NRIC National Reactor Innovation Center

NRIC Program Overview and Industry Engagement

July 8, 2020

INL Industry Engagement Webinar Series

Ashley E. Finan, Ph.D., NRIC director

nric.inl.gov

INL Industry Engagement Webinar Series

https://procurement.inl.gov/SitePages/WebinarSeries.aspx

- June 10th slides
  - Doing Business with INL
  - Small Business Program
  - Technical Assistance Program
  - Economic Development Grants
- Session Video
- Future sessions

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inspire

empower

deliver

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NRIC Strategy Elements

Inspire

- ***With Action, Urgency, and Results***
  - Outreach/Showcase/Events
  - Convening space
  - Practical aesthetic design
  - Visualization, augmented reality, etc.
  - Test groundbreaking and cost-cutting techniques

Empower

- ***With Preparation, Teamwork, and Leadership***
  - Provide access to government resources, facilities, sites, materials, expertise, & infrastructure
  - Support permitting/regulatory needs
  - Facilitate contracting and local engagement
  - Collaborate with and support existing projects

Deliver

- ***With Follow-Through and an Intense Focus on Outcomes***
  - Prepare sites
  - Create demonstration pathways
  - Provide navigation support from start to finish
  - Core team for rapid demonstration excellence
  - Understand private sector needs and meet them

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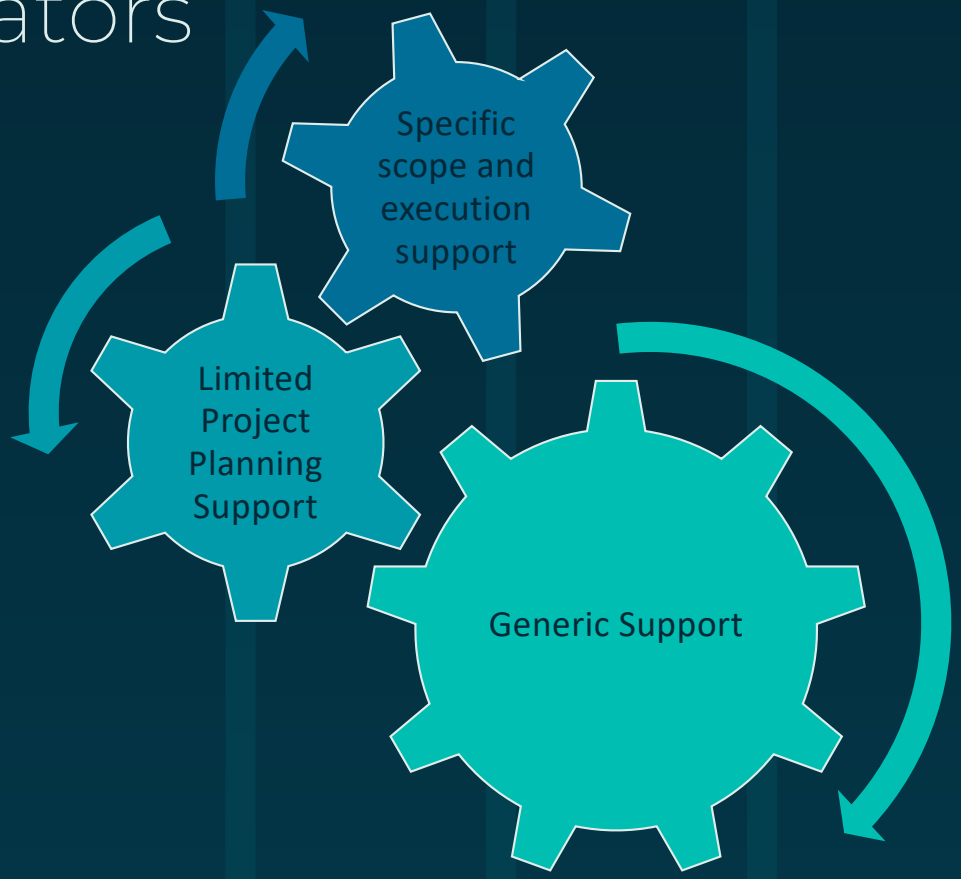
NRIC Enabling Innovators

- NRIC is prepared to enable innovators from start to finish, including support from generic infrastructure and process improvements through specific project scope for experiments and demonstrations.
- A generic MOU has been developed for working with NRIC on nuclear technology demonstrations



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Siting and Infrastructure

- National siting evaluation (ANL, ORNL, U Michigan)
- INL siting evaluation, environmental impact assessments (INL, PNNL)
- Fuel material and fabrication space (PNNL, INL)
- Demonstration Reactor Test Beds [EBR-II, ZPPR] (INL)
- Virtual Test Bed [NEAMS-NRIC] (LANL, INL, ANL)
- Spent fuel transportation and disposition (INL, PNNL)

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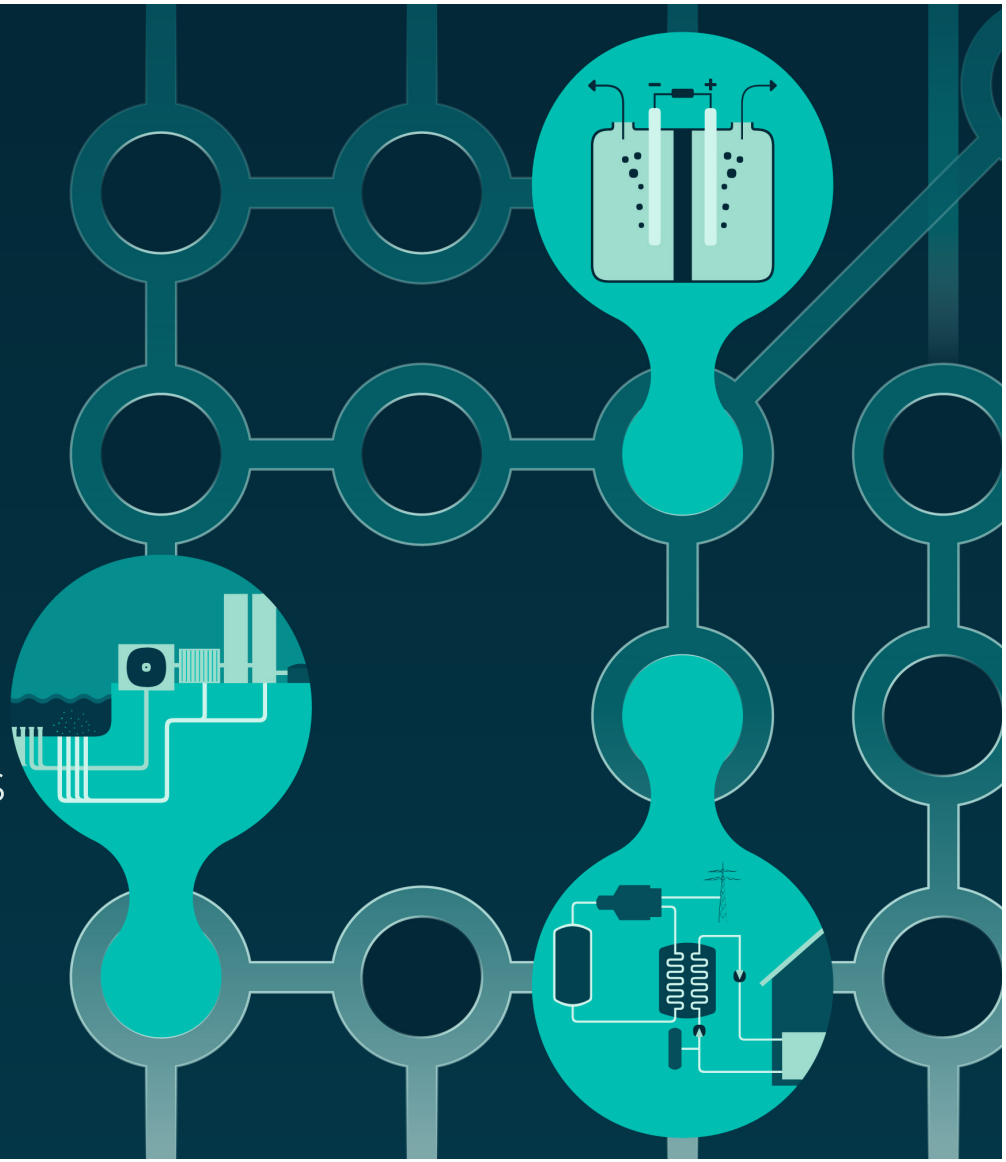
Supporting Technologies and Capabilities

- Digital Engineering (MBSE)
- Advanced Construction Technologies Initiative
- Integrated Energy Systems
- NRC Coordination
- Experimental infrastructure
- Safety and environmental analysis
- Project Planning & Coordination
- Outreach and communications



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Additional Information

- # Advanced Construction Initiative (Slide 9)
- # Demonstration Reactor Test Beds (Slide 12)
- # Digital Engineering (Slide 19)
- # Site Preparations (Slide 25)
- # Virtual Test Bed (Slide 31)
- # Supporting Initiatives: Regulatory & Fuel (Slide 33)

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Advanced Construction Initiative

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Nuclear Cost Drivers Identified in Recent Reports

- Dominant cost categories:
  - Civil construction
  - Site preparations and site-specific activities
  - Installation
  - Indirect costs

- Key cost drivers:
  - Standardization
  - Speed of construction/installation
  - Design stability
  - Quality control
  - Regulatory approach
  - Governance, contracting, organization, risk management

References:

- *The Future of Nuclear Energy in a Carbon-Constrained World*, Massachusetts Institute of Technology 2018
- *ETI Nuclear Cost Drivers Project: Summary Report*, Energy Technologies Institute (ETI), 2018
- *Advanced Nuclear Technology: Economic-Based Research and Development Roadmap for Nuclear Power Plant Construction*, Electric Power Research Institute (EPRI), 2019
- *Strategic Project Management Lessons Learned & Best Practices for New Nuclear Power Construction,* Nuclear Energy Institute (NEI), 2020.

