INL/MIS-22-65987-Revision-0

NRIC 2022 Program Review Session 1

March 2022

Ashley E Finan, Philip Lee Schoonover II, Craig L Reese, Aaron L Balsmeier, Stephen R Grabinski, Evans Damenortey Kitcher, Kyle G Metzroth, Gregory M Core, Samuel Matthew Reiss

Changing the World's Energy Future

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

INL/MIS-22-65987-Revision-0

NRIC 2022 Program Review Session 1

Ashley E Finan, Philip Lee Schoonover II, Craig L Reese, Aaron L Balsmeier, Stephen R Grabinski, Evans Damenortey Kitcher, Kyle G Metzroth, Gregory M Core, Samuel Matthew Reiss

March 2022

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

NRIC
National Reactor
Innovation Center

INL
Idaho National Laboratory

NRIC Program Review

February 14, 2022
NRIC Program Review, Session 1

NRIC Overview, Accomplishments, FY-22 Plans

February 14, 2022

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

ashley.finan@inl.gov

nric.inl.gov

NRIC is a DOE-NE program, launched in FY 2020

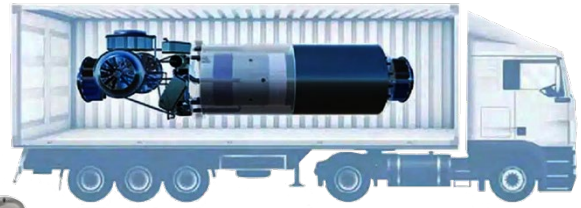
NRIC
National Reactor Innovation Center

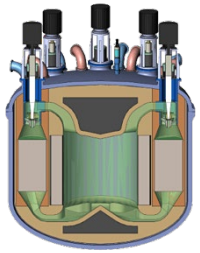
NRIC Accelerates Nuclear Reactor Demonstrations

- Authorized by the Nuclear Energy Innovation Capabilities Act (NEICA)
- Partner with industry to bridge the gap between research and commercial deployment
- Leverage national lab expertise and infrastructure
- Manage demonstrations to success

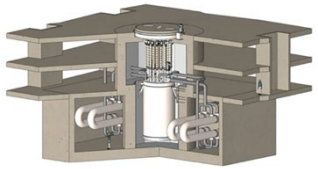
Accelerating Advanced Reactor Demonstration and Deployment

MARVEL

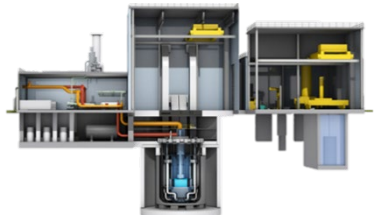




TerraPower
Southern Company



Kairos Power

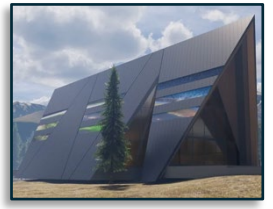


TerraPower
GE HITACHI

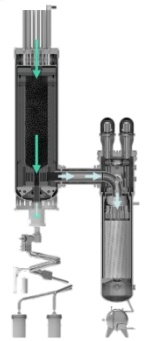
2030

NRIC National Reactor Innovation Center

OKLO



energy



LAMPS

NUSCALE
Power for all humankind

NRIC Vision

Commercial Advanced Nuclear by 2030

inspire

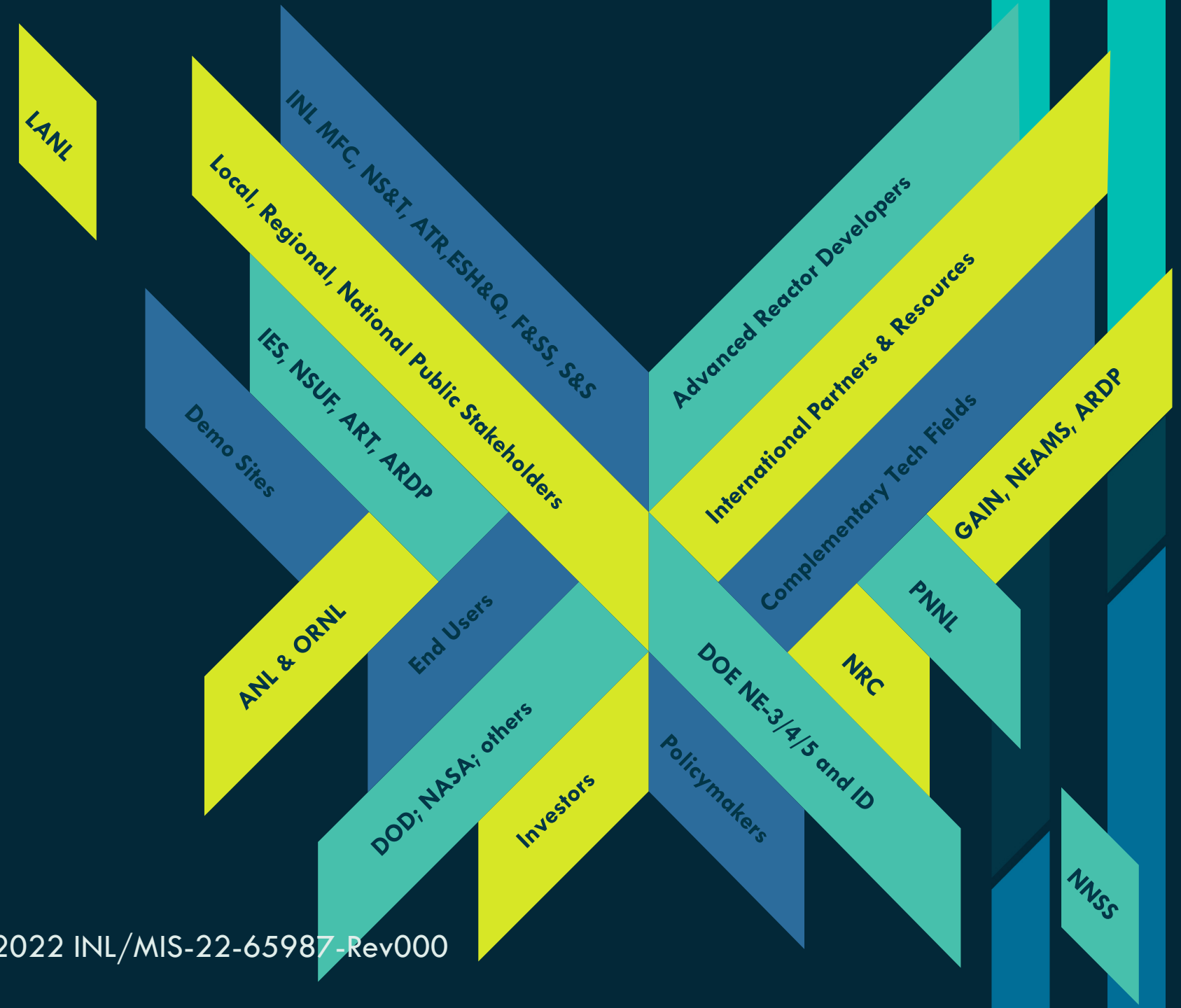
empower

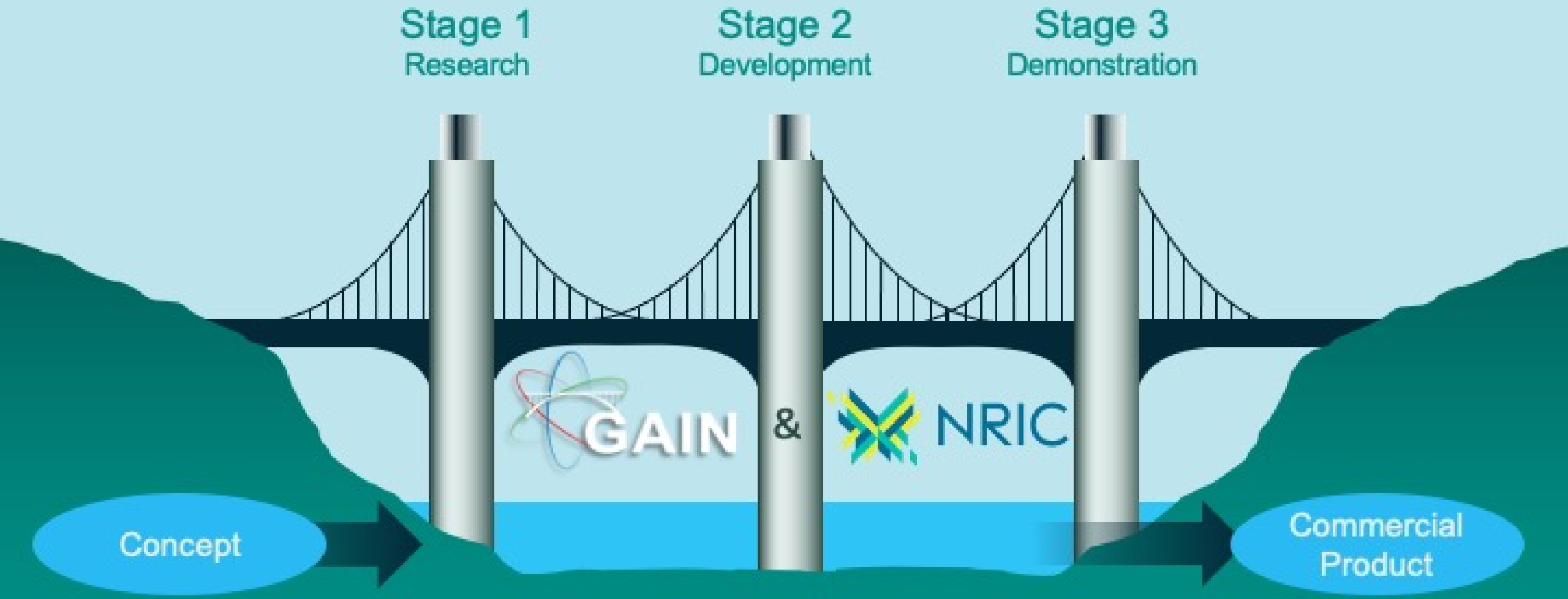
deliver

NRIC

02/14/2022 INL/MIS-22-65987-Rev000

NRIC is partnering regionally and nationally to support demonstrations




Stage 1
Research
Stage 2
Development
Stage 3
Demonstration
GAIN
&
NRIC
Concept
Commercial
Product

NRIC Budget

NRIC Budget (millions)	FY-20 (20M)	FY-21 (30M)	FY-22 (CR $30M)	FY-22 (mark $55M)
Program Management	2.5	1.5	1.6	1.8
NRIC Operations	2.0	4.6	1.9	2.0
Stakeholder Engagement	0.45	1.2	0.0	0.3
Demonstration Reactor Infrastructure	4.3	9.98	16.3	34.0
Experimental Infrastructure	0	3.9	5.4	6.34
Regulatory and Economic Risk Reduction	8.7	3.8	0.0	0.35
Analysis & Evaluations	1.6	0.02	0.0	0.0
Integrated Energy Systems and Non-Electric Applications	0	0.49	0.0	0.75
MARVEL	0	1.1	0.0	0.0
TOTAL	**19.5**	**26.6**	**25.2**	**45.5**

National Reactor Innovation Center

Inspiring Stakeholders

- Engagement & Outreach
  - Stakeholder engagement strategy
  - Web and social media
  - Testimony and presentations
  - NRIC Tech Talks & webinars
- Proactive Impact Management
- Advanced Siting Approaches
- Best Practices Development

NRIC

Empowering Innovators

- Demonstration Test Beds
- Experimental Facilities
- Regulatory Risk Reduction

- Planning Tools
  - NRIC Resource Team
  - NEPA guidance
  - Demonstration Resource Network (https://nricmapping.inl.gov/)
  - Siting Tool for Advanced Nuclear Development

Delivering Successful Outcomes

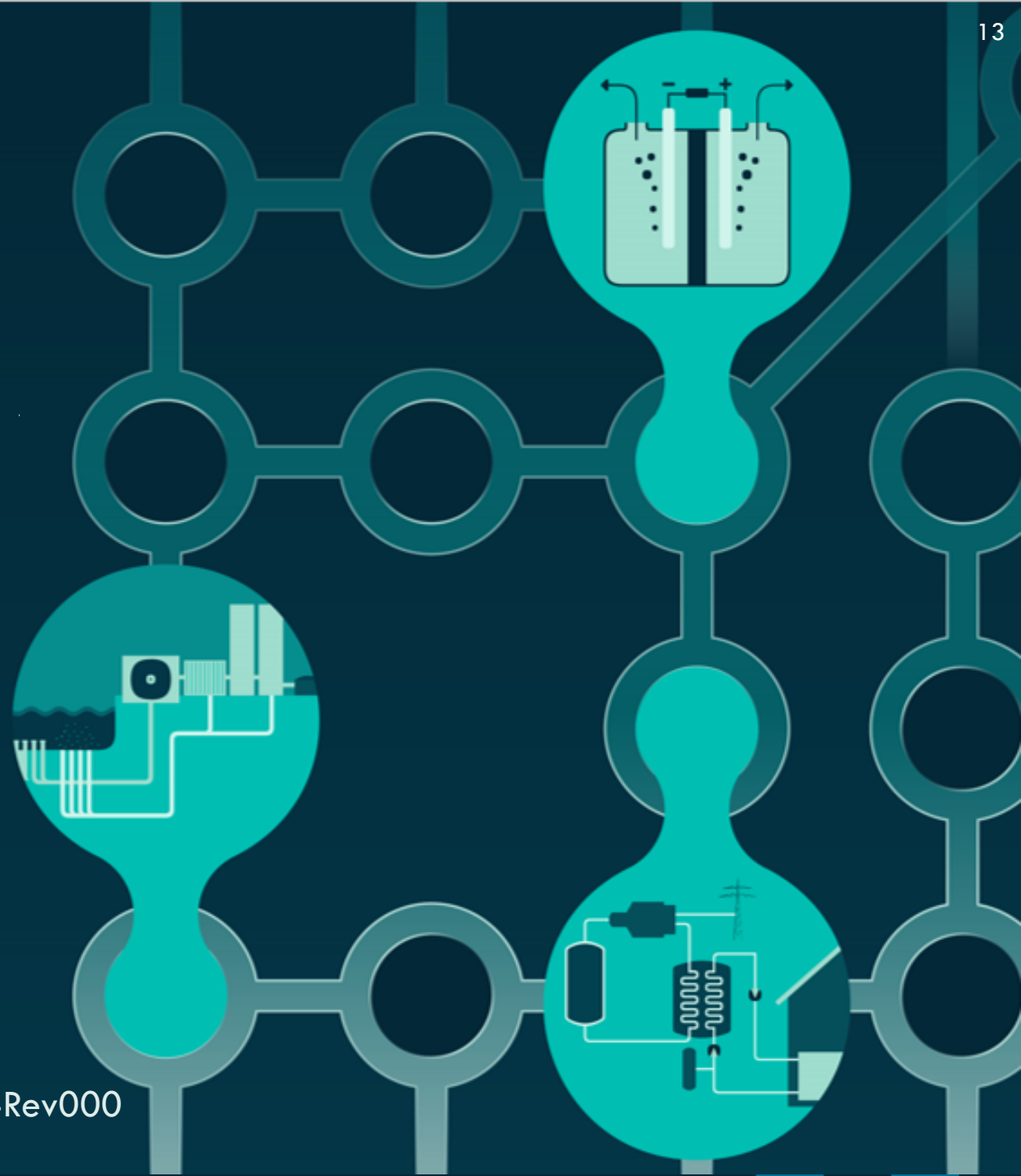
- Coordination & Collaboration
  - DOE/NRC
  - ARDP
  - GAIN, Labs
  - Cross-functional core team
- Digital Engineering
- Advanced Construction Technology
- Integrated Energy Systems

National Reactor Innovation Center – C300

Ashley Finan, Director
Brad Tomer, Chief Operating Officer
Vacant, Collaboration Manager
Jasminne Corado Mayorga, Administrative Assistant

Demonstration Infrastructure and Support/Demonstration Project Partnerships – C310

Brad Tomer, Acting Department Manager
Greg Core, Tech Program Manager
Emily Gallegos, Project Coordinator
Stephen Grabinski, Project Manager
Samuel Reiss, Tech Program Manager
Philip Schoonover, Senior Program Manager
Stacie Strain, Risk Coordinator/Program Manager
Luke Voss, Tech Program Manager
Stephanie Weir, Regulatory & Siting Manager
Christine Williams, Project Manager



NRIC INL

Companies Working with NRIC Include:

- Terrapower
- X-Energy
- Kairos
- BWXT
- Oklo
- Holtec
- ARC
- General Atomics
- Micronuclear
- Radiant
- GEH
- CorePower
- Westinghouse
- USNC
- GERA
- MARVEL

TerraPower

Westinghouse

OKLO

energy

Kairos Power

GENERAL ATOMICS

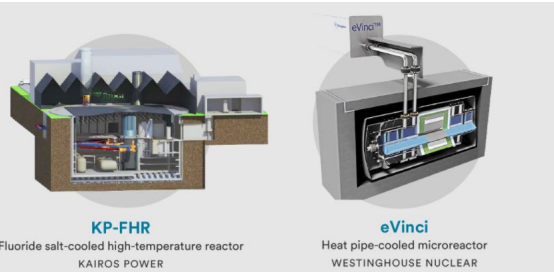
RADIANT

BWXT
BWX Technologies, Inc.

