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Spotlight on National Labs

Los Alamos National Laboratory

Thom Mason, Director of Los Alamos National Laboratory
Alan Carr, Historian of Los Alamos National Laboratory
Leslie Sherrill, Group Leader, XTD-IDA (Integrated Design and Assessment)
Alexis Trahan, Engineer, NEN-1 (Safeguards Science and Technology)
Joetta Goda, Engineer, NEN-2 (Advanced Nuclear Technology)
Dave Poston, Chief Reactor Designer, NEN-5 (Systems Design and Analysis)

Moderator
Nicholas Thompson, Engineer, NEN-2 (Advanced Nuclear Technology)

May 6, 2020

ANS Spotlight on National Labs

Los Alamos National Laboratory

Thom Mason

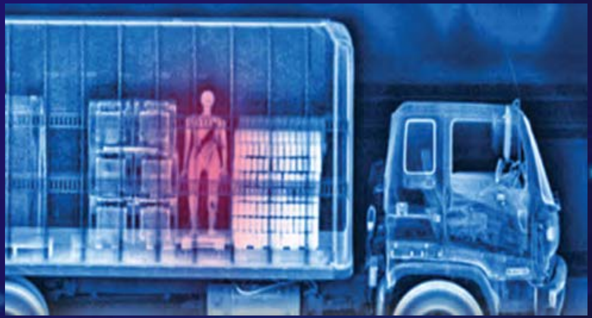
Director of LANL

May 6, 2020

LA-UR-20-23309

75+ years serving the nation

- In 1943, Los Alamos Laboratory was founded with a single, urgent purpose: build an atomic bomb
- The future holds no shortage of national security threats, but there is no shortage of innovative ways to combat those threats
- LANL leverages strategic nuclear deterrence to solve challenges to our nation's security



LANL’s national security focus means we are uniquely qualified to tackle big, novel problems such as COVID-19

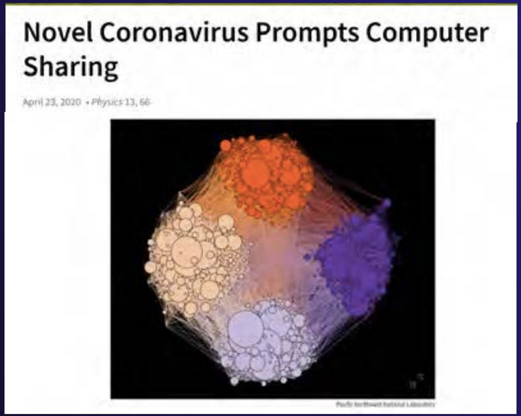

Los Alamos National Lab COVID-19 model helping guide the country


LANL researchers developing coronavirus vaccine design

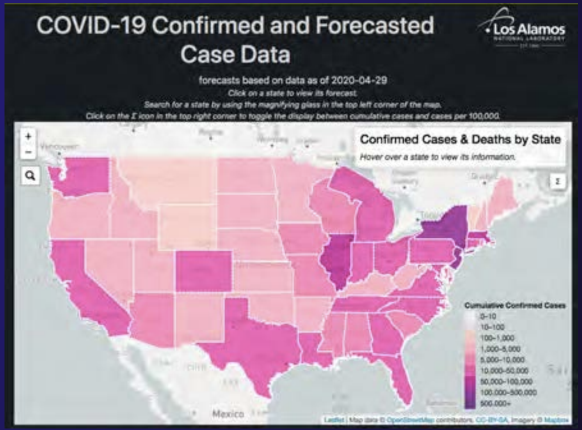
The coronavirus continues to spread throughout the world as researchers and scientists fight to create a vaccine.


COVID-19 Super-spreaders: New Study Shows Coronavirus is Twice as Infectious Than Previously Thought

Staff Reporter Apr 13, 2020 12:58 AM EDT


Novel Coronavirus Prompts Computer Sharing

April 23, 2020 • Physics 13, 66

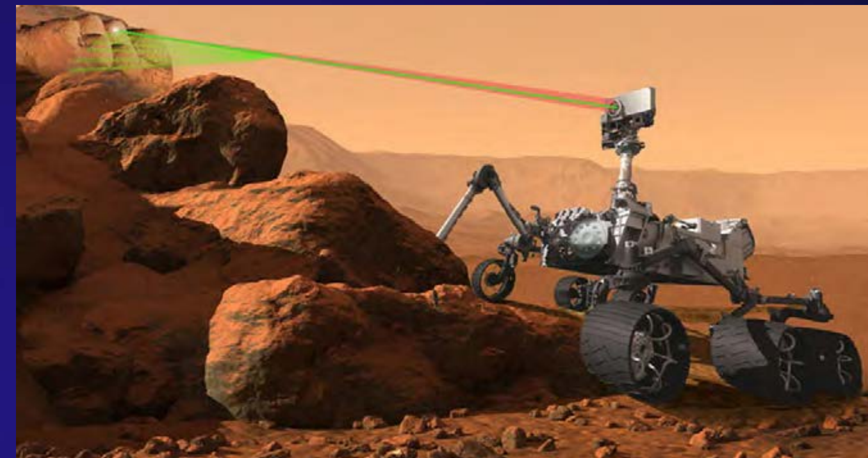


Our 12,866 employees rely on cutting-edge equipment and facilities to solve grand challenges on Earth and in space

- **37.8 sq. mile campus**
  (about the size of D.C.)

- **Flagship research facilities**
  For plutonium, explosives, simulations, chemistry, and more, enabling work that’s impossible anywhere else

- **Much of our stockpile research is applied to complex challenges in:**
  – Climate change
  – Vaccine development & epidemic prediction
  – Cybersecurity
  – Space exploration and monitoring



We expect to hire at least 1,250 employees in FY20 to meet our growing mission

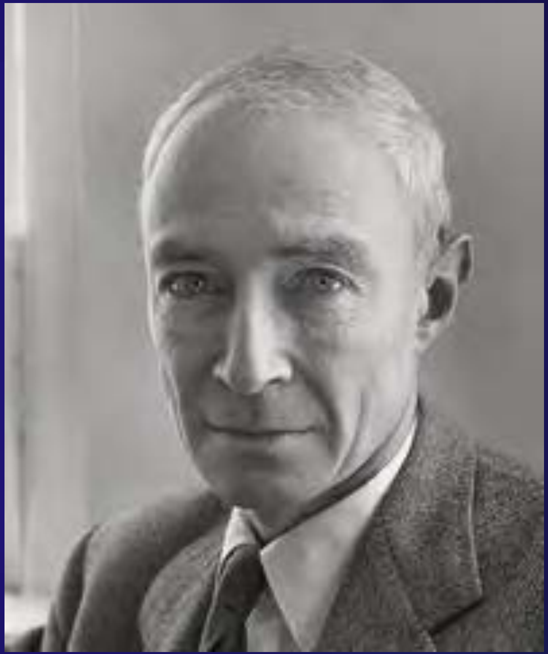
- Our workforce includes business professionals, project managers, construction workers, IT, and many students—1,850 students total in FY19
- LANL has summer schools in fields such as geophysics, quantum computing, cybersecurity, space science, and earth science
- We aim to foster an inclusive environment where employees stay, thrive, and advance
- We need the best and the brightest to protect our nation

LANL is poised for 75 more years of service to our nation

"There must be no barriers for freedom of inquiry. There is no place for dogma in science.

The scientist is free, and must be free, to ask any question, to doubt any assertion, to seek for any evidence, to correct any errors."