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Advanced Construction Technology EOI Request

- https://beta.sam.gov/opp/dd45e829b2b8416fa4af633a2eb32caa/view
- Points of Contact: Steven.Gihring@inl.gov; George.Wood@inl.gov
- Published: April 13, 2020
- Responses Submitted: May 16, 2020 5:00 pm MDT
- Purpose: Information capture and planning
- Topic area: development and/or demonstration of advanced construction technologies and processes that would be transformative in nuclear energy system project economics and schedule success.
- Objective: Support reductions in nuclear energy construction and deployment costs. Increase confidence in the capability of nuclear energy systems to be delivered on schedule and on budget.

Next Steps: Review of responses completed June 1, 2020. Next steps under development.

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Demonstration Reactor Test Bed Program

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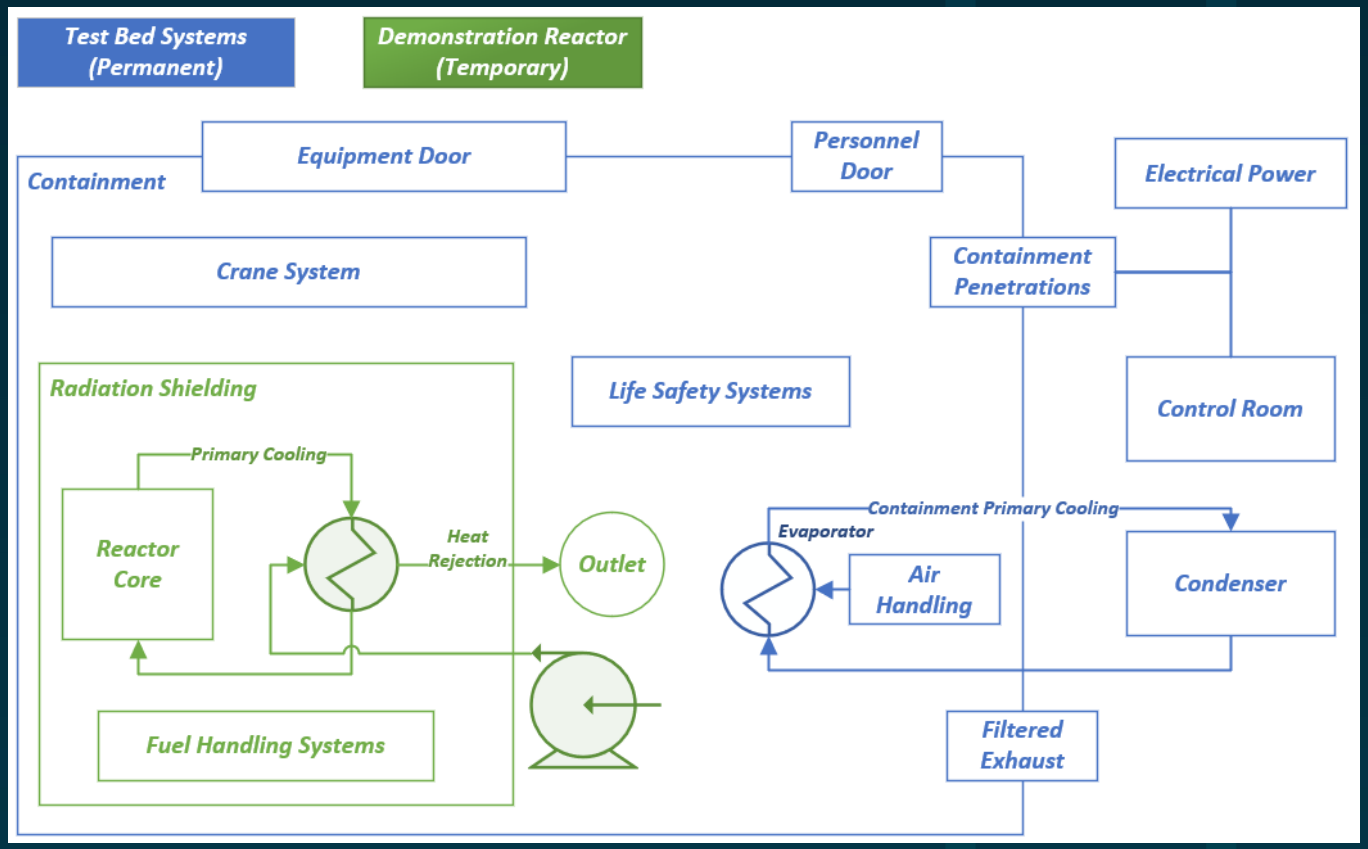
Initial Demonstration Reactor Test Bed Concept



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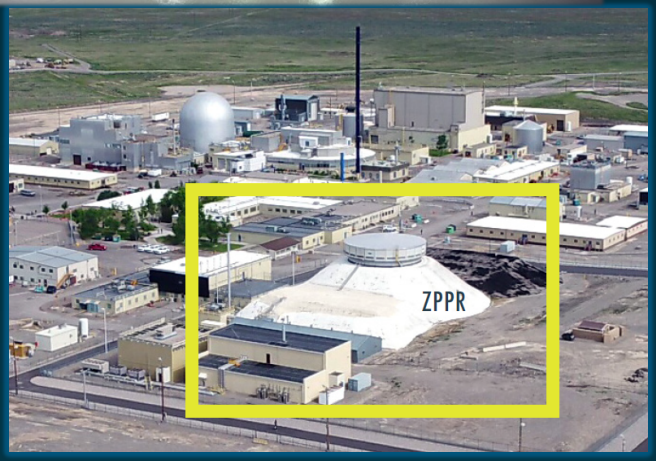
ZPPR Test Bed (ZTB) Information

- Built as Safeguards Category 1, Hazard Category 2 facility
- HEU and Pu fuel capable
- 500kW heat rejection system*
- Co-located with other MFC Capabilities:
  - Fuel production, hot cells, characterization, and machine shop
- Floor loading 3,000 psf or 500,000 lbs total
- 200 kVA, 480V electrical service
- Class 1E battery backup power and non-safety-related 100kW diesel generator*
- Compressed gas systems
- ~1,300 sqft floor space
- Co-located Control Room
- Roof entry point for installation of equipment and reactor packages*



*currently proposed in design

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EBR-II Test Bed (ETB) Information

- 80 ft diameter, 1ft thick rebar reinforced concrete walls with steel plating on exterior
- 10 MW heat rejection system*
- Reactor can be co-located with existing capabilities at MFC
  - Fuel production, hot cells, characterization, and machine shop
- Floor loading capacity of 3,750 psf
- Available utilities, including electrical power, communications, and compressed gas systems*
- ~4,800 sqft of floor space inside dome
- Near ground level entry point for installation of equipment*
- Class 1E battery backup power and non-safety-related 100kW diesel generator*
- Currently Safeguards Category 2, Hazard Category 2

