Pacific Northwest
NATIONAL LABORATORY

Pacific Northwest National Laboratory OVERVIEW

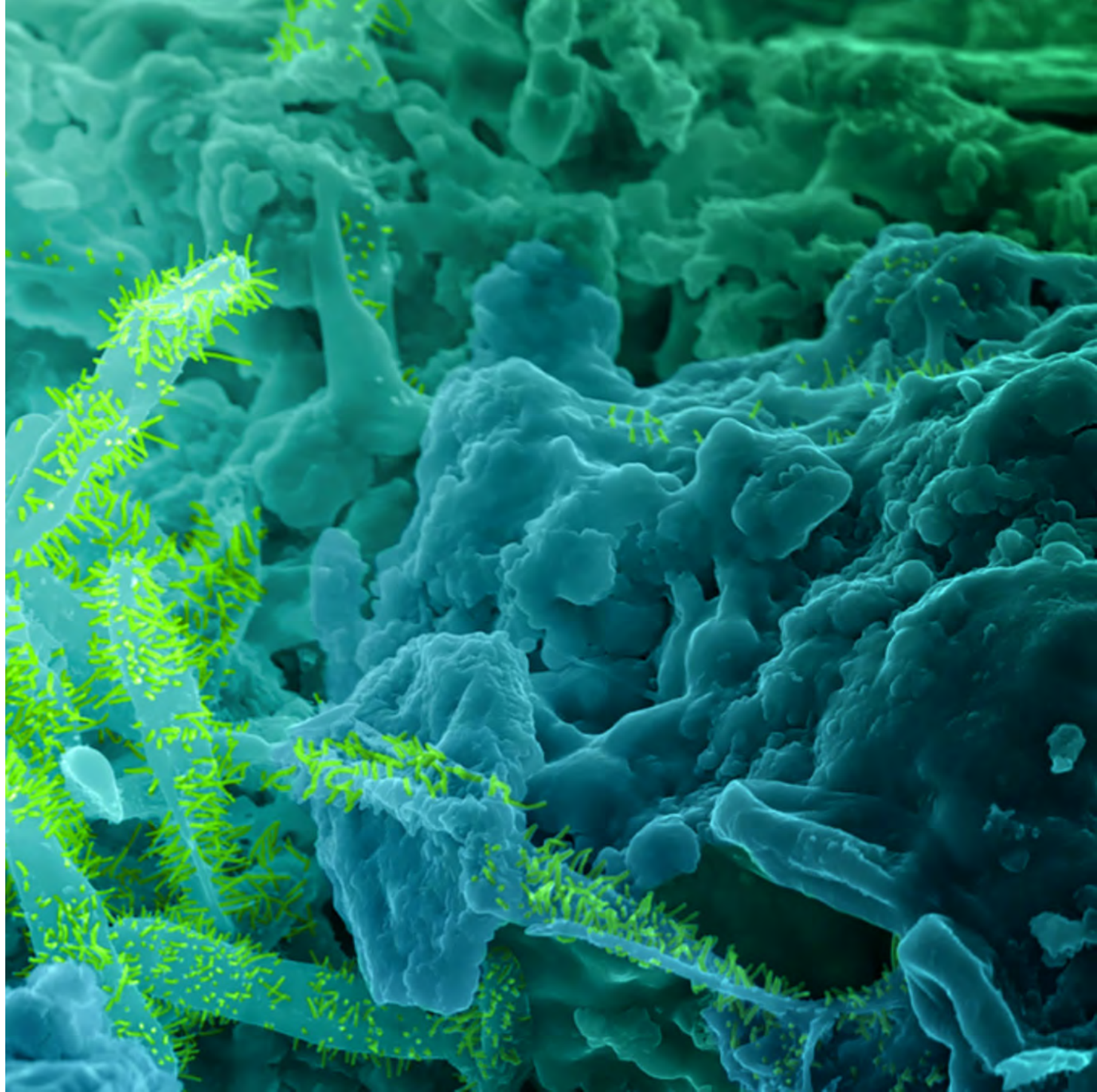
July 1, 2020

Steve Ashby
Laboratory Director

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

PNNL-SA-152042



Pacific Northwest NATIONAL LABORATORY

DOE's 17 **national laboratories** tackle critical scientific challenges

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PNNL is a regional, national, and international **scientific resource**

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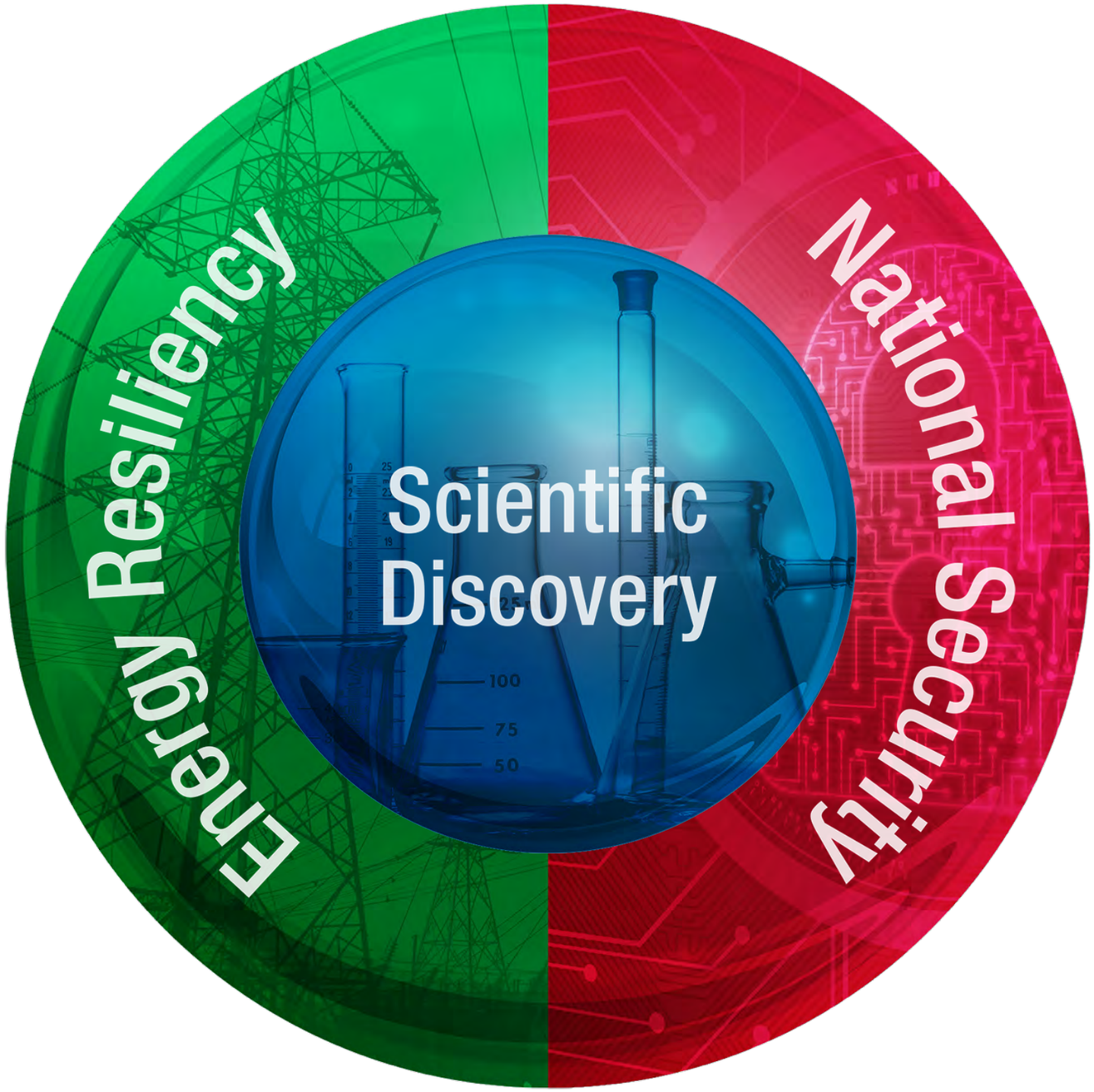
PNNL is addressing **complex challenges** and providing solutions to critical **national needs**



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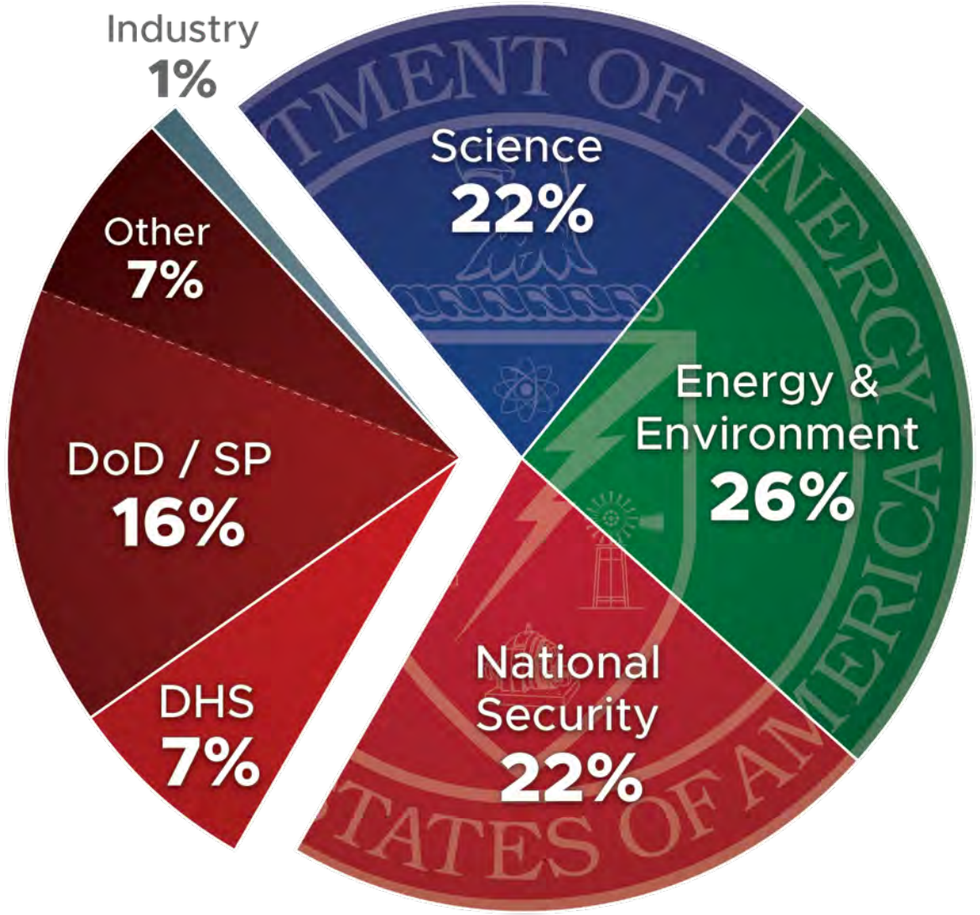
PNNL supports a **breadth of sponsor missions**

4,700 Staff

$1B Spending

1,193 Peer-reviewed publications

265 Invention disclosures



FY2019 Staff

Pacific Northwest
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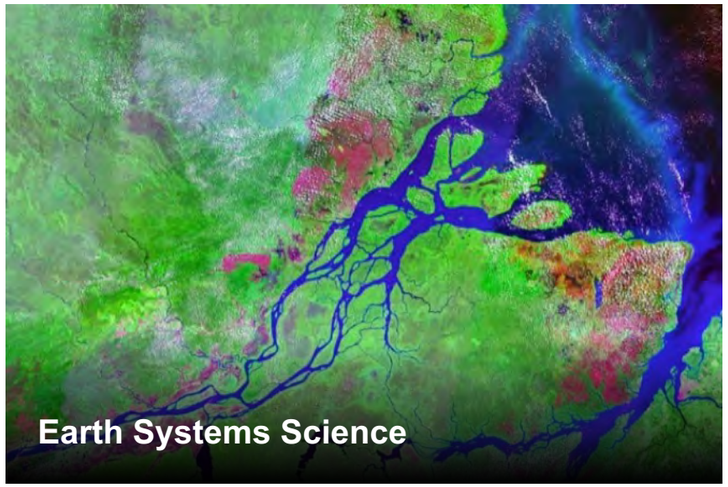
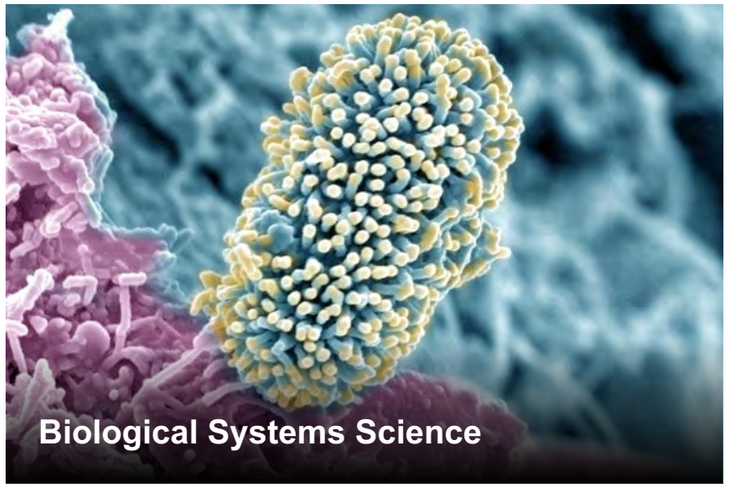
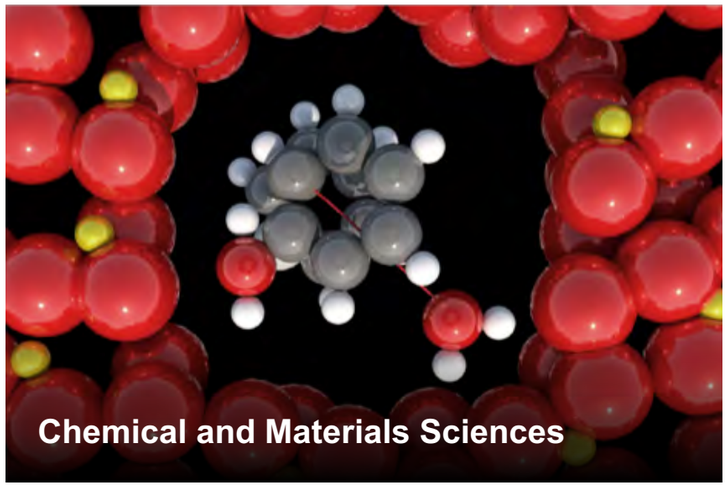
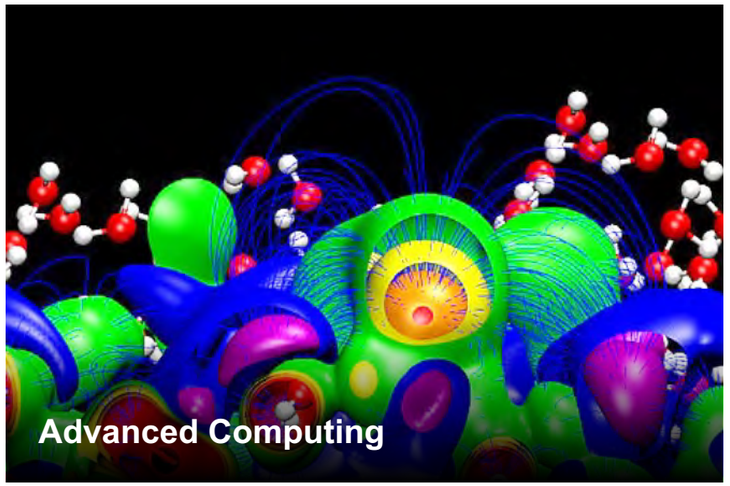
PNNL's **Science** mission advances our understanding of the world around us









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PNNL's **Energy and Environment** mission delivers innovations for our energy future

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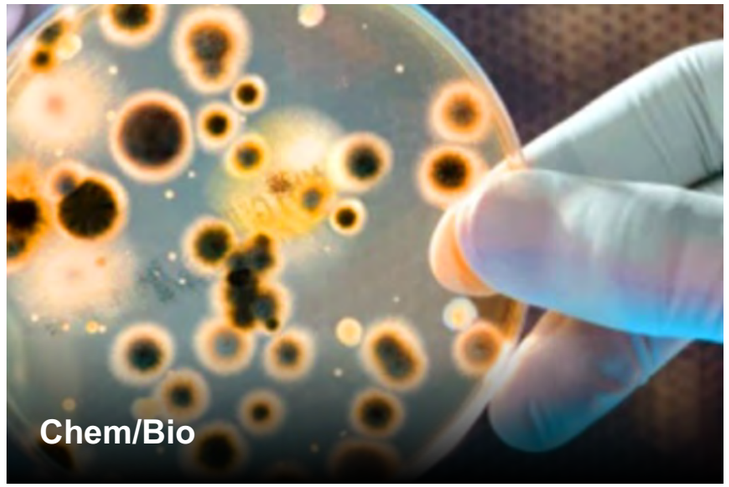
PNNL's **National Security** mission is reducing the threat from weapons of mass effect