Southern Company

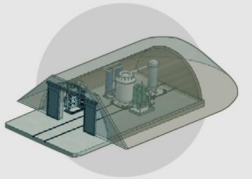
HITACHI

ARC
ADVANCED REACTOR CONCEPTS, LLC



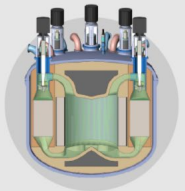
KP-FHR
Fluoride salt-cooled high-temperature reactor
KAIROS POWER

eVinci
Heat pipe-cooled microreactor
WESTINGHOUSE NUCLEAR



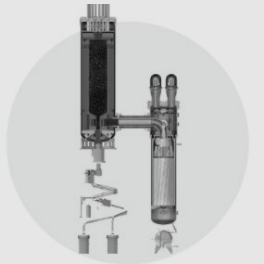
BWXT Advanced Nuclear Reactor (BANR)
High-temperature gas-cooled microreactor
BWX TECHNOLOGIES

SMR-160
Advanced light-water small modular reactor
HOLTEC INTERNATIONAL



Molten Chloride Fast Reactor
SOUTHERN COMPANY

Natrium Reactor
Sodium-cooled fast reactor + molten salt energy storage system
TERRAPOWER



Xe-100
High-temperature gas reactor
X-ENERGY

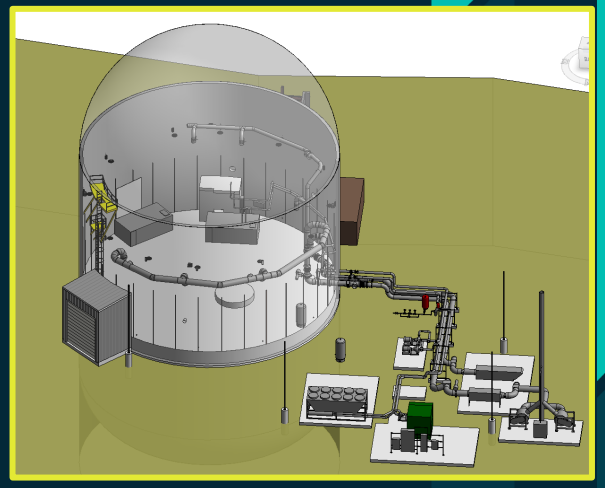
NRIC INL

02/14/2022 INL/MIS-22-65987-Rev000

National Reactor Innovation Center

Conceptual Design Reviews for Advanced Microreactor Testbed Completed

- NRIC completed the conceptual design to reestablish EBR-II as the NRIC Demonstration of Microreactor Experiments (NRIC-DOME) testbed.
- NRIC-DOME is suitable for reactors that are < 20MWth and fall into safeguards category 4 (i.e., high-assay low-enriched Uranium or HALEU).
- NRIC awarded preliminary and final design contracts for the facility in December and are proceeding to finalize the designs as a General Plant Project.
- Final design is expected to complete in April 2022 and construction is expected to complete in June 2023.
- NRIC has had robust interest in the DOME from various types of microreactor developers including for space applications, commercial and Department of Defense (DOD) users vying for testing slots, with the DOD Pele project being the lead demonstrator expected in 2024.



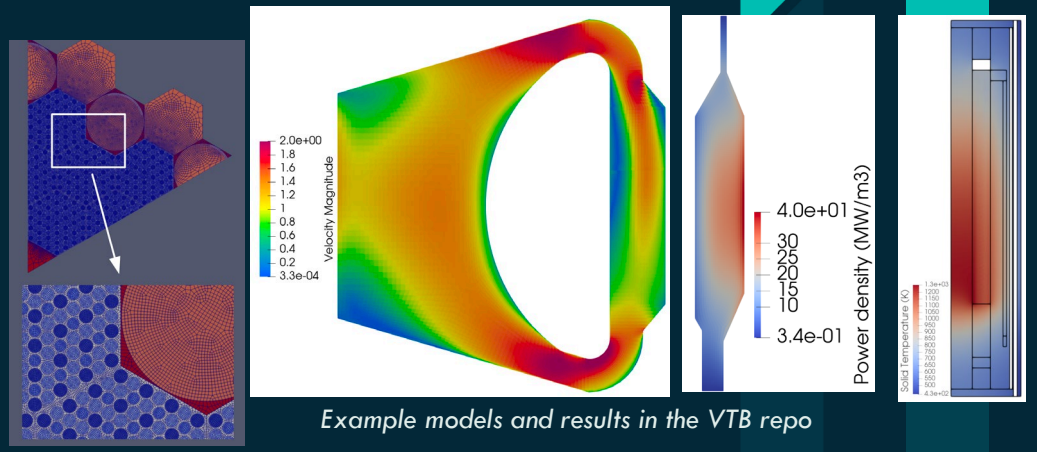
Conceptual design of the DOME testbed.

Location of the DOME at INL's Materials and Fuels Complex

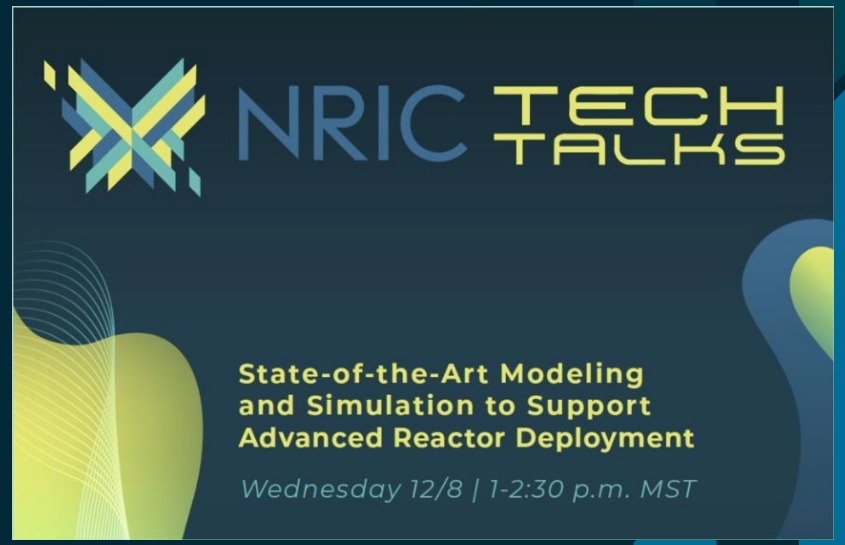
National Reactor Innovation Center

NRIC Officially Launches Virtual Test Bed

- The Virtual Test Bed (VTB) was launched during a special session at the American Nuclear Society Winter 2021 conference.
- This project was a cross-laboratory collaboration between NRIC and the Nuclear Energy Advanced and Modeling Simulation (NEAMS) programs.
- The VTB is a repository of NEAMS advanced reactor models including sodium, micro, gas, molten salt, and fluoride high-temperature reactors.
- The VTB currently hosts 14 distinct advanced reactor models, with seven NEAMS codes showcased, and more coming soon.
- A recent NRIC Tech Talk highlighted the state-of-the-art VTB held on with 170 attendees from 50+ institutions attending.
- The INL project team includes Abdalla Abou-Jaoude, Guillaume Guidicielli, Mauricio Tano Ratamales, Cody Permann, Jason Miller, and Derek Gaston.



Example models and results in the VTB repo



Announcement of Tech Talk on VTB

NRIC Hosts NRC Rotational Assignment

Work is being conducted under a Memorandum of Understanding (MOU) on nuclear energy innovation between DOE and the NRC. The purpose of the MOU is to coordinate DOE and NRC technical readiness and sharing of advanced reactor technical expertise and knowledge, including through NRIC.

- Frederick Sock, a structural engineer with the NRC, has joined NRIC on a year-long rotational assignment beginning in January 2022.
- Mr. Sock's work will support development of NRIC's advanced construction technology initiative, including participation in an advanced construction demonstration project designed to evaluate:
  - Vertical shaft construction
  - Steel Bricks™
  - Advanced monitoring, coupled with digital twin technology

Illustration of vertical shaft boring technology

NRIC'S Advanced Construction Technology Initiative

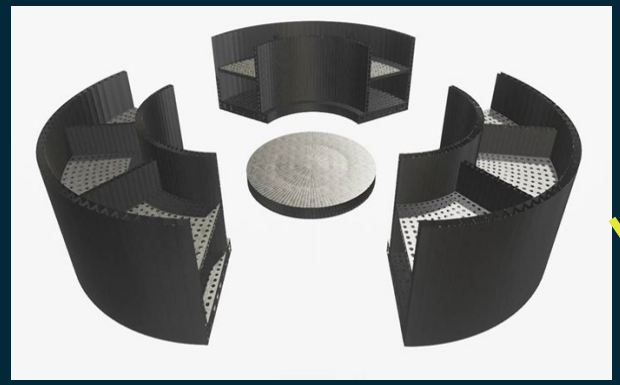
NRIC's Advanced Construction Technology (ACT) Initiative aims to reduce cost overruns and schedule slippages that have plagued the construction of nuclear power plant projects. With this initiative NRIC is facilitating development of advanced nuclear plant construction technologies and approaches through partnerships that could provide game changing benefits to the construction of advanced nuclear power plants.

DOE / NRC / NRIC Collaboration

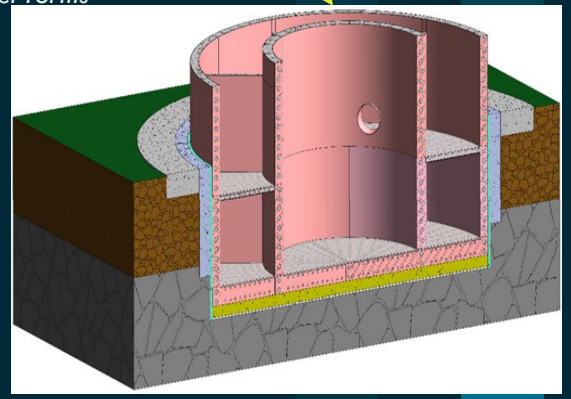
First Project in NRIC's Advanced Construction Technology Initiative Kicks Off

The initiative's purpose is to demonstrate construction technologies that will reduce nuclear energy construction schedules and costs. The first projects is under contract and underway as of January 2022:

- Led by General Electric Hitachi Nuclear Energy (GEH)
- Team includes Industry, Science Centers, and Academia
- Technologies to be demonstrated in nuclear builds
  - Tunneling – reduce excavation and back fill requirements
  - Steel Brick™- Steel-Concrete composite (off-site built)
  - Digital Twin – Cradle-to-Grave data simulation
- Phase 1 – 1 year for design, site selection, and determination
- Phase 2 – Demonstrate technology for regulators and advanced reactor developers
- Cost-Share Public Private Partnership
  - 70% DOE-NE : 30% GEH

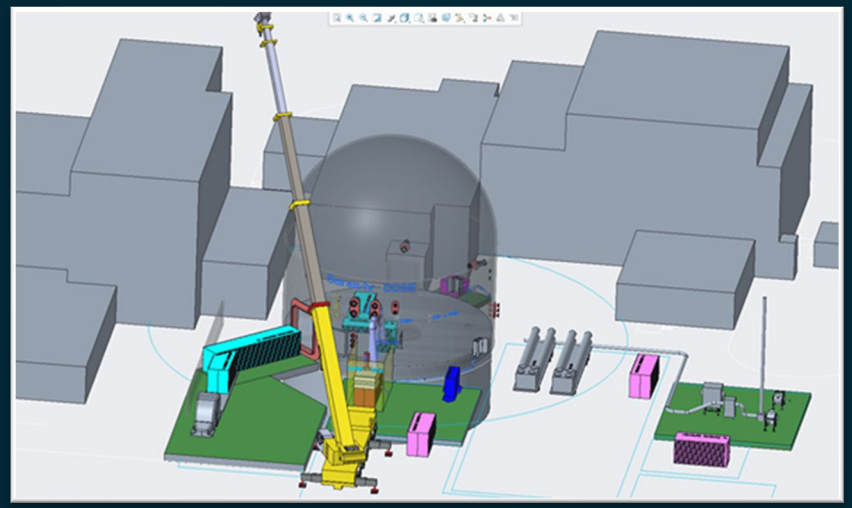


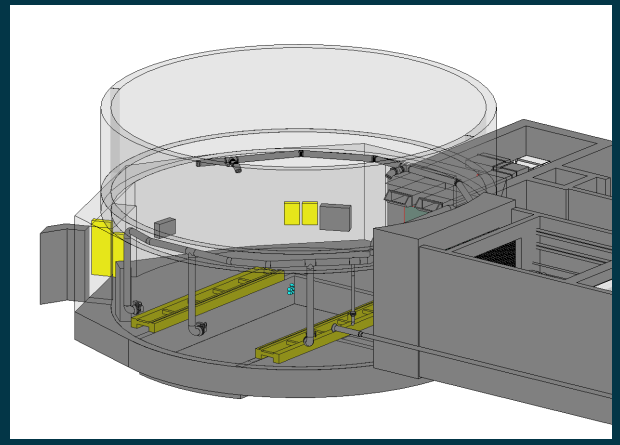
Factory built wedge-shaped steel forms used in nuclear energy construction

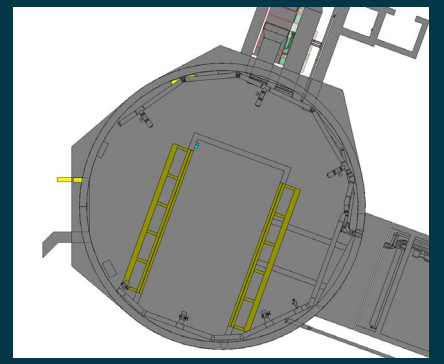


NRIC INL

Reduce risk related to budget and schedule for advanced reactor construction

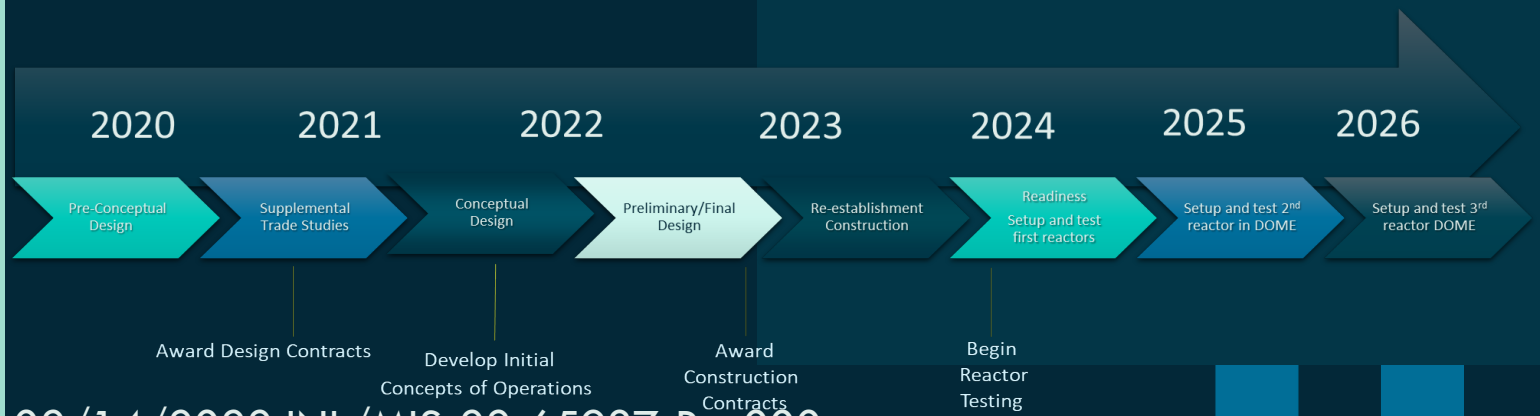




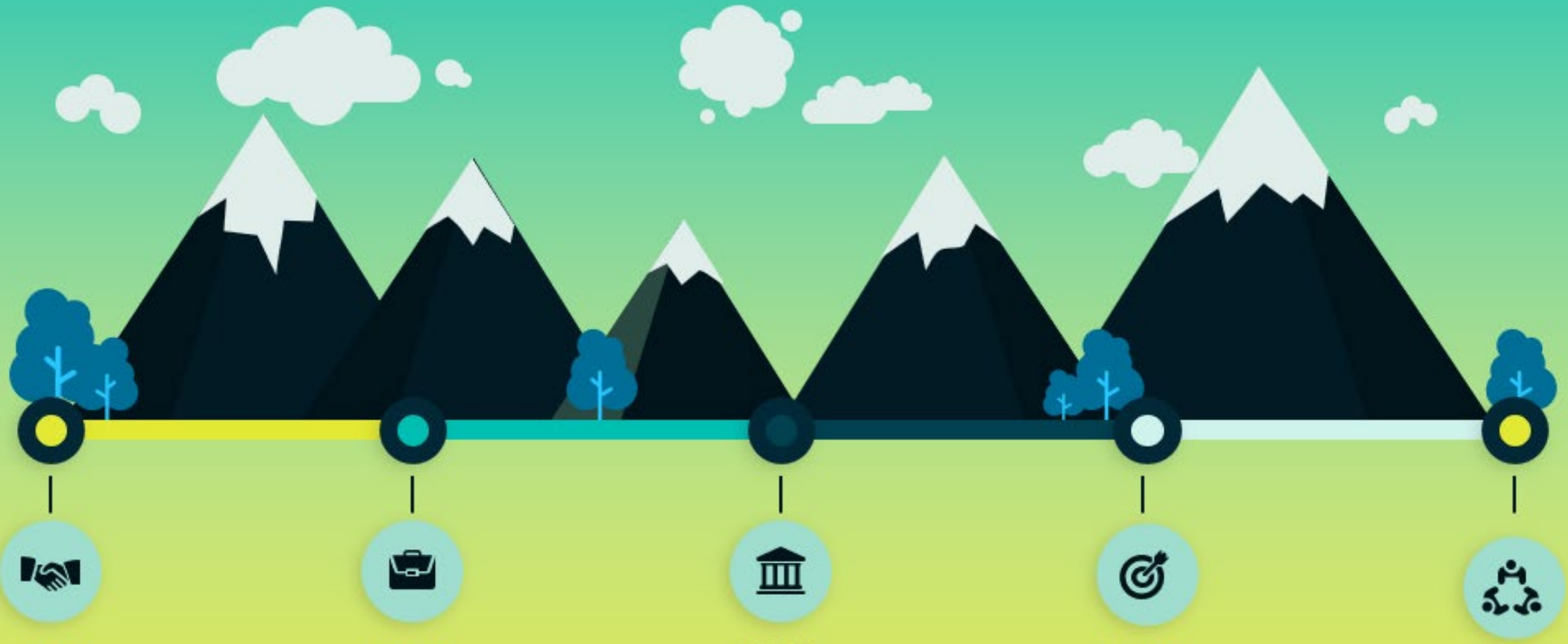


Demonstration Test Beds In Development

- Enable continuing innovation by refurbishing and leveraging existing infrastructure for multiple demonstration projects
- Pre-conceptual design completed in FY20
- Initial trade studies, updated costs completed in FY21
- Conceptual design planned for completion in early FY22 (DOME completed Dec '21)
- Prelim/Final design planned for FY22, pending DOE decisions
- DOME construction RFP late FY22 budget permitting



