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Careers in Fusion and High Energy Density science at Los Alamos National Laboratory

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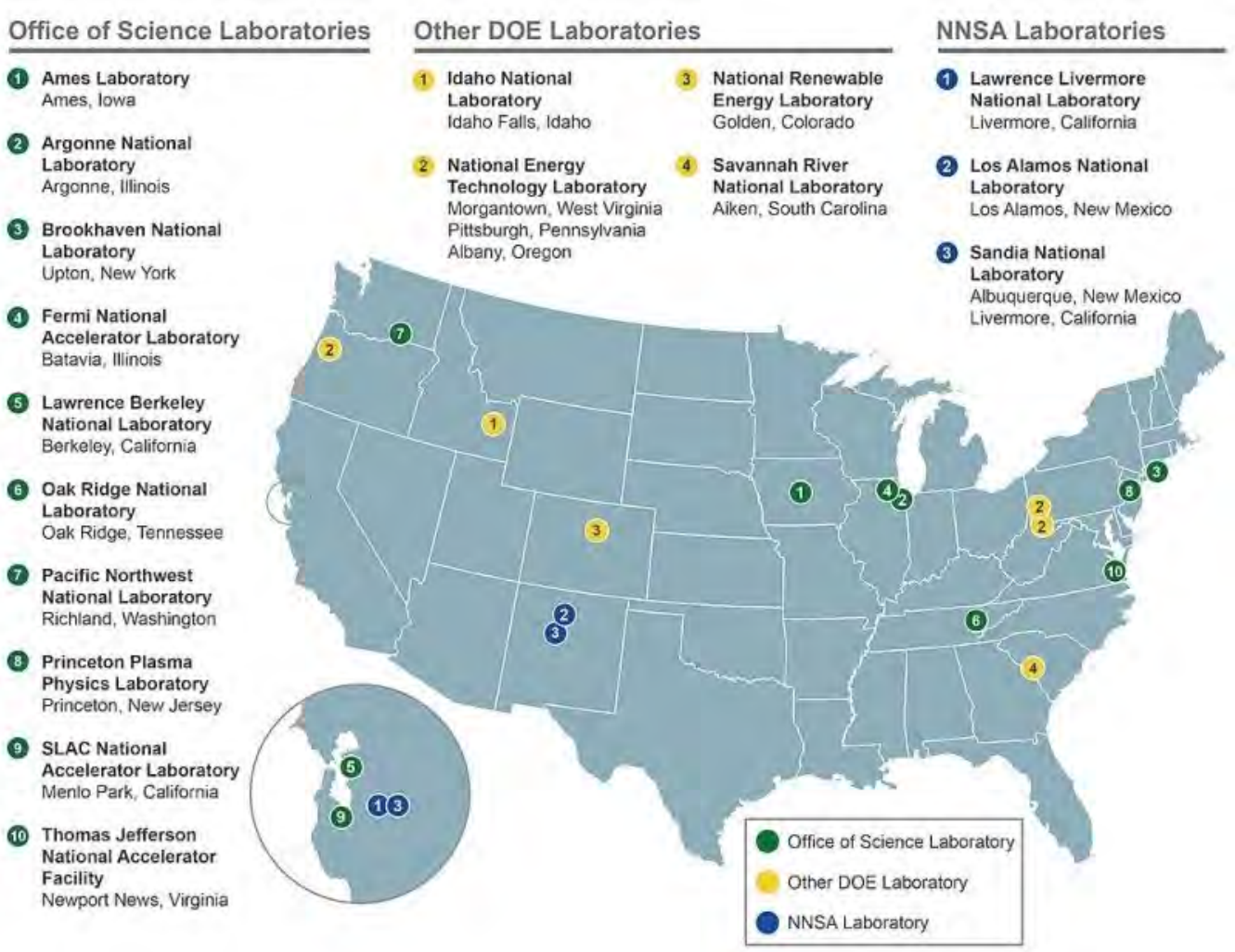
Thermonuclear Plasma Physics, P-4

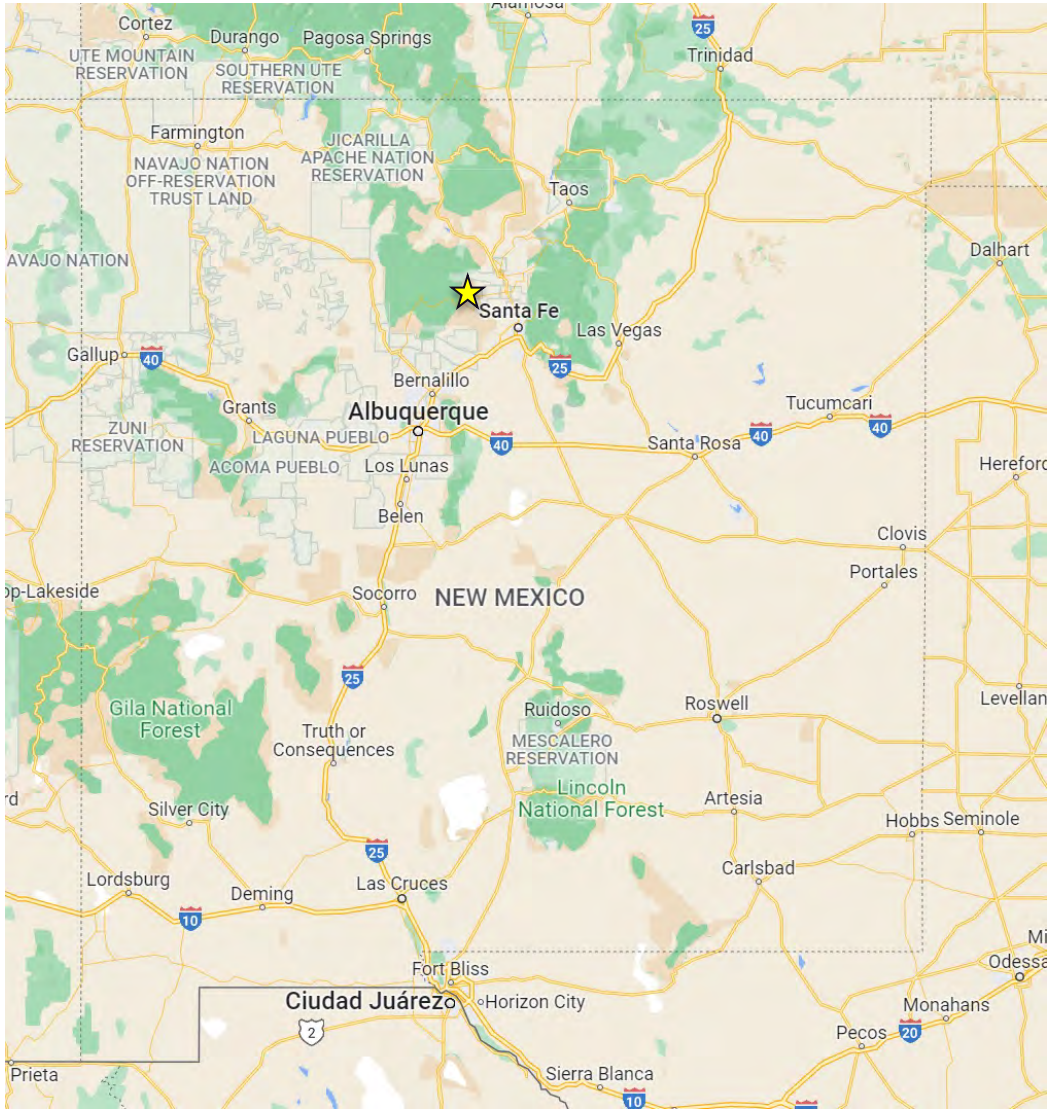
National Nuclear Security Administration
Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