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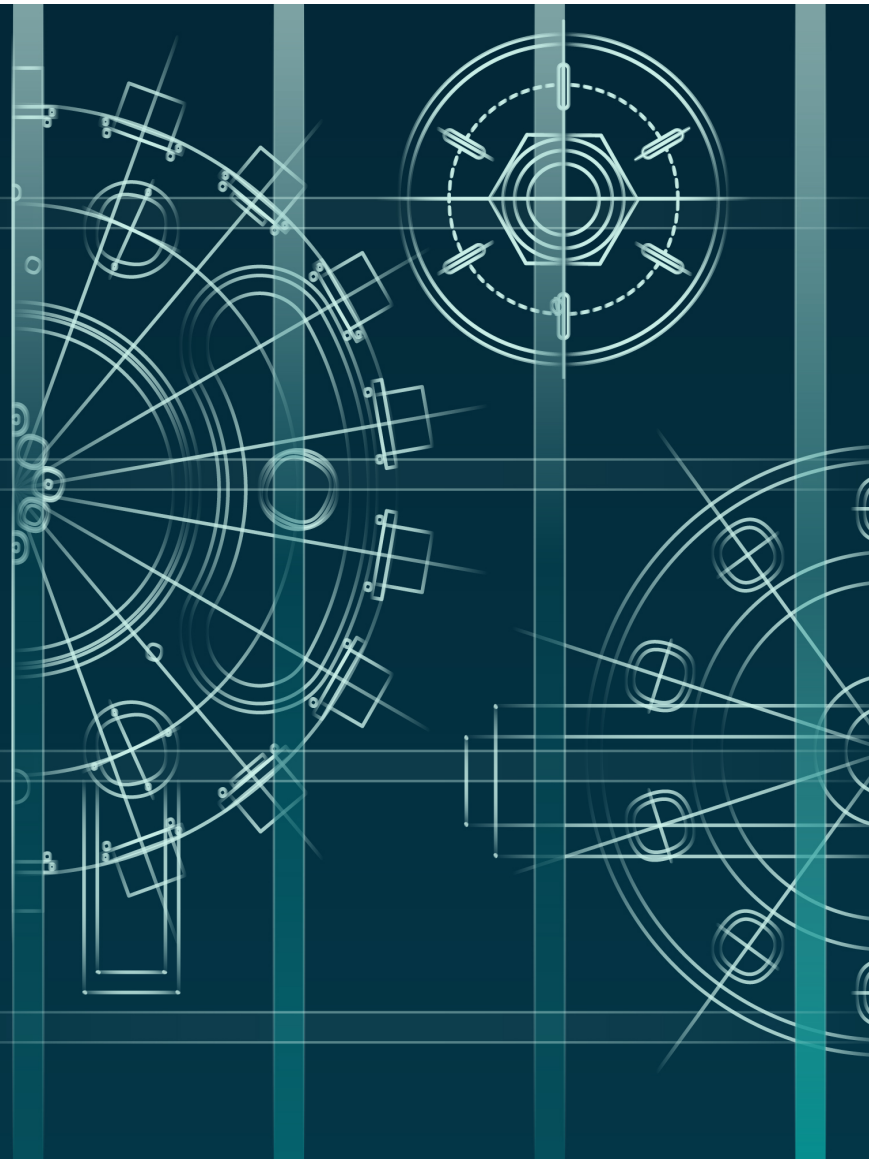
*currently proposed in design

Concept of Operations: EBR-II Test Bed (ETB) for Demonstration Reactors

- Reactors will be installed in the dome via a loading zone capable of handling trailer mounted containers (ex. Conex)
- Reactors will be removed utilizing the same path
- The ETB will consist of structures and equipment to enable the critical operation of non-power reactors
- Intended to reduce time and money required to permit, install, commission, operate, and decommission demonstration reactors
- Safety basis broad enough to cover range of reactors
- INL to receive shipment of assembled demonstration unit at MFC
- INL to install and commission the reactor in collaboration with innovator
- INL to train operators in collaboration with innovator
- INL to operate the reactor according to experimental plan developed with innovator
- INL to execute deactivation plan at end of life



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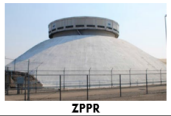
Demonstration Test Bed Requirements Gathering Initiative

NRIC needs your input to effectively enable your demonstration

In 2020, the National Reactor Innovation Center (NRIC) initiated projects to develop test beds to provide capable facilities to support reactor demonstrations. Two existing facilities at Idaho National Laboratory were chosen for initial test beds: the Experimental Breeder Reactor-II (EBR-II) dome and the Zero Power Physics Reactor (ZPPR). Each provides unique capabilities to enable a wide range of demonstration projects. To support preparing these facilities for demonstrations, NRIC is gathering requirements from potential users. Your responses, along with those of other potential users, will influence project decisions and become part of the formal requirement documentation.

Please note which requirements may be negotiable and feel free to contact NRIC with follow-up questions or clarifications.

Reactor demonstration projects are assumed to be modularly constructed, delivered, and installed into the test bed facilities. Other baseline technical assumptions for the facilities are as follows.

Parameter	EBR-II	 ZPPR
Maximum Reactor Thermal Power (MW)	10	0.5
Maximum Floor Loading (lbs) (total/psf)*	Not evaluated / 3,750	500,000 / 3,000
Module Transfer Port and Location	Near ground-level Door/Hatch	Roof Hatch
Largest Dimension of Opening (ft)*	9	Up to 20
Usable Area Inside Containment (ft^2)	~4,000	~1,300
On-site Power Available	200 kVA @ 480V	200 kVA @ 480V
Target Ready-for-Demonstration Date	End of 2023	End of 2023

*May be negotiable depending on needs

Demonstrator Requirement Input

1. **Heating and Cooling**
   Our thoughts thus far regarding heat rejection are that the demonstration site's HVAC system would be capable of rejecting a specific amount of thermal energy deposited from reactor operations. The site's HVAC system would then interface with the reactor's heat removal system, if any.
   1.1. Planned maximum thermal power (steady-state) of the reactor system (e.g. 500kW)?
   1.2. Please describe the planned cooling system for the reactor. Consider the following questions.
      1.2.1. If the reactor system includes a heat removal system, is it planned to be a closed loop?
      1.2.2. If gas is used for the primary cooling and is not a closed loop, what is the flow rate? This information supports understanding requirements for rejecting radionuclides to the environment outside of the demonstration facility.
   1.3. Describe any environmental (dew point, ambient temperature, humidity, etc.) requirements for inside the demonstration site?
2. **Mechanical/Structural**
   2.1. What are the general dimensions of the reactor system?
   2.2. What are the general dimensions of the largest component?
   2.3. What are the general dimensions of components needing transport via shielded cask?
   2.4. To aid in understanding floor loading limitations, what is the rough weight of the heaviest component? *Optionally, floor loading requirements can be provided.*
   2.5. To aid in understanding floor loading limitations, what is the rough weight of the combined system? *Optionally, floor loading requirements can be provided.*

Activities

- Solicited technical requirements information from potential demonstrators
- Feedback will inform design of:
  - Heat Rejection Systems
  - Mechanical/Structural
  - Lifting and Crane Support
  - Electrical
  - Gas Supply
  - Operations Support

Pre-Conceptual Design of Test Beds – FY 20

Phase 1 - Requirements Definition
Phase 2 - Technical Solution Definition
Phase 3 - Product Realization
Phase 4 - Technical Planning and Readiness

Expected to be operational in 2023

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Example Engagement Opportunities – Demonstration Test Beds

- Final design and construction process for test beds
- Consultation
- Operations strategy
- Decommissioning strategy and design

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Digital Engineering

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NRIC National Reactor Innovation Center

Idaho National Laboratory

Digital Engineering @ NRIC

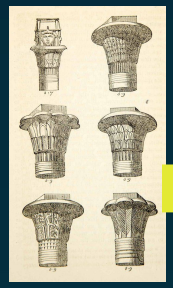
Implementation of digital engineering principles applied to micro reactor design and construction

Chris Ritter

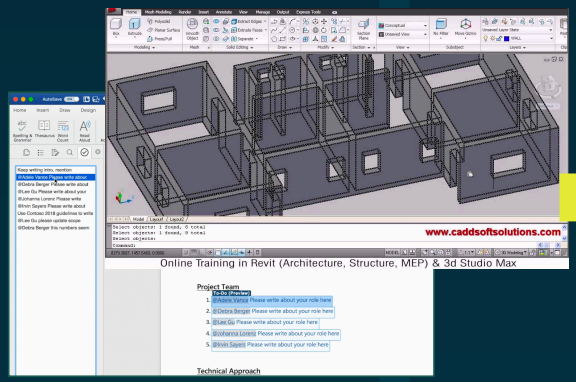
Group Lead, Digital and Software Engineering

What is Digital Engineering?