J. Robert Oppenheimer



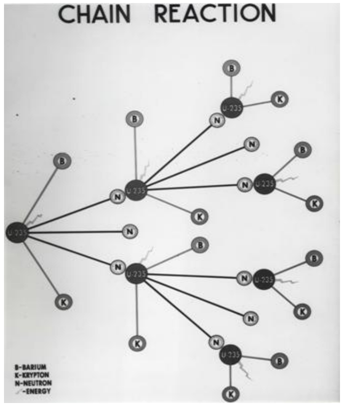
Los Alamos
NATIONAL LABORATORY
EST. 1943

75 Years in 75 Minutes… *or thereabouts*

A Brief History of Los Alamos National Laboratory

In the Beginning

- Fission was first produced in Nazi Germany in 1938
- Einstein, at the urging of Leo Szilard, warned FDR in August 1939
- In September 1939, the Germans *and* the Soviets invaded Poland
- Japan attacked Pearl Harbor on December 7, 1941
- In April 1943, the first technical conference was held in Los Alamos
- Two types of nuclear bombs were completed in ~28 months
- The world's first nuclear test was conducted on July 16, 1945
- The Trinity test achieved a yield equivalent to 21,000 tons of TNT

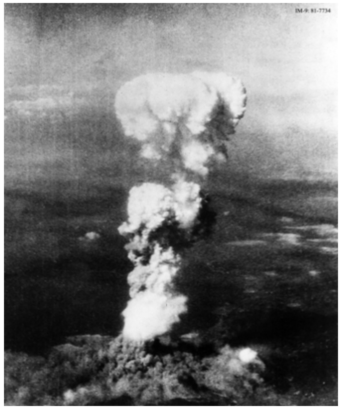


The End of World War II

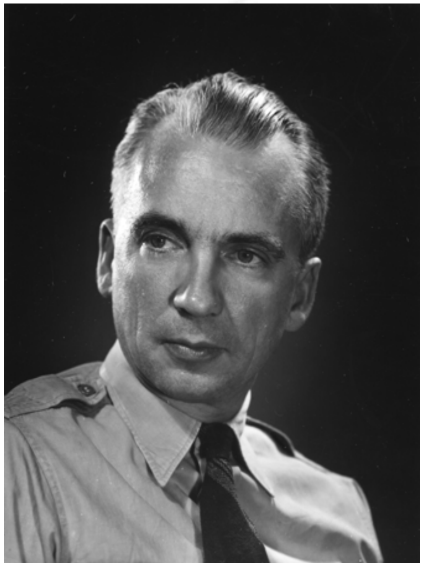
- On August 6, 1945 Hiroshima was bombed (LB = 15 kt)
- 64,500 had died by mid-November 1945
- On August 8th the Soviet Union declared war on Japan
- On August 9th Nagasaki was bombed (FM = 21 kt)
- 39,214 had died by mid-November 1945
- An armistice was declared on August 14th
- Los Alamos received the Army-Navy "E" Award for excellence in wartime production on October 16th

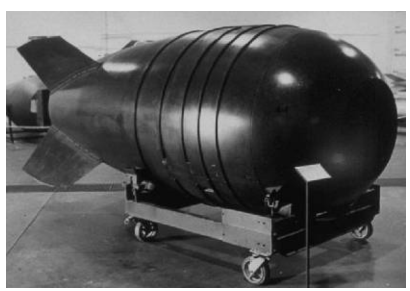
百人斬り超記録
向井106-105野田
両少尉さらに延長戰

"百人斬り競爭"の両將校



Bradbury's Laboratory





- Norris Bradbury was named Oppenheimer's successor
- He created a future for the Lab:

  1.) *We will set up the most nearly ideal project we can.*

  2.) *We will not discontinue weapon research until it is clearly indicated that this can be done.*

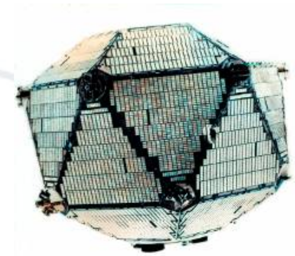
  3.) *We will decrease the project in size so that it can be accommodated on the mesa on a civilian basis.*

- Bradbury served as Director from 1945 to 1970
- He rebuilt the Laboratory physically and intellectually

The “Golden Age” of Nuclear R&D

- The nation’s stockpile grew from two to 31,255 weapons between 1945 and 1967
- During that same time, the United States conducted more than 500 nuclear tests
- The first thermonuclear test was conducted on October 31, 1952
- The first tactical nuclear weapon was tested in May 1953
- CASTLE-Bravo, the nation’s largest test, achieved a yield equal to 15,000,000 tons of TNT

An Expanding Mission



- In the late 1950s, the Laboratory began to diversify its mission
- Under Bradbury, Los Alamos became a nuclear science laboratory:

The development of nuclear powered rockets for space exploration (Project ROVER)

The development of nuclear verification technologies (Vela, CORRTEX etc.)

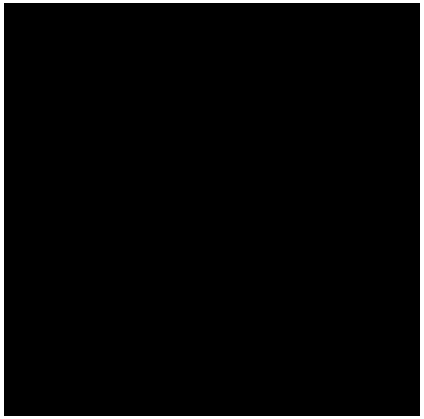
Controlled thermonuclear fusion research (Project SHERWOOD, SCYLLA)

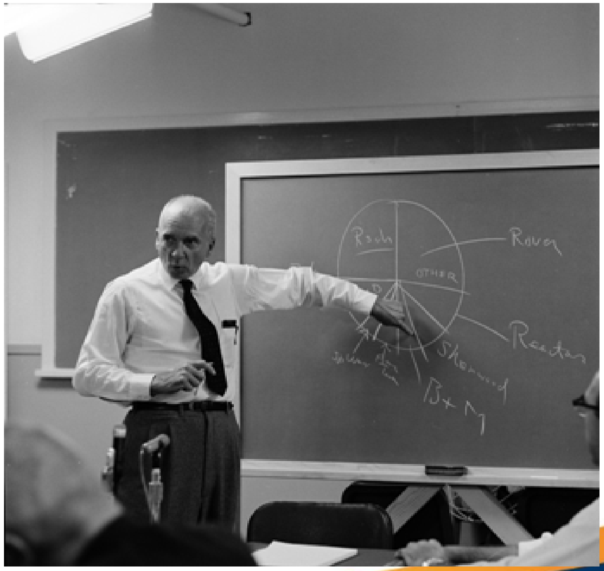
Industrial applications for nuclear explosions (Operation PLOWSHARE)

Health Physics research

Subatomic exploration

los alamos
scientific laboratory
of the University of California





UNCLASSIFIED

NNSA National Nuclear Security Administration

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Los Alamos NATIONAL LABORATORY EST. 1943

The 1970s: A Time of Growth and Change

- The Laboratory doubled in size during the 1970s: 4000 to 8000 employees
- Under Harold Agnew, the multidisciplinary laboratory of today was born
- The Lab's portfolio grew to include fields of research wholly unrelated to nuclear weapons, such as the development of alternative energy sources
- Since the 1970s, thousands of IAEA inspectors have received training from Los Alamos

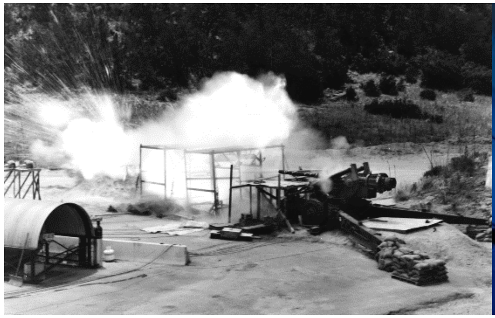
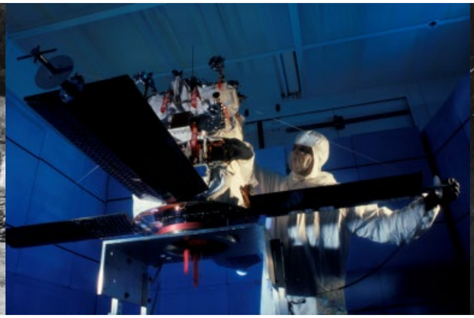
The Lab of the 80s and early 90s

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

- The 80s was a decade big, diverse projects at the Laboratory:
  - The SDI Program attempted to build an impenetrable space-based missile defense shield
  - The MLIS Program produced fissile materials economically
  - LANL built two of the world's most powerful laser
  - Studies of the human genome mapped all human genes
  - LANL worked to develop armor-piercing munitions
  - Environmental restoration became a major priority

[redacted]

- For the first time in decades, the elimination of nuclear weapons appeared to be a possibility
- It started to become clear testing would come to an end, but when?

