OAK RIDGE National Laboratory

Oak Ridge National Laboratory Big Science, Big Opportunities

Thomas Zacharia
Laboratory Director

American Nuclear Society Young Members Group
Spotlight on ORNL
August 12, 2020

ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Our vision for ORNL: World's premier research institution

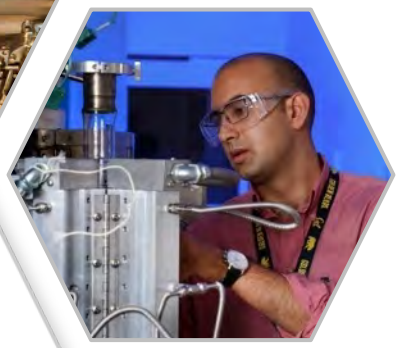
Focus on the most difficult problems

Conduct world-leading research

Ensure the nation's energy future

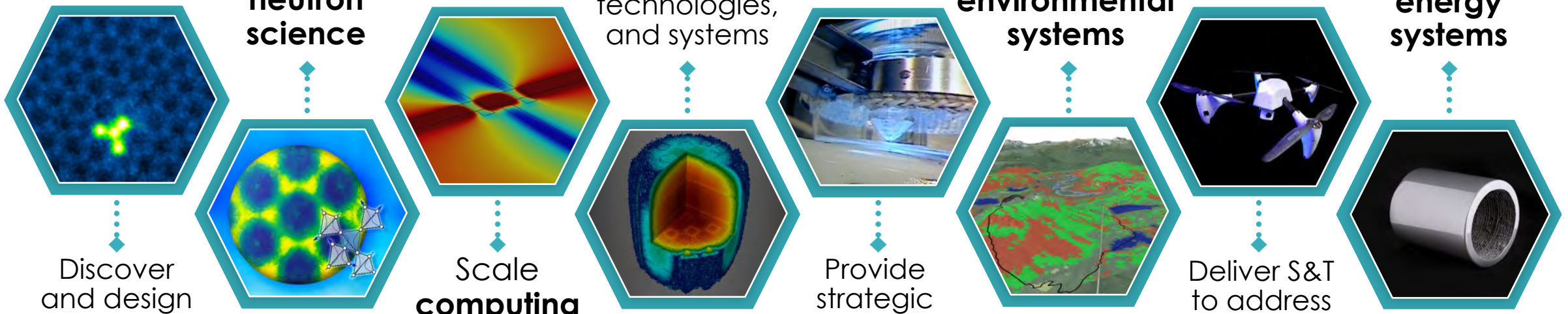
Relentlessly pursue institutional effectiveness

Strengthen national security



Deliver innovative break-throughs

ORNL's major science and technology initiatives



Discover and design next-generation **materials and chemical processes** for energy

Advance the impact and application of **neutron science**

Scale **computing and data analytics** to exascale and beyond for energy

Achieve breakthroughs in **nuclear** science, technologies, and systems

Provide strategic capabilities in **isotope R&D and production**

Understand complexity in **biological and environmental systems**

Deliver S&T to address pressing **national security** challenges

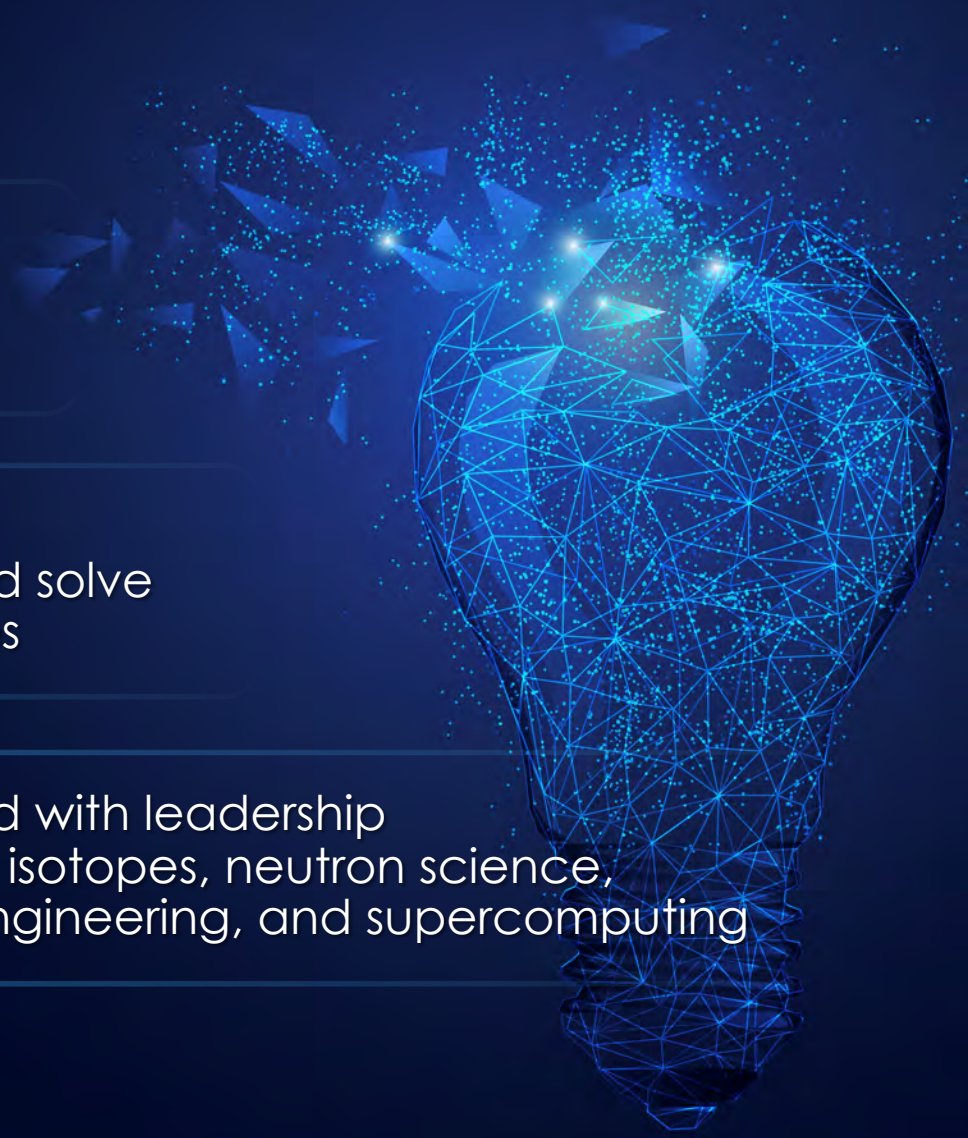
Deliver transformational R&D on integrated **energy systems**

Reimagining ORNL

ORNL was created to help win a war and then focused on changing the world

We have always adapted to meet national needs and solve the most difficult challenges

Today, we are entrusted with leadership in advanced materials, isotopes, neutron science, nuclear science and engineering, and supercomputing



Reimagining our science, structure, and goals has always been key to our success

Preparing for the next 20 years

Creating and deploying diverse high-quality teams to solve compelling national and global problems

Developing and exploiting world-leading facilities to deliver cutting-edge science and technology breakthroughs

Building and leveraging regional and national networks to accelerate innovation and foster economic growth

Engaging with universities and industry to train future scientists and engineers

OAK RIDGE National Laboratory

Oak Ridge National Laboratory Nuclear Innovation: Past, Present & Future

Alan Icenhour

Associate Laboratory Director

Nuclear Science and Engineering

August 12, 2020

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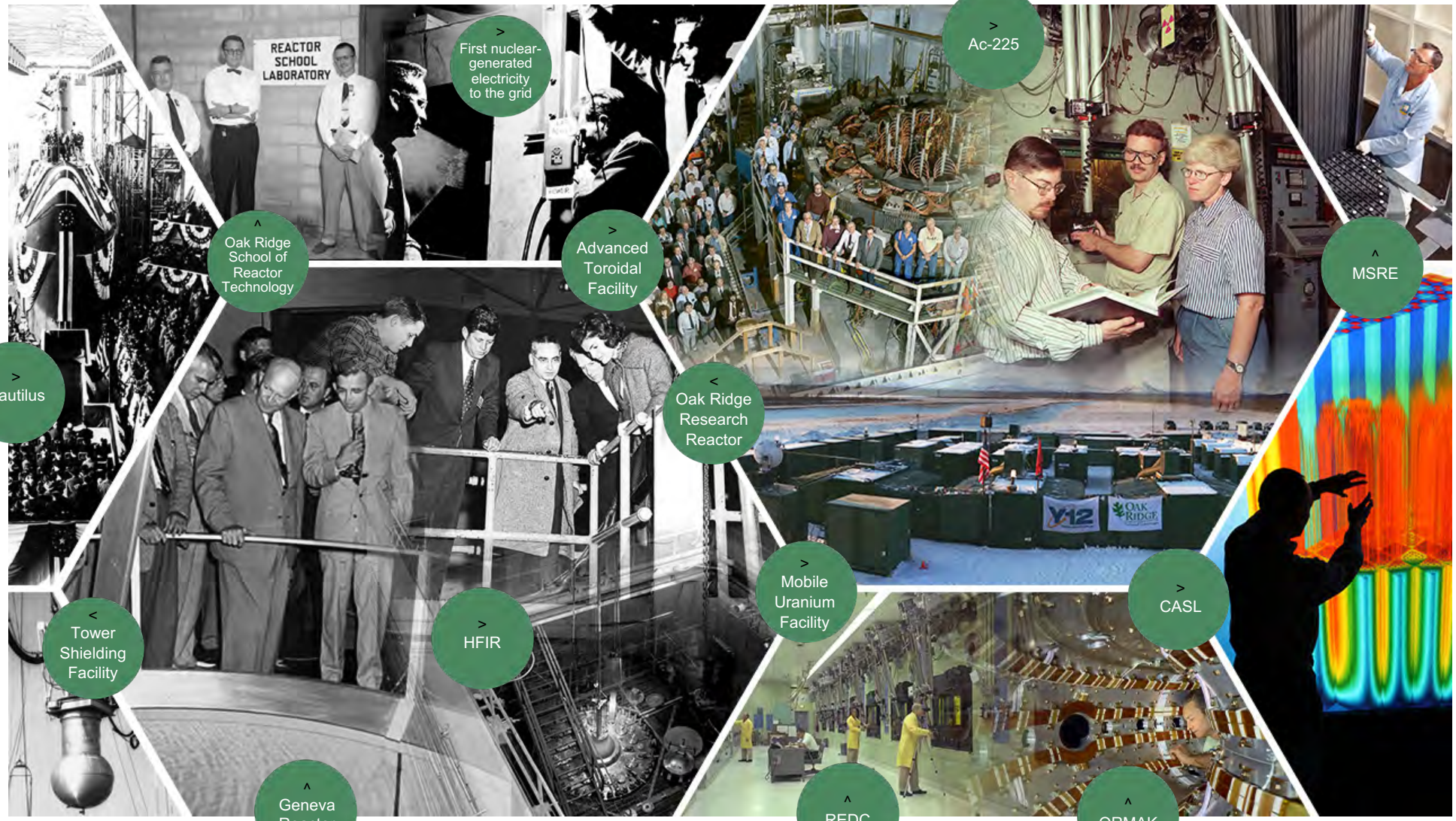
The historic beginnings of ORNL

