INL/MIS-22-65980-Revision-1

# NRIC 2022 Program Review Session 2

March 2022

Changing the World's Energy Future

Philip Lee Schoonover II, Abdalla Abou Jaoude, Toni Y Karlsson, Stephen A Warmann, Samuel Matthew Reiss, Stacie Lyn Strain, Terry James Morton, Luke M Voss, Allen Roach, Christopher Grandy, Christopher S Ritter, Peter Anton Suyderhoud

Idaho National Laboratory

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**March 2022**

**Idaho National Laboratory**
**Idaho Falls, Idaho 83415**

**http://www.inl.gov**

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NRIC
National Reactor Innovation Center

Idaho National Laboratory

# NRIC Program Review

February 14, 2022

NRIC Program Review, Session 2

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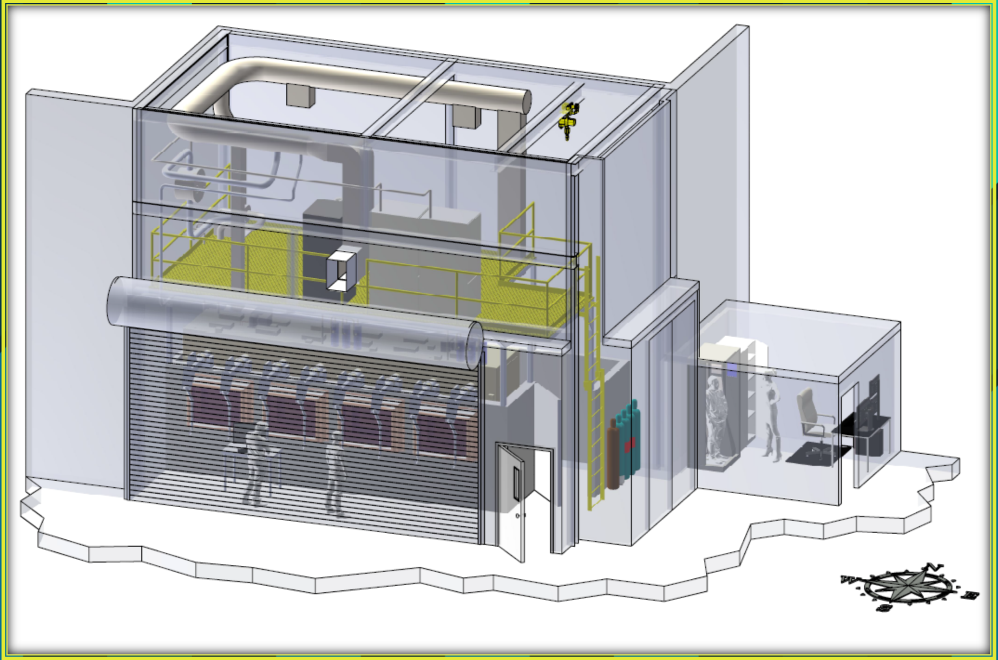
National Reactor Innovation Center

Idaho National Laboratory

# NRIC MSTEC

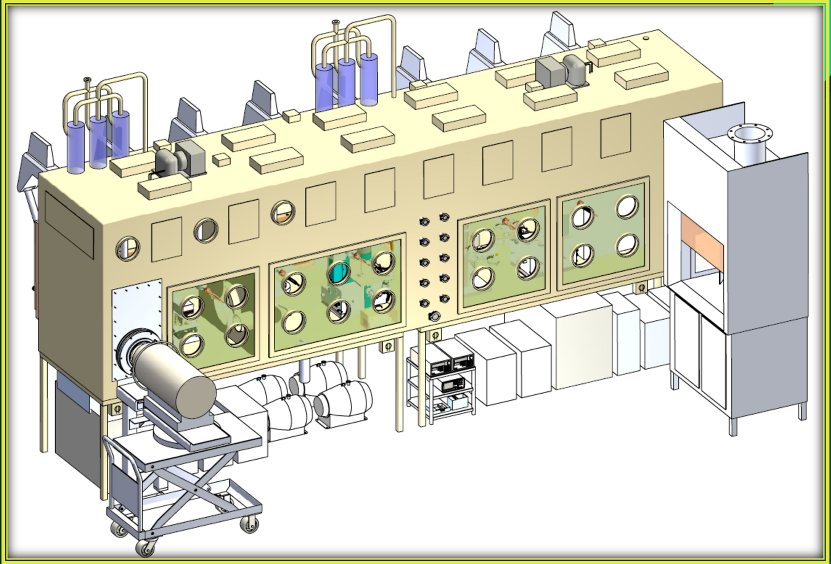
## Molten Salt Thermophysical Examination Capability

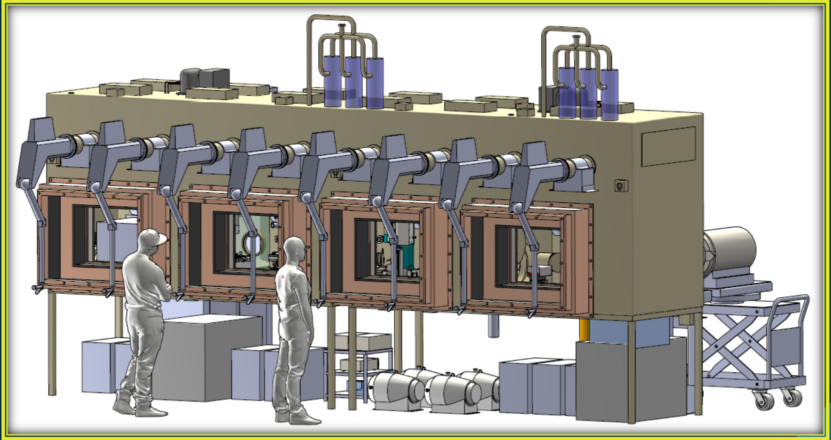
Stephen Warmann, PM
&
Toni Karlsson, WPM



# MSTEC Project Overview

- Technical Description – MSTEC is a shielded modular hotcell with an inert argon atmosphere, housing characterization equipment for determining thermophysical and thermochemical properties of high temperature liquids not limited to but focusing on highly irradiated fuel salts.
- Location – MFC, FCF, rm 35
- Compatible Materials:
  - Chloride, fluoride salts
  - Fresh fuel salts and irradiated fuel salts
  - Pyrophoric material - U, Pu metal
  - Gases – $H_2$, HCl, $Cl_2$, HF, $F_2$, $NF_3$
  - Beryllium containing salts
  - Many others





# MSTEC Project Overview

## Core INL Team Members

Sam Reiss
NRIC TPOC

Stephen Warmann
WPM

Toni Karlsson
Lead Scientist

Dale Whalquist
Lead Design Eng.

Mark Borland
Glovebox SME

Evan Lovel
Lead Electrical Eng.

Barbara Houck
Lead Nuc. Safety

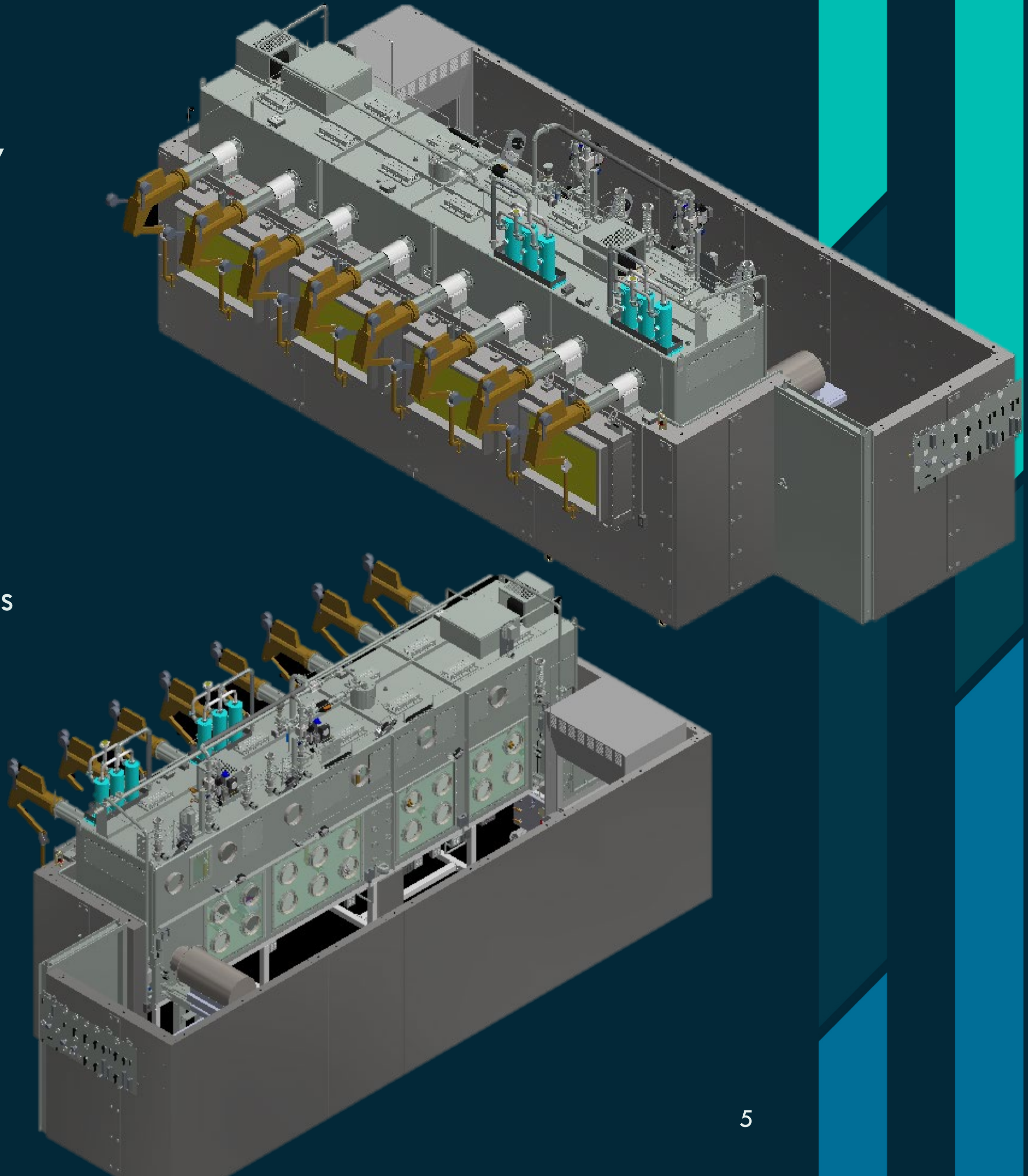
Numerous other individuals that contribute to the success of MSTEC

## Subcontracts

- Walker Barrier –Glovebox and Shielding
- Wälischmiller Engineering GMBH – Manipulators
- Amentum – Nuclear Safety
- Applied Engineering Services – Engineering support design, construction, ventilation
- C&H Construction – D&D

# MSTEC Project Overview

- Modular hot cell
  - Shielded on one side
  - Glove ports on the other side
- Instrumentation (≥ 1000°C)
  - Rheometer – viscosity
  - Densitometer/pycnometer – solid and liquid density
  - STA – invariant and transition temps, weight loss, off gas analysis, vapor pressure
  - DSC – specific heat capacity
  - TMA – volumetric and linear thermal expansion
  - Transient hotwire – thermal conductivity
  - Well furnace – corrosion, salt synthesis, fundamental electrochemistry
  - Versatile experimental space



# MSTEC Project Overview

- Purpose/objective – Provide users with characterization equipment, infrastructure, and technical staff necessary to produce critical data needed to design, demonstrate, license, and operate an MSR
  - Provide reliable data sets on properties including viscosity, density, heat capacity, thermal conductivity, melt temperature, vapor pressure, redox chemistry, and salt purification methods
  - Offers versatile space for users to setup one-of-a-kind experiments and to perform small-scale exotic salt fabrication

# NRIC MSTEC Progress (out year funding needs)

- INL had a cost-plus contract with Fluor for decontamination activities in many MFC buildings
- The MSTEC project has taken on $500k of additional scope so far to make rm 35 usable
- Estimated $100-200k construction change order to support rm 35 preparation related to D&D
  - Costs will be refined after contractor walk through of washroom facility
- Expected to stay within budget through 2022
- Increased costs hit in 2023/24
  - Schedule impact next slide
- Working with multiple potential customers
  - INL researchers, KAERI, Seaborg, TerraPower, Southern Company

| Year | Old Cost Estimate | New Cost Estimate |
|---|---|---|
| 2020 | $ 1,782,072 | $ 1,782,072 |
| 2021 | $ 3,033,919 | $ 3,033,919 |
| 2022 | $ 3,475,481 | $ 3,475,481 |
| 2023 | $ 2,696,446 | $3,071,446 |
| 2024 | $898,816 | $1,023,816 |
| Total | $ 11,886,734 | $12,386,734 |

Risks: Unfinished decontamination of room, construction in legacy nuclear facility, Safety Analysis Report (SAR) review pending

# Tasks & Timeline

Notes:
- Extended schedule
- Increased costs in out years

# Accomplishments to Date and Next Steps

## FY20

- Kickoff, May 1, 2020
- Assembled a team of diverse and uniquely skilled people
- Developed a program plan
- Procured characterization equipment
- Completed the design requirements for MSTEC
- Finished numerous INL engineering documents (source term and shielding calcs, floor loading analyses, south wall removal analysis, ventilation evaluation, installation logistics evaluation, etc.)

## FY21

- Instrumentation
  - Integrated feedthroughs (cooling, electrical, gas) in interim glovebox
  - Setup rheometer, TMA, DSC, pycnometer, densitometer
  - Initiated testing equipment in non-rad lab
  - Making necessary hot cell modifications
  - Developed a Concept of Operations
- Engineering
  - Held several design reviews for MSTEC (>40 people)
  - Facility mods drawings and specs
  - Finished MSTEC conceptual design
  - Issued manipulator PO
  - Issue PO for MSTEC hot cell
  - Put out to bid the RFP for construction work for FCF facility mods
- Nuclear Safety
  - Finalized major mod determination
  - determination process with DOE-ID
  - Finalized Hazards Evaluation and accident scenarios
  - Reviewing safety design strategy (SDS)

## FY22 so far…

- Instrumentation
  - Testing of equipment on non-rad salts
  - Finalized electrical and feed through drawings
  - Initiated INL quality process on instrumentation
- Engineering
  - FAT test for manipulators
  - 90% Design Review
  - Decontamination of FCF rm 35
  - Ready to initiate D&D of the sodium washroom
- Nuclear Safety
  - Finalize draft revision of SAR-403
  - Submitted to ISRC for comments

# NRIC MSTEC Progress

## What's Left to do in FY22?

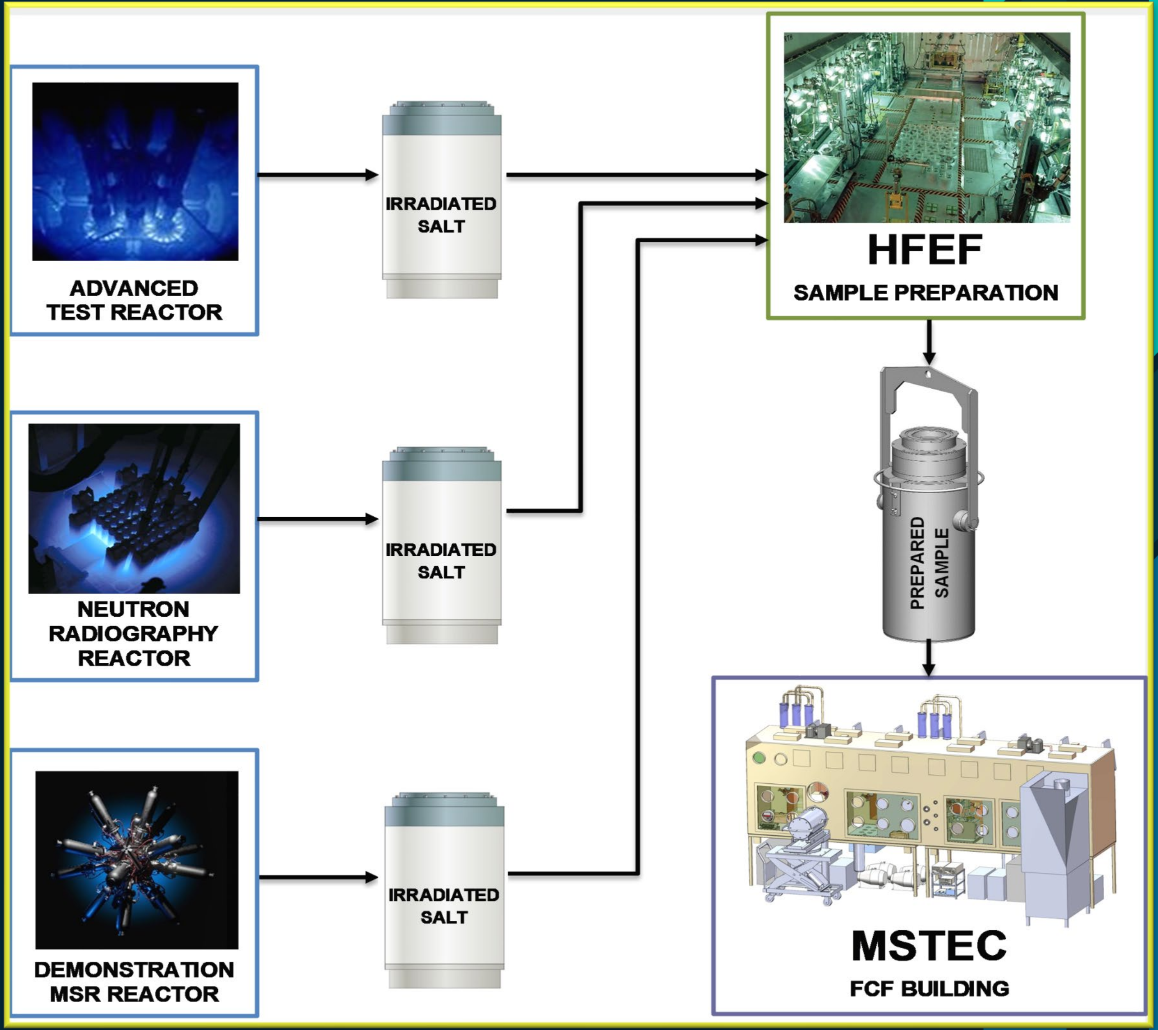
- Characterization
  - Continue drafting qualification plans
  - Continue procedure development at high temperature
  - Optimize characterization equipment for high fidelity results
  - Finalize all modifications needed for hot cell use
- Engineering
  - Finalize 3D model
  - 100% Design Review with Walker Barrier
  - Design review at INL
- SAR
  - Address comments from ISRC
  - Draft DOE Submittal letter
  - Send Submittal letter, TSR-403 and SAR-403 to operation lead (INL)
  - Submit to DOE for review