Stone Tablet



Paper Blueprint



Digital Engineering

Information Management

1. Use Models
   MBSE & BIM
2. Source Of Truth
   Central Datawarehouse
3. Technological Innovation
   Lab and University Research
4. Infrastructure and Environment
   Cloud Computing & HPC
5. Transform Culture
   Training & Culture Integration

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Opportunity

- Significant program impacts, for example published impacts at Mortenson Construction demonstrate
  - **600 cumulative day** direct **schedule reductions**
  - **25% productivity increase**
  - Use across 416 VDC programs
- 40% improvement in first-time quality through use of digital twins (Boeing)
- Expected $30M savings at NNSA
- Proven across engineering domains: Construction (Mortenson VDC), Aerospace (Boeing 777), Automotive (Bugatti)

Level 7	automated design optimization	Artificial Intelligence
Level 6	analytics automation	Advanced Analytics
Level 5	connections across lifecycle	Digital Thread
Level 4	connections within in each domain	Digital Links
Level 3	data storage are centralized	Data Lake
Level 2	document storage are centralized	Content Management
Level 1	data and documents disconnected	Siloed Program

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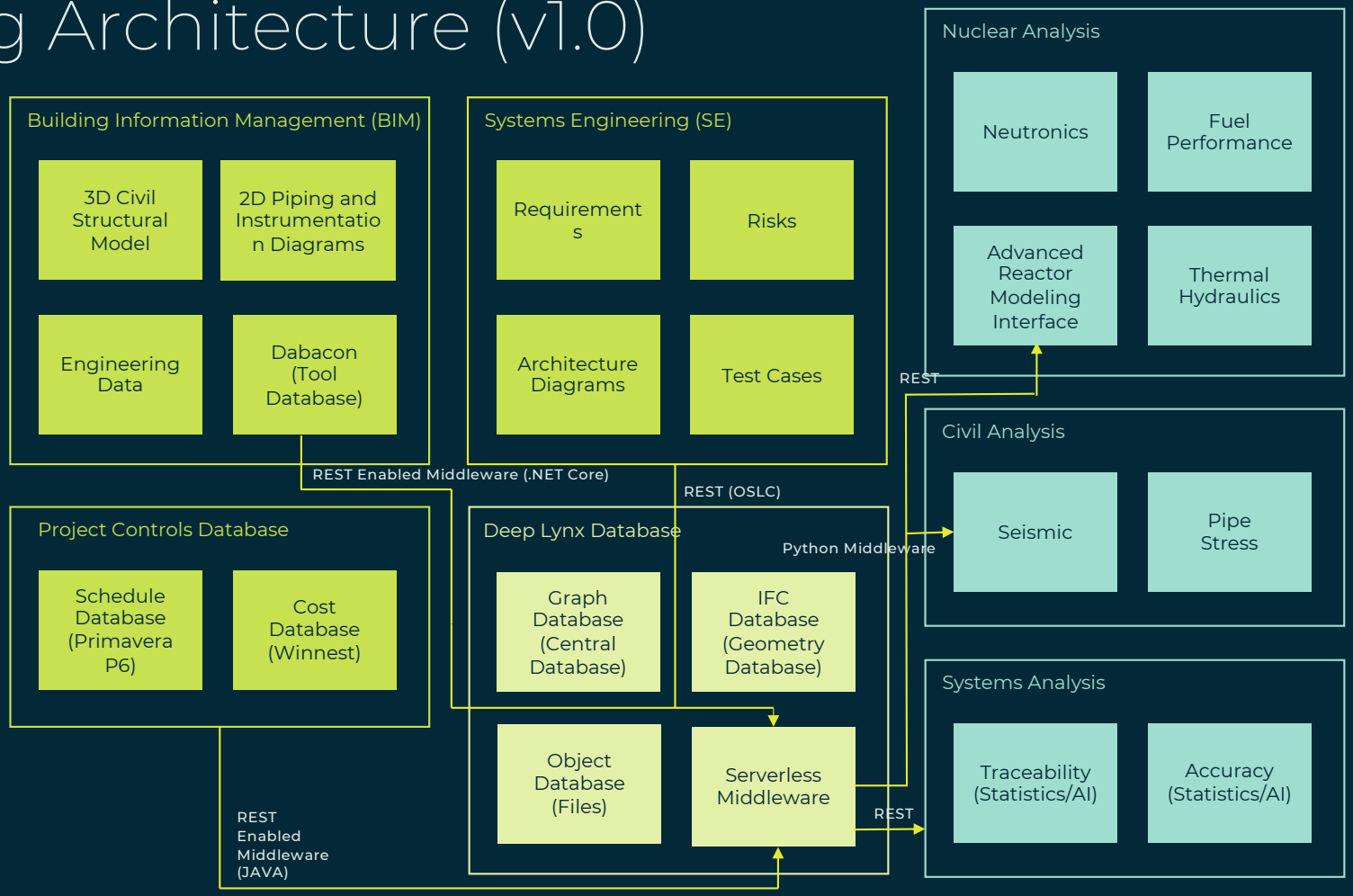
Example Derivative Solution: Plant Digital Engineering Architecture (v1.0)

- Cloud-based service of industry leading COTS tools
- Automation of design, modeling, & analysis integration
- Visualization of traceability between siloed tools
- Analysis of overall system traceability and accuracy



Current project

- Scope
  - This work scope will utilize model-based systems engineering (MBSE) to design traced physical, functional, and requirements models. These models will be developed in a data-first paradigm where the underlying database is the authoritative source of truth which generates visual representations of the data. To develop these models a data model will be developed and infrastructure will be deployed to DOE internal and/or cloud systems.

- Deliverables
  - Model-Based Systems Engineering (MBSE) Tool Study: **April 2020**
  - Tool Infrastructure (installation and configuration) and Data Model: **May 2020**
  - Export to report from operational database of ZPPR Cell requirements: **June 2020**
  - Conceptual level architecture (functional/physical) of ZPPR Pre-Conceptual design: **September 2020**
  - Prototype Model-Based Systems Engineering (MBSE) Digital Engineering Integration: **September 2020**

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Site Preparations

These slides pertain primarily to preparations being undertaken for INL sites. A few items have applicability more broadly, and some of these activities could later be performed at other promising sites.

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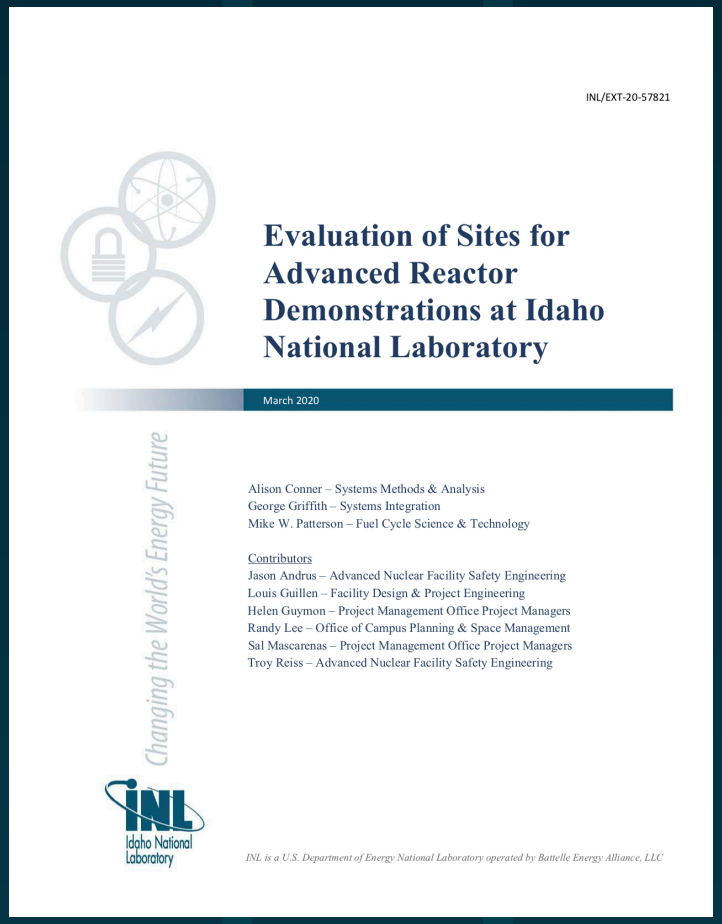
Identification of Potential Demonstration Sites

- Report INL/EXT-20-57821, **Evaluation of Sites for Advanced Reactor Demonstrations at Idaho National Laboratory**, available on NRIC website.
- Identifies list of candidate site locations or areas within INL boundaries
  - Existing buildings
  - Previously developed sites
  - Undeveloped sites
- Applies screening criteria
- Identifies preferred sites



INL/EXT-20-57821

Evaluation of Sites for Advanced Reactor Demonstrations at Idaho National Laboratory

March 2020

Changing the World's Energy Future

Alison Conner – Systems Methods & Analysis
George Griffith – Systems Integration
Mike W. Patterson – Fuel Cycle Science & Technology

Contributors
Jason Andrus – Advanced Nuclear Facility Safety Engineering
Louis Guillen – Facility Design & Project Engineering
Helen Guymon – Project Management Office Project Managers
Randy Lee – Office of Campus Planning & Space Management
Sal Mascarenas – Project Management Office Project Managers
Troy Reiss – Advanced Nuclear Facility Safety Engineering