NRIC Timeline for Microreactor in 2024 (example)



2021
Design DOME

2022
Complete DOME design; award construction contract

2023
DOME Refurbishment

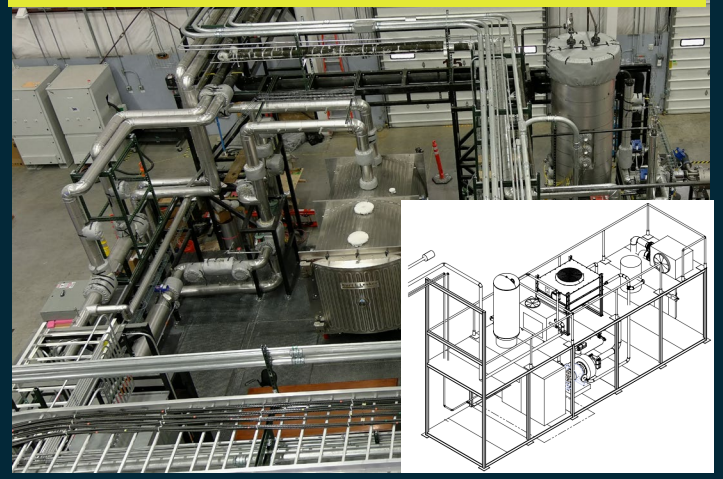
2024
DOME Readiness Final Preparations and Reactor integration; Startup

2025
Reactor Operations

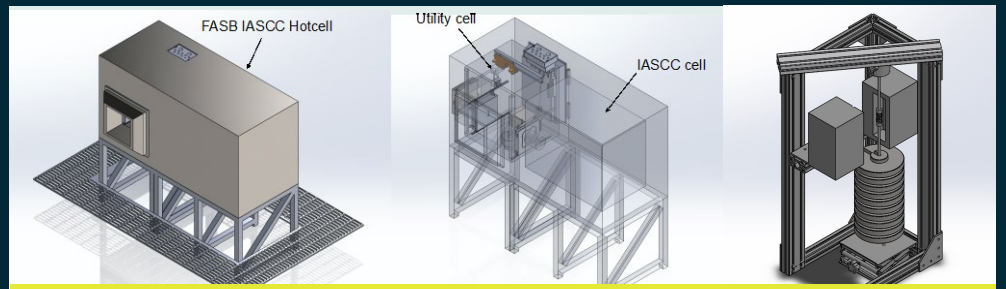
NRIC INL

NRIC Experimental Test Beds

Helium Component Test Facility [2022]

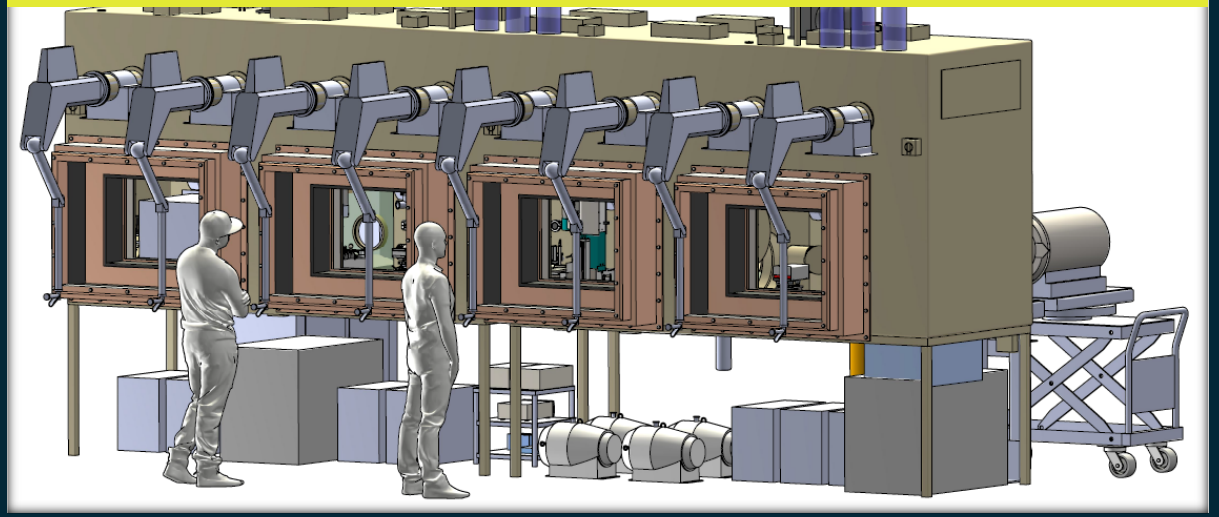


In-HotCell Thermal Creep Frame [2022]

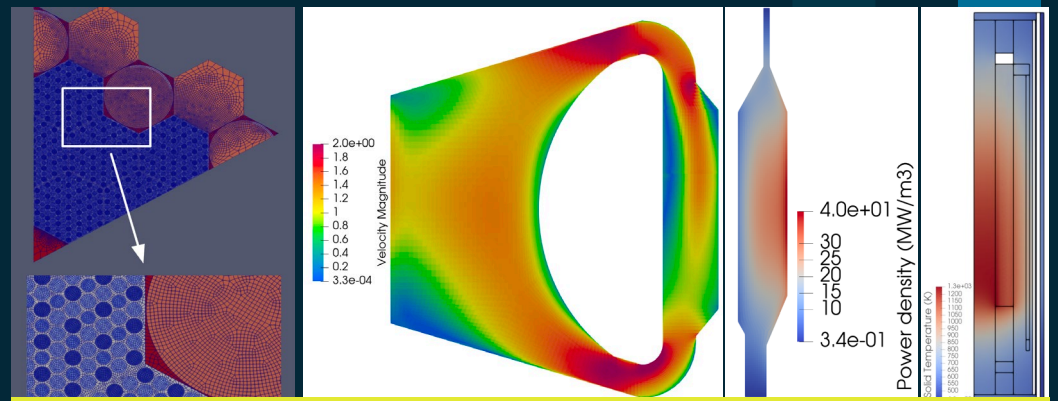


Mechanisms Engineering Test Lab (METL) [Operating]

Molten Salt Thermophysical Examination Capabilities (MSTEC) [2024]

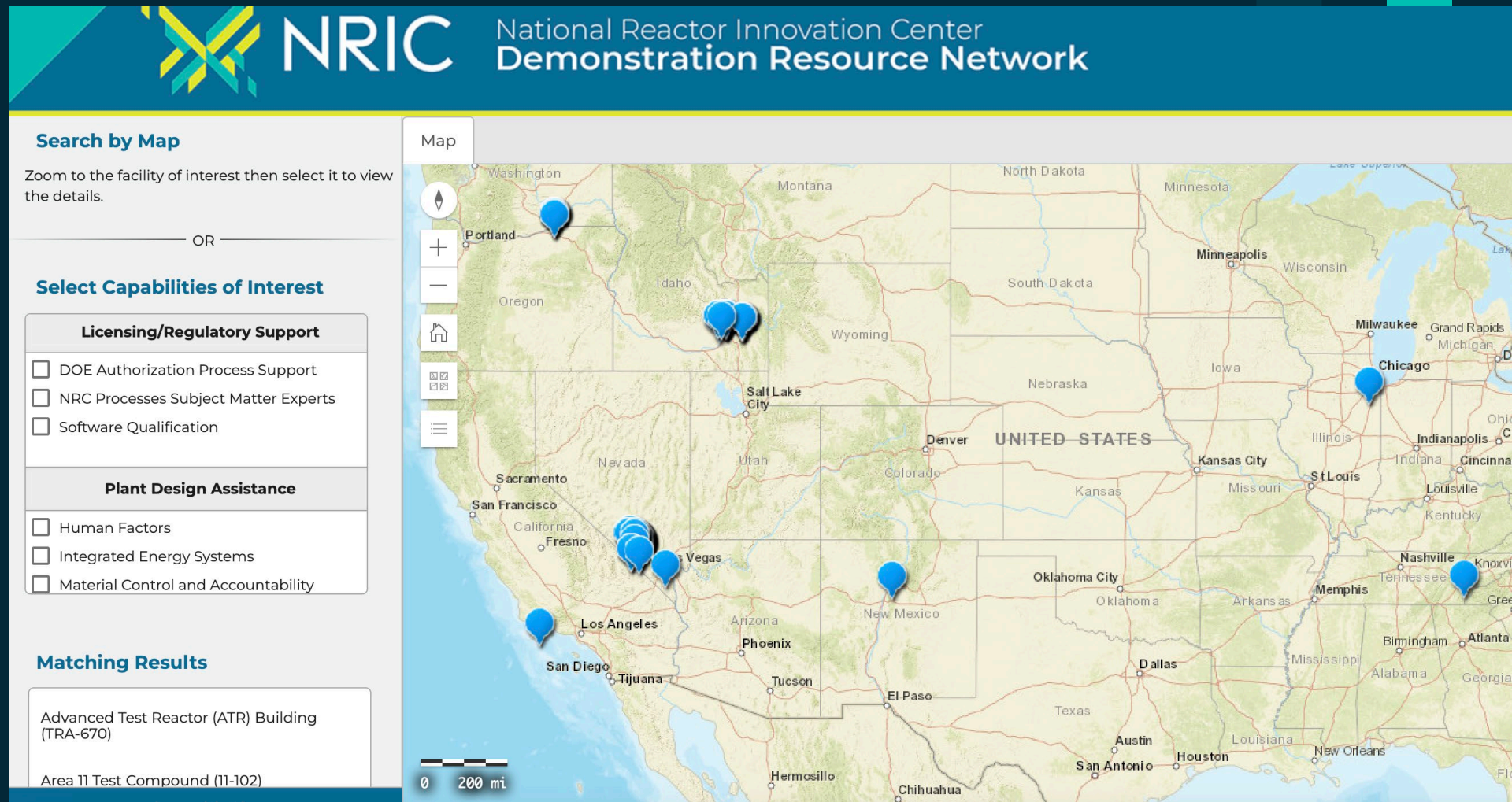


Virtual Test Bed [Launched 2020]



Planning Tools

- Demonstration Resource Network (https://nricmapping.inl.gov/)
- NRIC Resource Team



02/14/2022 INL/MIS-22-65987-Rev000

Nuclear Reactor Innovation Center

NRIC Launches STAND Tool to Help Advanced Reactor Companies Locate and Compare Potential Reactor Sites

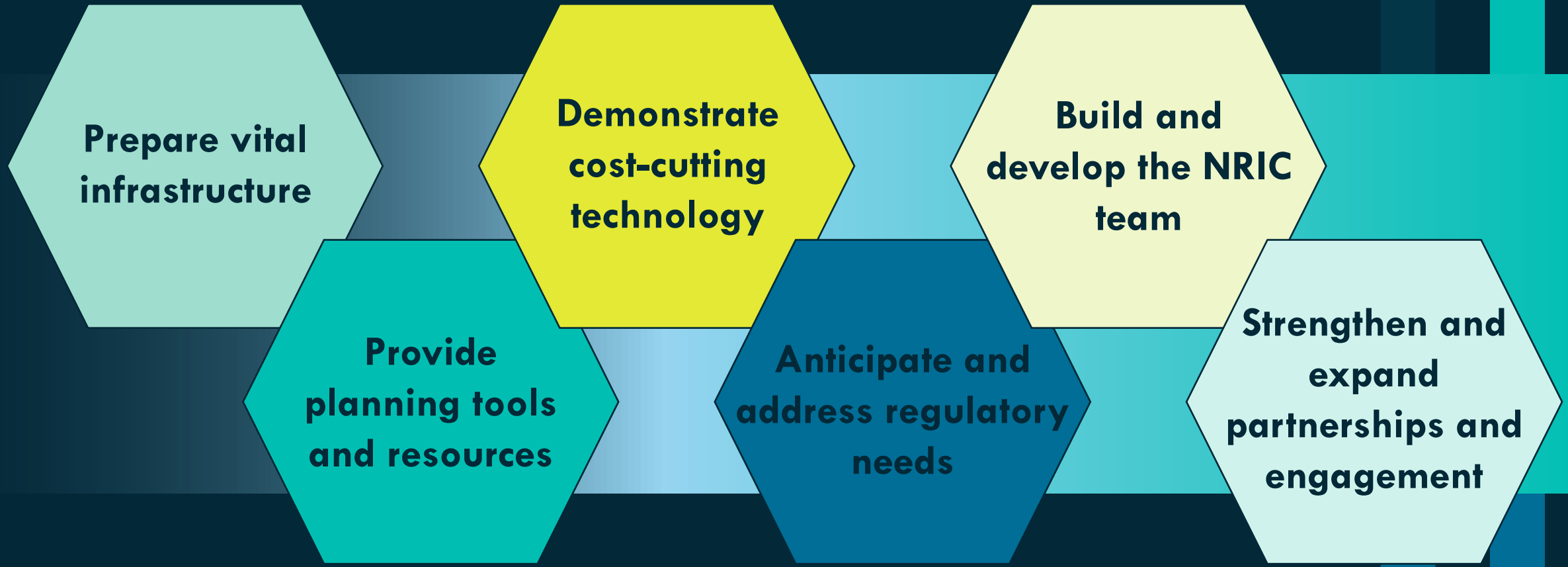
- NRIC's Tech Talk on January 26 introduced NRIC's Siting Tool for Advanced Nuclear Development (STAND). Users are now gaining access to the tool and tutorial sessions are being scheduled for February.
- STAND is a user-friendly decision tool that supports current and emerging advanced nuclear companies with locating and comparing potential sites for nuclear energy projects.
- STAND's expansive data set goes beyond traditional proximity and safety siting data to also include socioeconomic, cultural, and sociopolitical data at the community level.
- STAND is an NRIC-led collaboration with University of Michigan, Argonne National Laboratory, and Oak Ridge National Laboratory.

Flyer announcing NRIC Tech Talk

Addressing Cost and Markets

- Advanced Construction Technologies – Project kicked off January 2022
- Digital Engineering & Knowledge Sharing/Lessons Learned
- Construction Readiness – With TVA, EPRI, NEI
- Integrated Energy Systems – Design of IES demonstration platform
- Work with Communities on Deployment Opportunities (coal retirements; Alaska; maritime)

Goals for FY22
Maintain progress to support demonstrations by the end of 2025 and sustained innovation



Thank you!

Questions?
Time Permitting

NRIC
National Reactor
Innovation Center

INL
Idaho National Laboratory

Demonstration Infrastructure & Support

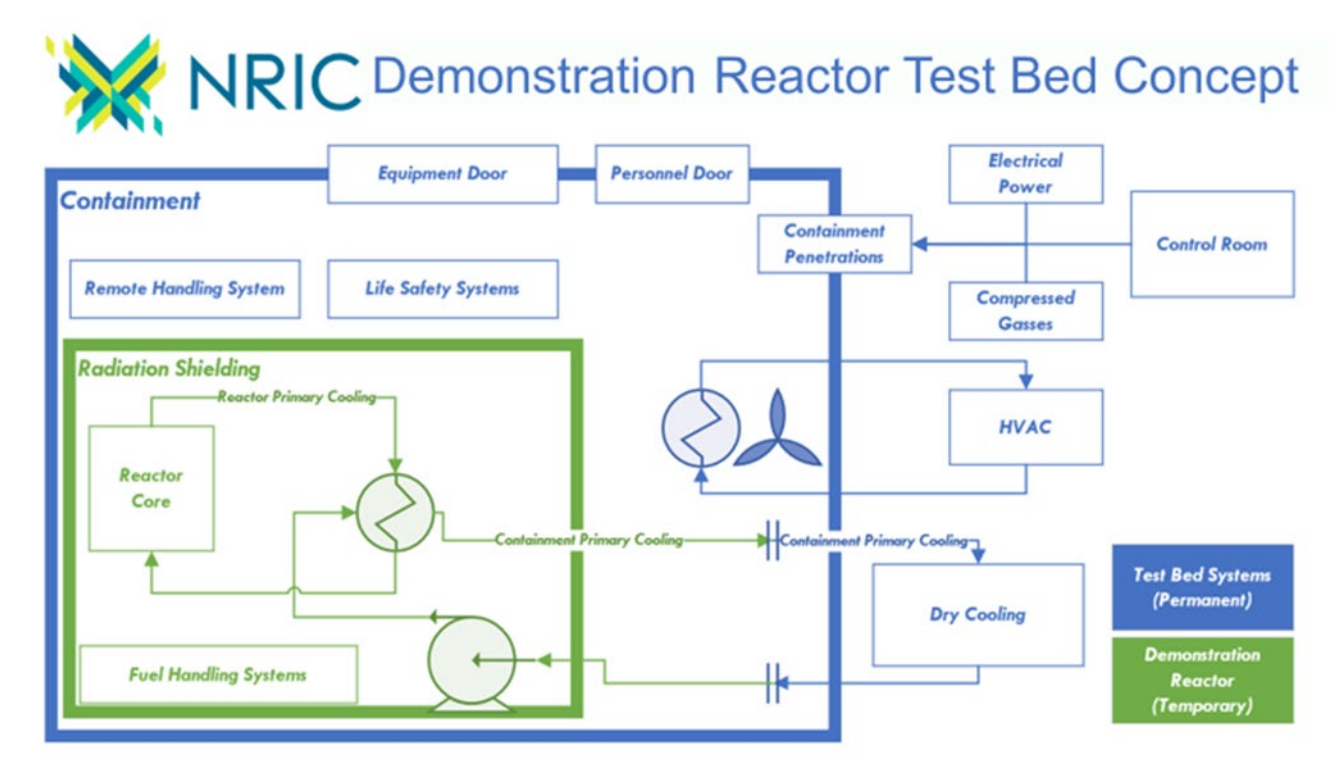
NRIC Program Review Schedule
Project Review Portion

- Plan is to review status of each NRIC project
- Questions may be addressed at the end of each presentation (time permitting) - Emily Gallegos will track time
- Questions can be asked by using:
  - TEAMS chat feature
  - TEAMS hand raising feature
- You are welcome to attend all sessions (links in the agenda)
  - Session 1: Reactor Demonstration Infrastructure & Support
  - Session 2: Experimental Infrastructure and Digital Engineering
  - Session 3: Siting, Regulatory, and Stakeholder Engagement.