## • MSTEC Milestone FY22

- WP1
  - M3 – Final Draft of FCF Facility SAR revision – Due – 03/24/2022
  - M2 – Initiate Construction Work in FCF (Phase I) - Due 05/31/2022
  - M2 – Initiate Qualification Tests on MSTEC Characterization Equipment using Molten Salts - Due – 09/26/2022
- WP2
  - M2 – Initiate Fabrication of MSTEC Modular Hot Cell - Due – 07/14/2022
  - M3 – Receipt of Remote Manipulators - Due – 08/30/2022

# NRIC MSTEC ConOps

- ConOps has been developed and available for public release
- Process flow for receiving irradiated salt
- Example Use Scenarios:
  - Process flow for non-irradiated and synthesized salts
  - Process flow for receiving irradiated salt in HFEF and preparing samples to be transferred to NRIC-MSTEC.
  - Process flow for receiving irradiated salt in FCF and characterizing salts in NRIC-MSTEC
- Other info: ownership, costs, trainings/qualifications



# Benefits of MSTEC (once complete)

- Provide high temperature characterization capabilities nonexistent elsewhere
- Study the interaction of fuel/coolant with material of construction
- Provide a space where salts can be synthesized and characterized in close proximity to facilities for irradiation testing and analytical analysis
- Provide data to aid in long term storage or disposal solutions
- Allow for development and validation of multi-physics models and simulations
- Provide critical data needed for predicting safe operating conditions of MSRs and determine the behavior of salts in "off-normal" conditions
- Generate data sets needed by stakeholders to design and license MSRs

# Thank you!

## Questions?

## Time Permitting

Contact: Toni.Karlsson@inl.gov

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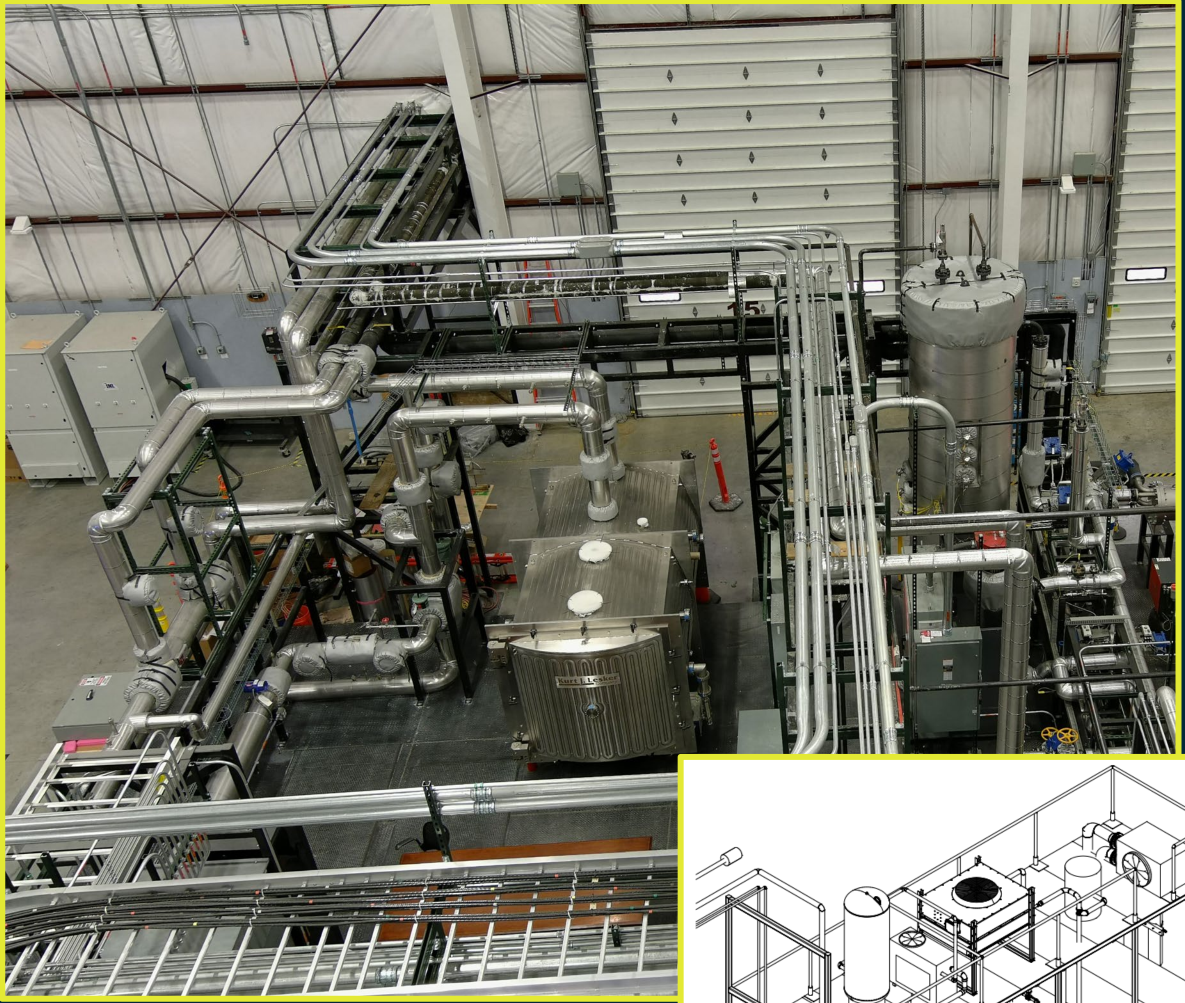
# HeCTF

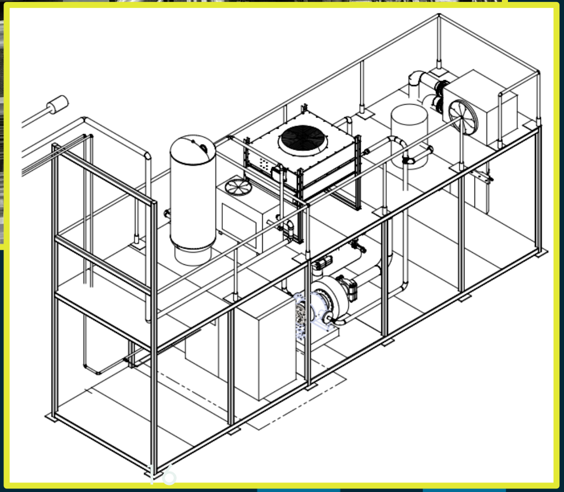
Helium Component Test Facility

Stacie Strain- Project Manager
TJ Morton- Project Engineer

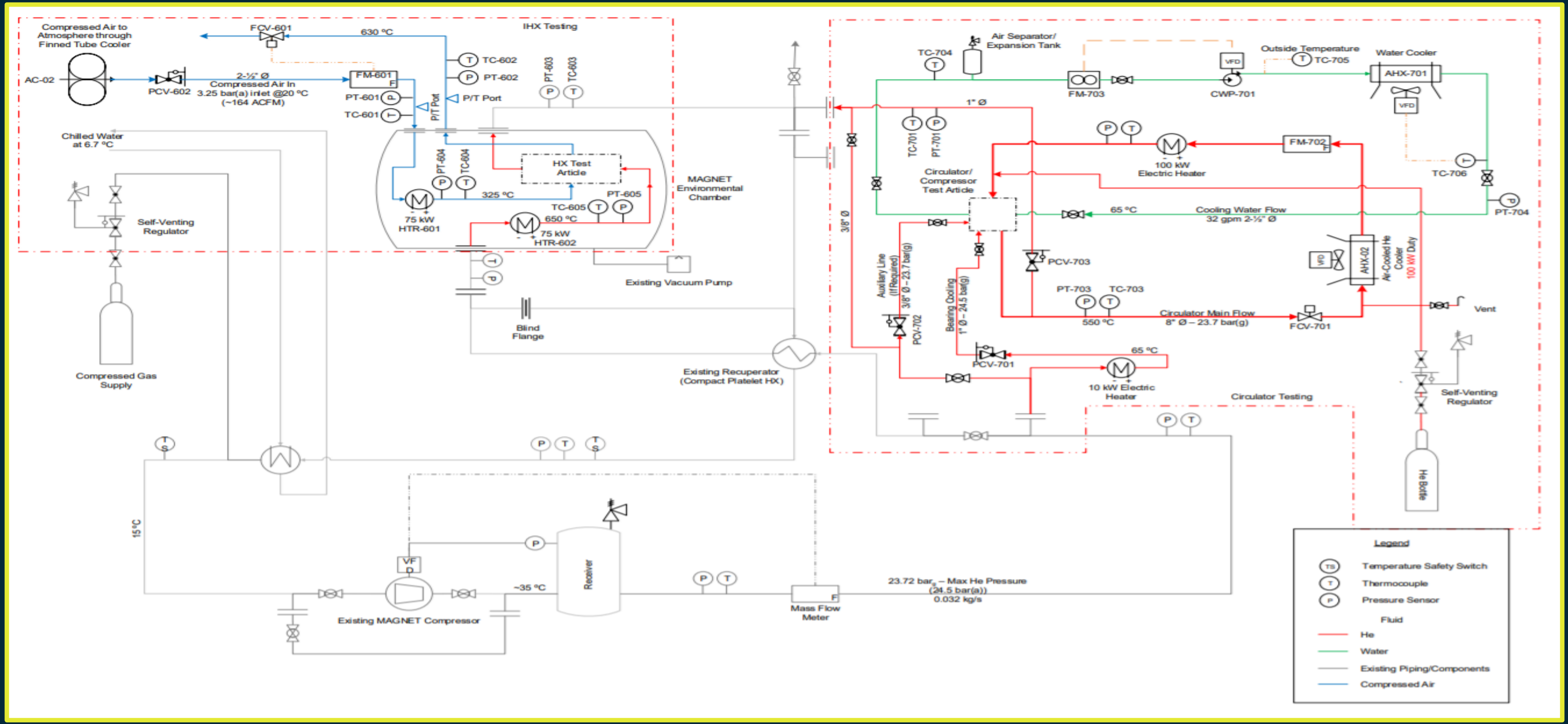
# HeCTF Project Overview

- Establishment of HeCTF Test Bed in conjunction with the Microreactor AGile Non-nuclear Experimental Test bed (MAGNET)
- Construction of a helium component test facility in ESL that can be used by industry to support the development and component qualification of gas cooled reactors.
- This component test facility will specifically be used to support the testing of components such as heat exchangers, control drum and control rod drives, and re-circulators.
- Supports NRIC's FY22 goal of maintaining progress to support demonstrations by the end of 2025 and sustained innovation and preparing vital infrastructure.
- Will be the first established test bed under the NRIC Program.





# HeCTF Project Overview Continued…




HeCTF Schematic

# HeCTF Project Funding

- Project Total Funding: $3.3M

NRIC FY21 Funding = $1,250,000

NRIC FY22 Funding = $450K ($1.7M total)

TBD FY22 Funding = $1.6M for installation CIRC, remaining materials, increased resource support

| HeCTF Project Team |
|---|
| Stacie Strain- NRIC PM |
| Luke Voss- NRIC Technical Lead |
| TJ Morton- Project Engineer |
| Steve Swanson- ESL Engineering Manager |

# HeCTF Progress: Cost

| | | |
|---|---|---|
| NRIC FY21 Costs | = $97,446 | Project initiation, Preliminary design of IHX/CDDS/CIRC, capital authorization |
| NRIC FY22 Current Costs | = $441,674 | Project documentation, procurements, RFP, Final design of IHX/CDDS completed, Final design of CIRC 85% |
| TBD FY22 Current Costs | = $0 | *Requested $1.6M capital (installation of permanent support CIRC infrastructure, subcontract drafting support, MR, and INL support labor)* |

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Total Spent to date = $539,120

Remaining Budget = $377,302 after Outstanding Commitments of $783,538 (installation subcontract & remaining GFE)

# HeCTF Progress: Schedule & Accomplishments

| REMAINING ACTIVITIES | START | FINISH |
|---|---|---|
| Finalize GFE Procurements | 01/04/22 | 02/28/22 |
| Install IHX & CDDS Infrastructure- Subcontractor (Permanent & Temporary) | 12/15/21 | 04/15/22 |
| IHX/CDDS Installation Testing/Walkdown | 04/18/22 | 05/06/22 |
| Test Bed Turnover: IHX/CDDS Complete | | 05/06/22 |
| Complete CIRC Final Design | 11/01/21 | 02/11/22 |
| Issue Amendment for CIRC | 02/14/22 | 02/18/22 |
| Install CIRC Infrastructure- Subcontractor (Permanent & Temporary) | 02/21/22 | 06/20/22 |
| CIRC Installation Testing/Walkdown | 06/21/22 | 07/11/22 |
| Test Bed Turnover: CIRC Complete | | 07/12/22 |
| Project Closeout | 08/23/22 | 09/09/22 |

- Accomplishments:
  - Final Design of IHX (Intermediate Heat Exchanger) and CDDS (Control Drum Drive System) completed
  - Procurement of long-lead materials at 99%
  - RFP for IHX/CDDS awarded
  - Final Design of CIRC (Circulation system) at 90%

| MILESTONE DESCRIPTION | M1-M5 | DUE DATE | STATUS |
|---|---|---|---|
| Helium Component Test Facility Ready to Perform Vendor Tests | M2 | 06/01/22 | On schedule |
| Project Completion | M3 | 09/30/22 | On schedule |

# HeCTF Progress: Risks

- Using NRIC Risk Management Plan INL/EXT-21-62081and NRIC Risk Analysis Plan NRIC 21 PRG-005
- Risk Register released on 11/15/21
- 7 out of 12 risks have been realized

| Risk ID | Risk Title | Risk Owner | Risk Statement | Initial Risk Rating | Residual Risk Rating |
|---|---|---|---|---|---|
| T1 | T1- Long-lead Procurements | TJ Morton | If the long lead procurements are not placed early, then the project will face delays to account for the additional time needed for acquisition and delivery. | High | Moderate |
| T4 | T4- Cost Estimates for Procurements are low | Stacie Strain | If cost estimates are lower that final quotes, then the project will face over-runs and will need to look at the possibility of additional funds for price differences. | High | Moderate |
| T6 | T6- Raw Material Procurement | TJ Morton | If the raw materials for the piping and fittings are delayed due supply chain issues (COVID-19), then the project will be unable to begin installation delaying the schedule. | High | Moderate |
| T7 | T7- Subcontractor Bids Exceed Estimate | Stacie Strain | If the submitted subcontractor bids exceed the level 5 estimate by more that 10%, then the project/estimating will have to justify the price difference which will delay the RFP award. | Moderate | Low |
| T8 | T8- Installation Deadlines | Stacie Strain | If the aggressive installation schedule cannot be met, then the project milestone will be missed, and the demonstrator will be delayed. | High | Moderate |
| T11 | T6- IHX Demonstrator Component U-Stamp Requirement | TJ Morton | If the IHX demonstrator component U-Stamp requirement pulls resources off the test-bed scope, then the test-bed deliverables will be delayed. | Low | Low |
| T12 | T12- Test bed is not ready for demonstrators | Stacie Strain | If the test bed is not ready for demonstrators equipment/testing, then the initial set of component testing will be delayed or unable to be conducted. | High | Moderate |

| | | | | | |
|---|---|---|---|---|---|
| Initial | 6 | 5 | 1 | Total Open Threats | 12 |
| Residual | 0 | 7 | 5 | Total Open Opportunities | 0 |

# HeCTF Concept of Operations

- The He-CTF has been designed to progress the technical readiness of components and equipment that will use helium as a working fluid for reactor organizations.
- Nominal specifications for testing capabilities will be:
  - Helium Temperature IHX: ambient to 650C
  - Helium Temperature CIRC: ambient to 550C
  - Helium Pressure: atmospheric to 22bar
  - Helium Flow Rate; 0.3Kg/s to 1.5Kg/s
- Interested reactor organizations will coordinate with NRIC/INL representatives to determine the feasibility of testing components (within specifications) in the He-CTF.
- If testing is possible, an agreement will be executed between the parties, scope will be defined, and dates scheduled to perform testing at INL facilities.
- The components desired to be tested will be shipped by the reactor organization to INL facilities.
- INL will conduct the testing and generate data as determined in the agreement.
- After the completion of testing, INL will disposition components in accordance with the instructions in the agreement.