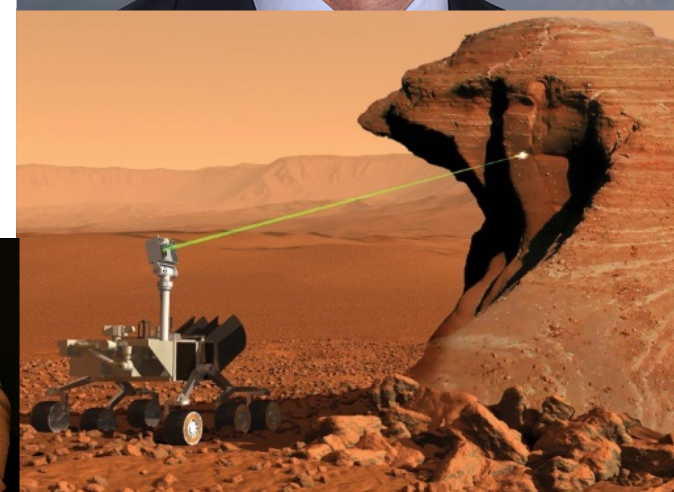



Life After the Cold War

- The last US nuclear test was conducted in September 1992
- The Stockpile Stewardship Program uses world class science to assess the state of US nuclear weapons
- The Laboratory Director reports those findings to the President annually as required by law
- The technical strength of the weapons program enables LANL to make valuable contributions to non- and counter-proliferation activities
- The Laboratory also models changing sea ice levels, ocean temperatures, and the possible spread of pandemics

Today's Laboratory

- For 20 years the Stockpile Stewardship Program has ensured the safety and reliability of US nuclear weapons without full-scale testing
- The new Trinity supercomputer will be 40 times faster than the historic Roadrunner machine
- LANL scientists are exploring Mars while developing the next generation Curiosity Rover
- Project ATHENA may soon provide a vastly superior approach for testing new drugs
- LANL scientists are doing pioneering work in nanotechnology at CINT



A Tradition of Innovation

1945: Los Alamos scientists conduct the world's first nuclear test

1945: Nuclear weapons developed at Los Alamos help end World War II

1946: The Monte Carlo method devised by LASL scientists

1946: LASL completes the world's first plutonium-fueled reactor

1951: First underground nuclear test conducted by LASL

1951: LASL conducts the first nuclear test producing thermonuclear burn

1952: LASL conducts the first full-scale thermonuclear test

1953: LASL conducts the first tactical nuclear weapon test

1954: The largest United States nuclear test conducted by LASL

1956: The existence of the neutrino proven by LASL scientists

1963: The heat pipe is invented by LASL scientists

1963: LASL-developed Vela satellites launched

1965: The cell sorter is invented by LASL scientists

1967: Gamma-ray bursts first detected by Vela satellites

1968: The 4000+ MW Phoebus 2A nuclear engine is successfully tested

1972: LAMPF produces an 800 MEV beam

1973: LASL's Nuclear Safeguards Program begins

1974: LAMPF ships its first medical radioisotopes

1979: IHE, a LASL innovation, is first used in a stockpiled nuclear weapon

1982: GenBANK established at LANL

1982: LANL's Cray X-MP named world's fastest computer

1984: LANL x-ray detectors used on GPS satellites

1988: Center for Genome Studies established at LANL

1988: LANL participates in Joint Verification Experiment

1990: National High Magnetic Field Laboratory established at LANL

1990: LANL begins participation in experiments that ultimately confirm neutrino mass

1992: LANL conducts the last US nuclear weapons test

1995: Chromosome 16 is mapped at LANL

2002: The first 3D full-system weapons simulation is performed at LANL

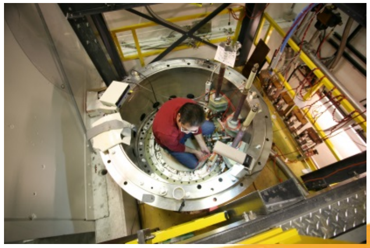
2008: LANL's Roadrunner supercomputer, the world's fastest, breaks the petaflop barrier

2009: DARHT becomes the world's most powerful x-ray machine

2012: LANL scientists produce a 100T non-destructive magnetic field

2012: Curiosity Rover lands on Mars equipped with several LANL instruments

2015: LANL scientists develop a breakthrough portable medical MRI device



The Weapons Design Mission at Los Alamos National Laboratory

A focus on the science of X Theoretical Design Division

Leslie Sherrill

Group Leader, XTD-IDA

X Theoretical Design Division
Integrated Design and Assessment

May 6, 2020

Reference: The Scientific Challenges in Stewarding the U.S. Nuclear Weapons Stockpile, W.S. Wilburn, LA-UR-17-21138

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

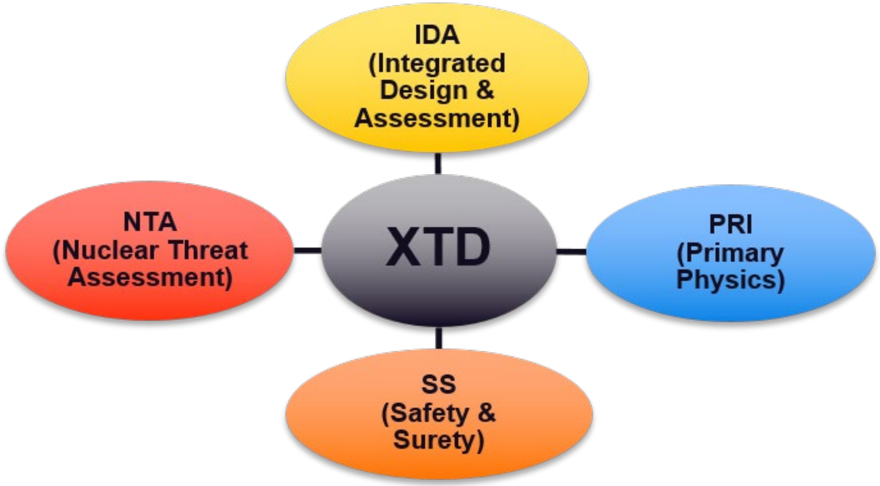
LA-UR-20-23290

The X Theoretical Design Division is a national resource for all aspects of nuclear weapons physics and design.

LANL's weapons design mission:

- Play a leading role in sustaining the effectiveness and safety of the current U.S. stockpile.
- Develop and underwrite design and certification options for the future evolution of the U.S. stockpile.
- Apply our expertise to the analysis of global nuclear weapon issues and the assessment of emerging threats.

To accomplish these missions, we use state-of-the-art scientific theoretical, numerical, and experimental tools and methods to understand nuclear weapon design, performance, safety and surety, outputs, and effects.



LANL stewards much of the U.S. nuclear stockpile.

- 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

One of the greatest scientific challenges in stewarding the U.S. nuclear stockpile is mission execution without nuclear testing since 1992.

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 relevant 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.

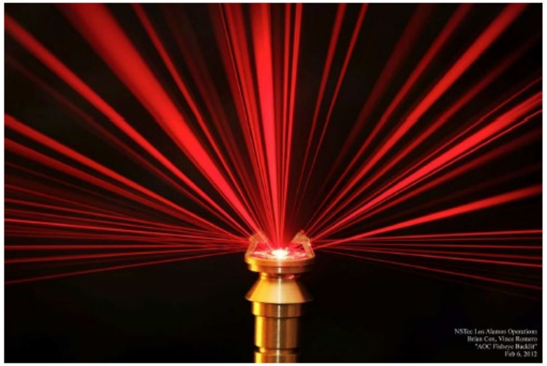
- Multi-physics codes model a wide range of relevant physics.
  - Radiation hydrodynamics
  - Neutronics
  - Thermonuclear burn

- Physical data is incorporated.
  - Neutron cross sections
  - Equation of state
  - Opacities

- Simulations are run on high-performance computers.
  - Trinity is one of the fastest supercomputers on Earth at ~41 petaflops.