What are the National Labs?

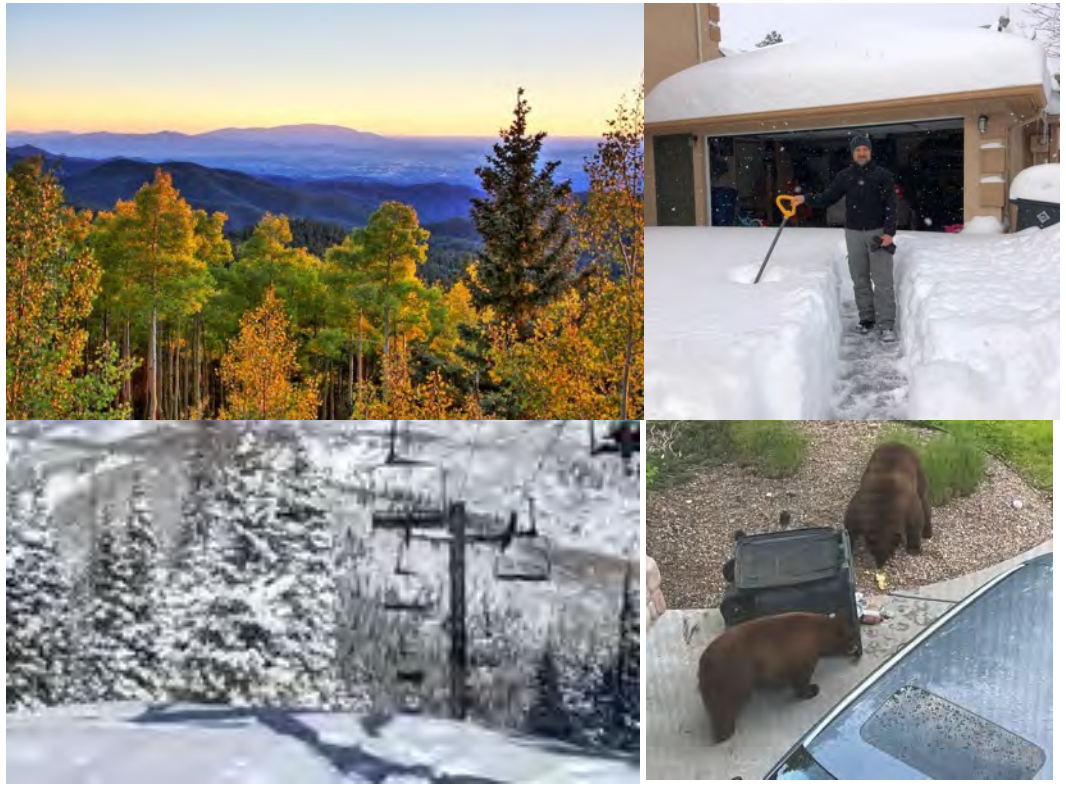


- Department of Energy oversees labs that focus on large-scale, complex research that are national priorities: energy, climate, national security, health, etc.
- Many have unique facilities (e.g., NIF, various accelerators, Z machine etc.)
- LANL is governed by the NNSA, along with SNL and LLNL

Los Alamos is located in North Central New Mexico



- Elevation: ~7300 feet - an outdoorsy mountain town
- Snow, Ski Hill, lots of great hiking, MTB trails
- National parks and historical sites (Santa Fe, Pueblos)



Los Alamos National Laboratory

	LANL
Number of People	14,000 (~ 18% Ph. D)
Budget (2022)	$4 B
# of department	> 32
Campus size	40 $mile^2$
Nobel Laureates affiliated	20
Starbucks	1.5 (in Los Alamos)

Excellence in
Nuclear Security

Design, produce, and certify current and future nuclear weapons, and reduce global nuclear threats

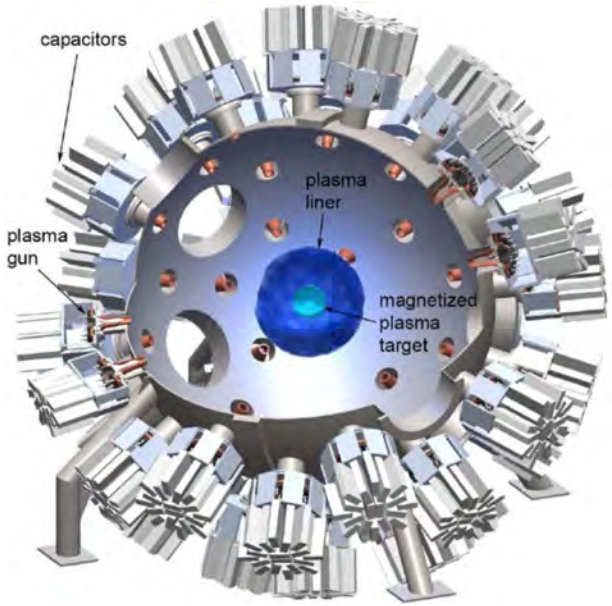
Excellence in
Mission-Focused ST&E

Deliver scientific discovery and technical breakthroughs that support DOE and NNSA missions

Our world-class staff solves grand challenges on earth and in space

- Extremely broad research efforts in support of Stockpile Stewardship research are applied to:
  - Energy (solar, fission, fusion)
  - Materials (quantum, structure, photonics)
  - Nanotechnology
  - Climate change
  - Vaccine development & epidemic prediction
  - Cybersecurity, including disaster modeling
  - Space exploration and monitoring
  - And many others

SuperCam, an instrument on the newest Mars Rover (photo by NASA/JPL – CalTech.