# HeCTF Summary

- Project has experienced significant challenges in resources, escalating costs and aggressive deadlines
  - Increasing material costs, material shortages, and labor availability have impacted the schedule and budget
- The project is still on schedule through:
  - accelerated scope management (e.g., reduction of INL processing time for procurements and contracts saved at least 3 weeks)
  - working parallel work efforts
  - approving overtime
- The project will need increased funding before the end of March to continue the CIRC scope.

# Thank you!

# Questions?

# Time Permitting

Contact: Stacie.strain@inl.gov

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# In-Cell Thermal Creep Frames

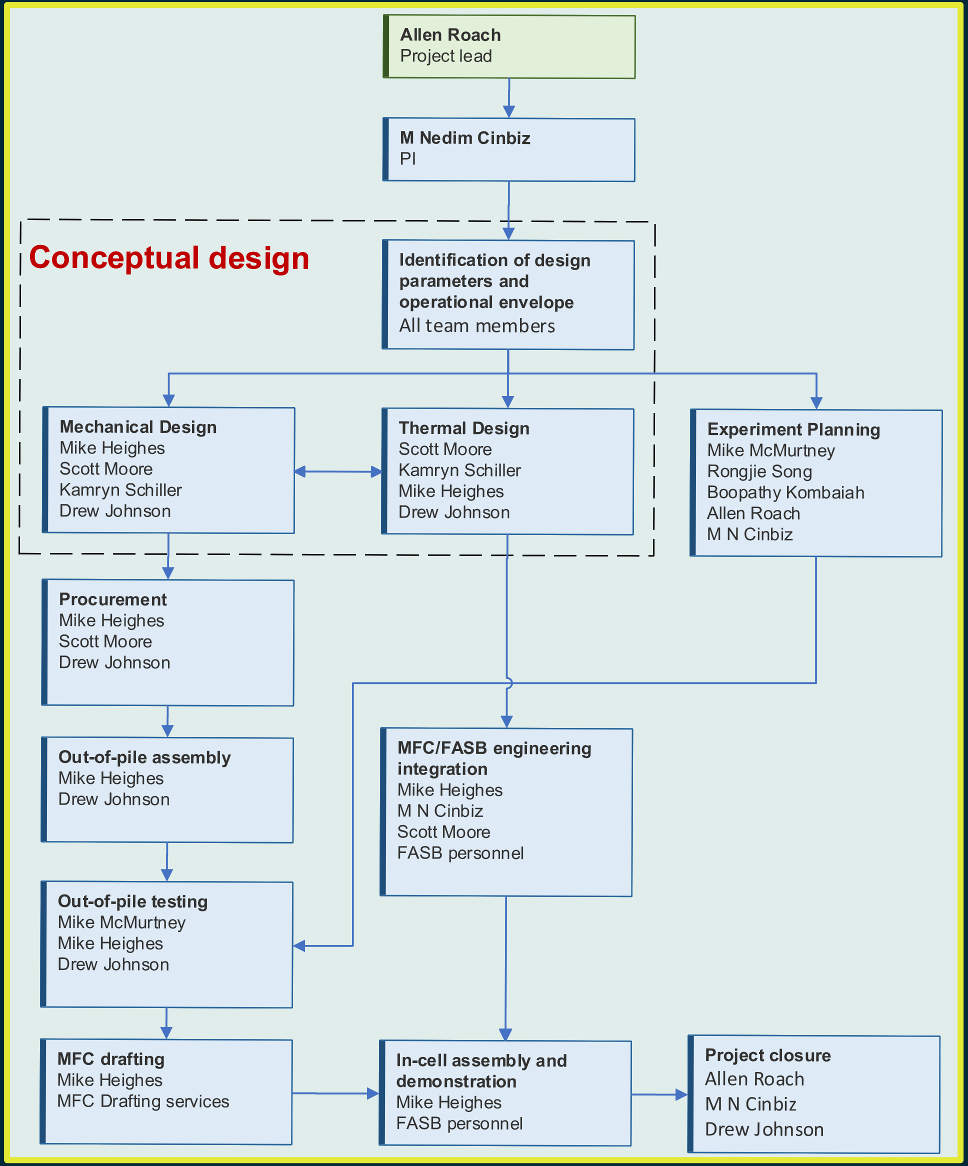
R. Allen Roach
M. Nedim Cinbiz

# In-Cell Thermal Creep Frames Project Overview

- Project initiated April 2021
- Scope: Design, purchase, and test an in-cell thermal creep frame that supports materials development, qualification, and licensing for advanced reactor materials.
  - Phase 1: Design phase
  - Phase 2: Frame purchase, assembly, and out-cell demonstrations
  - Phase 3: In-cell demonstrations
- $320K total funding (labor $189K, materials $131K)

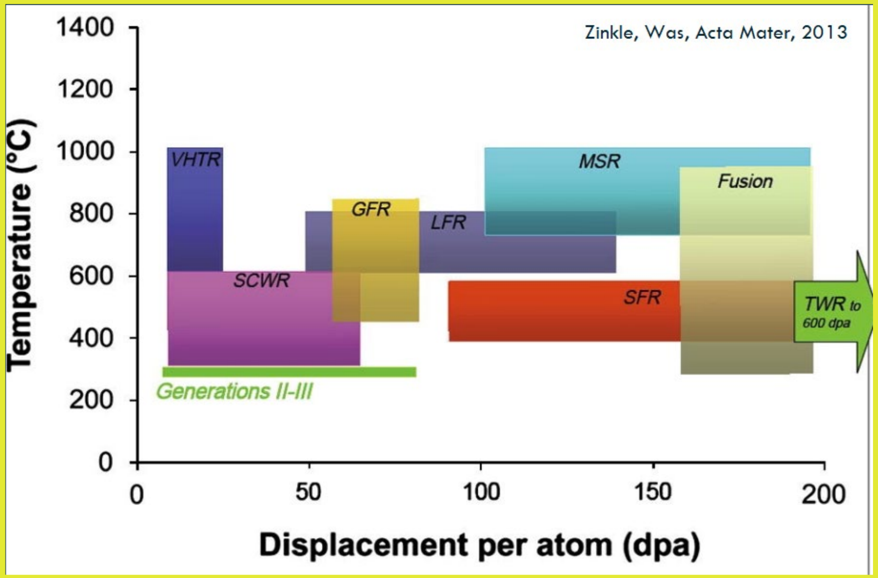
# Core Team Members

- Allen Roach
- M Nedim Cinbiz
- Michael Heighes
- Michael McMurtrey
- Rongjie Song
- Drew Johnson
- Scott Moore
- Kamrynn Schiller
- Boopathy Kombaiah

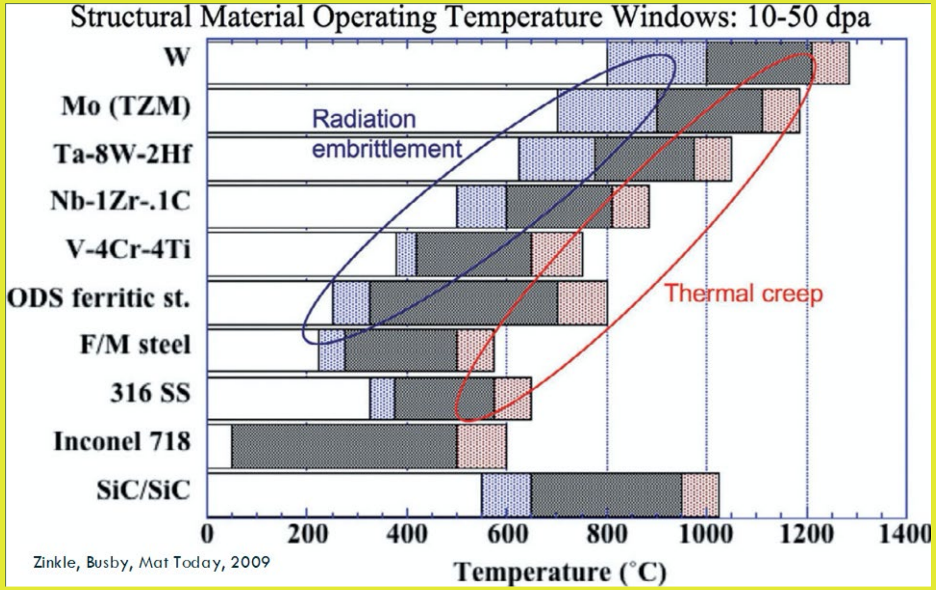


# What Is Materials Challenge? Reactor Lifetime

Advanced reactors operate at high-temperatures and high-dose




At these conditions, creep and creep/fatigue are design-limiting



# Lack of In-Cell Thermal Creep Testing Capability

Typical creep lab

## Challenges:

Creep is a very slow deformation process requiring testing of multiple samples in parallel

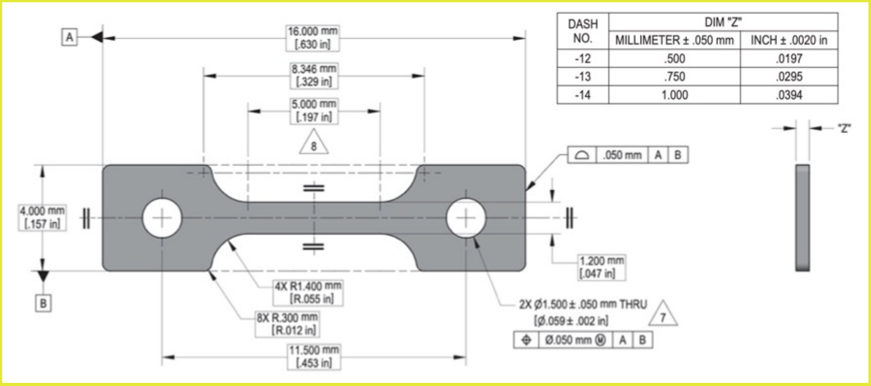
Standard creep testing approaches are not feasible due to hot cell space restrictions (equipment footprint)

## Solution:

Develop compact creep testing for hot cells

Subsize specimen testing and irradiations already available (SSJ specimen)

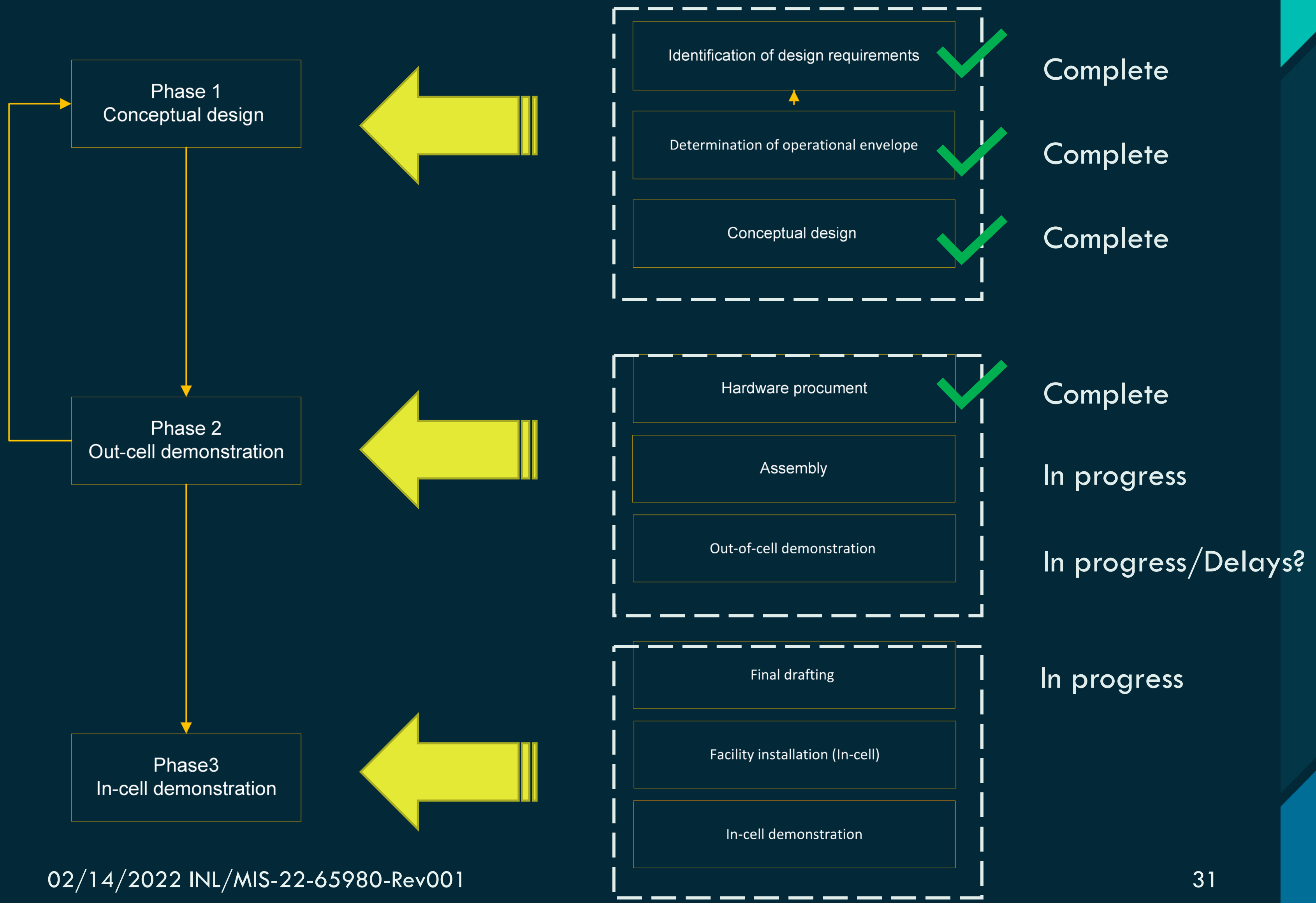
Qualification strategy for SSJ is essential and under development



# Benefits of an In-cell Thermal Creep Capability

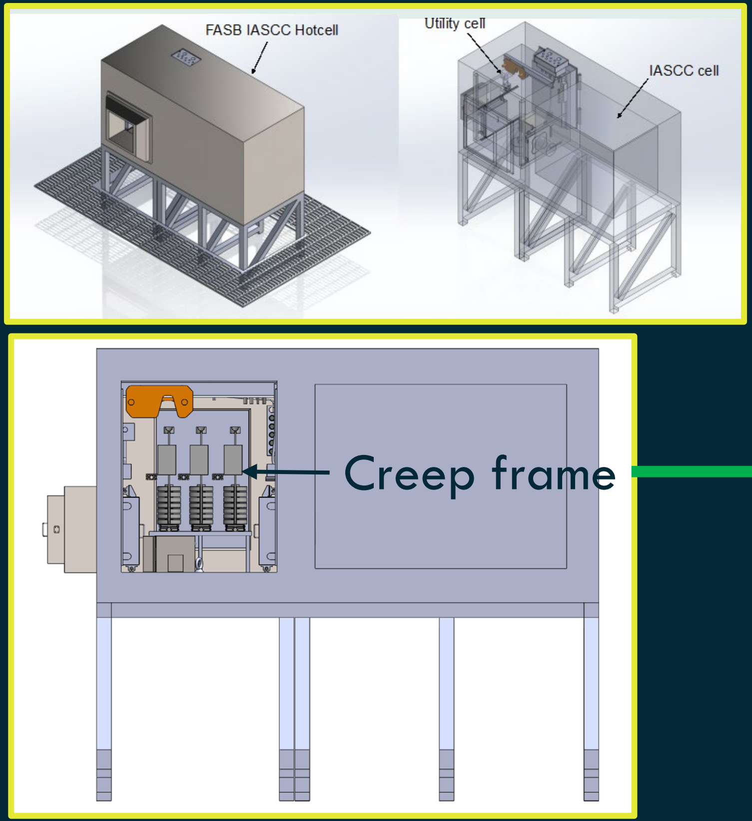
- A test bed for materials qualification
- Cost-effective testing opportunity
- Use of radioactive subsize specimens in the DOE inventory for licensing
- Providing disruptive data to physics-based code developers