The Graphite Reactor: A solid foundation and true legacy

OAK RIDGE National Laboratory

Expanding nuclear impact through the decades



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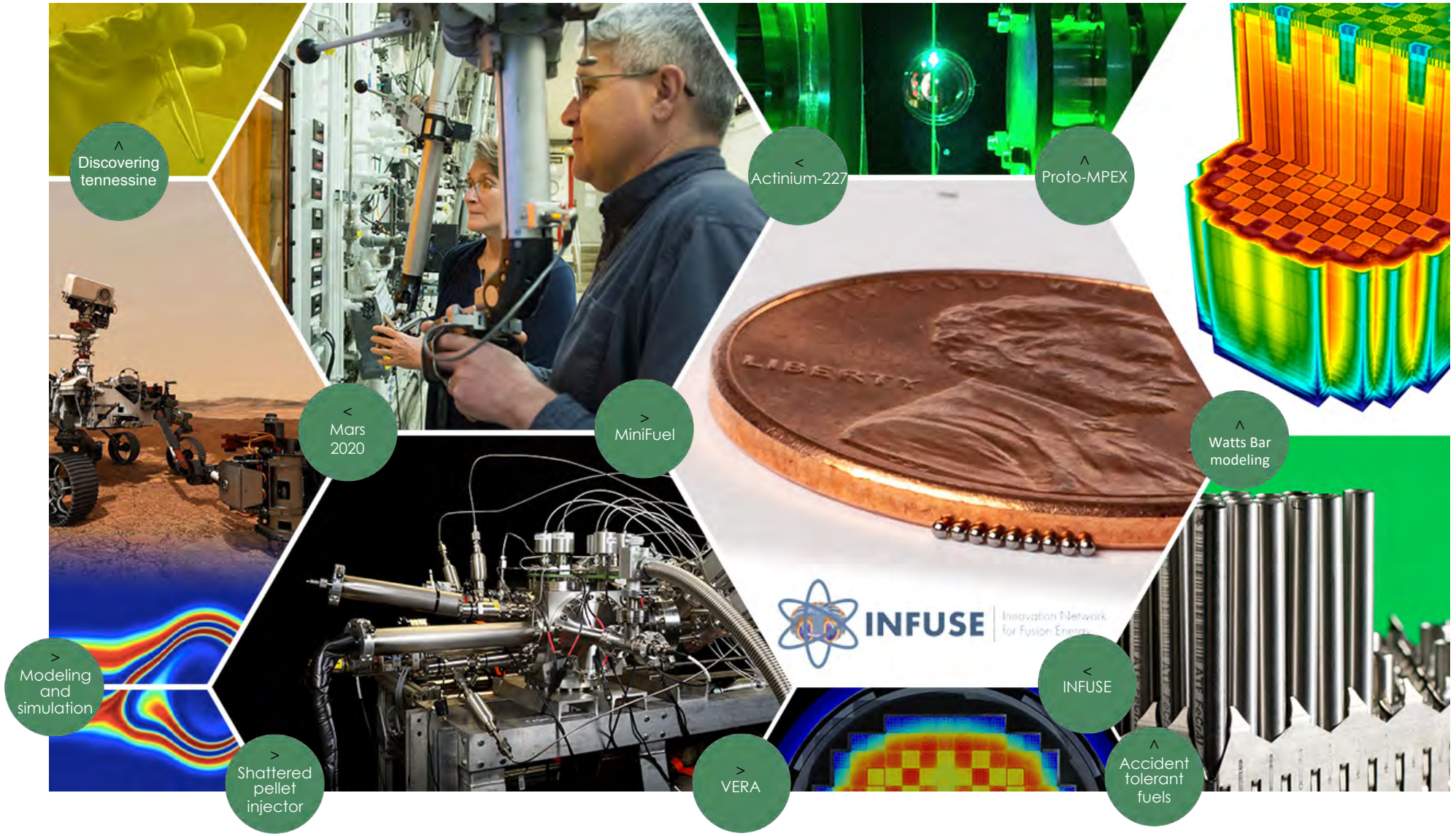
Today's innovation in nuclear science and technology



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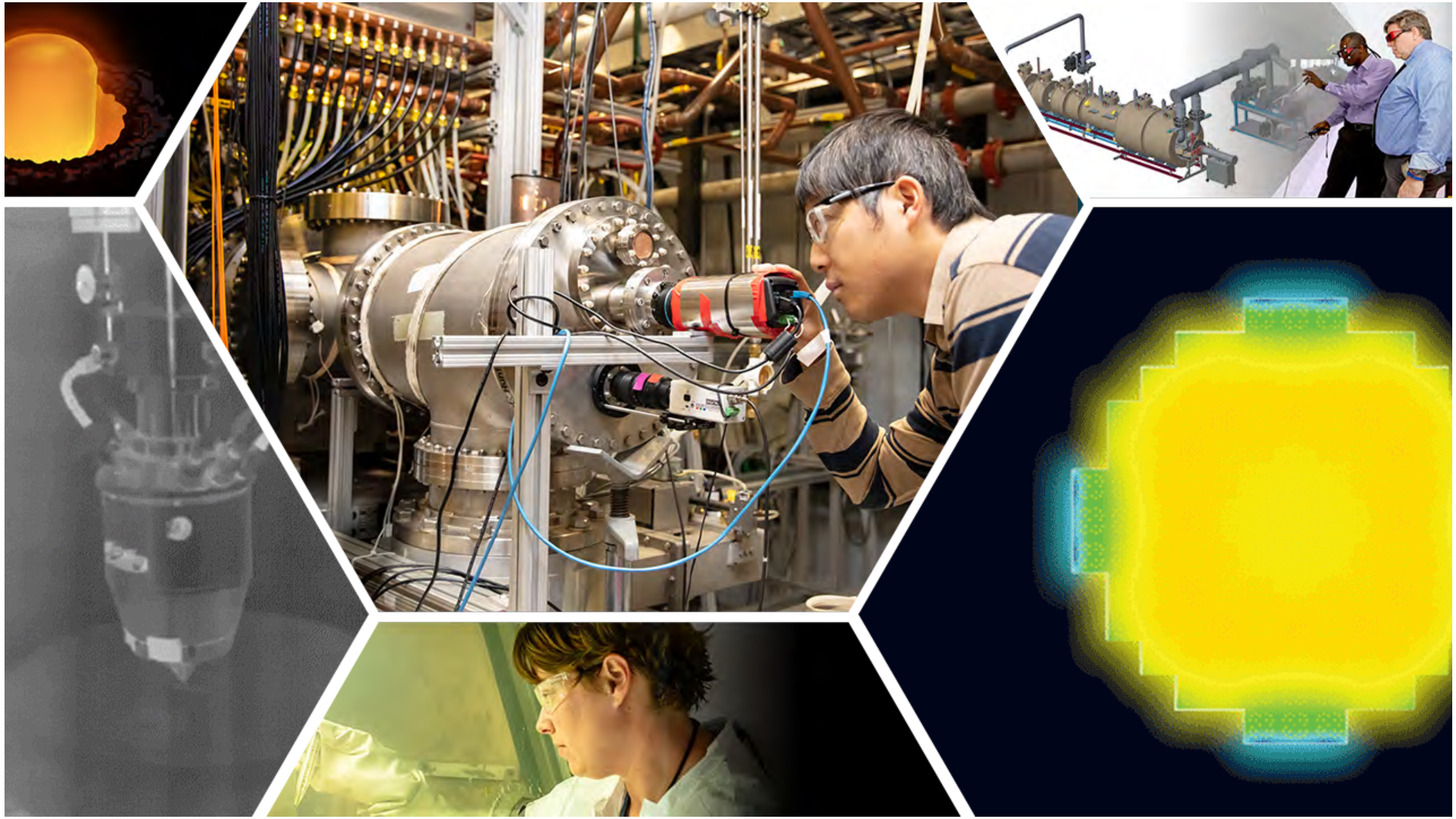
Where we are headed



OAK RIDGE National Laboratory

ANS Spotlight on Oak Ridge National Laboratory

Rose Montgomery,
Sr. Research Staff &
Group Leader, Used Fuel Systems

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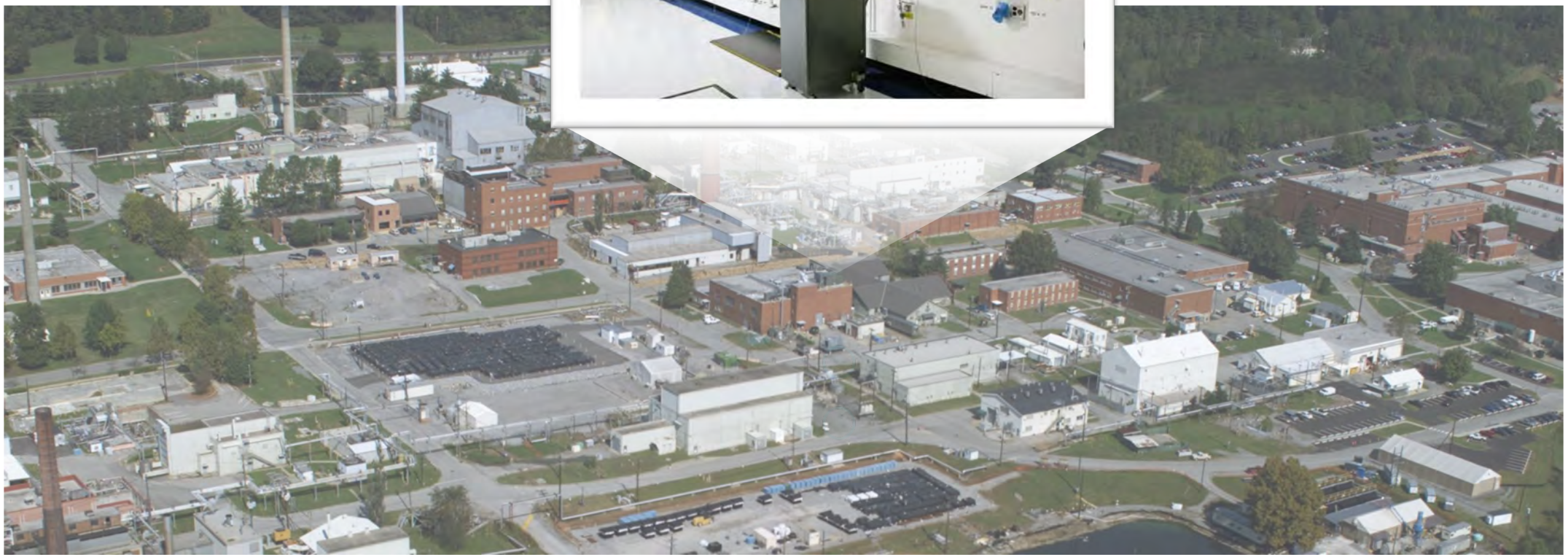
Used Nuclear Fuel Research Snapshots