Plasma Liner Experiment (PLX).

A diverse research portfolio provides opportunity for collaborations across organizations

Our world-class staff solves grand challenges on earth and in space

LANL's Flagship Facilities provide access to the state-of-the-art capabilities in multiple research fields

LANSCE (800 MeV proton, ½ mile long)

DARHT (20 MeV x-ray, 550 R)

Plutonium Facility

TRINITY Supercomputer

Why would YOU like to work at LANL?

- **The people:** World-class experts in a wide range of topics (i.e. astrophysics, climate modelling, cyber security, vaccine development, etc.)

- **The projects:** Challenging projects in support of the lab mission that allow you to use creativity and expertise to determine how to solve them

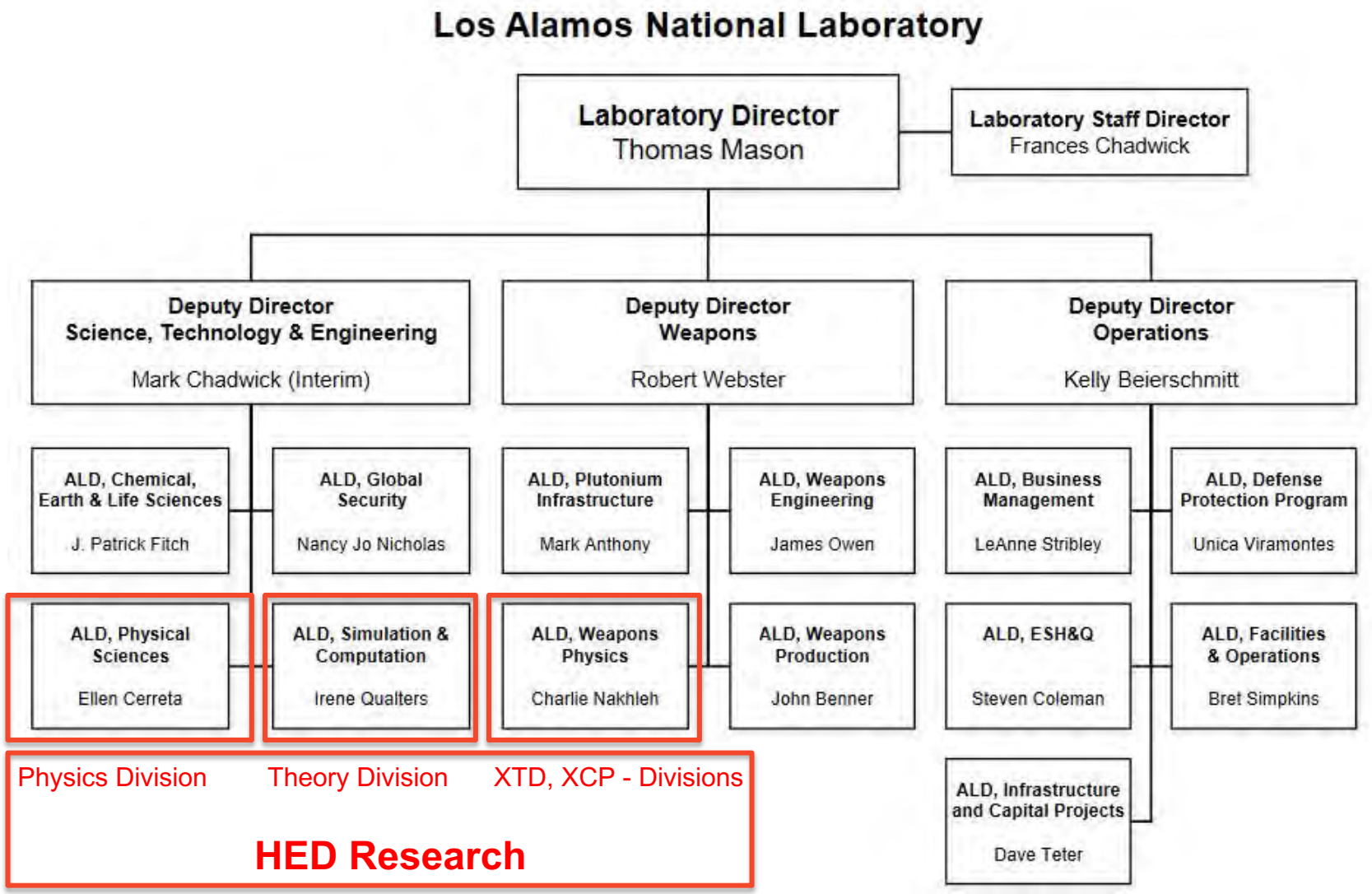
- **The place:** New Mexico has a rich cultural history and incredible scenery. Ski hill and National parks in our backyard! Excellent school system & community. Housing is expensive, but not as bad as Bay Area

P-4 students and postdocs on the tour to the Museum of Nuclear Science

LANL encourages our employees to become a part of, or create an Employee Resource Group (ERG) and find ways to shape the workforce of the future

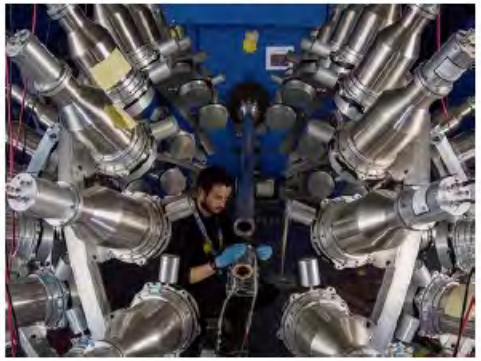
- Active Bystander ERG
- SOUL: African American ERG
- American Indian ERG
- Asian and Pacific Islander ERG
- Atomic Women: Women in STEM ERG
- Connect: New Employee and Early Career ERG
- Dependent Caregiver ERG
- DiverseAbility ERG
- HOLA: Hispanic ERG
- Prism: LGBTQ+ ERG
- Veteran and Transitioning Service Members ERG
- Women of Computing ERG
- Women's Institutional ERG

LANL Organizational Structure



Physics Division

Our science answers questions about the nature of the universe and delivers solutions for national security concerns.

