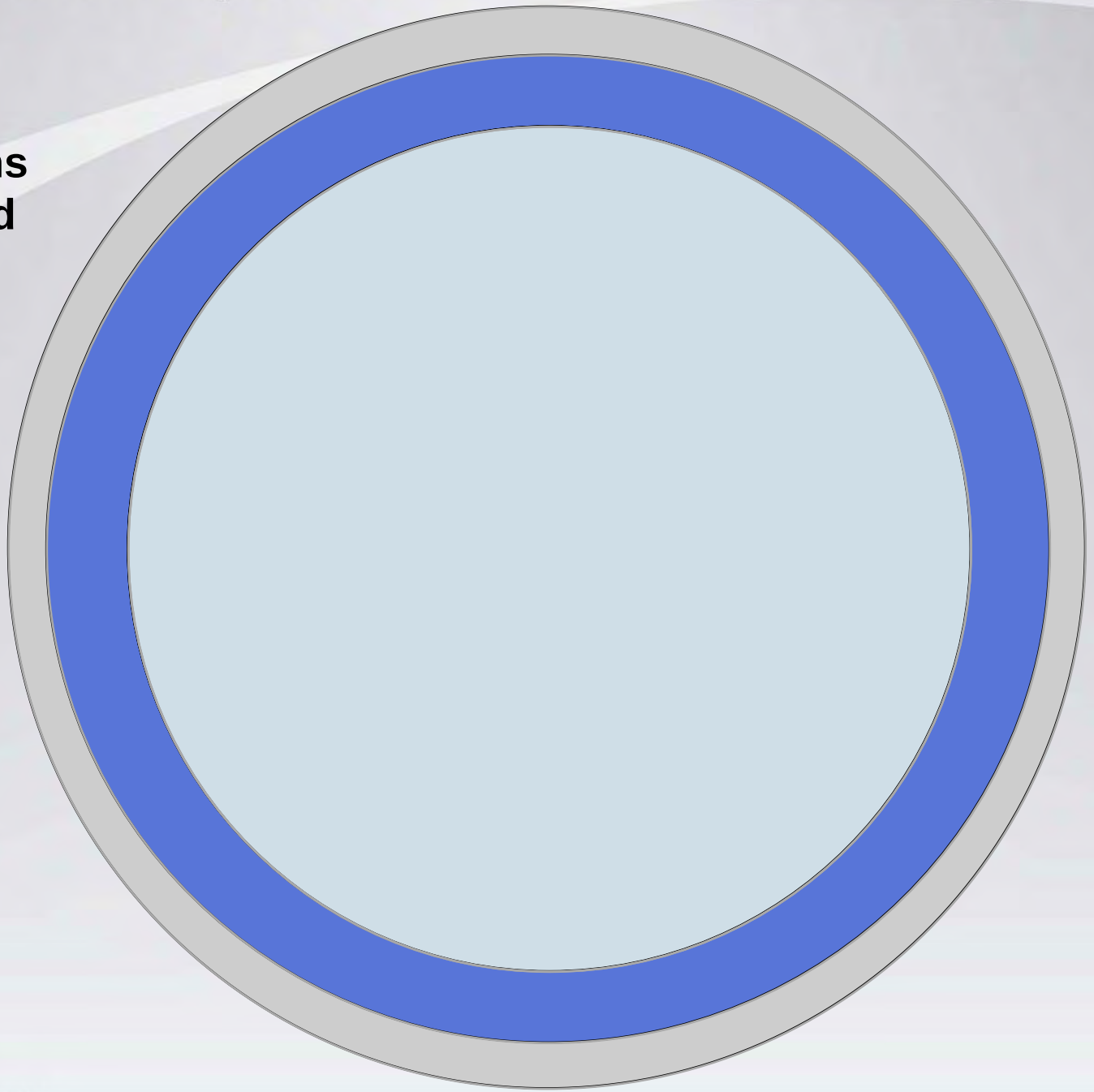

...in the target chamber

DT implosion capsule

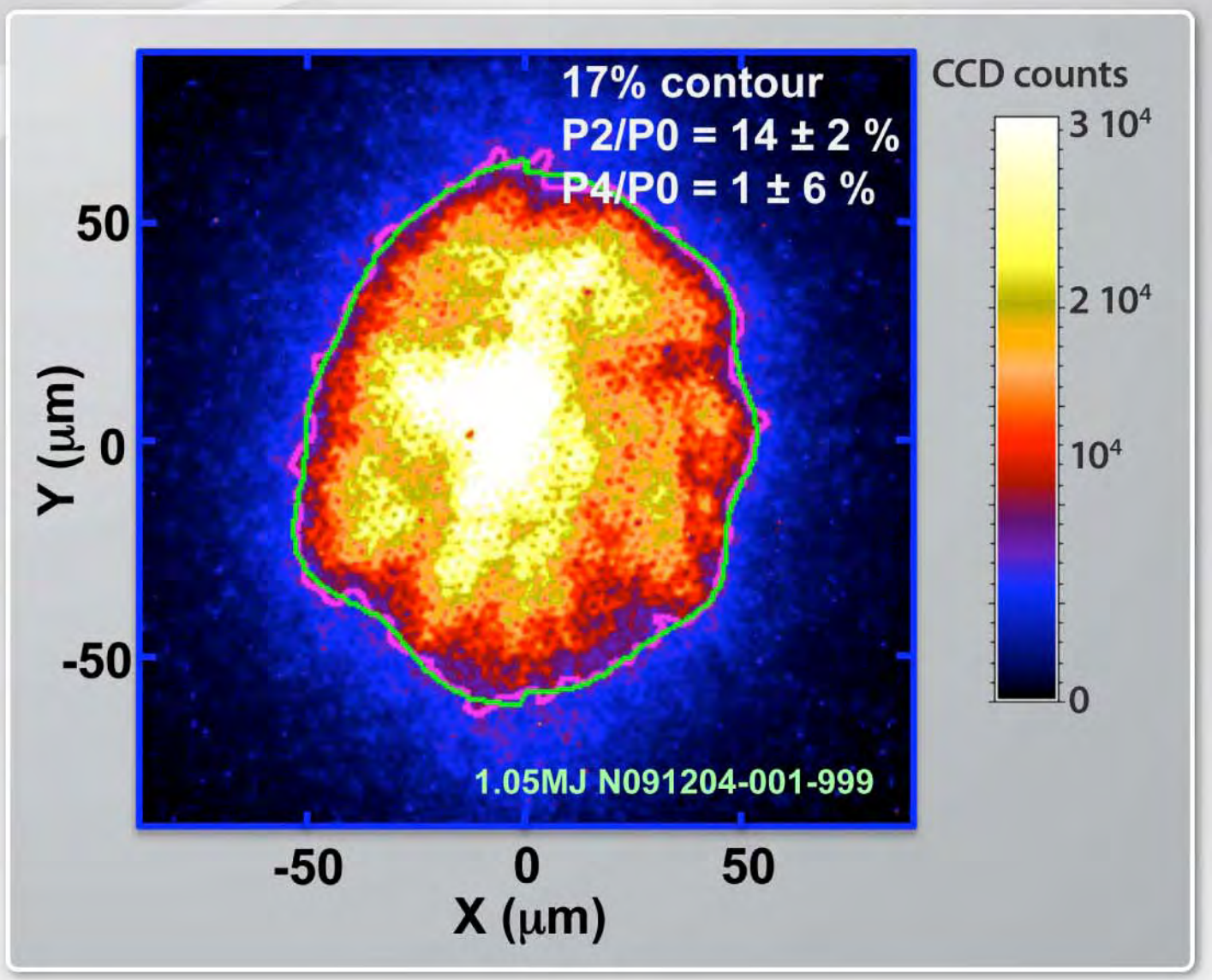


DT implosion capsule

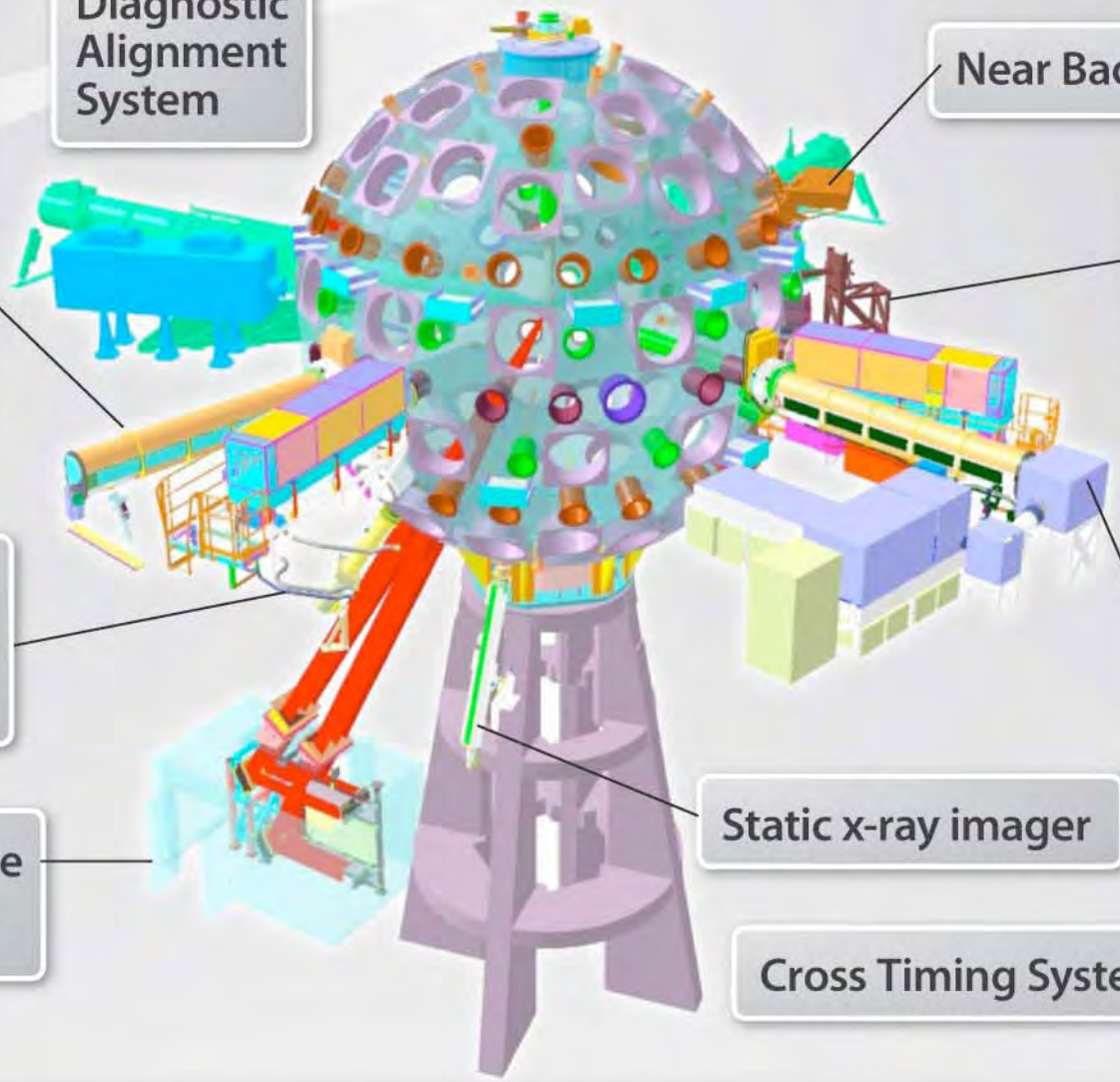
10 billionths of a second later!



