Oak Ridge National Laboratory
The Influence and Impact on Pressure Safety

Mark Lower
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ORNL’s mission

Deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security, and in doing so create economic opportunity for the nation

Signature strengths

- Computational science and engineering
- Materials science and engineering
- Neutron science and technology
- Nuclear science and technology

ORNL's Secret Mission

1939

Albert Einstein writes to President Franklin Roosevelt warning of the possible development of "extremely powerful bombs of a new type"

1942

Army Corps of Engineers forms the Manhattan Engineer District. This leads to the decision to buy 59,000 acres in East Tennessee to separate uranium, and demonstrate plutonium production and separation

1943

The world's first operational nuclear reactor, the Graphite Reactor serves as a plutonium production pilot plant during World War II. It operates until November 1963, pioneering the production of radioisotopes, studies of radiation damage in materials, and development of neutron diffraction as a research tool.

WWII Ends

The X-10 facilities served as a pilot plant for the massive plutonium production complex built at Hanford, Washington, which supplied the plutonium used in the "Fat Man" bomb.

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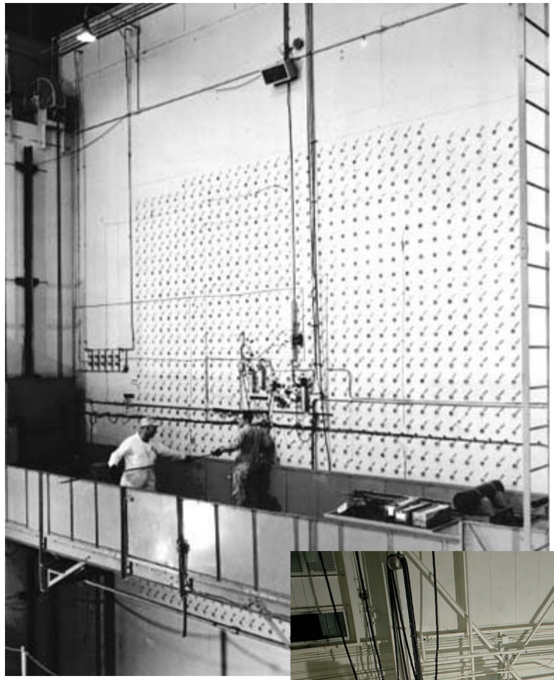
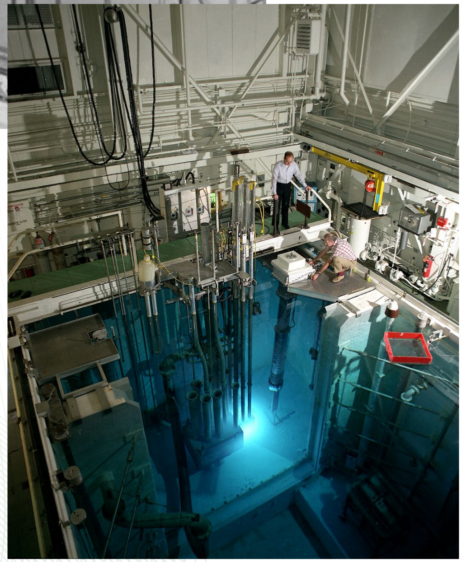
Transition to Peacetime Laboratory



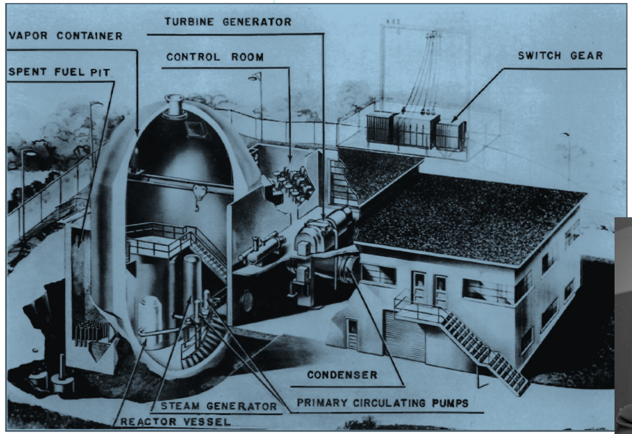


Purpose

- use nuclear energy to pioneer medical therapies,
- study the nature of matter, and power homes

Activities

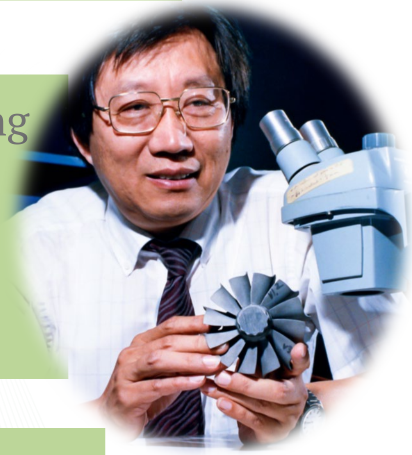
- Construction of new research reactors to enable exploration of the potential of nuclear power for generating electricity
- Discoveries in materials, chemical, and nuclear sciences.



