Title:	Engineering Programs and Opportunities: Los Alamos National Laboratory and Sigma Division
Author(s):	Cummins, Dustin Ray
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Engineering Programs and Opportunities:

Los Alamos National Laboratory and Sigma Division

Dustin Cummins

R&D Engineer

SIGMA-1

Los Alamos National Laboratory

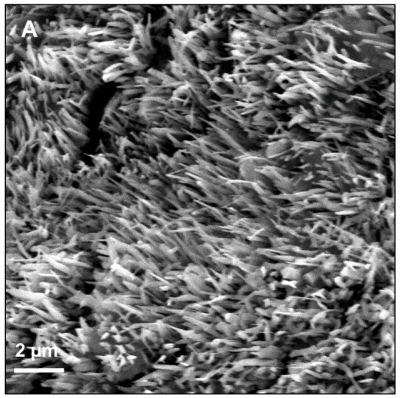
National Nuclear Security Administration

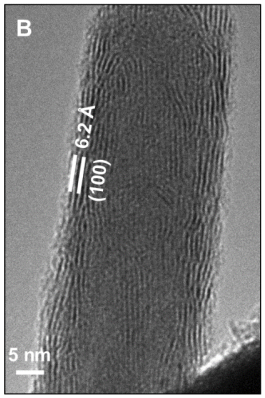
Los Alamos NATIONAL LABORATORY

A little about me

UNIVERSITY OF LOUISVILLE
CONN CENTER FOR RENEWABLE ENERGY RESEARCH

- Graduated from University of Louisville
  - Chemical Engineering
  - Bachelors in 2008
  - M.Eng in 2009
  - Ph.D. in 2014





- Ph.D. work was in metal oxide nanowire synthesis and understanding phase transformation
  - Advisor: Mahendra Sunkara
  - "*Phase transformation in transition metal chalcogenide nanowires*"

- Electrocatalysis with MoS_2 at Los Alamos as Graduate Student (MPA-11)
  - Gautam Gupta
- Post-Doc in Materials Science and Technology (MST-6)
  - Plasma Spray on Radioactive Materials
- R&D Engineer in SIGMA-1: materials aging, novel materials engineering, and Global Security programs

Los Alamos NATIONAL LABORATORY

Outline

- Los Alamos National Lab
  - **Mission and Science**
- Sigma Division
  - **Advanced Manufacturing and Engineering**

- Engineering Projects at LANL
  - **Nuclear Fuels**
  - **National Security and HAZMAT**
  - **Plasma Spray Techniques**
  - **Neutron Diffraction**

National Labs and how Los Alamos fits into science for the nation

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Office of Science Laboratories

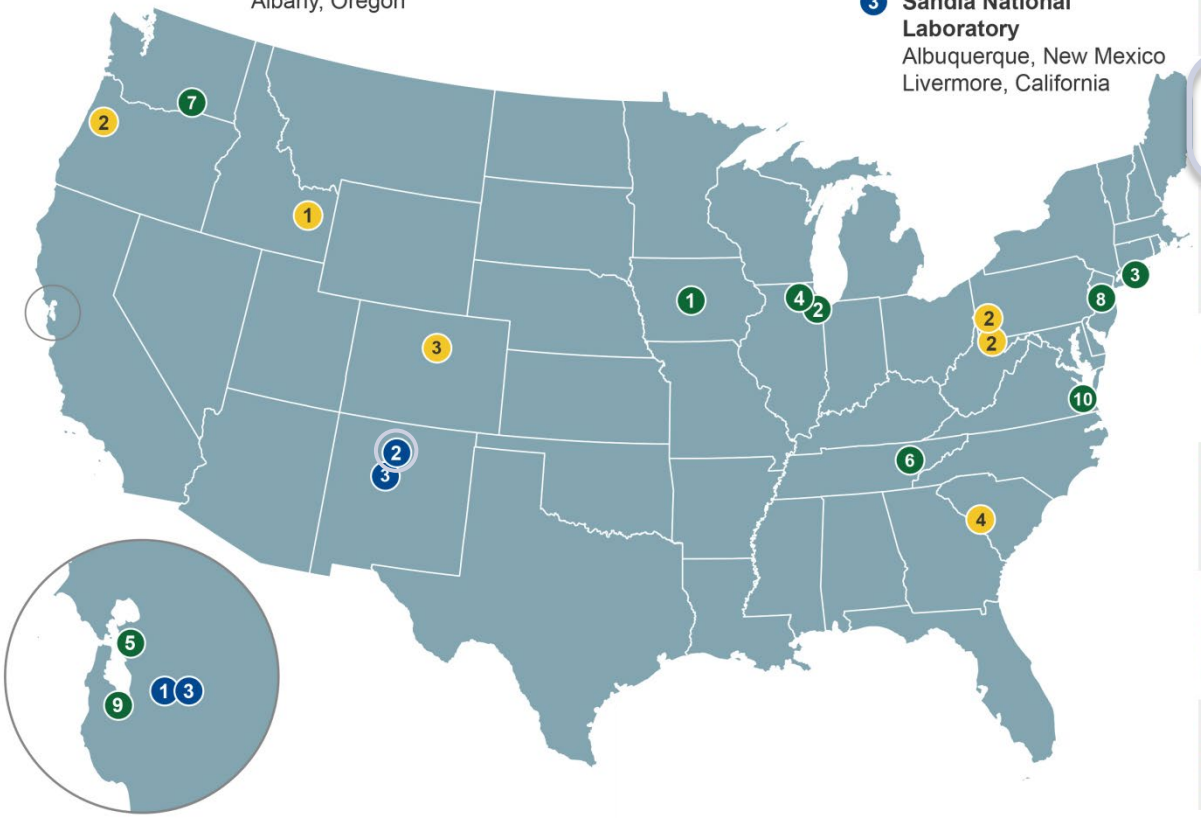
1. **Ames Laboratory**
   Ames, Iowa
2. **Argonne National Laboratory**
   Argonne, Illinois
3. **Brookhaven National Laboratory**
   Upton, New York
4. **Fermi National Accelerator Laboratory**
   Batavia, Illinois
5. **Lawrence Berkeley National Laboratory**
   Berkeley, California
6. **Oak Ridge National Laboratory**
   Oak Ridge, Tennessee
7. **Pacific Northwest National Laboratory**
   Richland, Washington
8. **Princeton Plasma Physics Laboratory**
   Princeton, New Jersey
9. **SLAC National Accelerator Laboratory**
   Menlo Park, California
10. **Thomas Jefferson National Accelerator Facility**
    Newport News, Virginia