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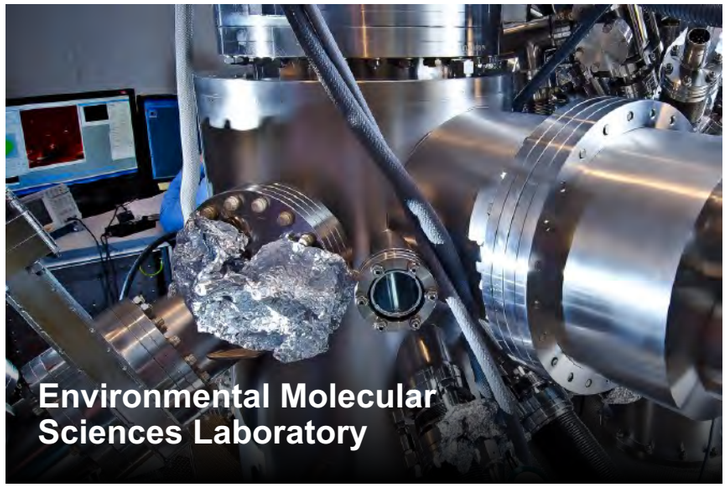
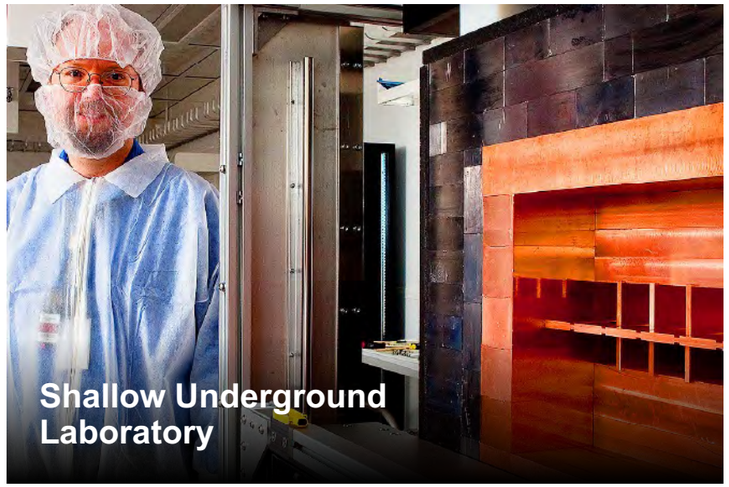
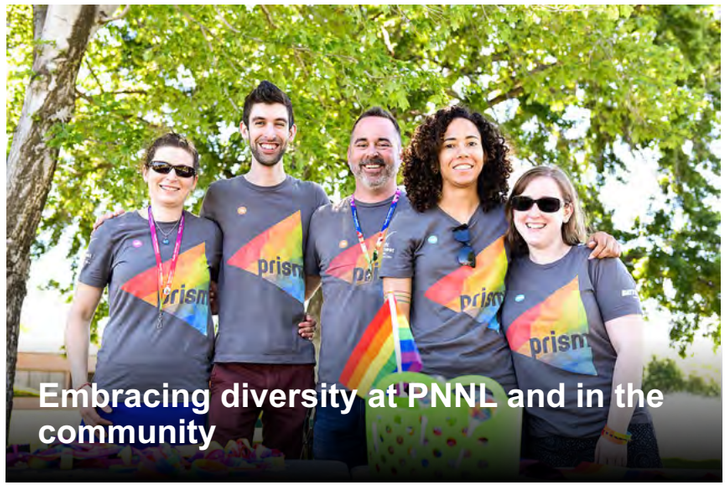
PNNL operates **state-of-the-art** scientific facilities





PNNL partners to make an **impact**



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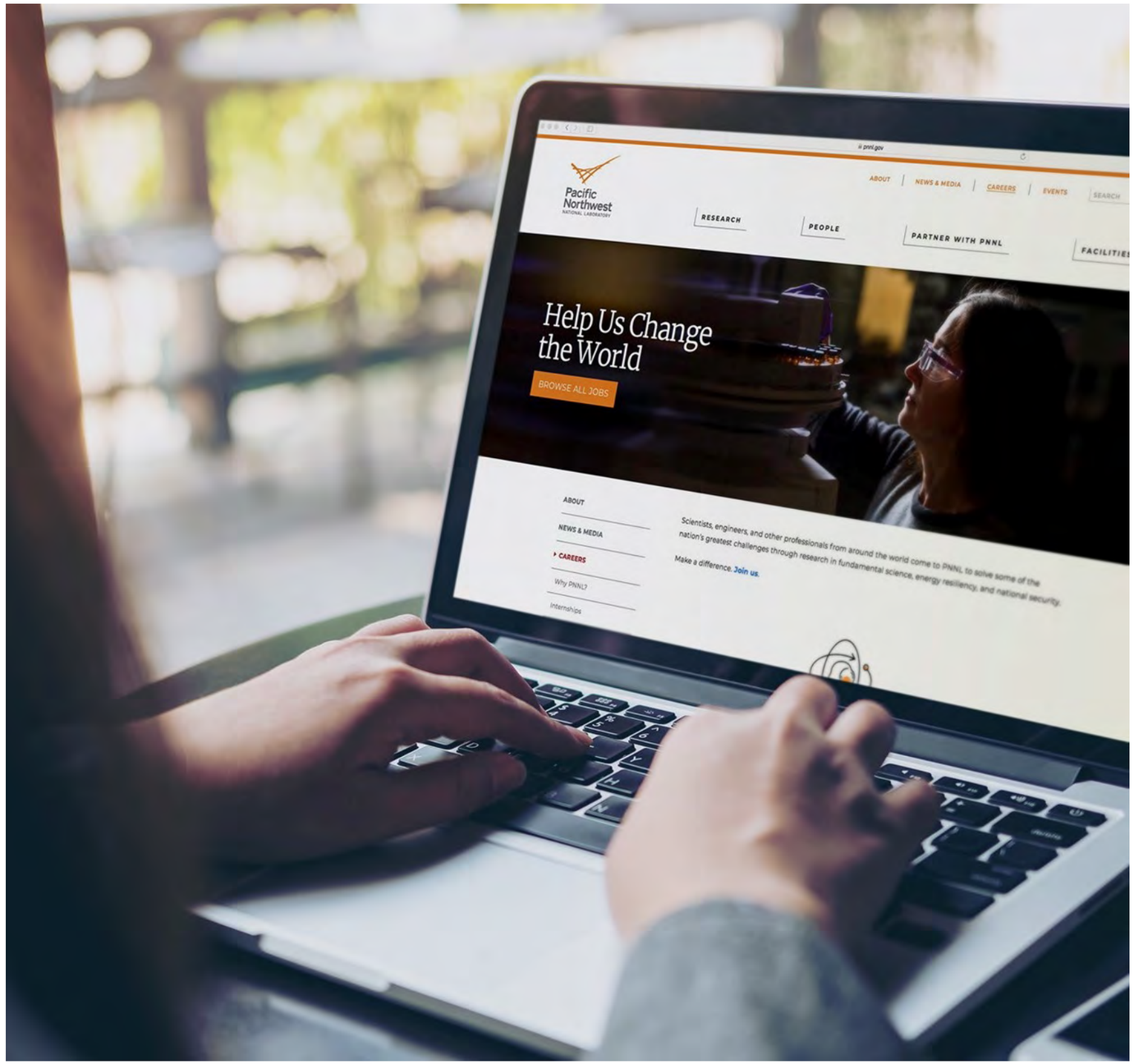
PNNL tackles critical **challenges** and provide **solutions** to critical **national needs.**

Explore opportunities to join PNNL
www.pnnl.gov/careers



PNNL is an affirmative action and equal opportunity employer.

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Pacific Northwest National Laboratory National Security

July 1, 2020

Daniel Stephens
National Security Directorate

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PNNL-SA-154039

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Manhattan Project and the Cold War

- Hanford Site produced plutonium for defense missions
- PNNL traces its history to the research laboratories supporting that mission

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National Security Directorate

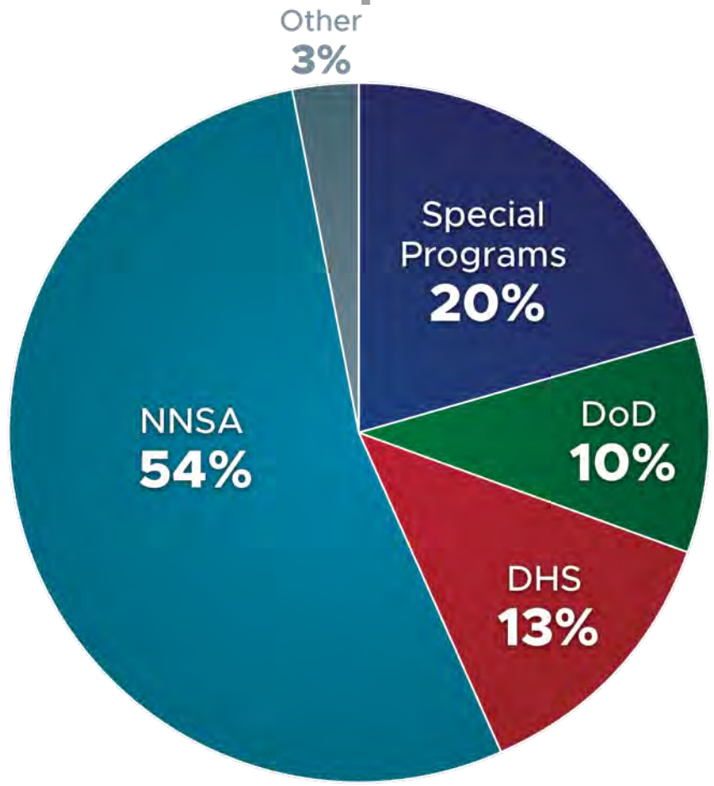
1342 Staff

$534.5M FY19 Funding

1900 Cleared Staff at PNNL

2291 Advanced Academic Degrees

FY19 National Security Mission Sponsors



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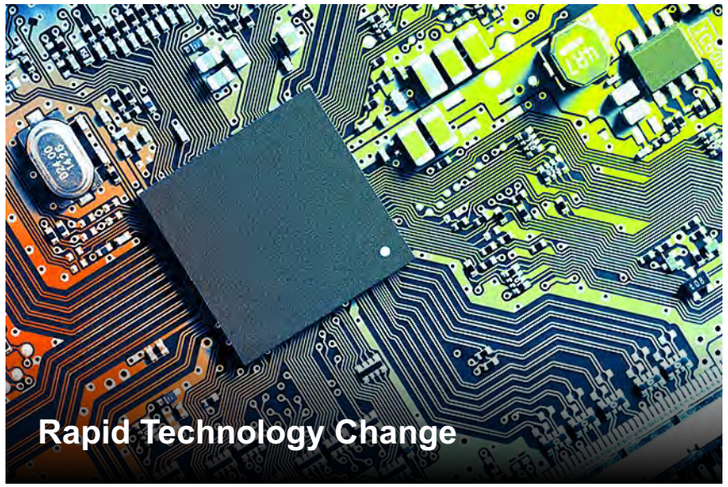
Increasingly Complex Security Environment



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Strengthening the National Security of the United States

PNNL's work supports the missions of these U.S. Government sponsors

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Work for NNSA and the U.S. Department of State

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National Security
HIGHLIGHT

Detecting the **signatures of nuclear weapons** to support nonproliferation

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National Security
HIGHLIGHT

Replicating processing methods to **identify signatures** that could correlate **plutonium** with where it was produced

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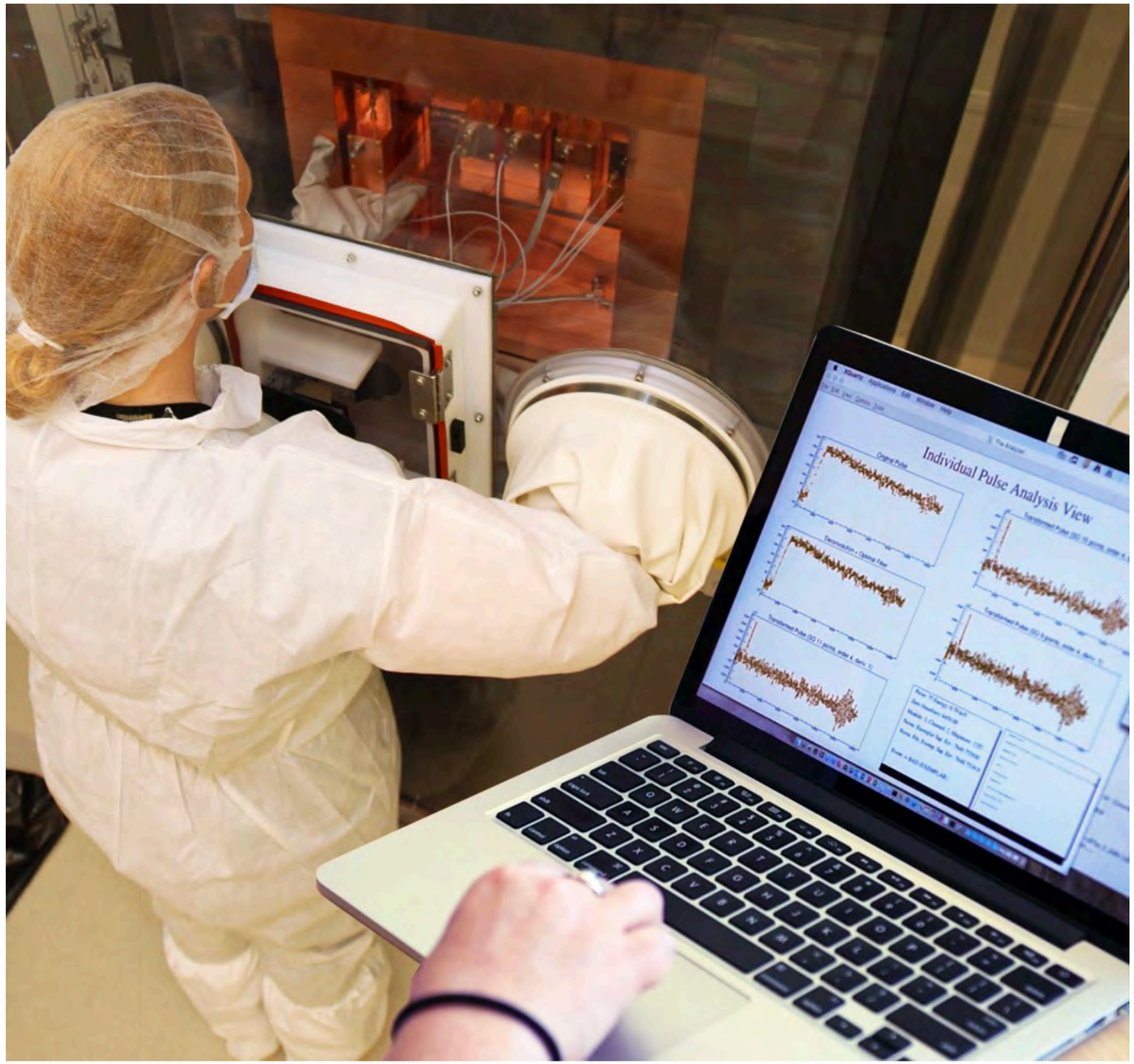
National Security
HIGHLIGHT

Using **machine learning** to accurately detect nuclear events



Student programs increase impact of our collaborative research with academia

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Energy & Environment Research

July 1, 2020

Jud Virden

Associate Laboratory Director
Energy & Environment Directorate
Pacific Northwest National Laboratory

U.S. DEPARTMENT OF ENERGY BATTELLE

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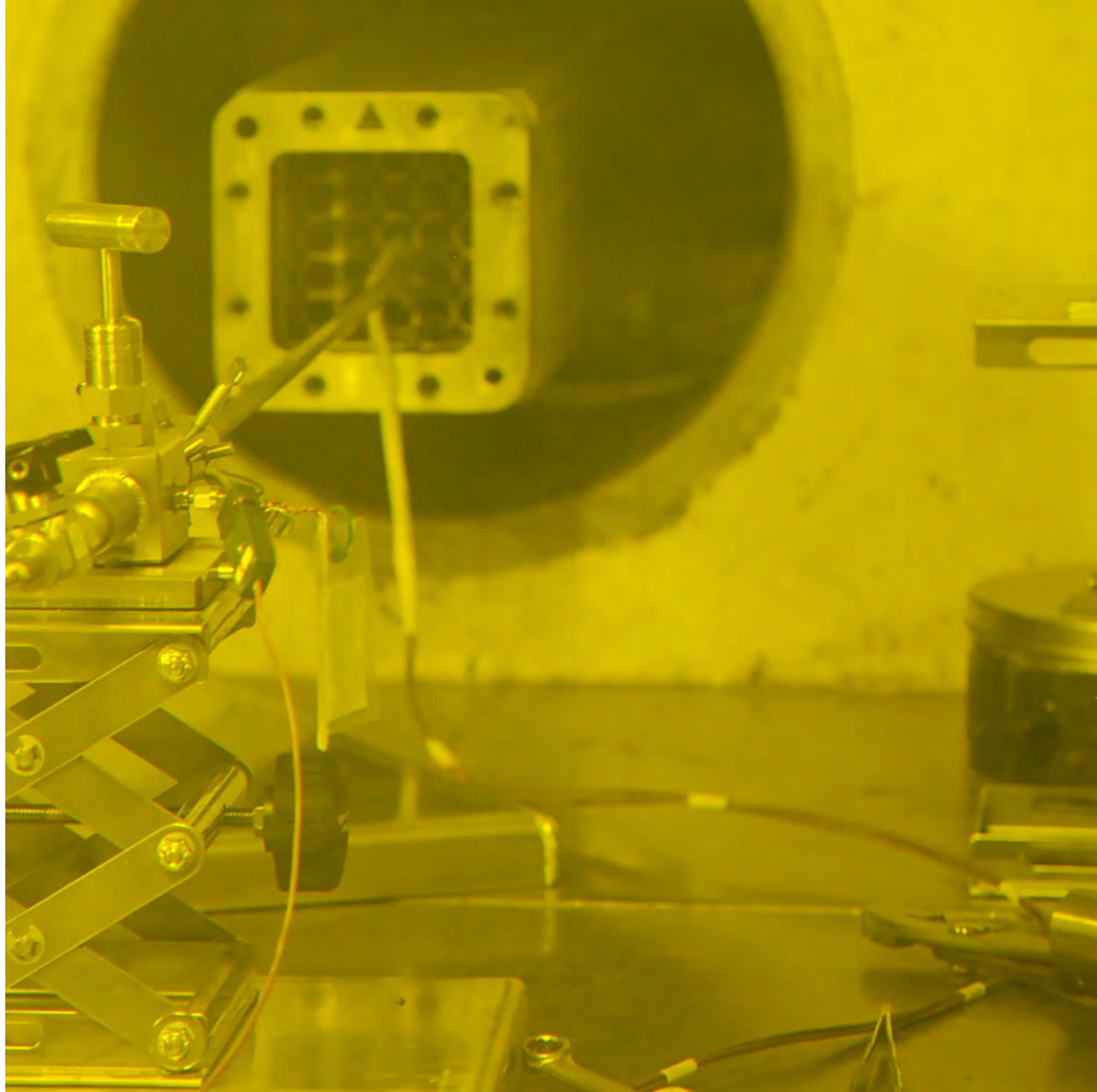
PNNL-EX-10235