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



Diagnostic Alignment System

Diagnostic Instrument Manipulator (DIM)
X-ray imager
Streaked X-ray detector

Near Backscatter Imager

FFLEX
Hard x-ray spectrometer

DANTE
Soft x-ray temperature

Diagnostic Instrument Manipulator (DIM)

Full Aperture Backscatter

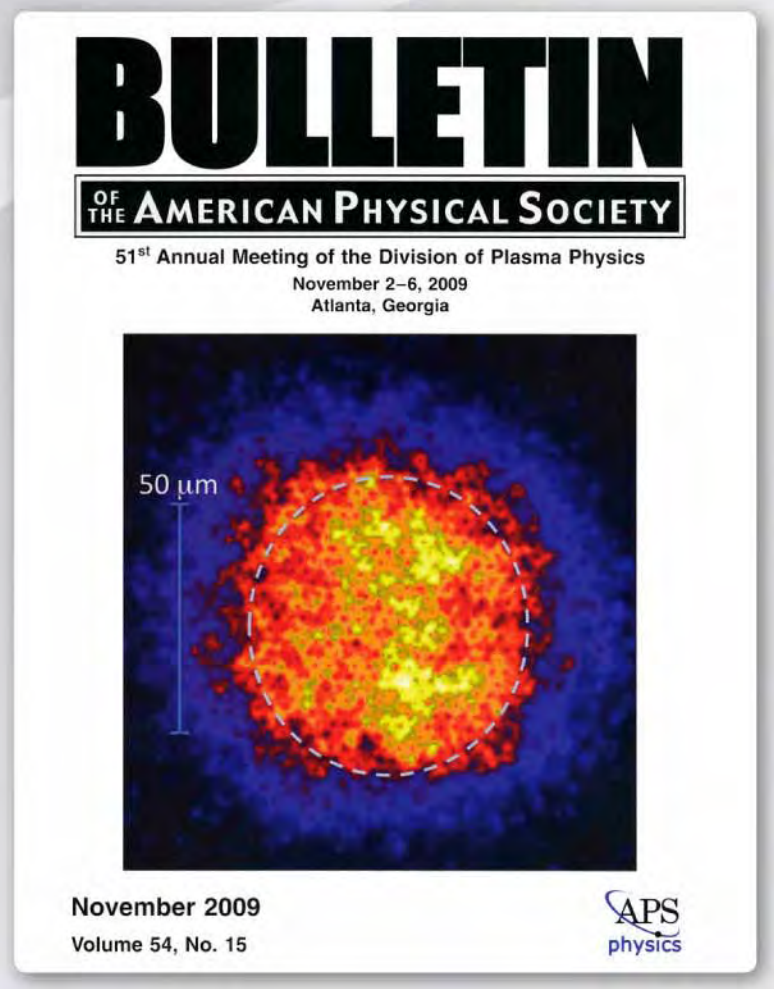
Static x-ray imager

Cross Timing System

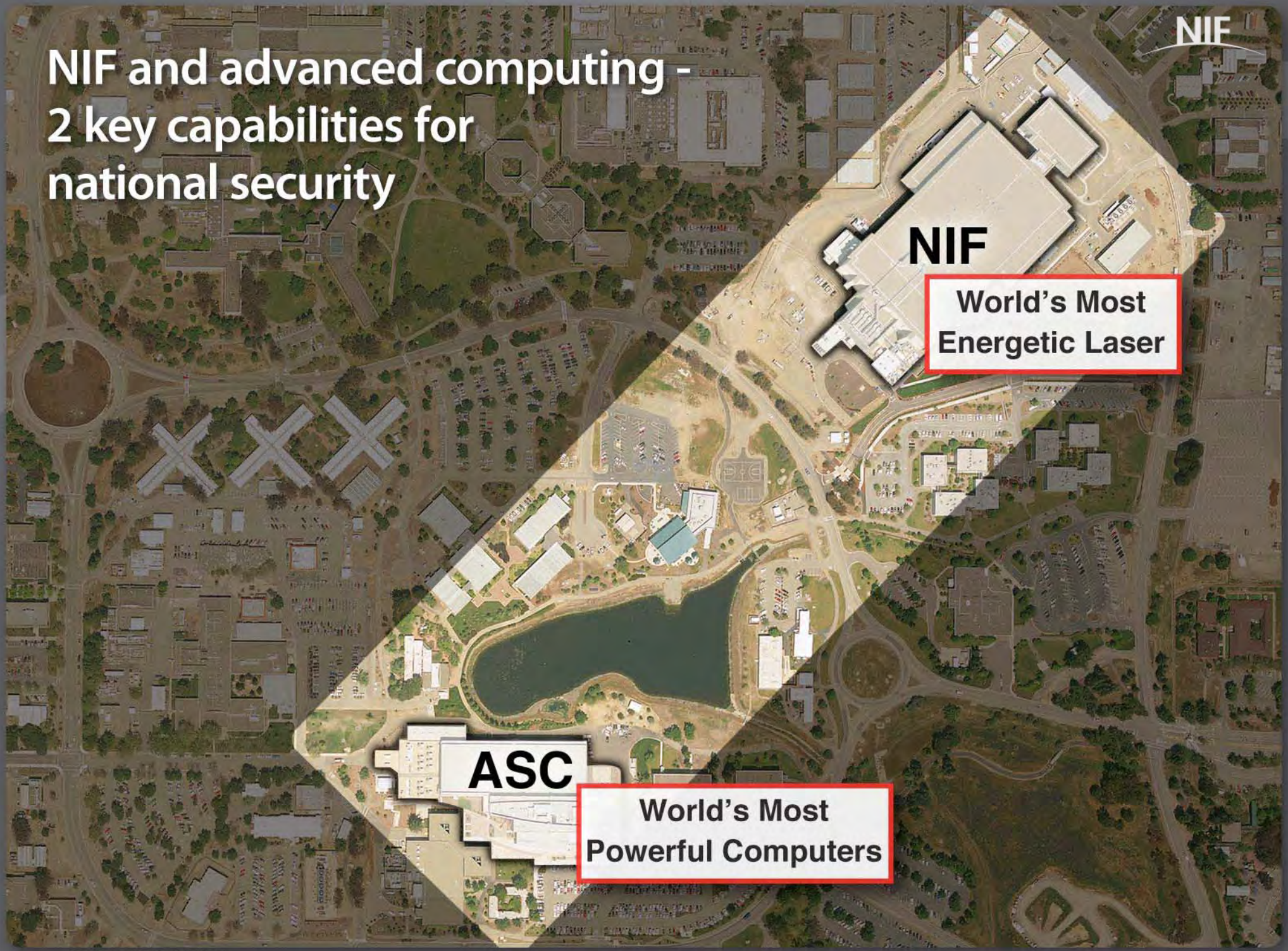
We successfully fielded half of all the types of diagnostic systems on NIF with 200 channels taking data on energetics campaign


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

NIF is ready for fusion demonstration experiments



NIF fusion in the News

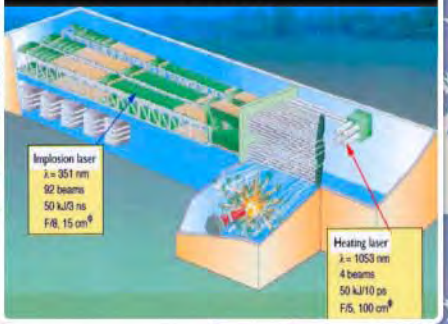

NIF and advanced computing -
2 key capabilities for
national security
NIF
NIF
World's Most
Energetic Laser
ASC
World's Most
Powerful Computers

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

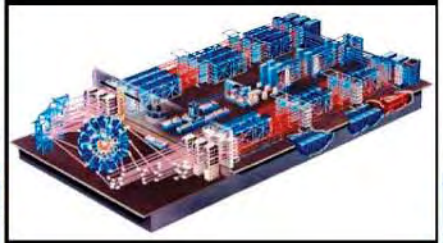
U.S Partners in NIF Enterprise:

