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Los Alamos
NATIONAL LABORATORY

LANL Weapons Physics Directorate: Mission Scope and Opportunities

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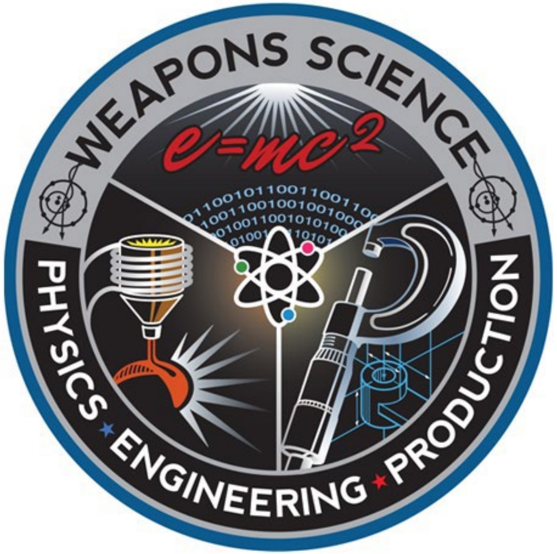
Resources:
"Nuclear Fundamentals Orientation: Weapons Physics Directorate Overview", LA-UR-20-25578 Version 2
"An Overview of the Los Alamos Weapons Program", Jon Ventura and Mike Port, LA-UR-19-29421
"The Scientific Challenges in Stewarding the U.S. Nuclear Weapons Stockpile", W.S. Wilburn, LA-UR-17-21138

Agenda

- Historical and current mission of the LANL Weapons Program
- Stockpile Stewardship Science
- Weapons Physics Directorate capabilities and mission spaces
- What you need to know if you are interested in a career in the LANL Weapons Program



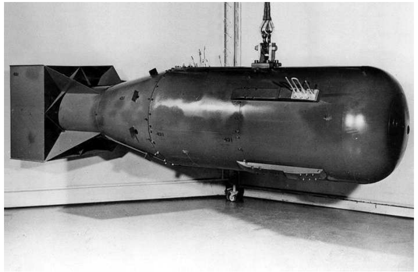
Los Alamos National Laboratory is a national security science resource for the Nation.

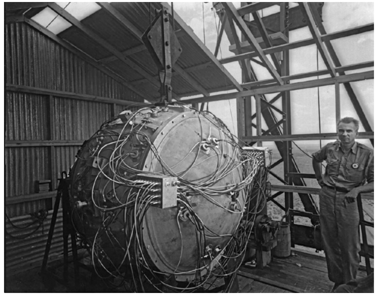
- Established in 1943 as part of the Manhattan Project
  - Designed, tested, and delivered to the Army Air Corps two weapons that helped end World War II, Little Boy and Fat Man
- To date, Los Alamos has designed and certified 46 of the 63 nuclear weapons systems put into the US stockpile.
- Today's stockpile consists of seven types of weapons.
  - W76* and W88* are carried on Trident submarines
  - W78* and W87 are carried on ICBMs
  - B61*, B83, and W80* are carried on aircraft
- Annually, Los Alamos, Sandia, and Lawrence Livermore Labs are legally obligated to report to the President on the state and health of the deterrent.

** Designed by LANL*

Early nuclear weapons used only fission, and functioned by creating a super-critical mass.

- A gun weapon assembles sub-critical pieces of fissile material into a super-critical mass.
  - Simple design that required no proof test
  - Little Boy, Hiroshima, August 6, 1945, yield of 15 kt
- An implosion weapon compresses a sub-critical piece of fissile material into a super-critical mass.
  - More complex and efficient design that requires explosives
  - Trinity, Alamagordo, July 16, 1945 and Fat Man, Nagasaki, August 9, 1945, yield of 21 kt
- Ivy/Mike was the first thermonuclear test
  - Eniwetok Atoll, October 31, 1952





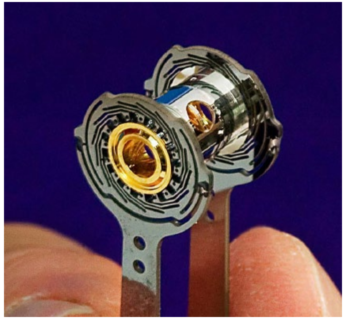
The current US stockpile was designed for the Cold War.