Other DOE Laboratories

1. **Idaho National Laboratory**
   Idaho Falls, Idaho
2. **National Energy Technology Laboratory**
   Morgantown, West Virginia
   Pittsburgh, Pennsylvania
   Albany, Oregon
3. **National Renewable Energy Laboratory**
   Golden, Colorado
4. **Savannah River National Laboratory**
   Aiken, South Carolina

NNSA Laboratories

1. **Lawrence Livermore National Laboratory**
   Livermore, California
2. **Los Alamos National Laboratory**
   Los Alamos, New Mexico
3. **Sandia National Laboratory**
   Albuquerque, New Mexico
   Livermore, California

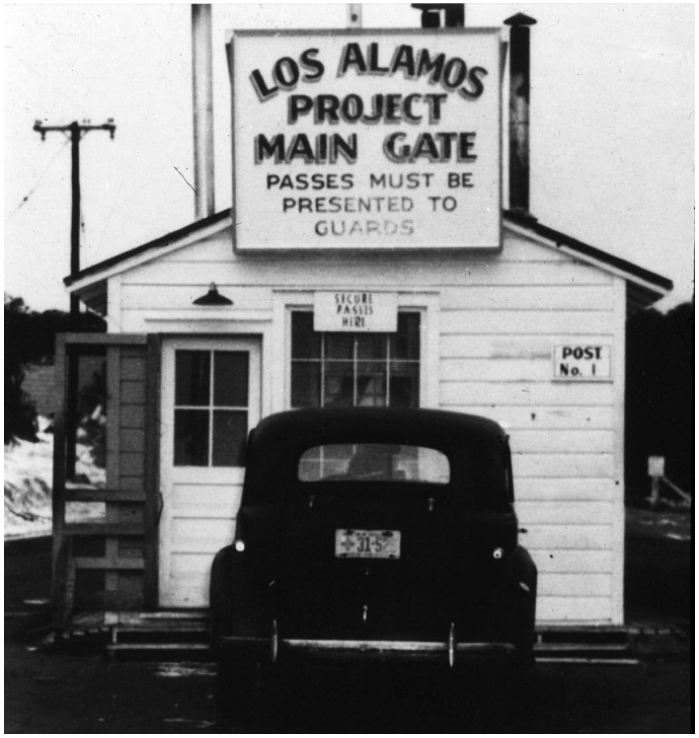


Nuclear Security Enterprise

1. **Kansas City Plant**
2. **Lawrence Livermore National Laboratory**
3. **Los Alamos National Laboratory**
4. **Nevada National Security Site**
5. **Pantex Plant**
6. **Sandia National Laboratories**
7. **Savannah River Site**
8. **Y-12 National Security Complex**

Los Alamos NATIONAL LABORATORY

Los Alamos is a Federally Funded Research and Development Center (FFRDC)



- Currently ~12,000 total employees
  - ~8,000 Full Time staff
  - ~300 Security Force
  - ~1,200 Undergrad & Grad Students
  - ~400 Postdocs
- ~$2.7 Billion Annual Budget
- 36 sq. miles
  - ~ 270 miles of roads

Founded in 1943 as "Site Y" of the Manhattan Project

University of California:1943 to 2006.