Materials Research

Researchers investigate the properties of 120 laboratory melts and determine the recommended composition and heat treatment of a chrome-moly steel that has better tolerance of design stresses with no loss of ductility, higher resistance to thermal stress, immunity to stress corrosion cracking in chloride-bearing water, and resistance to radiation-induced swelling. Chrome-moly steel is used in electric utility boilers and oil refinery furnaces worldwide.

From the mid-1970s to early 1980s, ORNL works with Combustion Engineering (now Alston Power Inc.) to develop the first creep-strength enhanced ferritic (CSEF) steel, Grade 91. The steel debuts in 1982. Grade 91 and subsequent CSEF steels become a worldwide standard for achieving high efficiency and safe and reliable performance.



CF8C-Plus steel, developed through a cooperative research and development agreement between ORNL and Caterpillar, is commercialized by Caterpillar in 2007 for regeneration systems for diesel particulate filters, and 550 tons is used in more than 35,000 heavy-duty highway diesel engines.

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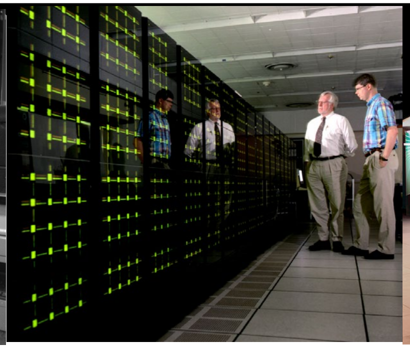
Supercomputing



Oracle

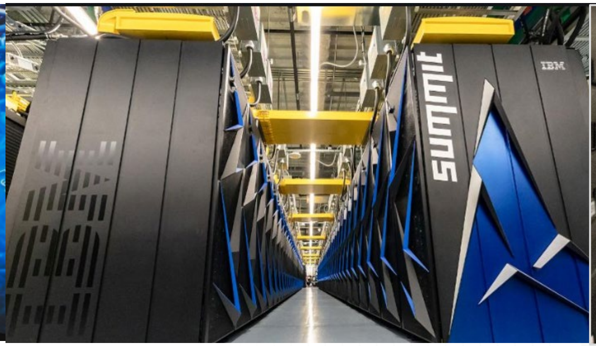
14 kiloflops (1,000 floating-point operations per second). It has an original storage capacity of 1,024 words of 40 bits each and contains a magnetic-tape auxiliary memory.

Paragon

Jaguar
#1 in 2009, 2010

Kraken

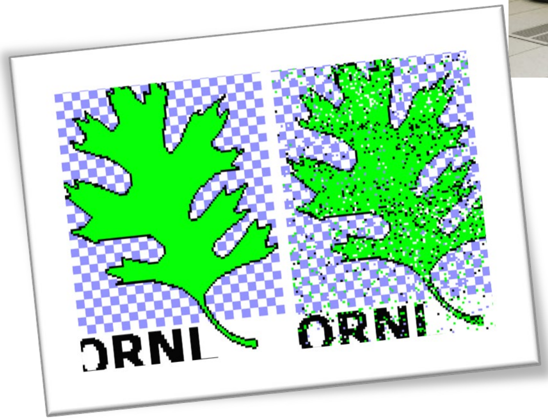
Titan
#1 in 2012



Summit
#1 in 2018

Frontier
Debut in 2022

Performance >1.5 exaflops exceeding a quintillion, or 10^{18}, calculations per second