West end of the ORNL Main Campus

Used Nuclear Fuel Research Snapshots

Irradiated Fuels Examination Laboratory

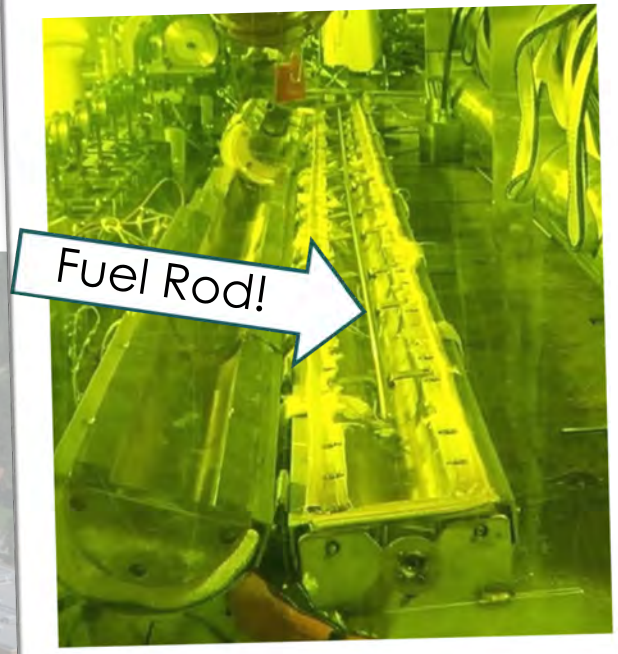


West end of the ORNL Main Campus

Used Nuclear Fuel Research Snapshots

Irradiated Fuels Examination Laboratory

Full-length rod heat treatment oven capable of a variety of temperature profiles



West end of the ORNL Main Campus

Used Nuclear Fuel Research Snapshots

Irradiated Fuels Examination Laboratory

Full-length rod heat treatment oven capable of a variety of temperature profiles

Four-point bend test of 150mm long segment to measure bending modulus

Hear the rod breaking @NSED_ORNL

Used Nuclear Fuel Research Snapshots

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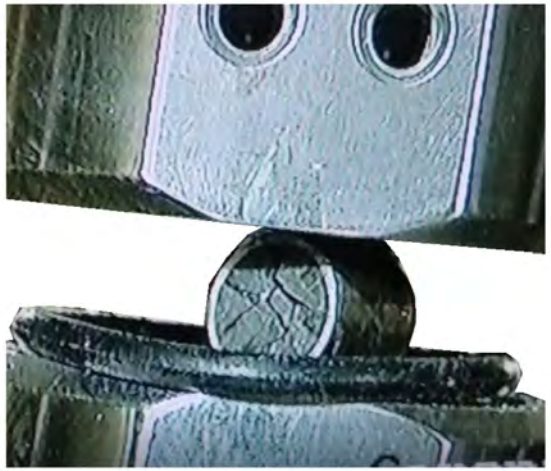

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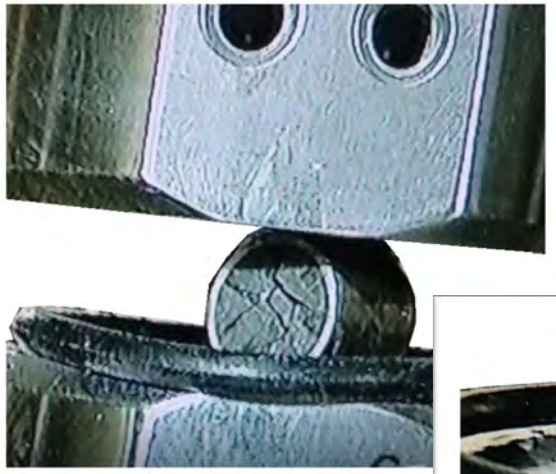

Ring compression test – Before and after

Hear the rod breaking @NSED_ORNL

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Used Nuclear Fuel Research Snapshots

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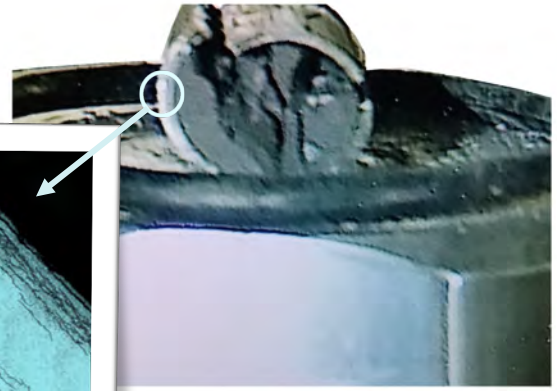
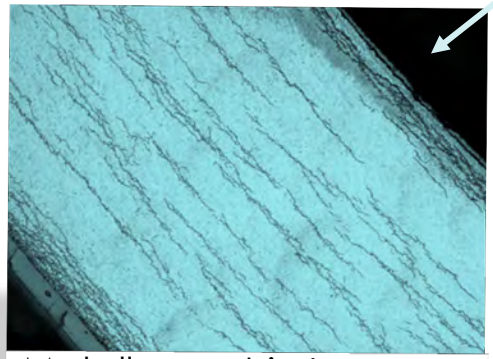




Metallographic image of cladding cross-section

Hear the rod breaking @NSED_ORNL

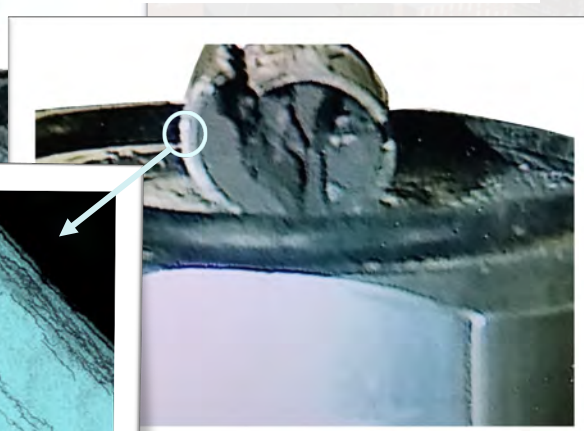
Four-point bend test of 150mm long segment to measure bending modulus

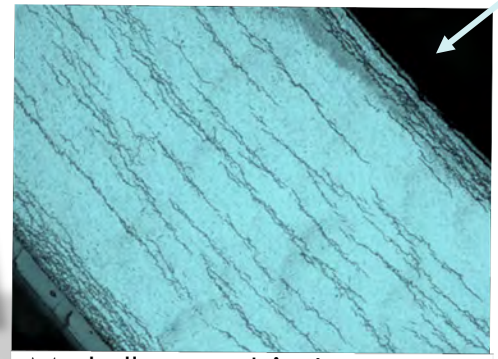
Used Nuclear Fuel Research Snapshots

Measuring spent fuel isotopes leaching into deionized water

Irradiated Fuels Examination Laboratory

Ring compression test – Before and after





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Women in Nuclear and Global Security (WINGS)

What it is:

- ORNL Directorate level employee resource group focused on issues that disproportionately impact women
- Operates under the umbrella of the ORNL Committee for Women

Mission:

- Support women in the NSED and NSSD through a welcoming social network
- Work with management and promote policies that improve morale, recruitment and retention of all employees at ORNL

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Activities:

- Coffee breaks and virtual socials
- Lunch & Learns
- New employee meetups
- Mentoring opportunities
- Discussion forums on selected topics

May Coffee Social "show & tell your favorite mug"

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Visit **wings.pages.ornl.gov**

Email us at **wingsboard@ornl.gov**

OAK RIDGE National Laboratory

Transformational Challenge Reactor

Kurt Terrani
Director, Transformational Challenge Reactor

August 12, 2020

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A transformational change in nuclear energy deployment in the nation is needed

Break the 40+ year hiatus in building a non-water advanced reactor in the US

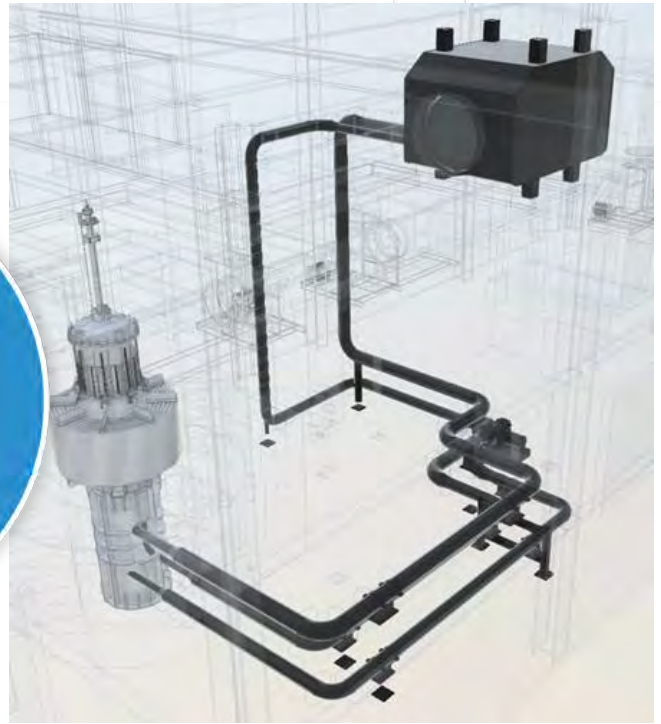
Leverage advances in manufacturing and computational sciences to deliver advanced nuclear technology at significantly reduced cost

Inform the modern regulatory framework for licensing of advanced reactors

Transfer knowledge base at the right TRL to industrial sector

First continuously operating reactor constructed in 9 months

First additively manufactured nuclear reactor core



Transformational Challenge Reactor:
3 MW high-temperature helium-gas-cooled reactor with a small AM core of < 0.5 m^3

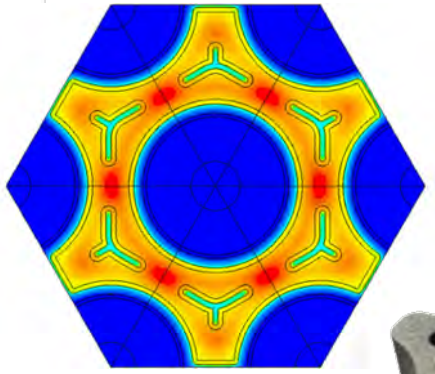
TCR is bringing to bear additive manufacturing (AM) and artificial intelligence (AI) to deliver a new approach

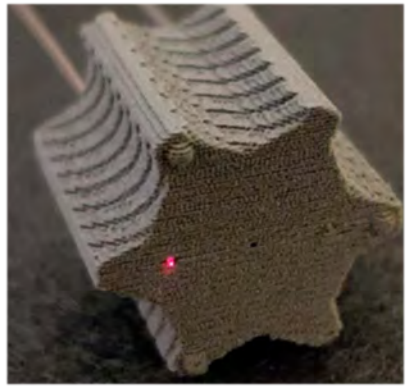
Using AI to navigate an unconstrained design space and realize superior performance

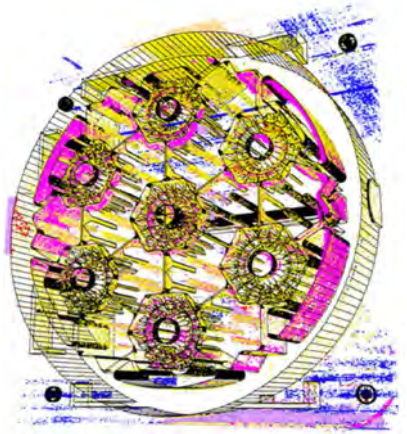
Leveraging AM to arrive at high-performance materials in complex geometries

Exploiting AM to incorporate integrated and distributed sensing in critical locations

Using AI to assess critical component quality using in situ manufacturing signatures