NRIC Reactor Demonstration Infrastructure and Support

9:00	1. Reactor Demonstration Infrastructure & Support • Overview	Brad Tomer
9:15	• DOME	Phil Schoonover/ Craig Reese/ Aaron Balsmeier
9:35	Break	
9:50	• LOTUS	Phil Schoonover/ Scott Smith/ Aaron Balsmeier
10:10	• Test Bed Operations Support	Phil Schoonover/ Stephen Grabinski/ Evans Kitcher/ Kyle Metzroth
10:30	• ARDP Support i. Natrium (short status on how NRIC supports) ii. BWXT (short status on how NRIC supports) iii. MCRE (short status on how NRIC supports)	Ashley Finan Greg Core Sam Reiss Phil Schoonover
10:45	1. Comments and Questions	

Enabling Industry Demonstrations is Critical to Resurgence of U.S. Nuclear Energy Leadership



- Leverage unique existing facilities including:
  - Experimental Breeder Reactor II (EBR-II)
  - Zero Power Physics Reactor (ZPPR)
- Implement new way of doing business:
  - Balance public/private sector interests
  - Lean startup principles
  - Systems Engineering
  - Digital Engineering

NRIC INL

Not the typical national lab research project

NRIC Advanced Reactor Testing Infrastructure

Goal:

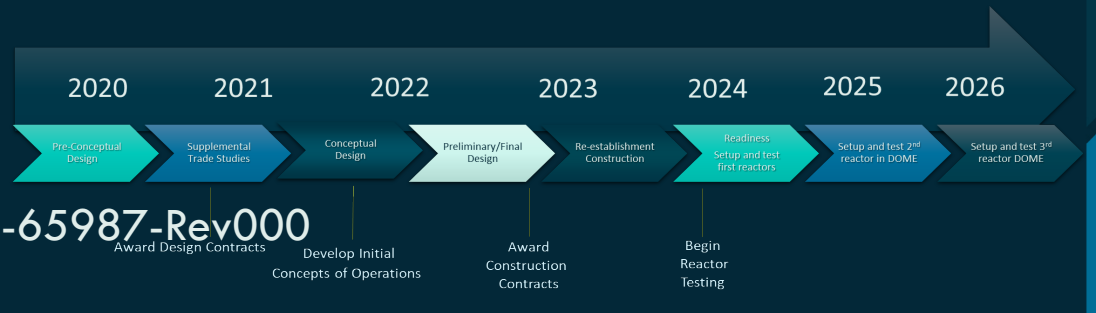
- Demonstrate two advanced reactors by 2025

Strategy:

- Repurpose two facilities at INL and establish two test beds to provide confinement for reactors to go critical for the first time

Capabilities:

- NRIC DOME (Demonstration of Microreactor Experiments)
  - Advanced Microreactors up to 20MWth
  - High-Assay Low-Enriched Uranium (HALEU) fuels < 20%
  - General Plant Project (GPP) <$20M Capital Cost
  - First reactor test anticipated in 2024
- NRIC LOTUS (Laboratory for Operations and Testing in the United States)
  - Up to 500KWth experimental reactors
  - Safeguards category one fuels
  - DOE Order 413.3B Program and Project Management for the Acquisition of Capital Assets <$100M
  - First reactor test anticipated for 2025



Thank you!

Questions?
Time Permitting

NRIC
National Reactor
Innovation Center

INL
Idaho National Laboratory

NRIC DOME Test Bed

Demonstration of Microreactor Experiments

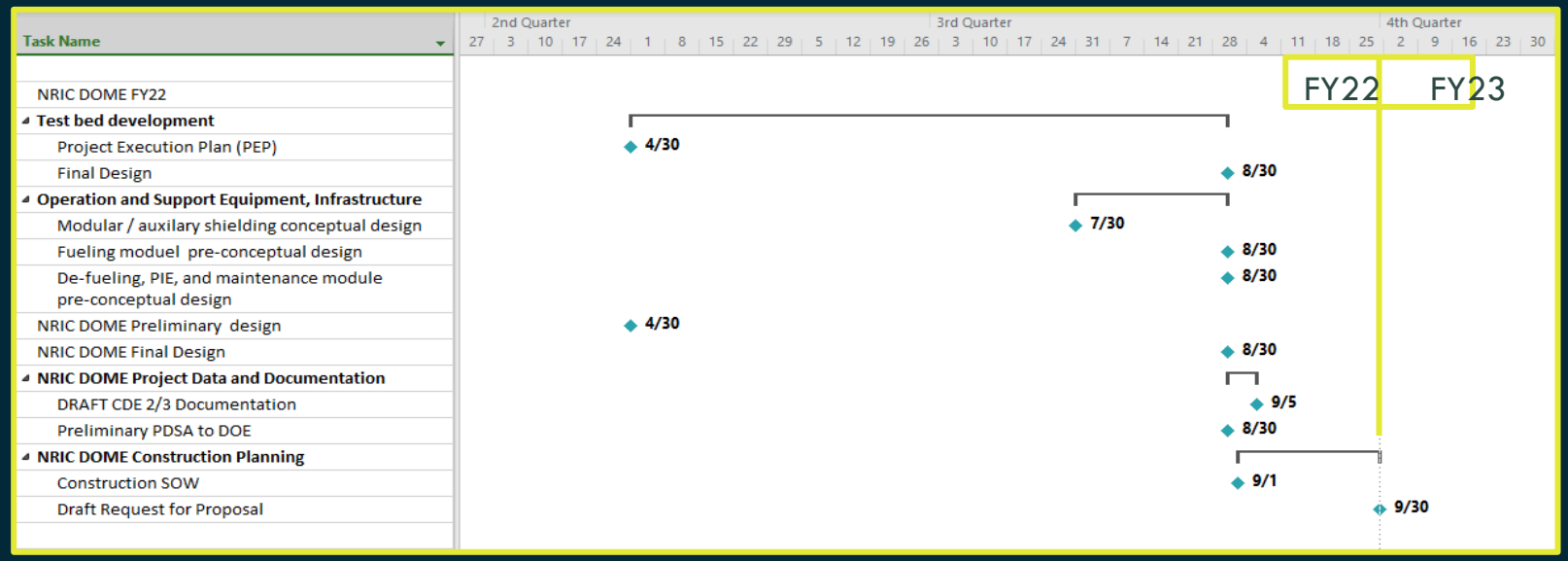
Philip Schoonover
Program Manager

Craig Reese
Work Package Manager

NRIC DOME Introduction

- DOME utilizes the existing EBR-II structure and refurbishes it to allow Advanced Reactor demonstrators to achieve first criticality of their designs. It is designed to accommodate reactors using HALEU fuels and having < 20 MW thermal power levels.
- The DOME will support the NRIC goal of 2×25, the first criticality of two new microreactor designs by 2025.
- There are at least five interested demonstrators over the next 3–5 years. They are at various stages of design completion and program funding.
  - PELE (2024)
  - USNC (2024)
  - Radiant (2025)
  - Westinghouse (2025)
- NRIC is leading the Digital Transformation by implementing advanced Digital Engineering tools and processes.
  - DOORS, Innoslate, Windchill, Deep Lynx, CREO, Revit
  - Requirements Engineering, Model Based Systems Engineering, Configuration control and change management, Data Democratization, 3D CAD Digital Twins

NRIC DOME 2022 Schedule Milestones



All preparations for achieving DOE approvals and awarding the construction contract will be completed in FY22.

- Complete Preliminary Design
- Complete Final Design
- Complete auxiliary / modular shielding conceptual design
- Complete fueling / defueling / PIE equipment / module requirements and pre-conceptual design
- Complete PDSA
- Prepare Request for Proposal package

NRIC DOME Integrated Project Team (IPT)

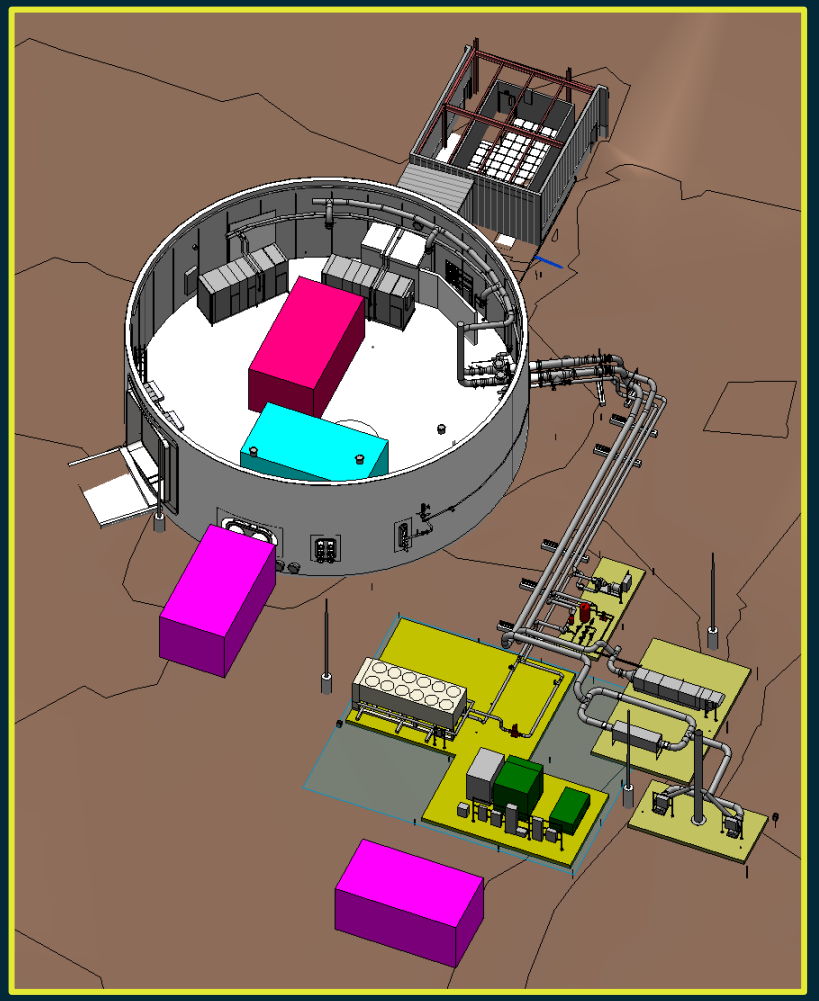
- Integrated Project Team members: A cross functional team of subject Matter experts.
  - Brad Tomer – NRIC COO
  - Philip Schoonover – NRIC Senior Program Manager
  - Craig Reese – Project Manager
  - Aaron Balsmeier – NRIC Chief Engineer (Design Authority)
  - Scott Reynolds – Nuclear Research Facility Engineer- Mechanical
  - Marwan Mohamed – Nuclear Research Facility Engineer – Electrical
  - Brad Moulton – Nuclear Research Facility Engineer – Lead
  - Matthew Lund – Advanced Nuclear Facility Safety Engineer
  - Walsh Engineering – Facility Design Agent
  - Stacie Strain – Risk Manager
  - Stacy Nottestad – NEPA Lead
  - Peter Suyderhoud – Digital Engineering Implementation Lead
  - AnnMarie Marshall – Configuration Control and Change Management Lead
  - J.R. Biggs – Nuclear Facility Manager, Operations
  - Ben Coryell – Civil / Structural Lead

NRIC DOME Goals

- NRIC is providing a safe, affordable nuclear testbed for development of Advanced Microreactor designs using HALEU fuels (<20% enrichment).
  - DOME will provide significant cost, schedule, and technical risk reductions for the demonstrators. They do not need to develop, construct, authorize, and fund a separate facility individually.
  - Developers do not need to achieve DOE authorization separately from INL.
- Current Funding plan:
  - 2022 $5.8MM
  - 2023 $32.1 MM (includes construction)
- The DOME project contains six PICS work packages and is broken down into capital project items and operations preparation items. (backup)
- INL PEMP Notable Outcomes for NRIC DOME Includes :
  - Complete conceptual design for both LOTUS and DOME test beds;
  - Complete final design for DOME test beds;
  - Submit the preliminary documented safety analysis Preliminary Documented Safety Analysis (PDSA) for DOME to DOE for review and approval; and
  - Submit the Draft Critical Decision Equivalent (CDE)-2/3 documentation for DOME to DOE for review.

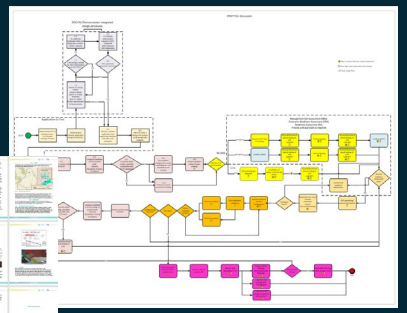
NRIC DOME Progress

- The DOME project has an expected budget of $38 MM with capital costs of $19.75 MM .
- FY21 saw the award and completion of the Conceptual Design for the DOME facility.
- FY22 has seen the award of the Preliminary and Final Design contract.
- The preliminary design review is scheduled for February 28–March 4, 2022.
- Key risks are around unknown vendor design data, program costs vs. funding, and design resources.
- Our risk register tracks individual risks and is reviewed and updated monthly or on-condition if there is a known change with risk impacts.

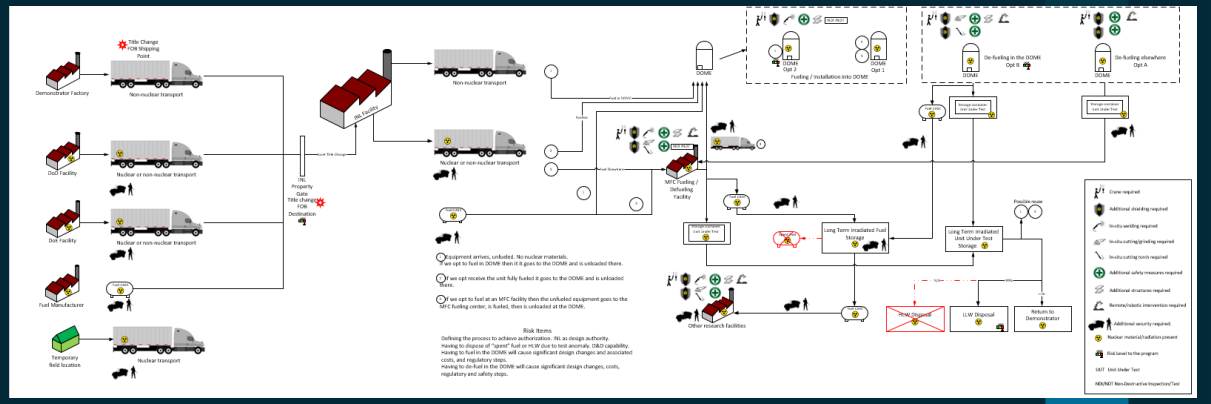


NRIC DOME Test Bed Concept of Operations

- The overall program process for getting a demonstrator through the testing campaign is identical in terms of setting up design authority, authorization processes, and general NRIC/INL to demonstrator program interfaces. Design and safeguards considerations will differ based on fuel types, and environmental considerations.
- The ConOps covers the process from first contact, through engineering and nuclear safety reviews, installation and commissioning, fueling, operations, defueling, and disposition of the irradiated fuel and reactor unit hardware.
- NRIC/INL remains the design authority throughout the process.
- The demonstrator remains the design agent for their deliverables and hardware, with NRIC approvals.
- NRIC collects, reviews, approves, and provides all authorization and readiness review materials to the DOE with subject matter expert (SME) input and oversight of each discipline.
- NRIC will follow the existing INL process for facility authorization for nuclear operations, utilizing demonstrators' documentation and SME support.
- The ConOps for the NRIC DOME testbed has had 2 revisions and will be released in March ‘22 for review and comment post Preliminary Design Review, and again after Final Design May ‘22.
- Environmental considerations are integrated during the design review process and the planning for the environmental assessment.



Process flow chart



Shipping, transport, fueling, defueling, and disposal diagram.

NRIC DOME Summary

The NRIC DOME Testbed will:

- Provide Hazard Category 2, suitable for HALEU fuels, facility for safe affordable demonstrations of first of type reactors and first criticality.
- Reduce schedule risks to developer timelines by separately funding and managing the construction and providing access to DOE facilities and expertise to many users.
- Reduce costs and funding risk to developers by providing a large capital investment for multiple users. Currently there are various interested developers.
- Reduce technical risks by providing INL experts in nuclear facility design, construction, authorization, and operations.
- The NRIC DOME will make it faster, easier, and less expensive for Advanced Microreactor developers to reach commercialization of their designs.

Thank you!