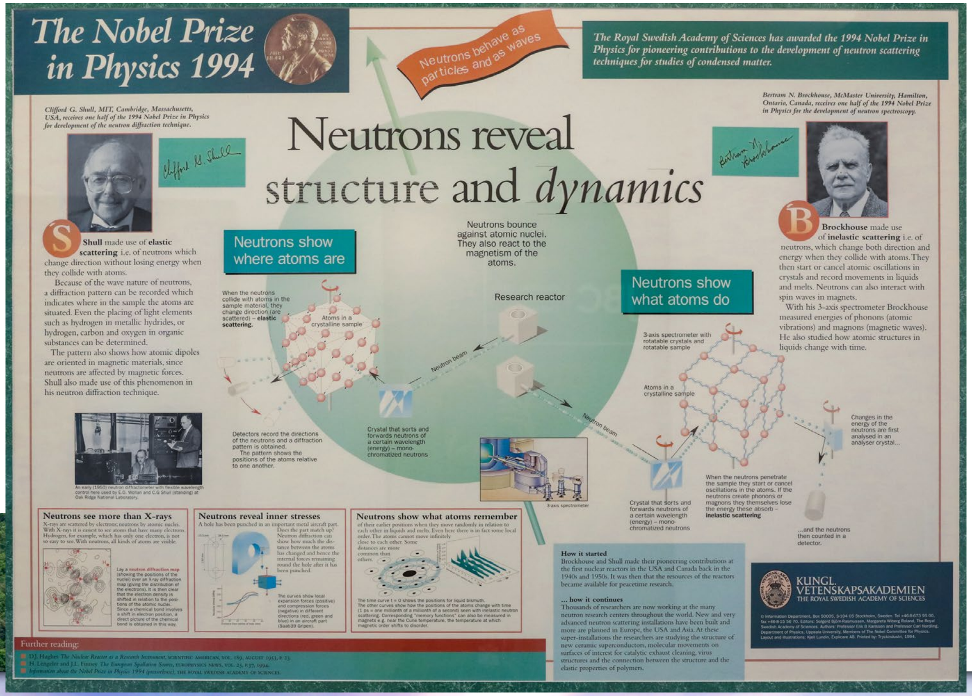


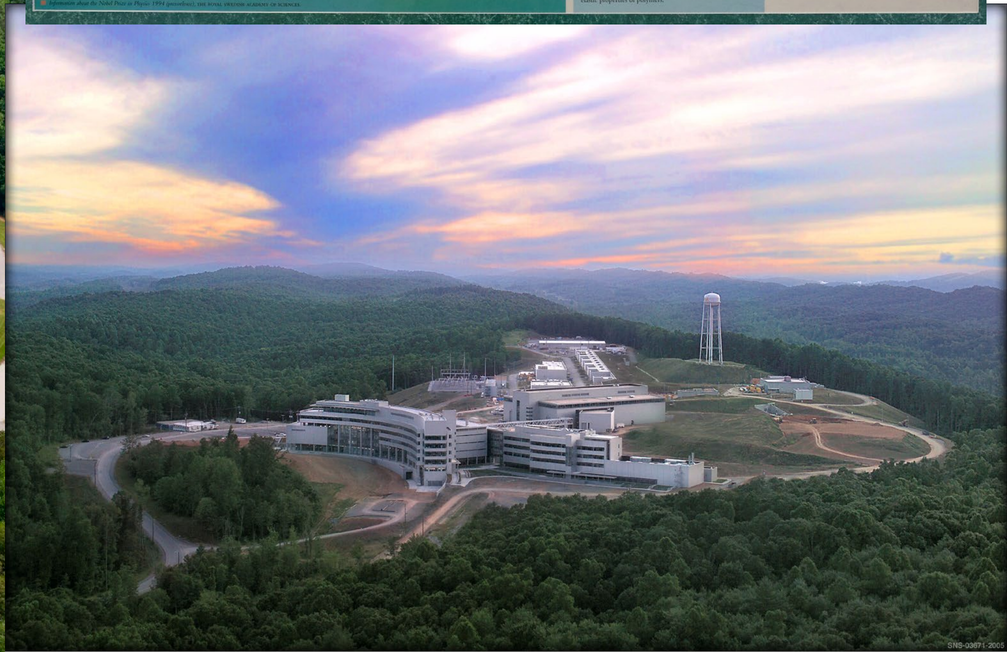
~1M attacks per day

One gram in 50 years

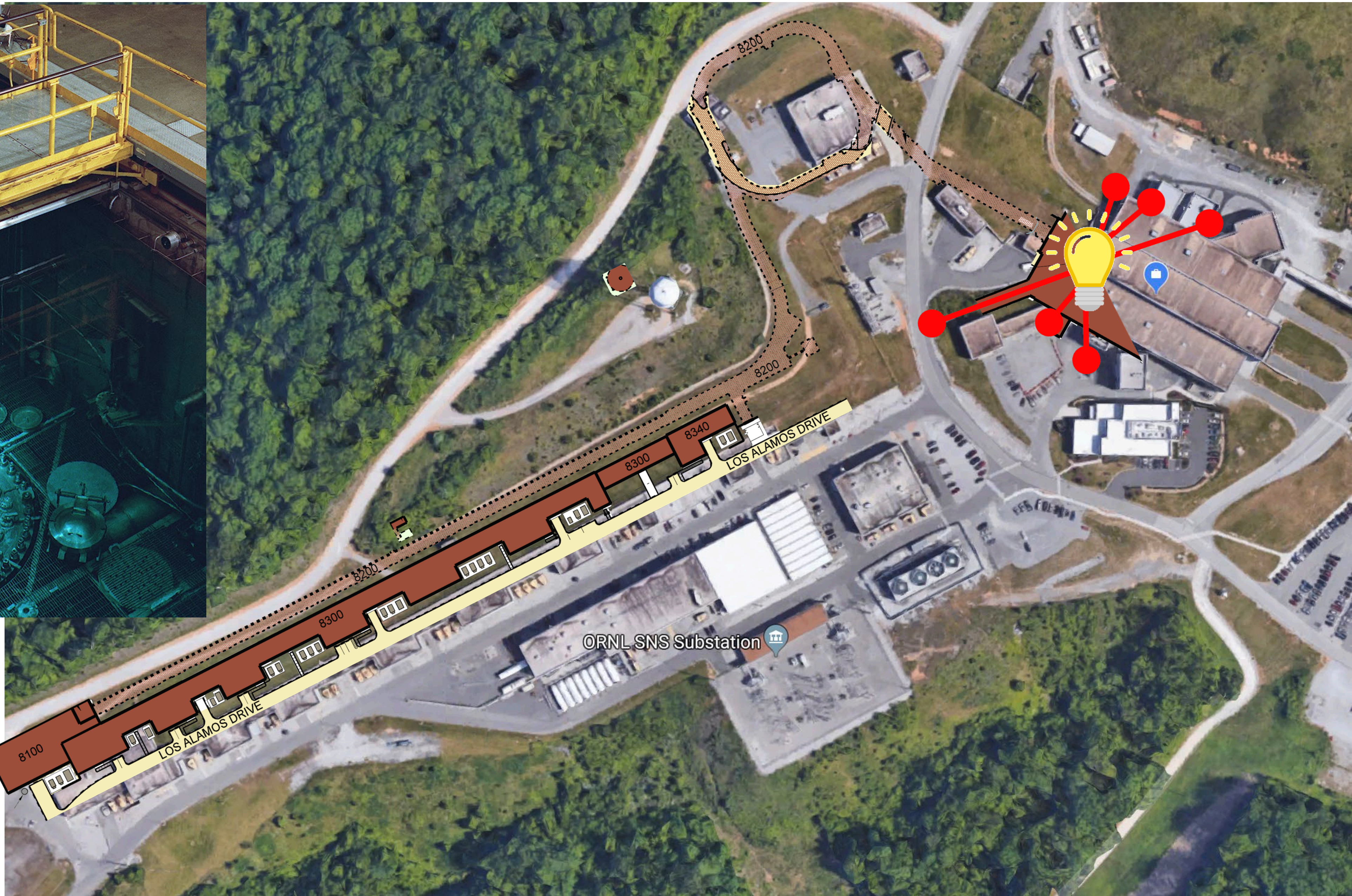
It is ***really hard*** to make neutrons.

Little known fact… Fermi was about a year or two away from discovering the Higgs Boson before CERN came online





How do we make neutrons



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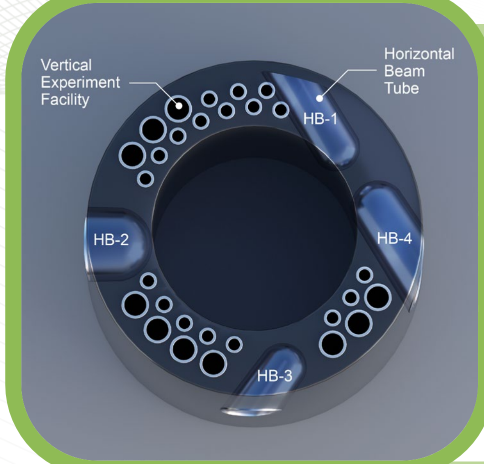
High Flux Isotope Reactor



Constructed in the mid-1960s to fulfill a need for the production of transuranic isotopes—heavy elements such as plutonium and curium

World's highest producer of steady-state neutrons

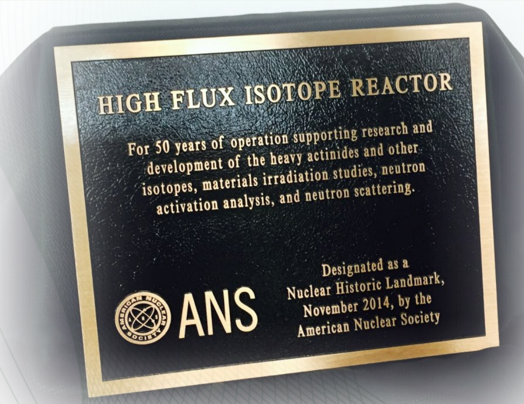
Cold Source is designed to cool neutron beams to 20 K (-425°F)

Average core lifetime is ~23 days at 85 MW

One of its original primary purposes was to produce californium-252 and other transuranic isotopes for research, industrial, and medical applications. HFIR is the western world's sole supplier of californium-252, an isotope used for cancer therapy and detection of pollutants in the environment and explosives in luggage.

Mission now includes materials irradiation, neutron activation, and, most recently, neutron scattering.

capabilities enable the exploration of the molecular and magnetic structures and behaviors of materials including high temperature superconductors, polymers, metals, and biological samples.