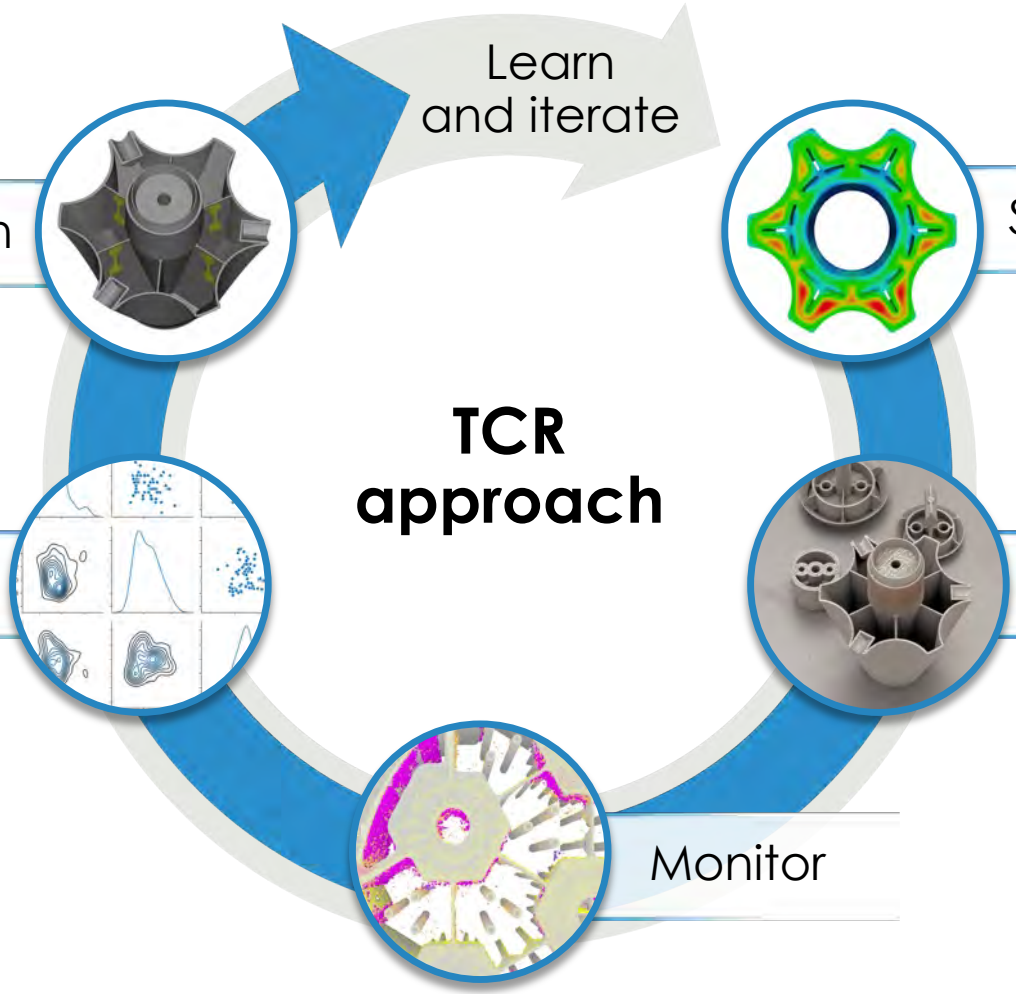






TCR is demonstrating that agile development can be applied to accelerate deployment

Agile approach breaks with traditional linear development models to exercise an iterative, dynamic development process



This approach lends itself to complex projects, in which a large, multidisciplinary team works closely to complete a product

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Advanced Modeling and Simulation for Fission Systems

Tara Pandya

Reactor and Nuclear Systems Division

August 12, 2020

ANS YMG ORNL Spotlight

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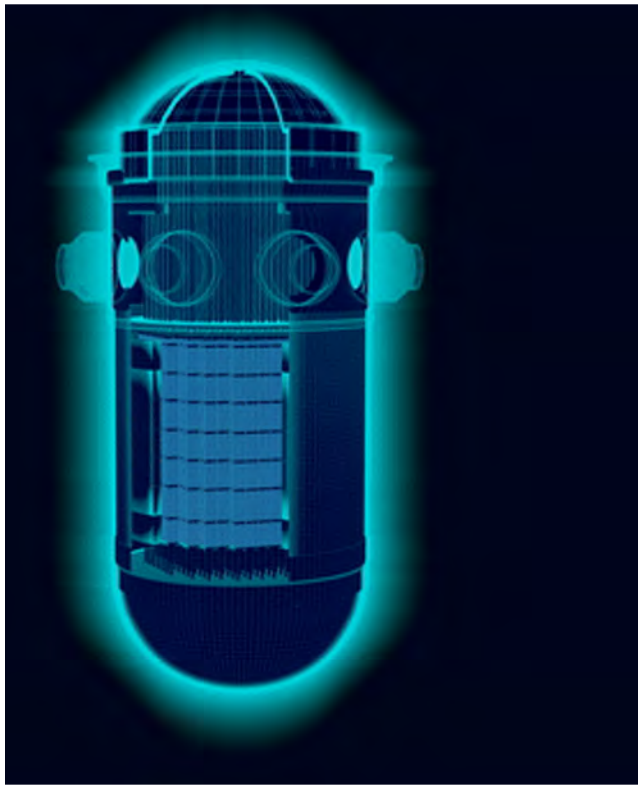
Overview of Mod-Sim Software

Leader in hybrid radiation transport methods

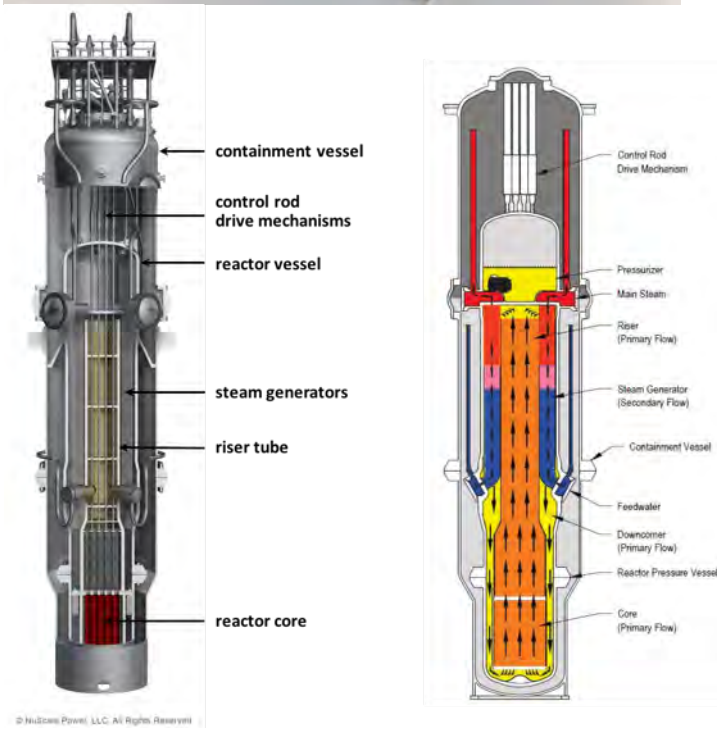
- **SCALE**
  - Comprehensive suite for nuclear safety analysis and design
  - > 15000 licenses in 61 countries
- **Exnihilo**
  - Massively parallel radiation transport code package (deterministic and Monte Carlo)
  - Integrated into SCALE, ADVANTG, and VERA
- **ADVANTG** – AutomateD VAriaNce reducTion Generator
  - Automates generation of space- and energy-dependent variance reduction parameters for MCNP simulations
  - Couples Exnihilo and MCNP
- **VERA** – Virtual Environment for Reactor Applications
  - High-fidelity simulation tool for reactor multiphysics analysis
  - 15 commercial licenses in process



courtesy of Michelle Lehman

Mod-Sim on Next-Generation HPC: **ExaSMR**

- Small modular nuclear reactors present significant simulation challenges
  - Small size invalidates existing low-order models
  - Natural circulation flow requires high-fidelity fluid flow simulation
- ExaSMR will couple most accurate available methods to perform "virtual experiment" simulations
  - Monte Carlo neutronics (Shift and OpenMC)
  - CFD with turbulence models (Nek5000)



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Contact Me: pandyatm@ornl.gov

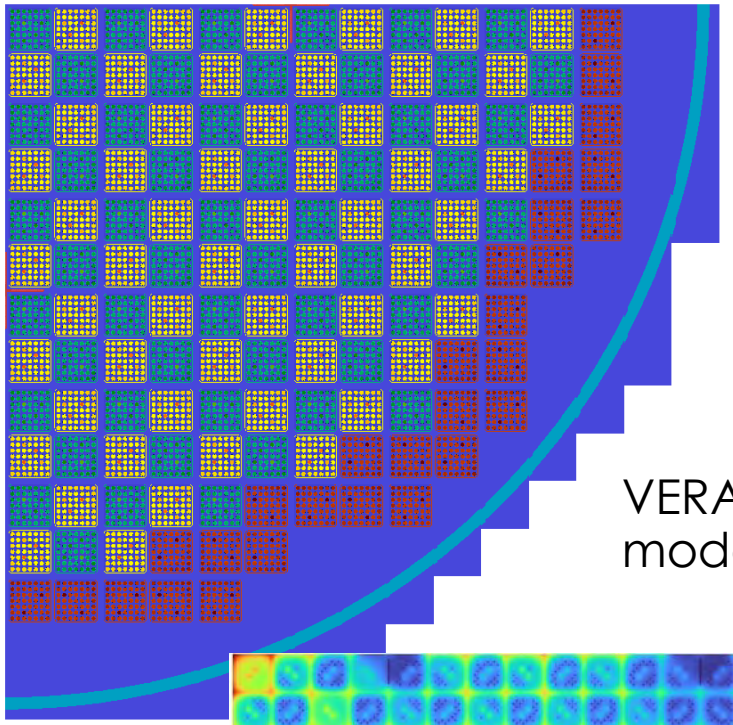
More information on ORNL Mod-Sim:

SCALE https://www.ornl.gov/scale

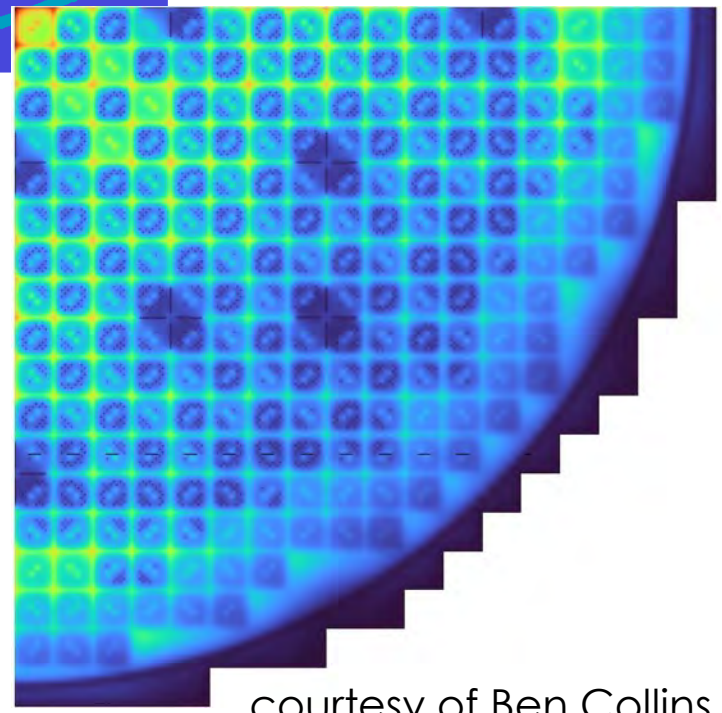
VERA https://vera.ornl.gov/

General

https://www.ornl.gov/content/modeling-and-simulation



VERA BWR model



courtesy of Ben Collins

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Extreme-Temperature Experiments in support of Molten Salt Reactor Development

N. Dianne Bull Ezell

Lou Qualls (MSR NTD)

David Holcomb

Jake McMurray (Chemistry PI)

This work is funded by the US Department of Energy's office of Nuclear Energy, Molten Salt Reactor (MSR) Campaign under the Advanced Reactor Technology (ART) program.