Questions?
Time Permitting

NRIC
National Reactor
Innovation Center

INL
Idaho National Laboratory

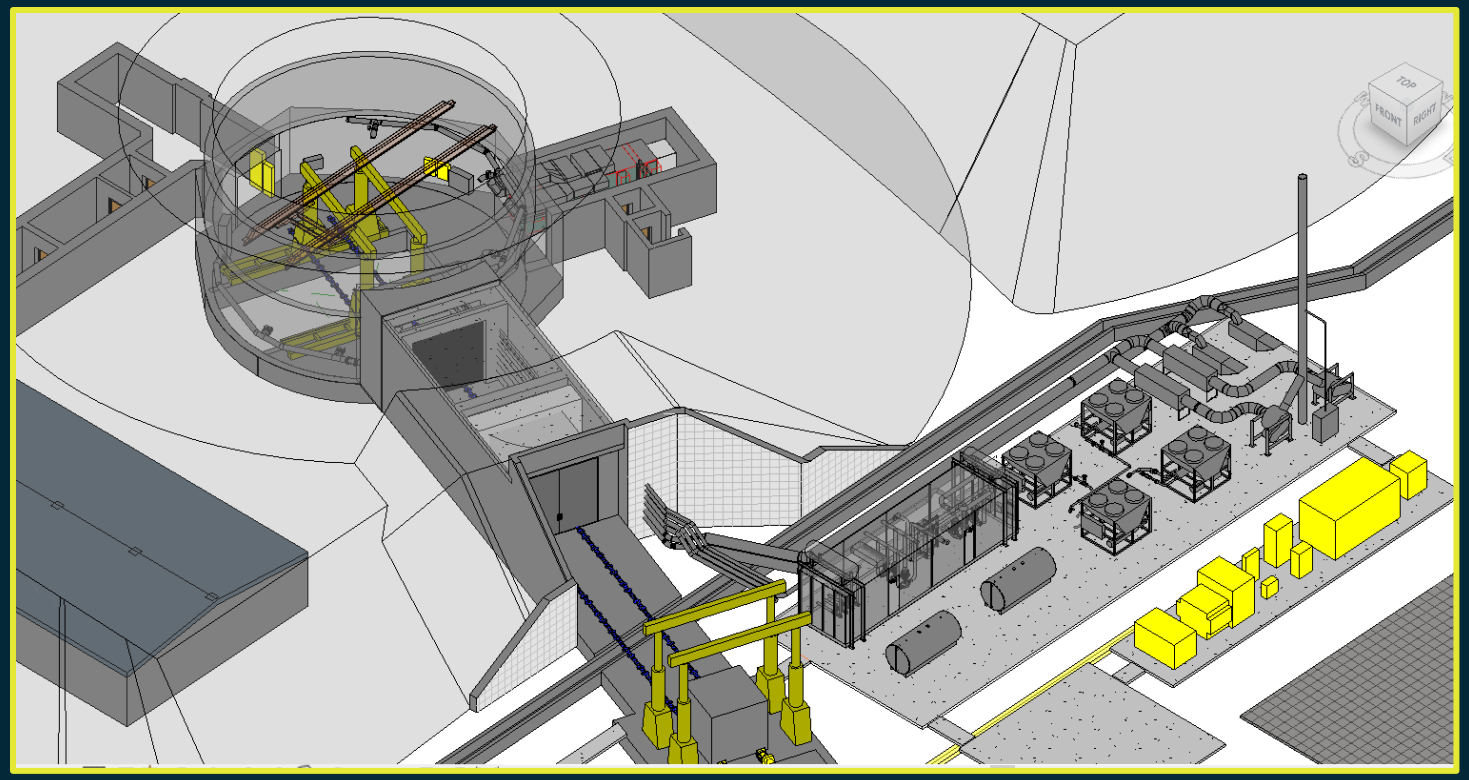
NRIC-LOTUS Test Bed

Laboratory for Operations and Testing in the United States, DOE
Designation as Category 1 Demonstration Test Bed Capability Project

Program Manager – Phil Schoonover
WP Manager – Scott Smith

NRIC-LOTUS Test Bed Overview

- LOTUS Digital Twin 3D model post Conceptual Design



NRIC-Planned LOTUS Test Bed Overview

Strategy: Repurpose ZPPR facility to provide small modular research reactor support systems including:

Reconfiguration of ZPPR Cell:

- Establish a minimum 10'x10' side entry for the research reactor and equipment (13'x13')
- Mechanical and electrical penetrations

Power Supply:

- Backup power: 1.2 kVA battery backup; 350 KW diesel generator;
- 480V 400A primary power supply to cell

Ventilation System:

- Standalone/upgraded ventilation system with ability to maintain negative pressure
- New stack and monitoring system to meet environmental regulations

500 kWth Demonstration Direct Reactor Cooling System, 100kW decay heat removal

Installation of Security Door to maintain security posture between ZPPR/vault and the LOTUS cell; will facilitate construction activities

Safeguards Category 1 Security posture

Safety Significant Confinement

Instrumentation and Controls

Interested Demonstrator Companies:

- Southern Company Services/Terrapower (MCRE 2024)
- Micronuclear LLC (MsNB 20XX)

NRIC-LOTUS Test Bed Integrated Project Team

- Brad Tomer, NRIC COO
- Phil Schoonover, NRIC Program Manager
- Cory Brower, Nuclear Facility Manager
- Josh Woodard, Nuclear Facility Manager
- Brady Orchard, Project Director
- Scott Smith, Project Manager
- Dee Radford, Project Controls
- Stuart Jensen, MFC Design Authority
- Stacy Nottestad, NEPA compliance lead
- Aaron Balsmeier, NRIC Chief Engineer (Delegated Design Authority)
- Scott Reynolds, Nuclear Facility Engineering Lead, Mechanical
- Mitch Woolf, System Engineer
- Ben Coryell, Civil Engineering
- Marwan Mohamed, Nuclear Facility Engineering Lead, Electrical
- Michael Ordway, Mechanical Engineering
- Troy Reiss, Nuclear Safety Engineer
- Michael Ruddell, Nuclear Facility Manager, Operational Readiness

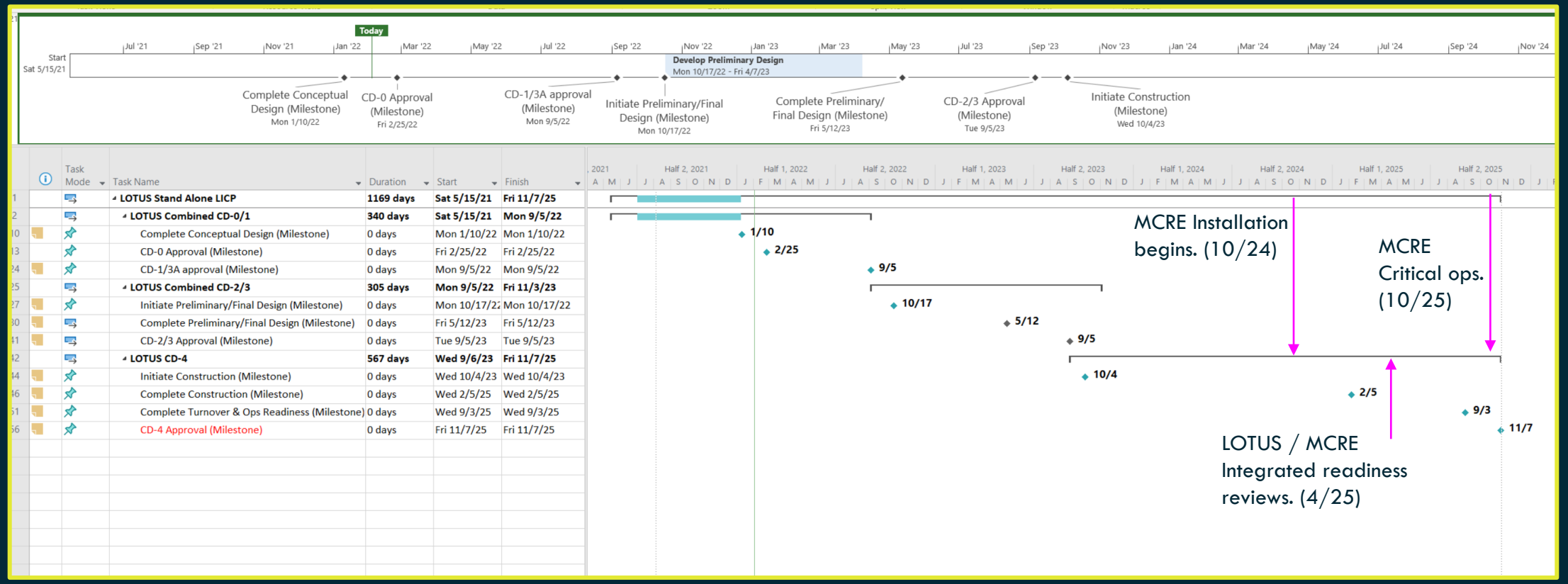
Primary IPT personnel. Many other disciplines are brought in as stakeholders for input and consultation as needed.

NRIC Test Bed Tailoring Strategy – Line Item <$100M

- DOE O 413.3B Applicability (3.a) – "The requirements identified in this Order are mandatory… for all capital asset projects having a Total Project Cost (TPC) greater than $50M… The ***principles*** (see Appendix C, Paragraph 1.a.-1.) as set forth in this Order apply to all capital asset projects."
- Order provides ability to tailor requirements considering size, complexity, costs, and risks
- Completed Conceptual Design (Jan/22)
- Proposed tailoring strategy –
  - Combined CD-0/1/3A and CD-2/3B
  - Document Mission Need, Analysis of Alternatives, and Acquisition Strategy in Project Execution Plan
  - Proceed directly from conceptual to preliminary/final design (prior to formal CD-0/1/3A approval)
  - Tailor independent reviews – focused reviews led by NE
  - Utilize Early Contractor Involvement Acquisition Approach to engage constructor in preliminary/final design review and provide input to constructability and accelerate start of construction
  - Consider integrated test bed operational readiness with first reactor operational readiness review
- DOE to provide specific program guidance to INL to execute as tailored approach
- Considerations:
  - With tailoring as outlined, schedule meets demonstrator needs (MCRE: initiate install – Oct 24; initiate readiness review – Apr 25; Critical ops – Oct 25)
  - Current FY22 House language supports capital design and construction

LOTUS – Planning Based on Tailoring

- Total Estimated Pre-Conceptual Design Cost = $55.5MM with a range of $45MM - $83MM



NRIC-LOTUS Tailored Test Bed Funding Profile

Current (October 2021) Baseline to CD-0/1 (Other Project Costs)

Current ZPPR reconfiguration option														
WBS		**To Sep 2021**	**OCT 2021**	**NOV 2021**	**DEC 2021**	**JAN 2022**	**FEB 2022**	**MAR 2022**	**APR 2022**	**MAY 2022**	**JUN 2022**	**JUL 2022**	**AUG 2022**	**Cumulative**
C.C.32.12.10.10 Project Management	Scheduled	$29,755	$83,117	$82,060	$86,351	$90,957	$92,959	$80,730	$64,259	$64,830	$75,152	$57,890	$2,219	**$810,279**
C.C.32.12.10.30 NRIC Lotus Design & Construction Integration	Scheduled	$79,418	$164,512	$179,463	$55,236	$52,279	$60,930	$75,363	$59,987	$60,520	$70,156	$54,042	$2,071	**$913,978**
C.C.32.12.10.50 NRIC LOTUS Project Data/Documents	Scheduled	$0	$14,886	$27,450	$21,213	$39,734	$24,233	$10,550	$56,993	$31,806	$20,284	$7,525	$0	**$254,673**
C.C.32.12.20.10 Conceptual Design	Scheduled	$925,221	$573,662	$652,375	$168,593	$4,043	$0	$0	$0	$0	$0	$0	$0	**$2,323,894**
Grand Total	**Scheduled**	**$1,034,394**	**$836,177**	**$941,349**	**$331,392**	**$187,013**	**$178,122**	**$166,644**	**$181,239**	**$157,156**	**$165,592**	**$119,457**	**$4,290**	**$4,302,824**

Projected Funding Profile (Pre CD-1/3A Cost Estimate)

	Current Expected Funding Needs					
	FY21 ($K)	**FY22 ($K)**	**FY23 ($K)**	**FY24 ($K)**	**FY25 ($K)**	**Total ($K)**
NRIC-LOTUS	2,000	6,300	40,000	31,700	3,000	83,000

Per 413.3B we must have DOE CD-1 to move to next phase of design.
Can not award preliminary design without DOE approval of MNS and CD-1/3A (3A for Security door long lead)

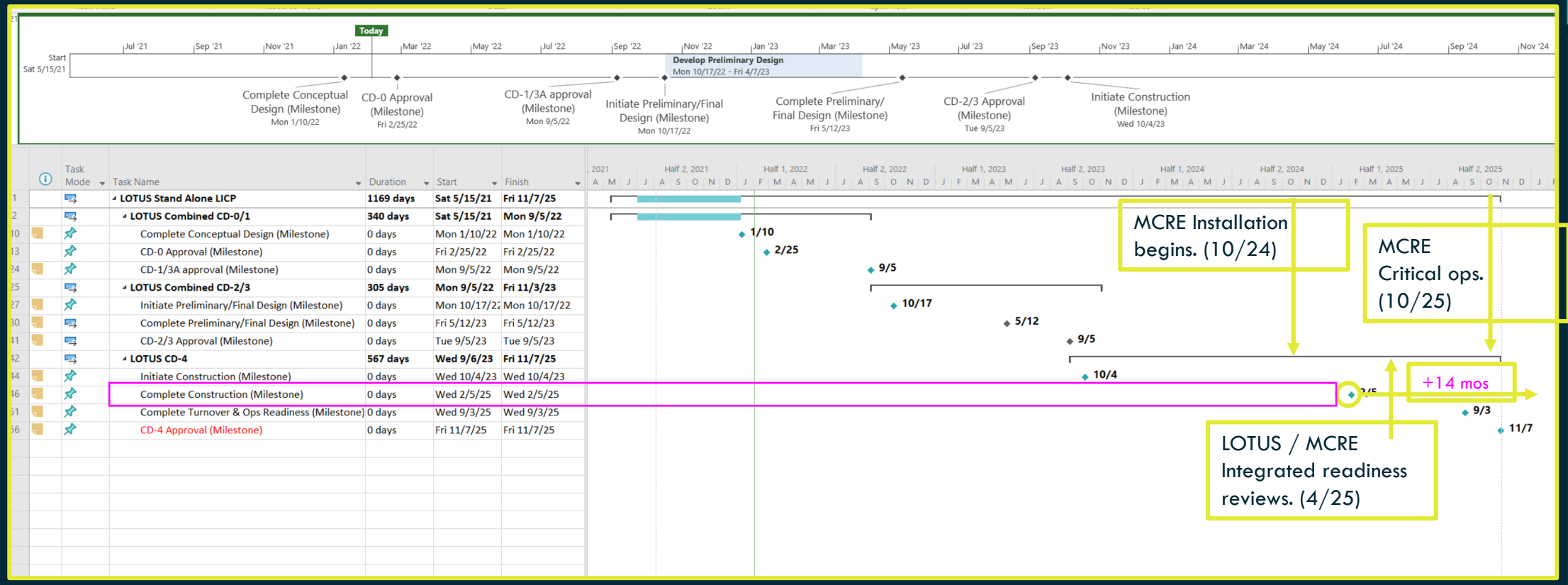
Expected schedule given uncertainty for CD-0/CD-1

- TBD DOE approval of CD-0, Mission Need.
- As early as 9 months following DOE CD-0, obtain DOE approval of CD-1/3A, Approve Alternative Selection, Cost Range, and Long Lead Items.
- 12 months following DOE CD-1/3A approval, obtain DOE approval of CD-2/3B, Approve Performance Baseline and Execution.
- 16 months following DOE CD-2/3 approval, complete construction.
- 25 months following DOE CD-2/3 approval, obtain DOE approval of CD-4, Project Complete, and obtain Authorization to Start Testing.

NRIC INL

Lack of CD-0 and CD-1 creating program delay to LOTUS and MCRE of 9-14 months

LOTUS – Planning if Impacted by AoA



Impact Analysis of Tailored Plan Deviation

- If DOE selects location other than ZPPR for testbed:
  - 14+ month delay to schedule for LOTUS
    - Contracting, AoA /review/decision, complete redesign
  - Day for day slip to MCRE project
  - ≈$5MM increased cost | support for AoA / rework conceptual design plus contractor fee.
- If DOE selects ZPPR as preferred location:
  - 6–12-month delay to schedule for LOTUS
    - Contracting, AoA /review/decision
    - ≈$2MM increased cost | support for AoA plus contractor fee
  - Day for day slip to MCRE project
- If DOE proceeds with NRIC tailored approach:
  - ≈3-month schedule delay to LOTUS to resolve CD-0, CD-1/3A
  - Up to equivalent delay for MCRE | Potential to makeup portion.

Lowest cost, most expeditious schedule, and lowest risk option to DOE is to proceed as planned at ZPPR.

NRIC-LOTUS Test Bed Milestones

- **Accomplishments for FY22 include:**
  - Completed the Conceptual Design – January ’22
  - Received the Department of Energy's Expectations for Safety-in-Design for the National Reactor Innovation Center Safeguards Category I Demonstration Test Bed Capability Project (CLN220620) – February ’22

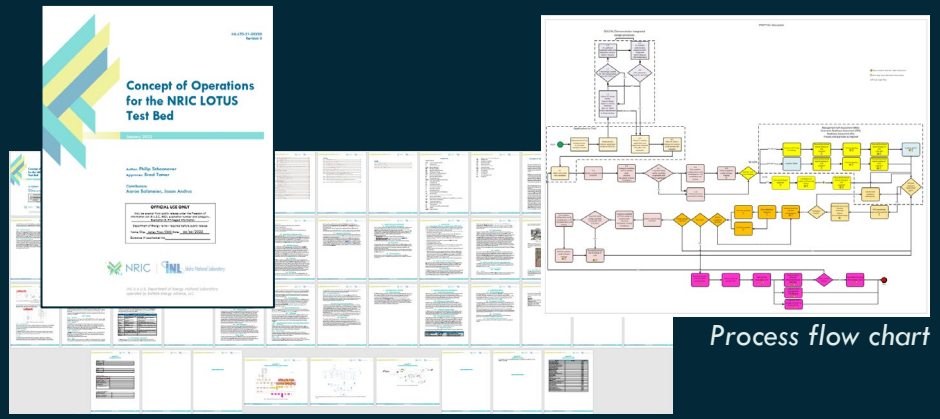
- **FY22 Milestones**
  - Developing the CD-1 cost estimate based on the Conceptual Design projected to complete February ’22
  - Continued finalization of the Safety Design Strategy projected to complete July ’22
  - Continued finalization of the Conceptual Safety Design Report projected to complete July ’22
  - Continued finalization of the Analysis of Alternatives projected to complete March ’22
  - Finalizing Preliminary Project Execution Plan projected to complete March ’22
  - Finalizing CD-1/3A support documentation. CD-1/3A approval is projected for September ’22.