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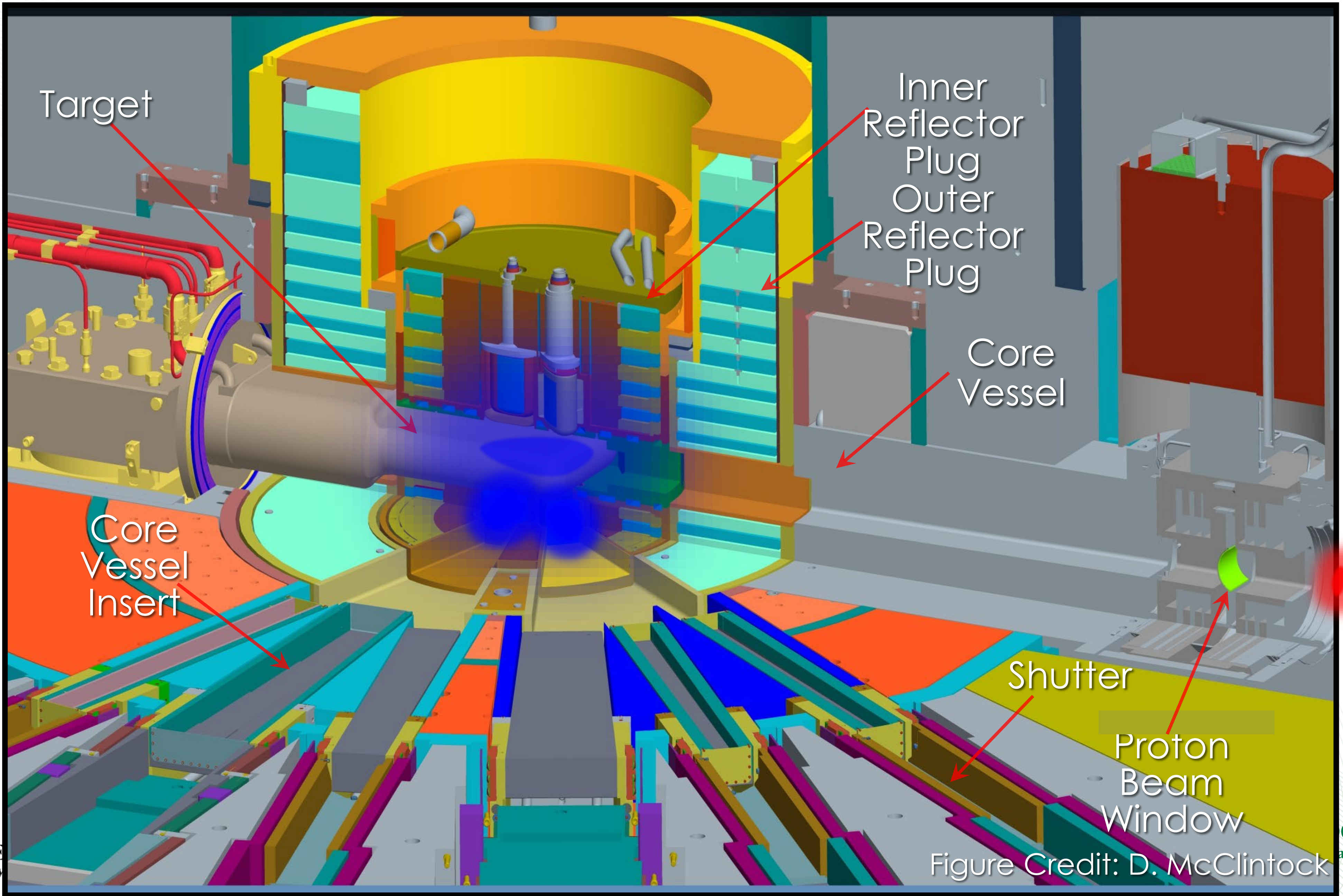
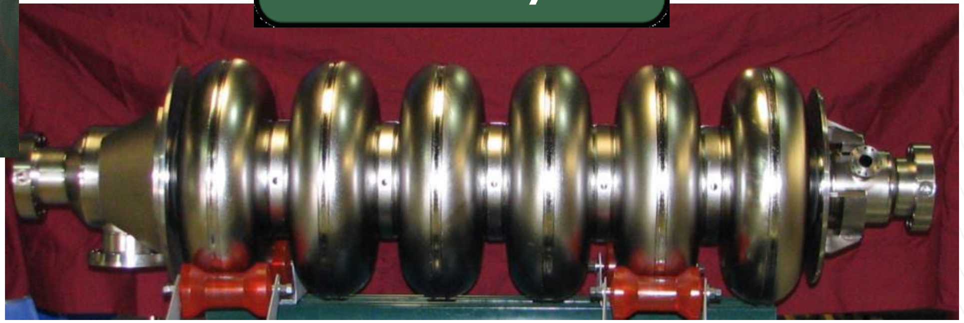
The target provides neutrons to 24 beam lines



A Stick of Dynamite 5 Million Times/Day!