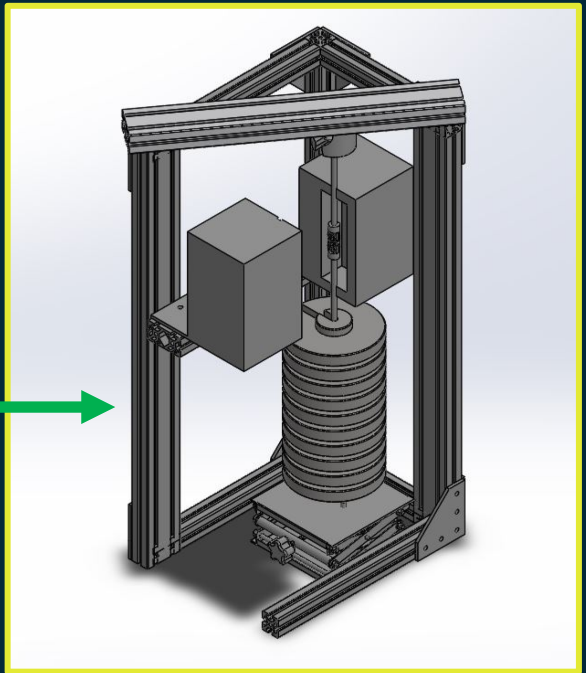
# In-Cell Thermal Creep Frames Progress

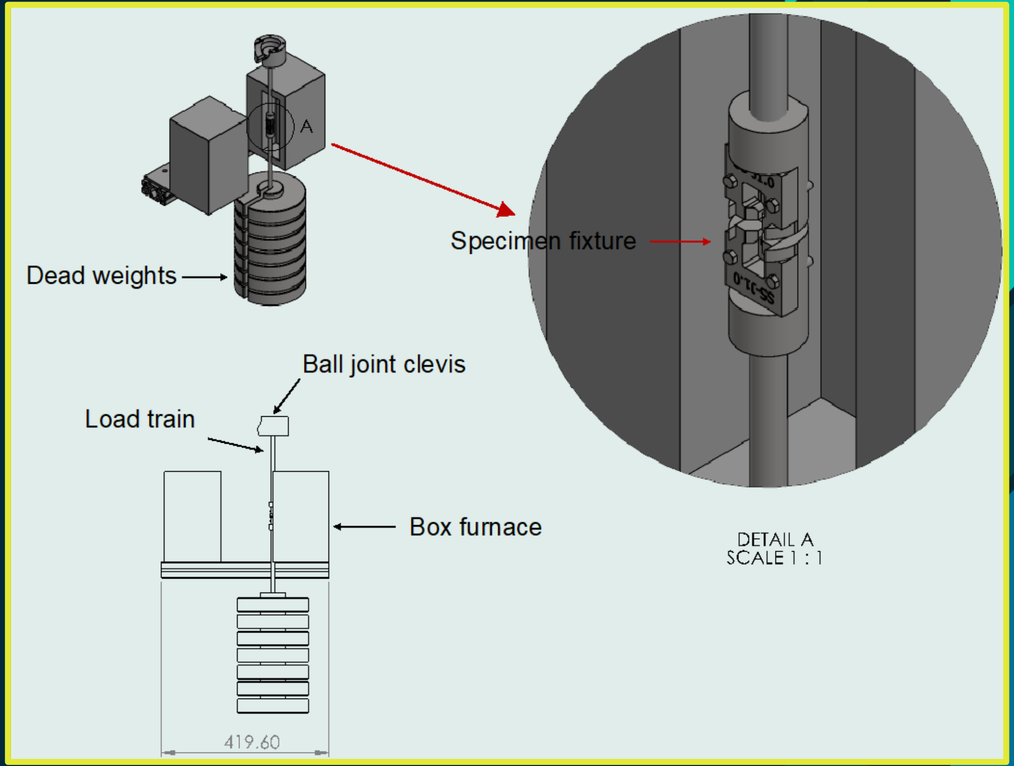



Risk Mitigation Plan: Built-in schedule flexibility for assembly, setup, and testing

# FY21 Accomplishments: Conceptual design



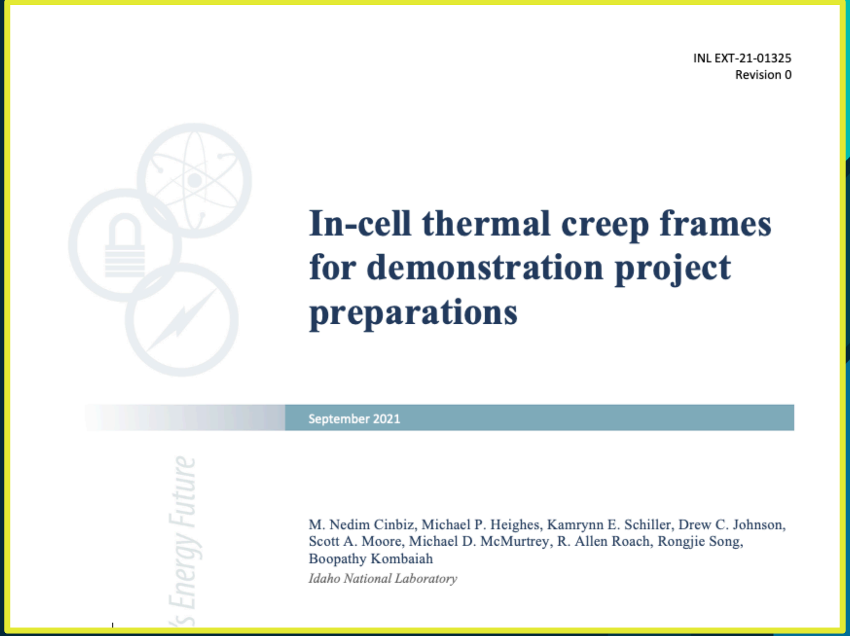






Creep frame design allows for testing of multiple subsize specimens with individual temperature control up to 1000°C with 100-lb max load.

# FY22 Accomplishments

- Materials purchases – All hardware arrived, except the heating furnace
- Frame assembly underway but final assembly delayed
- Finalized test matrix for out-of-cell demonstrations
    - Materials
    - *Temperature (delayed)*
    - *Stress (delayed)*


INL EXT-21-01325
Revision 0

In-cell thermal creep frames for demonstration project preparations

September 2021

M. Nedim Cinbiz, Michael P. Heighes, Kamrynn E. Schiller, Drew C. Johnson, Scott A. Moore, Michael D. McMurtrey, R. Allen Roach, Rongjie Song, Boopathy Kombaiah
*Idaho National Laboratory*

# Risk Assessment

- Acquisition of materials (Medium Schedule Risk – build in 8-week time cushion)
- Ability to begin installation in hot-cell (Medium Risk)
- Unpredicted facility outages/repairs (Low Risk)

  [Note: 9-week delay to date in furnace delivery]
- Active communication with hotcell facilities significantly reduces potential risks

# FY22 Revised Schedule (no time flexibility)

- February: Partial assembly and begin out-of-cell “tests” at room temperature
  - Includes SSJ3 testing using standard creep frames and new grips
- March: Arrival of the furnace
- March–May: Full creep frame assembly and data acquisition setup
- May–June: Out-of-cell shake down testing at temperature
- July–August:
  - Finalizing out-of-cell design (completion of phase 2)
  - Initiation of in-cell integration and planning
  - Milestone completion
- September/FY23?: In-cell assembly

# In-Cell Thermal Creep Frames Summary

- In-cell thermal creep capability is critical for materials qualification and licensing
- Creep frame design allows for in-cell testing of multiple subsize specimens with individual temperature control up to 1000C with 100lb max load
- Supply chain challenges impacting schedule

# Thank you!

# Questions?

# Time Permitting

Contact: robert.roach@inl.gov

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# METL

## Mechanisms Engineering Test Loop Operations and Maintenance

Christopher Grandy
Argonne National Laboratory

# METL O&M Project Overview (1/2)

- This work provide the necessary funding to operate and maintain the Mechanism Engineering Test Loop facility and supporting infrastructure located at Argonne National Laboratory
  - Work is currently funded by the DOE's Advanced Reactor Technologies (ART) program
  - Funding for METL O&M will be supported by NRIC around April 2022.
- Personnel working on METL O&M
  - Derek Kultgen – Manager of the METL Facility
  - Teddy Kent – METL Operations Engineer
  - Jordan Rein – METL Operations Engineer
  - Matt Weathered – METL Operations Engineer
  - Two plus technicians
  - Other support from various organizations on site

# METL O&M Project Overview (2/2)

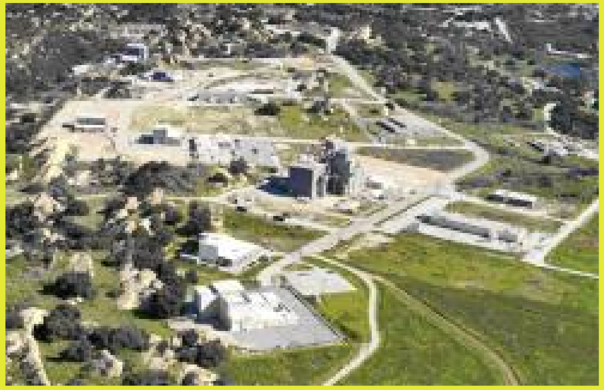
- *ART-AFR Program Objective - Develop advanced fast reactor technology solutions to allow commercial deployment*

1. Train next generation engineers and scientists by engaging them in advanced reactor concept design and analysis and fundamental studies that support fast reactor R&D
2. Design and develop scalable advanced technologies for reducing the cost and/or increasing the performance of fast reactor technology
   - Cost reduction
   - Improve safety performance
   - Increase system reliability
3. Preserve and manage data, knowledge, and experience related to past U.S. DOE fast reactor design, operations, tests, and component technology.
4. Re-establish the U.S. infrastructure to support the testing of advanced technologies for fast reactor applications.
5. Collaborate internationally on advanced reactor R&D through bilateral or multilateral agreements
   - Utilize international collaborations to leverage and expand R&D investments

- METL supports all these Program Objectives
- METL also supports the NRIC Mission to support the deployment of advanced reactors

# METL Facility Purpose - Re-establish U.S. infrastructure

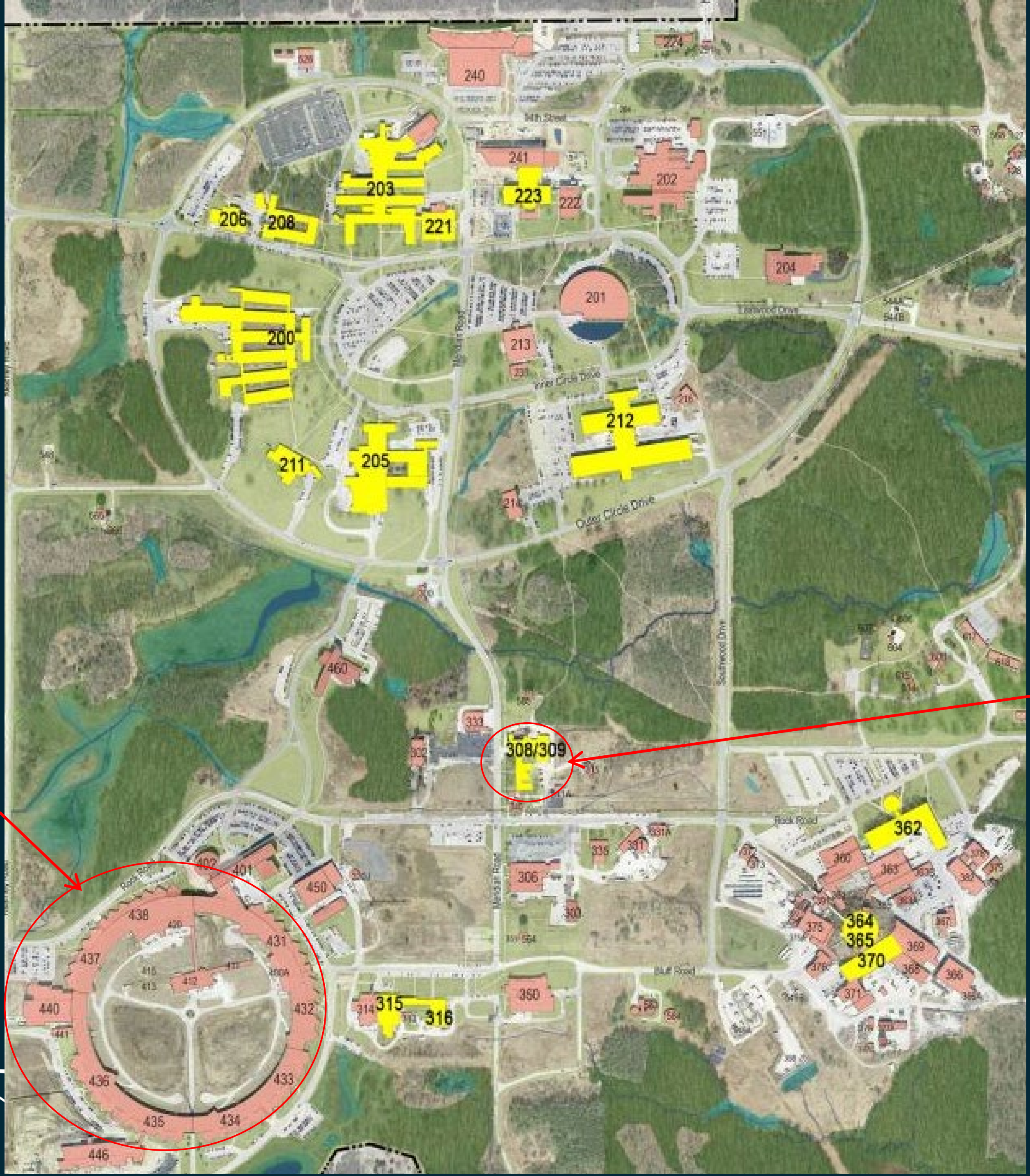
- To test small or intermediate scale advanced liquid metal components and instrumentation in sodium for the future of advanced fast reactor system development
- To develop and provide performance data on systems and components used in sodium and reduce the risk of failures during reactor plant operations
- Will provide needed U.S. infrastructure (both personnel and hardware) to test liquid metal systems and components
- This work supports our international collaborations
- The U.S. lacks this testing infrastructure



https://www.etec.energy.gov/

# METL

- Located in B308
- Large highbay structure
- Historically used for liquid metal technology development
- Currently houses
- METL
- NSTF
- USV/TAS/$H_2$




B308

APS

# METL is located in B308 Highbay

- B308 is protected by an alkali metal passivation booth
- Permitted for alkali metal treatment
  - 300 lbs/hr – normal
  - 600 lbs/hr in emergency
- 30,000 scfm scrubber blower
- Can treat all alkali metals via burning and reaction
- Facility is unique in the DOE and U.S. complex
- B206 is also protected by an alkali metal passivation booth

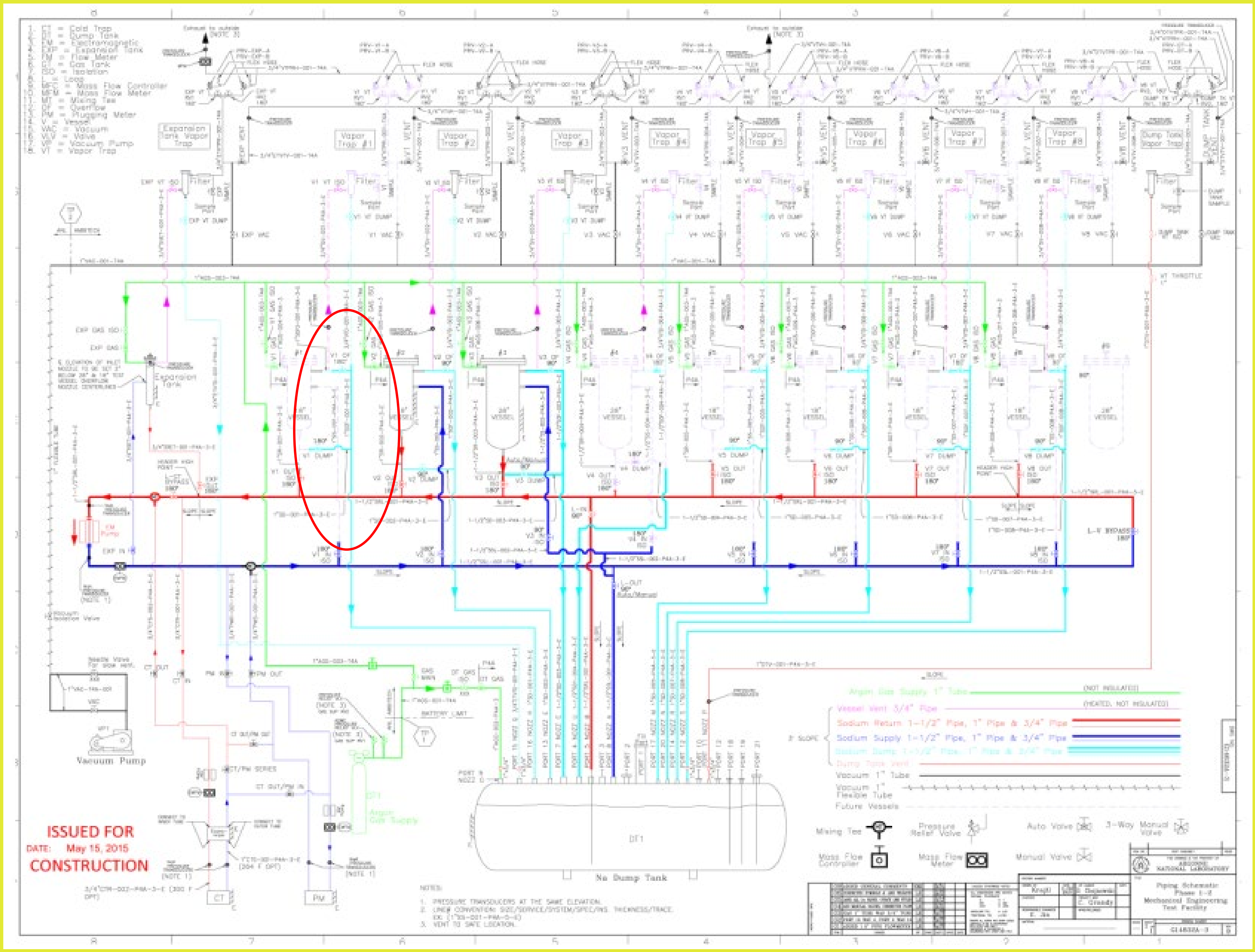
# Mechanisms Engineering Test Loop (METL)