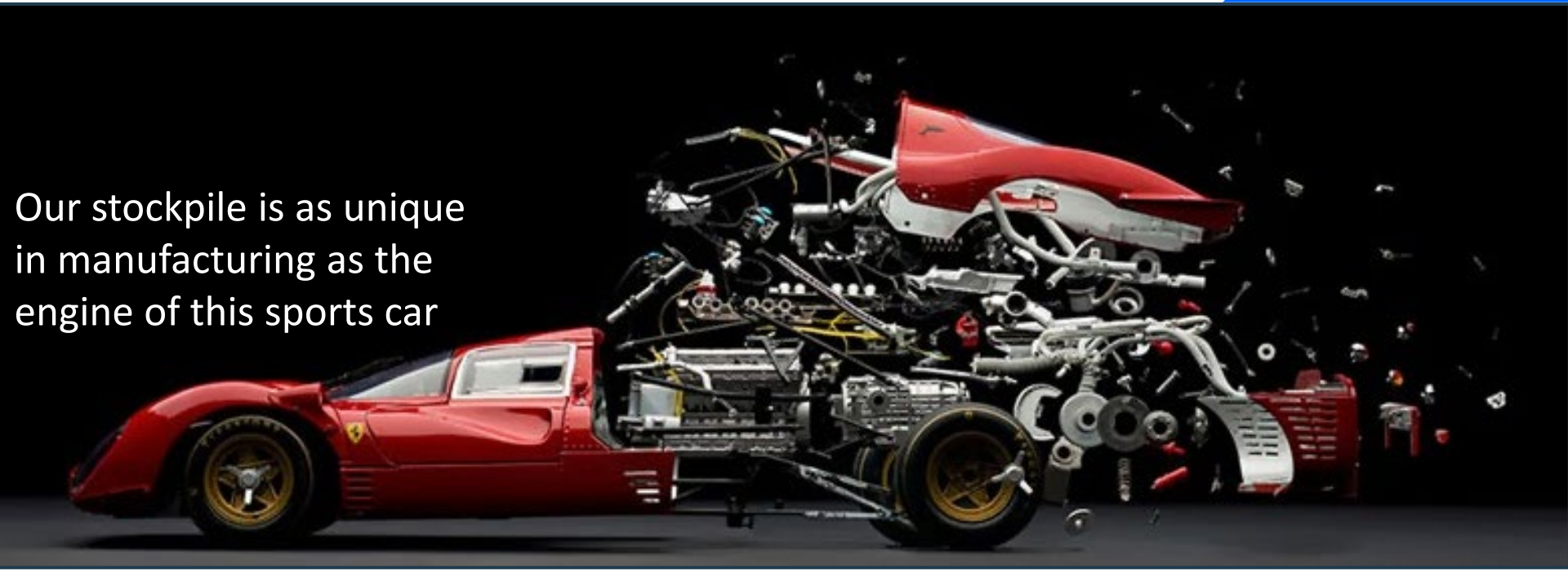
Los Alamos National Security, LLC: 2006 to 2018

Triad National Security, LLC: Nov. 2018

Los Alamos NATIONAL LABORATORY

Our core mission is to ensure the U.S. nuclear deterrent

How could you ensure this worked, *without* starting the engine?



- High performance race cars are made up of 80,000 components
- If they were assembled 99.9% correctly
  - They would still start the race with 80 things wrong

The United States faces a much more complex challenge in caring for its nuclear stockpile

Design Agency for the U.S. Nuclear Stockpile

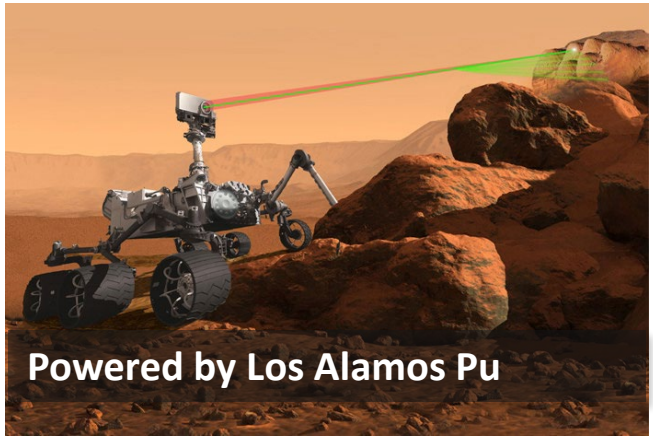
Mission Delivery

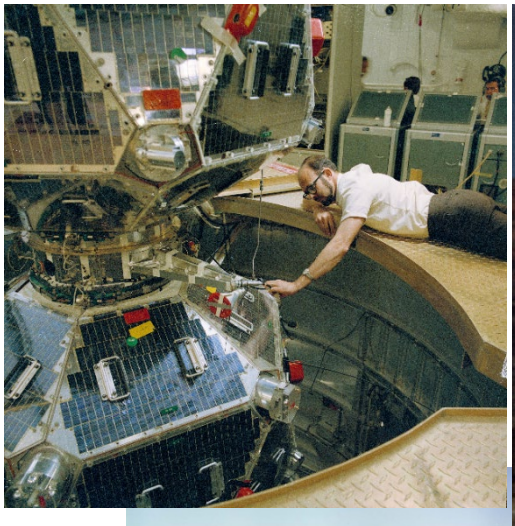
» The U.S. ceased underground testing in 1992.

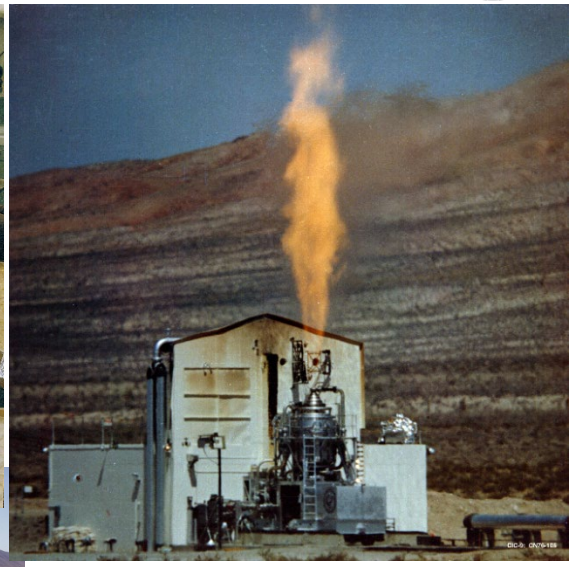
- Los Alamos's mission is ensure the safety, reliability, and performance of stockpile
- Design agency for four out of seven warhead systems constituting nation's deterrent
- Los Alamos uses a combination of fundamental science, sub-critical testing, and high performance computing and modeling to accomplish this mission