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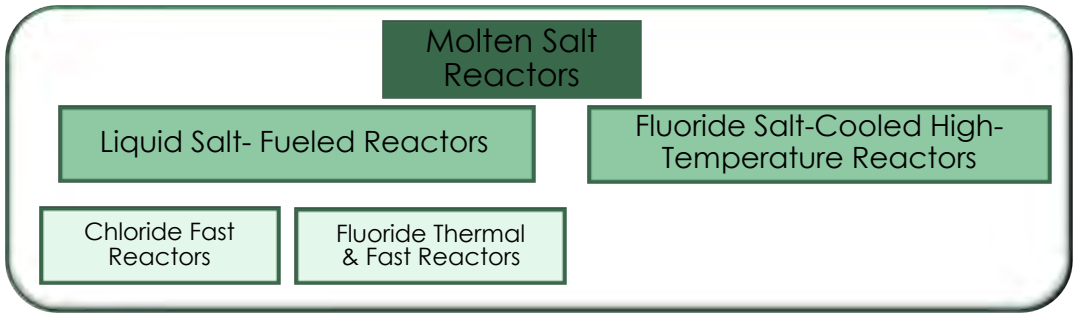
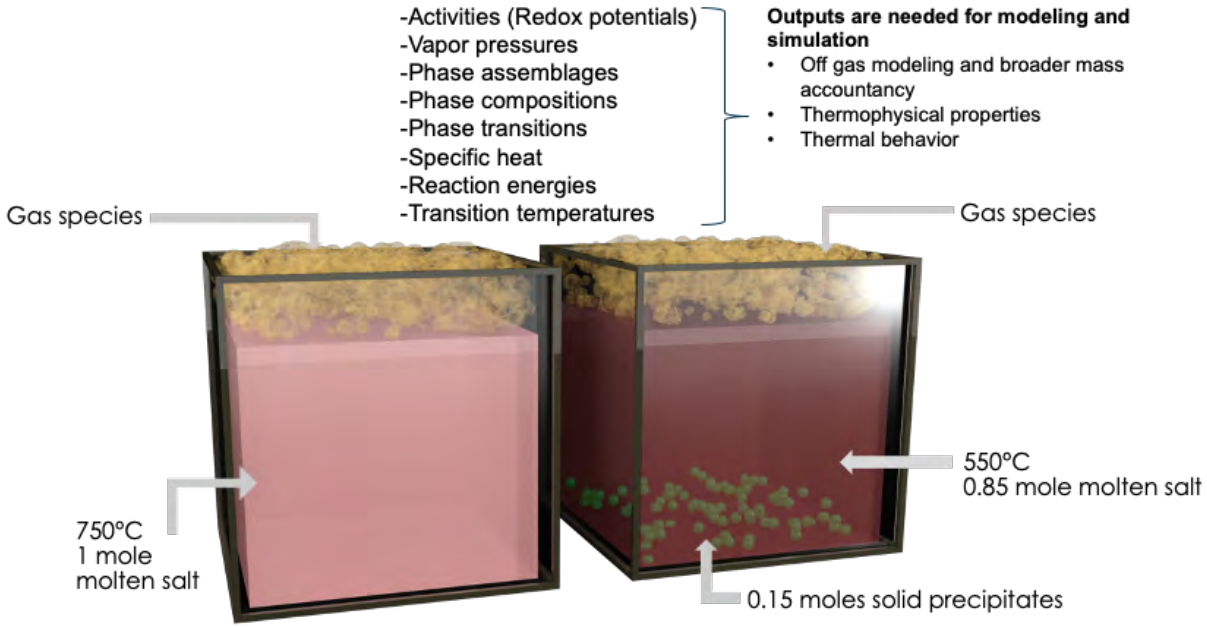
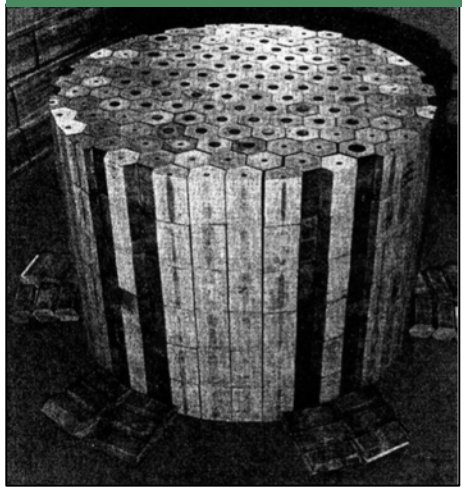
Molten Salt Reactors





Aircraft Nuclear Propulsion Program

ARE Core Assembly



- **Why salt for Gen IV Reactors?**
- High solubility for uranium, plutonium, and thorium
- Stable thermodynamically
- Excellent heat transfer
- Very high boiling points
- Low vapor pressure
- Compatible with nickel-based structural alloys and graphite
- Compatible with chemical processing

MSRE Core Assembly

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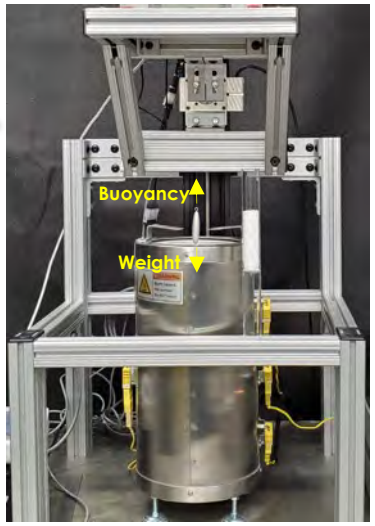
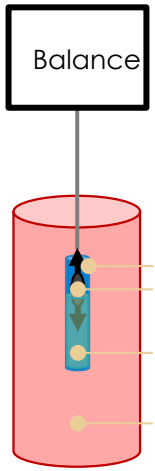
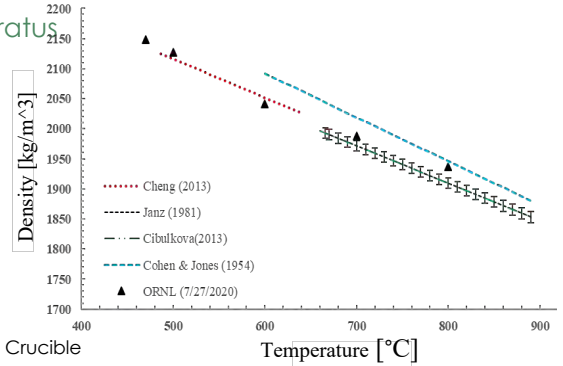
Thermophysical Characterizations

Density

Archimedes Bob Density Measurement Apparatus

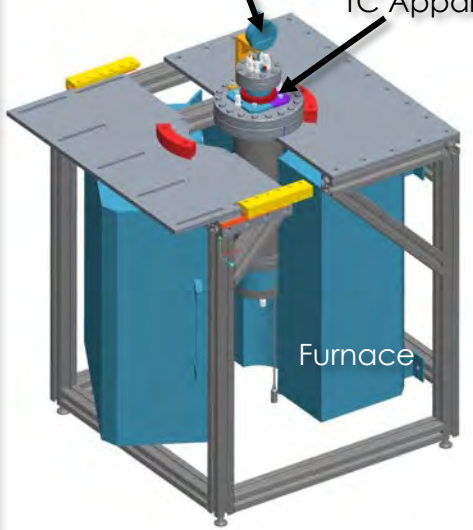


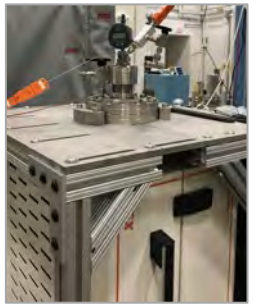




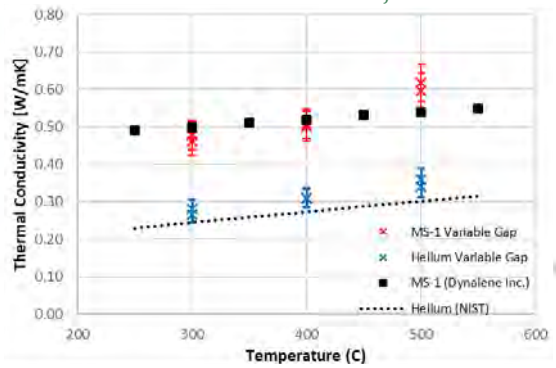
Alternate methods:
- Optical dilatometry
- X-ray dilatometry

Thermal Conductivity





$$\text{Thermal Resistance} = \frac{\text{Change in temperature across gap}}{\text{heat flux}}$$



Viscosity

X-Ray Falling Ball

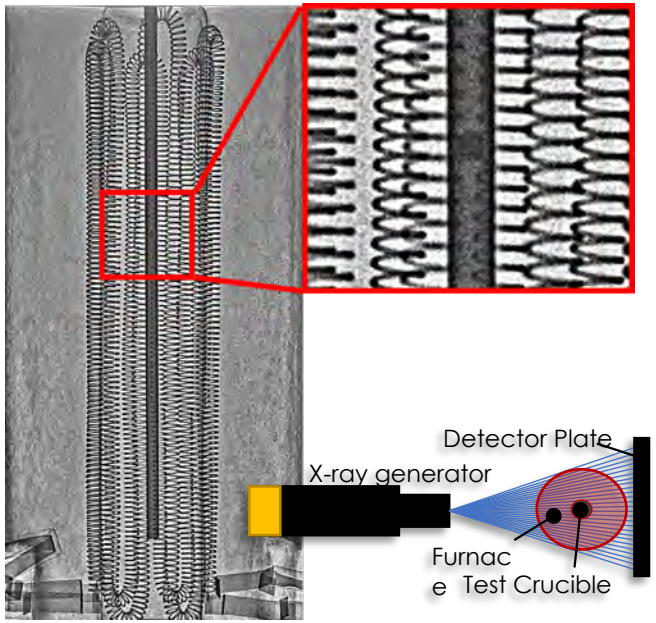
Equivalent to falling-ball optical measurements

Ratio of the differences between densities

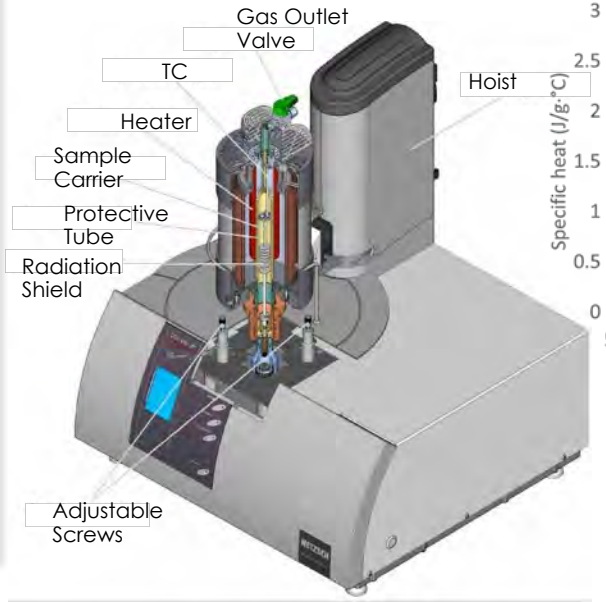
$$\frac{\eta_{salt}}{\eta_{H_2O}} = \frac{\rho_{ball}-\rho_{salt}}{\rho_{ball}-\rho_{H_2O}} \frac{V_{salt}}{V_{H_2O}}$$