- **To test small or intermediate scale advanced liquid metal components and instrumentation in sodium:**
  - Gear Test Assembly for Compact Refueling Machine
  - Sodium Level sensor technology
  - Thermal-Hydraulic Experimental Test Article (THETA)
  - Gripper Device for Compact refueling machine
- **METL consists of:**
  - ~3,000 kg of reactor-grade sodium – purified via cold trap
  - Two 18-inch test vessels and two 28-inch test vessels (Phase I)
  - Max system temperature = 1000°F (except for 28-inch test vessels – 1200°F)
  - Test vessels can be isolated from main loop
- **Provides much needed U.S. infrastructure (both personnel and hardware) to test liquid metal systems and components**

# METL Systems and Components

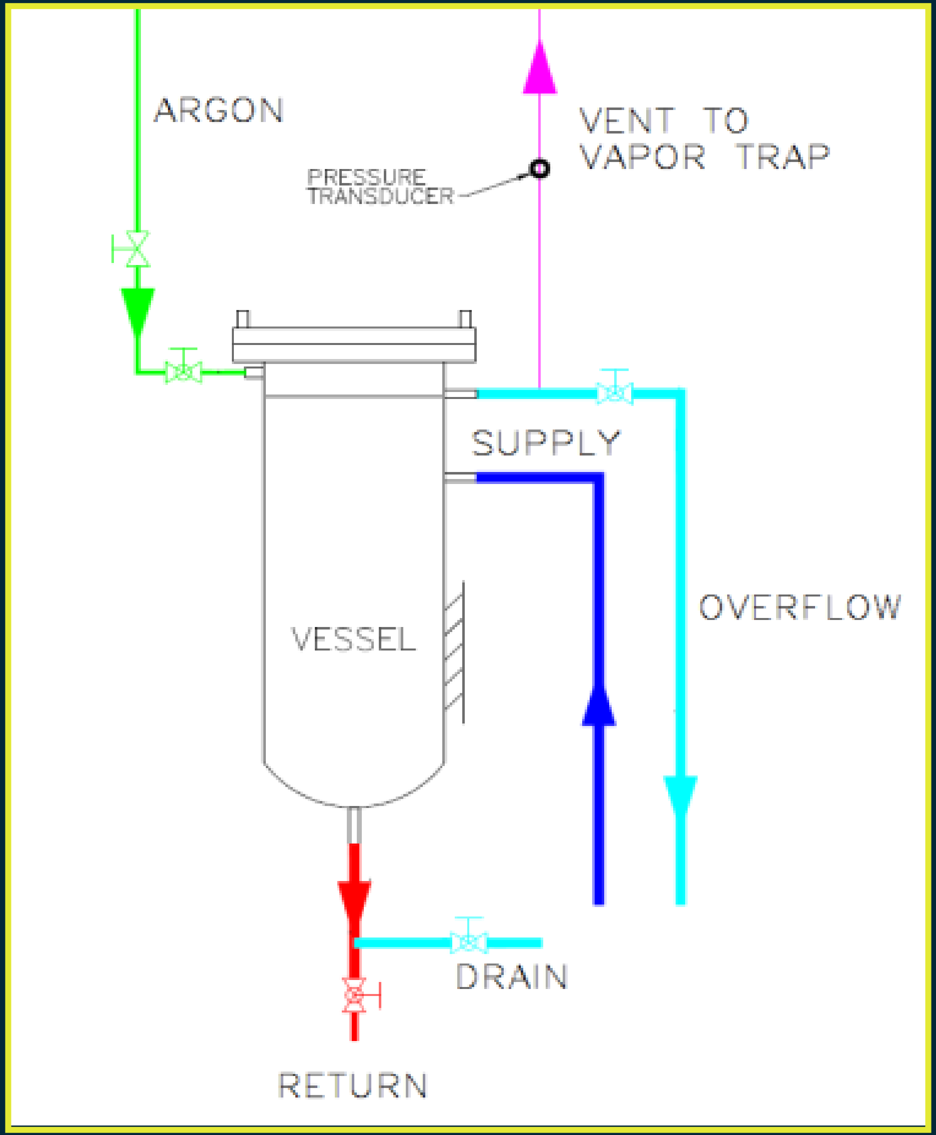
- METL consists of:
  - Four Test Vessels (18 and 28 inch)
  - Dump Tank
  - Expansion Tank
  - Purification System (cold trap)
  - Plugging meter
  - Vapor trap
  - Inert gas system
  - Valves
  - Connected piping system
  - Mezzanine
  - Catchpan
  - R-grade sodium
  - Heat Tracing
  - Heater and Valve control cabinets
  - Instrumentation and Control
- METL Auxiliary and supporting Infrastructure and systems

# METL P&ID

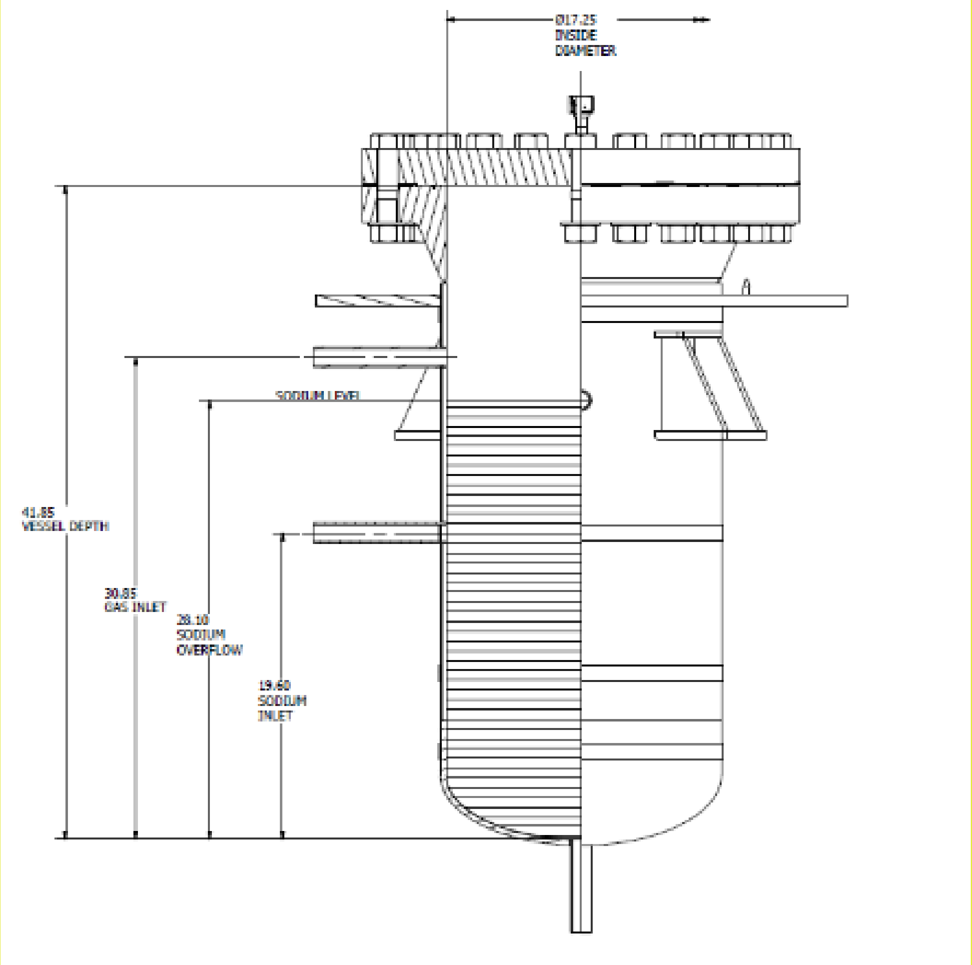


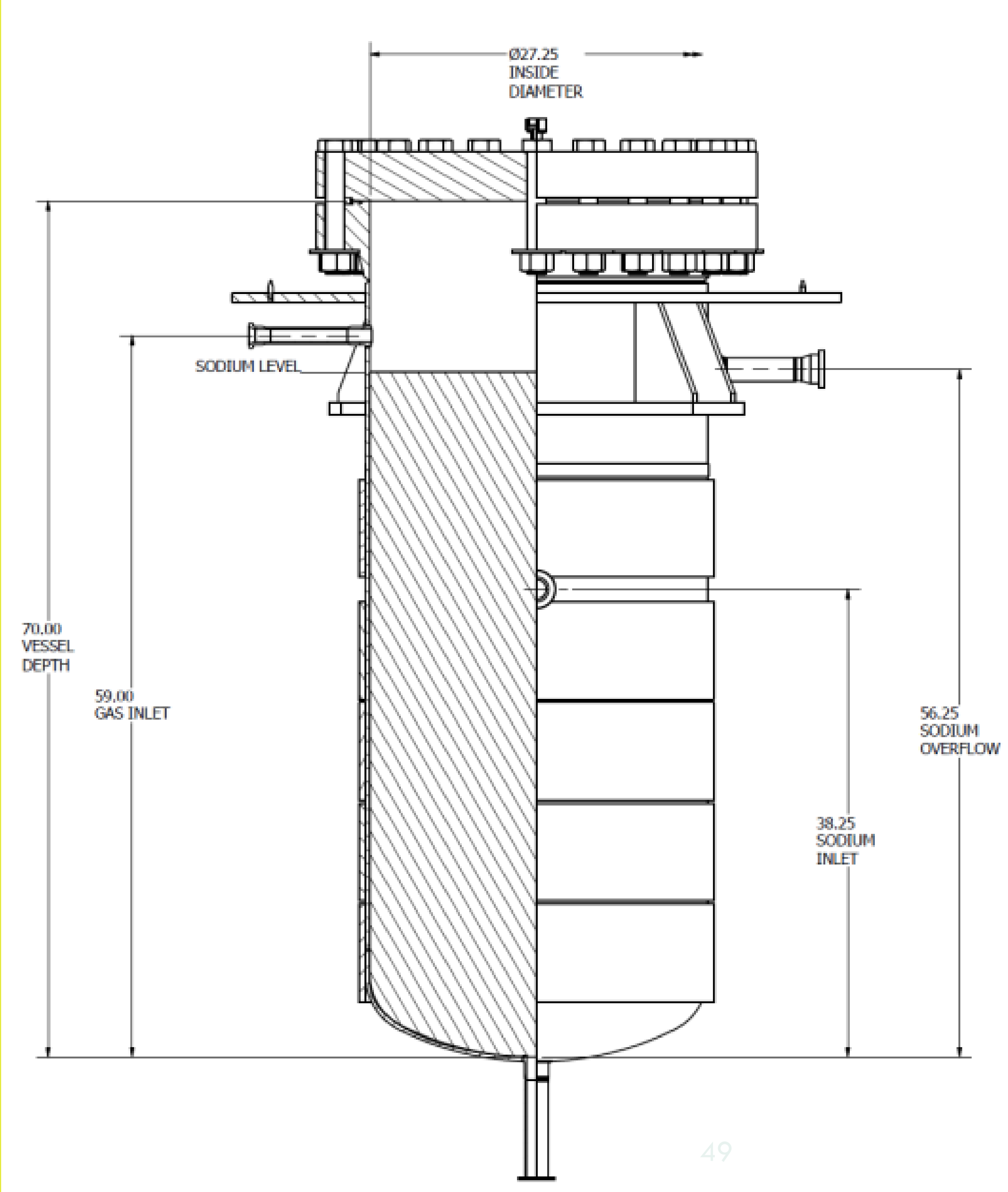
ISSUED FOR
DATE: May 15, 2015
CONSTRUCTION
Vacuum Pump
Na Dump Tank
Expansion Tank