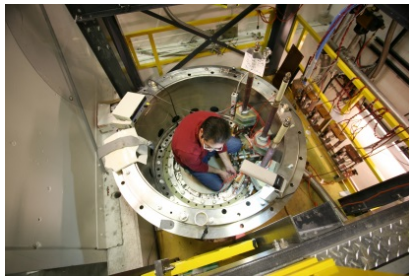
Confidence without nuclear testing requires a fundamental understanding of science and engineering

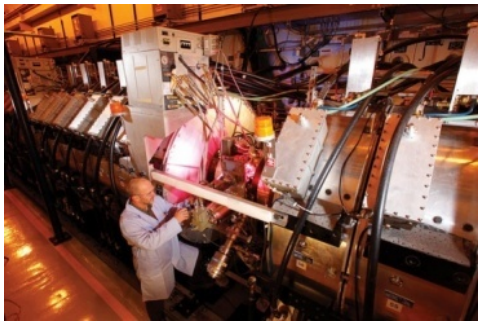
Los Alamos extends from fundamental science to engineering applications





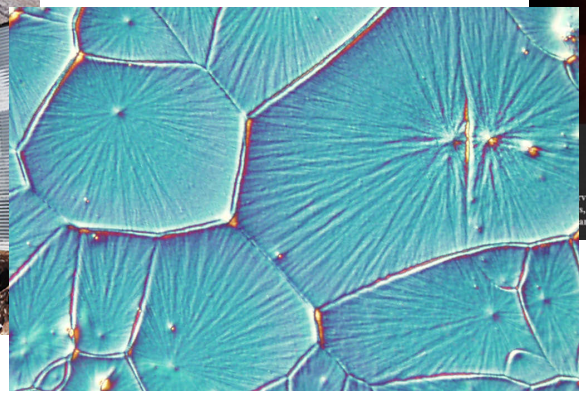


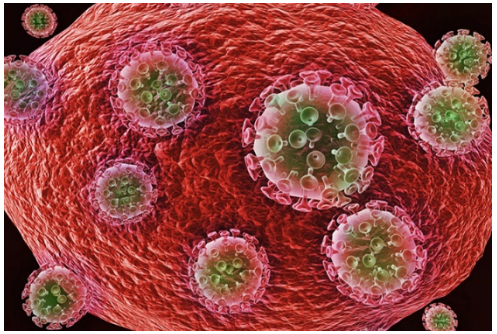




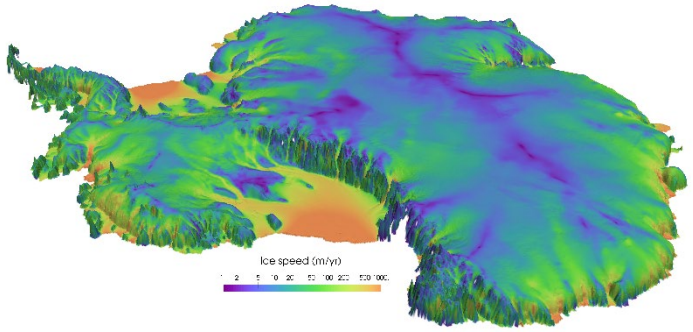
- **Fundamental Physics**
  - Discovery of the neutrino in 1950's
  - DARHT – world's most powerful Xray source
  - Muon Spectroscopy
- **1960's and 1970's – Operation PLOWSHARE**
  - Industrial applications for nuclear explosives
- **Nuclear powered rockets for space exploration**
  - Project ROVER
- **ChemCam laser on the Curiosity Rover – SuperCam on Mars 2020 mission**
  - Laser Ablation paired with Raman Spectroscopy and other detectors

Science for the nation… not just weapons…





- **Advances in Astrophysics**
  - High Altitude Water Cherenkov (HAWC) Gamma-Ray Observatory
  - LIGO – Gravity Wave Detection
- **Biological modeling**
  - Understanding how disease spread in populations
  - Designing vaccines for complex viruses
- **Renewable Energy Research and Advanced Materials**
  - Climate and Weather Modeling
  - Hydrogen Fuel Cell Development
  - Solar Energy

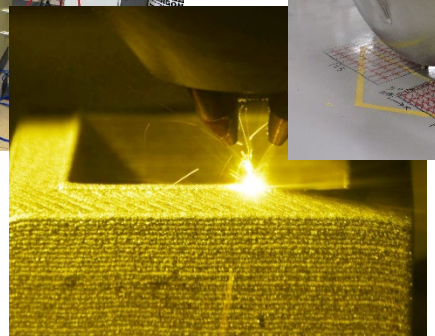


Sigma Complex – Handling Hydrogen to Uranium

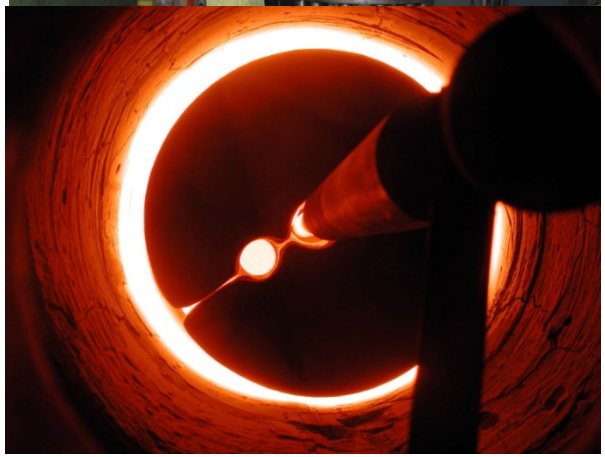
- **Secure Secret\RD and Top Secret level facility**
- **Handle all elements between hydrogen and uranium on the periodic chart in many forms i.e metals, ceramics, solutions**
- **200,000 sq. ft R&D/Processing Facility**
- **Sigma's core mission is developing fundamental science into practical engineering solutions**
  - Additive Manufacturing
  - Casting
  - Forming
  - Powder Metallurgy
  - Plasma Spray
  - Welding
  - Chemical Analysis
  - Characterization
  - Corrosion / Electrochemistry
  - Integrated prototyping / testing / characterization