…and we have growing international capabilities

FIREX

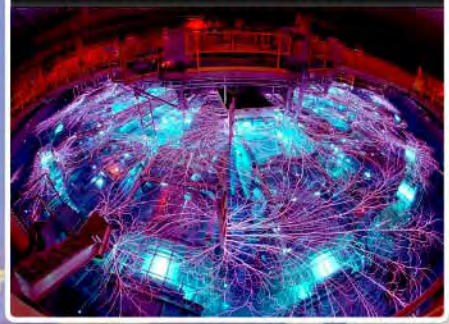


Omega, OMEGA EP Lasers



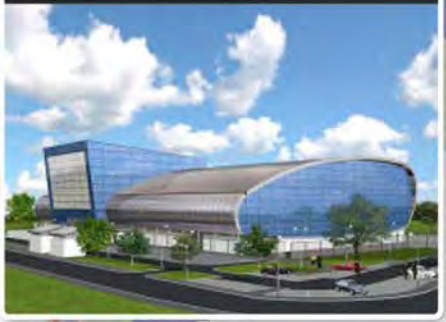
LMJ

Z, ZR Z-Pinch Facility



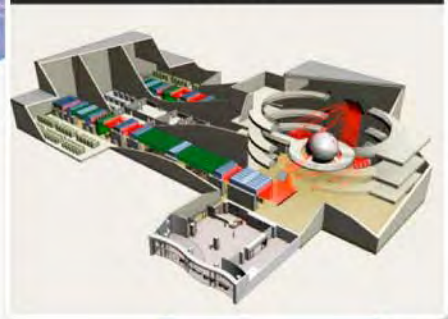
SGIII

ORION



National Ignition Facility

HiPER

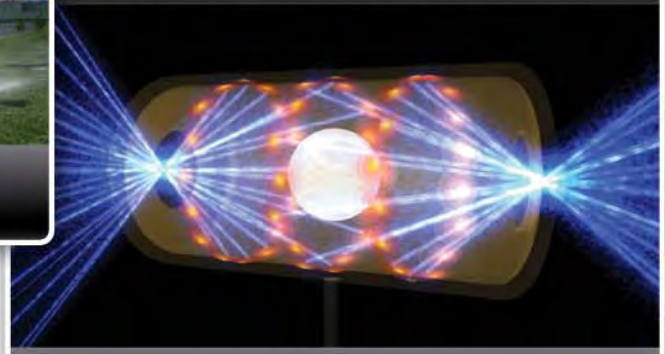


NIF Master Strategy

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

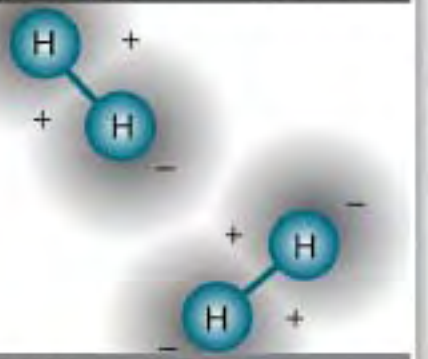
2006–2012

National User Facility

2009–2030

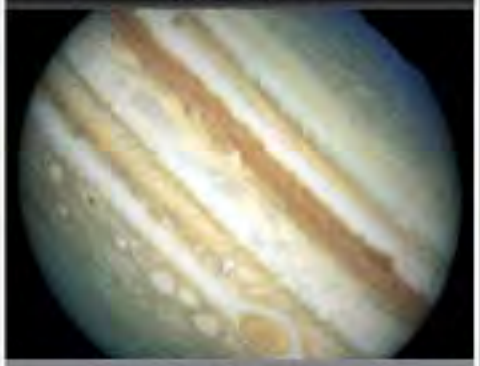
NIF will provide unprecedented capabilities to study matter at high-energy density conditions

Hydrogen Molecule



Binding energy
~10^{11} J/m^3

Jupiter

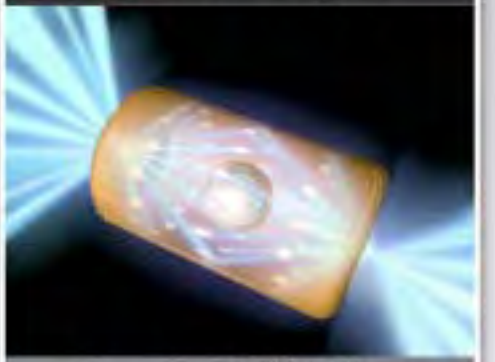


P ~ 80 MBar
(core)

Sun

P ~ $3x10^5$ MBar
(core)

Fusion Target

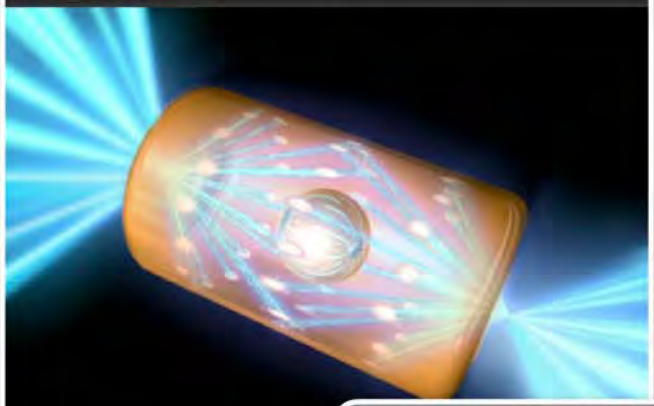


P ~ $2x10^6$ MBar
(peak burn)

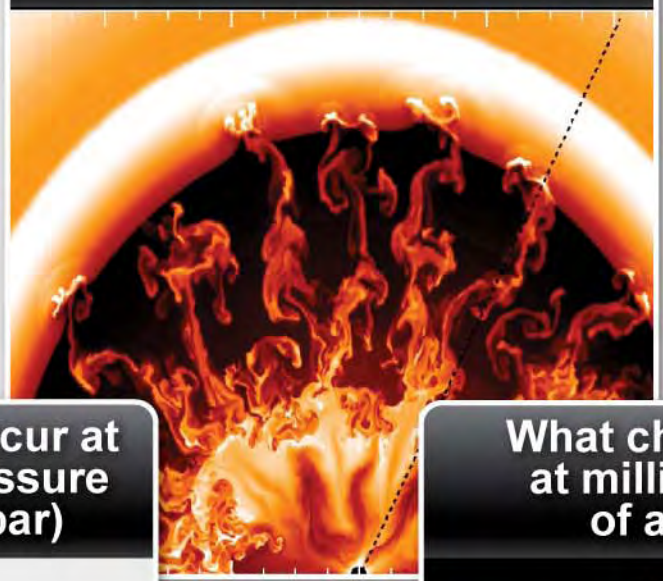
1 atm = .98 Bar

Compelling scientific questions for NIF

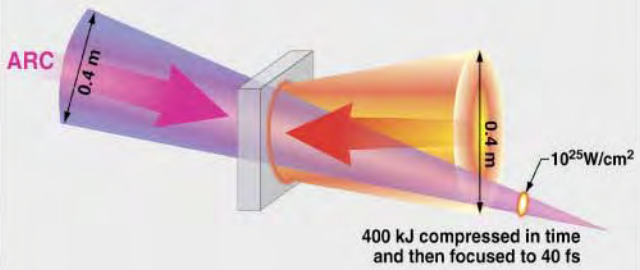
Can we demonstrate laboratory ignition?



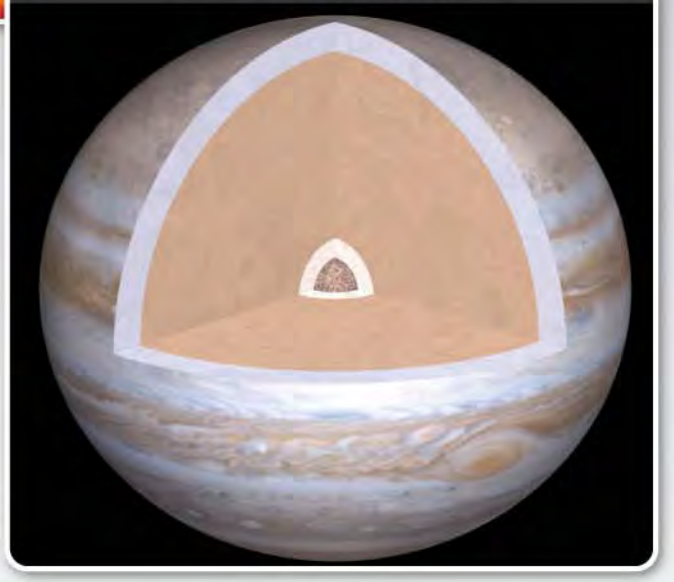
How are elements with Z>26 created?



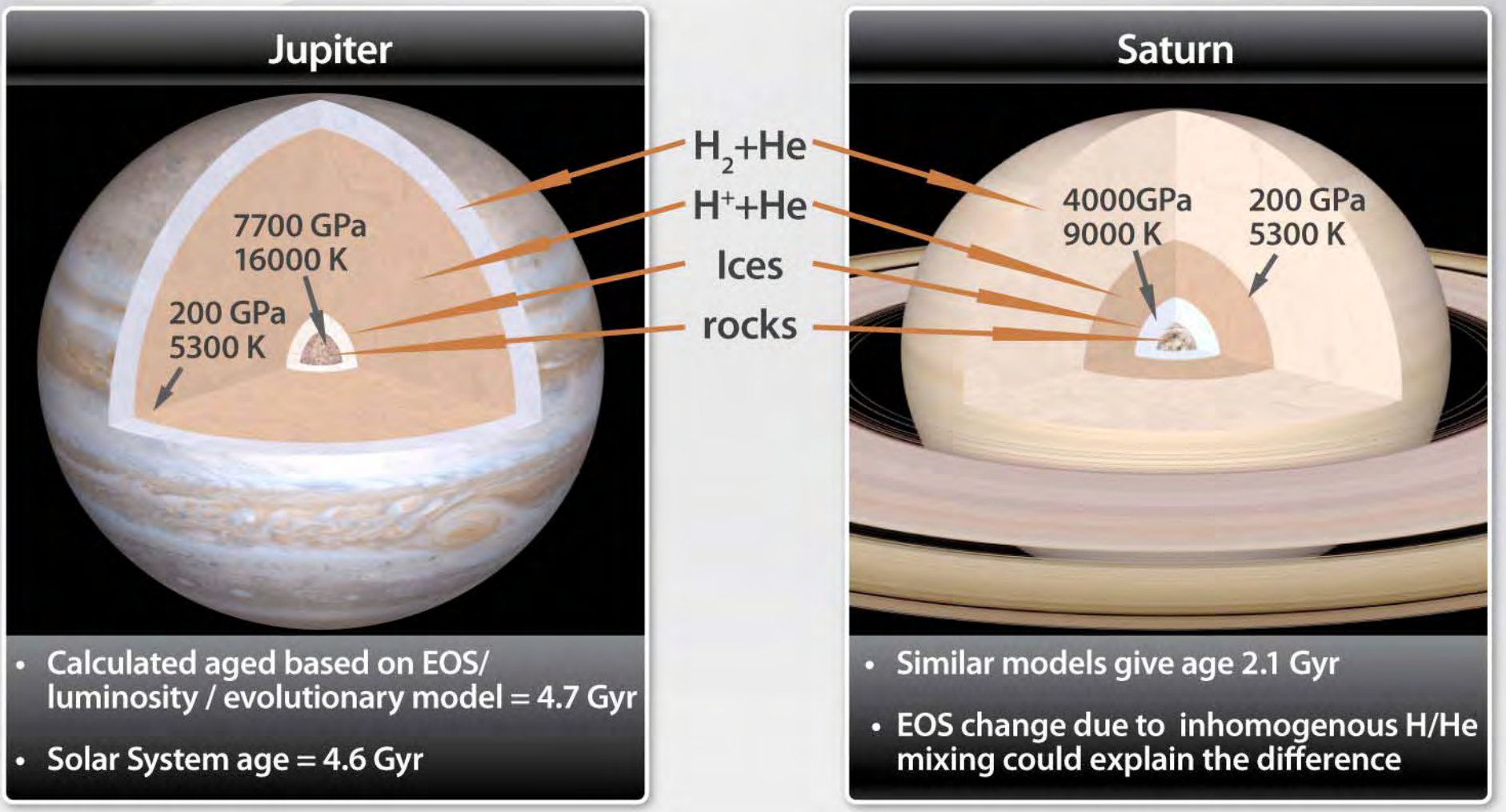
What phenomenon occur at ultra high photon pressure (10^{25} w/cm^3, 10^{10} M bar)



What chemistry occurs at millions to billions of atmopheres?