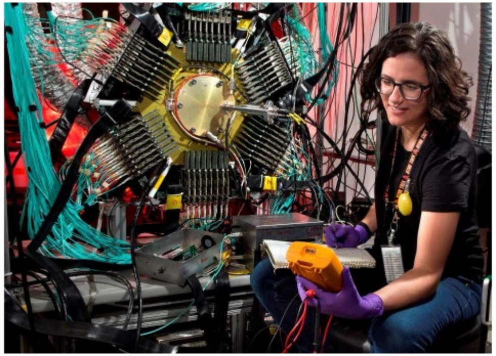
The LANL design groups use many experimental facilities to study behaviors and provide validation for modeling.

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

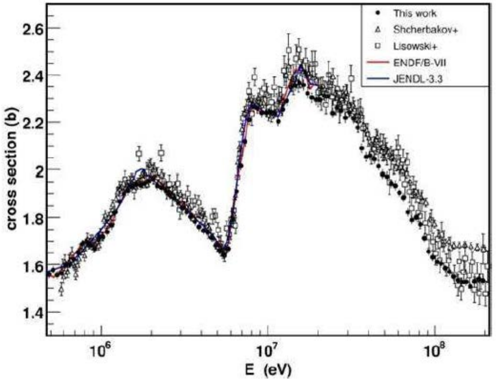


Multi-Point Photon Doppler Velocimetry (MPDV) is used to study implosion dynamics.

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.



International Safeguards and Verification for Nonproliferation at LANL

Los Alamos
NATIONAL LABORATORY
EST. 1943

Alexis Trahan

May 6, 2020

NNSA
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LA-UR-20-23335

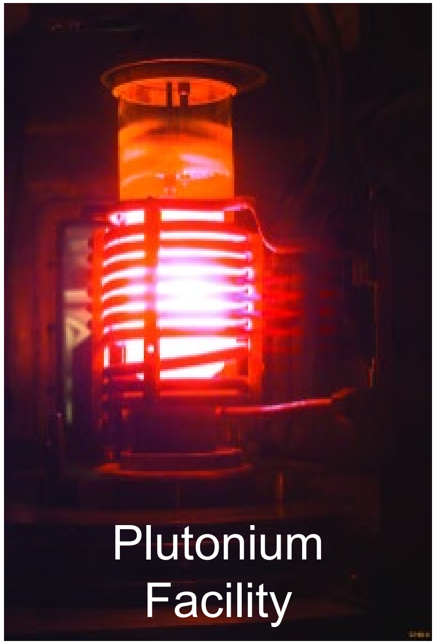
Los Alamos
NATIONAL LABORATORY
EST. 1943

"We are one team, dedicated solely to the success of our Laboratory's national security mission."
- Thom Mason, Laboratory Director

Global Security

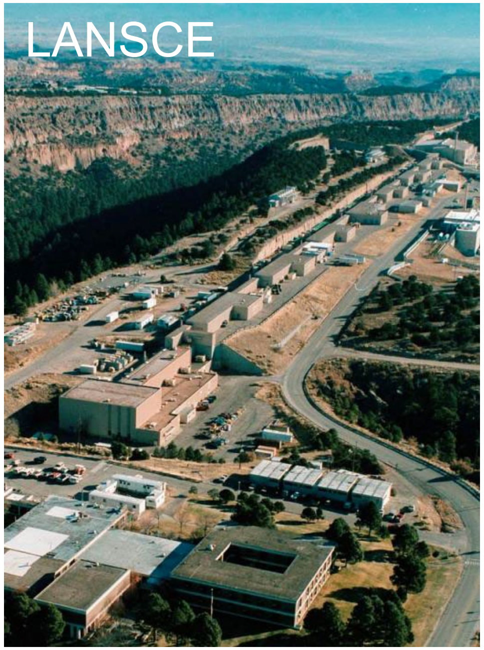
- "It takes a weapons laboratory to find a weapons laboratory"
- We leverage facilities and expertise from LANL's long history to develop and support programs that span the entire nuclear threat spectrum

Trinity Supercomputer



Plutonium Facility

DARHT



LANSCE

International Safeguards

50 years of support for the International Atomic Energy Agency (IAEA) through…

Technology development

Training

Expertise

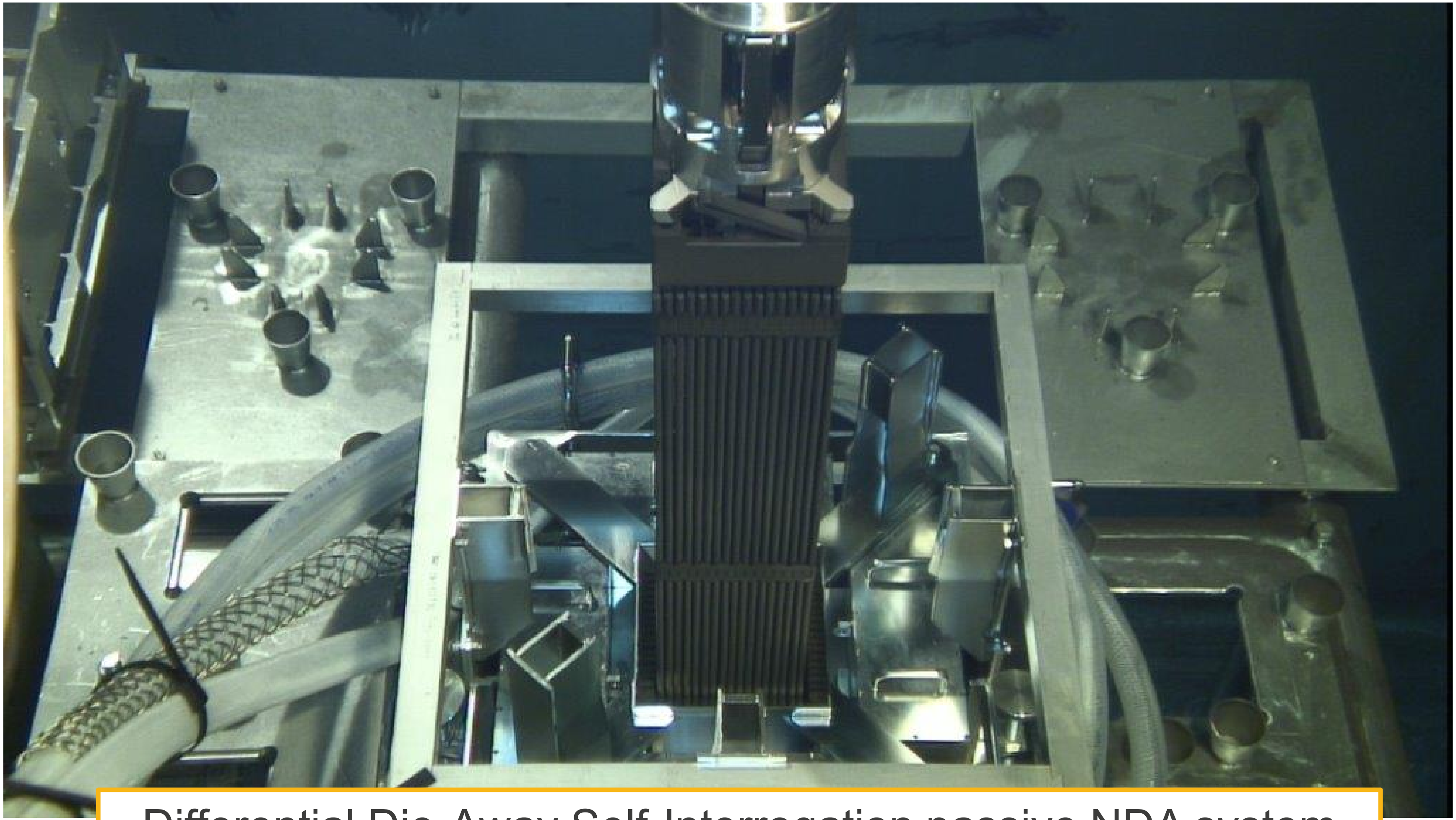
Nuclear Verification

Developing and maintaining the technical means to monitor whether the terms of a nuclear arms control treaty or other international agreement are fulfilled