P-1: Dynamic Imaging & Radiography	P-2: Applied & Fundamental Physics	P-3: Nuclear & Particle Physics	P-4: Thermonuclear Plasma Physics
			
pRad Radiographic science Weak interactions Neutron imaging	Nevada SCE/NDSE Prompt diagnostics Neutrinos HED Fluid Lujan/WNR operation	High-energy nuclear Low-energy nuclear Gamma-ray astro. Neutron Neutrinos	Implosion physics Radiation transport Magnetized plasma Thermonuclear burn Diagnostic eng.

https://www.youtube.com/watch?v=PRWM6faFmkA

P-4: Thermonuclear Plasma Physics

By leveraging plasma under extreme conditions, we concentrate on solving critical scientific challenges in understanding the matter under extreme conditions. Our research spans from advancing weapons physics to generating fusion energy

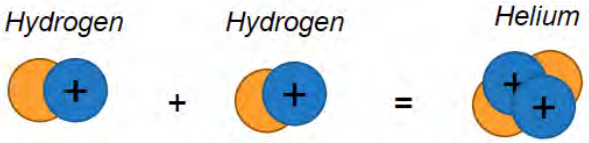
TEAMS:

- Radiation transport and material properties
- Thermonuclear burn
- Implosion physics
- Diagnostics engineering
- Magnetized plasmas

FACILITIES:

- Magnetized Shock Experiment - Field-reversed configuration for magnetized target fusion development
- Plasma Liner Experiment - Converging and colliding plasma jets for inertial confinement fusion and basic astrophysics
- Plasma Physics supports laboratories such as x-ray calibration, target characterization, optical development and darkrooms, and engineering design.
- National Ignition Facility at LLNL
- Omega Laser Facility at the University of Rochester
- Z Pulsed Power Facility at Sandia National Laboratories
- Linac Coherent Light Source, X-Ray free electron laser at SLAC
- Wendelstein 7-X stellarator
- ITER

Controlled Fusion: Ignite the Stars in the Lab



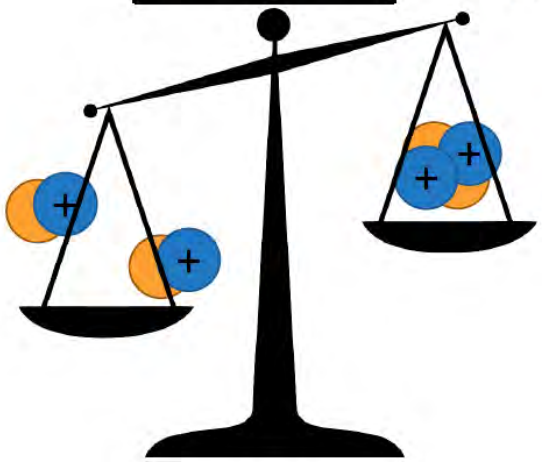
Fusion makes new elements that weigh a little bit less, the extra mass is released as energy

$$E = mc^2$$

Speed of light is a very BIG number
For a little mass, you get A LOT of energy

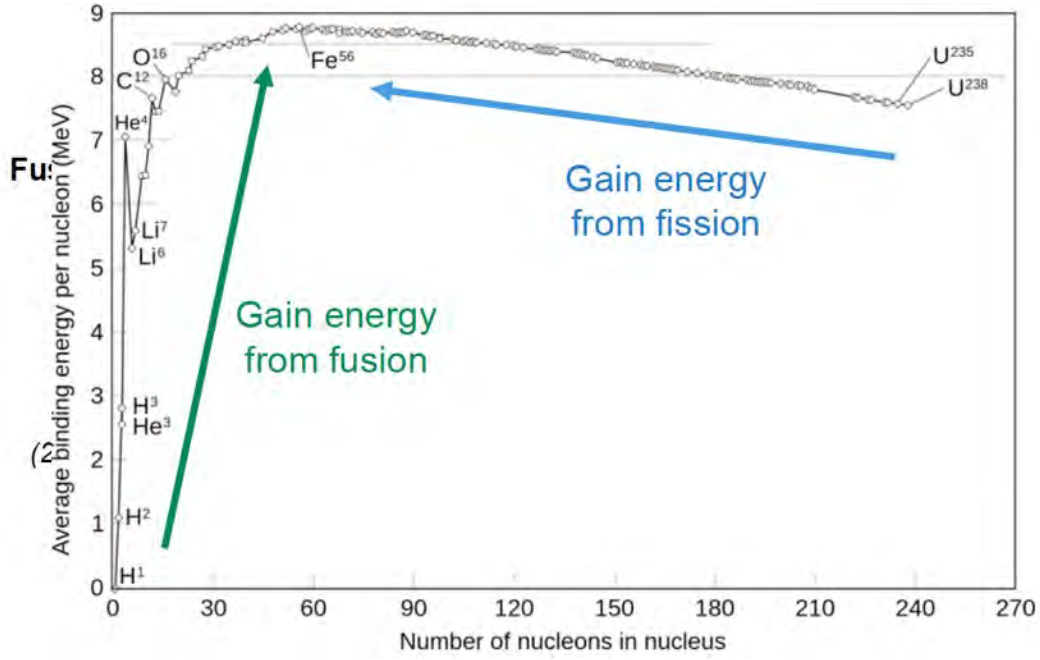
Two Hydrogen
(2 protons, 2 neutrons)

Weighs MORE



One Helium
(2 protons, 2 neutrons)

Weighs LESS



Controlled Fusion: Ignite the Stars in the Lab

Challenge: fusion only happens at insane temperatures and densities, $>10^7$ °C

How do you make a sun on Earth? Need to make something as HOT as possible

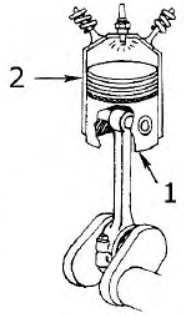
The central question of making a fusion power plant on Earth –
How can you make something very hot?

Burn stuff? Nothing burns hot enough

Send electricity to heat stuff up?

Microwave? Shoot radiation?

Squeeze stuff?