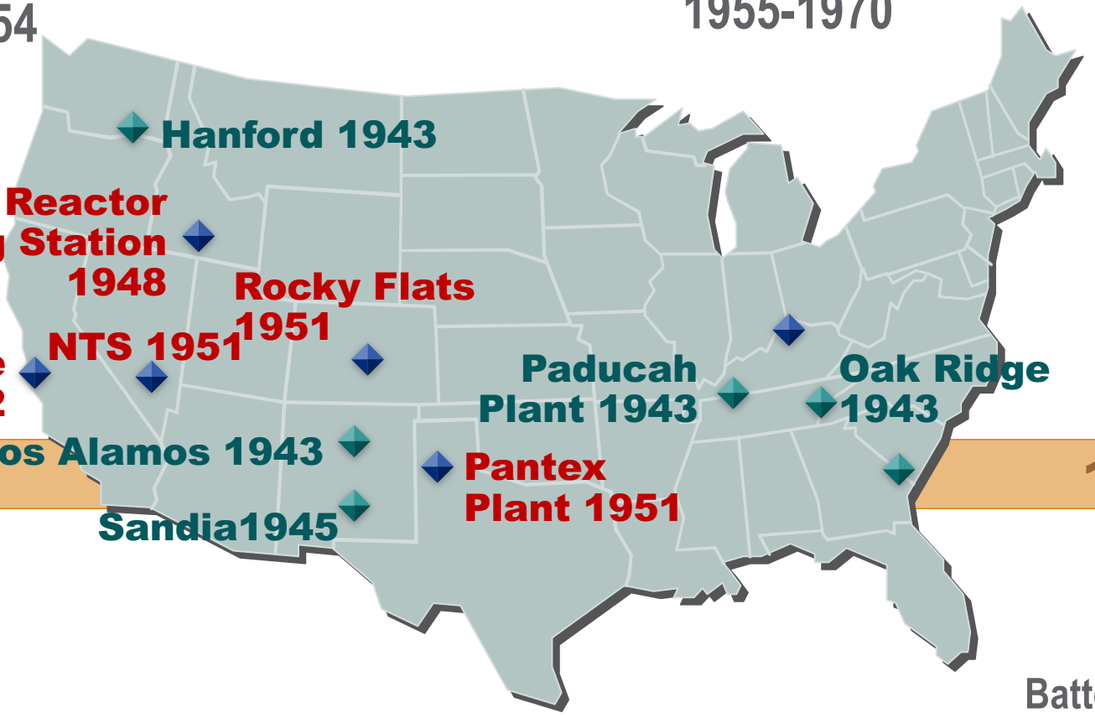
PNNL Was Born Out Of World War II

Manhattan Project Era 1942-1945

B-Reactor at Hanford

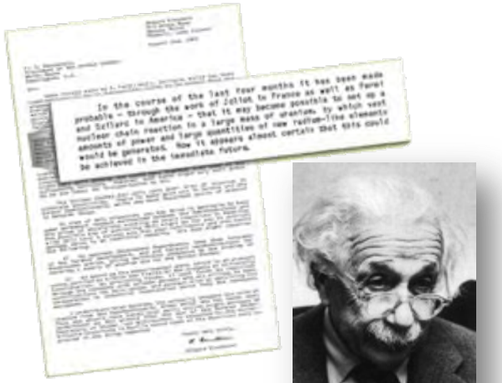
Weapons Complex Era 1946-1954

Civilian Nuclear Power Era 1955-1970



1939 — 1942 — 1946 — 1965

Einstein's Letter



Atomic Energy Commission established (1946)

- Research Reactor
- Plutonium Laboratory
- Hot Cells
- Critical Assembly

Battelle takes over Hanford Works Lab contract, renamed Pacific Northwest Laboratory

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Pacific Northwest National Laboratory - Locations

Pacific Northwest
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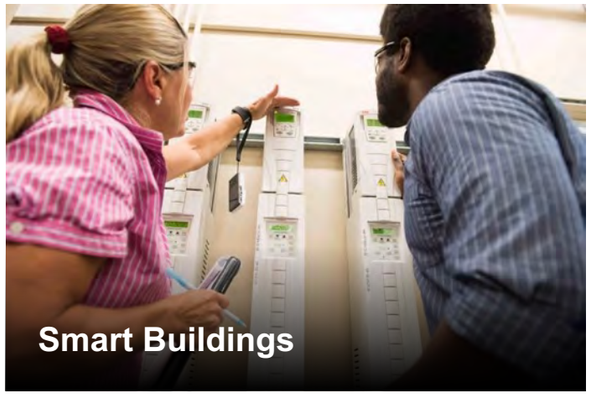
PNNL's Energy and Environment Programs



PNNL Offers Broad Career Opportunities!

- Hired 236 new staff in the last two years!
- Virtual interviewing and onboarding
- Mentoring by senior-level researchers
- Our diverse R&D portfolio gives staff a lot of interesting things to work on over a career!
- See opportunities at www.pnnl.gov/careers


Wasteform Development (glass & grout)


Molten Salt & Actinide Chemistry


Radiochemical Processing


Shear Assisted Processing and Extrusion (ShAPE) for metals manufacturing

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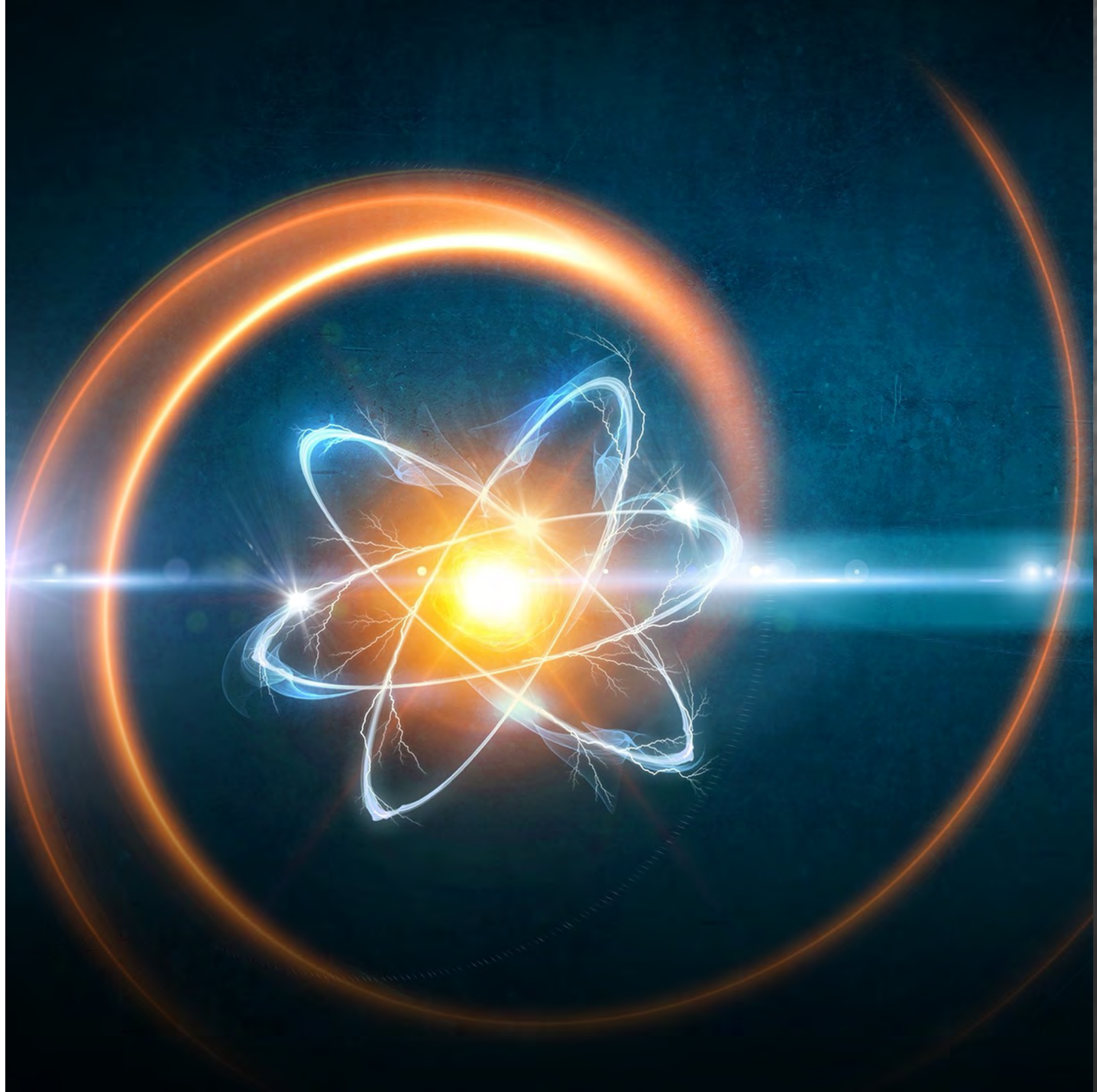
Nuclear Research at Pacific Northwest National Laboratory

July 1, 2020

Mark Nutt
Nuclear Energy Sector Manager
Energy & Environment Directorate



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PNNL-SA-153986

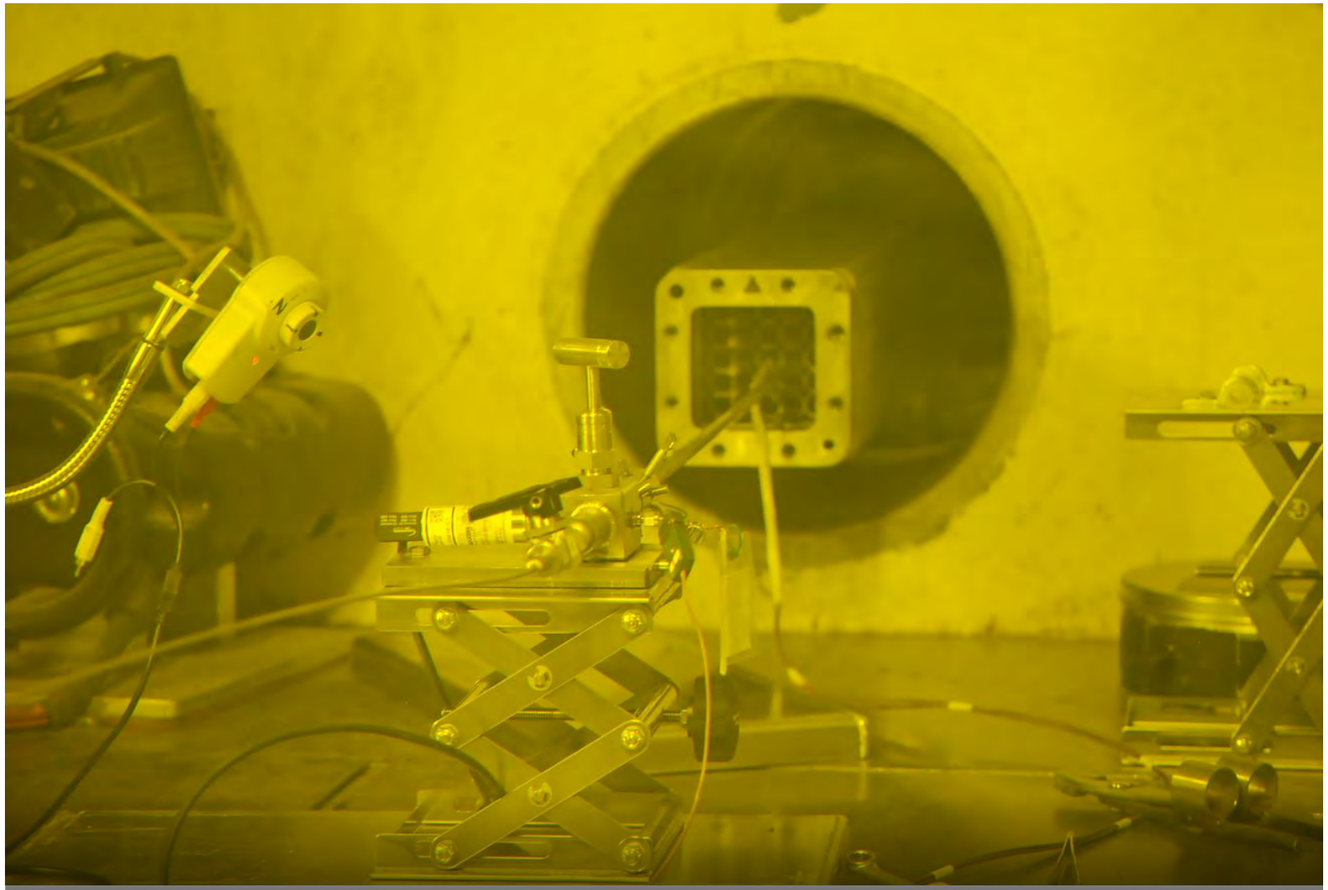
Nuclear Energy Can and Should be a Part of the U.S. Energy Generation Portfolio

- Important for clean electricity and other uses within the evolving 21st century grid
- R&D is necessary to both enable the **deployment** of nuclear reactors and supporting infrastructure and to support their **continued operation**
- The entire fuel cycle is important – from front end to back end
  - Completing the fuel cycle is as important as deploying advanced technologies
- PNNL's world-class researchers and capabilities are supporting the sustainability of nuclear energy

Delivery of North Anna sibling pins to PNNL's Radiochemical Processing Lab (RPL) for characterization analysis.

PNNL's Nuclear Energy R&D Leadership is Advancing Sustainable Clean Nuclear Energy

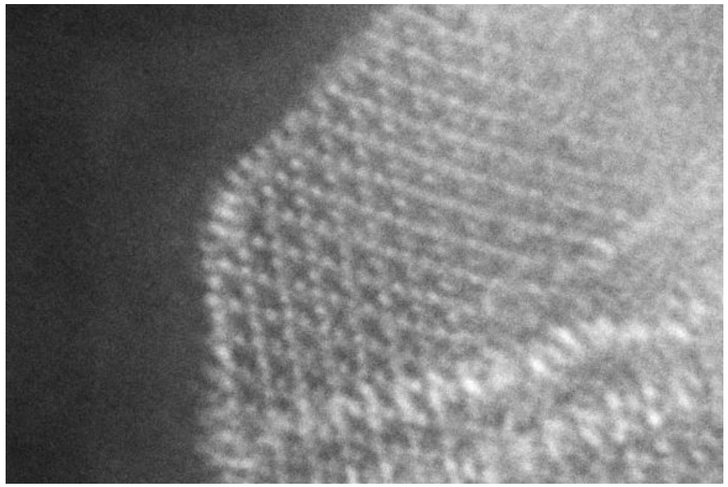
- We understand nuclear power and its many benefits
- We apply and leverage our expertise, built over several decades, to help advance nuclear energy—now and into the future
- We ensure that our expertise and research assets are having tangible impacts on U.S. energy security

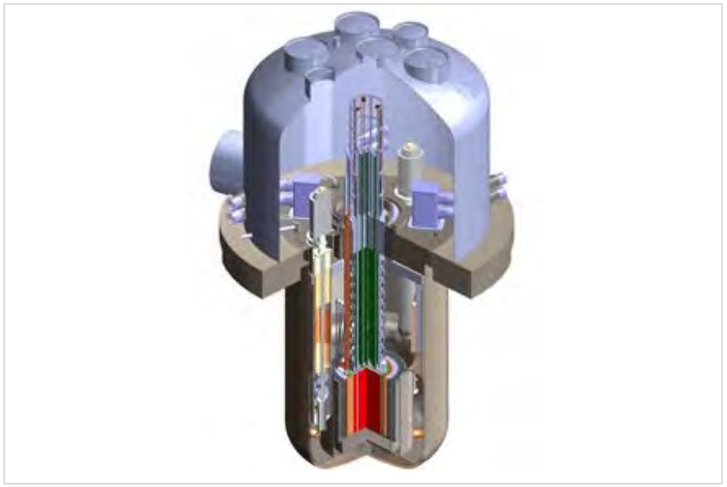


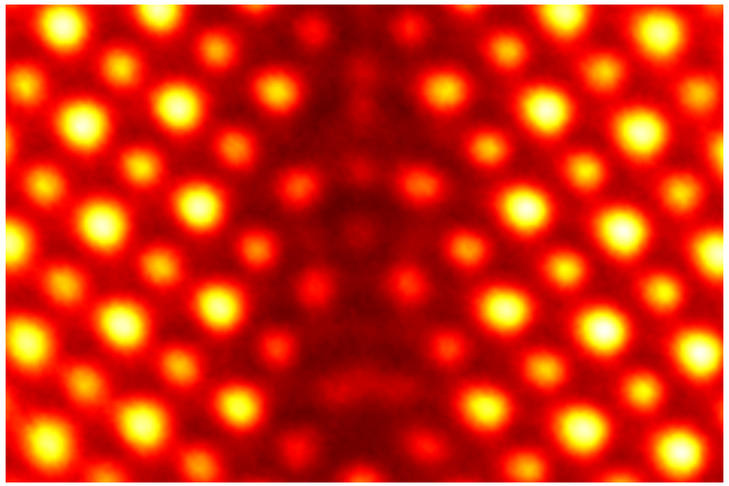
Post Irradiation Examination of High Burnup Nuclear Fuel in RPL.