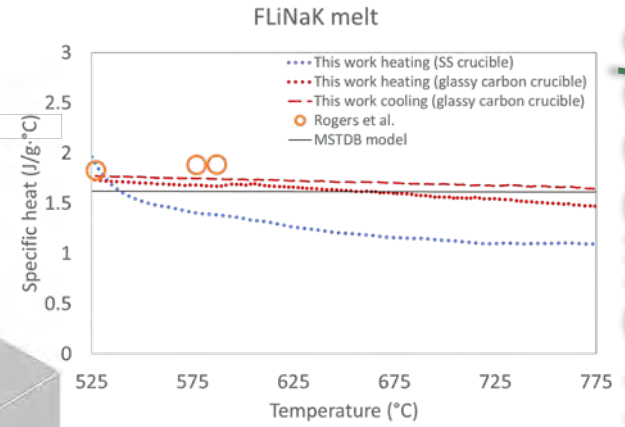
Ratio of viscosities

Ratio of terminal velocities



Specific Heat





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ORNL and superheavy element discovery: Tennessine (Ts) and beyond (Z=119, 120)

Clarice Phelps

Medical, Industrial, and Research Isotopes Group

Isotope and Fuel Cycle Technology Division

Oak Ridge National Laboratory

August 2020

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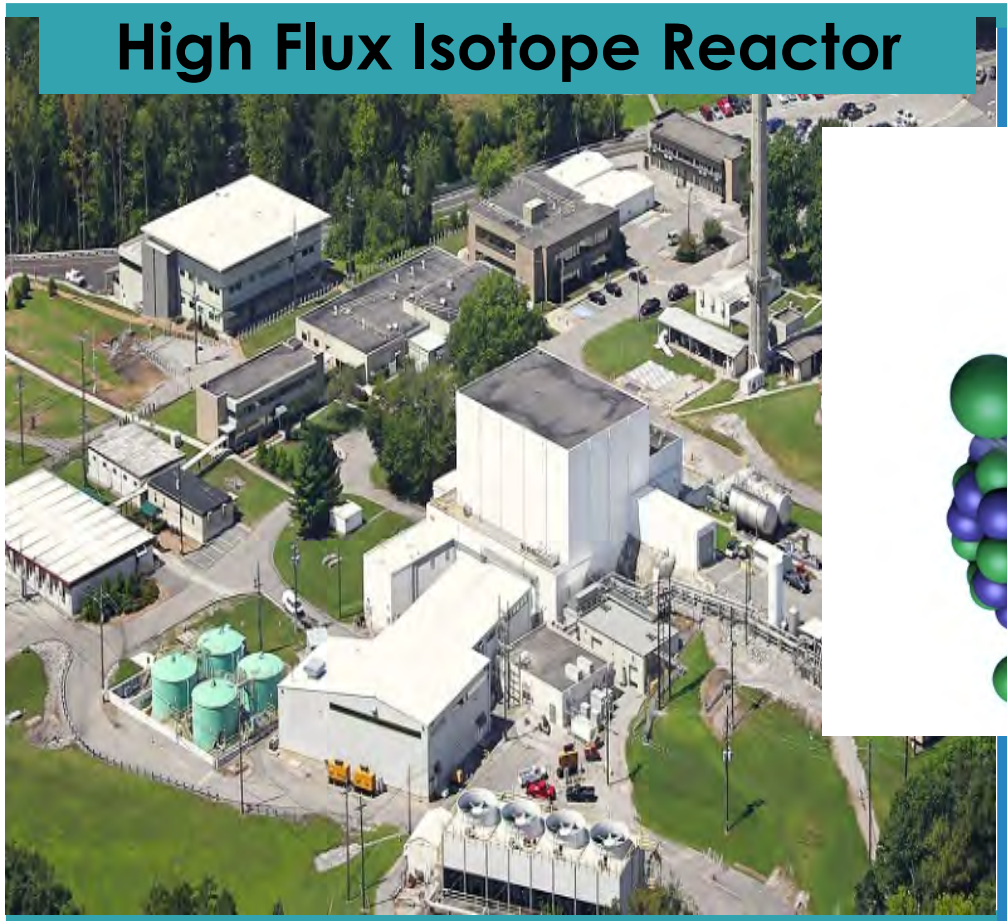
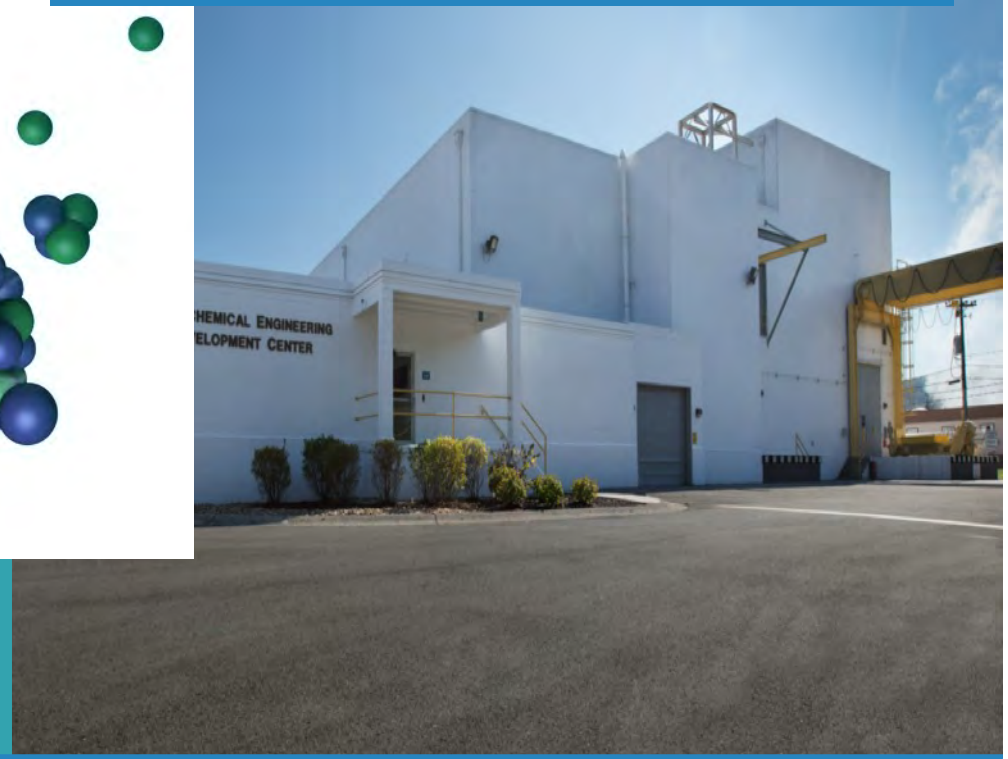
ORNL's globally unique nuclear facilities enable production and separation of rare isotopes as well as groundbreaking scientific discoveries towards superheavy element (SHE) discovery.

High Flux Isotope Reactor



Radiochemical Engineering Development Center



International collaboration was essential to produce a few atoms of element 117

Bk-249 production	Produced by 250-day neutron irradiation at ORNL's High Flux Isotope Reactor (HFIR)
Chemical separation and purification	Bk separated from bulk Cf-252 material at the Radiochemical Engineering Development Center (REDC) at ORNL. ~22 mg recovered
Preparation of Bk-249 target foils	Specially produced at Dmitrovgrad to survive bombardment from Ca-48 beam
Target irradiation with Ca-48	150 days continuous irradiation in the world's most intense Ca-48 beam at the Flerov Laboratory in Dubna
New elements added to periodic table	In November 2016, Tennessine (Ts) joined the periodic table along with Nh, Mc, and Og

HFIR/REDC reactor/ hot cell complex (ORNL)

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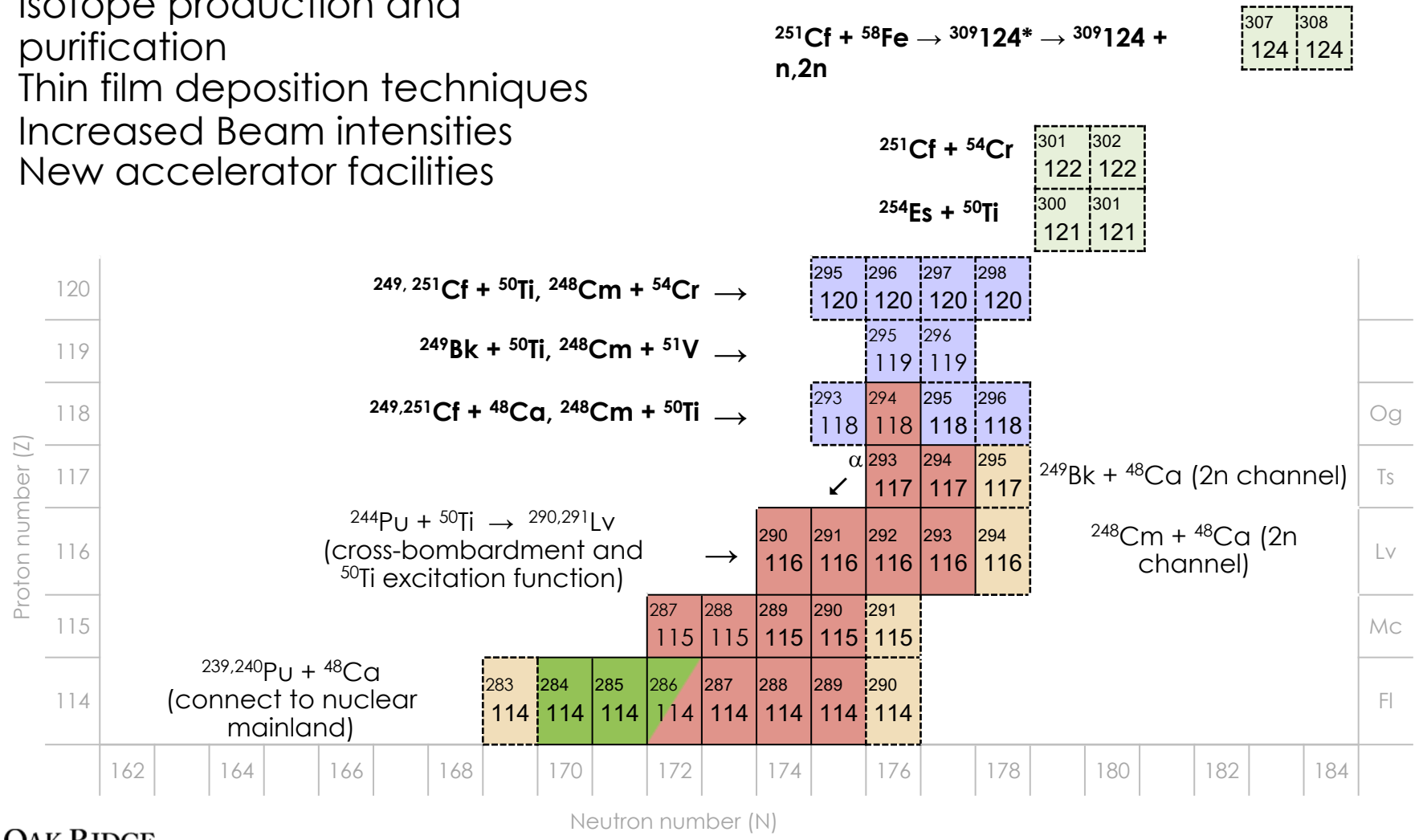
All aspects of Superheavy Element (SHE) research must be advanced to continue scientific discovery