Leverage LANL's unique facilities and capabilities to train ONV resources who may be needed for rapid deployment

Develop tools and technologies for U.S.-led on-site verification and/or monitoring activities

Spent Power Reactor Fuel Measurements in Sweden



Differential Die-Away Self-Interrogation passive NDA system

Chernobyl Waste Assay Device

Active NDA system for waste drum characterization, to be deployed to Ukraine

Improved Plutonium Canister Assay System

Passive NDA system for plutonium canister assay, deployed to Japan

Los Alamos
NATIONAL LABORATORY
EST. 1943

National Criticality Experiments Research Center (NCERC) Overview

Los Alamos
NATIONAL LABORATORY
EST. 1943

NNSA
National Nuclear Security Administration

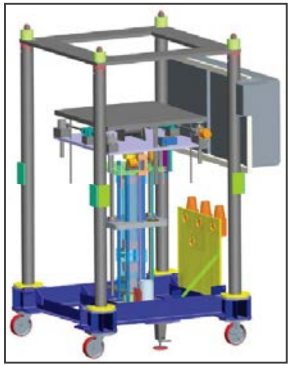
What is NCERC?

- **NCERC: National Criticality Experiments Research Center**
- **Location: Device Assembly Facility (DAF) at the Nevada National Security Site (NNSS)**
- **Operated by: Los Alamos National Laboratory**
- **NCERC Mission Statement:**
  – The mission of the National Criticality Experiments Research Center (NCERC) is to conduct experiments and training with critical assemblies and fissionable material at or near criticality in order to explore reactivity phenomena, and to operate the assemblies in the regions from subcritical through delayed critical. One critical assembly, Godiva-IV, is designed to operate above prompt critical.

History of Los Alamos Critical Experiments

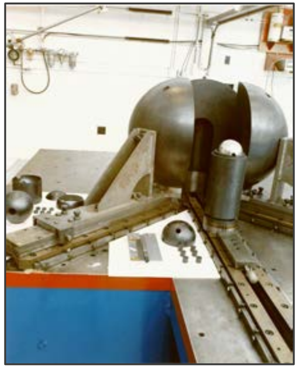
- 1943-1945: Dragon Experiment and Water Boilers at Omega Site (LOPO, HYPO)
- 1945: Daghlian criticality accident at Omega Site
- 1946: Los Alamos Critical Experiments Facility (LACEF) founded at Pajarito Site (Technical Area-18) at LANL
- 2004: First material shipment to move critical experiments to the Device Assembly Facility (DAF) at the Nevada National Security Site (formerly the Nevada Test Site)
- 2011: Approved to start critical operations

NCERC General Activities: Capabilities



- Planet

- Comet



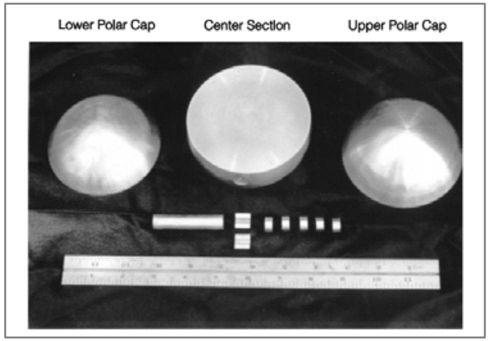
- Flat-Top

- Godiva IV

- Highbays for subcritical measurements

NCERC General Activities: Subcritical Mass Measurements

- **NCERC is our nation's only general-purpose critical experiments facility and is only one of a few that remain operational throughout the world**
  - High neutron multiplication, static objects (bare, reflected, moderated, etc.)
  - Radiation Test Objects (RTOs)
  - Subcritical benchmarks for nuclear data/radiation transport code validation
    - International Criticality Safety Benchmark Evaluation Project (ICSBEP)



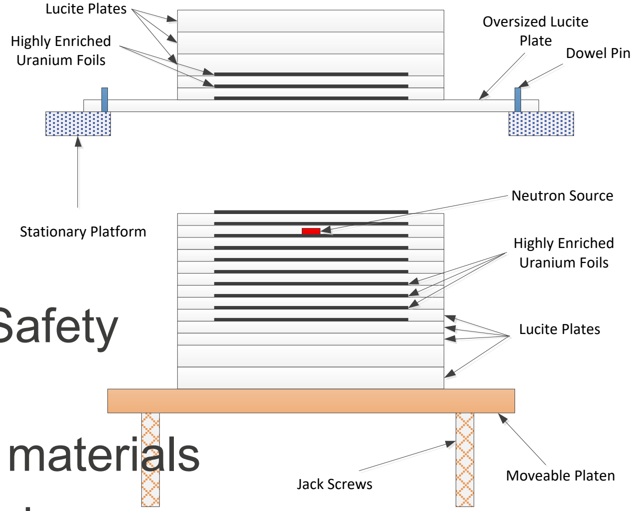
Thor core
9.6 kg delta-phase Pu-239

Beryllium Reflected Plutonium (BeRP) Ball
4.5 kg alpha-phase Pu (94 wt% Pu-239)

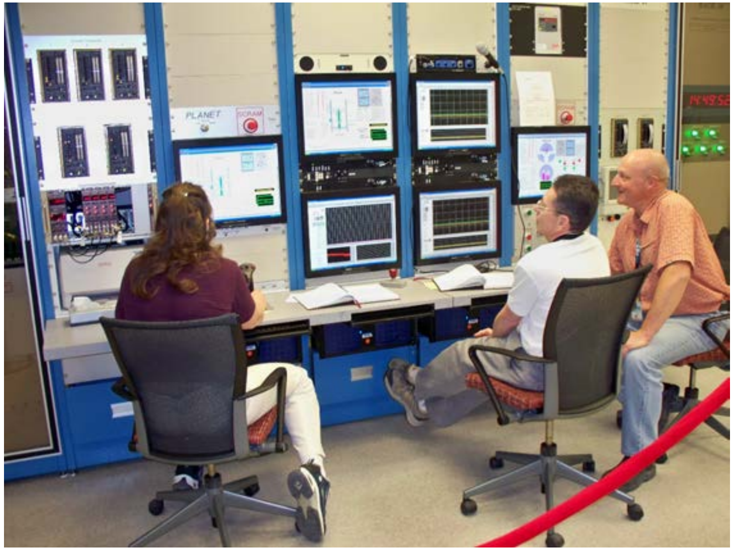
Rocky Flats shells
Metal HEU nesting hemishells