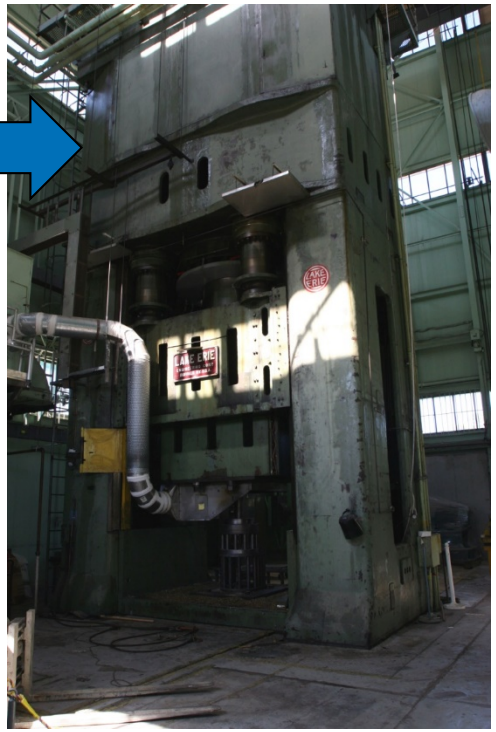
Mixing the Old with the New…

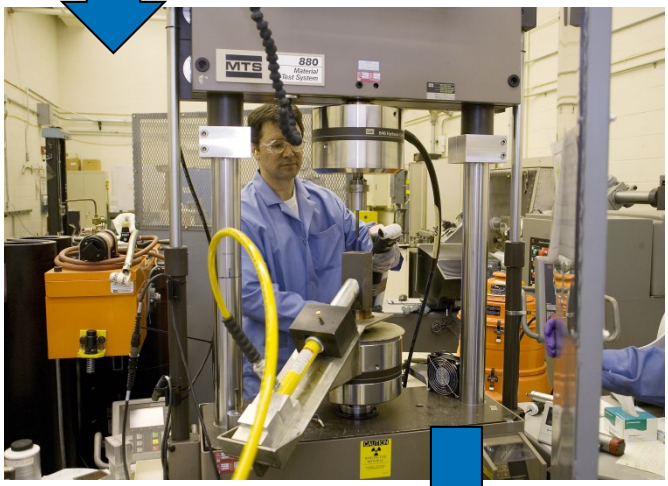
- **Sigma has a unique capability within the National Security Complex**
- **There are a combination of experts in all aspects of manufacturing**
  - Welding, casting, forming, rolling
  - Additive manufacturing, lab scale synthesis
- **What's the use of developing a great material if it can't actually be engineered and used?**
  - How can you Scale it? Form it? Weld it?