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

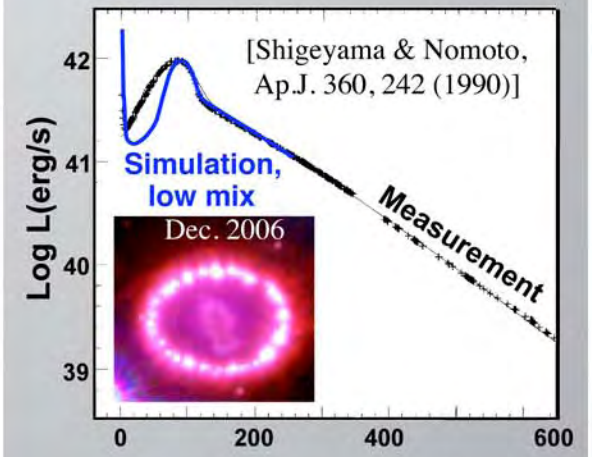


- Calculated aged based on EOS/ luminosity / evolutionary model = 4.7 Gyr
- Solar System age = 4.6 Gyr

- Similar models give age 2.1 Gyr
- EOS change due to inhomogenous H/He mixing could explain the difference

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

SN1987A measured light curve does not match low-mix simulation

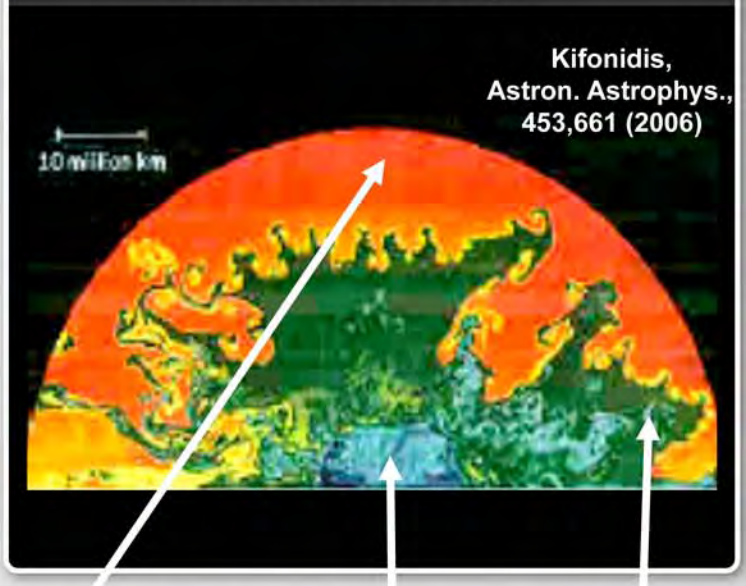


Type II supernova simulation

5 x 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?

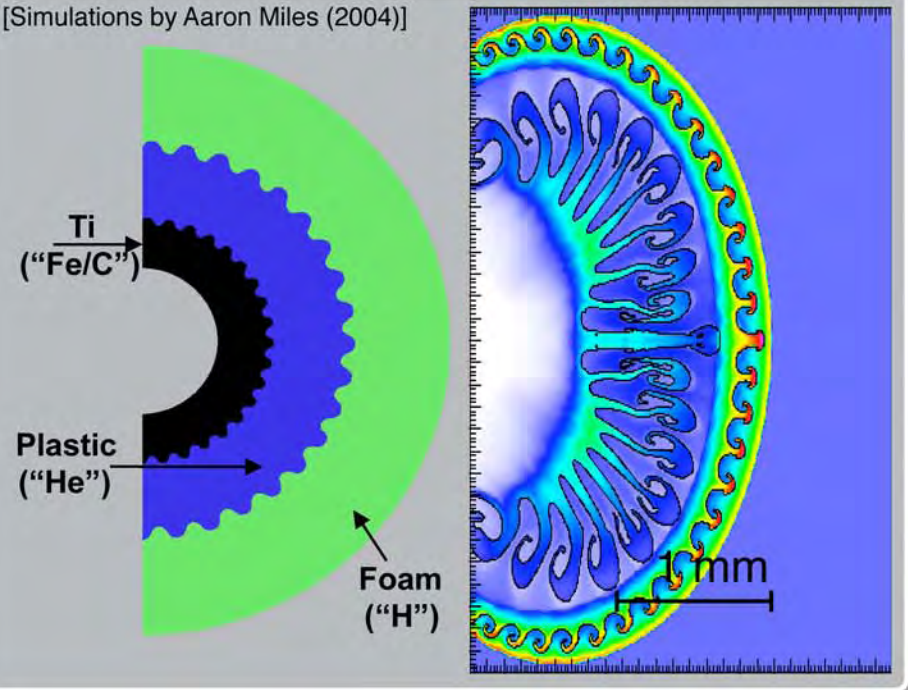
NIF has sufficient energy to test multi-interface simulations of core-collapse supernovae turbulent hydrodynamics

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

[Courtesy of Paul Drake et al.]

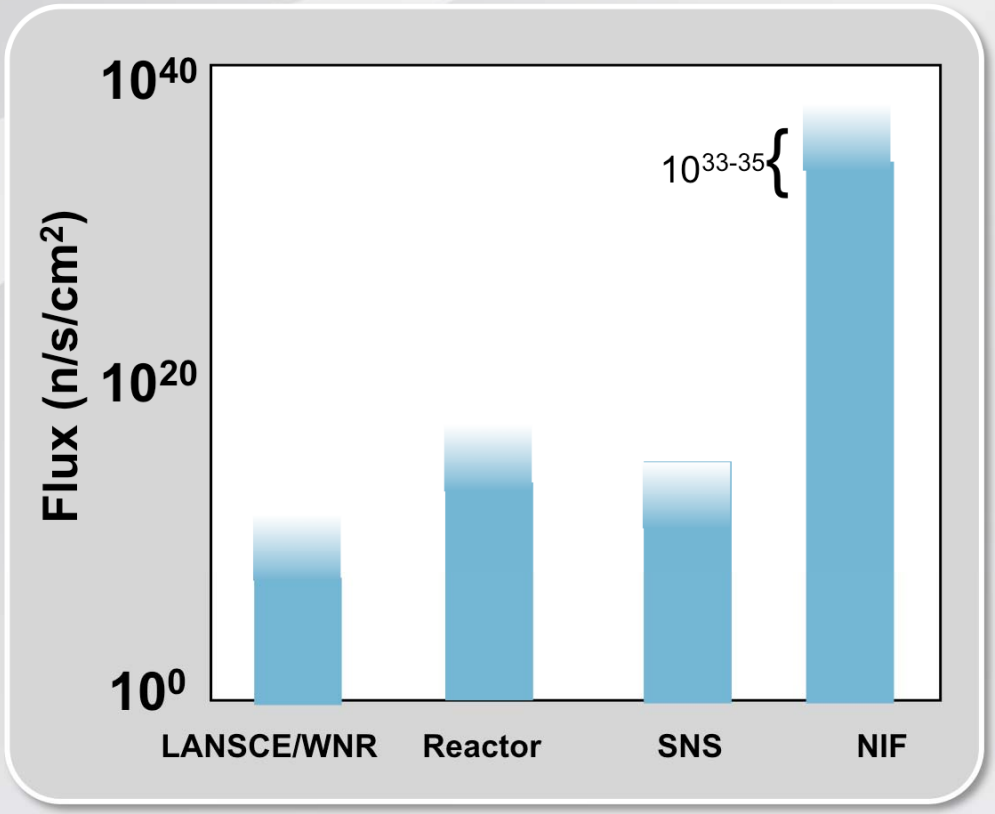
NIF hemisphere target and simulation- sufficient energy for multi-interface, diverging, scaled SN experiment

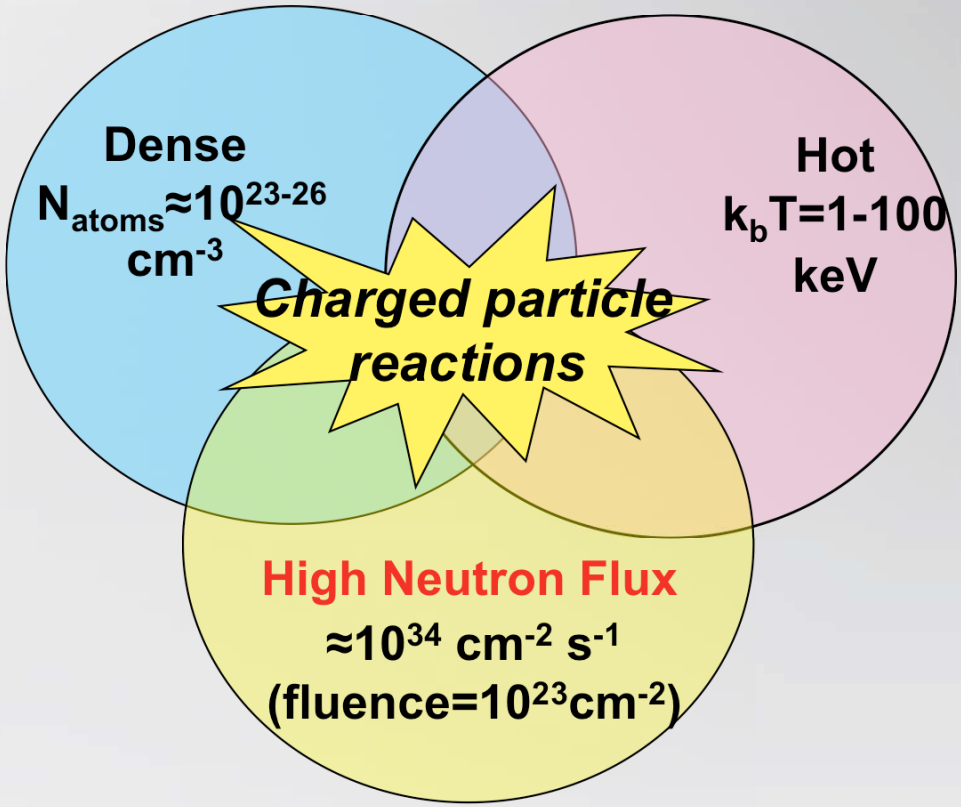
[Simulations by Aaron Miles (2004)]