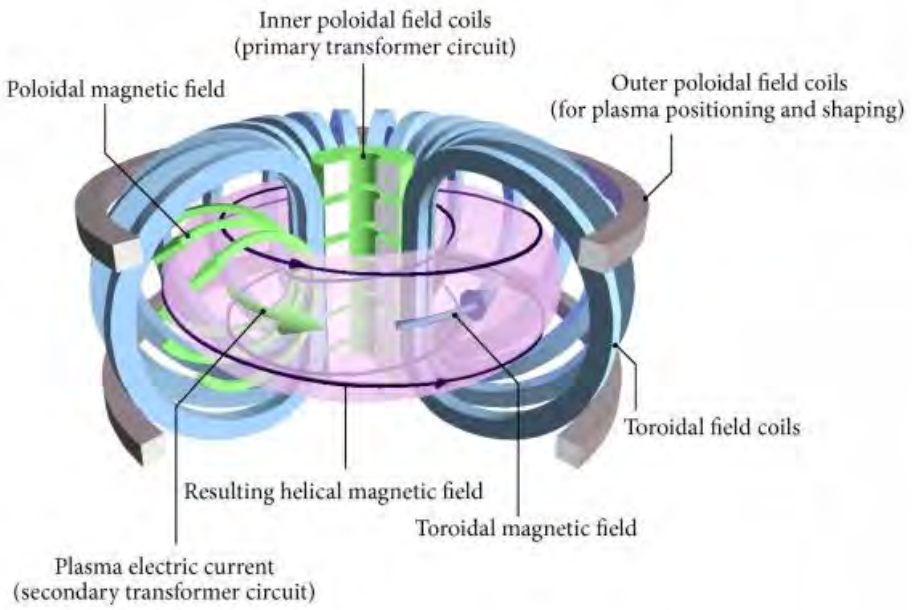


One Approach: Magnetic Confinement

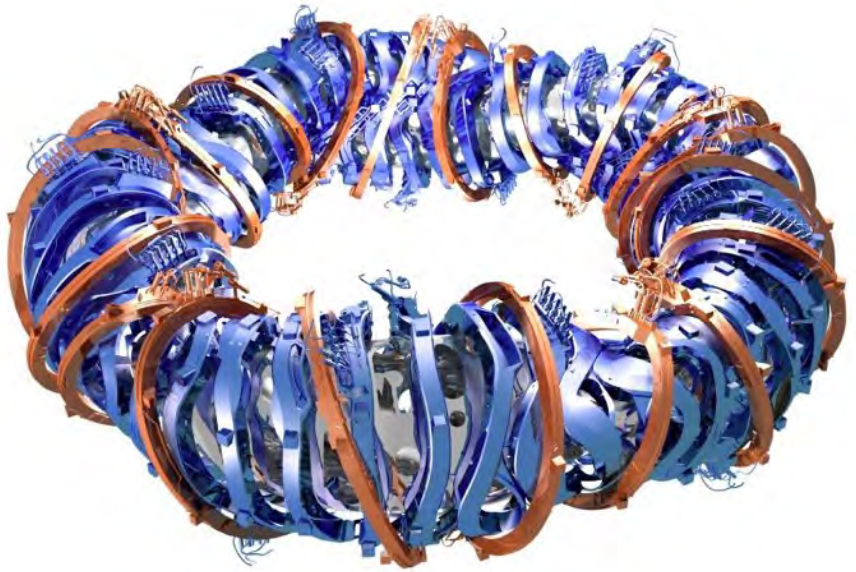
The fusion temperatures are so hot, no material can hold it

Idea: Use electricity or radiation to heat a plasma to ultra high temperatures and hold the plasma away from walls using magnetic fields

Tokamak (Donut)



Stellarator (Twisted)

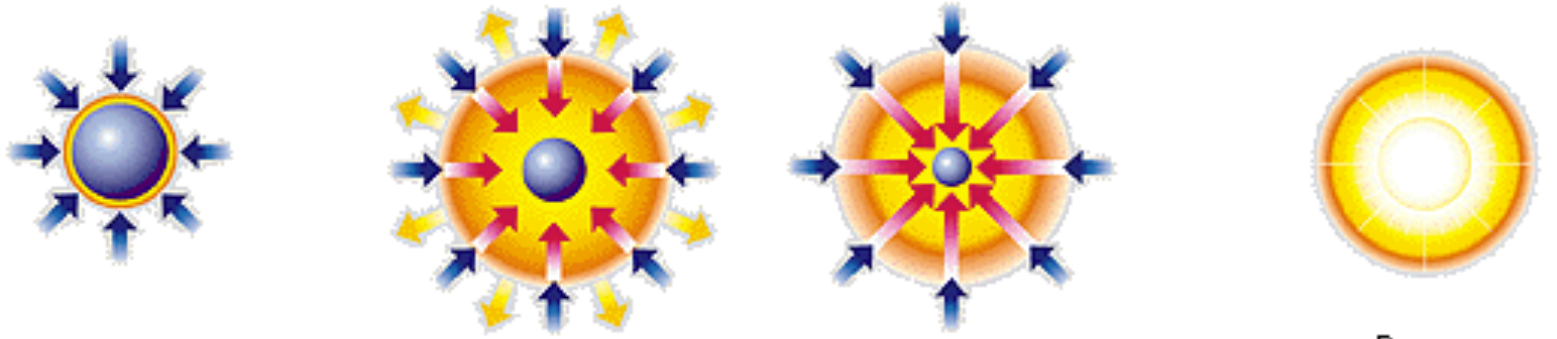


Magnetized Plasma Team in P-4 focuses on development of novel approaches to magnetic plasma confinement, and diagnostics to monitor plasma dynamics

Alternative Approach: Inertial Confinement

Idea: Don't even try to contain the ultra hot plasma - do fusion before the system blows up

- Fusion is very fast compared to the movement of objects
- Shoot a pellet with gigantic massive laser to squeeze it
- The fusion burns before the pellet blows apart



Atmosphere Formation

Laser beams rapidly heat the surface of the fusion target, forming a surrounding plasma envelope

Compression

Fuel is compressed by the rocket-like blowoff of the hot surface material.

Ignition

During the final part of the laser pulse, the fuel core reaches 20 times the density of lead and ignites at 100,000,000 C