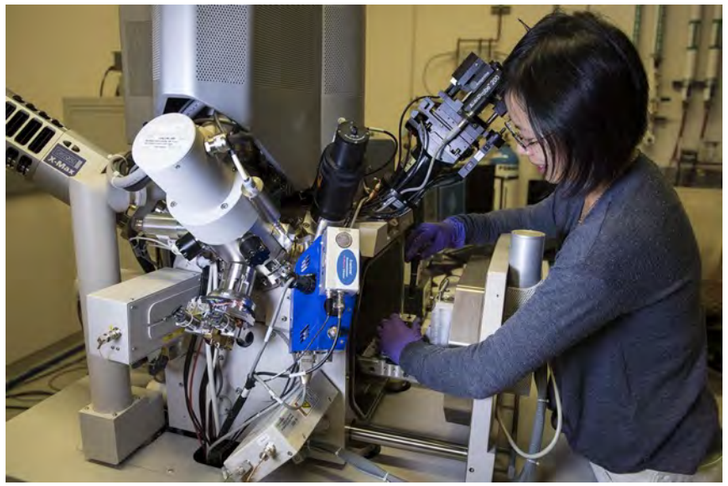
Approximately Half of PNNL's R&D is in Nuclear Science and Technology

- ~$400M to $500M of R&D
- DOE Offices of Nuclear Energy, Environmental Management, and Science; U.S. Nuclear Regulatory Commission; National Nuclear Security Administration
- Trusted partner in advancing nuclear technologies
  - Enabling advanced safeguards for nuclear technologies
  - New reactor licensing and regulatory infrastructure
- Materials science and engineering for reactor systems









R&D and Advanced Technology Development is Necessary Across the Nuclear Fuel Cycle

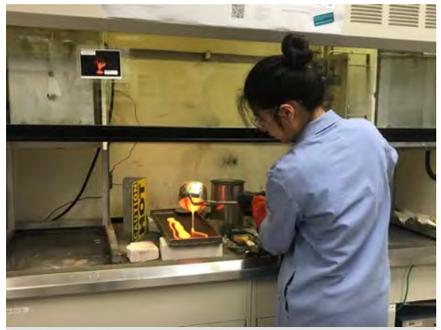
Courtesy: Dr. Jenifer Braley, Colorado School of Mines, NAMP webinar, January 2014

High Resolution Microscopy of Irradiated Fuel and Components

Recovery of Uranium from Seawater

In-Line Flow Through Optical Spectroscopy

R&D Pilger Roll for Advanced Cladding



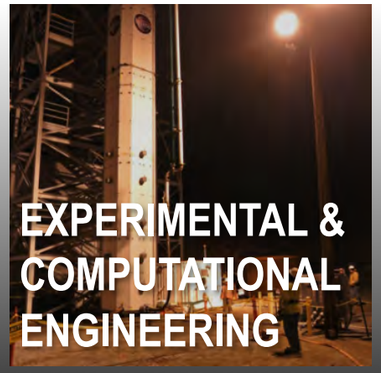
Simulated Nuclear Waste Glass

Engineered Metallic Frameworks for Off-Gas Capture and Immobilization

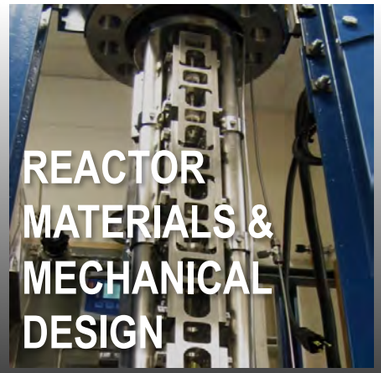
PNNL's Nuclear Energy Expertise and Capabilities are Broad and Diverse

- Wasteform Development
- Thermal Processing
- Process Engineering

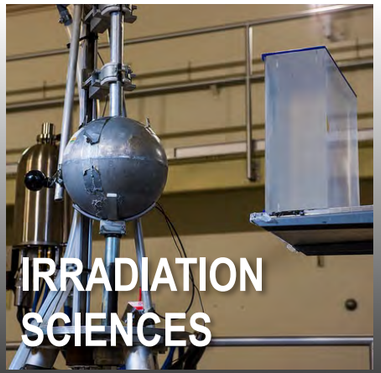
- Separations
- Radiochemistry
- Irradiated Materials Char.
- Actinide Sciences



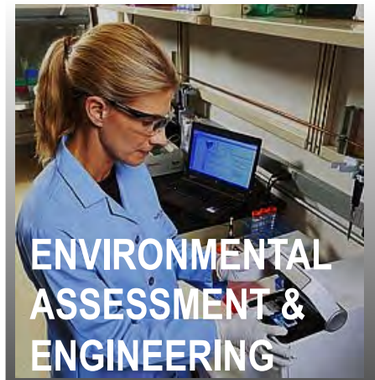
- Multi-Phase Fluids
- Simulant Development
- Structural Analysis
- Safety Analysis



- Stress Corrosion Cracking
- Radiation Effects
- Materials Modeling
- Nano Materials Science



- Neutron Metrology
- Radiation Effects on Materials
- Radiation Dosimetry & Measurement



- NEPA Assessments
- Human & Ecological Health
- Field & Systems Engineering
- Microbiology

- Nuclear Safety & Engineering
- Risk Informed Decision Analysis
- Software Based Decision Support Tools

- Geochemical Assessment
- Remediation Science & Engineering
- Geophysics/Geomechanics

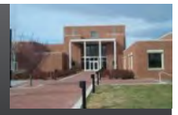
- Materials Development, Processing & Performance Testing
- Synthetic Chemistry
- Polymers

- NRC Lead Organization for Development and Evaluation of Techniques
- Finite Element and Semi-Analytical Simulations
- Prognostics & Health Management

- Core Design
- Criticality Safety Assessment
- Radiation Shielding Analysis
- Fuels and Materials Performance Analysis

PNNL's Nuclear Capabilities are Modern, Comprehensive, and Unique

Environmental Molecular Sciences Laboratory (EMSL), 6500 ft²



- Chemical kinetics and thermodynamics
- Interfacial sciences
- Subsurface Heterogeneity
- Subsurface flow and transport
- Mass contaminant flux
- Conceptual model development and high-performance subsurface modeling

Nondestructive Evaluation Laboratory

- Non-linear, phased array, guided wave ultrasound
- Eddy current
- On-line condition monitoring
- Simulation

Radiochemical Processing Laboratory, 9000 ft²

Cat 2 Nuclear Facility

- Material characterization
- Post-irradiation examination
- Actinide separations
- Molten salt chemistry
- Advanced microscopy

Advanced Process Engineering Laboratory,
3000 ft² laboratory
2000 ft² pilot-scale high-bay

- Waste Form Development Laboratory
- Solid Phase Processing – ShAPE, Friction Stir Welding, Cold Spray

Process Development Laboratory, 1000 ft²

- Pilot–scale High-Bay
- Advanced Melter Platform
- Multiphase Fluids & Scaled Test Platforms

Marine Sciences Laboratory, 15000 ft²

- **Half of the labs connected to Sequim Bay**
- **Recovery of uranium and other materials from seawater**

Material Sciences Laboratory, 3000 ft²

- Materials Synthesis and Characterization
- Materials characterization
- Controlling Process Laboratory
- Scaled Testing Laboratory
- Environmental Systems Engineering Laboratory

Radiation Measurements Laboratory, 9500ft²

- Dosimetry
- Metrology
- Nondestructive Assay
- Irradiation Materials Characterization

Ultra Low Background & Radiation Detection, 6600ft²

- 42.5 feet of overburden
- Low-background detector systems
- Ultra-sensitive measurements laboratory
- Assembly laboratory

Our Accomplishments Support Mission-Critical Needs

- Sibling Pin Post-Irradiation Destructive Examination
- Accurately Predicting Temperatures in Dry Spent Nuclear Fuel Storage and Transportation Systems
- Degradation and Failure Phenomena of Chromium Coated Zirconium Alloy Accident Tolerant Fuel Concepts
- Harvesting of Information During the Decommissioning of Nuclear Power Plants
- Cable Aging in Nuclear Power Plants
- Mechanical Properties of Materials for Advanced Reactors
- Capturing Radioactive Off-Gas from Nuclear Facilities
- Durability of Iodine Waste Forms
- Completed 4th CoDCon flowsheet test
- Pilgering of Advanced Nuclear Fuel Cladding
- Spent Fuel Degradation in Geologic Repository Environments
- Clinch River EIS for an SMR Early Site Permit
- NDE Reliability Issues for the Examination of CASS Components" NUREG/CR-7263

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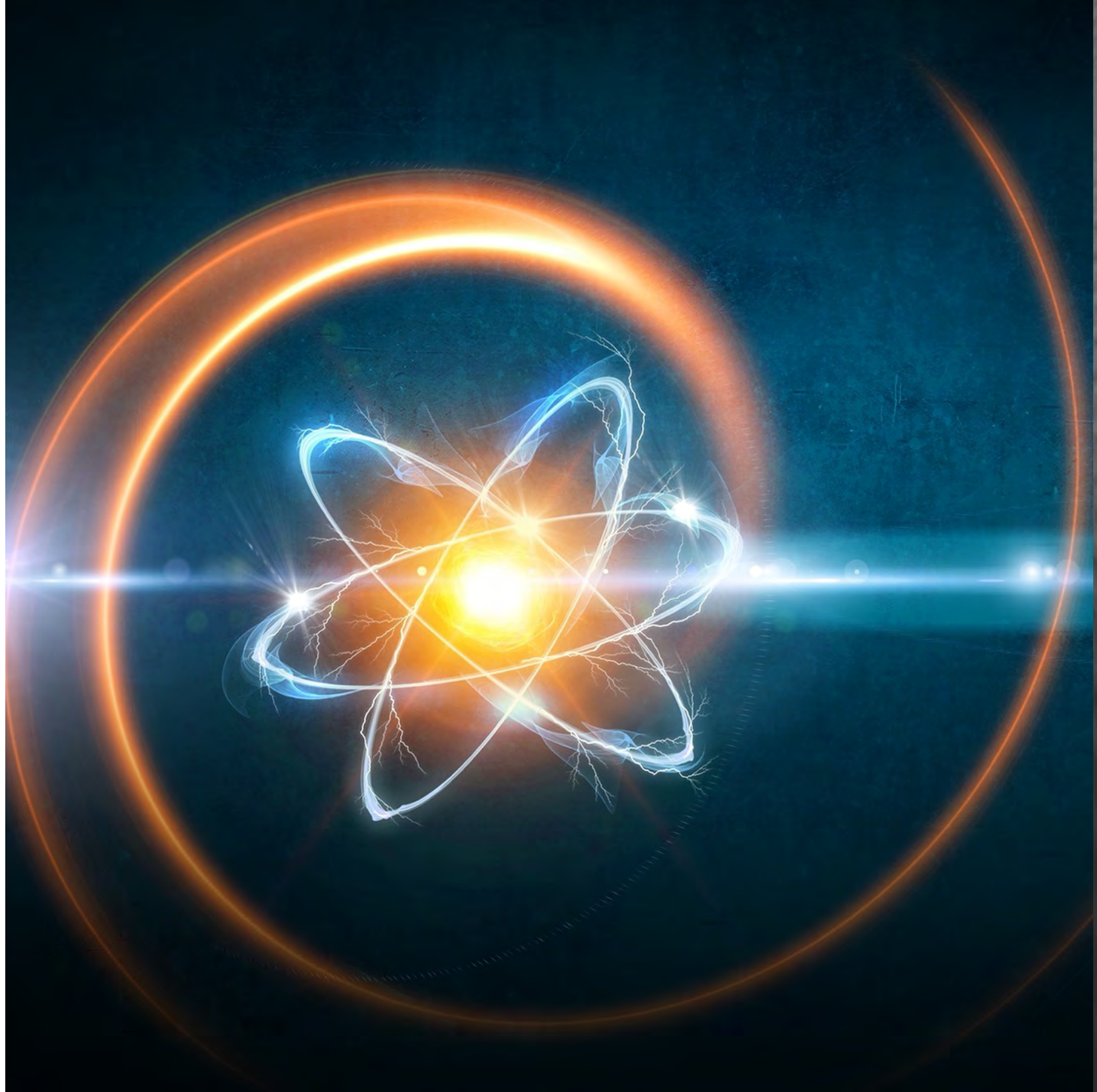
On-line Monitoring: Building Tools to Support Advanced Reactors and Fuel Cycles

July 1, 2020

Amanda Lines, PhD
Process Sensing & Separations
Nuclear Sciences Division
Energy & Environment Directorate



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PNNL-SA-153981

Supporting enhanced R&D and real-time operator control throughout the fuel cycle

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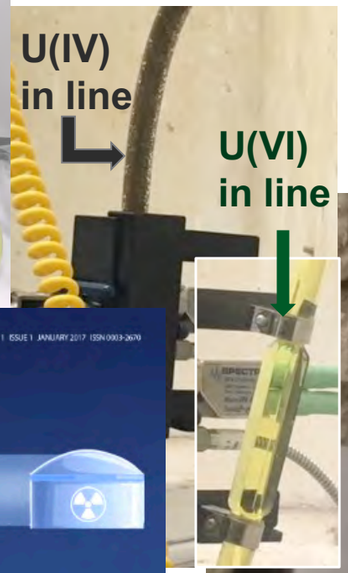
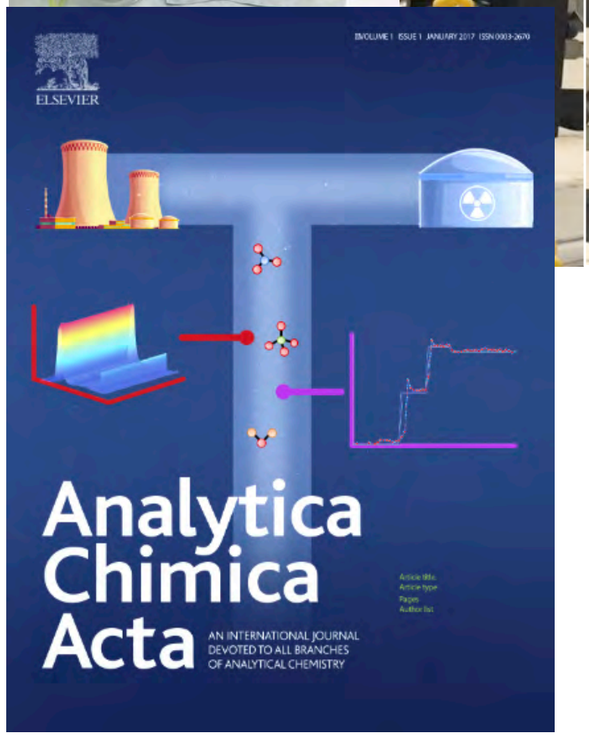
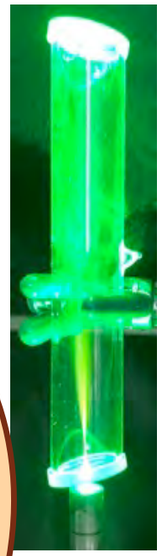
FUEL PRODUCTION

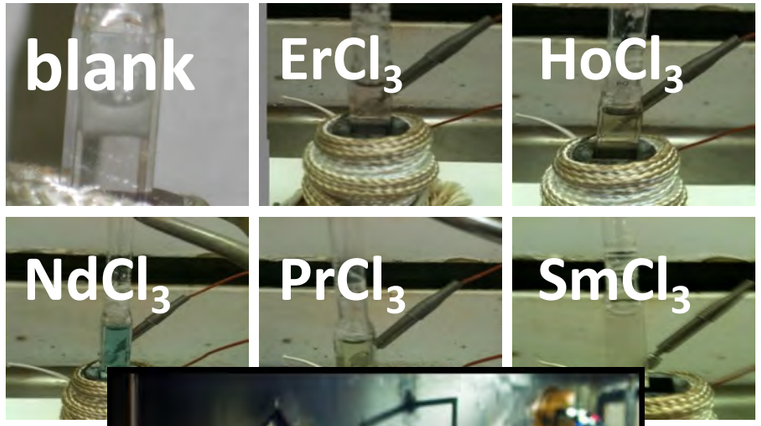


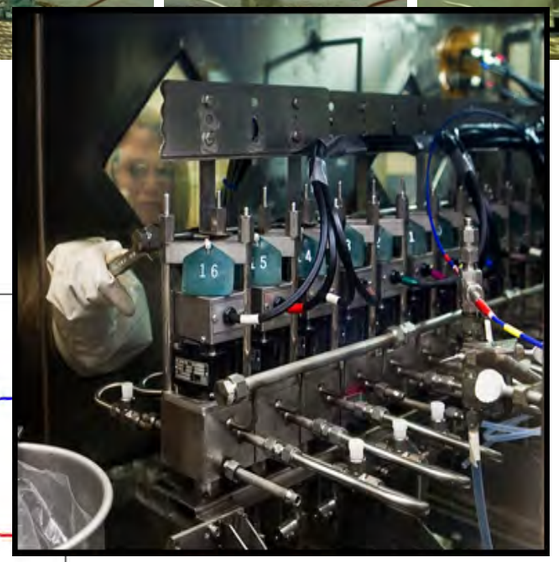


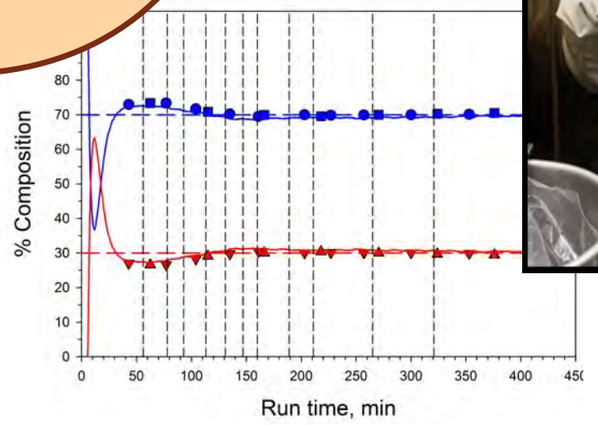
WASTE PROCESSING



REACTOR OPERATION



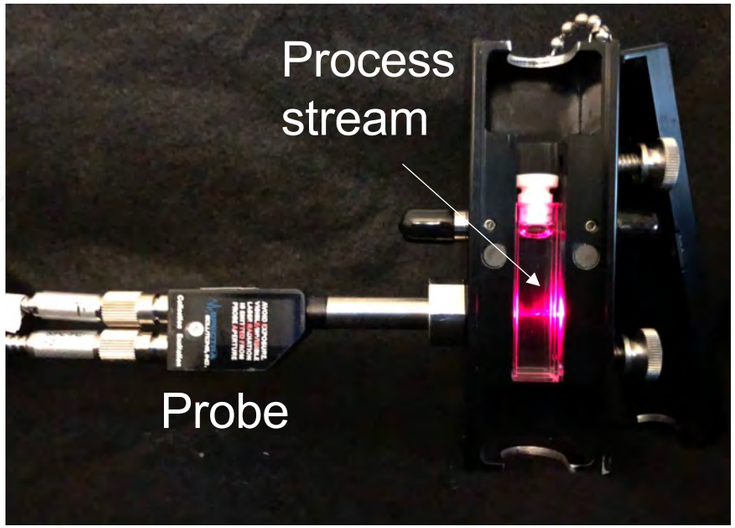




FUEL RECYCLE

Chemical Composition Monitoring: Optical Spectroscopy

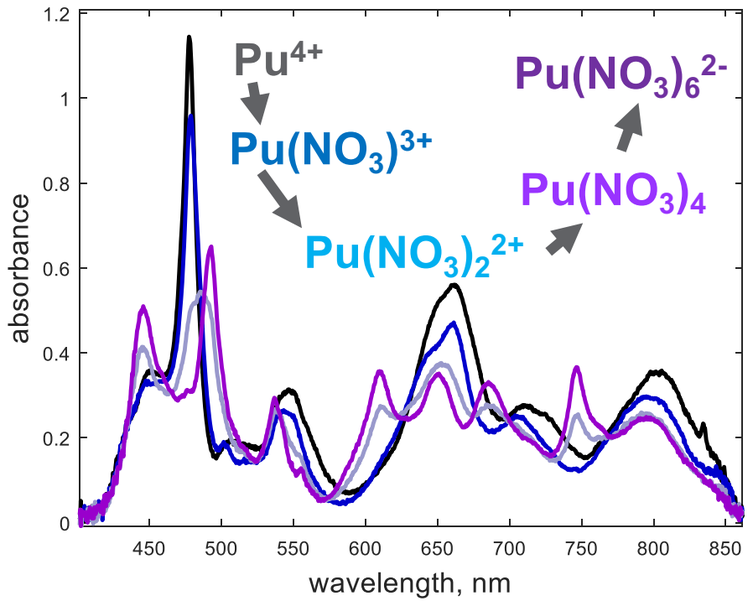
- Mature technology with well developed approach
- Efficient R&D of chemical processes
- Real-time operator control of processes
- Safeguards support