NIF experiments are planned to start in 2011-2012

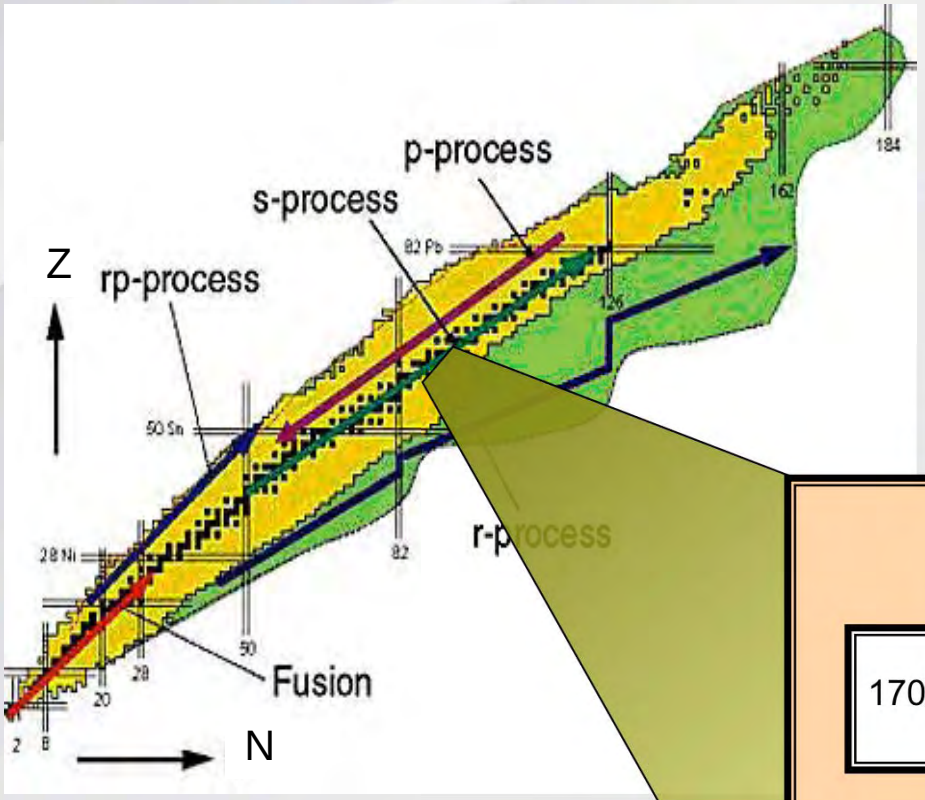
NIF enables a unique set of Nuclear Physics because NIF is a nuclear facility after all



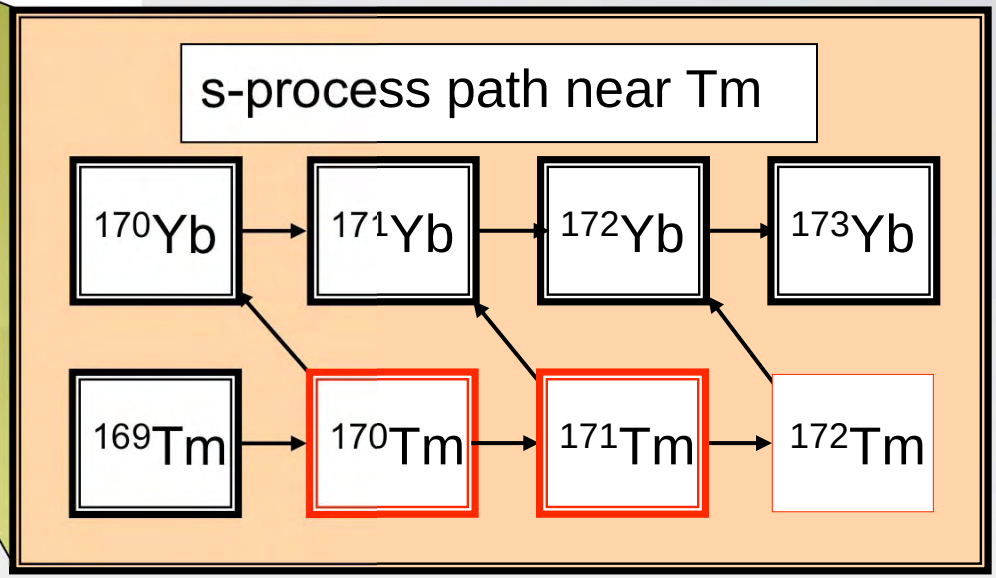


- NIF will enable us to measure nuclear cross sections involving new processes for the first time
- To measure things you need the right diagnostics

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



- **32 participants from 3 countries and 5 different institutions**

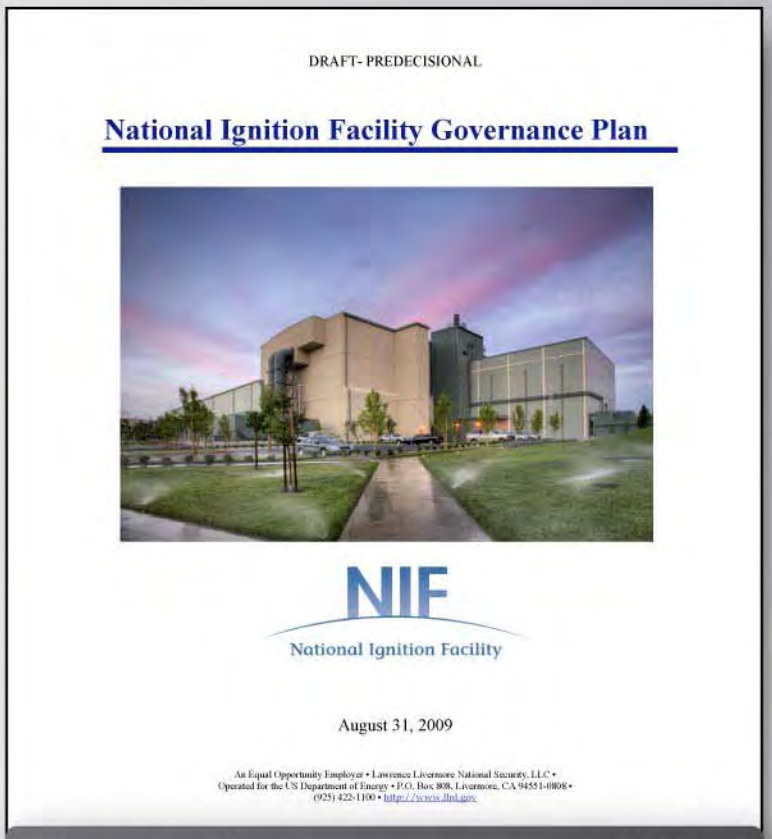


>1/2 of all nuclei with A>56 are made via the s-process

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**


DRAFT- PREDECISIONAL

National Ignition Facility Governance Plan

NIF

National Ignition Facility

August 31, 2009

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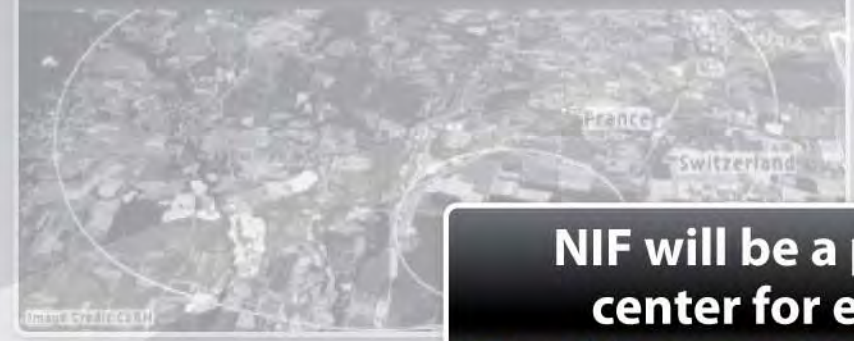
(925) 422-1100 • http://www.llnl.gov