Planet

- Stationary platform
- Moveable platen

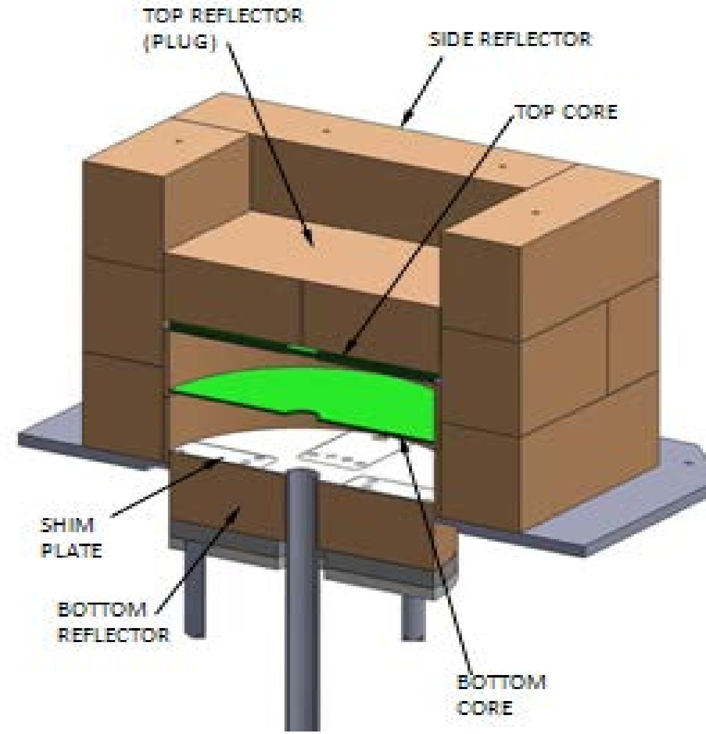


- Nuclear Criticality Safety Program training
- Alternative nuclear materials
- Criticality Benchmark Evaluations (ICSBEP)



Comet

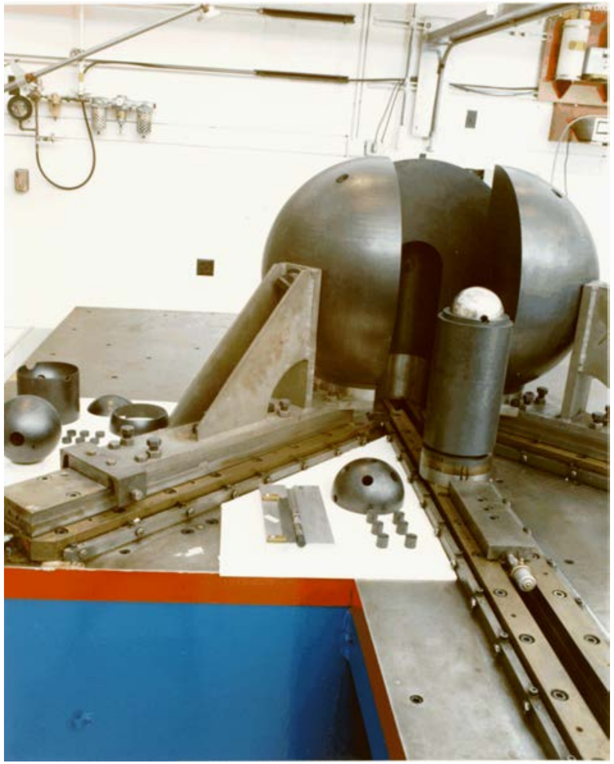
- Stationary platform
- Moveable platen
- Larger lift capacity than Planet



- Japan Atomic Energy Collaborations
- NASA Kilopower Reactor (KRUSTY)
- Nuclear Forensics irradiations
- Criticality Benchmark Evaluations (ICSBEP)

Flattop

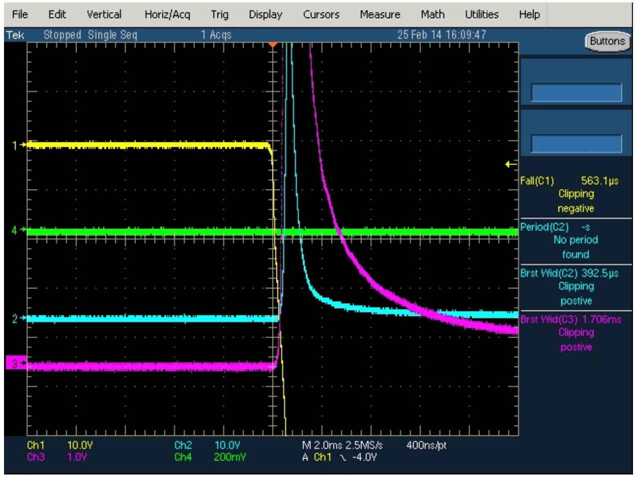
- Spherical, reflected fast system
- 1000 kg natural uranium reflector
  - 500 kg hemisphere
  - Two 250 kg quarter-sphere safety blocks
- Glory hole for mass adjustment, samples, activation foils, etc.
- Interchangeable U-235 and Pu-239 cores



- Nuclear Criticality Safety Program training
- Nuclear Forensics irradiations
- NASA DUFF Demonstration

Godiva IV

- Cylindrical uranium metal fast burst assembly
- 65 kg, 93% enriched
- 7-inch diameter (17.8 cm)
- 6-inch tall (15.2 cm)



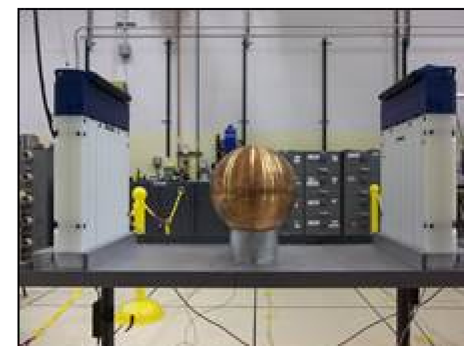
- Nuclear Criticality Safety Program training
- Nuclear Forensics irradiations
- Dosimetry Testing
- Criticality Alarm Testing

Recent Work at NCERC: Design and Application

- **Collaboration with French Nuclear Agency (IRSN)**
  - Subcritical Copper-Reflected alpha-phase Pu (SCRaP)
  - Subcritical benchmark included in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) handbook

SCRaP Interstitial Materials

SCRaP Experiment with BeRP Pu Core



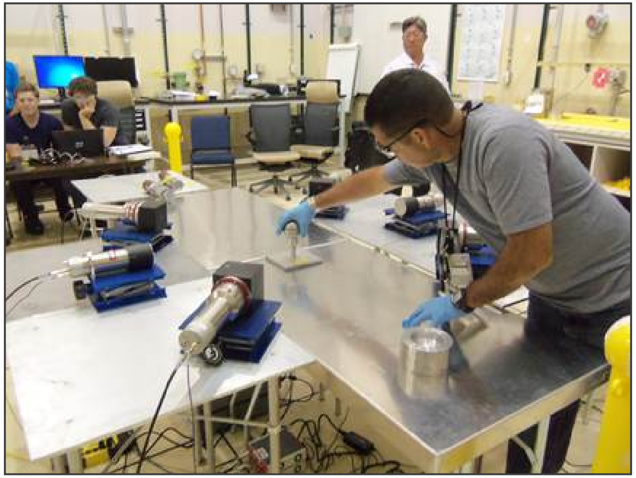
SCRaP Experiment Under Measurement

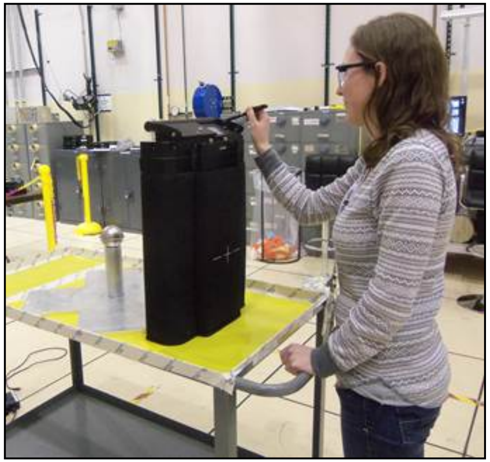
Recent Work at NCERC: Education

- **NCSP Two-Week Hands-On Criticality Safety Courses**
  - Multiple courses given per year, focus on DOE Criticality Safety Engineers, Officers, and Managers as well as Operators and Process Supervisors
    - Training supports activities across DOE complex, such as TA-55
  - One week in-class training, one week hands-on demonstrations at NCERC

Recent Work at NCERC: Education

- **University-Laboratory Consortia**
  - Collaborations between University research groups and Laboratory technical staff members
  - SNM detection system testing at NCERC on subcritical RTOs (Pu, HEU, Np)
    - Consortium for Nonproliferation Enabling Capabilities (CNEC) and
    - Consortium for Verification Technologies (CVT)
    - Consortium for Monitoring Technology and Verification (MTV)
    - Consortium for Enabling Technologies and Innovation (ETI)
    - Nuclear Science and Security Consortium (NSSC)





NCERC Key Points

- **NCERC is our nation's only general-purpose critical experiments facility and is only one of a few that remain operational throughout the world**
  - 70+ years of critical experiments and research
  - Capability to handle and conduct experiments with large quantities of SNM
- **Critical and Subcritical Experiments**
  - Outdoor operations with large quantities of SNM
  - Fission chambers and other measurement capabilities are on line
- **Making Investments in Pipeline and the Facility for Future Capability**
- **Directly Contributing to Important National and International Missions**
  - Theory, design and application, education and training

Acknowledgement

NCERC is supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.