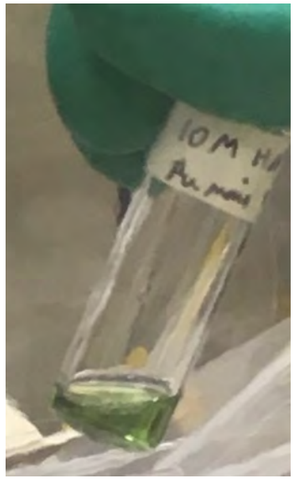


U?
Pu?
HNO_3?

Optical Spectroscopy: Highly Versatile Chemical Analysis

System targets





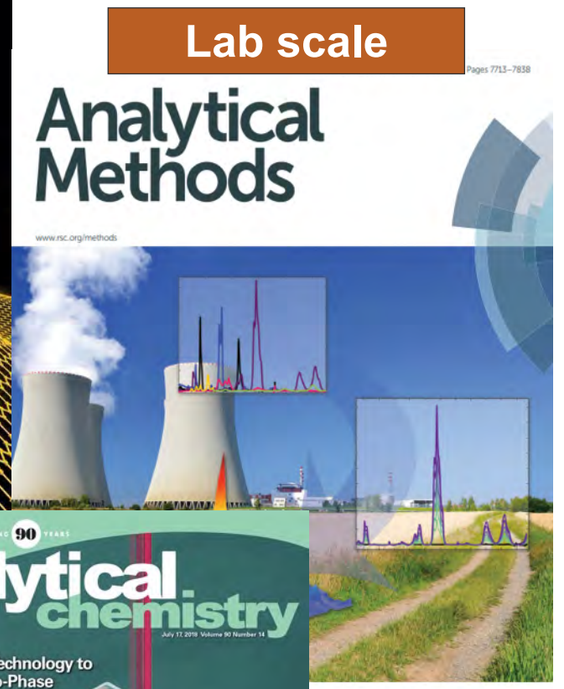
System matrix

- Solid
- Liquid
- Gas
- Molten salt

System scale

Commercial scale

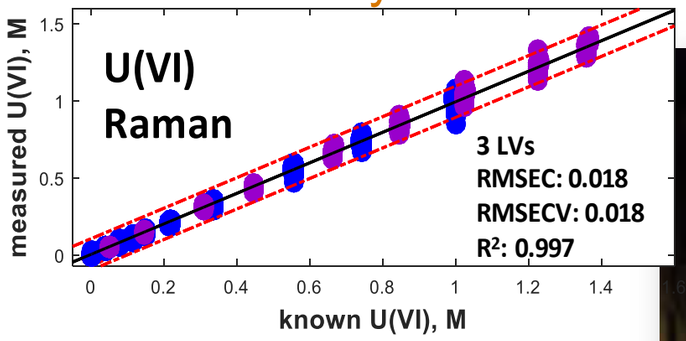
Lab scale

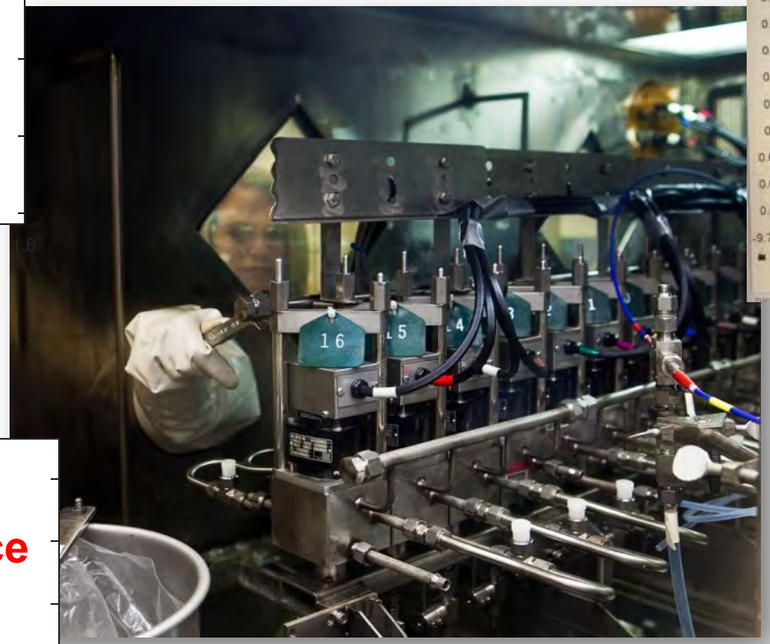


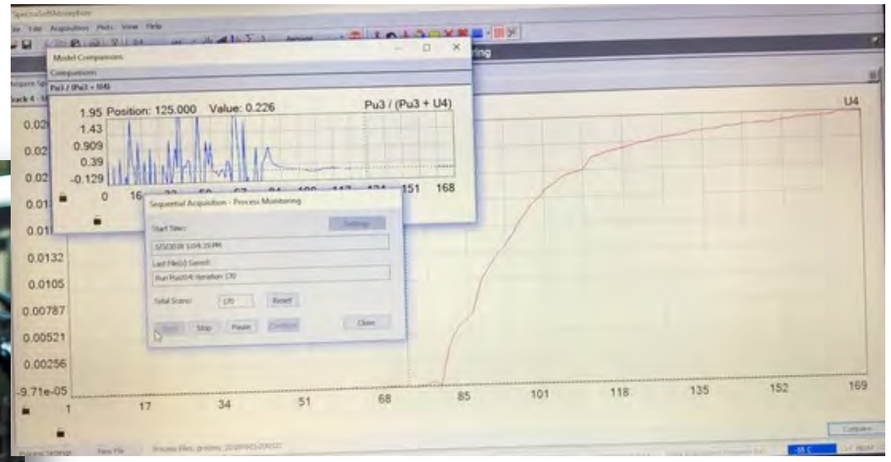
Microscale

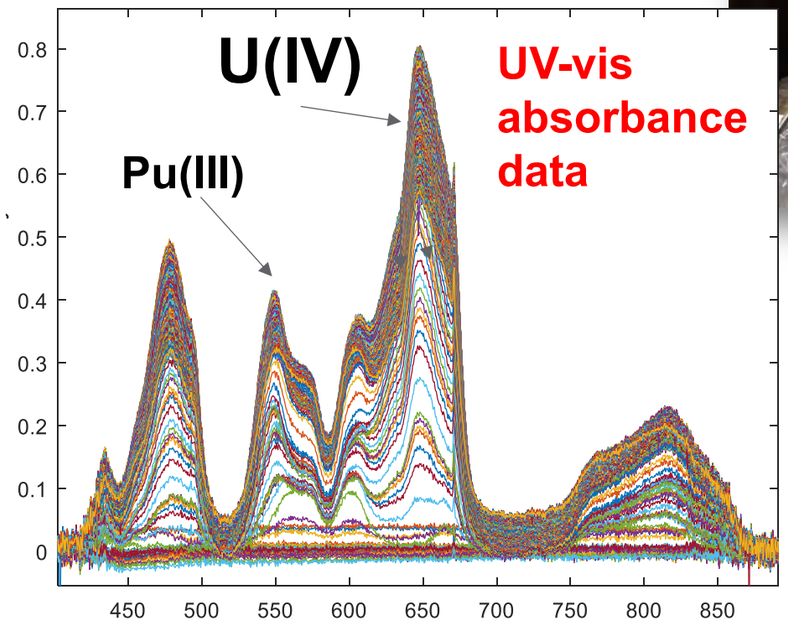
On-line Monitoring: An Example

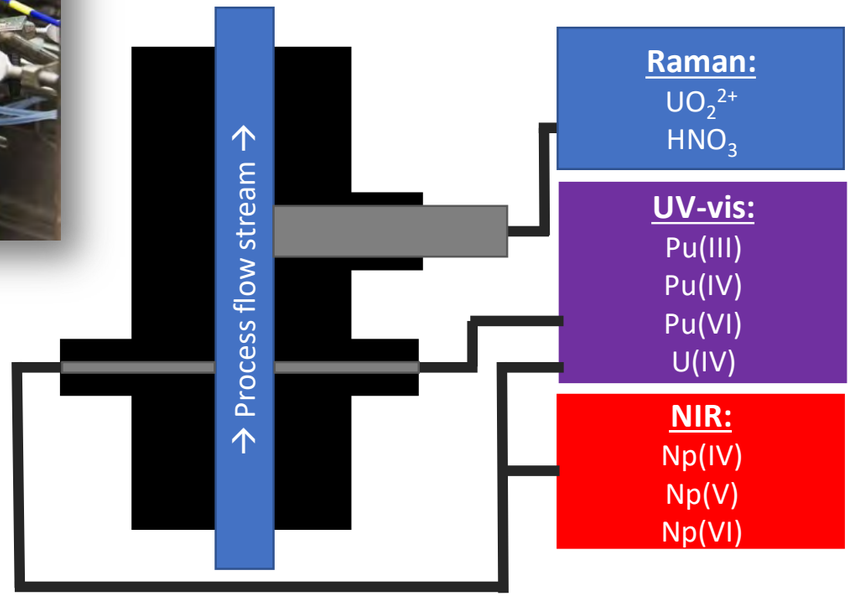
Chemometric Analysis





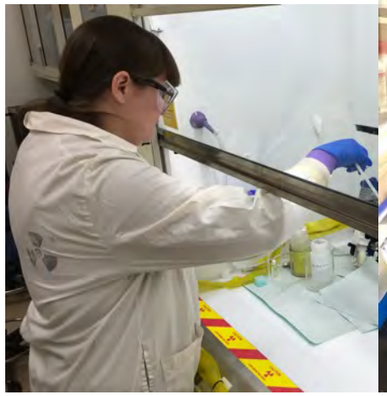






Building the Next Generation of Technology and Work Force

- On-line monitoring can support and enhance the deployment of nuclear energy through providing unprecedented insight into materials processing
- Our team aims to build these capabilities while also training the next generation



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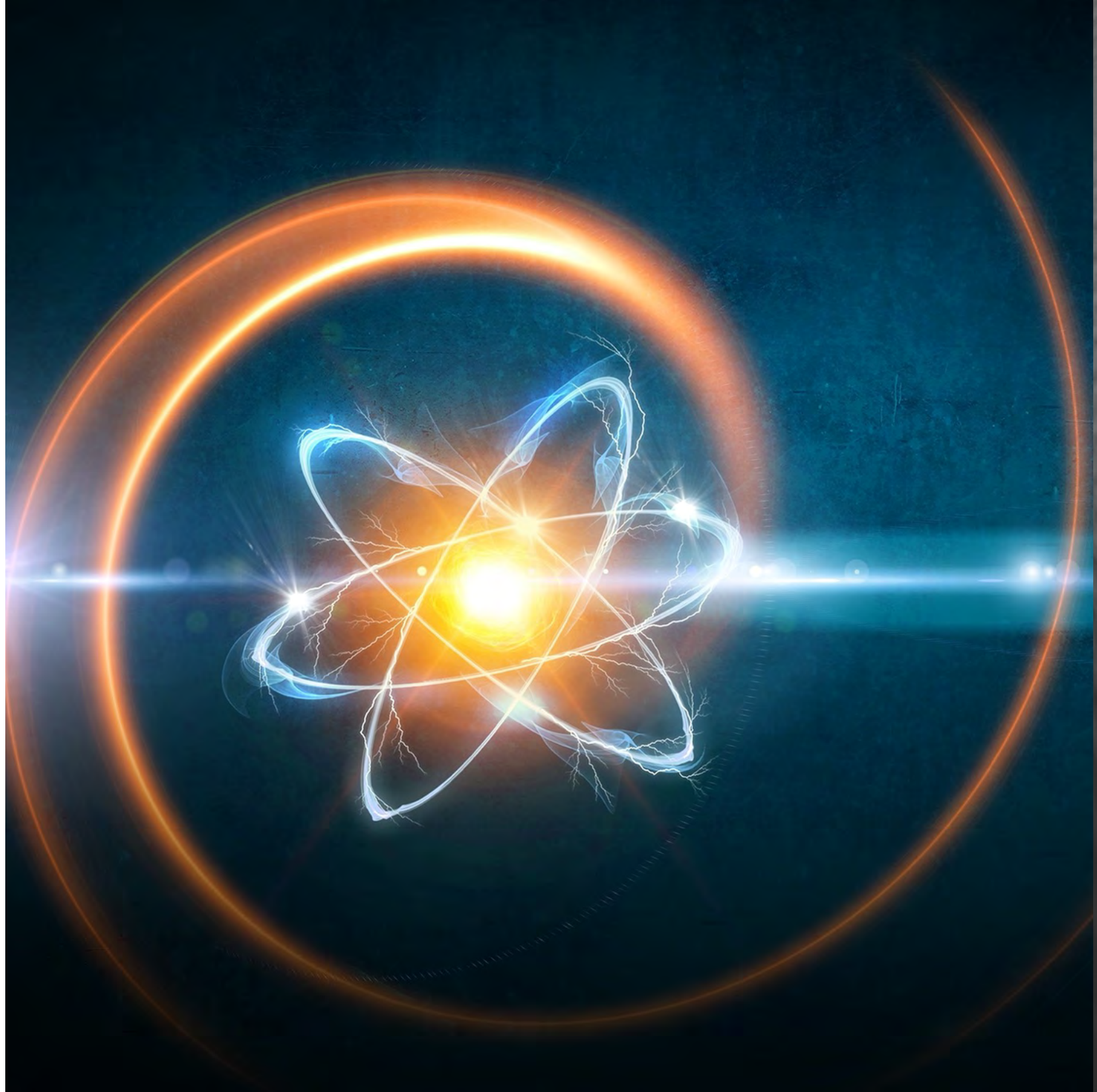
Nuclear Research at PNNL: Materials Characterization

July 1, 2020

Steven R. Spurgeon, PhD
Materials Characterization
Nuclear Sciences Division
Energy & Environment Directorate



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PNNL is home to unique facilities enabling cutting-edge nuclear engineering, materials science, and chemistry.