NRIC-LOTUS Test Bed Risk Management

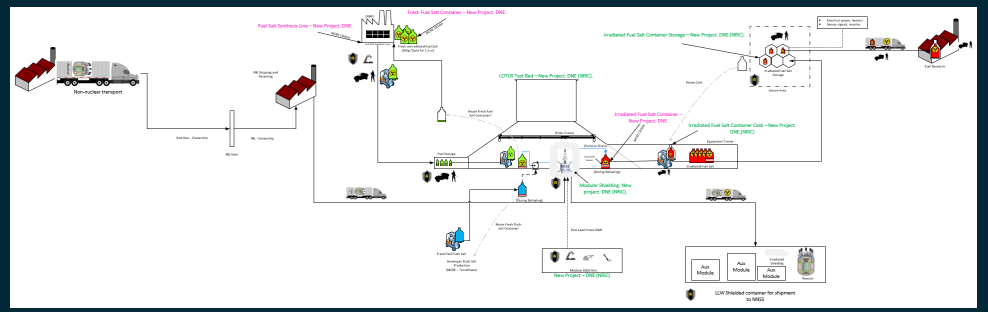
- LOTUS Risk Management is defined in a risk register in accordance with the following.
  - NRIC Risk Management Plan INL/EXT-21-62081
  - NRIC Risk Analysis Plan NRIC 21 PRG-005
- Significant risks include:
  - Approval of the Analysis of Alternatives and Mission Needs Statement to facilitate completion of the Safety Documentation and Product Data Sheet required for CD-1 approval.
  - Approach for Henry Door (supports security posture during construction) – potentially a 1-year delay or significantly increased security costs during construction. Need CD 1/3A to approve long lead procurement.
  - Turnaround time for required CD-1 support documentation including nuclear safety and the conceptual design.

NRIC-LOTUS Test Bed Concept of Operations

- The Concept of Operations documentation is closely aligned with the released DOME ConOps. The overall program process for getting a demonstrator through the testing campaign is identical in terms of setting up design authority, authorization processes, and general NRIC/INL to demonstrator program interfaces. Design and safeguards considerations will differ based on fuel types, and environmental considerations.
- The ConOps covers the process from first contact, through engineering and nuclear safety reviews, installation and commissioning, fueling, operations, defueling, and disposition of the irradiated fuel and reactor unit hardware.
- NRIC/INL remain the design authority throughout the process.
- The demonstrator remains the design agent for their deliverables and hardware, with NRIC approvals.
- NRIC collects, reviews, approves, and provides all authorization and readiness review materials to the DOE with subject matter expert (SME) input and oversight of each discipline.
- NRIC will follow the existing INL process for facility authorization for nuclear operations, utilizing demonstrators' documentation and SME support.
- The draft ConOps for the NRIC LOTUS testbed will be released in March '22 for review and comment.
- Environmental considerations are integrated during the design review process. Planning for the environmental Assessment.



Process flow chart



Shipping, transport, fueling, defueling, and disposal diagram.

Thank you!

Questions?
Time Permitting

NRIC
National Reactor
Innovation Center

INL
Idaho National Laboratory

Test Bed Operation Support

PM- Steve Grabinski

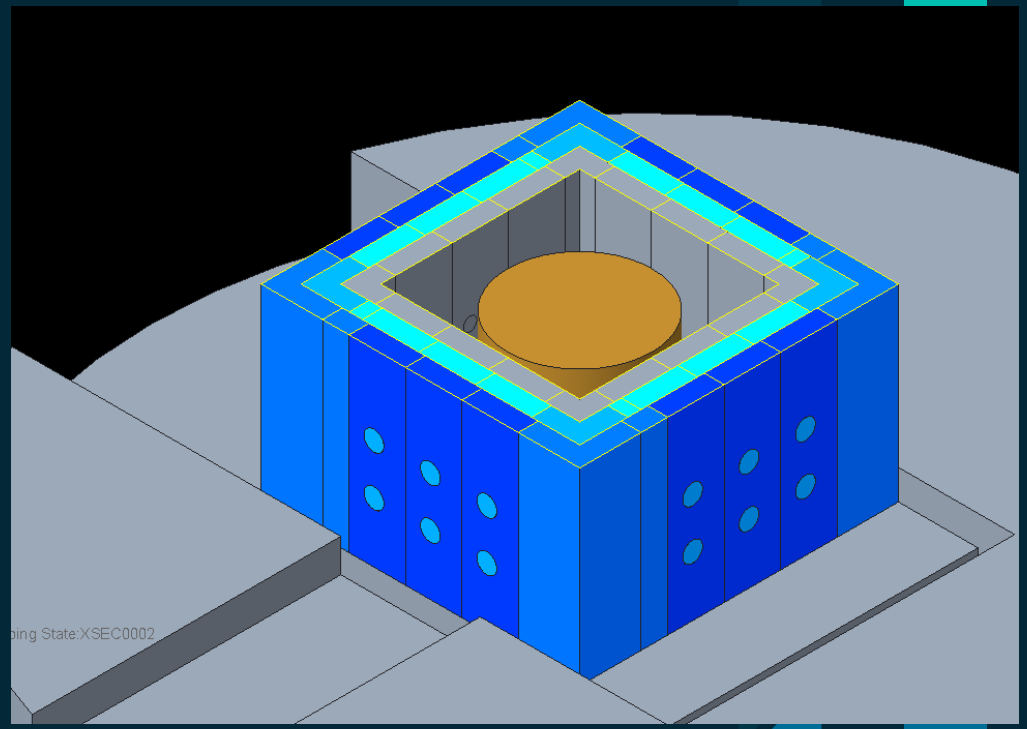
Project Overview

- Purpose – Identify and design necessary ancillary equipment to support the operation of test beds
  - DOME – RC – 22IN020303 – Test Bed Operations Support Equipment
    - Development of Requirements and Conceptual Design for DOME Test Bed Reactor Shielding
    - Pre-conceptual Design for Modular Reactor Handling System
    - Pre-conceptual Design for Irradiated Reactor Module Handling
  - LOTUS – RC – 22IN020312 – Developing Requirements, Guidelines, and Conceptual Design for Modular Shielding needs inside the NRIC LOTUS
    - Development of Requirements for LOTUS Test Bed Reactor Shielding
    - Removal of Irradiated Fuel and Other Radioactive Materials
    - Conceptual Design for LOTUS Irradiated Fuel Storage System
- INL Project Team:

Resource Name	Role/Title
Phil Schoonover	Test Bed Program Manager
Stephen Grabinski	Project Manager
Aaron Balsmeier	NRIC Lead Engineer
Shielding Team	
Kyle Metzroth	Technical Lead for LOTUS and Dome Shielding
Curtis Brown	Engineering and Design Support
Ryanne Kennedy	Engineering and Design Support
DOME E&I	
Wes Price	Technical Lead for DOME Equipment and Infrastructure
LOTUS E&I	
Evans Kitcher	Technical Lead for LOTUS Equipment and Infrastructure

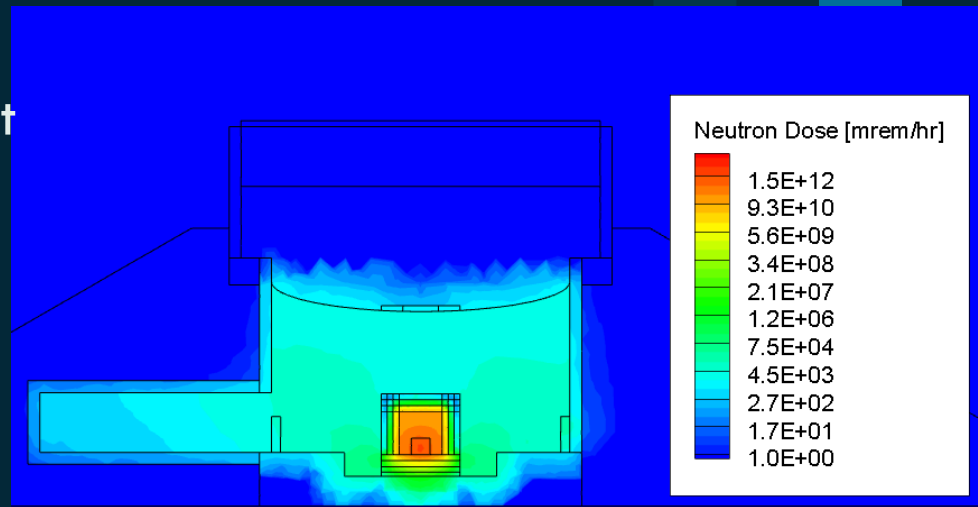
Project Overview

- Identify equipment required for an operational test bed system
- Design commercially unavailable equipment
  - Develop system-level requirements for identified interfacing equipment
    - Requirements hosted in IMB DOORS
  - Identify and develop alternative solutions
  - Perform and document trade studies to identify preferred alternatives
- Reduce risks of the test beds for the developer and DOE through early coordination and identification of unknown costs and requirements.
- Project supports NRIC strategy of two test reactors by 2025
- Funding
  - DOME- $902,016 (PY Carryover $23,816)
  - LOTUS- $1,914,479 (PY Carryover $49,732)

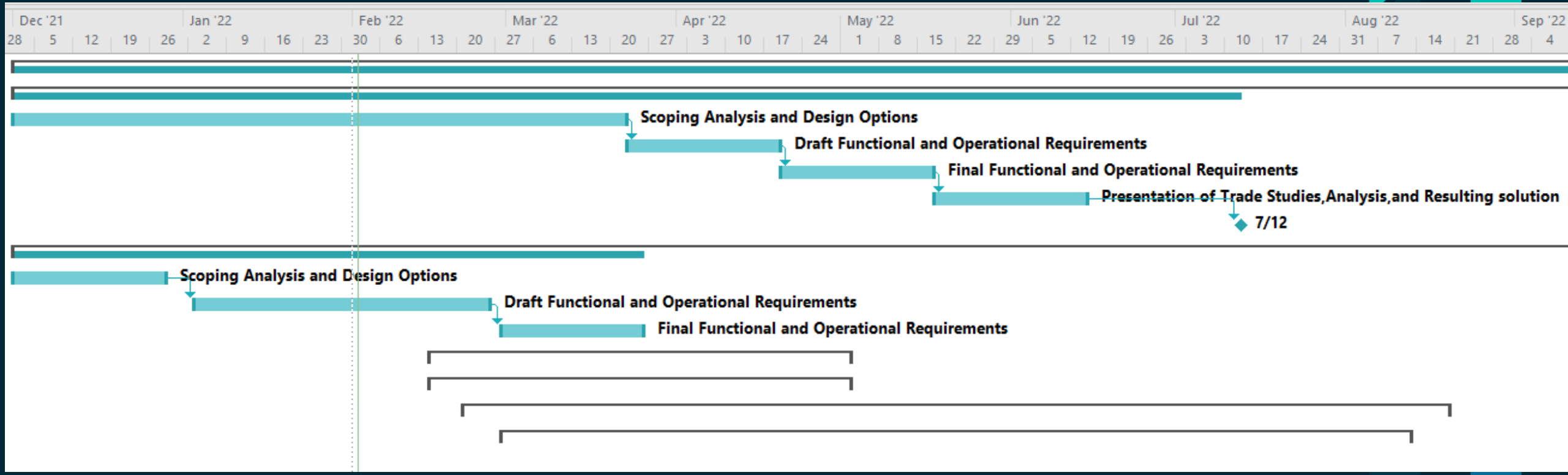


Test Bed Operation Support Progress- Shielding

- Costs- $410K
- FY22 Accomplishments
  - Scope, schedule, and budget complete
  - Resources Identified
  - Project Kicked off 12/1/21
- Milestones
  - M2- Complete Draft Conceptual Design Report – 7/15/22
  - M3- Complete Draft Shielding Requirements Report – 6/30/22
- Out year funding needs to be determined in July upon receipt of deliverables and review of trade studies
- Current Risks
  - Sufficient vendor data for reactors seeking to test in the Test Beds
  - Potential changes to LOTUS construction design

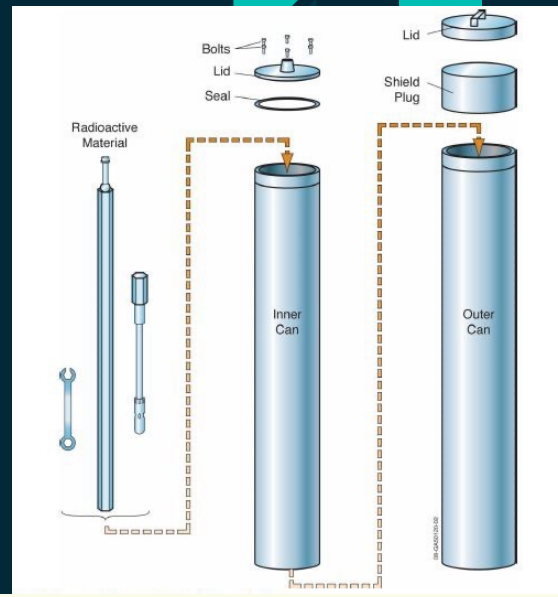


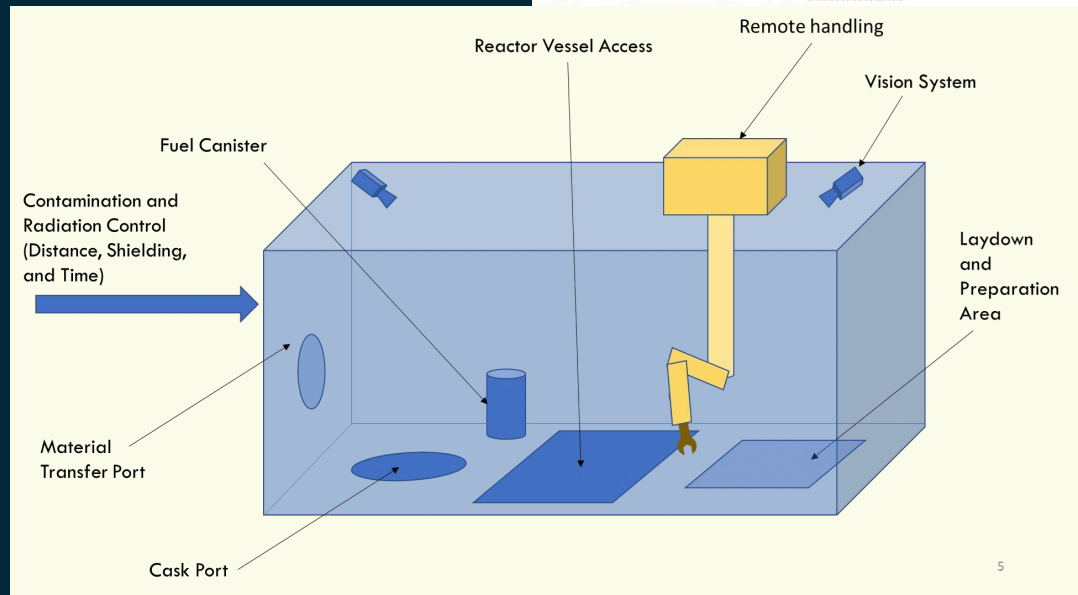
Test Bed Operation Support Timeline- Shielding



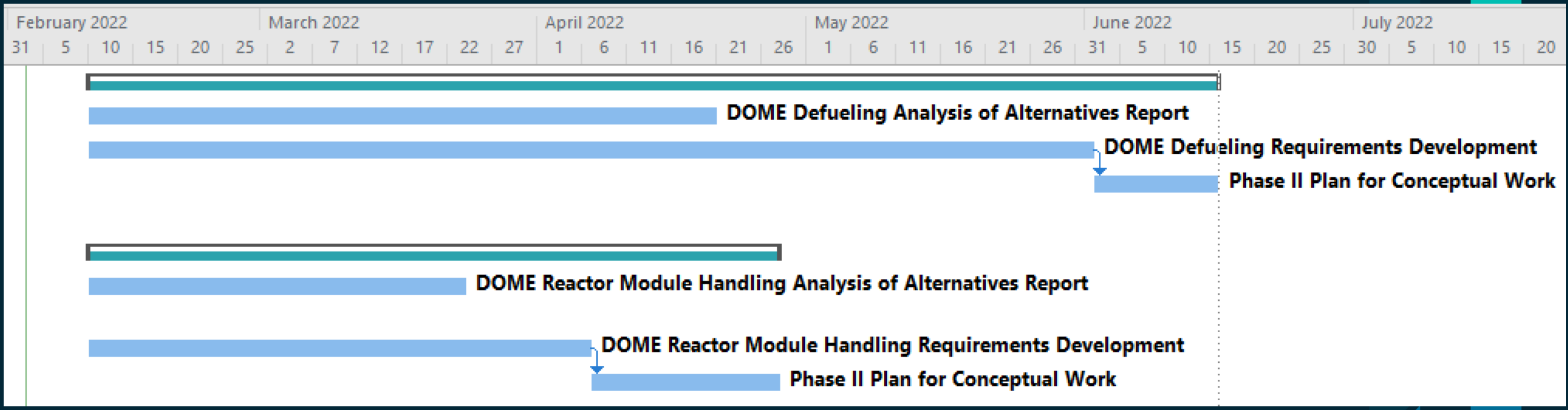
Test Bed Operation Support Progress – DOME Defueling & Irradiated Reactor Module Handling