# METL Test Vessel – generic flow



# 18-inch vessel + 28-inch vessel

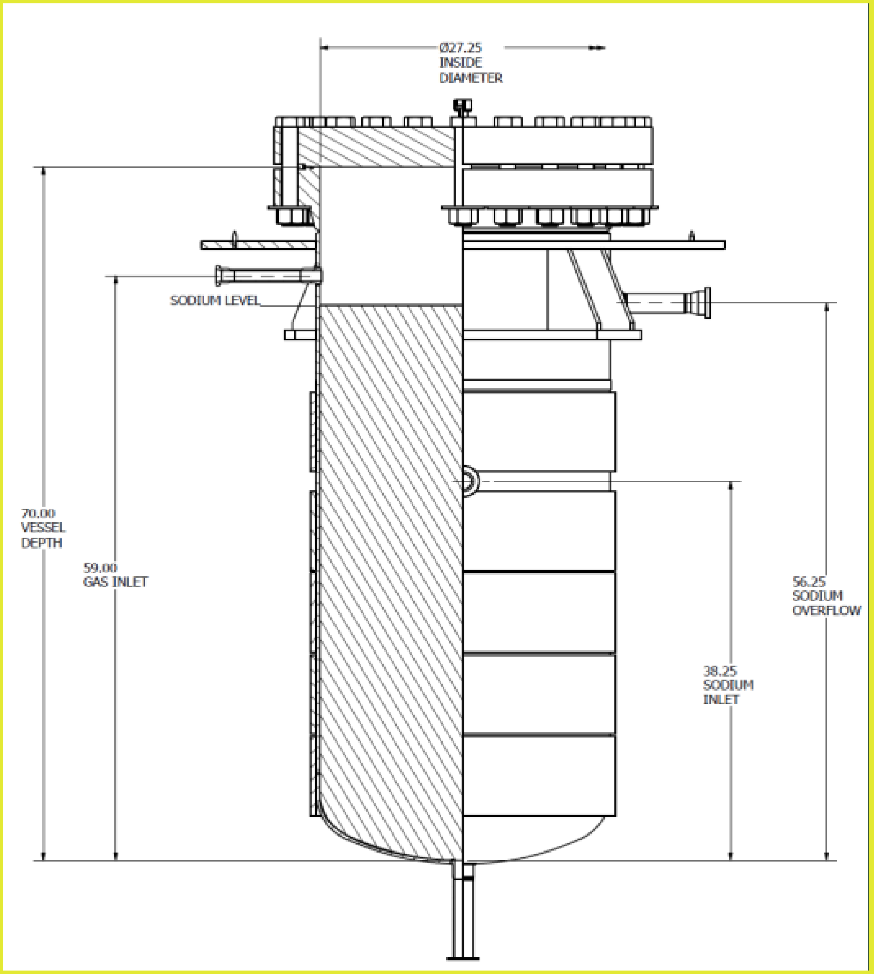


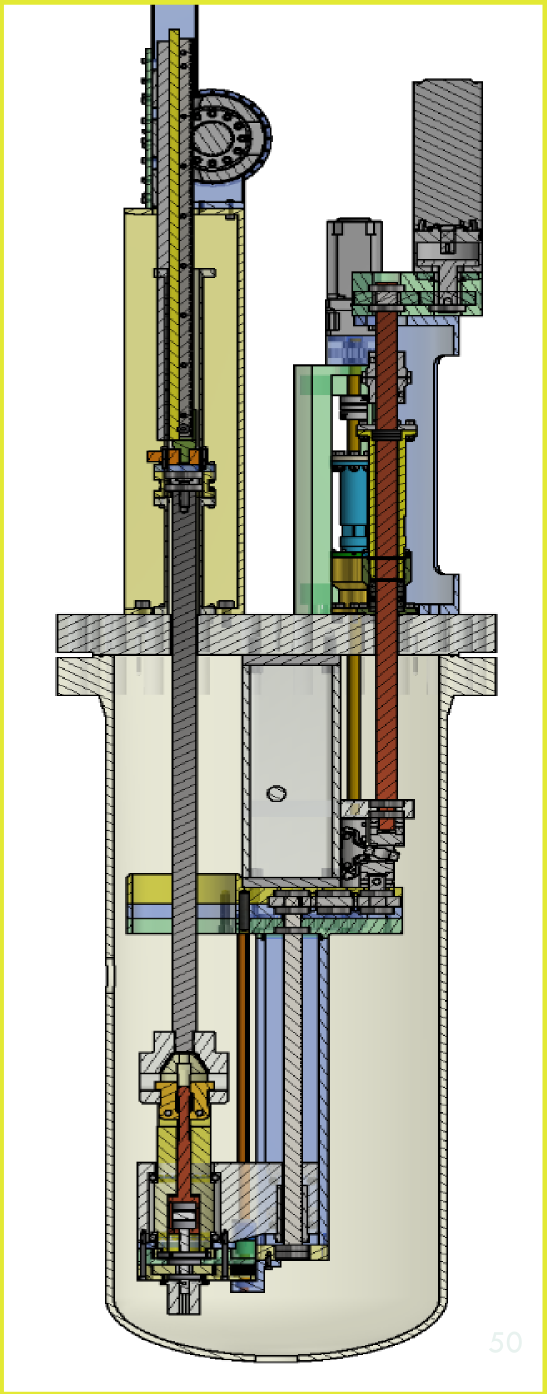




18-inch vessel - ~50 gallons

28-inch vessel - ~150 gallons

# 28-inch test vessel experiment – example



# METL Virtual Tour and Web Site

Virtual tour of METL

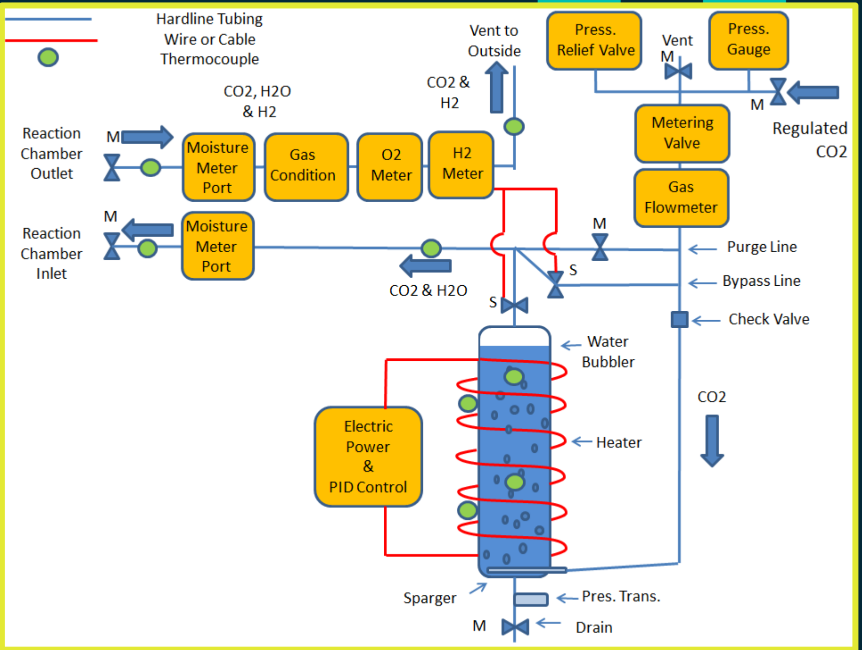
https://youtu.be/W4tfBd8rZ68

METL web site:

https://www.anl.gov/nse/mechanisms-engineering-test-loop-facility

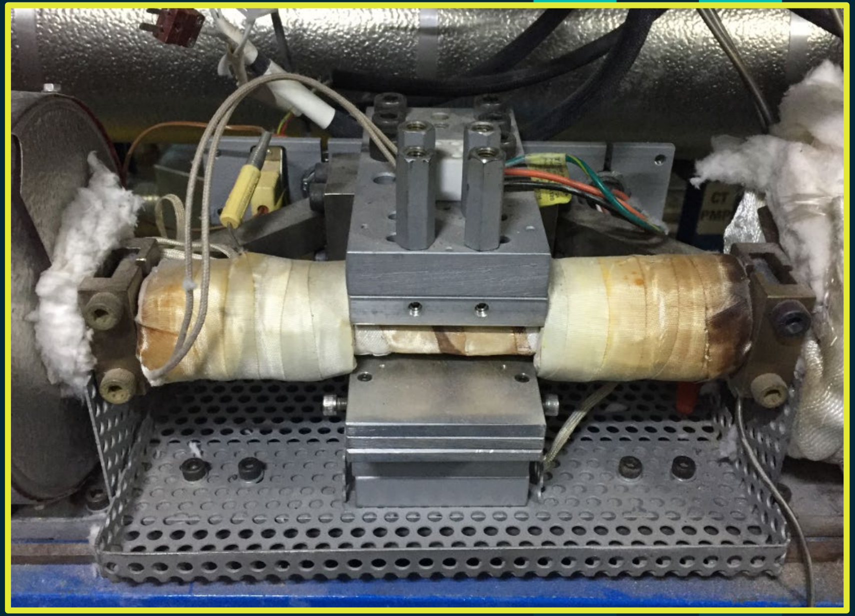
# METL O&M Project Progress (1/4)

- What is the full cost and schedule of the project?
  - METL has a design life of 30 years
  - Requested funding of ~$3.5M/year
- METL O&M project work scope includes
  - Operating and maintaining METL
  - Operating and maintaining the supporting infrastructure for METL
    - Carbonation process and other sodium cleaning processes
    - Alkali Metal Passivation Booth and Scrubber unit
    - Inert Glovebox(es)
    - Qualification system
    - Flexicask system
  - Qualifying experiments for insertion into METL
  - International collaborations under Gen-IV – CDBOP




# METL O&M Project Progress (2/4)

- Accomplishments for FY21 (under ART program)
  - METL was successfully operated continuously from September 19, 2018
  - METL was drained on April 20, 2021, and then frozen to effect modifications to the B308 scrubber unit – first time for drain and freeze
    - METL was operational for 943 days continuously
  - Two of METL's flow meters were modified from a hall-effect sensor to a permanent magnetic flow meter
  - METL supported the installation and testing of two test articles – GTA and THETA
  - Installed new inductive level sensor in expansion tank and dump tank
  - We installed ultrasonic flow sensors on METL
  - METL team supported the re-heating and re-filling of the METL loop



# METL O&M Project Progress (3/4)

- Accomplishments for FY22
  - Successfully complete the restoration to full operations of METL facility
  - Prepare a report of the METL flowmeter conversion (under ART program)
  - Operate and Maintain METL to support
    - GTA testing – related to milestone – M2AT-22AN0502011
    - THETA testing – related to milestone – M2AT-22AN0502012
    - Make preparations for GrTA and F-STAR testing
  - We are in the process of installing another 18-inch vessel

- FY22 Milestones
  - M2AT-22AN0502043 Report of METL related to conversion of installed METL flow meters (3/31/2022)
    - On schedule
  - M2RC-22AN0206043 – Complete Mechanisms Engineering Test Loop Facility Annual Operations and Testing Report
    - On Schedule

# METL O&M Project Progress (4/4)

- METL funding FY22
  - ART program – $500K with $1M in carryover
  - NRIC program – $2M
- METL outyear funding
  - Request is $3.5M/year
- What are the risks?
  - Some upset to the METL facility
    - We have an active CMMS and perform routine maintenance on METL
  - Stability of funding
    - We carryover sufficient funds due to CR
  - Cost inflation of components
    - We do have some spare parts on hand

# Additional Funding?

- Additional Loop
  - Currently removing an old test loop adjacent to the METL facility – called the steam generator test facility
  - Would design a taller test facility for the testing of tall test articles and thermal-hydraulic systems
- Extending the platform area around METL

# METL O&M Summary

- METL has been in an operational status since September 2018
  - About 6-month pause in operations in FY21

- It provides the infrastructure and capability of testing multiple test articles in a prototypic sodium environment

- It is the largest facility of its kind in the DOE complex

- It is ready to support DOE and industrial vendors

# Thank you!

# Questions?
# Time Permitting

Contact: Cgrandy@anl.gov

NRIC
National Reactor Innovation Center

Idaho National Laboratory

# NRIC Digital Engineering

Chris Ritter
Peter Suyderhoud

# NRIC DE Project Overview

- Digital Engineering embodies a deliberate transformational approach to the way systems are conceptualized, designed, constructed, operated, maintained and retired.
- In accordance with the NRIC mission statement, DE **empowers** INL and innovators to **deliver** successful outcomes by transforming legacy document-based INL engineering processes to align them with modern data-driven engineering practices
- Team:
  - Chris Ritter: WPM/CAM
  - Taylor Ashbocker: Lead cloud architect
  - Brennan Harris: Lead software engineer
  - Paul Plachinda: Model-based systems engineer
  - Peter Suyderhoud: Model-based systems engineering lead
- Current Funding: $219K (October–March)

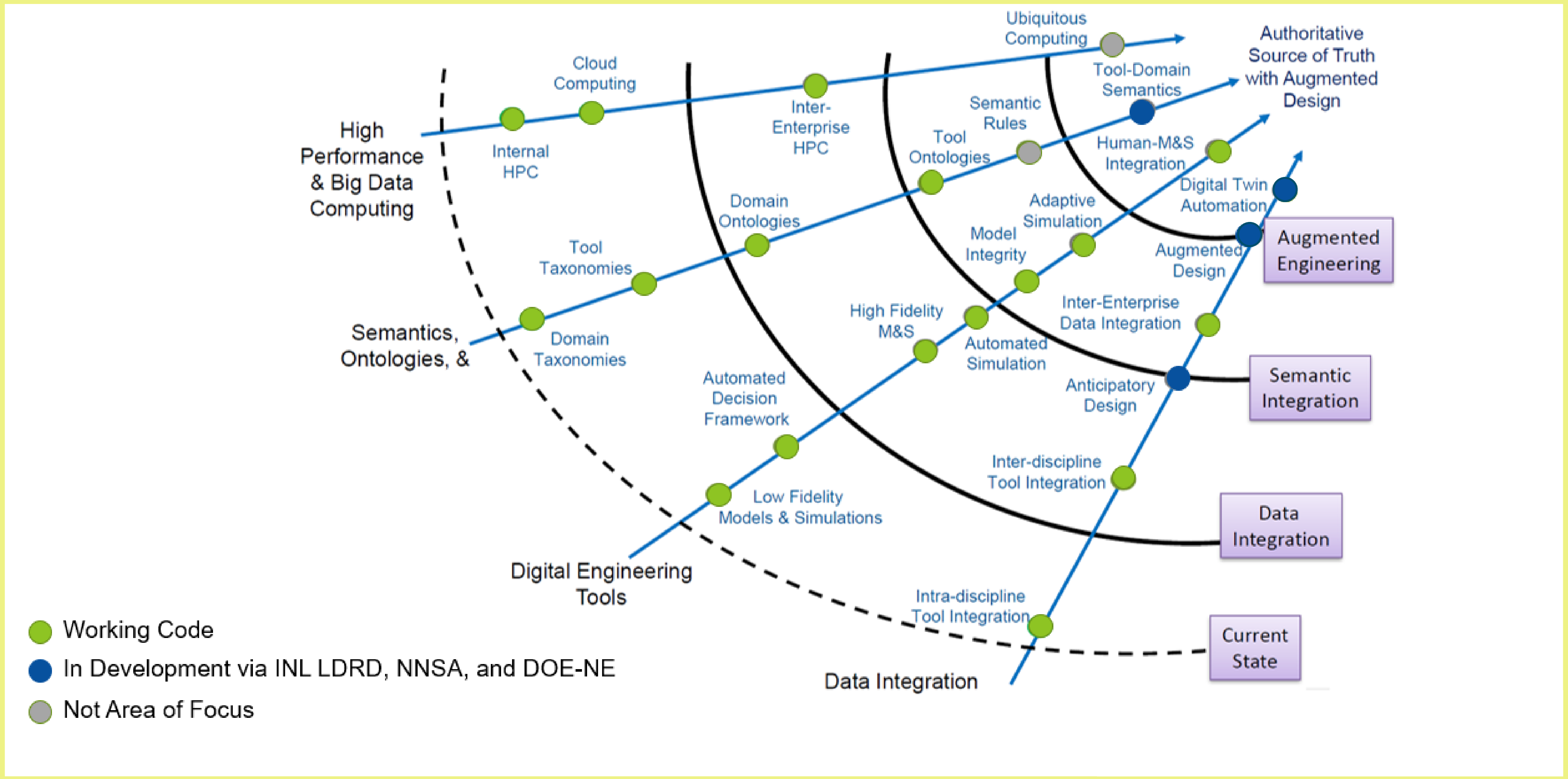
# Need for Digital Engineering

- A next generation R&D capability for nuclear facilities digital engineering
  - Linkage of facility information (requirements, equipment, processes, 3D) throughout design
    - Impact analysis of design changes
    - Reduction of silent errors earlier in design process
    - Improved communication across engineering teams
  - Enablement of digital twins in operations
    - Real-time operator feedback
    - Autonomous control functionality
    - Accurate predictions (e.g., maintenance, security)

**Benefits of Digital Engineering**

| |
|---|
| Artificial Intelligence and Machine Learning |
| Real-time Visualization and Trends |
| Centralized Source of Truth |
| Cost and Risk Reduction |
| Holistic View of Data |
| Process Optimization |

# Nuclear Digital Engineering Status (based on SERC DoD UARC)



# NRIC DE Past Progress

- FY20 Accomplishments ($265K)
  - 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
- FY21 Accomplishments ($747K)
  - Complete preliminary Model-based Systems Engineering (MBSE) architecture at **requirements level** for demonstration test bed: November 2020
  - Complete **systems level** Model-based Systems Engineering (MBSE) architecture for demonstration test bed: April 2021
  - Develop fully traced computer aided design (CAD) and cost/schedule artifacts to Model-based Systems Engineering (MBSE) model: September 2021

# FY22 NRIC DE Software Development Progress

- FY22 Q1/Q2 Milestones ($219K):
    - **January 7, 2022:** NRIC Asset Suite Engineering and Operations Data Integration Plan (COMPLETE)
    - **January 7, 2022:** NRIC Requirements Software Integration (COMPLETE)
    - **January 7, 2022:** Digital Engineering Cloud Ops Q1 (COMPLETE)
    - **March 31, 2022:** Start Asset Suite Integration (on schedule)
    - **March 31, 2022:** RM to MBSE Integration (ahead of schedule)
    - **March 31, 2022:** Digital Engineering Cloud Q2 (on schedule)
- FY22 Q3/Q4 Milestones ($290K):
    - **June 30, 2022:** Digital Engineering Cloud Q3
    - **September 30, 2022:** Digital Engineering Cloud Q4
    - **September 30, 2022:** Complete Asset Suite Integration

| Development and Demonstration of Digital Engineering Systems | | | | 01-Oct-21 | 31-Mar-22 | 01-Oct-21 | 31-Mar-22 | 31-Mar-22 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| NRIC - FY 2022 | | | | 01-Oct-21 | 31-Mar-22 | 01-Oct-21 | 31-Mar-22 | 31-Mar-22 | | |
| C.C.32.05.20.40.02 | DIGENG005 | 103818411 | NRIC Asset Suite Data Integration Plan | 01-Oct-21 | 07-Jan-22 | 01-Oct-21 | 07-Jan-22 | | | C |
| C.C.32.05.20.40.02 | DIGENG005MS4 | MILESTONE | M4 - NRIC Asset Suite Engineering and Operations Data Integration Plan | | 07-Jan-22 | | 07-Jan-22* | | I1 | F |
| C.C.32.05.20.40.02 | DIGENG010 | 103818411 | NRIC Requirements Management Software Integration | 01-Oct-21 | 07-Jan-22 | 01-Oct-21 | 07-Jan-22 | | | C |
| C.C.32.05.20.40.02 | DIGENG010MS4 | MILESTONE | M4 - NRIC Requirements Software Integration | | 07-Jan-22 | | 07-Jan-22* | | I1 | F |
| C.C.32.05.20.40.02 | DIGENG015 | 103818411 | Digital Engineering Cloud Operations (Q1) | 01-Oct-21 | 07-Jan-22 | 01-Oct-21 | 07-Jan-22 | | | C |
| C.C.32.05.20.40.02 | DIGENG015MS5 | MILESTONE | M5 - Digital Engineering Cloud Operations Q1 | | 07-Jan-22 | | 07-Jan-22* | | I1 | F |
| C.C.32.05.20.40.02 | DIGENG020 | 103818411 | MBSE Integration | 10-Jan-22 | 28-Feb-22 | 10-Jan-22 | 28-Feb-22* | | | C |
| C.C.32.05.20.40.02 | DIGENG020MS4 | MILESTONE | M4 - MBSE / Requirements Integration | | 28-Feb-22 | | 28-Feb-22* | | I1 | F |
| C.C.32.05.20.40.02 | DIGENG025 | 103818411 | Start Asset Suite Integration Configuration | 10-Jan-22 | 31-Mar-22 | 10-Jan-22* | 31-Mar-22 | 31-Mar-22 | | C |
| C.C.32.05.20.40.02 | DIGENG025MS4 | MILESTONE | M4 - Start Asset Suite Integration | | 31-Mar-22 | | 31-Mar-22* | | I1 | F |
| C.C.32.05.20.40.02 | DIGENG030 | 103818411 | Digital Engineering Cloud Operations Q2 | 10-Jan-22 | 31-Mar-22 | 10-Jan-22* | 31-Mar-22 | 31-Mar-22 | | C |
| C.C.32.05.20.40.02 | DIGENG030MS5 | MILESTONE | M5 - Digital Engineering Cloud Operations Start Q2 | | 31-Mar-22 | | 31-Mar-22* | | I1 | F |

# NRIC DE Systems Engineering Progress

- Configuration of PTC Windchill
  - Attribute mapping between engineering deliverables and Asset Suite/EDMS parameters
  - Development of product data structure
- Continued use, training, and management of DOORS Next for Requirements Management
  - Migration to Configuration Management processes
  - Onboarding of Walsh Engineering employees
- Continued use, training, and management of Innoslate for Model-Based Systems Engineering

# Known Future Work

- Maintenance and Operations of NRIC Cloud: Continued availability of single-sign-on, applications (DOORS, Innoslate, etc.), patching.
- Software Development of Asset Suite Integration: Ability to push equipment data from PLM (e.g., Windchill) to Asset Suite (Asset management software) while maintaining version control – this is currently a manual data entry job
- MBSE/CAD/PLM Synchronization Tool: Ability to maintain the asset/equipment list current with a corresponding CAD/PLM data structure.