Idaho National Laboratory

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

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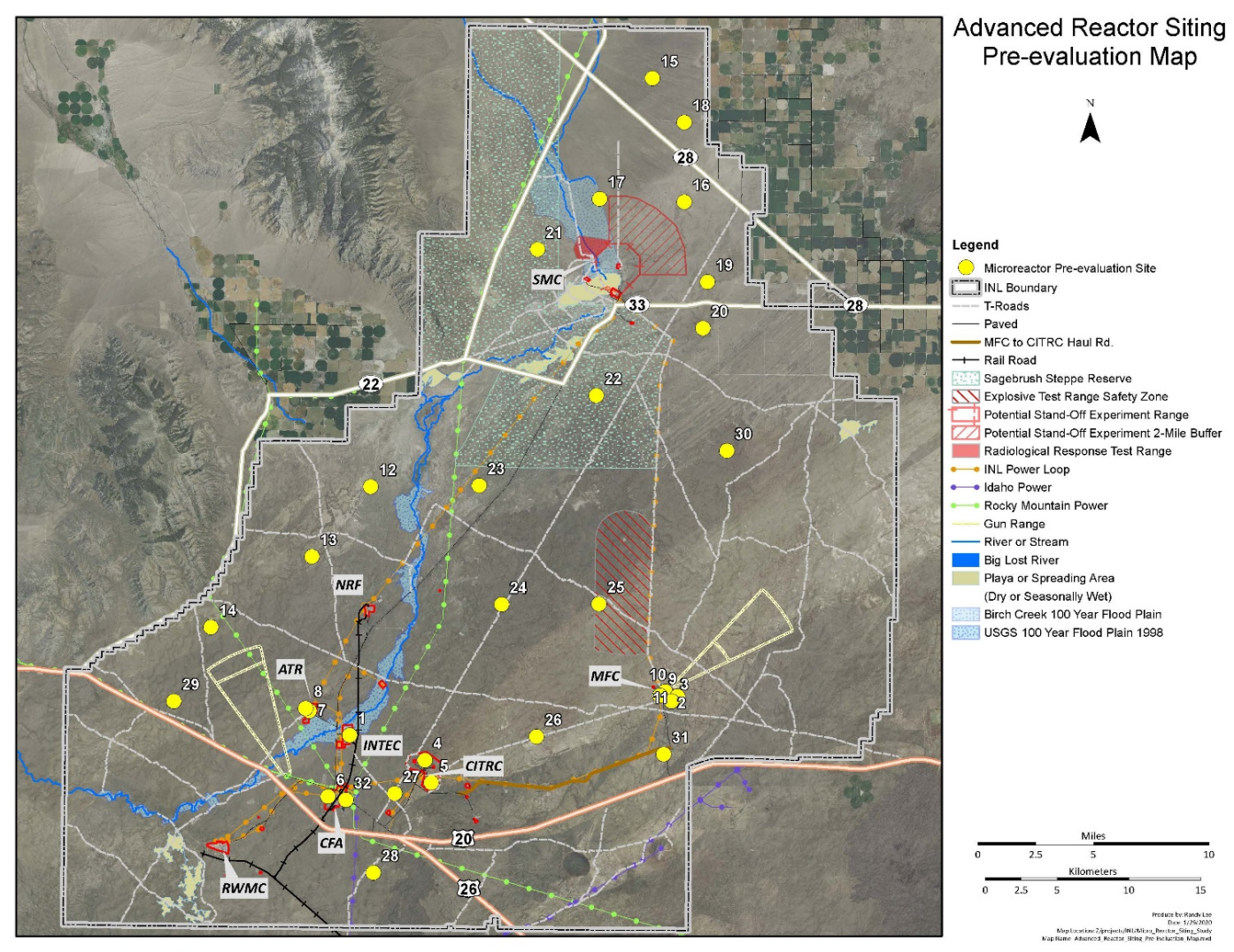
Candidate Sites

INL/EXT-20-57821, **Evaluation of Sites for Advanced Reactor Demonstrations at Idaho National Laboratory**



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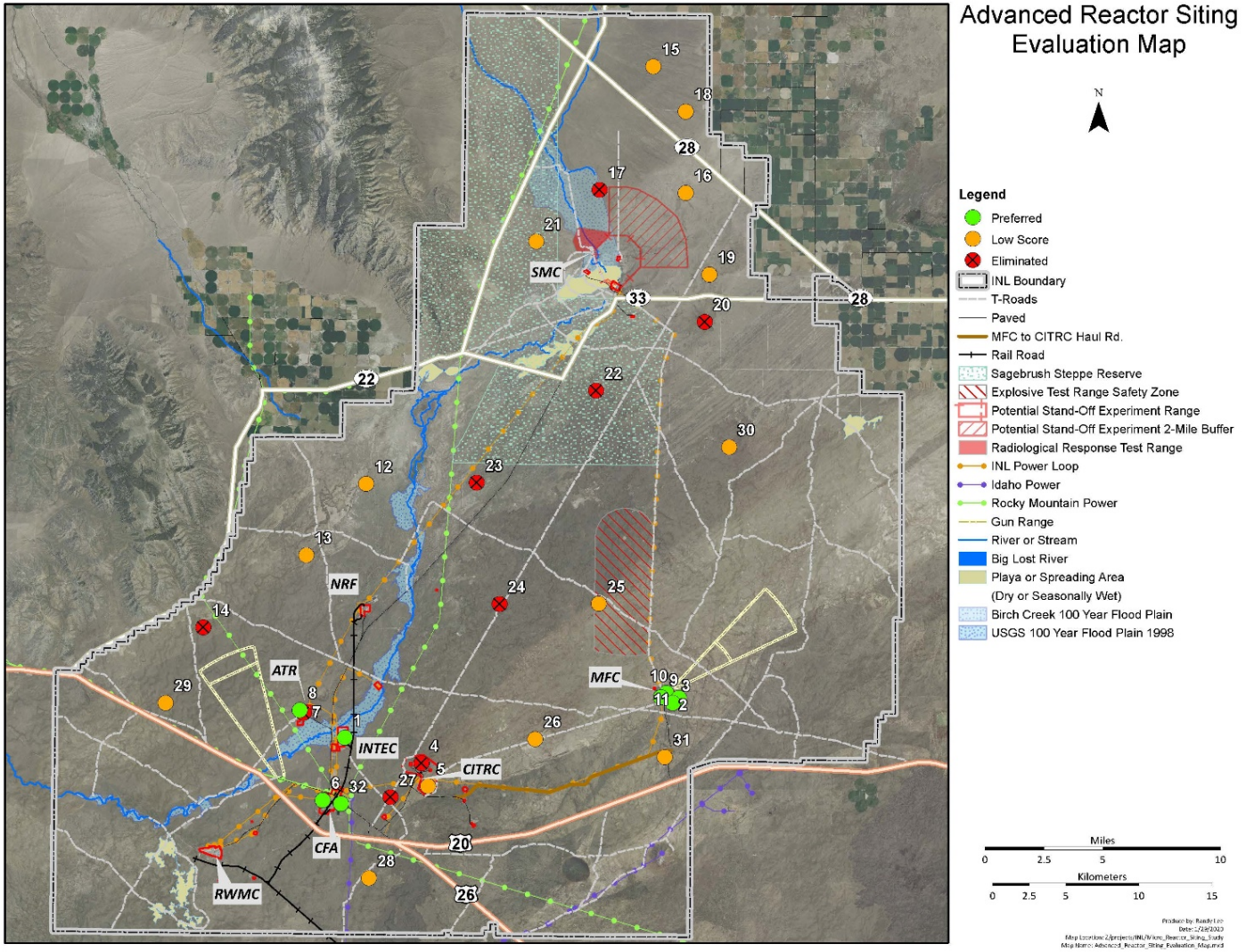
Preferred Sites

INL/EXT-20-57821, **Evaluation of Sites for Advanced Reactor Demonstrations at Idaho National Laboratory**



