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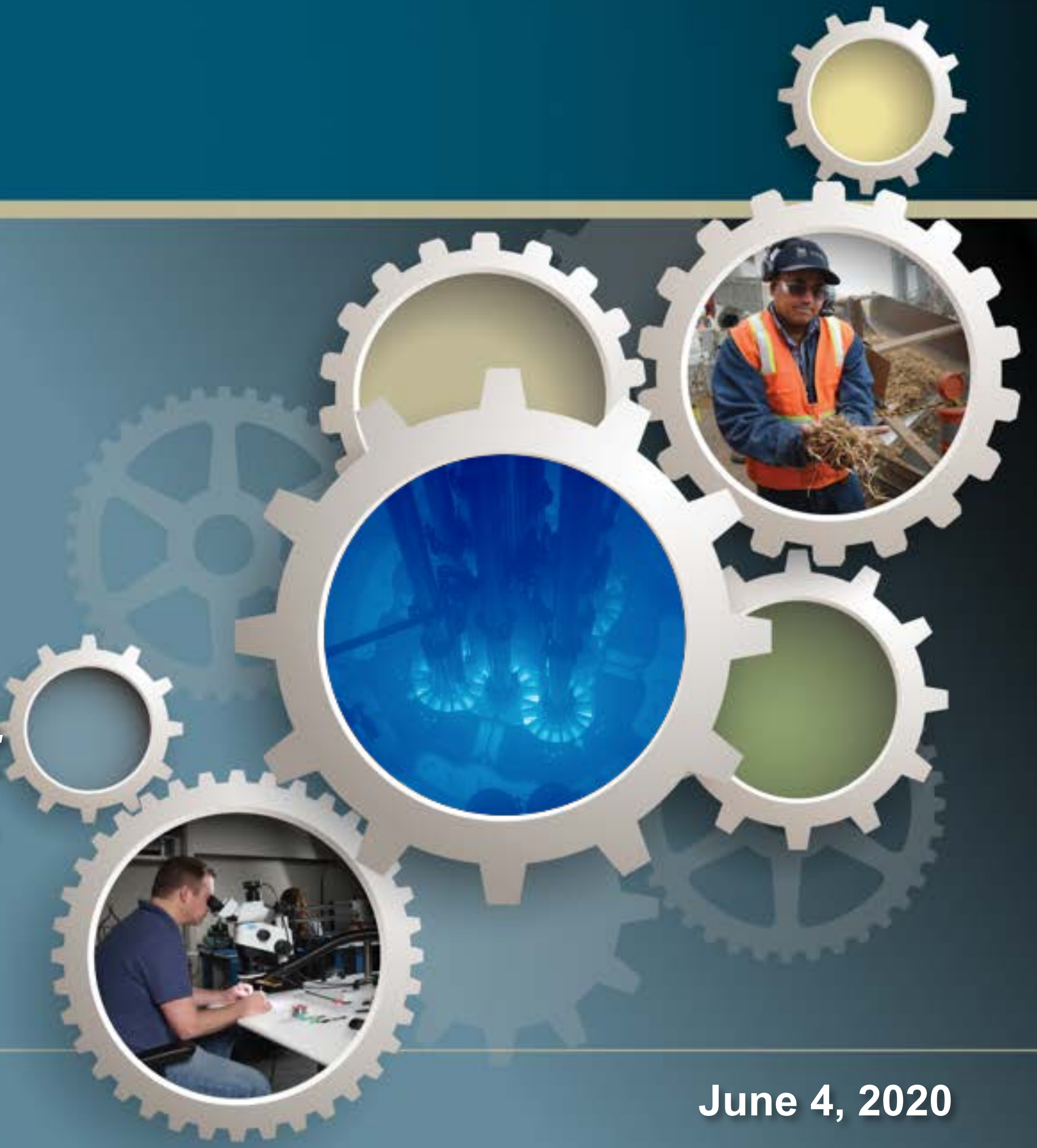
Nuclear Science & Technology

Advanced Reactor Demonstration Project Opportunities in Idaho

Dr. Corey McDaniel
Chief Commercial Officer
Nuclear Science & Technology



June 4, 2020

Idaho National Laboratory

The Idaho National Laboratory – 70 Years of Groundbreaking Nuclear Energy R&D

International Intellectual Leadership

Building a Laboratory

National Reactor Testing Station

INEL – Idaho National Engineering Laboratory

Energy Mission – Reactor Science, Safety and Sustainability Solutions

INEEL – Idaho National Engineering and Environmental Laboratory

Environmental Management Mission

INL – Idaho National Laboratory

INEEL & ANL-W combined to create the new Idaho National Laboratory

- **Nuclear Energy**
- **National and Homeland Security**
- **Energy and Environment**

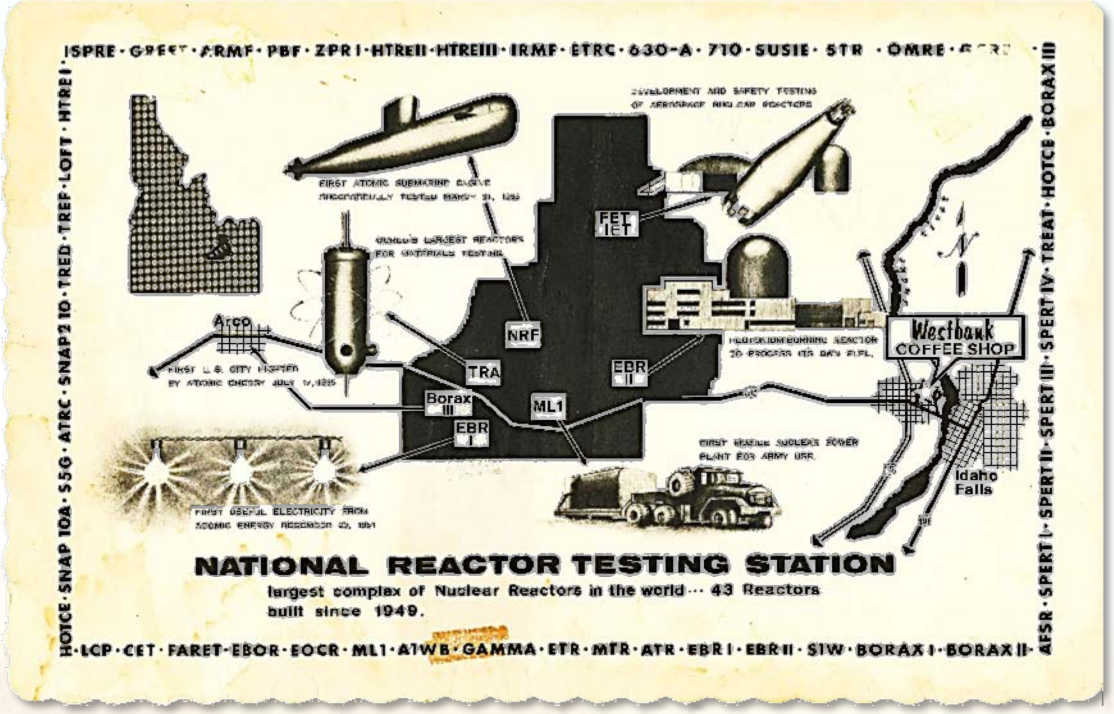
Argonne National Laboratory

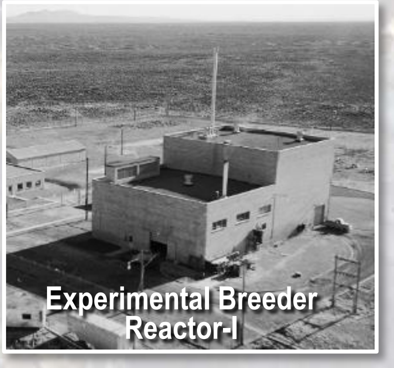
- **Advancing Nuclear Energy**
- **Securing & Modernizing Critical Infrastructure**
- **Enabling Clean Energy Systems**

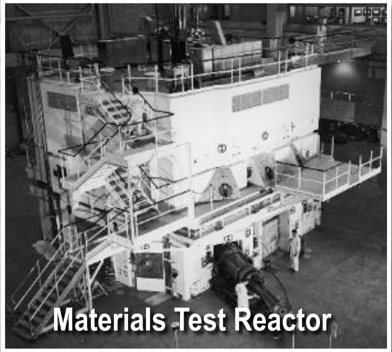
1949	1974	1997	2005	2020

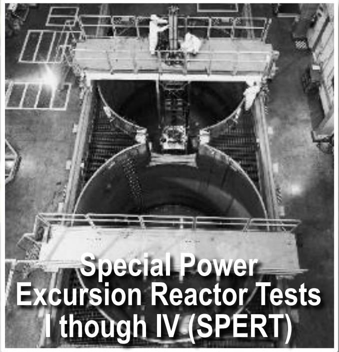
The National Reactor Testing Station drove nuclear innovation in the U.S. and around the world

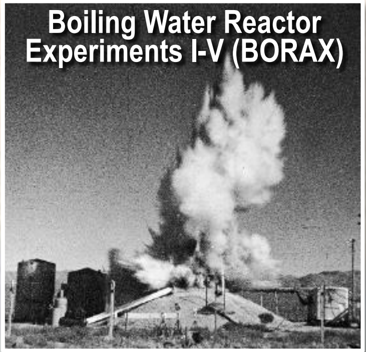
- First nuclear power plant
- First U.S. city to be powered by nuclear energy
- First submarine reactor tested; training of nearly 40,000 reactor operators until mid-90s
- First mobile nuclear power plant for the army
- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors




Experimental Breeder Reactor-I


Materials Test Reactor


Special Power Excursion Reactor Tests I though IV (SPERT)


Boiling Water Reactor Experiments I-V (BORAX)


S1W (aka Submarine Thermal Reactor (STR)