Kilopower

A small fission reactor for planetary surface and deep space power

Patrick McClure

Dave Poston

Los Alamos National Laboratory

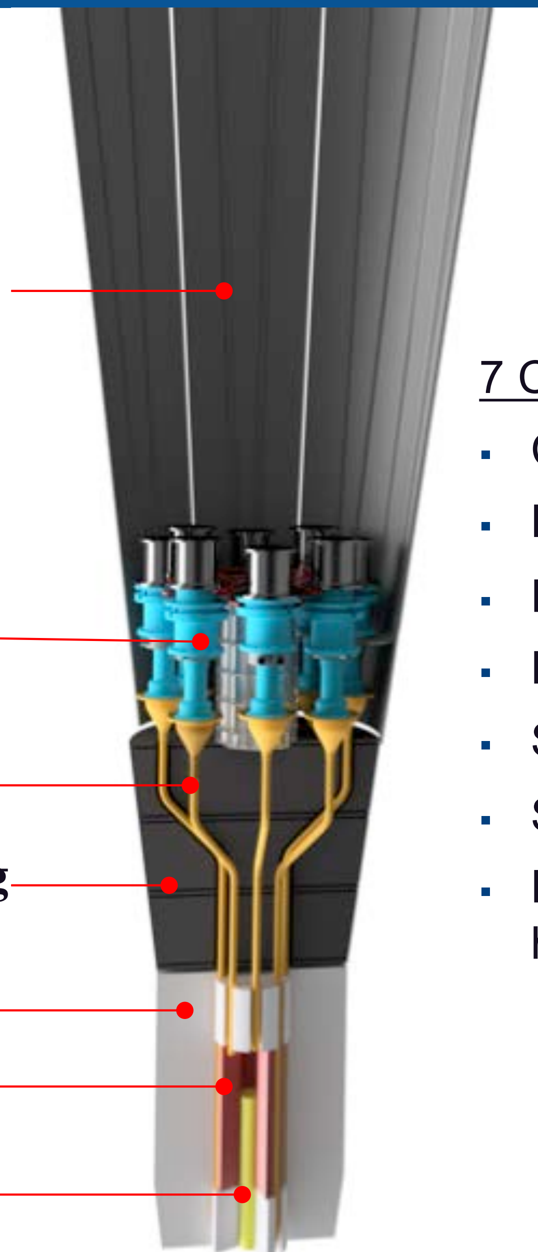
Marc Gibson

NASA Glenn Research

2020

Kilopower – Reactor Concept for Deep Space

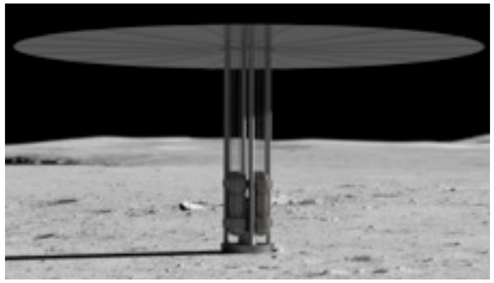
1000 W: 400 kg

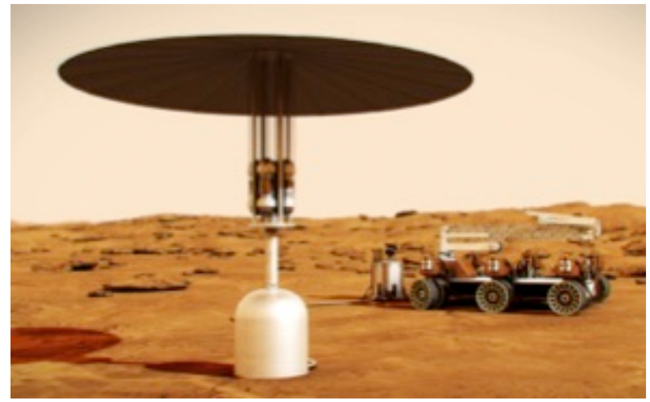


<u>7 COMPENENTS</u>

- Core
- Neutron reflector
- Heat pipes
- Radiation shielding
- Start-stop rod
- Stirling engine convertors
- Radiator to remove excess heat

1 to 10 kWe Kilopower Surface Reactors



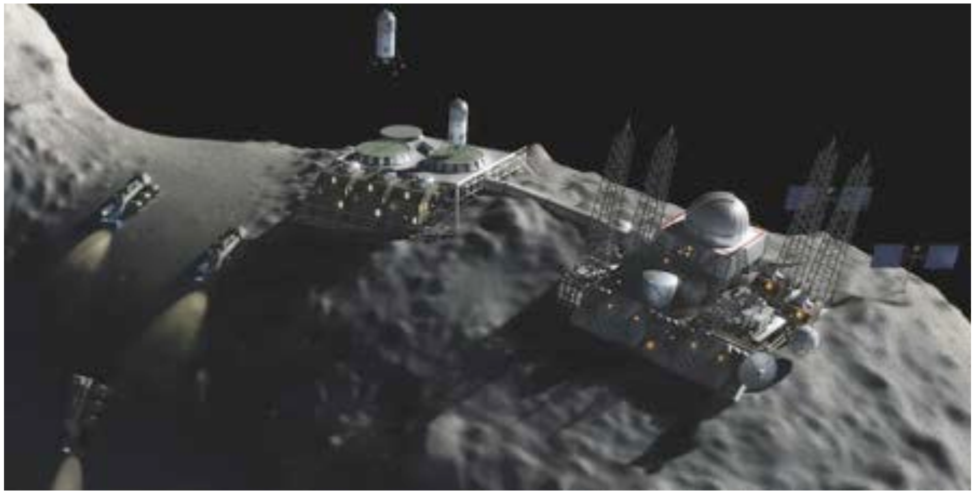


10 kW: 1500 kg

- Use multiple 10 kWe units for human missions
- Utilizes a deployable radiator
- Buried configuration at Lunar and Mars surface
- Full shield for lander configurations

Potential Applications

- **Government Missions**
  - Human Mars surface missions
  - Lunar (moon) surface missions
  - Planetary orbiters and landers:
    - Europa, Titan, Enceladus, Neptune, Pluto, etc.
- **Commercial Missions**
  - Space power utility
  - Asteroid/space mining
  - Lunar/Mars settlements