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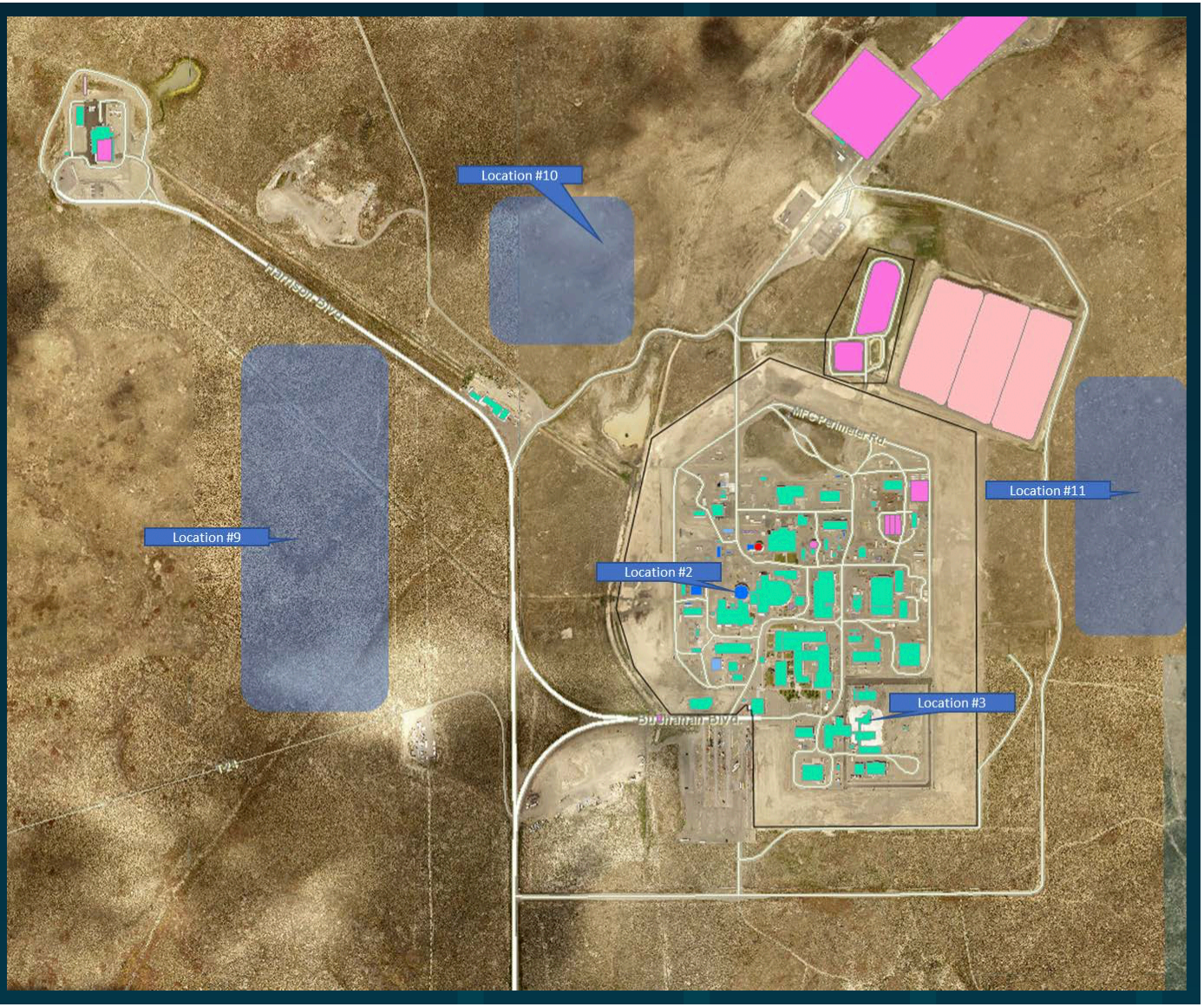
Example - MFC Sites

INL/EXT-20-57821, **Evaluation of Sites for Advanced Reactor Demonstrations at Idaho National Laboratory**



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Next Steps/Underway

- Early site permit & authorization roadmaps
- Meteorological tower study
- Electrical grid study
- Mapping/Info tools
- Surveying for cultural and biological resources
- Demonstration test beds

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Virtual Test Bed

NRIC-NEAMS project to develop modeling and simulation capabilities to support advanced reactors.

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NEAMS - NRIC Collaboration: Virtual Test Bed

- Mod-Sim can enhance NRIC's ability to build test reactors
  - Design analysis
  - Confirmatory safety analysis
  - Operations and shielding
- NRIC is catering to a diverse set of nuclear reactor designs with variation in:
  - Power
  - Size
  - Coolant
  - Fuel-form
- Therefore, a flexible mod-sim architecture is needed - and pluggable set of tools from NEAMS fits perfectly
  - Utilizing MOOSE, all tools can couple seamlessly to each other
  - Can be mixed/matched to achieve desired simulations
- NEAMS and NRIC have formed a partnership
  - NRIC will utilize and extend NEAMS-developed tools
  - NEAMS will view NRIC as a stakeholder and receive feedback
  - A Virtual Test Bed (VTB) will be created by NRIC to house simulations of demonstration reactors and provide a repository of examples of combining the NEAMS tools for vendor use

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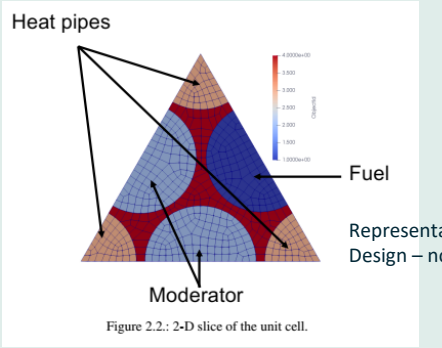
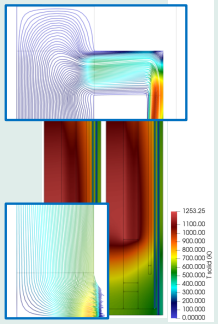
Microreactor Example



Representative Design – not final

Griffin + Sockeye + BISON

HTGR Example



PBMR-400 Benchmark

Griffin + Pronghorn + RELAP-7 + BISON

Supporting Initiatives: Regulatory and Fuel

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Regulatory Coordination – DOE Authorization

- Development of SRP for DOE Authorization Process for microreactors
- Demonstration test bed safety analysis and regulatory approach

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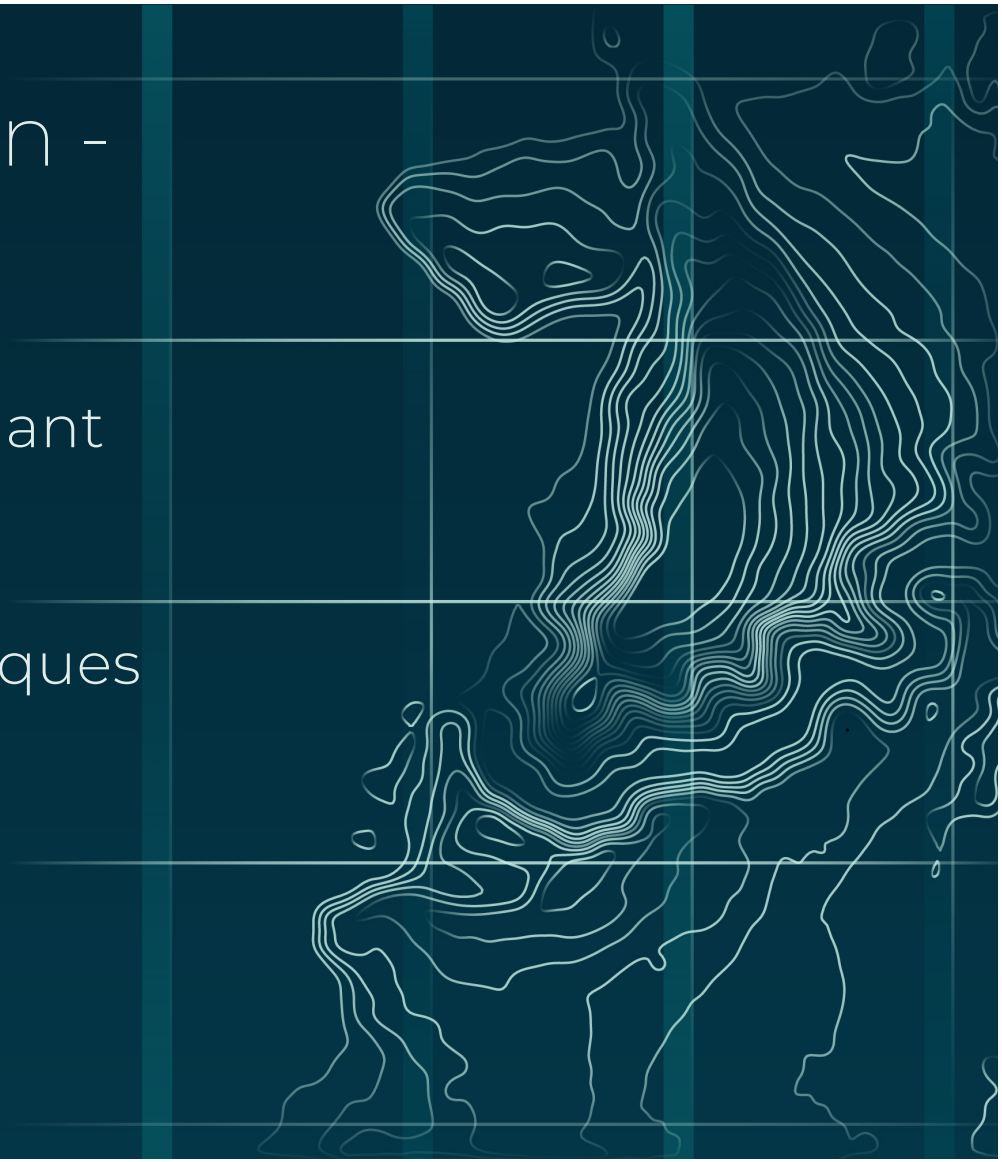
Regulatory Coordination - NRC