- 1 gigaelectronvolt (GeV) 60 Hz proton beam aimed at nose of SNS target assembly
- Neutrons produced via spallation reaction with mercury
- Mercury flow approx. 23 L/s
- Local pressure from proton beam pulse can reach almost 6,000 psi
- Temperature rise from a 1.4 MW beam causes 10^7 K/s temperature rise
- Cryogenic Test Facility produces useable liquid helium bath at 2.1 K (-456°F)
- Niobium has a superconducting transition critical temperature of 9.2 K

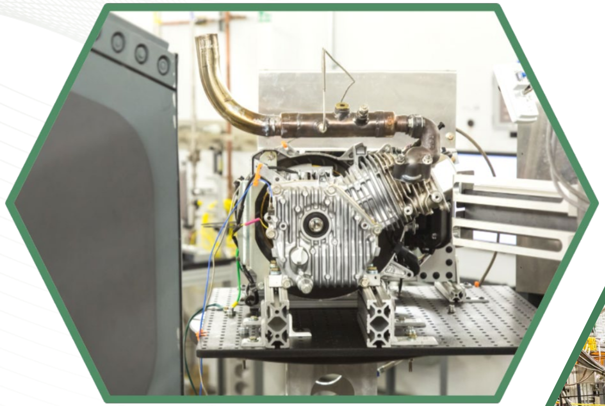
Bare Niobium Cavity

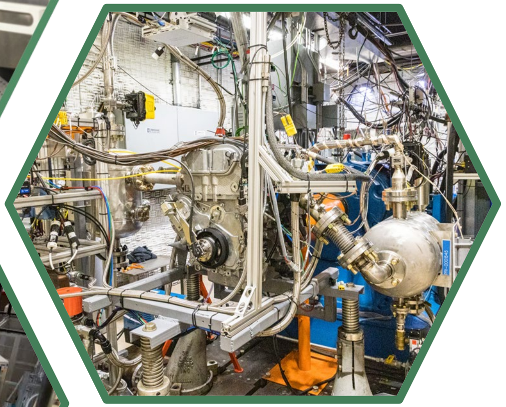


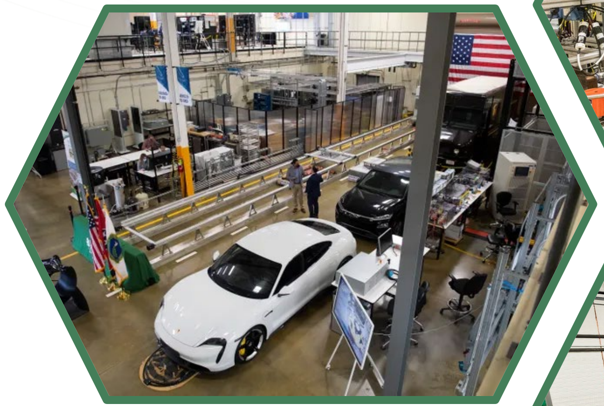
SNS makes the Guinness Book of World Records as the world's most powerful pulsed neutron source, producing 4.8 x 10e16 neutrons per second.

Every time the SNS ramps up, it will set a new neutron production standard.

Transportation & Grid Research







Wireless charging

Vehicle Systems Integration

Neutrons

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Additive Manufacturing

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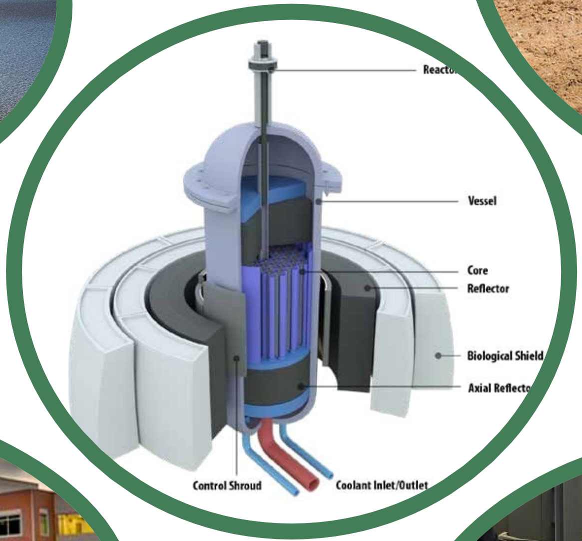
Additive Manufacturing



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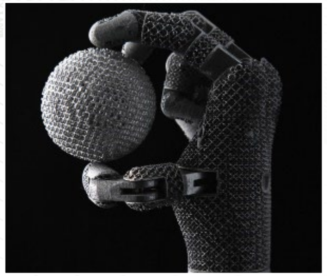
There are a lot of different technologies