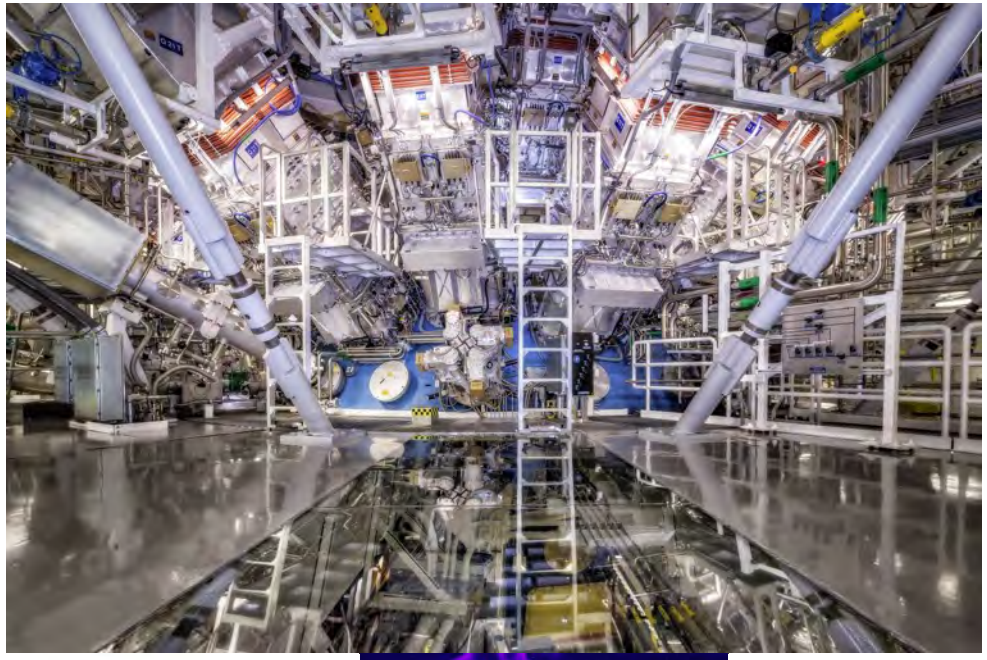
Burn

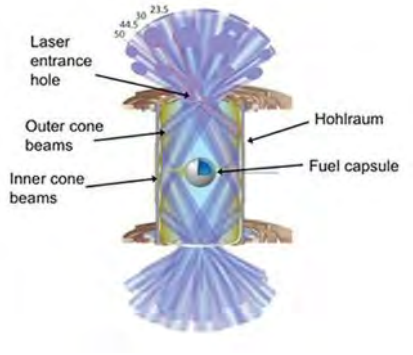
Thermonuclear burn spreads rapidly through the compressed fuel, yielding many times the input energy.

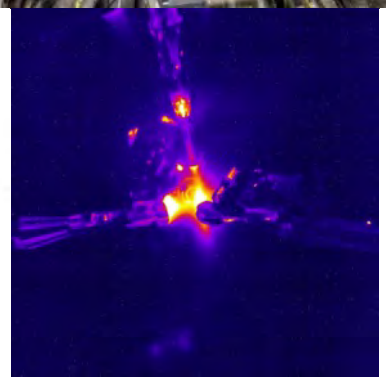
Alternative Approach: Inertial Confinement Fusion (ICF)

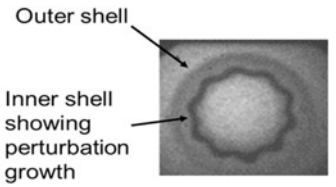
Inertial confinement fusion creates one of the most extreme environments in the universe

- **NIF** - World's most powerful laser (2 MegaJoule = car going 120 mph)
- Drives the shell (0.1 mg) at 1,000,000 mph = 0.15% the speed of light - fastest human made object
- Squeezed ~40x its original size
- Is extremely dense, ~500 g/cm^3, 45x the density of lead, 3x the density of the core of the sun
- Hot spot is 45 million °C, 6x the center of the sun
- Pressure of 400 Gbar - 1000x the pressure of Jupiter
- Fusion burns for 120 picoseconds - the time light moves 4 cm
- Similar conditions for seconds and minutes after the Big Bang
- **Similar conditions to thermonuclear weapon**









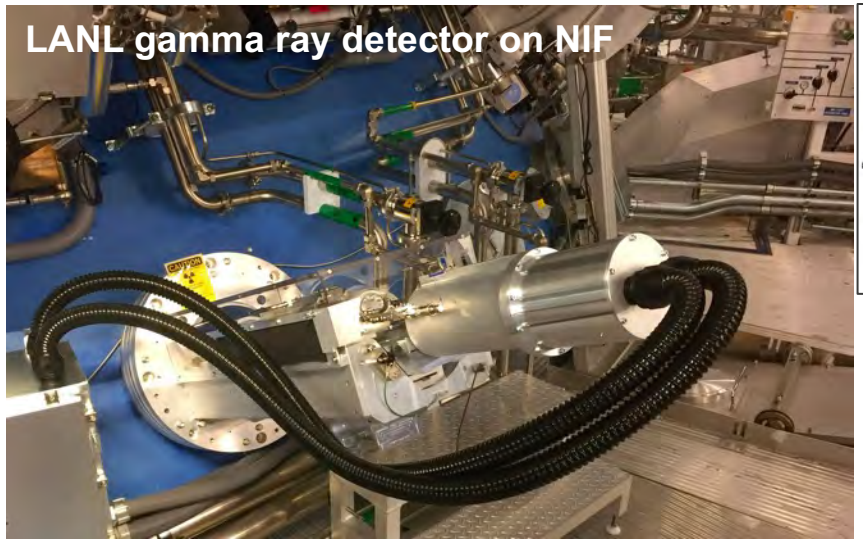
The double cylinder platform developed to directly test hydrodynamic instabilities

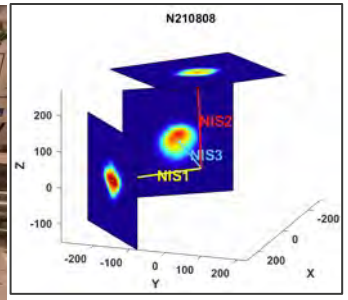
Alternative Approach: Inertial Confinement Fusion (ICF)

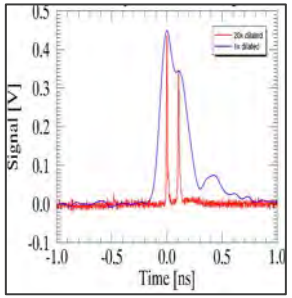
Inertial confinement fusion achieved fusion gain in 2022 !