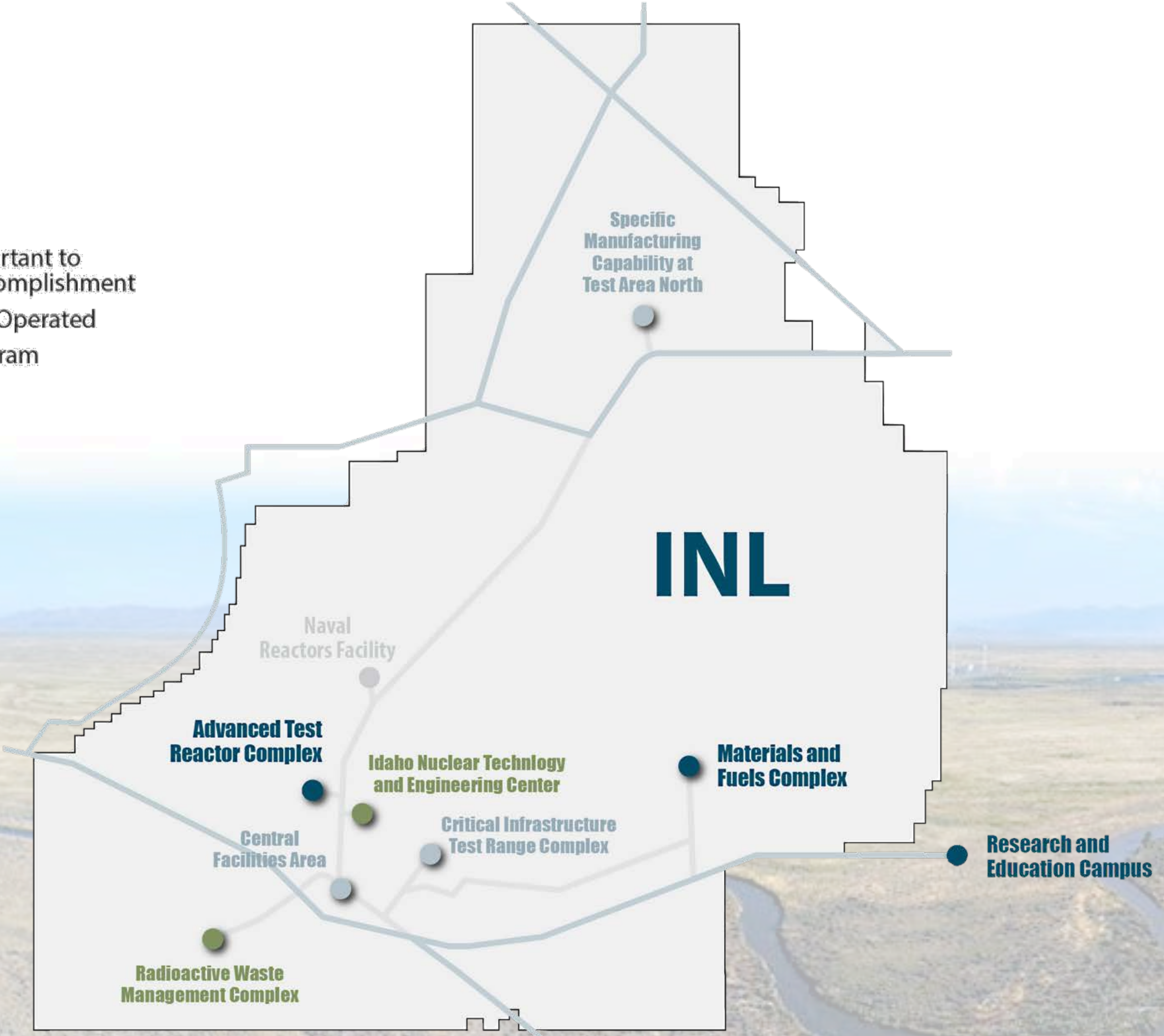

Loss Of Fluid Test Facility (LOFT)

The Idaho National Laboratory Site – A Unique Capability for the Nation

569,178 Acres
890 Square Miles

- Public Highways
- Main Site Roads
- Primary INL Campus Important to NE and other Mission Accomplishment
- Presently EM Owned and Operated
- Supporting INL Multiprogram Missions

0 2 4 6 8
Scale in Miles



16 Nuclear facilities (Haz Cat 1, 2 & 3)

44 Radiological facilities

4 Operating reactors

17.5 Miles railroad for shipping nuclear fuel

40 Miles primary roads (125 total)

7 Substations with interfaces to three power providers

112 Miles high-voltage transmission lines

3 Fire stations

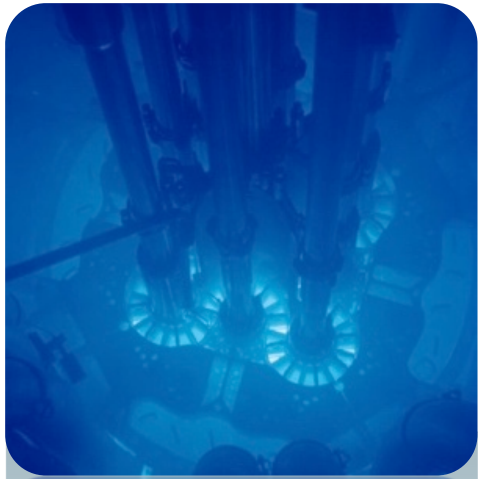
4,927 Employees

FY19 Business Volume $1.35 B

Addressing the world's most challenging problems

Nuclear S&T

- Nuclear fuels and materials
- Nuclear systems design and analysis
- Fuel cycle science and technology
- Nuclear safety and regulatory research
- Advanced Scientific Computing



Advanced Test Reactor

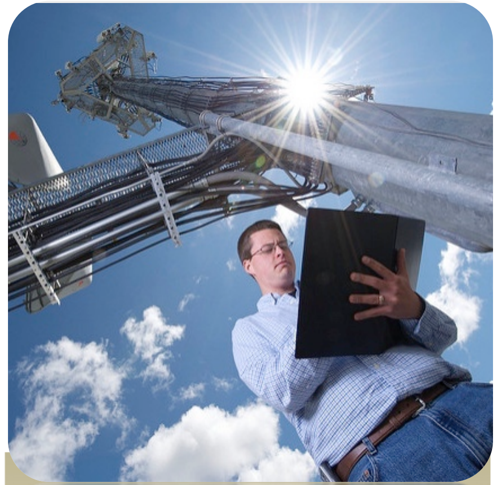
- Steady state neutron irradiation of materials and fuels
  - Naval Nuclear Propulsion Program
  - Industry
  - National laboratories and universities

Materials & Fuels Complex

- Transient testing
- Analytical laboratories
- Post-irradiation examination
- Advanced characterization
- Fuel fabrication
- Space nuclear power and isotope technologies

Energy & Environment S&T

- Advanced transportation
- Environmental sustainability
- Clean energy
- Advanced manufacturing
- Biomass



National & Homeland Security S&T

- Critical infrastructure protection and resiliency
- Nuclear nonproliferation
- Physical defense systems

Nuclear Science & Technology

Nuclear Capabilities of the Idaho National Laboratory

Dr. John Wagner

Associate Laboratory Director

Nuclear Science & Technology

john.wagner@inl.gov

June 8, 2020

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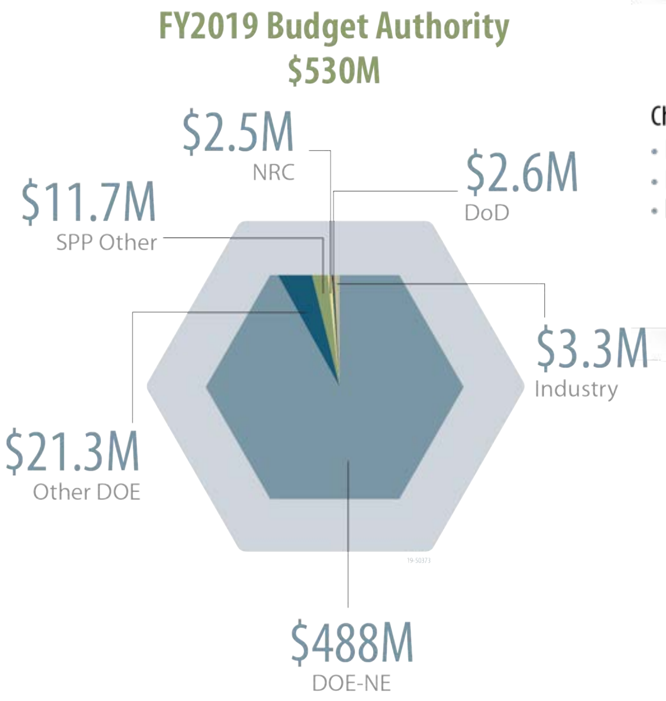
INL Idaho National Laboratory

Nuclear RD&D Team at INL

1559 staff working to revive, revitalize, and expand nuclear energy, enabled by unique research facilities, infrastructure & capabilities



Nuclear Science & Technology

Change the world's energy future by advancing nuclear energy.

- Nuclear fuels and materials
- Nuclear systems design and analysis
- Fuel cycle science and technology
- Nuclear safety and regulatory research
- Advanced Scientific Computing

- 465 Employees
- 178 PhD
- 109 Master
- 119 Bachelor
- 6 Associate
- 19 Postdoc

Materials & Fuels Complex

Experiments and engineering that drive the world's nuclear energy future.

- Transient testing
- Space nuclear power and isotope technologies
- Analytical laboratories
- Fuel Fabrication
- Post-irradiation examination
- Advanced characterization

- 671 Employees
- 44 PhD
- 79 Master
- 197 Bachelor
- 84 Associate
- 6 Postdoc

Advanced Test Reactor

Provide unique irradiation capabilities for nuclear technology research and development.

Steady-state neutron irradiation of materials and fuels

- Naval Nuclear Propulsion Program
- Industry
- National laboratories and universities

- 423 Employees
- 2 PhD
- 43 Master
- 133 Bachelor
- 44 Associate

19-50373

Unique Research Facilities and Infrastructure/Foundational Enablers

Nuclear S&T Directorate

465 staff

19 postdocs; growing

41% Ph.D.