Fully Integrated Science, Prototyping and Testing

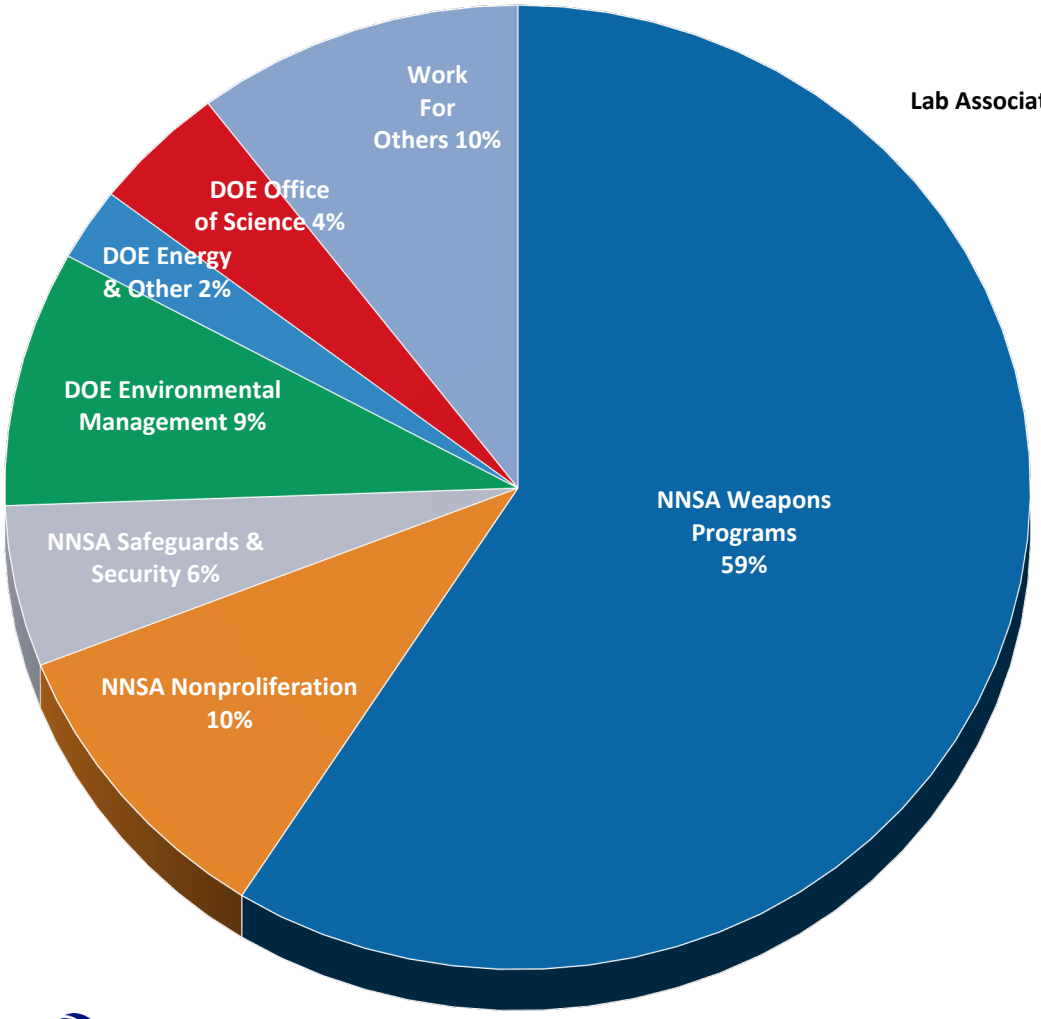




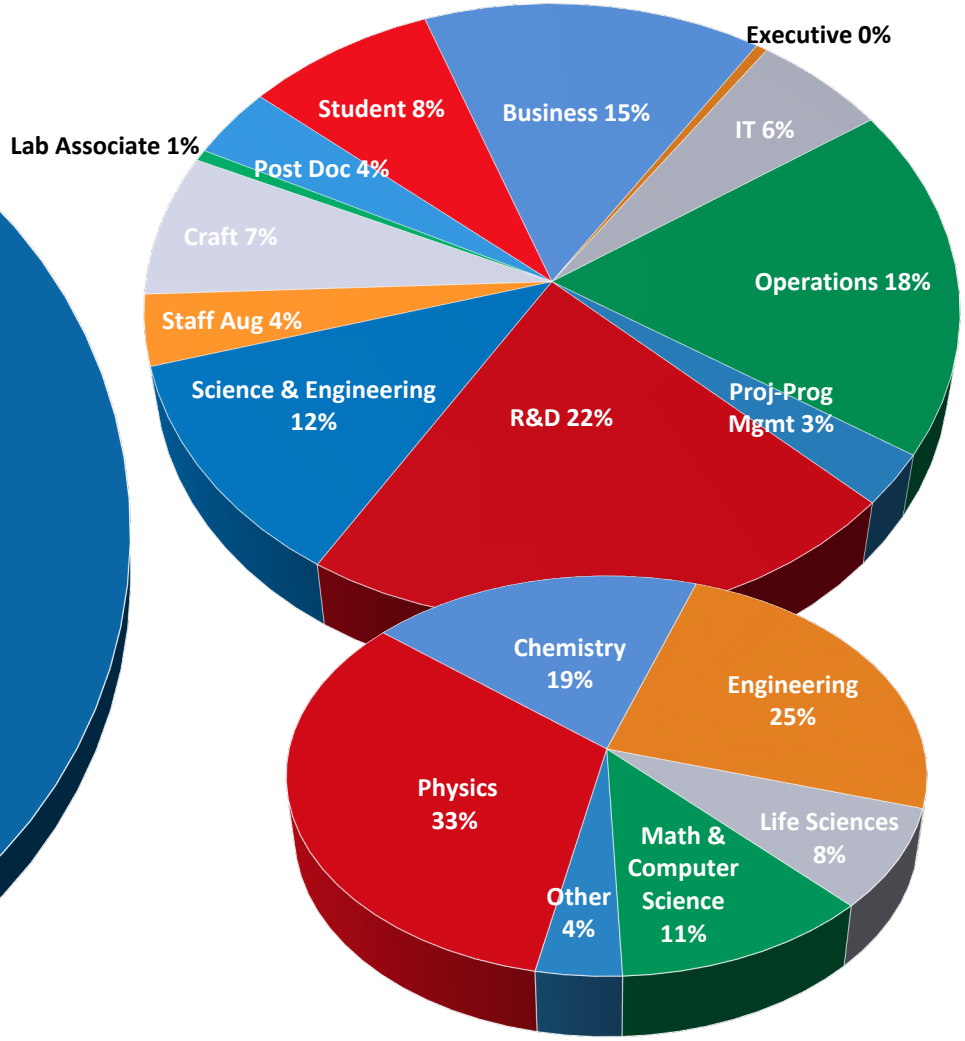


A wide variety of technical disciplines collaborate on our missions

FY21 LANL Budget ~ $4 Billion



Current Work Force – 13,800
~1,400 Students
~450 PostDocs



Los Alamos NATIONAL LABORATORY

NA-21/NA-23 Global Threat Reduction Initiative (GTRI) Program
"Remove as much HEU as possible"

GTRI MISSION

Reduce and protect vulnerable nuclear and radiological material located at civilian sites worldwide *by providing support for countries' own national programs*

A National Priority

"Lead a global effort to secure all nuclear weapons materials at vulnerable sites within four years"

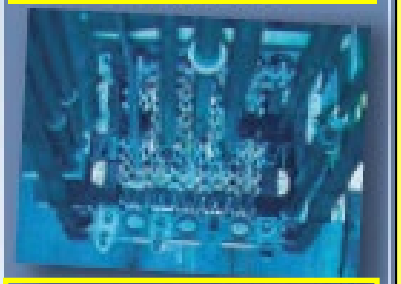
President Barack Obama

Nuclear Research Reactors tend to have less security than conventional power reactors.

Target for terrorism and enemy attack

HEU potentially could be used for weapons, but reactors also vulnerable to sabotage.