- Modern weapons are thermonuclear, and produce energy from fission and fusion.
  - Highly optimized for maximum yield in minimum size and weight
  - Intended to be replaced after 15-20 years, and now well past original design life
  - Use hazardous materials, which are expensive and difficult to handle today
  - Very complex systems, with many parts
  - Challenging to maintain without nuclear testing
- The US performed 1054 nuclear tests during the testing era, which ended in 1992.
  - Data from these tests are a critical archival tool used to validate simulation strategies.

Stockpile Stewardship challenges the national security laboratories to develop capabilities to assess and certify the stockpile without testing.

- Since 1992, the US has not tested nuclear weapons. A sophisticated national program of stockpile stewardship has been developed over the past 30 years to underpin confidence in our nuclear deterrent.
  - **Experiments**: Thousands of experiments are conducted annually to further our understanding of the science of nuclear weapons.
  - **Modeling and Simulation**: World-class computing hardware, software, and multi-physics codes are used to assess the current stockpile and design new weapons that may never be tested.
  - **Designer Judgement**: Experimental data is used to check judgement and train the next generation of designers.

Large bore powder gun – used to measure differences in performance of weapon materials of interest



High Energy Density experiments – can be used to investigate physics of interest

The Weapons Physics Directorate stewards a number of critical capabilities to meet the LANL mission.

- To execute our mission, ALDX develops and applies cutting-edge theory, computational models and multi-physics simulation codes, and designs, executes, and analyzes complex experiments.

ORGANIZATIONS

X Theoretical Design Division

- Employs theoretical, numerical, and experimental tools and methods to understand nuclear weapon design, performance, safety, and nuclear threats.

X Computational Physics Division

- Develops, integrates, and delivers LANL's mission-critical modeling and simulation software.

Weapons Research Services Division

- Preserves and safeguards nuclear weapons knowledge for tomorrow's innovations.

PROGRAMS

Advanced Simulation and Computing Program

- Develops the tools to underpin the use of simulations with confidence in assessing the current and future stockpile.

Office of Experimental Sciences

- Develops and fields experiments that underpin our modeling capability.

Engineering and Technology Maturation

- Develops technologies, tools, and capabilities to promote future nuclear deterrence.

Our mission is to sustain the current stockpile, provide future stockpile options, and help shape a globalized nuclear world.

- **Sustaining the current stockpile**
  - How long can the current stockpile be sustained?
  - What are its failure modes?
- **Providing options for the future stockpile**
  - What are options that can be developed and certified without the need for further nuclear testing?
- **Shaping a globalized nuclear world**
  - What are other countries pursuing regarding nuclear weapons?
  - What are potential developments (avoidance of technological surprise)?
  - What response options should the US have available?

The DARHT facility provides world-class radiography for non-nuclear tests. Experiments are fully contained to reduce environmental impacts.

LANL stewards much of the U.S. nuclear stockpile. One of our greatest challenges is mission execution without nuclear testing.

- We are the design agency for 4 of the 7 weapons systems in the U.S. stockpile.
- We are responsible for the safety (accidental detonation), surety (prevention against unauthorized use), and reliability (intentional use) of these systems.

W78 land-based warhead

B61 aircraft-carried bomb

W88 & W76 sub-launched warheads

Why is maintaining the stockpile so challenging?

- Operating conditions of a nuclear weapon exist nowhere else and cannot be replicated in a lab setting.
  - Temperatures > 10^8 K
  - Material velocities > 10^6 m/s
  - Pressures > 10^7 bar
  - Time scales < 10^{-8} s

- The problem requires multi-physics, often with non-linear interactions.
- A science-based method is used to steward the stockpile.
  - Use large-scale multi-physics simulations to predict weapon performance.
  - Perform small-scale experiments to continuously improve our understanding of the physics.
  - Validate the simulations against legacy test data and integrated non-nuclear and sub-critical experiments.

Sophisticated computational models are used to predict weapon performance.

Multi-physics codes model a wide range of relevant physics.

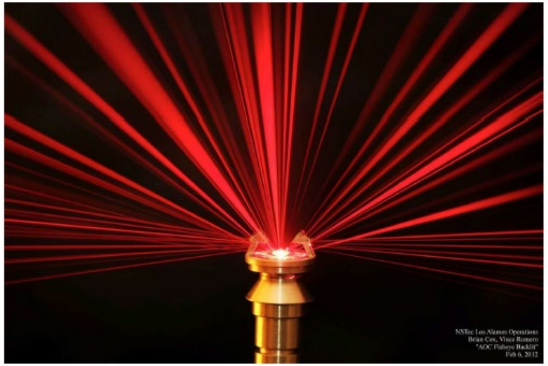
- High explosives
  - Detonation characteristics
  - Energetics and equation of state
- Material properties
  - Equation of state
  - Strength and damage
- Hydrodynamics
  - Material deformation, fracture, spall, and ejecta
  - Elastic and plastic flow and friction
  - Laminar to turbulent fluid flow
  - Material mixing and morphology
- Radiation transport
  - Transport methods
  - Opacities
  - Atomic physics
- Nuclear physics
  - Cross sections
  - Reaction rates
- Thermonuclear physics
  - Plasma physics
  - Reaction rates
  - Charged particle transport

High Performance Computing at Los Alamos opens the doors to many sophisticated modeling techniques.