- Isotope production and purification
- Thin film deposition techniques
- Increased Beam intensities
- New accelerator facilities



- To reach Z=119, 120, new actinide target materials and beams are needed, but are often rare and limited
- Cross sections of these new targets are increasingly smaller

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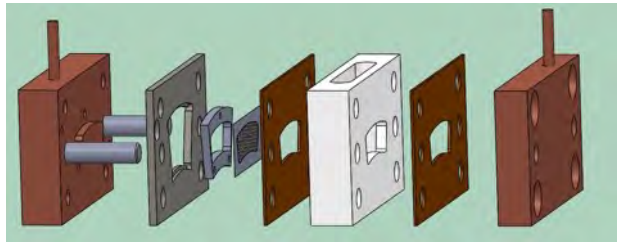
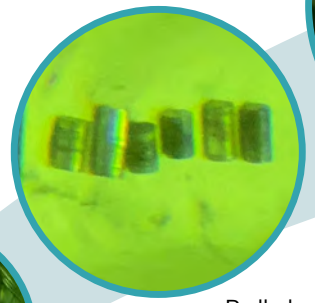
ORNL Scientists have purified 30-year-old Cf-252 sources for SHE research



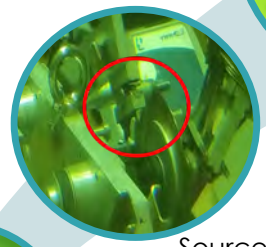
Electrodeposition unit assembly

Electrodeposition of Cf-251 for SHE research

Pellets dissolved to be purified for electrodeposition



Pellets retrieved



Sources opened with slow speed saw

Aged Cf-252 sources transferred to REDC

Target material isotopics	
^{249}Cf	48.1%
^{250}Cf	15.6%
^{251}Cf	36.3%
^{252}Cf	0.01%

~16mg of Cf was recovered

"…the ideal actinide target fabrication technique uses limited material efficiently, uses substrates that do not interfere with detecting the decay events of synthesized SHEs, produces target segments with reproducible characteristics, produces durable targets, and can be remotely performed."

J. B. Roberto, C. W. Alexander, R. A. Boll, J. D. Burns, J. G. Ezold, L. K. Felker, S. L. Hogle and K. P. Rykaczewski, "Actinide targets for the synthesis of super-heavy elements," *Nuclear Physics A,* vol. 944, pp. 99-116, 15 2 2015.

We are closer to reaching the island of stability through ongoing research and collaboration

The possibility of an "Island of Stability" of super-heavy elements with greatly increased lifetimes was originally postulated by Seaborg

When neutrons and protons completely fill the energy levels of a given nucleus, the nuclear binding is strongest, leading to longer lifetimes

Heaviest stable isotope (Pb-208) has closed nuclear shells for both protons (82) and neutrons (126)

Next "doubly magic" nucleus occurs around Z=114–126 and N=184, the presumed center of the "Island of Stability"

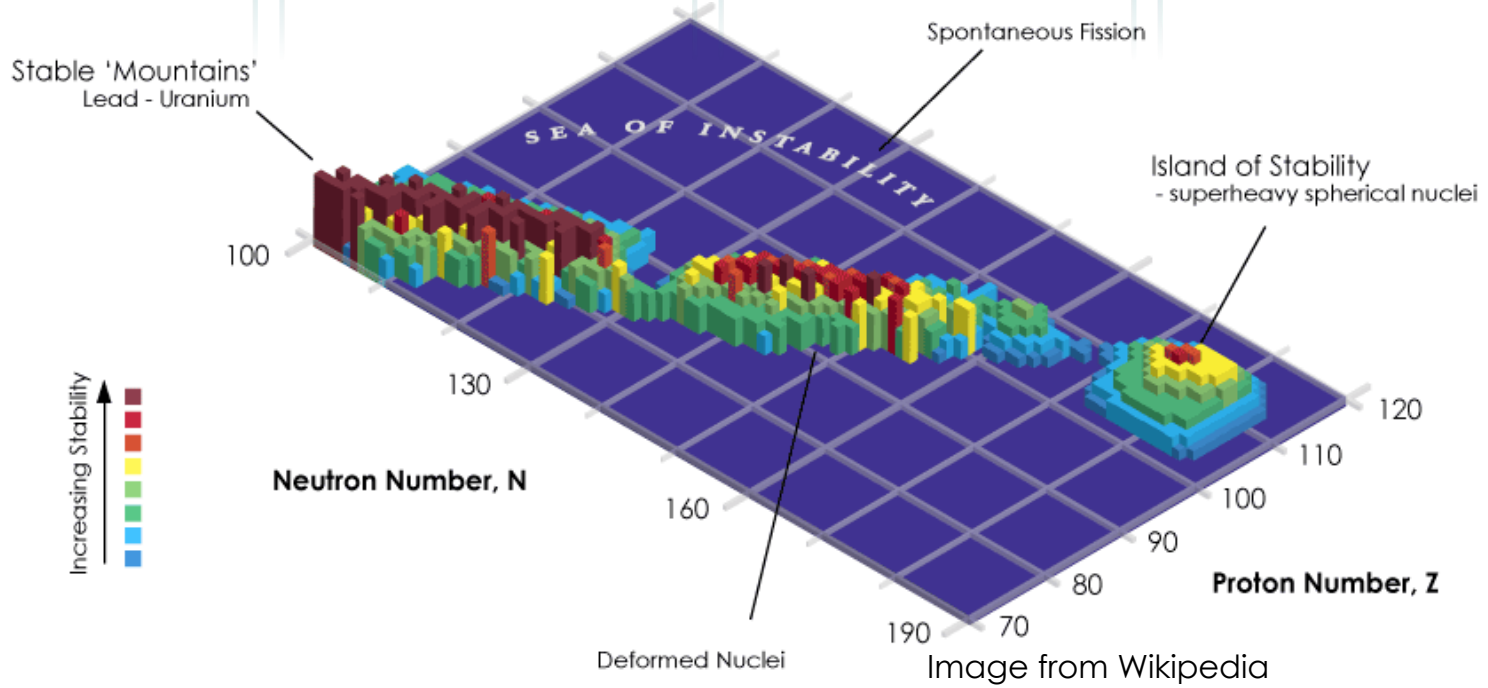


Image from Wikipedia

Acknowledgements

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- ORNL Radiochemical Engineering Development Center
- Collaborators: JINR, LLNL, Vanderbilt University, University of Tennessee- Knoxville

Questions?

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Enabling Fusion Power Using Radio Frequency (RF) Waves

Elijah H. Martin and Cornwall Lau

Fusion Energy Division, ORNL

Aug. 12th, 2020

ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

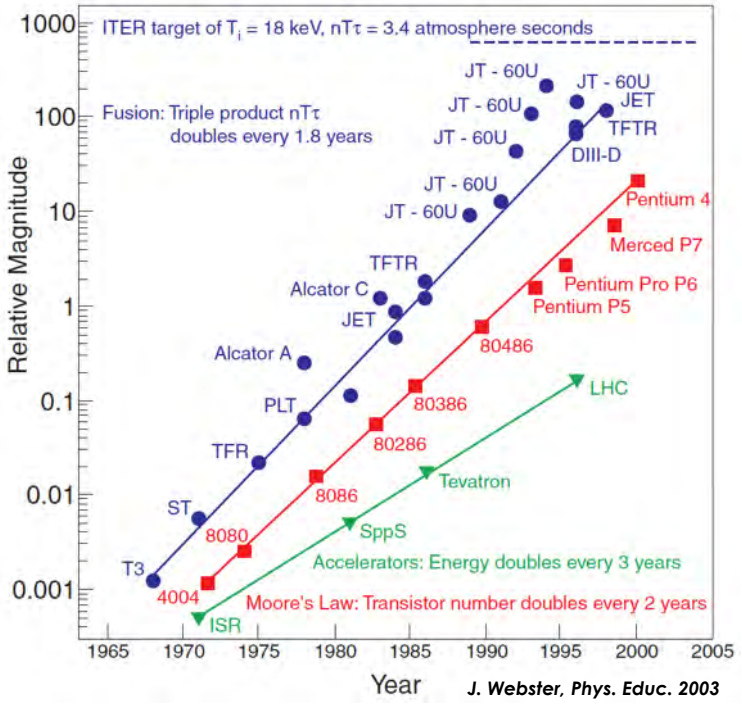
Fusion Research Is Transitioning To Prepare For A Reactor

Foundations → **Long Pulse** → **High Power**

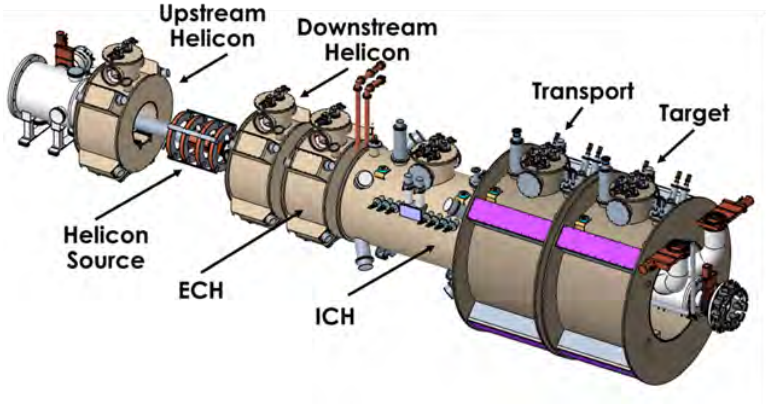
- Plasma Physics
- Predictive Capability

- Superconducting Magnets
- Non-inductive Plasma Current
- Advanced Materials

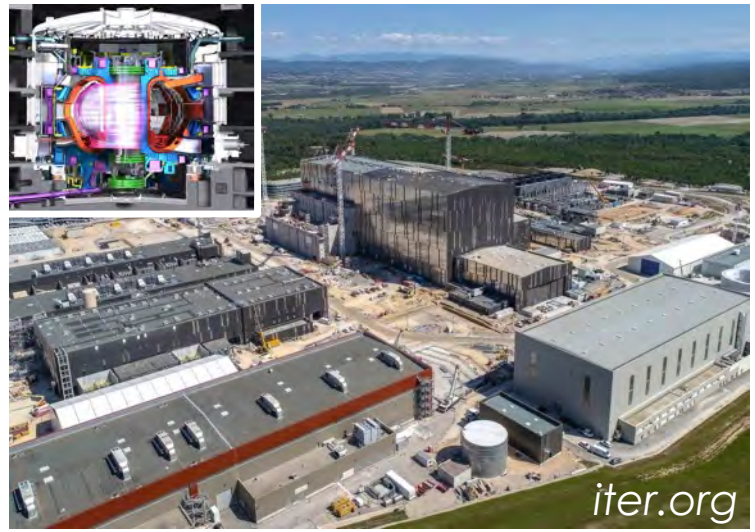
- Burning Plasma Physics
- Break-Even Demonstration
- Fuel Cycle



J. Webster, Phys. Educ. 2003



Material Plasma eXposure Experiment (MPEX) @ ORNL



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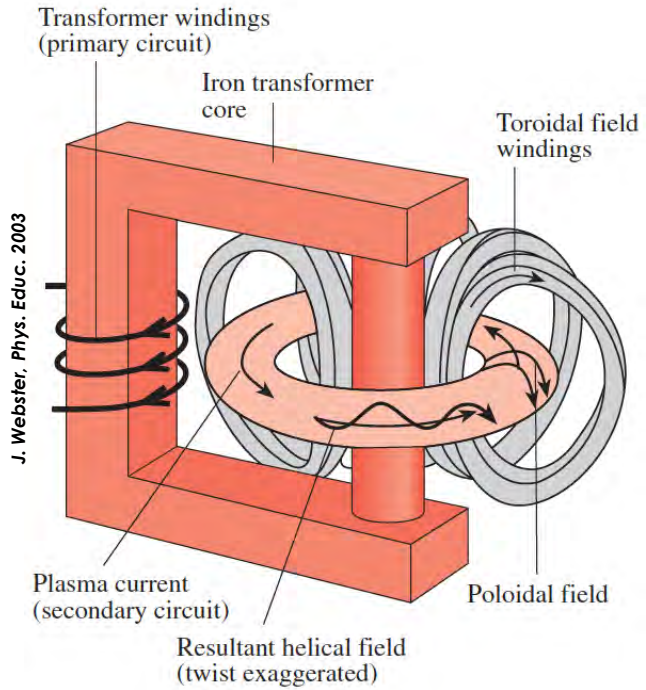
Non-Inductive Plasma Current Enables A Steady-State Reactor

- Plasma current is vital for **stability** and is typically produced using induction.