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

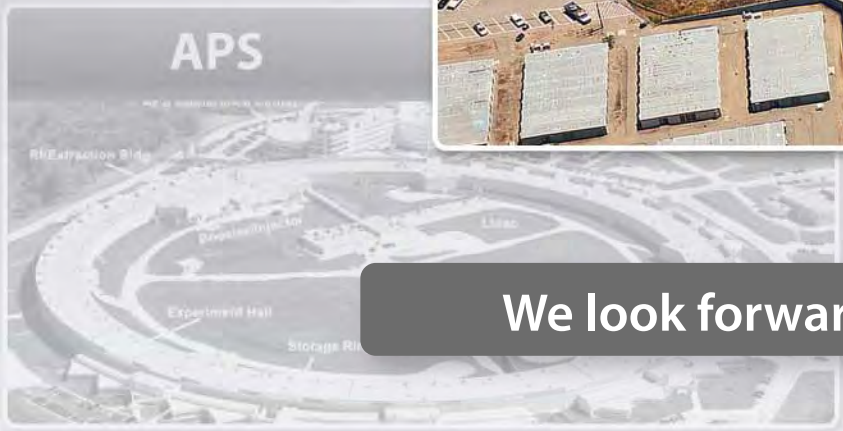
CERN



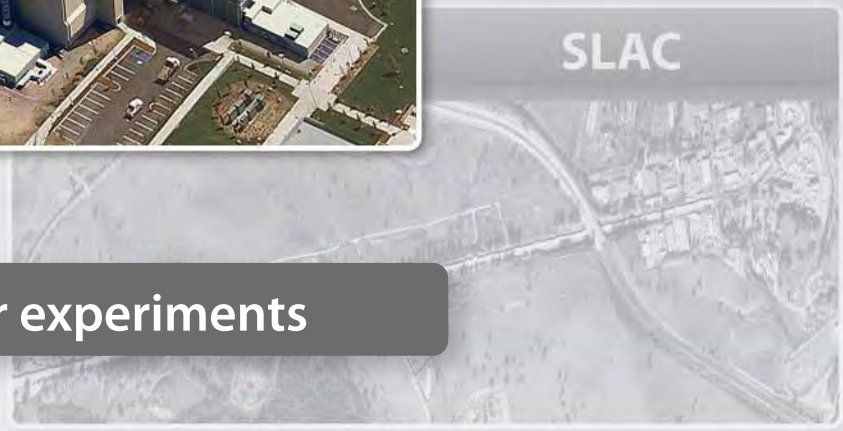
Chandra x-ray observatory

NIF will be a premier international center for experimental science

APS



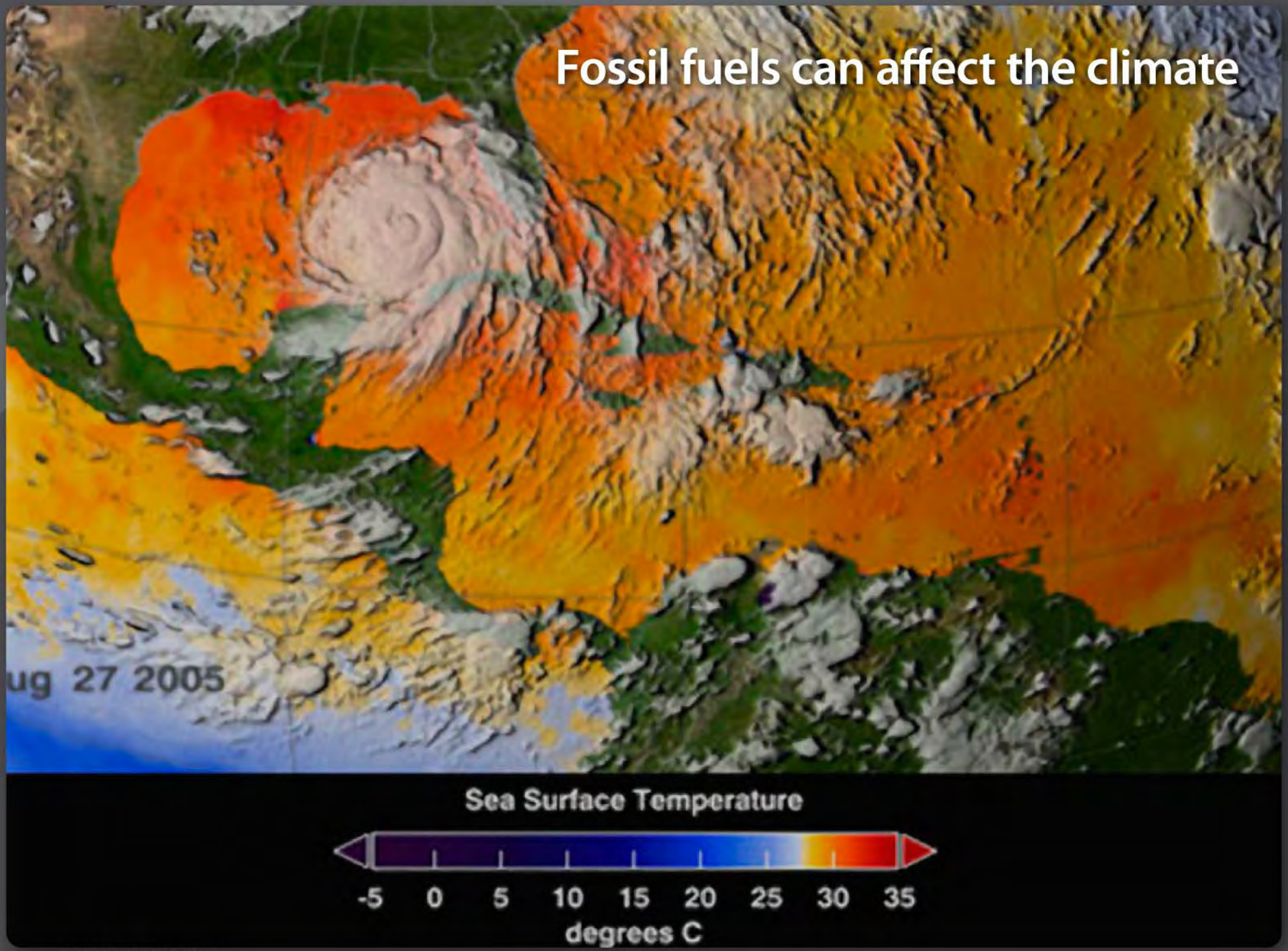
SLAC



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



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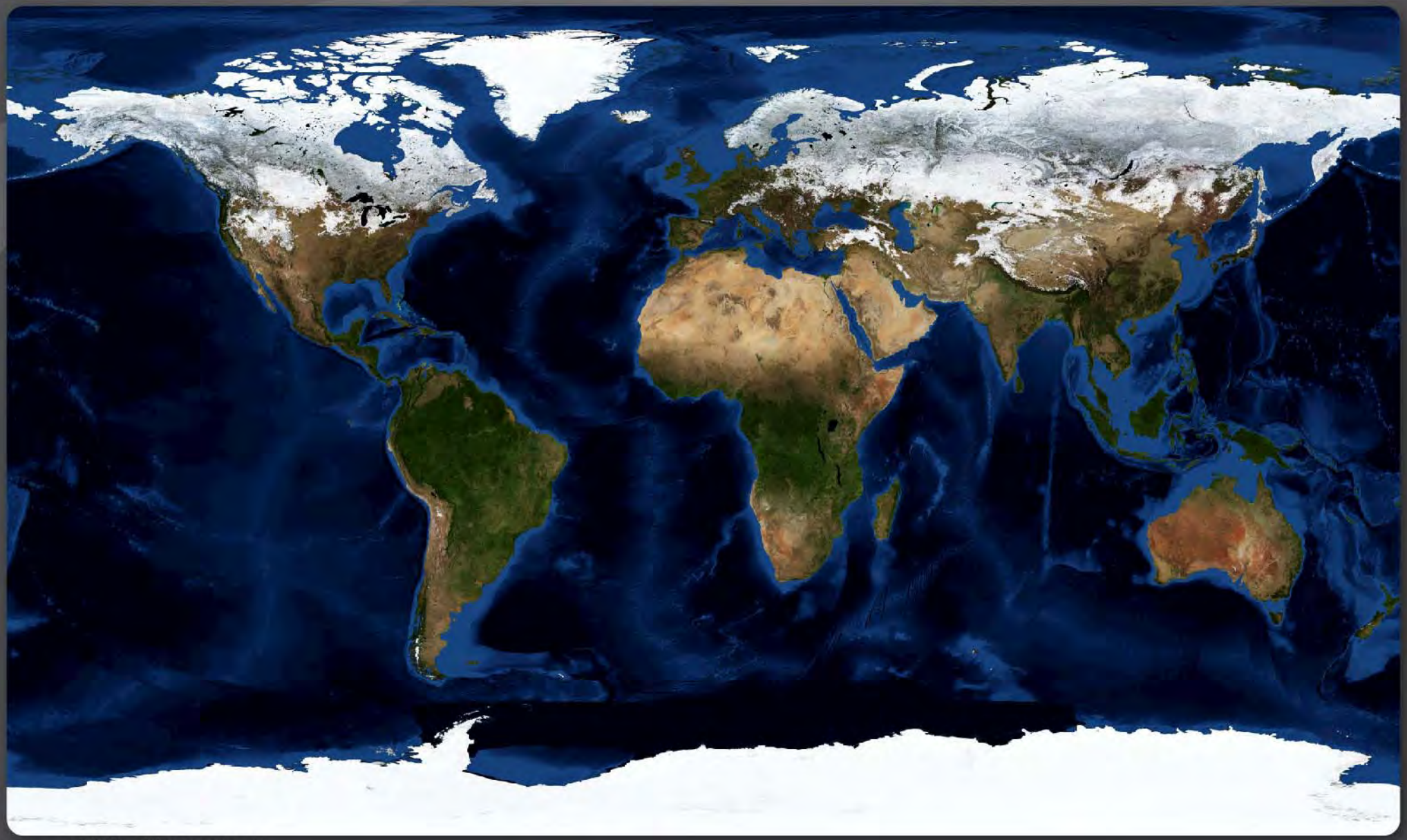
Fossil fuels can lead to environmental disaster