- Costs – $577,000
- FY22 Accomplishments
  - Scope, schedule, and budget complete
  - Resources Identified – MPR
- Milestones
  - M3- Draft Dome Defueling/Maintenance/PIE/ Inspections Module Pre-Conceptual Design Report – 8/15/22
  - M2 – Draft DOME Fueling Module Pre-Conceptual Design Report – 8/30/22
- Out year funding needs to be determined in September upon receipt of deliverables and review of trade studies
- Current Risks
  - Sufficient vendor data for reactors seeking to test in DOME



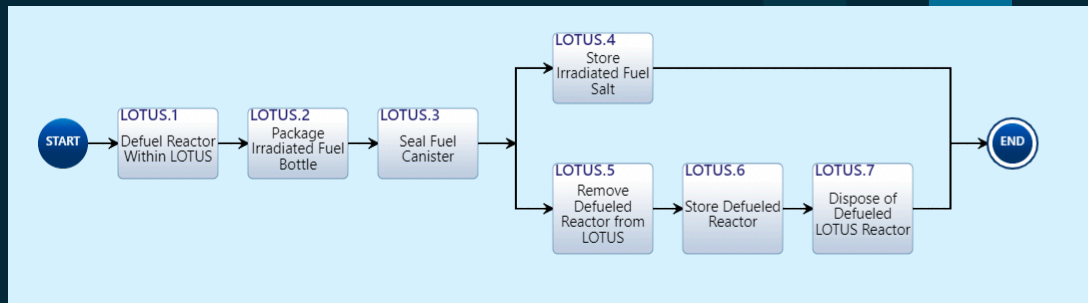


Test Bed Operation Support Schedule – DOME Defueling & Irradiated Reactor Module Handling

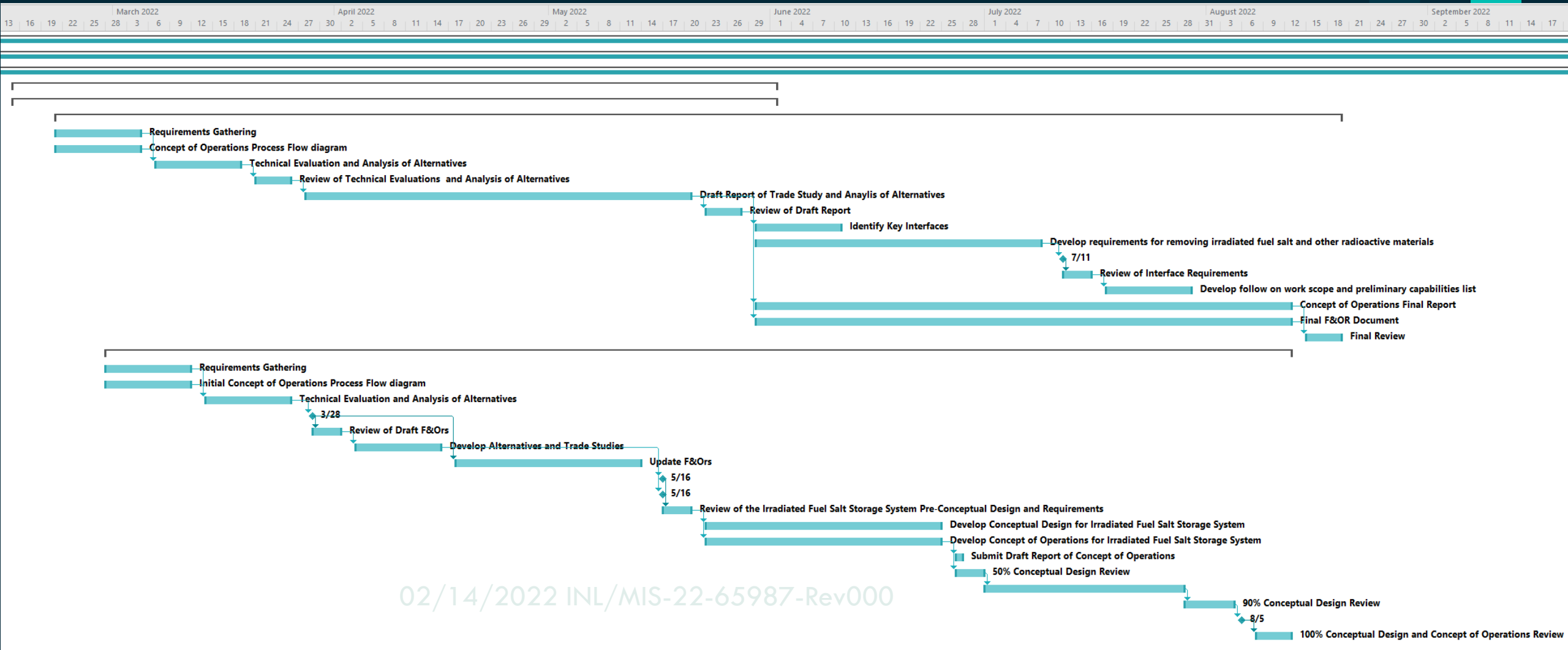


Test Bed Operation Support Progress – LOTUS Removal of Irradiated Fuel Salt & Fuel Storage System

- Costs – ~$1,460,000
- FY22 Accomplishments
  - Scope, schedule, and budget complete
  - Resources identified and contracting coordination in progress
- Milestones
  - M2 – Complete Draft LOTUS Fueling Requirements, interfaces, and Management Pre-Conceptual Design- 5/13/22
  - M3 – Complete Draft LOTUS Defueling CONOPS Pre-Conceptual Report – 7/30/22
- Out year funding needs to be determined in August upon receipt of deliverables and review of trade studies
- Current Risks
  - Sufficient vendor data for reactors seeking to test in LOTUS
  - Potential changes to LOTUS construction design

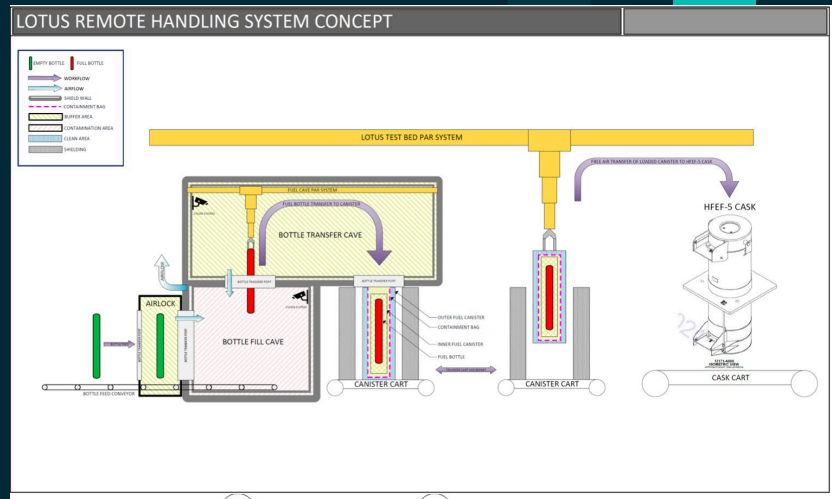


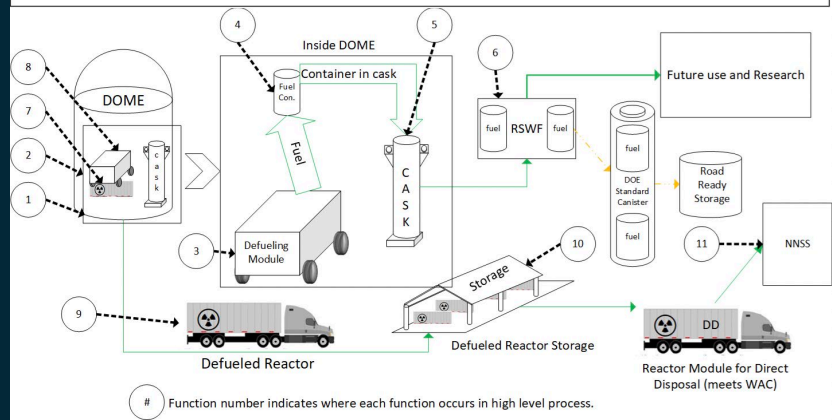
Test Bed Operation Support Timeline- LOTUS Removal of Irradiated Fuel Salt & Fuel Storage System



Test Bed Operation Support Summary

- Previously identified critical equipment required for multiple reactor demonstrations for each test bed
  - Conceptual design for DOME test bed reactor shielding
  - Pre-conceptual design for DOME modular reactor handling system
  - Pre-conceptual design for DOME irradiated reactor module handling
  - Development of requirements for LOTUS test bed reactor shielding
  - Pre-conceptual design for removal of irradiated fuel and other radioactive materials
  - Conceptual design for LOTUS irradiated fuel storage system
- Identifying and managing requirement to develop Pre-Conceptual/Conceptual designs to minimize costs and maximize return
  - Integrating system engineering tools of IBM DOORs to host requirements and Innoslate action diagrams into all work developed in this project will be integral to a functioning test bed system for demonstration reactors
- Additional funding for out years will further develop conceptual design of the test bed concept of operations and reduce risk to demonstrations





Thank you!

Questions?
Time Permitting

NRIC Coordination of Demonstration Projects

NRIC Demonstration Coordination within Labs

Why?

- Potential for learning among projects
- Common needs that can be served by centralized capabilities
- Lab leadership updates on all ARDP projects
- Accountability

What?

- NRIC Coordinator to assist with reporting and access to capabilities
- Regular meetings
  - Review quad charts
  - Share lessons/challenges
  - Alert NRIC to issues for assistance
- Standard resources/guidance for projects

[Demo Project]

Owner	[Quad chart owner]
Date	January 31, 2022
RAG Status	AMBER
Contract Type	CRADA(s)

Project Scope/Mission — Budget/Time:

Support [Demo Project], through the execution of … research and development including …, …, …, and the implementation of digital engineering practices.

Critical Milestones

Milestone	Baseline	Expected	RAG
Requirements Management Architecture Report	MM/DD/YY	MM/DD/YY	Green
Milestone	MM/DD/YY	MM/DD/YY	Green
Milestone	MM/DD/YY	MM/DD/YY	Amber
Milestone	MM/DD/YY	MM/DD/YY	Green

Risks/Issues/Assumptions

Technical Risks: None at this time

Management Risks: Same as previous

Site/Resource Risks:
- …equipment, human resources, etc.
- Funds are needed prior to MM/DD/YY to avoid impact to critical path

Recent Progress/Variance Analysis

- **Completed** : XYZ successfully delivered to X from Y on MM/DD/YY, two months ahead of schedule
- **Completed:** Draft CRADA modifications were provided to company on schedule on MM/DD/YY
- Held Quarterly review meeting on MM/DD/YY

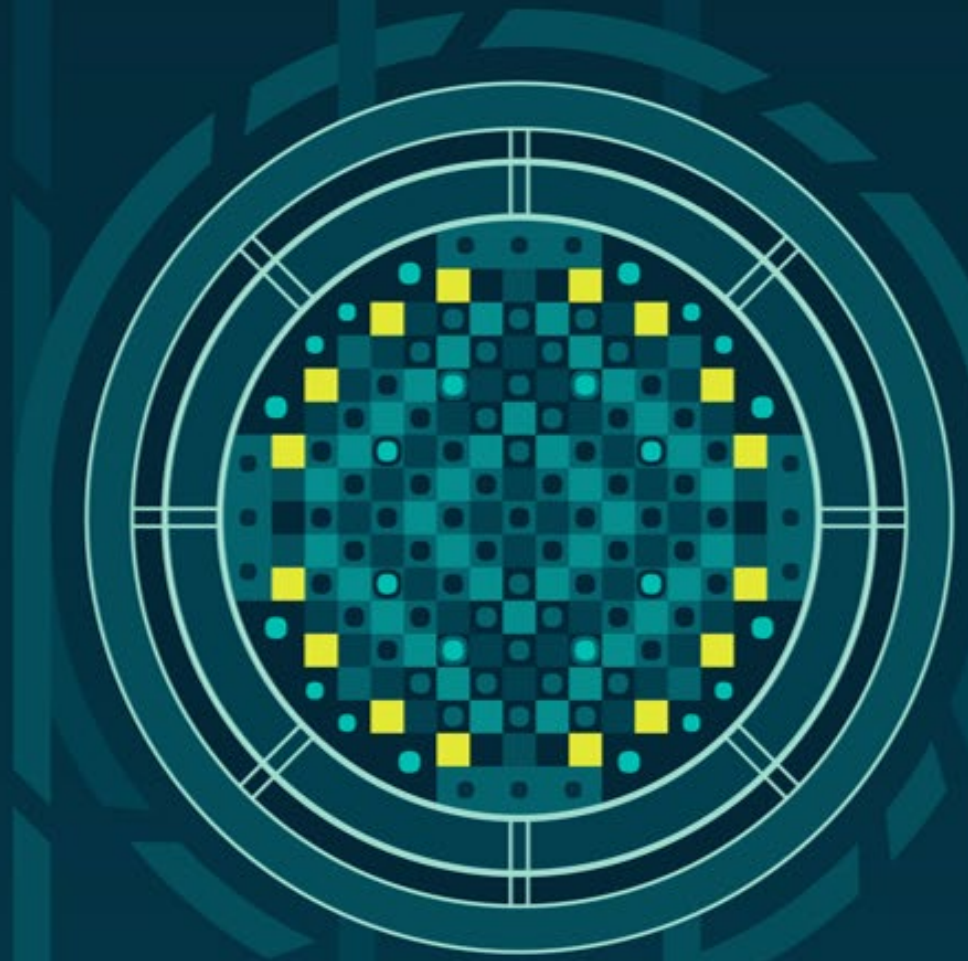
Cost Variance: CPI: #a (#b last month)
The program is underspent due to efficient activity execution.
Schedule Variance: SPI: #c (#d last month)
The program is (behind/ahead of) schedule primarily due to X.

Next Steps

- Work to mitigate risk of …
- Execute …

Key Resources

- Digital Engineering
- Resource Team
- Risk Management
- Infrastructure
- NEPA approaches
- Standardized planning docs
- Resource planning
- Coordination



NRIC
National Reactor
Innovation Center

Natrium Demonstration Reactor Support Program

Greg Core, Technical Program Manager

NRIC Supports TerraPower's Natrium Demonstration Reactor

NRIC resources manage and execute critical projects at INL that support technology licensing and development.

Program Initiated June 2021

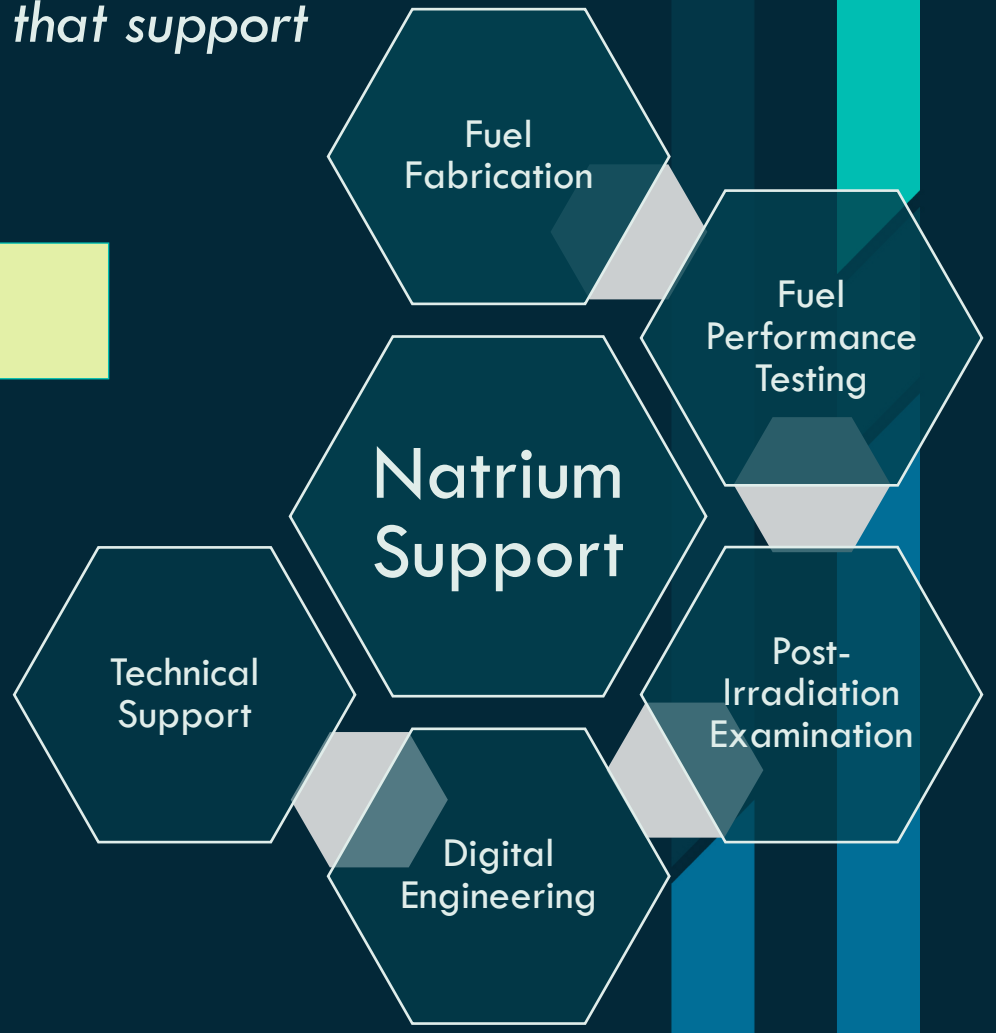
$65M over 7 years

Utilizes Key INL/DOE Facilities
Advanced Test Reactor
Transient Reactor Test Facility
Hot Fuel Examination Facility
High Performance Computing
Laboratory Fellows
Irradiated Materials Charac.