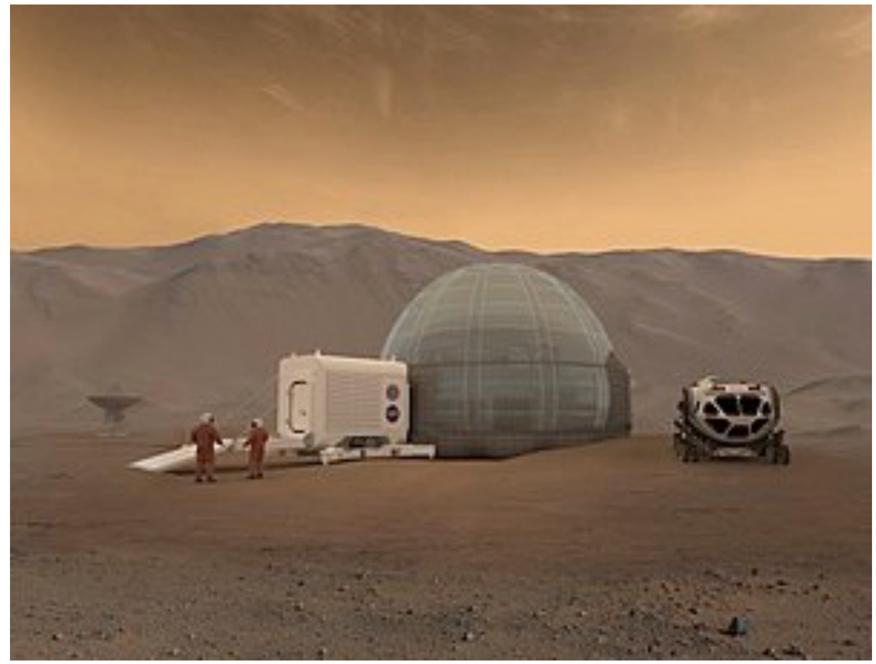


- **Power uses**
  - drilling, melting, heating, refrigeration, sample collection, material processing, manufacturing, video, radar, laser, electric propulsion, telecomm, rover recharging

What is needed for Humans to go to Mars

- **Electricity would be used to make:**
  - Propellant to get back to Mars orbit
    - Liquid Oxygen
    - Methane

International Mars Research Station – Shaun Moss



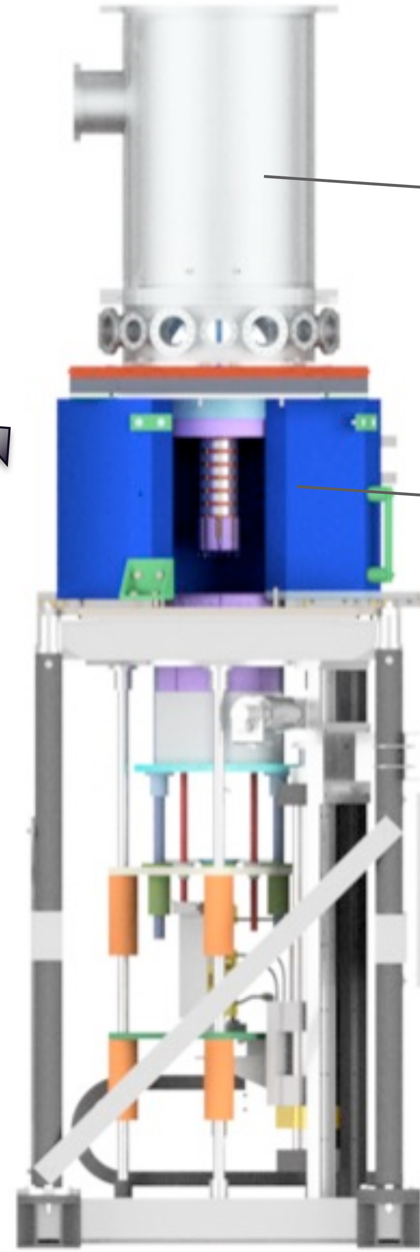
Mars Base Camp – NASA Langley

- **Electricity is needed for:**
  - Oxygen for astronauts
  - Purify water
  - Power of habitat and rover

KRUSTY: Kilopower Reactor Using Stirling TechnologY

Flight Concept

Flight Prototypic
Power System



Vacuum Chamber for Simulated Space Environment

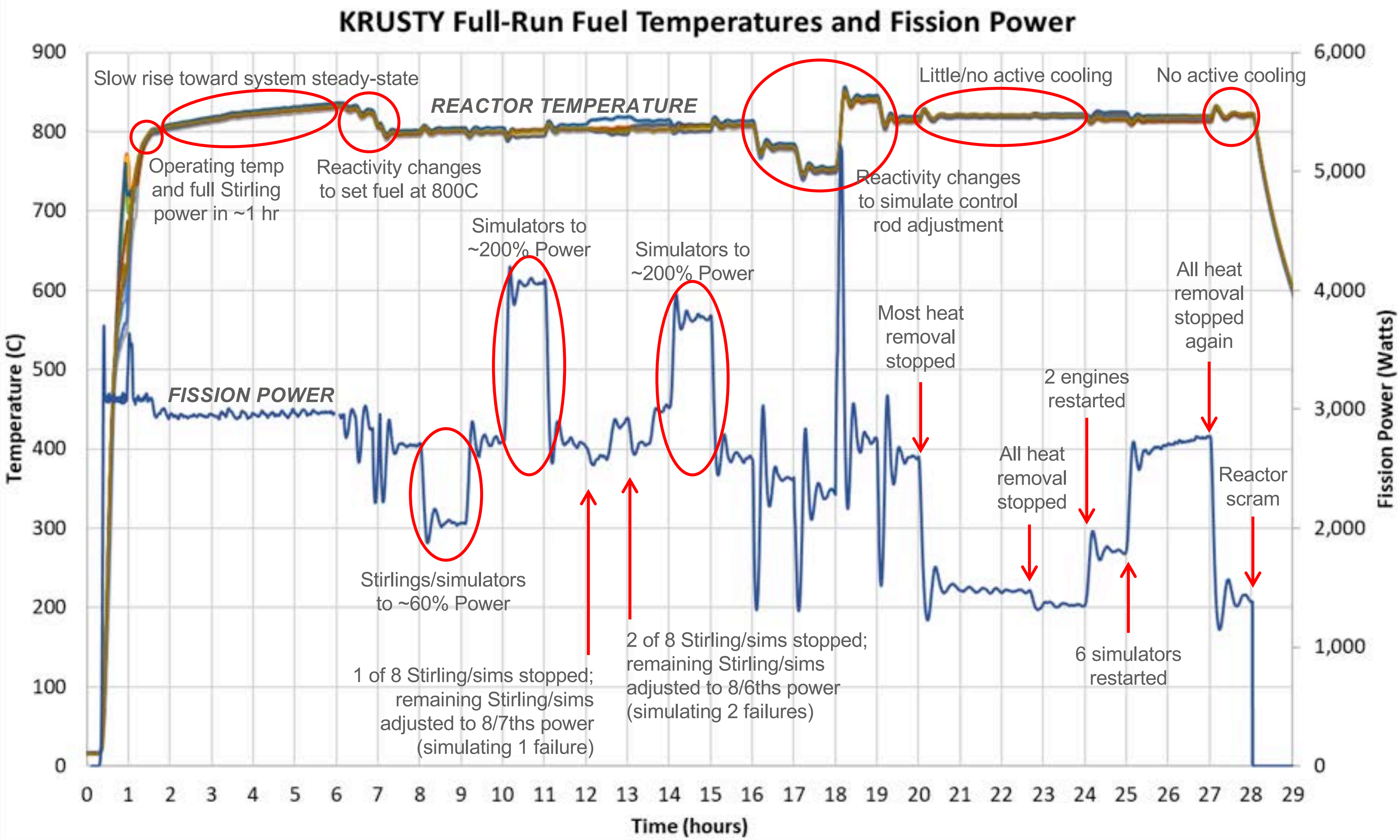
Facility Shielding

COMET
Machine used to start and stop reactor by lifting reflectors around core

KRUSTY
Experimental Setup

Experiment Assembly

KRUSTY 28 Hour Full Power Run



KRUSTY Performance Metrics

Event Scenario	Performance Metric	KRUSTY Experiment	Performance Status
Reactor Startup	< 3 hours to 800 deg. C	1.5 hours to 800 deg. C	Exceeds
Steady State Performance	4 kWt at 800 deg. C	> 4 kWt at 800 deg. C	Exceeds
Total Loss of Coolant	< 50 deg. C transient	< 15 deg. C transient	Exceeds
Maximum Coolant	< 50 deg. C transient	< 10 deg. C transient	Exceeds
Convertor Efficiency	> 25 %	> 30 %	Exceeds
Convertor Operation	Start, Stop, Hold, Restart	Start, Stop, Hold, Restart	Meets
System Electric Power Turn Down Ratio	> 2:1 (half power)	> 16:1	Exceeds

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