14% MS

109 Interns from 39 Universities

21 new hires each quarter

SPONSORS

88% DOE Office of Nuclear Energy

5% Other DOE

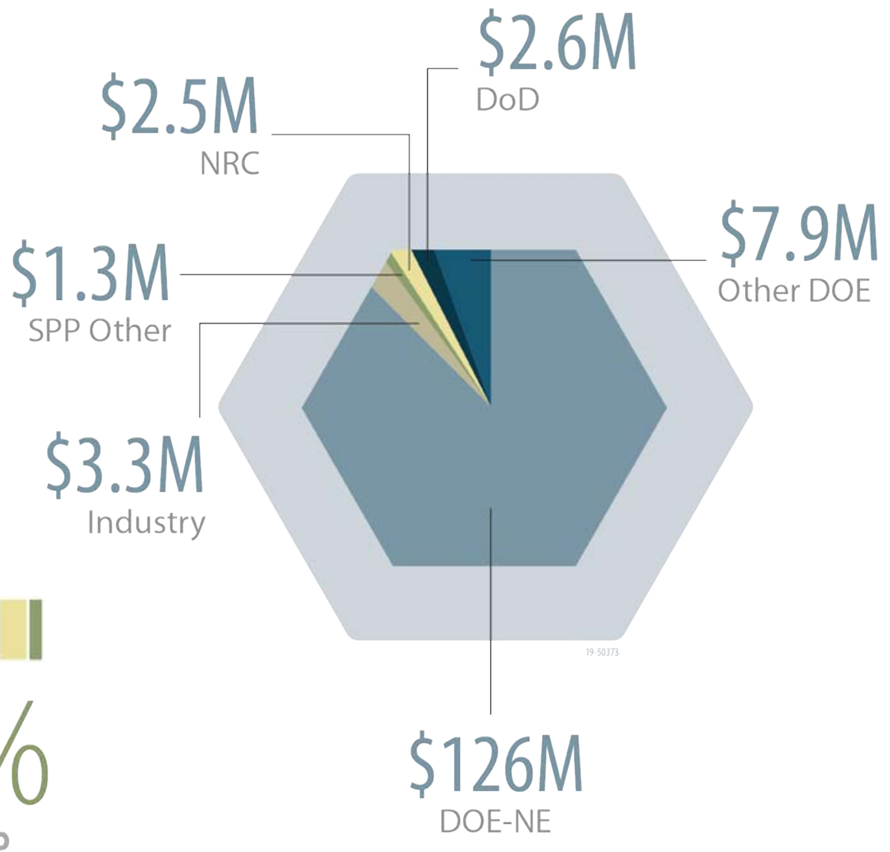
2% Industry

2% Department of Defense

2% Nuclear Regulatory Commission

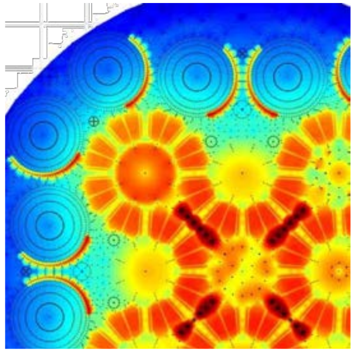
1% SPP DOE

NS&T FY 2019 Budget Authority



Nuclear S&T Directorate

Reactor Systems Design & Analysis

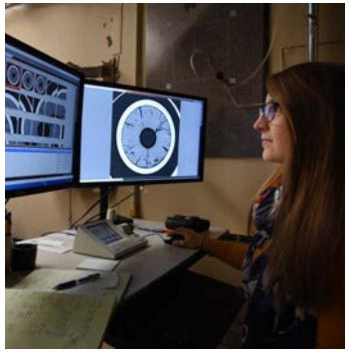


Nuclear Safety & Regulatory Research

Advanced Scientific Computing

Fuel Cycle Science & Technology

Nuclear Fuels & Materials



Leadership Positions in Major DOE-NE Initiatives/Programs

GAIN Gateway for Accelerated Innovation in Nuclear

NSUF Nuclear Science User Facilities

ART ADVANCED REACTOR TECHNOLOGIES

LWRS

AFC Advanced Fuels Campaign

MW Material Recovery & Waste Form Development

NEAMS

CASL

Sustaining the existing LWR fleet:

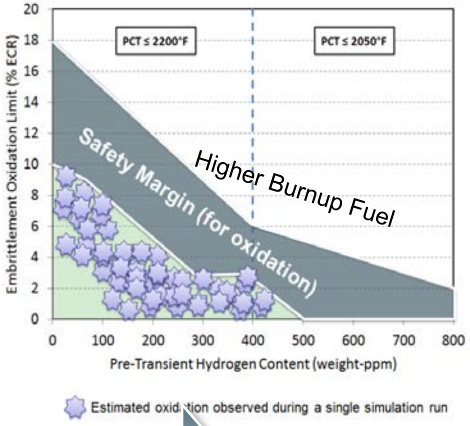
Vision for a Thriving Existing Fleet

Energy systems and market analyses

- Define attributes of zero-emission baseload energy for market recognition
- Establish vital relationships to other market and grid attributes – resilience, reliability, etc.

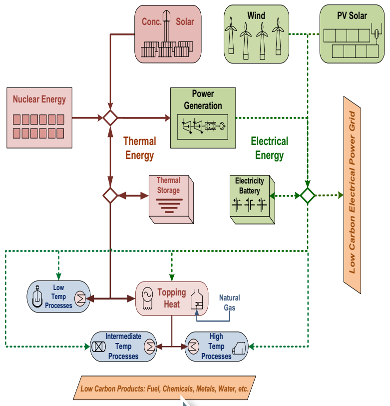
Risk-informed tools and analyses to recover plant margins and reduce cost

- Employ advanced PRA tools and best estimate codes to reduce unnecessary conservatisms that drive costs
- Key to NEI and industry initiatives



Integrated energy system testing

- Revenue and energy supply that addresses grid futures for US fleet
- CRADAs and industry engagement initiated to demonstrate technology

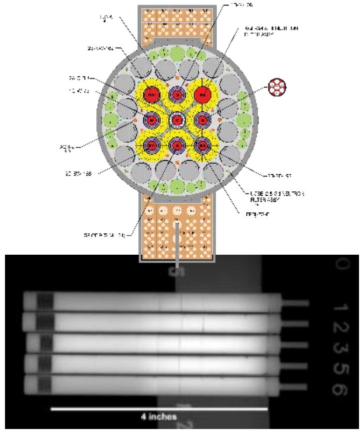


LWR modernization and life extension

- Work with plant operators to implement digital I&C upgrades to modernize plant control rooms
- Provide scientific basis of long-term material performance of SSCs to support license extension
- Develop sensors and more efficient methods and systems for plant health monitoring

Advanced Accident-Tolerant Fuel concepts

- Establish technical basis for licensing and deployment of accident-tolerant fuel concepts



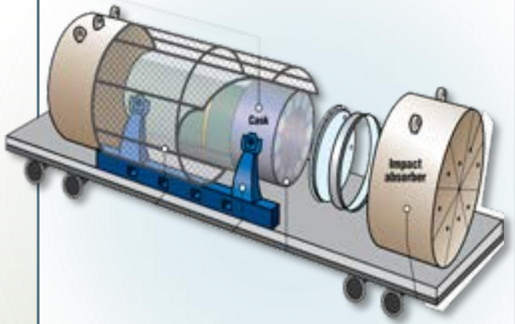
2019 2020 2021 2022

Creating the Next-Generation National Reactor Testing Station:

Vision for Advanced Reactor Demonstrations and Deployment

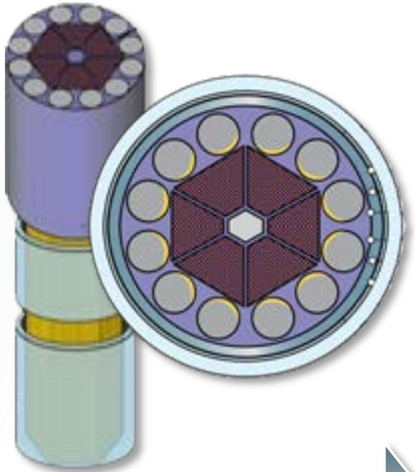
Demonstrate first microreactor by early 2020s

- Resolve key advanced reactor issues
- Open new markets for nuclear energy
- Provide a 'win' to build positive momentum



Commercial microreactors deployed

- Support deployment for remote site power and process heat customers
- RD&D to enable broader deployment

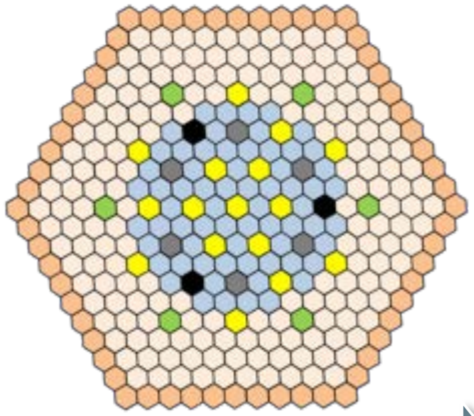


SMR(s) operating

- Enable deployment through siting and technical support
- Joint Use Modular Plant for federal RDD&D

Versatile Test Reactor (VTR) operating

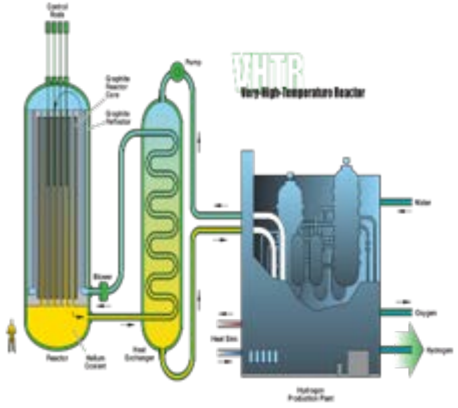
- Establish fast-spectrum testing and fuel development capability
- Support non-LWR advanced reactor demonstrations



Non-LWR advanced demonstration reactor by 2030

or before!

- Demonstrate non-LWR technology replacement of US baseload clean power capacity



2024 → **2025** → **2026** → **2030**

Enabling the nuclear energy future:

Vision for Effective, Integrated Fuel Cycle Solutions

Availability of Special Nuclear Materials

- Supply HALEU and other UNF to support advanced reactor start-ups
- Support development of HALEU transportation infrastructure

Management of Radiological Materials

- Develop computational tools to inform used nuclear fuel and waste management policy

Reduce Risk of Nuclear Proliferation

- Demonstrate direct immobilization of used nuclear fuel that increases proliferation resistance

Management of Legacy Fuels

- Develop technical and engineering modeling solutions to ensure safe and compliant storage of UNF

Infrastructure Updates

- Deploy test bed facilities that couple front and back-end fuel cycle processes with enhanced safeguards and security systems

National Reactor Innovation Center Will Provide Capabilities to Accelerate Technology Readiness From Proof-of-concept Through Proof-of-operation