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



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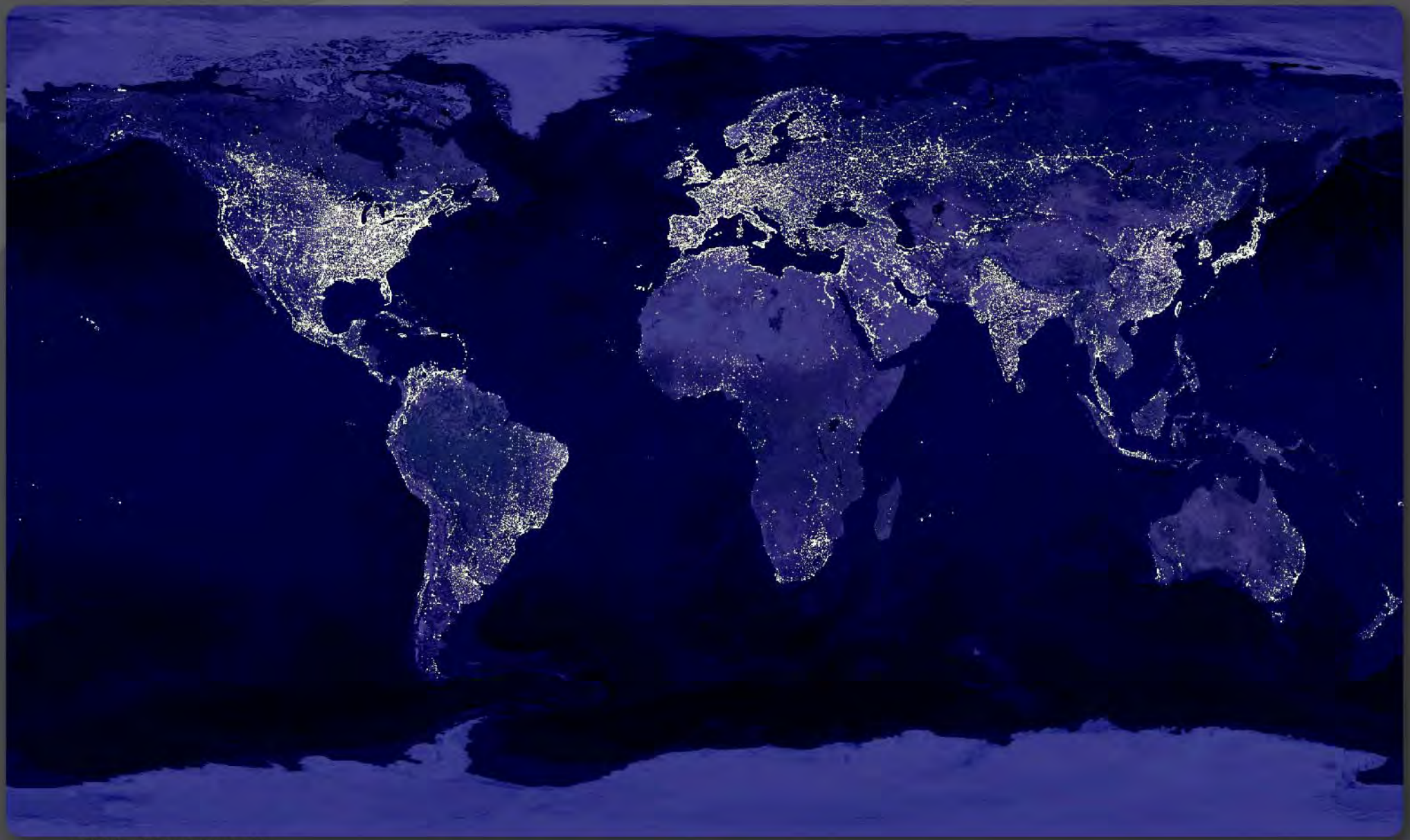
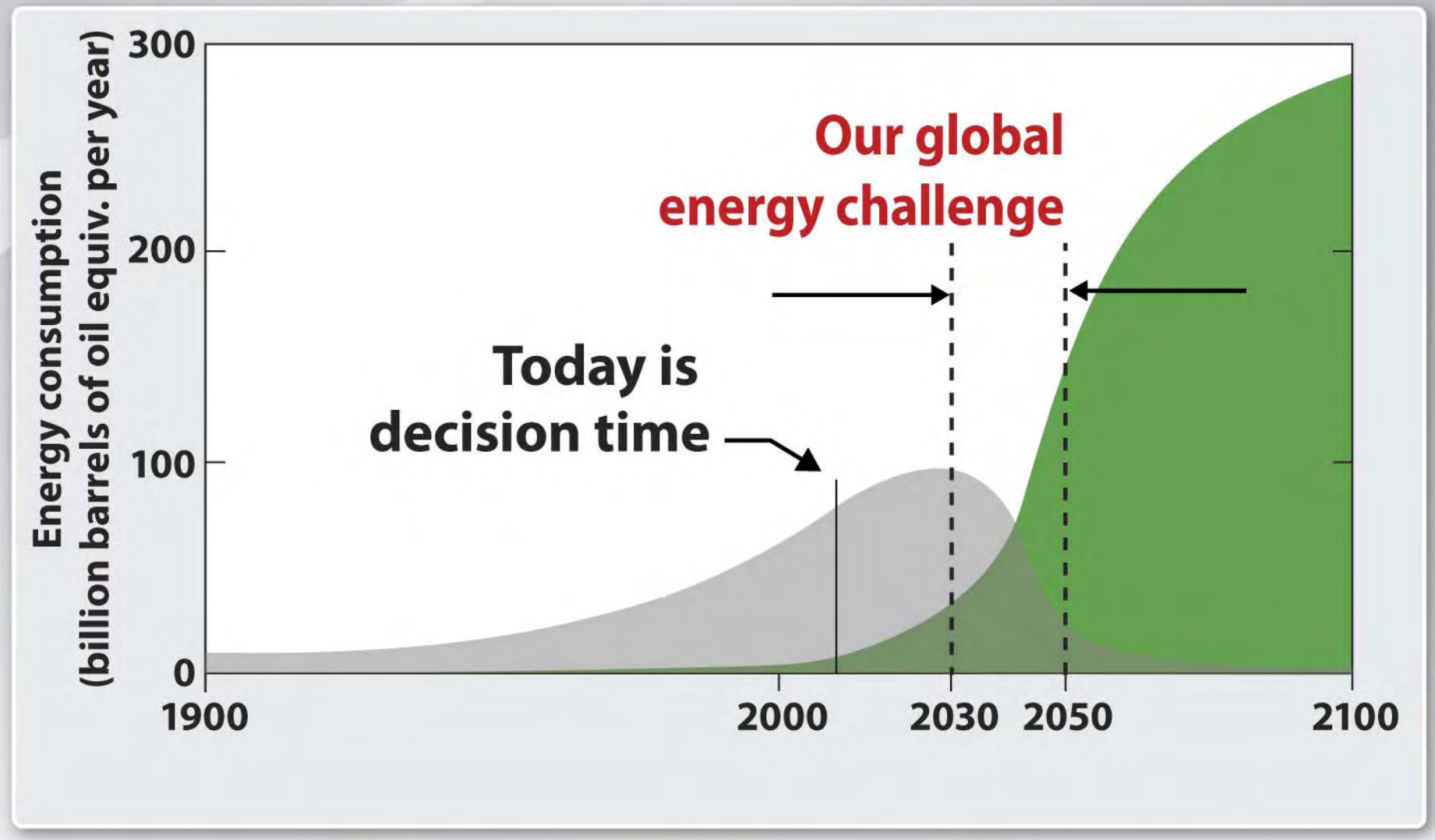
Energy fingerprint of humankind