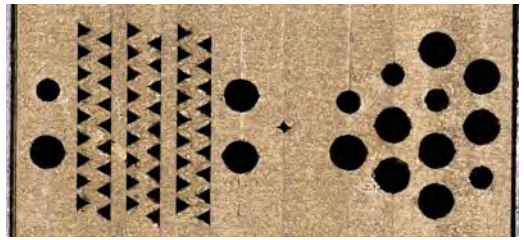
- NIF started in 2009
- High quality capsules were developed
- Higher laser energy reached 2.05 MJ
- Yield of ~10^{18} DT neutrons (~3 MJ)

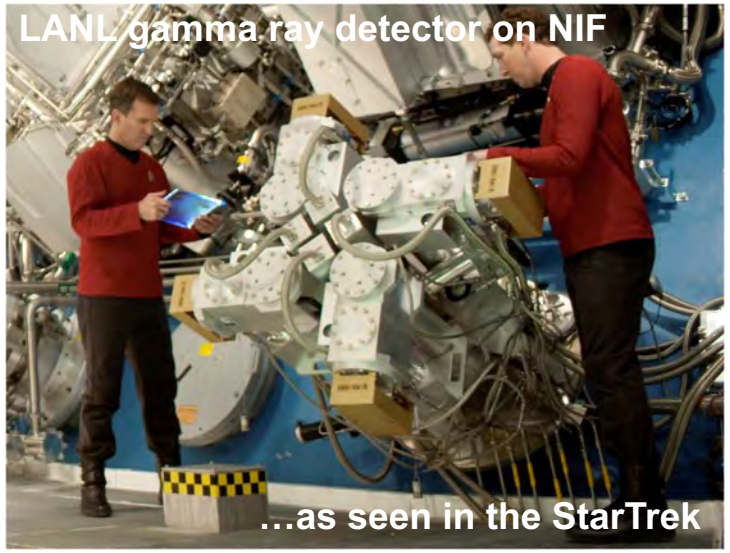
LANL / P-4 provided essential designs and nuclear diagnostics for achieving this feat











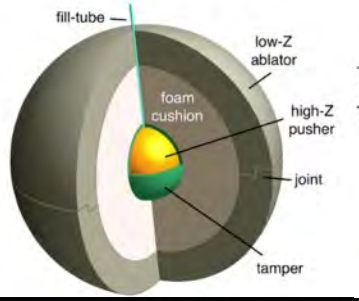
LANL ICF - developing HED platforms for energy and stockpile stewardship

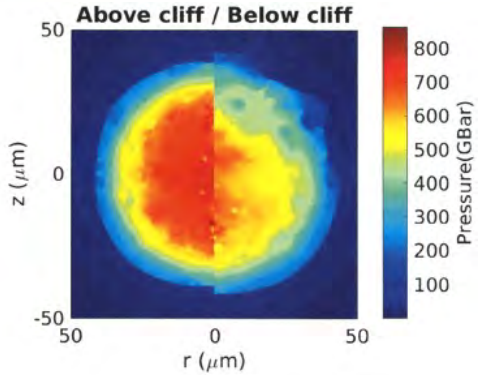
Although ignition has been demonstrated, we are still far away from the ultimate goal of reliable controlled fusion.

Develop applications of ignition for stockpile stewardship

- Understand ignition threshold to obtain robustness
- Rad-transport
- Hostile environments and survivability

Applications of igniting NIF capability





Develop volume burn platforms

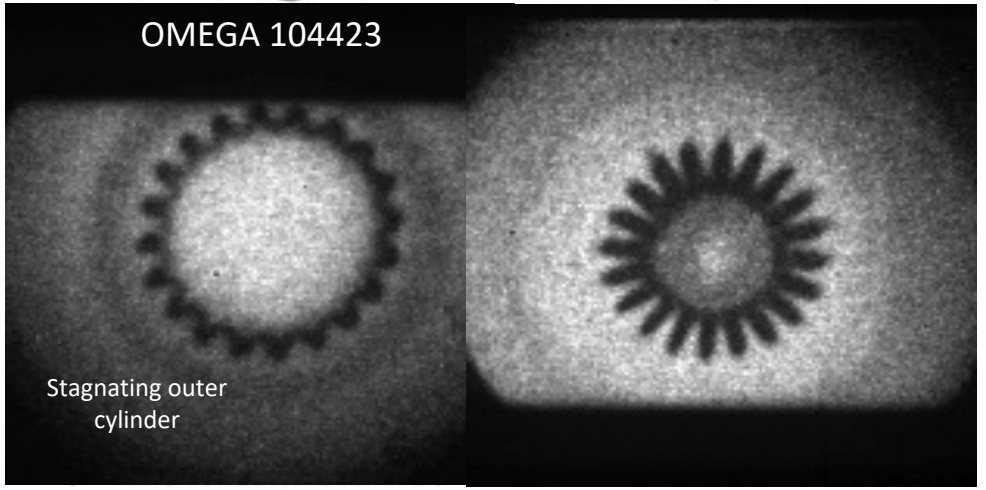
- Inner shell / DT mix
- Unique insight from sensitivities of volume burn platforms
- Stockpile questions hot-spot platform cannot answer

More aggressive on Volume Burn

Future facility development

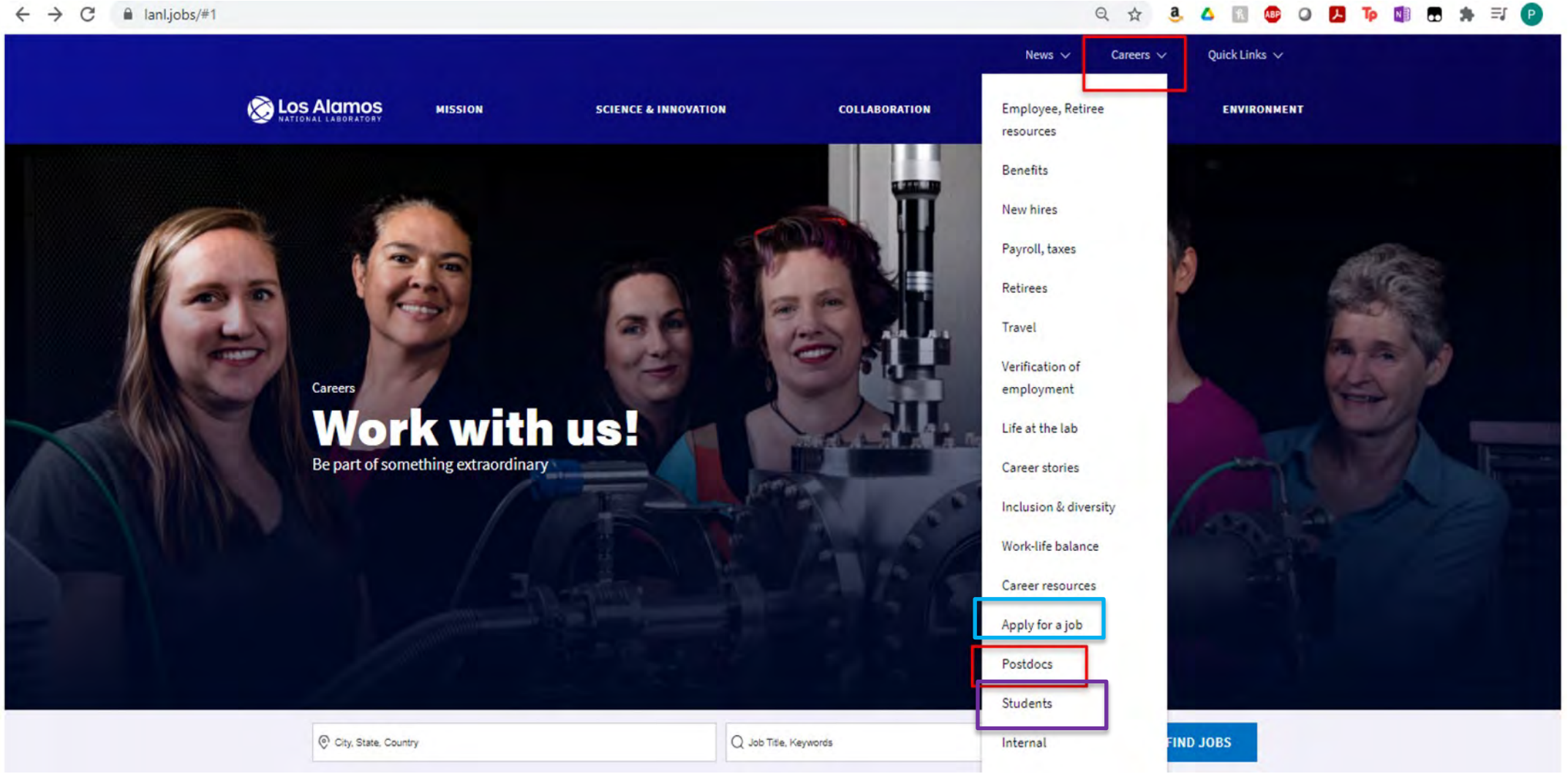
- Assessment of NGPP designs
- Future platform development with SNL/LLNL
- Diagnostics for yield on all facilities