- Petascale supercomputers are critical to Los Alamos' national security mission.
- Trinity, our flagship HPC system, is one of the fastest supercomputers on Earth at ~41 petaflops.

We use many experimental facilities to study behaviors and provide validation for modeling.

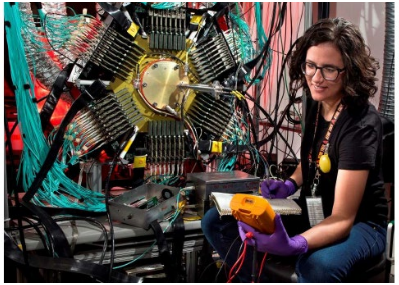
The Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) uses high-energy pulsed x-rays to test implosion dynamics using non-nuclear components.

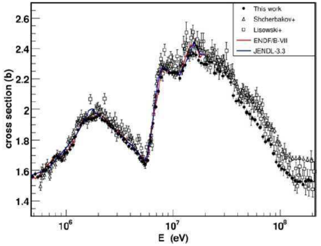


Multi-Point Photon Doppler Velocimetry (MPDV) is used to study implosion dynamics.

Sub-critical experiments are conducted underground at the Nevada National Security Site to study plutonium dynamics.

Precision measurements of nuclear cross sections provide nuclear data for simulations.



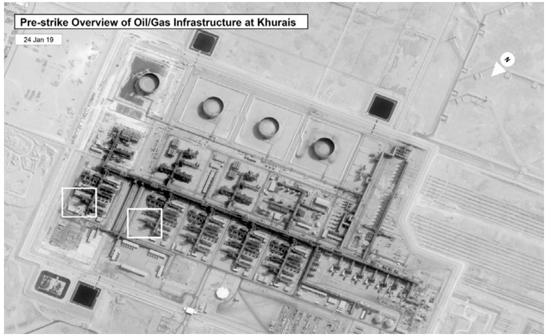


Geopolitical realities demand the Laboratory's excellence in providing solutions to national security problems.

- The nuclear threats faced by the US are evolving rapidly.
  - Russia
  - China
  - North Korea
  - Nuclear proliferation and nuclear development by non-peer states
- Potential new offensive nuclear weapons
  - New ICBMs
  - New air-and ground-launched cruise missiles
  - Hypersonic glide vehicles
  - Nuclear-powered cruise missiles
  - Unmanned aerial vehicles
- Potential new anti-ballistic missiles

We are helping to solve major technical challenges in the nuclear global security regime.

- We are advancing our capabilities for monitoring and countering foreign nuclear weapons programs.
  - Avoid technological surprise by an adversary
  - Understand alternative methods for manufacturing weapon components
  - Explore production and detection of functional materials (supply chain)
  - Design innovative technologies for disabling nuclear devices
  - Research potential “game changers” for speeding up nuclear forensics



Los Alamos National Laboratory At a Glance*

People

Employees: 13,500

- 460 postdocs
- 520 graduate students
- 800 undergraduate students
- 9,680 regular staff

Workforce

~40% of employees live in Los Alamos, remainder commute from surrounding areas

- Average age: 46
- 67% male, 33% female
- 44% minorities
- 66% university degrees
- 28% undergraduate degrees
- 17% master's degrees
- 21% doctoral degrees

Budget

Total: $2.6 billion (higher in FY22)

- 66% weapons program
- 12% strategic partnerships
- 9% nonproliferation programs
- 5% safeguards and security
- 4% DOE Office of Science
- 3% energy and other programs
- 1% environmental management

Place

Located 35 miles northwest of Santa Fe, New Mexico, on 38 square miles of DOE-owned property

- 894 buildings
- 268 miles of road (100 paved)

*As of September 2021

Robust student and postdoc programs are vital to the Laboratory's early-career pipeline.