# Potential Future Work

- Advanced visualization
  - Integrating Building Information Model with Augmented Reality (e.g., HoloLens) for final design reviews
  - Layering digital models on real-world physical assets (existing facilities) for construction verification
- Facility Digital Twin development for Operations

# Risks

- **Cultural**: Adoption of DE principles/technologies is contingent on INL participation – the resistance to DE by certain INL groups will delay DE delivery. *Mitigation: Interface with MFC engineering and DICE.*
- **Funding**: Currently all funding for this work package ends in March 2022. This will stop work on all software integrations, reporting, and cloud operation activities for the DE environment. *Mitigation: New BCP being issued.*
- **Technical**: Cloud environment availability is dependent upon Microsoft Azure and internal lab services for 100% uptime. *Mitigation: Containerization and platform services with higher reliability.*

# NRIC DE Summary

- Digital Engineering is an enabling capability to reduce project risk of missing cost/schedule targets and increase engineering efficiency
- Digital Engineering success is contingent on INL/project buy-in and management enforcement

# Thank you!

# Questions?

# Time Permitting

Contact: Christopher.ritter@inl.gov

NRIC
National Reactor Innovation Center

Idaho National Laboratory

# VTB

Virtual Test Bed

Abdalla Abou-Jaoude, Derek Gaston, Emily Shemon

Nuclear Energy Advanced Modeling and Simulation

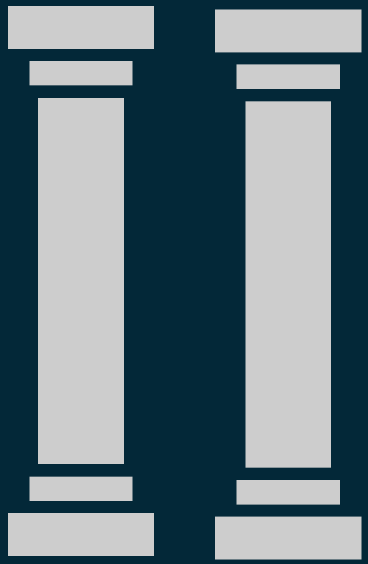
# Mission Statement

**NRIC**: Deliver successful demonstration and deployment of advanced nuclear energy

- **EBRII Test Bed (DOME)**
- **ZPPR Test Bed (LOTUS)**
- **Virtual Test Bed (VTB)**: Accelerate deployment of advanced reactors by leveraging state-of-the-art ModSim tools developed by NEAMS program

## Reactor Demonstrations

Ok but what is it?



### 1) Model Development

Leverage codes supported by NEAMS to provide powerful, highly-adaptable simulations:

- Analysis Tools
- Problem benchmarks
- Testing capabilities
- Safety review

### 2) Model Repository

- Storing and showcasing open use-cases
- Stewardship of industry-relevant models
- Integration with code development framework to avoid legacy issues

# VTB Benefits

## Short Term

- Accelerate Demonstration Timelines
  - Advance simulation capabilities of all advanced reactor types
  - De-risk model development early-on
  - Provide basis for industry/regulator use
- Cross-Collaboration across US Gov
  - INL – ANL initiative
  - Coordinate and leverage synergies between: NRIC, NEAMS, NRC, ART, LDRD…
  - Reduce redundancies and obsolescence
- Benefit wide range of end-users
  - Accelerate adoption of and confidence in advanced mod/sim tools through open examples and best practices
  - Harness community to solve challenge problems

## Medium Term

- Groundwork for DOE Authorization
  - Safety review of demonstration applications
  - Code-to-code comparison with applicant
- Groundwork for NRC Review
  - Potential starting point for BlueCRAB analysis
  - Advanced reactor licensing review

## Long Term

- Code validation via demos
  - Benchmark against reactor demonstration
  - Coordinate data gathering exercise
  - Bridge between operators and modelers

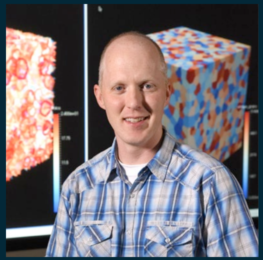
*Aligning with NRIC goal of accelerating demos by reducing timelines, de-risking technologies, and lifting all advanced developer 'boats'*

# VTB Team

## INL Team

**Abdalla Abou-Jaoude**
**VTB Workpackage Manager;** *PI salt irradiation LDRD; SA&I Technoeconomics Lead*

**Derek Gaston**
**VTB Co-Lead;** *NEAMS Deputy Director*



**Cody Permann**
**VTB Repo Manager;** *Computational Framework Dep. Manager*

**Guillaume Giudicelli**
**VTB Technical Lead;** *INL FHR POC; MOOSE Developer*

**Mauricio Tano**
**VTB MSR POC;** *Pronghorn Developer*

## ANL Team

**Bo Feng**
**VTB ANL ex-lead;** *National Technical Director Fast Reactor Program*

**Emily Shemon**
**VTB ANL lead;** *NEAMS Multiphysics Applications Lead*

**April Novak**
**VTB Model Developer;** *ANL Distinguished Postdoc*

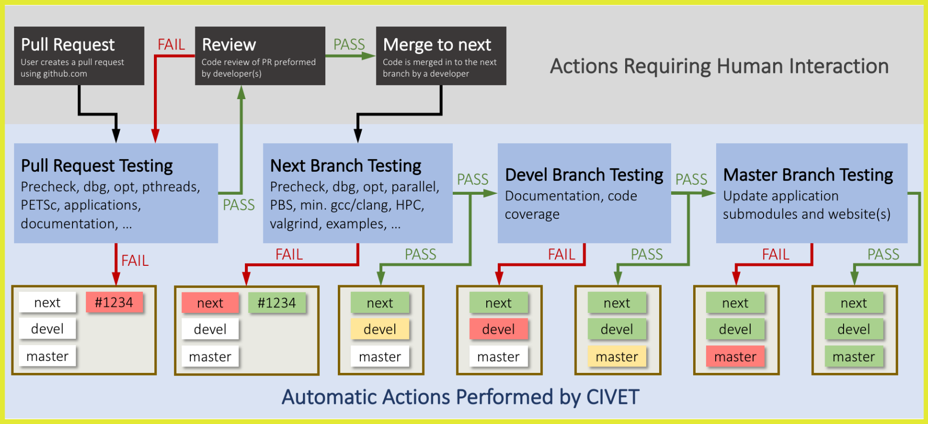
**Jun Fang**
**VTB Model Developer;** *ANL Nek+SAM analyst*

### Additional Contributors:

Nicolas Martin, Jason Miller, Logan Harbour, Paolo Balestra, Nicolas Stauff, Dillon Shaver, Rui Hu, Ling Zhou, Thanh Hua

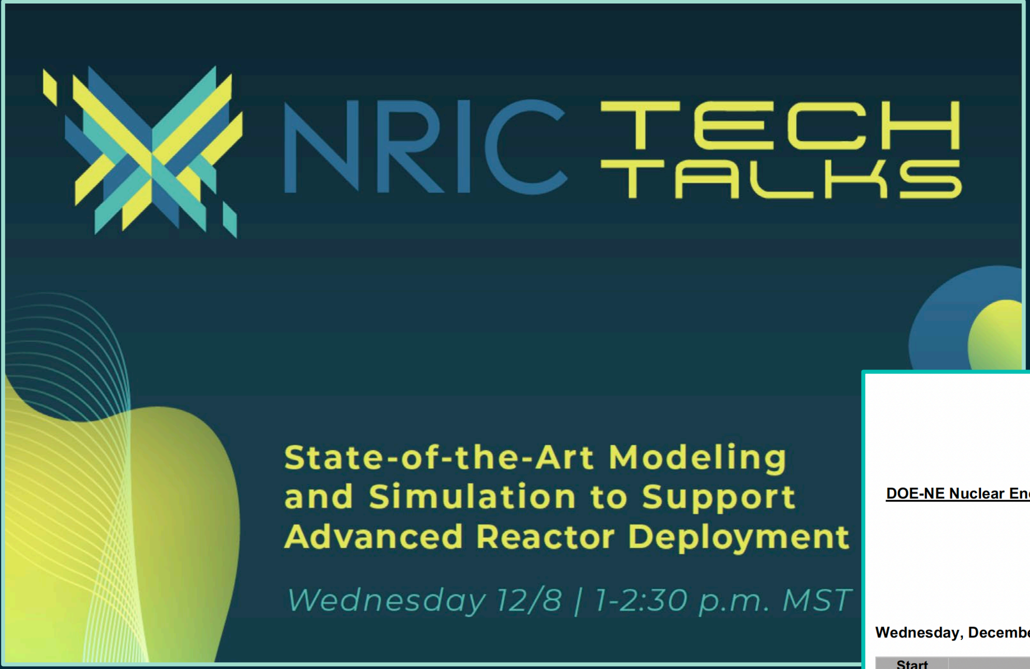
# VTB Accomplishments

- VTB Repository Release:
  - Beta Release: May 2021 (FY21)
  - Official Release: December 2021 (FY22)
    - 44 unique cloned repositories (329 total)
    - 26 unique visitors in January (138 views)
- Successful integration of VTB models with NEAMS tool development framework
  - Continuous testing to ensure models are kept up-to-date
  - Rigorous software QA methods used
- 10 models contributed, 2 developed with VTB funds,
  - accelerating timeline for MSR+FHR models by 6 months
- Publications:
  - INL/EXT-21-63162 (June 2021)
  - M&C Conf. paper on FHR multiphysics
  - ANS winter 2021: 6 papers + special session
  - Journal article on VTB overview under prep.
- External engagement:
  - DOE cross-program coordination (NEAMS, ART)
  - Formal monthly engagement with NRC
  - Industry engagement (Terrapower, Kairos, Radiant, Natura)

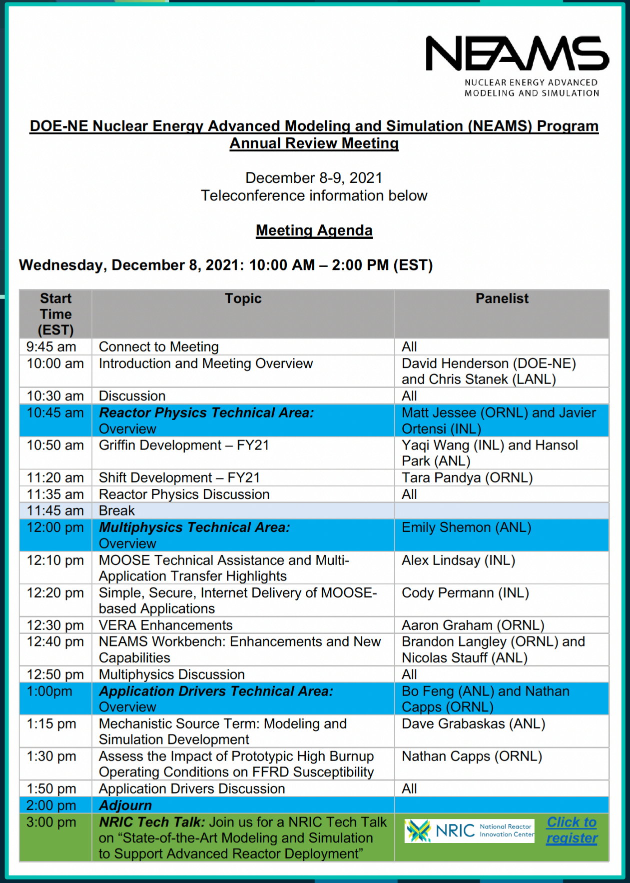



# NRIC Tech Talk on the VTB

- Wed 12/8/2021
- Showcasing VTB: Overview, code used, models hosted, and tutorial
- 170+ attendees representing over 70 institutions notably:
  - NRC, DOE-NEAMS, DOE-ART
  - Universities: MIT, Georgia Tech, Wisconsin, OSU, NC State, University of Michigan, etc.
- Overwhelmingly positive feedback from participants.




Register at: https://nric.inl.gov/nric-tech-talks-modeling_simulation/



NEAMS
NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

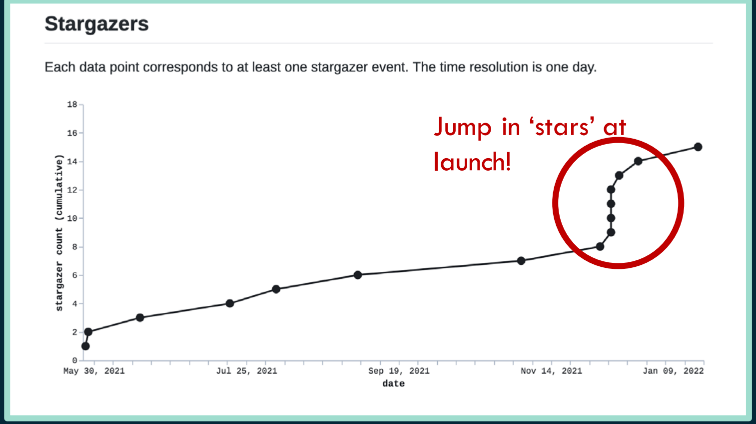
**DOE-NE Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program Annual Review Meeting**

December 8-9, 2021
Teleconference information below

**Meeting Agenda**

**Wednesday, December 8, 2021: 10:00 AM – 2:00 PM (EST)**

| Start Time (EST) | Topic | Panelist |
|---|---|---|
| 9:45 am | Connect to Meeting | All |
| 10:00 am | Introduction and Meeting Overview | David Henderson (DOE-NE) and Chris Stanek (LANL) |
| 10:30 am | Discussion | All |
| 10:45 am | ***Reactor Physics Technical Area:*** Overview | Matt Jessee (ORNL) and Javier Ortensi (INL) |
| 10:50 am | Griffin Development – FY21 | Yaqi Wang (INL) and Hansol Park (ANL) |
| 11:20 am | Shift Development – FY21 | Tara Pandya (ORNL) |
| 11:35 am | Reactor Physics Discussion | All |
| 11:45 am | Break | |
| 12:00 pm | ***Multiphysics Technical Area:*** Overview | Emily Shemon (ANL) |
| 12:10 pm | MOOSE Technical Assistance and Multi-Application Transfer Highlights | Alex Lindsay (INL) |
| 12:20 pm | Simple, Secure, Internet Delivery of MOOSE-based Applications | Cody Permann (INL) |
| 12:30 pm | VERA Enhancements | Aaron Graham (ORNL) |
| 12:40 pm | NEAMS Workbench: Enhancements and New Capabilities | Brandon Langley (ORNL) and Nicolas Stauff (ANL) |
| 12:50 pm | Multiphysics Discussion | All |
| 1:00pm | ***Application Drivers Technical Area:*** Overview | Bo Feng (ANL) and Nathan Capps (ORNL) |
| 1:15 pm | Mechanistic Source Term: Modeling and Simulation Development | Dave Grabaskas (ANL) |
| 1:30 pm | Assess the Impact of Prototypic High Burnup Operating Conditions on FFRD Susceptibility | Nathan Capps (ORNL) |
| 1:50 pm | Application Drivers Discussion | All |
| 2:00 pm | ***Adjourn*** | |
| 3:00 pm | ***NRIC Tech Talk:*** Join us for a NRIC Tech Talk on "State-of-the-Art Modeling and Simulation to Support Advanced Reactor Deployment" | NRIC National Reactor Innovation Center *Click to register* |