Convert



Convert research reactors from the use of highly enriched uranium (HEU) to low enriched uranium (LEU)

These efforts result in permanent threat reduction by minimizing and, to the extent possible, eliminating the need for HEU in civilian applications – each reactor converted or shut down eliminates a source of bomb material.

Remove

nove and dispose of
ess nuclear and
ological materials; and

se efforts result in
nanent threat reduction
liminating bomb
erial at civilian sites –
kilogram or curie of
dangerous material that
moved reduces the risk
terrorist bomb.

Protect

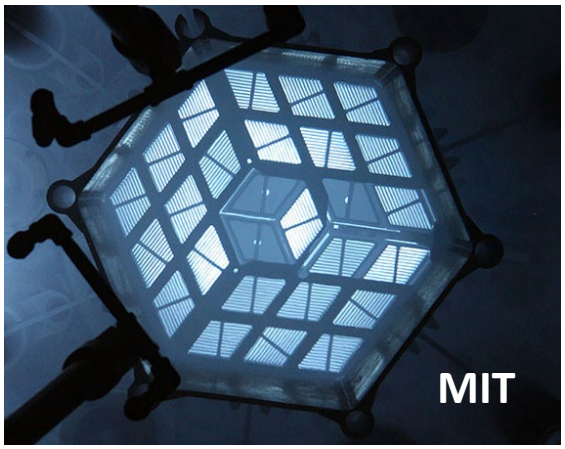
Protect high priority nuclear and radiological materials from theft and sabotage

These efforts result in threat reduction by improving security on the bomb material remaining at civilian sites – each vulnerable building that is protected reduces the risk until a permanent threat reduction solution can be implemented.

Global Threat Reduction Global Partners

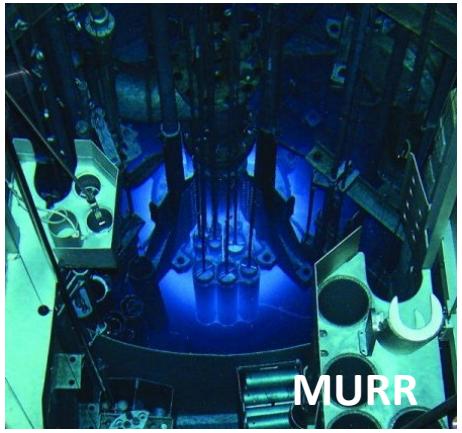
US Dept of Energy CONVERT Program

- **Conversion from highly enriched uranium fuels (vulnerable) to monolithic low enriched U-10Mo fuel plates in research reactors**
  - MIT-R, U. of Missouri (MURR), NIST, ATR (INL), HFIR (ORNL)



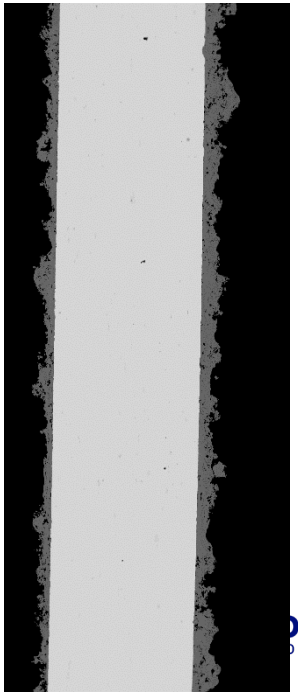
- **Conversion of research reactors is critical to global security. Starting with US reactors**

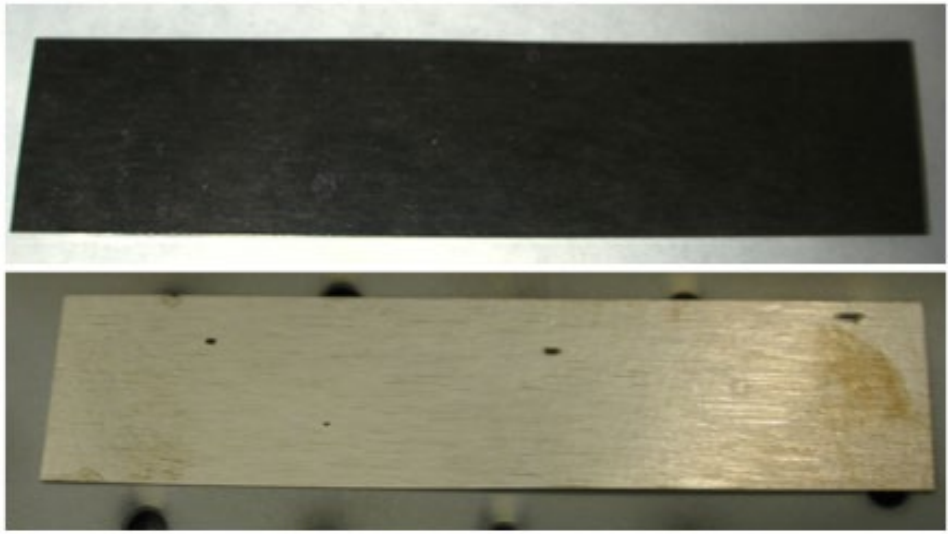
Most of these reactors use dispersion fuels, i.e. bound powder compared to solid plate