Benefit Status
17 On track; 1 In Jeopardy; 1

Current Performance
CPI: 1.18 / SPI: 0.81

BP1 Milestones
13 Completed On-target
1 Completed Late
14 Expected On-target
3 Expected Late



NRIC INL

Thank you!

Questions?
Time Permitting

Contact: Gregory.core@inl.gov

02/14/2022 INL/MIS-22-65987-Rev000

NRIC
National Reactor
Innovation Center

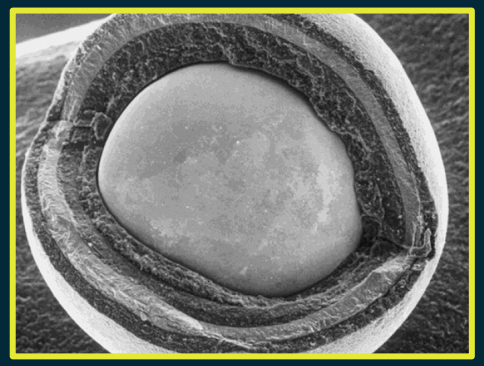
BWXT Advanced Reactor Demonstration Program:

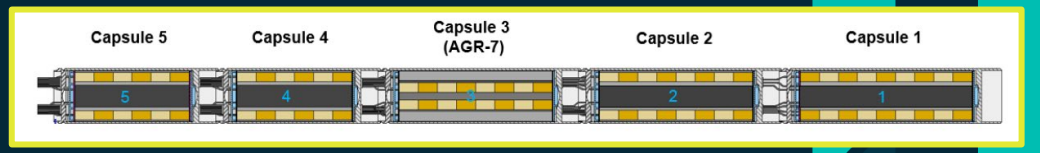
Irradiation of Uranium Nitride Tri-Structural Isotropic (TRISO) Fuel

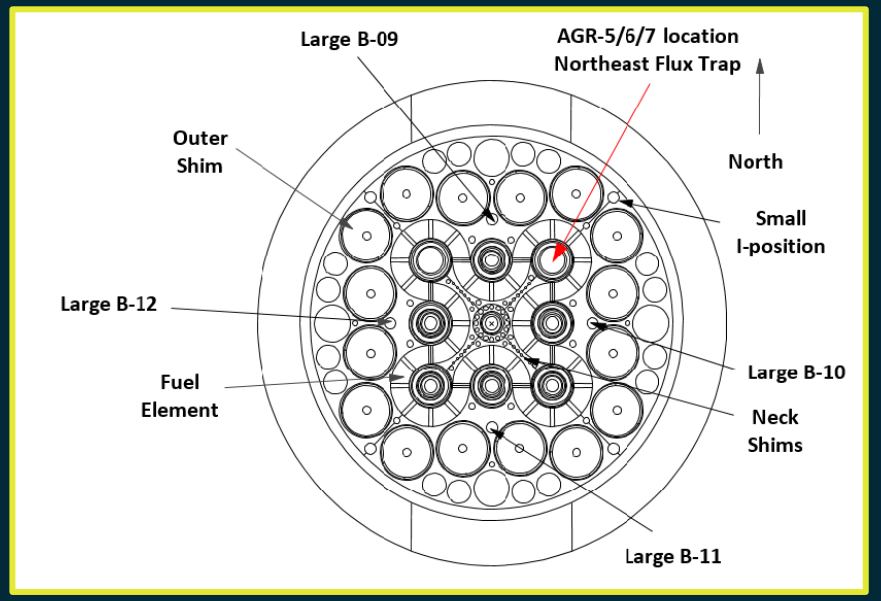
Sam Reiss, Justin Johnson

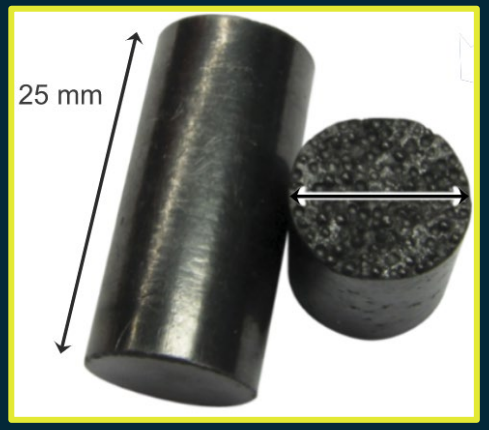
BWXT ARDP Overview

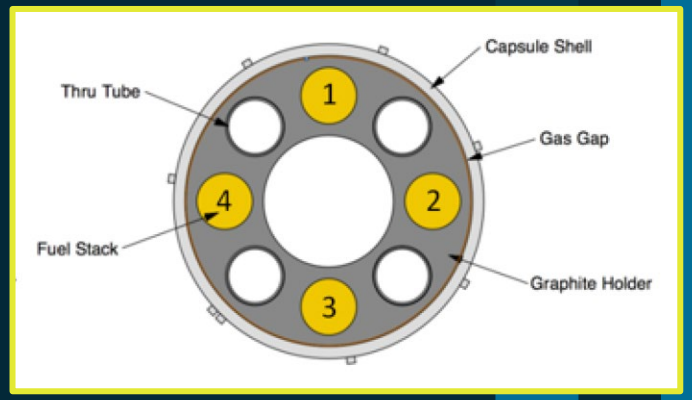
- Leverage INL learnings from Advanced Gas Reactor (AGR) programs and ORNL fuel expertise
  - Uranium Nitride (UN) instead of Uranium Carbon Oxygen (UCO)
  - Silicon Carbide (SiC) instead of graphitic matrix
- Program leverages multiple functional areas
  - Mechanical design, Neutronics, Thermal hydraulics, Modeling and simulation, structural analysis, TRISO expertise, Irradiation, Post-Irradiaton Examination (PIE)
- Aligns with NRIC mission of strong private-public partnerships to expedite advanced reactor commercialization
  - De-risking BWXTs gas-cooled reactor, providing expertise, irradiation, and PIE facilities
- Seven-year program, $24.3M scope at INL, $2.5M year one funding




Capsule 5
Capsule 4
Capsule 3
(AGR-7)
Capsule 2
Capsule 1
5
4
3
2
1


Large B-09
AGR-5/6/7 location
Northeast Flux Trap
North
Outer
Shim
Small
I-position
Large B-12
Large B-10
Fuel
Element
Neck
Shims
Large B-11

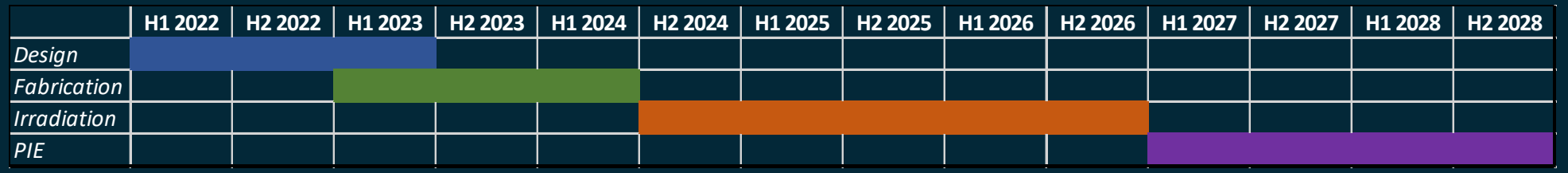

25 mm


Capsule Shell
Thru Tube
Gas Gap
Fuel Stack
Graphite Holder
1
2
3
4

BWXT ARDP Integrated Team

Sam Reiss – Technical Program Manager
Mike Davenport – Irradiation Experiment Manager
Pavel Medvedev – Irradiation Primary Investigator
Dave Laug – PIE Experiment Manager
Karen Wright – PIE Primary Investigator
Joe Palmer – Mechanical Design Lead
Adam Zabriskie – Modeling and Simulation Lead

BWXT ARDP Progress



- 7-year program, $24.3M scope at INL
- As of 2/1/22, waiting on CRADA agreement between BWXT and DOE
- Current activities scoping for thermal, neutronic, modeling and simulation
- Planned project start ~3/1/22 with 6-month conceptual design
- Risks: Quick design phase, moving target for ATR, back-loaded budget, large PIE scope

BWXT ARDP Summary

- Leveraging INL expertise and learnings from AGR and ORNL fuel expertise to expedite advance reactor fuel development
- Cross-functional team development and management through NRIC
  - Strong internal alignment and constant customer communication
- Challenging scope and timeline, aggressive but doable

Thank you!

Questions?
Time Permitting

Contact: Sam.reiss@inl.gov

02/14/2022 INL/MIS-22-65987-Rev000

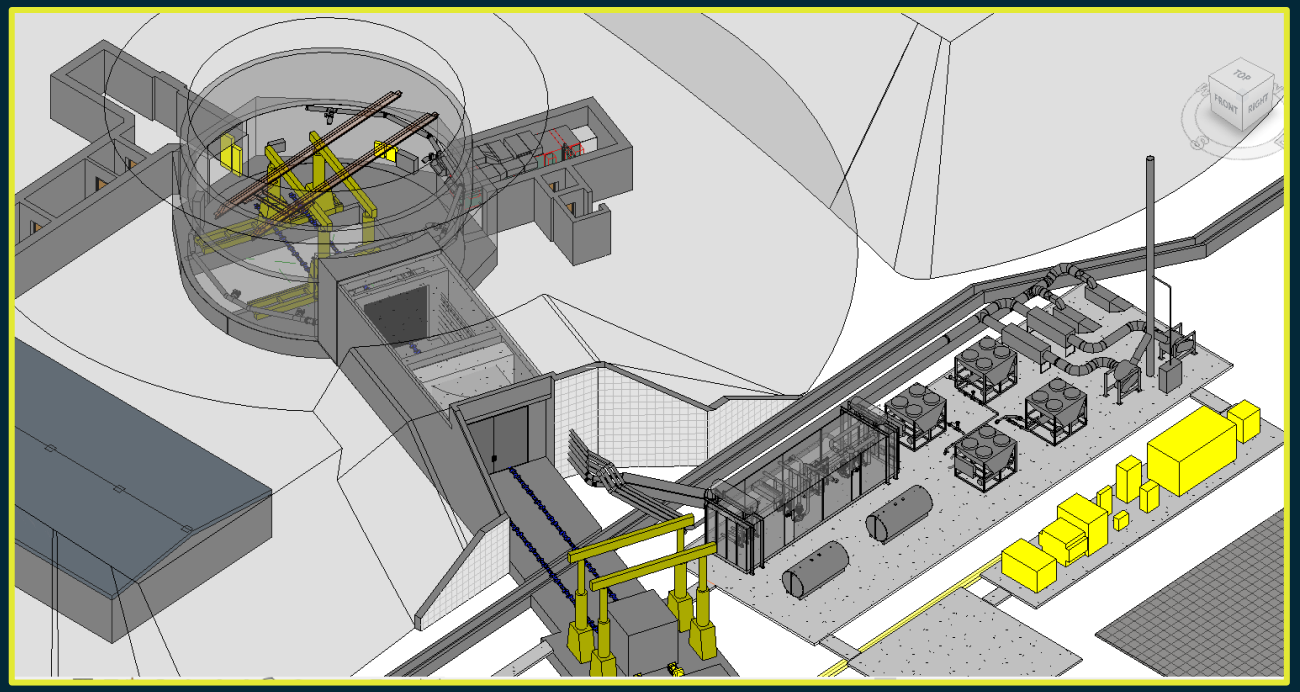
NRIC
National Reactor
Innovation Center

Idaho National Laboratory

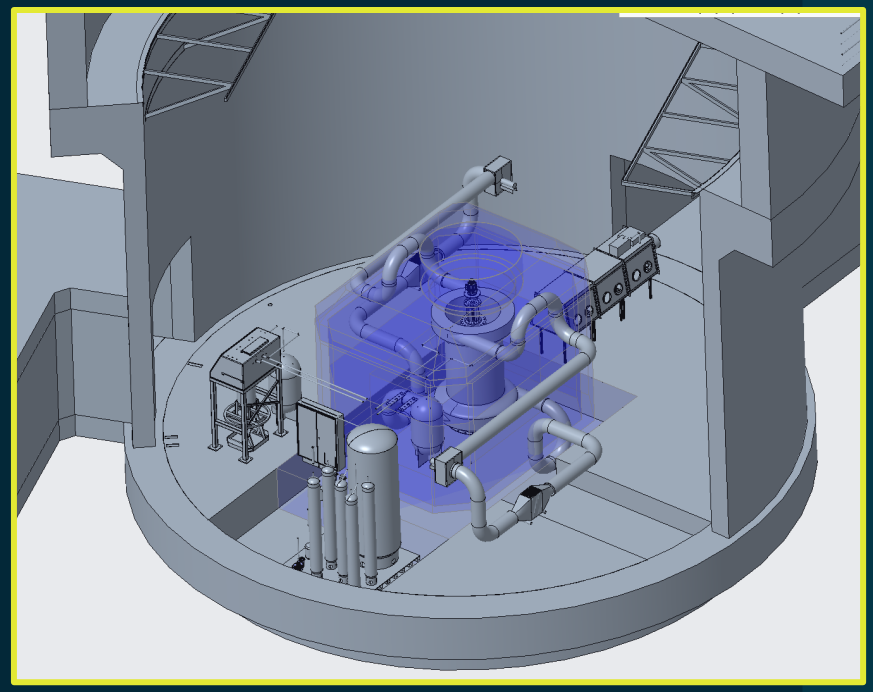
NRIC-LOTUS / MCRE Integration

Program Manager – Phil Schoonover
WP Manager – Scott Smith

NRIC-LOTUS / MCRE Integration Overview



- LOTUS Digital Twin 3D model post Conceptual Design



- MCRE Notional installation

LOTUS / MCRE Collaboration

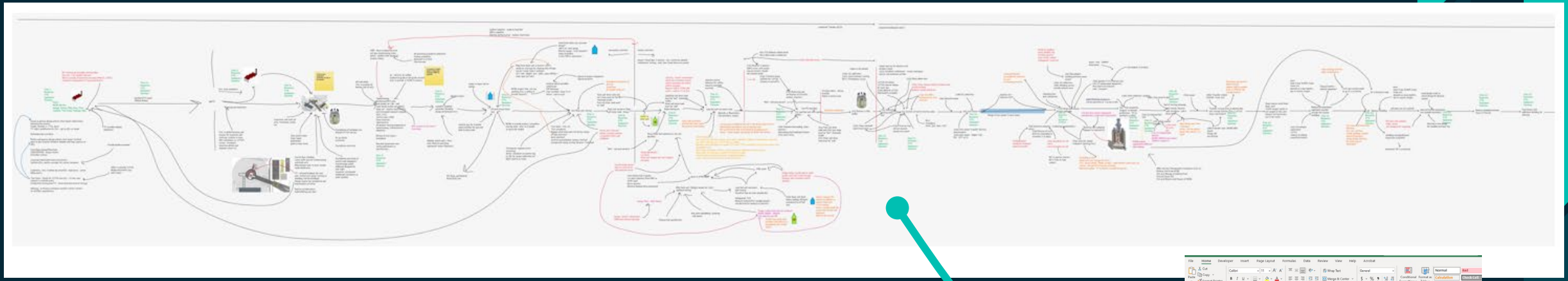
- Weekly project management status meeting
  - Project progress
  - Schedule
  - Action items
  - Ad hoc meetings as needed to resolve emergent questions

- Weekly Systems Engineering and Technical meeting
  - Exchange of technical design changes, data, analysis, model reviews
  - Interfaces
  - Performance parameters
  - Equipment / procedure needs

- Includes Reactor / FSSL / Fresh Fuel Salt Container / Irradiated Fuel Salt Container / Flush Salt Container
  - Transport, storage, utility support
  - Long term storage of Irradiated fuel

- Brad Tomer – NRIC COO
- Philip Schoonover – Program manager
- Aaron Balsmeier – NRIC Chief Engineer
- Nick Smith – MCRE ARD Project Director
- Brett Welty – MCRE ARD Project Manager
- Terrapower
- Southern Company
- INL

LOTUS / MCRE Integrated ConOps

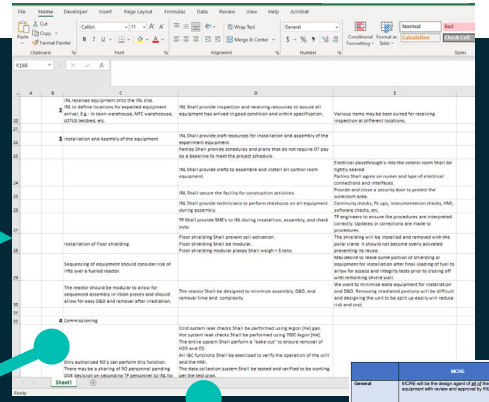


End to End Process

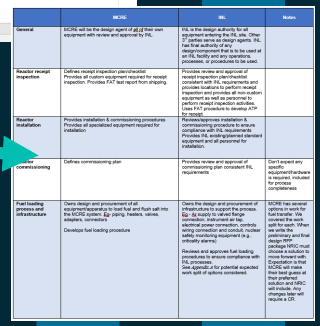
- 20+ participants
- NRIC / INL / MCRE ARD / Terrapower / Southern
- Process defined, gaps in process understanding defined, project equipment/infrastructure gaps identified
- LOTUS / MCRE interface requirements derived
- Operations requirements derived. Sequence of operations, procedures required.

- Similar process done for Fuel Synthesis/Storage/Transport

Requirements



Equipment / Infrastructure Project split



Flow down of derived requirements

- FSSL
- Gloveboxes
- Fuel transport cask
- Racks / storage
- Irradiated fuel storage
- LLW disposal cask
- Flush salt …

Thank you!

Questions?