NEICA

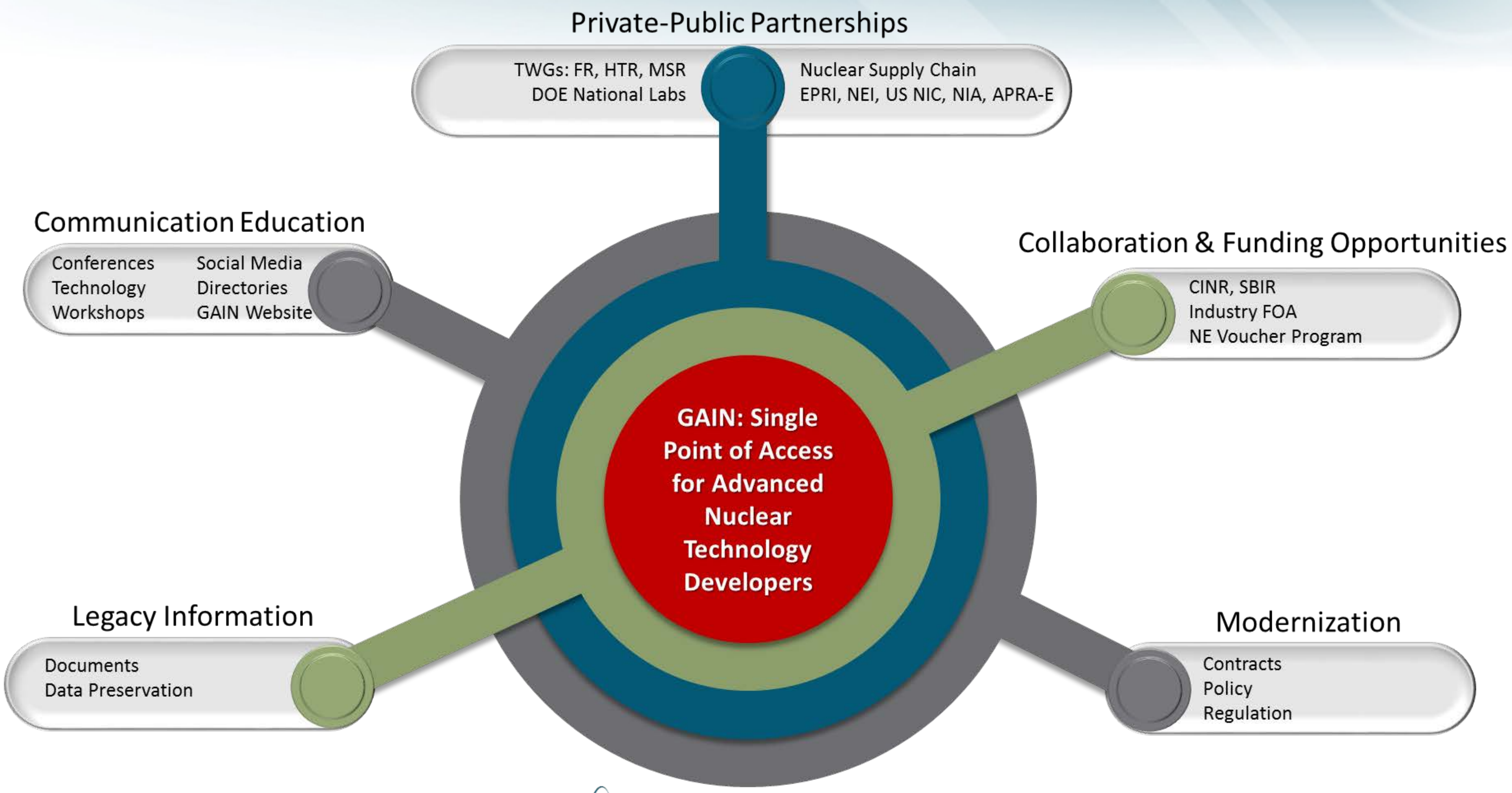
Nuclear Energy Innovation Capabilities Act

Signed into law September 2018, NEICA calls for the creation of a ***National Reactor Innovation Center*** *to support demonstration of cost-shared private reactors.*

NRIC

National Reactor Innovation Center

NRIC is a place where government and private companies can test and demonstrate new reactor designs, as well as materials, fuels, and other nuclear energy technologies.


Private-Public Partnerships
TWGs: FR, HTR, MSR
DOE National Labs
Nuclear Supply Chain
EPRI, NEI, US NIC, NIA, APRA-E
Communication Education
Conferences
Technology
Workshops
Social Media
Directories
GAIN Website
Collaboration & Funding Opportunities
CINR, SBIR
Industry FOA
NE Voucher Program
GAIN: Single Point of Access for Advanced Nuclear Technology Developers
Legacy Information
Documents
Data Preservation
Modernization
Contracts
Policy
Regulation

Other NST Topics for Discussion

- TRISO R&D (w/ ORNL)
- Microreactors (Jess Gehin)
- HALEU (Monica Regalbuto)
- Versatile Test Reactor (Kemal P.)
- Integrated Energy Systems (Shannon Bragg-Sitton)
- Others…

DOE Microreactor Program

Technology Development for Microreactor Development, Demonstration and Deployment

Jess. C. Gehin, National Technical Director (jess.gehin@inl.gov, 208-526-3486)

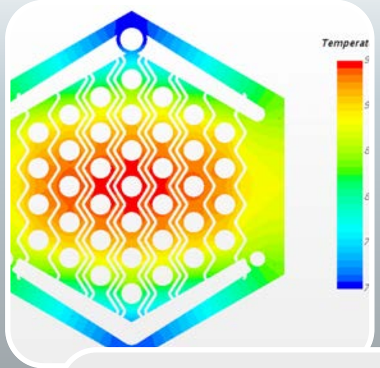
Program Vision

Through cross-cutting research and development and technology demonstration support, by 2025 the Microreactor Program will:

- Achieve technological breakthroughs for key features of microreactors
- Empower initial demonstration of the next advanced reactor in the US
- Enable successful demonstrations of multiple domestic commercial microreactors.

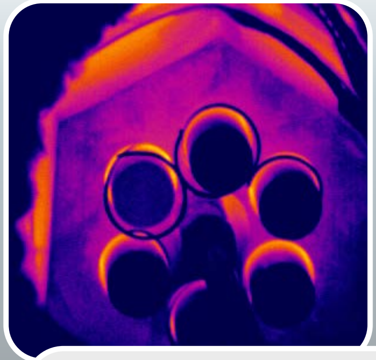
Program Objectives

- Engage with industry and private-sector developers to provide technologies
- Enable demonstration of microreactors
- Mature key technologies specifically needed by microreactor developers
- Assess microreactor specific regulatory and licensing issues



System Integration & Analyses

- Economics & Market Analysis
- Integrated Systems Analysis
- Applications of NEAMS computational Tools
- Technoeconomic Analyses
- Regulatory Development



Technology Maturation

- Advanced Heat Pipes
- Advanced Moderators
- Heat Exchangers
- Instrumentation & Sensors
- Advanced Materials and Material Code cases

Demonstration Support Capabilities

- Non-nuclear thermal and integration testing
- Microreactor Agile Non-nuclear Experimental Tesbed (MAGNET)
- Microreactor Applications Research, Validation and Evaluation (MARVEL)

Microreactor Demonstrations & Applications

- Reactor Demonstrations
- Remote heat & power
- Hydrogen co-generation
- District heating
- Desalination

R&D Capabilities to Support Microreactor Development

MAGNET - Microreactor AGile Non-nuclear Experimental Testbed

- 250 kW General-purpose non-nuclear test bed for performance evaluation of microreactor components and integrated system testing (heat pipe, gas-cooled, other).
- Demonstrate integration with relevant power conversion units and control Co-located with the Thermal Energy Distribution System (TEDS) and the High-Temperature Steam Electrolysis System to enable application and microgrid testing

Microreactor Design, Component Design & Safety Analysis

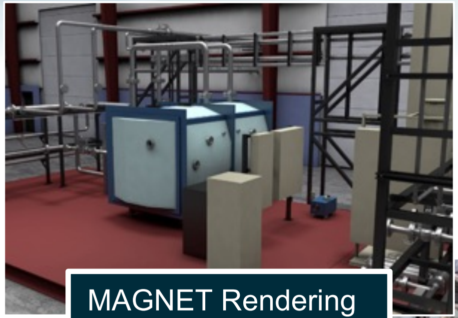
- Design and independent verification of microreactor components and design concepts
- Neutronics, thermal-hydraulics, structural analysis safety analysis
- Consequence-driven Cyber-informed Engineering (CCE) methodology for critical infrastructure

Instrumentation, Sensor and Control Development and Testing

- Sensor development and testing at High Temperature Test Lab (HTTL) for aa wide range of sensors (flux, temperature, strain)
- Control systems, wireless instrumentation, prognostics and component health

HPC Access and coupled code systems

- National Computational Resource Center provided industry access to HPC and Codes
- Integrated Neutronics, thermal, structural simulation capabilities targeting microreactors


MAGNET Rendering Operational Fall 2020


Human System Simulation Lab


Distributed Fiber Optic Temperature Sensor on Heat Pipe

Integrated Simulation of Microreactors

Sawtooth 6 PF Computer Available to Industry

Capabilities developed and support through multiple DOE-NE R&D programs

Nuclear Fuels & Materials

Mission:
Develop and qualify nuclear fuel systems and materials for use in nuclear energy systems

Major DOE Programs:

- Nuclear Technology Research and Development (NTRD, formerly FCRD)
- Accident Tolerant Fuels program (ATF)
- Advanced Gas Reactor Fuel Development and Qualification (AGR)
- Nuclear Energy Advanced Modeling and Simulation (NEAMS)
- High Performance Research Reactor (HPRR) Fuel Development
- Nuclear Scientific User Facility (NSUF)

Other Major Programs:

- TerraPower
- Ki-Jang Research Reactor fuel qualification – Phase II
- Defense-related fuel programs
- Two EPRI pilot projects

Fuel Cycle Science & Technology

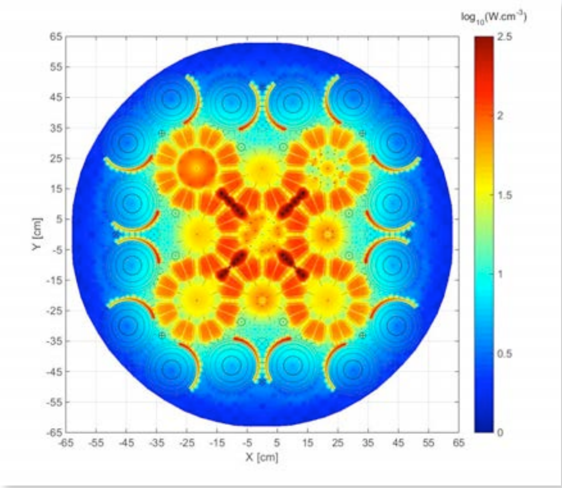
Mission:

Perform world-class separations research, from basic to applied, and complete demonstration activities to enable effective technology selection and implementation

Major Programs and Focus Areas:

- Office of Nuclear Energy Nuclear Technology R&D Program–Material Recovery and Waste Form Development
  - HEU Recovery Project/Zr volatilization
  - Joint Fuel Cycle Studies (incl. ROK CRADA)
  - Material Protection, Accountability and Control Tech. (MPACT)
- National and Homeland Security
  - NNSA, DHS, DOD
- Critical Materials Institute Hub
- EBR-II Spent Fuel Treatment
- Spent Fuel Storage and Transportation

Reactor Systems Design & Analysis



Reactor Physics, Design & Analysis:

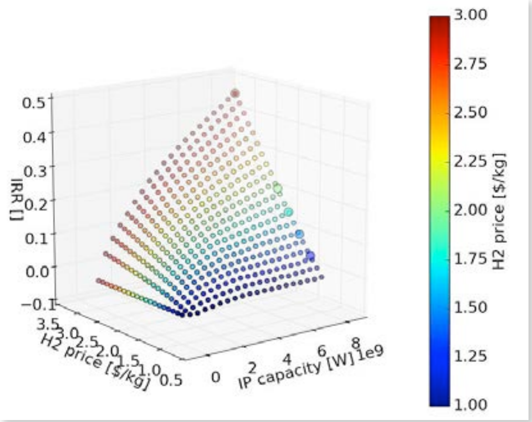
- Perform neutronics analysis, develop protocols and the verification & validation tools necessary to support design of advanced nuclear systems (reactors & fuel cycles) and the safe operation of INL test reactors.