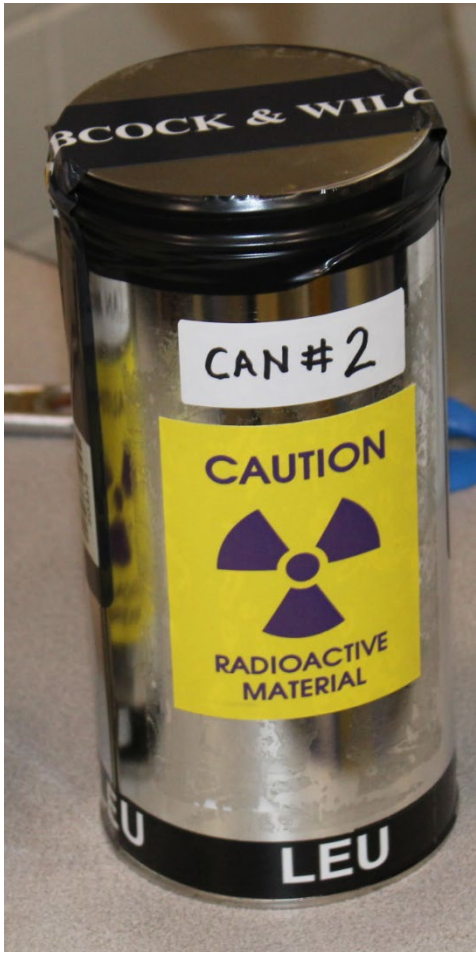


Low Enriched Uranium Fuels

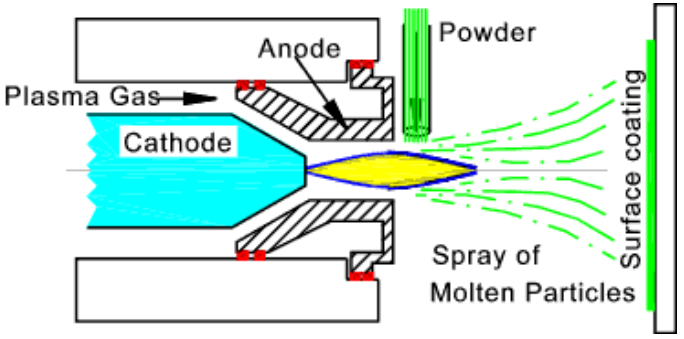
- To achieve desired uranium fuel density with low enrichment, we must first develop a dense, stable, monolithic alloy.
  - Uranium and Molybdenum form a stable alloy, with a BCC structure (gamma) that has predicatable response to irradiation damage
- These foils will be “low enriched” ~ 19.7% 235U.
  - Compared to “highly enriched” ~ 50% 235U
- **Typically clad in Aluminum**
  - Uranium and Aluminum form a eutectic which negatively affects reactor performance
  - Tasked with developing and certifying boundary coating





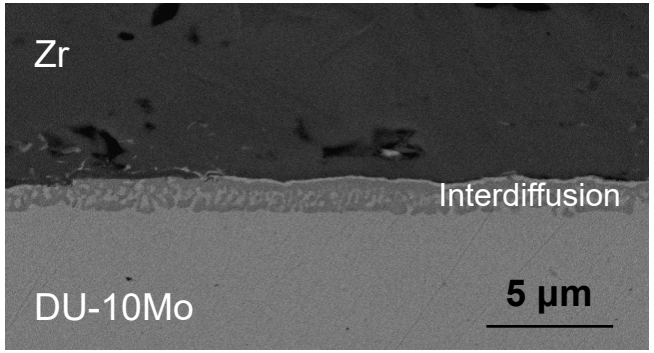


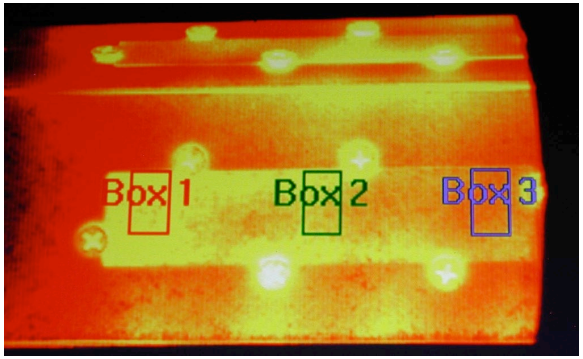
Plasma Spray for Nuclear Fuels

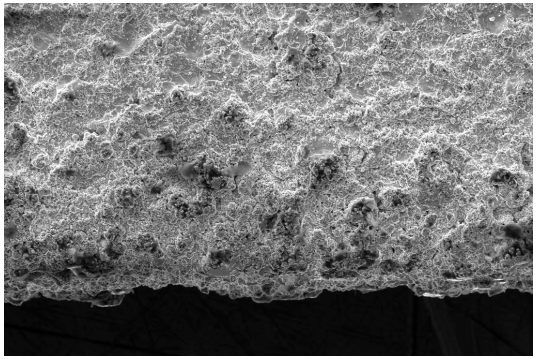


Beardmore, R.; www.roymech.co.uk; 2013

- Thermal Spray utilizes a “gun” to heat a powdered material (metals or ceramics) and accelerate those molten particles toward a substrate, where the particle deforms to create a layered coating.
  - Plasma spray utilizes a DC plasma torch as the heat source. Plasma temperatures reach ~15,000°C
- Multiple passes of the torch deposit one layer at a time, building up the thickness of the final coating.
- Efficient method and fully qualified for nuclear operations







Non-Proliferation and National Security

- In many non-proliferation and defense missions, hazardous materials and processes are involved, but everything is “theoretical” and rely on models

- LANL has unique capabilities and expertise to handle, process, and display these hazardous materials so researchers and collaborators can safely test sensors and operations in real-world conditions

- Our team acts as Auxiliary HazMat members for Emergency Response around Northern New Mexico

Los Alamos
NATIONAL LABORATORY

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R&D Engineer: SIGMA-1
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