Radiological Microscopy Suite

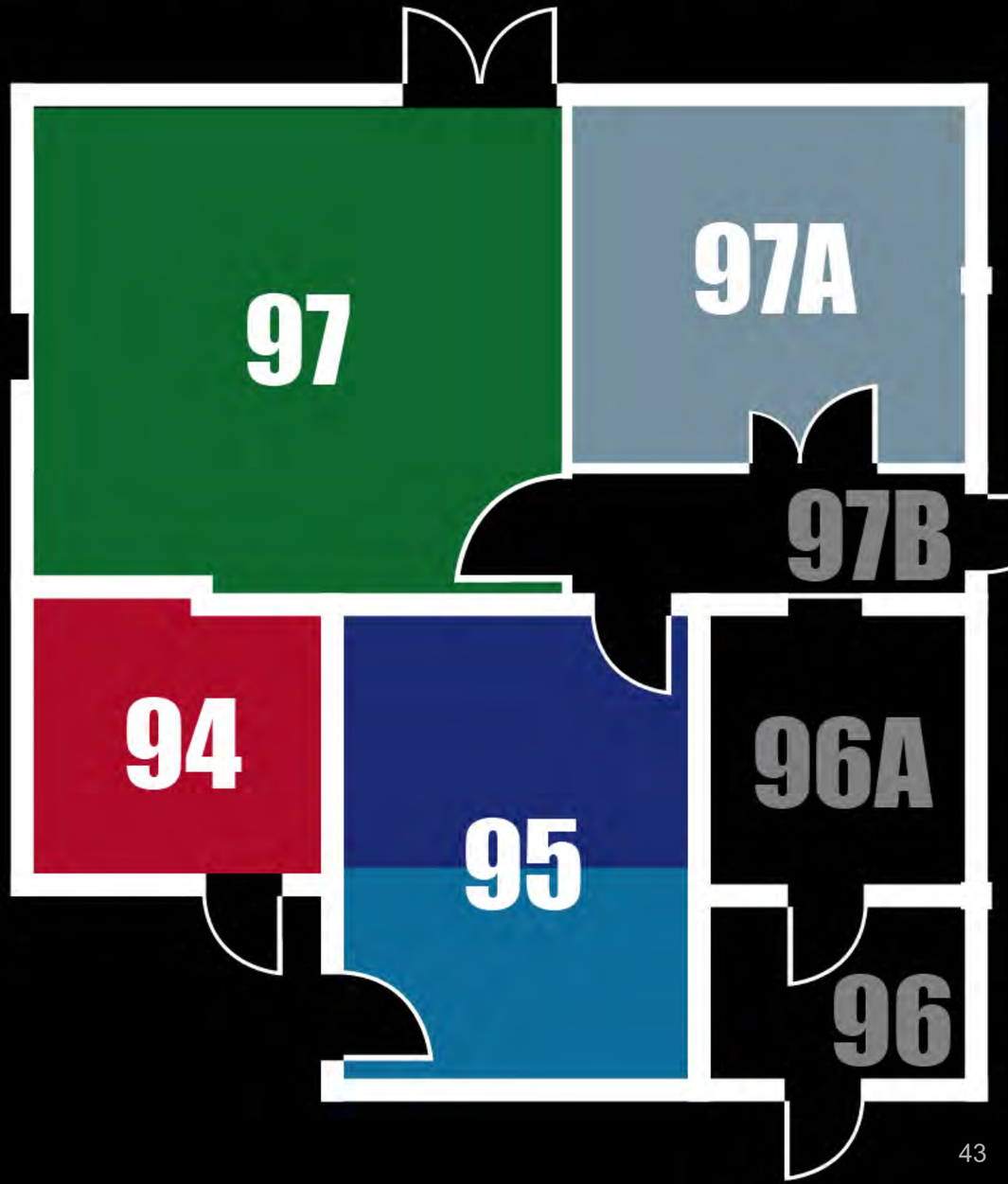
PREP LAB - 94

FEI Quanta 250 ESEM - 95

JEOL GrandARM 300F - 97

Asylum Infinity AFM - 95

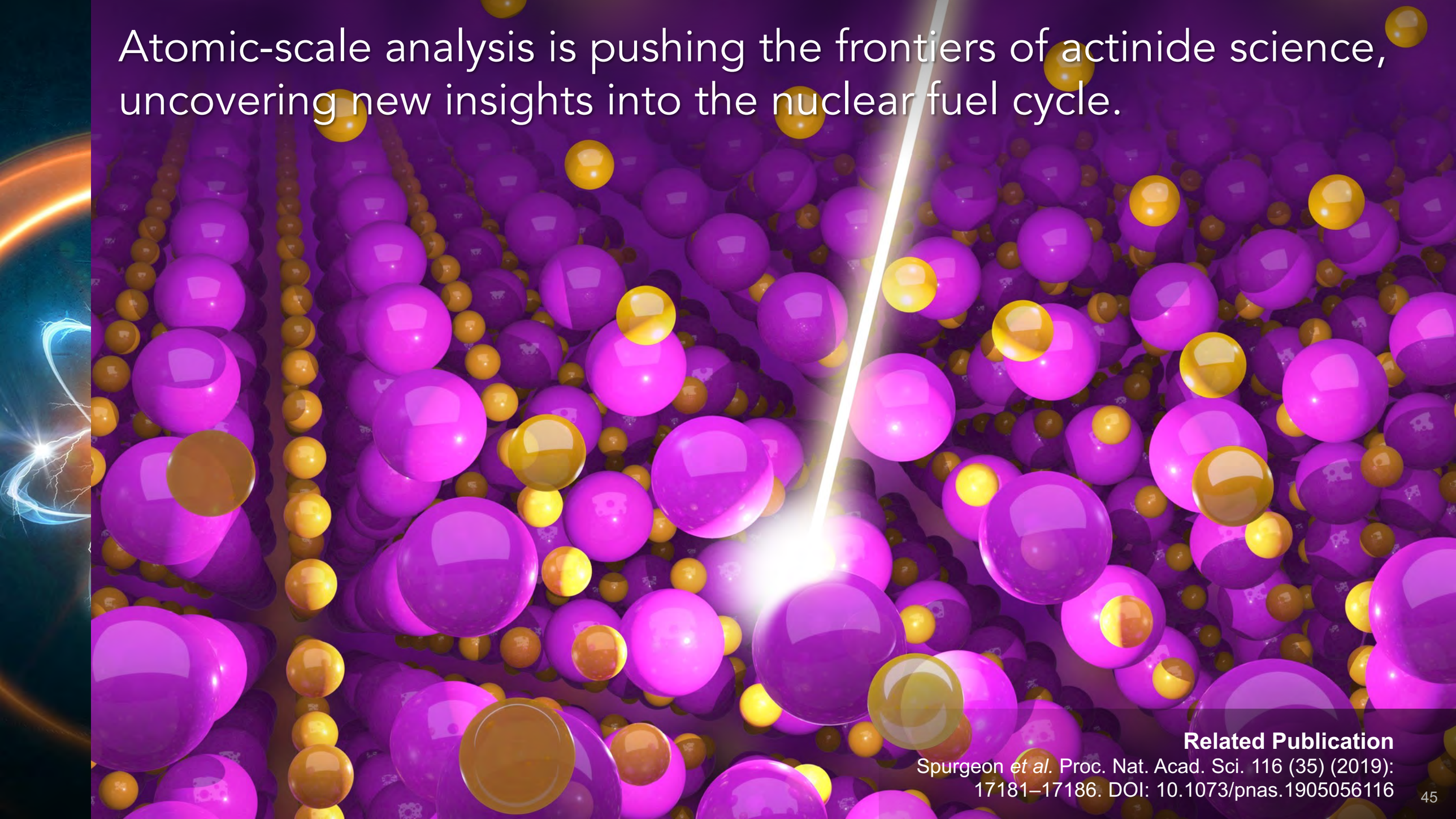
FEI Helios 660DualBeam - 97A



PNNL has made substantial investments in the next-generation of nuclear materials characterization and analysis.

Research Highlight
https://bit.ly/3hhaS9H

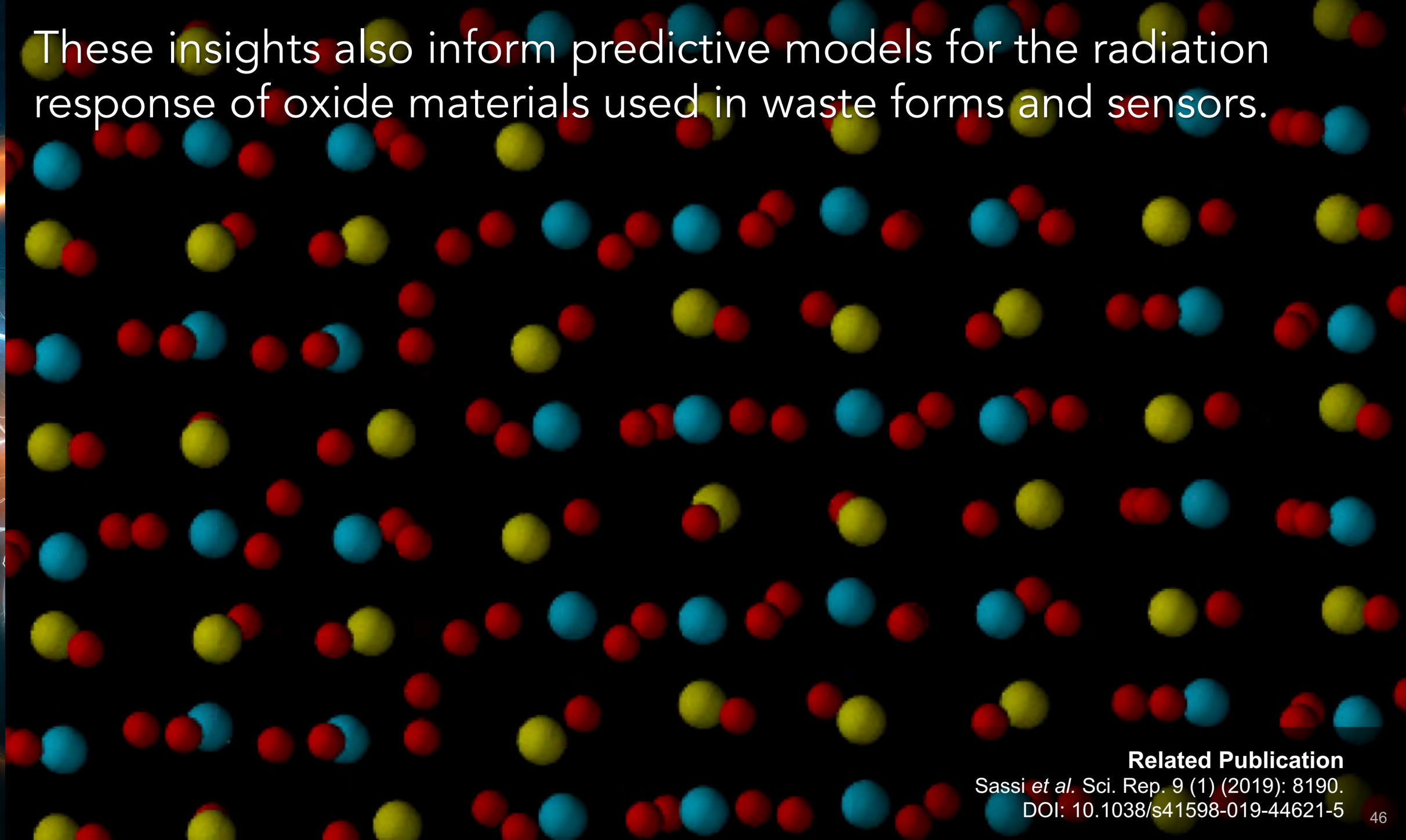
Atomic-scale analysis is pushing the frontiers of actinide science, uncovering new insights into the nuclear fuel cycle.



Related Publication

Spurgeon *et al.* Proc. Nat. Acad. Sci. 116 (35) (2019): 17181–17186. DOI: 10.1073/pnas.1905056116

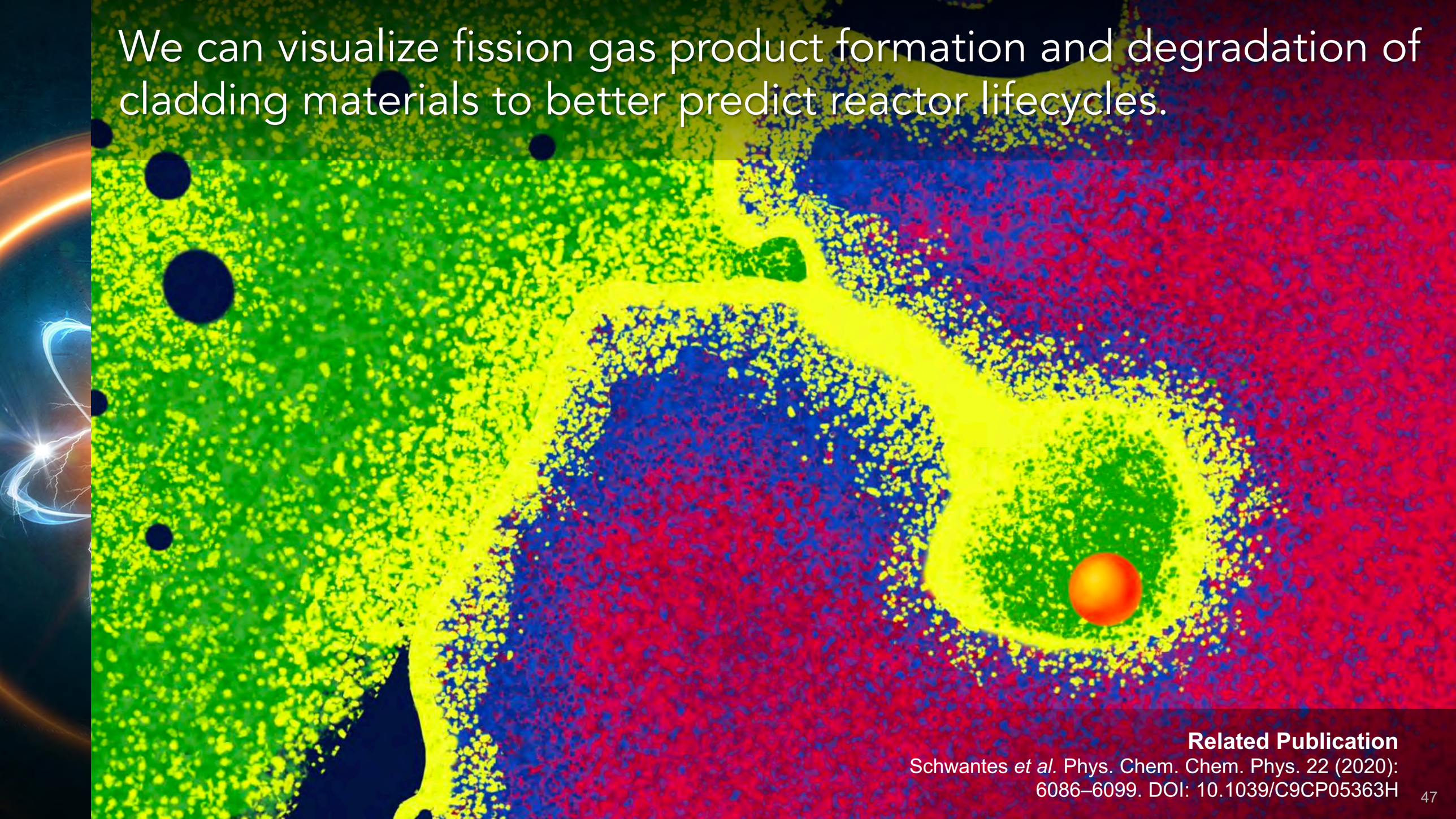
These insights also inform predictive models for the radiation response of oxide materials used in waste forms and sensors.



Related Publication

Sassi *et al.* Sci. Rep. 9 (1) (2019): 8190.
DOI: 10.1038/s41598-019-44621-5

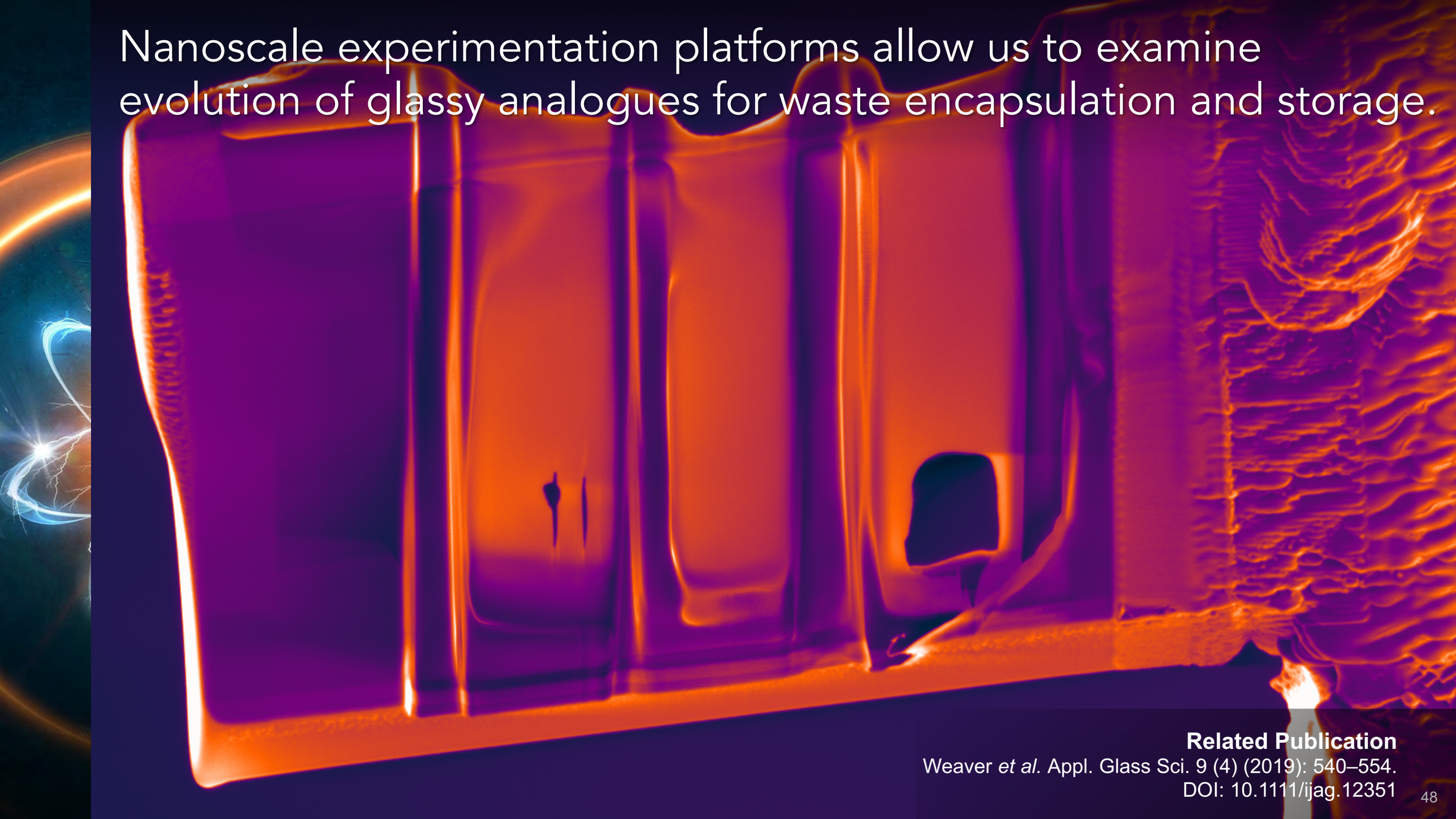
We can visualize fission gas product formation and degradation of cladding materials to better predict reactor lifecycles.