Nuclear Engineering Methods & Development:

- Provide the next-generation set of tools and methods for design and operation of nuclear systems through the use of the most advanced computational frameworks and validation methodologies.

Experiment Analysis:

- Support design, irradiation, shipping and post-irradiation examination of nuclear material experiments through efficient performance of neutronic, thermal-hydraulic and structural analyses.



Systems Integration:

- Systems research analyses and nuclear systems integration across interfacing technologies, including economics, non-electric applications, civil/structural/seismic engineering, and siting, to inform policy and technology considerations.

Nuclear Fuels and Materials Capabilities for NRIC and ARDP

Colby Jensen, Nick Woolstenhulme, Dave Kamerman, Dan Wachs, Jason Schulthess, Randy Fielding, Steve Hayes, Doug Porter

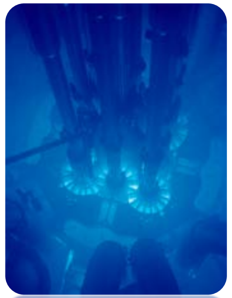
June 2020

www.inl.gov

Idaho National Laboratory

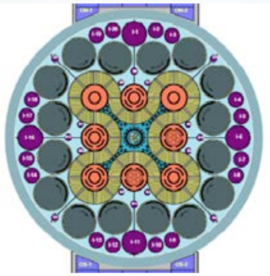
Unique World-Leading Capabilities for Nuclear Fuel R&D

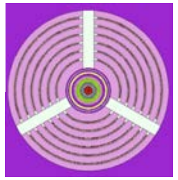
- **Advanced Test Reactor (ATR)**
  - High flux, multi-position test reactor for burnup/dose accumulation, methods for local spectra hardening
  - Instrumentation lead-out capability for real-time fuel performance data
- **Transient Reactor Test facility (TREAT)**
  - Versatile power maneuvering ability for transients from milliseconds to minutes, nuclear-heated specimens for fuel safety and separate effects research
  - Accessible layout for high quantity of data via in-situ instruments, ex-core fuel motion monitoring system to quantify fuel motion in real time, opportunities for real time radioisotope release
- **Fuel Fabrication Facilities**
  - Metallic and advanced ceramic fuel fabrication and fresh-state characterization capabilities
  - Demonstrated agility in establishing new pilot scale fabrication equipment (e.g. U_3Si_2 LTA)
- **Hot Fuel Exam Facility (HFEF) & Irradiated Materials Characterization Laboratory (IMCL)**
  - Hub for receiving, remanufacturing, and assembling experiments to/from TREAT, ATR
  - Engineering scale post irradiation exams (PIE) from macro-scale to optical metallography
  - Mechanical and furnace-based testing for properties and safety performance research
  - Various shielded instruments for characterizing microstructure and properties (e.g. thermal conductivity)
- **Irreplaceable fuel specimens irradiated in fast spectrum reactor (EBR-II)**
  - Metallic (U-Zr) & advanced ceramics (UN, UC), retained for future R&D opportunities
- **Unique personnel experience base**
  - Advanced fuel performance and reactor system modeling
  - Gathering/qualifying data under NQA-1, preparation of NRC topical reports

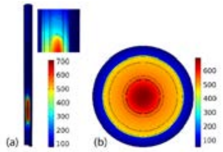


Advanced Reactor Capabilities at ATR

- **Diverse capabilities in neutronic conditions:**
  - 1.2 m long core, test positions up to 13 cm dia, enables large scale test specimens
  - Fluxes ranging from ~5E14 n/cm^{2}s (inner core) to ~5E13 n/cm^{2}s (outer reflector)
  - Water-moderated test reactor, well suited to thermal-spectrum advanced reactor irradiations, rich experience with TRISO-VHTR irradiations
  - Not a true fast reactor, but high flux positions enable respectable dose rates (5 dpa/yr in SST) on engineering-scale specimens (full diameter cladding tubes)
  - Spectral modification via flux boosting and thermal shrouds, fast-to-thermal ratio up to 40:1 achievable, mimics well fuel radial power profile in fast spectrum reactor (INL/EXT-17-41677)
  - Specimen geometry/enrichment scaling (paired with special fuel fabrication capabilities) for accelerated burnup accumulation (up to 10 at% per yr)
- **Specimen temperature achieved via self heating and thermal resistance gap:**
  - Capsule gas gap set and forget method with passive temperature monitoring (measure in PIE), cost effective strategy with increased temperature uncertainty
  - Lead-out experiments for real time measurements (e.g. fuel centerline temperature, internal pressure), temperature control via gas blend adjustment, and radioisotope release spectroscopy
- **Fluid chemistry control in flowing loops possible**
  - Vast majority of experience to date with pressurized water loops, but feasibility studies show viability of molten salt loop (INL/EXT-19-52917)







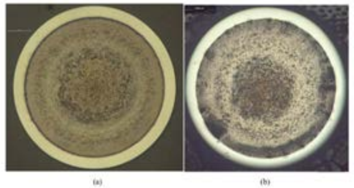
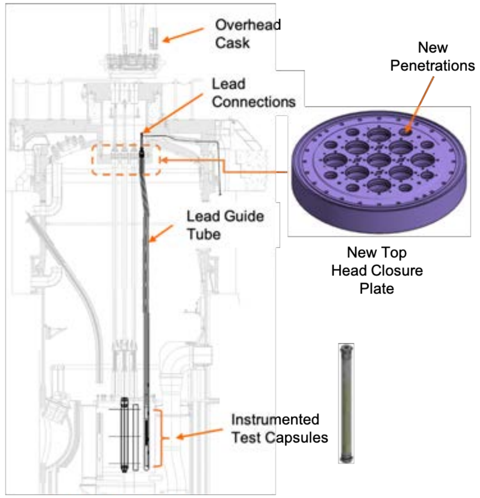


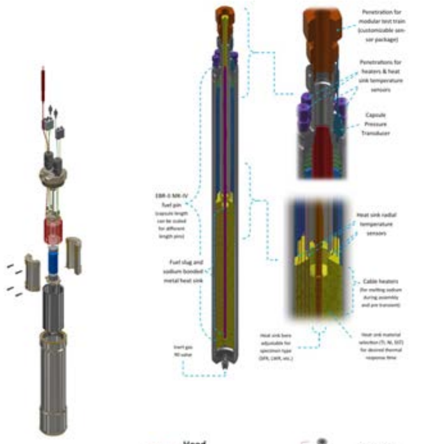
Figure 69. Metallography of Pu-12Am-40Zr irradiated to approximately 20% burnup in: a) Phénix fast reactor (FUTURIX-FTA DOE2), and b) cadmium-filtered position in ATR (AFC-1D R4).

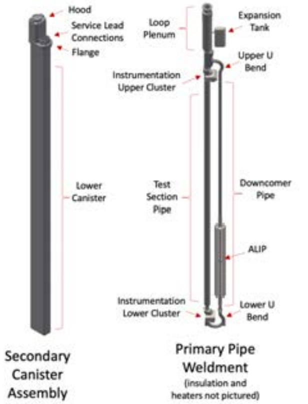


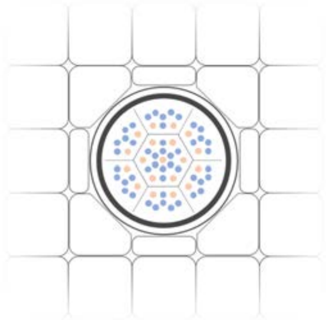
Advanced Test Reactor

Advanced Reactor Capabilities at TREAT

- **Inert gas test capsule (SETH)**
  - Helium filled capsule with specimen temperature instrument, cost effective testing for GFR overpower studies, recently used for fuel irradiations with SiC cladding
  - Modular heat sink holders with transient shaping for fuel thermomechanical studies (e.g. fuel fracture), to be used for first microreactor AM fuel tests in mere months
- **Sodium capsule (THOR)**
  - Larger capsule with single pin (EBR-II length) sodium bonded to heat sink, ideal for longer-term SFR transient overpower, first deployment 2021
  - Straightforwardly adaptable to other low temperature liquid metals (e.g. Pb, Pb-alloy)
- **Sodium loop (Mk-IIIR)**
  - Forced convection loop for single pins and 7-pin SFR bundles, highly prototypic for SFR transient overpower tests, first deployment 2022
- **Microreactor system scale benchmark experiments (NIMBLE)**
  - Large microreactor core lattice large enough for neutronics benchmarking, first deployment 2022
  - Nuclear-heated thermal-hydraulic and safety testing, modular for direct gas or heat pipe cooling
- **Gas Fast Reactor Loop**
  - Efforts underway for NASA H_2 loop in 2023, adaptation viable for inert gas GFR loop
- **Molten Salt**
  - Not designed in detail yet, but capsule and loop-based molten salt experimentation viable
  - FMMS uniquely equipped to measure salt volume expansion under nuclear heating