- Each year, more than 1800 students and 400 postdocs work at Los Alamos.
- Conversion of postdocs to technical staff is our most highly utilized early career pipeline.
- In the X Theoretical Design Division, we host a post-graduate 3-year classified program called TITANS (Theoretical Institute for Thermonuclear and Nuclear Science). TITANS provides academic-style training in physics, engineering, nuclear science, chemistry, material science, and other areas of relevance to weapons science.

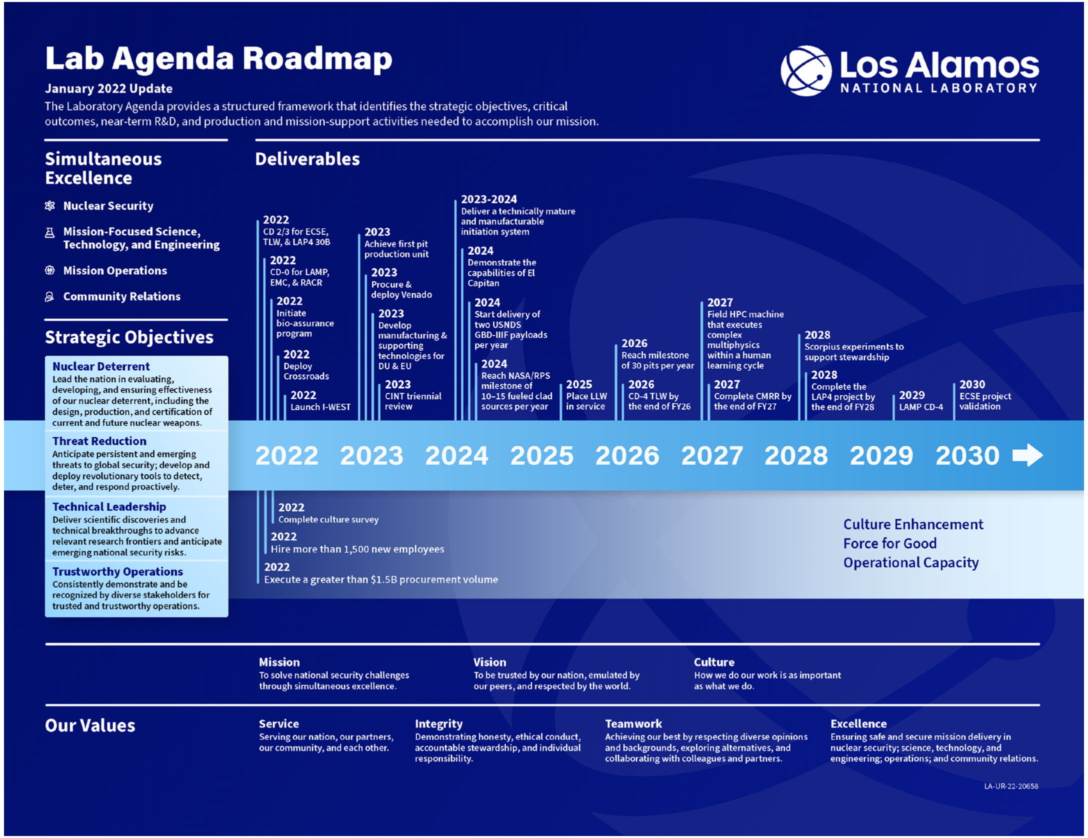
Percentage of total LANL population who were former students or postdocs

36%	61%	33%
All LANL employees (Reg, TRMA)	All R&D scientists & engineers	Managers

What to know if you are interested in a career path at Los Alamos

- Working as a scientist at a national lab offers a lot of flexibility!
  - It is common to move around the lab from division to division, changing technical areas.
  - It is also common to stay in one division and focus on one technical specialty for a career.
- Example: My career path
  - Graduate student during penultimate year of grad school
  - Postdoc for ~1.5 years
  - Converted to staff (promoted from Scientist 2 to 3 to 4 within 10 years)
  - Full-time technical work on multiple projects (~3/year) for about 6 years
  - Evolved to part-time technical work and part-time project leadership for about 4 years
  - Deputy Group Leader for a group of ~30 staff, also part-time project leadership and technical work
  - Group Leader for a group of ~40 staff, part-time project leadership

LANL senior leadership has recently unveiled a new Laboratory Agenda to provide a framework for progress in the next decade.



Questions?

Feel free to contact me at lwelser@lanl.gov.

LANL job board:

- Go to https://lanl.jobs
- In the Job Title box, either type in the technical area of interest (physics, chemistry, etc) or select a department (XTD, XCP, etc)
- Postdoc and Scientist 1, 2, and 3 jobs are currently posted