Related Publication

Schwantes *et al.* Phys. Chem. Chem. Phys. 22 (2020): 6086–6099. DOI: 10.1039/C9CP05363H

Nanoscale experimentation platforms allow us to examine evolution of glassy analogues for waste encapsulation and storage.



Related Publication

Weaver *et al.* Appl. Glass Sci. 9 (4) (2019): 540–554.
DOI: 10.1111/ijag.12351

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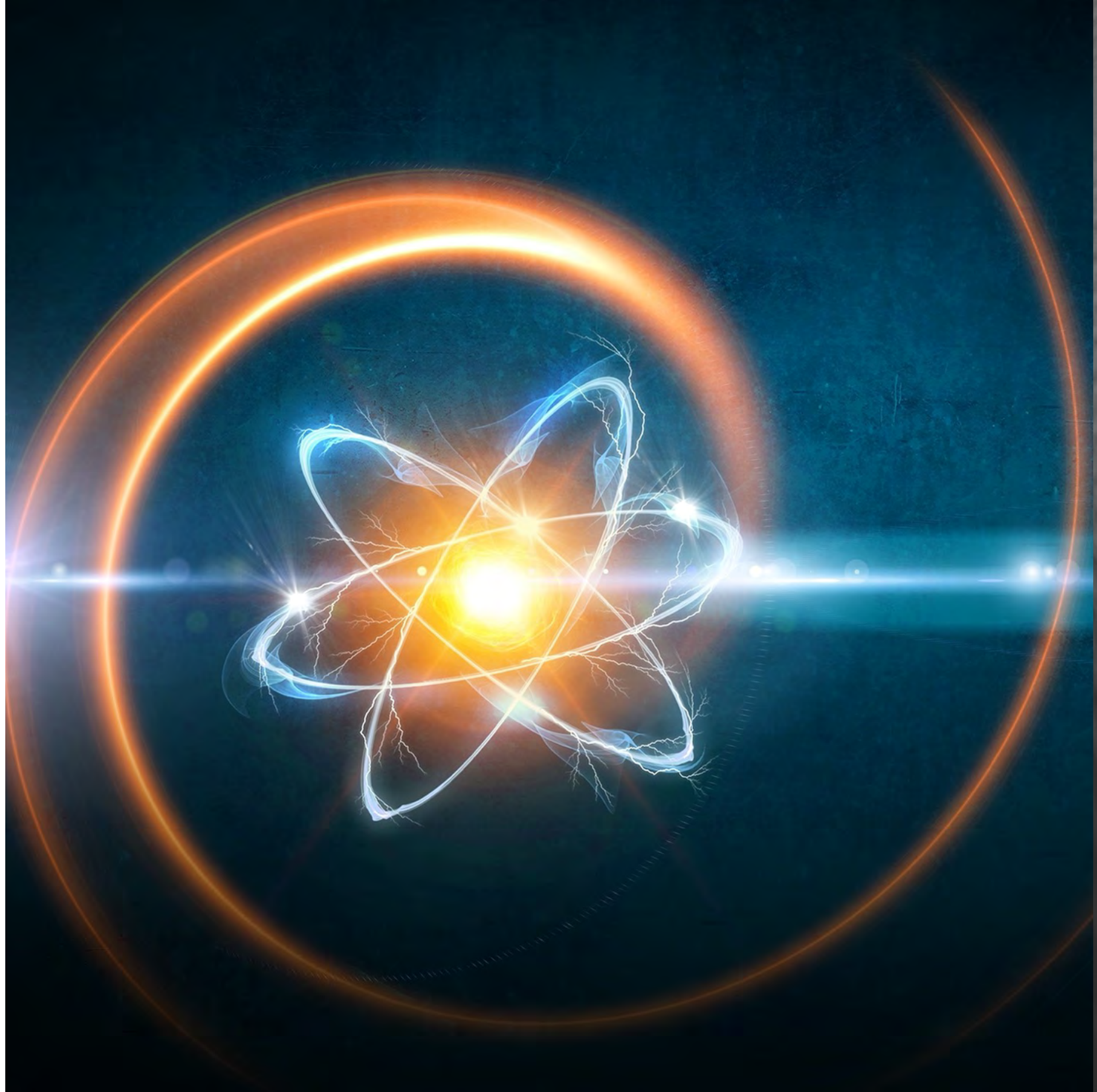
Radiation Detector Testing at PNNL

July 1, 2020

Paul Johns, PhD

Radiation Response & Characterization
Signature Science & Technology
National Security Directorate



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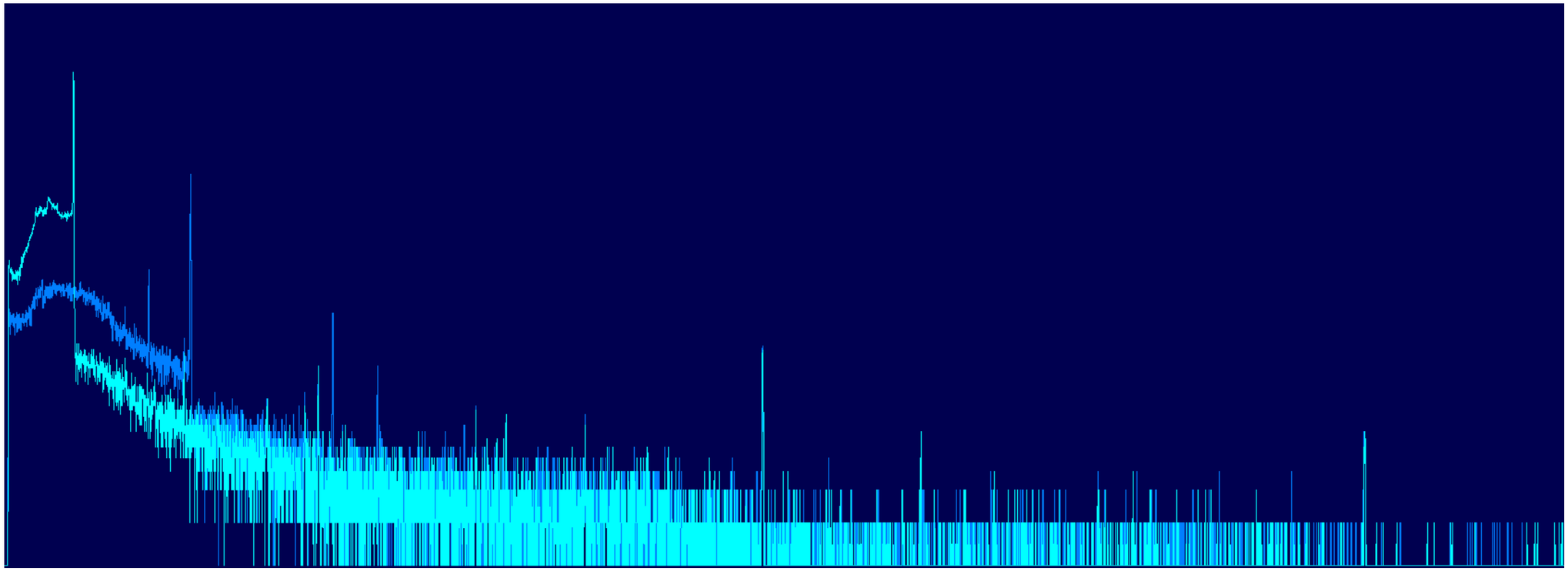
Radiation Detector Testing and Evaluation

- Detecting and deterring radiological threats is a key national security mission
- Most detection solutions are sourced from commercially available radiation detection systems
- How do stakeholders ensure that deployed equipment will meet their mission needs?

Challenges Among Detection Systems

- There is no “perfect sensor” practical for all missions.
- The field of detection science continuously develops new hardware and software toward more reliable spectroscopic detection systems.



Testing Emerging Radiation Detection Technologies

- Novel detection technologies must be assessed before being deployed.
- PNNL hosts a testbed for evaluating the performance of radiation detection equipment.
  - Interdiction Technologies Integration Laboratory (ITIL)
- Emphasis on two areas
  1. Testing under controlled and repeatable conditions.
  2. Representing conditions in the field.

What are detection systems and how are they used?

Personal Radiation Detector

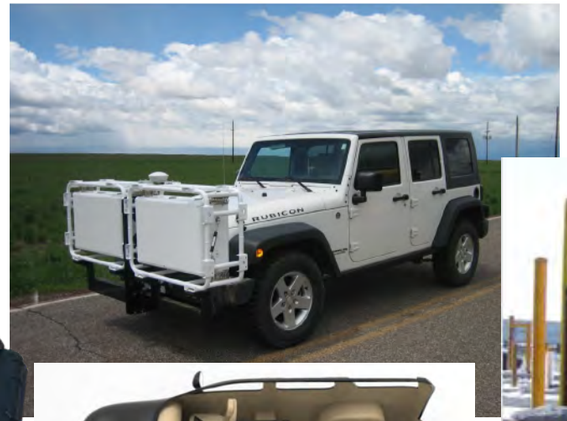
Size, $$$, Infrastructure

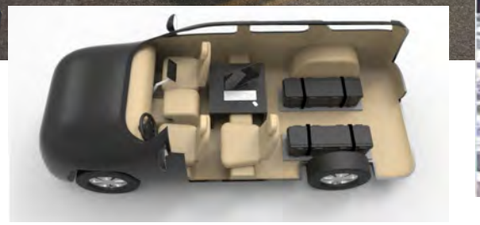
Handheld Identification Device

Backpack Radiation Detector

Mobile/Aerial Radiation Detection System

Radiation Portal Monitor





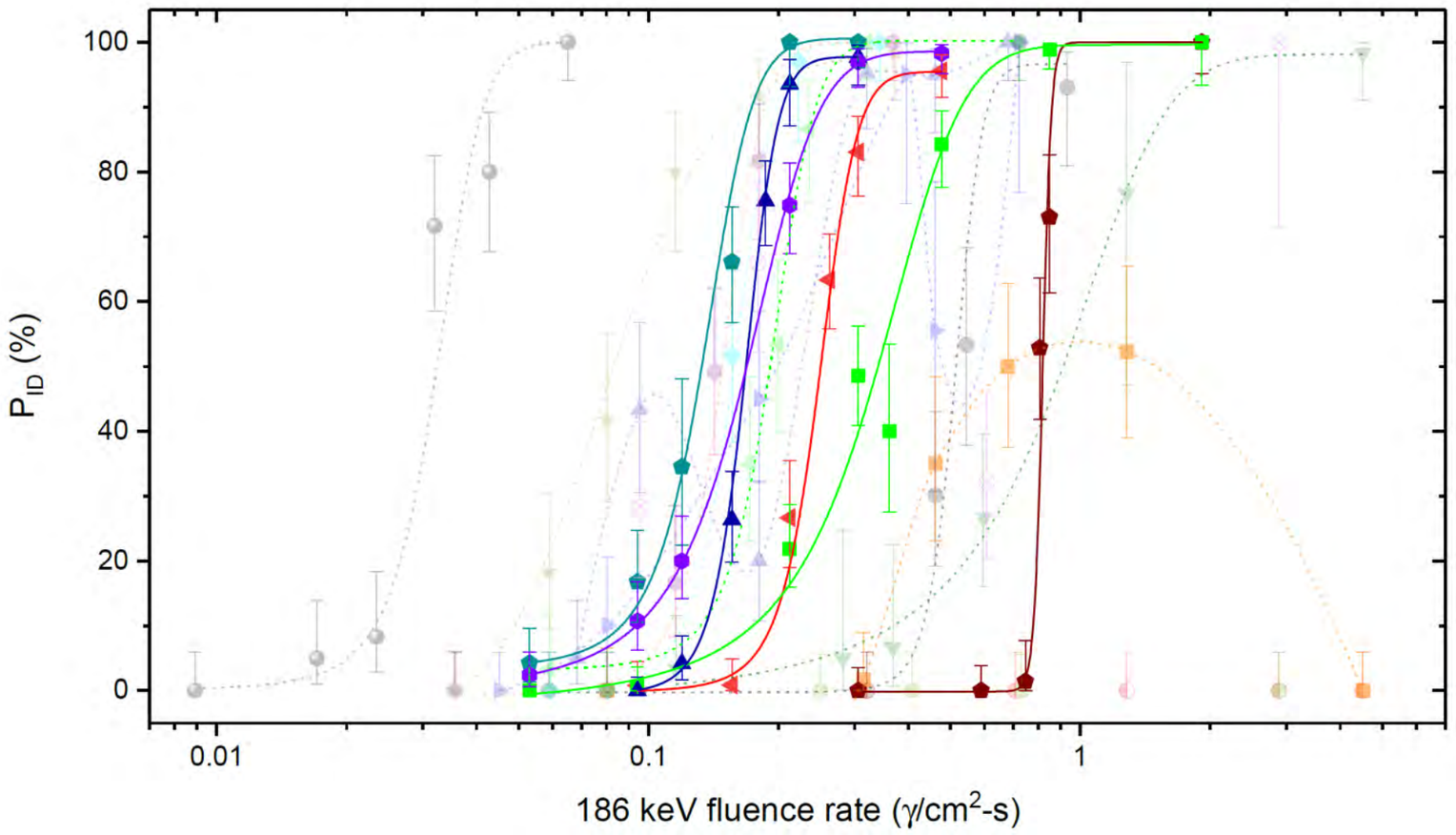
What makes a radiation detector suitable for deployment?

- Can it meet mission requirements?
  - I.e., target minimum detectable activity or quantity
  - Minimum “nuisance” alarms
- Is it operable?
  - End users are not scientists, but typically law enforcement officers
- Is it sustainable?
  - Equipment should be robust—threats cannot be detected with a broken detector

Analyzing Hardware and Algorithms

- Do candidate detection systems detect and/or identify at low fluence rates?
- What is the impact of shielding, NORM, or standoff distance on detection performance?
- What algorithm methods are most effective?

Analyzing Hardware and Algorithms

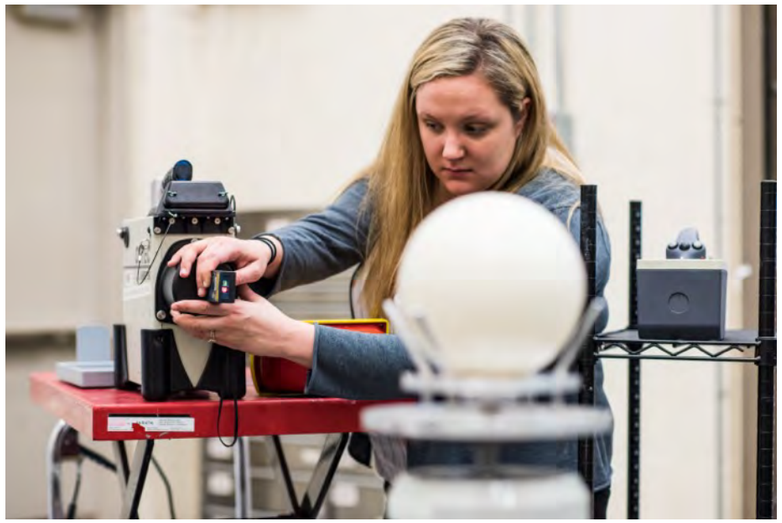


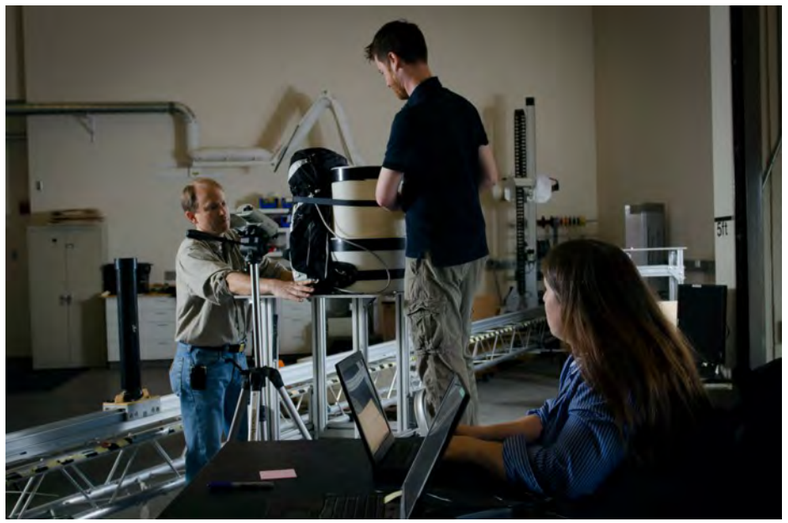
- Do candidate detection systems detect and/or identify at low fluence rates?
- What is the impact of shielding, NORM, or standoff distance on detection performance?
- What algorithm methods are most effective?

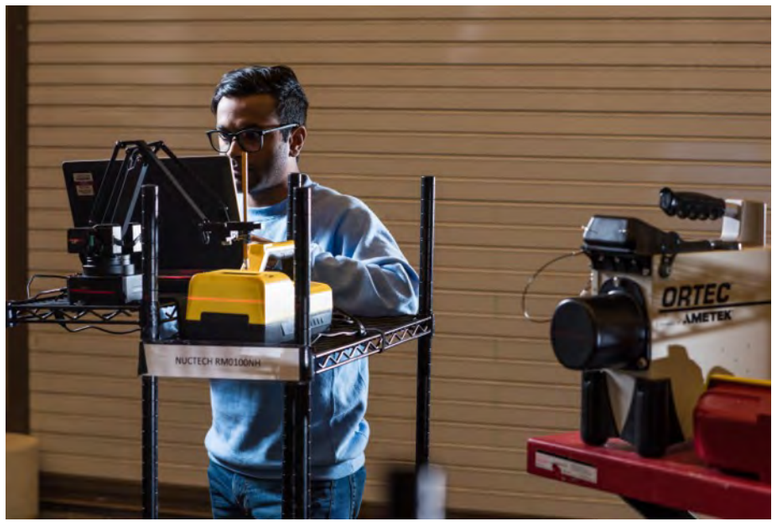
Summary

- Radiation detection science continually develops better sensors, smarter algorithms, and more reliable equipment.