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

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

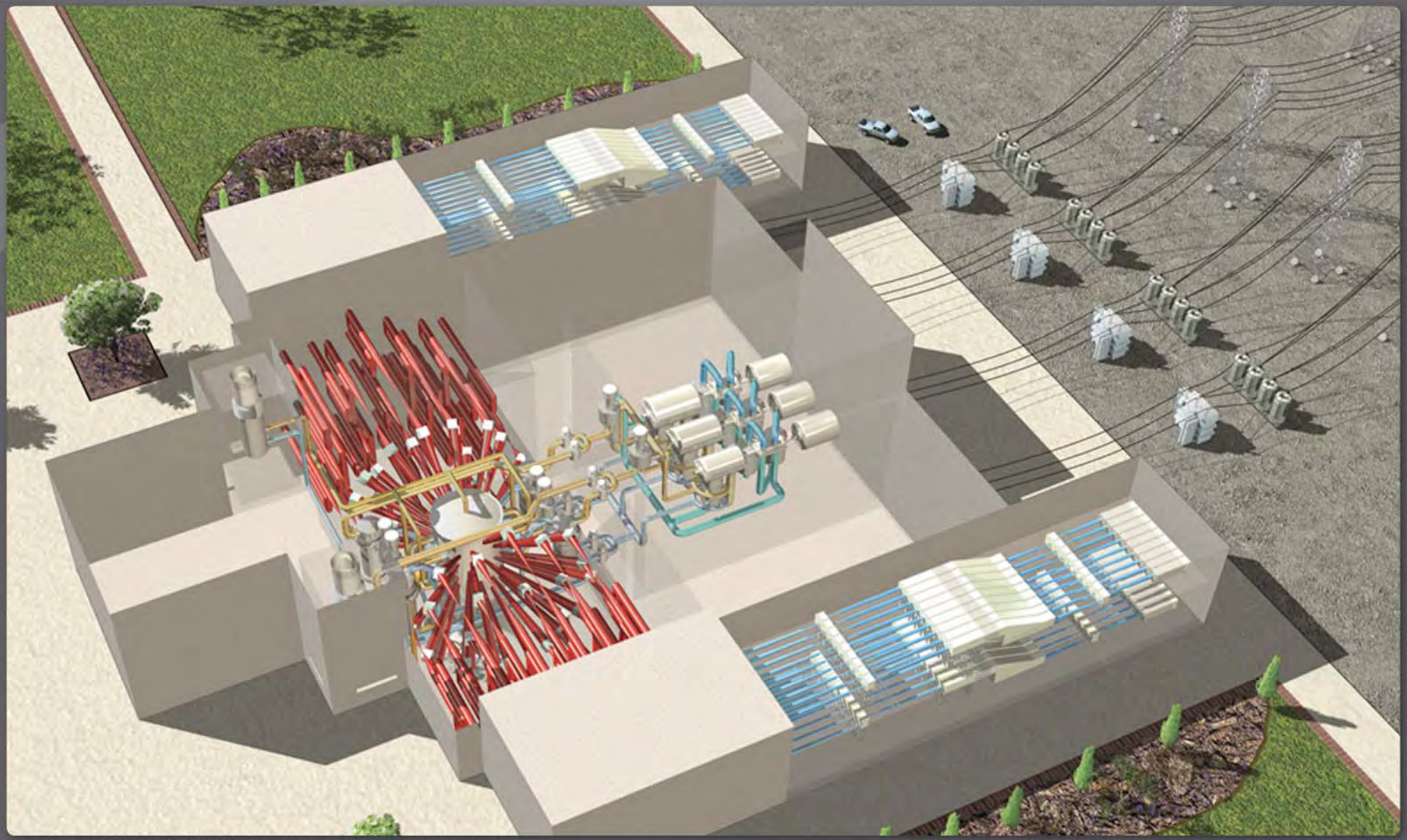
Gasoline

Heavy water

Think about the alternative

LIFE avoids 7 million tons of CO_2/year for a GW plant

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



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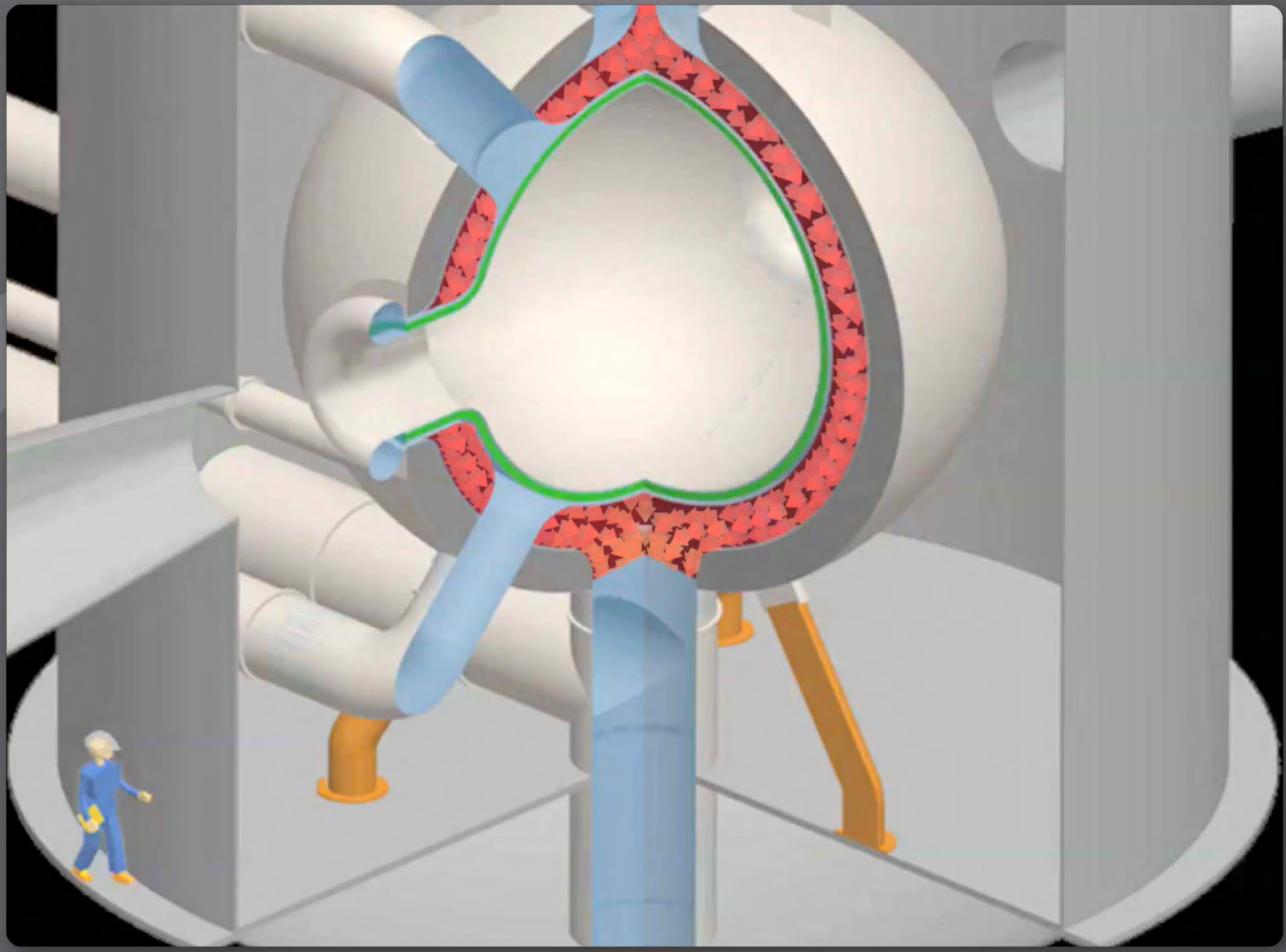
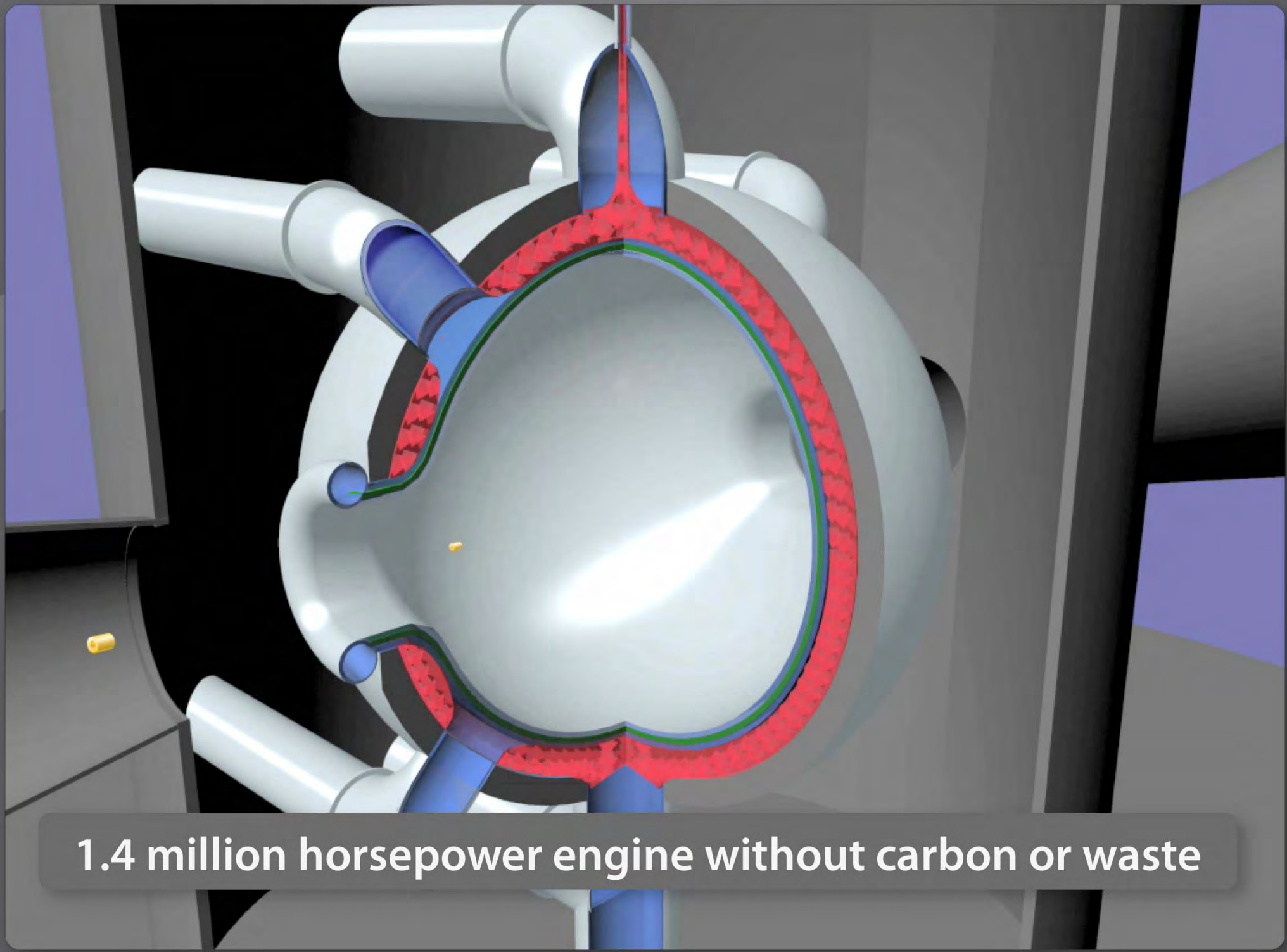
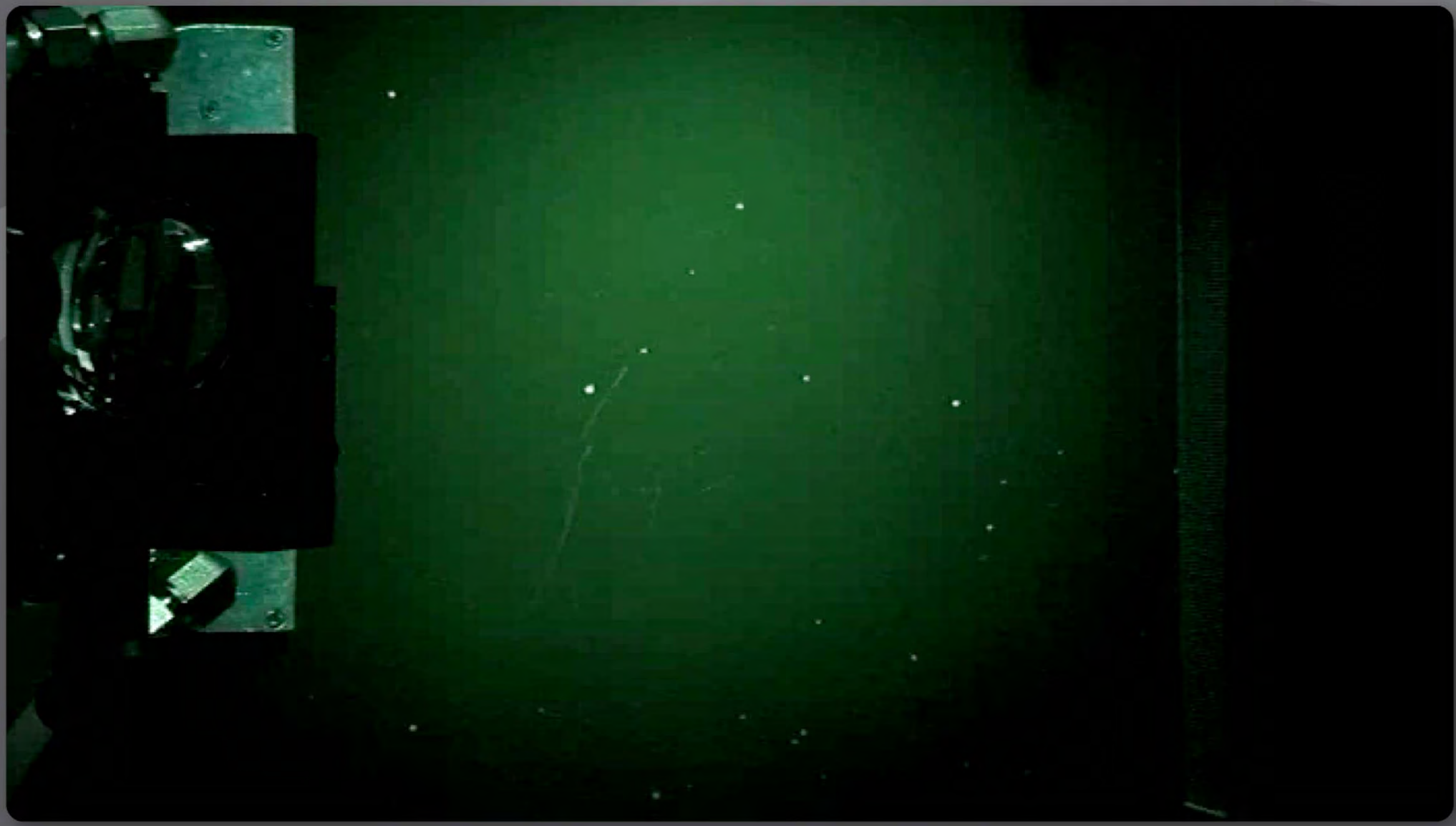
LIFE builds on NIF technology




1.4 million horsepower engine without carbon or waste

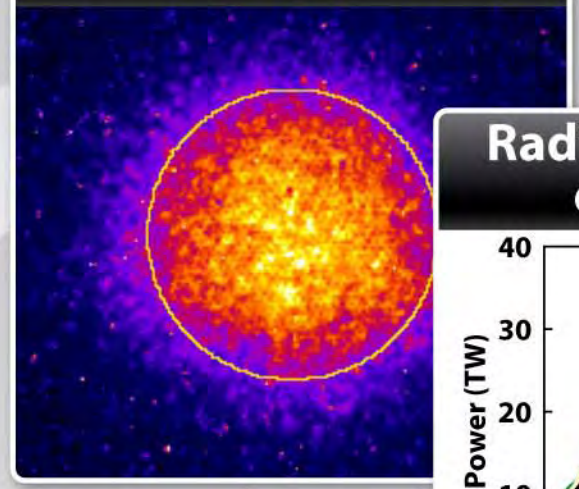
50 kWatt laser burning through steel



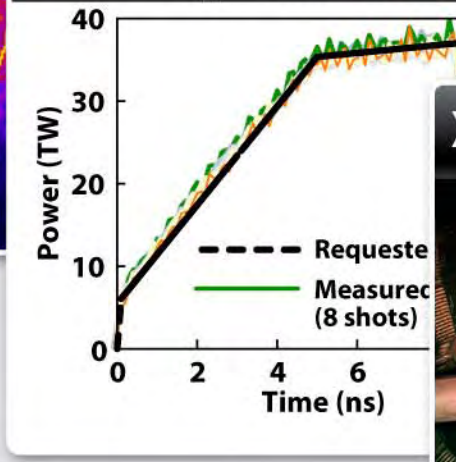
This is the Story of the National Ignition Facility and Our Energy Future!

NIF's experimental potential is already being realized

Ignition experiments



Radiation Transport experiments



X-ray Source Applications

Basic science experiments