Research in a Wide Range of AM Technologies

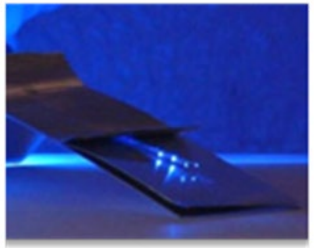
Electron Beam Melting



- Developing in-situ characterization, feedback, and control
- Heated powder bed
- Expanding range of materials (Ti64, CoCr, 625, 718)
- Precision melting of powder materials

CAD TO METAL® Arcam AB®

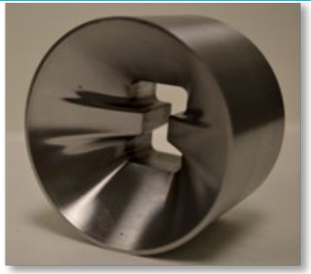
Ultrasonic Additive Manufacturing



- Simultaneous additive and subtractive process for manufacturing complex geometries
- Solid-state process allows embedding of optical fibers and sensors

FABRISONIC

Laser Metal Deposition

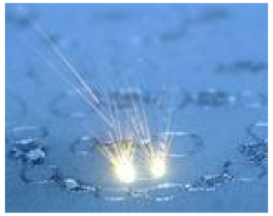


- Site-specific material addition
- Application of advanced coating materials for corrosion and wear-resistance
- Repair of dies, turbines, etc.

DM3D

BeAM BE ADDITIVE MANUFACTURING

Selective Laser Melting



- Unheated powder bed
- Wide range of material choices (316L, 17-4PH, H13, Al, Ti, 718, 625)
- Precision melting of metal powders
- Up to 630 x 400 x 500mm build volume

RENISHAW

SLM Solutions GmbH

AddUp

CONCEPTLASER

Metal Binder Jetting

- Metal matrix composites and sintered materials including:
- Stainless steel + bronze
- Tungsten + titanium
- Ceramics + sand
- Large build volumes (10 x 10 x 16in)
- Fast build times (30 sec/layer)

sinto 3DCERAM Global Advanced Ceramics

ExOne DIGITAL PART MATERIALIZATION

ADMATEC

Large-Scale Welding

- Open-air environment
- MIG welding arm with 6 DOF and 2 rotational degrees
- Print size not restricted
- Uses low-cost welding torches and wire
- CAD-to-path functionality

LINCOLN ELECTRIC

GKN

Hybrid Manufacturing

- Net shape manufacturing
- 5-Axis and more
- Laser wire, laser powder
- Direct manufacturing and repair.

Mazak

DMG MORI

OKUMA

Hot Isostatic Press

- First rapid-quench HIP in America
- 180mm diameter
- Can reach pressures of 25,000psi
- Cooling rates of 3000C/min when cooled from 3000C
- Can HIP and heat treatment in same cycle

Quintus TECHNOLOGIES

Large-Scale Polymer Deposition

- Deposits up to 1000lbs. of pellet feedstock material per hour
- Build volume up to 20' long x 6' wide x 8' tall
- Printed >37 different polymers and composites
- Dual material capabilities

CINCINNATI

3DP 3D PLATFORM

Ingersoll Large-Scale Polymer Deposition

- Under development
- Will have 46' x 23' x 10' build volume
- Target deposition rate of 1000 lbs./hr.
- Will be 10x larger and faster than previous commercial systems

INGERSOLL Machine Tools

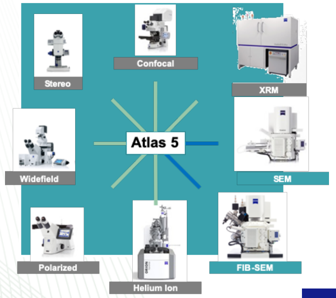
Thermoset Dual Material Extrusion

- Capable of depositing 300mL/minute
- Can control material properties and speed on the fly
- Cross-linking between layers
- 2-part resin