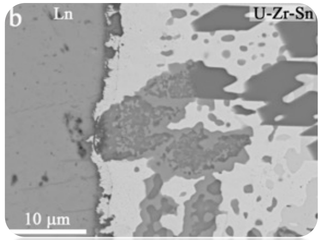






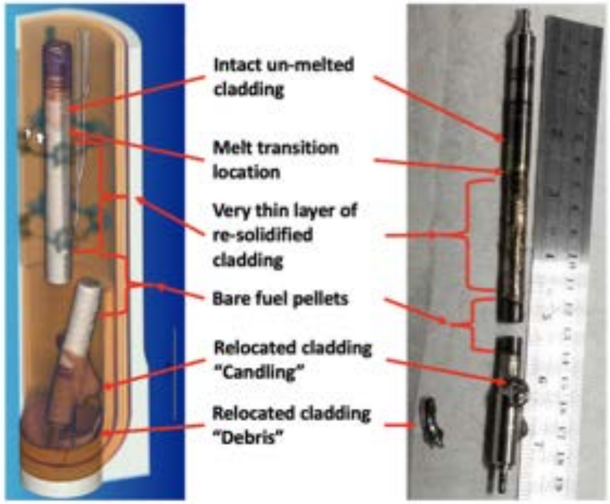
Fuel Fabrication

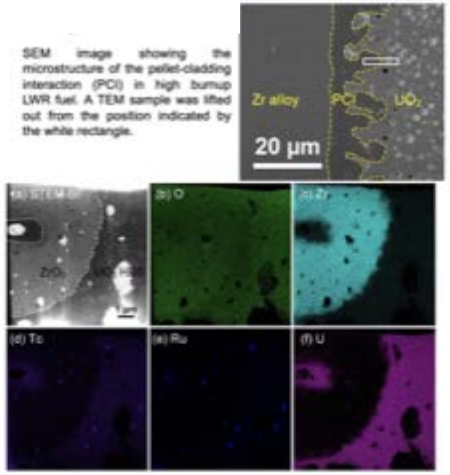
- Hazcat III fuel fabrication facilities (<700 g ^{235}U)
  - **Ceramic/intermetallic fuels**
    - Lab-scale synthesis, direct metal nitridation, direct melting for carbide and silicide
    - Demonstrated agility for pilot scale production of U_3Si_2 (hundreds of grams for LTAs)
    - Various presses, mills, & controlled atmosphere furnaces for conventional powder processing, sintering, and centerless grinding
    - Spark plasma sintering capability
  - **Metallic fuels**
    - Various alloying, casting, and post machining capabilities
    - Extrusion capabilities
  - **Cladding and assembly operations**
    - Pressure resistance, laser, and TIG end cap welding
    - Some experience with assembly of ceramic cladding (SiC)
    - Sodium bonding capability
  - **Reference material fabrication (large grain or single crystal material)**
- Hazcat II fuel fabrication facilities (<700 g ^{235}U and transuranic)
  - Similar as list above, except transuranic gloveboxes geometry constrain typically limits specimen size
- Fresh fuel characterization equipment
  - Microstructure: SEM/TEM, EPMA, APT, XRD
  - Thermal Characterization: DSC, TGA, Dilatometry, Laser flash diffusivity

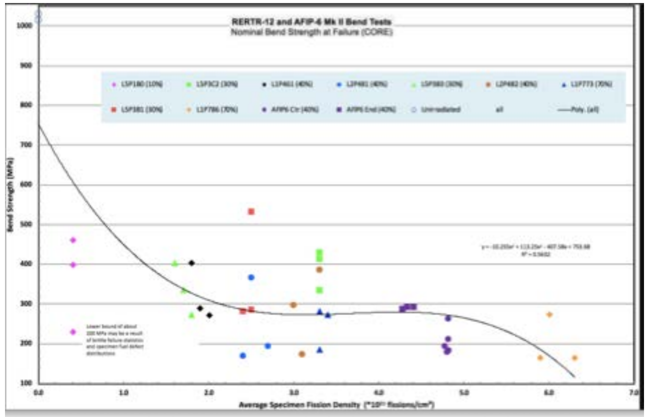


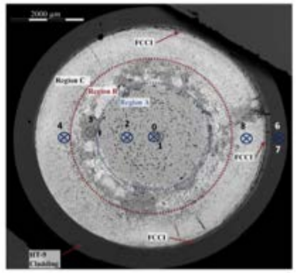
Shielded Exam and Testing

- **Engineering scale PIE in HFEF, metrology down to optical metallography**
  - GASR – fuel rod puncture and fission gas release analysis
  - NRAD – neutron radiography and re-irradiation for short lived isotopes
  - FACS – furnace for TRISO high temp accident with real time fission product release testing
  - Mechanical properties testing
  - Planned construction of transient furnace (modern whole pin furnace) (burst, creep, fatigue, pressure differential)
- **Remanufacturing, instrumentation, and assembly of materials for testing in furnaces, TREAT, and ATR**
  - Target sections of interest for follow on irradiation or furnace testing with instrumented segments
  - Prototypic integral materials, seal welding at desired pressure
- **Microstructural PIE in IMCL, microstructure, properties, etc.**
  - Plasma FIB, EPMA, SEM, TEM, Thermal Conductivity Microscope

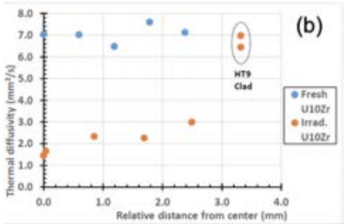


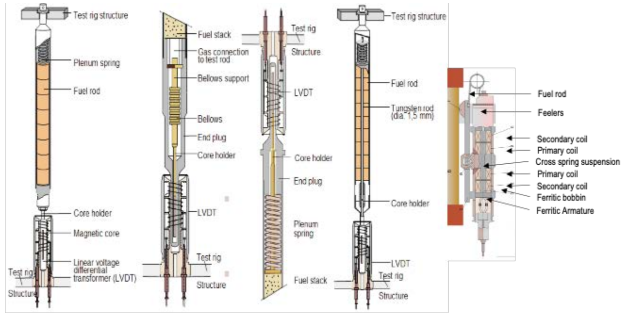






(a) SEM image of a polished section of the irradiated U-10 wt.% Zr fuel pin. The TCM measurement locations on the profile of the pin are marked along with the measurement number.





Cladding Elongation | Internal Pressure | Fuel Elongation | Fuel Expansion Thermometer | Diameter Gauge

Legacy Materials

- Lack of fast reactor testing capability is limiting for achieving long term goals for related technology
  - A lot can still be done with fabrication at MFC, out-of-pile experiments, and irradiation testing in ATR/TREAT
- Legacy materials originate from variety of programs including historical fast reactor programs as well as space program for UN
- Some material from small AFC rodlets from last ~15 years of DOE irradiations
  - U-Zr, U-Pu-Zr, MA-bearing Nitrides
- EBR-II/FFTF fuels and materials stored at INL are "**priceless**"
  - U-Fs, U-Zr, U-Pu-Zr
  - MOX
  - UN?, UC? (need to confirm)
- Includes variety of stainless-steel cladding alloys including austenitic, ferritic/martensitic; a few exotic materials (LANL)

INL facilities at the Materials and Fuels Complex

Nuclear Science & Technology

Siting in Idaho for Advanced Reactor Demonstration Projects

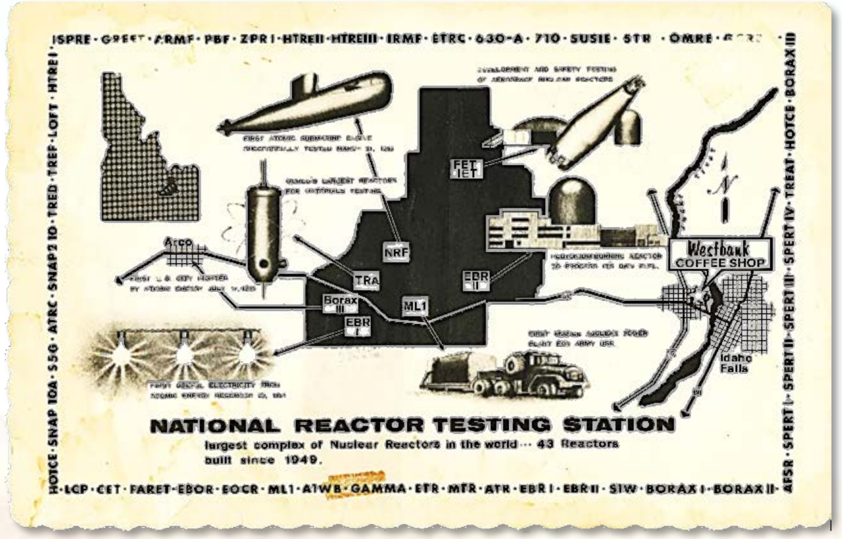
Dr. George Griffith
SMR Siting Lead
George.Griffith@inl.gov

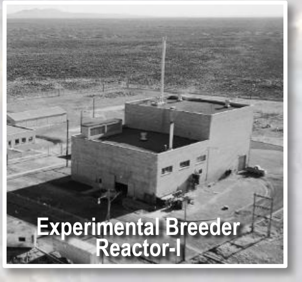
June 4, 2020

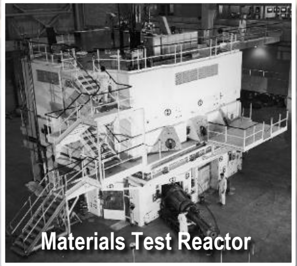
INL Idaho National Laboratory

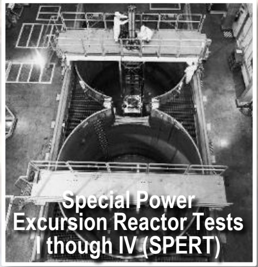
The National Reactor Testing Station drove nuclear innovation in the U.S. and around the world

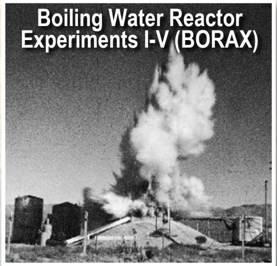
- First nuclear power plant
- First U.S. city to be powered by nuclear energy
- First submarine reactor tested; training of nearly 40,000 reactor operators until mid-90s
- First mobile nuclear power plant for the army
- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors



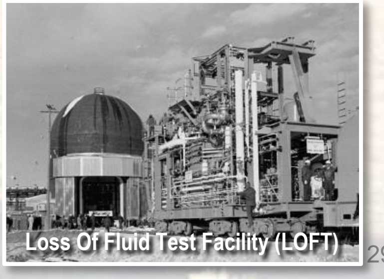

Experimental Breeder Reactor-I


Materials Test Reactor

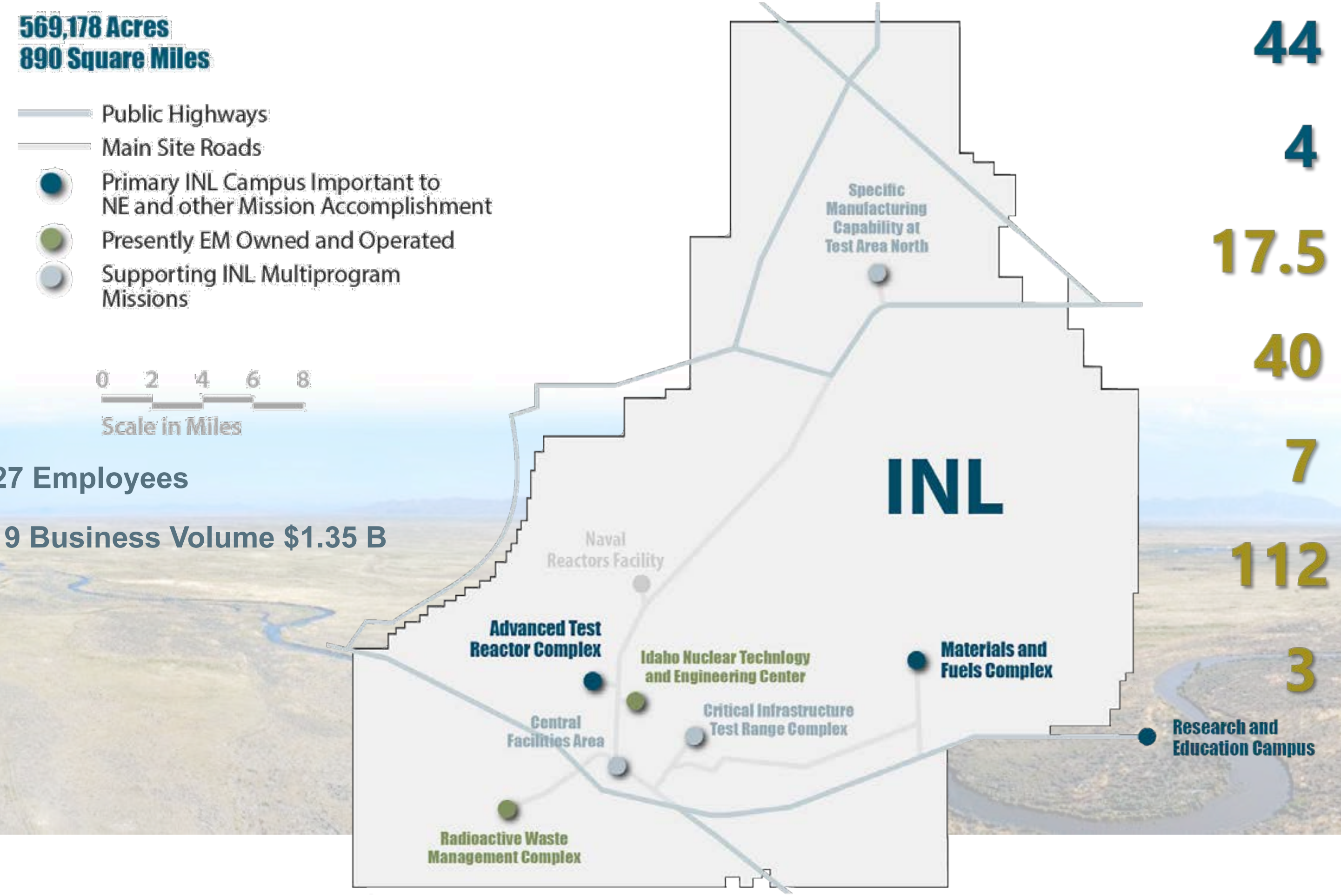

Special Power Excursion Reactor Tests I though IV (SPERT)


Boiling Water Reactor Experiments I-V (BORAX)


S1W (aka Submarine Thermal Reactor (STR)


Loss Of Fluid Test Facility (LOFT)

The Idaho National Laboratory Site
A Unique Capability for the Nation



4,927 Employees

FY19 Business Volume $1.35 B

16 Nuclear facilities (Haz Cat 1, 2 & 3)

44 Radiological facilities

4 Operating reactors

17.5 Miles railroad for shipping nuclear fuel

40 Miles primary roads (125 total)

7 Substations with interfaces to three power providers

112 Miles high-voltage transmission lines

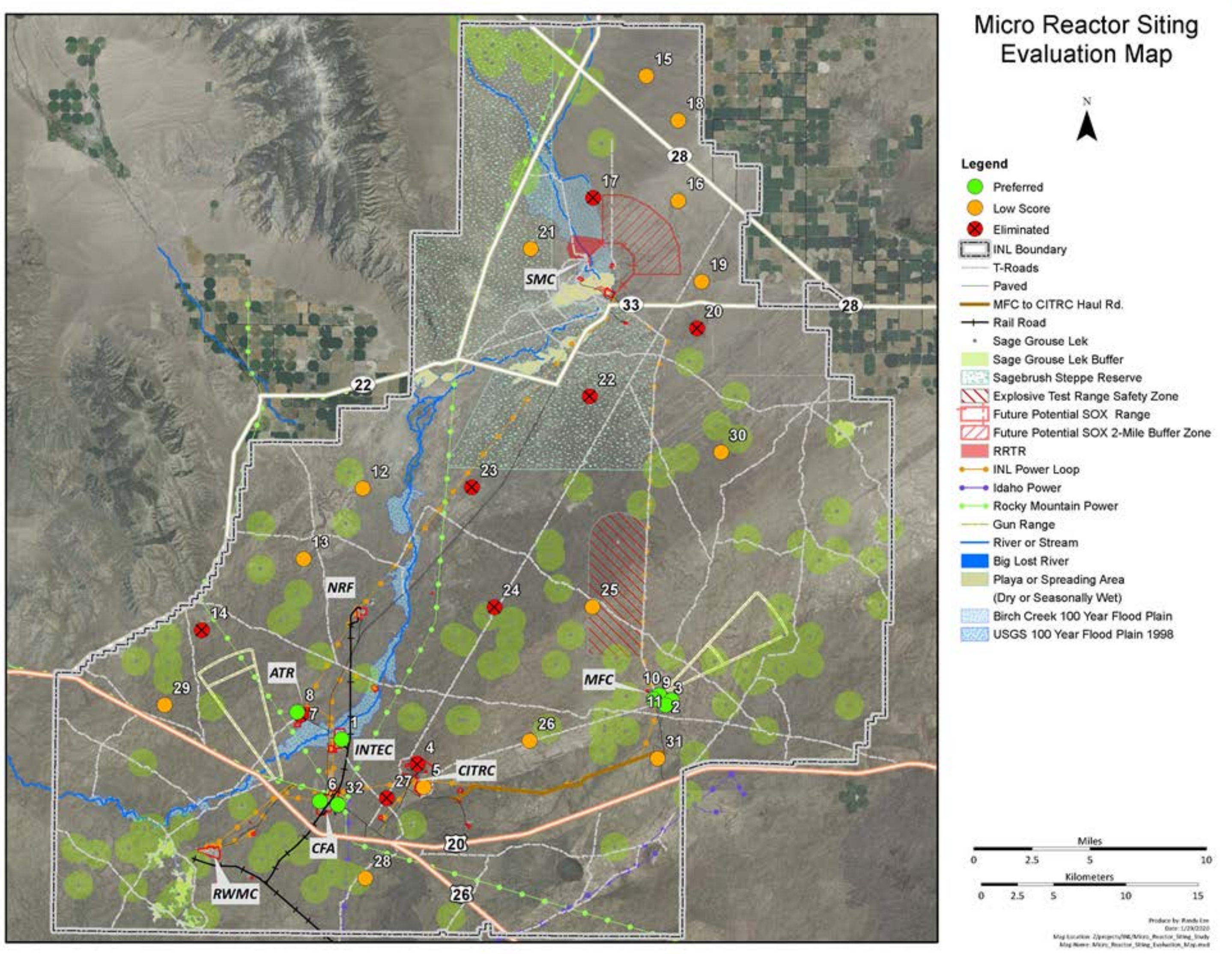
3 Fire stations

Siting Process has been Established and Used

- INL and DOE have an established Site Use Permit.
  - A 99 year camping permit to access and develop a site
  - Provides separation of DOE and NRC regulation
  - Access to INL services as desired
- INL is the only DOE site to grant site use permits
  - NuScale (2017)
  - Oklo (2019)
- INL is developing the site to assist vendors

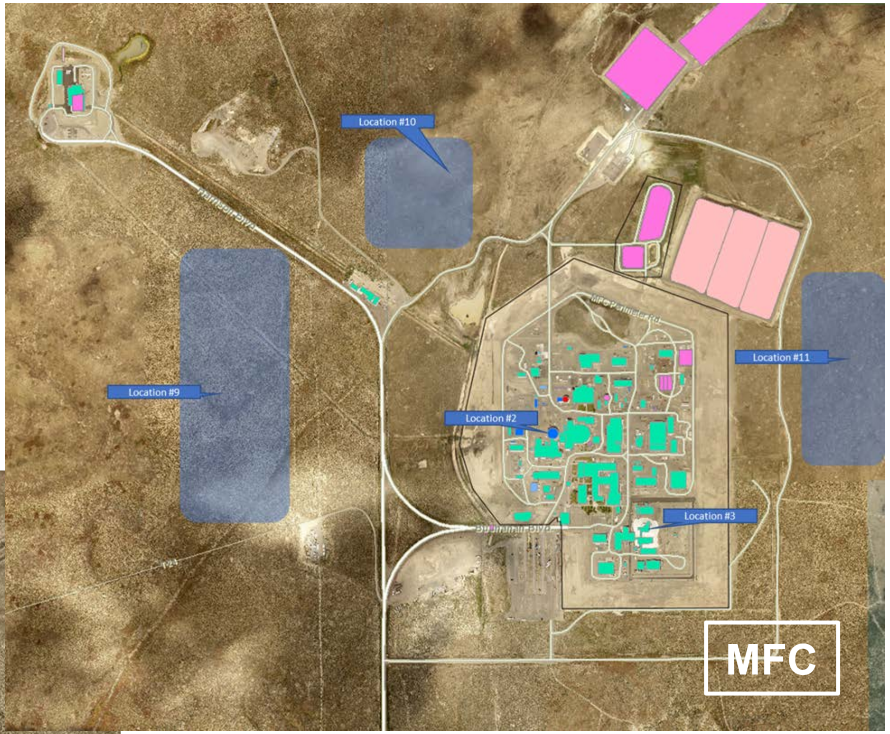
Candidate Sites

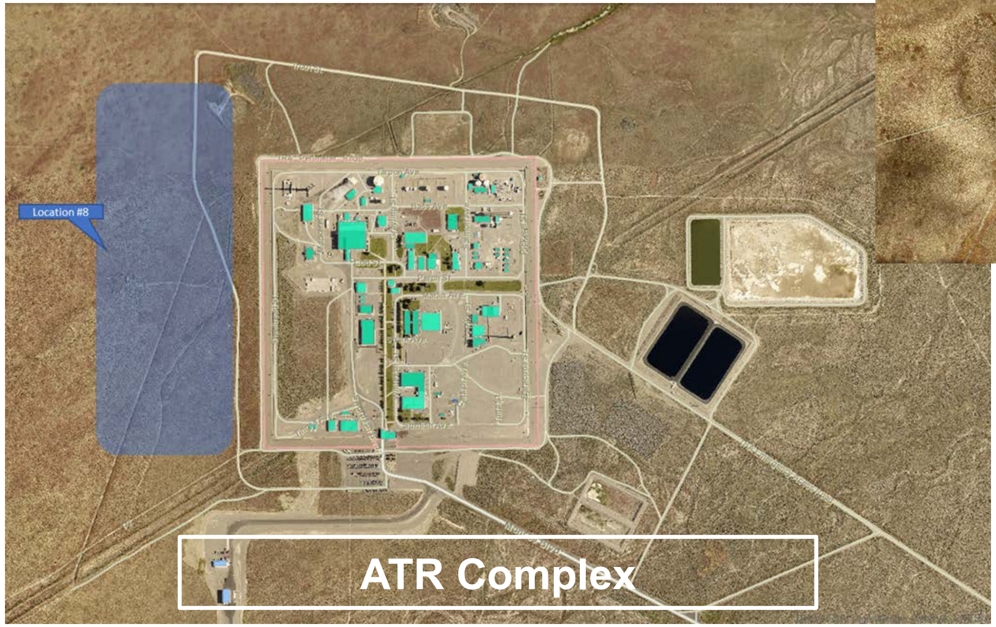
- Nine sites failed "Must" criteria
- Twenty-three sites evaluated by team of INL subject matter experts using "Want" criteria



Preferred Microreactor Sites – Green Fields

- Greenfield sites near MFC (#9, #10, #11) and ATR Complex (#8) ranked high based on existing site-specific characterization data, existing seismic hazard analysis data, and proximity to existing infrastructure (i.e., utilities, roads, security, etc.)