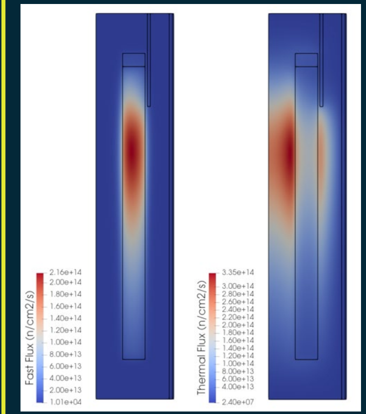

Integrated within NEAMS Program Annual Review meeting

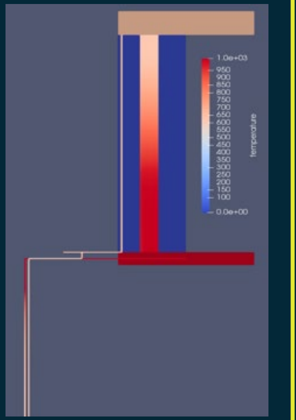
# Models Developed and Hosted

- **14** advanced reactor models under various conditions
- Codes showcased: **Griffin, Pronghorn, SAM, Nek, Sockeye, Bison**

## HTGR

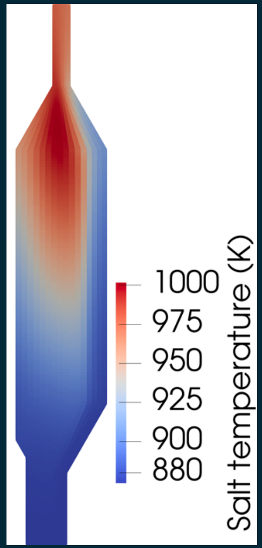
- 2D Griffin+Pronghorn Transient
- 1D SAM transient

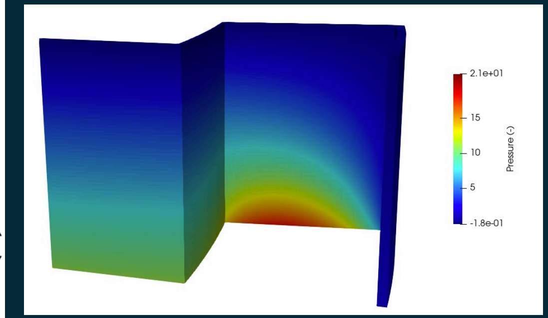


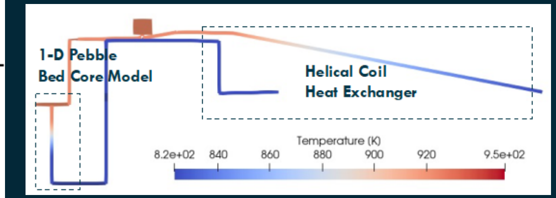




## FHR

- 2D Griffin+Pronghorn Transient
- 1D SAM transient
- Nek bypass flow CFD

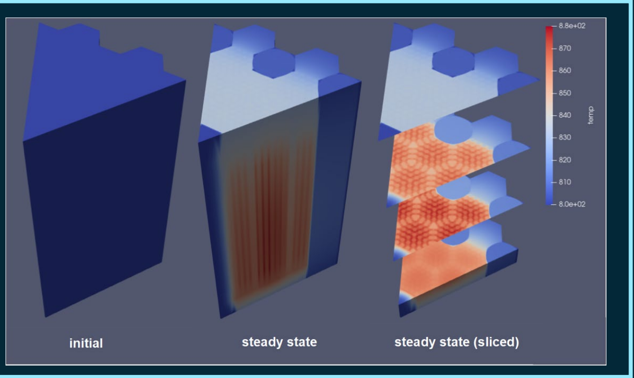


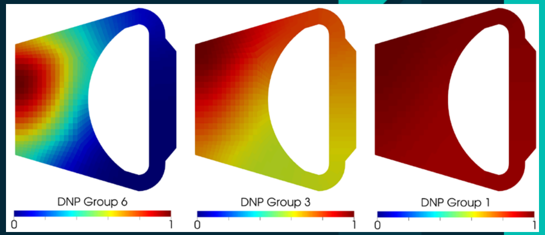

## HP-MR

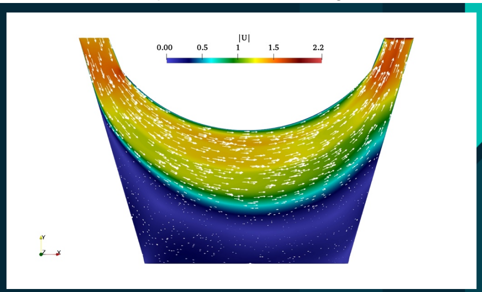
- 3D BISON-Sockeye steady state




## MSR

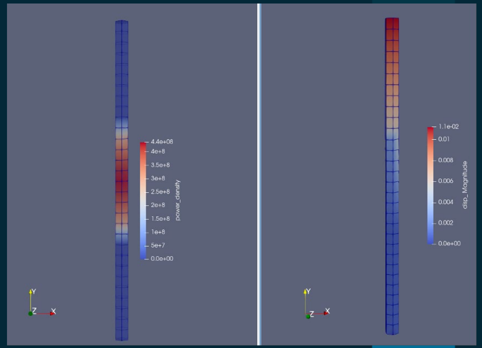
- 1D SAM steady state
- 2D Griffin+Pronghorn Transient
- 2D Nek CFD




## SFR

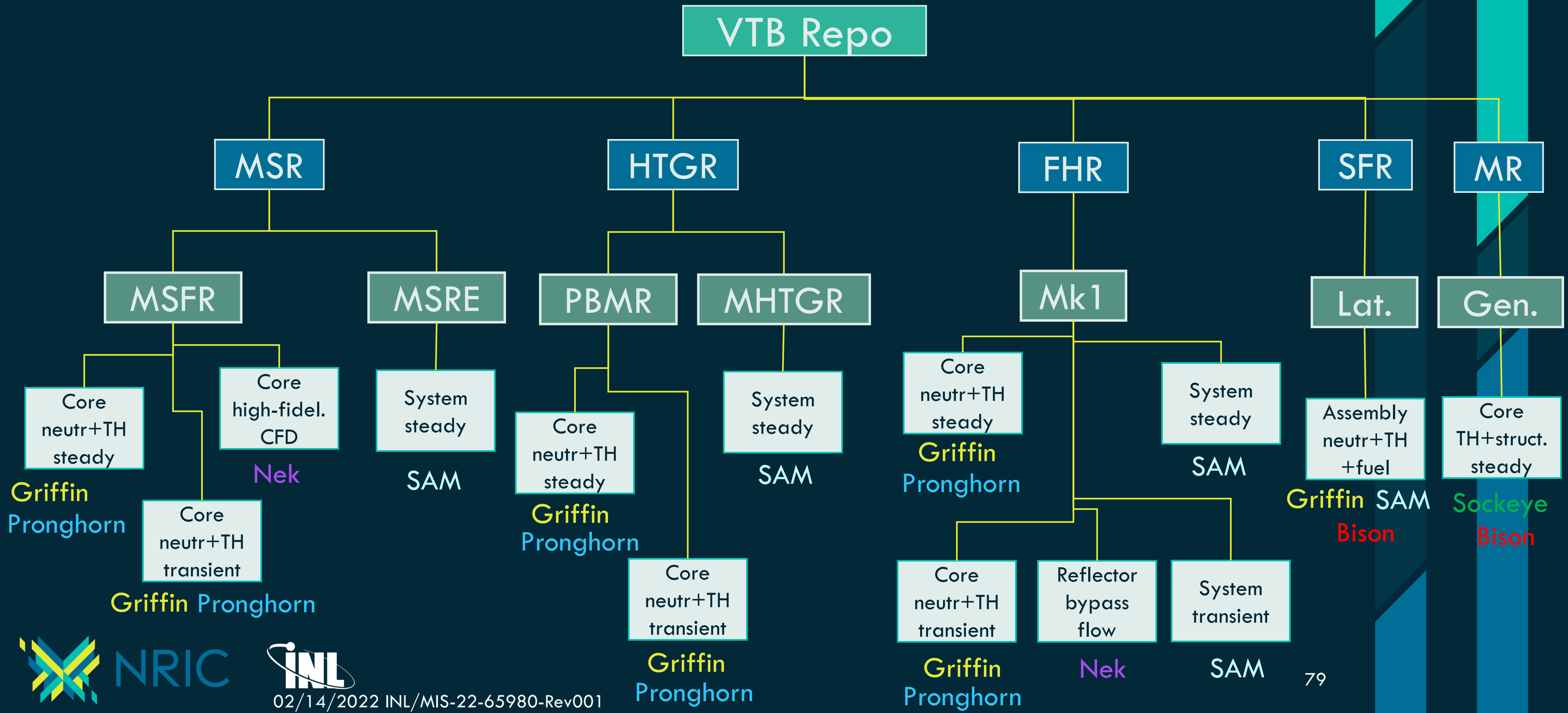
- Lattice Griffin-BISON-SAM Transient



NRIC INL

# VTB Model Tree

Codes Represented: Griffin, Pronghorn, SAM, Nek, Sockeye, Bison



# Potential Upcoming (External) Models

*33 Adv. Reactor models in the pipeline from other DOE programs in the VTB 'radar':*

- **FHR**: Cardinal CFD (NEAMS), SAM+Pronghorn coupled (NEAMS)
- **MSR**: Nek 3D (NEAMS), SAM+Pronghorn (NEAMS), Griffin+SAM (NEAMS), Species Tracking (ART-MSR)
- **HTGR**: Cardinal TH+Neutronics (NEAMS), HTTR Griffin+TH (ART-GRC), HTGR Vessel Pronghorn (UofI), HTTF SAM benchmark (NEAMS), HTTF Nek benchmark (NEAMS), PB-HTGR SAM transient (NEAMS), Griffin pebble depletion (NEAMS), PB-HTGR PKE transient (ART-GRC), MHGTR-350 Griffin (ART-GRC), HTR-PM Griffin (NRC), HTR10 Griffin (NRC), Grizzly vessel degradation (NEAMS)
- **SFR**: 3D Griffin+SAM+Bison (VTR), Nek CFD (ART-FR), Duct thermomechanics (NEAMS), ABTR SAM (NRC), ABTR Griffin (NRC), Pronghorub subchannel (NEAMS)
- **LFR**: Griffin pin-by-pin (NEAMS)
- **HP-MR**: 3D Griffin+Sockey+Bison (NEAMS), Empire Griffin (NEAMS), Design A Griffin (NRC), LANL-SPR Griffin (NRC)
- **GC-MR**: Griffin+SAM+Bison (NEAMS)
- **Materials**: TRISO Bison (NEAMS), Grizzly vessel quenching (LWRS), Grizzly concrete ageing (LWRS)

*VTB needs additional resources to integrate these models and future ones into the repo*

# VTB Customers

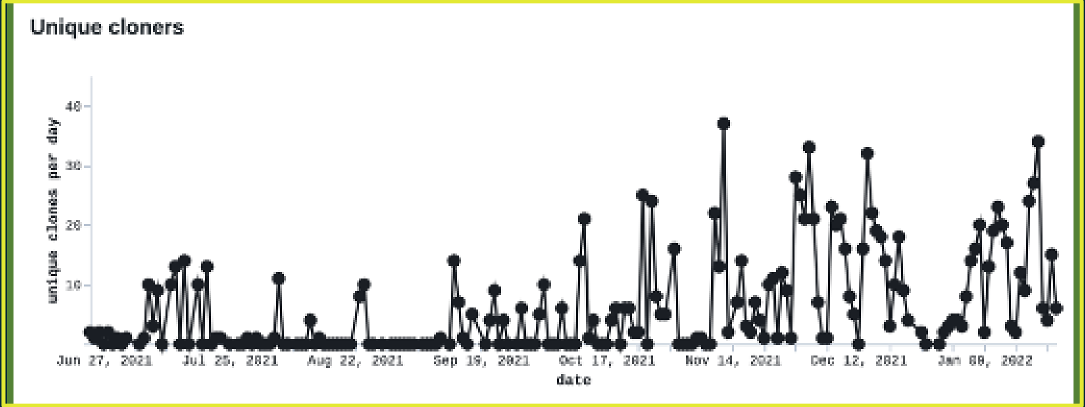
NRC:
- Formal collaboration
- Monthly meetings
- Agreed to host open NRC models on VTB
- ***Success stories**: Already using VTB MSFR + FHR models; Planning on Leveraging VTB for training*

DOE-NE:
- INL + ANL teams working on similar reactor types
- NEAMS code developers testing capabilities
- ***Success stories**: Already using VTB MSFR + FHR models*

Industry:
- Hosting open benchmark problems to increase confidence in modeling
- Guidance on challenge problems of interest
- ***Success stories**: strong interest in SAM + Pronghorn achieved*

Academia:
- Student training
- ***Success stories**: leveraging VTB for proposal submission*

Number of instances where users 'cloned' the VTB repo (i.e., downloaded or updated it)



# VTB Current FY22 Plan

- FY22: $0 new funds, ~$248K carryover
  - Minimized expenditures as much as possible
  - Temporarily halted majority of model development work
  - Focused on VTB launch, fixing bugs, and uploading existing models
- Milestones:
  - ✓ INL M2 Milestone 12/10/2021: launch VTB repo
  - ✓ ANL M4 Milestone 12/15/2021: support VTB launch
- Moving forward with current funds:
  - Support porting of external models to repo (notably NRC)
  - Fix and improvements to the repository

INL FY22 carryover: **$179K (~$90K rem.)**
ANL FY22 carryover: **$69K (~$30K rem.)**

# VTB Project Risks

*Risks for NRIC and reactor demos:*

- *Delays in NRC/DOE readiness to assess demos*
- *Inability to connect demos to codes for use in commercial reactors*
- *Less models on repo = less synergistic gains in model development activities (DOE, NRC, vendor…)*

Biggest risk is funding level

- Garnering a lot of attention but funding limited beyond Feb
- VTB momentum may fizzle out if not supported
- Challenges retaining & allocating staff

*Operating in 'survival' mode: only prioritizing critical short-term tasks to maintain project momentum*

Longer term risks:

- Limited external contribution → actively support and facilitating porting new models
- Code limitations → coordinate with code developers and fund targeted improvements
- Missing capabilities → coordinate between various programs to work synergistically
- Confidence in tools → support validation + benchmark exercises

# VTB FY22 Additional Funding Request

***Background:***

- Previous FY21 (total) Funding: INL $400k – ANL $200k
- FY21 Accomplishments:
  - Repo beta release
  - 9 adv reactor models
  - Industry engagement: Terrapower, Kairos, Natura, Radiant
  - ModSim Overview report

**New FY22 Funding Request:**

INL: $750k – ANL: $500k

- Coordination across different US gov programs: NEAMS, NRIC, NRC, ART
- New hire to support model development and repo maintenance
- Model development focus: MARVEL, gas-cooled microrx (relevant for DOME), FHR, MSR
- Incorporate fuel/material performance model (Bison, Grizzly)
- Support hosting of 33 models in pipeline

## Key Outcomes

- Accelerate maturation of reactor models for safety reviews
- Rapid growth in number of models in VTB
- Sustained engagement with NRC: licensing acceleration
- Improved integration of repository in code QA testing
- Cross DOE-NRC coordination for ModSim effort

# VTB Preliminary Concept of Operations

### Model Development

- Developing open adv reactor models
- DOE: NEAMS, ART, VTB, VTR, etc.
- Porting to VTB repo

### Hosting on VTB

- VTB team supports repo upload
- Model continuously integrated to software QA testing

### Open Access

- Nuclear community can pull model and repurpose for needs
- Industry, regulator, DOE, etc.

- **Repo Development work**. Benefit: gateway for stakeholders (e.g., industry, NRC) to access reactor models + improving the QA process for code development activities.
- **Model Development work**. Benefit: accelerate development of advanced reactor models by working on gaps important to NRIC stakeholders and not being filled by other programs.

| Task | FTE/FY | Note |
|---|---|---|
| Repo maintenance | 0.2 | Fixing unexpected bugs on website/github, updating models |
| Repo improvements | 0.3 | Linking more codes to testing suites, including regression testing etc. |
| Coordination activities | 0.3 | Reaching out to stakeholders and coordinating synergistic modsim scopes |
| Processing external models | 0.5 | Support for uploading models from other programs to VTB |
| Model improvement | 1.1 | Develop more capability to existing models (e.g., MSR, FHR) |
| New model development | 1.1 | Setting up new models with NEAMS tools (e.g., Gas-microreactor, MARVEL) |
| | | |
| Total | 3.5 | |

*Long term*: new Conops as demos are close to coming online → support assessment + validation activities

# Summary

- Key benefits of the VTB to NRIC:
  - Accelerating demonstration timelines by providing groundwork for safety review using NEAMS tools
  - Collaboration between labs, academia, industry, and NRC
  - Foundation for NEAMS validation once demos built
- Momentum with VTB repo launch, NRIC Tech Talk, NRC (and others) engagement
- Accomplishment thus far:
  - Launched online open repository
  - Integrated repository with code QA framework
  - Hosting 14 reference reactor models
- With additional funding:
  - Host more models to the repository
  - Develop additional model capability to fill key gaps
  - Facilitate coordination in ModSim across DOE, NRC, etc.

# Thank you!

## Questions?

## Time Permitting

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