- Environmental coordination: Microreactor GEIS and NRIC plant parameter envelope efforts
- Early site permit
- Advanced construction techniques
- Learning



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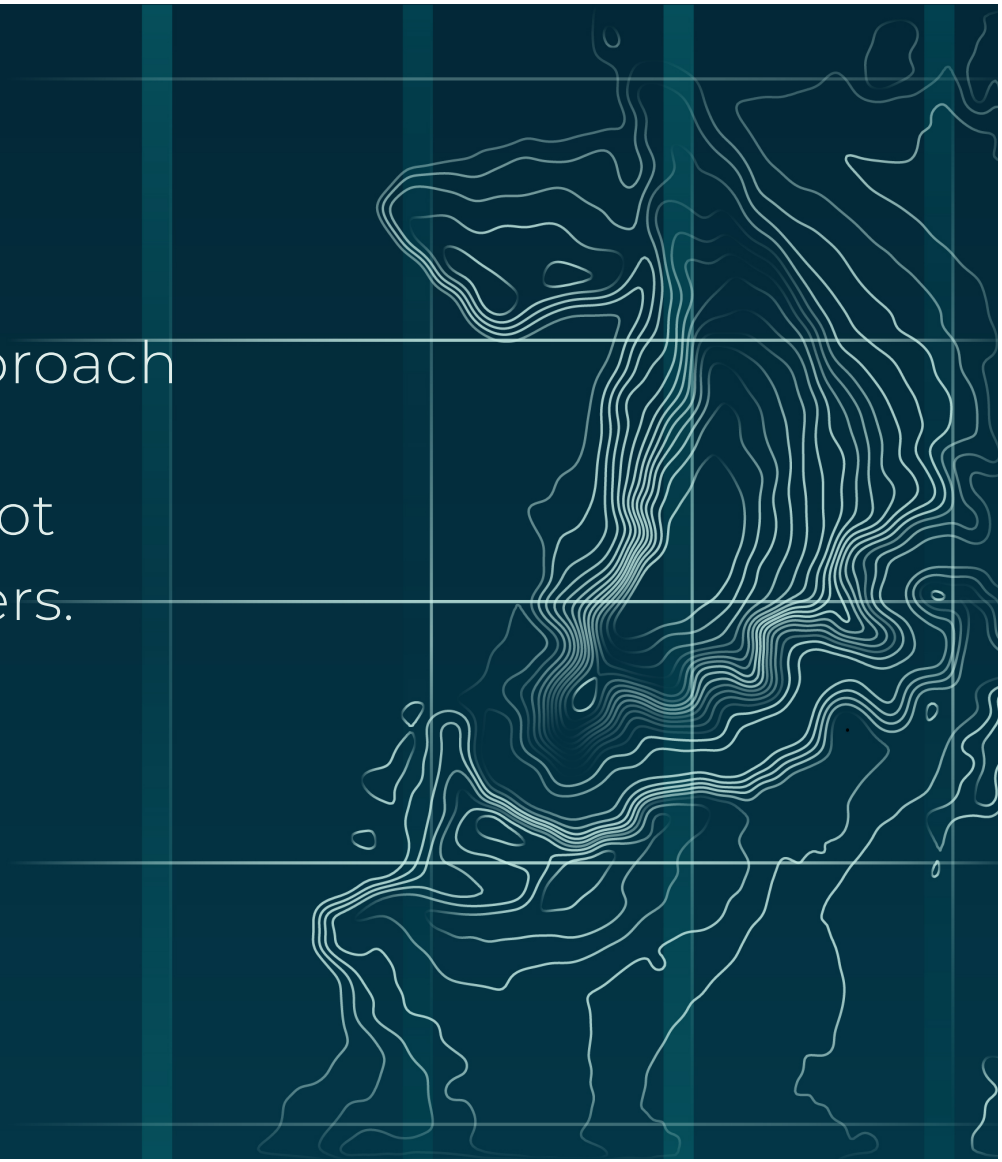
NEPA

- Plant parameter envelope approach (PNNL)
- Environmental assessment pilot
- Learning from VTR, PELE, others.



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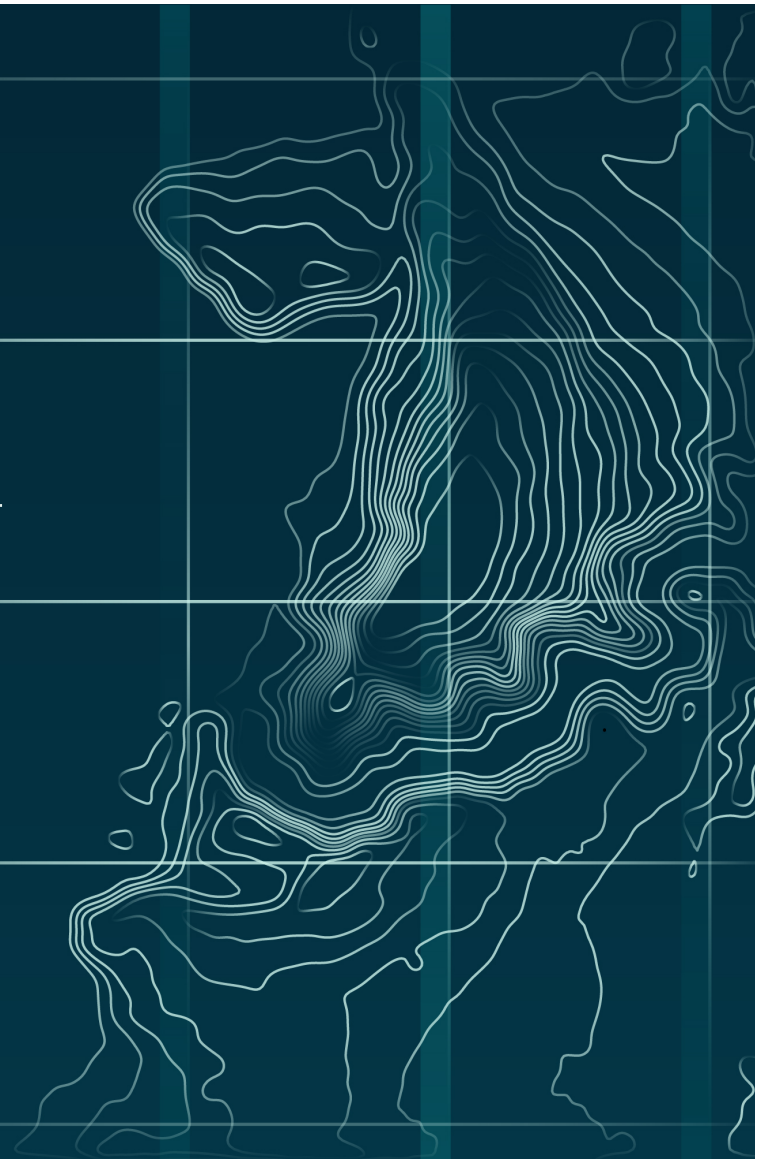
Fuel Supply Evaluations

- Compiling information about HALEU needs and sources for NRIC planning
- Evaluating needs and possible sites for fuel fabrication user facility/ies



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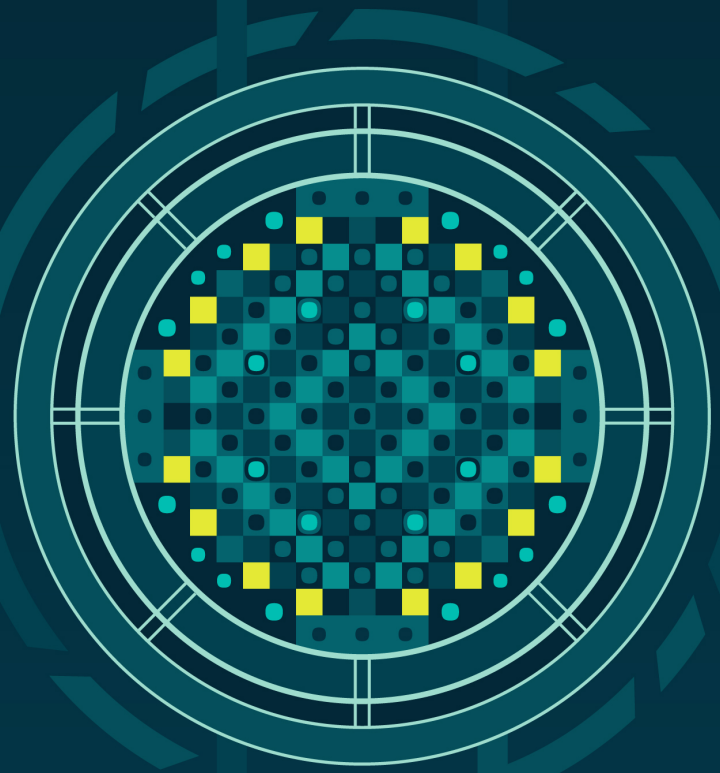
Fuel Disposition Evaluations