Integration with INL Site

- INL is initiating a site wide NEPA analysis.
  - Supports NRC EIS submittals
- DOE is supporting multiple site upgrades
  - SSHAC Seismic Study started in 2019

    3 year/$10m Study to provide probabilistic seismic hazard assessment
- LIDAR Study of INL site and surrounding area
  - Flooding, volcanic, seismic and cultural information
- Supporting multiple commercial siting activities are planned or started
  - Services established
  - Unique local studies on-going
  - Meteorology studies
  - Volcanology to support draft NRC methodology
- Electrical Grid Upgrades
  - 345keV upgrades
  - Commercial grid access

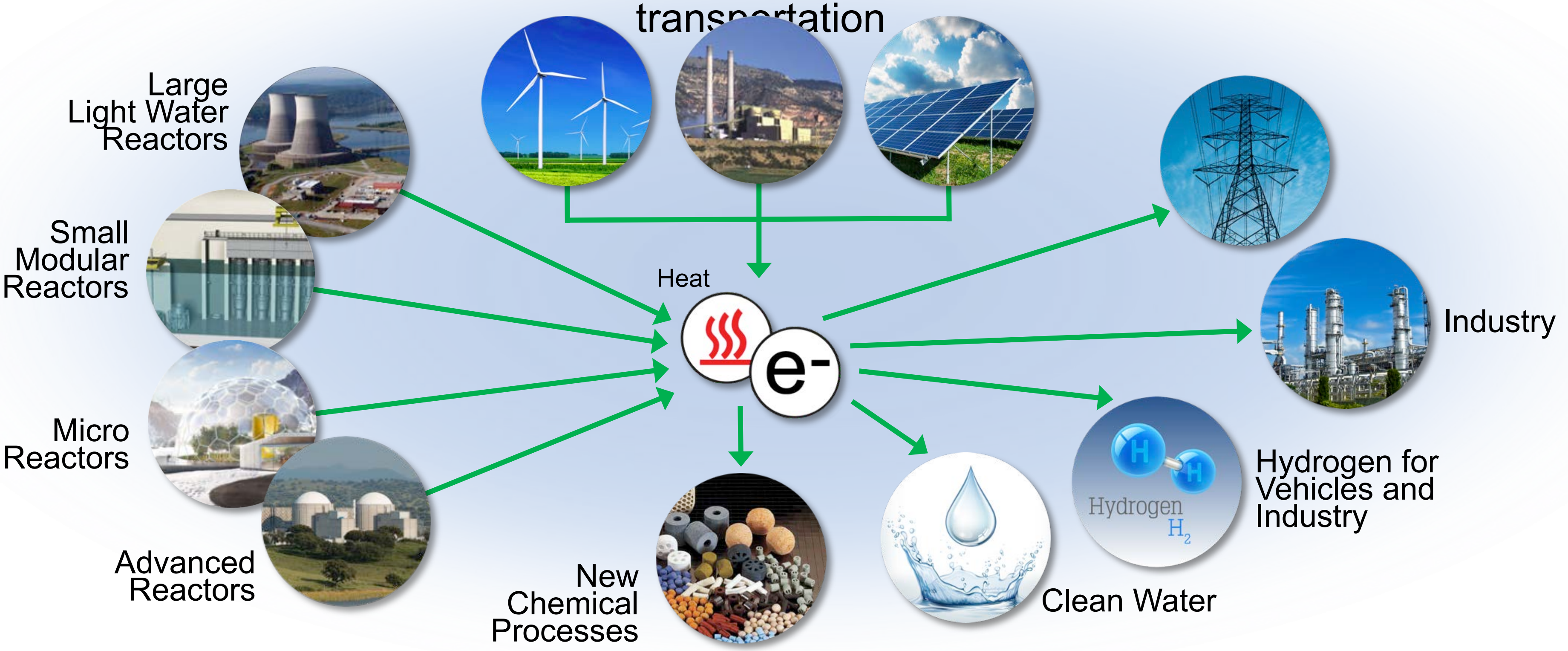
Integrated Energy Systems: A Key Opportunity

Today

Electricity-only focus

Potential Future Energy System

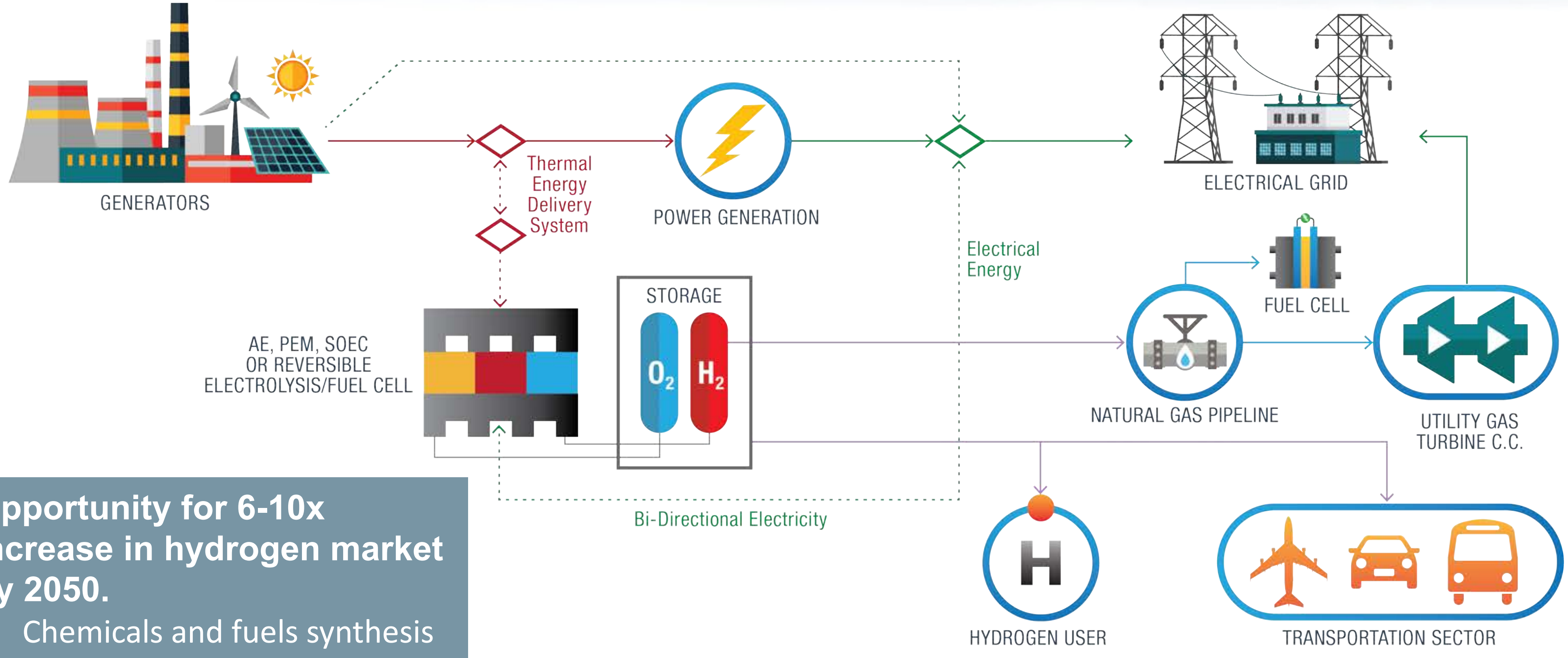
Integrated grid system that maximizes contributions from carbon-free energy generation for electricity, industry, and transportation



Flexible Generators ❖ Advanced Processes ❖ Revolutionary Design

For more information, contact Shannon Bragg-Sitton, email: Shannon.Bragg-Sitton@inl.gov

Example: Hydrogen Production via Electrolysis



Opportunity for 6-10x increase in hydrogen market by 2050.

- Chemicals and fuels synthesis
- Steel manufacturing

For details on upcoming LWR-H_2 demonstrations, see Part I of the Clean Nuclear Energy for Industry webinar series at https://gain.inl.gov/SitePages/GAINWebinarSeries.aspx

1) Provides second source of revenue
2) Provides energy storage, for electricity production or hydrogen user
3) Provides opportunity for grid services, including reserves and grid regulation

Meeting future **CLEAN** energy needs

Image courtesy of GAIN and ThirdWay, inspired by *Nuclear Energy Reimagined* concept led by INL.

Download this and other energy park concept images at:
https://www.flickr.com/photos/thirdwaythinktank/sets/72157665372889289/

INL is Open for Business to Support the Development, Demonstration and Commercial Deployment of your Reactor

- Idaho's track record is unprecedented – 52 reactors and counting
- INL is the first (and only) site where DOE has granted site use permits to an SMR (NuScale) or an AR (Oklo) – in less than 16 months and 8 months respectively.
- Utilities in Idaho have expressed interest in meeting prospective ARDP applicants, INL can facilitate these introductions.
- INL can support IES demonstrations and licensing in Idaho.
  - Hydrogen, Desalination, District Heating, Integration with Renewables, etc.
- HALEU is available for reactors demonstrated in Idaho.
- Next Steps?
  - Request additional information on siting and/or technical collaborations
- This presentation, contacts and supporting information are updated here:

https://inl.gov/inl-siting/

Questions / Discussion

we appreciate your feedback and input

corey.mcdaniel@INL.gov