PPG

MVP MAGNUM VENUS PRODUCTS

Characterization



- X-Ray, CT, FIB
- Full suite of characterization from powder to part

ZEISS

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3-D Printed Shelby Cobra

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Hydraulic hand

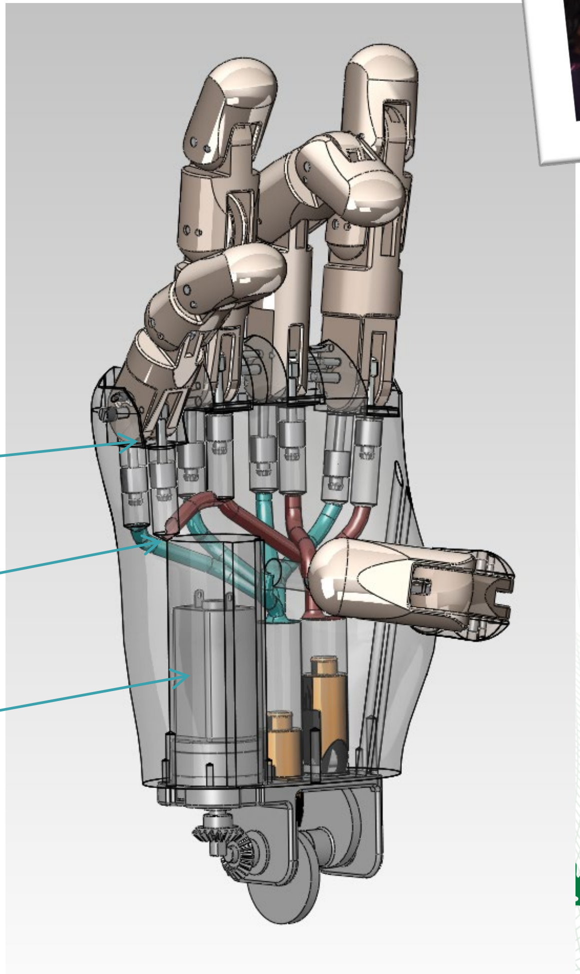
- Additive processes enable integrated pump, fluid passages and pistons into a structure with mesh for weight reduction
- Titanium hand made using E-beam fusion (operating pressure 3000 psi)

Solid palm weighing 857 grams.
Meshed palm weighing 178 grams

Pistons integrated into structure

Curved fluid passages

Integrated motor and pump



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World-Class Science

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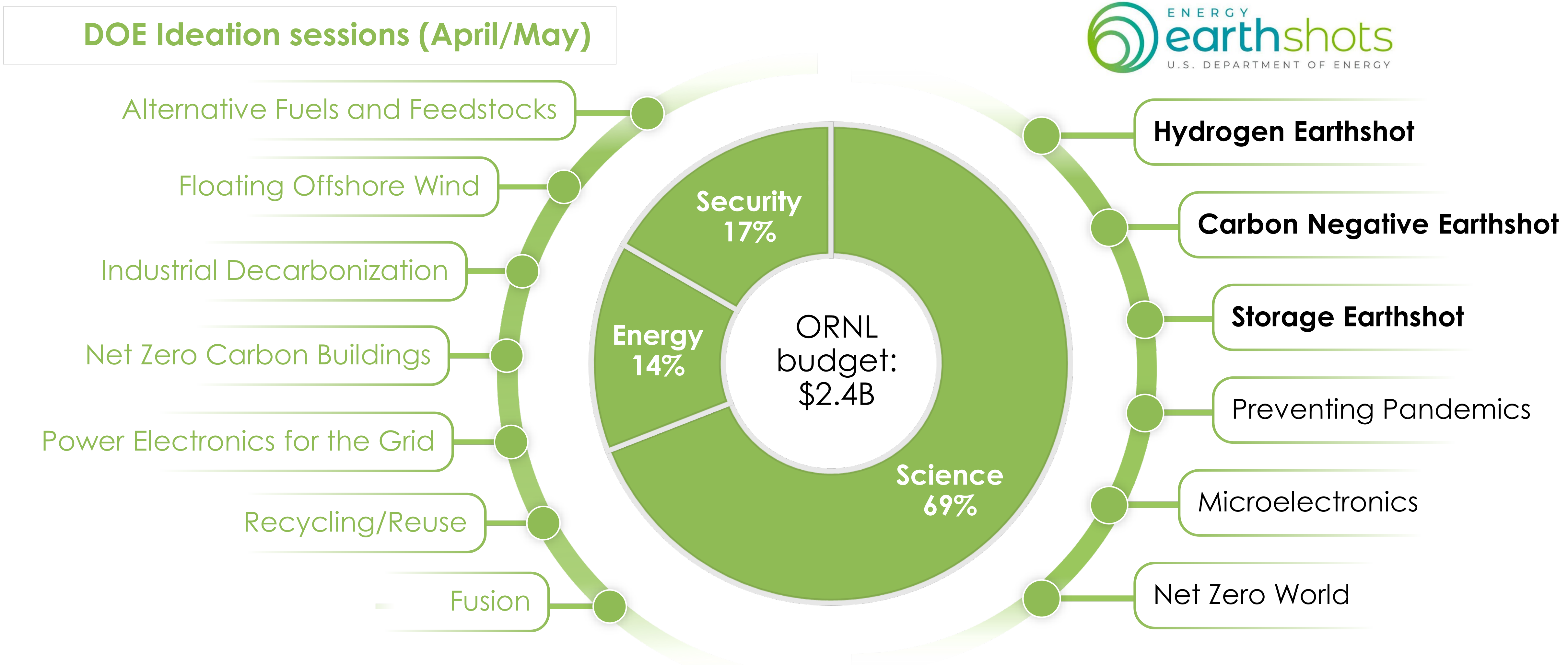
DOE investments at ORNL enable solutions to the most compelling challenges of our time



Questions??