- At PNNL we develop, test, and integrate emerging radiation detection solutions. Our work impacts global capabilities in detecting and deterring radiological threats.







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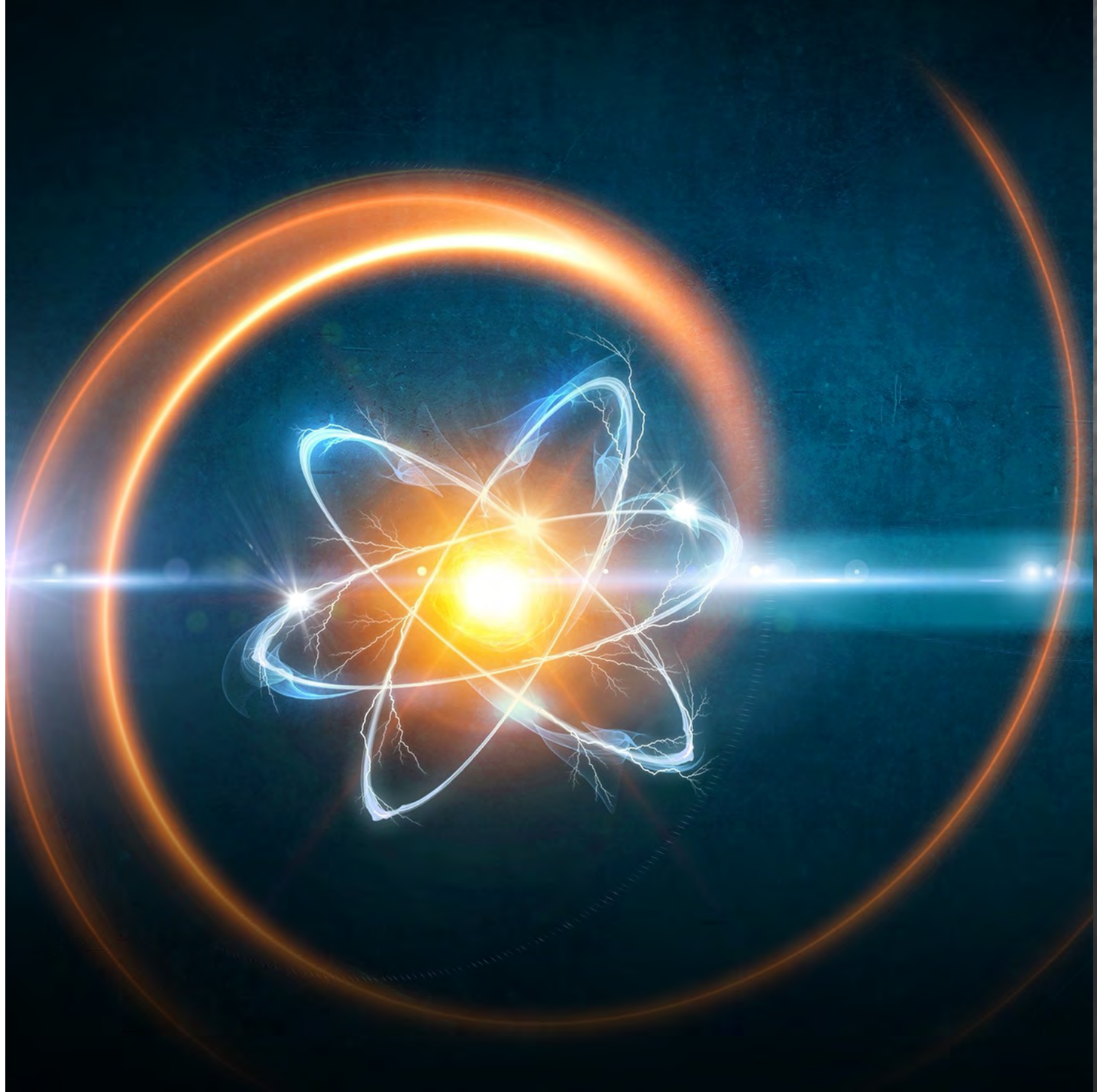
Nuclear Research at PNNL: Solid Phase Processing

July 1, 2020

Hellen Jiang, PhD

Solid Phase Processing Materials
Applied Materials & Manufacturing
Energy & Environment Directorate



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Materials Innovation Enables our Present … and will Define our Future

DOE and NRC research focus:

- ✓ Repair & Damage Mitigation
- ✓ High Performance Manufacturing
- ✓ New and Stronger Materials

PNNL offers new opportunities with the unique suite of ***solid phase processing*** capabilities

→ **Better**
Cheaper
Greener

Manufacturing

Manufacturing Path Comparison

- Conventional manufacturing and repair methods
  - Melting:
    - ✓ High energy input
    - ✓ Less optimal materials properties
    - ✓ Damages adjacent materials
- Novel manufacturing and repair methods
  - No melting
    - ✓ Lower energy input
    - ✓ Shear strain → high performance materials

Liquid phase processing: casting and arc welding

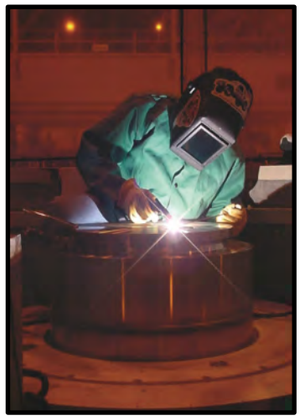
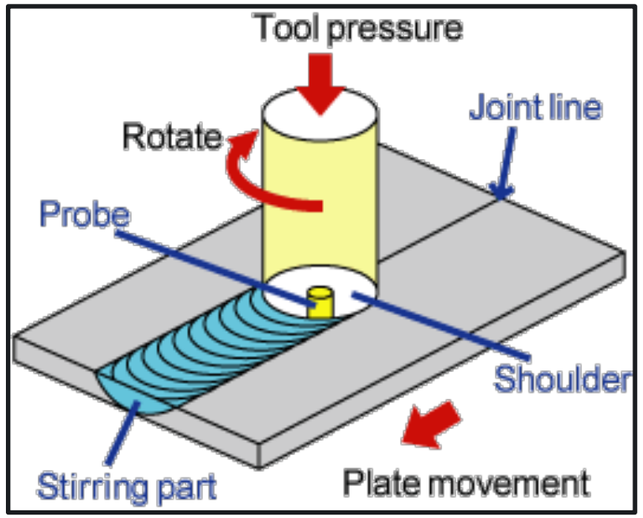
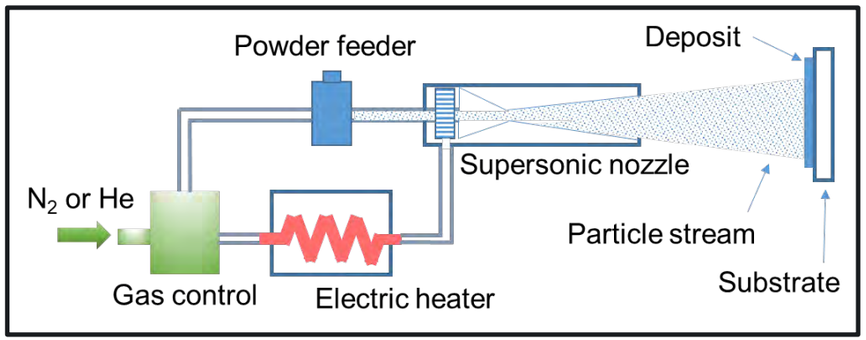


Image from Flor.Inc

Solid phase processing: friction stir welding and cold spray





Solid Phase Processing Capabilities at PNNL

Solid Phase Processing (SPP) is the application of a high shear strain during metals synthesis or fabrication, to produce high-performance microstructures in alloys, semi-finished products, and engineered assemblies, ***without melting the constitutive materials.***

Friction Stir Welding/Processing

Refurbishment/repair, joining, and introduction of *in-situ* sensors

UHV Cold Spray

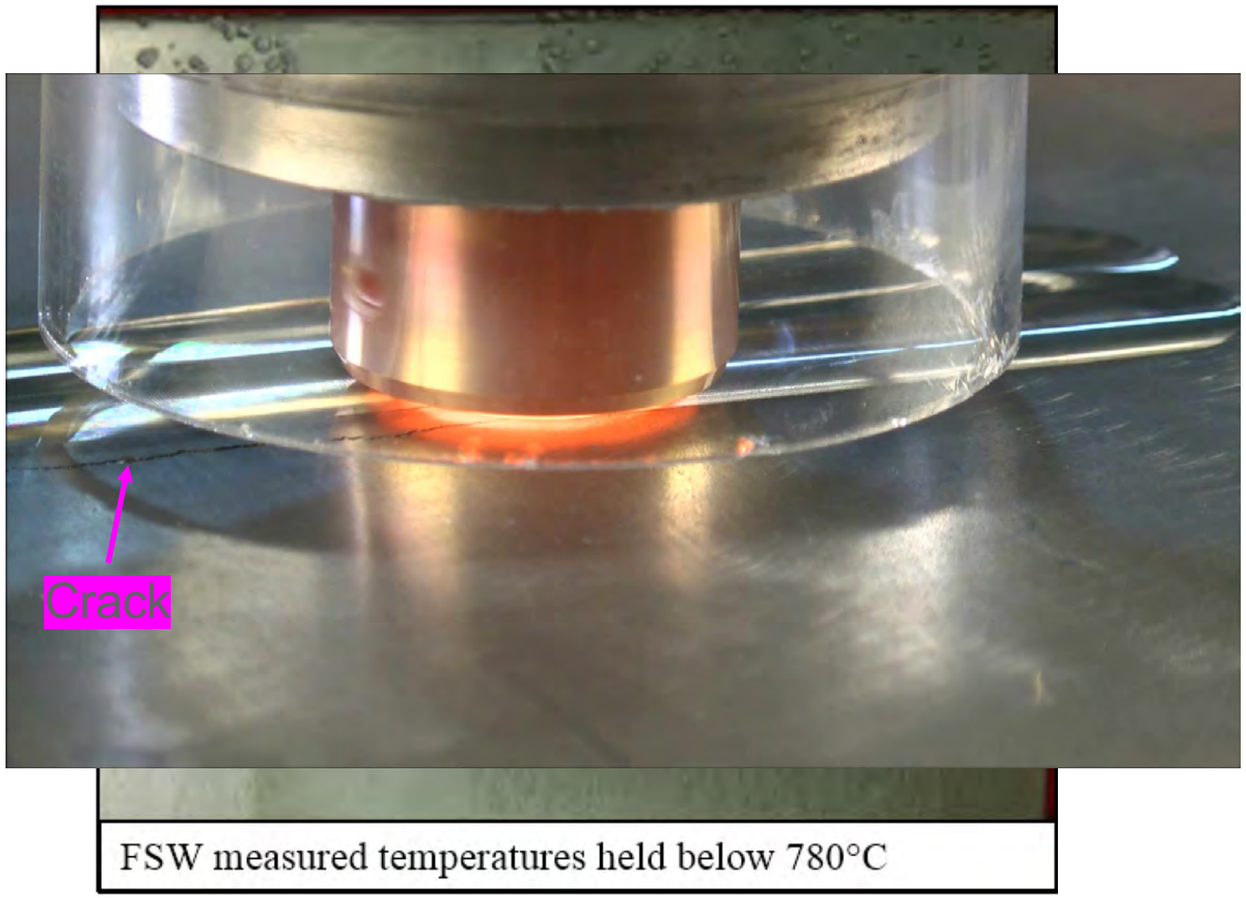
Refurbishment/repair, new coatings (including “smart” coatings), additive manufacturing

Shear Assisted Processing & Extrusion

New materials for structural components and for fuels

Solid Phase Processing: Demonstrated Advantages for Nuclear Applications

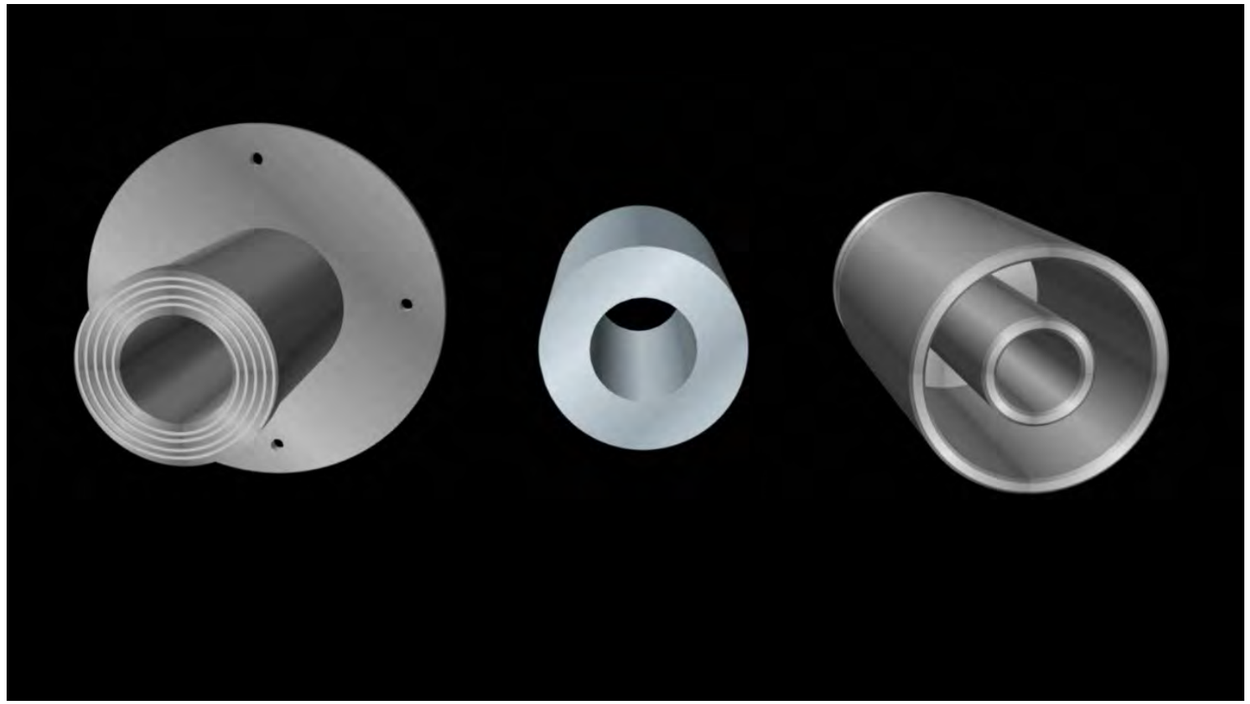
- Reduced susceptibility of **pitting** of friction stir welding compared to conventional fusion welds
- **Crack** repair/mitigation with friction stir welding and cold spray for

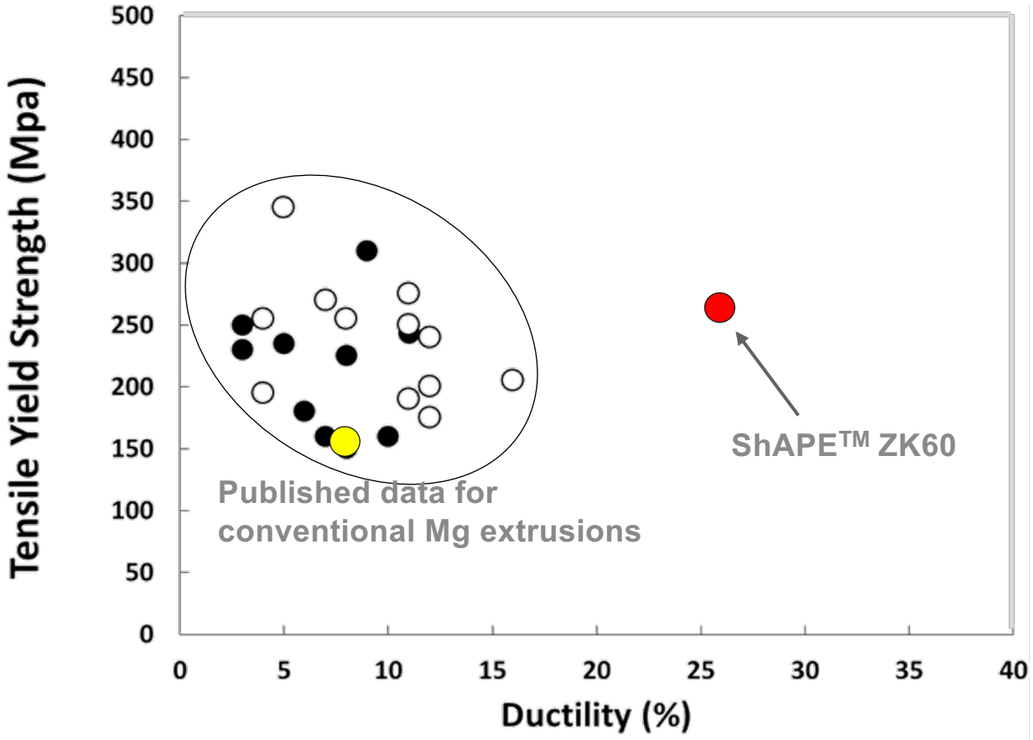


FSW measured temperatures held below 780°C

Solid Phase Processing: Demonstrated Advantages for Nuclear Applications

- Superior **mechanical** strength with ShAPE and FSW





Solid Phase Processing: Advantages for the Nuclear Industry

- ✓ Solid Phase Processing offers a different manufacturing pathway to higher-performance components without requiring that the constituent materials be melted.
- ✓ Better component properties lead to longer service life and longer maintenance cycles PLUS there are repair/refurbishment options.
- ✓ Solid Phase Processing methods are applicable to both existing and future nuclear power plants.

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Questions & Discussion

Learn more at
www.pnnl.gov