Expand Pulsed Power activities



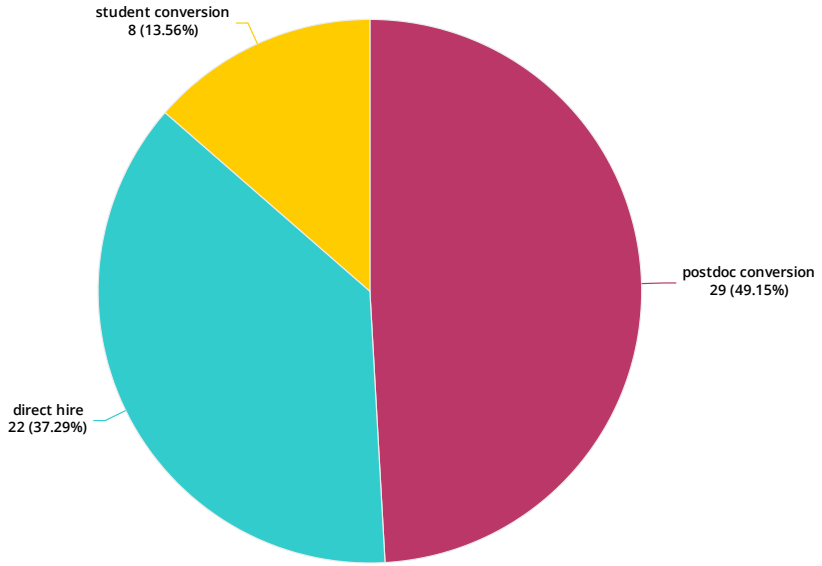
How do you join us?

Search lanl.jobs for current job opportunities and learn more about student and postdoc programs, and benefits



There are multiple pathways into the laboratory

- The Students and Postdoctoral Research Associate are the most common path into LANL
- Positions (especially students and postdocs) often do not require experience within that exact field. Don't be afraid to apply for positions that are not outside of your graduate work!
- Try to contact the scientist or management of the group you are interested in directly – HR might not be the best judge of your qualifications !
- A cover letter is often required for applying. The cover letter must address how you meet every minimum requirement and any desired requirements
- Things to emphasize on an application / CV
  - Publications (peer-reviewed, proceedings, accepted, submitted, arXiv, in progress…)
  - Presentations (invited talks, talks, posters)
  - Scientific skills (especially transferable skills to new position)
  - Professional services (outreach activities, conference orgabization, reviewing papers and proposals)



Student Opportunities

- Internship at LANL provides great research experience, great networking, and a “test run” of working in National Laboratory environment, which is quite different from the academic institutions
- There are several student categories retained by LANL, https://lanl.jobs/creative/students :
  - Must have GPA > 3.0
  - High School Students
  - Undergraduate Students
  - PostBachelor Students (up to 2 years)
  - PostMasters Students (up to 2 years)
  - Graduate Students
  - Student Affiliate Guest (paid by school but have access to LANL resources through collaboration with LANL scientist)
- Fellowships:
  - SULI, GEM Fellows – directly employed by LANL
  - DOE Office of Science Graduate Student Research Fellow (SCGSR) – Requires LANL host/mentor, join LANL as Student Guest Affiliate paid by fellowship through school. https://science.osti.gov/wdts/scgsr
  - DOE NNSA Stewardship Science Graduate Fellowship (SSGF) Program, Laboratory Residency Graduate Fellowship (LRGF), and Computational Science Graduate Fellowship (CSGF) Program – Requires LANL host/mentor, join LANL as Student Guest Affiliate paid by fellowship through school. https://www.nnsa-ap.us/Programs/Fellowship-Programs

Postdoc Opportunities

- LANL trains >600 postdoctoral researchers every year, https://www.lanl.gov/careers/career-options/postdoctoral-research/index.php
- Postdocs work with mentor to write and define their project at the time of application
- Benefits of postdoc internship at LANL:
  - Salary & benefits
  - Resources at the lab (institutional knowledge, equipment/funding, travel)
  - Wide range of research to choose, from very fundamental to very applied
  - Work-life balance
  - Relatively stable funding sources
  - Scientific mentorship opportunities, but don't have to teach classes
- There are several LANL Distinguished Postdoc Fellowships available
  - Directors, Feynman, Oppenheimer and others
  - Roughly 30 awarded per year
  - Require a LANL sponsor/mentor sponsor
  - Review of these applications 4 times a year (Feb, May, Aug, Dec)
  - Can apply for after hired as a Postdoctoral Research Associate (1 year)

Thanks for listening!

Feel free to contact me/ask questions at
dzmitry@lanl.gov