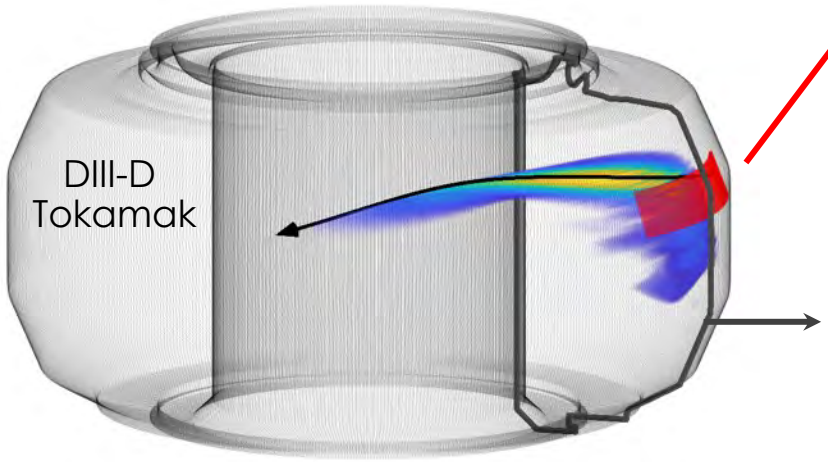


- An inductively driven plasma current can **only** support pulsed operations (ITER=6 to 10 min).

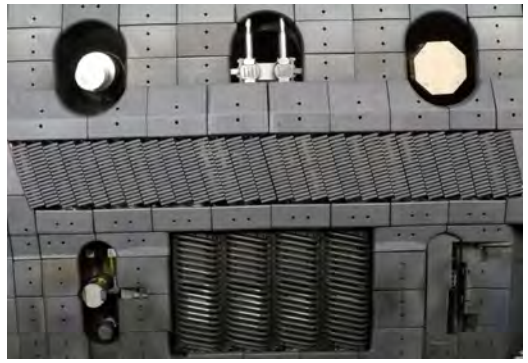
Radio Frequency (RF) Wave's Can Produce Plasma Current

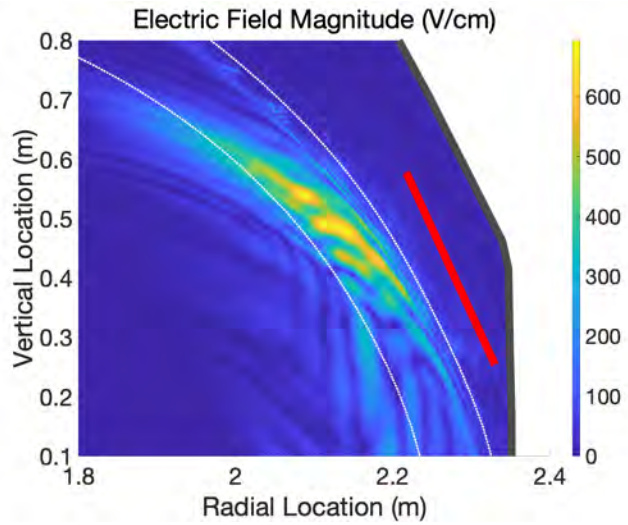
RF wave energy ⟹ *electron kinetic energy*

- Antennas are designed using modeling/simulation tools.



Helicon Antenna (Installed 2020)





- An experimental measurement of the RF wave's electric field is needed for optimization.

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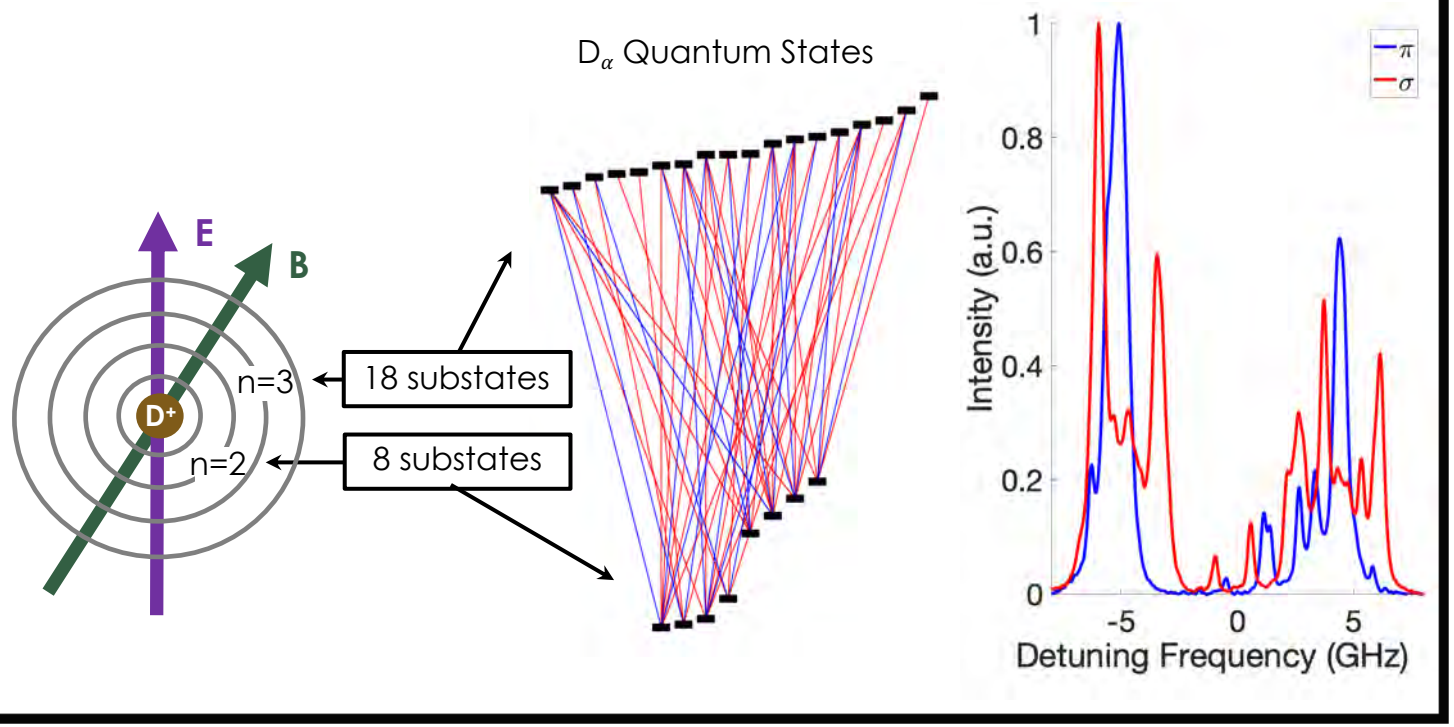
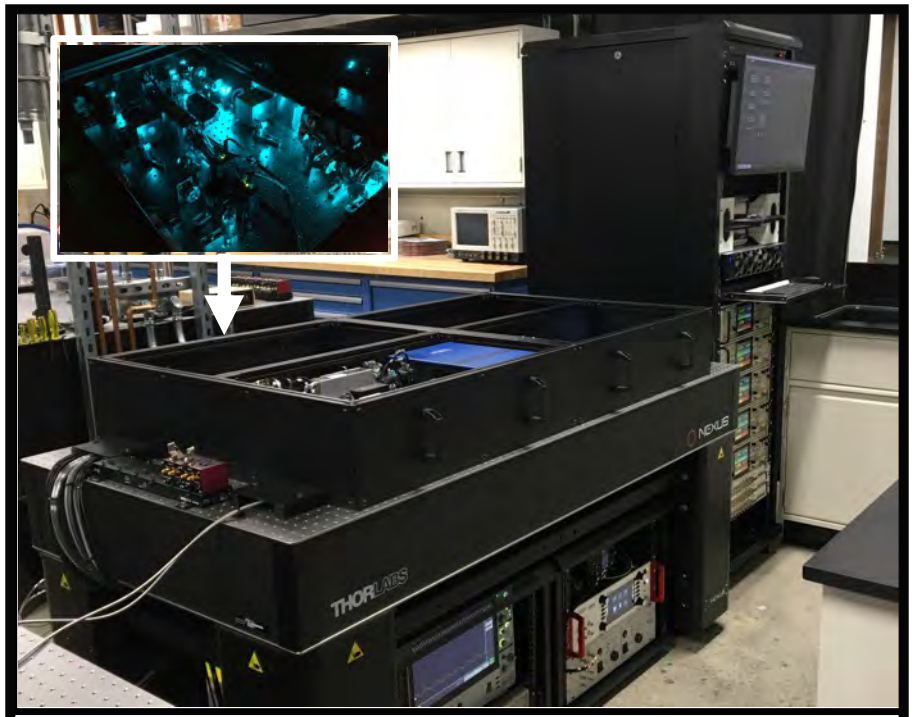
RF Wave E-Field Determined Using Quantum Mechanics

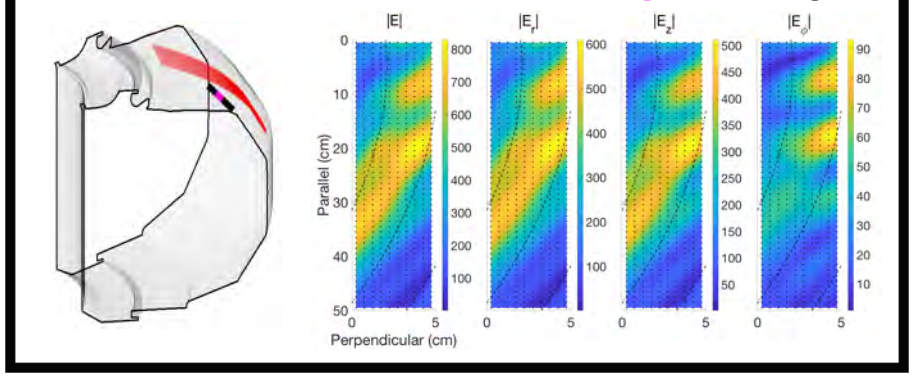
- Laser-based spectroscopy can measure the electronic quantum structure of the atom with high precision.
- The Schrödinger equation is fit to the spectral data to extract the RF wave electric field.

$$i\hbar\frac{\partial\Phi}{\partial t} = \left[H + H^B + H^E(t)\right]\Phi$$





Simulated Measurement from Magenta Region



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ORNL Fosters Cross-Cutting Research

Plasma Physics

Quantum Physics

Applied Math

High Performance Computing

Questions →
Comments →
Opportunities →

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