- "Initial Evaluation of Microreactor Disposition Options" INL/EXT-20-57291
  - Disposition options for DOE-owned HALEU at INL
  - Processes to support "road-ready" storage of fuel
  - Fuel types:
    - TRISO
    - Na/K-bonded uranium dioxide fuel



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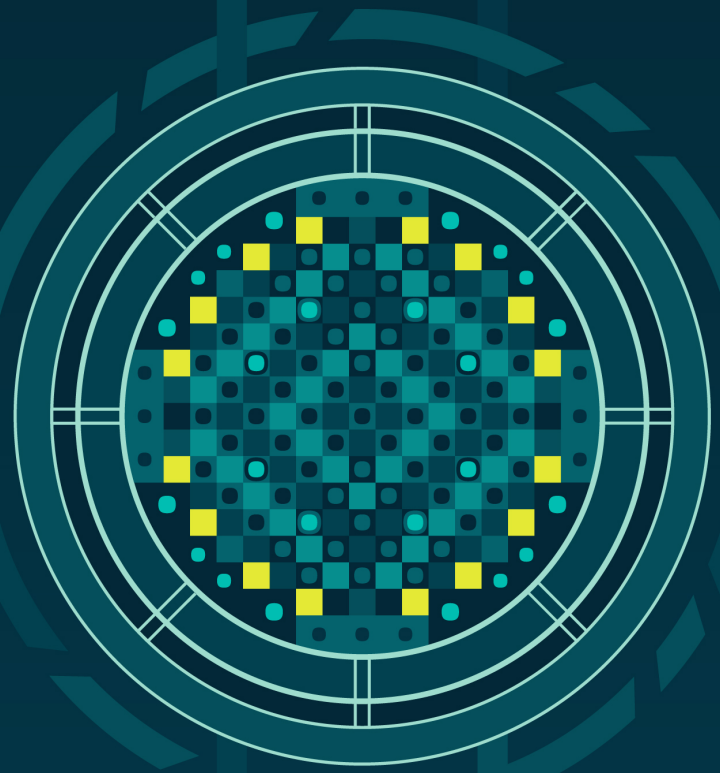
Fuel Disposition Evaluations

- "A White Paper: Potential Disposition Options for a Liquid-Fueled Molten Salt Reactor at INL" INL/EXT-20-57831
- "Documentation of Applicable Regulations and Regulatory Authority for Microreactor Transportation" PNNL-29718



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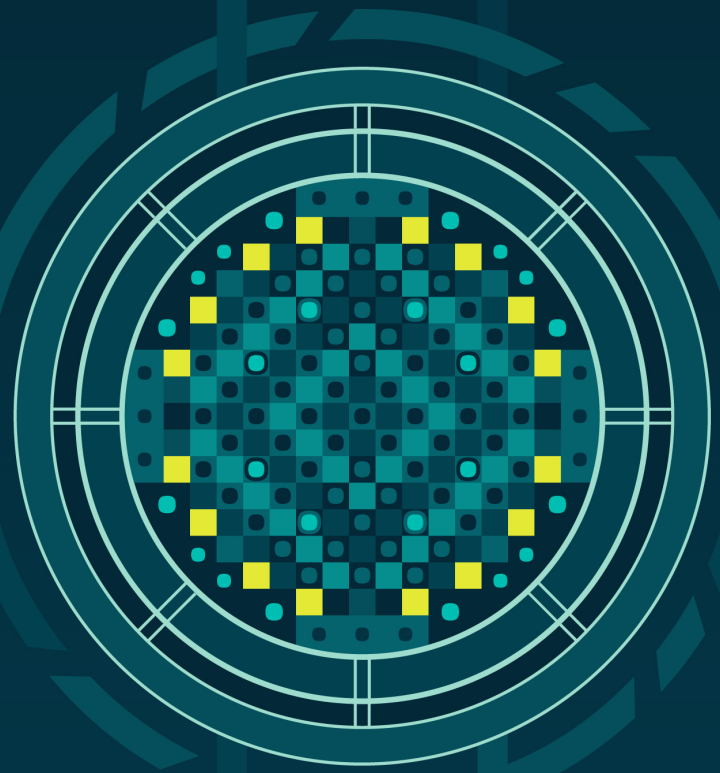
Fuel Disposition Evaluation Next Steps

- Transportation options for microreactor
- Treatment and/or storage of spent microreactors
- Environmental regulations, regulators, and approaches



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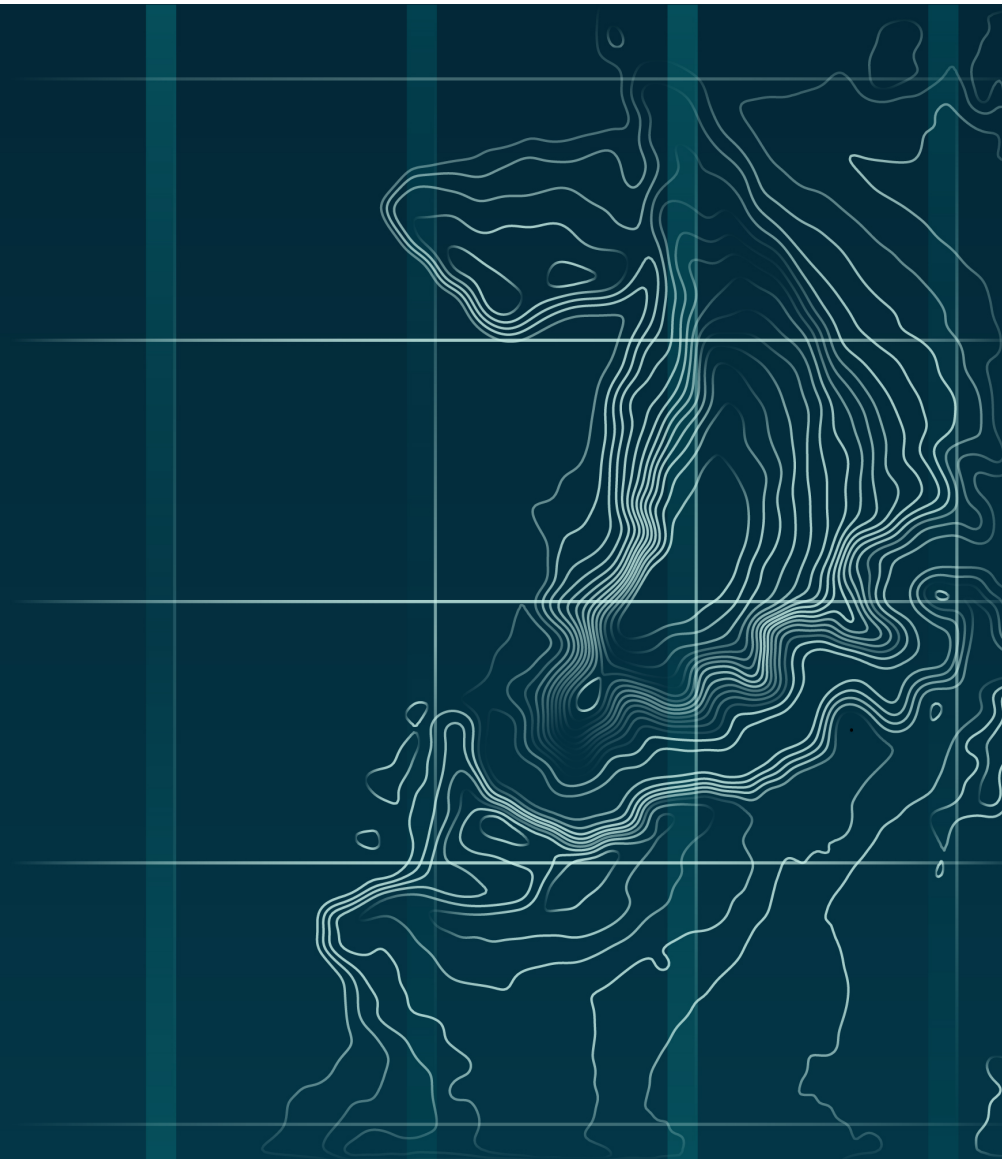
Please direct questions to
Ashley.Finan@inl.gov
nric.inl.gov



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